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This report contains 326 summaries of research projects which were carried out under funding of the Naval Postgraduate School Research Program. A list of recent publications are also included which consist of conference presentations, contributions to books, published papers, magazine articles, and technical reports. The research was conducted under the areas of Computer Science, Mathematics, Administrative Sciences, Operations Research, National Security Affairs, Physics, Electrical and Computer Engineering, Meteorology, Aeronautics and Astronautics, Oceanography, Mechanical Engineering, C3 Joint Group, Electrical Warfare Group, ASW Group and the Space Systems Academic Group.

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INTRODUCTION

This volume summarizes faculty research activity during fiscal year 1991, and it lists recent publications and conference presentations. A separate volume, "Naval Postgraduate School Compilation of Abstracts of Theses Submitted by Candidates for Degrees," is a compilation of abstracts of theses written at NPS during fiscal year 1991.

Research is an integral part of the graduate education and there is a close connection between faculty research and student theses. Approximately 800 Masters Theses are written annually at the Naval Postgraduate School and many of the projects shown here make reference to those theses.

The projects summarized in this volume are organized by the academic department of the principal investigator. This provides a natural grouping by subject area, but does not give adequate recognition to the significant amount of research in the interdisciplinary areas, in particular the work of the school's Academic Groups in Antisubmarine Warfare, Space Systems, Electronic Warfare, and in Command, Control, and Communications.

The Naval Postgraduate School wishes to acknowledge Millie Fidel for her efforts in the preparation of this volume.

Additional information about research activities at NPS can be obtained from the Research Office, Code 08, Naval Postgraduate School, Monterey, California, 93943.

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TABLE OF CONTENTS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

R.E. Ball	NPS Survivability Support	3
R.E. Ball	Surface Ship Survivability	4
O. Biblarz	Improvement of the Altitude Measurement Capability of the SAIP	5
O. Biblarz	Low-Voltage, Thermionic Breakdown for Xenon Ion Engines	5
M.S. Chandrasekhara M.F. Platzer	Compressibility Effects on and Control of Dynamic Stall of Oscillating Airfoils	6
M.S. Chandrasekhara M.F. Platzer	Compressibility Effects on Dynamic Stall of Airfoils Undergoing Rapid Transient Pitching Motion	7
M.S. Chandrasekhara M.F. Platzer	High Alpha High Speed Aerodynamics Research	8
M.R. Gorman	A Study of the Flexural Mode in Orthotropic Laminates	8
S.K. Hebbar	High-Alpha Low-Speed Aircraft Aerodynamics Research	9
S.K. Hebbar M.F. Platzer	Small Scale Wind Tunnel Investigation of F/A-18 Aircraft at High Angles of Attack	10
R.M. Howard	Advanced Development Research Program for Joint-Service Unmanned Air Vehicles	11
R.M. Howard	Canard/Wing Interaction for Enhanced Lift in Aircraft Supermaneuverability	12
D.W. Netzer D. Laredo	Particulate Behavior in Exhaust Nozzles and Plumes of Solid Propellant Rocket Motors	13
D.W. Netzer B. Natan	Combustion Behavior of Solid Fuel Ramjets and Boron/Boron Carbide Particles	14
C.F. Newberry	Exergy Methods for Aircraft Design	15
M.F. Platzer J.A. Ekaterinaris	Unsteady Heat Transfer on Turbine Blades	16
M.F. Platzer J.A. Ekaterinaris	Aircraft and Jet Engine Unsteady Flow Computations	16

M.F. Platzer S.K. Hebbar J.A. Ekaterinaris	Dynamic Lift Studies for Enhanced Fighter Maneuverability	17
L.V. Schmidt	Stability Augmentation for Improving Surface Ship Seakeeping	18
L.V. Schmidt	Aircraft Wing Rock by Inertial Coupling	18
L.V. Schmidt	Towed Cable Dynamics	19
E.M. Wu	Composite Reliability in Submarine Applications	19
R.P. Shreeve I.N. Moyle A.C. Ucer	Fan & Compressor Stall	20
R.P. Shreeve	Fan Shock-Boundary Layer Separation Alleviation	21

DEPARTMENT OF ADMINISTRATIVE SCIENCES

H.K. Bhargava	Computer-Aided Model Construction	27
H.K. Bhargava	Fleet Mix Modeling in the U.S. Coast Guard	28
D.C. Boger S.S. Liao	Data and Methods for Estimating Costs of Aircraft Modifications and Derivatives	29
D.R. Dolk K.J. Euske	Analysis of the Management Control and Information System Implications of RAMP	30
D.R. Dolk	A Decision Support System for Emergency Telecommunications	30
R. Doyle	Defense and Dissensus: The Impact of Congressional Budget Stalemate on Defense Resources	31
M.J. Eitelberg	Human Resource Development in the Department of Defense: The Role of Military Selection and Classification	32
J.C. Emery M.J. McCaffrey	AdA's Use for Management Information Systems in DoD	33
K.J. Euske M. Lebas C.J. McNair	Identification of Industrial Performance Measurement Procedures Supporting the Achievement of Strategic Objectives	34

K.J. Euske	Control of Ill-Defined Technology and Output: A Field Study	34
K.J. Euske L.R. Jones J.L. McCaffrey	Navy Fleet Budgeting and Impact of Budget Reduction	35
L. Gorman S.L. Mehay	Migration, Veteran's Pay, and Selectivity Bias	36
L.R. Jones K.J. Euske J.L. McCaffrey	Navy Fleet Budgeting and Impact of Budget Reduction	37
L.R. Jones	Navy Ship Maintenance and Repair and Impact of Budget Reduction	38
L.R. Jones	Navy Budgeting Justification and Impact of Budget Reduction	39
M.N. Kamel	CERTS: A Comparative Evaluation Method for Risk Management Methodologies and Tools	40
K. Kang L. Whitaker M. Bailey S.Y. Sohn M. Bartroli	Reliability Goal Determination for Major Caliber Ammunition	41
D.V. Lam	Definitions of Contracting Terms	42
D.V. Lam	Contract Negotiations	43
D.V. Lam	Contracting Taxonomies	44
A.W. McMasters	Resystemization Modeling Support	45
S.L. Mehay M.J. Eitelberg	Army Recruiting in the 21st Century (Phase II)	46
S.L. Mehay M.J. Eitelberg G. Thomas	Army Recruiting in the 21st Century (Phase II)	47
S.L. Mehay T. Moore L. Gorman M. Eitelberg	Naval Postgraduate School MPTA Faculty Research in Support of OP-01	48
O.D. Moses	An Analysis of Alternative Cost Progress Models	49

B. Ramesh	Knowledged-Based Support for Systems and Maintenance	50
B. Ramesh	Domain Analysis for Service Order Processing	51
N.C. Roberts	Military Decision Making	52
J.G. San Miguel	Cost Management, Standards, and Analysis: Case Studies	53
J.G. San Miguel	Evaluation of Costs for the National Industrial Security Program	54
J.G. San Miguel	Strategic Profit Analysis	54
N.F. Schneidewind	Enhancement of Schneidewind Software Reliability Model	55
N.F. Schneidewind	Validation and Application of Software Quality Metrics	56
N.F. Schneidewind	Software Quality Metrics	56
N.F. Schneidewind	Issues in Allocating Servers and Files in a Local Area Network	57
K. Sengupta	Resource Allocation in Naval Command Teams	58
K. Sengupta	Incorporating Decision Feedback in Group Decision Support Systems (Continued from 1990)	58
K. Sengupta	Complexity in the Design of User Interfaces (Continued from 1990)	59
K. Sengupta	Decision Support for Intelligence Analysis	59
J.E. Suchan	An Empirical Assessment of the Effects of Organization, Document Design, and Style of Adjudicative Decision Making	60
M.W. Suh	Telecommunication Plan for EDI	61
G.W. Thomas L. Gorman	High Quality Regional QMA&I	62
G.W. Thomas S.Y. Sohn	USAR Commute Distance Study	63

K.W. Thomas B.J. Roberts S.P. Hocevar G.F. Thomas F.J. Barrett	Behavioral/Attitudinal Surveys of Civilian Personnel Department and of Engineers at the Naval Avionics Center	64
K.W. Thomas S.P. Hocevar G.F. Thomas F.J. Barrett	Behavioral/Organizational Studies of Employee Involvement	65
D. Trietsch	Implementing TQM Methods in Naval Repair Facilities	66
D. Trietsch	Optimal Scheduling of PERT Activities with TREE Precedence Networks and an Application to HUB Operations	67
D. Trietsch	Near Optimal Transfer Lots for Job Ships with Several Departments	67
D.R. Whipple W.R. Gates L.R. Jones E.J. Laurance M.G. Sovereign K.L. Terasawa	Burden Sharing, International Armaments Cooperation, and U.S. Mobilization Capability	68
D. Zweig	Factors Affecting Software Reuse	69

DEPARTMENT OF COMPUTER SCIENCES

V. Berzins	Fundamental Theory for Systematically Combining Changes to Software	75
V. Berzins	Automated Software Tools for the Design of Large Ada Software Systems	76
V. Berzins	Automatically Combining Changes to Software Systems	77
D.A. Erickson	The NPS Academic Course Scheduler	77
D.K. Hsiao	The Object-Oriented Approach to Multi-Level Secure Databases	78
D.K. Hsiao	The Role of Federated Databases and System in Data-Intensive Applications	78
Y. Kanayama	Image Understanding for Autonomous Robots	79

U.R. Kodres S. Shukla	AN/UYS-2 Enhanced Modular Signal Processing (EMCR) and Processing Graph Methodology (PMG)	80
U.R. Kodres S.H. Kwak J.R. Clynch	Small Navigation Data Logger Software System	80
U.R. Kodres	Real-Time Prototyping on a Multiple Transputer System	81
Y.-J. Lee	Design and Application of Intelligence Computer-Based Training System	81
G.M. Lundy	Specification and Analysis of Communication Protocols	82
Luqi	Navy Ada for Combat Direction Systems Low Cost Combat Direction System	83
Luqi	Execution Support of a Computer Aided Prototyping System for Real-Time Systems	84
Luqi	Models for Prototypes of Dynamic Systems	85
Luqi	Modeling of Real-Time Systems at NRL	86
R.B. McGhee J.R. Clynch S.H. Kwak	Technology Survey and Preliminary Design for a Small AUV Navigation System	86
N.C. Rowe	Computer Planning of Safe Missiles Paths Using Discrete Regions	87
T.J. Shimeall	Safety Analysis of Software in Embedded Heterogenous-Multiprocessor Control Systems	88
M.T. Shing	A Stochastic Approach to the Weighted Region Shortest-Path Problem	89
C.T. Wu	Establishment of Infosec Center of Excellence	90
C.T. Wu	Design and Development of Prototype Onboard Information System on Multiple Hardware Platforms	90
C.T. Wu	Design and Implementation of Multimedia Information System by Using Object-Oriented Development Tools	91

A. Zaky	Efficient Software Pipelining on Super-scalar Processors	92
M.J. Zyda	NPSNET: Low-Cost, Networkable 3D Visual Simulation	93
M.J. Zyda	Development of a SIMNET-Compatible, Non-Line-of-Sight, 3D Visual Simulator	94
M.J. Zyda	Terrain Visualization and Reason - Year 3	95
M.J. Zyda	Inexpensive, Three-Dimensional Visual Simulation for the Command and Control Workstation of the Future - Year 3	96

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

R.W. Adler	Signal-to-Noise Enhancement Program (SNEP) Research and Support	105
J.B. Burl	Dynamic Image Processing in the Spatial Frequency Domain Using the Extended Kalman Filter	105
J.B. Burl	Senior and Actuator Placement for Large Space Structure Control	106
J.T. Butler C. Yang	On the Use of Multiple-Valued Logic in the Design of Digital Systems	107
W.-Z. Chen	Use of State Augmentation for Feedback Control Law Design - An Approach for Increased Performance and Robustness	108
M.P. Fargues	Tracking Sources Using the Rank Revealing QR Factorization	109
M.P. Fargues	The C-Rise Algorithm	110
D.J. Fouts	Design Principles for Very High-Speed Digital Circuits and Systems	111
T.T. Ha	Exploitation Analysis of Foreign Communications Systems	112
T.T. Ha G.A. Myers	Research in Low-Altitude Satellite Communications and Networks	113
R.D. Hippenstiel	Spectral Estimation of (Short Duration) Non-Stationary Processes	114

R. Janaswamy	On the Design of Anechoic Chamber Absorbers	114
D.C. Jenn	Radiation and Scattering Studies Using the Method of Moments	115
J.B. Knorr	Circuit Modeling for Microwave Computer-Aided-Design	116
A.W. Lam	M-ary Optical CDMA Communications	117
A.W. Lam	Wavelet Transform Theory and Its Applications	117
A.W. Lam	Sequential Acquisition Schemes for SSMA Systems with Generalized Signature Sequences	118
C.-H. Lee	Computer Aided VLSI Design for Tactical Image Processing	119
C.-H. Lee	Image Processing Applied to Sensor Data	120
H.-M. Lee	Short Range Anti-Air Radar Propagation	121
H.-M. Lee	M-Layer Improvement and Extension	121
S. Michael	Radiation Insensitive Semiconductor Networks	122
S. Michael	An Automated Monitoring System for Submarine Power Supply	123
S. Michael	On-Orbit Annealing of Satellite Solar Panels	123
J.H. Miller C.-S. Chiu	Monterey Bay Tomography Experiment	124
J.H. Miller C.-S. Chiu	Time Domain Localization	125
P.H. Moose	Communications Digital Signal Processing	125
P.H. Moose	Western European Undersea Warfare R&D Activity: Trends for 1991 and Beyond	126
M.A. Morgan	Impulse Radar Target Identification Using Natural Resonances	126

M.A. Morgan	Computer Aided Design of Navy Missile Radomes	127
R.J. Pieper	A Visibility-Dependent Depth-of-Focus for Incoherent Periodic Sources	128
J. Powers	Underwater Fiber Optic Communications	129
J. Powers	Propagation of Low-Diffraction Fields	129
R.C. Robertson	Performance of Frequency-Hopped M-ary Frequency-Shift Keying Systems Over Fading Channels with Partial-Band Interference	130
S.B. Shukla	Mapping Hard Real Time Applications on Loosely Coupled Microprocessors	131
S.B. Shukla C. Yang A. Zaky	Compile-Time Support for the Processing Graph Methodology on the AN/UYS-2 Parallel Signal Processor	132
S.B. Shukla C. Yang	A Framework for Node Failure/Repair Transparency in Distributed Real-Time Systems	133
C.W. Therrien M. Tummala	Noise Cancellation for Countermeasure Tolerant Tracking	134
C.W. Therrien M. Tummala	Research in Multidimensional Signal Processing	135
S.M. Williams	MTF Data Reduction Software	136

DEPARTMENT OF MATHEMATICS

S.R. Baker D.R. Canright C.L. Scandrett	Application of the T-Matrix Method to Low-Frequency Active Array Performance Prediction	139
D.R. Barr M. Weir	Evaluation of Effects of Incorporating Human Factors into Combat Models	140
D.R. Barr	Comparability Analysis for Model-Test-Model	141
D.R. Barr	Effects of Terrain Resolution Upon Intervisibility	141
D.R. Barr	Estimation of Unit Success/Mix Model for USAR	142

D.R. Canright	Analysis of Thermocapillary Convection in Welding	142
R. Franke	Real-Time Bias Correction for Satellite Data	143
V.E. Henson	Anterpolation Methods: Fourier Transforms on Irregular Grids	143
V.E. Henson	Multigrid, Multilevel and Multilevel Projection Methods	144
T. Jayachandran R. Franke	Quality Control of Meteorological Data	144
J. Leader	Analysis of Chaotic Iternation in R^n	145
B. Neta A.L. Schoenstadt R.T. Williams	Development of Finite Element Prediction Model	145
I.B. Russak	Astrodynamic Standardization	146
J. Thornton	Robot Arm Path Planning	147

DEPARTMENT OF MECHANICAL ENGINEERING

R. Crooks	JP-5 Thermal Breakdown in T56-A-427 Engine Fuel Nozzles	153
I. Dutta	Effect of Reinforcements on the Matrix Microstructure of Discontinuous Metal Matrix Composites	154
I. Dutta	Effect of Thermal Residual Stresses on the Mechanical Properties of Discontinuous Metal Matrix Composites	155
I. Dutta	Thermal and Mechanical Fatigue Behavior of Graphite Fiber Reinforced Aluminum Composites	156
I. Dutta	Characterization of Aluminum Nitride Substrates and Copper-Aluminum Nitride Metallizations for Electronic Packaging Applications	157
I. Dutta	Corrosion Behavior of Graphite-Aluminum Composites	157

I. Dutta	Processing-Microstructure Correlations in Cast SiC Particulate Reinforced Aluminum Matrix Composites	158
M. Driels	Object Recognition Through Remote Teleoperation	159
A.G. Fox	A Combinative Method for the Accurate Measurement of Structure Factors and Charge Densities of Intermetallic Alloys	160
A.G. Fox	The Crystallographic and Chemical Characterization of Microstructures and Non-Metallic Inclusions in High-Strength, Low-Alloy (HSLA) Steels and their Weldments	161
A.G. Fox	The Phases and Microstructures Resulting from Various Heat Treatments on Al-Li Aerospace Alloys	162
Y. Joshi M.D. Kelleher B. Neta	Convective Cooling of Electronic Equipment: Experiments and Computations	163
Y. Joshi M.D. Kelleher	Computer Aided Analysis of Electronic Equipment Cooling	164
Y. Joshi	Computations and Experiments on Heat Transfer and Fluid Dynamics of Fusion Welding	165
Y. Joshi	Heat Transfer and Fluid Flow in Fusion Welding	165
M.D. Kelleher K.T. Yang V.D. Hank	Field Modeling of Fire and Smoke Spread in Confined Spaces	166
Y.W. Kwon	Fracture Analysis in Metal-Matrix Composites	167
P.M. Ligrani	Effects of Embedded Longitudinal Vortices on Boundary Layers Film-Cooled Using Compound Angle Injection Holes	168
P.M. Ligrani	Study of Film Cooling from Compound Angle Injection Holes and Comparison to Results from Simple Angle Holes	169

P.M. Ligrani	Study of the Effects of Centrifugal Instabilities on Transition from Laminar to Turbulent Flow in Curved Channels for Dean Numbers from 160 to Fully Turbulent Conditions	170
P.M. Ligrani	Effects of Unsteadiness on Laminar-Turbulent Transition in Straight Channel Flow	172
P.M. Ligrani C.S. Subramanian	Turbulent Structural Characteristics of Film Cooling Jets With and Without Embedded Longitudinal Vortices in Turbulent Boundary Layers	173
P.J. Marto S.B. Memory	Evaluation of Refrigeration Techniques for Naval Applications	174
P.J. Marto S.B. Memory	Steam Condensation Heat Transfer Enhancement in Naval Condensers	174
P.J. Marto S.B. Memory	Boiling and Condensing Heat Transfer Characteristics of Alternative Refrigerants	175
T.R. McNelley	Grain Boundaries in Superplastic Aluminum	176
T.R. McNelley	Development of Ductile and Impact-Resistant Metal-Matrix Composites for Lightweight Military Applications	177
T.R. McNelley	Influence on Mechanical Properties of Residual Porosity in Intelligent HIPed Power-Metallurgy High-Temperature Ti Alloys	178
R. Mukherjee	Control of Free-Flying Under-Actuated Space Robots	179
J. Perkins	Mechanism of Lattice Transformations and Internal Friction in Martensitic and Antiferromagnetic High-Damping Alloys	180
D. Salinas	Thermoelastic Stresses in Electronic Packages	181
T. Sarpkaya	Numerical Analysis of Separated Flow About Bluff Bodies	182
T. Sarpkaya	Separation Points on a Cylinder in Oscillating Flow	183

T. Sarpkaya	Interaction of a Vortex Pair with a Free Surface	184
P.Y. Shin	Optimization Structural Design by a Homotopy Method	185
P.Y. Shin	Thermoelastic Stresses in Electronic Packages	186
Y.S. Shin	Dynamic Response and Failure of Composite and Metal Structures to Underwater Shockloads	187
Y.S. Shin	Machinery Noise, Vibration and Diagnostic: Analysis, Design and Testing	188
	DEPARTMENT OF METEOROLOGY	
C.P. Chang R.T. Williams	Tropical Cyclone Monsoon Studies	192
K.L. Davidson P.J. Boyle C. Skupniewicz	Air Sea Interaction and Remote Sensing	193
K.L. Davidson P.S. Guest P. Frederickson	Meteorological Studies of Arctic Regions	195
K.L. Davidson	Optical Properties of and Vertical Aerosol Model for the Marine Atmospheric Boundary Layer	196
K.L. Davidson P.S. Guest T. Neta	Meteorological Data Base for Eastern Arctic Regions	196
K.L. Davidson P.S. Guest P. Frederickson	Meteorological Studies of Arctic Regions	197
K.L. Davidson P.S. Guest	Atmospheric Boundary Layer Studies of Artic Regions	198
P.A. Durkee	Marine Stratocumulus Cloud Reflectance: Implications Aerosol-Cloud Interaction and Entrainment	199
P.A. Durkee	Sage III Science Team	200
P.A. Durkee	Electronic Weapon System Satellite Support	201

P.A. Durkee	Satellite Investigations of Aerosol Particle Distributions Associated with DMS and their Relationship to Marine Cloud Characteristics	203
R.L. Elsberry	Tropical Cyclone Motion (TCM-90) Research	204
R.L. Elsberry	Tropical Cyclone Motion Studies	206
R.L. Elsberry	Observation-Numerical Studies of Severe Synoptic Weather Phenomena	207
R.L. Haney	Eddy Generation Mechanisms in Eastern Boundary Current Regions	208
T.R. Holt	Numerical and Observational Studies of the Mesoscale Structure of the Atmospheric Boundary Layer	209
T.R. Holt	Modeling of Atmospheric Mesoscale Processes	210
T. Murphee C.-P. Chang J.-M. Chen	Global Atmospheric and Oceanographic Processes	211
W.A. Nuss	Boundary Layer Interaction in Cyclogenesis	213
W.A. Nuss	Boundary Layer Modeling in Explosive Cyclogenesis	214
W.A. Nuss	Mesoscale Coupled Air-Sea Interaction Studies	215
P.M. Pauley	Influence of Latent Heat Release and Static Stability Variations on the Development of Rapidly Intensifying Extratropical Cyclones	216
P.M. Pauley	Sensitivity of Numerical Forecasts of Rapidly Intensifying Extratropical Cyclones to Precipitation Parameterization	217
P.M. Pauley	A Comparison of Vertical Motions Obtained from the Flatland St Radar and from a Generalized Omega Equation	218
C.H. Wash R.L. Elsberry P. Pauley W.A. Nuss P. Hirschberg	Rapid Maritime Cyclogenesis Studies	219
C.H. Wash K.L. Davidson	Evaluation of Measurement Systems for the Integrated Oceanographic Tactical Aid (IOTA) System	221
F.R. Williams	Regional Synoptic Forecasting (Philippines)	222

R.T. Williams M.S. Peng	Theory of Tropical Cyclone Motion	223
R.T. Williams M.S. Peng	Numerical Modeling of Unique Atmospheric Phenomena	223

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

D. Abenheim	German Unity and Professionalism in German Officer Corps	226
T.C. Bruneau R.N. Channel	Relationship of War at Sea to Warfare Ashore	227
T.C. Bruneau	Defense Modernization and the Armed Forces in Portugal Implications for U.S. - Portuguese Relations	228
R.H. Magnus	Iran and Its Neighbors' Implications for the United States	229
R.H. Magnus	Islamist View of the United States in a Post Cold War Environment	229
P. Stockton	Deep Cuts - The Domestic Politics of Strategic Arms Control and Force Modernization	230
R.H.S. Stolfi	Tailoring the Marine Air-Ground Task Force for Combat Against a Strong Armored Enemy: Battle Fighting Lessons from the Germans in World War II	231
S.D. Tollefson	Brazil-United States Naval Relations: Opportunities and Obstacles in the 1990s	232
S.D. Tollefson	Defense Industrial Initiative in Brazil: Implications for U.S. Technology Transfers	233
J.J. Tritten	Strategic Management for the Defense Department	234
M. Tsypkin	The Soviet Navy in a New Military-Political Environment: The Military and Politics	237

D. Winterford	Expanding Chinese Naval Power and Maritime Security in Southeast Asia	238
D. Winterford R. Boynton C. Dressler	Report of the Expanded IMET Initiative Project	239
J.J. Wirtz	System Constraints and the Eruption of War Between Great and Weak Powers	240
D.S. Yost	Structural Factors in the Long-Term Competition	241
	DEPARTMENT OF OCEANOGRAPHY	
M.L. Batteen C.S. Nelson	Modeling Studies of Eddies in Eastern Boundary Current Regions	246
M.L. Batteen	Facilities for the Investigation of EBC Regions Through Coupled Satellite Imaging and Modeling Studies	247
M.L. Batteen	Modeling Studies of the Eastern Boundary Current Flow Off Western Australia	248
R.H. Bourke R.G. Paquette	Marginal Sea-Ice Zone Studies 1991	249
R.H. Bourke	Chair in Arctic Marine Science	250
E. Carter	Data Assimilation Modeling	251
C.-S. Chiu J.H. Miller	Time Domain Acoustic Signals Localization and Tracking	252

C.-S. Chiu J.H. Miller R.H. Bourke	Barents Sea Tomography Transmission Test: Shallow Water Vertical Array Component	252
C.-S. Chiu A.J. Semtner	Computer Simulation Studies of Low-Frequency Cross-Basin Acoustic Transmissions	253
C.-S. Chiu J.H. Miller	Feasibility Study for a Norwegian Continental Shelf-Barents Sea Acoustic Tomography Experiment	254
C.-S. Chiu	Greenland Sea Tomography Data Analysis	255
J.R. Clynch	Evaluation of Low Cost GPS Receivers for Geodetic Applications	256
C.A. Collins	California Undercurrent Studies	257
C.A. Collins J.R. Cherry	Marine Operations	258
C.A. Collins S.R. Ramp N. Garfield L.K. Rosenfeld M. Noble F. Schwing	Circulation on the Continental Shelf and Slope near the Farallon Islands, CA	261
R.W. Garwood, Jr. P.C. Chu	Enhancements to Deep Oceanic Convection in the Arctic System	262
R.W. Garwood, Jr. P.C. Chu	Studies of the Oceanic Planetary Boundary Layer	263
J.A. Nystuen	NPS Acoustic Drifting Buoy Program	264
J.A. Nystuen	Ambient Noise Generation at the Air/Sea Interface	265
J.D. Paduan	Large-Scale Mean Convergence in the Mixed Layer of the Canary Basin as Determined from Lagrangian Drifters	266
J.D. Paduan	Lagrangian Measurements of Surface Currents off the California Coast	267
S.R. Ramp P.F. Jessen	The Coastal Transition Zone Program	268

S.R. Ramp P. Jessen T. Anderson M. Stone	The Point Sur Transect (POST) Program	270
A.J. Semtner	Scientific Development of a Massively Parallel Ocean Climate Model	271
A.J. Semtner	Development of a Global Eddy Resolving Thermodynamic Ocean Model	271
T.P. Stanton	Upper Ocean Turbulent Flux Measurements Using Acoustic and Optical Techniques Deployed from an ROV	272
T.P. Stanton	Turbulence and Heat Flux Measurements in the Upper Ocean	273
E.B. Thornton	Nearshore Wave Processes	274

DEPARTMENT OF OPERATIONS RESEARCH

G.H. Bradley G.G. Brown A.R. Washburn	Optimization of Munitions Modeling	279
G.H. Bradley G.G. Brown R.K. Wood	Large-Scale Optimization and the Exploitation of Special Structure	280
G.H. Bradley G.G. Brown R.K. Wood	Exploiting Special Structure in Large-Scale Optimization	281
G.G. Brown A.R. Washburn	Frequency Planning	282
R.F. Dell S. Lawphongpanich	Scheduling Underway Replenishments for Carrier Battle Groups	283
J.D. Esary	Damage Aggregation Models for Weapons Salvos	284
D.P. Gaver P.A. Jacobs P. Purdue	Performance Analysis Studies	285
D.P. Gaver P.A. Jacobs	Meteorological Data Analysis: Estimation of Prediction Error Variances	285

D.P. Gaver P.A. Jacobs	Probabilistic Models for Shapes and Hierarchical Bayesian Modeling and Estimation	286
W.P. Hughes, Jr.	Development of a Theory of Combat	287
S. Lawphongpanich	Decomposition Topics in Large-Scale Optimization	288
S. Lawphongpanich	Analysis of Algorithms for Linearly Constrained Convex Programs	289
R.F. Dell S. Lawphongpanich	Scheduling Underway Replenishments for Carrier Battle Groups	289
K.T. Marshall	CNO Chair of Emerging Technologies	290
P.R. Milch	Navy Officer Hardfill Allocation and Distribution Analysis	291
S.H. Parry	Evaluation of Attrition Methodologies for Aggregated Combat Models	291
G.K. Poock	Controlling Shipboard Access with Signature and Finger Print Verification	292
R.R. Read	Range Calibration Studies	292
R.R. Read	Attrition Rate Generation for Manpower Models	293
R.E. Rosenthal	Operations Research Modeling of Anti-Satellite Architectures	293
D.A. Schrady D.B. Wadsworth	Battle Group Logistics Coordination Support System	294
S.Y. Young	Variable Selection in a Linear Curve Model with Autoregressive Errors	295
M. Sovereign	Combat Analysis	296
E.S. Theise	The Minimum Total Confusion Problem: Applications and Algorithms	297
L. Whitaker	Research in Reliability and Categorical Data Analysis	298

W.M. Woods	Approximate Confidence Intervals for Complex Systems	299
	DEPARTMENT OF PHYSICS	
A.A. Atchley	Basic Research in Thermoacoustic Heat Transport	305
A.A. Atchley	Basic Research in Thermoacoustic Heat Transport	305
S.R. Baker O.B. Wilson	Continued Investigation of the Use of Sympathetic Resonators to Improve Sonar Transducer Performance	306
S.R. Baker D.R. Canright C.L. Scandrett	Application of the T-Matrix Method to Low Frequency Active Array Performance Predictions	307
S.R. Baker O.B. Wilson	Continued Development of Automated Methods for In-Service Sonar Transducer Performance Monitoring	308
D.D. Cleary S. Gnanalingam	A Sounding Rocket Experiment for Remote Sensing of the Ionosphere	309
W.B. Colson J. Blau	Free Electron Laser Research	310
W.B. Colson	Free Electron Laser Research	311
W.B. Colson	Simulations of Whistler Waves in the Ionosphere	312
A.W. Cooper W.J. Lentz E.C. Crittenden, Jr. E.A. Milne	NACIT Infrared Search and Target Designation Research	313
A.W. Cooper E.A. Milne E.C. Crittenden, Jr. W.J. Lentz P.L. Walker	Environmental Effects on IR Sensor Systems	314

A.W. Cooper E.C. Crittenden, Jr. E.A. Milne G.W. Rodeback	Sea Surface Reflectivity and Laser Altimeter Testing	316
D.S. Davis	Research in Multiplexed Imaging and Imaging Spectroscopy	317
S.L. Garrett	Fiber-Optic Hydrophone Development	318
S.L. Garrett	Space Thermo-Acoustic Refrigerators	320
T.J. Hofler	Third Generation Thermoacoustic Refrigerator	321
R. Keolian	Nonlinear Dynamics of Waves and Oscillators	322
R. Keolian S. Garrett A. Larraza B. Denardo	Wave Turbulence and Soliton Dynamics	322
X.K. Maruyama	Facilities Support for the Naval Postgraduate School Linac and Flash X-Ray Machine	324
X.K. Maruyama	Novel Sources of Coherent and Quasi-Coherent Radiation	325
X.K. Maruyama	Total Dose Effects	327
X.K. Maruyama	Aircraft EMP Survivability Assessment	328
X.K. Maruyama	Unsponsored Research	329
J.R. Neighbours	Study of Mechanisms for Remote Observation of Directed Energy Beams	330
J.R. Neighbours	Characterization of Radiation from High Current Electron Beams	331
R.C. Olsen	Space Power Experiment Aboard Rocket (SPEAR)	332
R.C. Olsen	Plasma Heating at the Plasmapause	332

R.C. Olsen	Satellite Charge Control	333
F. Schwirzke X.K. Maruyama	Discharge Physics and Unipolar Arcing	334
D.L. Walters	Acoustic Sounder Characterization for the Air Force 4M Telescope at AMOS	336
D.L. Walters	Pacific Coast Mountain Atmospheric Turbulence Measurements	336
D.L. Walters	Atmospheric Optical Turbulence Developments for Adaptive Optical Programs	337
	SPACE SYSTEMS ACADEMIC GROUP	
R. Panholzer	Small Satellite Design Studies (PANSAT)	341
R. Panholzer	Thin-Film Ferroelectric Experiment (FERRO) NPS-001)	341

NAVAL POSTGRADUATE SCHOOL
1991 - PUBLICATIONS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

Published Papers	309
Published Conference Proceedings	311
Conference Presentations	312
Contribution to Book	315
Patent	316

DEPARTMENT OF ADMINISTRATIVE SCIENCES

Published Papers	317
Published Conference Proceedings	319
Conference Presentations	321
Book	325
Contribution to Books	326
Technical Reports and Notes	328

DEPARTMENT OF COMPUTER SCIENCE

Published Papers	331
Published Conference Proceedings	332
Conference Presentations	333
Technical Reports and Notes	334

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

Published Papers	335
Published Conference Proceedings	337
Conference Presentations	340
Books	343
Contributions to Books	344
Patents	345
Technical Reports and Notes	346

DEPARTMENT OF MATHEMATICS

Published Papers	347
Published Conference Proceedings	348
Conference Presentations	349
Books	350
Technical Reports and Notes	351

DEPARTMENT OF MECHANICAL ENGINEERING

Published Papers	353
Published Conference Proceedings	356
Conference Presentations	358
Contributions to Books	361
Technical Reports and Notes	362

DEPARTMENT OF METEOROLOGY

Published Papers	397
Published Conference Proceedings	399
Conference Presentations	400
Technical Reports and Notes	405

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

Published Papers	407
Published Conference Proceedings	411
Conference Presentations	412
Books	416
Contributions to Books	417
Technical Reports and Notes	418

DEPARTMENT OF OCEANOGRAPHY

Published Papers	419
Published Conference Proceedings	421
Conference Presentations	422
Books	425
Contributions to Books	426
Technical Reports and Notes	427

DEPARTMENT OF OPERATIONS RESEARCH

Published Papers	429
Published Conference Proceedings	431
Conference Presentations	432
Contributions to Books	435
Technical Reports and Notes	436

DEPARTMENT OF PHYSICS

Published Papers	439
Published Conference Proceedings	441
Conference Presentations	442
Contributions to Books	445

Patents 446
Technical Reports and Notes 447

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

The research program in the Department of Aeronautics and Astronautics is the product of the activities of the Department's five technical groups; namely, Aerodynamics, Structures, Propulsion, Flight Mechanics and Controls, and System Design (including spacecraft). Within these technical disciplines, the research effort is focussed on topics of current Navy importance. The present areas of focus are as follows:

Enhanced Maneuverability and High-Alpha Aerodynamics

A collaborative effort is underway by Professors Platzer, Chandrasekhara, Hebbar and Ekaterinaris to investigate the flow behavior around fighter configurations during high angle of attack maneuvers. The effort involves water tunnel studies of the effect of pitch rate on the vortex breakup in the flow around F-18 and X-31 aircraft models, wind tunnel studies of the effect of compressibility on the dynamic stall of airfoils, and the development of predictive computational methods based on both Navier-Stokes and viscous-inviscid interaction approaches. In related work, Professor Howard is studying canard-wing interaction for enhancing lift. Steady flow experiments with $\pm 25^{\circ}$ canard deflection have been carried out. Experiments with oscillating canard deflections are to follow. Also, a troublesome flight instrumentation problem is being examined by Professor Biblarz for the Pacific Missile Test Center.

Helicopter Aeromechanics

Three studies are ongoing. First, the unsteady aerodynamics of airfoils undergoing oscillatory motion is being studied experimentally by Professors Chandrasekhara and Platzer using a unique model actuator mechanism and applying point diffraction interferometry. Viscous computational simulation is being developed by Professor Ekaterinaris. Second, an interdisciplinary effort by Professors Wood and Kolar is the exploration of Higher Harmonic Control (HHC) for improving helicopter performance and modifying the helicopter's noise signature. The application of chaos methods to HHC is also examined here. Third, the problem of landing helicopters on ships has been tackled by Professor Healey from several viewpoints. The aerodynamics of AOR ships were studied experimentally in a wind tunnel in which the atmospheric boundary layer was properly simulated. Also, turbulence data were obtained in model tests along specific flight paths to the deck of a DD-963. Finally, vortex ring models of hovering rotors have been used to develop predictions of rotor inflows.

Structural Mechanics and Composite Materials

Because of their growing importance in aerospace applications, structures research efforts are heavily focussed on composite materials. Professor Wu has undertaken the fundamental problem of describing the time and stress dependent strength loss in composite materials. The approach is an analysis which separates fiber, matrix and interface mechanisms, and careful experiments which establish the necessary statistical strength and life data. Professor Gorman is experimenting with acoustic emission (AE) in the detection of matrix cracking in graphite-epoxy materials and debonding in adhesives. He is also assessing the potential of AE for monitoring fatigue cracks in aging aluminum aircraft.

Aircraft, Missile and Space Propulsion

Research is concentrated currently on problems related to gas turbine and solid fuel ramjet engines. Professors Shreeve, Hobson and associates have continued studies aimed ultimately at improving the stable off-design operating range of axial compressors and fans. LDV measurements and viscous code development to describe cascade blade stall are underway. An analytical and experimental study of tip-clearance effects in multi-

stage compressors was completed, while a finite element through-flow code was successfully modified to include 3D viscous effects resulting from secondary flows, tip-clearance and mixing. Alleviation of shock boundary interaction effects in transonic fans is being examined experimentally in a cascade simulation. Professors Platzer and Ekaterinaris have continued the development of viscous computational methods for predicting turbine blade heat transfer. Related to missile propulsion, Professor Netzer and his associates are conducting experiments on the combustion of boron-carbide fuels and experiments to examine the behavior of particulates in exhaust nozzles and plumes. Both light scattering techniques and particulate collection probes are applied in these studies. Also the performance of an integral-rocket solid-fuel ramjet-powered air-to-ground missile has been examined using JANNAF and AF codes, and a caseless motor was designed and tested to demonstrate feasibility. Related to space propulsion, Professor Biblarz and his student made progress in understanding low voltage, thermionic breakdown for xenon ion engines.

Flight Mechanics and Controls

Three areas of concentration are noted. Professor Howard has initiated and is developing a flight research program for unmanned air vehicles (UAV's). Fixed wing and rotary wing models are tested for the purposes of addressing problems identified in full scale programs. Nineteen flight vehicles are currently involved in the program. The most recent effort has been concentrated on a V/STOL half-scale ducted-fan technology demonstration model. Professor Schmidt is attempting to understand the phenomenon of "wing rock", which is experienced by many aircraft, with particular reference to the F-14. Professor Schmidt has also successfully addressed ship control problems aimed at improved sea keeping, and is currently studying the problem of the motion of long cables (antennas) towed by aircraft. Professor Collins has previously examined the application of neural networks in aircraft controls. Current work is aimed at applying neural networks in the identification of sonar signals, to ionospheric modeling and to PMA operator training. Work is also being conducted on neural network controllers as applied to reconfiguration of aircraft.

Spacecraft Dynamics and Controls

A new research effort has been initiated by Professor Agrawal to study effects of flexibility due to structures and liquid propellant motion on the attitude control of spacecraft. A unique apparatus has been constructed for experimental studies. An analytical model of the experimental system was developed and several classical and modern control techniques for slew maneuvers were evaluated both analytically and experimentally. A FLTSATCOM simulator is being used to develop improved spacecraft system design techniques.

Aircraft Survivability/Air Defense Lethality

Professor Ball has supported the tri-service Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) by performing a number of studies in aircraft combat survivability over the past 18 years. Among the most recent accomplishments are the development of MACSAP, a survivability assessment program on the Macintosh for use in the conceptual design of aircraft, a study of the survivability of an attack aircraft using weapon delivery tactics for the Advanced Bomb Family, and a survey of counter low observable technologies.

NPS SURVIVABILITY SUPPORT

Robert E. Ball, Professor of Aeronautics and Astronautics
Sponsor: The Joint Coordinating Group on Aircraft Survivability (JTCG/AS)
Funding: JTCG/AS

OBJECTIVE: The objective of the project is to continue the technical support provided to the JTCG/AS for the past 18 years by conducting research and performing analyses in aircraft combat survivability.

SUMMARY: This project consisted of seven tasks. They are: (1) the development of a monograph on "How to Design a Survivability Aircraft," (2) continued work on the rough draft of the 2nd edition of the PI'S AIAA textbook, "The Fundamentals of Aircraft Combat Survivability Analysis and Design," (3) continued work on the rough draft of the 2nd volume of the PI's textbook, "Aircraft Combat Survivability, the Directed Energy and Unconventional Threats," (4) the development of MACSAP, a survivability assessment program on the Macintosh for use in the conceptual design of aircraft, (5) survivability considerations in developing weapon delivery tactics for the Advanced Bomb Family (AFB), (6) survey of counter low observable technologies, and (7) reduction of the fuel system vulnerability of the F-14A. The major accomplishment during FY91 for each task was: (1) the rough draft of the monograph was begun, (2) the original textbook was scanned on to a computer disk, and the second edition was begun, (3) work from three previous theses was combined into the rough draft of one textbook, (4) Version 1.0 of the MACSAP computer program was completed and distributed to four beta sites, (5) this task was started and completed this year as a thesis, (6) this task was started in 1990 and completed this year. A classified thesis was written, and (7) this task was started this year and will be completed early in 1992.

THESES DIRECTED: Novak, M.J., classified thesis, March 1991.

Kavanagh, K.J., "Macintosh Survivability Assessment Program," MS Thesis, September 1991.

Farrell, R.E., classified thesis, MS Thesis, December 1991.

OTHER: The Macintosh Survivability Assessment Program (MACSAP) was sent to four beta sites.

SURFACE SHIP SURVIVABILITY

Robert E. Ball, Professor of Aeronautics and Astronautics
Sponsor: The Naval Sea Systems Command, Code 51122
Funding: NAVSEA

OBJECTIVE: The objective of this project is to conduct research and develop written material on the methodology used to assess the combat survivability of surface ships and on the technology used to enhance their survivability. This material will be used to further the development of survivability as a fundamental ship design discipline of equal importance with the other ship design disciplines, such as hull, mechanical, and electrical, stability, and combat systems.

SUMMARY: In developing the survivability discipline for aircraft at NPS, a number of survivability fundamentals were identified that are applicable to other weapon systems, such as surface ships. As a consequence of the universality of these fundamentals and of the importance of survivability to the effectiveness of all weapon systems, the PI proposes that the general approach developed for the survivability analysis and design of aircraft be adapted to surface ships. Basically, this approach consists of defining the combat survivability of a ship to be the ability of ship to avoid and/or withstand a man-made hostile environment. The ship avoids the hostile environment by avoiding or delaying detection and targeting by the threat sensors and by avoiding the impact of a threat weapon. The ship withstands the hostile environment by continuing to function after it is hit by the weapon. Initially, only the conventional gun and missile threats will be considered in the project. Eventually, the conventional directed energy weapons and unconventional nuclear and chemical/biological weapons will be added.

THESIS DIRECTED: Gannon, D.M., "Vulnerability Considerations During Warship Feasibility Design," Ms Thesis, September 1991.

Brovarone, T.J., "The Effects of Radar and IR Signature Reduction on the Design of Surface Combatants," Ms Thesis, December 1991.

IMPROVEMENT OF THE ALTITUDE MEASUREMENT CAPABILITY OF THE SAIP

Oscar Biblarz, Professor of Aeronautics and Astronautics
Sponsor: PMTC, Point Mugu, CA
Funding: NAVAIR

OBJECTIVE: The goal of this project is to identify the sources of error in the measurement of barometric-pressure altitude in the Navy's Service Aircraft Instrumentation Package (SAIP). Errors have been observed beyond those standard for this technique. In the long term we hope to influence new designs.

SUMMARY: Altitude measurements with the SAIP do not conform with the specifications for the probe. Errors seem to worsen with aircraft speed and altitude and, therefore, appear to be of aerodynamic origin. Our work with a second-generation SAIP [model# NCA S/N 0040, P/N 2111940-001] indicated that there is a grounding problem arising from an ambiguous specification. After correcting this, however, the probe continues to read above the static value of the pressure and we have identified the 5"-body of the SAIP as one of the culprits. We are in the process of doing more wind tunnel testing together with a computer description.

THESES DIRECTED: Eastburg, S.R., LT, USN, "An Engineering Study of Altitude Determination Deficiencies of the Service Aircraft Instrumentation Package (SAIP)," *Aeronautical Engineer* Thesis, December 1990.

Russell, R.J., LT, USN, "A Continuing Study of Altitude Determination Deficiencies of the Service Aircraft Instrumentation Package (SAIP)." MS Thesis, September 1991.

OTHER: Briefings at PMTC on 9 August 1991 and 15 October 1991. New student thesis (Engineer's) may lead to a publication during 1992.

LOW-VOLTAGE, THERMIONIC BREAKDOWN FOR XENON ION ENGINES

Oscar Biblarz, Professor of Aeronautics and Astronautics
Sponsor: Naval Research Laboratories
Funding: Naval Postgraduate School

OBJECTIVE: To better understand low-voltage thermionic discharges so that they may be implemented to ionization chambers. The advantages of low voltage operation may translate into less demand from power-conditioning equipment as well as less sputtering from energetic ions. These discharges are also of interest in many arc devices.

SUMMARY: We have arrived at an equivalent form of Paschen's law which applies to low-voltage, thermionic discharges. The key element is that there be a source of electrons at the cathode sheath prior to the formation of the arc. The small voltages observed require very small gaps so that the implementation of the scheme requires an auxiliary device such as an incandescent filament across the electrodes. NASA's work with the ionization xenon for ion engines has been scrutinized. Some preliminary modifications to this ionizer have been looked at.

CONFERENCE PRESENTATION: Biblarz, O., "Thermionic Breakdown, Aspects and Applications," 18th IEEE International Conference on Plasma Sciences, Williamsburg, VA, 3-5 June 1991.

THESIS DIRECTED: Bell, W.J., LT, USN, "Proposed Model of Thermionically Assisted Breakdown an Implementation on Electronic Thrusters," MS Thesis, December 1991.

OTHER: A publication is being prepared for submission to the IEEE Transactions on Plasma Science.

COMPRESSIBILITY EFFECTS ON AND CONTROL OF DYNAMIC STALL OF OSCILLATING AIRFOILS

M.S. Chandrasekhara, Adjunct Professor of Aeronautics and Astronautics
M.F. Platzer, Professor Aeronautics and Astronautics
Sponsor: U.S. Army Research Office
Funding: ARO

OBJECTIVE: To study the effects of compressibility on dynamic stall of oscillating airfoils and control the process of dynamic stall. The research has application in helicopter "retreating blade stall." The knowledge will be useful in extending the flight envelope of future helicopter systems. On-going program since March 1990.

SUMMARY: The flow over a helicopter "retreating" blade is being simulated in the newly built Compressible Dynamic Stall Facility (CDSF) and studied with a view to understand the basic flow physics for possible improvements in the blade design. During the reporting period, a new flow field diagnostic technique known as Point Diffraction Interferometry, (PDI), which is a real-time interferometry technique was developed and used to measure the flow field. An extensive series of tests using PDI was conducted to document the density and Mach number field over an oscillating airfoil. Also, another series of experiments was conducted that focused primarily on the flow near the airfoil leading edge. From the analysis conducted till now, it was found that the pressure coefficient when the flow stalls is the same at a given Mach number for all degrees of unsteadiness. This information will be valuable when the airfoil geometry is modified in future efforts at controlling this flow. Also, the LDV data obtained in the previous year was analyzed, papers were prepared and presented.

PUBLICATIONS: Carr, L.W., and Chandrasekhara, M.S., "Design and Development of a Compressible Dynamic Facility," *AIAA Journal of Aircraft*, forthcoming.

CONFERENCE PRESENTATIONS: Carr, L.W., Chandrasekhara, M.S., and Brock, N., "A Study of Dynamic Stall Using Real-Time Interferometry," AIAA Paper No. 91-0007 presented at the AIAA 29th Aerospace Sciences Meeting, Reno, NV, January 1991.

Chandrasekhara, M.S. and Ahmed, S., "Laser Velocimetry Measurements of Oscillating Airfoil Dynamic Stall Flow Field," AIAA Paper No. 91-1799 presented at the 22nd Fluid Dynamics, Plasma Dynamics and Lasers Conference, Honolulu, HI, 24-26 June 1991.

Carr, L.W., Chandrasekhara, M.S. and Brock, N., "A Quantitative Study of Unsteady Compressible Flow on an Oscillating Airfoil," AIAA Paper No. 91-1683 presented at the 22nd Fluid Dynamics, Plasma Dynamics and Lasers Conference, Honolulu, HI, 24-26 June 1991.

Chandrasekhara, M.S. and Van Dyken, R.D., "Velocity Measurements Around the Leading Edge of an Oscillating Airfoil Experiencing Dynamic Stall," proceedings of the 8th Symposium on Turbulent Shear Flows, 2:I-3.1-I-3.2, Münich, Germany, 9-11 September 1991.

Ahmed, S. and Chandrasekhara, M.S., "Reattachment Studies of Oscillating Airfoil Dynamic Stall Flow Field," AIAA Paper No. 91-3225, presented at the AIAA 9th Applied Aerodynamics Conference, Baltimore, MD, 23-25 September 1991.

COMPRESSIBILITY EFFECTS ON DYNAMIC STALL OF AIRFOILS UNDERGOING RAPID TRANSIENT PITCHING MOTION

M.S. Chandrasekhara, Adjunct Professor of Aeronautics and Astronautics
M.F. Platzer, Professor of Aeronautics and Astronautics
Sponsor: U.S. Air Force Office of Scientific Research
Funding: AFOSR

OBJECTIVE: To study the effects of compressibility on dynamic stall of an airfoil undergoing a rapid tamp type pitching motion with applications to supermaneuverability of fighter aircraft. On-going project since October 1989.

SUMMARY: In the reporting period, the capability of a real-time interferometry technique known as the Point Diffraction Interferometry, (PDI) was established during the last year was significantly improved to produce very high quality interferograms. This involved burning a hole through in a point diffractor plate using the laser in-situ instead of just creating a dark spot to serve as a point diffractor. Since more light is admitted by this method, better images are produced. A high power laser was acquired for the project through AFOSR funding to NASA for this purpose. Also, tools for analyzing the interferograms on an IRIS Workstation were developed. The method uses digitized images that are processed by a specially developed software package called "Digicurve" with which the interference fringes could be traced and also an undistorted airfoil could be superposed for extracting quantitative data from the fringes.

PUBLICATIONS: Carr, L.W. and Chandrasekhara, M.S., "A Study of Compressibility Effects on Dynamic Stall of Rapidly Pitching Airfoils ," *Computer Physics Communications*, 65:62-68, Elsevier Science Publishers, B.V., 1991.

Brock, N., Chandrasekhara, M.S. and Carr, L.W., "A Real Time Interferometry System for Unsteady Flow Measurements," ICIASF'91 RECORD, IEEE Publication 91CH3028-8, pp. 423-430.

Chandrasekhara, M.S., Ahmed, S. and Carr, L.W., "Schlieren Studies of Compressibility Effects on Dynamic Stall of Airfoils in Transient Pitching Motion," *AIAA Journal of Aircraft*, forthcoming.

CONFERENCE PRESENTATIONS: Carr, L.W. and Chandrasekhara, M.S., "Impact of Compressibility on Boundary Layer Environment of Dynamically Stalling Airfoils," presented at the EUROMECH 272 Colloquium on Response of Shear Flows to Imposed Unsteadiness, Aussois, France, January 1991.

Weber, B.J., Brock, N.J., Carr, L.W. and Chandrasekhara, M.S., "High Speed Cinematography of Interferometric Flow Visualization in a Rapidly Developing Flow Field," presented at the ASME/JSME Fluid Measurement and Instrumentation Forum - 1991, Portland, OR, 23-27 June 1991.

HIGH ALPHA HIGH SPEED AERODYNAMICS RESEARCH

M.S. Chandrasekhara, Adjunct Professor of Aeronautics and Astronautics
M.F. Platzer, Professor of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: To study the unsteady aerodynamic effects on an airfoil undergoing rapid maneuver such as a rapid pitch-up like that encountered in aircraft with supermaneuverability and agility capabilities.

SUMMARY: This project complements the research being carried out under funding from AFOSR and ARO. During CY-91, the software for unsteady LDV data acquisition and processing was modified to yield additional physical quantities such as vorticity distributions. A video of the processed LDV data was prepared using the existing IRIS Workstation graphics. The development of the PDI technique was also partially supported by this grant. Further, efforts at controlling the dynamics stall phenomenon using smart structures were initiated.

PUBLICATIONS: Same as in the AFOSR Project.

A STUDY OF THE FLEXURAL MODE IN ORTHOTROPIC LAMINATES

Michael R. Gorman, Associate Professor of Aeronautics and Astronautics
Sponsor: NASA Langley Research Center
Funding: NASA Langley Research Center

OBJECTIVE: To theoretically and experimentally investigate acoustic emission in composite materials which are of importance to aircraft and spacecraft. This is part of a continuing project to develop acoustic emission monitoring as a valuable and practical nondestructive evaluation technique.

SUMMARY: The interpretation of acoustic emission waveforms produced by a vertical step-like source has been treated quite successfully with classical plate theory for the case of a finite aluminum plate. This project will extend the treatment to laminated composite materials. As a first step, the frequency equation was examined and checked against experimental velocity measurements. Considerable error was discovered at the higher frequencies. This led to the use of a higher order plate theory which showed good agreement with experiment.

PUBLICATIONS: Initial results from this work should be available at the end of 1992.

CONFERENCE PRESENTATIONS: Initial results from this work were presented at the Quantitative Nondestructive Evaluation Conference.

THESIS DIRECTED: Prosser, William, H., December 1991.

HIGH-ALPHA LOW-SPEED AIRCRAFT AERODYNAMICS RESEARCH

S.K. Hebbar, Adjunct Professor of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: This is a multi-year program aimed at establishing a state-of-the-art research center for high angle-of-attack, low speed, steady/unsteady, aerodynamic studies at the Naval Postgraduate School.

SUMMARY: A low-speed experimental program on high-alpha, steady/unsteady aerodynamics was pursued in the low speed wind tunnel and the water tunnel of the Naval Postgraduate School, to carry out the investigations related to enhanced fighter maneuverability. During the period under review, the following major tasks were accomplished: (a) Flow visualization studies of a 2.3% canard-configured X-31A-like fighter aircraft model during pitching maneuvers; (b) Flow visualization studies of a 2.3% canard-configured X-31A-like fighter aircraft model during sideslipping maneuvers; (c) Visualization and wake analysis of the AN/ALQ-78 Antenna Pod; (d) Fabrication of a 2.3% X-31A-like model with an oscillating canard was completed and the bench testing of the model was in progress.

PUBLICATIONS: Hebbar, S.K., Platzer, M.F. and O.V. Cavazos, "A Water Tunnel Investigation of the Effects of Pitch Rate and Yaw on LEX Generated Vortices of an F/A-18 Fighter Aircraft Model," AIAA-91-0280, January 1991.

Hebbar, S.K., Platzer, M.F. and Kwon, H.M., "Static and Dynamic Water Tunnel Flow Visualization Studies of a Canard-Configured X-31A-like Fighter Aircraft Model," AIAA-91-1629, June 1991.

Hebbar, S.K. and Platzer, M.F., "Static and Dynamic Water Tunnel Study of a Canard-Configured X-31A-like Fighter Aircraft Model," in proceedings of the HTP-5 Workshop on Vortical Flow Breakdown and Structural Interactions, Hampton, VA, August 1991.

CONFERENCE PRESENTATIONS: Hebbar, S.K., Platzer, M.F., Park, S.N. and Cavazos, O.V., "A Dynamic Flow Visualization Study of a Two-Percent F/A-18 Fighter Aircraft Model at High Angles of Attack", NASA High-Angle-of-Attack Technology Conference, Hampton, VA, 30 October - 1 November 1990.

Hebbar, S.K., Platzer, M.F. and Cavazos, O.V., "A Water Tunnel Investigation of the Effects of Pitch Rate and Yaw on LEX Generated Vortices of an F/A-18 Aircraft Model," AIAA 29th Aerospace Sciences Meeting, Reno, NV, 7-10 January 1991.

Hebbar, S.K., Platzer, M.F. and Kwon, H.M., "Static and Dynamic Water Tunnel Flow Visualization Studies of a Canard-Configured X-31A-like Fighter Aircraft Model," AIAA 22nd Fluid Dynamics, Plasma Dynamics and Lasers Conference, Honolulu, HI, 24-26 June 1991.

Hebbar, S.K. and Platzer, M.F., "Static and Dynamic Water Tunnel Study of a Canard-Configured X-31A-like Fighter Aircraft Model," NASA HTP-5 Workshop on Vortical Flow Breakdown and Structural Interaction, Hampton, VA, 15-16 August 1991.

THESES DIRECTED: Small, J.F., LCDR, USN, "Flow Visualization and Wake Analysis for Standard and Modified Configurations of the AN/ALQ-78 Antenna Pod," Aeronautical Engineer Thesis, March 1991.

Kim, C.H., Major, Korean Air Force, "Flow Visualization Studies of a Sideslipping, Canard-Configured X-31A-like Fighter Aircraft Model," MS Thesis, December 1991.

OTHER: The results of the wind tunnel investigation on the AN/ALQ-78 antenna pod will be presented in the AIAA 30th Aerospace Sciences Meeting, Reno, Nevada, 6-9 January 1992. The results of the water tunnel investigation on the canard-configured X-31A-like model during sideslipping have been submitted for presentation in proceedings of the 5th Asian Congress of Fluid Mechanics, Seoul, Korea, 10-14 August 1992. Two papers due to appear in the Journal of Aircraft; one

deals with the wind tunnel investigation on YF-17 model (November - December 1992 issue), the other with the water tunnel investigation on F/A-18 model (July -August 1992 issue).

SMALL SCALE WIND TUNNEL INVESTIGATION OF F/A-18 AIRCRAFT AT HIGH ANGLES OF ATTACK

S.K. Hebbar, Adjunct Professor of Aeronautics and Astronautics
M.F. Platzer, Professor of Aeronautics and Astronautics
Sponsor: NASA Ames Research Center
Funding: NASA Ames Research Center (non-monetary support)

OBJECTIVE: This is the continuation of the second project of a series of cooperative studies of F/A-18 between the Aero/Astro Department of the NPS and the Fixed-Wing Aerodynamics Branch of NASA Ames Research Center and is aimed at studying the interaction between the F/A-18's LEX vortex and the vertical tail surfaces, with and without the LEX fences.

SUMMARY: A low speed investigation was conducted in the NPS wind tunnel to examine the vortex wake downstream of a 3% scale model of the YF-17 lightweight fighter prototype at high angles of attack. The study was in support of NASA-Ames Research Center's ongoing investigation of a full scale F/A-18 in the NASA-Ames 80-ft X 120-ft wind tunnel as part of NASA's High Alpha Technology Program. During the period under review, the data from vortical flowfield surveys and power spectra measurements in the vortex wake, with and without the LEX fences, were analyzed and the trends compared with the limited data available in the literature and a summary report on the test results submitted to NASA Project Director, NFAC F-18 High Alpha Test.

THESES DIRECTED: Frank, W.D., Jr., MAJ, USA, "Hot-Wire Surveys in the Vortex Wake Downstream of a Three-Percent Fighter Aircraft Model at High Angles of Attack," MS Thesis, December 1990.

OTHER: A Technical Note on this investigation is under preparation for publication in a journal.

ADVANCED DEVELOPMENT RESEARCH PROGRAM FOR JOINT-SERVICE UNMANNED AIR VEHICLES

R.M. Howard, Assistant Professor of Aeronautics and Astronautics
Sponsor: Unmanned Aerial Vehicles Joint Project Office
Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this project was to investigate developing technologies applicable to the Maritime Unmanned Air Vehicle mission.

SUMMARY: UAVs have found a useful role for combat surveillance. Yet current launch-and-recovery techniques aboard the battleship have lead to other options for fleet management of the air vehicles. Future systems will operate from small surface combatants, and will require the ability to takeoff and land vertically. Other concerns involve desk safety, leading to a desire for shrouded propellers or rotors in future configurations. A half-scale ducted-fan technology-demonstrator radio-controlled aircraft has been designed and built. The 6 foot-span, 25-pound air vehicle was built to fly in vertical (hover) and horizontal (conventional) modes to compare the tradeoffs between the two flight regimes and to explore the requirements for stability augmentation in hovered flight. To date, bench tests have been performed to quantify the roll effectiveness of the wake vanes, the thrust capabilities of various propeller configurations, and the power output of the engine in use. Continued testing will lead to inputs to be used in the full-scale development.

PUBLICATIONS: Howard, R.M., Tanner, J.C. and Lyons, D.F., "Flight Test Investigation of the Aerodynamic Performance of a Half-Scale Unmanned Air Vehicle," *Journal of Aircraft*, forthcoming.

Howard, R.M., "Airfoil Design for Endurance Unmanned Air Vehicles," *Journal of Aircraft*, 27(11): 971-973, February 1991.

THESES DIRECTED: Bray, R.M., "A Wind-Tunnel Study of the Pioneer Remotely Piloted Vehicle," MS Thesis, June 1991.

Aitcheson, K.R., "Stability and Control Flight Testing of a Half-Scale Pioneer Remotely Piloted Vehicle," MS Thesis, September 1991.

Wilhelm, K.T., "Development and Testing of An Unmanned Air Vehicle Telemetry System," MS Thesis, September 1991.

CANARD/WING INTERACTION FOR ENHANCED LIFT IN AIRCRAFT SUPERMANUEVERABILITY

R.M. Howard, Assistant Professor of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this project was to investigate the lift-enhancing interactions between a close-coupled canard and swept wing for a static and an oscillating canard.

SUMMARY: Canards located in close proximity to highly swept wings are known to lead to increased lift due to the interaction between the canard and wing leading-edge vortices. Few studies in the past, however, considered any optimum canard deflection for enhancement; most studies used co-planar wings and canards. Also of interest was whether dynamic-stall effects from an oscillating canard may be used to further enhance the vortex-vortex interaction. In the static experiment, canard deflections were varied from +25 to -25 degrees. Lift enhancements of up to 34 percent were found, with a maximum being in the first post-stall regime at 22 degrees angle of attack. Optimum canard deflection provided from five (5) to 40 percent of the enhancement over the co-planar case. The oscillating-canard experiments are continuing.

PUBLICATIONS: Howard, R.M. and Gwilliam, Jr., D.J., "Post-Stall Airfoil Response to a Periodic Freestream," *Journal of Aircraft*, 28(11):799-800, November 1991.

CONFERENCE PRESENTATIONS: Howard, R.M. and Kersh, J.M., Jr., "Effect of Canard Deflections on Enhanced Lift for a Close-Coupled Canard Configuration," AIAA Paper 91-3222, AIAA 9th Applied Aerodynamics Conference, Baltimore, MD, 23-25 September 1991.

Gwilliam, D.J., Jr. and Howard, R.M., "Time-Dependent Post-Stall Airfoil Behavior in a Periodic Wake Flow," AIAA Paper 91-0431, AIAA 29th Aerospace Sciences Meeting, Reno, NV, 7-10 January 1991.

THESIS DIRECTED: Kersh, J.M., Jr., "Lift Enhancement Using Close-Coupled Canard/Wing Vortex Interaction," MS Thesis, December 1990.

PARTICULATE BEHAVIOR IN EXHAUST NOZZLES AND PLUMES OF SOLID PROPELLANT ROCKET MOTORS

D.W. Netzer, Professor of Aeronautics and Astronautics
D. Laredo, NRC Research Associate
Sponsor: Air Force Phillips Laboratory
National Research Council
Funding: Air Force Phillips Laboratory

OBJECTIVE: Validate a combined light scattering/particulate collection probe for particle characterization in exhaust plumes. Use the probe, multiple-wavelength light transmission measurements, and through-motor laser scattering measurements to measure plume and across-nozzle particle size distributions and plume optical properties as a function of metal loading and motor operating conditions. Correlate plume IR signature with particle characteristics. Initiate investigation of high temperature optical properties of aluminum oxide. This is a continuing investigation.

SUMMARY: Initial validation of the combined optical probe was completed and it was used to measure the variation in particle size distribution along the plume axis. At the nozzle exit the particle size distribution was quadra-modal with most particles (>90%) smaller than 1μ and the largest particles with diameters less than 25 μ. Larger particles were not present in measurable quantities further aft in the plume, apparently due to breakup by plume Mach discs. Particle size distributions were also measured just above the propellant surface and at the nozzle entrance using a windowed motor with different aluminum loadings and chamber pressures. At the nozzle entrance the particle size distribution was bi-modal and in the plume, tri- or quadra-modal. Most particles were again <1μ in diameter (50-90% at the nozzle entrance, >90% in the plume). D_{32} was 132 μ above the propellant surface, 4-5 μ at the nozzle entrance and 1-2 μ in the plume. Multiple wavelength light transmission measurements made in the edge of the plume consistently showed that particles in this region have D_{32}= 0.150 $\pm$ 0.006 μ, σ= 1.50 $\pm$ 0.04 and m= 1.63 $\pm$ 0.13. Plume IR and thermocouple measurements indicated that the effective plume emissivity was approximately 0.16 and that significant afterburning occurred between 8-16 nozzle exit diameters from the nozzle exit. The air heater, IR microscope, fast-scan imaging software and hardware and the test apparatus were assembled for utilization in FY92 to examine the high temperature optical properties of aluminum oxide.

PUBLICATIONS: Brennan, W.D., Hovland, D.L. and Netzer, D.W., "Measured Aluminum/Aluminum Oxide Particle Behavior in a Subscale Solid Propellant Rocket Motor," *Journal of Propulsion and Power*, forthcoming.

CONFERENCE PRESENTATIONS: Laredo, D., Kellman, L.J., Eno, T. and Netzer, D.W., "Particulate Behavior in Exhaust Nozzles and Plumes," CPIA Pub. 568:691-698, 19th JANNAF Exhaust Plume Technology Meeting, Huntsville, AL, 13-16 May 1991.

Thorn, L.B. and Netzer, D.W., "Terminology and Classification of Propellant Exhaust Smoke Signature," CPIA Pub. 568:437-444, 19th JANNAF Exhaust Plume Technology Meeting, Huntsville, AL, 13-16 May 1991.

THESES DIRECTED: Kellman, L.J., "Modification and Experimental Validation of a combined Optical and collection Probe for Solid Propellant Exhaust Analysis," MS Thesis, March 1991.

Kim, H.-O., "Multiple Wavelength Transmission Measurements in Rocket Plumes," MS Thesis, September 1991.

Racine, J.A., "Subscale Solid Rocket Motor Infrared Signature and Particle Behavior," MS Thesis, December 1991.

COMBUSTION BEHAVIOR OF SOLID FUEL RAMJETS AND BORON/BORON CARBIDE PARTICLES

D.W. Netzer, Professor of Aeronautics and Astronautics
B. Natan, NRC Research Associate
Sponsor: Naval Weapons Center
National Research Council
Funding: Naval Weapons Center
National Research Council

OBJECTIVE: Determination of the effects of motor operating conditions and fuel composition on plume signature, determination of the feasibility of a low-cost IRR-SFRJ, investigation of the combustion characteristics of solid fuel scramjet combustors, measurements of the surface and near-surface temperatures and the burning rates of boron and boron carbide in air with various mole fractions of oxygen and determination of the effects of bypass air on the combustion of boron carbide loaded fuel grains.

SUMMARY: The IR signature of PMM, HTPB and HTPB with Al, Si, B_4C and Mg fuels were measured with equivalence ratios from 0.3-1.4. Plume irradiance increased approximately as the 2^{ND} power of the actual combustor stagnation temperature. Analytical design of an integral-rocket SFRJ powered air-to-ground missile capable of being fired from a RPV or helicopter was accomplished using current JANNAF and Air Force computer codes. The results showed that an IRSFRJ powered missile can exceed the velocity and range of current systems by more than a factor of two, without an increase in missile length or weight. A caseless IRSFRJ with a non-ejecting port cover was designed and successfully tested. Rocket-ramjet transition was demonstrated and ramjet ignition was found to be insensitive to the booster-tailoff/air-injection timing sequence. Diverging port area PMM grains were used together with an upstream mixed supersonic-subsonic flame holding region and a small amount of hydrogen bleed to demonstrate the feasibility of a supersonic combustion SFRJ. With combustor inlet conditions of 150 psia, 1000 R and M = 1.5, a combustor exit Mach number of approximately 1.4 was maintained. Combustion efficiencies in the initial geometries were between 57-75%. It was shown that the combustion efficiency of B_4C can be significantly increased by employing high bypass ratios with low dump momentum; the result of good mixing of bypass air with B_4C particles which are ignited upstream within the fuel grain. Increased pressure increased efficiency, apparently through increased residence time. Increased overall equivalence ratio (grain length) also increased efficiency, the result of a smaller percentage of larger particles which are generated within the recirculation zone. The air heater, IR microscope, fast-scan imaging software and the test apparatus were assembled for utilization in FY92 to examine the ignition and combustion characteristics of boron and boron carbide.

PUBLICATIONS: Karadimitris, A., Scott III, C., Gany, A. and Netzer, D., "Regression and Combustion Characteristics of Boron Containing Fuels in Solid Fuel Ramjets," *Journal of Propulsion and Power*, 7(3):341-347, May-June 1991.

Wooldridge, R.C. and Netzer, D.W., "Ignition and Flammability Characteristics of Solid Fuel Ramjets," *Journal of Propulsion and Power*, 7(5):846-848 September-October 1991.

Lee, T.-H. and Netzer, D.W., "Temperature Effects on Solid Fuel Ramjet Fuel Properties and Combustion," *Journal of Propulsion and Power*, forthcoming.

Campbell, Jr., W.H., Ko, B.N., Lowe, S.R. and Netzer, D.W., "Solid Fueled Ramjet Regression Rate/Thrust Modulation," *Journal of Propulsion and Power*, forthcoming.

Natan, B. and Netzer, D.W., "Experimental Investigation of the Effects of Bypass Air on Boron Combustion in a Solid Fuel Ramjet," in proceedings of the 2^{ND} International Symposium on Special Topics in Chemical Propulsion: Combustion of Boron-Based Solid Propellants and Solid Fuels,

forthcoming.

Nabity, J., Lee, T., Natan, B. and Netzer, D., "Combustion Behavior of Boron Carbide Fuel in Solid Fuel Ramjets," in proceedings of the 2ND International Symposium on Special Topics in Chemical Propulsion: Combustion of Boron-Based Solid Propellants and Solid Fuels, forthcoming.

Vaught, C., Witt, M., Gany, A. and Netzer, D., "An Investigation of Solid-Fuel, Dual Mode Combustion Ramjets," *Journal of Propulsion and Power*, forthcoming.

CONFERENCE PRESENTATIONS: Netzer, D.W., "Solid Fueled Ramjet Investigations at the Naval Postgraduate School," Air/Surface Launched Weaponry Propulsion 6.2 Program Technology Exchange, Naval Weapons Center, 5-6 March 1991.

Nabity, J., Lee, T., Natan, B. and Netzer, D., "Combustion Behavior of Boron Carbide Fuel in Solid Fuel Ramjets," 2ND International Symposium on Special Topics in Chemical Propulsion: Combustion of Boron-Based Solid Propellants and Solid Fuels, Lampoldshausen, Germany, 4-6 March 1991.

Natan, B. and Netzer, D.W., "Experimental Investigation of the Effects of Bypass Air on Boron Combustion in a Solid Fuel Ramjet", 2ND International Symposium on Special Topics in Chemical Propulsion: Combustion of Boron-Based Solid Propellants and Solid Fuels, Lampoldshausen, Germany, 4-6 March 1991.

Natan, B. and Netzer, D.W., "The Effects of Bypass Air on Boron Carbide Combustion in a Solid Fuel Ramjet," 28TH JANNAF Combustion Subcommittee Meeting, San Antonio, Texas, 28 October - 1 November 1991.

Natan, B. and Netzer, D.W., "Experimental Investigation of Boron Carbide in a Solid Fuel Ramjet with Bypass Air," 7TH Israeli Combustion Meeting, The Combustion Institute, Jerusalem, 14 November 1991.

THESES DIRECTED: Fruge', K.J., "Design and Testing of a Caseless Solid-Fuel Integral-Rocket-Ramjet Engine for Use in Small Tactical Missiles," MS Thesis, September 1991.

Angus, W.J., "An Investigation Into the Performance Characteristics of a Solid Fuel Scramjet Propulsion Device," MS Thesis, December 1991.

Luehrsen, R.S., "Solid Fuel Ramjet Infrared Signature," MS Thesis, December 1991.

EXERGY METHODS FOR AIRCRAFT DESIGN

C.F. Newberry, Professor of Aeronautics and Astronautics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to identify a methodology for using exergy as an aerospace vehicle design tool.

SUMMARY: Research publications related to exergy were examined to ascertain the extent to which exergy has been used to support aerospace vehicle analysis/design. Attention was given to simple models of vehicle components/flowfields. Consideration was given to methodologies which permit an assessment of the degree to which exergy can be used as a design and design optimization tool.

OTHER: It is expected that the PI will prepare a technical paper(s) describing study results when they are available.

UNSTEADY HEAT TRANSFER ON TURBINE BLADES

M.F. Platzer, Professor of Aeronautics and Astronautics
J.A. Ekaterinaris, Adjunct Professor of Aeronautics and Astronautics
Sponsor: NASA Lewis Research Center
Funding: NASA Lewis Research Center

OBJECTIVE: Develop a general method for the prediction of heat transfer on turbine blades subjected to flow unsteadiness.

SUMMARY: A general method was developed for calculating the unsteady heat transfer on turbine blades. It is based on the numerical solution of the unsteady boundary layer equations for laminar, transitional, and turbulent flows in combination with an inviscid panel code for airfoils in general unsteady motion. Heat transfer rates were calculated for airfoils subjected to a ramp change in angle of attack. Furthermore, a compressible unsteady Navier-Stokes solver was developed and applied to the computation of the heat transfer rates past steady and oscillating NACA 0012 airfoils.

PUBLICATION: Jang, H.M., Ekaterinaris, J.A., Platzer, M.F., and Cebeci, T., "Essential Ingredients for the Computation of Steady and Unsteady Blade Boundary Layers," *ASME Journal of Turbomachinery*, 13:608-616, October 1991.

AIRCRAFT AND JET ENGINE UNSTEADY FLOW COMPUTATIONS

M.F. Platzer, Professor of Aeronautics and Astronautics
J.A. Ekaterinaris, Adjunct Professor of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: Develop computational methods and obtain computational solutions for steady and unsteady flows over fighter aircraft configurations and helicopter blades at high angles of attack and through jet engine compressors and turbines.

SUMMARY: Two- and three- dimensional compressible Navier-Stokes computations were completed to study the dynamic stall characteristics of oscillating and rapidly pitching airfoils and the vortical flow and the vortex breakdown characteristics on delta and double-delta wings at high angles of attack.

CONFERENCE PRESENTATIONS: Ekaterinaris, J.A., Coutley, R.L., Schiff, L.B., and Platzer, M.F., "Numerical Investigation of the Flow over a Double-Delta Wing at High Incidence," AIAA Paper No. 91-0753, AIAA 29th Aerospace Sciences Meeting, Reno, NV, 7-11 January 1991.

Grohsmeyer, S.P., Ekaterinaris, J.A., and Platzer, M.F., "Numerical Investigation of the Effect of Leading-Edge Geometry on Dynamic Stall of Airfoils," AIAA Paper No. 971-1798, AIAA 22nd Fluid Dynamics, Plasma Dynamics and Lasers Conference, Honolulu, Hawaii, 24-26 June 1991.

Clarkson, J.D., Ekaterinaris, J.A. and Platzer, M.F., "Computational Investigation of Airfoil Stall Flutter," 6th International Symposium on Unsteady Aerodynamics, Aeroelasticity, and Aeroacoustics of Turbomachines and Propellers, University of Notre Dame, Indiana, 15-19 September 1991.

DYNAMIC LIFT STUDIES FOR ENHANCED FIGHTER MANEUVERABILITY

M.F. Platzer, Professor of Aeronautics and Astronautics
S.K. Hebbar, Adjunct Professor of Aeronautics and Astronautics
J.A. Ekaterinaris, Adjunct Professor of Aeronautics and Astronautics
Sponsor: Naval Air Warfare Center/Aircraft Division Warminster
Funding: Naval Air Warfare Center/Aircraft Division Warminster

OBJECTIVE: Identify promising methods for the generation and exploitation of dynamic lift. To this end, perform detailed experimental and computational studies on double delta wings and complete aircraft configurations in dynamic motion.

SUMMARY: Three-dimensional compressible Navier-Stokes calculations were completed for double-delta wings undergoing harmonic pitch oscillations at high incidence. Also, water tunnel studies were completed on F/A-18 and X-31 aircraft models to identify the vortex breakdown phenomena in dynamic motion.

CONFERENCE PRESENTATIONS: Ekaterinaris, J.A. and Schiff, L.B., "Navier-Stokes Solutions for an Oscillating Double-Delta Wing," AIAA Paper No. 91-1624, AIAA 22nd Fluid Dynamics, Plasma Dynamics, and Lasers Conference, Honolulu, HI, 24-26 June 1991.

Hebbar, S.K., Platzer, M.F., and Cavazos, O.V., "A Water Tunnel Investigation of the Effects of Pitch rate and Yaw on LEX Generated Vortices of an F/A-18 Fighter Aircraft Model," AIAA Paper No. 91-0280, 29th Aerospace Sciences Meeting, 7-11 January 1991.

Hebbar, S.K., Platzer, M.F., and Kwon, H.M., "Static and Dynamic Water Tunnel Flow Visualization Studies of a Canard-Configured X-31-Like Fighter Aircraft Model," AIAA Paper No. 91-1629, AIAA 22nd Fluid Dynamics, Plasma Dynamics, and Lasers Conference, Honolulu, Hawaii, 24-26 June 1991.

STABILITY AUGMENTATION FOR IMPROVING SURFACE SHIP SEAKEEPING

L.V. Schmidt, Professor of Aeronautics and Astronautics
Sponsor: Office of Naval Technology
Funding: Naval Postgraduate School

OBJECTIVE: Improve ship seakeeping by active control means for the purpose of increasing ship operational effectiveness as might be needed for encounters in high sea states of Northern Latitudes.

SUMMARY: The principles of active control using ship rudder roll stabilization (RRS) are becoming accepted on an international basis as an effective means of reducing ship roll response due to the actions of sea-surface wave forcing functions. The NPS sponsored research work has resulted in: (a) Identification of an adaptive (digital) filter concept that linearizes the current irregular, nonlinear behavior of the steering machinery as found on the Spruance and Ticonderoga ship classes; (b) Development of a Random Decrement procedure for analyzing ship roll angle time histories for the determination of roll resonance modal damping and frequencies; and (c), Related analyses to improve understanding of ship lateral-directional dynamics.

PUBLICATIONS: Schmidt, L.V., "An Adaptive Filter Study for Application to Ship Steering Machinery," accepted for publication by the ASNE Naval Engineering Journal after final editing, December 1991.

THESES DIRECTED: Wiser, M.K., LT., "Ship Roll Mode Extraction from Sea Trial Data," MS Thesis, September 1991.

Wendel, M.W., LT., "The Effects of Shipboard Steering Machinery Dynamics on Rudder Roll Stabilization," MS Thesis, September 1991.

AIRCRAFT WING ROCK BY INERTIAL COUPLING

L.V. Schmidt, Professor of Aeronautics & Astronautics
Sponsor: Principal Investigator

OBJECTIVE: Identify features of aircraft nonlinear flight mechanics which may contribute to limit-cycle motions colloquially defined as "wing rock".

SUMMARY: The term "wing rock" is used to describe the rocking motion of an aircraft about its longitudinal axis. Numerous high-performance aircraft (e.g., A-4, T-38, F-4, F-5, F-14, F-18, etc.) have shown this trait, usually when in flight near to stall onset. A candidate mechanism for a wing-rock limit cycle is the inertial coupling between an unstable lateral-directional (Dutch-Roll) mode with a stable longitudinal (Short Period) mode. Coupling is provided by the nonlinear interactions of inertially related terms in the complete set of motion equations. Further studies were made using F-14 reference data provided by Grumman Aircraft Co. The F-14 is known to experience wing rock at angles of attack above 20 degrees, which has an adverse effect upon flight scenarios such as during critical phases of one-on-one combat. The studies indicated that Dutch-Roll instabilities were so large that the nonlinear coupling was distorted using linear stability derivatives. Future studies require that the aerodynamics be modeled by table look up methods rather than Taylor series approaches.

PUBLICATIONS: Schmidt, L.V. and Wright, S.R., "Aircraft Wing Rock by Inertial Coupling," *AIAA Journal of Aircraft*, forthcoming.

Schmidt, L.V. and Wright, S.R., "Aircraft Wing Rock by Inertial Coupling," in proceedings of the AIAA Atmospheric Flight Mechanic Conference, New Orleans, LA, August 1991.

TOWED CABLE DYNAMICS

L.V. Schmidt, Professor of Aeronautics and Astronautics
Sponsor: Principal Investigator

OBJECTIVE: The goal is to identify an aircraft control law that is suitable for reducing cable motion experienced by an aircraft when towing a long cable while orbiting in a steady, banked turn at constant altitude.

SUMMARY: The U.S. Navy has an operational need to tow a long, antenna-like cable behind an aircraft that is holding a constant-altitude circular orbit. Because of unsteady weather experienced by the cable during its motion at lower altitudes, cable dynamics are incurred which in some cases has resulted in physical contact of the cable with the horizontal tail of the host aircraft. Studies have included: (a) Develop numerical models for identifying the static equilibrium position of the cable with inclusion of both aerodynamic and inertial terms acting on the cable; (b) Dynamically model the cable by a "Hanging Chain" with lengths corresponding to that of the cable; and (c), Planning of wind-tunnel tests to improve aerodynamic modelling of the cable. Results of the first dynamic approximations indicate that a potential exists for the first and second lateral motion modes of the hanging chain to couple with the excitation caused by the aircraft turn rate during representative orbit conditions.

OTHER: Two (2) students are currently performing graduate level research in support of the program.

COMPOSITE RELIABILITY IN SUBMARINE APPLICATIONS

Edward M. Wu, Professor of Aeronautics and Astronautics
Sponsor: Defense Advance Research Agency
Funding: DARPA Submarine Technology Program & Materials

OBJECTIVE: Analytically model the reliability of composite for tension dominated submarine applications by relating the strength statistics of the parent fiber filaments to the strength variability of the composite through mathematical modeling of the underlying failure process.

SUMMARY: Strength size effect (small-weak, large-strong) prediction and zero reject of large composite structures via quality assurance fiber filament strength statistics. Experimental measurements have been carried out on graphite fiber strength. Significant experimental data base for the single filament strength (400 samples each from two lots) has been established. Composites has been fabricate from the very same fiber spools and were tested for a definite assessment of the analytical model. Exceptional correlation between theory and data were observed. This experimentally verified model led to the identification of the special requirements for proof test of composites. Two proof test methods are developed. They are relevant to the certification and acceptance of critical composite structures and to the development of manufacturing process to achieve zero-reject for very large composite structures.

PUBLICATION: Wu, Edward M. and Bell, David M., LT, "Proof Test Methodology for Composites," in proceedings of the 9th DoD/NASA/FAA Conference on Fibrous Composites in Structural Design.

FAN & COMPRESSOR STALL

R.P. Shreeve, Professor of Aeronautics and Astronautics
I.N. Moyle, Ph.D. Candidate, University of Tasmania, Australia
A.C. Ucer, NRC Senior Research Associate
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: Investigations of phenomena which limit the off-design stable operating range of aircraft axial compressors and fans with a view to developing improved off-design performance prediction and therefore improved designs.

SUMMARY: Progress was made in three areas. First, the investigation of near-stalling flow in a subsonic cascade was continued and is reported by G.V. Hobson in MEASUREMENT AND COMPUTATION OF TURBOMACHINERY FLOWS. Second, further considerations of data from measurements in a two stage axial compressor led to a refinement of the explanation given of the effects of rotor tip clearance. The completed study was presented at the ASME 1991 IGTI meeting. Third, an axisymmetric throughflow code for multi-stage axial compressors was successfully modified to include the modelling of 3-D viscous effects which result from secondary, tip clearance flows and mixing. The code was applied the Pratt & Whitney 3S1 low aspect ratio 3-stage compressor and the UTRC 2-stage research compressor with promising results.

PUBLICATION: Shreeve, R.P., Elazar, Y., Dreon, J.W. and Baydar, A., "Wake Measurements and Loss Evaluation in a Controlled Diffusion Compressor Cascade," *Transactions of the ASME, Journal of Turbomachinery*, 113(4):591-599, October 1991.

CONFERENCE PRESENTATIONS: Moyle, I.N., Walker, G.J. and Shreeve, R.P., "Stator Averaged Rotor Blade-to-Blade Near Wall Flow in a Multistage Axial Compressor with Tip Clearance Variation," ASME Paper 92-GT-30 presented at the International Gas Turbine and Aeroengine Congress and Exposition, Orlando, FL, 3-6 June 1991.

Hobson, G.V. and Shreeve, R.P., "Inlet Turbulence Distortion and Viscous Flow Development in a Controlled-Diffusion Compressor Cascade at Very High Incidence," AIAA-91-2004 Paper presented at the AIAA/SAE/ASME/ASEE 27th Joint Propulsion Conference, Sacramento, CA, 24-26 June 1991.

THESIS DIRECTED: Moyle, I.N., "An Experimental and Analytical Study of Tip Clearance Effects in Axial Flow Compressors," Ph.D. Thesis submitted to the University of Tasmania, December 1991.

FAN SHOCK-BOUNDARY LAYER SEPARATION ALLEVIATION

R.P. Shreeve, Professor of Aeronautics and Astronautics
Sponsor: Naval Air Systems Command
Funding: Naval Air Systems Command

OBJECTIVE: To explore the effectiveness of passive low-profile vortex generators and vortex generating jets in reducing losses due to passage shock-boundary layer interaction in a simulated fan blade passage.

SUMMARY: Higher relative Mach numbers in advanced aircraft fans can result in the losses increasing as a result of growing regions of shock-induced boundary separation. Axisymmetric duct tests have shown that 'low profile' vortex generators can reduce the size of shock-induced separation regions. An experiment is underway to examine the benefits of vortex devices in a model simulation of the relative flow through transonic fan passages. Two adjacent fan passages are simulated in a two-dimensional blow-down wind tunnel at a Mach number of 1.4. The test section provides naturally aspirated bleed of all incoming boundary layers and flush-mounted windows within the blade passages. A back-pressure valve is used to control shock location and therefore pressure ratio. Following initial tests, the back pressure valve was redesigned to use hydraulic actuation, and shadowgraph movies were subsequently obtained of the unsteady shock structure. Pressure instrumentation has since been added to blade and side wall surfaces and a survey probe for loss measurements is planned. An Euler code was used to compute the reference flow field and qualitative agreement was observed in the wave structure in the supersonic region. A thin layer Navier-Stokes code is being used currently.

THESIS DIRECTED: Collins, C., "Preliminary Investigation of the Shock-Boundary Layer Interaction in a Simulated Fan Passage," A. Eng. Thesis, March 1991.

DEPARTMENT OF ADMINISTRATIVE SCIENCES

DEPARTMENT OF ADMINISTRATIVE SCIENCES

The Department of Administrative Sciences is responsible for academic programs designed to educate officers and DOD civilians in a variety of functional management specialties. The diversity of the faculty's professional expertise and scholarship is reflected in the wide variety of research projects conducted in the department.

In addition to permanent faculty, the department's research efforts have been augmented by the participation of a number of adjunct professors. The research projects cover a broad range of public sector management issues, ranging from basic scholarly research projects to applied research designed to assist policy makers and operational decision makers. For ease of exposition the research projects are grouped into the following functional areas: acquisition; logistics and transportation; computer and information systems; financial management; manpower, personnel, and training analysis; and policy analysis, management, and communications.

Acquisition

Professors D. Boger and S. Liao continued a multi-year, direct funded project under the sponsorship of the Naval Air Systems Command, Cost Analysis Division. The objective of the project is to develop parametric cost estimation models for aircraft modification (MOD) programs. In this phase, data on three aircraft modification or derivative programs were obtained. Also supported by NAVSEA's Cost Analysis Division, **Professor Doug Moses** began a direct funded project that compares the quality of cost forecasts produced by two standard cost estimation models: the learning curve and the production rate adjustment model.

Logistics and Transportation

In the logistics area, **Professor A. McMasters** continued his long-term research effort to develop improved wholesale inventory models under the sponsorship of Navy Fleet Material Support Office. **Professor Keebom Kang** collaborated with several professors in the O.R. Department on an on-going project for the Naval Weapons Support Center, Crane, Indiana, studying reliability performance measures for major caliber ammunition used in the Naval Gunfire Support System. **Professor D. Trietsch** continued his work for the Naval Sea Systems Command prioritizing set-up reduction times in shipyard repair operations. This project is part of an effort to implement TQM methods in Naval Repair Facilities.

Computers, Information and Communication Systems

The NPS Research Council supported the research efforts of several faculty members in the IS area. **Professor Hemant Bhargava** undertook a direct funded project on the design of computer systems to assist human modelers in the formulation of mathematical models. **Professor B. Ramesh** started a direct funded project to develop an environment to support various stakeholders involved in systems development by reasoning with design rational knowledge. **Professor K. Sengupta** continued a direct funded project aimed at developing design principles for incorporating feedback in group decision support systems. He started a second project aimed at investigating distributed decision making in Naval command teams in uncertain, risky environments.

Professor M. Suh started a direct funded project to identify an interoperable telecommunication infrastructure of EDI and to develop mathematical models for a minimum cost design of the system. **Professor N. Schneidewind** received funding from the Naval Surface Warfare Center to continue his research on enhancing his software reliability model. Professor Schneidewind also received reimbursable funding from the U.S. Army

Operational Test and Evaluation Command to develop a set of validated metrics for the Army's STEP program. **Professor M. Kamel** started a direct funded project to develop a comparative methodology to evaluate risk assessment methods and tools for their suitability to a particular organizational situation. **Professor Dani Zweig** continued a direct funded project to identify and quantity factors that determine the success of efforts to reuse existing software for new application systems.

Professors M. McCaffrey, T. Bui, T. Abdel-Hamid, D. Zweig, M. Kamel, and K. Sengupta completed a 2-year reimbursable effort funded by the Office of the Assistant Secretary of Defense (Director of Defense Information) that analyzed the effectiveness of ADA in DoD's management information system. **Professor Bui** also started a 2-year effort for OASD (Director of Defense Information) to conduct case studies on the implementation of management information systems in DoD. Finally, Professor Bui started a reimbursable project for the Army's TRADOC Analysis Command, Monterey, on the analysis, design, implementation, and verification of a single exercise analysis system (SEAS) prototype for combat training.

Financial Management

Professors D. Dolk and K. Euske collaborated on a direct funded project sponsored by the Naval Supply Systems Command to analyze the management control and information systems that supports the RAMP project, which is concerned with developing highly automated manufacturing facilities using advance robotics. **Professors Euske, Jones, and J. McCaffery** continued an on-going direct funded project analyzing the effect of the resource allocation process on CINCPACFLT. **Professor L. Jones** also continued work on a project sponsored by NAVCOMPT on the Navy budget justification process and the impact of Navy budget reductions. Professor Jones also started a reimbursable funded project to analyze methods to improve the cost-effectiveness of the Navy system for Ship Maintenance and Repair. **Professor J. San Miguel** started a direct funded case study of DoD and DoN cost management standards.

Manpower, Personnel, and Training Analysis

An umbrella reimbursable research project sponsored by the Deputy Chief of Naval Operations (OP-01, Manpower) supported several MPTA faculty members. Under the umbrella, sub-projects were proposed and completed by several individual professors. **Professors S. Mehay and T. Moore** examined BUPERS' manpower forecasting models, in particular the PCS Moves forecasting models and processes. **Professors L. Gorman and S. Mehay** analyzed the economic returns to naval service earned by veterans in their post-service careers. Professor Mehay also collaborated with Professor William Bowman of the Naval Academy to analyze the impact of various background factors (including graduate education, NROTC program, ship and duty assignments) on the subsequent performance of Naval officers.

Professors M. Eitelberg and S. Mehay continued the project on recruiting in the 21st century for the U.S. Army Recruiting Command. **Professor M. Eitelberg** also received reimbursable research funds from the Office of the Assistant Secretary of Defense (FM&P) to evaluate the effects of DoD's selection and classification systems on human resource development.

Policy Analysis, Management and Communications

A major umbrella research project funded by the Naval Avionics Center (NAC) supported several research efforts. **Professors K. Thomas, Gail Fann-Thomas, and Susan Hocevar** collaborated on the design, administration, and analysis of behavior/attitudinal surveys of engineers at NAC. The same group studied intrinsic task motivation of engineers and scientists at NAC. Finally, the group assessed the implementation of Total Quality Management (TQM) at NAC and compared it with other DoD organizations. **Professor S. Mehay** collaborated with researchers from Michigan State to develop a statistical profile of the scientists and engineer

workforce at NAC using a ten-year longitudinal data base previously developed at NPS under the NAC umbrella funding.

Professor J. Suchan used direct funds to determine whether changes in the Report of Investigation (ROI) document design affected adjudicators' determinations of security clearances. **Professor N. Roberts** continued her direct funded investigation of decision making in DoD organizations at both the strategic and operational levels.

COMPUTER-AIDED MODEL CONSTRUCTION

Hemant K. Bhargava, Assistant Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The main objective of this research was to investigate and develop methods for: (1) the representation and documentation of assumptions and rationales that justify the presence and mathematical form of the components of a mathematical model, and (2) to facilitate the derivation and efficient storage of new versions of a model that correctly reflect changes, and the propagated effects of these changes, to elements of an existing version.

SUMMARY: This research involves the design of computer systems to assist human modelers in the formulation of mathematical models. Specifically, it examines how model formulation can be supported with representation of, and reasoning with, assumptions. Modeling is an iterative process, and conclusions arrived at some iteration are often defeated in later iterations, in the face of new information. Thus several model versions, each reflecting a set of assumptions, are developed for the same problem. This research was specifically concerned with issues arising from this iterative refinement, and in enabling model management systems to: (1) represent and retrieve rationales and justifications behind modeling decisions, (2) examine, using modeling principles and knowledge about the application domain, whether proposed revisions to certain components of a model are consistent with the rest of the model; (3) propagate the effects of changes to model components throughout the model, and (4) manage the creation, and integration, of multiple and alternative versions of a model.

One significant side-effect of this research was the development of a language that integrates features in both data modeling and mathematical modeling. Such a language, though not an initial objective of this research, makes it possible to achieve the features stated above.

PUBLICATIONS: Bhargava, H.K. and Krishnan, R., "Computer-aided Model Construction," *Decision Support Systems*, forthcoming 1993.

Bhargava, H.K., Krishnan, R. and Mukherjee, S., "On the Integration of Algebraic and Data Modeling Languages," *Annals of OR*, forthcoming, 1992.

FLEET MIX MODELING IN THE U.S. COAST GUARD

Hemant K. Bhargava, Assistant Professor of Administrative Sciences
Sponsor: U.S. Coast Guard
Funding: U.S. Coast Guard Patrol Boats Acquisition Group

OBJECTIVE: The objectives of this project were: (1) to explore and examine systematic ways to address the problem of fleet mixing planning in the U.S. Coast Guard, and (2) to design and implement an analytic method for fleet mix planning in a system to support decision-making by the Patrol Boats Acquisition Office on the acquisition of about 100 patrol boats.

SUMMARY: Fleet mix planning involves determining the "optimal" configuration of a fleet, in terms of the type of assets within the fleet and the numbers of each type, that an organization must hold in order to optimize its defined objective satisfying the various environmental and organizational constraints. As a special case of this problem, the Patrol Boats Acquisition Office in the Coast Guard is tasked with selecting an ideal mix of about 100 boats to acquire. Patrol boats are primarily concerned with Search and Rescue, and Law Enforcement missions, but the demand for these missions over the boats' life span (about 30 years) is both uncertain and ambiguous. Further, it is hard to determine expected performance of such ships in terms of their mission requirements (i.e., number of lives saved, number of smuggling ships interdicted, etc.). A number of constraints such as cost constraints, and constraints of physical realities (e.g., availability of ports for certain kinds of ships) must be satisfied by the selected fleet mix. This research examined ways to solve these problems, structure them to a reasonable extent, and develop models for analyzing and solving this problem. These methods and models will be implemented in a decision support system to be used by the group.

PUBLICATIONS: Bhargava, H.K., "Fleet Mix Planning in the U.S. Coast Guard: Issues and Challenges for DSS," *Recent Developments in Decision Support Systems*, A.B. Whinston (ed.), Springer-Verlag, forthcoming 1992.

CONFERENCE PRESENTATION: Bhargava, H.K., "Models for Fleet Mix Planning in the U.S. Coast Guard," NATO Advanced Study Institute on Decision Support Systems, Lucca, Italy, 16-28 June 1991.

THESIS DIRECTED: Cortez, L. and Kaiser, T., "U.S. Coast Guard Fleet Mix Planning: A Decision Support System Prototype," MS Thesis, March 1991.

OTHER: (1) TEFA: A computer system for mathematical modeling being used for fleet cost modeling at Coast Guard headquarters; (2) FELIX: A computer system for patrol boats acquisition planning in the U.S. Coast Guard; (3) A simulation system for modeling and measuring the performance of alternative fleets in the U.S. Coast Guard's SAR (Search and Rescue) and ELT (Enforcement of Law and Treaties) missions.

DATA AND METHODS FOR ESTIMATING COSTS OF AIRCRAFT MODIFICATIONS AND DERIVATIVES

D.C. Boger, Associate Professor of Administrative Sciences
S.S. Liao, Professor of Administrative Sciences
Sponsor: Naval Air Systems Command, Cost Analysis Division
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to develop databases and parametric cost estimating models for aircraft modifications and derivatives. This is part of a continuing project.

SUMMARY: In prior reporting period of this multi-year project, a survey of data availability and the formulation of a cost element structure were completed, with most data acquisition completed. During this reporting period, data on the following three aircraft modification or derivative programs were obtained via student and PI visits to contractor sites: B-52 Strategic Radar, KC-135R Re-engine Program, and EF-111A Tactical Jamming System. Methods development and final database development will occur in the following period.

PUBLICATIONS: Boger, D.C. and Liao, S.S., "Aircraft Modifications Cost Analysis, Vol. 4: S-3A Increased Capacity Auxiliary Power Unit," NPS Project Report NPS-AS-91-006PR, March 1991.

Boger, D.C. and Liao, S.S., "Aircraft Modifications Cost Analysis, Vol. 5: S-3A Weapon System Improvement Program," NPS Project Report NPS-AS-91-007PR, April 1991.

Boger, D.C. and Liao, S.S., "Aircraft Modifications Cost Analysis, Vol. 6: Offensive Avionics System and Cruise Missile Integration of the B-52 Stratofortress," NPS Project Report NPS-AS-91-012PR.

THESES DIRECTED: Coffey, P., CPT, USMC, "Parametric Data Collection and Analysis for the KCR-135 and the B-52 Modification Programs," MS Thesis, December 1990.

Johnson, R.E., LT, USN, "Data Analysis for Cost Estimation Model of Aircraft Modification Programs," MS Thesis, December 1990.

ANALYSIS OF THE MANAGEMENT CONTROL AND INFORMATION SYSTEM IMPLICATIONS OF RAMP

D.R. Dolk, Associate Professor of Administrative Sciences
K.J. Euske, Associate Professor of Administrative Sciences
Sponsor: Naval Supply Systems Command

OBJECTIVE: The specific goals of this research project are to: (1) analyze the current management control and information systems currently in place to support the RAMP Project; (2) recommend adjustments to those systems such that the output of those systems will provide information that accurately appraises the RAMP Project; (3) ensure that the systems provide valid and reliable information regarding the cost, effectiveness, and efficiency of the RAMP Project.

SUMMARY: The RAMP Project within the Navy is concerned with developing highly automated manufacturing facilities using advanced robotics. A prototype facility currently exists. A full scale operating facility is being constructed. Information and accounting systems in the U.S., both in the private and public sectors, are not designed to support this technology. This project is designed to systematically analyze the information needs for efficient and effective resource allocation and control of such facilities.

A DECISION SUPPORT SYSTEM FOR EMERGENCY TELECOMMUNICATIONS

D.R. Dolk, Associate Professor of Administrative Sciences
Sponsor: National Communications Systems

OBJECTIVE: This project is involved with the development of the TEDSS (Telecommunications Emergency Decision Support System) for tracking and allocating telecommunications resources during a national emergency. It is an ongoing effort in which NPS has participated the past six years. NPS' involvement this past year was threefold: (1) serve as an internal validation and verification agent to NCS for the design of the overall system; (2) continue development of a suite of tutorials to educate potential users in how to operate the TEDSS. The current task in this stage is the development of a PC-based tutorial of the TEDSS; (3) develop a design for Version 2.0 of the TEDSS which is multimedia-based.

SUMMARY: We continue to provide technology assessment reports upon sponsor demand. For example, we delivered a report on the feasibility of using geographic information system technology as the basis of TEDSS architecture. The suite of tutorials has been contracted to VRC and Roland and Associates. An early prototype of a PC-based tutorial has been developed and demonstrated to the sponsor. Finally, the current version of TEDSS which relies largely upon DBMS technology is already out of date technologically. We have developed an architectural design for Version 2.0 of TEDSS which relies upon graphics, maps, voice recognition, and object-oriented databases to support crisis management.

THESIS DIRECTED: Browne, Nancy C., CAPT, USA, "Speech Recognition and the Telecommunications Emergency Decision Support System," MS Thesis, March 1991.

Carthon, Mitchel, MAJ, USMC, "The Telecommunications Emergency Decision Support System as a Crisis Management Decision Support System," MS Thesis, September 1991.

Manning, Stuart N., LT, USN, "A Conceptual Design for the Telecommunications Emergency Decision Support System (TEDSS)," MS Thesis, September 1991.

DEFENSE AND DISSENSUS: THE IMPACT OF CONGRESSIONAL BUDGET STALEMATE ON DEFENSE RESOURCES

Richard Doyle, Associate Professor of Public Budgeting
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to assess the impact of the Budget Enforcement Act of 1990 on budget outcomes for defense and the congressional budget process.

SUMMARY: As part of a continuing project, the roles of the major participants in congressional budgeting were examined throughout the budget cycle of 1991. The impact of the BEA on the congressional budget process, especially reconciliation, and on budget shares was assessed. Working budget documents -- committee reports, legislation, congressional testimony, CBO and OMB analyses -- and other materials describing and analyzing budget developments during the first full year under the Budget Enforcement Act of 1990 were collected and reviewed. Other information on the impact of the Budget Enforcement Act was obtained by conversations with congressional staffers and attendance at congressional hearings. A chronology of major budget events was prepared, as well as a bibliography of materials related to the Budget Enforcement Act. Significant attention was given to the enforcement mechanisms incorporated in this legislation and the extent to which political pressures associated with spending and the recession tested these limits. The relative influence of the executive branch and the congressional budgeting committees was evaluted.

PUBLICATIONS: Doyle, R., "Reconciliation and the Budget Process: A Review Essay," *Policy Studies Journal,* forthcoming.

Doyle, R. and McCaffery, J., "The Budget Enforcement Act in 1991: Isometric Budgeting," *Public Budgeting and Finance*, forthcoming.

Doyle, R., "Reconciliation Revisited: A Decade of Practice and Policy," *Public Budgeting and Finance*, forthcoming.

CONFERENCE PRESENTATIONS: Doyle, R., "The First Year of Budgeting Under the Budget Enforcement Act of 1990," presented at the Annual Meeting of the Section on Budgeting and Financial Management of the American Society for Public Administration, Washington, DC, October 1991.

THESIS DIRECTED: West, Steve, LT, USN, "An Analysis of the Role of the Budget Committees in the Congressional Budget Process," MS Thesis, December 1991.

HUMAN RESOURCE DEVELOPMENT IN THE DEPARTMENT OF DEFENSE: THE ROLE OF MILITARY SELECTION AND CLASSIFICATION

Mark J. Eitelberg, Associate Professor of Administrative Sciences

Sponsor: Office of the Assistant Secretary of Defense (Force Management and Personnel) Directorate of Accession Policy

OBJECTIVE: To review the historical role and accomplishments of the military in human resource development and to explore several additional contributions that can be made through the military's selection and classification system. To examine selected aspects of population representation in the military. This is part of a continuing project at NPS.

SUMMARY: The second phase of work on this project involved the preparation of a report to Congress. The report looked at the historical contributions of the Department of Defense with respect to human resource development. It also examined the results of a pilot project in pre-enlistment skill training that was undertaken by the University of Mississippi; a case study of recruits from Florida who entered the military with a juvenile arrest record; a study of the Montgomery GI Bill (enrollment patterns and usage rates since its introduction in July 1985); and new research on the transfer of military skills to the civilian sector. A second report was prepared for Congress on "population representation" in Operations Desert Shield and Desert Storm, following an extensive effort to develop and refine a database on personnel deployed to the Persian Gulf.

PUBLICATIONS: Eitelberg, M.J., "Human Resource Development: Issues and Initiatives for Military Selection," a report to the House and Senate Committees on Armed Services. Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), September 1991.

Eitelberg, M.J., "A Preliminary Assessment of Population Representation in Operations Desert Shield and Desert Storm," Appendix D in Population Representation in the Military Services, Fiscal 1990. Washington, DC: Office of the Assistant Secretary of Defense (Force Management and Personnel), July 1991.

Eitelberg, M.J., "Increased Use of Women and Minorities in Military Aviation Maintenance," in proceedings of the Fourth Federal Aviation Administration Meeting on Human Factors Issues in Aircraft Maintenance and Inspection, June 1991, Washington, DC: Office of Aviation Medicine, Federal Aviation Administration, pp. 154-178.

CONFERENCE PRESENTATIONS: Eitelberg, M.J., "A Preliminary Assessment of Population Representation in Operations Desert Shield and Desert Storm," 99th Annual Meeting of the American Psychological Association, San Francisco, CA, August 1991.

Eitelberg, M.J., "Population Representation in Operations Desert Shield and Desert Storm," Biennial Conference of the Inter-University Seminar on Armed Forces and Society, Baltimore, MD, October 1991.

Eitelberg, M.J., "The Effects of Military Downsizing on Opportunities for Minorities," Department of Education Conference on "The Role of Education in Restructuring Defense and Other Industries," Washington, DC, May 1991.

THESES DIRECTED: Turner, Robbie, LT, USN, "Minority Women Officers in the Navy: Past, Present, and Future Prospects," MS Thesis, March 1991.

Hines, Joseph, LT, USN, and Howard, Samuel, LT, USN, "College Resources and the Performance of Black Naval Officers," MS Thesis, June 1991.

Barnhill, Jack C., LT, USN, "An Assessment of the Relationship Between Aptitude Test Scores and Representation of Blacks and Hispanics in the U.S. Navy Occupations," MS Thesis, December 1991.

ADA's USE FOR MANAGEMENT INFORMATION SYSTEMS IN DoD

James C. Emery, Professor of Administrative Sciences
Martin J. McCaffrey, Professor of Administrative Sciences
Sponsor: Director of Defense Information,
Office of the Assistant Secretary of Defense (OASD),
Command, Control, Communications and Intelligence (C3I)
Funding: OASD C3I

OBJECTIVE: The goal of this project was to provide background information for formulating Ada programming language waiver policies in DoD.

SUMMARY: In the 1991 Defense Appropriations Bill, Congress mandated the use of Ada for all new software applications developed within the DoD, "where cost effective." This research documented the important issues and principles connected with the formulation of DoD waiver policies for implementing management information systems. Background issues on software development were reviewed and alternatives for software implementation examined. Extensive interviews and meetings were conducted with DoD, industry, and academic officials. Research centered around the software implementation process, the programming language Ada, and compliance alternatives to the Ada program language mandate from Congress. A unique contribution to this research was the research effort of five additional faculty members on relevant issues associated with implementing Ada. Their efforts were included as appendices in the report. The results of the research were documented in the publications cited below. Several hundred copies of this report have been distributed to industry, academia, and DoD agencies.

PUBLICATIONS: Emery, James C. and McCaffrey, Martin J., "Ada and Management Information Systems: Policy Issues Concerning Programming Language Options for the Department of Defense," a report for the Director of Defense Information, OASD C3I, June 1991.

OTHER: The previous report was also included in Ada and C++ A Business Case Analysis, July 1991 and published by the Deputy Assistant Secretary of the Air Force, Communications, Computers and Logistics, Washington, D.C.

IDENTIFICATION OF INDUSTRIAL PERFORMANCE MEASUREMENT PROCEDURES SUPPORTING THE ACHIEVEMENT OF STRATEGIC OBJECTIVES

K.J. Euske, Associate Professor of Administrative Sciences
Michel Lebas, Professor, HEC
C.J. McNair, Associate Professor, Babson College
Sponsor: CAMI International
Funding: CAMI International

OBJECTIVE: The purpose of the project is to identify how industry develops and uses performance measures to support the achievement of strategic objectives. The objective of the study is to bench mark existing performance measurement practices, detail the linkages to and divergence from "accepted" theory and identify areas where performance management systems can be improved.

The project has three phases. Phase I consists of interviews with managers from a stratified sample of firms. The results of these interviews will be used to develop a questionnaire for Phase II of the project. The questionnaire will be distributed to another sample of firms. The results of the questionnaires would then be validated in Phase III with interviews at another sample of firms.

The project directly supports DoD efforts to support and improve the stability and competitiveness of the U.S. defense industrial base.

PUBLICATION: Euske, K.J., Lebas, M. and McNair, C.J., "CAM-I Performance Measurement Project - Status Report," CAM-I Project Report, December 1991.

CONTROL OF ILL-DEFINED TECHNOLOGY AND OUTPUT: A FIELD STUDY

K.J. Euske, Associate Professor of Administrative Sciences
Sponsor: Harvard University
Funding: Harvard University

OBJECTIVE: The purpose of the study was to identify characteristics of evaluation systems that operate in environments with ill-defined technology and output. Institutional theory and the technical-rational models of organizations would lead one to the expectation that the control of ill-defined technology will differ in the for-profit and nonprofit sectors. The control and evaluation system in the for-profit organization should be oriented toward efficiency while the control system and evaluation processes in the nonprofit organization would be oriented toward maintaining legitimacy of the organization.

The environment studied is similar to DoD and more generally to the federal government. Understanding of the process operating in these organizations should contribute to a better understanding of how to effectively operate Navy organizations. The work on this project is directly relevant to the content of MN 4161 Financial Management Control Systems and MN 4122 Planning and Control. Results of the study were presented at the Performance Measurement and Incentive Compensation Colloquium at Harvard University, 25-26 June 1990.

PUBLICATION: Euske, K.J., "An Examination of Control Mechanisms in Organizations with Ill-Defined Technology and Output," forthcoming in Performance Measurement, Evaluation, and Incentives, W.J. Burns, Jr. (Ed.), Harvard Business School Press.

NAVY FLEET BUDGETING AND IMPACT OF BUDGET REDUCTION

K.J. Euske, Associate Professor of Administrative Sciences
L.R. Jones, Professor of Administrative Sciences
J.L. McCaffery, Professor of Administrative Sciences
Sponsor: Commander in Chief, U.S. Pacific Fleet

OBJECTIVE: The objective of this project was to assess the budgeting and accounting processes and the impact of budget reductions in the PACFLT command, to assess management control system and accounting system changes to respond to budget austerity, and to analyze opportunities for increased U.S. - Japanese defense resource burdensharing.

SUMMARY: Research was performed in the field in PACFLT to assess the characteristics of fleet budget and accounting systems. These systems were analyzed in terms of the roles of the participants and their relationships in budget preparation, analysis, and justification. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analysis.

PUBLICATIONS: Jones, L.R. and Euske, K.J., "Strategic Misrepresentation in Budgeting," *Journal of Public Administration Research and Theory*, 1(4):437-460, October 1991.

Doyle, R. and McCaffery, J., "The Budget Enforcement Act of 1990: The Path to No Fault Budgeting," *Budgeting and Public Finance*, 11(1), 1991.

Jones, L.R. and Doyle, R., "Public Policy and Land Management Issues in Budgeting for National Defense," *Defense Analysis*, forthcoming.

THESES DIRECTED: Clark, P., "An Analysis of Budgeting for the Pacific Fleet Command," MS Thesis, June 1991.

Wolfe, R., Pirmann, J. and Rhodes, R., "A Comparative Analysis of the Armed Services Flight Hour Program from a Budgetary Perspective," MS Thesis, December 1991.

Conn, Michael, "Policy and Procedures Regarding DoD Assistance to Private Organizations," MS Thesis, June 1991.

Gauthier, J., "U.S. - Japanese Defense Burdensharing," MS Thesis, September 1991.

MIGRATION, VETERAN'S PAY, AND SELECTIVITY BIAS

Linda Gorman, Adjunct Professor of Administrative Sciences
Stephen L. Mehay, Professor of Administrative Sciences
Sponsor: Chief of Naval Operations, OP-01
Funding: MPTA Faculty Support of OP-01/BUPERS

OBJECTIVE: Investigate whether veterans earn less than comparable civilians who have never served while taking into account post-service migration patterns and controlling for selectivity bias. This is part of a continuing project.

SUMMARY: Recent research has suggested that on average veterans earn less than civilians. This project takes a new approach to this question. The data set was constructed and preliminary tests were run on it this summer.

THESIS DIRECTED: Nuckols, Don, "Factors Affecting Post-Service Wage Growth for Veterans," MS Thesis, December 1991.

NAVY FLEET BUDGETING AND IMPACT OF BUDGET REDUCTION

L.R. Jones, Professor of Administrative Sciences
K.J. Euske, Associate Professor of Administrative Sciences
J.L. McCaffery, Professor of Administrative Sciences
Sponsor: CAPT Robert Osterhoudt, Comptroller
CINCPACFLT
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to assess the budget and accounting procedures and the impact of budget reductions in the PACFLT command, to assess management control system and accounting changes to respond to budget austerity, and to analyze opportunities for increased U.S. - Japan national defense resource burdensharing.

SUMMARY: Research was performed in the field in PACFLT to assess the characteristics of fleet budget and accounting systems. These systems were analyzed in terms of the roles of the participants and their relationships in budget preparation, analysis and justification. The budget preparation system was analyzed for methods and alternatives to improve efficiency and cost-effectiveness. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analysis. The climate and characteristics of the POM and budget preparation were assessed with the assistance of the sponsor to assist in the design of further research. Characteristics of U.S. - Japanese defense resource burdensharing also were examined from a budgetary, political and economic perspective.

PUBLICATIONS: Jones, L.R. and Euske, K.J., "Strategic Misrepresentation in Budgeting," *Journal of Public Administration Research and Theory*, 3 March 1991.

Doyle, R. and McCaffery, J., "The Budget Enforcement Act of 1990: The Path to No Fault Budgeting," *Public Budgeting and Finance*, 1 November 1991.

Jones, L.R. and Doyle, R., "Public Policy and Management Issues in Budgeting for National Defense," *Defense Analysis*, forthcoming.

CONFERENCE PRESENTATIONS: Jones, L.R., "U.S. and Allied Burdensharing for National Defense," Annual Conference of the Western Social Science Association, Reno, NV, April 1991.

THESES DIRECTED: Clark, P., LT, USN, "An Analysis of Budgeting for the Pacific Fleet Command," MS Thesis, June 1991.

Gauthier, J., LT, USN, "U.S. - Japanese Defense Burdensharing," MS Thesis, September 1991.

Conn, M., LT, USN, "Policy and Procedures Regarding DoD Assistance to Private Organizations," MS Thesis, June 1991.

Wolfe, R., LT, USN, Pirmann, J., LT, USN, and Rhodes, R., LT, USN, "A Comparative Analysis of the Armed Services' Flight Hour Program from a Budgetary Perspective," MS Thesis, December 1991.

NAVY SHIP MAINTENANCE AND REPAIR AND IMPACT OF BUDGET REDUCTION

L.R. Jones, Professor of Administrative Sciences
Sponsor: CDR Robert Williams, Director
NAVSEA, Ship Maintenance and Repair Division
Funding: NAVSEA - RR

OBJECTIVE: The goal of this project was to assess the roles, participants and relationships in the Navy system for Ship Maintenance and Repair and to analyze methods for improving the efficiency and cost-effectiveness of this system. Selected issues in programming and budgeting for ship maintenance and repair also were examined. The goals and funding for this project were provided late in FY 1991 and continued into FY 1992.

SUMMARY: Research was performed in the field in PACFLT and LANTFLT to assess the characteristics of the Navy ship maintenance repair system. This system was analyzed in terms of the roles of the participants and their relationships in the work preparation and documentation process for Navy ship repair and maintenance. The work preparation system was described and analyzed for methods and alternatives to improve efficiency and cost-effectiveness. Preliminary results were presented to the sponsor and feedback was obtained on approaches to further analysis. The climate and characteristics of the POM and budget preparation were assessed with assistance of the sponsor to assist in the design of further research.

PUBLICATION: Jones, L.R., "Public Budget Execution Control," in J. Rabin, ed., *Handbook of Public Budgeting and Financial Management,* (New York, NY: Marcel Dekker), forthcoming.

THESES DIRECTED: Ehrlich, D., LT, USN, "Ship Maintenance and Repair: A Comparative Perspective," MS Thesis, December 1991.

DeWitt, A., LT, USN, "Improving the Effectiveness of Ship Maintenance & Repair in the Navy," MS Thesis, December 1991.

NAVY BUDGETING JUSTIFICATION AND IMPACT OF BUDGET REDUCTION

L.R. Jones, Professor of Administrative Sciences
Sponsor: Charles P. Nemfakos,
NAVCOMPT, Office of the Secretary of the Navy
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop means for improving the justification of the Navy budget and to investigate the budgetary relationship between the Navy, the Office of Secretary of Defense and the Congress.

SUMMARY: A database was developed from the historical FYDP and utilized for analysis of relationships between Navy funding levels, force structure, size and composition, and personnel endstrength. The O&MN account was analyzed statistically to determine whether any of its component AG/SAGS could be selected as cost drivers to justify future O&MN budget requests. Results of the analysis were reported to the sponsor. Further, the relationships between the Navy, OSD and Congress were investigated and reported. An analysis of the impact of budget reduction in the Navy also was performed to determine some of the effects of FY 90 and FY 91 budgets.

PUBLICATIONS: Jones, L.R. and Bixler, Glenn C., "Mission Budgeting for National Defense," Westport, CT: JAI Press, forthcoming.

Jones, L.R., "Policy Development, Planning and Resource Allocation in the Department of Defense," *Public Budgeting and Finance*, 3 November 1991.

Jones, L.R., "Allocation in National Defense," *Public Budgeting and Financial Management,* 4 March 1991.

Jones, L.R., "Cutting the Defense Budget," *Government Executive*, forthcoming.

CONFERENCE PRESENTATIONS: Jones, L.R., "Cutting the Defense Budget, " Association for Public Policy Analysis and Management Annual Research Conference, Bethesda, MD, October 1991.

Jones, L.R., "Corporate Environmental Policy in North America," paper presented to the Biennial International Conference of the Association for Canadian Studies in the United States, Boston, MA, November 1991.

THESES DIRECTED: Babos, J., LT, USN, "Financial Management of Hazardous Waste Compliance and Mitigation Costs Constraints and Implications," MS Thesis (Conrad Scholar Award Thesis), December 1991.

Crouch, M., CAPT, USMC, "The V-22: Can the Nation Afford to Forgo its Production?" MS Thesis, December 1991.

McCarden, Y., LT, USN, "Base Closure and Health Coverage: The Case of Silas B. Hayes Community and Fort Ord," MS Thesis, December 1991.

CERTS: A COMPARATIVE EVALUATION METHOD FOR RISK MANAGEMENT METHODOLOGISTS AND TOOLS

Magdi N. Kamel, Assistant Professor of Administrative Sciences
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research project is to develop a comparative methodology to evaluate risk assessment methods and tools for their suitability to a particular organizational situation.

SUMMARY: The advent of decentralized computing and an increasingly important role for information as a resource has prompted the development of a variety of methods and tools for managing the risk exposure of a computer system. As a result of the diversity of risk management tools currently available, there is no effective means of determining which of the tools would be most suitable for any given organization's situation. A new technique is proposed to effectively and objectively evaluate these tools for suitability and to establish a means of comparing them. The technique shows promise in any case where a diversity of tools are available and choices must be made as to which to use.

THESIS DIRECTED: Garrabrants, W.M. and Ellis III, A.W., "CERTS: A Comparative Evaluation Method for Risk Management Methodologies and Tools," MS Thesis, March 1990.

RELIABILITY GOAL DETERMINATION FOR MAJOR CALIBER AMMUNITION

Keebom Kang, Adjunct Professor of Administrative Sciences
Lyn Whitaker, Associate Professor of Operations Research
Michael Bailey, Assistant Professor of Operations Research
So Young Sohn, Assistant Professor of Operations Research
Marcelo Bartroli, Adjunct Professor of Operations Research
Sponsor: Naval Weapons Support Center, Crane, IN
Funding: Naval Weapons Support Center, Crane, IN

OBJECTIVE: Continuing support from Naval Weapons Support Center. There are three major objectives: (1) to study reliability performance measures for major caliber ammunition used in Naval Gunfire Support (NGFS) system; (2) to develop a measure of reliability and a bonus system to reward contractors with products whose reliability exceeds the minimum acceptable reliability; (3) to provide depot managers with information regarding appropriate time for reorder or renovation of ammunition before the quality reaches unacceptable level.

SUMMARY: The summary consists of three parts. (1) A simulation model was developed that relates the reliabilities of ammunition components to the weapon system's performance in an NGFS environment. The simulation model was written using an object-oriented simulation language MODSIM. The model has graphics display capability, and automated statistical analysis for simulation output. The model can be executed by remote log-on via Defense Data Network. (2) It was shown that it is impractical to estimate reliabilities and find confidence intervals from the available lot acceptable data. An alternative approach was developed to award bonuses from this data. The bonus system initially designed for pyrotechnic devices is generally enough to be used for other devices. (3) Ammunition deterioration during storage has considerable economic consequences. A reliable prediction model for the ammunition deterioration rate is necessary for long-term procurement and maintenance planning. A random coefficient growth curve analysis was considered to formulate prediction models for ammunition deterioration in terms of the storage location and vendor information. A two-stage method was used to estimate the ammunition deterioration rate as a regression coefficient of logistic function of time. Its performance was compared to that of the simplified version using a Monte Carlo simulation. Performances of both methods appear not be significantly different.

PUBLICATIONS: Bailey, M.P., Bartroli, M., Callahan, A.J. and Kang, K., "Establishing Reliability Goals for Naval Major Caliber Ammunition," Technical Report NPS-OR-91-009, March 1991.

Whitaker, L. and Bailey, M.P., "Pyrotechnic Device Reliability," Technical Report NPS-OR-92-005, December 1991.

CONFERENCE PRESENTATION: Kang, K., Bailey, M.P., Callahan, A. and Bartroli, M., "Reliability Goal Determination for Ammunition," ORSA/TIMS Special Interest Conference on Applied Probability in the Engineering, Information and Natural Sciences, Monterey, CA, January 1991.

THESES DIRECTED: Ozkil, A., 1LT, Turkey Army, "Pyrotechnic Device Reliability," MS Thesis, March 1991.

Darden, R., LT, USN, "An Object-Oriented Model of Naval Gunfire Support Missions," MS Thesis, September 1991.

OTHER: The Navy is currently sponsoring data collection during fleet exercises, which will be used to update the database for NGFS simulation input. The condensed version of the technical report NPS-OR-91-009 (by Bailey, Bartroli, Callahan and Kang) was submitted to *Naval Research Logistics*.

DEFINITIONS OF CONTRACTING TERMS

D.V. Lamm, Associate Professor of Administrative Sciences

OBJECTIVE: The objective of this project was, and continues to be, the development of a dictionary of contracting terms.

SUMMARY: The contracting profession has been criticized over the past several years for the lack of clear definitions for a number of its terms. Beginning in 1988, NPS and the Air Force Institute of Technology (AFIT) have collaborated on a project to develop a dictionary of contracting terms to be used by the profession. The work has been accomplished principally by graduate thesis students at both institutions in the contracting curricula. Approximately 500 terms have been earmarked for definition, and approximately 350 term's have been defined. The process involves a comprehensive review of the literature, including the Federal Acquisition Regulation (FAR), to determine how a term is currently defined and to develop a "working" definition. A survey questionnaire is used with selected experienced contracting professionals to obtain feedback concerning the terms use in practice. Responses are synthesized and a new proposed definition is presented. Terms are then published in the Contract Management journal with an invitation to respond to the researcher regarding any recommended changes.

PUBLICATIONS: Lamm, D.V. and Pursch, W.C., "A Dictionary of Contracting Terms," *Contract Management*, 31(5):41-46, May 1991.

Pursch, W.C. and Lamm, D.V., "A Dictionary of Contracting Terms, Part II," *Contract Management*, 31(11):42-45, November 1991.

CONFERENCE PRESENTATION: Lamm, D.V. and Pursch, W.C., "Contracting Research," 1991 Acquisition Research Symposium, Washington, DC, August 1991.

THESES DIRECTED: Roe, R.G., LCDR, USN, "A Dictionary of Acquisition and Contracting Terms," MS Thesis, December 1991.

Cotters, J.F., LT, USN, "A Dictionary of Acquisition and Contracting Terms," MS Thesis, December 1991.

Robinson, M.W., LT, USN, "A Dictionary of Acquisition and Contracting," MS Thesis, December 1990.

Wilson, R.E., LT, USN, "A Dictionary of Acquisition and Contracting Terms," MS Thesis, December 1990.

OTHER: Future articles will be published in Contract Management during 1992. It is anticipated that a complete dictionary of terms will be published in approximately two to three years.

CONTRACT NEGOTIATIONS

D.V. Lamm, Associate Professor of Administrative Sciences

OBJECTIVE: The focus of this research was to examine the key differences among inexperienced negotiators and experienced negotiators related to general considerations as well as specific negotiation situations.

SUMMARY: A series of survey questionnaires were used to examine negotiations as perceived by experienced and inexperienced negotiators. The test groups for this study included students (considered to be inexperienced) participating in the Contract Pricing and Negotiations course (MN3304) at NPS and industry contract administrators (considered to be experienced) participating in a sequence of negotiations with the students. The factors centered around the strategy, tactics, and ethics of negotiations as perceived by the two groups. A series of four questionnaires was used during the study. The first questionnaire was of a general nature and was completed approximately 30 days before the negotiation sessions. The second third and fourth questionnaires were administered immediately before, during, immediately after the actual negotiation sessions. An analysis of the results includes a comparison of the two groups in terms of ethical versus unethical actions that might be taken during negotiations, the strategies considered most feasible, and the tactics each group as a whole are likely to consider employing throughout the negotiation process.

THESES DIRECTED: Fitzsimmons, MAJ, USMC, "Negotiations: Experienced Versus Inexperienced Negotiators," MS Thesis, December 1990.

Bennett, R.J., LT, USN, "Simulated Negotiations: A Measure of Their Effectiveness on Negotiated Outcome," MS Thesis, December 1991.

OTHER: The researcher continues to use the Contract Pricing and Negotiations course as a data collection base.

CONTRACTING TAXONOMIES

D.V. Lamm, Associate Professor of Administrative Sciences

OBJECTIVE: This project is a continuing effort to identify and examine various characteristics of the contracting profession through the development and use of the taxonomical approach. Taxonomies were developed for goods and for services.

SUMMARY: In order to research the acquisition and contracting profession, rigorous classification of significant characteristics must be accomplished. The premise that Federal Government goods exhibit elements that can be used from a strategic sense in the buying process led to an attempt to identify and classify these elements. Through a panel of experts, a theoretical structure was established. Questionnaires were used to obtain data for classification purposes. A model classification scheme was developed as the basis for further investigation. A second study was undertaken to examine homogeneous goods with specific sets of buyers. The study has also been expanded to include services purchased by the Federal Government.

PUBLICATIONS: Lamm, D.V. and Wenger, B.L., "A Proposed Taxonomy for Federal Government Goods," in proceedings of the 1991 Acquisition Research Symposium," Washington, DC, 6 June 1991.

THESES DIRECTED: Wenger, B.L., LCDR, USN, "A Taxonomical Structure for Classifying the Goods Purchased by the Federal Government," MS Thesis, December 1990.

Prendergast, J.J., LCDR, USN, "Application of a Taxonomical Structure for Classifying Goods Procured by the Federal Government," MS Thesis, December 1991.

Allen, S.T., CAPT, USMC, "A Taxonomy of Services Procured by the Federal Government," MS Thesis, December 1991.

OTHER: This is a continuing project in an attempt to integrate several taxonomies within the contracting profession into a theoretical body of knowledge.

RESYSTEMIZATION MODELING SUPPORT

A.W. McMasters, Professor of Operations Research and
Administrative Sciences
Sponsor: Navy Fleet Material Support Office
Funding: Naval Postgraduate School

OBJECTIVE: To develop a Wholesale level inventory model for the Navy to use to replenish their inventories of repairable items; the objective function of this model should be related to readiness.

SUMMARY: A new inventory model for managing repairables at the Wholesale or Inventory Control Point (ICP) level is needed to determine when to replenish repairable items. This model should have the same objective function as the Wholesale provisioning (or first buy quantity) model developed on this project between 1982 and 1986; namely, the minimization of the aggregate Mean Supply Response Time (MSRT). The intent of this model is to base decisions for replenishment buys and repair inductions into depot upon the Ready - for - Issue (RFI) inventory position (IP). The completion of model development depends on describing the probability distribution of the IP. Work this past year focused on developing a modification to the simulation model being used to help determine the empirical distribution for the IP. This modification reflects the time a carcass is in repair as the measured repair turn-around time (RTAT) and allows a batch to be phased into repair, one unit at a time. As each carcass is successfully repaired, both the IP value and the net inventory value area adjusted to reflect that fact. In addition, carcasses which fail to be repaired are discharged from repair as soon as they are inducted and the IP is updated at that time. This most recent modification to the simulation accurately reflects the way the ICPs update their IP values.

In addition to the simulation model improvements, NAVSUP ask us to look at their process of handling carcasses being returned from the customer called the Advanced Traceability and Control (ATAC) system. DMRD 901 has stated that carcasses should not be sent on to a depot until the ICP inventory manager decides that it will be needed after it is repaired. The fallacy in this logic is it assumed that most carcasses will never need to be repaired. That is only true for those very few weapon systems being phased out of service. A simple queuing analysis and simulation were conducted to examine the extent of delays created by DMRD 901 and a separate project was proposed to NAVSUP to study the problem in more detail.

THESES DIRECTED: Harris, Steven J., LCDR, SC, USN, and Munson, William S., LT, SC, USN, "An Analysis of Depot Level Repairables Carcass Management and Position Controls under the Advanced Traceability and Controls (ATAC) Program," MS Thesis, December 1990.

Dryer, Robert M., LT, SC, USN, "A Preliminary Simulation Model for the Advanced Traceability and Control (ATAC) Systems," MS Thesis, December 1991.

ARMY RECRUITING IN THE 21ST CENTURY (PHASE II)

Stephen L. Mehay, Professor of Administrative Sciences
Mark J. Eitelberg, Associate Professor of Administrative Sciences
Sponsor & Funding: U.S. Army Recruiting Command, Program Analysis and Evaluation Directorate, Ft. Sheridan, Illinois

OBJECTIVE: To provide an overview of the future environment in which Army recruiting will be conducted in the 1990s and beyond. The project involves an extensive review of the literature and on future trends in social, demographic, labor force, economic, geopolitical and other relevant areas. These trends and projections will be evaluated quantitively for their impact on Army recruiting requirements and markets.

SUMMARY: (1) We have constructed a computerized bibliographic reference system using the Q&A software package. The database includes over 200 separate sources of information on trends in the relevant subject areas. (2) We have initiated publication of a periodic report ("Trendlines") for high-level Army manpower and recruiting officials. The report highlights selected topics and analyzes various trends for their implications for Army recruiting and manpower policies.

PUBLICATIONS: Greenwood, M. and Mehay, S., "Trends in Regional Patterns of Migration, Immigration, and Economic Activity: Implications for Army Recruiting," NPS Technical Report NPS-AS-91-015, March 1991.

OTHER: One of the objectives of the project is to organize a conference in late 1991 or early 1992 on the topic of recruiting in the 21st Century. The conference will bring together experts from numerous fields and result in the publication of a book.

ARMY RECRUITING IN THE 21ST CENTURY (PHASE II)

Stephen L. Mehay, Professor of Administrative Sciences
Mark J. Eitelberg, Associate Professor of Administrative Sciences
George Thomas, Associate Professor of Administrative Sciences
Sponsor: U.S. Army Recruiting Command, Program Analysis and Evaluation Directorate

OBJECTIVE: To provide an assessment of the environment for Army recruiting in the 1990s and beyond. The project involves an extensive review of literature and future trends in social, demographic, labor force, economic, geopolitical, and other relevant areas. These trends and projections will be studied for their impact on Army recruiting requirements and markets. The "Army Futures" project is a three-year effort.

SUMMARY: Phase II of the project involved several tasks: (1) a study of the youth labor force in the 21st century; (2) a study of regional patterns of migration, immigration, and economic activity; (3) an assessment of the lessons learned for manpower and recruiting from Operations Desert Shield and Desert Storm; (4) an evaluation of trends in educational achievement and student performance on standardized tests; (5) a review of trends affecting the recruitment and retention of people for the reserve forces; (6) an examination of emerging management concepts for use in Army recruiting; and (7) updating of a computerized bibliographic reference system on future trends and issues. Phase II also involved the planning and organizing of a major conference on "Army Futures," which will result in the publication of a book.

PUBLICATIONS: Greenwood, M.J. and Mehay, S.L., "Trends in Regional Patterns of Migration, Immigration, and Economic Activity: Implications for Army Recruiting," NPS-AS-91-015, March 1991.

Kocher, K.M. and Thomas, G.W., "Youth Labor Force in the 21st Century," NPS Technical Report, forthcoming.

Kageff, L., "Predicting the Quality of Future Recruits by Test Score Trends," FR-PRD-91-18, Human Resources Research Organization, November 1991.

THESIS DIRECTED: Haumer, Mike A., LT, USN, "Occupational Trends in the Civilian and Navy Labor Markets," MS Thesis, December 1991.

OTHER: The principal investigators planned and organized a major conference on "Army Futures" to be held on 29-30 January 1992 in Arlington, Virginia. The conference, titled "Marching Toward the 21st Century," will bring together many of the nation's leading authorities on military manpower and recruiting. Twenty papers will be presented by experts in selected areas. These papers will be edited by the principal investigators and subsequently appear in a book to be published by Greenwood Press in late 1992.

Mehay, S.L. and Eitelberg, M.J., Several issues of Trendlines, a series of ten-page newsletter/reports on "Trends in Manpower and Recruiting," for the U.S Army Recruiting Command (various titles in series, which will later be combined in a single volume).

NAVAL POSTGRADUATE SCHOOL MPTA FACULTY RESEARCH IN SUPPORT OF OP-01

Stephen L. Mehay, Professor of Administrative Sciences
Thomas Moore, Assistant Professor of Administrative Sciences
Linda Gorman, Adjunct Professor of Administrative Sciences
Mark Eitelberg, Associate Professor of Administrative Sciences
Sponsor & Funding: Deputy Chief of Naval Operations (MPT), OP-01/BUPERS-2, Washington, D.C.

OBJECTIVE: This project provided an umbrella research effort within which individual projects were proposed and carried out by individual researchers. Mehay coordinated the project between individual MPT faculty and OPNAV. Also, Mehay was principal or co-principal investigator of several sub-projects: (1) "Economic Returns to Naval Service," (2) "OP-01 Model Validation and Technical Review," and (3) "Analysis of Naval Officer Performance."

SUMMARY: (1) This project involved exploring alternative databases to statistically estimate the earnings pattern of military veterans and to compare Navy veterans with those of other services; (2) This project was on-going from 1990; (3) This project involved determining the effects of several background factors on naval officer performance and retention: the factors examined were: (a) the impact of college resources on minority naval officers, (b) commissioning source, (c) receipt of graduate education, and (d) initial assignments of junior naval officers.

PUBLICATIONS: Mehay, S., "Post-Service Earnings of Military Veterans: Evidence from the Reserves," NPS Technical Report NPS-AS-01-016.

THESES DIRECTED: Miller, Carolyn J., "Post-Service Earnings of Veterans: A Survey and Further Evidence," March 1991.

Howard, Samuel and Hines, Joseph, "College Resources and the Performance of Black Naval Officers," June 1991.

French, Gregory, "A Case Analysis of OP-12/PERS-5 Manpower Organization," December 1991.

Jordan, Susan S., "An Analysis of the Impact of Graduate Education on the Performance and Retention of General Unrestricted Line Officers," December 1991.

Bellamy, LaToya, "Initial Assignment, Ship Type and the Performance of Junior Naval Officers," December 1991.

McQuilkin, Williams, "An Analysis of the Navy's Permanent Change of Station Planning Process and Move Forecasting Models," December 1991.

Nuckols, Don, "Factors Affecting Post-Service Wage Growth of Veterans," December 1991.

OTHER: Mehay, S. and Gorman, L., "Migration by Veterans and Post-Service Earnings: A Selectivity Approach," Technical Report in process.

Mehay, S., "Civilian Labor Market Experiences of Veterans: A Review of the Evidence," Technical Report in process.

AN ANALYSIS OF ALTERNATIVE COST PROGRESS MODELS

O.D. Moses, Associate Professor of Administrative Sciences
Sponsor: Naval Sea Systems Command, Cost Estimating and Analysis Division
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to compare the predictive ability of different cost progress models, specifically the learning curve and the production rate adjustment models.

SUMMARY: This study compared the quality of cost forecasts produced by two models commonly used in cost estimation: the learning curve and a production rate adjustment model. A simulation methodology was used to create artificial cost series data. Seven conditions were varied during the simulation: number of production lots, learning rate, cost burden, production rate growth, production rate stability, cost noise and future production level. The relative accuracy and bias of the two competing cost estimation models were evaluated under the various conditions simulated. Conditions under which each model could be expected to produce better (higher accuracy, lower bias) forecasts of future cost were identified.

PUBLICATIONS: Moses, O.D., "Learning Curve and Rate Adjustment Models: An Investigation of Bias," Naval Postgraduate School Technical Report NPS-AS-91-005, February 1991.

Moses, O.D., "Learning Curve and Rate Adjustment Models: Comparative Prediction Accuracy Under Varying Conditions," in R. Kankey and J. Robbins, Editors, Cost Estimating and Analysis: Shifting U.S. Priorities, Springer-Verlag, New York, pp. 65-101, 1991.

Moses, O.D., "An Investigation of Learning Curve and Rate Adjustment Model Bias: A Summary," in proceedings of the Decision Sciences Institute National Meeting, Miami, FL., pp. 1282-1284, November 1991.

Moses, O.D., "Learning Curve and Rate Adjustment Models: An Investigation of Bias," in T. Gulledge, W. Hutzler and J. Lovelace, Editors, *Cost Estimating and Analysis: Balancing Technology Advances and Declining Budgets*, Springer-Verlag, New York, forthcoming.

CONFERENCE PRESENTATIONS: Moses, O.D., "Alternative Cost Progress Models: An Analysis of Accuracy and Bias," presented at the 25th Annual Department of Defense Cost Analysis Symposium, Washington, DC, September 1991.

Moses, O.D., "An Investigation of Learning Curve and Rate Adjustment Model Bias," Decision Sciences Institute National Meeting, Miami, FL., November 1991.

KNOWLEDGED-BASED SUPPORT FOR SYSTEMS DESIGN AND MAINTENANCE

B. Ramesh, Assistant Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research is to develop an environment to support various stakeholders involved in systems development by reasoning with design rationale knowledge.

SUMMARY: Support for various stakeholders involved in software projects (designers, maintenance personnel, project managers and executives, end users) can be provided by capturing the history of about design decisions (or process knowledge) in the early stages of the systems development lifecycle. This research project builds on our earlier work in which a conceptual model characterizing the use of design rationale knowledge in systems development activities were developed. This model relates process knowledge to objects that are created during the systems development process. We have developed a prototype system based on our model that can provide assistance to the various stakeholders involved in the design and management of large systems. Various activities for which support is provided included the following areas: capturing design rationale, reuse of design knowledge components, domain knowledge acquisition, design synthesis, design decision support, maintenance of changing requirements, process knowledge reuse, design replay, temporal reasoning in project management.

PUBLICATIONS: Ramesh, B. and Dhar, V., "Process Knowledge Based Group Support for Requirements Engineering," *IEEE Transactions on Software Engineering*, forthcoming.

Ramesh, B. and Dahr, B., "Group Support and Change Propagation in Requirements Engineering," book chapter in Jarke M. (Ed): *Development Assistance for Interactive Database Applications*, Springer-Verlag, Heidelberg, Fall 1991.

CONFERENCE PRESENTATIONS: Ramesh, B., "Representation and Reasoning with Process Knowledge in Large Scale Systems Development," Information Systems Research Colloquium, University of California, Berkeley, CA, December 1991.

Ramesh, B. and Dhar, V., "Representation and Maintenance of Process Knowledge for Large Scale Systems Development," in proceedings of the Sixth Knowledge Based Software Engineering Conference, Rome Laboratory, Syracuse, NY, September 1991, (also selected for fast tracking and under review by IEEE Expert).

DOMAIN ANALYSIS FOR SERVICE ORDER PROCESSING

B. Ramesh, Assistant Professor of Administrative Sciences
Sponsor: Microelectric Computertechnology Corporation (MCC), Anderson Consulting
Funding: MCC, Anderson Consulting

OBJECTIVE: The objective of this research is to develop a domain model in a transaction processing domain that could support various type of reasoning activities in that domain.

SUMMARY: A domain model serves to encode specific knowledge about a particular application domain, and also supports various types of reasoning activities on the domain knowledge thus encoded. The reasons for ranging domain models are varied: ranging from analysis and generation of requirements to identifying the semantics of existing code. Domain models are engineered toward specific/customized representations that enable their client systems reason about them efficiently in particular ways. Such domain models have very little value to other systems that reason about these domains in different ways. We have developed a domain model taking into account the requirements of several systems, and represented it in a neural format such that it can be engineered to suit the requirements of a variety of systems.

PUBLICATION: Ramesh, B. and Lubars, M., "A Domain Analysis for Service Order Processing," Technical Report MCC-STP-RQ-236-91, Microelectronic Computer Technology Corporation, Austin, TX, July 1991.

MILITARY DECISION MAKING

N.C. Roberts, Associate Professor of Administrative Sciences
Sponsor: CNO Executive Panel
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate decision making in military and DoD related organizations at both the strategic and operational levels of analysis and to make recommendations for improvement.

SUMMARY: This research cautions against the transfer of "lessons learned" from decision making research in businesses to public organizations with their special missions and mandates like DoD/DoN. Decision making in strategic and operational settings, especially under combat conditions, requires a decision approach geared to these unique contexts and situations.

PUBLICATIONS: Roberts, N.C., "New Directions for Military Decision Making Research in Combat and Operational Settings," NPS Technical Report NPS-AS-92-004, December 1991.

Roberts, N.C., "Limitations of Strategic Management in Public Bureaus: The Case of the Department of Defense," NPS Technical Report NPS-AS-91-008, April 1991.

Roberts, N.C., "Case Development Program Naval Postgraduate School: An Overview," NPS Project Report, Working Paper No. 91-02, May 1991.

Roberts, N.C., "Limitations of Strategic Management in Bureaus: The Case of the Department of Defense," in B. Bozeman, (Ed) *Public Management Theory*, San Francisco: Jossey-Bass, forthcoming.

Roberts, N.C., "Limitations of Strategic Management in Bureaus," in proceedings of the Public Management Research Conference, Syracuse, NY: Maxwell School, forthcoming.

CONFERENCE PRESENTATIONS: Roberts, N.C., "Limitations of Public Management in Bureaus: The Case of the Department of Defense," National Public Management Research Conference, Maxwell School of Citizenship and Public Affairs, 19-20 September 1991.

Roberts, N.C., "Limitations of Public Management in Bureaus: The Case of the Department of Defense," Annual Meeting of the American Political Science Association, Washington, DC, 29 August -1 September 1991.

THESIS DIRECTED: Moes, C., LCDR, USN, "The Most Efficient Organization: Strategic Issue Management Case Study," MS Thesis, December 1991.

Fortson, J.C., LCDR, USN, "Paper Reduction in the Surface Navy: The Application of TQL?" MS Thesis, June 1991.

Schweizer, D.D., LCDR and Steele, J.P., LCDR, "Corporate Information Management: A Case Study," MS Thesis, March 1991.

Larson, C., LCDR, USN, "An Integrated Approach to the Selection Process of Independent Research and Development Projects," MS Thesis, March 1991.

Lewis, G.M., LCDR, USN, "Naval Postgraduate School 1990 Mainframe Procurement: A Case Study," MS Thesis, March 1991.

COST MANAGEMENT, STANDARDS, AND ANALYSIS: CASE STUDIES

J.G. San Miguel, Professor of Administrative Sciences
Sponsor: Case Program Executive Committee
Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this field based research project was to prepare a case study in the area of the Department of Defense and the Department of the Navy cost management in which new developments have taken place.

SUMMARY: This research project examined two recent Department of Defense initiatives that impact supply operations for all services and the Defense Logistics Agency. One initiative was the recent consolidation of supply depots in the San Francisco Bay Area under a new organization called Defense Distribution Region West. The other initiative was the Office of the Secretary of Defense's Comptroller's total cost per unit of output. Known as "unit costing," this latter initiative involves a major change in the resourcing of support activities for the U.S. military services. This research investigated the implementation of unit costing for supply depots of the Department of the Navy, Department of the Army, and the Defense Logistics Agency.

PUBLICATIONS: San Miguel, J.G., "Defense Distribution Region West (A)," Naval Postgraduate School, Case Number NPS-91837-01, 1991.

THESES DIRECTED: Faulk, D.P., LT, USN, "Cost Models and the Corporate Information Management (CIM) Initiative," MS Thesis, March 1991.

Hicks, W.S., LT, USN, and Hunter, J.F., LT, USN, "Unit Costing at the Naval Postgraduate School," MS Thesis, June 1991.

Asselin, R.R., LTC, USN, and Styron, E.L., Jr., LTC, USN, "Cost Benefit Analysis of General Services Administration's Proposed Relocation," MS Thesis, December 1991.

EVALUATION OF COSTS FOR THE NATIONAL INDUSTRIAL SECURITY PROGRAM

J.G. San Miguel, Professor of Administrative Sciences

Sponsor: National Industrial Security Program Interagency Task Force
Funding: National Industrial Security Program

OBJECTIVE: The aim of this research was to support the work of the Resources Working Group of the National Industrial Security Program which will recommend policy and program changes to improve the protection of classified information in industry.

SUMMARY: In 1990, the President directed the Secretaries of Defense and Energy and the Director of Central Intelligence to establish a government interagency and industry task force to develop elements of a National Industrial Security Program (NISP). This research for the Resources Working Group utilized a mail questionnaire to gather financial and operating information from a sample of over 500 U.S. companies having secured activities. This forms a baseline for the program. The ongoing research will analyze the data and develop an annual reporting system.

STRATEGIC PROFIT ANALYSIS

J.G. San Miguel, Professor of Administrative Sciences

OBJECTIVE: The aim of this research was to identify new theories and practices in strategic definitions of costs and revenue in profit oriented decisions.

SUMMARY: Due to global competition and changes in information and manufacturing technologies, U.S. companies are reexamining traditional management accounting and costing techniques and practices. This research investigates make-or-buy decisions, capital investment decisions, and other common decisions for strategic or long range implications. Positioning, marketing, and value chain analysis are also considered as well as Japan companies techniques such as target costing.

OTHER: Text and case studies are in process.

ENHANCEMENT OF SCHNEIDEWIND SOFTWARE RELIABILITY MODEL

Norman F. Schneidewind, Professor of Information Sciences
Sponsor: Strategic Systems Department, Naval Surface Warfare Center,
Dahlgren, Virginia

OBJECTIVE: Develope a methodology for validating software metrics. Develope a software testing strategy using the Schneidewind software reliability model.

SUMMARY: The research lead to the development of a methodology for metrics validation and a software testing strategy using a reliability model. This research has been used as follows: (1) The reliability model has been used by IBM and other organization. (See "other"); (2) The metrics validation methodology has been used by DoD's Software Engineering Institute and in the development of the IEEE standard for a Methodology for Software Quality Metrics (Draft).

PUBLICATIONS: Schneidewind, Norman F., "Methodology for Validating Software Metrics," *IEEE Transactions on Software Engineering*, forthcoming.

Scheidewind, Norman F. and Keller, T.W., "Application of Software Reliability Models to the Space Shuttle," *IEEE Software*, forthcoming.

Schneidewind, Norman, F., "Setting Maintenance Quality Objectives and Prioritizing Maintenance Work by Using Quality Metrics," in proceedings of the Conference on Software Maintenance, Sorrento, Italy, pp. 240-249, 14-17 October 1991.

Schneidewind, Norman, F., "Report on the Standard for a Software Quality Metrics (Draft) P1061, with Discussion of Metrics Validation," in proceedings of the Fourth Software Engineering Standards Application Workshop, pp. 155-157, 22 May 1991.

Schneidewind, Norman, F., "Validating Software Metrics: Producing Quality Discriminators," in proceedings of the International Symposium on Software Reliability Engineering, Austin, TX, pp. 225-232, 18 May 1991.

Schneidewind, Norman F., "Validating Software Metrics," 9th Annual Software Reliability Symposium, Colorado Springs, CO, 2 May 1991.

Schneidewind, Norman F., "Validating Software Metrics: Producing Quality Discriminators," in proceedings of the Third Annual Software Quality Workshop, Alexandria Bay, NY, 11-15 August 1991.

Schneidewind, Norman F., "Software Certification," in proceedings of the Conference on Software Maintenance, Sorrento, Italy, 14-17 October 1991.

Schneidewind, Norman F., "Influence of IEEE Software Engineering Standards on Industry," in proceedings of the Third Annual Software Quality Workshop, Alexandria Bay, NY, 11-15 August 1991.

Schneidewind, Norman F., "The Quantitative Specification of Software Quality Requirements," in proceedings of the Fourteenth Minnowbrook Workshop on Software Engineering, Blue Mountain Lake, NY, p. 119, 23-26 July 1991.

CONFERENCE PRESENTATIONS: Schneidewind, Norman F., "Software Engineering: Industry View," Fourteenth Minnowbrook Workshop on Software Engineering, Blue Mountain Lake, NY, 23-26 July 1991.

Schneidewind, Norman F., "Software Reliability Metrics: Emphasis on Validation," American Institute of Aeronautics and Astronautics Space-Based Observation Systems Workshop, Monterey, CA, 24 May 1991.

Schneidewind, Norman F., "Are Standards Necessary," Fourth Software Engineering Standards Applications Workshop, 21 May 1991.

Schneidewind, Norman F., "Validating Software Metrics: Producing Quality Discriminators," Department of Electrical and Computer Engineering, University of California, Irvine, CA, 4 November 1991.

Schneidewind, Norman F., "Validating Software Metrics: Producing Quality Discriminators,"

presented at the Linkoping University, Department of Mechanical Engineering, Linkoping, Sweden, 21 October 1991.

Schneidewind, Norman F., "Software Maintenance in the U.S.A., "Conference on Software Maintenance, Sorrento, Italy, 14-17 October 1991.

OTHER: The American Institute of Aeronautics and Astronautics Software Reliability Subcommittee has selected the "Schneidewind Software Reliability Model" as one of the models that will be recommended in its software reliability prediction and estimation handbook. This handbook will become an ANSI/IEEE standard. This model has been used at the following organizations: Naval Surface Warfare Center; IBM, Federal Systems Division-Houston; NASA-Jet Propulsion Laboratory; Hughes Aircraft Company-Fullerton; and NCR. It is used by IBM-Houston to report to NASA the estimated time of next software failure for the Space Shuttle.

VALIDATION AND APPLICATION OF SOFTWARE QUALITY METRICS

Norman F. Schneidewind, Professor of Administrative Sciences
Sponsor: U.S. Army Operational Test and Evaluation Command (CSTE-POC)

OBJECTIVE: Develop a set of validated metrics for the Army's STEP program.

SUMMARY: Validation criteria were identified to apply to the twelve software metrics that have been proposed for the Army's STEP program. Validation tests will be conducted on the twelve metrics. Part of the validation process will involve their project comparisons of metrics. Research will be undertaken to resolve scaling problems which arise when metrics are applied across projects which differ in size, language and development environment. The resultant prioritized set of validated metrics will be proposed for application to specific software systems. A measurement plan for putting the validated metrics into practice will be developed. Seminars will be conducted for the purpose of providing instruction in how to implement the measurement plan.

SOFTWARE QUALITY METRICS

Norman F. Schneidewind, Professor of Administrative Sciences
Sponsor: IEEE Computer Society Standards Activity Board

OBJECTIVE: Develop a standard for software quality metrics.

SUMMARY: As Chairman of the IEEE Software Quality Metrics Working Group, led the research effort that produced the draft standard. Currently comments are being resolved prior to the reballot. In 1991 four conference proceedings articles were published and twelve conference presentations and three colloquium presentations were made; in 1992 there will be two journal articles published. This research has been used as follows: by DoD's Software Engineering Institute and by a number of defense firms.

ISSUES IN ALLOCATING SERVERS AND FILES IN A LOCAL AREA NETWORK

Norman F. Schneidewind, Professor of Administrative Sciences

OBJECTIVE: Develop policies for allocating servers and files in a Local Area Network.

SUMMARY: There are several issues that confront LAN management with respect to allocating servers and files in a LAN. These are: (1) How many servers should be used for a given number of user computers? (2) Should files be replicated on the servers to provide better performance or should the available servers store different files in order to maximize the number and variety of programs on the LAN? (3) What should be the acceptable access times for users, singly and simultaneously, to access an application program, with a given number of servers and user computers? These issues were analyzed as a problem in optimization to determine the optimal server/user computer ratios and degree of file replication for given access times. Analytical and empirical results were reported.

In 1991 more refined results were obtained and presented at one conference. For 1992, a paper has been accepted for publication in a conference proceeding and for presentation at the conference.

PUBLICATIONS: Schneidewind, Norman F., "A System Response Time Model for Local Area Networks," in proceedings of the IEEE Third Workshop on Future Trends of Distributed Computing Systems, forthcoming.

Schneidewind, Norman F., "Issues in Allocating Servers and Files in a Local Area Network," in proceedings of the Silicon Valley Networking Conference, Santa Clara, CA, pp. 449-458, 25 April 1991.

THESIS DIRECTED: Stone, Larry, "Local Area Network Analysis," MS in Information Systems, September 1991.

RESOURCE ALLOCATION IN NAVAL COMMAND TEAMS

Kishore Sengupta, Assistant Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of the project was to investigate distributed decision making in Naval teams in uncertain, risky environments. Specifically, the project examined situation assessment, resource allocation and resource contention, uncertainty and the role of the leader.

SUMMARY: The study was conducted using the CWC-DDD (Composite Warfare Commander-Dynamic Decision Making) experimental paradigm. The CWC-DDD paradigm is an interactive computer software that has been used extensively in other studies of distributed decision making, and as such, constitutes a useful vehicle for laboratory experiments. The research question was operationalized through a partially counterbalanced factorial design. Several 4-member teams performed in a series of simulated air-sea battles.

PUBLICATION: Entin, E.D., Serfaty, D., Kleinman, D. and Sengupta, K., "Identification Error under Stress in Navy Teams," in proceedings of the Annual Conference of the American Psychological Association, forthcoming.

OTHER: Sengupta, K., "Resource Allocation in Command Warfare: the Impact of Uncertainty," in preparation.

INCORPORATING DECISION FEEDBACK IN GROUP DECISION SUPPORT SYSTEMS

(Continued from 1990)

Kishore Sengupta, Assistant Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop design principles for incorporating feedback in group decision support systems.

SUMMARY: Decision feedback has been shown to be effective in improving decision making. This project considered the feasibility of incorporating decision feedback in the context of group decision support systems.

PUBLICATION: Sengupta, K. and Te'eni, D., "Cognitive Feedback in Group Decision Support Systems: Improving Control and Convergence," MIS Quarterly, forthcoming.

CONFERENCE PRESENTATION: Sengupta, K. and Te'eni, D., "Reducing Cognitive Conflict through Feedback in GDSS: An Experiment in the Formulation of Group Preferences," in proceedings of the 24th Annual Conference of the Hawaii International Conference on System Sciences, Vol. III, J. Nunamaker (ed), pp. 631-640, IEEE Computer Society Press.

COMPLEXITY IN THE DESIGN OF USER INTERFACES

(Continued from 1990)

Kishore Sengupta, Assistant Professor of Administrative Sciences

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project was to develop theory-based guidelines for designing complex systems.

SUMMARY: Complex devices create high cognitive demands on users, often leading to poor performance and accidents. This project investigated the interaction of two components of overall complexity: task complexity and the complexity of the device itself.

PUBLICATION: Sengupta, K. and Te'eni, D., "Direct Manipulation and Command Language Interfaces: A Comparison of Users' Mental Models," in Bullinger, H.J. (ed) *Human Aspects in Computing: Design and Use of Interactive Systems and Work with Terminals*, 18A:429-434, Elsevier.

THESES DIRECTED: Frank, J., "Designing the User Interface: Considering the Concept of Complexity," MS Thesis, Information Systems, September 1991.

Reinhard, N., "The Effect of Task Complexity on User Interfaces: A Comparison of Command Language Interface and Direct Manipulation Interface," MS Thesis, Information Systems, March 1991.

Treharne, B., "The Impact of Verbal Protocol Analysis on a Model of Human-Computer Interface Cognitive Processing," MS Thesis in Information Systems, March 1991.

OTHER: Sengupta, K. and Reinhard, N., "The Role of Complexity in User Interfaces: A Comparison of Direct Manipulation and Command Language Interfaces, submitted to the *International Journal of Man-Machine Studies*.

DECISION SUPPORT FOR INTELLIGENCE ANALYSIS

Kishore Sengupta, Assistant Professor of Administrative Sciences

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate the feasibility for providing decision support tools for complex probabilistic tasks such as intelligence analysis.

SUMMARY: The project examined the efficacy of decision feedback as a support tool in enhancing the quality of decisions. An experiment was conducted using Naval Intelligence Analysts from COMPATWING at the Moffett Field Naval Air Station. Evidence indicates that the quality of Analysts' decisions was enhanced through the provision of feedback.

OTHER: Sengupta, K., "The Efficacy of Decision Feedback in Improving the Quality of Decisions in 32.2 Complex Probabilistic Tasks," in preparation.

AN EMPIRICAL ASSESSMENT OF THE EFFECTS OF ORGANIZATION, DOCUMENT DESIGN, AND STYLE OF ADJUDICATIVE DECISION MAKING

J.E. Suchan, Associate Professor of Administrative Sciences
Sponsor: Personnel Security Research & Education Center
Funding: Naval Postgraduate School

OBJECTIVE: This project determined whether changes in Report of Investigation (ROI) document design, organization, and style affected adjudicators determinations of security clearance.

SUMMARY: Forty adjudicators from four different central adjudication sites assessed ROIs written in the current bureaucratic style and a revised high-impact style, characterized by changes in organization, style, and document design. Adjudicators who read the high-impact ROIs did not make better quality adjudication decisions than those who read the bureaucratic ROIs. However, there were significant differences in adjudicators' decisions among the four central adjudication sites. Theses results indicate that factors outside the ROIs affect the reading and cognitive/structural information processing paradigm to assess the readability of texts needs to be altered. This study's results suggest that the social constructionist/ discourse community framework better explains how readers process functional documents.

PUBLICATION: Suchan, James, "The Effect of Organizational Metaphors on Writers' Stylistic Choices," Technical Communication, forthcoming.

CONFERENCE PRESENTATIONS: Suchan, James, "A Contingency Model of Managerial Communication Effectiveness," Conference on College Composition and Communication, Boston, MA, March 1991.

Suchan, James, "The Impact of Organizational Metaphors on Public Sector Professionals' Composing Processes," Conference on College Composition and Communication, Boston, MA, March 1991.

Suchan, James, "The Effect of Document Design, Organization, and Style on Decision Quality," The Association of Business Communication International Conference, Honolulu, HI, November 1991.

OTHER: The investigator is editing a technical report and revising two articles, based on conference presentations, for submission to journals.

TELECOMMUNICATION PLAN FOR EDI

M.W. Suh, Assistant Professor of Administrative Sciences
Sponsor: Naval Supply Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project is to identify an interoperable, telecommunication infrastructure of EDI and develop mathematical models for its minimum cost design.

SUMMARY: EDI is essentially a distributed application that enables geographically dispersed hosts to exchange business documents electronically. As such, it needs to be supported by an efficient, reliable, and secure telecommunication network. This project addresses the following two issues for the purpose of designing a network that will satisfy these needs: (1) specification of network architecture and (2) provisioning of telecommunication services. The former issues is concerned with what standard protocols to use in order to support EDI effectively. The emphasis is placed on the implication of Government Open Systems Interconnection Profile (GOSIP) on EDI networking. The latter issue deals with the optimal configuration of EDI networks in terms of costs, performance, reliability, and security. Mathematical models and heuristics are developed to guide decisions on network topology and service provisioning.

CONFERENCE PRESENTATIONS: Suh, M.W., "Minimum Cost Design of Leased DDS/T-1/T-3 Networks," ORSA/TIMS Joint Meeting at Nashville, TN, May 1991.

Suh, M.W., "Minimum Cost Design of Private T-1 Cross-connect Networks," ORSA/TIMS Joint Meeting at Anaheim, CA, November 1991.

THESES DIRECTED: Korzyk, A., Major, USA, "Multimedia Data Interchange for DoD CALS and EC/EDI," MS Thesis, September 1991.

Jung, J., Major, Korean Army, "An Overview of Electronic Data Interchange," MS Thesis, March 1991.

OTHERS: A paper titled "Optimal Design of Two-Tiered Distributed Database System" has been to IEEE Computer. Papers in progress include "EDI Networking for Defense Transportation," Architecture for Systems Integration in DoD," and "A Survey of Models for CALS." These papers will be completed by May 1992 for presentation in a conference and/or submission for publication.

HIGH QUALITY REGIONAL QMA&I

George W. Thomas, Associate Professor of Administrative Sciences
Linda Gorman, Adjunct Professor of Administrative Sciences
Sponsor: U.S. Navy Recruiting Command & U.S. Army Recruiting Command
Funding: U.S. Navy Recruiting Command & U.S. Army Recruiting Command

OBJECTIVE: To develop methodology for estimating local area qualified military available and interested in joining the military population.

SUMMARY: This project derived a method for obtaining regional estimates of the high-quality (high school graduates scoring about the 50th percentile on the Armed Forces Qualification Test) qualified military available (HQ QMA) population, accounting for the geographic variability in mental, moral, and physical qualifications necessary for military enlistment. Models and procedures were also developed for capturing geographic variability both in people's interest in military service and in their subsequent enlistment behavior. Multiplicative models were used to obtain estimates of the HQ QMA population as well as estimates of the subset of HQ QMA interested in joining the military (HQ QMJ) at the county level. The components of the multiplicative models were derived from regression analysis on National Longitudinal Survey of Youth data, with the set of explanatory variables limited to those for which satisfactory proxies are currently available at the county level. HQ QMA and QMJ estimates were provided by age/gender/racial market segments for 3,000 counties for years 1989-1995, 2000, 2005, and 2010. The HQ QMA and HQ QMJ measures of recruiting market potential improved the quality of extent measures of recruiting markets as well as subsequent recruiting management decisions, such as recruiter goals, allocation, and location.

PUBLICATION: Thomas, George W. and Gorman, Linda, "Estimation of High-Quality Military Available and Interested," U.S. Army Recruiting Command Study Report 91-3, August 1991.

CONFERENCE PRESENTATION: Gorman, Linda and Thomas, George W., "High Quality Recruiting Markets," Joint Market and Advertising Research Council, June 1991.

THESES DIRECTED: Uslar, Hans-Joachin, LCDR, German Navy, "A Prototypical Model for Estimating High Tech Navy Recruiting Markets," MS Thesis, December 1991.

Rickman, Jackie Lynn, MAJ, USMC, "Predicting High Quality AFQT with Youth Attitude Tracking Study Data," MS Thesis, December 1991.

Jackson, Kevin, A., CPT, USMC, "Weight Standards and Marine Corps Attrition," MS Thesis, June 1991.

Moreau, Ellen E., LT, USN, "Forecasting High Tech ASVAB Scores," MS Thesis, June 1991.

USAR COMMUTE DISTANCE STUDY

George W. Thomas, Associate Professor of Administrative Sciences
So Young Sohn, Professor of Operations Research
Sponsor: U.S. Army Recruiting Command
Funding: U.S. Army Recruiting Command

OBJECTIVE: To develop a model for determining the geographic dimensions of recruiting markets around Reserve Centers.

SUMMARY: A two-stage random effect model is applied to evaluate the geographical extent of the labor market for Army Reserve Centers. In the first stage model, a lognormal distribution is used to describe the commuting distance behavior of the Reserve Center members. In the second stage model, we estimate the mean of log transformed commute distance as a function of regional characteristics of the Reserve Center. An iterative weighted stepwise selection method is used to find a set of characteristics that adequately explain the variation of the mean distance over Reserve Centers. The resulting model can be used to assist the marketing and missioning decisions of the Army Recruiting Command.

PUBLICATIONS: Sohn, So Young and Thomas, George W., "U.S. Army Reserve Commute Distance Model," U.S. Army Recruiting Command Study Report 91-1, March 1991.

Sohn, So Young and Thomas, George W., "A Two-Stage Random Effects Model for Estimating Commute Distance," in proceedings of the American Statistical Association, August 1991.

CONFERENCE PRESENTATION: Sohn, So Young and Thomas, George W., "A Two-Stage Random Effects Model for Estimating Commute Distance," American Statistical Association, August 1991.

BEHAVIORAL/ATTITUDINAL SURVEYS OF CIVILIAN PERSONNEL DEPARTMENT AND OF ENGINEERS AT THE NAVAL AVIONICS CENTER

K.W. Thomas, Professor of Administrative Sciences
B.J. Roberts, Associate Professor of Administrative Sciences
S.P. Hocevar, Adjunct Professor of Administrative Sciences
G.F. Thomas, Associate Professor of Administrative Sciences
F.J. Barrett, Assistant Professor of Administrative Sciences
Sponsor: Naval Avionics Center
Funding: Naval Avionics Center

OBJECTIVE: To measure key behavioral/ attitudinal factors influencing the effectiveness of the Civilian Personnel Department (CPD) and of Engineering units at the Naval Avionics Center (NAC). (A subproject of a larger project, "Administrative Sciences Support for CPD," D.R. Whipple, Principal Investigator.)

SUMMARY: This subproject was originally funded for the period 1989-1990. In that period, an internal organizational effectiveness audit of the CPD had been performed, and factors which influenced key career decisions of engineers were identified. Technical reports on these two phases had been submitted by K.W. Thomas and B.J. Roberts in 1990. In the current reporting year, the second half of Phase II was completed. This study involved a determination of the profile of an effective engineering branch manager at NAC. Using survey questionnaires, branch managers were rated on effectiveness by subordinate engineers and by their immediate superiors. Engineers also rated 64 elements of the branch manager's behavior. Running correlations between behaviors and effectiveness variables allowed us to identify key skill areas related to effectiveness. A composite profile of the effective engineering manager was developed based on these results which emphasized the importance of four communications related functions performed by the manager. A technical report on these findings was completed, and feedback prepared for managers who participated in the study.

PUBLICATION: Thomas, K.W., Hocevar, S.P., Thomas, G.F. and Barrett, F.J., "Profile of an Effective Engineering Manager," NPS Technical Report, NPS-AS-92-006, December 1991.

THESIS DIRECTED: Chang, D.W., LCDR, USN, and Quick, N.A., LT, USN, "Profile of an Effective Engineering Manager at the Naval Avionics Center," MS Thesis, June 1991.

OTHER: Thomas, G.F., Thomas, K.W., Hocevar, S.P. and Barrett, F.J., "Managerial Communication Behaviors Related to Multiple Measures of Effectiveness: A Field Study," competitive paper submitted to the national meeting of the Academy of Management, December 1991.

BEHAVIORAL/ORGANIZATIONAL STUDIES OF EMPLOYEE INVOLVEMENT

K.W. Thomas, Professor of Administrative Sciences
S.P. Hocevar, Adjunct Professor of Administrative Sciences
G.F. Thomas, Associate Professor of Administrative Sciences
F.J. Barrett, Assistant Professor of Administrative Sciences
Sponsor: Naval Avionics Center
Funding: Naval Avionics Center

OBJECTIVE: To study intrinsic task motivation of engineers at the Naval Avionics Center (NAC) and to assess Total Quality Management (TQM) implementation at NAC and other DoD organizations. (This is a subproject of a larger project, "Administrative Sciences Research Support for CPD," S. Mehay, Principal Investigator.)

SUMMARY: Two aspects of employee involvement were studied during 1991. The first involved TQM initiatives at NAC and in other DoD organizations. Ten exemplary TQM organizations were identified. Using a combination of interviews with top executives, a survey measure of critical areas of TQM implementation, and examination of organizational documents, the following were identified: lessons learned during TQM implementation, innovative TQM practices, and an evaluation of the effectiveness of TQM implementation in different key areas. The second aspect of employee involvement concerned the intrinsic task motivation of employees--the psychological manifestation of employee involvement. A questionnaire survey was conducted using engineers at NAC. This survey measured four elements of intrinsic task motivation: meaningfulness of work, sense of impact, sense of competence, and sense of choice. Engineers also rated various factors believed to influence intrinsic task motivation, and provided ratings of variables believed to be consequences of intrinsic task motivation. Correlations were used to identify probable causal factors and consequences of intrinsic task motivation for these engineers.

PUBLICATIONS: Applegate, C., Hocevar, S.P. and Thomas, K.W., "Total Quality Management in Ten Exemplary Department of Defense Organizations: Lessons Learned, Innovative Practices, and Quality Measurements," NPS Technical Report NPS-AS-92-003, November 1991.

Hocevar, S.P., Applegate, C. and Thomas, K.W., "Self-Ratings of Eight Factors of Quality Management at Naval Avionics Center," NPS Technical Report NPS-AS-92-005, December 1991.

THESES DIRECTED: Applegate, C., LT, USN, "Total Quality Management in the Department of Defense: Lessons Learned, Innovative Practices, and Quality Measurements," MS Thesis, September 1991.

Sutz, S.S., CPT, USMC, "Sources and Consequences of Intrinsic Task Motivation in Engineers at the Naval Avionics Center," MS Thesis, December 1991.

IMPLEMENTING TQM METHODS IN NAVAL REPAIR FACILITIES

Dan Trietsch, Associate Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to identify process improvement opportunities in naval shipyards and investigate how best to implement them in the Navy.

SUMMARY: TQM calls for continuous process improvement efforts at all levels of DOD. Examples of such process improvements-investigated by this researcher in the past-include reducing setup times on various machines and equipment and utilizing smaller batches and transfer batches to reduce the leadtime in the repair environment. These and similar methods can also apply to other naval activities.

I consider the setup reduction project conducted by this PI in FY 1990 as part of this one, but in addition I tried to implement a statistical experimental design to reduce variance of machined dimensions (the major cause of defects at machine shops) at Mare Island NSY. I've also written a first draft of a technical report describing the application of experimental design to preliminary search of factors that impact on the consistency of machining parts. Lack of such consistency is a major cause of defects in machined parts. So far, however, Mare Island has not yet implemented this idea.

THESES DIRECTED: Bosch, Bradley, LT, MSC, USN, "A Process of Ongoing Improvements for Dispensing Medication Using a TQM Approach," MS in Management, June 1991.

OTHER: The investigator is finishing two working papers based on this research: (1) Some Notes on the Application of Single Minute Exchange of Die (SMED), and (2) An Experimental Design to Improve the Quality of Machined Parts. Completion is expected mid 1992.

OPTIMAL SCHEDULING OF PERT ACTIVITIES WITH TREE PRECEDENCE NETWORKS AND AN APPLICATION TO HUB OPERATIONS

Dan Trietsch, Associate Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project at this stage was to publish a paper which was accepted conditionally.

SUMMARY: In order to publish a paper in Transportation Research, a major programming effort was required. This was carried out successfully (in terms of the programs' output, and the revised paper was submitted on December 20, 1991.

PUBLICATION: Trietsch, Dan, "Scheduling Flights at Hub Airports," *forthcoming.*

CONFERENCE PRESENTATION: Trietsch, Dan, "The Effects of Variability and Congestion on Hub Airports Costs: A Computerized Experiment with Hypothetical Data." TIMS/ORSA Conference in Anaheim, CA, 3-6 November 1991.

NEAR OPTIMAL TRANSFER LOTS FOR JOB SHOPS WITH SEVERAL DEPARTMENTS

Dan Trietsch, Associate Professor of Administrative Sciences
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project at this stage was to publish a paper with a new collaborator, Professor Kenneth R. Baker.

SUMMARY: Professors Trietsch and Baker have worked independently on a similar problem, and both experienced difficulties in publishing because of this competition. Thus, a joint paper was prepared. Said paper was submitted and subsequently revised as per the instructions of the Area Editor of Operations Research.

PUBLICATION: Trietsch, Dan and Baker, Kenneth R., "Basic Techniques for Lot Streaming," Working Paper 262, The Amos Tuck School of Business Administration, Dartmouth College, January 1991 (revised for publication, September 1991).

OTHER: Pending success of the present submission we have enough material for at least one more paper on the same subject.

BURDEN SHARING, INTERNATIONAL ARMAMENTS COOPERATION, AND U.S. MOBILIZATION CAPABILITY

D.R. Whipple, Chairman of Administrative Sciences
W.R. Gates, Adjunct Professor of Administrative Sciences
L.R. Jones, Professor of Administrative Sciences
E.J. Laurance, Professor of National Security Affairs
M.G. Sovereign, Professor of Operations Research
K.L. Terasawa, Adjunct Professor of Administrative Sciences
Sponsor: Office of the Chief of Staff of the Army

OBJECTIVE: Determine the extent to which the U.S. can draw on allied industrial capabilities to increase allied contributions to our mutual defense. To successfully share the defense burden, we must establish the extent to which such sharing is acceptable to our allies and develop mechanism to facilitate equity.

SUMMARY: This research extends earlier work to begin creating a framework for analyzing burden sharing, international armaments cooperation and U.S. mobilization capability. Progress was made in developing a model of defense alliances to explain expenditure patterns among alliance members. This model considers the members' commitment, threat perceptions, and interactions with adversaries to help explain defense expenditures within an alliance. Research was also conducted to identify the costs and benefits of Operations Desert Shield/Desert Storm. The objective was to examine the burden sharing in this operation and identify possible future policy implications.

PUBLICATION: Gates, W.R. and Terasawa, K.L., "Commitment, Threat Perceptions, and Expenditures in a Defense Alliance," *International Studies Quarterly (36)*, forthcoming.

THESES DIRECTED: Bowen, G.J., II, LT, USCG, "The FSX Project, A Case Study in Burden Sharing And International Armaments Cooperation," MS Thesis, December 1990.

Bowman, L., LT, USN, "Reduction of U.S. Mobilization Capability due to Increased Foreign Source Dependency: New Concerns for the Intelligence Community," MS Thesis, December 1990.

Emerson, K.M., LT, USN, "Defense Procurement in the United Kingdom,: Which Way Will It Go?" MS Thesis, December 1990.

Johnson, W.A., CPT, USMC, "What Constitutes National Security in the Semiconductor Industry? A Look at the Competing Views Surrounding DOD's Support of Semiconductors," MS Thesis, December 1990.

Martello, C.P., LCDR, USN, "NATO Burden-Sharing: Redefinition for a Changing European Threat," MS Thesis, December 1990.

Sweatt, S.G., CPT, USMC, "The United States/Japan Responsibilities Sharing for the Marine Corps Forces," MS Thesis, December 1990.

Hinkley, B.E., "Cost Estimates for Operation Desert Shield/Desert Storm: A Burden Sharing Perspective," MS Thesis, December 1991.

Johnson, J.A., "Cost Estimates for Operation Desert Shield/Desert Storm: A Budgetary Analysis," MS Thesis, December 1991.

OTHER: Terasawa, K.L. and Gates, W.R. have two papers in progress which will be submitted for publication in 1992: "Allies, Adversaries and Commitment in Defense Alliances," and "Burden Sharing in the Persian Gulf: Lessons Learned and Implications for the Future."

FACTORS AFFECTING SOFTWARE REUSE

Dani Zweig, Assistant Professor of Administrative Sciences
Funding: Naval Postgraduate School

OBJECTIVE: This is the continuation of an empirical research project whose purpose is to identify (and quantify) factors which determine the success of efforts to reuse existing software for new application systems.

SUMMARY: We monitored and measured the software produced at two research sites (one investment bank and one retailer) which are using an integrated, object-based CASE development environment. On the basis of preliminary research (reported last year at the Workshop on Information Systems) we had hypothesized that the CASE technology supporting software reuse would be relatively ineffective without an accompanying change in software management. The data collected and analyzed in this past year has allowed us to confirm this, and to present our findings more precisely: The new technology supports and encourages the reuse of software within a given project or team, but has little effect on the reuse of software across systems or organizations, although that is where the greatest savings could be realized. Such reuse repairs requires fundamental changes in the way software requirements are developed.

CONFERENCE PRESENTATIONS: Banker, R., Kauffman, R., and Zweig, D., "Factors Affecting Code Reuse: Implications for a Model of Computer Aided Software Engineering Development Performance," workshop on Information Systems and Economics, Copenhagen, Denmark, December 1990.

OTHER: This study has resulted in two articles submitted this year for publication, but none of these has, as yet, completed the review process. One of them ("Monitoring the software Asset: Using Repository Evaluation for Computer Aided Software Engineering (CASE) Performance Evaluation") is under review at IEEE Transactions on Software Engineering and one ("Automating Output Size and Reusability Metrics in an Object-Based CASE Environment") is under review at IEEE Software Transactions.

DEPARTMENT
OF
COMPUTER SCIENCE

DEPARTMENT OF COMPUTER SCIENCE

Research in the Department of Computer Science is carried out by faculty, research professionals and by students at both the M.S. and Ph.D. levels. All funded research is conducted under the supervision of a faculty member serving as principal investigator. The research activities of the department can be grouped into five areas corresponding to the specialization tracks of our curriculum. A summary of activities in each of these areas follows. When individual faculty members are cited, it is to be understood that the work described also involves research carried out by students and staff under the supervision of the faculty member.

Artificial Intelligence and Robotics

Professor McGhee investigated basic technologies related to the real-time control, artificial intelligence and computer architectures needed for the support of autonomous underwater vehicles (AUV). He also investigated the design of small GPS/INS package for the NPS Model 2 AUV.

Professor Kanayama worked on research problems of the autonomous underwater vehicle project and the Yamabico autonomous mobile robot project. In the first project, he worked on 3D environmental description, path planning, sonar data interpretation, graphics simulation, and real-time control of the AUV. In the second, he has been working on shortest path planning, improving the sonar data interpretation system, and designing an image understanding system.

Professor Rowe investigated the theory of best paths when the cost of travel is a discontinuous function of heading, or has discontinuous derivatives.

Professor Shing investigated efficient algorithms for finding optimal paths and layouts. Such algorithms find applications in many critical military functions, ranging from navigation of autonomous vehicles to the layout of VLSI circuits. He applied the technique of simulated annealing to the problem of finding optimal paths for the weighted region shortest-path problem, and performed experimental studies to evaluate the method.

Professor Lee continued his work on the artificial intelligence and real-time computer system aspects of the autonomous underwater vehicle project. Prof. Lee also investigated issues related to applying artificial intelligence and software engineering methodologies to the design and development of military training and simulation systems. A generic tutoring shell was developed and applied to training systems for helicopter recognition and Ada programming.

Professor Se-Hung Kwak continued his work with Prof. McGhee on rule-based motion coordination for a hexapodal walking machine. Additionally, he worked on a mission planning expert system for the NPS autonomous underwater vehicle.

Professor Erickson worked on developing algorithms for the school-scheduling problem. The scheduling system he developed is based on simulated annealing and performs significantly better than previous solutions utilizing traditional optimization techniques.

Software Engineering

Professor Berzins continued his work on specifications and computer-aided design for Ada. The main part of this work consists of a project funded by the Army Research Office and a project sponsored by the Office of Naval Research. The first project is developing both fundamental theory and practical algorithms for combining changes to software systems, a central problem in software maintenance with additional applications to view integration in software specifications, organization of software design databases, and the semantics of

programming languages with multiple inheritance. This work resulted in the first general semantic model for change merging, and the publication of a new formal method for deriving combined software changes that is the most powerful known to date. The second project covers specification-based software tools for the design and analysis of Ada software. This work includes tools for checking the internal consistency of behavioral specifications, automatically generating information for design review meetings, automatically generating Ada interface code, and automatically generating Ada test harnesses that produce test inputs and determine whether test outputs conform to the behavioral specifications. He has also worked on the specification, design, and implementation of an Ada prototype for a low cost combat direction system in a project funded by the Naval Sea System Command, and on projects sponsored by the Naval Surface Warfare Center and the Naval Research Lab.

Professor Luqi won a five year Presidential Young Investigator Award from the National Science Foundation to continue her work on computer-aided prototyping of real-time Ada software. Prof. Luqi also heads two projects funded by the Navy Sea Systems Command, which seek to develop a low cost combat direction system and to demonstrate the use of Navy Ada for combat direction systems. These projects have the goal of creating a low cost combat direction system on a commercially available workstation. Both projects have taken advantage of her computer-aided prototyping system and serve as case studies for testing, evaluating, and improving the suite of computer-aided design tools being developed in companion projects. A working prototype of a low cost combat direction system was produced.

Professor Luqi also heads a project sponsored by the Office of Naval Research for developing execution support for a computer aided prototyping system for real-time software. For this project, she has developed and evaluated several real-time scheduling algorithms as well as improved tools for generating prototype Ada code. Approximately 25,000 lines of code in Ada and C++ were developed.

Professor Luqi also heads a project funded by the Naval Surface Warfare Center for developing models for prototypes of dynamic systems. This project is developing ways to enable computer-aided design of flexible real-time systems that can consist of variable numbers of subsystems whose interconnection patterns can change with time, such as C3I systems.

Professor Luqi also heads a project funded by the Naval Research Laboratory for modeling real-time systems at NRL. This project assessed current software development practices at NRL, determined the characteristics of the real-time systems involved, and recommended a suitable methodology and supporting tools for use at NRL.

Computer Graphics and Visual Simulation

Professor Zyda continued his work on real-time techniques useful for the development of inexpensive, three-dimensional visual simulation systems. He heads a project funded by US Army Engineer Topographical Laboratories to develop terrain database standards, a project funded by US Army Project Manager Training Devices for developing low cost networkable 3D Visual simulations, two projects funded by US Army Test and Experimentation Command for development of a SIMNET-compatible, non-line-of-sight 3D visual simulator and for developing line-of-sight and visual enhancements to the moving platform simulator. The work has been focused on the NPSNET system, a low-cost, commercially available workstation-based version of the DARPA SIMNET system.

Professor Zyda also heads a project funded by Headquarters, Department of the Army AI Center for terrain visualization and reasoning, and a project sponsored by the Naval Ocean Systems Center for developing inexpensive 3D visual simulation for the command and control workstation of the future. During the current year, that project continued to explore data structures for supporting real-time visual simulations, and developed techniques for hierarchical organization of bottom data for real-time display in the simulation of an autonomous underwater vehicle.

Professor Pratt's primary research area is real-time networked 3D vehicle simulations, with emphasis on the management and representation of complex terrain, vehicular and feature databases. He is also interested in user interfaces that help users discern motion clues from the simulation, in improvement of man-machine interaction, and in AI techniques to control vehicles.

Computer Systems and Architectures

Professor Kodres continued his work on a project sponsored by the Naval Sea Systems Command for developing an AN/UYS-2 Enhanced Modular Signal Processor (EMCR) and Processing Graph Methodology (PGM). This project is exploring the use of a single chip computer, the transputer, as a component of a larger multicomputer, real-time network. Prof. Kodres completed the design of the communications system for the network of transputers. The system is fault tolerant, communications dead-lock free and dynamically adjustable to any communications link failure. The electronic re-configuration capabilities of the system were used to solve a linear algebra problem on a network of up to 16 processors, and benchmarks were run to compare the performance to that of a hypercube iPCS processor. Prof. Kodres also heads a project funded by the Pacific Missile Test Center for developing a navigation data logger software system to explore Ada interfaces between small computers and GPS systems.

Professor Lundy continued his work on specification and analysis of communications protocols, sponsored by SPAWAR. This year he made progress on modeling VSAT networks for communications satellites and explored applications of very high speed networks to improve the Navy's AEGIS combat system, and to improve communications within hospitals and between hospitals and emergency vehicles. He also specified an improved version of the FDDI protocol for high speed fiber optic networks.

Professor Zaky investigated efficient fine-grained scheduling of recurrence loops on VLIW architectures in a project sponsored by NPS. The project is currently being extended to scheduling more general classes of loops on VLIW/Superscalar architectures, which can perform more than one instruction per clock cycle. The significance of this work lies with the fact that such architectures are becoming the architectures of choice for the new generation of high performance workstations.

Data and Database Engineering

Professor Hsiao worked on a project sponsored by the Naval Pacific Missile Test Center on the role of federated databases and systems in data-intensive applications, where he evaluated parallel database architectures. He also worked on a project funded by NRL to apply an Object Oriented Data Model to the specification of multilevel security policies for databases. Prof. Hsiao worked on database systems on a project sponsored by ONR. His efforts were directed at organizing international database conferences.

Professor Wu worked on the design of a prototype on-board information system on multiple hardware platforms supported by funding from the Naval Weapons Station, Concord. This project is developing the Argos system (the paperless ship). This year work focused on incorporating a real DBMS into the prototype, and porting it to the MS-Windows environment. Prof. Wu also headed a project sponsored by the Naval Security Agency on the design and implementation of multimedia information systems by using object-oriented development tools. He worked on extending current prototypes of a multimedia database system with a capability for processing complex queries. He used the Oracle DBMS on the Macintosh system to provide and SQL-based relational capability, explored architectures for connecting the Macintosh with PC's via a network, and developed a method that allows users to specify visual queries based on dataflow diagrams, which are translated into SQL queries. Prof. Wu also worked on the establishment of an INFOSEC center of excellence as part of a project funded by the National Security Agency. This year he developed two computer security courses as a step towards the goal of establishing an information security track within the Computer Science major at NPS.

Professor Shimeall is working on a project sponsored by the Naval Weapons Center for evaluating the safety of life-critical software, by integrating fault tree analysis with state transition modeling.

FUNDAMENTAL THEORY FOR SYSTEMATICALLY COMBINING CHANGES TO SOFTWARE

V. Berzins, Professor of Computer Science
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: We seek to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in the development of large Ada software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has important potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

SUMMARY: We have developed a semantic model and automaticable methods for combining changes to programs and specifications. We have extended previous semantic models of programs by embedding approximation lattices in a new class of complete, countably-based Boolean algebras. This structure provides a different operator on programs which was used to formalize the semantics of an ideal operator for combining changes to programs. This ideal operator produces results that are semantically correct with respect to a natural criterion, and which locate inconsistencies in cases where two changes produce incompatible results for the same design decision. We have derived some of the general properties of the change merging operation, and have developed new methods for practically merging such changes for a simple imperative programming language and for the real-time prototyping language PSDL.

PUBLICATION: Berzins, V., "Software Merge: Models and Methods for Combining Changes to Programs," *Journal of Systems Integration*, 1(2):121-141, August 1991.

AUTOMATED SOFTWARE TOOLS FOR THE DESIGN OF LARGE ADA SOFTWARE SYSTEMS

V. Berzins, Professor of Computer Science
Luqi, Professor of Computer Science
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: Our goal is to develop new technologies for computer-aided design of Ada software systems. A set of software tools for validating requirements and formalizing design efforts of Ada Software Systems are under design and development by applying and extending state of the art research results in software engineering and in artificial intelligence to automate a larger part of the effort in software development. This project emphasizes the refinement of a formal specification tool set suitable for supporting computer-aided development of large Ada programs. To meet urgent needs of DOD, the primary goals of this work are to improve programmer productivity and the quality, reliability, and flexibility of software systems.

SUMMARY: We have refined our previous work on developing a formal specification language and explored the use of formal specifications to support the design of Ada software via case studies. The specification language complements Ada in the design of large systems, and supports descriptions of distributed and real-time systems on a large scale, and is supported by a set of tools for computer-aided software design. We have developed a specification of an embedded control system to demonstrate that the facilities for describing real-time constraints in the Spec language are adequate for designing realistic systems. We have developed techniques for modeling changes to software systems that can serve as the basis for automated tools for managing and coordinating changes to a software system. Our approach views the evolution of a software system as a partially ordered collection of transformations that reflects the semantics of the set of design decisions leading to the design of the software system. This structure can be exploited by computer-aided design tools addressing some of the problems of software maintenance.

PUBLICATIONS: Berzins, V., "Black-Box Specification in Spec," *Journal of Computer Languages*, 16(2):113-127, April 1991.

Berzins, V., "Distributed Algorithms for Generating Unique Identifiers," revised for *IEEE Transactions on Computers*.

AUTOMATICALLY COMBINING CHANGES TO SOFTWARE SYSTEMS

V. Berzins, Professor of Computer Science
Sponsor: U. S. Army Research Office
Funding: U. S. Army Research Office

OBJECTIVE: We seek to develop fundamental theory and practical methods for combining several changes to a software system with mathematically provable guarantees of correctness. The main goal of this research effort is to enable a higher level of computer-aided design in development and maintenance of large software systems. Combining changes to software is a fundamental problem in software engineering. This process is important in all phases of developing large software systems, where multiple changes must be developed concurrently and then combined. This work has important potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

SUMMARY: This process is important in all phases of developing large software systems, where multiple change must be developed concurrently and then combined. This work has potential applications to software maintenance, view integration in specifications, version control in design databases, and multiple inheritance in specification or programming languages.

PUBLICATIONS: Berzins, V., "Software Merge: Models and Methods for Combining Changes to Programs," in proceedings of the European Conference on Software Engineering, 221-250, October 1991, Lecture Notes in Computer Science, Vol. 550, Springer-Verlag.

Berzins, V. Luqi, Yehudai, A., "Using Transformations in Specification-Based Prototyping," *IEEE Transactions on Software Engineering*, forthcoming.

THE NPS ACADEMIC COURSE SCHEDULER

D. A. Erickson, Adjunct Professor of Computer Science
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop algorithms for the school-scheduling problem; to create a working school scheduling program for use at NPS. Continued work done in previous year.

SUMMARY: During 1991, the school scheduling program (SSP) received the following modifications: A user-interface was prototyped and underwent several cycles of redesign which incorporated feedback from end users. That work is continuing during 1992 (two students are investigating human factors and managerial aspects of the problem; their thesis projects are due to be completed in March 1992).

PUBLICATION: Erickson, D.A., "School Scheduling, A Stochastic Approach," Ph.D. Thesis, Stanford University, September 1990. Published in Dissertation Abstracts, January 1991.

THE OBJECT-ORIENTED APPROACH TO MULTI-LEVEL SECURE DATABASES

David K. Hsiao, Professor of Computer Science
Sponsor: Naval Research Laboratory (NRL)
Funding: Naval Research Laboratory

OBJECTIVE: Conventional data models and data languages are known to be inadequate to support the multilevel security policy and its access control requirements for the classified database. The emergence of a new data model with its built-in data language known as the Object-Oriented Data Model (OODM) has raised the question whether OODM can be used to support the DoD-required multilevel security policy and its read-down and write-up requirements of the user with clearance over classified data in an object-oriented database.

The research is, therefore, focused on the database constructs of OODM, on the use of these constructs for specifying the multilevel security policy and its access control requirements, and on the adequacy or inadequacy of these constructs in conducting the specifications.

SUMMARY: Some important results have been obtained from this research: (1) The OODM constructs are not only adequate for the specification of the multilevel security policy and access control requirements, but also natural for the specification; (2) The OODM constructs are also adequate and natural in the specification of other security policies and their respective access control requirements such as the need-to-know policy and its access control requirement using the views; (3) The Object-Oriented Database Management System (OODBMS) is the only DBMS which can support not only classified databases under the multilevel security policy, but also secure databases under different and multiple security policies.

THE ROLE OF FEDERATED DATABASES AND SYSTEM IN DATA-INTENSIVE APPLICATIONS

David K. Hsiao, Professor of Computer Science
Sponsor: Naval Pacific Missile Test Center (NPMT)
Funding: Naval Postgraduate School

OBJECTIVE: The architecture of the federated databases and system may have significant impact on the support software activities at NPMTC. In particular, the research results on the architecture may yield some important solutions towards the NPMTC's support software requirements.

PUBLICATIONS: Hsiao, D.K., "A Parallel, Scalable, Microprocessor-Based Database Computer for Performance Gains and Capacity Growth," *IEEE MICRO*, II(6):44-60, December 1991.

Hall, J.E., Hsiao, D.K., and Kamel, M.N., "Performance Evaluations of a Parallel, Scalable, and Expandable Database Computer," in proceedings of the 24th Hawaii International Conference on System Sciences, Koloa, Hawaii, January 1991.

CONFERENCE PRESENTATION: Hsiao, D.K. and Kamel, M.N., "The Multimodel and Multilingual Approach to Interoperability of Multidatabase Systems," International Conference in Interoperability of Multidatabase Systems, Kyota, Japan, April 1991.

IMAGE UNDERSTANDING FOR AUTONOMOUS ROBOTS

Yutaka Kanayama, Professor of Computer Science
Sponsor: Research Council
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate the effectiveness and limitation of the use of the image understanding technique in navigation, guidance and spatial learning of an autonomous mobile robot. This project is a part of the research initiation program for the principal investigator.

SUMMARY: In this project, the Yamabico-11 autonomous mobile robot and its image understanding capabilities has been used. A color CCD camera and a digitizer were procured by the first year budget of the research initiation program.

The investigator conducted the following tasks under this program in this year. (1) Shortest path planning for indoor mobile robots. A student was involved in this part. (2) Development and improvement of Yamabico's sonar understanding system. A student and a staff member helped in this part. (3) We started the task for linear feature extraction from gray scale images. This task is a part of image understanding in an indoor environment. (4) The three dimensional geometric model design and construction task was also initiated. This and the previous tasks are being integrated into the major task of pattern matching. (5) Path tracking task was started. This tries to solve the problem of guiding a rigid body robot vehicle by an abstract spatial model of vehicles. (6) Also, we started the project of layered pathplanning, which divides the conventional path planning problem into two; skeleton planning and end motion planning.

PUBLICATIONS: Kanayama, Y. and Onishi, M., "Locomotion Functions in the Mobile Robot Language, MML," in proceedings of the IEEE International Conference on Robotics and Automation, pp. 1110-1115, Sacramento, CA, 9-11 April 1991.

Floyd, C., Kanayama, Y. and Magrino, C., Underwater Obstacle Recognition Using a Low-Resolution Sonar," in proceedings of the Seventh International Symposium on Unmanned Untethered Submersible Technology, pp. 309-327, Durham, New Hampshire, 23-25 September 1991.

Kanayama, Y., Kimura, Y., Miyazaki, F. and Noguchi, T., "A Stable Tracking Control Method for a Non-Holonomic Vehicle," in proceedings of the Workshop on Intelligent Robots and Systems, pp. 1236-1241, Osaka, Japan, 2-5 November 1991.

THESES DIRECTED: Sherfey, Solomon, LT, USN, "Sonar System Architecture for an Autonomous Mobile Robot," MS Thesis, 20 September 1991.

Crane, J., CPT, USA, "Shortest Path Planning in a Polygonal World," MS Thesis, 20 September 1991.

Floyd, C., CDR, USN, "Design and Implementation for a Collision Avoidance System for the NPS Autonomous Underwater Vehicle (AUV II) Utilizing Ultrasonic Sensors," MS Thesis, 26 September 1991.

Magrino, Christopher, LT, USN, "3D Guidance for the NPS Autonomous Underwater Vehicle," MS Thesis, 26 September 1991.

OTHER: Kanayama, Y. and Brutzman, D. "Shortest Path Planning in a Circle World," submitted to Proceedings of the IEEE Conference on Robotics and Automation, Nice, France, 10-15 May 1992.

Sherfey, S., Kanayama, Y. and Williams, M., "Sonar System Architecture for an Autonomous Mobile Robot," submitted to Proceedings of the IEEE Conference on Robotics and Automation, Nice, France, 10-15 May 1992.

Kanayama, Y. and Lombardo, C., "Shortest Path Planning in a Convex Polygonal World," submitted to Eighth Annual Symposium on Computational Geometry, Berlin, Germany, 10-12 June 1992.

AN/UYS-2 ENHANCED MODULAR SIGNAL PROCESSOR (EMCR) AND PROCESSING GRAPH METHODOLOGY (PMG)

U.R. Kodres, Professor of Computer Science
Shridhar Shukla, Assistant Professor of Electrical and Computer Engineering
Sponsor: Naval Sea Systems Command
Funding: Naval Sea Systems Command

OBJECTIVE: To support the development of the Navy standard signal processor, the AN/UYS-2, which is a shared memory parallel processor. The central idea of the project was to enhance the scheduling of the nodes of the PGM graph.

SUMMARY: An approach to use compile time analysis, to exploit the periodic arrival of data and an "a prior" knowledge of the amount of computation and communication overhead was investigated. A simulation model using C++ was created to implement the Revolving Cylinder scheduling algorithm. This algorithm was observed to improve the performance in cases with high communication overhead, or when the PGM nodes are of uniform size.

THESES DIRECTED: Little, Brian, LT, USN, "A Technique for Predicting Real-time Execution in the AN/UYS-2 Parallel Signal Processor Architecture." MS in Electrical Engineering, December 1991. (Advisor S. Shukla)

Richmond, Clay, LT, USN "On Programming Transputers to Capture Ada Multitasking for the NPS Autonomous Underwater Vehicle." MS in Engineering Science, December 1991. (Advisor S. Shukla)

Yuktadatta, Panurit, LT, Royal Thai Navy, "Simulation of a Parallel Processor Model of a Small Tactical System," MS in Engineering Science, December 1991. (Advisor U.R. Kodres)

SMALL NAVIGATION DATA LOGGER SOFTWARE SYSTEM

U.R. Kodres, Professor of Computer Science
S.H. Kwak, Adjunct Professor of Computer Science
J.R. Clynch, CNOC MC&G, Professor of Oceanography
Sponsor: Pacific Missile Test Center
Funding: Pacific Missile Test Center

OBJECTIVE: To develop Ada language software for the use of desktop computers and preferably on lap-top computers, which in turn could be linked to various Global Positioning System (GPS) input sources. The development when completed should not only operate with one type of GPS system, but if needed be easily converted to any new GPS system. Additionally, this system will be easy to modify so that inputs can be accepted from new GPS systems.

SUMMARY: The project is a generic project for many such systems. Our conclusions after generating an Ada language program for one such system, the TRIMBLE 4000S receiver, which we demonstrated to the sponsor. We concluded that it is very easy to adapt this system to any GPS System.

THESIS DIRECTED: Chin, Yu-Chi, CDR, China Navy, "The Navigation Data Logger for a Suitcase Navigation System," MS in Engineering Science, June 1991. (Advisor U. Kodres)

REAL-TIME PROTOTYPING ON A MULTIPLE TRANSPUTER SYSTEM

U.R. Kodres, Professor of Computer Science
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The project explores the use of a single chip computer, the so-called transputer, as a component of a larger multi-computer real-time network. The software and hardware design to make such a network as reliable, as well as, a fault tolerant system is the main long-term objective of this project. The project in Jon Hartmann's thesis which uses the electronic reconfiguration control of the transputer network to solve a linear algebra problem on a network of up to 16 processors and compares the solution to the 8 processor hypercube iPCS in the Mathematics Department.

THESIS DIRECTED: Hartmann, J.E., CPT, USMC, "Hypercube Solutions for Conjugate Directions," MS in Computer Science and Mathematics, December 1991, (Uno Kodres and William B. Gragg - Co-Advisors).

DESIGN AND APPLICATION OF INTELLIGENT COMPUTER-BASED TRAINING SYSTEMS

Y.-J. Lee, Assistant Professor of Computer Science
Sponsor: NRL, U.S. Army Artificial Intelligence Center
Funding: Naval Postgraduate School and
U. S. Army Artificial Intelligence Center

OBJECTIVE: The primary goal of the work proposed under this proposal is to investigate fundamental issues related to the advancement and application of Intelligent Computer Assisted Instructional (ICAI) technology to military training.

SUMMARY: We investigated several interrelated issues in ICAI research. We explored the design of a generic tutoring shell, incorporating expert system tools and hypermedia approach. A prototype was implemented, using CLIPS as the control mechanism interfacing with commercial software package for display of tutoring materials and with language compilers such as Ada. For knowledge representation, we attempted using a qualitative model to emulate the structure and reasoning process in the instruction, using boiler model as a domain. In addition, intelligent training systems for specific applications such as helicopter recognition training and Ada programming were designed and implemented.

CONFERENCE PRESENTATIONS: DeLooze, L.L., and Lee, Y.-J., "A Portable Tutor for the Ada Programming Language," 1991 Conference on Intelligent Computer-Aided Training, Houston, TX, 20-22 November 1991.

Lee, Y.-J., and Campbell, L., "A Domain Specific Shell for Intelligent Computer-Aided Training," 1991 Conference on Intelligent Computer-Aided Training, Houston, TX, 20-22 November 1991.

THESES DIRECTED: DeLooze, L.L., "ITS Ada: Intelligent Tutoring Systems for the Ada Programming Language, MS Thesis, December 1991.

Ling, M.T., "An Intelligent Training System for Helicopter Recognition," MS in Computer Science, September 1991.

McGinn, E.M., "A Hypermedia Approach to the Design of an Intelligent Tutoring System," MS in Computer Science, September 1991.

Scurlock, R.E., Jr., "Design of an Intelligent Tutoring System Shell," MS in Computer Science, September 1991.

Stascavage, J.F., "BOILERMODEL: A Qualitative Model-Based Reasoning System Implemented in Ada," MS in Computer Science, September 1991.

SPECIFICATION AND ANALYSIS OF COMMUNICATION PROTOCOLS

G.M. Lundy, Professor of Computer Sciences
Sponsor: SPAWAR
Funding: Naval Postgraduate School

OBJECTIVE: To specify and analyze various high speed protocols formally; seek out potential applications of high speed networks; and search for improvements to these or other networks.

SUMMARY: In 1991, we made progress in applications of high speed networks, and in the modeling of VSAT (Very Small Aperture Terminal) networks. VSAT networks use a communication satellite. In the applications area, we showed that the high speed network FDDI can be used to improved the Navy's Aegis combat system. Another application of high speed networks was in improving communications in a hospital, and between hospitals and emergency vehicles.

A very high speed network, which is an improved version of FDDI was formally specified. The specification describes the operation of both FDDI and its improvement in considerable details.

A design, specification and analysis of a VSAT network was also carried out in 1991. This work explored the applications of VSAT networks and their applications.

PUBLICATIONS: Lundy, G. M. and Miller, R. E., "Specification and Analysis of a Data Transfer Protocol Using Systems of Communicating Machines," *Distributed Computing*, Springer & Verlag, 5:145-157.

Lundy, G.M., "Specification and Analysis of the FDDI Network Protocol," in proceedings of the European Fiber Optics and Local Area Networks Conference, London, UK, 19-21 June 1991.

Lundy, G.M. and Kvaslerud, O., "Improving the Aegis Combat System with High Speed Networks," in proceedings of the IEEE Military Communications Conference, McLean, VA, 4-7 November 1991.

Lundy, G.M., "European Fiber Optics/LAN 91: Conference Report," *Computer Communications*, 14(8):498-500, October 1991.

THESES DIRECTED: Kvaslerud, O., "Applications of High Speed Networks," September 1991.

Elmiro, L., "Formal Specification of an Improved FDDI-MAC Protocol," September 1991.

Benvenutti, S., "Selection and Specification of a Protocol for a VSAT Based Network," September 1991.

NAVY ADA FOR COMBAT DIRECTION SYSTEMS LOW COST COMBAT DIRECTION SYSTEM

Luqi, Professor of Computer Science
Sponsor: Naval Sea Systems Command
Funding: Naval Sea Systems Command

OBJECTIVE: The objective is to show the feasibility of using commercial workstations, off-the-shelf software packages, and Navy Ada for creating low-cost CDS prototypes. Modern Combat Direction Systems (CDS) require the capability to process real-time tactical data from multiple weapons interfaces, electronic warfare and multiple tactical data link systems. The demands for efficient computation and lucid display in such sophisticated systems have greatly increased the development cost of CDS. Our group at the Naval Postgraduate School has provided an experimental CDS project with opportunity to utilize the thesis efforts of the students and advanced software research results at NPS. The implementation of CDS in Ada has an experimentation phase to translate the Ada code via the Navy Ada Compiler. We have explored the CDS capabilities that can be provided by contemporary commercial workstations with suitable Ada software. The project will demonstrate a low cost approach to providing state of the art software for shipboard use. We have addressed the feasibility of translating the Ada CDS prototypes containing the basic features of a Combat Direction System to target AN/UYK code.

SUMMARY: We have completed implementation of a prototype low cost combat direction system. This has involved the initial design of a user interface for the LCCDS that utilizes the capabilities of commercial workstations such as graphical displays, multiple windows, and pointing devices. We have chosen a computer system and operating system to host the prototype CDS, and a portable graphical interface package. We have also evaluated several object-oriented database systems and software packages for generating graphical interfaces for use in the implementation of the prototype CDS, and worked out a way to interface programs written in Ada to graphics packages written in C.

THESES DIRECTED: Bolick, W. and Irwin, R., "The Integration System for the Low Cost Combat Direction System," MS Thesis.

Stockwell, M., "A Graphical User Interface for the Low Cost Combat Direction System," MS Thesis, September 1991.

OTHER: COMPUTER PROGRAM PRODUCED: Approximately 15,000 lines of executable online Ada code have been produced under the project. The programs run on several types of machines, including Dec vax and Sun workstations.

EXECUTION SUPPORT OF A COMPUTER AIDED PROTOTYPING SYSTEM FOR REAL-TIME SYSTEMS

Luqi, Professor of Computer Science
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: A computer aided rapid prototyping system to support the development of software systems with hard real-time constraints is especially important for the critical early stages of software design. This research focuses on formal techniques for specifying such complex systems using a Prototype System Description Language and the associated tools for further analysis and design. A major goal of this work is to enable the automation of a larger part of hard real-time software development via execution of real-time prototypes. A special scheme is used to treat the hard real-time constraints and to integrate guidelines beyond conventional compiler technology.

SUMMARY: This project studied automated tools for designing and constructing large real-time software systems. Specific subjects that were addressed include:

1. Providing the conceptual design of CAPS tools, e.g., static scheduler, dynamic scheduler, run-time debugging system, etc.

2. The application of CAPS tools to the specification of real-time systems to establish its ability to handle practical problems.

3. Proposing simplifications and extensions to the PSDL language to improve the treatment of hard real-time constraints.

4. Developing execution support tools to handle a subset of the PSDL language constructs sufficiently rich to illustrate the feasibility of automatic generation of executable prototypes for the specified systems.

This research uniquely links the two major research flows on modeling of real-time systems and complexity studies on scheduling algorithms in this research area. The hard real-time computational model used and specification based prototyping language provide systematic and unified constructs for modeling, specifying, designing and testing software systems with hard real-time properties.

THESES DIRECTED: Levine, J., "An Efficient Heuristic Scheduler for Hard Real-Time Systems," September 1991.

Bayramoglu, S., "Design of an Expander for the Hierarchical Real-Time Constraints of CAPS," MS Thesis, September 1991.

Lewis, G., and Dwyer, A., "The Development of a Design Database for the Computer Aided Prototyping System," MS Thesis, September 1991.

McDowell, J., "A Reusable Component Retrieval System for Prototyping," MS Thesis, September 1991.

O'Loughlin, M., "Development of Operations for the CAPS Engineering Database," (complete by September 1992).

Hammar, G., "Specification, Establishment and Performance Evaluation of a High Performance Computer Network," (complete by September 1992).

OTHER: COMPUTER PROGRAM PRODUCED: Approximately 25,000 lines of executable on line Ada and C++ code have been produced under the project.

MODELS FOR PROTOTYPES OF DYNAMIC SYSTEMS

Luqi, Professor of Computer Science
Sponsor: Naval Surface Warfare Center
Funding: Naval Surface Warfare Center

OBJECTIVE: This project addresses the development of analytical models of dynamic software systems to support rapid prototyping, computer-aided analysis of hard real-time constraints, and new real-time scheduling methods for dynamic systems. The objective of the proposed research is to enable the design of flexible real-time systems that consist of variable numbers of subsystems whose connection patterns can change with time. Potential applications include distributed C3I systems and damage-tolerant systems that can automatically reconfigure themselves in response to component failures. The results of this research support tools for analyzing hard real-time constraints and synthesizing executable software prototypes.

SUMMARY: The set of subsystems comprising a dynamic system can change with time. Such changes can be due to subsystems physically crossing the boundaries of the dynamic system, such as aircraft entering and leaving a controlled airspace, or due to subsystems failing and coming back on-line after repairs, such as automatically reconfigurable systems designed to survive damage to subcomponents. Embedded software systems are typically subject to hard real-time constraints. However, current approaches to designing real-time systems depend on the assumption that the system structure is static. Our work is developing the basis for removing this restriction.

PUBLICATIONS: Luqi, Berzins, V., Kodres, U., and Lee, Y., "Prototyping a Low Cost Tactical Display System," in proceedings of ONT/NSWC Systems Evaluation and Assessment Technology Workshop, pp. 23-30, August 1991.

Luqi, Hughes, G., and Schweiger, J., "Ada Software Prototypes of C3I Systems," in proceedings of 1991 Systems Design Synthesis Technology Workshop, September 1991.

MODELING OF REAL-TIME SYSTEMS AT NRL

Luqi, Professor of Computer Science
Sponsor: Naval Research Laboratory
Funding: Naval Research Laboratory

OBJECTIVE: The tasks of this study for FY 1991 were to assess the current state of software development at NRL, to determine the characteristics of the real-time systems involved, and to recommend a suitable methodology and tools to support the design and development of hard real-time systems at NRL. Most of the hard real-time software systems of interest to NRL are specialized, require a high degree of reliability, are typically embedded in larger systems, and typically perform critical control functions. Currently most real-time systems developed by NRL run on a single dedicated cpu. Systems involving both tightly coupled multiprocessors and distributed multiprocessor networks are growing concerns of NRL. Real-time systems at NRL are expected to get significantly more complex in the coming years. Systematic methods are needed for success on a large scale, due to the difficulties in managing the development process and difficulties in achieving sufficient product reliability.

SUMMARY: Most engineers at NRL developed system specifications from discussion with the sponsors. They then used their programming experience to determine the system requirements and module designs, which were reviewed either in-house or with the sponsors to see if they meet the functional and operational specifications of the users. Prototypes for the design were then developed and tested with test cases that were either developed in-house or provided by the sponsors. In order to meet the real-time constraints, engineers usually designed and developed their systems to run as fast as possible, without formal assurance that performance will meet the requirements or formal analysis to determine the range of operating conditions under which all deadlines can be met. Given the fact that most engineers at NRL have neither experience nor training for any structured design methods, we recommend that NRL adopt the Hatley - Pirbhai extension of the informal Yourdon method now and switch to a more powerful method when stable tools are available and the engineers have gained some experience with systematic design methods and some more formal training.

TECHNOLOGY SURVEY AND PRELIMINARY DESIGN FOR A SMALL AUV NAVIGATION SYSTEM

R.B. McGhee, Chairman and Professor of Computer Science
J.R. Clynch, CNOC MC&G Resident Professor of Oceanography
S.H. Kwak, Adjunct Professor of Computer Science
Sponsor: NOSC Hawaii
Funding: NOSC Hawaii

OBJECTIVE: The goal of this project was to accomplish a technology survey and preliminary design for a very small, light weight, low powered navigation and mission control package suitable for external attachment to any autonomous underwater vehicle (AUV).

SUMMARY: Characteristics of available and anticipated Global Positioning Service (GPS) receivers, inertial measurement units (IMU), and low power, physically small, single-board computers were investigated by literature survey, experimentation, and contact with vendors. Two illustrative systems were designed, one using currently available components, and another using components expected to be available in FY94. The overall conclusion was that the location of objects detected by an AUV operating in shallow waters can be determined to an accuracy of approximately 10 meters rms, worldwide, by a navigation and mission control package occupying not more than 120 cu.in., and requiring not more than 10 watts average power.

COMPUTER PLANNING OF SAFE MISSILES PATHS USING DISCRETE REGIONS

Neil C. Rowe, Associate Professor of Computer Science
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate knowledge-based approaches to computerized planning of missile routes that maximize concealment and minimize energy cost of maneuvering close to the ground.

SUMMARY: We extended our work of the previous year by developing a theory of best paths when cost of travel is a discontinuous function of heading, or the derivatives of the cost are discontinuous. This theory greatly simplifies analysis of factors like wind resistance and nonlinearity of power with climb angle. We produced two computer programs representing two different applications of these ideas.

PUBLICATION: Steed, A., Rowe, N., and Carter, E., "An Artificial-Intelligence Approach to Locating Stations for Range-Range Surveys," *The Hydrographic Journal*, forthcoming.

THESIS DIRECTED : Steed, A., M.S., co-advisor.

OTHER: Two other publications finished this year are in journal review.

SAFETY ANALYSIS OF SOFTWARE IN EMBEDDED HETEROGENOUS-MULTIPROCESSOR CONTROL SYSTEMS

T.J. Shimeall, Assistant Professor of Computer Science
Sponsor: Naval Weapons Center
Funding: Naval Postgraduate School & Naval Weapons Center

OBJECTIVE: The goal of this project was to develop a model of the safety-critical multiprocessing aspects of control systems, along with design and partial implementation of a set of tools and techniques to apply this model in the analysis of real systems.

SUMMARY: The problem of distinguishing safe and unsafe courses of execution in control system software is a complex one. As the processors on which the control system executes are specialized to deal with varying aspects of the mission profile, prediction of courses of execution and evaluation of the risks thereof become increasingly difficult. In 1991, we have addressed these problems by providing a model of safety-critical processing and by supporting that model with the design and partial implementation of a prototype set of software analysis tools. The model integrates event-condition modeling (performed via a Fault Tree Analysis) with state-transition modeling (performed via Petri Net Analysis). The two forms of modeling provide an integrated means to specify all possible execution paths for a piece of software and evaluate those paths for finite set of risks. The tools exploit this model to produce documentation needed for MIL-STD 882B-compliant projects.

PUBLICATION: Shimeall, T.J., McGraw, R., and Gill, J.A., "Software Safety Analysis in Heterogenous Multiprocessor Control Systems," proceedings of the 1991 Annual Reliability and Maintainability Symposium, January 1991.

OTHER: SOFTWARE:

a. FTE - A FAULT THREE ANALYSIS EDITOR

b. FT2PN - a fault tree/Petri net integration tool

c. PN2FT - a Petri net/fault three integration tool

THESIS DIRECTED: Gill, Janet A., "Software Safety Analysis of Heterogeneous-Multiprocessor Control System Software," MS Thesis, December 1990.

A STOCHASTIC APPROACH TO THE WEIGHTED REGION SHORTEST-PATH PROBLEM

M.T. Shing, Associate Professor of Computer Science
Sponsor: Navy Center for Applied Research in Artificial Intelligence
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to design and develop efficient heuristic algorithms for finding near-optimal paths through the weighted regions.

SUMMARY: Planning efficient long-range movement using map data is a fundamental requirement of most military operations. This project concerns the problem of planning near-optimal high-level paths for a point agent through complex terrain modeled by the Weighted-Region Problem. In 1991, we have designed and developed a very efficient algorithm for finding near-optimal solutions for the Weighted-Region Problem. The algorithm, called path annealing, is based on our customization of the simulated annealing technique. In addition, we have developed a set of heuristics and bounding techniques to further enhance the performance of the algorithm. Extensive results indicate that path annealing, augmented with these heuristics and bounding techniques, runs much faster than previous known algorithms for the Weighted-Region Problem with a very minimal sacrifice in optimality. We have also extended the proposed algorithm to finding near-optimal paths through anisotropic weighted regions.

PUBLICATIONS: Kindl, M.R., Shing, M.T., and Rowe, N.C., "A Stochastic Approach to the Weighted- Region Problem: I. The Design of the Path Annealing Algorithm," NPS Technical Report NPS-CS-91-014, June 1991. (Manuscript submitted to ORSA Journal on Computing).

Kindl, M.R., Shing, M.T., and Rowe, N.C., "A Stochastic Approach to the Weighted-Region Problem: II. Performance Enhancement Techniques and Experimental Results," (Manuscript submitted to ORSA Journal on Computing).

THESIS DIRECTED: Kindl, M.R., "A Stochastic Approach to Path Planning in the Weighted Region Problem," Doctoral Dissertation, March 1991.

Hilton, C.A., Jr., "A Stochastic Approach to Solving the Two-And-A-half Dimensional Weighted Region Problem," Ms Thesis, June 1991.

ESTABLISHMENT OF INFOSEC CENTER OF EXCELLENCE

C. Thomas Wu, Associate Professor of Computer Science
Sponsor: National Security Agency
Funding: National Security Agency

OBJECTIVE: The overall goal of this project is to develop an academic infrastructure for educating military officers with, advanced degrees in computer science specializing in information security. The immediate goal for the funding period is to develop a course syllabus for the security curriculum.

SUMMARY: To move toward the overall goal of establishing an information security track within the computer science major, we have initiated a development of security courses. It resulted in designing two security courses: CS 3601 and CS 4601. CS3601 is intended for all students, and CS 4601 is intended for computer science students. Because of this initiative, we will be offering more sections of security courses.

OTHER: Course syllabus and notes for CS 3601 and CS 4601.

DESIGN AND DEVELOPMENT OF PROTOTYPE ONBOARD INFORMATION SYSTEM ON MULTIPLE HARDWARE PLATFORMS

C. Thomas Wu, Associate of Computer Science
Sponsor: Naval Weapon Station, Concord
Funding: Naval Weapons Station, Concord

OBJECTIVE: The main goal of this on-going project is to extend the capabilities of prototype ARGOS system. Issues related to better user interface is also explored. The secondary goal is to port the current prototype on MacIntosh computer to MS-Windows environment.

SUMMARY: Our main focus in extending the capabilities of current prototype is to incorporate a real DBMS into the prototype. We have also ported a kernel portion of ARGOS to MS-Windows environment. The current system running in MS-Windows is very inefficient in space. This shortcoming must be resolved in the future.

PUBLICATIONS: Wu, C.T., "Making Windows Follow Their Leader," *PC Techniques*, 2(1):69-70, April/May 1991.

Wu, C.T., "Polymorphism for Achieving Extensibility," *Journal of Object-Oriented Programming*, 4(2):58-63, May 1991.

THESES DIRECTED: Mahoney, Jeffrey, LT, USN, "Development of a Graphical Interface for a Maintenance Management Database System," September 1991.

Suprapto, CPT, Indonesian Air Force, "Design and Implementation of Visual Interface to Database," September 1991.

OTHER: Program codes for the prototypes were developed.

DESIGN AND IMPLEMENTATION OF MULTIMEDIA INFORMATION SYSTEM BY USING OBJECT-ORIENTED DEVELOPMENT TOOLS

C. Thomas Wu, Associate Professor of Computer Science
Sponsor: Naval Security Agency
Funding: Naval Postgraduate School

OBJECTIVE: The primary goal of this project is to extend the current prototypes to incorporate capability for processing complex queries. To do so, we will use a SQL-based relational DBMS. In order to facilitate a faster development and easier extension later, we will be using object-oriented development tools.

SUMMARY: For a SQL-based relational DBMS, we decided to use Oracle DBMS. At present, Oracle resides in MacIntosh. We will explore the architecture where Oracle resides in the workstation with MacIntosh and PC connected over the network. For the development tools, we have used various object-oriented tools, namely, Prograph, Actor, Hypercard, ToolBook, and Knowledge Pro Windows (some are fully object-oriented, while others are only partially object-oriented). Facility that allows users to visually creating queries is implemented. Once the user specify the visual queries based on dataflow diagram, equivalent query statements in SQL is generated and passed to the backend Oracle DBMS for processing.

PUBLICATIONS: Wu, C.T., "OOP + Visual Data-flow Diagram = Prograph," *Journal of Object-Oriented Programming*, 4(3):71-75, June 1991.

Wu, C.T., "Steps Toward Increasing Reliability," *Journal of Object-Oriented Programming*, 4(5):64-66, September 1991.

Wu, C.T., "Benefits of Abstract Superclass," *Journal of Object-Oriented Programming*, 3(6):57-62, February 1991.

THESES DIRECTED: Clark, Gard, J., LT, USN, "DFQL: A Graphical Dataflow Query Language," September 1991. Recipient of Grace Hopper Award.

Leontakianakos, Ioannis M., LT, Hellenic Navy, "Design and Implementation of Control Command Check System (CCCS) Multimedia DBMS for Security Applications," September 1991.

OTHER: Program codes for prototypes were generated. A journal paper reporting part of our work was written.

EFFICIENT SOFTWARE PIPELINING ON SUPERSCALAR PROCESSORS

Amr Zaky, Professor of Computer Science
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To study the applicability of software pipelining techniques to superscalar processors.

SUMMARY: Software pipelining is a powerful technique for the fine-grained scheduling of loops. Superscalar processors are capable of executing more than one instruction per clock cycle. Superpipelined processors are capable of executing one instruction per cycle; their clock cycle, however, can be made shorter than the clock cycle of a non-pipelined superscalar processor. It has been demonstrated that scheduling techniques applied to either kind of architecture is almost always applicable to the other. Work is in progress to apply software pipelining techniques to either architecture. Issues investigated are: software pipelining of multiply-nested loops, and cache memory techniques for superscalar processors.

OTHER: Zaky, A., "Finer-Grained Waveforms: Marrying Fine-Grained Loop Scheduling to the Wavefront Technique," in preparation.

Zaky, A. and Byrnes, R., "Evaluating the Performance of a Lockup-Free Cache Interface for Superpipelined RISC Processors," in preparation.

NPSNET: LOW-COST, NETWORKABLE 3D VISUAL SIMULATION

Michael J. Zyda, Associate Professor of Computer Science
Sponsor: US Army Project Manager Training Devices
Funding: US Army Project Manager Training Devices

OBJECTIVE: The Graphics and Video Laboratory of the Department of Computer Science at the Naval Postgraduate School is currently conducting research on building low-cost, three-dimensional visual simulators on commercially available graphics workstations. The goal of these simulators is the generation of three-dimensional views of terrain, cultural features and vehicles using DARPA SIMNET databases. Additional work is being performed on the integration of those systems into the actual SIMNET system through the use of SIMNET networking formats. Real-time graphics techniques, data structures and the utilization of semi-automated forces are also being examined.

SUMMARY: Work was conducted on developing the NPSNET-2 system. NPSNET-2 contained several new features not in the original system. One new feature is a hierarchical data structure, the quadtree, utilized for minimizing polygon flow through the graphics pipeline, thereby speeding up the performance of the original system. An additional feature added into NPSNET-2 was that of collision detection between all buildings, trees, miscellaneous cultural features and moving platforms. Additional work was performed in the development and documentation of a SIMNET compatible library of networking routines.

PUBLICATIONS: Pratt, David, R., Zyda, Michael J., Mackey, Randy L. and Falby, John S., "A Networked Vehicle Simulator with Hierarchical Data Structures," accepted by abstract for the IMAGE VI Conference, Scottsdale, AZ, July 1992. Final paper due soon.

Zyda, Michael, J., Monahan, James G. and Pratt, David R., "NPSNET: Physically-Based Modeling Enhancements to an Object File Format," in proceedings of the Computer Animation '92, Swiss Federal Institute of Technology, Geneva, Switzerland, forthcoming. The proceedings for the conference will appear in a book published by Springer-Verlag.

Zyda, Michael J., Pratt, David R., Monahan, James G. and Wilson, Kalin P., "NPSNET: Constructing a 3D Virtual World," to be published in the proceedings of the 1992 Symposium on Interative 3D Graphics, MIT Media Laboratory, 29 March - 1 April 1992. The symposium proceedings will be a special issue of Computer Graphics.

Zyda, Michael J. and Pratt, David R., "NPSNET: A 3D Visual Simulator for Virtual World Exploration and Experience," short paper in *Tomorrow's Realities*, July 1991, pp. 30 (Note: This is a short paper contained in the gallery catalog. This paper is different than the abstract below of the same title.)

Zyda, Michael J. and Pratt, David R., "NPSNET: A 3D Visual Simulator for Virtual World Exploration and Experience," abstract in *Computer Graphics*, 25(4):383, July 1991.

CONFERENCE PRESENTATION: Zyda, Michael J., "NPSNET in the Tomorrow's Realities Gallery, attended SIGGRAPH '91 for presentation of live demonstration, 27 July - 3 August 1991.

OTHER: Appearance/Participation in/on Videotape, Zyda, Michael J. and Pratt, David R., "NPSNET: A 3D Visual Simulator for Virtual World Exploration and Experience," demonstrated in the Tomorrow's Realities Gallery, SIGGRAPH '91, Las Vegas, NV, 28 July - 2 August 1991. The presentation of SIGGRAPH was a live demonstration showing the NPSNET system running networked over three IRIS workstations. This was a juried/reviewed gallery. An abstract and short paper were published on this exhibit.

THESES DIRECTED: Mackey, Randall Lee, "NPSNET: Hierarchical Data Structures for Real-Time Three-Dimensional Visual Simulation," MS Thesis, September 1991.

Monahan, James G., "NPSNET: Physically-Based Modeling Enhancements to an Object File Format,"

MS Thesis, September 1991.

Osborne, William Dale, "NPSNET: An Accurate Low-Cost Technique for Real-Time Display of Transient Events: Vehicle Collisions, Explosions and Terrain Modifications, MS Thesis, September 1991.

Pleochroic, James Stolarski, "Using Solid Modeling Techniques to Construct Three-Dimensional Icons for a Visual Simulator," MS Thesis, September 1991.

West, Phillip D., "NPSNET: Object Animation Script Interpretation System," MS Thesis, September 1991.

DEVELOPMENT OF A SIMNET-COMPATIBLE, NON-LINE-OF-SIGHT, 3D VISUAL SIMULATOR

Michael J. Zyda, Associate Professor of Computer Science
Sponsor: U.S. Army Test and Experiment Command, Fort Ord, CA

OBJECTIVE: The Graphics and Video Laboratory of the Department of Computer Science at the Naval Postgraduate School has developed expertise in constructing SIMNET compatible 3D visual simulators on commercially available graphics workstations (NPSNET). USATEC has the requirement for the addition of a FOG-M missile component into that simulator. The goal of this project is to provide that capability within the current NPSNET system.

SUMMARY: The work accomplished so far for this project has been the continued development of the NPSNET system, including accurate missile weapons firing.

PUBLICATIONS: Zyda, Michael J., Pratt, David R., Monahan. James G. and Wilson, Kalin P., "NPSNET: Constructing a 3D Virtual World," to appear in the proceedings of the 1992 Symposium on Interactive 3D Graphics, MIT Media Laboratory, 29 March - 1 April 1992. The symposium proceedings will be a special issue of Computer Graphics.

Zyda, Michael J. and Pratt, David R., "NPSNET: A 3D Visual Simulator for Virtual World Exploration and Experimentation," 1991 SID International Symposium Digest of Technical Papers, XXII:361-364, 8 May 1991.

CONFERENCE PRESENTATION: Zyda, Michael J., "NPSNET in the Tomorrow's Realities Gallery," attended SIGGRAPH '91 for presentation of live demonstration, 27 July - 3 August 1991.

TERRAIN VISUALIZATION AND REASON - YEAR 3

Michael J. Zyda, Associate Professor of Computer Science
Sponsor: Headquarters, Department of the Army AI Center,
Washington, DC

OBJECTIVE: The Department of Computer Science at the Naval Postgraduate School is currently conducting research on terrain visualization and reasoning and robotics using a combination of high-performance graphics workstations and expert systems running on Lisp machines. This proposal is for a continuation of that work, with particular emphasis on the following areas: terrain visualization, terrain reasoning, path planning and knowledge representation/exploitation of terrain databases.

SUMMARY: The main focus of the work for the current year was to develop the programmable network harness process for the NPSNET system (NPSNET-HARNESS). The purpose of NPSNET-HARNESS is to serve as an example program for network interaction with the NPSNET system. NPSNET-HARNESS is programmable, i.e. it can be modified to include code for semi-automated force manipulation within NPSNET. One such system, NPSNET-MES, was developed as a test of NPSNET-HARNESS. The eventual goal of our efforts is to provide a well-documented interface to NPSNET that is also usable for communication with the DARPA SIMNET system.

PUBLICATIONS: Pratt, David R., Zyda, Michael J., Mackey, Randy L. and Falby, John S., "A Networked Vehicle Simulator with Hierarchical Data Structures," accepted by abstract for the IMAGE VI Conference, Scottsdale, AZ, 14-17 July 1992. Final paper due soon.

Zyda, Michael J., Pratt, David R., Monahan, James G. and Wilson, Kalin, P., "NPSNET: Constructing a 3D Virtual World," to appear in the proceedings of the 1992 Symposium on Iterative 3D Graphics, MIT Media Laboratory, 29 March - 1 April 1992. The symposium proceedings will be a special issue of Computer Graphics.

Zyda, Michael J., Pratt, David R., Monahan, James G., and Cecil, Carl P., "NPSNET-MES: Semi-Automated Forces Integration," submitted to the technical program of Artificial Intelligence '92 (Vancouver, 11-15 May 1992).

Zyda, Michael J. and Pratt, David R., "NPSNET: A 3D Visual Simulator for Virtual World Exploration and Experimentation," 1991 SID International Symposium Digest of Technical Papers, XXII:361-364, 8 May 1991.

CONFERENCE PRESENTATION: Zyda, Michael J., "NPSNET: A Look at a 3D Visual Simulator for Virtual World Exploration and Experimentation." Attended and spoke at the "Fifth Workshop on the Interoperability of Defense Simulations," 23-25 September 1991, Orlando, FL.

OTHER: Attended the "Second Behavioral Representation and Computer Generated Forces Symposium," Orlando, FL, 6-7 May 1991. Attended to understand the current work on semi-automated forces for application to NPSNET.

THESIS DIRECTED: Cecil, Carl Patrick "NPSNET-MES: Semi-Automated Forces Integration," MS Thesis, September 1991.

INEXPENSIVE, THREE-DIMENSIONAL VISUAL SIMULATION FOR THE COMMAND AND CONTROL WORKSTATION OF THE FUTURE - YEAR 3

Michael J. Zyda, Associate Professor of Computer Science
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The Graphics and Video Laboratory in the Department of Computer Science at the Naval Postgraduate School is designing and implementing a prototype command and control system utilizing three-dimensional, real-time interactive graphics on high-performance, commercially available graphics workstations. The primary goal of this work is to develop real-time visualization tools and techniques useful for rapidly producing three-dimensional scenes such as would be seen from the bridge of a surface ship, the cockpit of an airplane, the periscope of a submarine and the bridge of a submarine (synthetic view).

SUMMARY: In the past year, we continued our work on examining the databases and data organizations necessary to support real-time visual simulation for the surface, air and sub-surface displays. One particular effort of note is our work with the NPS autonomous underwater vehicle project where techniques were developed for the hierarchical organization of bottom data for real-time display. Additional work was performed on physically-based modeling of the AUV's movement underwater. Additional work was carried out in examining the use of parallel processing for speeding up the generation of our simulation systems.

PUBLICATIONS: Zyda, Michael J., Pratt, David, R., Monahan, James G. and Wilson, Kalin P., "NPSNET: Constructing a 3D Virtual World," to appear in the proceedings of the 1992 Symposium on Interactive 3D Graphics, MIT Media Laboratory, 29 March - 1 April 1992. The symposium proceedings will be a special issue of Computer Graphics.

Brutzman, Donald P., Kanayama, Yutaka and Zyda, Michael J., "Integrated Simulation for Rapid Developement of Autonomous Underwater Vehicles," accepted for IEEE AUV '92 conference, 20 November 1991.

Zyda, Michael, J., Jurewicz, Thomas A., Floyd, Charles A. and McGhee, Robert B., "Physically Based Modeling of Rigid Body Motion in a Real-Time Graphical Simulator," submitted to *IEEE Computer Graphics & Applications*, 10 January 1992 for additional reviewers.

THESES DIRECTED: Mackey, Randall Lee, "NPSNET: Hierarchical Data Structures for Real-Time Three-Dimensional Visual Simulation," MS Thesis, September 1991.

Monahan, James G., "NPSNET: Physically-Based Modeling Enhancements to an Object File Format," MS Thesis, September 1991.

Osborne, William Dale, "NPSNET: An Accurate Low-Cost Technique for Real-Time Display of Transient Events: Vehicle Collisions, Explosions and Terrain Modifications," MS Thesis, September 1991.

DEPARTMENT
OF
ELECTRICAL AND COMPUTER
ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

The research program of the Department of Electrical and Computer Engineering involves projects in the following areas: Communications, Computer Engineering, Electromagnetics, ElectroOptics, Electronic Systems, Power Systems, Radar and Electronic Warfare, Signal Processing, Systems and Controls, and Underwater Acoustics. Some research projects span one or more of these areas, although they are listed here in only one category. Where projects are externally or partially externally funded, that is noted in the summary. Graduate students are involved in many efforts, as indicated by the numbers of theses completed and their titles which are listed with the detailed project descriptions.

Communications

Professor Alex Lam is investigating M-ary optical code-division multiple-access (CDMA) communications with avalanche photodiode detectors. This research has resulted in one journal paper and one conference paper.

Professor Lam has also been working with Sawasd Tantaratana, of the Univ. of Mass. in an investigation of fast sequential acquisition schemes and system performance of spread-spectrum systems with complex signature sequences. This project has produced one journal paper and three conference papers.

Professor John Powers has continued his study of the use of fiber optic cables for transmitting data in the underwater environment. This work has produced a design for a multi-channel fiber optic data link from undersea experiments to shore. The work has produced a Master's thesis.

Professor Tri Ha is working on a project to study the capabilities and vulnerabilities of three foreign communications systems and to provide a document for future reference. This project has resulted in one Engineer's thesis.

Professors Ha and Glen Meyers have continued their investigation of the performance of four types of frequency-hopped spread spectrum receivers suitable for satellite communications in low earth orbits. Techniques to reduce the effects of partial-band jamming multipath fading were developed. Two journal papers and two conference papers were produced, and five MS theses were completed.

Professor Clark Robertson is engaged in a project whose goal is to perform error probability analyses for M-ary orthogonal frequency shift keying (MFSK) receivers employing frequency hop (FH) spread spectrum waveforms transmitted over a fading channel with partial-band interference. The ability of diversity, implemented using multiple hops per data symbol, to improve performance was investigated. Two papers, three conference papers and 4 MS theses have resulted from this work.

Professor Richard W. Adler is continuing in the fourth year of an extramurally funded project to conduct numerical analysis and experimental research in support of the Navy's requirement to site VLF through UHF communication antenna systems and support equipment in non-ideal locations such as polar and equatorial regions containing rugged terrain. In addition, a program of support for investigating the radiowave propagation characteristics of the polar (high-latitude) and the equatorial ionosphere was initiated in 1990 and continued in 1991. Two MS theses have resulted from this work.

Professor Adler is also engaged in an externally funded project to evaluate the viability of using active (amplified) antennas to receive weak signals in the strong-signal environment at Navy HF SIGINT sites world-wide. Two Master's theses were the result of this project.

Professor Adler is engaged in another externally funded project was to develop techniques and methodology for identifying and locating radio noise sources at Navy HFDF receiving sites worldwide. An automated Performance Evaluation Technique (PET) was initiated for improving the efficiency of HFDF site surveys that are conducted. A method of predicting the signal environment that can be expected at HFDF sites is under development and will reduce the labor-intensive measurements that are currently required for site performance surveys. This project has produced two MS theses.

Computer Engineering

Professors Jon Butler and Chyan Yang have been working jointly on a project to develop logic synthesis techniques and computer-aided design tools for multiple-valued logic circuits, and ultimately to produce extremely compact and reliable circuits for use in Navy electronics systems. This work has resulted in the porting of a computer-aided design (CAD) method for multiple-valued circuits developed in the previous two years of this project to a parallel computer, IPSC/2 (Intel Personal Supercomputer). Also, a new minimization approach to the design of multiple-valued programmable logic arrays has been produced. This project has resulted in the production of one monograph, one journal paper and three conference papers, as well as three theses.

Professor Douglas Fouts is studying design principles for very high-speed digital circuits in this NPS funded Research Initiation Project. Gallium arsenide (GaAs) digital integratedcircuits (ICs) have the potential to increase the speed of computers and digital systems by up to half an order of magnitude. However, GaAs-implemented systems lose much of their raw speed in the interconnections between ICs and subsystems. This research proposes to study both high-speed chip-to-chip interconnection networks and networks for interconnecting high-speed digital subsystems, and to develop new circuits, implementation techniques, and design guidelines that will allow systems to take full advantage of the inherent speed of GaAs logic. This work has produced one journal paper, one conference paper, and one MS thesis.

Professor Herschel Loomis and Mr. Ray Bernstein have been conducting externally funded research into computer algorithms and architectures for the processing of tactical information. A major activity was the participation in the data collection experiment on commercial shipping in a "Chokepoint," the English Channel. This project has produced four MS theses and four current thesis students are working on analyzing the data from the "chokepoint" experiment.

Professors Loomis Fouts and Yang have been working jointly on the automated design of VLSI devices for Navy space applications. This project is jointly funded by NPS and extramural sources. In it, they are investigating computer aided design (CAD) techniques for complex VLSI chips to achieve high performance or special functionality. To provide a vehicle for the evaluation of Application Specific Integrated Circuits (ASICs) to the problems of DoD. The work has produced one conference paper and presentation and eight MS theses.

Professor Chin-Hwa Lee has been working on computer aided VLSI design for tactical image processing. In this research, image processing algorithms have been implemented directly onto ASIC chips using programmable gate arrays. Nonlinear algorithms such as dynamic programming and simulated annealing are studied and implemented. Emphasis is concentrated on an integrated CAD environment using the VHDL for ASIC chip design and modeling. Particular interests are in the behavioral modeling of programmable VLSI chips with timing elements. This research has resulted in one journal paper, one conference paper, and two MS theses.

Professor Shridhar Shukla has been working on a two-year project to develop a framework for mapping hard real-time applications on loosely coupled multiprocessors to guarantee performance. The emphasis is on task allocation to minimize contention-based communication cost and on contention-free message routing. This project has produced two conference papers.

Professors Shukla, Yang and Amr Zaky (Computer Science) have been working on a NAVSEA funded project on compile-time support for the processing graph methodology on the AN/UYS-2 parallel signal processor. The goal of this continuing project is to develop a methodology for determining the optimal chains of primitives in processing graph methodology (PGM) applications running on the AN/UYS-2. The project has resulted in one MS thesis and in one submitted conference paper.

Professors Shukla and Yang have begun research into the design and implementation of two layers of software to manage the communication and reconfiguration in distributed, real-time combat systems platforms that are completely immune to node failure/repair. Two theses and a submitted conference paper have resulted from this work.

Electromagnetics

Professor Jeffrey Knorr has been engaged in a continuation of research on circuit modeling for microwave computer-aided-design. The objective of this project is to complete the development of a circuit model for the inductive strip in homogeneous finline, to begin development of a circuit model for the inductive strip in inhomogeneous finline and to conduct experiments to validate the models. Two journal papers, one conference paper, and two MS theses have been produced.

Professor Rama Janaswamy has been conducting research on the design of anechoic chamber absorbers. The goal of his multiyear project is to develop a method for treating electromagnetic scattering from the walls of an anechoic chamber and to develop a computer code to facilitate computer-aided-design. This work has produced one journal paper.

Professor David Jenn is performing radiation and scattering studies using the method of moments with the goal to develop accurate analytical models for various complex microwave antennas and scatterers. These modeling techniques are used in the design and evaluation of high performance radar, communication and EW systems. All aspects of electromagnetic design are considered: radiation from antennas, electromagnetic compatibility between system components, and radar cross section prediction and control. One journal paper, one conference paper, and one MS thesis have resulted from this work.

Professor Hung-Mou Lee is engaged in studies of short range anti-air radar propagation, investigating the effects of ducting and the curvature of Earth on sea clutter up to the vicinity of radar horizon. The results will support tactical operation of a fleet and the local defense of individual ships. The research has produced one conference paper, one conference abstract, and two MS theses.

Professor H-M Lee has also been working to improve the execution speed and accuracy of the m-Layer program, which was developed by NOSC. It predicts ducting effects of over-the-horizon EM propagation when the mean atmospheric profile over the propagation path can be considered as vertically stratified. This project will improve the numerical accuracy and execution speed of the program by converting its extended precision algorithm for the representation of large numbers into complex logarithmic format. The work, which is externally funded, has produced a execution speed improvement of up to 30%, as well as two MS theses.

Professor John Powers has begun a new project to study the predicted propagation properties of low-diffraction fields. There is one MS thesis student working on the problem.

ElectroOptics

Professor Ron Pieper is working to analyze the depth-of-focus for incoherent periodic sources using the optical visibility as a criterion. The original direction of this work has been shifted from the theoretical to somewhat more practical considerations in which the visibility concept is applied to generate a performance measure for thermal imaging systems. Elements of the project are being continued for the purposes of submitting the finalized theory to a fully reviewed journal. The research has produced one journal paper, one accepted conference paper, and one MS thesis.

Electronic Systems

Professor Sherif Michael is developing the process for On-Orbit Annealing of Satellite Solar Panels in this externally funded project. This is a continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include the development and testing of a microprocessor based experiment suitable for small satellites, and incorporating the system proposed in FY 89 research. The Photovoltaic current annealing processes and other related topics of radiation effects on GaAs, InP, and Si devices. The research has produced one conference paper and one MS thesis.

Professor Michael is also studying radiation insensitive semiconductor networks with the objective of applying the new Composite OPAMP techniques for radiation hardening of analog networks, using the NPS Linear Accelerator. One conference paper and presentation and one MS thesis have been produced by this work.

Power Systems

Professor Sherif Michael has been developing an automated monitoring system for submarine power supply. This research is aimed at the investigation of the possibility of developing a Microprocessor based system to monitor individual device performance in submarine power supplies. The research is also intended to investigate alternative spectral analysis techniques that could be of benefit in determining degraded performances of various power supply active devices. The work has produced one MS thesis.

Professor Steve Williams has been conducting research on integrated electric drive signature analysis. the goal of this project is to predict electrically induced noise on a shipboard system with large non-linear electric drive loads. Results of this research were a model for accurately predicting the propagation of harmonic noise throughout the shipboard electric system. The prediction model was compared with field measurements to verify its accuracy. These results have appeared in one journal paper and one MS thesis.

Professor Williams is also working on an externally funded project to develop, code, and test a computer software package for reducing the data resulting from tests performed by the EPIC Mobile Test Facility (MTF). The deliverables of the effort will be computer programs which condense the data output from the MTF into formats which are readily interpreted and directly comparable to specifications required by relevant industry and military standards (e.g., IEEE Std 519, DOD-STD-1399 Section 300A). The work has produced one conference paper.

Radar and Electronic Warfare

Professor Michael Morgan continued research in radar target identification using aspect-independent annihilation filtering of natural resonances. Novel and robust signal processing algorithms are being considered for estimation of resonances in transient impulse radar scattering data using scale model aircraft targets.

Professor Harold Titus investigated the simulation of designated Soviet missiles and missile radars in support of the Crossbow committee and several of their intelligence teams.

Professor Titus also investigated optimal methods of chaff placement and ship maneuver for ship defense against anti-ship cruise missiles. A simulation was developed to investigate the effectiveness of the NULKA chaff systems.

Signal Processing

Professor Jeffrey Burl is conducting research on dynamic image processing in the spatial frequency domain using the extended kalman filter. The processing of image sequences containing a moving object was investigated in this research. An algorithm based on the extended Kalman filter was proposed. The algorithm was developed and applied to some sample image sequences to evaluate its performance. This performance was compared with that of other algorithms found in the literature. As part of this research project, he and his students developed software for implementing all of the major image motion analysis algorithms currently available. The work has produced one conference paper, two submitted journal papers and one MS theses.

Professor Ralph Hippenstiel is working on an externally funded project on spectral estimation of (short duration) non-stationary processes. The objective is to devise an improved method of spectral estimation of short duration signals which also permits separation of signals more closely spaced (in a spectral sense) than current techniques can resolve. The research has produced one conference paper and one MS thesis.

Professor Monique Fargues is conducting research into tracking sources using the rank revealing QR factorization. The goal of this project is to investigate the application of the Rank Revealing QR (RRQR) factorization to compute the signal information, and to take advantage of the simplicity of the QR update to track moving sources. A conference paper has been published on this research and one MS thesis is in progress.

Professor Fargues is also studying the C-Rise algorithm. The project is part of an on-going work studying the optimization and extension of an order-recursive algorithm designed to compute the generalized eigendecomposition of Hermitian pencils. A journal paper has been submitted and one conference paper on the research has been published.

Professor Alex Lam is investigating wavelet transform theory and its applications. The goal of this project is to investigate wavelet theory and its applications in transient signal analysis and image processing. One conference paper has been produced as a result.

Professors Charles Therrien and Murali Tummala are conducting externally funded research into noise cancellation for countermeasure tolerant tracking. This research investigates the application of adaptive filters, artificial neural networks, and ESPRIT based algorithms to the wideband countermeasure interference suppression for recovering the tracking signal emitted by underwater vehicles at NUWES's test ranges. Work included modeling of the Nanoose test range by taking the propagation losses, surface reflection, Doppler shift, and propagation delay into account. This work has resulted in the production of a technical report and one MS thesis.

Professors Therrien, Tummala and Roberto Cristi are doing research in multidimensional signal processing, investigating several techniques for the detection and estimation of one and two-dimensional signals. Work includes iterative methods with application to multidimensional spectrum estimation, methods for estimation of parameters for modeling and classification of transients, and theoretical investigations of change detection procedures in time series data. The research has generated one journal paper, seven conference papers, one PhD dissertation, and three MS theses.

Professor Chin-Hwa Lee is studying the application of image processing to sensor data in this externally funded research. In this research, image processing techniques applied to sensor data are being studied. The dynamic programming and simulated annealing techniques for image processing have already been studied. Specific experiments are planned to process acoustic lofargrams to reveal the characteristics of these techniques. On the other hand, other image processing techniques for sensor data will also be compared. One conference publication and one MS thesis have been produced.

Professors Herschel Loomis and M. Soderstrand (Visiting) and R. Bernstein have been performing advanced signal processing studies for the Secretary of the Air Force. They have been investigating advanced signal processing algorithms and architectures for the detection and characterization of broadband communications signals in noise and interference. A workshop on cyclostationary signals and processing was held at NPS in April 1991. One journal paper, four conference papers, and four theses were produced.

Systems and Controls

Professor Jeff Burl is studying sensor and actuator placement for large space structure control. An H controller was synthesized for a simulated space station. Simulated annealing, gradient descent, and an algorithm based on the influence coefficients of the Karhunen-Loeve transform were investigated as methods of optimizing actuator placement. The signal processing software for the LACE dynamics experiment was completed. This experiment measured the structural dynamics of a satellite on orbit. This experiment provides valuable data on the accuracy of large space structure models which has an important influence on the design of LSS controllers and their sensitivity to actuator placement. The software developed has been sent to NRL for publication, one journal paper has been submitted and one MS thesis has been completed.

Professor Won-Zon Chen has been studying the use of state augmentation for feedback control law design. The main goal of this Research Initiation Project (RIP) was to study the role and the approach of using state augmentation for design of better and more robust feedback controllers as compared with the standard Linear-Quadratic Regulator (LQR) designs. The work has resulted in three conference papers and one MS Thesis.

Underwater Acoustics

Professor Lawrence Ziomek has been studying underwater acoustic propagation and scattering in a random ocean using a linear systems theory approach in a partially externally funded project. The objective of this research is the continued development and generalization of a full-wave, pulse-propagation model for 3-D wave propagation in an ocean waveguide based on the principles of linear, time-variant, space-variant, filter theory and the physics of wave propagation in random media. The research has produced one journal paper (in press) and three MS theses.

Professors Miller and C. Chui (Oceanography) have been working on the monterey bay tomography experiment which has the objectives to develop and test a tomographic system to analyze the effects of ocean surface waves, internal waves, and complex 3-dimensional bathymetry on long-range acoustic propagation. The experimental data corroborated a theory developed by Miller that described the way surface gravity waves affect the travel time of acoustic signals. This work has resulted in one accepted journal paper, one conference paper, two conference presentations with published abstracts and two MS theses.

Professors Miller and Chiu and A. J. Semtner have also been conducting research in conjunction with the Heard Island Experiment. The jointly NPS and externally funded work is concerned with the determination of the feasibility of monitoring global warming with long range acoustic transmissions. Two conference papers and three MS theses have been produced under this research.

Professors Miller and Chiu have also been working with R. Bourke (Oceanography) in investigating tomography techniques in the Barents Sea Tomography Transmission Test. The goal of this jointly NPS and externally funded experiment was to determine the feasibility of conducting tomography in the Barents Sea and to investigate space-time coherence of the acoustic field. The research has resulted in one journal paper and one MS thesis.

Finally, Professors Miller and Chiu have been performing studies of Time Domain Localization. The goal of this work is the determination of source range and depth in an ocean acoustic waveguide given a time domain representation of a source-generated signal.

SIGNAL-TO-NOISE ENHANCEMENT PROGRAM (SNEP) RESEARCH AND SUPPORT

Richard W. Adler, Adjunct Professor of
Electrical Computer Engineering
Sponsor: Naval Security Group
Funding: Naval Security Group

OBJECTIVE: The goal of this project was to develop techniques and methodology for identifying and locating radio noise sources at Navy HFDF receiving sites worldwide.

SUMMARY: An automated Performance Evaluation Technique (PET) was initiated for improving the efficiency of HFDF site surveys that are conducted for NSG. The use of PET will enable NSG to conserve financial resources during these times of reduced DoD funds. The design and evaluation of a series of portable antennas for field use in locating radio noise sources near SIGINT sites is nearly complete. A method of predicting the signal environment that can be expected at HFDF sites is under development and will reduce the labor-intensive measurements that are currently required for site performance surveys.

THESES DIRECTED: Poussard, Marc, LCDR, USN, "The Development of the Electronic Goniometer for use in High Frequency Direction Finding Systems," MS Thesis, September 1991.

Bentz, Troy, LCDR, USN, "On the Use of Topological Barriers as a Means of Controlling Noise in Electronic Support Measures Aircraft," MS Thesis, December 1991.

DYNAMIC IMAGE PROCESSING IN THE SPATIAL FREQUENCY DOMAIN USING THE EXTENDED KALMAN FILTER

Jeff B. Burl, Associate Professor of Electrical
and Computer Engineering
Sponsor: Naval Weapons Center
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to develop a better algorithm for processing sequences of images containing a moving object to extract information on the objects motion.

SUMMARY: The processing of image sequences containing a moving object was investigated in this research. An algorithm based on the extended Kalman filter was proposed. The algorithm was developed and applied to some sample images sequences to evaluate its performance. This performance was compared with that of other algorithms found in the literature. As part of this research project, my students and I developed software for implementing all of the major image motion analysis algorithms currently available.

PUBLICATION: Aksu, I., Ildiz, F. and Burl, J.B., "A Comparison of the Performance of Image Motion Analysis Algorithms Operating on Low Signal to Noise Ratio Images," proceedings of the 34th Midwest Symposium on Circuits and Systems, forthcoming.

THESES DIRECTED: Aksu, I., "Performance Analysis of Image Motion Analysis Algorithms," MS Thesis, June 1991.

Ildiz, F., "Estimation of Motion Parameters from Image Sequences," MS Thesis, June 1991.

OTHER: The following papers were submitted for publication in relation to this research: (1) Burl, J.B., "A Reduced Order Extended Kalman Filter for Sequential Images Containing a Moving Object," IEEE Transactions Image Processing, 1991, submitted, (2) Burl, J.B., "Estimating the Motion of Multiple Objects in Low Signal to Noise Image Sequences," in proceedings of the International Conference on Robotics and Automation, Santa Fe, New Mexico, 1992, submitted.

SENIOR AND ACTUATOR PLACEMENT FOR LARGE SPACE STRUCTURE CONTROL

Jeff B. Burl, Associate Professor of Electrical and
Computer Engineering
Sponsor: Naval Research Laboratories
Funding: Naval Postgraduate School

OBJECTIVE: The placement of sensors and actuators used for the control of large space structures was investigated in this research. The performance of all algorithms will be compared by evaluating closed loop control system performance. H$ control design methods will be used in an attempt to minimize the sensitivity of the control system to sensor/actuator location.

SUMMARY: An H$ controller was synthesized for a simulated space station. Simulated annealing, gradient descent, and an algorithm based on the influence coefficients of the Karhunen-Loeve transform were investigated as methods of optimizing actuator placement. The signal processing software for the LACE dynamics experiment was completed. This experiment measured the structural dynamics of a satellite on orbit. This experiment provides valuable data on the accuracy of large space structure models which has an important influence on the design of LSS controllers and their sensitivity to actuator placement.

THESES DIRECTED: McClusky, J., "A Comparison of H$ and Linear Quadratic Gaussian Optimal Control Applied to Space Station Freedom," MS Thesis, December 1991.

Thorngren, F.R., "Kalman Filtering for the Estimation of the Differential Doppler Velocity Between Two Retro-Reflectors on the LACE Satellite," MS Thesis, December 1991.

OTHER: The signal processing algorithms and software for the LACE dynamics experiment were completed and sent to NRL for application. The following paper was submitted for publication in relation to this research: Burl, J.B., "Convergence of the Karhunen-Loeve Transform to the Natural Modes for Lightly Damped Structures," *Journal of Guidance, Control and Dynamics*, 1991, submitted.

ON THE USE OF MULTIPLE-VALUED LOGIC IN THE DESIGN OF DIGITAL SYSTEMS

J.T. Butler, Professor of Electrical and Computer Engineering
C. Yang, Assistant Professor of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: Develop logic synthesis techniques and computer-aided design tools for multiple-valued logic circuits, and ultimately to produce extremely compact and reliable circuits for use in Navy electronics systems.

SUMMARY: There were three significant accomplishments this year. First, a computer-aided design (CAD) method for multiple-valued circuits developed in the previous two years of this project (the neighborhood decoupling algorithm) have been ported to a parallel computer, IPSC/2 (Intel Personal SuperComputer). This is an important advance because of the large amount of computation time needed to produce economical realizations of specified functions. A paper entitled "Experiences of Parallel Processing with Direct Cover Algorithms for Multiple-Valued Logic Minimization" has been submitted.

Second, we have developed a new minimization approach to the design of multiple-valued programmable logic arrays using simulated annealing. This is the first application of simulated annealing to multiple-valued logic. The results show improvements in the design over all previous techniques at the expense of longer computation times. Simulated annealing is a probabilistic process, which can guarantee a minimal solution if run long enough.

The experiences of using the parallel computers and the development of simulated annealing inspired our next research: Parallel computation and simulated annealing for multiple-valued logic minimization. A thesis student LT Cem Yildirim is working on the problem.

We also performed a study on the implementation costs of residue and high radix arithmetic units since these units are necessary when binary digital circuits co-exist with the multiple valued circuits.

PUBLICATIONS: Yang, C., Lu, H. and Gilbert, D., "An Investigation into the Implementation Costs of Residue and High Radix Arithmetic," in proceedings of the 21st International Symposium on Multiple Valued Logic, pp. 364-371, May 1991.

Butler, J.T. and Schueller, K.A., "Worst case number of terms in symmetric multiple-valued functions," in proceedings of the 21st International Symposium on Multiple-Valued Logic, pp. 130-138, May 1991.

Chang, Y.-H., and Butler, J.T., "The design of current-mode CMOS multiple-valued circuits," in proceedings of the 21st International Symposium on Multiple-Valued Logic, pp. 130-138, May 1991.

Butler, J.T., "Multiple-Valued Logic in VLSI," *IEEE Computer Society Press*, June 1991.

Tirumalai, P.P. and Butler, J.T., "Minimization algorithms for multiple-valued programmable logic arrays," *IEEE Transactions on Computers*, pp. 167-177, February 1991.

CONFERENCE PRESENTATIONS: Gilbert, David, "An Investigation into the Implementation Costs of Residue and High Radix Arithmetic," presented at the 21st International Symposium on Multiple-Valued Logic, Victoria, BC, Canada, 28 May 1991.

Butler, J.T., "Worst case number of terms in symmetric multiple-valued functions," presented at the 21st International Symposium on Multiple-Valued Logic, Victoria, BC, Canada, 27 May 1991.

Butler, J.T., "The design of current-mode CMOS multiple-valued circuits," presented at the 21st International Symposium on Multiple-Valued Logic, Victoria, BC, Canada, 27 May 1991.

THESES DIRECTED: Gilbert, D.E., LT, USN, "Investigation into Efficient Conversion Methods Between Residue and Binary Systems," MS Thesis, September 1991.

Oral, Sabri Onur, LTJG, Turkish Navy, "The Minimization of Multiple Valued Logic Expressions Using Parallel Processors," MS Thesis, September 1991.

Earle, R. Charles, LT, USN, "Minimization of Multiple-Valued Programmable Logic Array Using Simulated Annealing," MS Thesis, December 1991.

OTHER: Butler, J.T., "Multiple-valued logic research at the Naval Postgraduate School," presentation to Dr. Paul Saalfield on 30 July 1992.

In addition to the papers above, three others have been submitted to the International Symposium on Multiple-Valued Logic, all of which have been accepted.

USE OF STATE AUGMENTATION FOR FEEDBACK CONTROL LAW DESIGN - AN APPROACH FOR INCREASED PERFORMANCE AND ROBUSTNESS

Won-Zon Chen, Associate Professor of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The main goal of this Research Initiation Project (RIP) was to study the role and the approach of using state augmentation for design of better and more robust feedback controllers as compared with the standard Linear-Quadratic Regulator (LQR) designs.

SUMMARY: Various robustness measures were examined first and a multivariate stability margin concept based on principal region in the Nyquist plot was selected. The new design approach developed in this research converted the frequency-dependent performance criterion into an equivalent time-domain criterion, and then solved the robustness constrained optimization problem by parameters optimization. This design approach has been successfully applied to a Multi-Input-Multi-Output (MIMO) flight control system of a statically unstable fighter aircraft.

Special attention was also given to identify the conditions under which serious robustness problems could occur if the standard LQR theory was directly applied. Alternative design methods for suboptimal, but robust controllers without resorting to parameters optimization were developed. A similar condition that could cause non-robust Kalman Filter designs were found. This condition could be resulted when either the sensor measurements contained colored noises or there was correlation between system and measurement noises.

PUBLICATIONS: Chen, W., and Levan, N., "Design of Robust Linear-Quadratic Controllers with Dynamic Compensators," AIAA Guidance, Navigation, and Control Conference, New Orleans, LA, August 1991.

Chen, W., and Schmidt, L.V., "Orifice Topologies and Failures Detection and Isolation for Flush Air Data Systems," IEEE/AIAA 10th Digital Avionics Systems Conference, Los Angeles, CA, October 1991.

Chen, W., "Reliability/Redundancy Allocation for Integrated Vehicle Management Systems: A Mathematical Programming Approach," IEEE/AIAA 10th Digital Avionics Systems Conference, Los Angeles, CA, October 1991.

THESIS DIRECTED: Morrill, K.V., "Reliability/Redundancy Optimization with Application to Shipboard Gun Fire Control System," MS Thesis, December 1991.

OTHER: Chen, W., "Robust Linear Regulators for a Generalized Quadratic Criterion," submitted to the 1992 American Control Conference.

Chen, W., "Parameter Optimization for a H_2 Problem with Multivariable Gain and Phase Margins Constraints," submitted to the 1992 American Control Conference.

Chen, W., "Reliability/Redundancy Allocation for Integrated Vehicle Management Systems: A Mathematical Programming Approach", submitted to the IEEE Transaction on Aerospace and Electronic Systems.

Chen, W., and Schmidt, L.V., "Quantitative Measures for Fault-tolerant Flush Air Data System Design," in preparation and completion is expected in February 1992.

TRACKING SOURCES USING THE RANK REVEALING QR FACTORIZATION

Monique P. Fargues, Assistant Professor of Electrical and
Computer Engineering
Sponsor: NOSC
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate the application of the Rank Revealing QR (RRQR) factorization to compute the signal information, and to take advantage of the simplicity of the QR update to track moving sources.

SUMMARY: Subspace decomposition methods are a powerful tool used in different areas of Signal Processing in which the signal information is usually obtained via eigen-based on SVD-based methods. These techniques are numerically very stable but expensive to update. The RRQR factorization provides an attractive alternative to accomplish subspace selection. In this project we have added an updating capability to the RRQR factorization, and have applied it to the Direction Of Arrival (DOA) problem. The technique considered allows for tracking of moving sources by taking advantage of the simplicity of the regular QR updating scheme, and the rank revealing property of the RRQR factorization.

PUBLICATION: Fargues, M.P., "Tracking Moving Sources Using The Rank Revealing QR Factorization," in proceedings of the 25th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, 4-6 November 1991.

THE C-RISE ALGORITHM

Monique P. Fargues, Assistant Professor of Electrical and
Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: This project is part of an on-going work studying the optimization and extension of an order-recursive algorithm designed to compute the generalized eigendecomposition of Hermitian pencils.

SUMMARY: The Hermitian (regular or generalized) eigenproblem occurs in various areas of signal processing, such as array processing, spectral estimation, and filtering. Classical eigendecomposition techniques are numerically stable but computationally intensive which is a drawback for real-time implementations. As a consequence, techniques capable of highly parallel and localized data flow have become an active domain of research.

In this work we investigated the extension of an order-recursive/iterative generalized Hermitian Toeplitz eigendecomposition algorithm with high parallel capabilities (C-RITE) to more general definite Hermitian pencils. An important feature of the Colored Recursive/Iterative Self-adjoint Eigendecomposition (C-RISE) algorithm is its potential parallel capability which can be taken advantage of for decreasing computational time.

PUBLICATION: Beex, A.A., Wilkes, D.M. and Fargues, M.P.,"The C-RISE Algorithm and the Generalized Eigenvalue Problem," proceedings of the IEEE ICASSP-91, Toronto, Canada, 14-17 May 1991.

OTHER: Beex, A.A., Wilkes, D.M. and Fargues, M.P "The C-RISE Algorithm and the Generalized Eigenvalue Problem," submitted to Signal Processing, January 1991.

DESIGN PRINCIPLES FOR VERY HIGH-SPEED DIGITAL CIRCUITS AND SYSTEMS

Douglas J. Fouts, Assistant Professor of Electrical and Computer Engineering

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: Gallium arsenide (GaAs) digital integrated circuits (ICs) have the potential to increase the speed of computers and digital systems by up to half an order of magnitude. However, GaAs-implemented systems lose much of their raw speed in the interconnections between ICs and subsystems. This research will study both high-speed chip-to-chip interconnection networks and networks for interconnecting high-speed digital subsystems, and to develop new circuits, implementation techniques, and design guidelines that will allow systems to take full advantage of the inherent speed of GaAs logic.

SUMMARY: New, high-speed, low-power, output driver and input receiver, bus driver and receiver, and bus transceiver circuits have been designed for interconnecting GaAs digital ICs. Simulations have shown that the use of the new circuits will increase the system speed of computers and digital systems that are implemented with GaAs logic. Full characterization of the new circuits requires fabrication and testing. Fabrication can not be accomplished at the Naval Postgraduate School, but an industrial partner has been located that is interested in a cooperative research and development agreement (CRDA). A CRDA is currently under development, and when completed, will allow the fabrication of test circuits. Systems applications for high-speed GaAs digital ICs have also been studied. The inherent radiation hardness of GaAs, together with its high speed and low power consumption, make it ideal for use in space-born systems. Recent efforts to further improve the speed-power consumption product of GaAs logic for use in space systems has focussed on dynamic logic circuits. The results are very promising, although the new circuits still need to be radiation tested.

PUBLICATIONS: Fouts, D.J. and Butner, S.B., "Architecture and Design of a 500 MHz Gallium Arsenide Processing Element for a Parallel Super Computer," *IEEE Journal of Solid State Circuits*, 26(9):1199-1211, September 1991.

Fouts, D.J., "A Phasing Adjustment and Fanout Buffer For Distributing Clock and Control Signals in High-Speed Digital Systems," IEEE Midwest Symposium of Circuits and Systems, May 1991.

THESIS DIRECTED: Gonter, T.C., CPT, USMC, "A Microprocessor Interface for the NM24CF04 Serial-Access Ferroelectric Memory," MS Thesis, December 1991.

OTHER: The principle investigator has one paper that is currently being reviewed for publication in a research journal, a second paper that is currently being reviewed for publication at a conference, and a third paper in preparation. Four thesis students are currently working on topics related to the described research.

EXPLOITATION ANALYSIS OF FOREIGN COMMUNICATIONS SYSTEMS

Tri T. Ha, Professor of Electrical and Computer Engineering
Sponsor: Naval Maritime Intelligence Center
Funding: Naval Maritime Intelligence Center

OBJECTIVE: The goal of this project was to study the capabilities and vulnerabilities of three foreign communications systems and to provide a document for future reference.

SUMMARY: The exploitation of foreign communications systems supports the United States intelligence community and research and development. Such research can lead to a direct enhancement of the national defense and intelligence assets. The knowledge of the system capabilities, limitations, and vulnerabilities can permit more accurate assessments to be made about the outcomes of potential conflicts. Follow-on use of information gained from exploitation research can yield equipment and procedures which help debilitate foreign assets in future conflicts and subsequently promote national interests. The primary purpose of this study was to exploit three previously unanalyzed foreign communications systems. The emphasis was to perform engineering research and analysis to determine, define, document, and report on characteristics, limitations, and vulnerabilities of each system.

THESIS DIRECTED: Dipert, S.F., LT, USN, "Exploitation Analysis of Foreign Communications Systems: Cluster Drain, Cluster Worry, and Cluster Grave," MSEE and EE, December 1991.

RESEARCH IN LOW-ALTITUDE SATELLITE COMMUNICATIONS AND NETWORKS

Tri T. Ha, Professor of Electrical and Computer Engineering
Glen A. Myers, Associate Professor of Electrical and Computer Engineering
Sponsor: Naval Ocean Systems Center
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this multi-year project was to investigate the performance of various types of frequency-hopped spread spectrum receivers suitable for satellite communications in low earth orbits.

SUMMARY: Four types of frequency-hopped spread spectrum receivers were investigated. These were the noise-normalization receivers, the self-normalization receivers, the ratio-statistic receivers and the simultaneous frequency hopped sequence receiver. The first three types of receivers employed signal normalization to reduce the effect of partial-band jamming. Diversity was also employed to combat the multipath fading effect using multiple hops per data symbol. Additive white Gaussian noise was included in all performance analyses. The fourth type of receiver was analyzed for a fading channel with broadband jamming. Use of many simultaneous frequency hopped transmissions was studied. By suitable selection and assignment of hopping sequences, the transmissions can be non-interfering. The research considered means of selecting good frequency-hopped sequences. The jamming performance of the system was determined, and the multipath attributes were considered.

PUBLICATIONS: Robertson, R.C. and Ha, T.T., "Error probabilities of fast-frequency hopped FSK with self-normalization combining in a fading channel with partial-band interference," *IEEE Journal on Selected Areas in Communications*, forthcoming.

Robertson, R.C. and Ha, T.T., "Error probabilities of fast frequency-hopped MFSK with noise normalization combining in a fading channel with partial-band interference," *IEEE Transactions in Communications*, forthcoming.

CONFERENCE PRESENTATIONS: Clemons, T.M., III, Robertson, R.C. and Ha, T.T., "Error probabilities of frequency-hopped MFSK with noise normalization combining in a fading channel with partial-band interference," GLOBAL '90, November 1990.

Robertson, R.C. and Ha, T.T., "Error probabilities of frequency-hopped FSK with self-normalization combining in a fading channel with partial band interference," MILCOM '90, October 1990.

Myers, G.A., "Calculated noise performance of a form of frequency hopping with applications to low-altitude satellite communications systems," MILCOM '91, October 1991.

THESES DIRECTED: Karaagac, Ahmet Cem, "Noncoherent detection of BFSK signals with linear and nonlinear diversity combining over Rician fading channels with partial band interference," March 1991, (Co-advisor: T.T. Ha).

Riley, John F., "Performance of a fast frequency-hopped noncoherent MFSK receiver with ratio-statistic combining over Rician fading channels with partial-band interference," MS in Electrical Engineering, June 1991, (Co-advisor: T.T. Ha).

Vece, Thomas W., "Effects of non-uniform windowing on the performance of a fast frequency-hopped noncoherent MFSK receiver over Rician fading channels with partial-band interference and Doppler shift," MS in Electrical Engineering, June 1991, (Co-advisor: T.T. Ha).

Lee, Kang Y., "Performance of a fast frequency-hopped noncoherent MFSK conventional and self-normalization receiver over Rician fading channels with partial-band interference," MS in Electrical Engineering, September 1991, (Co-advisor: T.T. Ha).

Ozden, Mehmet T., "Calculated noise performance of a frequency-hopped sequence system with applications to low-altitude satellite communications," MS in Electrical Engineering, December 1990, (Advisor: G.A. Myers).

SPECTRAL ESTIMATION OF (SHORT DURATION) NON-STATIONARY PROCESSES

Ralph D. Hippenstiel, Associate Professor of Electrical and
Computer Engineering
Sponsor: Naval Ocean System Center (NOSC), San Diego, CA

OBJECTIVE: Devise an improved method of spectral estimation of short duration signals which also permits separation of signals closer spaced (in a spectral sense) than current techniques can resolve.

SUMMARY: A modeling approach was used, which was followed by time or spatial domain data extrapolation. The extrapolated data was then processed using classical techniques. The technique works down into the negative SNR region allowing some improvements in terms of probability of detection. At higher SNR's separation of sources much closer than classical or plain model based techniques permit were achieved.

PUBLICATION: Hippenstiel, R., "Spectral Estimation of Short Duration Signals using Time Domain Extrapolation," IEEE 1991 International Conference on Acoustics, Speech and Signal Processing, Toronto, Canada, 14-17 May 1991.

THESIS DIRECTED: Moore, Hal, LT, USN, "Improved Tactical Towed Array Signal Processing using Extrapolation Techniques," MS Thesis, September 1991.

Thornlow, Robert T., LT, USN, "Spectrum Estimation Using Extrapolated Timeseries," MS Thesis, December 1990.

ON THE DESIGN OF ANECHOIC CHAMBER ABSORBERS

Ramakrishna Janaswamy, Associate Professor of
Electrical and Computer Engineering
Sponsor: Naval Weapons Center, China Lake, CA
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this multi-year project is to develop a method for treating electromagnetic scattering from the walls of an anechoic chamber and to develop a computer code to facilitate computer-aided-design.

SUMMARY: In the first year, plane wave scattering from lossy, periodic surfaces, with periodicity in one direction was investigated. The problem was considered for arbitrary polarization and incidence angles. The material comprising the absorber was assumed to be homogeneous, characterized by complex values of permittivity and permeability. Müller type coupled integral equations were derived for the surface electric and magnetic currents. A new power reflection coefficient was defined in terms of the scattered farfields. The integral equations were solved by the boundary element method with constant elements. Arbitrary surfaces are accommodated by approximating the actual profile by means of linear segments. Other speed up techniques were utilized to generate a numerically efficient solution. Substantial comparison was made for special cases to verify the formulation. Reflection coefficient was calculated for a variety of surface shapes such as rectangular, sinusoidal and triangular. A new profile shape has evolved that results in a lower reflection coefficient compared to the commonly used triangular. For the specific case of the triangular profile, a systematic study was carried out for the dependence of reflection coefficient on various parameters.

PUBLICATION: Janaswamy, R., "Oblique scattering from lossy periodic surfaces with application to anechoic chamber absorbers," forthcoming.

THESIS DIRECTED: Chang, Jennifer, LT, USN, "Scattering from 2D absorbers using impedance boundary conditions," ongoing.

RADIATION AND SCATTERING STUDIES USING THE METHOD OF MOMENTS

David C. Jenn, Associate Professor of Electrical and
Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal is to develop accurate analytical models for various complex microwave antennas and scatterers. These modeling techniques are used in the design and evaluation of high performance radar, communication and EW systems. All aspects of electromagnetic design are considered: radiation from antennas, electromagnetic compatibility between systems components, and radar cross section prediction and control.

SUMMARY: During the last year research has been conducted in four areas. A brief description of each is as follows: (1) Design of small, efficient dual reflector antennas for radar, EW and communication systems: A Computer code has been developed to analyze a large class of reflector antennas and optimize their performance for a range of geometrical and electrical design parameters. The primary result has been a new compact feed design that has the potential to reduce the size of many topside shipboard antennas; (2) Evaluation of conformal subdomains in the method of moments solution: It has been demonstrated that conformal subdomains are computationally more efficient than the standard piecewise linear subdomains for tightly curved wire structures. This will result in a faster, more accurate analysis of broadband spiral antennas of the type used in many EW systems; (3) Analysis of curved radome effects: Work is in progress to computer code a method of moments solution that can be used to evaluate the defocusing and depolarization effects of curved radomes on microwave scanning antennas. This type of radome is frequently used in fighter aircraft and missile applications, and its presence may adversely affect the radar's performance; and (4) Radar cross section synthesis: A synthesis procedure has been developed to determine the material properties of an arbitrary target so that a specified radar cross section is obtained. The method can be used in the design of low observable targets, and can be extended to handle the treatment of isolated areas of a target's surface to reduce hot spots. Radar cross section control has been designated as a critical technology by the Department of Defense.

PUBLICATIONS: Jenn, D.C. and Rusch, W.V.T., "Low-sidelobe reflector synthesis and design using resistive surfaces," *IEEE Transactions on Antennas & Propagation*, 39(9):1372, September 1991.

CONFERENCE PRESENTATIONS: Jenn, D.C., "Method of moments analysis of cavity-backed wire antennas, Applied Computational Electromagnetic Society," presented at the 7th Annual Review of Progress in Applied Computational Electromagnetics, March 1991.

Jenn, D.C., "Method of moments analysis of symmetric dual reflectors including the feed," presented at the North American Radio Science Meeting, June 1991.

THESIS DIRECTED: Walter, B.A., "The use of conformal subdomain basis functions in the method of moments computations for a thin wire," MS Thesis, December 1991.

OTHER: Abstract accepted for the Eight Annual Review of Progress in Applied Computational Electromagnetics; abstract accepted for 1992 North American Radio Science Meeting.

CIRCUIT MODELING FOR MICROWAVE COMPUTER-AIDED-DESIGN

Jeffrey B. Knorr, Professor of Electrical Computer Engineering
Sponsor: Naval Weapons Center
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project was to complete the development of a circuit model for the inductive strip in homogeneous finline, to begin development of a circuit model for the inductive strip in inhomogeneous finline and to conduct experiments to validate the models.

SUMMARY: Work on the model for the inductive strip in homogeneous finline was completed and results were reported in the publications listed below. An inhomogeneous finline model was developed for substrates with dielectric constant 2.22 and experiments were conducted to measure parameters of inductive strips in finlines with such dielectric substrates. The experimental work is reported in the thesis by Muir. Preliminary work was done on modeling strips in inhomogeneous finline and is reported in the thesis by Linzey. This work was not very successful and much remains to be done.

PUBLICATIONS: Knorr, J.B., "Synthesis of Equivalent Circuits for Inductive Strips in Homogeneous Finline: W/b = 1," *International Journal of Microwave and Millimeter-Wave Computer-Aided Engineering*, 1(3):306-314, July 1991.

Knorr, J.B. and Morua, M.L., "A Circuit Model for the Inductive Strip in Homogeneous Finline," *International Journal of Microwave and Millimeter-Wave Computer-Aided Engineering*, 1(4):395-402, October 1991.

Knorr, J.B., "Equivalent Circuits for Finline Computer-Aided-Design," in proceedings of the 3rd International Symposium on Recent Advances in Microwave Technology, pp. 58-61, Reno, Nevada, 18-21 August 1991.

THESES DIRECTED: Linzey, M., "A Circuit Model for an Inductive Strip in Inhomogeneous Finline," MS Thesis, June 1991.

Muir, J., "Measurement of Scattering Parameters for Inductive Strips in Inhomogeneous Finline," MS Thesis, September 1991.

M-ARY OPTICAL CDMA COMMUNICATIONS

Alex W. Lam, Assistant Professor of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate M-ary optical code-division multiple-access (CDMA) communications with avalanche photodiode detectors.

SUMMARY: Arbitrary tight upper and lower bounds on the probability of bit error (p.b.e.) for optical code-division multiple-access (CDMA) systems are developed. These bounds are necessary because the exact evaluation of the p.b.e. is intractable and computer simulation would require formidable amount of computation time. The techniques can be applied to general multiple-access systems. The simple modified Chernoff upper bound as well as the Gaussian approximation results can therefore be calibrated using these computational efficient bounds.

PUBLICATIONS: Lam, A.W. and Hussain, A.M., "Performance analysis of direct-detection optical CDMA communication systems with avalanche photodiodes," forthcoming.

Lam, A.W., "Direct-detection APD-based optical CDMA using orthogonal signalings," in proceedings of the 1991 International Phoenix Conference on Computers and Communications, pp. 513-519, March 1991.

WAVELET TRANSFORM THEORY AND ITS APPLICATIONS

Alex W. Lam, Assistant Professor of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate wavelet theory and its applications in transient signal analysis and image processing.

SUMMARY: Compactly supported wavelets were employed to analyze deterministic and stochastic signals corrupted by random noise. Due to the multiresolutional nature of the wavelet transform, excellent time-resolution and frequency-resolution decompositions of signals can be achieved. Detection schemes in the wavelet phase-time domain are developed.

PUBLICATION: Lam, A.W., "Spectrum of wavelet-decomposed random processes," in proceedings of the 1991 Conference on Information Sciences and Systems, pp. 896-901, Johns Hopkins University, March 1991.

SEQUENTIAL ACQUISITION SCHEMES FOR SSMA SYSTEMS WITH GENERALIZED SIGNATURE SEQUENCES

Alex W. Lam, Assistant Professor of Electrical and Computer Engineering
Sawasd Tantaratana, Associate Professor of Electrical and Computer Engineering
Sponsor: Army Research Office
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate fast sequential acquisition schemes and system performance of spread-spectrum systems with complex signature sequences.

SUMMARY: This research proposed to investigate sequential code sequence acquisition schemes for spread-spectrum multiple-access communication systems with generalized signature sequences. Fast, robust sequential code sequence acquisition schemes will be developed and analyzed for systems with or without the presence of data modulation. Parametric and nonparametric schemes are proposed. Noncoherent and M-ary digital modulations will be employed together with the generalized (nonbinary and polyphase) sequences. Product sequences that are efficient for rapid multiple-level sequential and/or parallel detections are proposed. The anticipated results are essential to the understanding of the system efficiency and reliability.

PUBLICATIONS: Lam, A.W. and Ozluturk, F.M., "Performance analysis of direct-sequence spread-spectrum communications with complex signature sequences," forthcoming.

Lam, A.W., Ozluturk, F.M., and Tantaratana, S., "M-ary DS/SSMA communications with complex signature sequences," *in proceedings of the 1991* Conference on Information Sciences and Systems, Johns Hopkins University, pp. 512-517, March 1991.

Lam, A.W. and Ozluturk, F.M., "Performance bounds for direct-sequence spread-spectrum communications with complex signature sequences," *in proceedings of the 1991 International Phoenix* Conference on Computers and Communications, pp. 408-414, March 1991.

Tantaratana, S. and Lam, A.W., "Noncoherent sequential acquisition of PN sequences for DS/SS communications," in proceedings of the 29th Allerton Conference on Communication, Control, and Computing, University of Illinois, pp. 370-379, October 1991.

COMPUTER AIDED VLSI DESIGN FOR TACTICAL IMAGE PROCESSING

Chin-Hwa Lee, Professor of Electrical and Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: In this research, image processing algorithms will be implemented directly onto ASIC chips using programmable gate arrays. Nonlinear algorithms such as dynamic programming and simulated annealing will be studied and implemented. Emphasis is concentrated on an integrated CAD environment using the VHDL for ASIC chip design and modeling. Particular interests will be the behavioral modeling of programmable VLSI chips with timing elements.

SUMMARY: Our confidence to start with a VHDL behavior model and push it through the intermediate design levels to an actual chip implementation is increased to a large extent in the FY91 effort. Just as was planned for FY92, the algorithm development of the simulated annealing algorithm will continue. Modeling and system implementation will be directed to a FPGA chip demonstration. This experience and capability in NPS should be interesting to other operations in the Navy. Further efforts to provide this expertise for reimbursable works will be pursued.

PUBLICATION: Lee, C.-H. and Ouek, G.P., "Digital Matching of Two Dimensional Shapes," *Journal of Information Science & Engineering*, 7(1).

Lee, C.-H., "Back Annotation in VHDL Design," in proceedings of the 1991 Government Microcircuit Applications Conference, 12 August 1991.

THESES DIRECTED: Deng, A.D., "VHDL Structural Description of Cosine Transform," MS Thesis, September 1991.

Ailes, J.W., LT, "Automatic Digital Hardware Synthesis Using VHDL," MS Thesis, September 1991.

IMAGE PROCESSING APPLIED TO SENSOR DATA

C.-H. Lee, Professor of Electrical and Computer Engineering
Sponsor: Naval Research Laboratory (Y.S. Wu - Code 8120)
Funding: Naval Research Laboratory

OBJECTIVE: In this research, image processing techniques applied to sensor data will be studied. The dynamic programming and simulated annealing techniques for image processing are of particular interest. Specific experiments are planned to process acoustic lofargrams to reveal the characteristics of these techniques. On the other hand, other image processing techniques for sensor data will also be compared.

SUMMARY: The FY91 effort was concentrated on studying the simulated annealing technique. A series of experiments involving artificially generated lofargrams were tested in the prototype algorithms. Test cases are divided into three categories: (1) single tonal tracking; (2) multitonal tracking, and (3) sweep tonal tracking. The signals are buried in white noise with signal to noise ratios (SNR) of 3 db, 0 db, -3 db, -6 db, -9 db, -12 db, and -18 db. The prototype algorithm can achieve successful tracking in a -18 db signal to noise ratio environment. These remarkable results can not be paralleled by any known algorithm at this point in time. This simulated annealing (SA) process assumed known starting track positions. The cost function of SA depends on the signal to noise ratio (SNR) of the signal. When the SNR is low it is very important to assure that equilibrium conditions are reached before the next state generation is adopted. Detailed results are published in CPT Chen's thesis (11) and in a paper of the 1990 Asilomar Conference on Circuit, Systems, and Computers (12). The shortcoming of the prototype algorithm is still that a priori knowledge of the starting positions of the tracks is still required. Furthermore, different algorithms are required to handle multiple tonal tracking problems.

PUBLICATION: Lee, C-H., "Top Down Methodology Using VHDL," in proceedings of the 1991 System Design Synthesis Technology Workshop, 10-13 September 1991.

THESIS DIRECTED: Messa, N., "SCSI Interface Design Using FPGA," MS Thesis, March 1991.

SHORT RANGE ANTI-AIR RADAR PROPAGATION

H.-M. Lee, Associate Professor of Electrical and
Computer Engineering
Sponsor: Office of the Chief of Naval Operations (OP-03B)
Funding: Naval Postgraduate School

OBJECTIVE: To investigate the effects of ducting and the curvature of Earth on sea clutter up to the vicinity of radar horizon. The results will support tactical operation of a fleet and the local defense of individual ships.

SUMMARY: A new earth-flattening approximation based on the differential equations governing wave propagation was found to be consistent with the integral formulation derived and reported earlier. The differential formulation allows ready solution of the fields in the air. The effects of the rough surface can then be coupled into these fields consistently through the integral equations. The M(ulti)-Layer waveguide propagation program developed by NOSC had been investigated. A thorough update of the documentation of this FORTRAN program including a critical review of its theoretical background was completed. This program was installed and has been running at NPS under Microsoft FORTRAN compiler, version 5. Improvements on the program by NPS is being proposed. Experimentally measured data are needed to evaluate the predictions of the theories. Work has been in progress to assemble test equipment for propagation and sea clutter data acquisitions.

PUBLICATIONS: Lee, H.-M., "Earth-fattening: A new approximation," forthcoming.

Lee, H.-M., "Earth-flattening approximation and piecewise linear refractive index profile," in proceedings of the Progress in Electromagnetics Research Symposium, 49, Cambridge, Massachusetts, 1-5 July 1991.

THESES DIRECTED: Ting, C., CPT, Taiwan Army, "Over-the-Horizon Performance of EREPS," MS Thesis, March 1991.

Chang, T.-H., LT, Taiwan Navy, "Piece-wise Profile Selection for MLayer," MS Thesis, March 1991.

M-LAYER IMPROVEMENT AND EXTENSION

H.-M. Lee, Associate Professor of Electrical and Computer Engineering
Sponsor: Naval Ocean Systems Center
Funding: Naval Ocean Systems Center

OBJECTIVE: To improve the execution speed and accuracy of the m-Layer program.

SUMMARY: The m-Layer program developed by NOSC predicts ducting effects of over-the-horizon EM propagation when the mean atmospheric profile over the propagation path can be considered as vertically stratified. This project will improve the numerical accuracy and execution speed of the program by converting its extended precision algorithm for the representation of large numbers into complex logarithmic format. The complex root-finding algorithm and the root search and ordering protocol will be reviewed for improvement. Prospects of extending the multi-layer formulation to include ocean wave scattering will be investigated.

OTHER: A computer code in which the conversion of the 'extended precision' arithmetic to complex exponent representation has been delivered. Execution speed improvement of up to 30% has been observed.

RADIATION INSENSITIVE SEMICONDUCTOR NETWORKS

Sherif Michael, Associate Professor of Electrical and
Computer Engineering
Sponsor: NRL, Naval Research Laboratories

OBJECTIVE: Investigate the advantage of applying the new Composite OPAMP techniques for radiation hardening of analog networks, using the NPS Linear Accelerator.

SUMMARY: In this research a novel technique for reducing active device sensitivity to radiation is investigated. The new designs are based on Composite Amplifiers, previously introduced by the investigator. The technique is applicable to both hard and soft devices. Preliminary data demonstrates the impressive results when device parameters were measured during irradiation using NPS LINAC. Further study is needed to fully address all the advantages of these designs in different network topologies, and under various radiation conditions. This research also has direct application in the investigation of current ORION satellite hardware survivability in space.

PUBLICATION: Michael, S. and Cristi, R., "Active Compensated Integrated Programmable Operational Amplifiers with Improved Characteristics," proceedings of the 1991 International Symposium on Circuits & Systems, (IASTED), Zurich, Switzerland, pp. 73-76, July 1991.

CONFERENCE PRESENTATION: Michael, S. and Cristi, R., "Active Compensated Integrated Programmable Operational Amplifiers with Improved Characteristics," the 1991 International Symposium on Circuits & Systems, (IASTED), Zurich, Switzerland, pp. 73-76, July 1991.

THESIS DIRECTED: Conklin, William, LT, "Design of Radiation Insensitive Analog Linear Circuits Utilizing Composite Operational Amplifiers," MS in Electrical Engineering, September 1991.

AN AUTOMATED MONITORING SYSTEM FOR SUBMARINE POWER SUPPLY

Sherif Michael, Associate Professor of Electrical and
Computer Engineering
Sponsor: NAVSEA, Naval Sea Systems Command

OBJECTIVE: Developing a Microprocessor-Based Portable Tester for monitoring and detecting individual devices with degraded parameters in submarine power supplies.

SUMMARY: This research is proposed to investigate the possibility of developing a Microprocessor based system to monitor individual device performance in submarine power supplies. The research is also intended to investigate alternative spectral analysis techniques that could be of benefit in determining degraded performances of various power supply active devices.

THESIS DIRECTED: Raisor, Ralph, LT, "Stray Insensitive Switched-Capacitor Composite Operational Amplifiers," MS in Electrical Engineering, June 1991.

ON-ORBIT ANNEALING OF SATELLITE SOLAR PANELS

Sherif Michael, Associate Professor of Electrical and
Computer Engineering
Sponsor: SPAWAR, Space and Naval Warfare Command

OBJECTIVE: Investigate the possibility of on-orbit annealing of satellite's InP and GaAs Solar Cells using the new Minority Carriers Annealing Techniques.

SUMMARY: This is a continuation of the ongoing research on Photovoltaic Power Technology. Research tasks include the development and testing of a microprocessor based experiment suitable for small satellites, and incorporating the systems proposed in FY89 research. The tasks also include investigation of Photovoltaic current annealing processes and other related topics of radiation effects on GaAs, InP and Si devices.

PUBLICATION: Michael, S., "Minority Carrier Annealing of Radiation Degraded Indium Phosphide and Gallium Arsenide Solar Cells," in proceedings of the IAPG meeting at the 22nd IEEE Photovoltaic Specialists Conference, Las Vegas, NV, August 1991.

THESIS DIRECTED: Pinzon, Dimas, MAJ, "Analysis of Radiation Damaged and Annealed Gallium Arsenide and Indium Phosphide Solar Cells Using Deep Level Transient Spectroscopy Technique," MS in Electrical Engineering, March 1991.

MONTEREY BAY TOMOGRAPHY EXPERIMENT

James H. Miller, Assistant Professor of Electrical and Computer Engineering
Ching-Sang Chiu, Assistant Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objectives of this research were to develop and test a tomographic system to analyze the effects of ocean surface waves, internal waves, and complex 3-dimensional bathymetry on long-range acoustic propagation.

SUMMARY: Ocean acoustic tomography (OAT) is the ocean acoustic analog to medical X-ray computer-assisted tomography (CAT). Whereas CAT uses the X-ray intensity fluctuations measured at a number of angles through the imaged tissue, OAT uses the fluctuations of measured travel times from a number of acoustic multipaths though an ocean body. These fluctuations are then "inverted" to provide an information on surface waves, internal waves, density structure, etc. A system was developed to test some of the above ideas. A successful experiment was held during the week of December 12, 1988 in cooperation with the Woods Hole Oceanographic Institution. An acoustic source with a center frequency of 225 Hz was placed on a minor seamount 20 miles off Point Sur. Modified sonobuoys (with anchor, bottom-mounted hydrophone, large capacity battery, and large (float) were placed in Monterey Bay to receive the acoustic signals from the source. The sonobuoy RF signals were received and recorded ashore. Analysis of the data is complete and the results are to be published shortly. The experimental data corroborated a theory that described the way surface gravity waves affect the travel time of acoustic signals.

PUBLICATIONS: Lynch, J.F., Newhall, A.E., Miller, J.H. and Chiu, C.S., "Three Dimensional Ray Acoustics in a Realistic Ocean," Ocean Prediction and Acoustic Propagation Models, eds., D. Lee and A. Robinson, forthcoming.

Miller, J.H., Lynch, J.F., Chiu, C.S., Hippenstiel, R., Chaulk, E., and Gerber, J.S., "Surface Wave Tomography in Monterey Bay using Mode Travel Time Fluctuations," *Journal of Acoustical Society of America," 90:2302, 1991.*

Westreich, E.L., Chiu, C.S., Miller, J.H., Lynch, J.F., and Collins, M.D., "Modeling Pulse Transmission in Monterey Bay using Parabolic Equation Methods," *Trans. Am. Geophys. Union,* 72(51):47, 1991.

THESIS DIRECTED: Chaulk Edward, LT, Canadian Navy, "Arrival time tracking of partially resolved acoustic rays with application to ocean acoustic tomography," MS in Engineering Acoustics, January 1991.

Westreich, Eric L., LT, USN, "Modeling Pulse Transmission in Monterey Bay using Parabolic Equation Methods," MS in Physical Oceanography, September 1991, (co-advised with C.S. Chiu).

TIME DOMAIN LOCALIZATION

J.H. Miller, Assistant Professor of Electrical and Computer Engineering
C.S. Chiu, Assistant Professor of Oceanography
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this work is the determination of source range and depth in an ocean acoustic waveguide given a time domain representation of a source-generated signal.

SUMMARY: One of the spin-offs of the Monterey Bay Tomography Experiment was a capability to model broadband pulse propagation in a complicated environment such as the Bay. Using a broadband parabolic equation model, we have successfully explained the time domain characteristics of received signal and interpreted the propagation in terms of coupled normal modes using the source and receiver locations, bathymetry, and sound speed profile. This success leads naturally to the inverse problem for solving for the source location given the received signal. We are interfacing with operational Naval facilities to determine the feasibility of this technique.

COMMUNICATIONS DIGITAL SIGNAL PROCESSING

Paul H. Moose, Associate Professor of Electrical and Computer Engineering
Sponsor: Mr. Darrell Marsh, NOSC
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project is to develop high-speed bandwidth efficient digital communications modulation and coding methods that can be implemented utilizing low cost DSP chips.

SUMMARY: The utility of multi-frequency modulation (MFM), a highly bandwidth efficient DSP based digital modulation technique, is severely impaired by frequently offset or doppler shift. These types of channel impairments are present in acoustic links and in radio links due to transmitter/receiver motion and due to oscillator drift in bandshifting stages. This year we have developed and tested an all DSP technique to measure and correct frequency offset using the MFM encoded signals themselves, that is, there are no "pilot tones" as in previous systems. The technique uses a maximum likelihood estimation (MLE) algorithm to measure frequency offset from frequency domain data. It is very accurate and completely insensitive to time spread in the channel such as occurs due to multipath. Simulation results agree very closely with theoretical predictions.

PUBLICATION: Moose, Paul H., "A Technique for Orthogonal Frequency Division Multiplexing Frequency Offset Correction," forthcoming.

THESIS DIRECTED: Wisniewski, John W., LT, "Implementation of MFM with Trellis Encoding and Viterbi Decoding using a DSP Board," MS Thesis, June 1991.

PATENT: Moose, Paul H., "Multi-Frequency Differentially Encoded Digital Communication for High Data Rate Transmission Through Unequalized Channels," U.S. Patent No. 5,063, 574, 5 November 1991.

WESTERN EUROPEAN UNDERSEA WARFARE R&D ACTIVITY: TRENDS FOR 1991 AND BEYOND

Paul H. Moose, Associate Professor of Electrical and Computer Engineering
Sponsor: Dr. William Reese, Naval Intelligence Support Center
Funding: Naval Intelligence Support Center

OBJECTIVE: The objective of this study was to gauge the degree to which post WWII institutional arrangements in Western Europe for research, development and production of surveillance, tracking and communications systems for undersea warfare would be altered after 1992 and to speculate about the future of the undersea warfare community in a united Europe.

SUMMARY: The principal investigator of this study was in Europe on Sabbatical Leave from the Naval Postgraduate School during the first three quarter of CY91. The focus of his research activity during the leave period was in the field of advanced modulation and coding for digital communications. His background in undersea systems allowed him, in addition to his Sabbatical visits at leading signal processing and telecommunications research institutes and industrial laboratories, to visit several activities traditionally devoted to undersea systems such as the GERDSM and CERTEL laboratories in Toulon, France and to attend the UDT-91 (Undersea Defense Technology) Conference in Paris, France in April 1991. Experience gained from these travels and visits was used to make an assessment about the direction for undersea warfare R & D and production in the coming years in Western Europe. The results were documented in a report and submitted to the NISC sponsor in October 1991.

PUBLICATION: Moose, Paul H., "Western European Undersea R&D Activity: Trends for 1992 and Beyond," Final technical report for the reporting period February 1991 through September 1991, submitted to NISC, October 1991.

IMPULSE RADAR TARGET IDENTIFICATION USING NATURAL RESONANCES

Michael A. Morgan, Professor and Chairman of Electrical and Computer Engineering
Sponsor: U.S. Army Redstone Arsenal
Funding: U.S. Army Redstone Arsenal

OBJECTIVE: (1) Investigate new signal processing methods for the identification of radar targets using aspects-independent complex resonances; (2) To provide an experimental facility for measurement of ultra-wideband scattering signals from scale-model radar targets, including effects of impulse radars.

SUMMARY: Target Identification using annihilation filtering of natural resonances was investigated. Two signal processing algorithms were investigated for estimation of complex natural resonances in experimental radar scattering data. Target pole invariance to aspect was demonstrated for metallic scale model tactical aircraft. An inverse ARMA resonance annihilation filter was developed which provides increased discrimination potential by canceling the entire scattering signal of matched targets. A new discrete interaction concept for computing natural resonances of electromagnetic and acoustic scattering structures was developed. The ultra-wideband Transient Electromagnetic Scattering Laboratory (TESL) was upgraded using new dual power amplifiers and MatLab based software. These enhancements increased the usable system passband to 1 - 13 GHz and increase typical SNR to over 30 dB.

PUBLICATION: Morgan, M.A. and Walsh, N.J., "Ultra-Wideband Transient Electromagnetic Scattering Laboratory," *IEEE Transactions Antennas and Propagation*, AP-39:1230-1234, August 1991.

THESES DIRECTED: Bersani, A.E., LT, Peruvian Navy, "Performance Enhancement of the NPS Transient Electromagnetic Scattering Laboratory," MS in Electrical Engineering and MS in Systems Engineering (EW), September 1991.

Lazarakos, L.A., LTJG, Hellenic Navy, "Radar Target Identification by Natural Resonances: Evaluation of Signal Processing Algorithms," MS in Systems Engineering (EW), September 1991.

COMPUTER AIDED DESIGN OF NAVY MISSILE RADOMES

Michael A. Morgan, Professor and Chairman of
Electrical and Computer Engineering
Sponsor: Naval Weapons Center, China Lake, CA
Funding: Naval Postgraduate School

OBJECTIVE: To investigate analytical and numerical techniques for improving the performance of computer aided design software for Navy and DoD use in designing missile radomes.

SUMMARY: This research is directed towards development of optimal finite element computer programs for evaluating the radiation patterns of radome enclosed antennas on Navy missiles. Efforts this year were focused on basic research in improving the efficiency of computation for electromagnetic radiation and scattering problems through use of the analytically exact Field Feedback Formulation (F3). This approach allows proper coupling of arbitrarily shaped finite element mesh regions to unbounded space in lieu of approximate methods such as on-surface radiation conditions. The advantage is increased accuracy, while permitting a minimal mesh region which is conformal to the object being considered. A computer program based on the F3 approach was developed and validated. This program computes the radar cross section of arbitrarily shaped lossy dielectric cylinders having multi-wavelength dimensions. The F3 is also being used for computation of scattering from grooves in metal surfaces having arbitrary 2-D cross-sectional profiles.

PUBLICATION: Morgan, M.A. and Welch, T.B., "Field Feedback Computation of Scattering by 2-D Penetrable Objects," *IEEE Transactions Antennas and Propagate*, forthcoming.

CONFERENCE PRESENTATION: Schwering, F.K. and Morgan, M.A., "Backscatter Enhancement for a Planar Metal Surface with a Random Distribution of Parallel Grooves of Rectangular Profile," Progress in Electromagnetics Research Symposium (PIERS), Cambridge, MA, 1-5 July 1991.

A VISIBILITY-DEPENDENT DEPTH-OF-FOCUS FOR INCOHERENT PERIODIC SOURCES

R.J. Pieper, Associate Professor of Electrical and
Computer Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: Analyze the depth-of-focus for incoherent periodic sources using the optical visibility as a criterion. The original direction of this work has been shifted from the theoretical to somewhat more practical considerations in which the visibility concept is applied to generate a performance measure for thermal imaging systems. Elements of the project are being continued for the purposes of submitting the finalized theory to a fully reviewed journal, (e.g. Optical Engineering).

SUMMARY: During this period the final adjustments on the paper dealing with incoherent sinusoidal sources were completed. The shift in the direction of the research is to apply visibility as a criterion for evaluation of thermal imaging systems, for which incoherent optical analysis applies. This has led to what appears to be a more realistic model for predicting the minimum resolvable temperature difference (MRTD).

PUBLICATION: Pieper, R.J., Raj, K. and Poon, T.-C., "A Visibility Dependent Depth of Focus for Incoherent Sinusoidal Sources," forthcoming.

CONFERENCE PRESENTATION: Raj, K., Poon, T-C. and Pieper, R.J., "A Visibility Dependent Depth of Focus for Incoherent Sources," Optical Society of America, National Meeting, Boston, MA, October 1990.

THESIS DIRECTED: Ugarte, A.R., "Modeling for Improved Minimum Resolvable Temperature Difference Measurements," MS Thesis, September 1991.

UNDERWATER FIBER OPTIC COMMUNICATIONS

John Powers, Professor of Electrical and Computer Engineering
Sponsor: Space and Naval Warfare Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: To study the use of fiber optic cables for transmitting data in the underwater environment.

SUMMARY: Design efforts continued on a multi-channel fiber optic data link from undersea experiments to shore. Fiber links were successfully designed and inserted into a token-ring network connecting two computers. Commercial token-ring boards that use a wire-based ring were successfully connected with fibers. Electrical-to-optical and optical-to-electrical convertors were designed and tested to provide an interface at the computer board. In order to implement the design it was necessary to subvert the wire continuity checks performed by the commercial boards. This subversion was implemented by analyzing the test signals and returning the correct responses and impedance levels at the output pins of the token-ring board.

THESIS DIRECTED: Bibeau, Gary, CPT, "USMC, "Design and Implementation of a Fiber Optic Token-Ring Local Area Network," MS Thesis, December 1991.

PROPAGATION OF LOW-DIFFRACTION FIELDS

John Powers, Professor of Electrical and Computer Engineering
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: To study the predicted propagation properties of low-diffraction fields.

SUMMARY: This is a new project that began in the Fall of 1991. There have been mathematical predictions of low-diffraction fields. For example, it is generally believed that a continuous-wave truncated Bessel function will have lower diffraction than a truncated Gaussian wave. Other researchers have disputed these findings, based on causality arguments. We want to investigate the properties of the wave propagation of these waves in both a continuous-wave format and in a transient format. The analysis tool is a transient-wave propagation model developed in earlier work. Effort has focussed on implementing the model on a large memory microcomputer using the commercial program MATLAB and in using visualization tools to display the calculated four-dimensional wave (three space dimensions and time).

PERFORMANCE OF FREQUENCY-HOPPED M-ary FREQUENCY-SHIFT KEYING SYSTEMS OVER FADING CHANNELS WITH PARTIAL-BAND INTERFERENCE

R. Clark Robertson, Associate Professor of Electrical and Computer Engineering

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to perform error probability analyses for M-ary orthogonal frequency shift keying (MFSK) receivers employing frequency hop (FH) spread spectrum waveforms transmitted over a fading channel with partial-band interference. The ability of diversity, implemented using multiple hops per data symbol, to improve performance was investigated.

SUMMARY: The performance of noncoherent binary and M-ary FSK receivers with linear, ideal noise-normalization, ratio-statistic combining, and self-normalization combining was analyzed. In addition, the performance of an ideal MFSK noise-normalization receiver with forward error correction coding was obtained. The ideal noise-normalized receiver provides the best immunity from hostile partial-band jamming. The performance of the self-normalized receiver and the ratio-statistic receiver is comparable. The performance of the conventional FFH/MFSK noncoherent receiver is significantly degraded by worst case partial-band interference regardless of the amount of diversity or modulation order and regardless of channel fading conditions; although, there is an overall improvement in system performance due to diversity for weakly Rician and Rayleigh channels. Increasing the modulation order has very little effect on the performance of the conventional FFH/MFSK noncoherent receiver under conditions of worst case partial-band interference. In sharp contrast, for a wide range of channel conditions, by using diversity the FFH/MFSK self normalized noncoherent receiver can be made immune to the negative effects of worst case partial-band interference while simultaneously experiencing an overall performance improvement. In general, the key to obtaining an overall performance improvement with the self-normalized receiver is to maintain a sufficiently large signal-to-thermal noise ratio so that degradation due to nonlinear combining losses is minimized. For all channel conditions, increasing the modulation order of the self-normalized receiver results in improved receiver performance. For Rician channels, increasing the modulation order increases the sensitivity of the self-normalized receiver to worst case partial-band interference, but the improvement in overall receiver performance that results from increasing the modulation order generally offsets this additional sensitivity.

PUBLICATIONS: Robertson, R.C. and Ha, T.T., "Error Probabilities of Fast Frequency-Hopped FSK with Self-Normalization Combining in a Fading Channel with Partial-Band Interference," *IEEE Journal on Selected Areas in Communications*, forthcoming.

Robertson, R.C. and Ha, T.T., "Error Probabilities of Fast Frequency-Hopped MFSK with Noise Normalization Combining in a Fading Channel with Partial-Band Interference," *IEEE Transactions on Communications*, forthcoming.

CONFERENCE PRESENTATION: Robertson, R.C. and Lee, K.Y., "Performance of Fast Frequency-Hopped MFSK Receivers with Linear Combining in a Rician Fading Channel with Partial-Band Interference," presented at the 25th Asilomar Conference on Signals, Systems, and Computers, 4-6 November 1991.

THESES DIRECTED: Lee, Kang Y., "Performance of a Fast Frequency-Hopped Noncoherent MFSK Conventional and Self-Normalization Receivers Over Rician and Rayleigh Faded Channels with Partial-Band Interference," MS Thesis (Electronic Warfare), September 1991.

Vece, T.W., "Effects of Non-Uniform Windowing on the Performance of a Fast Frequency-Hopped Noncoherent MFSK Receiver Over Rician Fading Channels with Partial-Band Interference and

Doppler Shift," MS Thesis, June 1991.

Riley, J.F., "Performance of a Fast Frequency-Hopped Noncoherent MFSK Receiver with Ratio Statistic Combining over Rician Fading Channels with Partial-Band Interference, MS Thesis, June 1991.

Karaagac, A.C., "Noncoherent Detection of BFSK Signals with Linear and Nonlinear Diversity Combining over Rician Fading Channels with Partial-Band Interference, MS Thesis, March 1991.

MAPPING HARD REAL TIME APPLICATIONS ON LOOSELY COUPLED MULTIPROCESSORS

Shridhar B. Shukla, Assistant Professor of Electrical and Computer Engineering

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this two-year project is development of a framework for mapping hard real-time applications on loosely coupled multiprocessors to guarantee performance. The emphasis is on task allocation to minimize contention-based communication cost and on contention-free message routing.

SUMMARY: Current multicomputer mapping strategies are unsuitable for hard real-time applications because different mapping stages do not relate to each other very well, and therefore, make performance guarantees difficult to achieve. In this project, an integrated mapping strategy with a task allocation algorithm that minimizes the number of hot-spots in the network has been developed. It is based on a routing technique that generates and executes a distributed message transmission schedule computed using time bounds on individual messages. Simulation experiments on various 64 node multicomputer topologies have shown that routing and allocation based on contention yield mappings with guaranteed performance.

CONFERENCE PRESENTATIONS: Shukla, S.B. and Agrawal, D.P., "Scheduling Pipelined Communication in Distributed Memory Multiprocessors for Real-time Applications," presented at the 18th Annual International Symposium in Computer Architecture, Toronto, Canada, May 1991.

Shukla, S.B. and Agrawal, D.P., "Task Allocation in Distributed Memory Multiprocessor for Periodic Real-time Applications," presented at the International Conference on Parallel Processing, St. Charles, Illinois, August 1991.

OTHER: Shukla, S.B. and Agrawal, D.P., "Mapping Real-time Applications on Multicomputers," submitted to the IEEE Transactions on Parallel and Distributed Computing.

COMPILE-TIME SUPPORT FOR THE PROCESSING GRAPH METHODOLOGY ON THE AN/UYS-2 PARALLEL SIGNAL PROCESSOR

Shridhar B. Shukla, Assistant Professor of Electrical and Computer Engineering
Chyan Yang, Assistant Professor of Electrical and Computer Engineering
Amr Zaky, Assistant Professor of Electrical and Computer Engineering
Sponsor: Steve Kasputis, LCDR, US Navy, PMS 412, Naval Sea Systems Command, Washington, DC 20362-5101
Funding: Naval Sea Systems Command

OBJECTIVE: The goal of this continuing project is to develop a methodology for determining the optimal chains of primitives in processing graph methodology (PGM) applications running on the AN/UYS-2.

SUMMARY: Performance of the AN/UYS-2 can be improved if the primitives of the PGM graph are chained together appropriately. In order to construct the best possible chains automatically instead of manually, a framework, based on a technique called revolving cylinder analysis, was developed. This technique is based on mapping the graph at compile-time on a cylinder whose curved surface area is determined by the number of processors and graph characteristics such as primitive computation times and data arrival rate. The potential of this technique for chaining as well as for predictable execution was demonstrated by building a simulator for the AN/UYS-2. Work is in progress to determine the feasibility of deploying this technique in the actual AN/UYS-2 programming environment.

THESES DIRECTED: Little, B.S., LT, USN, "A Technique for Predictable Real-time Execution in the AN/UYS-2 Parallel Signal Processing Architecture," MS Thesis, December 1991.

OTHER: Shukla, S., Little, B. and Zaky, A., "A Compile-time Technique for Controlling Real-time Execution of Task-level Data-flow Graphs," submitted to the 1992 International Conference on Parallel Processing.

A FRAMEWORK FOR NODE FAILURE/REPAIR TRANSPARENCY IN DISTRIBUTED REAL-TIME SYSTEMS

Shridhar B. Shukla, Assistant Professor of Electrical and Computer Engineering
Chyan Yang, Assistant Professor of Electrical and Computer Engineering

OBJECTIVE: This project, aimed at funding from NSWC, Dahlgren, deals with the design and implementation of two layers of software to manage the communication and reconfiguration in distributed, real-time combat systems platforms that are completely immune to node failure/repair.

SUMMARY: This continuing project has developed a framework for a fault-tolerant, real-time distributed system which enables different functions of a single overall application program to be distributed over a network of processing modes. It consists of two layers of functionality existing at each node, viz., the location invariant function to function communication layer and the reconfiguration layer. It has been specified as finite state machines and its correctness has been verified using an Ada simulation. Work is in progress to implement it using Isis software from Cornell University.

THESES DIRECTED: Puett, Ronnie, LT, USN, "Reconfiguration in Robust Distributed Real-time Systems Based On Global Checkpoints," MS Thesis, December 1991.

Lehman, Karen, LT, USN, "Function Allocation in a Robust Distributed Real-Time Environment," MS Thesis, December 1991.

NOISE CANCELLATION FOR COUNTERMEASURE TOLERANT TRACKING

Charles W. Therrien, Professor of Electrical and
Computer Engineering
Murali Tummala, Associate Professor of Electrical and
Computer Engineering
Sponsor: Naval Undersea Warfare Engineering Station, Keyport, WA
Funding: Naval Undersea Warfare Engineering Station, Keyport, WA

OBJECTIVE: To investigate the application of adaptive filters, artificial neural networks, and ESPRIT-based algorithms to the wideband countermeasure interference suppression for recovering the tracking signal emitted by underwater vehicles at NUWES test ranges. Work included modeling of the Nanoose test range by taking the propagation losses, surface reflection, Doppler shift, and propagation delay into account.

SUMMARY: The Nanoose-test range consists of several hydrophone arrays mounted on the ocean floor. The hydrophone arrays are 2,500 meters apart, and each has a circular range of coverage with a radius of 1,500 meters. Each array in turn consists of four hydrophones. The hydrophones have a finite frequency response of bandpass nature. The vehicle being tested on the range transmits a sequence of 48 bits, which includes identification and telemetry data; the center frequency of transmission is 75kHz, and the modulation scheme used is binary phase shift keying (BPSK). To facilitate the investigation, a model of the test ranges was developed. The model assumes spherical spreading of the propagated acoustic waves. The effects of both spreading loss (inversely proportional to the squared distance) and attenuation loss (proportional to the logarithm of the distance) are included in the model. Additionally, the Doppler effect due to relative motion between the vehicle and receiving hydrophone arrays, multipath due to surface reflection, finite propagation time delays, and bandpass frequency response nature of the hydrophones are taken into consideration. Reflections from the ocean bottom are assumed to be absent.

Two adaptive algorithms, least mean squares (LMS) and recursive least squares (RLS), were studied for countermeasure suppression. The LMS algorithm is simple to implement but slow to converge to the desired filter response; on the other hand, the RLS algorithm is quick to converge to the desired solution but computationally expensive to implement. Once converged to the desired solution, both algorithms exhibited similar steady state behavior. Two schemes of adaptive filter, adaptive noise canceler and adaptive line enhancer, were applied to the test range model. The schemes were tested down to -20 dB of signal-to-noise ratio, and the average behavior was obtained by one hundred Monte Carlo simulations. The noise canceler consistently improved the signal recovery performance by 6 dB compared to when no adaptive filter was used; the line enhancer, however, degraded the performance.

A three layer feedforward backpropagation neural network algorithm was used in this study for countermeasure suppression. Two network configurations were proposed, signal waveform recovery and binary sequence recovery. The spectral features of the signal received at the hydrophone arrays were utilized to train the network in both schemes. The signal waveform recovery scheme failed to extract the signal in countermeasure noise below -10 dB. The binary sequence recovery scheme, however, was tested down to -20dB of signal-to-noise ratio. The performance of the neural network schemes degraded when the Doppler effect was introduced in the model. Future work in this approach includes an investigation into selection of signal features that are insensitive to the Doppler shift.

The signal copy feature of the ESPRIT algorithm was also being investigated for improved recovery of the tracking signal in countermeasure noise. The total least squares (TLS) ESPRIT algorithm has been found particularly useful here.

PUBLICATIONS: Tummala, M. and Therrien, C.W., "Application of Adaptive Filters to Countermeasure Suppression at the NUWES Test Ranges," NPS Technical Report NPS-EC-92-003,

December 1991.

Tummala, M. and Therrien, C.W., "Artificial Neural Networks for Countermeasure Tolerant Tracking of Underwater Vehicles," NPS Technical Report, forthcoming.

THESIS DIRECTED: Herdegen, D.W., "Adaptive Noise Cancellation Applied to the NUWES Test Ranges," MS Thesis, December 1991.

Wellington, C.H., "Application of Artificial Neural Networks for Countermeasure Tolerant Tracking," MS Thesis, December 1991.

OTHER: Tummala, M., Therrien, C.W., Herdegen, D.W., Wellington, C.H. and Scout, J.C., "CM Tolerant Tracking," Progress Report prepared for NUWES, Keyport, WA, August 1991.

RESEARCH IN MULTIDIMENSIONAL SIGNAL PROCESSING

Charles W. Therrien, Professor of Electrical and Computer Engineering
Murali Tummala, Associate Professor of Electrical and Computer Engineering
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: To investigate several techniques for the detection and estimation of one and two-dimensional signals. Work includes iterative methods with application to multidimensional spectrum estimation, methods for estimation of parameters for modeling and classification of transients, and theoretical investigations of change detection procedures in time series data.

SUMMARY: The work on iterative algorithm continued with emphasis on data adaptive methods. An investigation into the application of multigrid techniques to iterative algorithms was initiated. Much progress has been made in the design of iterative algorithms for one-dimensional MA and ARMA model parameter estimation which provided significant improvement over the existing methods. Also, the two-dimensional AR modeling problem has been studied. Data adaptive algorithms have been developed for both one and two-dimensional problems. Our investigation focused on estimating these parameters with short data lengths and on "over" and "under" modeling of unknown systems. The two-dimensional AR algorithm has been applied to spectral line estimation and to noise cancellation in images.

Several methods of ARMA modeling were investigated in the context of transient modeling in the time domain. Essential features of the methods were identified for this application and the most successful methods were applied to the modeling of several acoustic transients. Other related work addressed the problem of classifying transients by evaluating the probability that the observed data was produced by a sequence of ARMA models whose parameters changed abruptly at unknown times. A methodology based on ARMA modeling and sequential observation and classification of a certain change statistic was developed for this problem.

Some general theoretical investigation of change detection methods known as "cumsum" procedures were also carried out. In particular, a new algorithm which bases decision on the data within a sliding window was developed that yields a higher probability of detection than previous algorithms. In a non-Bayesian framework a Brownian motion-based approach was introduced to analyze the performance of cumsum procedures and a technique was developed for computing the parameters of a cumsum procedure to yield an optimal compromise between detection delay and false alarm rate.

PUBLICATIONS: Tummala, M., "New Algorithm for Solving Block Matrix Equations with Applications in 2-D AR Spectral Estimation," *IEEE Transactions on Signal Processing*, 39:759-764,

March 1991.

Therrien, C.W., "2-D Rational Models for Spectrum Estimation," in proceedings of the 7th workshop on Multidimensional Signal Processing, September 1991, Lake Placid, N.Y.

Delaney, K.J. and Therrien, C.W., "Detecting Abrupt Changes in ARMA Models," in proceedings of the 25th Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, CA, November 1991.

Therrien, C.W. and May, G.L., "Comparison of ARMA Modeling Methods in the Time Domain," in proceedings of the 34th Midwest Symposium on Circuits and Systems, Monterey, CA, May 1991.

Aviv, D. and Cristi, R., "Detection of Signals with Discontinuities," in proceedings of the 34th Midwest Symposium on Circuits and Systems," Monterey, CA, May 1991.

Tummala, M., "Iterative Algorithms for Identification of Third Order Volterra Systems," in proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, Toronto, Canada, May 1991.

Tummala, M. and MacHardy, W.R., "Adaptive Algorithm for IIR Filtering Based on Matrix Iterative Techniques," in proceedings of the IEEE International Symposium on Circuits and Systems, Singapore, June 1991.

Tummala, M., and Eremic, J.C., "Iterative Methods for Estimation of 2-D AR Parameters Using a Data-Adaptive Toeplitz Approximation Approach," in proceedings of the 25th Asilomar Conference on Signal, Systems, and Computers, Pacific Grove, CA, November 1991.

THESES DIRECTED: Aviv, David, "Quickest Detection of Changes in Signals," Ph.D. Thesis, June 1991.

May, Gary L., "Comparison of ARMA Modeling Methods in the Time Domain," MS Thesis, March 1991.

Eremic, J.C., "Adaptive Algorithm for 2-D AR Parameter Estimation Based on Iterative Methods," MS Thesis, September 1991.

Richter, Dean A., "Multigrid Algorithms for System Modeling," MS Thesis, December 1991.

MTF DATA REDUCTION SOFTWARE

S.M. Williams, Assistant Professor of Electrical and Computer Engineering

Sponsor: Naval Surface Warfare Center
Funding: Naval Surface Warfare Center

OBJECTIVE: The goal of this project was to develop, code, and test a computer software package for reducing the data resulting from tests performed by the EPIC Mobile Test Facility (MTF). The deliverables of the effort will be computer programs which condense the data output from the MTF into formats which are readily interpreted and directly comparable to specifications required by relevant industry and military standards (e.g., IEEE Std 519, DOD-STD-1399 Section 300A).

SUMMARY: This is an ongoing two year project. In the first year, an overall structure for the computer software has been developed. Preliminary codings of individual modules have been written and tested.

The second year will see completion of the final product. This software product will be installed on a Department of the Navy tester to qualify contractor deliverables.

PUBLICATION: Sityar, I., Williams, S., Rager, P. and Reitweisner, J., "Design of an Electric Power Interface Compatibility 200 KVA Mobile Test Facility," forthcoming.

DEPARTMENT OF MATHEMATICS

DEPARTMENT OF MATHEMATICS

The research program of the Mathematics Department seeks to advance the state of knowledge in the areas important to the Department of the Navy and Department of Defense, such as scientific and parallel computing, weather forecasting, fluid flow, orbital mechanics, and simulation and modeling.

The specific research areas of our faculty and their students are reported in detail, including sponsors, later in this book. Output given in the form of student these, technical reports, conference presentations, and refereed journal articles.

Scientific Computation

The area of scientific computation includes both numerical (on serial and parallel computers), and analytical (symbolic) solutions to a variety of problems of interest to the Department of the Navy and Department of Defense. Research has been conducted by Professors Neta, Gragg and Lustman to develop algorithms for the INTEL hypercube to solve systems of ordinary differential equations in parallel. Such systems appear in many areas of application, such as weather forecasting and prediction of satellite orbits.

Professors Danielson, Neta and several students are working on the parallelization of several existing algorithms for prediction of orbits of satellites. The serial version of these algorithms is in use at NAVSPASUR and AFSPACECOM. Other algorithms will be investigated.

Professors Neta, Schoenstadt, and Lustman continued their joint work with Professor R. T. Williams of Meteorology on the development of schemes for weather forecasting using the INTEL iPSC/2 hypercube.

Professors Gragg and Thornton are working on fast parallel algorithms for the symmetric tridiagonal eigenvalue problem and the bidiagonal singular value problem. Important areas where these algorithms find application include, but are not limited to, heat conduction, the fundamental frequencies of vibrating structures, and the analysis of the sensitivity of solutions to perturbations in data.

On scientific, non-parallel computing, Professor Franke continues his work on scattered data approximation especially with application to meteorological data.

Professor Henson is working with multigrid methods. Such methods can be applied to a variety of problems. He will be joining Professor Neta in developing adaptive schemes for solution of shallow water equations and weather forecasting.

Professors Canright and Scandrett are continuing their work on the application of the T-matrix approach to analyze an array of radiating transducers. This work is applicable in Anti submarine Warfare.

Professor Canright is also working on welding problems as applied to the construction of ships and submarines. Professor Scandrett is also working on scattering from double-hulled structures for the new double-hulled ships. Professor Danielson is contributing to the design of such ship structures in his work with civil engineers at Lehigh University. This work is part of a preliminary design of new ships for the Navy.

Professor Frenzen is continuing his work in asymptotic analysis. Asymptotic Expansions have been applied to problems in nonlinear wave propagation and mathematical physics. Also, with Danielson, he has studied the buckling behavior of a rectangular plate with parallel T-stiffeners subjected to a combination of axial compression and lateral pressure.

Simulation Computation

Professors Franke and Jayachandran are working on quality assessment of meteorological data by estimating satellite biases. This work will improve quality of weather prediction.

Professors Barr and Weir are continuing their work on combat models for the U.S. Army TRADOC Analysis Center. This work is aimed at using high level measures of combat effectiveness in training applications.

Professor Thornton is working on path planning problems. Although the motivation for this work is obstacle avoidance for robots, it is also relevant to other path planning situations, such as steering submarines among sonar detectors or mines, or path planning for aircraft in the vicinity of anti-aircraft fire.

Professor Jayachandran is continuing his work on fault-tolerant computing. Fault Tolerant Computing is a Methodology for building in redundancy in critical software to avoid catastrophic failures. Two types of fault-tolerant implementations are currently in vogue. First is the N-version Programming where N independently developed programs are run in parallel and in case of a discrepancy a majority rule is applied. The second approach is called the Recovery Block Scheme where a second independently generated program is on stand-by and kicks in when a failure in the primary program is discovered. Professor Jayachandran is evaluating the efficacy of each method.

Discrete Mathematics

Professor Fredricksen continues his research in communication protocols. The work is theoretical at present but has promise for practical application in certain broadcast communications scenarios. His work on covers in de Bruijn graphs has application to an error correction system for stream ciphers which is analogous to the block ciphers of classical coding systems. Single error correcting codes in this design occur when certain vertices in the appropriate graph preclude others from appearing in the code. The topology of the underlying graph is different for the stream cipher problem.

Professor Guillermo Owen continues his research into game theory and voting. In game theory, he is working on a study of the discrepancies between the equilibrium and disruption results in large market games. In voting theory (jointly with B. Grofman of U.C. Irvine) he is studying racial-related voting patterns.

Professor Leader is working with students on problems applicable in cryptography and wargaming.

APPLICATION OF THE T-MATRIX METHOD TO LOW-FREQUENCY ACTIVE ARRAY PERFORMANCE PREDICTION

S. R. Baker, Associate Professor of Physics
D. R. Canright, Assistant Professor of Mathematics
C. L. Scandrett, Associate Professor of Mathematics
Sponsor: Naval Underwater Systems Center
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is an accurate yet computationally efficient model for the performance of sonar arrays, particularly low-frequency active, closely spaced arrays. This is a continuing project.

SUMMARY: The method employed is an extension of the T-Matrix method, which has been previously applied to scattering problems, but has not been used in the problem of coupled electroacoustic transducers. Multiple scattering to all orders is rigorously included, so that arbitrarily dense arrays may be described. Each element may be represented analytically in the simplest cases, or may be described more generally by a finite element model.

In FY 90 Professors Canright and Scandrett developed a numerical model of an array of closely spaced, identical spherical shell radiators. In FY 91, the numerical method for obtaining the solution to the acoustic problem has been revised and extended, allowing for larger and more closely packed arrays.

CONFERENCE PRESENTATION: Scandrett, C.L. and Canright, D.R., "Acoustic Interactions in Arrays of Fluid Loaded Spheres," presented at the International Conference of Industrial and Applied Mathematics, Washington DC, July 1991.

"Acoustic Interaction in Transducer Arrays," presented at the ATILA Users Mini-Workshop, NPS, August 1991.

EVALUATION OF EFFECTS OF INCORPORATING HUMAN FACTORS INTO COMBAT MODELS

D. R. Barr, Adjunct Professor of Mathematics
M. Weir, Professor of Mathematics
Sponsor: TRADOC Analysis Command - Monterey
Funding: TRADOC Analysis Command - Monterey

OBJECTIVE: The goal of this project is to develop methods of comparing combat results from Army combat models and other data sources such as field tests and the National Training Center. These methods are to be applied to assessing enhancements to combat models and to providing measures useful in training contexts. The long-term goal is to develop and evaluate methods for making comparisons from a broad range of sources.

SUMMARY: A family of measures of combat success was developed using results related to the Lanchester Square Law. This measure is similar to the elasticity in combat-induced casualties, measured as a function of time into the battle. We call this measure the "battle trace." Methods of computation of the battle trace were investigated and formats for presentation of the information in a training context were investigated. Methods of making statistical comparisons of battle traces in designed experi-ments were developed and applied to the problem of determining the effects of introducing a fratricide module into the Janus combat simulation.

PUBLICATIONS: Barr, D., Weir, M. and Hoffman, J., "Evaluation of Combat," NPS Technical Report NPS-MA-92-001, October 1991.

CONFERENCE PRESENTATIONS: Barr, D., Weir, M. and Green, R., "Approach to Validation of Combat Simulation Models," presented at the 59th Military Operations Research Symposium, West Point, NY, 12 June 1991.

THESES DIRECTED: Green, John, CAPT, "Comparing Combat Models Using Analytical Surrogates," MS Thesis, 1991.

Feil, Mike, "A Sensitivity Analysis of the Janus(A) Combat Simulation that Supports the Use of Janus(A) in Army Training," MS Thesis, 1991.

COMPARABILITY ANALYSIS FOR MODEL-TEST-MODEL

D. R. Barr, Adjunct Professor of Mathematics
Sponsor: Director, TEXCOM Experimentation Center
Funding: Director, TEXCOM Experimentation Center

OBJECTIVE: A major problem in the implementation of the Army's Model-test-model (MTM) process is the lack of methods for comparing results from simulated combat, because of differences in sources of the data and because of the inherent large variability in combat dynamics. The goal of the proposed research is to assist in development of methods of making credible comparisons of battle results from combat simulation models and field tests. Included in the investigation is development of approaches which can answer the following question:

* How should one compare results from a Janus run with results from a related field test trial?
** What measures should be used for such comparisons?
** What methods should be used to make the comparisons, for the selected measures?
** What are the appropriate sample sizes for credible comparisons?
* How much control should (or must) be exercised in the combat simulation or field test to make the results comparable?

SUMMARY: A prototype exercise of the MTM process was designed around the Army's test of the M1A1 tank at Fort Hunter Liggett. Several technical issues related to representation of the M1A1 in the Janus combat simulation were resolved. A range of traditional measures related to casualty process (such as range at detection, number of engagements, casualty ratios, movement rates, etc.) were evaluated for use in making MTM comparisons. Attention was given to traces of such measures over time or over distance, defined in ways to account for lulls and sprints in the battle. Statistical methods of comparing distributions of engagement range, detection range and player movement rate were developed and evaluated. Possible use of the battle trace measure was investigated. The M1A1 tests were not satisfactorily completed due to equipment problems; additional testing is scheduled for 1992. This project will be continued into 1991.

THESES DIRECTED: East, Allen, CAPT, "Comparison of Tank Engagement Ranges from an Operational Field Test to the Janus(A) Combat Model," MS Thesis, 1991.

Paulo, Gene, CAPT, "Analysis of Line of Sight-Forward-Heavy Engagement Ranges," MS Thesis, 1991.

EFFECTS OF TERRAIN RESOLUTION UPON INTERVISBILITY

D. R. Barr, Adjunct Professor of Mathematics

OBJECTIVE: The purpose of this project is to investigate the degree of terrain resolution needed in combat simulation models.

SUMMARY: A definition of intervisibility on one and two-dimensional terrain has been developed, based on arc length and surface area concepts. The effects on intervisibility of representing continuous functions of one and two variables (the "terrain") in terms of step functions over partitions of their domains has been investigated.

THESIS DIRECTED: Toy, David, CAPT, "Evaluation of Terrain Resolution in the Janus Combat Simulation," MS Thesis to be completed March 1992.

ESTIMATION OF UNIT SUCCESS/MIX MODEL FOR USAR

D. R. Barr, Adjunct Professor of Mathematics
Sponsor: U.S. Army Recruiting Command
Funding: U.S. Army Recruiting Command

OBJECTIVE: The goal of this project was to develop models for predicting the recruiting success of Army Reserve units, as functions of demographic factors, location characteristics and unit characteristics.

SUMMARY: This was a continuation of research performed in 1990. The set of statistical models for predicting the fill rates of Army Reserve units developed earlier was revised to incorporate suggestions made by the Army Recruiting Command. The performance of the models was evaluated in terms of error rates in predicting satisfactory fill for reserve units with specified characteristics. Examples showing how the models could be applied to Reserve Unit relocation were developed.

PUBLICATIONS: Barr, D. and Thomas, G., "Regional Models of Labor Market Success: U.S. Army Reserves," Army Recruiting Command Technical Report (1991).

Barr, D. and Thomas, G., "Goodness-of-Fit Classification Threshold Selection for Discrete Choice Models," in proceedings of the 20th Decision Sciences Institute, Kauai, Hawaii, March 1991.

CONFERENCE PRESENTATION: Barr, D. and Thomas, G., "Goodness-of-Fit Classification Threshold Selection for Discrete Choice Models," presented at the 1991 Meetings of the Decision Sciences Institute, March 1991.

THESIS DIRECTED: Buning, Daniel, CAPT,"U.S. Army's Delayed Entry Program: Attrition Modeling," MS Thesis, 1991.

ANALYSIS OF THERMOCAPILLARY CONVECTION IN WELDING

D.R.Canright, Assistant Professor of Mathematics
Sponsor: Office of the Naval Research
Funding: Office of Naval Research and
Naval Postgraduate School

OBJECTIVE: The goal of this project is to determine the scaling and structure of the "cold-corner singularity" in thermocapillary flow in weld pools. This is a continuing project.

SUMMARY: Recent work in modeling thermocapillary convection in materials processing, for example in the pool of liquid metal formed during welding, shows a region of rapid flow and intense heat transfer, concentrated in the "cold-corner" region. A theoretical understanding of this region, currently lacking, is essential for accurate numerical models. The objective of this study is to analyze the coupled thermal and flow fields in this important region, including the dependence on the governing parameters. The result should be useful in developing more complete numerical models of the welding process, to understand how to make welds more reliable. This research is in progress; a scaling analysis has identified different regimes of behavior (in parameter space), and preliminary numerical computations of flows have validated this scaling.

OTHER: An article is in preparation; its current form is a short working paper including figures which has been sent to selected colleagues.

REAL-TIME BIAS CORRECTION FOR SATELLITE DATA

Richard Franke, Professor of Mathematics
Sponsor: Naval Oceanographic and Atmosphere Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: Use of high quality coastal region radiosonde readings as background values to estimate the bias in thickness/temperature values derived from polar orbiting satellite reports is to be investigated.

SUMMARY: A reliable scheme for interpolation over a significant portion of the sphere is necessary for the success of the project. Two such schemes were investigated: Pseudosplines on the sphere, and a triangle based method. Investigations with real data indicated that the pseudosplines perform most reliably and that the triangle based method was subject to artifacts of the triangulation. The next stage is the identification of a network of reliable radiosondes to serve as input to the interpolation routines. It is expected that this work will be continued under reimbursable funding from NOARL.

ANTERPOLATION METHODS: FOURIER TRANSFORMS ON IRREGULAR GRIDS

Van Emden Henson, Assistant Professor of Mathematics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop and implement a numerical scheme called the ADFT (Anterpolated Discrete Fourier Transform) by which the Fourier transform of a data set may be computed, when the data are known only at irregularly spaced locations.

SUMMARY: Theoretical aspects of the ADFT are developed, and conditions under which the ADFT is more efficient or more accurate than conventional methods are determined. Numerical experimentation is carried out, to validate the theoretical analysis. Application of the technique to problems in computer tomography are explored.

CONFERENCE PRESENTATION: Henson, Van Emden, "DFTs on Irregular grids:the Anterpolated Discrete Fourier Transform," NSF-CBMS Conference on Multilevel Projection Methods, George Washington University, Washington, DC, 24 June 1991.

OTHER: The investigator will submit, in January 1992, the paper "DFTs on Irregular grids: the Anterpolated Discrete Fourier Transform" for publication in SIAM JOURNAL ON SCIENTIFIC AND STATISTICAL COMPUTING. In addition, work on the paper "Anterpolated Image Reconstruction" is in progress, to be submitted to a refereed publication on medical imaging. Results of this project are to be included in a book, "A Discrete Fourier Transform Tutorial" to be co-authored by the investigator and Professor William L. Briggs (University of Colorado at Denver).

MULTIGRID, MULTILEVEL AND MULTILEVEL PROJECTION METHODS

Van Emden Henson, Assistant Professor Of Mathematics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

SUMMARY: Multigrid and multilevel methods are numerical computation methods that take advantage of all of the scales of a problem in order to accelerate the convergence to the solution.This project investigates the application of these methods to several types of problems: integration and integral transform methods such as the Gauss and Legendre transforms; grid refinement methods for PDEs, specially the shallow water equations of meteorology and oceanography, and the underwater acoustic equation; and multilevel methods for image reconstruction (the Radon Transform problem).

OTHER: This project is ongoing research. It has not yet resulted in publications or conference presentations. It is anticipated, however, that results will be obtained in the next year, in the form of papers, presentations, and perhaps theses directed.

QUALITY CONTROL OF METEOROLOGICAL DATA

Toke Jayachandran Professor of Mathematics
Richard Franke, Professor of Mathematics
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory
Funding: Office of Naval Technology

OBJECTIVE: The aim of this project is to develop a quality control methodology to eliminate or modify some of the potentially erroneous data collected worldwide and used for making meteorological forecasts.

SUMMARY: The investigators worked on two different problems. The first problem was to develop an adaptive procedure to determine appropriate corrections to geopotential heights data used in meteorological forecasts. This required the use of "smoothed" historical data to predict future values. The second problem was to devise a scheme for identifying recording stations that provide erroneous data or highly variable data. The approach we took was to divide all recording stations in US (or worldwide) into contiguous groups in the sense that the weather patterns over the regions are similar and compare the measurements within a group to identify outliers.

A paper describing the developed adaptive correction procedure has been published in the Preprint of the Ninth Conference on Numerical Weather Prediction. A technical report describing an outlier test for identifying reporting station that consistently produce erroneous data,has been issued.

PUBLICATIONS: Baker, N., Franke, R. and Jayachandran, T. "An Adaptive Correction Procedure for Radiosonde Geopotential Height Bias, "Preprint Volume of the Ninth Conference on Numerical Weather Prediction, Denver, CO, 14-18 October 1991.

Jayachandran, T. and Franke, R., "Quality Control of Meteorological Observations," NPS Technical Report NPS-MA-91-013, January 1991-June 1991.

ANALYSIS OF CHAOTIC ITERATION IN R^n

Jeffery J. Leader, Assistant Professor of Mathematics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate a chaotic iteration and to begin applying the theory of chaotic discrete dynamical systems to issues of Department of Defense interest.

SUMMARY: Further refinement of the theory of the Generalized Theodorus Iteration resulted. An application is currently being made (with my thesis student Lt. Jim Heyman, USN) of this iteration and the Hènon map to the generation of pseudorandom numbers for use as keystreams in cryptography. We believe that this will be of interest to NSA.

Possibilities for future sponsorship have been, and are being, actively investigated, including applications to wargaming with the USA TRADOC command at NPS.

PUBLICATIONS: Leader, J., "Limit Orbits of a Power Iteration for Dominant Eigenvalue Problems," *Applied Mathematical Letters*, 4(4):41-4.

Leader, J., "A Weekly Chaotic Iteration in Rn," *Applied Mathematical Letters*, 4(4):49-52.

Leader, J., "Boundedness and Asymptotics of a Chaotic Matrix Iteration," *Rocky Mountain Journal of Mathematics*, forthcoming.

OTHER: Other publications submitted or in preparation. A chapter on the subject of chaotic discrete dynamical systems was contributed to an undergraduate text due to be published in 1992.

DEVELOPMENT OF FINITE ELEMENT PREDICTION MODEL

B. Neta, Associate Professor of Mathematics
A.L. Schoenstadt, Professor of Mathematics
R.T. Williams, Professor of Meteorology
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop parallel algorithm based on finite elements to solve the shallow water equations.

SUMMARY: We have concentrated on parallel computation using the INTEL Hypercube for problems related to weather prediction. We have developed a domain decomposition finite difference conservative scheme and software for the solution of systems of linear and nonlinear ordinary differential equations.

PUBLICATIONS: Staniforth, A.N. and Williams, R.T., "Influences of Linear Depth Variations on Barotropic Kelvin and Poincave's Waves," *Journal of Atmospheric Sciences*," submitted for publication.

Lustman, L., Neta, B. and Katti, C.P., "Solution of Linear Systems of Ordinary Differential Equations on an INTEL Hypercube," *SIAM Journal on Scientific and Statistical Computing*, 12:1480-1485, 1991.

Lustman, L., Neta, B., and Gragg, W., "Solution of Ordinary Differential Initial Value Problems on an INTEL Hypercube," *Computers and Mathematics with Applications*, forthcoming.

Lustman, L. and Neta, B., "Software for the Parallel Solution of Systems of Ordinary Differential Equations," NPS Technical Report NPS-MA-91-009, February 1991.

Neta, B., "Analysis of Finite Element and Finite Differences for Shallow Water Equations: A Review," *Mathematics and Computers in Simulation*,

forthcoming.

Neta, B. and Navon, I.M., "Analysis of the Turkel-Zwas Scheme for the Shallow Water Equations on a Sphere, in proceedings of the 13th IMACS World Congress, Dublin, Ireland, 22-26 July 1991.

ASTRODYNAMIC STANDARDIZATION

I.B. Russak, Associate Professor of Mathematics
Sponsor: Naval Weapons Center Dahlgren

OBJECTIVE: To develop a new high precision satellite tracking code for the Navy in order to: (1) use theory more current than that used in developing the existing tracking code some twenty years ago and; (2) resolve discrepancies in tracking results among various military tracking codes.

SUMMARY: I and Professor B. Neta met in Dahlgren with Dr. S. Knowles, the technical director of NAVSPASUR and Dr. P. Schumaker. On the basis of those meetings, broad approaches to the task of developing a new high precision satellite tracking code were formulated. All of those involved obtaining and understanding the high-precision satellite tracking codes that currently exist in both the military and civilian communities. The incorporation of the best of those together with relatively recent advances in computer technology will form the basis of a new code.

Investigation into existing high precious satellite tracking codes was started with the reading of the Aerospace Corporation's code (named "TRACE') and also the Navy's code ("NAVSPASUR Satellite Tracking Model PPT2"). In addition, investigation into the "analytic" method of orbit generation was started. The purpose of these investigations is to see whether numerical integration or a variation of analytic theory might best be adapted to newer computing techniques.

ROBOT ARM PATH PLANNING

John Thornton, Assistant Professor of Mathematics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to perfect an approach to robotic path planning among obstacles which combines the strengths of two different approaches.

SUMMARY: Two competing approaches to the problem of finding obstacle avoiding paths for robot arms have complementary strengths. One approach entails the representation of the set of realizable configurations by a hypergrid in configuration space, which must then be searched. This approach is both straightforward and slow. In the other approach, governing equations are written and constraints are imposed which caused obstacles to be avoided. A variant of this approach developed by this investigator employs an efficient product-automaton-based mechanism to monitor and change constraints during integration of the equations of motion. While this approach can be much faster than the first, it requires special starting information.

The key observation for the current line of inquiry is that an efficient event detecting mechanism can remove the need for a finely discretized hypergrid. The search for an obstacle avoiding path can begin on a coarse mesh, which can be examined for violations of the obstacles and refined only as needed-locally in the neighborhood of any infeasible regions in configuration space which impede the robot's progress. The resulting approach should be substantially faster than the classical hypergrid search while avoiding the need for special starting information.

Activities which were conducted in pursuit of this project are:

(1) Carried out analysis of computational expense incurred by the event detection mechanism on which the entire approach depends. Results explain favorable computational characteristics that are observed in computer simulation of robot's action. Presented this work for conference.

(2) Directed two theses which explore important aspects of the second of the above methods.

(3) Designed a non-rectangular grid on which to represent configurations, and method to refine it locally in the neighborhood of infeasible regions of configuration space.

(4) Made significant progress on draft of a paper to establish a theoretical basis for a comprehensive approach to path planning among obstacles.

CONFERENCE PRESENTATION: Thornton, J.R., "On Computational Complexity of Event Detection in Discrete-Continuous Product Automaton Simulation of a Robot Arm," in proceedings of the Twenty Second Annual Pittsburgh Conference on Modeling and Simulation, University of Pittsburgh School of Engineering, May 1991.

THESIS DIRECTED: Cuerington, Andre, M., CPT, USA, "The Shortest Path Problem in the Plan with Obstacles: Bounds on Path Lengths and Shortest Paths within Homotopy Classes," MS Thesis, June 1991.

Jenkins, Kevin, D., CPT, USMC, "The Shortest Path Problem in the Plane with Obstacles: A Graph Modeling Approach to Producing Finite Search Lists of Homotopy Classes," MS Thesis, June 1991.

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

The primary thrust of the Department of Mechanical Engineering's research program continues to advance the state of knowledge in areas important to the U.S. Navy, in particular those areas involving solid mechanics and composite structure optimization; underwater shock and vibration/noise; control of dynamic systems, fundamentals of fluid mechanics, hydrodynamics, and heat transfer including applications to electronic cooling, welding, boiling and condensation, and applied thermodynamics; and materials science applied to metal and metal matrix composites. Results of research are published in the student theses, NPS technical reports, and in papers both presented at, and appearing in, national conference proceedings, and published in the scientific journals.

In addition to the research activities of the 18 tenure track facility, the department has 8 to 10 adjunct and visiting faculty.

Solid Mechanics, Shock and Vibration

Professor Y. Shin continued his work in the area of underwater shock, machinery diagnostics and vibration damping sponsored by DNA, NAVSEA, DTRC as well as NPS Direct Research Fund. The project funded by DNA are concerned with the nonlinear dynamic response and failure mechanism of submerged structures to underwater explosion (UNDEX). The research includes both analytical and experimental studies of UNDEX behavior of flat plate and cylindrical shell type structures made of aluminum and S-2 glass/polyester composite materials. Funded by NAVSEA, he continued the project in machinery noise and diagnostics and the condition monitoring of transient machinery typical to turbine-driven torpedo ejection pumps (TEP's). Time-frequency domain spectra were developed to characterize the response signatures of transient machinery. Backpropagation in neural networks are used in identification of machinery failure diagnostics. In addition, he continued to develop effective means for vibration control of primary structures using constrained layer treatments, tuned dampers, and waveguide absorbers with direct application to the advanced submarine technology.

Professor D. Salinas has worked (with Y.W. Kwon) on techniques for solving nonlinear problems with the finite element method. Bellman's quasilinearization technique was fully developed and applied to several nonlinear problems. Comparisons were made with solutions from two other linearization techniques. An NPS technical note (with P. Shin) on thermoelastic stresses in soldered electronic packages for NWSC was completed. The report presents methods for thermal stress calculations. Work (with P. Marto) on the analysis of rotating heat pipes was completed. Work (with Y.W. Kwon) began on thermoelastic stresses in layered media in transient nonuniform thermal fields.

Professor Y.W. Kwon developed a novel analysis model, along with its finite element formulation for both two-dimensional and three-dimensional analyses of composites structures including plate bending. The analysis model was found suitable to investigate material nonlinear deformations of composite structures such as metal-matrix composites as well as the effects of micro-scale cracks on the composite structure level, in other words a study of interaction between the micro-scale cracks and macro-scale cracks. This project was funded by the Naval Postgraduate School. In addition, he has been working with Y. Shin on the underwater explosion research project sponsored by DNA. Experiments were performed for cylindrical shells subjected to a far-field side-on or an end-on explosion. The physics related to the response of the cylinders was examined. Furthermore, the experimental data were compared to numerical results. One of the major objectives of the project was to enhance the capability of numerical prediction of structural responses subjected to underwater explosion.

Dynamics Systems and Control

Professor A. Healey continued working with the project on Autonomous Underwater Vehicles. Contributing work was done by Professor F. Papoulias, and Professors Kwak, Lee, and McGhee from Computer Science, and Professor Cristi from the Electrical Computer Engineering Department. During this year, progress has included a major effort in the experimental verification of closed loop controlled speed, steering and depth changing of the NPS AUV II vehicle in the NPS swimming pool. Theoretical studies in matching the experimental maneuvering behavior have been started and to date show that first principles prediction of the steering and diving behavior are reasonably accurate. The identification of the vehicle hydrodynamic coefficients parameters from experimental data has begun using Kalman filtering, and a new effort (funded in part by NCSC Panama City) in the use of Neural Networks for system status and autonomous failure diagnostics has been started. The use of Neural Networks in adaptive autopilot operations has been studied. A design outline for the use of a small GPS/INS package (funded in part by NOSC Hawaii) has been performed with a view to providing a strap-on navigational unit for underwater use.

Professor M. Driels focussed his research on two major areas. The first of these is Haptic Search, and involves understanding the methods employed by humans in exploring and recognizing objects using only the sense of touch, particularly when a telemanipulator is placed between them and the object being probed. This work results in two masters theses and three journal publications either submitted or published. The second area of research is Robot Calibration in which methods are developed to improve the positioning accuracies of robot manipulators. Three thesis students performed work on novel measurement methods used to perform calibration and led to one conference publication, two papers and two patent applications. All of the work reported was supported by the NPS direct research fund.

Professor F.A. Papoulias continued in research on guidance and control laws for marine vehicles and dynamics and bifurcations of towed vehicles. The above were treated as problems in nonlinear dynamics. The occurrence of both subtle and catastrophic Hopf bifurcations was identified and methods were developed to assess their effect on system response and safety of operations. Research in the area of stability of positively buoyant submersibles concentrated on application of catastrophe theory for analyzing the system dynamics during emergency ascend/descend situations and dive plane jam recovery procedures.

Professor R. Mukherjee started working at NPS since 1st of October 1991. His research topics include control of under-actuated dynamical systems, motion planning and repeatability of nonholonomic mechanical systems, and control of flexible space structures.

Fluid Mechanics, Thermodynamics and Heat Transfer

Professor T. Sarpkaya worked on vortex/free-surface interactions (ONR), on vortex motion in time-dependent flow about bluff bodies (NSF), on non-acoustic detection of submarines (DARPA), and on the computational fluid dynamics of wave-current-body interactions (NSF) and wrote about a dozen papers in which the results of this year's work have been disseminated.

Professor P. Marto, together with Adjunct Professor S. Memory, continued his research on enhanced two-phase heat transfer. Significant efforts were made to improve upon the overall accuracy of the data reduction procedures that are used to measure film condensation heat transfer coefficients for steam. A wide variety of nucleate boiling data of R-113 and R-114 have been obtained during boiling from various enhanced surfaces. The influence of oil on boiling performance was also studied. Results can be used to design more compact shipboard evaporators and condensers.

Professor M. Kelleher has developed a finite difference model to simulate the spread of fire and smoke in confined spaces. The present version of the model uses a system of general orthogonal coordinates so that the specification of the geometry is not a major constraint. The model is also capable of including the presence of solid objects or obstruction, such as machinery components, within the enclosure. The effects of surface radiation have also been included. The model can also accommodate the presence of forced ventilation within

the space so that the presence of fans or ventilation ducts can be included. Graphics post-processing capabilities have been developed which provide color representations of the isotherms at any instant in the fire. Routines have also been developed which provide two dimensional plots of the instantaneous isobars and vector plots of the instantaneous velocity vectors. These routines greatly enhance the presentation of the results. Work has also begun to modify the code to model the experimental facility currently in operation at the Naval Air Warfare Center, China Lake, CA.

Professor Y. Joshi continued his research in the areas of electronics cooling and fusion welding heat transfer and fluid flow continued. The three-dimensional code developed earlier was used to model existing natural convection liquid cooling measurements. Experimental activities included studies of power pulsations on natural convection. Also, the mixed/forced convection channel flow facility for studying the effects of flow pulsations was completed. On the fusion welding activity, the laser vision system recently installed in the Welding Laboratory has been used extensively to examine the flow patterns on the free surfaces of weld pools during Gas Tungsten Arc Welding of steels.

The research of Professor P.M. Ligrani focussed on several areas in the thermal/fluid sciences, including convective heat transfer topics related to high temperature engines like the gas turbine. One study pertained to compound angle film cooling, a method of cooling currently used to protect gas turbine surfaces from exposure to hot gases. The influences of embedded longitudinal vortices on film cooling were also examined. Other investigations examined transition from laminar to turbulent flow under the influence of imposed, bulk flow unsteadiness, and under the influence of centrifugal instabilities resulting from flow near a concave surface.

Materials Science

While on sabbatical leave, Professor J. Perkins continued his research on developing models which delineate the damping mechanisms in certain so-called "quiet metals". A unified mechanistic model has been developed, on the microscopic and sub-microscopic level, for the damping behavior of high damping alloys. Results to date indicate that damping in these alloys is always linked to phase transformations, which may be magnetic transitions, lattice-displacive transformations, and more particularly to boundaries which result from such transformations. In general, high damping mechanisms in quiet metal alloys area associated with the internal friction created near various types of boundaries. However, different alloys have different types of boundaries, and there are different atomistic mechanisms of damping, and therefore different controlling and operational parameters. For example, the domain boundaries in ferromagnetic alloys are quite different from the intervariant boundaries in martensitic alloys. On the other hand, the intervariant boundaries are quite similar in form and character to the inter-domain twin boundaries which separate the antiferromagnetic domains in quenched homogeneous FCT Cu-Mn-based alloys. Aged Cu-Mn alloys, however, present a completely different microstructural form, in which it has only recently been recognized that the "boundaries" are effectively very broad, with a gradual transition of structure. This latter case, in contrast to the distinct nature of martensitic intervariant boundaries, suggests a "boundaryless" mechanism, or at least a broad gradient of structure within which the internal friction mechanism operates.

In June, Professor T. McNelley presented an invited lecturer entitled "The Deformation Mechanisms of Low Temperature Superplasticity in Al-Mg Alloys" at the International Conference on Superplasticity in Advanced Materials held in Osaka, Japan. This lecture reviewed the extensive work at NPS on processing of Aluminum alloys of interest for advanced applications in Naval systems. Also, these studies on deformation processing were applied during the year to processing of metal-matrix composite (MMC) materials with a view to improving their ductility and toughness. Such MMC materials offer improved property combinations, reduced weight and enhanced performance for many military platforms.

During 1991, Professor A. Fox worked on three projects. These are as follows: (1) "A Combinative Method for the Accurate Structure Factors and Charge Densities of Intermetallic Alloys" which is sponsored by the Naval Air Development Center, Warminster, PA., through the directly funded research program at the Naval

Postgraduate School and is also in collaboration with the Department of Energy at the Lawrence Berkeley Laboratory, University of California, Berkeley; (2) "The Crystallographic and Chemical Characterization of Microstructures and Non-metallic Inclusions in HSLA Steels and their Weldments" which is sponsored by the David Taylor Research Center, Annapolis, MD., through reimbursable support and (3) "The Effect of Various Heat Treatments on the Microstructures and Mechanical Properties of A1-Li Aerospace alloys". This project has been sponsored by the NPS DFR program and by the Naval Air Systems Command. These projects resulted in two publications, five conference proceedings and six completed theses during 1991.

During FY91, Professor I. Dutta was involved in research in the areas of Composites and Ceramics with funding from the Naval Weapons Support Center, Crane and the Naval Surface Warfare Center, White Oak, as well as the Naval Postgraduate School (direct funds). Specific activities in Composite materials involve micro-mechanical modeling of discontinuous whisker composites, fatigue of continuous fiber composites and therm-mechanical properties of particulate composites. Activities in Ceramics constituted studies of sintering and properties of high thermal conductivity materials for electronic packaging. The work resulted in 5 Master's theses and two conference presentations during FY91. Additionally, 5 journal papers based on past and continuing work appeared in print during calendar years 1991.

JP-5 THERMAL BREAKDOWN IN T56-A-427 ENGINE FUEL NOZZLES

R. Crooks, Adjunct Professor of Mechanical Engineering
Sponsor: Naval Air Test Center, Patuxent River, MD

OBJECTIVE: The goal of this study was to characterize the coking, or thermal breakdown of JP-5 fuel which occurs at temperatures above 300#F. This project was initiated in FY91 and is to be continued in FY92.

SUMMARY: Operational effectiveness of the T56-A427 engine used in the E2-C+ has been adversely affected by coking of JP-5 in fuel nozzles due to thermal soakback after shutdown. This study examined the kinetics of coke formation to determine the time and temperature limits for temperature control measures. This project began in the last quarter of FY91. Efforts in that period focussed on a literature review and design and evaluation of a reaction chamber based test facility. An experimental approach was devised which is similar to one previously performed under NAPC funding. In the test apparatus, samples of nozzle material were immersed in JP-5, which was then heated to the desired test temperature for periods of from one to four hours. Preliminary results showed an unexpectedly low deposit rate by this method, and modifications to the apparatus design were suggested for continuing work. These modifications included means of independently heating the substrate to develop a temperature gradient across the fuel/metal interface. This modification better simulates the conditions during thermal soakback, during which time nozzle heating is primarily external and radiant.

PUBLICATIONS: Crooks, R., Kalu, P.N. and McNelley, T.R., "Use of Backscattered Electron Imaging to Characterize Microstructures of a Superplastic A1-10Mg-0.1Zr Alloy," *Scripta Metallallurgica et Materialia*, 25:1321-1325, June 1991.

CONFERENCE PRESENTATION: Crooks, R., Kalu, P.N., and McNelley, T.R., "Microstructures of Superplastic Aluminum Alloys," presented at the TMS Annual Meeting, New Orleans, LA, 10 February 1991.

EFFECT OF REINFORCEMENTS ON THE MATRIX MICROSTRUCTURE OF DISCONTINUOUS METAL MATRIX COMPOSITES

I. Dutta, Assistant Professor of Mechanical Engineering

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To investigate the cause of accelerated aging in metal matrix composites and to determine the effect of matrix microstructure on the properties of MMCs from a mechanistic standpoint. In FY89-90, the work was based on 6061 Al-matrix MMCs. In FY91, 2014 Al-matrix MMCs were studied.

SUMMARY: The effect of reinforcements on the early stages of precipitation in composite matrices has been studied. Resistivity measurements and differential scanning calorimetry have been utilized to measure the thermodynamic and kinetic parameters influencing aging in the monolithic matrix alloy and the composite matrix. The importance of this project to the Navy and the scientific community lies in the fact that without a proper understanding of the aging behavior of MMCs, heat treatments to obtain the optimum combination of mechanical properties in these materials cannot be designed. Currently, trial and error techniques are being used to heat treat the MMCs to the peak aged condition. The knowledge gained from this work will facilitate the prediction of heat treatments and obviate the need for trial and error.

PUBLICATIONS: Dutta, I. and Allen, S.M., "A Calorimetric Study of Precipitation in Commercial Aluminum Alloy 6061," *Journal Material Science Letters*, 10:323, 1991.

Dutta, I., Allen, S.M. and Hafley, J.L., "Effect of Alumina Particulate Addition on Precipitation in 6061 Aluminum-Matrix Composites," *Metallurgica Transactions A*, 22A:2553, 1991.

CONFERENCE PRESENTATIONS: Dutta, I., Allen, S.M., and Hafley, J.L., "Effect of Reinforcement on the Early Stages of Precipitation in Cast 6061A1-$A1_20_3$ Particulate Composites," presented in the 118th Annual Meeting of TMS-AIME, Anaheim, CA, February 1991.

THESES DIRECTED: Allen, S.M., "Effect of Alumina Particle Addition on the Aging Kinetics of 6061 Aluminum Matrix Composites," MS Thesis, June 1990.

Harper, C., "Effect of Alumina Particle Additions on the Aging Kinetics of 2014 Aluminum Matrix Composites," MS Thesis, September 1991.

EFFECT OF THERMAL RESIDUAL STRESSES ON THE MECHANICAL PROPERTIES OF DISCONTINUOUS METAL MATRIX COMPOSITES

I. Dutta, Assistant Professor of Mechanical Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: (1) To find the effects of residual stresses on composite properties and; (2) to characterize the corrosion behavior of continuous fiber composites in aqueous environments. The first part of the project is still in progress.

SUMMARY: In this project, the effect of thermal residual stresses on composite flow stress is being studied via Finite Element Modeling. Metal Matrix Composites are being considered for use in various components for naval sea and air systems and a fundamental understanding of the role of thermal residual stresses (which are always present in MMCs) in determining composite properties is essential for proper design and selection of materials. The results obtained indicate that residual stresses affect the contribution of load transfer to composite strengthening. The effects of fiber volume fraction, fiber aspect ratio and reinforcement distribution on the composite properties have also been studied. The effect of residual stresses have been found to be significantly different in tensile and compressive loading. Continuing effort is underway to better understand the role of thermal stresses on localized flow and load transfer in composites.

PUBLICATIONS: Dutta, I., "The Nature and the Effect of Thermal Residual Stresses in Discontinuous Fiber Reinforced Metal Matrix Composites," *Comp. Sci. Tech.*, 41:193, 1991.

Dutta, I., Sims, J.D., and Seigenthaler, D.M., "An Analytical Study of Residual Stress Effects on Uniaxial Deformation of Whisker Reinforced Metal-Matrix Composites," submitted to *Acta Metallurgica et Materialia*.

CONFERENCE PRESENTATION: Dutta, I., "Residual Stresses and their Effect on Composite Strength," presented in the 1989 Fall Meeting of TMS-AIME, Indianapolis, Indiana, October 1989.

THESIS DIRECTED: Sims, J., "Effect of Thermal Residual Stresses on the Uniaxial Tensile Properties of Discontinuous Fiber Composites," MS Thesis, September 1990.

Seigenthaler, D.M., "Effect of Thermal Residual Stresses on the Stress-Strain Behavior of Metal-Matrix Composites," MS.Thesis, June 1991.

THERMAL AND MECHANICAL FATIGUE BEHAVIOR OF GRAPHITE FIBER REINFORCED ALUMINUM COMPOSITES

I. Dutta, Assistant Professor of Mechanical Engineering
Sponsor: Naval Weapons Support Center, Crane, IN
Funding: Naval Postgraduate School

OBJECTIVE: To characterize the thermal and mechanical fatigue behaviors of continuous graphite fiber reinforced aluminum composites.

SUMMARY: Initial work done on FY90 reimbursable funds showed that the composite shows significantly different response to both thermal and mechanical fatigue with respect to the unreinforced matrix material. Crack initiation and crack propagation studies are currently being conducted to identify the fatigue damage mechanisms of the composite with special emphasis on the residual stress state and the nature of the fiber-matix interfaces.

PUBLICATIONS: Mitra, S., Dutta, I., and Hansen, R.C., "Thermal Cycling Studies of a Cross-Plied P100 Graphite Fiber Reinforced 6061 Aluminum Composite Laminate," *Journal Material Science*, 26:6223, 1991.

Dutta, I., Mitra, S. and Hansen, R.C., "Flexural Fatigue Behavior of a Cast P100 Graphite Fiber Reinforced 6061 Aluminum Composite," *Scripta Metall.*, 25:1601, 1991.

CONFERENCE PRESENTATION: Mitra, S., Dutta, I., and Hansen, R.C., "Thermal Cycling Behavior of a P100 Graphite-6061 Aluminum Composite Laminates," presented at the 119th Annual Meeting of TMS-AIME, New Orleans, LA, February 1991.

THESES DIRECTED: Hansen, R.C., "Thermal and Mechanical Fatigue of P100 Gr-6061A1 Composite Laminates," MS Thesis, September 1990, Co-advisor: Prof. S. Mitra.

Baker, C.R., "Fatigue Behavior of Cross-Plied P100 Graphite - 6061 Aluminum Composite Laminates," MS Thesis, June 1991, Co-Advisor: Prof. S. Mitra.

CHARACTERIZATION OF ALUMINUM NITRIDE SUBSTRATES AND COPPER-ALUMINUM NITRIDE METALLIZATIONS FOR ELECTRONIC PACKAGING APPLICATIONS

I. Dutta, Assistant Professor of Mechanical Engineering
Sponsor: Naval Weapons Support Center, Crane, IN
Funding: Naval Weapons Support Center, Crane, IN

OBJECTIVE: To correlate the process-microstructure-property relationships of aluminum nitride substrates, and characterize Cu-AlN interfaces in metallized substrates.

SUMMARY: The sintering kinetics in liquid phase sintered aluminum nitride bulk pieces are being investigated to optimize processing parameters with respect to resultant microstructural changes. Thermal conductivity, which is a very important property of good substrate materials for electronic packaging, is being measured to investigate the effect of process variables on substrate properties. The effect of post-sintering cooling rate on the resulting microstructure, especially with respect to the nature of oxygen related defects, is being studied in detail using transmission electron microscopy (TEM). At a later stage, copper-AlN metallizations will also be studied in detail.

THESIS DIRECTED: Cooper, J., "Correlation of Processing and Properties of AlN Substrate Materials for Electronic Packaging," MS Thesis, December 1991.

CORROSION BEHAVIOR OF GRAPHITE-ALUMINUM COMPOSITES

I. Dutta, Assistant Professor of Mechanical Engineering
Sponsor: Naval Postgraduate School and NWSC, Crane (FY90)

OBJECTIVE: To characterize the corrosion behavior of continuous fiber composites in aqueous marine environments.

SUMMARY: NWSC, Crane is currently considering the possibility of using Gr-Al composites as electronic module frame materials, which are subjected to various marine environments. This project consists of two parts. The study constitutes an in-depth investigation of the corrosion behavior of Gr/Al MMCs in aqueous environments with special emphasis on the effects of pH, sulphite ion contamination from stack gases and heat treatment on the corrosion behavior of Gr-Al composites in aqueous salt solutions. In addition, the principal mechanism of corrosion of Gr/Al composites has been identified.

PUBLICATIONS: Dutta, I., Elkin, L.R., and King, J.D., "Corrosion Behavior of a P130x Graphite Fiber Reinforced 6063 Aluminum Composite Laminate in Aqueous Environments," *Journal of Electrochemical Society*, 138:3199, 1991.

CONFERENCE PRESENTATIONS: Dutta, I., Elkin, L.R. and King, J.D., "Corrosion Behavior of P130x-6063 Al Composite Laminates in Aqueous Environments," presented at the 119th Annual Meeting of TMS-AIME, New Orleans, LA, February 1991.

THESES DIRECTED: King, J.D., "Characterization of the Corrosion Behavior of a P130x Graphite-6063 Aluminum Metal Matrix Composite," MS Thesis, December 1989.

Elkin, L.R., "Corrosion Mechanisms and Behavior of Gr-Al Composites in Aqueous Environments," MS Thesis, September 1990.

PROCESSING-MICROSTRUCTURE CORRELATIONS IN CAST SiC PARTICULATE REINFORCED ALUMINUM MATRIX COMPOSITES

I. Dutta, Assistant Professor of Mechanical Engineering
Sponsor: Naval Surface Warfare Center, White Oak
Funding: Naval Surface Warfare Center, White Oak

OBJECTIVE: To correlate the process-microstructure-property relationships in centrifugally cast Al/Sic composites.

SUMMARY: This research project stemmed from the promise of the economically lucrative cast metal matrix composites. This project was aimed at studying the mechanical properties resulting from casting, and alleviating some of the problems associated with it via post fabrication thermo-mechanical treatments. The project was initiated in FY89 and was unfunded. In July 1991, funding on the project was obtained from NSWC, White Oak, to study the properties and microstructure of centrifugally cast composites in the as-cast, and cast and processed conditions.

PUBLICATIONS: Dutta, I., Tiedemann, C.F., and McNelley, T.R., "Effect of Hot Working on the Microstructure and Properties of a Cast 5083 Al-SiCp Metal-Matrix Composite," *Scripta Metallurgica*, 24:1233, 1990.

Dutta, I., Tiedemann, C.F., and McNelley, T.R., "Effect of Thermo-mechanical Processing on the Properties of a Cast 5083Al-SiC Metal Matrix Composite," NPS Technical Report NPS-69-90-001, November 1989.

THESES DIRECTED: Tiedemann, C.F., "Effects of Thermo-Mechanical Processing on the Properties of a Cast 5083 Al-SiC Metal Matrix Composite," MS Thesis, June 1989, co-advisor with Prof. T.R. McNelley.

May, C., "Correlation of Processing, Microstructure and Properties in Centrifugally Cast Al/SiC Composites," MS Thesis expected June 1992.

OBJECT RECOGNITION THROUGH REMOTE TELEOPERATION

Morris Driels, Professor of Mechanical Engineering
Sponsor: Naval Ocean Systems Center
Funding: Naval Postgraduate School

OBJECTIVE: The objectives of this project were to complete the acquisition and installation of the force reflecting telemanipulator in the laboratory, and then use it to investigate the basic structure of haptic sensing.

SUMMARY: A non-anthropomorphic, force reflecting telemanipulator was procured in FY91 and installed in a custom facility in the laboratory. This allowed a basic research program to be undertaken into the mechanics of haptic probing. This was started by means of a study which compared the exploratory procedures for haptic and visual search, and involved close collaboration with Dr. L. Stark of the Optometry School at UC Berkeley. This study concluded that there is strong a correlation between the fovea visual sense and the haptic sense, at least in terms of their use in exploring objects. Further work was started into developing a computer simulation model which reflects the influence of finite memory and identification errors on the ability of humans to correctly identify objects using the sense of touch.

PUBLICATIONS: Driels, M., Spain, H., and Aviles, W., "The Effect of Sensory Feedback on the Identification of Objects Using a Teleoperator," *International Journal of Robotics and Autonomous Systems*.

THESES DIRECTED: Wiegand, M., LCDR, USN, "Calibration of Telemanipulators Using Passive End-Point Motion Constraints," MS Thesis, June 1991.

Acosta, J., LT., Colombian Navy, "Modeling of Explorative Procedures for Remote Object Identification," MS Thesis, September 1991.

OTHER: Collaborative research project initiated with Professor L. Stark, University of California, Berkeley.

A COMBINATIVE METHOD FOR THE ACCURATE MEASUREMENT OF STRUCTURE FACTORS AND CHARGE DENSITIES OF INTERMETALLIC ALLOYS

A.G. Fox, Associate Professor of Mechanical Engineering,
Materials Science Group
Sponsor: Department of Energy and the
Naval Postgraduate School

OBJECTIVE: To accurately measure the low angle structure factors of intermetallic alloys by various diffraction methods so that their electronic bonding mechanisms can be investigated.

SUMMARY: A knowledge of the distribution of bonding electrons in solids can give important information about their physical properties. One way to gain such knowledge is to accurately measure the low-angle structure factors by some means, and then use these to generate maps of the electronic charge distributions. In the present work electron diffraction has been used to measure the low-angle structure factors of ßNiA1 and an electron charge distribution has been generated for this alloy and important bonding information has emerged. During 1991 work has commenced on the TiA1 system.

PUBLICATION: Fox, A.G. and Tabbernor, M.A., "The Bonding Charge Density of ßNiA1," *Acta Metallurgica et Materiala*, 39: 669, 1991.

CONFERENCE PRESENTATIONS: Fox, A.G. and Tabbernor, M.A., "Bonding and the Physical and Mechanical Properties of ßNiA1," presented at the Institute of Metals High Temperature Intermetallics Conference, The Royal Society, London, UK, April/May 1991.

Fox, A.G., "High Accuracy Electron Densities by Electronic Diffraction," an invited plenary talk presented at the Sagamore X Conference, Konstanz, Germany, September 1991.

THESIS DIRECTED: Cade, S.C., LT., USN, "An Investigation of the Interatomic Bonding Characteristics of a Ti-51 at.% A1 Alloy by X-ray Diffraction," MS Thesis, June 1991.

OTHER: Fox, A.G., "Accurate Charge Densities and Electron Diffraction," a seminar presented at Oak Ridge National Laboratory, TN, August 1991.

THE CRYSTALLOGRAPHIC AND CHEMICAL CHARACTERIZATION OF MICROSTRUCTURES AND NON-METALLIC INCLUSIONS IN HIGH-STRENGTH, LOW-ALLOY (HSLA) STEELS AND THEIR WELDMENTS

A.G. Fox, Associate Professor of Mechanical Engineering,
Materials Science Group
Sponsor: David Taylor Research Center (USN), Bethesda, MD.

OBJECTIVE: To investigate the microstructure and mechanical properties of HY and HSLA 80-130 series steels and their weldments to evaluate new weld consumables and parent steels for Naval shipbuilding applications.

SUMMARY: In recent years the U.S. Navy has been replacing the HY80-100 series of high strength alloy steels with their high-strength, low-alloy (HSLA) equivalents. This is being done because the stringent weld pre-heat requirements associated with the HY steels are not necessary for the HSLA series. So, despite the higher manufacturing costs of high-strength, low alloy steels, the U.S. Navy should make significant savings by changing over to HSLA or ultra low carbon bainitic (ULCB) steels for ship and submarine construction. This project aims to support these objectives with fundamental physical metallurgy studies at NPS. This project is proceeding extremely well with four Masters Theses completed in 1991, two publications submitted and two conference proceedings presented.

PUBLICATIONS: Haddock, J.T., Fox, A.G., Batham, J.K., and Jones, E.T.R., "A New Magnesium-Based Reagent for the Ladle Treatment of Steel, Part I, Theory and Laboratory Evaluation" submitted to *Metallurgical Transaction B*.

Hussain, I., Haddock, J.T., Fox, A.G., Batham, J.K. and Jones, E.T.R., "A New Magnesium Based Reagent for the Ladle Treatment of Steel, Part II Steelworks Evaluations," submitted to *Metallurgical Transactions B*.

CONFERENCE PRESENTATIONS: Fox, A.G., Haddock, J.T. and Batham, J.K., "A New Magnesium-based Reagent for the Ladle Treatment of Steel," presented at the International Conference on Processing, Microstructure and Properties of Microalloyed and Other Modern Low Alloy Steels, Pittsburgh, PA, June 1991.

Fox, A.G., Mattes, V.R., Mikalac, S. and Vassilaros, M.G., "Electron Microscope Studies of the Microstructures Present in As-quenched and Aged HSLA 100 Mechanical Properties," presented at the 49th Meeting of EMSA, San Jose, CA, August 1991.

THESES DIRECTED: Comerford, L.W., LT, USN, "A Study of the Microstructural Basis for the Strength and Toughness Properties of an Overaged HSLA 100 Steel," MS Thesis, March 1991.

Mohr, T.C., LT, USN, "A Study of the Microstructural Basis for the Strength and Toughness Properties of Water Quenched and Air-cooled HSLA 100, HSLA 100 with Increased Copper and a ULCB steel," MS Thesis, September 1991.

Winters, H.A., LT, USN, "A Study of the Microstructural Basis for the Strength and Toughness Properties of As-quenched and Tempered High Copper HSLA 100 Steel," MS Thesis, December 1991.

McHale, P.F., LT, USN, "Factors Influencing the Microstructure and Mechanical Properties of ULCB Steel Weldments," MS Thesis, December 1991.

THE PHASES AND MICROSTRUCTURES RESULTING FROM VARIOUS HEAT TREATMENTS ON Al-Li AEROSPACE ALLOYS

A.G. Fox, Associate Professor of Mechanical Engineering, Materials Science Group
T.R. McNelley, Professor of Mechanical Engineering,
Materials Science Group
Sponsor: Naval Postgraduate School and
the Naval Air Systems Command

OBJECTIVE: To fully understand the relationships between heat treatment, microstructure and mechanical properties for Al-Li base alloys so that their range of applications in the aerospace industry can be extended.

SUMMARY: The relationship between thermo-mechanical processing, microstructure and physical and mechanical properties is important for any alloy system. Despite the many proposed uses of low density, high stiffness Al-Li alloys, particularly in aerospace applications, many have not been released because the necessary properties have not been achieved. One of the major reasons for this is because the fundamental properties of these alloys is not properly understood. This work, initiated by Professors Fox, Thomas and Radmilovic when Professor Fox was at the Department of Energy, aims to clarify the basic physical properties of Al-Li base alloys so that more potential uses of these can be released. From 1989 to 1991, Professor Fox has interacted with Professor McNelley at NPS and this work has been extended to help with the understanding of the creep properties of Al-Li alloys.

PUBLICATIONS: Fox, A.G., Fuller, S.C., Whitman, C.E. and Radmilovic, V., "A Powder X-Ray Diffraction Study of a Solution Treated and Ice-Brine-Quenched Al-14.25 at .% Li Alloy," *Journal of Materials Research*, 6:712, 1991.

Ellison, K.G., McNelley, T.R., and Fox, A.G., "Creep Behavior of an Al-2.0 Wt. Pct. Alloy in the Temperature Range 300-500 C," submitted to *Metallurgical Transactions B.*

CONFERENCE PRESENTATIONS: Fox, A.G., and Radmilovic, V., "X-Ray Diffraction Studies of As-Quenched Al-Li Alloys," presented at The Metallurgical Society Annual Meeting, New Orleans, LA, February 1991.

THESIS DIRECTED: Wang, T.K., Major, Taiwan Army, "A Powder X-Ray Diffraction Study of the Al-Li Alloy Navalite," MS Thesis, January 1991.

CONVECTIVE COOLING OF ELECTRONIC EQUIPMENT: EXPERIMENTS AND COMPUTATIONS

Yogendra Joshi, Associate Professor of Mechanical Engineering
Matthew D. Kelleher, Professor of Mechanical Engineering
Beny Neta, Associate Professor of Mathematics
Sponsor: Naval Weapons Support Center and
the Naval Postgraduate School

OBJECTIVE: Investigation of convective flow and heat transfer characteristics of simulated and actual electronic components.

SUMMARY: The combined conduction and convection processes associated with liquid cooling of electronic devices were examined experimentally and computationally. Experimental natural convection studies of flush heat sources in liquid filled vertical channels and enclosures continued. Additional experiments were initiated to study boiling from simulated electronic components in dielectric liquids. The general purpose code ELLPACK was used to model three-dimensional heat conduction in rectangular systems.

PUBLICATIONS: Joshi, Y. and Paje, R.A., "Natural Convection Cooling of a Ceramic Substrate Mounted Leadless Chip Carrier in Dielectric Liquids," *International Communications in Heat and Mass Transfer*, 18:39-47, 1991.

CONFERENCE PRESENTATIONS: Sathe, S.B. and Joshi, Y., "Natural Convection Liquid Cooling of a Substrate-Mounted Protrusion in a Square Enclosure: Effects of Thermophysical Properties, Geometric Dimensions and Boundary Conditions," ASME Winter Annual Meeting, Dallas, TX, 25-30 November 1990.

Joshi, Y., Kelleher, M.D., Torres, E. and Powell, M., "Natural Convection From an Array of Protruding Heat Sources in an Enclosure Filled with Dielectric Liquid," ASME Winter Annual Meeting, Atlanta, Georgia, 1-6 December 1991.

THESIS DIRECTED: Eren, A.S., LTJG, TN, "Heat Transfer Enhancement Due to Bubble Pumping in FC-72 Near the Saturation Temperature," MS Thesis, March 1991.

Aytar, E., LTJG, TN, "Natural Convection Immersion Cooling of an Array of Heated Protrusions in an Enclosure Filled with Dielectric Liquid: Effects of Enclosure Width and Fluid Pandtl Number," MS Thesis, March 1991.

van Joolen, V.J., LT, USN, "Calculations of Chip Temperatures using ELLPACK," MS Thesis, June 1991.

Larsen, S., LT, USN, "Effects of Power Pulsations on Natural Convection from Discrete Heat Sources," MS Thesis, December 1991.

Mathews, S.T., LT, USN, "Natural Convection Immersion Cooling of an Array of Vertically Oriented Heated Protrusions in an Enclosure Filled with a Dielectric Liquid: Effects of Enclosure Width, Pandtl Number and Component Orientation," MS Thesis, December 1991.

Egger, R.A., LT, USN, "Enhancement of Boiling Heat Transfer in Dielectric Liquids," MS Thesis, September 1991.

COMPUTER AIDED ANALYSIS OF ELECTRONIC EQUIPMENT COOLING

Yogendra Joshi, Associate Professor of Mechanical Engineering
Matthew D. Kelleher, Professor of Mechanical Engineering
Sponsor: Naval Weapons Support Center, Crane, Indiana

OBJECTIVE: Computational modeling of electronic equipment cooling.

SUMMARY: Two-dimensional computations were carried out to model prior natural convection experimental studies on isolated components. The three-dimensional code developed for the analysis of steady heat transfer and fluid flow problems in rectangular systems during FY90 was used to study two configurations. The first involved the modeling of a chip carrier during liquid immersion cooling. The second study simulated the natural convection transport from a three-by-three array of heated protrusions. The steady 3-D code was enhanced to allow the investigation of unsteady problems.

PUBLICATIONS: Joshi, Y. and Knight, D.L., "Natural Convection from a Column of Flush Heat Sources in a Vertical Channel in Water," *Journal of Electronic Packaging, Transactions of ASME*, pp. 367-374, December 1990.

Sathe, S.B. and Joshi, Y., "Natural Convection Arising from a Heat Generating Substrate-Mounted Protrusion in a Liquid-Filled Two-Dimensional Enclosure," *International Journal of Heat and Mass Transfer*, 34:2149-2163, 1991.

Sathe, S.B., and Joshi, Y., "Natural Convection Cooling of a Substrate-Mounted Protrusion in a Square Enclosure: A Parametric Study," *Journal of Heat Transfer*, forthcoming.

CONFERENCE PRESENTATIONS: Mukutmoni, D., Kelleher, M.D. and Joshi, Y., "Computations of Liquid Immersion Cooling for a Three by Three Array of Chips in a Rectangular Enclosure," forthcoming.

Wroblewski, D. and Joshi, Y., "Transient Natural Convection From a Leadless Chip Carrier in a Liquid Filled Enclosure: A Numerical Study," forthcoming.

THESES DIRECTED: Carling IV, L.J., LT, USN, "Effects of Flow Pulsations on Heat Transfer from a Discrete Heat Source in a Liquid Filled Parallel Plate Channel," MS Thesis, December 1990.

Akdeniz, E.M., LTJG, TN, "Effects of Power Pulsations on Heat Transfer from Discrete Heat Sources," MS Thesis, March 1991.

OTHER: Two additional studies on the three-dimensional computations are currently in review for publication.

COMPUTATIONS AND EXPERIMENTS ON HEAT TRANSFER AND FLUID DYNAMICS OF FUSION WELDING

Yogendra Joshi, Associate Professor of Mechanical Engineering
Sponsor: David Taylor Research Center and the
Naval Postgraduate School

OBJECTIVE: Investigation of applications of heat transfer and fluid flow in the automation of fusion welding processes.

SUMMARY: Heat transfer and fluid flow patterns during fusion welding are known to be modified by various anomalies during the process. These need to be detected and corrected systematically in an automated arrangement. This study aimed to characterize these defects through measurements and models of surface temperatures and weld-pool geometry. During the reporting period, an experimental setup was constructed for the determination of welding efficiencies. Measurements of surface temperatures using thermocouples were made to detect the presence of sub-surface impurities. The laser vision system was installed and tested.

THESIS DIRECTED: Espinosa, D.C., LT, USN, "Visualization of Gas Tungsten arc Weldpools," MS Thesis, September 1991.

OTHER: The experimental results obtained with the laser vision system are in preparation for publication.

HEAT TRANSFER AND FLUID FLOW IN FUSION WELDING

Yogendra Joshi, Associate Professor of Mechanical Engineering
Sponsor: Naval Science Foundation, Washington, D.C.

OBJECTIVE: To study the heat transfer and fluid flow associated with fusion welding processes.

SUMMARY: The research report here was started during FY 1988. It involves computational modeling and accompanying experimental investigations of heat transfer and fluid flow processes during fusion welding. During the past year, a three-dimensional computational model of heat transfer in fusion welding was developed. In high welding current applications, fluid flow within the fusion zone may significantly alter the weld pool shape and cooling rates compared to a pure diffusion situation. A two-dimensional model was developed to study these effects. The model uses an enthalpy formulation of the energy equation and solves the governing equations in the primitive variables form. Results of this model will be compared with the conduction model and the laser vision system measurements.

PUBLICATIONS: Ule, R.L., Joshi, Y., and Sedy, E.B., "A New Technique for Three-Dimensional Transient Heat Transfer Computations of Autogenous Arc Welding," *Metallurgical Transactions B*, December 1990.

OTHER: The computational results to date are currently in preparation for publication.

FIELD MODELING OF FIRE AND SMOKE SPREAD IN CONFINED SPACES

Matthew D. Kelleher, Professor of Mechanical Engineering
K.T. Yang, Professor of Engineering, University of Notre Dame,
Notre Dame, Indiana
Viola D. Hank, Professor of Engineering, University of Notre Dame,
Notre Dame, Indiana
Sponsor: Naval Research Laboratory

OBJECTIVE: Develop a finite difference numerical model for the realistic determination of the time dependent fire and smoke spread in confined spaces. Develop graphics postprocessing routines, both color and monochrome, to provide effective presentation of results. The computer code is to be used to simulate various fire scenarios in submarines and surface ships for fire safety and design considerations.

SUMMARY: A finite difference model to simulate the spread of fire and smoke in the FIRE-I research chamber at the Naval Research Laboratory has been developed. The present version of the model uses a system of general orthogonal coordinates so that the specification of the geometry is not a major constraint. The model is also capable of including the presence of solid objects or obstruction, such as machinery components, within the enclosure. The effects of surface radiation as well as volumetric gaseous radiation have also been included. The model can also accommodate the presence of forced ventilation within the space so that the presence of fans or ventilation ducts can be included. Algorithms are being developed to incorporate combustion processes in the model. Graphics post-processing capabilities have been developed which provide color representations of the isotherms at any instant in the fire. Routines have also been developed which provide two dimensional plots of the instantaneous isobars and vector plots of the instantaneous velocity vectors. These routines greatly enhance the presentation of the results. Work has also begun to modify the code to model the experimental facility currently in operation at the Naval Air Warfare Center, China Lake, CA.

THESIS DIRECTED: McCarthly, Timothy G., LT, "Numerical Field Model Simulation of Full-Scale Fire Tests in a Closed Spherical/Cylindrical Vessel Using Advanced Graphics Techniques," MS in Mechanical Engineering, September 1991.

FRACTURE ANALYSIS IN METAL-MATRIX COMPOSITES

Y.W. Kwon, Assistant Professor of Mechanical Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to develop a nonlinear analysis model for fiber-reinforced composites and to investigate the crack tip fields of metal-matrix composites at the micromechanical level.

SUMMARY: A new analysis model was developed to bridge the gap between the micromechanical analysis model and the macromechanical analysis model for both two- and three- dimensional structures including plates and shells. The model can analyze not only macroscale cracks but also microscale cracks. An interaction between a macroscale crack and microscale cracks such as matrix cracks and broken fibers was studied. The result showed that the effect of microscale cracks on the macroscale cracks on the macroscale crack tip was significant. Its magnitude was dependant on material properties of the constituents. Crack closure in plate bending was also investigated. Crack closure at the compression side of a crack increased the crack opening displacement at the tension side of a composite plate which had a high shear flexibility.

PUBLICATIONS: Kwon, Y.W., "Elasto-Viscoplastic Analysis of Fiber-Reinforced Composites," *Engineering Computations*, 8(3):273-284, 1991.

Kwon, Y.W., "Material Nonlinear Analysis of Composite Plate Bending Using a New Finite Element Formulation," *Computers and Structures*, 41(5):1111-1117, 1991.

Kwon, Y.W., "Thermo-Elastoviscoplastic Finite Element Plate Bending Analysis of Composites," *Engineering Computations*, forthcoming.

Kwon, Y.W., "Finite Element Analysis of Thermoelastoplastic Stresses in Composites," *European Journal of Mechanical Engineering*, forthcoming.

Kwon, Y.W., "Analysis of Crack Closure in Unidirectional Composite Plates Subject to Bending Loads," *Engineering Fracture Mechanics*, forthcoming.

CONFERENCE PRESENTATIONS: Kwon, Y.W., "Elastoviscoplastic Analysis of Plate Bending of Composites," ASME Pressure Vessels and Piping Conference, PVP-Vol. 218, pp. 141-145, San Diego, CA, June 1991.

Kwon, Y.W., "Material Nonlinear Analysis of Composites," in proceedings of the 13th Canadian Congress of Applied Mechanics, pp. 630-631, Winnipeg, Manitoba, Canada, June 1991.

Kwon, Y.W., "Analysis of Composite Plates Containing Cracks," Recent Advances in Structural Mechanics 1991, PVP-Vol. 225/NE-Vol. 7, ASME Winter Annual Meeting, pp. 33-40, Atlanta, Georgia, December 1991.

OTHER: One paper has been accepted for presentation and publication at a conference, and two papers have been submitted for publication in refereed journals. Two students have been working on this project as their thesis topic.

EFFECTS OF EMBEDDED LONGITUDINAL VORTICES ON BOUNDARY LAYERS FILM-COOLED USING COMPOUND ANGLE INJECTION HOLES

P.M. Ligrani, Associate Professor of Mechanical Engineering
Sponsor: Aero-Propulsion Laboratory, Wright-Patterson AFB, Ohio
Funding: Aero-Propulsion Laboratory, Wright-Patterson AFB, Ohio

OBJECTIVE: To investigate the effects of film injection from holes with compound angle orientations, as compared to injection from holes with simple angle orientations. Also investigated are the effects of embedded longitudinal vortices on heat transfer and injectant distributions downstream of single and double rows of holes with compound angle configurations. Injection from compound angle holes is used for end-wall and blade surfaces in the first stages of gas turbine engines in state-of-the-art high-temperature engines.

SUMMARY: Film cooling is currently used as a heat sink and as thermal barrier to protect gas turbine surfaces from exposure to hot gases. The present study investigates the effects of film injection from holes with compound angle orientations, as compared to injection from holes with simple angle orientations. The comparisons are made based on measured surveys of injectant distributions and all three components of mean velocity. Also measured are surface distributions of heat transfer coefficients, as well as the adiabatic film cooling effectiveness determined using the technique of linear superposition.

Intense secondary flows, such as embedded longitudinal vortices, disturb the injectant as well as the protection nominally provided by the injectant. In the present study, investigated are the effects of single embedded longitudinal vortices on heat transfer and injectant in a turbulent boundary layer downstream of one and two rows of film-cooling holes with compound angle orientations. Attention is focussed on the changes which result as vortex size, vortex position with respect to injection holes, and vortex circulation magnitudes are varied. Mean temperature results are to be obtained which show how injectant is distorted and redistributed by vortices, along with heat transfer measurements and mean velocity surveys. To quantify the influences of the vortices on the injectant and local heat transfer, the parameter defined as the ratio of vortex circulation to vortex core diameter times mean injection velocity is used. Except for special circumstances, the vortices reduce the protection provided by the film injection.

PUBLICATIONS: Ligrani, P.M., Ciriello, S. and Bishop, D.T., "Heat Transfer, Adiabatic Effectiveness and Injectant Distributions Downstream of a Single Row and Two Staggered Rows of Compound Angle Film-Cooling Holes," *ASME Transactions-Journal of Turbomachinery*, forthcoming.

Ligrani, P.M. and Mitchell, S.W., "Interactions Between Embedded Vortices and Injectant From Film Cooling Holes with Compound Angle Orientations in a Turbulent Boundary Layer," *ASME Transactions-Journal of Turbomachinery*, forthcoming.

Ligrani, P.M. and Mitchell, S.W., "Interactions Between Embedded Vortices and Injectant From a Single Row of Film Cooling Holes with Compound Angle Orientations in a Turbulent Boundary Layer," in preparation for *ASME Transactions-Journal of Turbomachinery*, 1992.

CONFERENCE PRESENTATION: Ligrani, P.M., Ciriello, S. and Bishop, T., "Heat Transfer, Adiabatic Effectiveness and Injectant Distributions Downstream of a Single Row and Two Staggered Rows of Compound Angle Film-Cooling Holes," HTD-Vol. 188, Heat Transfer in Gas Turbine Engines, ASME 1991, pp. 37-51, ASME Winter Annual Meeting, Atlanta, Georgia, 1-6 December 1991.

THESES DIRECTED: Mitchell, S.W., LT, USN, "The Effects of Embedded Vortices on Heat Transfer in a Turbulent Boundary Layer with Film Cooling from Holes with Compound Angles," MS Thesis, September 1990.

Bishop, D.T., LT, USN, "Heat Transfer, Adiabatic

Effectiveness and Injectant Distributions Downstream of Single and Double Rows of Film-Cooling Holes with Compound Angles," MS Thesis, September 1990.

Ciriello, S., LT, USN, "Study of the Adiabatic Film Cooling Effectiveness Downstream of One Row and Two Rows of Radially Oriented and Compound Angle Film-Cooling Holes," MS Thesis, March 1991.

STUDY OF FILM COOLING FROM COMPOUND ANGLE INJECTION HOLES AND COMPARISON TO RESULTS FROM SIMPLE ANGLE HOLES

P.M. Ligrani, Associate Professor of Mechanical Engineering
Sponsor: Naval Sea Systems Command, Washington, DC
Funding: Naval Sea Systems Command, Washington, DC

OBJECTIVE: To investigate the effects of film injection from holes with compound angle orientations, as compared to injection from holes with simple angle orientations. Injection from compound angle holes is used for end-wall and blade surfaces in the first stages of gas turbine engines in state-of-the-art high-temperature engines.

SUMMARY: Film cooling is currently used as a heat sink and as a thermal barrier to protect gas turbine surfaces from exposure to hot gases. The present study investigates the effects of film injection from holes with compound angle orientations, as compared to injection from holes with simple angle orientations. The comparisons are made based on measured surveys of injectant distributions and all three components of mean velocity. Also measured are surface distributions of heat transfer coefficients, as well as the adiabatic film cooling effectiveness determined using the technique of linear superposition.

PUBLICATION: Ligrani, P.M., Wigle, J.M., Jackson, S.M. and Ciriello, S., "Effects of Spanwise Hole Spacing on Effectiveness and Heat Transfer Downstream of Film Cooling Holes with Compound Angle Orientations," in preparation for *ASME Transactions-Journal of Heat Transfer*, 1992.

THESES DIRECTED: Wigle, J.M., LT, USN, "Heat Transfer, Adiabatic Effectiveness and Injectant Distributions Downstream of Single and Double Rows of Film-Cooling Holes with Compound Angles," MS Thesis, December 1991.

Jackson, S.M., LT, USN, "Heat Transfer, Adiabatic Effectiveness and Injectant Distributions Downstream of Single Rows and Two Staggered Rows of Film-Cooling Holes with Simple and Compound Angles, MS Thesis, December 1991.

STUDY OF THE EFFECTS OF CENTRIFUGAL INSTABILITIES ON TRANSITION FROM LAMINAR TO TURBULENT FLOW IN CURVED CHANNELS FOR DEAN NUMBERS FROM 160 TO FULLY TURBULENT CONDITIONS

P.M. Ligrani, Associate Professor of Mechanical Engineering
Sponsor: Propulsion Directorate, U.S. Army Aviation Research and
Funding: Propulsion Directorate, U.S. Army Aviation Research and Technology Activity-AVSCOM, NASA-Lewis Research Center, Cleveland, OH

OBJECTIVE: To study of the effects of centrifugal instabilities on transition from laminar to turbulent conditions. Of particular interest is the development of Dean vortices and their influences on heat transfer and the later stages of transition.

SUMMARY: The structure and development of flow in a curved rectangular channel with 40 to 1 aspect ratio is studied. Results are obtained for Dean numbers ranging from 160 to values where fully turbulent flow is present. Of interest are the effects of centrifugal instabilities on: (1) convective heat transfer processes, and (2) the later stages of transition from laminar to turbulent flow. The experimental data are also intended to be used for comparison with and development of computational and simulation models of curved channel flows. In order to understand flow characteristics, high-speed movies and still photographs are to be made of the flow when it is visualized using smoke. Measurements are also to be made of wall heat transfer, mean velocity components, mean vorticity components, and spectra of voltage signals from ordinary sized as well as subminiature sized hot-wire probes.

PUBLICATIONS: Ligrani, P.M., Finlay, W.H., Fields, W.A., Fuqua, S.J. and Subramanian, C.S., "Features of Wavy Vortices in a Curved Channel from Experimental and Numerical Studies," *Physics of Fluids A*, forthcoming.

Subramanian, C.S., Ligrani, P.M. and Tuzzolo, M.F., "Surface Heat Transfer and Flow Properties of Vortex Arrays Induced Artificially and From Centrifugal Instabilities," *International Journal of Heat and Fluid Flow*, forthcoming.

Ligrani, P.M., "Transient, Oscillatory and Steady Characteristics of Dean Vortex Pairs in a Curved Rectangular Channel," Ordered and Turbulent Patterns in Taylor-Couette Flow (editor: C. David Andereck) NATO ASI Series Volume, 1992.

Ligrani, P.M., Longest, J.E., Fields, W.A., Kendall, M.R., Fuqua, S.J. and Baun, L.R., "Initial Development and Structure of Dean Vortex Pairs in a Curved Rectangular Channel Including Splitting, Merging and Spanwise Wavenumber Selection," submitted to *Physics of Fluids A*, forthcoming.

CONFERENCE PRESENTATIONS: Ligrani, P.M., Baun, L.R., Longest, J.M. and Fields, W.A., "Development and Structure of Dean Vortices in a Curved Rectangular Channel with 40 to 1 Aspect Ratio for Dean Numbers Less Than 200," EUROMECH 261, First Symposium on Goertler Vortex Flows, University of Nantex, France, 10-12 June 1990.

Ligrani, P.M. and Longest, J.E., "Appearance, Disappearance and Spanwise Wavenumber Selection of Dean Vortex Pairs in a Curved Rectangular Channel," Paper CK1, American Physical Society, Division of Fluid Dynamics, 43rd Annual Meeting, Cornell University, Ithaca, NY, 18-20 November 1991.

Ligrani, P.M., "Transient, Oscillatory and Steady Characteristics of Dean Vortex Pairs in a Curved Rectangular Channel," 7th Taylor-Couette Workshop: Ordered and Turbulent Patterns in Taylor-Couette Flow, NATO Advanced Research Workshop, Ohio State University, Columbus, OH, 22-24 May 1991.

THESES DIRECTED: Hughes, R.E., LT, USN, "Development, Qualification and Measurements in Two Curved Channels with 40 to 1 Aspect Ratio," MS Thesis, September 1989.

Skogerboe, P.E., LT, USN, "Local and Spatially Averaged Heat Transfer Distributions in a Curved Channel with 40 to 1 Aspect Ratio for Dean Numbers from 50 to 200," MS Thesis, March 1990.

Fields, W.A., LT, USN, "Study of the Effects of Centrifugal Instabilities on Flow in a 40 to 1 Aspect Ratio Rectangular Curved Channel for Dean Numbers from 35 to Fully Turbulent Conditions," ME Thesis, December 1990.

Kendall, LT, USN, "Effects of Centrifugal Instabilities on Fluid and Heat Transfer Phenomena in Curved Rectangular Channels with 40 to 1 Aspect Ratios for Dean Numbers from 200 to 450," ME Thesis, June 1991.

Fuqua, S.J., LT, USN, "Study of the Transition to Turbulence Within a Curved Rectangular Channel with 40 to 1 Aspect Ratio," MS Thesis, September 1991.

Payne, B.W., LT, USN, "A Study of Spatially-Averaged Nusselt Number Distributions in a Curved Channel with 40 to 1 Aspect Ratio for Dean Numbers from 175 to 375," MS Thesis, September 1991.

EFFECTS OF UNSTEADINESS ON LAMINAR-TURBULENT TRANSITION IN STRAIGHT CHANNEL FLOW

P.M. Ligrani, Associate Professor of Mechanical Engineering
Sponsor: Office of Naval Research, Arlington, VA.
Funding: Naval Postgraduate School

OBJECTIVE: To investigate the influences of imposed, bulk flow unsteadiness on transition in a straight channel with large aspect ratio. Of particular interest are the interactions between the imposed unsteadiness and transition flow phenomena and, during these interactions, whether certain frequencies and amplitudes of unsteadiness stabilize or de-stabilize transition events.

SUMMARY: Results from this study elucidate fundamental mechanisms operative dur ag the laminar/turbulent transition process as it is affected by imposed bulk flow unsteadiness. Information is obtained on: (1) parameters governing the unsteady flow, (2) events occurring during the onset and development of transition, (3) interactions between the imposed bulk flow unsteadiness and transition phenomena, and (4) how heat transfer in the transitioning flow is affected by the imposed bulk flow unsteadiness. Results for Reynolds numbers from 1400 to 8400 and Strouhal numbers Str from 0.004 to 0.050 show different subcritical transition events including two- and three-dimensional Tollmien-Schlichting waves, vortex-array type motions evidenced by smoke swirls (normal/span planes) and ribbon-like patterns (stream/span planes), turbulent spots, and fully turbulent flow. With high inlet disturbance levels, longitudinal fluctuating intensities near the edge of the Stokes layer are reduced by imposed unsteadiness at 1 Hz for $2000 < Re < 2400$ or $0.032 > Str > 0.028$. At 2 Hz, this occurs for $2200 < Re < 2400$ or $0.059 > Str > 0.054$. Within the range of Str so far considered (and with high inlet disturbance levels), transition events appear at lower Reynolds number and persist over a wider range of Reynolds number compared to flows with no unsteadiness.

PUBLICATIONS: Ligrani, P.M., Subramanian, C.S., Coumes, T.M., Greco, F.J., Koth, H., and Longest, J.M., "Study of the Imposition of Bulk Flow Pulsations on Plane Channel Flow at Moderate Stokes Numbers", Experimental Thermal and Fluid Science, forthcoming.

Ligrani, P.M., Subramanian, C.S., Smith, B.J. and Morrow, D.S., "Transition from Laminar to Turbulent Flow in a Straight Channel With and Without Imposed Pulsations," in preparation for Physics of Fluids A, 1992.

CONFERENCE PRESENTATIONS: Subramanian, C.S., Ligrani, P.M. and Koth, H.E., "Experimental Observation of the Center Mode of Instability During Laminar/Turbulent Transition in Plane Poiseuille Flow," Paper CK4, American Physical Society, Division of Fluid Dynamics, 43rd Annual Meeting, Cornell University, Ithaca, NY, 18-20 November 1990.

Ligrani, P.M., Subramanian, C.S., Morrow, D.S. and Smith, B.J., "Experimental Observations of Laminar/Turbulent Transition in Plane Poiseuille Flow," Paper B15, American Physical Society, Division of Fluid Dynamics, 43rd Annual Meeting, Arizona State University, Scottsdale, AZ, 24-26 November 1991.

THESES DIRECTED: Koth, H.E., LT, USN, "Effects of Imposed Bulk Flow Oscillations at 1,2,3 and 4 Hz on Transition in a Straight Channel with 40 to 1 Aspect Ratio," MS Thesis, June 1990.

Morrow, D.S., LT, USN, "Effects of High Amplitude Imposed Oscillations on Laminar/Turbulent Transition in a Straight Channel at Imposed Frequencies Less Than 2 Hertz," MS Thesis, March 1991.

Smith, B.J., LT, USN, "Effects of High Amplitude Imposed Oscillations on Laminar/Turbulent Transition in a Straight Channel at Imposed Frequencies Greater Than 2 Hertz," MS Thesis, March 1991.

TURBULENCE STRUCTURAL CHARACTERISTICS OF FILM COOLING JETS WITH AND WITHOUT INTERACTIONS WITH EMBEDDED LONGITUDINAL VORTICES IN TURBULENT BOUNDARY LAYERS

P.M. Ligrani, Associate Professor of Mechanical Engineering
C.S. Subramanian, Adjunct Research Professor of Mechanical Engineering
Sponsor: Office of Naval Research, Arlington, VA.
Funding: Naval Postgraduate School

OBJECTIVE: To survey and study the Reynolds stress tensor components and turbulent transport triple products resulting from the presence of film cooling injection in turbulent boundary layers both with and without interactions with embedded longitudinal vortices.

SUMMARY: The vortex is produced in a zero-pressure gradient turbulent boundary layer using delta wing on the wind tunnel floor at a location 63 injection hole diameters upstream of the injection site. The single, circular wall jet is inclined at 30 degrees to the horizontal. Vortex circulation is 0.085 m2/x 41.9 diameters downstream of injection holes. With the jet opposing the vortex downwash and the blowing ration increasing from 0 to 4.8, maximum streamwise vorticity decreases from 750 to 150 s-1, while circulation decreases from 0.148 to 0.05 m2//s. For a 1.5 blowing ratio, the six Reynolds stress components and associated triple products are altered significantly in the embedded vortex because of the presence of the wall jet. Because of the jet, the longitudinal and spanwise normal Reynold stress components are increased in the vortex upwash. Changes due to the jet are smaller in the vortex core and downwash region. Reynolds shear stress components indicate regions of negative production near the vortex core which are more intense with a blowing ratio of 1.5 than with zero injection. This situation also gives stress gradients which are severely distorted by the jet beneath the vortex core.

CONFERENCE PRESENTATION: Subramanian, C.S., Ligrani, P.M., Green, J.G. and Doner, W.D., "Development and Structure of a Film-Cooling Jet in a Turbulent Boundary Layer with Heat Transfer," 3rd International Symposium on Transport Phenomena and Dynamics of Rotating Machinery (ISROMAC-3), Vol. 1: Transport Phenomena, pp. 49-64, Honolulu, HI, 1-4 April 1990.

EVALUATION OF REFRIGERATION TECHNIQUES FOR NAVAL APPLICATIONS

P.J. Marto, Distinguished Professor of Mechanical Engineering
S.B. Memory, Adjunct Professor of Mechanical Engineering
Sponsor: David Taylor Research Center
Funding: David Taylor Research Center

OBJECTIVE: The goal of this project is to provide a critique of the various options open to the Navy for future shipboard refrigeration needs, including the use of alternative refrigerants in vapor compression systems and newly-proposed refrigeration schemes that operate on non-vapor compression principles.

SUMMARY: A comprehensive literature search was performed with particular emphasis on pool boiling from enhanced surfaces, EHD enhancement of boiling and condensing hot transfer and thermo-acoustic refrigeration. The usefulness and practicality of each of these techniques for naval applications were evaluated. With regard to EHD and thermoacoustic refrigeration, the feasibility of shipboard use and the difficulties that might have to be overcome before successful operation were studied. While these alternatives have promise, significant research and development is still required before they could be put into practice. A Public Works design study to modify the two-phase heat transfer laboratory to accommodate alternative, environmentally-safe refrigerants was completed and modifications to the laboratory space to improve ventilation and to maintain air quality will be made in FY92.

PUBLICATION: Memory, S.B., "An Evaluation of Alternative Refrigeration Systems for Naval applications," NPS Technical Report NPS-ME-91-005, December 1991.

STEAM CONDENSATION HEAT TRANSFER ENHANCEMENT IN NAVAL CONDENSERS

P.J. Marto, Distinguished Professor of Mechanical Engineering
S.B. Memory, Adjunct Professor of Mechanical Engineering
Sponsor: David Taylor Research Center
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to determine the best steam condensation heat transfer coefficients that are achievable when using finned condensor tubes by conducting a systematic set of experiments at both atmospheric and vacuum conditions.

SUMMARY: Because of observed differences in some of the previously obtained steam condensation data, a significant effort has been made to determine the cause of these variations. It is believed that the differences in the data may be due to the method of processing the measured data to obtain the steam-side heat transfer coefficient. Consequently, emphasis during FY91 was placed on determining the coolant-side heat transfer coefficient. Previously-obtained data were evaluated for the best coolant-side heat transfer coefficient.It was discovered that additional data with tubes having wall thermocouples to measure the wall temperature were needed. Efforts were begun to have new, instrumented tubes constructed. These tubes will be manufactured during FY92. Until more precise inside (i.e., coolant-side) correlations can be obtained, the steam condensation heat transfer coefficients obtained will have potential uncertainties of as much as 20-30 percent. This effort to improve accuracy will continue into FY92.

PUBLICATION: Marto, P.J., "Heat Transfer in Condensation," Boilers, Evaporators and Condensers, S. Kakac (Ed.), John Wiley and Sons, Inc., pp. 525-570, 1991.

BOILING AND CONDENSING HEAT TRANSFER CHARACTERISTICS OF ALTERNATIVE REFRIGERANTS

P.J. Marto, Distinguished Professor of Mechanical Engineering
S.B. Memory, Adjunct Professor of Mechanical Engineering
Sponsor: David Taylor Research Center
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to experimentally study the boiling and condensing heat transfer characteristics of alternative refrigerants and refrigerant/oil mixtures. Tests are to be conducted using various commercially-available and laboratory-designed enhanced surfaces.

SUMMARY: During FY91 efforts were begun to convert the existing experimental apparatusses to permit operation with R-124 (a proposed alternative refrigerant to R-114). Difficulties were experienced in that Dupont Corp., who manufacturers R-124, had not completed its toxicity study of this new refrigerant. Until this is completed, special precautions must be taken by potential users, including using proper air monitoring instrumentation and the using proper air monitoring instrumentation and the use of a controlled-access laboratory. These necessary modifications delayed the operation with R-124 into FY92. During FY91, test data were therefore obtained with conventional CFCs (R-113 and R-114) during both boiling and condensing operations. Significant time was spent on studying bundle effects in a refrigerant evaporator and the use of wire-wrapped tubes to enhance the condenser performance.

THESES DIRECTED: Chilman, S.V., "Nucleate Boiling Characteristics of R-113 in a Small Enhanced Tube Bundle," MS Thesis, September 1991.

Sugiyama, D.C., "Nucleate Pool Boiling of R-114 and R-114/Oil Mixtures from Single Enhanced Tubes," MS Thesis, September 1991.

Mazzone, R.W., "Enhanced Condensation of R-113 on a Small Bundle of Horizontal Tubes," MS Thesis, December 1991.

PUBLICATION: Marto, P.J., "Nucleate Boiling Characteristics of R-113 in a Small Tube Bundle," in proceedings of the 3rd ASME/JSME Thermal Engineering Joint Conference, 2:311-319, March 1991.

GRAIN BOUNDARIES IN SUPERPLASTIC ALUMINUM

T.R. McNelley, Professor of Mechanical Engineering
Sponsor: Naval Air Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this program is to study the role of grain boundaries in fine-grained, superplastic aluminum alloys and the development of such grain boundaries during thermomechanical processing of these materials.

SUMMARY: This work has focused on the identification of the mechanisms of recrystallization during thermomechanical processing of fine-grained aluminum alloys and the types of grain boundaries that form during processing. This work has also addressed the associated mechanisms of superplastic deformation of fully processed materials. It has been demonstrated that recovery facilities the formation of moderately misoriented boundaries. Also, precipitated intermetallic second-phase particles may provide nucleation sites for recrystallization for certain processing conditions and thus facilitate the formation of fine-grained microstructures.

PUBLICATIONS: McNelley, T.R. and Kalu, P.N., "Investigation of the Deformation Mechanisms in Superplastic Al-Mg Alloys by Microtexture Technique," in *Light Weight Alloys for Aerospace Applications II*, E.W. Lee and N.J. Kim (eds.), TMS-AIME, Warrendale, PA, (1991), pp. 287-296.

Hales, S.J., McNelley, T.R. and Mcqueen, H.J., "Recrystallization and Superplasticity at 300#C in an Aluminum-Magnesium Alloy," *Metallurgical Transactions A*, 22A:1037-47, 1991.

Crooks, R., Kalu, P.N. and McNelley, T.R., "Use of Backscattered Electron Imaging to Characterize Microstructures of a Superplastic A1-10Mg-0.1Zr Alloy," *Scripta Metallurgica et Materialia*, 25:1321-1325, 1991.

McNelley, T.R. and Kalu, P.N., "The Deformation Mechanisms of Low Temperature Superplasticity in A1-Mg Alloys," in *Superplasticity in Advanced Materials*, S. Hori, M. Tokizane and N. Furushiro (eds.), The Japan Society for Research on Superplasticity, 2-1 Yamadaoka, Suita, Osaka, Japan (1991), pp. 413-423.

CONFERENCE PRESENTATIONS: McNelley, T.R. and Kalu, P.N., "Microstructural Development by Progressive Continuous Recrystallization of Superplastic A1 Alloys," in the Symposium on Light Weight Alloys for Aerospace Applications, 120th Annual Meeting of TMS-AIME, New Orleans, LA, 17-21 February 1991.

Crooks, R., Kalu, P.N. and McNelley, T.R., "Microstructures of Superplastic Aluminum Alloys," 120th Annual Meeting of TMS-AIME, New Orleans, LA, 17-21 February 1991.

McNelley, T.R. and Kalu, P.N., "The Deformation Mechanisms of Low Temperature Superplasticity in A1-Mg Alloys," The International Conference on Superplasticity in Advanced Materials, Osaka, Japan, 3-6 June 1991.

THESES DIRECTED: Meyer, C.D., "Precipitation and Recrystallization During Thermomechanical Processing of and A1-10Mg-0.1Zr Alloy for Superplasticity," MS AS, September 1991 (Advisor; co-advised with P.N. Kalu).

Meyer, C.D., "Processing Microstructure and Superplasticity in A1-Mg-Mn Alloys," MSAS, December 1991 (Advisor; co-advised with P.N. Kalu).

DEVELOPMENT OF DUCTILE AND IMPACT-RESISTANT METAL-MATRIX COMPOSITES FOR LIGHTWEIGHT MILITARY APPLICATIONS

T.R. McNelley, Professor of Mechanical Engineering
Sponsor: Proposed to the Army Materials Technology Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this program is to obtain improved combinations of strength, ductility and toughness in Al-based metal-matrix composite materials by thermomechanical processing.

SUMMARY: Discontinuously reinforced metal-matrix composite materials have many attractive properties but lack adequate ductility and toughness for many engineering and military applications. In this work improved combinations of strength and toughness have been obtained in some Al-based metal-matrix composites via thermomechanical processing. Following one processing route, an ambient temperature ductility of 10 pct. was obtained in a 6061 Al-$A_2 0_3$ heat treated to peak strength.

PUBLICATIONS: Kalu, P.N. and McNelley, T.R., "Microstructural Refinement by Thermomechanical Treatment of a Cast and Extruded 6061 Al-$Al_2 0_3$ Composite," *Scripta Metallurgica et Materialia*, 25: 853-858, 1991.

McNelley, T.R. and Kalu, P.N., "The Effects of Thermomechanical Processing on the Ambient Temperature Properties and Aging Response of a 6061 Al-$Al_2 0_3$ Composite," *Scripta Metallurgica et Materialia*, 25:1041-1046, 1991.

INFLUENCE ON MECHANICAL PROPERTIES OF RESIDUAL POROSITY IN INTELLIGENT HIPed POWDER-METALLURGY HIGH-TEMPERATURE Ti ALLOYS

T.R. McNelley, Professor of Mechanical Engineering
Sponsor: Naval Air Development Center, Warminster, PA
Funding: Naval Air Development Center

OBJECTIVE: The goal of this program is to provide data on the effect of residual porosity on the ambient and elevated temperature mechanical properties of powder-metallurgy high-temperature Ti alloys consolidated by hot isostatic pressing (HIP).

SUMMARY: Sensors have recently been developed which allow continuous monitoring of powder compact density during HIPing and this provides the basis for intelligent control of the HIP process. The concept of intelligent processing of materials (IPM) uses sensors not only to monitor process variables such as temperature and pressure but also quantities that relate to the processed material's fitness for subsequent service. Such quantities may include density as in HIPed components as well as microstructural or other parameters. A model relating density and microstructural parameters such as grain size to process variables is essential in order to achieve control and allow design or an optimum process. In HIPing the optimum process will achieve the required density with a minimum adverse effect on other material properties - e.g. by minimizing grain size. Densification of a powder compact is aided by diffusion - controlled processes and thus is facilitated by increased temperature or more prolonged heating. However, these same factors may also result in grain growth. At some point the residual porosity in a consolidated component will no longer affect service properties and further HIPing may result in coarsening and degradation of microstructure. It is the purpose of this proposed research to characterize residual porosity in a HIPed high-temperature titanium or titanium-aluminide alloy and its effect on material properties. This will be accomplished by analysis of material subjected to varying HIP times at temperatures to be determined. The microstructural effect of the HIPing cycles will be assessed and the response of this material to subsequent heat treatment will be characterized. Finally, the mechanical response at ambient temperature and in the range 500-900#C will be evaluated. This is a new program in 1991 and efforts during the reporting period have been directed mainly at acquisition of equipment and modification of apparatus to enable testing with simultaneous monitoring of axial and diametral strains.

CONTROL OF FREE-FLYING UNDER-ACTUATED SPACE ROBOTS

Ranjan Mukherjee, Assistant Professor Mechanical Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research is to develop control strategies for space robot systems that are underactuated in nature. Underactuated space robots are those that have fewer joint actuators than the robot can support. Since the actuators contribute largely to the cost of the robot system, underactuated robots in space on earth shall provide low cost automation. Control strategies developed for underactuated manipulators shall also be very useful in the event of actuator failures for ordinary manipulators on earth and more importantly in space. Underactuated systems will find very useful applications in space because of three primary reasons. The actuators contribute significantly to the mass of the whole system and therefore fewer actuators shall largely reduce the payload of the rocket that will send the robotic system in space. More importantly, solar power that will be consumed by the joint actuators is extremely limited in quantity. Though the solar batteries can be recharged, the amount of energy that can be stored in them is quite limited. A robot system with fewer actuators would therefore be ideal for space applications. Finally, robot systems in space have a long and a lightweighted structure. Therefore, lumped masses of the actuators located at the joints would cause considerable flexure of the manipulator links during its motion. This would create difficulties for precise manipulator motion control. This problem can be partially remedied by using underactuated systems.

The concept of underactuation will also find useful applications for large space structures. These structures usually consist of large flexible members that easily pick up vibrations. Vibrations could be thermally induced by differential heating of the structure or could be induced by differential gravitational forces. In the case of structures like the space station, vibrations could be induced easily through dynamic interaction between a space robot and the structure. A free-flying multidegree of freedom system in space is a nonholonomic mechanical system. Such systems have a noninvolutive property and they experience a change in orientation under periodic motion. Naturally space structures will disorient themselves if vibrations persist. Though piezo-electric actuators may be used to damp out the vibrations, the system performs oscillations and undergoes an undesirable change in orientation over prolonged periods of time. We could consider the prospect of replacing a large flexible space structure by a concatenated chain of rigid bodies. In order to achieve control over the system, motors can be used at some of the joints (instead of piezo-electric actuators). The other joints would be left unactuated. If we can control such a system so that it can reconfigure itself in any given way, underactuated systems would provide a better alternative to large flexible space structures.

SUMMARY: The project started in the Fall Quarter of 1992. Some preliminary results have been obtained so far. Control strategies have been developed to stabilize the free-flying under-actuated robot system to equilibrium manifolds. The efficacy of this control is contingent upon the following conditions: (1) more number of actuated joints than the number of unactuated joints, and (2) the inertia matrix must necessarily be a function of the unactuated joint angles.

PUBLICATIONS: Mukherjee, R. and Chen, D., "Stabilization of Free-Flying Under-Actuated Mechanisms in Space," in proceedings of the 1992 American Control Conference, forthcoming.

Mukherjee, R., "Stabilization of Free-Flying Under-Actuated Mechanisms in Space, NPS Technical Report, NPS-ME-91-003, September 1991.

OTHER: A manuscript is being written for submission to the IEEE Transactions on Robotics and Automation: special issue on Space Robotics.

MECHANISMS OF LATTICE TRANSFORMATIONS AND INTERNAL FRICTION IN MARTENSITIC AND ANTIFERROMAGNETIC HIGH-DAMPING ALLOYS

J. Perkins, Professor of Mechanical Engineering
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The main objective of this research was to develop models to delineate the damping mechanisms in certain so-called "quiet metals". The ultimate aim was to develop, on the microscopic and sub-microscopic level, a unified mechanistic model for the damping behavior of high damping alloys. Since results to date indicate that damping in these alloys is always linked to phase transformations (which may be magnetic transitions, lattice-displacive transformations, or diffusional transformation), and more particularly to boundaries which result from such transformations, a major objective was to define the microstructural features which play a role in the damping mechanisms.

SUMMARY: In general, high damping mechanisms in quiet metal alloys are associated with the internal friction created near various types of boundaries. However, different alloys have different types of boundaries, and there are different atomistic mechanisms of damping, and therefore different controlling and operational parameters. For example, the domain boundaries in ferromagnetic alloys are quite different from the intervariant boundaries in martensitic alloys. On the other hand, the intervariant boundaries are quite similar in form and character to the inter-domain twin boundaries which separate the antiferromagnetic domains in quenched homogeneous FCT Cu-Mn-based alloys. Aged Cu-Mn alloys, however, present a completely different microstructural form, in which it has only recently been recognized that the "boundaries" are effectively very broad, with a gradual transition of structure. This latter case, in contrast to the distinct nature of martensitic intervariant boundaries, suggest a "boundaryless" mechanism, or at least a broad gradient of structure within which the internal friction mechanism operates. This is a primary area in which further investigation is required.

PUBLICATIONS: Farkas, D.M., Yamashita, T. and Perkins, J., "On the Energetics of Flickering Contrast Observed in TEM Images of an Aged 53Cu-45MN-2A1 Alloy," *Acta Metallurgica*, 38, 1991.

Perkins, Jeff, "Tweed Contrast in Microstructures," in Encyclopedia of Materials Science, Supplement, 1991.

CONFERENCE PRESENTATIONS: Perkins, Jeff, "Transformation Kinetics in Shape Memory Alloys," 1991 Fall Meeting of the Metallurgical Society, Cincinnati, OH, October 1991.

THERMOELASTIC STRESSES IN ELECTRONIC PACKAGES

D. Salinas, Associate Professor of Mechanical Engineering
Sponsor: Naval Weapons Support Center
Funding: NWSC and the
Naval Postgraduate School

OBJECTIVE: To (a) formulate a model for the determination of thermoelastic stresses in electronic packages comprised of a chip, a solder connection, and a board substrate and (b) compare the effectiveness of two types of solder connections, the leaded device and the unleaded device.

SUMMARY: Typical electronic packages consist of a chip connect to a board substrate by a solder connection. During fabrication of the electronic package and during its operation, thermoelastic stresses develop because the chip, solder and substrate are of different materials and hence have different properties. In particular, the Youngs modulii, Poison's ratio, and thermal coefficients of expansion differ. The geometric configuration of the soldered connection plays a major role in determining the magnitude of the thermoelastic stresses that develop.

PUBLICATION: Salinas, D. and Shin, P.Y., "Stresses in Solder Joints of Electronic Packages," NPS Technical Report NPS-ME-91-004, December 1991.

OTHER: The investigation has been completed. The results of the investigation, which are presented in a NPS technical report, show that the leaded device develops significantly smaller stresses than the unleaded device for the same uniform thermal field.

NUMERICAL ANALYSIS OF SEPARATED FLOW ABOUT BLUFF BODIES

T. Sarpkaya, Distinguished Professor of Mechanical Engineering
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: Basic numerical and experimental research towards the understanding of the effect of unsteadiness on the characteristics of the resulting time-dependent flow.

SUMMARY: A two-step, three-level, finite-difference, predictor-corrector scheme (based on the second-order Adams-Bashforth method) and a Fast Poisson Solver based on FFT methods are used to carry out the numerical experiments. A von Neumann linear stability analysis was performed and the mesh sizes and time steps were chosen to provide a conditionally stable solution. The physical experiments were carried out in a U-shaped oscillating-flow tunnel for various Reynolds and Keulegan-Carpenter numbers. The results were found to be in reasonable agreement with those obtained experimentally. The methodology is being extended to Gaussian oscillations of the flow about a cylinder to simulate the ocean environment.

PUBLICATIONS: Sarpkaya, T., "Non-Impulsively Started Steady Flow about a Circular Cylinder," *American Institute of Aeronautics and Astronautics Journal*, 29(8):1283-1289, August 1991.

Sarpkaya, T. and Lindsey, P., "Unsteady Flow about Porous Cambered Shells," *Journal of Aircraft*, 28(8):502-508, August 1991.

CONFERENCE PRESENTATIONS: Sarpkaya, T., "Recent Progress in Basic Numerical and Physical Experiments on Oscillating Flow About Cylinders," in proceedings of the Osaka International Colloquium on Viscous Fluid Dynamics in Ship and Ocean Technology, 1:45-63, September 1991.

Sarpkaya, T., "Methods of Analysis for Flow Around Parachute Canopies," in proceedings of the 11th AIAA Aerodynamic Decelerator Systems Technology Conference, AIAA-91-0825, 1:1-17, 9-11 April 1991.

Sarpkaya, T., "Hydrodynamic Lift and Drag on Rough Circular Cylinders," in proceedings of the Offshore Technology Conference, 1:191-197, May 1991.

THESIS DIRECTED: Putzig, Christopher J., LT, USN, "Numerical Experiments in Unsteady Flows through the use of Full Navier-Stokes Equations," MSME Thesis, June 1991.

Gordon, David, R., LCDR, USN, "Computational Unsteady Flow Dynamics: Oscillating Flow About A Circular Cylinder," MS Thesis, December 1991.

OTHER: The investigator is preparing a book entitled "Vortex-Element Methods" for publication. Completion is expected in December 1992.

SEPARATION POINTS ON A CYLINDER IN OSCILLATING FLOW

T. Sarpkaya, Distinguished Professor of Mechanical Engineering
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: The purpose of this investigation is to determine the excursion of the separation points on smooth and sand-roughened circular cylinders in a sinusoidally oscillating flow. The unsteady flow used in this investigation is a special case of a more general harmonic flow composed of many frequencies. The latter is the subject of another investigation.

SUMMARY: Experiments have been carried out in a U-shaped water tunnel at various Reynolds numbers, Keulegan-Carpenter numbers, and relative roughnesses using a wave of constant frequency. In addition, flow visualization experiments have been performed in a large basin. The motion of the separation points on smooth and sand-roughened circular cylinders has been determined as a function of a normalized time and relative roughness for various Keulegan-Carpenter numbers and Reynolds numbers. The results will serve several purposes: (i) they will be compared with those obtained numerically through the use of finite-difference and the vortex element methods to guide and complement the analysis; (ii) they will enhance our basic understanding of separation through the use of a relatively idealized time-dependent flow about bluff bodies; and (iii) they will help to devise methods to delay the occurrence of separation. A parallel investigation will extend the results obtained with the mono-harmonic flow to the more general case of multi-frequency harmonic oscillations about smooth and rough cylinders.

PUBLICATIONS: Sarpkaya, T., "*Comments on the* Accurate Calculation of Vortex Shedding," *Physics of Fluids A*, 3(8):2013, August 1991.

Sarpkaya, T., "Comments on the Calculation of Asymmetric Vortex Separation on Cones and Tangent Ogives Based on a Discrete Vortex Model," *American Institute of Aeronautics and Astronautics Journal*, 29(9):1535-1536, September 1991.

CONFERENCE PRESENTATION: Sarpkaya, T. and Butterworth, W., "Separation Points on a Cylinder in Oscillating Flow," in proceedings of the Offshore Mechanics and Arctic Engineering International Conference, Stavanger, Norway, 1-A:9-19, June 1991.

Sarpkaya, T., "Recent Progress in Basic Numerical and Physical Experiments on Oscillating Flow About Cylinders," in proceedings of the Osaka International Colloquium on Viscous Fluid Dynamics in Ship and Ocean Technology, 1:45-63, September 1991.

THESIS DIRECTED: Hooper, Richard W., LT, USN, "Instability of Sinusoidally Oscillating Flow Along a Cylinder," MSME Thesis, June 1991.

Ozel, M., LT, Turkish Navy, "Separation Points on a Cylinder in Sinusoidally Oscillating Flow," MSME Thesis, December 1990.

INTERACTION OF A VORTEX PAIR WITH A FREE SURFACE

T. Sarpkaya, Distinguished Professor of Mechanical Engineering
Sponsor: Chief of Naval Research (ONR) and the
Naval Postgraduate School
Funding: ONR and NPS (Continuing Cost-Sharing Research)

OBJECTIVE: Basic research towards the understanding of the fundamental mechanisms and physical processes underlying two- and three-dimensional vortex/free-surface interactions in homogeneous, stratified, and sheared media, taking into account ambient turbulence, viscous effects, and various large-scale instabilities (sinusoidal instability and vortex breakdown) for ship and submarine related hydrodynamics in a real ocean environment.

SUMMARY: Numerous physical experiments have been carried out in a large towing tank with various lifting surfaces and submerged bodies in homogeneous and density-stratified medium. Second, experiments with two-dimensional vortex pairs have been conducted in a large water basin using both stratified and homogeneous medium. Third, experiments have been performed in a recirculating water funnel with a single turbulent vortex. The characteristics of the resulting surface scars have been evaluated in terms of the governing parameters through the use of a Motion Analysis System and a Sun computer. Extensive numerical analysis has been performed and a computer code has been developed to predict numerically the characteristics of the surface disturbances, the energy spectra, and the fractal dimension. The evidence presented herein shows that numerous tentacle-like vortex sheets of finite length, resulting from helical instabilities, stretch out or are thrown away from the outer edges of the vortex core. The vortex peels off randomly and sheds vorticity along its length. The core of a turbulent vortex is not a benign, smooth, axisymmetric, solid body of rotation. The exchange of momentum between the outer regions and the core leads to the oscillation of the vortex core and the various velocity components. Experiments and analysis are continuing towards the evaluation of the behavior of the scars in terms of the prevailing Froude numbers, Atwood numbers and the Vaisala-Brunt frequencies.

PUBLICATIONS: Sarpkaya, T. and Suthon, P., "Interaction of a Vortex Pair with a Free Surface," *Experiments in Fluids*, 11:205-217, July 1991.

Sarpkaya, T. and Suthon, P.B.R., "Scarred and Striated Signature of a Vortex Pair on the Free Surface," in proceedings of the 18th Symposium on Naval Hydrodynamics, National Academy Press, 1:503- 519, 1991.

THESIS DIRECTED: Lundblad, Warren P., LT, USN, "Evolution of Vorticity at and Near the Free Surface," MSME and Engineer Degree Thesis, September 1991.

OPTIMIZATION STRUCTURAL DESIGN BY A HOMOTOPY METHOD

P.Y. Shin, Assistant Professor of Solid Mechanics
Sponsor: David Taylor Research Center
Funding: Naval Postgraduate School

OBJECTIVE: Structural optimization has gained popularity in recent years as the importance of minimum weight design has been recognized in many industry or military applications. One approach to find the optimum design is to treat the optimality conditions as a set of nonlinear equations and to solve these equation using a homotopy method. The objectives of the research are to further develop the homotopy technique to design structures made of composite materials and to compare the effectiveness of the method with existing mathematical programming techniques.

SUMMARY: Probability-one homotopy methods are a class of algorithms for solving nonlinear system of equations that are accurate, robust, and convergent from an arbitrary starting point. To apply this technique to design optimization, a Lagrangian multiplier method is used to derive all necessary equations. The technique is applied for design of composite plate structures. A finite element computer code for composite plates buckling analysis is written. The classical laminate theory is used to obtain flexural stiffness matrix and in-plane stiffness matrix. The above computer program is used to find the optimal design using a nested approach in optimization which yields a system of nonlinear equations. These equations are then solved using the homotopy method. When the procedure is applied to find the optimal design of stiffened laminated plates a number of difficulties arises. As the total weight of the plate is increased, the number of simultaneous buckling modes of corresponding optimal design is also increased. So, the design formulation had to be changed to accommodate all different simultaneous modes. The homotopy technique was compared to the existing nonlinear programming methods using package programs, DOTS and IMSL. The performance was tested and it was found the homotopy method worked slowly in overall CPU time but it showed advantage in that the technique can be used to find multiple optimum designs.

PUBLICATIONS: Shin, P.Y., "A Homotopy Method for Optimal Design Using An Envelope Function," to be presented at the 33rd AIAA/ASME/ASCE/AHS Structures Structural Dynamics and Materials (SDM) Conference.

Shin, P.Y. and Achenbach, M.R., "Design Optimization of Blade Stiffened Laminated Composite Plates," ASME paper PVP-Vol. 225/NE-7:143-150, 1991.

Watson, L.T., Haftka, R.T., Lutze, F.H., Plaut, R.H. and Shin, P.Y., "The Application of Globally Convergent Homotopy Methods to Nonlinear Optimization," in *Advances in Numerical Partial Differential Equations and Optimization*, S. Gomez, J.P. Hennart and R.A. Tapia (eds.), SIAM, Philadelphia, PA, pp. 284-298, 1991.

Shin, P.Y., "Optimal Design of Stiffened Laminated Plates Using a Homotopy Method," The 32nd AIAA/ASME/ASCE/AHS Structures Structural Dynamics and Materials (SDM) Conference, Baltimore, MD, 8-10 April 1991.

THERMOELASTIC STRESSES IN ELECTRONIC PACKAGES

P.Y. Shin, Assistant Professor of Solid Mechanics
Sponsor: Naval Weapons Support Center
Funding: Naval Weapons Support Center

OBJECTIVE: To formulate a model for the determination of thermoelastic stresses in electronic packages compressed of a chip, a solder connection, and a board substrate and to compare the effectiveness of two types of solder connections, the leaded device and the unleaded device.

SUMMARY: Typical electronic packages consists of a chip connected to a board substrate by a solder connection. During fabrication of the electronic package and during its operation, thermoelastic stresses develop because the chip, solder and substrate are of different materials and hence have different properties. In particular, the Young's modulii, Poison's ratio, and thermal coefficients of expansion differ. The geometric configuration of the soldered connection plays a major role in determining the magnitude of the thermoelastic stresses that develop.

PUBLICATIONS: Salinas, D. and Shin, P.Y., "Stresses in Solder and Joints of Electronic Packages," NPS Technical Report NPS-ME-91-004, December 1991.

OTHER: The investigation has been completed. The results of the investigation, which are presented in a NPS technical report, show that the leaded device develops significantly small stresses than the unleaded device for the same uniform thermal field.

DYNAMIC RESPONSE AND FAILURE OF COMPOSITE AND METAL STRUCTURES TO UNDERWATER SHOCKLOADS

Y.S. Shin, Professor of Mechanical Engineering

Sponsor: Defense Nuclear Agency

OBJECTIVE: To advance our understanding on shock induced dynamic behavior and failure mechanism of composite and metal structures through the analytical studies and the underwater explosion testings.

SUMMARY: The significant progress in this research was made in understanding the failure process and physics of submarine hull collapse when subjected to underwater explosions (UNDEX). Navy conducted significant amount of UNDEX testings in the past two decades and observed catastrophic collapse of submarine hull structures. However, there was no significant progress in numerical precision prediction of this important collapse phenomenon. This is caused by the fact that it is a nonlinear large deformation/strain-rate dependent problem with complex fluid-structure interactions effects. With the advent of extremely fast computers, we developed the computational capabilities to overcome such difficulties by coupling DYNA3D (Nonlinear Explicit Dynamic Analysis in Three Dimensional Code) and USA (Underwater Shock Analysis Code). This newly coupled code, USA-DYNA3D has now full capabilities to handle both material and geometric nonlinear structures submerged in the fluid with 31 different material modeling capabilities. This code has been released to DON/DOD communities for shock calculations. We conducted the underwater shock testing using scaled aluminum cylinder and the test results were used to compare with the precision calculation. The types of materials include strain-rate insensitive aluminum, strain-rate sensitive steel alloy such as HY-80 and HY-100, and S-2 glass fiber composites.

PUBLICATIONS: Jones, R.A. and Shin, Y.S., "The Response and Failure Mechanisms of Circular Metal and Composite Plates Subjected to Underwater Shock Loading," in proceedings of the 61st Shock and Vibration Symposium, III:163-178, Pasadena, CA, 16-18 October 1990.

Kwon, Y.W., Fox, P.K. and Shin, Y.S., "Response of Cylindrical Shell Subjected to a Near-Field Side-On Explosion," in proceedings of the 62nd Shock and Vibration Symposium, Pasadena, CA, II:483-492, Springfield, VA, 29-31 October 1991.

CONFERENCE PRESENTATIONS: Jones, R.A. and Shin, Y.S., "The Response and Failure Mechanisms of Circular Metal and Composite Plates Subjected to Underwater Shock Loading," presented at the 61st Shock and Vibration Symposium, Pasadena, CA, 16-18 October 1990.

Kwon, Y.W., Fox, P.K. and Shin, Y.S., "Response of Cylindrical Shell Subjected to a Near-Field Side-On Explosion," presented at the 62nd Shock and Vibration Symposium, Springfield, VA, 29-31 October 1991.

MACHINERY NOISE, VIBRATION AND DIAGNOSTIC: ANALYSIS, DESIGN AND TESTING

Y.S. Shin, Professor of Mechanical Engineering
Sponsor: Naval Sea Systems Command and the Naval Postgraduate School
Funding: Naval Sea Systems Command and the Naval Postgraduate School

OBJECTIVE: To develop condition monitoring and diagnostics methods for transient machinery such as turbine-driven torpedo ejection pump system.

SUMMARY: The significant progress was made in: (a) Characterizing the time-frequency dependent signatures of transient machinery such as turbine-driven torpedo ejection pump (TEP) system of Trident Class submarine, and (b) Developing successful diagnostics methods for detection of faults in machine operation, and predicting machinery failure using backpropagation neural net approach. The Pseudo Wigner-Ville distribution (PWVD) was investigated, and computer program has been developed and extensive studies were performed to process the time-dependent transient signatures to generate PWVD function for turbine-driven torpedo ejection pump signatures. As we are developing the monitoring scheme to characterize the TEP signatures, we are also developing the diagnostics method using Artificial Neural Network (ANN), which is based on massively parallel distributed processing system consisting of a series of interconnected individual processing elements which process information in a manner similar to neurons in biological systems. Among the many different paradigms in ANN, the back-propagation method was configured to provide machinery diagnostics for simple mechanical system to evaluate the detectability of mechanical component failure. The results were quite promising to apply to TEP condition monitoring and diagnostics which will eventually eliminate expensive and unnecessary periodic maintenance.

PUBLICATIONS: Rossano, G.W., Hamilton, J.F. and Shin, Y.S., "The Pseudo Wigner-Ville Distribution as a Method for Machinery Condition Monitoring of Transient Phenomena," in proceedings of the 2nd International Machinery Monitoring & Diagnostics Conference, pp. 163-173, Los Angeles, CA, 22-25 October 1990.

Kim, D.S., Shin, Y.S. and Carlson, D.K., "Machinery Diagnostics for Rotating Machinery Using Backpropagation Neural Network," in proceedings of the 3rd International Machinery Monitoring & Diagnostics Conference, pp. 309-320, Las Vegas, NV, 9-12 December 1991.

CONFERENCE PRESENTATIONS: Rossano, G.W., Hamilton, J.F. and Shin, Y.A., "The Pseudo Wigner-Ville Distribution as a Method for Machinery Condition Monitoring of Transient Phenomena," presented at the 2nd International Machinery Monitoring & Diagnostics Conference, Los Angeles, CA, 22-25 October 1990.

Kim, D.S., Shin, Y.W., and Carlson, D.K., "Machinery Diagnostics for Rotating Machinery Using Backpropagation Neural Network," presented at the 3rd International Machinery Monitoring & Diagnostics Conference, Las Vegas, NV, 9-12 December 1991.

THESIS DIRECTED: Carlson, David K., LT, USN, "Artificial Neural Networks and Their Applications in Diagnostics of Incipient Faults in Rotating Machinery," Master's Degree in Mechanical Engineering, March 1991.

DEPARTMENT OF METEOROLOGY

DEPARTMENT OF METEOROLOGY

The research program in the Department of Meteorology continues in several areas: (1) numerical air/ocean modeling and prediction; (2) dynamics of fronts and flow over and around mountains; (3) analysis and dynamics of tropical weather systems; (4) analysis and dynamics of extra tropical weather systems; (5) climate dynamics (6) atmospheric boundary layers over the sea, ice and in coastal regions; (7) regional weather studies and; (8) remote sensing. A number of related investigations have been pursued by various faculty members under each of these headings.

Numerical Modeling and Prediction

R. T. Williams is developing and testing numerical procedures for global and regional weather prediction. He is investigating various finite element and semi-Lagrangian formulations with respect to treatment of small-scale flow fields. He is also applying the techniques to the prediction of cyclogenesis. R. T. Williams, C.-P. Chang and M. S. Peng are investigating the "Mei-Yu" front over eastern Asia with a dynamical frontal model.

Numerical-observational studies of rapid maritime cyclogenesis events are being pursued by C. H. Wash, W. A. Nuss, P. M. Pauley, R. L. Elsberry, and P. A. Hirschberg. Diagnostic studies of analyses and predictions by the Naval Operational Regional Atmospheric Prediction System (NORAPS) are used to evaluate physical processes that occur during rapid cyclogenesis observed in the ONR ERICA field program. P. Harr and R. L. Elsberry are examining a large set of global model predictions to identify error tendencies in the forecasts of maritime cyclone intensities and positions. A decision theoretic approach is being used to examine the utility of model error tendencies to the operational forecaster. On a similar topic, P. M. Pauley is examining the sensitivity of the National Meteorological Center's Nested Grid Model (NGM) forecasts of rapid cyclogenesis to various physical processes.

J. W. Glendening is employing large-eddy closure techniques to investigate turbulence and boundary layer development in the strongly baroclinic zone above and down wind of arctic leads. Large eddy models provide state of the art simulations of turbulent phenomena.

T. R. Holt is examining the effects of mesoscale marine atmospheric boundary layer processes on coastal cyclogenesis for GALE and ERICA case studies. Diagnostic studies of numerical simulations from the NRL mesoscale model are conducted to investigate the importance/interaction of the low-level baroclinic one, latent heat release and upper level forcing. In addition, numerical studies to consider important physical processes and/or parameters such as latent heat release associated with convective precipitation, surface wind speed, and integrated water vapor are examined through the use of an observing system simulation experiment (OSSE) using assimilated SSM/I data. The NRL mesoscale model has also been implemented for case studies of complex flow along the west coast of the U.S. Simulations are performed under varying synoptic conditions to assess the interaction of boundary layer flow with the complex terrain. Cloud parameterization schemes are being evaluated along the coastal regions and improvements to the existing NRL stratus parameterization are being developed.

W. A. Nuss is investigating the role of boundary layer processes in frontogenesis and cyclogenesis over the ocean using the NCAR/Penn State mesoscale model. Diagnostic studies of the model predictions were used to evaluate the alteration of baroclinic processes by surface forcing. Observational studies of these processes are also being performed using aircraft data taken during ERICA.

Other modeling efforts include: (1) a marine atmospheric boundary layer model for predicting (6-12 hours) properties that affect radar and optical propagation within the boundary layer, and those factors (radiation and boundary fluxes) that affect the upper part of the ocean, directed by K. L. Davidson and; (2) data

assimilation studies of the dynamics and prediction of synoptic scale variability in the coastal ocean off California observed in the ONR Coastal Transition Zone (CTZ) program, led by R. L. Haney.

Dynamics of Fronts and Flow Over and Around Mountains

R. T. Williams and M. S. Peng are studying the conditions that determine whether or not the air will flow over or around a long mountain range. Also, R. T. Williams and M. S. Peng are studying the interaction of fronts with topography, and R. L. Haney is investigating the effects of topography and baroclinity in the coastal ocean circulation.

Analysis and Dynamics of Tropical Weather Systems

C.-P. Chang, R. T. Williams, J.-M. Chen and M. S. Peng continue to investigate various aspects of the dynamics of tropical synoptic and planetary motions, and tropical mid-latitude interactions. The diagnostic analysis of the oceanic tropical weather systems using the Navy Operational Global Atmospheric Prediction System (NOGAPS) is being pursued by C.-P. Chang and J.-M. Chen.

A multi-year basic research program to understand the dynamics of tropical cyclone motion has been completed. R. L. Elsberry served as the Technical Director of the overall research initiative for the Office of Naval Research. P. Harr and R. L. Elsberry are examining the relationship between tropical cyclone track characteristics and large scale tropical circulation anomalies. R. T. Williams and M. S. Peng are developing analytical and numerical models of tropical cyclone motion. R. L. Elsberry and P. Harr continue applied research efforts to improve tropical cyclone prediction via statistical evaluations and expert systems.

C.-P. Chang, R. L. Elsberry and T.-C. Yeh are studying the effects of big island terrain on typhoon motion in the western Pacific near Taiwan and the Philippines.

Analysis and Dynamics of Extra Tropical Weather Systems

Observational studies of rapid maritime cyclogenesis events are being pursued by W. A. Nuss, C. H. Wash and P. M. Pauley. Operational and special experimental data taken during the ERICA field program are used to diagnose the structure and physical process that contribute to the rapid development of oceanic cyclones. W. A. Nuss is also studying the development of several cyclones along the coast of Japan to characterize boundary layer processes in ocean cyclogenesis.

P. Harr and R. L. Elsberry are examining the error characteristics of the Fleet Numerical Oceanography Center (FNOC) global model during periods of cyclogenesis. Statistical techniques to adjust the forecast fields to improve accuracy are being pursued.

Climate Dynamics

Tom Murphree is examining the mechanisms of large scale, low frequency variations of the atmosphere and ocean. His studies emphasize variations that occur on intraseasonal to interannual time scales; i.e., short term time scales. A new focus in this work is the synoptic scale mechanisms that lie behind these low frequency variations. The synoptic meteorology topics are being investigated in collaboration with C.-P. Chang, J.-M. Chen and Pat Harr. Other collaborators are at the NPS Department of Oceanography, the Naval Research

Laboratory-Monterey, the Climate Analysis Center, and the University of Hawaii. The four major components of this work are:

1. modeling and observational studies of the atmospheric planetary wave dynamics of tropical-extratropical teleconnections;

2. observational and modeling analyses of tropical synoptic scale forcing of the midlatitude atmosphere;

3. observational and dynamical analyses of tropical air-sea interaction at synoptic to intraseasonal time scales; and

4. analyses of modeled and observed large scale tropical ocean waves.

TROPICAL AND MONSOON STUDIES

C.P. Chang, Professor of Meteorology
R. T. Williams, Professor of Meteorology
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: The purpose of this project is to study the structure and behavior, including the dynamical and thermodynamic mechanisms, of large and cyclone-scale atmospheric motion systems in the tropics and subtropic, particularly those in the western Pacific and vicinity.

SUMMARY: A 14-season global data set is used to study the relationship between the occurrence of cold surges over the South China Sea and the variation of the 200 mb and surface tropical divergence front he western Pacific to the eastern Indian Ocean. A canonical correlation analysis showed that the cold surge-related 200 mb tropical divergence variations have two centers. The primary one is located in the equatorial South China Sea between the Malay Peninsula, Sumatra and Borneo, which is about 50° to the west of the long-term winter mean divergence center in the equatorial western Pacific around 155°E. The secondary center is over the Bay of Bengal. At both centers the surge-related fractional variances are approximately 40% two days after the onset, and become >50% five days after the onset. There is no indication of cold surge influences on the long-term mean divergence center in the equatorial western Pacific.

A 20-year data set from 22 surface stations to describe the impact of the Central Mountain Range, whose horizontal scale is comparable to the radius of a typhoon, on the surface structure of typhoons. The data include 82 typhoons between 1971-1990, with 1446 three-hourly data sets. Empirical orthogonal function analysis on the pressure field is first used to identify the primary structure modes. A regression technique is then used to determine the surface wind, temperature, relative humidity and hourly rainfall associated with each pressure mode. In all cases these fields are consistent and show the effects of the terrain blocking or deflection, and their consequent ascending and descending motions. The relative importance of each mode depends strongly on the location of the typhoon center. No dependence on the direction or speed of motion is discernable when all cases are considered.

However, when clearly different, persistently-smooth tracks are identified, the variation due to motion direction can be recognized because the terrain effect is affected by the mean steering flow.

It was discovered that a commonly used Extended Empirical Orthogonal Function (EEOF) analysis technique, first introduced by Weare and Nasstrom (1982), has some fundamental faults. Since the derivation of EOFs is based on the maximization of variance of every EOF as a entity and it has no reference to the correlation among partial structures within one EOF, the application of EEOF for investigating relationships between fields is questionable.

A paper is being written to discuss this finding. The passage of a front over a long ridge was studied with two-dimensional numerical model. The basic current was stratified with no vertical shear. Frontogenesis was forced by a horizontal deformation field that moved with the basic flow. The fronts weakened as they moved up the slope, and they strengthened as they moved down the lee slope. These solutions were compared with the semi-geostrophic solutions that were obtained by Zehnder and Bannon. Frontal solutions with no forcing were compared with the advection of a scaler field, following the semi-geostrophic theory of Blumen and Gross. The agreement was good for the large scale mountain, but it was poorer for the steep mountains over which the flow was less semi-geostrophic.

PUBLICATIONS: Chang, C.-P., Peng, M.S. and Boyle, J. S., "Interannual Variations of Tropical Upper Tropospheric Divergence and Pacific Teleconnections during Northern Winter," Terrestrial, Atmospheric and Oceanic Sciences, 1:337-362, 1991.

Lim, H., Lim, T. and Chang, C.-P., "Vertical wind shear effects on Kelvins wave-CISK modes:

Possible relevance to 30-60 day oscillations," Terrestrial, Atmospheric and Oceanic Sciences, Vol. 1, 1991.

Chen, J.-M., "Turbulence-Scale Condensation Parameterization," *Journal of the Atmospheric Sciences*, 48:1510-1512, 1991.

Peng, M.S. and Williams, R.T., "Stability Analysis of Barotropic Vortices," *Geophysical and Astrophysical Fluid Dynamics*," 58:263-283, 1991.

AIR SEA INTERACTION AND REMOTE SENSING

K. L. Davidson, Professor of Meteorology
P. J. Boyle, Meteorologist
C. Skupniewicz, Meteorologist
Sponsor: Office of Naval Research (1121RS)
Funding: Naval Postgraduate School

OBJECTIVE: Objectives in these continuing data analysis and interpretation studies are to investigate the relationships between the near surface wind and wind stress and between the wind stress and radar backscatter for both equilibrium and non-equilibrium wind and sea conditions.

SUMMARY: The wind and surface data under study were obtained in the Frontal Air Sea Interaction Experiment (FASINEX), in the Humidity Exchange Main Experiment (HEXMAX), and in the NORwegian Continental Shelf Experiment (NORCSEX). FASINEX results show that a SST front enhances the surface wind stress as well as properties of the whole mixed layer properties (Freihe et al., 1991). They also characterize the variability of atmospheric forcing of the Ocean by transiting storms (Davidson et al., 1991). HEXMAX results show that a drag coefficient can be established for shallow water regimes (Davidson et al., forthcoming) but that wave stage as well as wind speed has to be included as a defining parameter (Smith et al., forthcoming). NORCSEX buoy and shipboard wind stress results show that the regime is typical of other open ocean regions (Skupniewicz and Davidson, 1991) and that good correlation occurs between wind stress and radar backscatter changes (Johannessen et al, 1991 and Davidson, et al, Proceeding OCEANS91, 1991).

PUBLICATIONS: Davidson, K. L. and Skupniewicz, C. E., "Wind Stress Surface Truth Measurements for NORCSEX," *IEEE Transactions on Geoscience and Remote Sensing*, 29:186-189, January 1991.

Davidson, K. L., Boyle, P. J., Gautier, C., Hanson, H. and Khalsa, S., "Medium to Large Scale Atmospheric Variability in FASINEX," *Journal of Geophysical Research*, 96:8531-8552, May 1991.

Freihe, C., Shaw, W. J., Rogers, D., Davidson, K. L., Large, W., Stage, S., Crescenti, G., Khalsa, S. J. S., Greenhut, G. K. and Li, F. , "Air-Sea Fluxes and Surface Layer Turbulence Around A Sea Surface Temperature Front," *Journal of Geophysical Research*, 96:8593-8610, May 1991.

Skupniewicz, C. E. and Davidson, K. L., "Hot-Film Measurements from a Small Buoy: Surface Stress Estimates using the Inertial-Dissipation Method," *Journal of Atmospheric and Oceanic Technology*, 8: 309-322, June 1991.

Johannessen, J. A., Shuchman, R. A., Johannessen, O. M., Davidson, K.L. and Lyzenga, D. R., "Synthetic Aperture Radar Imaging Capabilities of Upper Ocean Circulation Features and Wind Fronts," *Journal of Geophysical Research*, 96: 10411-10422, June 1991.

Davidson, K. L. , Boyle, P. J., and Edson, J. B., "Shipboard Surface Wind Stress and Comparison with Tower Values during HEXMAX," in proceedings of the 5th AMS Conference on Meteorology and Oceanography of the Coastal Zone, Miami, FL, pp. 151-155, 6-10 May 1991.

Weissman, D.E., Plant, W. J., Davidson, K. L., Brown, R. A. and Shaw, W. J., "Relating the Microwave Radar Cross Section to the Sea Surface

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Davidson, K. L., Skupniewicz, C. E., Ross, D., Onstott, R. G., Johannessen, J. A. and Skagseth, O., "Relationship Between Wind Stress, Backscatter, and the Directional Wave Spectrum," in proceedings of the OCEAN91, Honolulu, HI, pp. 998-1005, 1-4 October 1991.

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Weissman, D. E., Davidson, K. L., Plant, W. J. and Brown, R. A., "Relating the Microwave Radar Cross Section to the Sea Surface Stress: Developing a New Model Function," in proceedings of the OCEAN91, Honolulu, HI, pp. 1013-1018, 1-4 October 1991.

Davidson, K. L., Boyle, P. J. and Guest, P. S., "Atmospheric Boundary Layer Properties Affecting Wind Forecasting in Gulf and Coastal Regions," *Journal of Applied Meteorology*, (Forthcoming).

Smith, S. D., Anderson, R., Oost, W. A., Kraan, C., Maat, N. , DeCosmo, J., Katsaros, K. B., Davidson, K. L., Bumke, K., Hasse, L. and Chadwick, H. M., "Wind Stress and Drag Coefficients during HEXMAX," *Journal of Geophysical Research* (Forthcoming).

CONFERENCE PRESENTATIONS: Davidson, K.L., "Forecasting Boundary Layer Phenomena in Coastal Regions," Symposium on Air-sea Interaction and Air Mass Modification over the Gulf of Mexico, Galveston, TX, 7-9 January 1991.

Davidson, K. L., Boyle, P. J., and Edson, J. B., "Shipboard Surface Wind Stress and Comparison with Tower Values during HEXMAX," 5th AMS Conference on Meteorology and Oceanography of the Coastal Zone, Miami, FL, 6-10 May 1991.

Davidson, K. L., Skupniewicz, C. E., Ross, D., Onstott, R. G., Johannessen, J. A. and Skagseth, O., "Relationship Between Wind Stress, Backscatter, and the Directional Wave Spectrum," OCEAN91, Honolulu, HI, 1-4 October 1991.

Davidson, K. L., and Weissman, D., "Surface Wind Stress Measurements Compared with Airborne Microwave Backscatter," OCEAN91, Honolulu, HI, 1-4 October 1991.

Weissman, D. E. , Davidson, K. L., Plant, W. J. and Brown, R. A., "Relating the Microwave Radar Cross Section to the Sea Surface Stress: Developing a New Model Function," OCEAN91, Honolulu, HI, 1-4 October 1991.

METEOROLGICAL STUDIES OF ARCTIC REGIONS

K. L. Davidson, Professor of Meteorology
P. S. Guest, Meteorologist
P. Frederickson, Physical Scientist
Sponsor: Office of Naval Research (ONR-1125AR), and
Naval Oceanographic and Atmospheric Research Laboratory
(NORAL- West)
Funding: Naval Postgraduate School

OBJECTIVE: Objectives of continuing Arctic Meteorology Studies are to describe arctic atmospheric boundary layer structure from analyses and interpretations of data collected in two Marginal Ice Zone EXperiments (MIZEX-84 and -87) and in the Coordinated Eastern ARctic EXperiment (CEAREX- 88 & 89).

SUMMARY: Analyses and interpretations of vector wind and wind stress data collected in MIZEX-84 and -87 yielded results relating surface roughness to ice types (Guest and Davidson, 1991). MIZEX-84 Rawinsonde and surface radiation data were used to evaluate results from a model study of summer radiation budget (Francis et al., 1991). The ice/snow surface temperature was found to be controlled by a balance between upward and downward longwave emission. The latter is greatly influenced by the warm isothermal layer above the inversion (Overland and Guest 1991).

PUBLICATIONS: Francis, J. A., Ackerman, T.P., Katsaros, K.B., Lind, R.J., and Davidson, K.L., "A Summer Radiation Budget for the Fram Strait Marginal Ice Zone," Journal of Climate, 4:218-235, February 1991.

Guest, P. S. and Davidson, K.L., "The Aerodynamic Roughness of Different Types of Sea Ice," *Journal of Geophysical Research*, 96:4709-4722, March 1991.

Overland, J. E. and Guest, P.S., "The Arctic Snow and Air Temperature Budget over Sea Ice during Winter," *Journal of Geophysical Research*, 96: 4651-4662, March 1991.

Guest, P. S., and Davidson, K.L., "Meteorological Triggers for Deep Convection in the Greenland Sea," Elsevier Oceanography Series, 57, *Deep Convection and Deep Water Formation*, pp. 369-376, July 1991.

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CONFERENCE PRESENTATION: Guest, P.S. and Davidson, K.L., "The Effect of Cloudiness on Heat Loss From Pack Ice During Dark Seasons," Fall Meeting, American Geophysical Union, San Francisco, CA, 9-13 December 1991.

OPTICAL PROPERTIES OF AND VERTICAL AEROSOL MODEL FOR THE MARINE ATMOSPHERIC BOUNDARY LAYER

K. L. Davidson, Professor of Meteorology
Sponsor: Naval Ocean Systems Center (Code 54)
Funding: Cost Share: NPS and NOSC, Code 54

OBJECTIVE: Objectives of this continuing study are to perform evaluations of the Navy Oceanic Vertical Aerosol Model (NOVAM) with a range of aerosol and meteorological data sets [Eastern North Pacific (FIRE), west North Atlantic (FASINEX), and Tropical (KEY-90)] with regard to different boundary layer structure components of NOVAM.

SUMMARY: Editing was performed on aerosol and meteorological data collected during the FIRE experiment from the R/V Pt. Sur. Extinction coefficients were calculated from the aerosol size distributions for visible, and near and far infrared wavelengths. These calculations indicate that success estimating the observed extinction exists with the surface component of NOVAM (NAM). Interpretations of combined rawinsonde, surface layer meteorology and aircraft aerosol profiles indicated that the NOVAM shallow convection model had reasonable success in estimating the aerosol extinction profile shape up to the top of the mixed layer. Average (climatological) estimates performed as well as the individual predictions due to spatial variabilities occurring in regions influenced by free convection (Cerece, 1991).

THESIS DIRECTED: Thomas H, Cerece, LT, USN, " An Evaluation of the Naval Oceanic Vertical Aerosol Model during KEY90," MS Thesis, June 1991.

METEOROLOGICAL DATA BASE FOR EASTERN ARCTIC REGIONS

K. L. Davidson, Professor of Meteorology
Peter S. Guest, Meteorologist
Tamar Neta, Computer Analyst
Sponsor: Office of Naval Research (Code 1125AR)
Funding: ONR, Code 1125

OBJECTIVE: Objectives of this continuing study were to create a data base of meteorological parameters for regions around Spitzbergen archipelago and the Greenland Sea.

SUMMARY: Final editing was performed on meteorological data collected during the MIZEX 83, 84 and 87 experiments and the CEAREX 88-89 experiments. These were provided on computer compatible media to the National Snow and Ice Data Center (NSIDC), Boulder CO for distribution as CD media formats. The distribution is being performed by NSIDC with documentation and updated information provided by NPS.

METEOROLGICAL STUDIES OF ARCTIC REGIONS

K. L. Davidson, Professor of Meteorology
P. S. Guest, Meteorologist
P. Frederickson, Physical Scientist
Sponsor: Office of Naval Research (ONR-1125AR), and
Naval Oceanographic and Atmospheric Research Laboratory
(NORAL- West)
Funding: Naval Postgraduate School

OBJECTIVE: Objectives of continuing Arctic Meteorology Studies are to describe arctic atmospheric boundary layer structure from analyses and interpretations of data collected in two Marginal Ice Zone EXperiments (MIZEX-84 and -87) and in the Coordinated Eastern ARctic EXperiment (CEAREX- 88 & 89).

SUMMARY: Analyses and interpretations of vector wind and wind stress data collected in MIZEX-84 and -87 yielded results relating surface roughness to ice types (Guest and Davidson, 1991). MIZEX-84 Rawinsonde and surface radiation data were used to evaluate results from a model study of summer radiation budget (Francis et al., 1991). The ice/snow surface temperature was found to be controlled by a balance between upward and downward longwave emission. The latter is greatly influenced by the warm isothermal layer above the inversion (Overland and Guest 1991).

PUBLICATIONS: Francis, J. A., Ackerman, T.P., Katsaros, K.B., Lind, R.J., and Davidson, K.L., "A Summer Radiation Budget for the Fram Strait Marginal Ice Zone," Journal of Climate, Vol. 4, 218-235, February 1991.

Guest, P. S. and Davidson, K.L., "The Aerodynamic Roughness of Different Types of Sea Ice," Journal of Geophysical Research, 96, 4709-4722, March 1991.

Overland, J. E. and Guest, P.S., "The Arctic Snow and Air Temperature Budget over Sea Ice during Winter," Journal of Geophysical Research, Vol 96, 4651-4662, March 1991.

Guest, P. S., and Davidson, K.L., "Meteorological Triggers for Deep Convection in the Greenland Sea," Elsevier Oceanography Series, #57, Deep Convection and Deep Water Formation, 369-376, July 1991.

Von de Heydt, N. R., Galbraith, A. B., Baggeroer, R., Muench, Guest, P. S., and Davidson, K. L., 1991: "CEAREX 'A'-Camp: Navigation, Bathymetry, CTD, Meteorology, and LOFAAR Data Report," Woods Hole Oceanographic Institution, Technical Memorandum WHOI-1-91, January 24, 1991.

CONFERENCE PRESENTATION: Guest, P.S., and Davidson, K.L., "The Effect of Cloudiness on Heat Loss From Pack Ice During Dark Seasons," Fall Meeting, American Geophysical Union, San Francisco, CA, December 9-13, 1991.

ATMOSPHERIC BOUNDARY LAYER STUDIES OF ARCTIC REGIONS

K. L. Davidson, Professor of Meteorology
P. S. Guest, Meteorologist
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory (NORAL- west)
Funding: NORAL - West

OBJECTIVE: The goal of this project is to improve our understanding of atmospheric forcing of interior ice regimes by analyses of in situ and satellite data obtained during the Coordinated Eastern Arctic Experiment (CEAREX).

SUMMARY: Analysis of in situ data obtained during storm passages over CEAREX platforms provided information on the value of meteorological satellite imagery to describe regional variations (Hamilton, 1991). A complied data set relates mixed-layer depth, stability, clouds, radiation, and surface fluxes to distance from the ice edge and air mass origin. Relationships were obtained to relate central arctic surface winds to the geostrophic wind (Overland and Davidson, forthcoming).

PUBLICATIONS: Frederickson, P.A., Guest, P.S., and Davidson, K.L., "CEAREX/ Haakon Mosby Meteorological Atlas," NORAL TN 82, Naval Oceanographic and Atmospheric Research Laboratory, Monterey, CA, 57 pp, December 1990.

Overland, J. E., and Davidson, K.L., "Geostrophic Drag Coefficients Over Sea Ice," Tellus (Forthcoming).

CONFERENCE PRESENTATION: Davidson, K.L., Guest, P.S., and Frederickson, P.A., "The Effect of Stratification the in Lower Marine Arctic Atmosphere on Interactions with the Surface," Fall Meeting, American Geophysical Union, San Francisco, CA, December 9-13, 1991.

THESIS DIRECTED: Hamilton, S.W., LT, USN, "Meteorological Features during Phase I of the Coordinated Eastern Arctic Experiment (CEAREX) from 17 September to 7 January 1989," Master's Thesis, March 1991.

MARINE STRATOCUMULUS CLOUD REFLECTANCE: IMPLICATIONS FOR AEROSOL-CLOUD INTERACTION AND ENTRAINMENT

Philip A. Durkee, Associate Professor of Meteorology
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The proposed effort investigated the effects of aerosol variation and cloud-top entrainment on marine stratocumulus cloud reflectance. Previous experimental results were used to examine the signature of variable entrainment. The study will culminate in participation in ASTEX during FY92.

SUMMARY: This program of study was in the second of three years, culminating in participation in the ASTEX field program in June 1992. The primary objective was investigation of the radiative processes that result from cloud and aerosol particle interaction and the effects of cloud-top entrainment. Emphasis was placed on analysis of aerosol and cloud observations to gain insight into the effects of aerosol particles and entrainment on the microphysics of clouds. Investigations focused on cloud types that are most affected by aerosol and cloud interactions, especially in the ASTEX region (Azores/Madeira Islands). These include marine stratocumulus, especially where variable marine and continental effects are important. Since marine stratocumulus cloud processes are largely driven by radiative heating/cooling, cloud reflectance effects should provide valuable insight into cloud formation/dissipation mechanisms. Specific accomplishments included continued examination of the ASTEX region with emphasis on case studies of aerosol-cloud interactions. LT Karen Ruppe began her thesis work which will focus on analysis of the ASTEX region with comparisons to Tettelbach (1987). Emphasis will be on Saharan dust, North American and European continental sources, and oceanic sources. Planning of observation strategies necessary to examine the effects of aerosol-cloud interaction and entrainment on cloud reflectance was conducted through participation in FIRE/ASTEX Science Team meetings in Wichita, KS and Fair Lakes, VA. Plans for collaboration with aircraft, ship and ground-based measurements were developed. Results of the planning efforts are documented in the ASTEX Operations Plan (in preparation). A site visit was conducted to Santa Maria, Azores to plan logistics for operation of a real-time satellite data receiver. HRPT receipt and analysis of AVHRR and TOVS data will be conducted in coordination with mission operations to support aircraft, ship and surface measurement programs. The planning includes inclusion of full analysis capabilities to produce imagery, estimates of aerosol optical depth, aerosol size index, cloud reflectance at 0.63 and 3.7 microns wavelength.

PUBLICATIONS: Durkee, P.A. and Mineart, G.M., "Multispectral Satellite Analysis of Marine Stratocumulus Cloud Microphysics." Submitted to *Journal of Geophysical Research*.

Mineart, G. M. and Durkee, P.A., "Cloud Reflectance and Entrainment." To be submitted as a note to the *Journal of Geophysical Research*.

Durkee, P. A., Motell, C.E. and Tettelbach, F.M., "Aerosol-Cloud Interactions in the Northeast Pacific Ocean." To be submitted to the *Journal of Geophysical Research*.

Durkee, P. A., Kren, R. and Smolinski, S., "Marine Boundary Layer Depth and Relative Humidity Estimation using Multispectral Satellite Measurements." To be submitted to *International Journal of Remote Sensing*.

CONFERENCE PRESENTATION: Twohy, C. H., Huebert, B. J., Durkee, P. A. and Charlson, R. J., "Airborne Measurements of Droplet Chemistry in Stratiform Clouds." Presented at IUGG General Assembly, Vienna, Austria, August 1991.

THESES DIRECTED: Kren, R., "Marine Boundary Layer Depth and Relative Humidity from Multispectral Satellite-Detected Radiance." MS Thesis, 1987.

Mineart, G. M., "Multispectral Satellite Analysis of Marine Stratocumulus Cloud Microphysics." MS Thesis.

Rogers, J. M., "Investigation of Anomalous Cloud Features in 3.7 Micrometer Satellite Imagery." MS Thesis, 1988.

Smolinski, S., "Marine Boundary Layer Depth and Relative Humidity Estimation using Multi-Spectral Satellite Measurements." MS Thesis, 1988.

Tettelbach, F. M., "Stratocumulus and Cloud-Free Reflectance from Multispectral Satellite Measurements." MS Thesis, 1987.

SAGE III SCIENCE TEAM

Philip A. Durkee, Associate Professor of Meteorology
Sponsor: National Aeronautics and Space Administration
Funding: National Aeronautics and Space Administration

OBJECTIVE: The objectives during phase B of SAGE III development to examine global aerosol distribution observations from NOAA AVHRR and SAGE I and II measurements and identify regions of potentially high aerosol- climate impact. Primary emphasis was on the upper tropospheric observations available from SAGE I and II.JA second objective was to examine case studies of AVHRR-SAGE II comparisons. AVHRR aerosol optical depth was compared to profiles of extinction from SAGE II. Issues such as upper tropospheric cloud contamination were also considered. The goal of this work was to show the usefulness of analyses incorporating SAGE III observations with nadir views from high spectral and spatial resolution radiometers on EOS such as MODIS and HIRIS.

SUMMARY: Global summaries of aerosol optical depth have been prepared for April 1982-84 using NOAA-7 AVHRR. Features such as Saharan dust, continental plumes of anthropogenic pollution, and advected smoke from biomass burning were detected. Also apparent in these analyses was a distinct difference between optical depth in the northern and southern hemispheres. These results are consistent with SAGE I tropospheric results reported by Kent et al. (1988) and SAGE II results distributed by Kent to the SAGE III Science Team (unpublished). From these results it appears that much of the hemispheric differences observed in the total aerosol optical depth from AVHRR measurements are due to upper tropospheric aerosols advected from continental sources (anthropogenic and terrestrial). Comparisons between SAGE II extinction profiles and AVHRR optical depth are in progress. Cases are being identified from April (peak in Asian dust transport across the Pacific) and July (Saharan dust cases) 1985. The phase C/D efforts will include continued comparison of AVHRR and SAGE II cases. Emphasis will be placed on sources responsible for long range aerosol transport at mid-tropospheric levels. Saharan and Gobi Desert dust events, pollution episodes in eastern Asia and northeastern US, and smoke from agricultural and natural burning will all be examined. To the extent that tropospheric aerosols are included in the SAGE III studies, this effort will investigate relationships between various aerosol optical depth regimes and cloud reflectance characteristics. These studies will include examination of multispectral radiative signatures of aerosol features and the impact of MODIS and HIRIS estimates of aerosol characteristics. Also in phase C/D, support of field measurement programs planned under the SAGE III effort will be provided using satellite-based measurements and analyses of spectral optical depth and aerosol transport. These observations will be applicable to real time aircraft operations and post experiment analysis.

PUBLICATIONS: Durkee, P. A., F. Pfeil, Frost, E. and Shema, R., "Global Analysis of Aerosol Particle Characteristics and Implications for Effects on Climate." *Atmos. Environ.*, 25A:2457-2465. (Also supported by other projects).

ELECTRONIC WEAPON SYSTEM SATELLITE SUPPORT

Philip A. Durkee, Associate Professor of Meteorology
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory
Funding: Naval Oceanographic and Atmospheric Research Laboratory

OBJECTIVE: Development continued on a method to estimate visibility from satellite measurements of upwelling radiance. The technique was be validated against sources of ground truth measurements.

SUMMARY: Electro-optical sensors on weapon systems are sensitive to regions of reduced extinction by atmospheric aerosols. Meteorological range (or visibility) is one parameter used to characterize the amount of optically active aerosol in the atmosphere. The variation of aerosol optical depth is detectable by current meteorological satellites. The work proposed here will continue development of a system for estimating meteorological range from estimates of aerosol optical depth. This proposal is a continuation of work begun in FY86. That effort began with an evaluation of the Defense Meteorological Satellite Program - Optical Line Scan sensor (DMSP OLS) and the National Oceanic and Atmospheric Administration - Advanced Very High Resolution Radiometer (NOAA AVHRR). The limitations of these sensors were examined and it was shown that the DMSP OLS system has severely limited sensitivity to aerosol scattering. Further, the AVHRR has been shown to be capable of distinguishing marine from continental aerosol distributions (Durkee, 1985). This has been shown to greatly aid the meteorological range estimation process. Therefore, the work performed in FY87 concentrated on techniques employing the AVHRR on the NOAA polar orbiting satellites. During FY88 the algorithms were developed into an operational system. Also, work was begun on incorporation of a boundary layer depth estimation scheme into the meteorological range estimation. During the last two years, emphasis was placed on validation of the algorithms. Comparisons were made between satellite-based estimates and ship-based observations of aerosol properties, using data from cruises through the western Mediterranean Sea and central North Pacific Ocean. The meteorological range estimation technique relies on determination of aerosol optical depth from satellite measurements of scattered solar irradiance. Meteorological range is estimated from the optical depth estimate in areas where most of the aerosol resides in the marine atmospheric boundary layer. This is a good assumption over much of the subtropical and midlatitude ocean basins. Given an estimate of boundary layer depth, and a value of extinction by aerosols, an estimate of boundary layer meteorological range can be calculated. Inexact relationships within the estimation procedure allow for only very crude categories of range estimation (such as low - 0-5 km, medium - 5-15 km and high - > 15 km). Also, careful and extensive validation of the scheme is necessary. In this year's effort, the techniques were be expanded to include a direct estimate of boundary layer depth from satellite measurements. Also, given dual-wavelength radiance measurements, an estimate of infrared extinction were also be studied. Validation of the aerosol optical depth and meteorological range estimation schemes is a continuing requirement to understand the effects of variable particle composition, size distribution and vertical profile. Once the meteorological range estimation scheme has been developed and validated, the potential exists for production of global climatologies of meteorological range.

PUBLICATION: Haggerty, J. A., Durkee, P. A. and Wattle, B. J., "A comparison of surface and satellite-derived aerosol measurements in the western Mediterranean." *Journal of Geophysical Research*, 95:1547-1557.

THESES SUPPORTED: Clifford, M., "Effects of Water Vapor on Detection of Aersosol Properties in the Central Pacific Ocean." MS Thesis, 1991.

Frost, E. M., "Global Estimates of Aerosol Particle Characteristics." MS Thesis, 1988.

Garcia de Quevedo, M., "Estimation of Extinction Coefficients at 3.75 and 11.00 mm from Satellite Measurements at 0.63 and 0.86 mm." MS Thesis, 1987.

Kren, R., "Marine Boundary Layer Depth and Relative Humidity from Multispectral Satellite-Detected Radiance." MS Thesis, 1987.

Mahony, T. P., "Water Vapor Influence on Satellite-Measured Aerosol Characteristics." MS Thesis, 1991.

Miller, B. H., "Improved Aerosol Optical Depth and Particle Size Index from Satellite Detected Radiance." MS Thesis, 1991.

Pfeil, F. R., "Developing a Physical Basis for an Aerosol Climatology of the Pacific Basin." MS Thesis, 1986.

Smolinski, S., "Marine Boundary Layer Depth and Relative Humidity Estimation using Multispectral Satellite Measurements." MS Thesis, 1988.

SATELLITE INVESTIGATIONS OF AEROSOL PARTICLE DISTRIBUTIONS ASSOCIATED WITH DMS AND THEIR RELATIONSHIP TO MARINE CLOUD CHARACTERISTICS

Philip A. Durkee, Associate Professor of Meteorology
Sponsor: National Aeronautics and Space Administration
Funding: National Aeronautics and Space Administration

OBJECTIVE: The objectives of this project are two-fold. First, we have supported the planning, implementation and execution of the field programs under the PSI (Pacific Sulfur/Stratus Investigation). Second, we are continuing our regional and global scale analysis of aerosol and cloud properties.

SUMMARY: Planning of location and timing of field programs were aided by analysis of global scale cloud and aerosol characteristics, particularly plans to participate with JGOFS in the central Pacific Ocean in spring 1992. We are preparing summaries and composites of PSI-1, -2 and -3 aerosol and cloud characteristics from our satellite techniques. These will be compared with ship and aircraft observations. A priority task is to composite our satellite data into on-shore and off-shore cases to assess the impact of continental (anthropogenic and terrestrial) sources. We have studied our preliminary results of global analyses for April 1982, 1983, and 1984 and have included improvements to our analysis of aerosol optical depth, size index, and cloud reflectance. We are proceeding with summaries of July, October and January 1983 and 1984. We have also finalized our results of comparisons between satellite composites and plankton blooms detected near Iceland. Results of comparisons during the RITS cruise (April 1988) are also complete and show a strong correlation between aerosol features and cloud reflectance properties. We are beginning and analysis of the RITS 1989 cruise in the eastern Pacific Ocean where we will concentrate on southern latitudes to examine the effects in a relatively clean atmosphere.

PUBLICATIONS: Durkee, P. A., Pfeil, F., Frost, E. M. and Shema, R. A., "Global Scale Aerosol Particle Characteristics from Satellite-Detected Radiance." *Atmos. Environ.*, 25A:2457-2465. (Also supported by other projects)

Durkee, P. A., "Global Scale Analysis of Aerosol and Cloud Properties: Implications for Anthropogenic influences on Climate." In preparation for submission to Nature.

TROPICAL CYCLONE MOTION (TCM-90) RESEARCH

Russell L. Elsberry, Professor of Meteorology
Patrick A. Harr, Adjunct Professor of Meteorology
Sponsor: Office of Naval Research (Code 1122MM)
Funding: Naval Postgraduate School

OBJECTIVE: The overall objective of the ONR Accelerated Research Initiative on tropical cyclone motion is to improve basic understanding. The long-term goal is to improve track predictions of these dangerous cyclones.

SUMMARY: One short-term goal during this fiscal year was to complete the data collections from the Tropical Cyclone Motion (TCM-90) field experiment and three coincidental international field experiments (Elsberry et al. 1990). The data user's guide (Harr et al. 1991) was published and the two magnetic tapes have been widely distributed. A supplemental data set will be distributed when processing of the final enhancement cloud-drift wind sets during 15-20 August 1990 are available. A set of final analyses are in preparation using the four-dimensional data assimilation system at the National Meteorological Center.

The influence of the environmental vorticity gradient on tropical cyclone motion has been modelled with a shallow-water equation model (Evans et al. 1991). Systematic deviations from the background steering flow occur for cyclones placed in the monsoon trough, between the trough and the subtropical ridge, and poleward of the ridge. An analytical representation of the asymmetrical circulation in tropical cyclones has been demonstrated (Carr and Elsberry, 1992) to remove the slow bias in the track predictions with barotropic models. This slow bias is a problem that has always degraded the early portions of dynamical model track predictions. Thus, the application of the proposed initial conditions should result in improved track predictions for operational fleet support.

PUBLICATIONS: Evans, J.L., Holland, G.J. and Elsberry, R.L., "Interactions Between a Barotropic Vortex and an Idealized Subtropical Ridge: I. Vortex Motion," *Journal of Atmospheric Science*, 48(2):301-314, January 1991.

Carr, L.E. III and Elsberry, R.L., "Analytical Tropical Cyclone Asymmetric Circulation for Barotropic Model Initiation Conditions," accepted by *Monthly Weather Review*, 120(3), March 1992.

Elsberry, R.L. (with others), "ONR Tropical Cyclone Motion Research Initiative: Field Experiment Summary." NPS Technical Report NPS-MR-91-001, December 1990.

Elsberry, R.L., "Recap and Future Research Opportunities for the Tropical Cyclone Motion (TCM-90) Field Experiment," Technical Document WMO/TD, No. 426, Report TCP-27. World Meteorological Organization, Geneva, Switzerland, pp. 3-22, 1991.

Harr, P.A., Neta, T. and Elsberry, R.L., "ONR Tropical Cyclone Motion Research Initiative: Data User's Guide to Observations," NPS Technical Report NPS-MR-91-002, July 1991.

Elsberry, R.L. and Abbey, R.F., Jr., "Recent Advances in Understanding Tropical Cyclone Motion," NPS Technical Report NPS-MR-92-001, September 1991.

CONFERENCE PRESENTATIONS: Elsberry, R.L., "Recap of the Tropical Cyclone Motion (TCM-90) Field Experiment and Future Research," Keynote address, 45th Interdepartmental Hurricane Conference, Homestead, FL, 5-8 February 1991.

Elsberry, R.L., "Recap of the Tropical Cyclone Motion (TCM-90) Field Experiment and Future Research," in proceedings of the 1991 Tropical Cyclone Conference, Honolulu, HI, February 1991.

Elsberry, R.L. and Abbey, R.F., Jr., "Overview of the Tropical Cyclone Motion (TCM-90) Field Experiment," preprints, 19th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 1-6 May 1991.

Dobos, P.H., Lind, R.J. and Elsberry, R.L., "Doppler Radar Wind Profiler Observations From Okinawa During TCM-90," preprints, 19th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 10-15 May 1991.

Dunnavan, G., Elsberry, R.L., Ritchie, L., Holland, G.J. and Lauritsen, D., "Structure of Supertyphoon Flo During TCM-90" preprints, 19th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, 21-26 May 1991.

Elsberry, R.L., "Summary of the Tropical Cyclone Motion (TCM-90) Field Experiment," Keynote address, Fifth International Symposium on Tropical Meteorology, Obninsk, USSR, May 1991.

Elsberry, R.L., "Update on the Tropical Cyclone Motion (TCM-90) Field Experiment," Keynote address, International Tropical Cyclone Symposium, Tokyo, Japan, July 1991.

Elsberry, R.L., "Status of the Tropical Cyclone Motion (TCM-90) program," Keynote address, Technical Conference on SPECTRUM, Guangzhou, PRC, November 1991.

Elsberry, R.L., "Tropical Cyclone Motion and Environmental Steering," Keynote lecture, Technical Conference on SPECTRUM, Guangzhou, PRC, November 1991.

TROPICAL CYCLONE MOTION STUDIES

Russell L. Elsberry, Professor of Meteorology
Patrick A. Harr, Adjunct Professor of Meteorology
Sponsor: Office of Naval Research (1122MM)
Funding: Naval Postgraduate School

OBJECTIVE: The long-term goal is to understand the processes involved in tropical cyclone motion.

SUMMARY: Harr and Elsberry (1991) have demonstrated that large-scale circulation features that exist at the time of tropical cyclone formation determine the subsequent track-type in a majority of cases. An index based on the anomalous 700 mb zonal winds averaged in 5° lat bands between 100° E and 140°E has been formulated to predict the track type, and is being tested.

A status report on tropical cyclone intensity prediction has been prepared (Elsberry et al. 1992) based on a panel discussion at the 19th Conference on Hurricanes and Tropical Meteorology. As tropical track predictions improve, the understanding of the structure and structure change (including intensity prediction) is becoming more important.

An observational and numerical track study of the upstream track deflections for tropical cyclones approaching Taiwan from the east has been completed (Yeh and Elsberry 1991). Contrary to prior studies, no systematic upstream deflection is found. A previously indicated acceleration in track translation is shown to be attributed to large-scale circulations rather than the topography of Taiwan.

Gunzelman (1991) has represented the influence of adjacent synoptic features on tropical cyclone motion by means of Empirical Orthogonal Functions of the vorticity fields. In addition to interactions with other tropical cyclones, other cyclones or anticyclones appear to influence the track changes.

PUBLICATIONS: Harr, P.A. and Elsberry, R.L., "Tropical Cyclone Track Characteristics as a Function of Large-Scale Circulation Anomalies," *Monthly Weather Review*, 119(6):1448-1468.

Elsberry, R.L., DeMaria, M., Holland, G.J., Gerrish, H., Guard, C.P. and Emanuel, K., "Is There Any Hope for Tropical Cyclone Intensity Prediction? -- A Panel Discussion," accepted by the Bulletin American Meteorological Society, 73(3), March 1992.

Elsberry, R.L., "Tropical Cyclone Motion," Chapter 4, in proceedings of the Second WMO International Workshop on Tropical Cyclones (ITWC-II). WMO/TD, No. 361, World Meteorological Organization, Geneva, Switzerland, pp. 27-34, 1990.

CONFERENCE PRESENTATIONS: Harr, P.A. and Elsberry, R.L., "Tropical Cyclone Track Characteristics as a Function of Large-Scale Circulation Anomalies," preprints, 19th Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, Boston, MA, pp. 284-289, May 1991.

Harr, P.A. and Elsberrym R.L., "Relationships Between Tropical Intraseasonal Oscillations and Tropical Cyclone Characteristics over the Western North Pacific," preprints, 5th Conference on Climate Variations, American Meteorological Society, Boston, MA, pp. 244-248, October 1991.

Yeh, T.-C. and Elsberry, R.L., "Upstream Track Deflections Caused by the Taiwan Orography," preprints, conference on Mesoscale Meteorology and TAMEX, Taipei, Taiwan, ROC, pp. 342-349, December 1991.

THESIS DIRECTED: Gunzelman, M.J., LCDR, USN, "Tropical Cyclone Motion due to Environmental Interactions Represented by Empirical Orthogonal Functions of the Vorticity Fields," MS Thesis, June 1991.

OBSERVATIONAL-NUMERICAL STUDIES OF SEVERE SYNOPTIC WEATHER PHENOMENA

Russell L. Elsberry, Professor of Meteorology
Patrick A. Harr, Adjunct Professor of Meteorology
Sponsor: Naval Oceanographic and Atmospheric Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research project is improved numerical guidance of severe synoptic-scale weather features that have a large impact on Fleet operations.

SUMMARY: The potential increase in utility of numerical forecasts of maritime sea-level cyclones was investigated via comprehensive examination of a large data base that describes the error characteristics of the numerical forecasts. Harr et al. (1992) showed that the quality of the numerical forecasts are very depended upon several physical factors such as the cyclone location, movement and large-scale environment. Numerical forecast errors for certain types of maritime cyclones can be quite different from the systematic errors defined from an average of many cyclones types. Harr et al. (1992) also conclude that the variability in numerical forecasts accuracy and its dependence upon several physical factors precludes the use of many statistical approaches for increasing the utility of the numerical forecast to the general user.

PUBLICATIONS: Clune, W.M., Harr, P.A. and Brody, L.R., "The Man-Machine Mix in Operational Product Quality Control and Verification at Fleet Numerical Oceanography Center," *Weather and Forecasting*, 7(2), (accepted for publication).

Harr, P.A., Elsberry, R.L., Hogan, T. and Clune, M., "Forecasts of North Pacific Maritime Cyclones with the Navy Operational Global Atmospheric Prediction System," *Weather and Forecasting*, (submitted).

CONFERENCE PRESENTATIONS: Harr, P.A., Elsberry, R.L., Hogan, T. and Clune, W.M., "North Pacific System (NOGAPS)," preprints, 9th Conference on Numerical Weather Prediction, American Meteorological Society, Boston, MA, pp. 746-749, October 1991.

EDDY GENERATION MECHANISMS IN EASTERN BOUNDARY CURRENT REGIONS

Robert L. Haney, Professor of Meteorology
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to investigate ocean processes that lead to the formation of jets, squirts, eddies and other turbulent phenomenon in eastern boundary current regions. Numerical model studies using data collected in the ONR-sponsored Coastal Transition Zone (CTZ) program are being carried out to investigate the circulation and dynamics of cold filaments in the CTZ region.

SUMMARY: As a first step to study the effects of bottom topography on cold filaments in the CTZ, a study was competed which documents the numerical resolution and methods required to accurately model flow over steep topography (Haney, 1991). A data assimilation study of the three dimensional circulation associated with a cold filament observed in the California coastal transition region is in progress. The results show a strong offshore jet along the northern edge of the observed filament with maximum horizontal currents of the order of 1 m s^{-1} near the surface. Currents associated with this jet are coherent to a depth of well over 500 m. meandering jets such as this in the CTZ are found to display divergence and upwelling downstream of pressure troughs, where the jet is generally directed onshore, and convergence and downwelling upstream of pressure troughs, where the jet is generally directed offshore. In the main offshore jet, the diagnosed downwelling at the base of the thermocline is 10-20 m d^{-1}. These values are consistent with independent estimates of subduction rates in this and similar coastal filaments made from biological studies.

PUBLICATIONS: Strub, P.T. and 21 more authors including Haney, R.L., "The Nature of Cold Filaments in the California Current System," *Journal of Geophysical Research, 96:14743-14768.*

Haney, R.L., "On the Pressure Gradient Force over Steep Topography in Sigma Coordinate Ocean Models," *Journal of Physical Oceanography*, 21:610-619.

CONFERENCE PRESENTATIONS: Haney, R.L., and Stanton, T.P., "The three dimensional velocity structure of a meandering jet in the eastern boundary coastal transition zone." XX General Assembly of the IUGG, Vienna, Austria, 11-24 August 1991.

Haney, R.L., "On the pressure gradient force over steep topography in sigma coordinate ocean models." XX General Assembly of the IUGG, Vienna, Austria, 11-24 August 1991.

Haney, R.L., "Estimating subthermocline density fluctuations from upper ocean observations." Presented at the Fall AGU Meeting, San Francisco, CA, 9-13 December 1991.

THESIS DIRECTED: Mallette, J.R., Jr., "A diagnostic study of the velocity structure of a meandering jet in the California current system using a primitive equation model." MS Thesis, June 1991.

NUMERICAL AND OBSERVATIONAL STUDIES OF THE MESOSCALE STRUCTURE OF THE ATMOSPHERIC BOUNDARY LAYER

T.R. Holt, Assistant Professor of Meteorology

Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project was to examine important coastal mesoscale phenomena using the three-dimensional Naval Research Laboratory (NRL) regional numerical model. Implementation of the numerical model was accomplished for a case study of varying synoptic conditions along the west coast of the United States during May 1990 in which observational NPS Doppler wind profiler data were available.

SUMMARY: Previous research (1990 RIP by Holt) involving the NRL numerical model along the east coast of the U.S. has indicated that the use of the advanced turbulent kinetic energy (TKE) boundary layerclosure scheme in a three-dimensional numerical mesoscale model provided better forecasts of the horizontal and vertical structure of complex mesoscale phenomena, such as developing coastal fronts, than simpler bulk boundary layer parameterizations. Progress in the area of numerical modeling of complex terrain was accomplished in this project by the implementation and development of the NRL mesoscale model with the above mentioned complex TKE boundary layer closure for case studies along the west coast of the U.S. The case study of present interest (See "OTHER" below for description of two student theses in progress) is the 1-5 May 1990 case of varying synoptic conditions. NPS Doppler wind profiler data were available along with NPS student cruise data to provide enhanced observational data for model verification. In addition, the period was one is which the varying large scale flow patterns allowed for examination of model flow and its interaction with complex terrain under conditions of offshore, alongshore and onshore flow.

OTHER: Two students are presently working on their theses pertaining to numerical simulations involving complex coastal flow using the NRL mesoscale model. LCDR Frank Grandau, USN ("Evaluation of the NRL limited area dynamical weather prediction model along the west coast of the United States", March 1992 graduation) is investigating model simulations and their sensitivity to complex terrain for the May 1-5, 1990 case study with NPS Doppler wind profiler data. LT Paul Stewart, USN ("A developmental and comparative evaluation of cumulus and stratus parameterization schemes in the NRL limited area dynamical weather prediction model", September 1992 graduation) is investigating improved cloud parameterizations and their effects on NRL model simulations for the same May 1990 case study.

MODELING OF ATMOSPHERIC MESOSCALE PROCESSES

T.R. Holt, Assistant Professor of Meteorology
Sponsor: Naval Research Laboratory
Funding: Naval Research Laboratory

OBJECTIVE: The goal of this project was to understand the importance and interaction of physical processes occurring in the marine boundary layer using Observing System Simulation Experiments (OSSE) for cases of coastal and oceanic cyclogenesis during the Genesis of Atlantic Lows Experiment (GALE) and the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA).

SUMMARY: The fraternal twin OSSE design, using the advanced NRL numerical mesoscale model and DMSP Special Sensing Microwave Imager (SSM/I) data, is employed to consider the role of three important parameters in the development and intensification of coastal and oceanic cyclones. Numerical simulations were conducted to examine the importance of diabatic heating (i.e., rainfall rate), surface wind speed, and integrated water vapor. Results focused on the sensitivity of simulations to high or low bias, assimilation frequency, forcing period, data time lag, determination of vertical profiles, and swath width. Significant conclusions were that (i) a progressive, but diminishing, benefit can be derived from more frequently assimilated observations, (ii) simulations are not extremely sensitive to model/algorithm error (bias), supporting the theory that preconditioning, or timing, of the important parameters is often more important than their magnitude, (iii) observed vertical profiles provide improved forecasts over model-determined profiles, particularly for integrated water vapor profiles, and (iv) simulations are sensitive to the dominant physical mechanisms responsible for cyclogenesis, i.e., is the storm primarily diabatically or dynamically forced.

CONFERENCE PRESENTATIONS: Holt, T.R., and Chang, S., "Numerical studies of important physical processes in the evolution of the GALE IOP2 cyclone," First International Symposium on Winter Storms, New Orleans, LA, 13-18 January 1991.

Chang, S.W. and Holt, T.R., "Impact of SSM/I rainfall rate on numerical prediction of cyclones: An observing system simulation," First International Symposium on Winter Storms, New Orleans, LA, 13-18 January 1991.

Chang, S.W., Sashegyi, K.D. and Holt, T.R., "Important physical processes in the evolution of mesoscale frontal structure of the ERICA IOP4 cyclone," Ninth Conference on Numerical Weather Prediction, Denver, CO, 14-18 October 1991.

OTHER: For his thesis LT William J. Schulz, USN ("Wind speed and moisture sensitivity tests with a numerical model simulation of an explosive north Atlantic cyclone: An OSSE", March 1992 graduation) is examining the ERICA IOP4 cyclone using SSM/I data. A journal article entitled "Sensitivity of GALE IOP2 cyclogenesis to low-level diabatic processes" by T.R. Holt and S.W. Chang has been submitted to Monthly Weather Review.

GLOBAL ATMOSPHERIC AND OCEANOGRAPHIC PROCESSES

Tom Murphree, Adjunct Research Professor of Meteorology
C.-P. Chang, Professor of Meteorology
J.-M. Chen, Adjunct Research Professor of Meteorology
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory
Funding: Naval Oceanographic and Atmospheric Research Laboratory

OBJECTIVE: The purpose of this study is to uncover the mechanisms behind global scale atmospheric and oceanographic variations. Our studies emphasize variations that occur on weekly to monthly time scales (i.e., short term climate scales) and that involve significant air-sea interactions.

SUMMARY: This research has been conducted in collaboration with colleagues in the Department of Oceanography at NPS, and at NOARL, FNOC, CAC, and the University of Hawaii. There are four major components of this research:

1. modeling and observational studies of the wave dynamics of global scale interactions;
2. observational and modeling studies of interactions modulated by intra-seasonal fluctuations in tropical convective heating;
3. observational and dynamical studies of tropical air-sea interactions;
4. analyses of modeled and observed large scale tropical waves.

The wave dynamics work has focused on the propagation and amplification of planetary waves associated with interactions of the tropics and midlatitudes. We have found that the sensitivity of the atmospheric wave response is strongly mediated by the temporally varying propagation, amplification, and instability characteristics of the ambient atmosphere.

In our second research area, we are examining how this wave-mediated interaction is affected by intraseasonal variations in tropical heating. The observational and modeling results indicate that such high frequency heating changes may lead to a distinct far-field response.

In the third area, we have established an ocean data and model output database which we are using to explore tropical air-sea feedbacks. Our preliminary analyses show that major low frequency variations of the equatorial air-sea system are strongly dependent on synoptic scale variations in the ocean's vertical motion field. In addition, several characteristic correlations of atmospheric and oceanographic processes have been identified that will provide a basis for improving the limited theory for tropical air-sea processes.

In our fourth area, we have identified the major structures and mechanisms of large scale waves in a model and in observations of the equatorial Pacific. Shear and thermal instabilities contribute about equally to the wave energetics. The three dimensional equatorial current system is strongly mediated by the wave-driven momentum and energy fluxes.

CONFERENCE PRESENTATIONS: Gelaro, R. and Murphree, T., "Waves, Instabilities, and Climate Variations," NPS Nonlinear Dynamics Colloquium, December 1991.

Murphree, T., Chen, J.-M., Harr, P. and Gelaro, R., "Short Term Climate Variations in the Pacific-North American Region," Climate Variations Conference, October 1991.

Murphree, T., Semtner, B. and Chervin, B., "Equatorial Instability Waves in an Ocean General Circulation Model," International Association of the Physical Sciences of the Ocean Symposium, August 1991.

Murphree, T., "The Role of Subtropical Waveguiding and Amplification in North American Climate," International Association of Meteorology and Applied Physics Symposium, August 1991.

Murphree, T., "Global Scale Tropical Forcing of North American Climate Anomalies," Hurricanes and Tropical Meteorology Conference, May 1991.

Murphree, T., Chen, J.-M. and Harr, P., "Anomalies

in North American Climate: the South Asian - Tropical West Pacific Connection," Pacific Climate Workshop, April 1991.

Harr, P., Chen, J.-M. and Murphree, T., "The Relationship of West Pacific Tropical Storm Activity to North Pacific and North American Climate Anomalies," Pacific Climate Workshop, April 1991.

McCann, M. and Murphree, T. , "Graphical Computer Analysis of a Global Ocean Model," NPS Meteorology Seminar Series, April 1991. NOARL reimbursable.

OTHER: H. van den Dool, J. Feng, and T. Murphree, "Dynamic Calculation of Teleconnections," in proceedings of the Climate Diagnostics Workshop, March 1991.

Murphree, T., "North American Climate Anomalies: The Role of Subtropical Waveguiding and Wave Amplification," submitted to J. Climate.

Murphree, T., "The Extratropical Planetary Wave Response to Global Scale Patterns of Tropical Forcing," submitted to J. Atmos. Sci.

Murphree, T., "Dynamically Consistent Correction of Systematic Model Errors," submitted to J. Atmos. Sci.

Gelaro, R. and Murphree, T., "Time-Varying Teleconnection Dynamics," to be submitted to J. Climate, March 1992.

Van den Dool, H. M., Feng, J. and Murphree, T., "Dynamical Evaluations of Statistical Teleconnection Patterns," to be submitted to J. Climate, March 1992.

Murphree, T., McCann, M. and Flament, P., "A Comparison of Modeled and Observed Tropical Instability Waves," to be submitted to J. Geophys. Res., April 1992.

BOUNDARY LAYER INTERACTION IN CYCLOGENESIS

W.A. Nuss, Professor of Meteorology
Sponsor: Naval Postgraduate School Research Foundation
Funding: Naval Postgraduate School

OBJECTIVES: The aim of this study is to describe the boundary layer structure in the vicinity of warm and cold fronts in extratropical cyclones. The primary objective is to understand how boundary layer structure and processes influence the dynamics of a developing cyclone.

SUMMARY: During 1991, the analysis of 30 cases of cyclogenesis along the coast of Asia were examined using data obtained from the National Center for Atmospheric Research (NCAR). This analysis characterized the boundary layer structure and forcing as well as the upper-level forcing in cyclones using the gridded analyses. Upper-level forcing and boundary layer forcing were found to favorably combine in moderate to intense cyclones and to be essentially independent in weak cyclones. Strong surface heating along the warm front was found to occur in the strongest cyclones, which potentially contributed to instability and a greater intensification rate. The generality of this coupling as previously identified by Nuss and Kamikawa (1990) has resulted in a set of key observables for forecasters to use in identifying the most significant cyclones when making forecasts along the coast of Asia.

THESIS DIRECTED: Adam Kippes 1991 (M.S.), Characteristics of Upper-Level and Boundary Layer Forcing in Western Pacific Cyclones.

BOUNDARY LAYER MODELING IN EXPLOSIVE CYCLOGENESIS

W.A. Nuss, Professor of Meteorology
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The long-range goal of this research is to understand the role of boundary layer processes in fronto-genesis and cyclogenesis and to better represent these processes in numerical simulations of cyclogenesis. The objectives of this research are to describe the effect that horizontally varying boundary layer structure and processes have on frontogenesis associated with oceanic cyclogenesis and to investigate the role of the sea surface temperature distribution and initial boundary layer structure in forcing warm frontogenesis in numerical simulations of oceanic cyclones.

SUMMARY: During 1991, model simulations of the Genesis of Atlantic Lows Experiment (GALE) ocean cyclone of Feb. 24-26, 1986 were run to investigate the effects of ocean wind-generated waves on the cyclogenesis. The standard surface roughness parameterization used in the NCAR/Penn. State mesoscale model was replaced with a roughness formulation based on Toba and Koga (1986). This new surface roughness parameterization simulates the effects that air-sea interaction in a growing wind wave regime have on the boundary layer momentum transfer. The result of including this surface interaction in the cyclone simulation was a substantially improved cyclone forecast for this case. Although the cyclone developed to the same degree by 48 hours, the intensity of the early development was much more realistic when compared to observations. In addition to this overall improvement, the inclusion of the wind-wave effects produced much more realistic frontal structures. Detailed analysis of the frontogenetical forcing was done and the increase in differential friction across the front was determined to be the critical component for increasing the frontal intensity. Since these results are limited to one case, plans for 1992 are to extend this investigation to additional cases.

CONFERENCE PRESENTATION: Nuss, W. A., "Marine boundary layer and surface frontogenesis in numerical simulations of an oceanic cyclone." Invited presentation at the Symposium on Air-Sea Interaction and Air-Mass Modification, Galveston, TX, 7-9 January 1991.

OTHER: A manuscript describing this work on wind-generated waves is currently in preparation for submission to Monthly Weather Review and a second article based on the work presented at the Symposium on Air-Sea Interaction is under revision for submission to Monthly Weather Review.

MESOSCALE COUPLED AIR-SEA INTERACTION STUDIES

W.A. Nuss, Professor of Meteorology
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory (NOARL)
Funding: NOARL

OBJECTIVES: The overall objective of this research is to demonstrate the potential for and importance of two-way coupling on the mesoscale between the atmosphere and the ocean . This project is supported by NOARL as part of a joint effort by NOARL, NPS and Scripps Institution of Oceanography to examine coupled mesoscale air-sea interaction in ocean storms.

SUMMARY: The activity during 1991 for this ongoing project has focused on the production of gridded surface analyses for one of the ERICA storms that occurred on Dec. 13-14 1988 (IOP 2). Surface observations from ships, buoys and constructed from the aircraft have been used to generate objective gridded analyses for the IOP-2 cyclone. The sea-level pressure and temperature analyses have been completed using multiquadric interpolation as described by Hardy (1990). Considerable effort has gone into the development of this objective analysis scheme for use with meteorological data. Satellite derived wind speeds have been processed and are currently being prepared for use in the wind analysis. Subjective diagnosis of synoptic analyses at upper-level and the hand-drawn mesoscale surface analysis have indicated that the location of cyclogenesis is determined by the air-sea interaction processes that initiate the low-level circulation. Quantitative determination of these air-sea interaction processes depends upon the completion of the gridded analysis and is planned for 1992.

CONFERENCE PRESENTATION: Nuss, W. A. and Lilly, C. "Boundary layer convergence along the Gulf Stream during ERICA IOP 2." Preprints of the International Winter Storms Symposium} New Orleans, LA, January 1991.

OTHER: A paper describing the observed mesoscale surface structure and its relationship to upper-level processes is being prepared for publication.

INFLUENCE OF LATENT HEAT RELEASE AND STATIC STABILITY VARIATIONS ON THE DEVELOPMENT OF RAPIDLY INTENSIFYING EXTRATROPICAL CYCLONES

Patricia M. Pauley, Adjunct Teaching Professor of Meteorology
Sponsor: Office of Naval Research--Marine Meteorology
(Subcontract through the University of Wisconsin-Madison

OBJECTIVE: To quantify the influences of latent heat release and static stability variations on model simulations of rapidly intensifying oceanic extratropical cyclones, using expanded forms of the omega and height tendency equations as well as a static stability budget.

SUMMARY: This contract expired in July 1991. Over this past year, work has focussed on preparing manuscripts for publication based on work performed in conjunction with graduate students at the University of Wisconsin-Madison. Results from an examination of resolution effects on the depiction of intense cyclones and from diagnoses of vertical motion were written up, submitted, revised, and accepted for publication in a refereed AMS journal. Continuing work includes writing up the results of a stability budget for a LAMPS model simulation of the so-called QE II storm from Sept 1978.

PUBLICATIONS: Pauley, P.M., and Nieman, S.J., "A Comparison of Quasi-Geostrophic and Non-Quasi-Geostrophic Vertical Motions for a Model-Simulated Rapidly Intensifying Marine Extratropical Cyclone. Monthly Weather Review, in press.

Pauley, P.M. and Bramer, B.J., "The Effect of Resolution on the Depiction of Central Pressure for an Intense Oceanic Extratropical Cyclone. Monthly Weather Review, in press.

CONFERENCE PRESENTATIONS: Fairgrieves, T.J. and Pauley, P.M., "Evolution of the static stability field within a model-simulated rapidly intensifying marine extratropical cyclone." Preprints of the First International Symposium on Winter Storms, New Orleans, LA, pp. 351-354, 14-18 January 1991.

Nieman, S.J. and Pauley, P.M., "A Diagnosis of Non-Quasi-Geostrophic Vertical Motion for a Model-Simulated Rapidly Intensifying Marine Extratropical Cyclone." Preprints of the First International Symposium on Winter Storms, New Orleans, LA, pp. 355-358, 14-18 January 1991.

Bramer, B.J., and Pauley, P.M., "An Examination of Model Resolution Effects on the Depiction of Central Pressure for the ERICA IOP-4 Cyclone." Preprints of the First International Symposium on Winter Storms, New Orleans, LA, pp. 359-364, 14-18 January 1991.

SENSITIVITY OF NUMERICAL FORECASTS OF RAPIDLY INTENSIFYING EXTRATROPICAL CYCLONES TO PRECIPITATION PARAMETERIZATION

Patricia M. Pauley, Adjunct Teaching Professor of Meteorology
Sponsor: Office of Naval Research--Marine Meteorology

OBJECTIVE: To investigate the influence of cumulus parameterization on numerical forecasts of rapid oceanic cyclogenesis. Diagnoses will be calculated using datasets described by Kuo and Low-Nam (1990) from the PSU/NCAR model, with the objective of examining the influence of latent heat release on storm development.

SUMMARY: Over this past year, output was obtained from eight numerical forecasts (four experiments each for two cases) run on the PSU/NCAR mesoscale model at the National Center for Atmospheric Research. The only difference between these experiments was in the computation of latent heat release; they include the Arakawa-Schubert, Kuo, and Explicit cumulus computations, as well as a Dry forecast with no latent heating. I implemented versions of their codes to compute vertical motion and heating rate in sigma coordinates, and to post-process the sigma-level data to pressure coordinates. In addition to examining output of primary model variables, I also wrote code to compute a vorticity budget to examine the spin-up of the model cyclone. Results showed that the Arakawa-Schubert and Explicit experiments yielded similar results, with the Kuo and Dry experiments yielding weaker cyclones. Spin-up was primarily a result of convergence at low-levels, with mid- and upper-level spin-up showing the influence of the enhanced vertical motions and therefore tilting and vertical advections. Significant differences in 300 mb jet streaks were also apparent, with implications for the development of the surface system. Preliminary results were presented at an AMS meeting in early January 1992. These results will be prepared for publication this coming year.

OTHER: Pauley, P.M., Low-Nam, S., and Kuo, Y-.H., 1992: Sensitivity of forecasts of rapid oceanic cyclogenesis to the parameterization of convective latent heat release. *Fifth Conf. on Mesoscale Processes*, Atlanta, GA, 6-10 January 1992.

A COMPARISON OF VERTICAL MOTIONS OBTAINED FROM THE FLATLAND ST RADAR AND FROM A GENERALIZED OMEGA EQUATION

Patricia M. Pauley, Adjunct Teaching Professor of Meteorology
Sponsor: National Science Foundation
(Subcontract through the University of Wisconsin-Madison)

OBJECTIVE: To compare large-scale vertical motions measured from the Flatland ST radar (located near Champaign, IL) with values calculated from a generalized form of the omega equation (based on operational NMC analyses).

SUMMARY: Horizontal and vertical motions measured by the Flatland ST radar were compared with NMC-analyzed horizontal winds and associated computations of large-scale vertical motion. The comparison was carried out over a 10 month period from February to November 1990. Emphasis was placed on the latter half of the period; performance of the profiler improved after tuning and re-phasing in early July. Horizontal winds compared very closely, with mean magnitudes within 1 m/s and correlation coefficients of 0.95 or greater. The vertical velocities did not correlate as well, reflecting in part a difficulty in verifying this quantity. However, a negative correlation was apparent at lower altitudes, reflecting contamination by precipitation processes, with a positive correlation aloft. In addition, the profiler vertical motions had a 5 cm/sec downward bias, the subject of future work. Results from this research were presented at an international conference and are currently being prepared for publication.

CONFERENCE PRESENTATIONS: Pauley, P., Creasey, R., Clark, W., VanZandt, T., Warnock, J. and Nastrom, G., "A Statistical Comparison of Horizontal Velocities from the Flatland ST VHF Radar and from NMC Analyses. In proceedings of the Fifth Workshop on Technical and Scientific Aspects of MST Radar, Aberystwyth, Wales, 6-9 August 1991.

Pauley, P., Creasey, R., Clark, W., VanZandt, T., Warnock, J. and Nastrom, G., "A Statistical Comparison of Vertical Velocities from the Flatland VHF Radar and Computed from NMC Analyses." In proceedings of the Fifth Workshop on Technical and Scientific Aspects of MST Radar, Aberystwyth, Wales, 6-9 August 1991.

Nastrom, G.D., Clark, W.L., Creasey, R., Gage, K.S., Pauley, P.M., VanZandt, T.E. and Warnock, J.M., "Case Studies of the Vertical Velocity Seen By the Flatland Radar Compared with Indirectly Computed Values." In proceedings of the Fifth Workshop on Technical and Scientific Aspects of MST Radar, Aberystwyth, Wales, 6-9 August 1991.

THESIS DIRECTED: Creasey, Robert, "A Comparison of Horizontal and Vertical Velocities obtained from the Flatland ST Wind Profiler and Nested Grid Model Analyses." M.S.in UW, July 1991.

RAPID MARITIME CYCLOGENESIS STUDIES

C. H. Wash, Professor of Meteorology
R. L. Elsberry, Professor of Meteorology
P. Pauley, Adjunct Professor of Meteorology
W. A. Nuss, Assistant Professor of Meteorology
P. Hirschberg, Adjunct Professor of Meteorology
Sponsor: Naval Postgraduate School
(outside sponsor-Office of Naval Research-Marine Meteorology)
Funding: Naval Postgraduate School

OBJECTIVE: To understand the physical processes that lead to rapid cyclogenesis at sea using Genesis of Atlantic Lows Experiment (GALE) and Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA) data.

SUMMARY: A study utilizing statistics of composite diagnostics of collections of explosive and nonexplosive cyclone was completed and will appear shortly in Mon. Wea. Rev. This study emphasized the role of upper-level processes in rapid cyclogenesis. Case studies have been completed for ERICA IOP-2, IOP-5 and IOP-5A cyclones utilizing experimental and operational data and new data sources such as SSM/I satellite microwave analyses of precipitation rates. A series of papers addressing the role of upper-level process on rapid development have been published and provide the foundation for present ERICA studies. Model simulations using the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) NORAPS model have been initiated and compared to objective analyses from the complete ERICA data. A height tendency equation is being used to quantitatively assess the role of various forcing mechanisms in the development and evolution of rapidly developing cyclones.

PUBLICATIONS: Wash, C. H., Hale, R.A., Dobos, P.H. and Wright, E.J., "Study of Explosive and Nonexplosive Cyclogenesis during FGGE," *Monthly Weather Review*, 120(1):40-51.

Hirschberg, P. A. and Fritsch, J. M., "Tropopause Undulations and the Development of Extratropical Cyclones. Part I: Overview and Observations from a Cyclone Event," *Monthly Weather Review*, 119:496-517.

Hirschberg, P. A. and Fritsch, J. M., "Tropopause Undulations and the Development of Extratropical Cyclones. Part II: Diagnostic Analysis and Conceptual Model," Monthly Weather Review, 119: 518-550.

Hirschberg, P. A. and Fritsch, J. M., "An Analytic Five-Layer Quasi-Geostrophic Model for Initial-Value Problems," Journal of Atmospheric Science, 48:2524-2533.

THESES DIRECTED: Almario, B. J., "SSM/I rain analyses for ERICA." MS Thesis, June 1991.

Frailey, L. A., "Integrated microwave and infrared precipitation estimation." MS Thesis, September 1991.

Gardner, E. B., "Mesoscale vertical structure of an explosive oceanic cyclone." MS Thesis, June 1991.

Greer, S. N., "Mesoscale surface analysis of the ERICA IOP-5 cyclone." MS Thesis, June 1991.

CONFERENCE PRESENTATIONS: Wash, C. and Miller, R., "An Investigation of the ERICA IOP-2 Cyclone using the NORAPS Model. Preprints of the First International Symposium on Winter Storms. New Orleans, LA, American Meteorological Society, January 1991.

Wash, C., Hale, R., Dobos, P. and Wright, E., "Study of Explosive and Nonexplosive Cyclogenesis during FGGE." Preprints of the First International Symposium on Winter Storms. New Orleans, LA, American Meteorological Society, January 1991.

Hirschberg, P. A. and Fritsch, J.M., "The Combined Effects of Stratospheric and Tropospheric structure on the development of Extratropical Cyclones. First International Winter Storm Symposium, 13-18 January 1991, pp.

44-49.

Hirschberg, P. A. and Langland, R. H., "The Effects of Lower-Stratospheric Temperature Change in a Numerical Simulation of the Cyclogenesis Event during ERICA IOP 5A. Ninth Conference on Numerical Weather Prediction, Denver, CO, 14-18 October 1991.

Hirschberg, P. A. and Langland, R. H., "The Effects of a Mesoscale Tropopause Undulation in a Numerical Simulation of the Cyclogenesis Event during ERICA IOP 5A. Fifth Conference on Mesoscale Processes, Atlanta, Georgia, pp. 97-102, 5-10 January 1992.

Wash, C., Motell, C. and Almario, B., "SSM/I Precipitation Analyses of ERICA Ocean Cyclones." In proceedings of the AGU 1992 Ocean Sciences Meeting, New Orleans, LA. American Geophysical Union, January 1992. Abstract published in EOS, 17 December 1991.

Frailey, L., and Wash, C., "Integrated Microwave and Infrared Precipitation Analyses. In proceedings of the AGU 1992 Ocean Sciences Meeting. New Orleans, LA. American Geophysical Union, January 1992. Abstract published in EOS, 17 December 1991.

EVALUATION OF MEASUREMENT SYSTEMS FOR THE INTEGRATED OCEANOGRAPHIC TACTICAL AID (IOTA) SYSTEM

C. H. Wash, Professor of Meteorology
Kenneth L. Davidson, Professor of Meteorology
Sponsor: Naval Underwater Systems Command
Funding: Naval Underwater Systems Command

OBJECTIVE: The goals of this project is to evaluate measurement systems to support the Integrated Oceanography Tactical Aids (IOTA) program. These measurements were taken on NPS cruises using the R/V Pt Sur and in the NPS tactical laboratory established last year by NUSC and NPS.

SUMMARY: The following tasks were accomplished under this proposal. An experimentation and evaluation laboratory was established at the Naval Postgraduate School for research to include eight networked 386 UNISYS PCs and appropriate meteorological sensors and software. The Geophysical Fleet Mission Program Library (GFMPL), the Mobile Ocean Support System (MOSS) and other prototype software packages were installed for use in instruction, research and thesis work. An IOTA measurement package was developed and evaluated to include Coastal Climate measurement systems. Continuous evaporative duct estimates were made using IOTA continuous surface measurements taken during the May 1991 cruise. APT satellite imagery software was acquired and used to ingest APT data for PC satellite displays. IOTA projects and studies were organized for NPS thesis and course project activity. Martinez (1991) completed the first IOTA thesis reporting on the May 1991 refractivity survey and Pt. Sur cruise.

CONFERENCE PRESENTATIONS: Wash, C., Davidson, K.L. and Martinez, T., "High Frequency Measurements of Refractivity During the May Refractivity Survey. Workshop on Refractivity Measurements for IOTA, Monterey, CA. Naval Postgraduate School, July 1991

Davidson, K. L., and Wash, C., "Factors Influencing the Evaporation Duct Height and Measurement Considerations. Workshop on Refractivity Measurements for IOTA, Monterey, CA. Naval Postgraduate School, July 1991.

Davidson, K.L., Wash, C., and Pastore, M., "Regional survey of refractive conditions along the California coast, May 1991." In proceedings of the URSI Commission F on Wave Propagation and Remote Sensing. Ravenscar, North Yorkshire, England. International Union of Radio Science, June 1992.

THESIS DIRECTED: Martinez, A., "High frequency analyses of coastal meteorological phenomena affecting refractivity." MS Thesis, December 1991.

REGIONAL SYNOPTIC FORECASTING (PHILIPPINES)

F. R. Williams, Adjunct Professor of Meteorology
Sponsor: Naval Research Laboratory, Monterey
Funding (Cost Sharing): Naval Postgraduate School and the Naval Research Laboratory, Monterey

Objective: A continuing project to produce handbooks describing the analysis and forecasting of atmospheric and oceanic conditions important to air/sea operations over key areas of interest to the Navy. In particular, the handbooks contain case studies (with analyses, prognoses and satellite imagery) providing newly arriving naval personnel with examples of the accuracy of the Navy Operational Global Atmospheric Prediction System in the area. The current handbook will cover the Philippine Islands and surrounding waters (4-21°N, 116-127°E).

SUMMARY: Following the data-gathering trip of 1990, remote collection of case study material for the two monsoon seasons, transition seasons and typhoon episodes has continued. Data are collected via the Navy Oceanographic Data Distribution System, the NPS IDEA Laboratory and the Digital Weather Imagery Processing System. By the end of CY 1991 the following portions (142 pp.) of the handbook were completed: Chapter 1, The Philippine Islands; Chapter 4, Oceanic Aspects of Operational Weather Forecasting (contracted); References; Appendix A, Comprehensive Ocean-Atmospheric Data Set (Winds, Sea surface temperature and Sea level pressure); Appendix B, Characteristics of Tropical Cyclones Affecting the Philippine Islands; Appendix C: Climatic Normals of the Philippines (1951-1985)(60 stations). The remaining chapters and appendices will be delivered to NRL, Monterey by 30 September 1992.

THEORY OF TROPICAL CYCLONE MOTION

R. T. Williams, Professor of Meteorology
M. S. Peng, Adjunct Professor of Meteorology
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: To understand the physical processes which control the motion of tropical cyclones. This is an ongoing project.

SUMMARY: The motion of tropical vortices in east-west mean flows was studied with the barotropic vorticity equation on the beta-plane. The vorticity equation was integrated numerically from an initially symmetric vortex flow embedded in (a) linear shear flow or (b) a parabolic jet. The first experiment with flow (a) had b = 0 and it was linearized about the mean flow. The vortex was distorted by the mean flow so that the even Fourier components around the vortex grew, but the vortex did not move. When nonlinear effects were included the distortion was damped in the inner part of the vortex, but wavenumber two grew in the outer region. The addition of the beta effect caused the vortex to move in the same direction as the no mean flow solution provided the mean flow advection was removed from the trajectories. The trajectory for the anticyclonic mean flow was significantly longer than the cyclonic and no mean flow trajectories which were about equal. For mean flow (b), with the same absolute vorticity gradient as b, but on a f-plane the vortex had a much shorter trajectory and a more westerly direction of movement than the no mean flow solution with beta. This effect came from the advective distortion of the vortex, which projected on wavenumber one in the disturbance vorticity equation. It was shown with other experiments that beta has a stronger effect on vortex motion than the relative vorticity gradient.

PUBLICATION: Peng, M.S. and Williams, R.T., "Stability Analysis of Barotropic Vortices," *Geophysical and Astrophysical Fluid Dynamics*, 58, 263-283, 1991.

NUMERICAL MODELING OF UNIQUE ATMOSPHERIC PHENOMENA

R. T. Williams, Professor of Meteorology
M. S. Peng, Adjunct Professor of Meteorology
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: Develop and test better numerical techniques for use in Navy weather forecasting models. This is a continuing project.

SUMMARY: A numerical model based on the hydrostatic Boussinesq equations was used to simulate atmospheric frontogenesis driven by an irrotational non-divergent deformation wind field. The equations were numerically integrated by using the semi- Lagrangian technique associated with two different time schemes: explicit and semi- implicit. Both schemes produced realistic fronts after approximately 40 hours of model integration. The semi-Lagrangian semi-implicit scheme was more successful in handling the sharp gradients associated with the front. Also, the semi-Lagrangian semi-implicit equations were integrated with time steps as long as 3600 sec. producing solutions with relatively small errors. This indicates that this numerical scheme is appropriate for use in mesoscale regional models. In addition, the effect of the Coriolis Force on flows over mountains was investigated with a two-dimensional numerical model. It was found that for high, small scale mountains the blocking which occurs for f = 0 does not occur for mid-latitude values of f.

THESIS DIRECTED: Ricardo Carvalho de Almeida, "Simulation of Atmospheric Frontogenesis with a Semi-Lagrangian Numerical Model," MS Thesis, September 1991.

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

DEPARTMENT OF NATIONAL SECURITY AFFAIRS

The research conducted by the faculty in the Department of National Security Affairs is supported by funds received both reimbursably and from the Navy Direct research program administered by the School. In 1991 the former funding expanded very considerably to support projects dealing with a number of regional areas, nuclear issues, and strategic scenarios. The research resulting from this diversified support is provided to the sponsors through reports, briefings, and even student theses which have also drawn on the research. The Department made good use of the Navy Direct program, particularly with regard to new faculty.

The research is encompassed largely within the two broad and overlapping categories of Regional Studies and Strategic Planning. In the former category are found studies on all areas except for Africa, with particular emphasis on political/military affairs and defense policies of the more important regional actors. In the latter category are found studies on nuclear issues, naval cooperation, the role of Congress in the formulation of defense policy, and the new U.S. base force strategy.

Virtually all faculty published books or articles in 1991. Of particular note are the following: Roman Laba, Roots of Solidarity (Princeton: Princeton University Press, 1991); Paul Stockton, "The New Game on the Hill: The Politics of Arms Control and Strategic Forces Modernization," International Security Vol. 6, No. 2, Fall 1991; Jim Tritten's many publications on the base force strategy; Misha Tsypkin, "The Soviet Military: Glasnost Against Secrecy," Problems of Communism May-June 1991; James Wirtz, The Tet Offensive: Intelligence Failure in War (Ithaca: Cornell University Press, 1991); and David Yost, "France in the New Europe," Foreign Affairs Vol. 69, Winter 1990-1. Professors Stockton and Tritten also co-edited a technical report with contributions from other NSA faculty which will be published as a book by Praeger Publishers in mid-1992. The technical report is "Reconstituting National Defense: The New U.S. National Security Strategy" NPS-NS-91-012, September 1991.

GERMAN UNITY AND PROFESSIONALISM IN GERMAN OFFICER CORPS

Donald Abenheim, Associate Professor of National Security Affairs
Sponsor: Chief of Naval Operations, Executive Panel
Funding: Naval Postgraduate School

OBJECTIVE: The present research has sought to assess the impact of the collapse of a Communist military on officer professionalism and examine the efforts of the Western Germans to absorb former communists into ranks of a NATO military. Also key to provide insights as to officer professionalism in other USSR style armies and navies.

SUMMARY: The sudden end of the GDR in 1989/90 created the extraordinary situation of one Army/Navy/Air Force absorbing most of the officers of a former opponent organizes along the lines of the armed forces of the USSR. Chief among the problems has been the role of political indoctrination in the concept of command and the social welfare of the officers affected. While western ideas of civil-military relations came as foreign to many GDR officers, the several thousand who have adapted to new conditions seem confident of their future once questions of social welfare have been resolved. Explicit communist indoctrination led to a widely different ideal of command. Nonetheless, the western Germans have made important strides and learned lessons applicable to future experience in NATO.

PUBLICATIONS: In preparation: technical report and two journal papers (Germans Studies Review, and European Security).

CONFERENCE PRESENTATIONS: Abenheim, Donald, "German Soldier and German Unity," Center for International Security and Arms Control, Stanford, CA, 17 January 1991.

Abenheim, Donald, "Refoundation of Bundeswehr?" HQ, US Army, DCSOPS, 20 June 1991.

OTHER: The investigator is preparing a book-length monograph publication with Princeton University Press on the results of this project. Completion is expected in late 1993.

RELATIONSHIP OF WAR AT SEA TO WARFARE ASHORE

T.C. Bruneau, Professor and Chairman of National Security Affairs
R.N. Channel, Adjunct Professor of National Security Affairs
Sponsor: Chief of Naval Operations (OP-60)
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project is to conduct continuing research into the interrelationship of war at sea to warfare on land. This relationship is becoming increasingly important as the nation moves into a new era of potential contingency and limited warfare.

SUMMARY: This is a continuing project that attempts to analyze the relationship of war at sea to warfare ashore, using various analytic methods including the RAND Strategy Assessment System (RSAS). The RSAS was well developed in the areas of nuclear warfare and the air/ground battle on the old Central Front, but the naval models were, and still remain, largely in the development stages. There have been major changes in the world situation in the last year, and RAND has made correspondingly major changes in the RSAS to keep it as current as possible. There is an ongoing key project to permit more theater contingency planning and an upgrade of the naval models to include littoral operations (amphibious operations, mining, cruise missile operations, shallow water ASW, etc.). The NPS RSAS team has continued to learn the new system, and to use it in support of research into former Soviet naval thinking, the importance of seapower in U.S. strategy, and in assessing various nuclear alternatives. The team has played a major role in stating requirements for naval aspects of the RSAS and in pointing out inadequacies where they exist. Comments and evaluations of naval models have been submitted to the RAND Corporation for possible assistance.

This research project is directly related to DOD and U.S. Navy activity. OPNAV (OP-06) is the sponsor and has commented favorably on the results thus far. The project has made major contributions to NSA courses in strategic planning, intelligence, and net assessment.

CONFERENCE PRESENTATION: The status of RSAS teaching and research at NPS was presented to the RSAS Working Group in Washington, DC, September 1991.

OTHER: A technical report on "Naval Modeling with the RAND Strategy Assessment System" is in final draft stages. Also in draft are reports on the RSAS at NPS, and a preliminary report on the relationship of war at sea to warfare ashore.

DEFENSE MODERNIZATION AND THE ARMED FORCES IN PORTUGAL IMPLICATIONS FOR U.S. - PORTUGUESE RELATIONS

T.C. Bruneau, Professor and Chairman of National Security Affairs
Sponsor: Chief of Naval Operations (OP-614)
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to analyze the implications of the modernization of the Portuguese Armed Forces for U.S. - Portuguese relations.

SUMMARY: A thorough review of open and classified documents was conducted by the PI followed by interviews in Washington, D.C. and Lisbon Portugal. The Portuguese Armed Forces have undergone substantial modernization during the past decade and have recently been reorganized in line with other West European democracies. The implications of these changes are analyzed in terms of the overall relationship with the United States, particularly regarding the issue of base access. It is concluded that the opportunities are very promising for closer cooperation.

PUBLICATIONS: Bruneau, T.C., "Defense Modernization and the Armed Forces in Portugal: Implications for U.S. - Portuguese Relations". An unclassified report submitted to OP-614, 7 July 1991.

Bruneau, T.C., "Defense Modernization and the Armed Forced in Portugal," *Portuguese Studies Review*, 1(2) (in press, 1991).

CONFERENCE PRESENTATIONS: Bruneau, T.C., "Defense Modernization and the Armed Forces in Portugal: Implications for U.S. - Portuguese Relations." Presentation to an inter-agency group in Washington, DC, May 1991.

Bruneau, T.C., "The Modernization of the Portuguese Armed Forces." Presentation to the Foreign Service Institute, Rosalyn, VA, September 1991.

OTHER: The PI briefed the material gathered in this research project to the new Deputy CINCIBERLANT, RADM Guilbault, in September 1991. It was also found useful by the new Naval Attache to Lisbon, CPT Robert Young, USN. It is hoped that this project will provide the basis for a new project on the Armed Forces and Defense Policies of Portugal and Spain.

IRAN AND ITS NEIGHBORS' IMPLICATIONS FOR THE UNITED STATES

R.H. Magnus, Associate Professor of National Security Affairs
Sponsor: Naval Security Support Group Activity
Funding: Naval Security Support Group Activity

OBJECTIVE: The goal of this project is to arrive at an understanding of Iranian foreign policy through the examination of the patterns of its relations with its neighbors outside of the commonly examined areas of Iraq and the Persian Gulf states. Such relationships have always concerned Iran, regardless of regime, and have been on the whole more cooperative than its relations with Arab neighbors. With the end of the Soviet Empire in Asia, a new area for these relations is just emerging in Central Asia. These relations are interesting in themselves, for with the fall of the USSR Iran will be in an even stronger position to assert its leadership and interests in a region that is highly important to U.S. interests. The working hypothesis of the study is that Iran's relations with its non-Arab neighbors, because they are less hostile and less controversial domestically, are likely to show early indications of the general directions of Iranian foreign policy towards the United States as well.

SUMMARY: Funding for this study was obtained in the last quarter of 1991. In that year, I have prepared and discussed the trip report of my London visit and discussed other issues with the sponsor during my trip to Washington for the Middle East Studies Association Meeting.

THESIS DIRECTED: Wells, Robert, S., LCDR, "U.S. National Interests and Iran: Perspectives and Projections of U.S. Diplomacy and Policy in the 1990s," MA Thesis, December 1991.

ISLAMIST VIEWS OF THE UNITED STATES IN A POST COLD WAR ENVIRONMENT

R.H. Magnus, Associate Professor of National Security Affairs
Sponsor: Office of Naval Research (OP-611)
Funding: Naval Postgraduate School

OBJECTIVE: This project examines the international viewpoints of four of the leading contemporary Islamist movements: the Jama'at-i-Islami of Pakistan, the Saudi Arabian Wahhabis, the Egyptian Muslim Brethern, and the Islamic Republic of Iran, with particular reference to their views of the United States and its policies. It is based upon the working hypothesis that the views of these organizations are issue oriented, and not uniformly ideologically hostile to the United States.

SUMMARY: Due to funds and travel freeze, the planned field research in Pakistan could not be accomplished. A thirteen page interim report on theoretical issues among leading Islamists, scholarly research, and views of contemporary movements on the issue of the Persian Gulf crisis was presented to the sponsor. At the end of the fiscal years some funds became available for brief research visit to London, for consulations with scholars at the University of London, School of Oriental and African Studies. Contacts developed with pro-Iraqi resistance scholars in London led to their referral to OP-611 during their visit to Washington. The trip report from this visit was discussed, along with other relevant issues, at a meeting with the sponsor in Washington. Participation in the Middle East Studies Association and other conversations with scholars in Washington were reported to the sponsor in another trip report.

DEEP CUTS -- THE DOMESTIC POLITICS OF STRATEGIC ARMS CONTROL AND FORCE MODERNIZATION

Paul Stockton, Assistant Professor of National Security Affairs
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to investigate how the end of the Cold War will affect the way Congress relates arms control to Navy and Air Force requests for strategic force modernization funding.

SUMMARY: A survey was made of congressional votes on key strategic force modernization initiatives of the past 30 years, and the way modernization advocates made their support for arms control contingent on modernization funding. Then, using the B-2 as a case study, and examination was made of the way that method of political coalition-building is being undermined by the end of the Cold War. This analysis included interviews with Members of Congress and their staffs, as well as research from journal and periodical accounts of votes on the B-2. The study offered a number of conclusions about what this change in congressional behavior implies for the future of U.S. defense and arms control policymaking -- a subject that I intend to explore more fully in 1992.

PUBLICATIONS: Stockton, P., "The New Game on the Hill: The Politics of Arms Control and Strategic Force Modernization," *International Security*, 6(2):146-171, Fall 1991.

Stockton, P. and Tritten, J., Eds., "Reconstituting National Defense: The New U.S. National Security Strategy," NPS Technical Report NPS-NS-91-012, prepared for the Director, Net Assessment, OSD, 30 September 1991.

CONFERENCE PRESENTATIONS: Stockton, P., "Congressional Policymaking Beyond the Cold War," presented at the International Studies Association West Conference, Los Angeles, CA, 1-2 November 1991.

Stockton, P., "Congress and Defense," presented at a conference on Congress and New Challenges of Foreign and Defense Policy, The Mershon Center, Ohio State University, 12-20 September 1991.

Stockton, P., "Arms Control and Force Modernization: The Congressional Connection," presented at the American Political Science Association Convention, Washington, DC, 29 August 29 - 1 September 1991.

THESIS DIRECTED: Mohs, Sam, LT, USN, "The Politics of Strategic Weapons," MS Thesis, December 1991.

OTHER: The investigator is preparing a book-length manuscript for publication using the results of this project. Completion is expected in 1994.

TAILORING THE MARINE AIR-GROUND TASK FORCE FOR COMBAT AGAINST A STRONG ARMORED ENEMY: BATTLE FIGHTING LESSONS FROM THE GERMANS IN WORLD WAR II

Russell H.S. Stolfi, Professor of National Security Affairs

Sponsor & Funding: Marine Corp University and the Marine Corp Warfighting Center, Quantico, VA

OBJECTIVE: The main research objective was to describe the deep advances and associated command style of German mobile formations in combat against the Soviets in the summer of 1941, extract the reasons for the German successes, and translate those reasons into a modified organization of the Marine Air-Ground Task Force (division, air wing, and force service support group) for combat against a strong armored enemy.

SUMMARY: The primary investigator examined approximately 13,000 pages of war records of German mobile divisions engaged in the advance into the Soviet Union during June-October 1941. The investigator extracted the command style and combat techniques of the German formations in a great mobile advance and applied them to the reorganization of a Marine Air-Ground Task Force (MAGTF) for combat against a strong armored enemy. Based on the German successes, the investigator recommended that the Marine Corps streamline the staffs, moderately increase the number of tanks and double the ground reconnaissance elements of the Ground Combat Element of the MAGTF and embrace similarly styled changes in the Air and Service Elements. The study was completed in the period April-June 91.

PUBLICATION: The Marine Corps study supervisor, Colonel M. Wyly, projected publication of the report as part of the Marine Corps University series, Perspectives on War Fighting.

CONFERENCE PRESENTATION: The primary investigator used material from this study in his address to the Marine Corps University Symposium on War Fighting at Quantico, VA, 15 July 1991.

THESIS DIRECTED: The investigator applied some material from the study in support of the LT T. Sears thesis, "War as Art or Science: A Humanistic Version," December 1991.

BRAZIL-UNITED STATES NAVAL RELATIONS: OPPORTUNITIES AND OBSTACLES IN THE 1990S

Scott D. Tollefson, Assistant Professor of National Security Affairs
Sponsor: Director, Strategy Plans and Policy Division, OP-60
Funding: Naval Postgraduate School

OBJECTIVE: The purpose of this research is to focus on the Naval dimension of the U.S.-Brazilian defense relationship and to identify those areas where obstacles can be overcome and opportunities exploited. It looks at how seemingly peripheral issues affect, or could affect, the naval dimension of the U.S.-Brazilian security relationship. The study concludes with a set of recommendations for the U.S. Navy, taking into consideration broader regional interests and commitments.

SUMMARY: Two trips were made to Brazil - one in November 1990, and one in November 1991. On the first trip, interviews were conducted with four Brazilian admirals, the U.S. naval attaché in Brasília, and various other U.S. and Brazilian officials and military officers, in Brasília, Rio de Janeiro, and Sao Paulo. In the second trip, investigator participated in the XXXII UNITAS maritime exercises between Brazil and the United States, met with the new U.S. defense/naval attaché, and various officials in Brazil's foreign ministry. Three trips were made to Washington, D.C., to conduct archival research, and to meet with sponsor and various officials, both Brazilian and American.

PUBLICATION: A report will be submitted to OP-60 in February 1992.

CONFERENCE PRESENTATION: Tollefson, Scott, D., "Critical Issues in U.S.-Brazilian Security Issues," for the XVI Conference of the Latin American Studies Association, Crystal City, VA, 6 April 1991. Panel co-sponsored by investigator. Paper delivered by NSA department chairman, Thomas C. Bruneau.

THESES DIRECTED: Jenkins, Brent, P., LT, USN, "United States Warship Transfers to Argentina, Brazil and Chile: Options for U.S. Policy," MS Thesis, December 1991.

Collins, Harold, H., LCDR, USN, "The United States and Brazil: A Naval Partnership for the Twenty-First center?" MS Thesis, March 1991.

Oakenell, Robert, F., LT, USN, "Brazilian Nuclear Submarine Construction: A Paradigm for Capability Assessment," MS Thesis, March 1991.

OTHER: During the UNITAS exercise, investigator briefed the UNITAS Admiral and his staff on Brazil's navy and security issues.

DEFENSE INDUSTRIAL INITIATIVE IN BRAZIL: IMPLICATIONS FOR U.S. TECHNOLOGY TRANSFERS

Scott D. Tollefson, Assistant Professor of National Security Affairs
Sponsor: Inter-American Region, OSD/ISA
Funding: Office of the Undersecretary of Defense (Policy)

OBJECTIVE: The purpose of the study is to assessed Brazil's defense industrial initiatives and their implications for U.S. technology transfers. Specifically, the study looks at missile and nuclear technologies and other defense-related areas such as supercomputing.

SUMMARY: Trips were made to Brazil in November 1990 and November 1991, in order to conduct interviews with various U.S. and Brazilian officialls and military officers. Three trips were made to Washington, D.C., to conduct archival research, and to meet with sponsor and various government officials.

PUBLICATION: A report will be submitted to OSD/ISA in February 1992.

CONFERENCE PRESENTATIONS: Tollefson, Scott, D., "Critical Issues in U.S.-Brazilian Security Issues," for the XVI Conference of the Latin American Studies Association, Crystal City, Virginia, 6 April 1991. Panel co-sponsored by investigator. Paper delivered by NSA department chairman, Thomas C. Bruneau.

Tollefson, Scott, D., and Looney, Robert, "Latin American Military Expenditures and Arms Production: The En ironmental Consequences," presented at a conference sponsored by the International Peace Research Institute of Oslo (PRIO) and the United Nations Environmental Program (UNEP) in Perm, Russia, 26 November 1991.

THESES DIRECTED: Martin, Francis, X., LT., USN, "The Guadalajara Accord Between Brazil and Argentina: A Tentative Step Toward the Nuclear Weapons-Free Latin America Envisioned by the Treaty of Tlatelolco," MS Thesis, December 1991.

Collins, Michael J., LT, USN, "Evaluating the Military Potential of a Developing Nation's Space Program: A Case Study of Brazil," MS Thesis, September 1991.

Jenkins, Brent, P., LT, USN, "United States Warship Transfers to Argentina, Brazil, and Chile: Options for U.S. Policy," MS Thesis, December 1991.

Collins, Harold, H., LCDR, USN, "The United States and Brazil: A Naval Partnership for the Twenty-First Century?" MS Thesis, March 1991.

Oakenell, Robert F., LT, USN, "Brazilian Nuclear Submarine Construction: A Paradigm for Capability Assessment," MS Thesis, March 1991.

OTHER: A draft of the research paper was submitted to OSD/ISA in January 1992, and was used as part of a briefing for Secretary of Defense Richard Cheney prior to his trip to Brazil.

STRATEGIC MANAGEMENT FOR THE DEFENSE DEPARTMENT

James J. Tritten, Associate Professor of National Security Affairs
Sponsors: Director Net Assessment (OSD/NA)
OSD/Competitive Strategies Office
Office of the Under Secretary of Defense - Acquisitions/
Directorate for Program Integration
Strategic Planning Branch, and
Director of Defense Policy on the National Security Council (NSC) Staff

OBJECTIVE: Historical and current research and analysis in the area of strategic management for the DoD. Examination of DoD philosophy and mission, to establish long- and short-range objectives for the DoD, strategies to be used in achieving those objectives; and strategic implementation with the goal to develop an organizational strategy, create functional activities necessary to support the strategy, and design control systems to monitor the effectiveness of the strategy in achieving DoD objectives. Multi-year project.

SUMMARY: Investigators visited businesses and government agencies that have strategic planning staffs and programs, interviewed civilian and military personnel connected with the varying aspects of strategic management within DoD, and obtained the cooperation of industrial leaders in the project. They reviewed two graduate seminars in strategic planning and strategic management for the National Security and Administrative Sciences Departments and routinely offer these revised courses. They were instrumental in a thorough overhaul of the National Security Affairs Strategic Planning Curriculum as well as the applicable portions of DRMEC courses. They developed initial historical cases for use in these courses.

PUBLICATIONS: Tritten, J.J., "American Promises to Come Back: A New National Strategy," NPS Technical Report NPS-NS-91-003, December 1990.

Tritten, J.J., "A New National Security Strategy," NPS Technical Report NPS-NS-91-006, 18 January 1991.

Tritten, J.J., "America's New National Security Strategy," NPS Technical Report NPS-NS-91-005, 11 March 1991.

Tritten, J.J., "America's New National Security Strategy," *The Submarine Review*, pp. 15-24, April 1991.

Tritten, J.J., "America Promises to Come Back: A New National Strategy," NPS Technical Report NPS-NS-91-003A, 13 May 1991.

Tritten, J.J., "America's New National Security Strategy: New Scenarios for Military Operations Research," NPS Technical Report NPS-NS-91-008, 11 June 1991.

Tritten, J.J., "America's New National Security Strategy: New Scenarios for Military Operations Research," in proceedings of the 59th Military Operations Research Symposium (U), June 1991, forthcoming.

Tritten, J.J., "America Promises to Come Back: A New National Strategy," Summary Report of the 6th Conference on Stability and the Offense/Defense Relationship: New Challenges for Strategic Programs (U), Thomas Marshall & Maurice A. Mallin, Eds., SAIC/MCDC# 91:TBA, McLean, VA, SAIC July/August 1991, forthcoming.

Tritten, J.J., "America Promises to Come Back: A New National Strategy," NPS Technical Report NPS-NS-91-003B, 5 August 1991.

Tritten, J.J. and Stockton, P.N., "Reconstituting National Defense: The New U.S. National Security Strategy," NPS Technical Report NPS-NS-91-012, 30 September 1991.

Tritten, J.J., "America Promises to Come Back: Our New National Security Strategy," NPS Technical Report NPS-NS-91-003C, 23 October 1991.

Tritten, J.J., "What If It's Peace?" *U.S. Naval*

Institute Proceedings, 117(10):36-41, October 1991.

Tritten, J.J., "America Promises to Come Back: The President's New National Security Strategy," *Security Studies*, I(2):173-234, Winter 1991.

Tritten, J.J., "A New National Security Strategy," *Phalanx*, 24(1):11-13, March 1991.

Tritten, J.J., "The New American National Security Strategy," *SSHA: Ekonomika, Politika, Ideologiya*, 12:28-42, 1991.

Tritten, J.J. and Stockton, P.N., "Reconstituting National Defense: The New U.S. National Security Strategy," New York, NY: Praeger Publishers, forthcoming.

Tritten, J.J., "The New National Security Strategy and The Base Force," in Reconstituting National Defense: The New U.S. National Security Strategy, Eds. James J. Tritten and P.N. Stockton, New York, NY: Praeger Publishers, forthcoming.

Tritten, J.J., "Our New National Security Strategy: America Promises to Come Back", New York, NY: Praeger Publishers, forthcoming.

CONFERENCE PRESENTATIONS: Tritten, J.J., "America Promises to Come Back: A New National Strategy," What if Peace? A National Science & Technology Policy Conference sponsored by the California Engineering Foundation and Aviation Week & Space Technology, Costa Mesa, CA, November 1990.

Tritten, J.J., "Resolving Remaining East-West Issues," presented at the Maritime Security and Naval Arms Control After the Cold War Conference, Vancouver, British Columbia, November 1991.

Tritten, J.J., "America's New National Security Strategy: New Scenarios for Military Operations Research," presented at a General Session of the 59th Military Operations Research Society (MORS) Symposium, at the U.S. Military Academy, West Point, NY, June 1991.

Tritten, J.J., "Implications of Competitive Strategies for Professional Education & Development," presented at a Working Group of the 59th Military Operations Research Society (MORS) Symposium, presented at the U.S. Military Academy, West Point, NY, June 1991.

Tritten, J.J., "**America Promises to Come Back: A New National Strategy**," presented at the following: a meeting of the Military Operations Research Society (MORS) Board of Directors and Sponsors, McLean, VA, December 1990; the Hoover Institution on War, Revolution and Peace, Stanford University, January 1991; Beyond War, Monterey Chapter, January 1991; broadcast presented on "Barry Gray Live," WOR Radio, New York, February 1991; 1991 Fleet CINC Planner's Conference (Admiral Charles M. "Savvy" Cooke Conference), March 1991; Heritage Foundation, April 1991; SHAPE Technical Centre, The Hague, Netherlands, to the staff and to the Tri-MNC Maritime Requirements Conference, June 1991; Danish Commission on Security and Disarmament, Copenhagen, Denmark, June 1991; International Peace Research Institute, Oslo, Norway, June 1991; National Defense Research Institute, Stockholm, Sweden, July 1991; 6th Conference on Crisis Stability and the Offense/Defense Relationship: New Challenges for Strategic Programs, sponsored by the Arms Control and Disarmament Agency (ACDA), the Strategic Defense Initiative Organization (SDIO), the Defense Nuclear Agency (DNA), the Department of Energy (DOE), and the Office of the Assistant Secretary of Defense for International Security Policy, Monterey, CA., July/August 1991; Acoustic Sciences and Technology Panel, sponsored by an agency of the U.S. Government, Monterey, CA, September 1991; Center for Technical Studies of Security, Energy and Arms Control, Lawrence Livermore National Laboratory, Livermore, CA, October 1991; International Studies Association-West Conference, Los Angeles, CA, November 1991; Gerry Taylor Lecture Series for the Monterey Institute of International Studies, Pebble Beach, CA, November 1991; New Forum, Pebble Beach, CA, November 1991; OP-603, Washington, DC, April 1991, OP-06 at the Naval Postgraduate School, May 1991; CINCUSNAVEUR, London, United Kingdom, June 1991; SHAPE Headquarters, Mons, Belgium, June 1991; U.S. Mission to NATO, Brussels, Belgium, June 1991; the staff of the U.S. Embassy, Copenhagen, Denmark, June 1991; Danish Atlantic

Treaty Association, Copenhagen, Denmark, June 1991; U.S. Embassy (to the staff and the media), Oslo, Norway, June 1991; and National Defense Research Institute, Stockholm, Sweden, July 1991.

Tritten, J.J., "Resolving Remaining East-West Issues," presented at the Maritime Security and Naval Arms Control After the Cold War Conference, Vancouver, British Columbia, November 1991.

Tritten, J.J., "America's New National Security Strategy: New Scenarios for Military Operations Research," presented at a General Session of the 59th Military Operations Research Society (MORS) Symposium, at the U.S. Military Academy, West Point, NY, June 1991.

Tritten, J.J., "Implications of Competitive Strategies for Professional Education & Development," presented at a Working Group of the 59th Military Operations Research Society (MORS) Symposium, presented at the U.S. Military Academy, West Point, NY, June 1991.

THE SOVIET NAVY IN A NEW MILITARY-POLITICAL ENVIRONMENT: THE MILITARY AND POLITICS

Mikhail Tsypkin, Assistant Professor of National Security Affairs
Sponsor: Naval Security Group Support Activity
Funding: Naval Postgraduate School

OBJECTIVE: Investigate the impact of the rapidly changing political situation in the former Soviet Union upon the future role and influence of the military establishment in the successor states of the USSR.

SUMMARY: While the policies of reform, initiated by Gorbachev, have resulted in a demilitarization of the Soviet society, the concomitant collapse of the political system left the military with a greater potential for political influence than before. The crisis of legitimate authority, combined with a relatively high level of popularity enjoyed by the armed forces, left the military with an ample opportunity for political intervention against reform. Gorbachev's policies have left the military with a variety of serious grievances, more than sufficient to motivate such an intervention. The military failed to move against reforms because no Russian hyper-nationalist political movement emerged to provide legitimacy for such an action. Moreover, the coup took place at the moment when civilian control over the armed forces was already split between the declining USSR government and the rising star of Russia under Boris Yeltsin. Nevertheless, the possibility of military intervention in politics in Russia remains high for the near future.

PUBLICATION: Tsypkin, M., "Military and Politics during the Crisis of Soviet Communism," NPS Technical Report, forthcoming.

THESES DIRECTED: Corrigan, M.J., "Gorbachev, the Generals and the Turn to the Right," MA in National Security Affairs, June 1991.

Ziebarth, K.W., "Civil-Military Relations in the Soviet Union: Poised for Conflict?" MA in National Security Affairs, December 1991.

EXPANDING CHINESE NAVAL POWER AND MARITIME SECURITY IN SOUTHEAST ASIA

David Winterford, Assistant Professor of National Security Affairs
Sponsor: Chief of Naval Operations
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this research was to investigate Chinese strategic perceptions of Southeast Asia, China's new maritime strategy, China's evolving naval capabilities and the impact of Chinese naval capabilities on the security order in the region. This research examined implications of these developments for the U.S. Navy in the Pacific. This is part of a larger continuing project which examines Chinese, Japanese and Indian naval rivalries in Asia.

SUMMARY: The unfolding post Cold War era is dramatically affecting security and stability in Southeast Asia. During the past decade, the old Soviet Union and its regional ally, Vietnam, were the chief threats to Southeast Asian security. However the collapse of communism in the Soviet Union, the collapse of the Soviet Union itself, the retrenchment of Russian external military power and now the sharp cutback in Russian aid to Vietnam have all worked to reduce drastically a Russian or Russian/Vietnamese threat to the region.

Nevertheless, the end of East-West competition for global preeminence is unleashing powerful forces for strategic change in the Asia-Pacific region. A reconfiguration of the regional security balance may be taking place, especially a resurging naval rivalry, as aspiring hegemons--notably China, Japan and India--jostle for leadership roles. This research examined the central role being played by China in the unfolding security changes in Asia. Chinese naval modernization was analyzed within the context of China's Southeast Asian maritime interests, its new maritime strategy, and its evolving naval capabilities.

This research examined implications for the United States, especially for U.S. naval planning, of China's burgeoning regional naval capability. The research resulted in recommendations concerning the U.S. naval presence in Asia; the need to protect American economic and political interests in the region; the desirability of creating a loose yet textured and inclusive multilateral set of security relations in the Asia-Pacific region; and the need to initiate a Sino-American naval reapproachment as a prelude to enhanced regional naval cooperation. In view of China's maritime strategy and its naval capabilities, this research indicated a pressing need to reassure America's friends and in the region through a continuing American naval presence.

CONFERENCE PRESENTATIONS: Winterford, D., "Security in Southeast Asia--A U.S. Perspective," presented at a seminar on Southeast Asian Security, Institute for Southeast Studies, Singapore, 19 September 1991.

Winterford, D., "The Changing U.S. Security Presence in Southeast Asia," Roundtable on Asian Security, Center ford International and Strategic Studies, Kuala Lumpur, Malaysia, 24 September 1991.

THESES DIRECTED: Little, John, LT, USN, "Vietnam and U.S. Foreign Policy: Future Partners for the Strategic Balance in Southeast Asia?" MS Thesis, December 1991.

Stouffer, Robert, LT, USN, "ASEAN-United States Relations: Prospects for the 1990s," MS Thesis, June 1991.

Taylor, Mark, CDR, RAN, "From Alliance to Acquaintance: Australian Security Policy and the U.S. Military Withdrawal from Asia," MS Thesis, December 1991.

OTHER: This is part of a larger project investigating prospects for Chinese, Japanese and Indian naval rivalries in Asia. The investigator is preparing a book-length manuscript for publication on New Naval Rivalries in Asia.

REPORT OF THE EXPANDED IMET INITIATIVE PROJECT

David Winterford, Assistant Professor of National Security Affairs
Robert Boynton, Associate Professor of DRMEC
Cynthia Dressler, Adjunct Professor of Administrative Sciences
Sponsor: Defense Security Agency
Funding: Defense Security Agency

OBJECTIVE: The goal of this project was to evaluated the United States Military Services capability to support an expanded role for the International Military Education and Training (IMET) Program.

SUMMARY: Congress has shown a strong interest in the IMET program and directed the Defense Security Assistance Agency (DSAA) to make the program more responsive to changing global and regional political conditions. The focus of Congressional interest is to make available intensive, professional level training in the management of defense ministries, forces and budgets, and in creating and implementing effective military justice systems and codes of conduct, with special emphasis on the protection of human rights. Congress mandated that DSAA report back to the Congress on the services' capability to support this change in emphasis.

In accordance with guidance contained in SECDEF MSG 240539Z, the DSAA tasked NPS to survey, review and evaluate all approved IMET courses offered in the United States. This project obtained the necessary information from all services and from throughout the United States and evaluated the content of all of the courses in order to make a determination of those courses meeting the criteria of contribution to: responsible defense resource management; improving military justice systems; and, teaching the principle of civilian control of the military.

PUBLICATION: Winterford, D., Boyton, R. and Dressler, C., "Report of the Expanded IMET Initiative Project," submitted to the Director, Defense Security Assistance Agency. The results of this project were subsequently included in a report made by the DSAA to the Senate Foreign Relations Committee.

SYSTEM CONSTRAINTS AND THE ERUPTION OF WAR BETWEEN GREAT AND WEAK POWERS

James J. Wirtz, Assistant Professor of National Security Affairs
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To explore the different constraints and incentives facing states in bipolar and multipolar worlds, and how these different constraints and incentives will influence the likelihood of war between weak and strong states.

SUMMARY: Work is progressing well. Already two publications can be linked to the project. Two conference papers are currently under revision for publication. Results also have been presented at two academic conferences in 1991 and two more papers will be presented at academic conferences in 1992. The project is expanding to explore questions of nuclear deterrence in the post-Cold War world.

PUBLICATIONS: Wirtz, James, J., "Miscalculation, Surprise and American Intelligence After the Cold War," *International Journal of Intelligence and Counterintelligence*, 5(1), 1991.

Wirtz, James, J., "After the Cold War: Miscalculation, Surprise and U.S. Intelligence," *Studies in Intelligence*, Fall 1991.

CONFERENCE PRESENTATIONS: Wirtz, James, J., "The Straw that Broke the Camel's Back: Westmoreland, Wheeler and the Post-Tet Troop Request," Northeast Political Science Annual Meeting, Philadelphia, PA, 16-17 November 1991.

Wirtz, James, J., "The Outbreak of the 'Big-Unit' War in Vietnam," Annual Meeting of the Society of Historians of American Foreign Relations, Washington, DC, 19-22 June 1991.

Wirtz, James, J., "U.S. Military Intelligence: Focus West, East, and Points in Between," Annual Meeting of the International Studies Association, Vancouver, B.C., 19-23 March 1991.

OTHER: Research from this project is expected to culminate in an edited book and a separate book-length manuscript.

STRUCTURAL FACTORS IN THE LONG-TERM COMPETITION

D.S. Yost, Professor of National Security Affairs
Sponsors: Under Secretary of Defense for Policy
and Director of Net Assessment
Funding: Under Secretary of Defense for Policy
and Director of Net Assessment,
Office of the Secretary of Defense

OBJECTIVE: When the research began in 1986, the research monitor, the Director of Net Assessment in the Office of the Secretary of Defense, directed that the research effort focus on the analysis of security issues relating to Western Europe.

SUMMARY: The research involved analysis of primary sources dealing with European security problems, including West European views on topics such as the Conference on Security and Cooperation in Europe and possible Western responses to potential crises in Eastern Europe and the Soviet Union. Special attention was devoted to France, Britain, and Germany, especially with respect to the future of NATO and nuclear deterrence in Europe as well as West European security cooperation.

PUBLICATIONS: Yost, D.S., "France in the New Europe," *Foreign Affairs*, 69:107-128, Winter 1990-1991.

Yost, D.S., "La France dans la nouvelle Europe," *Politique Étrangère*, 55:887-901, Winter 1990-1991.

Yost, D.S., "Frankreich in einem neuen Umfeld," *Europa-Archiv*, (23):691-702, 10 December 1990.

Yost, D.S., "La prospettiva francese per la cooperazione di difesa europea occidentale," in Luigi Caligaris, ed., *La Difesa Europea: Proposte e Sfide,* Milano: Edizioni di Communità, 110-134, 1990.

Yost, D.S., "Franco-German Defense Cooperation," in Stephen Szabo, ed., *The Bundeswehr and Western Security*, London: Macmillan and New York: St. Martin's Press, 217-258, 1990.

Yost, D.S., "Shin-Ohshu ni okeru Furansu no Yakuwari," *Chuo Koron*, Tokyo, (2):375-395, February 1991.

Yost, D.S., "France and West European Defense Identity," *Survival*, 33:327-351, July/August 1991.

Yost, D.S., "U.S. Military Power and Alliance Relations," *The Annals of the American Academy of Political and Social Science*, (517):80-93, September 1991.

Yost, D.S., "Mitterrand and Defense and Security Policy," *French Politics and Society*, 9:141-158, Summer/Fall 1991.

Yost, D.S., "Western Nuclear Force Structures", in Beatrice Heuser, ed., *Nuclear Weapons and the Future of European Security*, London: Brassey's for the Centre for Defense Studies, King's College, University of London, 26-46, 1991.

Yost, D.S., "Western Nuclear Force Structures," in Beatrice Heuser, ed., *Nuclear Weapons and the Future of European Security*, College Park, Maryland: Center for International Security Studies, School of Public Affairs, University of Maryland, 26-46, 1991.

Yost, D.S. "La politique américaine et les nouveaux équilibres stratégiques", in Quelle sécurité en Europe á l'aube du XXIe siécle?, tome 1, Paris: École Supérieure de Guerre, 161:145-147, 1991.

Yost, D.S., "France [and Arms Control]," in Fen Hampson, Harald von Riekhoff, and John Roper, eds., *The Allies and Arms Control*, Baltimore: Johns Hopkins University Press, forthcoming.

CONFERENCE PRESENTATIONS: Yost, D.S., "France and the New Atlantic Alliance," Fondation du Futur, Paris, 24 January 1991.

Yost, D.S., "French Security Policy after German

Unification and the Persian Gulf War," École Supérieure de Guerre, Paris, 8 March 1991.

Yost, D.S., "French Strategic Culture and Public Opinion on Nuclear Weapons," Institut d'Histoire des Relations Internationales Contemporaines, Paris, 8 March 1991.

Yost, D.S., "France and the New Atlantic Alliance," University of Paris (Sorbonne) 14 March 1991.

Yost, D.S., "The United States and Security in Europe," École Supérieure de Guerre, Paris, 10 April 1991.

Yost, D.S., "Current Issues in French Security Policy," National Defense University, Washington, DC, 2 May 1991.

Yost, D.S., "Current Issues in French Security Policy," School of Advanced International Studies, Johns Hopkins University, Washington, DC, 3 May 1991.

Yost, D.S., "Current Issues in French Security Policy," The Pentagon, Washington, DC, 7 May 1991.

Yost, D.S., "U.S. Policy on the Future of European Security," Centre d'Étude des Relations entre Technologies et Stratégies (CREST), École Polytechnique, Paris, 24 June 1991.

Yost, D.S., "Nuclear Force Structures," presented at a two day conference on "Nuclear Weapons and the Future of European Security" at the Institut de France, Paris, 25 June 1991.

Yost, D.S., "British and French Nuclear Forces and Prospects for a Joint West European Nuclear Deterrent," presentation at a one-day workshop on the future of nuclear deterrence in Europe, Center for National Security Studies, Los Alamos National Laboratory, Los Alamos, New Mexico, 26 July 1991.

THESES DIRECTED: Durnan, M., LCDR, USN, "Resource Management Strategy in the French Navy," MS Thesis, June 1991.

Martin, F.X., LT, USN, "The Guadalajara Accord between Brazil and Argentina: A Tentative Step toward the Nuclear Weapons-Free Latin America Envisioned by the Treaty of Tlatelolco," MS Thesis, December 1991.

DEPARTMENT
OF
OCEANOGRAPHY

DEPARTMENT OF OCEANOGRAPHY

Coastal and Nearshore Oceanography

Professor S. R. Ramp has been a participant in three projects. He is completing the analysis and interpretation of hydrographic and acoustic doppler current profiler (ADCP) data which he collected for the "Coastal Transition Zone" project. Professor Ramp is presently making direct measurements of the currents on the shelf and slope off Pt. Sur and the Farallon Islands using moored current meters. The technical sponsors for these studies are ONR, WESTDIV and the Environmental Protection Agency.

Professors C. A. Collins and N. Garfield are studying the kinematics of the currents across the continental margin off Pt. Sur using velocity sounding techniques. The sponsor for this study is ONR. Professors Collins, Garfield, and Rosenfeld also collected data in the region to the west of the Farallons; this study was sponsored by the Environmental Protection Agency.

Professor L. Rosenfeld is studying the circulation of Monterey Bay using shipboard CTD and acoustic doppler current measurements and moored temperature and current measurements.

Professor N. Garfield is utilizing AVHRR data to assist in the analyses of different coastal phenomenon in the Central California region.

Professors E. B. Thornton and C. S. Kim are measuring and developing models of nearshore wave dynamics. Models have been developed to describe wave transformation and mean alongshore currents. Shear waves developed due to instability of the wave induced alongshore current are shown to be responsible for turbulent mixing in the nearshore. A field experiment, Delilah, was conducted in October. The technical sponsor for these studies is ONR.

Under sponsorship of ONR, Professor M. L. Batteen is utilizing climatological data bases for wind and thermal forcing in an eddy-resolving, primitive equation model to study the generation of currents and eddies in the California Current System.

Professor J. A. Nystuen is completing a study of mesoscale circulation in the Caribbean Sea using GEOSAT altimeter data.

Acoustical Oceanography

Professors C.-S. Chiu and A. J. Semtner are conducting simulation studies of the variability of cross-basin sound transmissions using output of the Semtner-Chervin global eddy-resolving ocean model. This research is sponsored by ONR.

Professor R. H. Bourke continued studies of the ambient noise generated in Arctic ice-covered waters based on noise measurements acquired by drifting buoys and, as part of Project CEAREX, from hydrophones north of Svalbard. Additionally, under ice scattering as modeled by ICECAP was compared to measured transmission loss data. The sponsor is the Arctic Submarine Laboratory and the Naval Oceanographic Office.

Professor C.-S. Chiu is studying the circulation of the Greenland Sea gyre using inverse techniques and acoustic tomography data collected by WHOI and SIO in the Greenland Sea Project (GSP). This research is sponsored by WHOI.

Professors R. H. Bourke and C.-S. Chiu are participating in the Barents Sea Transmission Test Experiment. In this joint experiment with WHOI and SAIC, they will collect acoustic and hydrographic data and perform the subsequent data analysis. This research is sponsored by ONR.

Professor J. A. Nystuen is developing techniques for monitoring air/sea interaction processes at sea through ambient sound measurements. He is continuing laboratory analysis of the small scale physics of sound production by raindrops. He is collecting field measurements of sound generated by heavy rain on the Gulf of Mexico. His continuing efforts to develop an acoustic ocean drifting buoy to acoustically monitor the ocean in conjunction with satellite measurements. Drifting acoustic buoys have been deployed off the California coast. The technical sponsor is NOARL.

Professor T. P. Stanton is developing very high resolution acoustic doppler instrumentation capable of measuring three component velocity structure down to dissipation scales. Coherent doppler estimation and combinations of monostotic and bistatic geometries have been successfully used to provide a unique capability to measure turbulent processes in the upper ocean. This research has been sponsored by ONR.

Professors R. H. Bourke and R. G. Paquette are involved in studies of water mass and mesoscale circulation associated with ice edges of the Atlantic and Pacific Oceans as well as studies of Arctic sea ice. Most recently, they have studied the characteristics of the Jan Mayen Current from two summertime cruises as part of the Greenland Sea Project. Other on-going studies include the spatial and seasonal distribution of under ice roughness parameters. Future studies include an investigation of the Bear Island Polar Front of the Barents Sea and an analysis of CTD data acquired throughout the Arctic Basin by naval sources. The Arctic Submarine Laboratory sponsors this research.

Air-sea Interaction and Ocean Turbulence

Professors R. W. Garwood, Jr. and P. Chu are sponsored by ONR to investigate the thermodynamic and dynamic coupling between the oceanic and atmospheric turbulent boundary layers. A new mechanism for feedback between the oceanic mixed layer and cloud formation in the tropics has been discovered and will be applied to the Western Pacific Warm Pool and TOGA COARE. A new theory about El Nino phenomenon was proposed.

Professors Garwood, Chu and Glendenning have recently received an NSF grant to study the role of turbulent mixing in the Arctic system of ocean-ice-atmosphere (ARCSS) interactions. They have found a thermodynamic instability for deep mixing that may help explain deep water formation in the polar seas, and they will be investigating these processes with large-eddy numerical simulation.

Professor T. P. Stanton is studying the turbulent structure of the surface turbulent boundary layer using both high resolution acoustic doppler and laser instrumentation developed by his research group. These instruments are currently being deployed in an ONR sponsored Lead program to quantify the fluxes and mixing mechanisms associated with winter leads in the arctic. He is also participating in collaborative research with MBARI investigating surface mixing and diffusion in Monterey Bay using the MBARI ROV as a semi-Lagrangian instrument platform.

Numerical Prediction and Data Assimilation

Under sponsorship of the NSF, Professor A. J. Semtner, Jr., completed a numerical simulation of global ocean circulation with mesoscale resolution. This calculation has established the feasibility of ocean prediction using modern large-scale computers. An analysis of the ocean general circulation of the model is underway.

Under sponsorship of ONR, through the "Coastal Transition Zone" (CTZ) and Eastern Boundary Current (EBC) research initiatives, Professor M. L. Batteen has been using an eddy-resolving, primitive equation model to understand the role of wind forcing in eddy and jet formations in EBCs. The EBCs have expanded from the California Current system to the EBCs off Portugal and Chile.

Under sponsorship of NSF, Professor Batteen has expanded her modeling efforts to include thermal as well as wind forcing in the EBC region off Western Australia. This research has resulted in the first eddy-resolving model simulation of eddies off Western Australia.

Professor E. Carter began studies on data assimilation into numerical ocean models. The sponsor for this work is NPS.

Marine Operations

Commander F. M. Reynolds, USN, managed shipboard support for NPS at sea research projects off the Central California coast. Seventy-nine days of operations were carried out on the R/V Pt. Sur and an additional thirty-seven days at sea were supported on other research vessels including the USNS DeSteiguer and USNS Bartlett. Students and faculty participating in these shipboard projects included the Departments of Oceanography, Meteorology, and Physics. The sponsor for this project is the Commander, Naval Oceanography Command.

MODELING STUDIES OF EDDIES IN EASTERN BOUNDARY CURRENT REGIONS

Mary L. Batteen, Associate Professor of Oceanography
C.S. Nelson, Captain, NOAA
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this project is to better understand the roles of forcing mechanisms in eastern boundary current (EBC) regions, particularly the EBC regions off California, Portugal and Chile. The ultimate goal is to understand the roles of eddy generation mechanisms in each region well enough to provide a basis for prediction in the EBC and other dynamically similar regions.

SUMMARY: Different forcing (e.g., wind and thermal) have been incorporated into an existing primitive equation model. The effects of each mechanism have been analyzed by varying the type of forcing. In particular, we have focused on cases of steady/transient winds, with and without the curl, in a flat-bottom ocean. Preliminary results show the development of eddies and jets. Model improvements in these studies are to incorporate topography and finer horizontal and vertical resolution (to look at fronts).

PUBLICATIONS: Batteen, M.L., Lopes da Costa, C.N. and Nelson, C.S., "A Numerical Study of Wind Stress Curl Effects on Eddies and Filaments off the Northwest Coast of the Iberian Peninsula," *Journal of Marine Systems*, 3, (in press, 1991).

Bakun, A., and Nelson, C.S., "The Seasonal Cycle of Wind Stress Curl in Subtropical Eastern Boundary Current Regions," *Journal of Physical Oceanography*, 21:1815-1834,1991.

Strub, P.T., Kosto,P.M., Huyer, A., Brink, K.H., Hayward, T.L., Niiler, P.P., James, C., Dewey, R.K., Walstad, L.J., Chavez, F., Ramp, S.R., Mackas, D.L., Swenson, M.S., Washburn, L., Barth, J.A., Hood, R.R., Kadko, M.R., Barber, R.T., Haidvogel, D.B., Batteen, M.L. and Haney, R.L., "The Nature of the Cold Core Filaments in the California Current System," *Journal of Geophysical Research*, 96:14,743-14,768, 1990.

Batteen, M.L., Nelson, C.S., Edson, R.W. and Bayler, E.J., "Model Simulations and Comparisons of Eastern Boundary Coastal Circulations," *IAPSO Abstracts*, 83.

Batteen, M.L., "Modeling Studies of the California Current System," *EPOC Abstracts* (in press, 1991).

Bacon, J.L., Batteen, M.L. and Nelson, C.S., "A Numerical Study of the Effects of Wind Forcing on the Chilean Current System," Naval Postgraduate School Technical Report, NPS-OC-91-001.

Buss, S.L., Batteen, M.L. and Nelson, C.S., "A Numerical Study of Time-Dependent Wind Forcing off the West Coast of Portugal, 1987-1988," Naval Postgraduate School Technical Report, NPS-0C-91-002.

Batteen, M.L., Lopes da Costa, C.N. and Nelson, C.S., "Wind Stress Curl Effects on Eddies and Filaments off the Northwest Coast of the Iberian Peninsula," Research Activities in Atmospheric and Oceanic Modeling (G. J. Boer, Editor), WMO/JSC Working Group on Numerical Experimentation (in press, 1991).

CONFERENCE PRESENTATIONS: Batteen, M.L., Nelson, C.S., Edson, R.W. and Bayler, E.J., "Model Simulations and Comparisons of Eastern Boundary Coastal Circulations," IAPSO General Assembly, Vienna, Austria, 12-21 August 1991.

Batteen, M.L., "Modeling Studies of the California Current System," Eastern Pacific Oceanic Conference (EPOC), Lake Arrowhead, CA.

THESES DIRECTED: Bacon, J.L., LCDR, U.S. Navy, "A Numerical Study of the Effects of Wind Forcing on the Chilean Current Systems," MS Thesis, June 1991.

Buss, S.L., LT, U.S. Navy, "A Numerical Study of Time-Dependent Wind Forcing off the West Coast

of Portugal," MS Thesis, June 1991.

OTHER: Batteen, M.L., Lopes da Costa, C.N. and Nelson, C.S., "A Numerical Study of Time-Dependent Wind Forcing off the West Coast of Portugal," submitted to *Journal of Marine Research*.

Batteen, M.L., Edson, R.W. and Nelson, C.S., "Effects of Spatially Varying Winds in the Central California Current System." To be resubmitted to *Journal of Geophysical Research*.

Stanton, T.P., Stockel, J.A., Batteen, M.L. and Ramp, S.R., "Upper Ocean Response to a Wind Relaxation Event in the Coastal Transition Zone," submitted to *Journal of Geophysical Research*.

FACILITIES FOR THE INVESTIGATION OF EBC REGIONS THROUGH COUPLED SATELLITE IMAGING AND MODELING STUDIES

M. L. Batteen, Associate Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Office of Naval Research

OBJECTIVE: The goal of this project is to acquire and utilize the facilities of workstations and video equipment to aid in the interpretation, presentations, and verification of model results obtained in other ONR-sponsored research.

SUMMARY: Modeling studies, sponsored by ONR, are currently being used to investigate the generation of currents, eddies and jets in eastern boundary current (EBC) regions. To aid in the interpretation, presentation, and verification of the model results, we have acquired and utilized the facilities of workstations and video equipment (for time series of the model output).

MODELING STUDIES OF THE EASTERN BOUNDARY CURRENT FLOW OFF WESTERN AUSTRALIA

Mary L. Batteen, Associate Professor of Oceanography
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: The objectives of this project are to investigate (1) why the eastern boundary flow off Western Australia (W.A.) is generally poleward rather than equatorward, and (2) why mesoscale eddies are present in this region. To accomplish these goals, we propose to (1) adapt an existing primitive equation (PE) ocean model presently being used in the eastern boundary flow region off California to the eastern boundary flow region of W.A.; (2) incorporate different initial conditions appropriate for the W.A. region into the model: and (3) run a series of numerical model experiments using the different initial conditions. Analysis of the results from each experiment should determine under what conditions a poleward flow (called the Leeuwin Current) and/or mesoscale eddies are generated. The ultimate goal is to provide the physical understanding necessary for high resolution ocean prediction in this region.

SUMMARY: Different numerical model experiments in a regional primitive equation ocean model were run to investigate the eastern boundary flow off W.A. Particular attention was given to investigating (1) why the flow is generally poleward rather than equatorward as in other eastern boundary currents and (2) why there are mesoscale eddies present. The roles of thermal and wind forcing studies have been completed, while the study of seasonal wind and thermal forcing effects on the ocean circulation off W.A. is ongoing.

PUBLICATIONS: Batteen, M.L., Nelson, C.S., Edson, R.W. and Bayler, E.J., "Model Simulations and Comparisons of Eastern Boundary Coastal Circulations," *IAPSO Abstracts*, 83, 1991.

Bayler, E.J. and Batteen, M.L., "Seasonal Wind and Ocean Thermal Forcing Influences on the Generation of the Leeuwin Current and Its Eddies," Naval Postgraduate School Technical Report, NPS OC-91-003, 193 pp.

CONFERENCE PRESENTATION: Batteen, M.L., "Model Simulations and Comparisons of Eastern Boundary Coastal Circulations," IAPSO General Assembly, Vienna, Austria, 11 - 24 August 1991.

THESIS DIRECTED: Bayler, E.J., LCDR, U.S. Navy, "A Numerical Study of Seasonal Wind and Thermal Forcing Effects on the Ocean Circulation off Western Australia," MS Thesis, September 1991.

OTHER: Batteen, M.L., Rutherford, M.J. and Bayler, E.J., "A Numerical Study of Wind and Thermal Forcing Effects on the Ocean Circulation off Western Australia," *Journal of Physical Oceanography* (in press, 1992).

MARGINAL SEA-ICE ZONE STUDIES 1991

Robert H. Bourke, Professor of Oceanography
Robert G. Paquette, Emeritus Professor of Oceanography
Sponsor: Arctic Submarine Laboratory
Funding: Arctic Submarine Laboratory and the Naval Postgraduate School

OBJECTIVE: Carry out physical oceanographic research, including field measurements, in the marginal sea-ice zone of the Bering, Chukchi, and Greenland Seas. This work has the long-term applied objective of facilitating the operation of submarines under ice. It is part of the continuing MIZPAC and MIZLANT programs.

SUMMARY: This is an ongoing program to study the oceanographic and acoustic phenomena associated with the ice edges of the Atlantic and Pacific Oceans. Measurements, primarily CTD lowerings, have been carried out from ice breakers since 1971 and include observations both in summer and winter. The data obtained during the Greenland Sea Project August 1990 cruise of the BARTLETT to study the Jan Mayen Current have been edited and reduced and a data report prepared. Analysis of the upper layer waters is still in progress. The formation of various deep waters in the Greenland Sea based on our 1989 and 1990 data was presented at the IUGG conference and is being written up for publication. We completed the study of ambient noise measured during CEAREX (Fall 1989) and found the noise level to be highly correlated with ice drift and tidal forcing. The performance of the ICECAP underice transmission loss (TL) model was assessed using measured sound speed profiles (SSP) and ice roughness values obtained during ICEX-88 and simulations were compared against measured TL values. The need for accurate SSP's was demonstrated. Preparations were initiated for our next field project to be conducted in the Barents Sea in August 1992.

PUBLICATIONS: Bourke, R.H., Paquette, R.G. and Blythe, R.F., "The Jan Mayen Current of the Greenland Sea," *JGR-Oceans* (in press, 1992).

Pritchard, R.S., R.H. Bourke, and J.D. Cousins, "Eastern Arctic Ambient Noise: October-November 1988," submitted to JASA Acoustical Society of America.

Paquette, R.G., Bourke, R.H. and Stone, M.D., "USNS BARTLETT Cruise to the Greenland Sea in August 1990 Data Report, NPS Technical Report, NPS-OC-92-001, November 1991.

CONFERENCE PRESENTATIONS: Bourke, R.H., Blythe, R.F., Paquette, R.G. and Stone, M.D.,"On the Deep and Bottom Waters of the Greenland Sea from Summer 1989 and 1990 Data, XX General Assembly, International Union of Geodesy and Geophysics, Vienna, Austria, August 1991.

Bourke, R.H., "Overview of Arctic Education and Research at NPS," AEAS Arctic Data Analysis meeting, NOARL-West, Monterey, July 1991.

Bourke, R.H., "Overview of Arctic Research at NPS," Arctic Research Commission, Monterey, December 1991.

Stone, M.D., Bourke, R.H., and Paquette, R.G., "Studies of the Jan Mayen Current and Deep Water Formation from 1989 and 1990 Summer Data," Greenland Sea Project Workshop, Copenhagen, December 1991.

THESES DIRECTED: Cousins, J.D., LT, USN, "CEAREX Ambient Noise Data Measured Northeast of Svalbard," MS Thesis, March 1991.

Coglan, A.J., LT, USN, "Acoustic Propagation in the Greenland Sea Marginal Ice Zone Using the ICECAP Model," MS Thesis, September 1991.

Emblidge, J.M., LT, USN, "A Feasibility Study of Ocean Acoustic Tomography in the Barents Sea," MS Thesis, September 1991.

OTHER: Provided fifty page report to Director, Arctic Submarine Laboratory (research sponsor) which discussed tactical impact of our oceanographic and acoustic research on submarine operations under ice; for use in the submarine Prospective Commanding Officer Course.

CHAIR IN ARCTIC MARINE SCIENCE

Robert H. Bourke, Professor of Oceanography

Sponsor: Office of Naval Research
Funding: Office of Naval Research and the Naval Postgraduate School

OBJECTIVE: To foster oceanographic research in the Arctic, acquaint naval officer students with Arctic problems, reduce results of pure research to operational usage, and publicize Navy interest in the Arctic.

SUMMARY: Professor Bourke served as administrator of the Chair handling such details as selecting Chair candidates, writing IPA's and proposals and setting up visits and seminars for the Chair incumbent. Dr. John L. Newton, a private consultant, was the Chair incumbent during FY 91. He had a productive year at NPS providing seminars, taught an environmental acoustics course and provided lectures in the polar oceanography course, writing papers, attending conferences and spending two months in the field. During his stay at NPS he wrote a paper on the hydrographic and current structure along the Lincoln Sea continental slope stressing the boundary undercurrent, updated his earlier analysis of the Arctic density (salinity) distribution for use in submarine buoyancy considerations and completed a study of the sound speed structure of the central Arctic and marginal ice zone areas. He obtained and installed the latest version of the underice transmission loss model, ICECAP, and directed a Master's thesis which investigated the credibility of the models' database information. He also advised another thesis concerning the variability of acoustic propagation in various regions of the Arctic basin. He organized and hosted the AEAS Arctic Data Analysis meeting. He attended eight various professional and analysis working meetings during the year.

THESIS DIRECTED: Coglan, Adam J., LT, USN, "Acoustic Propagation in the Greenland Sea Marginal Ice Zone Using the ICECAP Model," September 1991.

DATA ASSIMILATION MODELLING

Everett Carter, Assistant Professor of Oceanography
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: This project considered the problem of assimilating observations of ocean data into an evolving numerical model of the ocean dynamics. The intent is to improve the implementation of the two dimensional version of a one dimensional scheme developed by the principal investigator. This research is continuing.

SUMMARY: As part of this project, some theoretical results were found and presented at UCLA (see conference presentations). A useful technique for estimation was developed and is described in a paper that is now in the review process.

CONFERENCE PRESENTATIONS: Carter, E.F., "The Behavior of the Covariance Equation in the Kalman/Data Assimilation Filters," presented to the Department of Atmospheric Sciences, UCLA, May 1991.

Carter, E.F.,"On Estimation Methods in Oceanography," presented to the Operations Research Department, Naval Postgraduate School, December 1991.

TIME DOMAIN ACOUSTIC SIGNALS LOCALIZATION AND TRACKING

Ching-Sang Chiu, Assistant Professor of Oceanography
James H. Miller, Assistant Professor of Electrical and Computer Engineering
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this new project is to investigate the use of time-domain sound propagation models and processing techniques for localizing sources of short-duration, acoustic signals.

SUMMARY: In December 1988, an acoustic experiment was held in the Monterey Bay, which had as one of its goals, to understand underwater acoustic pulse propagation in a complicated coastal environment. We have recently been able to accurately model the pulse propagation on a workstation. The agreement between the modeled results and the data obtained in the Monterey Bay is extraordinary. It motivated us to think about the problem of localizing sources of short-duration, acoustic signals using time-domain processing.

An optimal time-domain processing algorithm was developed. Using the Monterey experiment as a test case, we were able to localize the sound source on a given line-of-bearing to high accuracy using the computer and a modeled pulse from a single sonobuoy. The algorithm's localization error was at most 0.6 nautical miles in range and 45 feet in depth for the Monterey test case. The next steps in this project are: (1) Fully explore the capabilities and limitations of the algorithm; (2) Demonstrate the technique in an experiment; and (3) Evaluate the algorithm's compatibility with present and new generation Navy ASW systems and environmental databases.

THESIS DIRECTED: Westreich, Eric L., "Modeling Pulse Transmission in the Monterey Bay using Parabolic Equation Methods," MS in Physical Oceanography and Meteorology, December 1991.

BARENTS SEA TOMOGRAPHY TRANSMISSION TEST: SHALLOW WATER VERTICAL ARRAY COMPONENT

Ching-Sang Chiu, Assistant Professor of Oceanography
James H. Miller, Assistant Professor of Electrical and Computer Engineering
Robert H. Bourke, Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Reimbursable, Cost-Shared

OBJECTIVE: Our objectives for this experiment are: (1) to study the geoacoustic parameters and oceanographic processes that control the acoustic wavefields and their space-time coherence in the Barents Sea through data collection, analysis, and modeling, (2) to determine the feasibility of monitoring ocean circulation using tomographic techniques in the Barents Sea region, and (3) to investigate the dynamics of the ocean circulation in the Barents Sea, particularly in the vicinity of the Polar Front, through data collection, analysis, and modeling.

SUMMARY: In this new two year project, NPS will participate in the Barents Sea Tomography Transmission Test in the summer of 1992 and to perform subsequent data analysis. Our participation would include the deployment of a shallow water vertical array. This array would be used to monitor tomography signals emitted by three sound sources to be deployed by Woods Hole Oceanographic Insti-tution at a range of 50-75 km. The planned experimental configuration would allow for acoustic paths which either cross or are parallel to the Barents Sea Polar Front.

COMPUTER SIMULATION STUDIES OF LOW-FREQUENCY CROSS-BASIN ACOUSTIC TRANSMISSIONS

Ching-Sang Chiu, Assistant Professor of Oceanography
Albert J. Semtner, Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: An underwater acoustic technique was proposed by Munk and Forbes (1989) for monitoring greenhouse warming. It involves making decadal measurements of cross-basin acoustic travel-time variability. A two-week global acoustic transmission experiment was carried out in January 1991 to evaluate the feasibility of this acoustic method. In support of the experimental effort, the objective of this modelling work was to simulate the influence of ocean fronts, eddies and seasonal cycles on the three-dimensional acoustic ray paths crossing the Indian and Pacific Oceans to the west coast of the United States from Heard Island, the location of the sound source.

SUMMARY: For the computation of the cross-basin acoustic paths, a three-dimensional Hamiltonian acoustic raytracing code developed originally by Jones et al. (1986) was upgraded. The input sound speed fields to the acoustic ray model were interpolated from gridded temperature and salinity output data from the Semtner-Chervin eddy-resolving global general circulation model (1988). The variabilities of the cross-basin ray paths, travel times, illuminated locations, and azimuthal arrival angles were examined. This analysis provided important input to experimental planners for receiver placement off the California coast.

CONFERENCE PRESENTATIONS: Baggeroer, A.B., Lashkari, K., Miller, J.H., Chiu, C.-S., Frogner, G., Mikhalevsky, P.N. and Von der Heydt, K., "Vertical Array Resolution of the Normal Modes from the Heard Island Signals," Houston ASA Meeting, 4-8 November 1991.

Chiu, C.-S., Semtner, A.J., Ort, C.M., Miller, J.H. and Ehret, L.L., "A Ray Variability Analysis of Sound Transmission from Heard Island to California," Houston ASA Meeting, 4-8 November 1991.

THESES DIRECTED: Ogawa, Hiroyuki "Testing the Accuracy of a Three-Dimensional Acoustic Coupled Mode Model," MS in Physical Oceanography, December 1991.

Crocker, Steven, E., "Time Domain Modal Beamforming for a Near Vertical Acoustic Array," MS in Engineering Acoustics, December 1991.

Pimentel, Fernando, M.M.,"Computation of Acoustic Normal Modes in the Ocean using Asymptotic Expansion Methods," MS in Physical Oceanography, September 1991.

Frogner, Gary, R., "Global Acoustic Transmissions: Signal Processing and Preliminary Data Analysis," MS in Physical Oceanography and Meteorology, September 1991.

FEASIBILITY STUDY FOR A NORWEGIAN CONTINENTAL SHELF-BARENTS SEA ACOUSTIC TOMOGRAPHY EXPERIMENT

Ching-Sang Chiu, Assistant Professor of Oceanography
James H. Miller, Assistant Professor Electrical and Computer Engineering
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of the project was to investigate the feasibility of a Norwegian Continental Shelf-Barents Sea tomography experiment for studying the dynamics of the region's ocean circulation.

SUMMARY: This feasibility study consisted of two major parts. In the first part, tomographic array performance in the Norwegian Sea was simulated in the computer. These simulations gave estimates of system resolution and variance for various array geometries and were essential for assessing the adequacy of acoustic tomography and the selection of optimal configurations in the deep locations. The second part addressed the acoustic issues of ray resolvability and variability in the Barents Sea. These issues are critical for solving the forward problem of acoustic tomography in this coastal environment and were investigated using measured environmental data in a 3D ray acoustics model. Synthetic inversions will be conducted in early 1992 to evaluate system performance of tomography in the Barents Sea.

In addition to the above numerical assessments of tomography performance, another accomplishment was the development of a linear predictive filter to track arrival times of partially resolved acoustic rays. The predictive filter is useful for providing additional travel time data from partially resolved rays in coastal tomography experiments.

CONFERENCE PRESENTATION: Miller, J.H., Lynch, J.F., Chiu, C.-S., Hippenstiel, R., Chaulk, E. and Gerber, J.S., "Surface Wave Tomography in Monterey Bay using Mode Travel Time Fluctuations," Houston ASA Meeting, 4-8 November, 1991.

THESIS DIRECTED: Emblidge, John M., "A Feasibility Study of Ocean Acoustic Tomography in the Barents Sea," MS in Physical Oceanography, September 1991.

GREENLAND SEA TOMOGRAPHY DATA ANALYSIS

Ching-Sang Chiu, Assistant Professor of Oceanography
Sponsor: Woods Hole Oceanographic Institution
Funding: Reimbursable

OBJECTIVE: An acoustic tomography array consisting of six transceiver moorings was jointly deployed by Woods Hole Oceanographic Institution (WHOI) and Scripps Institution of Oceanography in the Greenland Sea during the late summer to early fall of 1988. The array has a pentagonal geometry, with five transceiver moorings occupying each of the five corners plus one more in the middle of the pentagon. The diameter of the pentagon is approximately 200 km. Supplementary to the acoustic observations, there were in situ temperature, salinity and current measurements made by other investigators using moored sensors and meters as well as surveying ships. The tomography array was recovered in the summer of 1989. Two primary objectives of this year-long experiment are to investigate the processes leading to the ventilation of the deep waters and to study the dynamics of the Greenland Sea Gyre.

SUMMARY: We have successfully developed a computer code for inversion of the Greenland Sea tomography data. This 3-D inversion code has two special features. First, it allows for the use of vertical layers of variable thicknesses in the ocean parameterization. It is appropriate and computationally efficient to discretize the more variable upper ocean into more layers and the quiter lower ocean into fewer layers. Secondly, it permits the inverse solution to have a variance that decreases with depth and a correlation length that increases with depth. With this option, realistic field covariances can be used in the estimation. We have applied the inversion code to a set of ray travel time data provided by WHOI. These travel times were derived from measurements at two of the transceiver moorings. A time series of the estimated sound speed fluctuations on a vertical slice was generated (in the form of a movie). The time series shows a cooling cycle over the winter season. In addition, synoptic scale events were also estimated. A very encouraging result is that the vertical-slice tomography estimate compares remarkably well with the temperature record obtained by a temperature sensor. Future work will include mapping and analyzing the evolution of the temperature and current fields using both the acoustic tomography and in situ temperature sensor/current meter data.

CONFERENCE PRESENTATION: Chiu, C.-S., and Miller, J.H., "On the Use of Ocean Dynamics to Improve Acoustic Tomography Estimates," Baltimore ASA Meeting, 29 April - 3 May 1991.

THESIS DIRECTED: Joseph, John E., "Acoustic Tomography in the Greenland Sea," MS in Physical Oceanography and Meteorology, June 1991.

OTHER: Video animations of the tomographic inverse solution.

EVALUATION OF LOW COST GPS RECEIVERS FOR GEODETIC APPLICATIONS

J.R. Clynch, Adjunct Professor of Oceanography
Sponsor: DMA Systems Center
Funding: Defense Mapping Agency

OBJECTIVE: This work evaluated a new class of GPS receivers for geodetic applications. These receivers are normally intended for navigation applications, but produce the same data types used in standard GPS surveying. At one tenth to one third the cost of geodetic quality receivers, any survey use that can be made of these would be very cost effective.

SUMMARY: Two Magnavox MX 4200 receivers were obtained. These were evaluated in static survey applications using lines at NPS and within the Monterey Bay area. Lines from 1 km to 50 km were studied. It was found that these receivers were potentially capable of survey work, but required one more satellite than the more expensive receivers for an equivalent quality solution. An extensive examination of the clock effects was performed to quantify this result.

THESIS DIRECTED: Pardo, M., LCDR, Spanish Navy, "Characterization of the Clock in a New Inexpensive GPS Receiver: The Magnavox MX 4200," September 1991.

CALIFORNIA UNDERCURRENT STUDIES

C. A. Collins, Chairman and Professor of Oceanography
Sponsor: Department of Oceanography
Funding: Office of Naval Research

OBJECTIVE: To understand the dynamics and kinematics of the California Undercurrent off Central California. The following questions formed the basis for our investigation. What is the mean pattern of poleward and equatorward flow off Pt. Sur? What is the annual variability of these flows? What are the poleward transports of heat and salt? Is there a reference level that can be used for geostrophic calculations? How can various velocity measuring techniques be used in a consistent manner?

SUMMARY: The Undercurrent was observed in each of 19 research cruises between April 1988 and April 1991. The Current is usually located over the continental slope, but on occasion is found further offshore. The poleward flow is usually within a triangular shaped region, extending from the surface nearshore down to at least 700 m (often much deeper) along the slope, thence to the surface approximately 70 km offshore. The computed poleward transport varies from 3 to 7 Sv. The north-south component of flow is often barotropic in character across the continental slope, but the east-west component of flow is strongly sheared, with flow in the upper 200 m directed more strongly offshore than flow at depth. In an investigation of the continuity of the alongshore flow in May 1989, we were able to trace the dynamic signature of the Undercurrent (isopycnals sloping downward at the coast) and the water mass anomaly associated with the Undercurrent (high salt and spiciness) from Pt. Sur to Pigeon Pt; the flow separates from the margin at Pt. Sur and subsequently weakens.

PUBLICATIONS: Robson, A.J. and Collins, C.A., "Circulation of the California Undercurrent Near Monterey in May 1989," submitted to *Journal Geophysical Research*.

Schwing, F.B., Husby, D.M., Garfield, N. and Tracy, D.E., "Mesoscale Response of Coastal Waters off Central California to Wind Events During Spring 1989: Analysis of CTD Surveys and AVHRR Imagery," *Calif. Coop. Oceanic Fish. Invest. Repts.*, 32:47-62.

Tisch, T.D., Ramp, S.R. and Collins, C.A., "Observations of the Geostrophic Currents and Water Mass Characteristics off Point Sur, CA from May 1988 through November 1989," *Journal of Geophysical Research* (in press, 1991).

Edson, R., "A Comparison of XCP and Pegasus Current Profiles off the California Coast," Technical Report, July 1989.

CONFERENCE PRESENTATIONS: Collins, C.A., Carter, E. and Garfield, N., "The California Undercurrent: New Meanders for the 90's," East. Pac. Ocean. Conf., Lake Arrowhead, CA.

Garfield, N., Rago, T.A., Collins, C.A. and Schnebele, K.J., "Movement of Bottom-Deployed Instruments in Monterey Bay Canyon during the 17 October 1989 Loma Prieta Earthquake", EOS 72(44):246, AGU Fall Meeting, San Francisco, CA, December 1991.

Gezgin, E., Collins, C.A., Rosenfeld, L.K. and Schwing, F.B., "Hydrography, Transport and Salt Budget for the Gulf of the Farallones," Estuar. Res. Foun., San Francisco, CA., August 1990.

Rago, T.A., and Kennan, S.C., "A 2-year Intercomparison of Measurements of Salt Water Samples Between the University of Hawaii and the Naval Postgraduate School," EOS 72(44):260, AGU Fall Meeting, San Francisco, CA, December 1991.

THESES DIRECTED: Gezgin, E., "A Study on Hydrographic Conditions and Salt Budget Calculation for the Gulf of Farallones with the Data Collected in August 1990," MS Thesis.

Haskell, M.F., "An Assessment of the Precision of the Short Baseline Acoustic Navigation System used by Pegasus," MS Thesis.

Tziagidis, G., "An Analysis of Hydrographic Data Collected off Point Sur, California in June 1990," MS Thesis.

MARINE OPERATIONS

Curtis A. Collins, Professor and Chairman of Oceanography
James R. Cherry, Supervisory Oceanographer
Sponsor: Commander, Naval Oceanography Command
Funding: Naval Postgraduate School

OBJECTIVE: To provide administrative and logistical support for shipboard operations necessary for research and instruction.

SUMMARY: The marine operations program supported 60 days at sea in FY91 on the **R/V Point Sur**. An additional 14 days at sea were supported on another research vessel, **USNS DeSteiguer**. Activities included the Operational Oceanography course (OC/MR 3570) in spring and fall quarters, and Descriptive Physical Oceanography (OC 3230) in winter, summer, and fall. Research along the Pt. Sur transect included current meter moorings and direct current observations. CTD and Pegasus data were obtained at a proposed Navy dumpsite off the Farallons. The marine operations program maintains equipment which is routinely used at sea: CTDs, XBTs, and a shipboard data acquisition system. Salinometers and calibration facilities are also maintained. The program actively interfaces with other local ship users through the Central California Consortium (CENCAL), with other national academic ship users through the University National Ocean Laboratory System (UNOLS), and with Navy research vessels through the Naval Oceanographic Office. Two moorings buoys were obtained and installed near the Coast Guard pier in Monterey Harbor during 1991 as replacement of existing buoys (used by the **Acania** and other UNOLS vessels).

An additional 20 days of ship support was provided by EPA for studies related to the location of a dumpsite off San Francisco.

PUBLICATIONS:

Paquette, R.G., Bourke, R.H. and Stone, M.D., "USNS BARTLETT Cruise to the Greenland Sea in August 1990 Data Report," NPS Technical Report, NPS-OC-92-001, November 1991.

Bourke, R.H. and Paquette, R.G., "Formation of Baffin Bay Bottom and Deep Water," in: *Deep Convection and Deep Water Formation in the Oceans*, ed. Gascard, J.C. and Chu, P.C., 135-155, Elsveier, 1991.

Jendro, L.M., Bourke, R.H. and Ramp, S.R., "A Range-Dependent Analysis of Acoustic Transmission Across a Cold Filament in the California Current," in: *Ocean Variability and Acoustic Propagation*, ed. Potter, J.R. and Warn-Varnas, A., 343-358, Kluwer, 1991.

Schwing, F.B., Husby, D.M., Garfield, N. and Tracy, D.E., "Mesoscale Oceanic Response to Wind Events off Central California in Spring 1989: CTD Surveys and AVHRR Imagery," *Calif. Coop. Oceanic Fish. Invest. Repts.*, 32:41-62, November 1991.

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Ramp, S.R., Jessen, P.F., Brink, K.H., Niiler, P.P., Daggett, F.L. and Best, J.S., "The Physical Structure of Cold Filaments near Point Arena, California during June 1987," *Journal of Geophysical Research*, 96:14,859-14,884, 1991.

Kosro, P.M., Huyer, A., Ramp, S.R., Smith, R.L., Chavez, F.P., Cowles, T.J., Abbott, M.R., Strub, P.T., Barber, R.C., Jessen, P.F. and Small, L.F., "The Structure of the Transition Zone between Coastal Waters and the Open Ocean off Northern California, Winter and Spring 1987," *Journal of Geophysical Research*, 96:14707-14730, 1991.

Huyer, A., Kosro, P.M., Fleischbein, J., Ramp, S.R., Stanton, T.P., Washburn, L., Chavez, F.P., Cowles, T.J., Pierce, S.D. and Smith, R.L., "Currents and Water Masses of the Coastal Transition Zone off Northern California, June to August 1988," *Journal of Geophysical Research*, 96:14,809-14,832, 1991.

Brink, K.H., Beardsley, R.C., Niiler, P.P., Abbott,

M.R., Huyer, A., Ramp, S.R., Stanton, T.P. and Stuart, D., "Statistical Properties of Near Surface Flow in the California Coastal Transition Zone," *Journal of Geophysical Research*, 96:14,693-14,706, 1991.

Washburn, L., Kadko, D.C., Jones, B.H., Hayward, T., Kosro, P.M., Stanton, T.P., Ramp, S.R. and Cowles, T.J., "Water Mass Subduction and the Transport of Phytoplankton in a Coastal Upwelling System," *Journal of Geophysical Research*, 96:14,927-14,946.

Chavez, F.P., Barber, R.T., Kosro, P.M., Huyer, A., Ramp, S.R., Stanton, T.P. and Rojas de Mendiola, B., "Horizontal Transport and the Distribution of Nutrients in the Coastal Transition Zone off Northern California: Effects on Primary Production, Phytoplankton Biomass, and Species Composition," *Journal of Geophysical Research*, 96: 14,833-14,848, 1991.

Strub, P.T., Kosro, P.M., Huyer, A., Brink, K.H., Hayward, T.L., Niiler, P.P., James, C., Dewey, R.K., Walstad, L.J., Chavez, F.P., Ramp, S.R., Mackas, D.L., Swenson, M.S., Washburn, L., Barth, J.A., Hood, R.R., Abbott, M.R., Kadko, D.C., Barber, R.T., Haidvogel, D.B., Batteen, M.L. and Haney, R.L., "The Nature of Cold Filaments in the California Current System," *Journal of Geophysical Research*, 96:14,743-14,769, 1991.

Jessen, P.F. and Ramp, S.R., "Hydrographic Data from the Coastal Transition Zone Program, 5-19 July 1988," Naval Postgraduate School Technical Report, NPS-OC-92-002, 1991.

Jones, B.H., Flegal, R., Mooers, C.N.K., Reinecker, M., Stanton, T.P. and Washburn, L., "Chemical and Biological Structure Observed off Northern California in July 1986," *Journal of Geophysical Research*, 96:22,207-22,225.

Marom, M., Shemer, L. and Thornton, E.B., "Energy Density Directional Spectra of Nearshore Wave Field Measured by Interferometric Synthetic Aperture Radar," *Journal of Geophysical Research*, 96(C12):22,125-22,143, 1991.

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Baggeroer, A.B., Lashkari, K., Miller, J.H., Chiu, C.-S., Frogner, G., Mikhalevsky, P.N. and von der Heydt, K., "Vertical Array Resolution of the Normal Modes from the Heard Island Signals," submitted to the *Acoustical Society of America.*

Miller, J.H., Lynch, J.F., Chiu, C.-S. and Gerber, J., "Acoustic Measurements of Surface Gravity Wave Spectra in Monterey Bay Using Mode Travel Time Fluctuations," submitted to the *Journal of Acoustical Society of America.*

Westreich, E.L., Chiu, S.-S., Miller, J.H., Collins, M.L. and Lynch, J.F., "Modeling Pulse Transmission in Monterey Bay Using Parabolic Equation Methods," submitted to the *Journal of Acoustical Society of America.*

Tisch, T.D., Ramp, S.R. and Collins, C.A., "Observations of the Geostrophic Current and Water Mass Characteristics off Point Sur, California from May 1988 through November 1989," submitted to *Journal of Geophysical Research.*

CONFERENCE PRESENTATIONS: Bourke, R.H., Blythe, R.F., Paquette, R.G. and Stone, M.D., "On the Deep and Bottom Waters of the Greenland Sea from Summer 1989 and 1990 Data, XX General Assembly, International Union of Geodesy and Geophysics, Vienna, Austria, August 1991.

Stone, M.D., Bourke, R.H., and Paquette, R.G., "Studies of the Jan Mayen Current and Deep Water Formation from 1989 and 1990 Summer Data," Greenland Sea Project Workshop, Copenhagen, December 1991.

Miller, J.H., Lynch, J.F., Chiu, C.-S., Hippenstiel, R., Chaulk, E. and Gerber, J.S., "Surface Wave

Tomography in Monterey Bay Using Mode Travel Time Fluctuations," Houston ASA Meeting, 4-8 November 1991.

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Collins, C.A., Garfield, N. and Carter, E., "California Undercurrent Investigations at the Naval Postgraduate School: New Meanders for the 90's," Joint CALCOFI and Eastern Pacific Oceanic Conference, Lake Arrowhead, CA, October 1991.

Garfield, N., Rago, T.A. and Collins, C.A., "Movement of Bottom Deployed Instruments in Monterey Bay Canyon During the 17 October Loma Prieta Earthquake," American Geophysical Union Fall Meeting, San Francisco, CA, December 1991.

Collins, C.A., "Circulation of the Outer Waters of the Monterey Bay," the Second Annual Monterey Bay Research Symposium, 1 November 1991.

Ramp, S.R., Tisch, T.D. and Anderson, T., "Two-year Time series of Current, Temperature, and Conductivity on the Continental Slope off Point Sur, CA, and their Relation to Local and Remote Forcing," poster presentation, presented at the 38th Annual EPOC Meeting, Lake Arrowhead, CA, 21-23 October 1991, and at the AGU Annual Fall Meeting, San Francisco, CA, December 1991.

Ramp, S.R., "The Physical Oceanography of the Farallon Islands Shelf and Slope Region: Program Overview," presented at the 38th Annual EPOC Meeting, Lake Arrowhead, CA, 21-23 October 1991.

Gezgin, E., Collins, C.A., Rosenfeld, L.K., and Schwing, F.B., "Hydrography, Transport, and Salt Budget for the Gulf of the Farallons," Estuar. Res. Foun., San Francisco, CA, August 1990.

Sielbeck, S.L., Ramp, S.R. and Rosenfeld, L., "Bottom-Trapped Diurnal Period Waves off Point Sur, CA," Eastern Pacific Ocean Conference, October 1991.

Stanton, T.P., "Oceanic Turbulence Measurements Using High Resolution Coherent Acoustic Doppler Techniques," Session PS09, XX IUGG Meeting, Vienna, Austria, August 1991, IAPSO abstracts, p149.

THESES DIRECTED: Westreich, Eric L., LT, USN, "Modeling Pulse Transmission in the Monterey Bay Using Parabolic Equation Methods," MS Thesis, December 1991.

Frogner, Gary R., LT, USN, "Global Acoustic Transmissions: Signal Processing and Preliminary Data Analysis," MS Thesis, September 1991.

Pardo, M., LCDR, Spanish Navy, "Characterization of the Clock in a New Inexpensive GPS Receiver: The Magnavox MX 4200," MS Thesis, September 1991.

Tziagidis, George, LT, Greek Navy, "An Analysis of Hydrographic Data Collected off Point Sur, California in June 1990," MS Thesis, September 1991.

Taggart, Douglas, Michael, LCDR, USN, "Determination of Near-Surface Velocity Fields in the CTZ Using Combined Altimetire and Inverse Modeling Techniques," MS Thesis, March 1991.

Sielbeck, Stephen L., LCDR, USCG, "Bottom Trapped Waves at Tidal Frequencies off Point Sur, CA," MS Thesis, September 1991.

Abbott, Christopher L., LT, USN, "Observations of the Wind-Forced Circulation on the Continental Shelf off Point Sur, CA from a Bottom-Mounted Acoustic Doppler Current Profiler (ADCP)," MS Thesis, December 1991.

Gezgin, Erhan, LTJG, Turkish Navy, "A Study of Hydrographic Conditions and Salt Budget Calculation for the Gulf of Farallons with the Data Collected in August 1990," MS Thesis, March 1991.

Coelho, Emanuel F., LT, Portuguese Navy, "Acoustic Sampling of Ocean Turbulence," MS Thesis, December 1991.

Grinker, Barry, LCDR, Israeli Navy, "Accuracy of Shipborne Kinematic GPS Surveying," MS Thesis, September 1991.

Haskell, Margaret F., U.S. Naval Oceanographic Office, "An Assessment of the Precision of the Short Baseline Acoustic Navigation System Used by Pegasus," MS Thesis, March 1991.

OTHER: Abreu, M., LT, Portuguese Navy, "Nonlinear Directional Wave Spectrum Transformation in Shallow Water," Ph.D. Dissertation, Naval Postgraduate School, p116, September 1991.

CIRCULATION ON THE CONTINENTAL SHELF AND SLOPE NEAR THE FARALLON ISLANDS, CA

Curtis A. Collins, Professor and Chairman of Oceanography
Steven R. Ramp, Assistant Professor of Oceanography
Newell Garfield, Adjunct Professor of Oceanography
Leslie K. Rosenfeld, Adjunct Professor of Oceanography
Marlene Noble, USGS, Menlo Park, CA
Frank Schwing, PFEG, NOAA, Monterey, CA
Sponsor: WESTDIV, Naval Facilities Engineering Command
Funding: The U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, WESTDIV, and USGS

OBJECTIVE: To describe the ocean circulation over the continental shelf and slope near the Farallon Islands, CA, particularly as it pertains to the dispersal of dredged material which may be dumped in the area at ocean dumpsites whose exact location has not yet been designated. We will provide scientific input to managers at WESTDIV and EPA who will be making the site designation decisions.

SUMMARY: The approach is to use a series of 5 high-resolution shipboard hydrographic and ADCP surveys to resolve the spatial variability over the study region at different times, and combine this information with data from six current meter moorings in the region which resolve the temporal variability well but have limited spatial coverage. Satellite AVHRR data will be used extensively to interpret both the moored and shipboard results. Four shipboard surveys have been completed as of this writing with excellent results, and a fifth will take place during February 1992. A 100% data return was achieved from the NPS current meters during the first 6-month deployment and the second 6 months will be recovered in February. Very little analysis has been completed at this time. A few noteworthy features are the clear presence of the California Undercurrent (although much weaker than to the south off Point Sur), and currents which appear to be bottom trapped and topographically steered near a small submarine canyon at one of the current meter moorings on the continental slope. In the forthcoming analyses, Drs. Collins, Schwing, and Garfield will be focusing on the hydrographic data, Drs. Rosenfeld and Ramp will work on the ADCP data, and Drs. Ramp and Noble will perform the current meter data analysis. Results will appear in the form of data reports, technical reports to the sponsors, and journal publications in the refereed literature.

Hydrographic data collected in early August 1990 have been analyzed by Gezgin (M.S. Thesis, 1991). Late August 1990 hydrographic data indicate a reversal in the direction of the flow of the undercurrent which agrees with current measurements made at the proposed dumpsite by USGS. We are currently acquiring satellite imagery to try to determine the larger scale synoptic picture associated with the undercurrent reversal.

CONFERENCE PRESENTATIONS: Gezgin, E., Collins, C.A., Rosenfeld, L.K. and Schwing, F.B., "Hydrography, Transport, and Salt Budget for the Gulf of the Farallones," Estuar. Res. Foun., San Francisco, CA., August 1990.

Ramp, S.R., "The physical oceanography of the Farallon Islands Shelf and Slope Region: Program Overview," presented at the 38th Annual EPOC

meeting, Lake Arrowhead, CA, 21-23 October 1991.

THESIS DIRECTED: Gezgin, Erhan, "A Study of Hydrographic Conditions and Salt Budget Calculation for the Gulf of Farallones with the Data Collected in August 1990," MS in Physical Oceanography, March 1991 (Collins, Rosenfeld, and Schwing, Co-advisors).

ENHANCEMENTS TO DEEP OCEANIC CONVECTION IN THE ARCTIC SYSTEM

R.W. Garwood, Jr., Professor of Oceanography
P.C. Chu, Adjunct Professor of Oceanography
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: This is a two-year program of research to explore the roles of turbulent mixing processes that have been neglected in traditional mixed layer modeling applied to the arctic systems for ocean-atmosphere-ice interactions.

SUMMARY: Results include discovery of several important and new mechanisms for deep convection in oceans (e.g., symmetric instability, pressure-augmentation of the buoyancy flux), exploration of wind effect on the flexural-gravity wave, and development of a new concept of non buoyancy-conserving oceanic chimneys.

PUBLICATIONS: Chu, P.C., "Geophysics of Deep Convection and Deep Water Formation in Oceans," *Elsevier Oceanography Series*, 57:3-15, 1991.

Chu, P.C., "Vertical Cells driven by Vortices - A Possible Mechanism for the Preconditioning of Open-Ocean Deep Convection," *Elsevier Oceanography Series*, 57:267-281, 1991.

Chu, P.C., "Wind Effect on Flexural-Gravity Waves, Atmospheric and Oceanic Waves and Stability," American Meteorology Society, 8:265-268, 1991.

Chu, P.C., "Symmetric Instability of Gulf Stream - A Mechanism for Exchange between Deep and Shelf Waters," *IAPSO P & A*, 43, 1991.

Chu, P.C., "Low Frequency Acoustic Turbulence Attenuation and Eddy Viscosity Measurement," *TOSSSM*, the Oceanography Society, 33.

CONFERENCE PRESENTATIONS: Garwood, R. W., Jr., "Thermobaric Enhancement of Deep Ocean Convection," Invited talk, National Oceanic and Atmospheric Research Laboratory Distinguished Lecturer Series, Stennis Space Center, 10 October 1991,.

Chu, P.C., "A Possible Mechanism for the Preconditioning of Open-Ocean Deep Convection," the Ocean Society Second Scientific Meeting, St. Petersburg, Florida, 24-28 March 1991.

Chu, P.C., "Symmetric Instability of Boundary Currents," the International Liege Colloquium on Hydrodynamics, Liege, Belgium, 6-10 May 1991.

Chu, P.C., "Symmetric Instability of Gulf Stream - A Mechanism for Exchange between Deep and Shelf Waters," the 20th General Assembly, International Union of Geophysics and Geodesy, Vienna, Austria, 11-24 August 1991.

Chu, P.C., "Instability of Flexural-Gravity Waves," 8th Conference on Atmospheric and Oceanic Waves and Stability, American Meteorological Society, Denver, CO, 14-18 October 1991.

Chu, P.C. and Gascard, J.C., editors, "Deep Convection and Deep Water Formation in Oceans," *Elsevier Publishing Company*, 382 pages.

STUDIES OF THE OCEANIC PLANETARY BOUNDARY LAYER

R.W. Garwood, Jr., Professor of Oceanography
P.C. Chu, Adjunct Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The scientific objective is to understand the thermodynamic and dynamic processes that couple the oceanic and atmospheric planetary boundary layers.

SUMMARY: The results include exploration of a positive feedback mechanism between ocean mixed layer and cumulus clouds, establishment of a new ENSO theory, and discovery of incompatible wind and buoyancy forcing in ocean numerical models.

PUBLICATIONS: Chu, P.C. and Garwood, R.W., Jr., "On the Two-Phase Thermodynamics of the Coupled Cloud-Ocean Mixed Layer," *Journal of Geophysical Research*, 96:3425-3436.

Chu, P.C., "Air-Ocean Surface Heat Exchange Model and Low Frequency Unstable Modes in Atmosphere and Ocean," *Climate Variation*, 5:488-491, 1991, American Meteorology Society.

Chu, P.C., "An El Nino/La Nina Switcher," *TOGA Notes*, 5:16-21, 1991.

Chu, P.C., "An Important Ocean Feature Overlooked in Current El Nino and Southern Oscillation Theories," *AGU Transactions*, 72(42):77, 1991.

Ramp, S.R., Garwood, R.W. Jr., Davis, C.O., and Snow, R.L., "Surface Heating and Patchiness in the Coastal Ocean off Central California during a Wind Relaxation Event," *Journal of Geophysical Research*, 96:14947-14957.

CONFERENCE PRESENTATIONS: Garwood, R. W., Jr., "Turbulent Kinetic Energy Budget for Deep Ocean Convection," Invited talk, XX General Assembly, International Union of Geodesy and Geophysics, Vienna, Austria, 11-24 August 1991.

Chu, P.C., "Wind Effect on Flexural-Gravity Waves," 8th Conference on Atmospheric and Oceanic Waves and Stability, American Meteorological Society, Denver, CO, 14-18 October 1991.

Chu, P.C., "An Air-Ocean Surface Heat Exchange Model," 5th Conference on Climate Variations, American Meteorological Society, Denver, CO, 14-18 October 1991.

Chu, P.C., "An Important Ocean Feature Overlooked in Current ENSO Theories," American Geophysical Union Fall Meeting, San Francisco, 9-13 December 1991.

THESES DIRECTED: Prazuck, Christopher, "Anomalous Diurnal Currents in the Vicinity of the Yermak Plateau," Doctoral dissertation.

White, Jonathan, "Optical Effects on Upper Ocean Mixing Dynamics," MS Thesis.

NPS ACOUSTIC DRIFTING BUOY PROGRAM

Jeffrey A. Nystuen, Professor of Oceanography
Sponsor: NOARL (ASW Oceanography) and NPS (ASW Group)
Funding: FY92 - $ 60788 (cost sharing)

OBJECTIVE: To improve our understanding of the physics of underwater sound generation by wind and precipitation to the point at which surface phenomena generating the sound can be monitored using passive acoustic devices.

SUMMARY: Field measurements of sound generated during heavy rainfall were continued. An in situ calibration of the hydrophone equipment was conducted. The data collected in 1990 were analyzed. High correlations between rainfall rate and sound levels were observed. Wind above 10 m/s decreased correlations above 10 kHz, presumably due to bubble clouds from breaking waves. At very high rainfall rates (> 150 mm/hr), decreased levels at high frequency were observed, suggesting the presence of a bubble cloud. Sound levels at the beginning of a storm were higher than at the same rainfall rate later in the storm. This is likely due to changes in drop size distributions. A preliminary algorithm is proposed.

Field data was collected from two prototype acoustic drifting buoys deployed off the coast of California. Coincident satellite data was collected. Acoustic wind speed measurements north of 31#N agreed with satellite wind speed measurements. South of 31#N, the influence of shallow warm surface layers resulted in a different, but still good, linear relationship with respect to the satellite measurements. Limited rainfall data was collected, however the acoustic detection of rainfall using acoustic drifters was demonstrated.

PUBLICATIONS: Nystuen, J.A., "An Explanation of the Sound Generated by Light Rain in the Presence of Wind", *Natural Physical Sources of Underwater Sound* (in press, 1992).

Nystuen, J.A., "Comments on "An Evaluation of the WOTAN Technique of Inferring Oceanic Winds from Underwater Ambient Sound" by Vagle et al." Report to NOARL, February 1991. [Non-refereed technical report]

CONFERENCE PRESENTATIONS: Nystuen, J.A. and McGlothin, Charles C. Jr.,"The Sound Generated by Heavy Precipitation," Acoustical Society of America, Fall 1991 Meeting, Houston.

THESES DIRECTED: McGlothin, Charles C. Jr., USN, "Ambient Sound in the Ocean Induced by Heavy Precipitation and the Subsequent Predictability of Rainfall Rate," June 1991.

Dailey, Charles, USN, "Evaluation of Wind Measurements Using Acoustic Drifting Buoys."

AMBIENT NOISE GENERATION AT THE AIR/SEA INTERFACE

Jeffrey A. Nystuen, Professor of Oceanography
Sponsor: NOARL (ASW Oceanography) and NPS (ASW Group)
Funding: FY92 $24800 (DFR - ASW Group)

OBJECTIVE: To improve our understanding of the physics of underwater sound generation by wind and precipitation to the point at which surface phenomena generating the sound can be monitored using passive acoustic devices.

SUMMARY: Laboratory measurements evaluating the sound generated by large raindrops were conducted. The influence of water/drop temperature and salinity were measured. The underwater spectra for individual sizes were estimated in the laboratory. Using realistic natural rainfall drop size distributions, artificial sound spectra were generated which compare well with recorded field measurements.

Laboratory measurements were made of the acoustic radiation pattern of drop impacts. Two components to the pressure field were discovered, an acoustic dipole impulse and a non-acoustic pressure field associated with the establishment of the splash flow. These two components were modelled using a general numerical code for fluid flow with multiple free surfaces.

PUBLICATIONS: Nystuen, J.A., "An Explanation of the Sound Generated by Light Rain in the Presence of Wind," *Natural Physical Sources of Underwater Sound* (in press, 1992).

Medwin, H., Jacobus, P.W., Snyder, D.E. and Nystuen, J.A., "The Anatomy of Underwater Rain Noise", submitted to the *Journal of Acoustical Society of America*, October 1991.

Nystuen, J.A, Ostwald, L.H. and Medwin, H., "Hydroacoustics of a Drop Impact," in preparation for the *Journal of Acoustical Society of America*.

CONFERENCE PRESENTATIONS: Jacobus, Peter W., Medwin, H. and Nystuen, J.A., "Sound Radiation from Large Raindrops," Acoustical Society of America, Spring 1991 Meeting, Baltimore, MD, (Presented by P. Jacobus).

Ostwald, Leo H. and Nystuen, J.A., "The Hydroacoustics of a Drop Impact," Acoustical Society of America, Fall 1991 Meeting, Houston, TX.

Jacobus, P.W., Medwin, H. and Nystuen, J.A., "Underwater Sound Energy from Large Terminal Velocity Raindrops as a Function of Drop Volume, Temperature and Salinity," Acoustical Society of America, Fall 1991 Meeting, Houston, TX (Presented by H. Medwin).

THESIS DIRECTED: Jacobus, Peter W., USN, "Underwater Sound Radiation from Large Raindrops," MS in Engineering Acoustics, September 1991 (co-advisor H. Medwin).

LARGE-SCALE MEAN CONVERGENCE IN THE MIXED LAYER OF THE CANARY BASIN AS DETERMINED FROM LAGRANGIAN DRIFTERS

J.D. Paduan, Assistant Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Office of Naval Research

OBJECTIVE: The objective of this project is to obtain statistically-reliable estimates of the mean surface currents and temperatures in the Subduction region of the northeast Atlantic Ocean and to use this information, gathered over two years, to describe the mean large-scale horizontal convergence near the surface (~15 m). We hope to be able to expose the relative importance of this large-scale frontal convergence as compared with more localized observations and to compare observed convergence with Ekman convergence estimates in order to partition it into wind-driven and non-wind-driven components.

SUMMARY: The approach being used is to make direct measurements of surface currents and temperatures using satellite-tracked Lagrangian drifters. These instruments, although confined to remain at a fixed depth of approximately 15 m, are free to travel with water parcels in the horizontal plane. The modern drifters being used have very high drag area ratios, which means they have very large and effective drogue elements and very small surface floats and tethers. This reduces error in the measurement of surface current to below 2 cm/sec for most wind and wave conditions. The relatively low unit cost of a drifter allows the deployment of a large number of instruments. This project is deploying about 30 drifters per year in each of two field years. The deployment pattern that is being used was designed to assess the importance of the semi-permanent oceanic front, which occurs south of the Azores Islands, in the north-to-south convergence over the larger Subduction region. The pattern consists of five release points along an east-west line north of the frontal area and five release points along a parallel line south of the frontal area. The pattern will be repeated at least six times. Tasks completed during 1991 have been related, primarily, to the field aspect of the project. Procurement of the first 29 drifters was accomplished early in the year and the instruments were delivered to Scripps Institution of Oceanography for inspection and packaging on May 2, 1991. The most important task undertaken during the year was to research the availability and suitableness of Volunteer Observing Ships (VOS) for deployment of drifters near the preferred sites in the Subduction region. Two VOS that make port calls in Miami, Florida were identified as potential deployment vessels. The first ten drifters were shipped to Miami in May and placed on the VOS in June. They were deployed north and south of the Azores frontal zone during the ship's transects into and out of the Mediterranean Sea. Because the drifting instruments being used return data in real time via satellite telemetry, some preliminary insights are already available. The most striking result is the highly eddy-like nature of the trajectories. The largest eddy motions appear in the drifter tracks along the northern side of the Azores frontal zone. Both the mean displacements and eddy motions are weaker along the southern side. Most of the eddy motion is cyclonic (counterclockwise). There is evidence for a strong current parallel to the line of the Azores Islands, flowing from southeast to northwest, in one of the drifter tracks.

LAGRANGIAN MEASUREMENTS OF SURFACE CURRENTS OFF THE CALIFORNIA COAST

J.D. Paduan, Assistant Professor of Oceanography

Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this program is to expose surface circulation patterns, including potential differences between upwelling and non-upwelling regimes, in and around Monterey Bay. A primary goal is to describe the flow of the upwelling plume offshore of Monterey Bay, including whether or not the plume actually enters the Bay from the north as is hypothesized and how water subsequently circulates within the outer portions of the Bay. Recovered drifters will be used to repeat the Monterey Baystudy during non-upwelling conditions.

SUMMARY: These research efforts will concentrate on making effective measurements of surface currents off the central California coast. Recent improvements in drifting buoy technology will be exploited to obtain Lagrangian measurements of surface currents with highly-accurate, satellite-based positioning systems. Procurement is under-way for components necessary to build surface drifters to be tracked using Global Positioning System (GPS) with local data telemetering using VHF packet radio. This technical challenge will constitute the bulk of the effort this year. GPS-tracked drifters will provide positions with ten times more accuracy than currently-available instruments, which will be crucial for near-shore measurements. Field measurements will be conducted in the spring of 1992 (if equipment is available) and spring of 1993 in cooperation with the Monterey Bay Aquarium Research Institute (MBARI).

THE COASTAL TRANSITION ZONE PROGRAM

Steven R. Ramp, Assistant Professor of Oceanography
Paul F. Jessen, Oceanographer
Sponsor: Office of Naval Research
Funding: Office of Naval Research

OBJECTIVE: The objective of the CTZ program is to enhance our understanding of the kinematics and dynamics of the cold upwelling filaments which are often observed in the satellite AVHRR and CZCS imagery of the central California coastal waters, and to assess the impact of these features on the across-shelf transport and the biological productivity of the region.

SUMMARY: Detailed results from the papers published are too numerous to discuss in detail, so a short summary of the key results from some of the group descriptive papers follows. The 1987 large scale surveys between Point Reyes and north of Cape Mendocino (Kosro et al., 1991) provided evidence that the occurrence of the cold filaments is seasonal, with strong features first appearing in late spring. These four surveys (in February, March, May, and June 1987) also provided evidence that a continuous, meandering equatorward jet could play an important role in filament formation. A real time feature mapping cruise in June 1987 (Ramp et al., 1991) successfully described the structure of a large cold filament off Point Arena, several smaller, more transient features within it, and pieces of the surrounding eddy field, using CTD (conductivity, temperature, and depth), ADCP (acoustic Doppler current profiler) and remotely sensed sea surface temperature data. The large filament had a depth which exceeded the sample depth (500m), and was bounded by a meandering current with strong offshore currents to the north and onshore flows to the south. A net offshore transport of 2.6 - 3.8 x 106 m2 s-1 was observed. The smaller, shallower features within the large filament were correlated with bursts of equatorward wind stress, but not with local convergence / divergence of the wind stress between Point Arena and Eel River to the north, or between Point Arena and Bodega Bay to the south. Some interesting observations of the near surface heating during a wind relaxation event (Ramp et al., 1991) were also made during this cruise. The 1988 sequence of six surveys near Point Arena during July - August 1988 (Huyer et al, 1991) provided evidence that lower salinity waters are advected into the region from the north by the strong equatorward jet. The core of the jet lay between the 8.6 and 9.4 J kg-1 contours of geopotential anomaly (relative to 500 dbar), and had maximum baroclinic velocities exceeding 50 cm s-1 at the surface which transported about 3.8 x 10-6 m3 s-1 of water offshore. The maximum offshore velocities lay along the thermal gradient between the cold upwelled water and the warmer oceanic water, rather than along the core of the cold filament itself. The region of highest nutrients and biological activity coincided with the cold water (Chavez et al., 1991), which did move offshore, but much more slowly than the maximum observed velocities in the jet core.

PUBLICATIONS: Abbott, M.R., Brink, K.H., Booth, C.R., Blasco, D., Codispoti, L.A., Niiler, P.P. and Ramp, S.R., "Observations of Phytoplankton and Nutrients from a Lagrangian Drifter off Northern California," *Journal of Geophysical Research*, 95:9393-9409, 1990.

Ramp, S.R., Jessen, P.F., Brink, K.H., Niiler, P.P. Daggett, F.L. and Best, J.S., "The Physical Structure of Cold Filaments Near Point Arena, California, during June 1987," *Journal of Geophysical Research*, 96:14,859-14,884.

Ramp, S.R., Garwood, R.W., Davis, C. and Snow, R.L., "Surface Heating and Patchiness in the Coastal Ocean off Central California During a Wind Relaxation Event," *Journal of Geophysical Research*, 96:14,947-14,958.

Huyer, A., Kosro, P.M., Fleischbein, J., Ramp, S.R., Stanton, T., Washburn, L., Chavez, F.P. and Cowles, T.J., "Currents and Water Masses of the Coastal Transition Zone off Northern California, June to August 1988," *Journal of Geophysical Research*, 96:14,809-14,833.

Kosro, P.M., Huyer, A., Ramp, S.R., Smith, R.L.,

Chavez, F.P., Cowles, T.J., Abbott, M.R., Strub, P. T., Barber, R.C., Jessen, P.F. and Small, L.F., "The Structure of the Transition Zone between Coastal Waters and the Open Ocean off Northern California Winter and Spring 1987," *Journal of Geophysical Research*, 96:14,707-14,731.

Brink, K.H., Beardsley, R.C., Niiler, P.P., Abbott, M.R., Huyer, A., Ramp, S.R., Stanton, T.P. and Stuart, D., "Statistical Properties of Near Surface Flow in the California Coastal Transition Zone," *Journal of Geophysical Research*, 96:14,693-14,706.

Washburn, L., Kadko, D.C., Jones, B.H., Hayward, T., Kosro, P.M., Stanton, T.P., Huyer, A., Ramp, S.R. and Cowles, T.J., "Water Mass Subduction and the Transport of Phytoplankton in a Coastal Upwelling System," *Journal of Geophysical Research*, 96:14,927-14,946.

Chavez, F.P., Barber, R.T., Huyer, A., Kosro, P.M., Ramp, S.R., Stanton, T.P. and Rojas de Mendiola, B., "Transport of Nutrients and Phytoplankton by the Jets of the Coastal Transition Zone," *Journal of Geo-physical Research*, 96:14,833-14,849.

Strub, P.T., Kosro, P.M., Huyer, A., Brink, K.H., Hayward, T.L., Niiler, P.P. James, C. Dewey, R.K., Walstad, L.J., Chavez, F.P., Ramp, S.R., Mackas, D.L., Swenson, M.S., Washburn, L., Barth, J.A., Hood, R.R., Abbott, M.R., Kadko, D.C., Barber, R.T., Haidvogel, D.B., Batteen, M.L. and Haney, R.L., "The Nature of Cold Filaments in the California Current System," *Journal of Geophysical Research*, 96:14,743-14,769.

Stanton, T.P., Stockel, J.A., Batteen, M.L. and Ramp, S.R., "Upper Ocean Response to a Wind Relaxation Event in the Coastal Transition Zone," submitted to the *Journal of Geophysical Research*.

OTHER: The results from this project were published in a special dedicated issue of the *Journal of Geophysical Research*, 96(C8), August 1991.

THE POINT SUR TRANSECT (POST) PROGRAM

Steven R. Ramp, Assistant Professor of Oceanography
Paul Jessen, Oceanographer
Todd Anderson, Oceanographer
Marla Stone, Oceanographer
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To resolve the physical and biological variability of the California Current System off Point Sur, CA at seasonal and longer time scales, using both shipboard and moored measurements maintained for a period of at least 5 years. Two problems of particular interest are the dynamics and kinematics of the California Undercurrent and the resolution of El Nino/Southern Oscillation (ENSO) events.

SUMMARY: A single oceanographic mooring, called P2, has been maintained on the 800 m isobath off Point Sur, CA (36 20'N, 123 10'W) since May 1989. Other moorings at 84 m (P1), 1800 m (P3), and 200 km to the south at 1100 m (P4) have also been deployed when the resources were available. A complete suite of current meter data processing programs from Oregon State University and the Woods Hole Oceanographic Institution is now up and running on the NPS VAX cluster. The NOAA offshore buoys and NOS coastal sea level stations are being used to examine the local and remote forcing by wind and coastal trapped waves.

Four theses have been completed so far, two during 1991. The work of LT Stephen Sielbeck focussed on the high frequency part of the spectrum, particularly the diurnal and semidiurnal tides. The amplitudes and phases of the tidal ellipses at moorings P2 and P3 were examined. The tidal energy was found to be bottom trapped at site P2 in agreement with the theory of Rhines, 1970, while the data at P3 formed an inadequate test. LT Chris Abbott examined the wind-forced motions over the continental shelf using a moored upward looking acoustic Doppler current profiler (ADCP). The observed currents were explained surprisingly well using a simple model of wind-forced currents in the presence of a long, straight coast, as described by Ekman (1905) and Csanady (1978). The low-frequency analysis is still continuing. The energetics of flow over the continental slope is being investigated in the PhD dissertation of LT Tim Tisch, NOAA Corps. An energetic band exists between 25-60 days, which may be due to the presence of remotely-forced internal Kelvin waves. Additional scientific results are anticipated as the field work continues.

PUBLICATION: Tisch, T.D., Ramp, S.R. and Collins, C.A., "Observations of the Geostrophic Current and Water Mass Characteristics off Point Sur, California from May 1988 through November 1989," submitted to the *Journal of Geophysical Research*.

CONFERENCE PRESENTATION: Ramp, S.R., Tisch, and Anderson, T., "Two-year Time Series of Current, Temperature and Conductivity on the Continental Slope off Point Sur, CA, and their Relation to Local and Remote Forcing," presented at the AGU Annual Fall Meeting, San Francisco, CA, December 1991 and the 38th Annual EPOC meeting, Lake Arrowhead, CA, 21-23 October 1991.

THESES DIRECTED: Sielbeck, Stephen L., "Bottom Trapped Waves at Tidal Frequencies off Point Sur, CA," Master of Science in Physical Oceanography, September 1991, (co-advised with Prof. Leslie Rosenfeld).

Abbott, Christopher L., LT, "Observations of the Wind-Forced Circulation on the Continental Shelf off Point Sur, CA from a bottom-mounted acoustic Doppler current profiler (ADCP)," Master of Science in Meteorology and Physical Oceanography, December 1991 (advisor).

SCIENTIFIC DEVELOPMENT OF A MASSIVELY PARALLEL OCEAN CLIMATE MODEL

A.J. Semtner, Professor of Oceanography
Sponsor: U.S. Department of Energy
Funding: U.S. Department of Energy - CHAMMP Climate Research

SUMMARY: The research will move an existing global eddy-resolving ocean model onto massively parallel computers, for climate studies related to CHAMMP. To guide the proper physical development of a comprehensive model, scientific study in three areas will be undertaken: (i) investigation of the physics of ocean heat transport; (ii) inclusion of near-surface oceanic processes relevant to climate; and (iii) examination of resolution requirements for ocean climate modeling. The final and most important aspect of the research will be the demonstration of feasibility and scalability of a climatically-sound global ocean model for performing multi-century integrations at a grid spacing as fine as 1/8 degree on massively parallel machines.

DEVELOPMENT OF A GLOBAL EDDY RESOLVING THERMODYNAMIC OCEAN MODEL

A.J. Semtner, Professor of Oceanography
Sponsor: National Science Foundation
Funding: National Science Foundation - Physical Oceanography Program

SUMMARY: The objective is to implement and test a free-surface formulation for the global eddy-resolving ocean model, in order to improve certain physical and numerical aspects of the calculation. Since very complicated geometries can be handled, the global ocean will be configured with fully realistic geometry, including the Arctic Basin and all marginal seas, at both 1/2 and 1/4 degree gridsizes. Prognostic test integrations of the improved model are planned for 20 years and 2.5 years at the two gridsizes, respectively.

PUBLICATIONS: Fleming, G.H., and Semtner, A.J., "A Numerical Study of Interannual Ocean Forcing of Arctic Ice," *Journal of Geophysical Research*, pp. 4589-4603.

Semtner, A.J., and Chervin, R.M., "Ocean General Circulation from a Global Eddy-Resolving Model," *Journal of Geophysical Research*, (in press, 1992).

McCann, M.P., Semtner, A.J., and Chervin, R.M., "Volume, Heat, and Salt Budgets of a Global Ocean Model with Resolved Eddies," submitted to the *Journal of Geophysical Research*.

UPPER OCEAN TURBULENT FLUX MEASUREMENTS USING ACOUSTIC AND OPTICAL TECHNIQUES DEPLOYED FROM AN ROV

T. P. Stanton, Adjunct Research Professor of Oceanography

Sponsor: MBARI
Funding: Joint NPS and MBARI

OBJECTIVE: This proposal supported the deployment of a turbulence-resolving microstructure package and scanned laser system on the MBARI ROV, and to conduct three-day timeseries measurement of turbulent diffusion and upper ocean structure in Monterey Bay. These measurements were designed to allow inter-comparison of larger scale forcing (wind stress, internal wave and shoaling tidal forcing) in generating turbulent layers in the upper ocean.

SUMMARY: A scanned laser imaging system and turbulence-resolving microstructure package were deployed on the ROV for two sea trials and a scientific cruise with the Point Sur in September 1991. The ROV deployments involved a significant technical effort to allow both systems to "plug in " to existing broadband instrument ports on the ROV. Bulk vertical and horizontal diffusion measurements were made by injecting dye into the water column 3m in front of the ROV, and then using a micro-processor-controlled, scanned laser and video imaging system to quantify the structure of the tracer dye patch as it diffused, advected and sheared in response to physical processes in the water column. (The tracer imaging system was developed by our group at NPS, while fabrication of the underwater package was provided by the MBARI workshops.) Simultaneous estimates of thermal and velocity dissipation and Reynolds stresses were obtained by the acoustic doppler microstructure mounted in front of the ROV. In September 1991 this instrument suite was successfully deployed from the Point Lobos during a four day repeated, 2Km box survey of thermohaline and current structure in the upper 100m of the ocean made by the Point Sur. Concurrent bulk atmospheric forcing measurements were made from the Point Sur. These data sets provide a uniquely detailed view of forcing and diffusion in a typical coastal regime where strong horizontal structure exists right to the ocean surface, and there is a pronounced diurnal wind forcing cycle. A technical paper describing the dye diffusion measurement technique is being prepared while analyses and preprocessing of this complex data set is completed.

THESIS DIRECTED: Coelho, E.F., LT, Portugese Navy, "Acoustic Sampling of Ocean Turbulence," MS Thesis, December 1991.

OTHER: As the field component of this research has just been completed, neither analysis nor papers have been completed. However it is anticipated that a JOAT paper describing the scanned laser imaging system, and a comparison of acoustic doppler and CODAR measured surface currents will be completed in 1992.

TURBULENCE AND HEAT FLUX MEASUREMENTS IN THE UPPER OCEAN

T.P. Stanton, Adjunct Professor of Oceanography
Sponsor: ONR Physical Oceanography
Funding: Joint ONR Physical Oceanography and the
Naval Postgraduate School

OBJECTIVE: This research program is developing flow visualization techniques and microscale acoustic doppler velocity instrumentation to allow momentum and tracer fluxes to be estimated in the upper ocean. Collaborative measurement programs have been made off the California Coast in the CTZ program and in the Arctic CEAREX and LEADS program.

SUMMARY: Analyses and paper preparation of the Coastal Transition Zone (CTZ) program cruises have been completed with a range of collaborative research describing processes determining the evolution of a persistent coastal jet off Point Arena. Analysis of a three-week timeseries of the sub-ice boundary layer during CEAREX are continuing with two papers in preparation. A bistatic geometry, coherently sampled doppler profiler developed at NPS provided 15cm vertical resolution velocity profiles to a 25m depth, allowing turbulent shear production, dissipation and Reynolds stresses to be explicitly measured over a range of forcing conditions. The competing effects of internal wave-forced turbulence, local severe topography and surface roughness effects are being studied. Following participation in the pilot LEADEX program, a diurnal cycle of the thermohaline and turbulent structure of a large lead is being analyzed. A loose-tethered microstructure profiler provided 10 minute sampled timeseries of the water column structure, revealing an unexpected warm, turbulent surface layer due to late afternoon solar heating. These results are being prepared for publication.

PUBLICATIONS: Brink, K.H., Beardsley, R.C., Niiler, P.P., Abbott, M., Huyer, A., Ramp, S.R., Stanton, T.P. and Stuart, D., "Statistical Properties of Near Surface Flow in the California Coastal Transition Zone," *Journal of Geophysical Research*, 96:14693-14706, 1991.

Chavez, F.P., Barber, R.T., Kosro, P.M., Huyer, A., Ramp, S.R., Stanton, T.P. and de Moendiola, B.R., "Horizontal Transport and the Distribution of Nutrients in the Coastal Transition Zone off Northern California: Effects on Primary Production, Phytoplankton Biomass, and Species Composition, *Journal of Geophysical Research*, 96:14833-14848, 1991.

Huyer A., Kosro, P.M., Fleischbein, J., Ramp, S.R., Stanton, T.P., Washburn, L., Chavez, F. and Cowles, T., "Currents and Water Masses of the Coastal Transition Zone off Northern California, June to August 1988," *Journal of Geophysical Research*, 96:14809-14831, 1991.

Stanton, T.P., Stockel, J.A., Batteen, M.L. and Ramp, S.R., "Upper Ocean Response to a Wind Relaxation Event in the Coastal Transition Zone," submitted to *Journal of Geophysical Research*.

Washburn, L., Kadko, D.C., Jones, B.H., Hayward, T., Kosro, P.M., Stanton, T.P., Huyer, A., Ramp, S.R. and Cowles, T., "Water Mass Subduction and the Transport of Phytoplankton in a Coastal Upwelling System," *Journal of Geophysical Research*, 96:14927-14945, 1991.

Jones, B.H., Flegal, R., Mooers, C.N.K., Reinecker, M., Stanton, T.P. and Washburn, L., "Chemical and Biological Structure Observed off Northern California in July 1986," *Journal of Geophysical Research*, 96:22207-22225, 1991.

CONFERENCE PRESENTATIONS: Stanton, T.P., "Oceanic Turbulence Measurements Using High Resolution Coherent Acoustic Doppler Techniques," Session PS09, XXIUGG meeting, IAPSO abstracts, p149, Vienna, August 1991

Pluddemann, A.J., Padman, L., Stanton, T.P., Sherman, J.T., Pinkel, R., "Simultaneous Observations of Acoustic Scattering and Ocean Microstructure in the Arctic," Session PS10, XXIUGG meeting, IAPSO abstracts, p176, Vienna, August 1991.

Stanton, T.P., "Subcentimeter Resolution Measurements of Oceanic Turbulence Using an Acoustic Doppler Backscatter Probe," ASA Mtg, JASA Vol 90, p2283, Houston, November 1991.

NEARSHORE WAVE PROCESSES

Edward B. Thornton, Professor of Oceanography
Sponsor: Office of Naval Research
Funding: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: Predict the wave-induced three-dimensional velocity field over arbitrary bathymetry in the nearshore describing the waves with a nonlinear directional wave spectrum.

SUMMARY: Using field data from the 1986 SUPERDUCK experiment (a barred beach) and the 1980 NSTS experiment (a plane beach), the model for shear instability of longshore currents by Bowen and Holman (1989) was extended to include the effects of dissipation in the form of bottom friction. Observed frequency-cyclic wavenumber (f-k) spectra were examined and compared with theoretical predictions. Good qualitative agreement between observation and theory was found at SUPERDUCK, where these motions dominate the observed f-k spectra and where theoretical growth rates of the temporal instability tend to be large. This comparison supports the shear instability hypothesis. Results from NSTS are less conclusive. It is suggested that shear instabilities may be a more common feature on barred beaches.

Abreu, Larraza, and Thornton (1991) developed a shallow water, nonlinear spectral wave transformation model for conditions of a mild sloping bottom and small amplitude effects. Nonlinearities and combined shoaling and refraction effects act on the same time and length scales. The evolution equation of the wave action is prescribed by the wave Boltzmann equation, whereby resonant collinear triad interactions transfer energy among Fourier components. A numerical solution of the three wave collision integral is developed, and the steady state wave Boltzmann equation integrated using a piecewise ray method. Good comparisons are obtained with the high-resolution frequency-directional wave measurements by Freilich, Guza and Elgar (1990).

We participated in the prototype-scale wave/sediment laboratory experiment SUPERTANK during July-August 1991, contributing 16 current meters to measure the velocities under waves.

PUBLICATIONS: Shemer, L., Dodd, N. and Thornton, E.B., "Slow-time Modulation of Finite Depth Nonlinear Water Waves: Relation to Longshore Current Oscillations," *Journal of Geophysical Research*, 96(C4):7105-7113, 1991.

Marom, M., Shemer, L. and Thornton, E.B., "Energy Density Directional Spectra of Nearshore Wave Field Measured by Interferometric Synthetic Aperture Radar," *Journal of Geophysical Research*, 96(C12),22:125-22,134, 1991.

Dodd, N., Oltman-Shay, J. and Thornton, E.B., "Instabilities of Longshore Current: Comparison of Observation and Theory," *Journal of Physical Oceanography*, 22(1):62-82, 1991.

Abreu, M., Larraza, A. and Thornton, E., "Nonlinear Transformation of Directional Wave Spectra in Shallow Water," submitted to *Journal of Geophysical Research*.

Abdelrahman, S.M. and Thornton, E.B., "Longshore Current Induced by Oblique Incident Waves Riding on Infragravity Waves," submitted to *Journal of Geophysical Research*.

Whitford, D.J. and Thornton, E.B., "Longshore Currents Over a Barred Beach, I: Field Experiment," submitted to *Journal of Physical Oceanography*.

Thornton, E.B. and Whitford, D.J., "Longshore Currents Over a Barred Beach, II: Model," submitted to *Journal of Physical Oceanography*.

Whitford, D.J. and Thornton, "Comparison of Wind and Wave Forcing of Longshore Currents," submitted to *Journal of Coastal Engineering*.

Thornton, E.B. and Abdelrahman, S., "Sediment Transport in the Swash Due to Obliquely Incident

Wind-Waves Modulated by Infragravity Waves," Sediments, in proceedings of the 1991 Conference, ASCE, 100-113.

Scott, K.A. and Thornton, E.B., "Mean Currents and Sediment Transport at DELILAH," in proceedings of the Sediments '91 Conference, ASCE, 477-488.

Thornton, E.B. and Abdelrahman, "Sediment Transport in Swash due to Obliquely Incident Wind-Waves Modulated by Infragravity Waves," in proceedings of the Sediments '91 Conference, ASCE, 100-113.

Wyland, R.M. and Thornton, E.B., "Comparison of Extremal Wave Statistics Using Three Hindcast Data Sets," *Journal of Waterway, Port. Coastal and Ocean Division*, in proceedings of the American Society of Civil Engineering, 117(1), 60-74.

CONFERENCE PRESENTATIONS: Thornton, E.B. and Abdelrahman, "Sediment Transport in the Swash Due to Obliquely Incident Wind-Waves Modulated by Infragravity Waves," Sediments '91, ASCE, Seattle, WA.

Scott, K.A. and Thornton, E.B., "Mean Currents and Sediment Transport at DELILAH, Sediments '91 Conference ASCE, Seattle, WA.

McGowan, T. and Thornton, E.B., "Broad-banded Wave Transformation Across the Surf Zone," Fall Meeting, American Geophysical Union, San Francisco.

Abreu, M., Thornton, E.B. and Larraza, A., "Nonlinear Transformation of Direction Wave Spectrum in Shallow Water," Fall Meeting, American Geophysical Union, San Francisco.

THESIS DIRECTED: Abreu, Manual, LT, Portugese Navy, "Nonlinear Transformation of Direction Wave Spectrum in Shallow Water," Ph.D. Dissertation, 115 p., September 1991.

DEPARTMENT OF OPERATIONS RESEARCH

DEPARTMENT OF OPERATIONS RESEARCH

The research program in the department of Operations Research seeks to advance the field's state of knowledge in areas important to the Department of Navy, Department of Defense, and military planning. The study of operational problems often involves the structuring and integration of a number of interdisciplinary components, and the results is a very rich collection of applications. In many instances the methodologies developed are of general interest extending well beyond the problems that spawned them. In these cases our researchers will generalize their work and seek broader recognition.

This report contains the research summaries submitted by the department faculty for the calendar year 1991. For the convenience of the reader, a "summary of the summaries" appears in this cover statement. It is organized according to academic content, and the descriptions are largely in terms of the applied problems treated. Authors are identified in parentheses, and upon occasion, names of collaborators outside of our department are also identified. The specific areas currently represented are optimization, stochastic models and simulation, statistics and data analysis, emerging technologies, combat modelling and war gaming. Sponsors are not immediately identified, but can be located in the individual summaries.

Tangible output appears in the form of student theses, reports to sponsors, conference presentations, Naval Postgraduate School technical reports, and refereed articles in the open professional literature. The research summaries of department faculty whose efforts involved projects sponsored outside of the department are reported elsewhere. Also, research involving security classified matters are not reported here.

Optimization

A broad spectrum of mixed integer programming applications have been treated as a general class. The identification and exploitation of special problem structure is a continuing theme (Bradley, Brown, Wood) in treating large scale optimization problems. Specialized decomposition and relaxation methods have been developed for the sub problems. Also some network basis factorizations have been successfully implemented. Applications include models and algorithms to solve network interdiction problems related to traffic in illegal drugs.

Advances in cutting plane algorithms have been made (Lawphonpanich). These results have been useful in the vehicle routing problems being studied (Dell) for use relating to underway replenishment. Work analyzing the design and operation of anti-satellite architectures continues (Rosenthal). The work on optimizing munitions modeling has continued after its successful application in Operation Desert Storm, (Bradley, Brown, Washburn). Performance characteristics of a world-wide HF/DF net are being treated (Brown, Washburn).

Special purpose algorithms are being developed for the analysis of stimulus-response compatibility interfaces (Theise).

Stochastic Modeling and Simulation

Probabilistic models have been formulated and studied for a common channel signaling system (Gaver, Jacobs, Purdue). Work continues on environmental shapes and hierarchical statistical models (Gaver, Jacobs); their work on meteorological data analysis continues.

Development of reliability growth assessment techniques continues (Woods), with emphasis on lower confidence limits for the reliability of complex coherent systems. Salvo damage aggregation models continue to

be developed (Esary). PC based computer models have been constructed to treat the near term billet vacancy problem.

Reliability simulations and studies related to the performance of major caliber ammunition continue (Bartroli, Bailey, Kang, Sohn, Whitaker).

Statistics and Data Analysis

Development has begun on the use of long base line methods for the calibration of short base line of three dimensional underwater tracking ranges (Read). Studies of sequential maintenance policies and categorical data analysis policies continues (Whitaker) are expanding. Research was done on the variable selection problem in the analysis of growth curves (Sohn).

Models for very short period (monthly) attrition rate estimation are being studied for use in the USMC Officer Rate Generator (Read). Comparative studies have been made of fingerprint and signature automatic verification equipment (Poock). The use of expert judgement is being evaluated in the analysis of geographical data (Kemple). The development of tools for the analysis of visual, acoustic and tactile stimulus-response compatibility in human-system interfaces continues (Theise).

Emerging Technologies

The inaugural work of our new chair of Emerging Technologies was completed (Marshall).

Wargaming and Combat Analysis

Several methods were developed to evaluate attrition methodologies for aggregated combat models (Parry). The work to predict the use and replenishment of fuels and ordnance in battle group operations continues (Schrady, Wadsworth).

Development of a theory of combat continues (Hughes). Methodology has been developed to evaluate the impact of changing the equipment of elements in the single channel architecture of a MAGTF (Bailey, Kemple, Sovereign).

OPTIMIZATION OF MUNITIONS MODELING

G. H. Bradley, Professor of Operations Research
G. G. Brown, Professor of Operations Research,
A. R. Washburn, Professor of Operations Research
Sponsor: HQ, USAF
Funding: USAF Aero Systems Division, Eglin AFB

OBJECTIVE: Research and development of computational models of sorties with air-dropped conventional munitions seeks to provide quick response decision support for theater-level logistics planning and stockpiling.

SUMMARY: The sortie planning and munitions expenditure models developed in this research program ($HEAVY ATTACK & in particular) have enjoyed renewed interest following Desert Storm. Desert Storm provided valuable anecdotal tests of model efficiency, while stressing computational abilities to the limit of model technology. This research has accommodated larger, more challenging problems, rendered faster, more reliable model response, enhanced model interfaces, and provided alternatives to the customary techniques for solving the problems at hand. In concert with this effort, munitions planners are being re-equipped with new, customized, portable, decision support computer hardware and software suites.

PUBLICATIONS: Brown, G., Washburn, A., and Coulter, D., "Optimization of Munitions Procurement," 1991 draft awaiting sponsor release.

THESES DIRECTED: Wirths, K., "A Nonlinear Programming Model for Optimized Sortie Allocation," MS in Operations Research, March 1989, (A. Washburn advisor).

Jackson, J., "A Taxonomy of Advanced Linear Programming Techniques," MS in Operations Research, Air Force Institute of Technology, September 1988, (G. Brown advisor).

Wallace, D.E., "Analysis Tools for United States Air Force Sortie Optimization and Planning," MS in Operations Research, in progress, (G. Bradley advisor).

OTHER: The computer codes HEAVY ATTACK in operation at HQ,USAF, Eglin AFB, and elsewhere.

LARGE-SCALE OPTIMIZATION AND THE EXPLOITATION OF SPECIAL STRUCTURE

G. H. Bradley, Professor of Operations Research
G. G. Brown, Professor of Operations Research
R. K. Wood, Associate Professor of Operations Research
Sponsor: Office of Naval Research and Air Force Office of Scientific Research
Funding: Office of Naval Research,
Naval Postgraduate School and the
Air Force Office of Scientific Research

OBJECTIVE: This continuing research program develops theory and algorithms for solution of large-scale optimization models.

SUMMARY: One focus has been on persistence of integer and nonlinear optimization solutions, automatic exploitation of special structure in integer and nonlinear enumeration, and communication of model structure from modeler to solver. Another focus was the development of optimization and game theoretic models and algorithms to solve network interdiction problems with emphasis on the US Army's optimal allocation of assets to the interdiction of illegal drugs and precursor chemicals in South America.

PUBLICATIONS: Brown, G., Wood, K., Clemence, R., and Teufert, W., "An Optimization Model for Modernizing the Army's Helicopter Fleet," *Interfaces*, 21(4):39-52, July-August 1991.

Brown, G. Bausch, D., Hundley, D., Rapp, S. and Rosenthal, R., "Mobilizing Marine Corps Officers," *Interfaces*, 21(4):26-28, July-August 1991. (1989 Koopman Award winner).

Brown, G. and Wood, K., Avery, W., and Rosenkrantz, J., "Optimization of Purchase, Storage and Transshipment Constraints for Natural Gas Utilities," *Operations Research*, forthcoming.

CONFERENCE PRESENTATIONS: Bradley, G., "Presentation and Analysis of Optimization Results using a Computer Workstation Graphical User Interface," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 29-31 October 1990.

Bradley, G., and Jones, C., Tutorial: "Strategic Vision for Modeling and Problem Solving," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 29-31 October 1990 (75 minute invited tutorial).

Brown, G. and Wood, K., "Optimization of Purchase, Storage and Transmission Contracts for Natural Gas Utilities," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 19-31 October 1990.

Wood, K.,and Mamer, J., Tutorial: "Production/Inventory/Models,"TIMS/ORSAJoint National Meeting, Nashville, TN, 12-15 May 1991 (45 minute invited tutorial for the Management Sciences Roundtable).

Wood, K., "Basis Factorization Applied to Large Scale Production and Distribution Planning," TIMS/ORSA Joint National Meeting, Nashville, TN, 12-15 May 1991.

Brown, G., Bausch, D., and Ronen, D., "Scheduling Oil Transportation with Elastic Set Partitioning," TIMS/ORSA Joint National Meeting, Anaheim, CA, 3-6 November 1991.

Wood, K., "New Network Interdiction Models," TIMS/ORSA Joint National Meeting, Anaheim, CA, 3-6 November 1991.

THESES DIRECTED: Lee, D.K., "Optimal Routing of Military Convoys through a Road Network," MS in Operations Research, March 1991, (K. Wood advisor).

Loh, D.K., "Modeling Strategic Strikes Against Transportation Networks," MS in Operations Research, September 1991, (K. Wood advisor).

Steinrauf, R., "Network Interdiction Models," MS in Operations Research September 1991, (K. Wood advisor).

Glaser, T., "A Single Commodity Mine Transshipment Problem," MS in Operations Research, September 1991, (K. Wood advisor).

H. Fernandes Oliveira, "Design and Implementation of a Toolbox of Modularized C Programs to Construct, Analyze and Test Network Optimization Algorithms," MS in Operations Research, September 1991, (G. H. Bradley, advisor).

Bither, C. and Dougherty, J., "A Modeling Strategy for Large-scale Optimization Based on Analysis and Visualization Principles," MS in Operations Research, September 1991, (G. H. Bradley, advisor).

EXPLOITING SPECIAL STRUCTURE IN LARGE-SCALE OPTIMIZATION

G.H. Bradley, Professor of Operations Research
G.G. Brown, Professor of Operations Research
R.K. Wood, Associate Professor of Operations Research
Sponsor: Air Force Office of Scientific Research
Funding: Air Force of Scientific Research

OBJECTIVE: This continuing research program develops theory and algorithms for solution of large-scale optimization models.

SUMMARY: The research project emphasized theory, analysis and algorithms that exploit special structure in real-world optimization problems. One focus of the research has been a mathematical development of a dynamic factorization approach to large-scale linear programs. The research used the theory to reinterpret existing algorithms, discover common principles and then applied them to develop new algorithms. Another focus has been the design and prototyping of a computer workstation environment to support optimization experts as they build models and design, analyze and test innovative algorithms.

PUBLICATIONS: Brown, G., and Wood, K., "An Optimization Model for Modernizing the Army's Helicopter Fleet," *Interfaces*, 21(4):39-52, July-August 1991.

Brown, G., Bausch, D., Hundley, D., Rapp, S., and Rosenthal, R., "Mobilizing Marine Corps Officers," *Interfaces*, 21(4):26-38, July-August 1991. (1989 Koopman Award Winner).

Brown, G., Wood, K., Avery, W., and Rosenkranz, J., "Optimization of Purchase, Storage and Transshipment," *Operations Research*, forthcoming.

CONFERENCE PRESENTATIONS: Bradley, G., "Presentation and Analysis of Optimization Results Using a Computer Workstation Graphical User Interface," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 29-31 October 1990.

Bradley, G. and Wood, K., "Optimization of Purchase, Storage and Transmission Contracts for Natural Gas Utilities," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 29-31 October 1990.

Bradley, G., and Jones, Chris, Tutorial: "Strategic Vision for Modeling and Problem Solving," TIMS/ORSA Joint National Meeting, Philadelphia, PA, 29-31 October 1990. (75 minute invited tutorial).

Wood, K., Tutorial: "Production/Inventory Models," TIMS/ORSA Joint National Meeting, Nashville, TN, 12-15 May 1991. (45 minute invited tutorial for the Management Science Roundtable).

Wood, K., and Mamer, J., "Basis Factorization Applied to Large Scale Production and Distribution Planning," TIMS/ORSA Joint National Meeting, Nashville, TN, 12-15 May 1991.

Brown, G., Bausch, D., and Ronen, D., "Scheduling Oil Transportation with Elastic Set Partitioning," TIMS/ORSA Joint National Meeting, Anaheim, CA, 3-6 November 1991.

Wood, K., "New Network Interdiction Models," TIMS/ORSA Joint National Meeting, Anaheim, CA, 3-6 November 1991.

THESES DIRECTED: Lee, D.K., "Optimal Routing of Military Convoys Through a Road

Network," MS in Operations Research, March 1991, (K. Wood advisor).

Loh, K.H., "Modeling Strategic Strikes Against Transportation Networks," MS in Operations Research, September 1991, (K. Wood advisor).

Steinrauf, R., "Network Interdiction Models," MS in Operations Research, September 1991, (K. Wood advisor).

Glaser, T., "A Single Commodity Mine Transshipment Problem," MS in Operations Research, September 1991, (K. Wood advisor).

Oliveira, H. Fernandes, "Design and Implementation of a Toolbox of Modularized C Programs to Construct, Analyze and Test Network Optimization Algorithms," MS in Operations Research, September 1991, (G.H. Bradley advisor).

Bither, C., and Dougherty, J., "A Modeling Strategy for Large-Scale Optimization Based on Analysis and Visualization Principles," MS in Operations Research, September 1991, (G.H. Bradley advisor).

FREQUENCY PLANNING

G.G. Brown, Professor of Operations Research
Alan R. Washburn, Professor of Operations Research
Sponsor: Naval Security Agency

OBJECTIVE: There were two objectives. First, find a fast way to evaluate the probability of detection for a given frequency allocation to the receivers of a world-wide HF/DF net. Second, find the optimal frequency allocation.

SUMMARY: The first objective has been reached in the sense that we have developed a computer code that is more accurate and over an order of magnitude faster than the code that was previously in use at NSA. The second objective has been partially reached by a scheme that quickly finds the local optimum corresponding to a randomly chosen initial frequency allocation. Experiments with other optimization schemes and objective functions are continuing.

CONFERENCE PRESENTATION: Washburn, A. R., "Search and Rescue Network Optimization," Nashville ORSA/TIMS, May 1991.

OTHER: FORTRAN codes are in operation at NSA.

SCHEDULING UNDERWAY REPLENISHMENTS FOR CARRIER BATTLE GROUPS

Robert F. Dell, Assistant Professor of Operations Research
Siriphong Lawphongpanich, Associate Professor of Operations Research
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop an optimization based tool for scheduling underway replenishment of carrier groups.

SUMMARY: As carrier battle groups must potentially operate under varied tactical formations dispersed over a wide geographical area, how to provide efficient logistic support can be viewed as a dynamic decision making problem. With explicit consideration of varied replenishment tactics, these problems have been reduced to a unique class of optimization problems. Tailored solution procedures have been developed with excellent preliminary results. We classified the process of scheduling underway replenishment by their underlying characteristics such as the replenishment tactic used, the number of lift assets (helicopters and/or station ships), type of replenishment (vertical or connected), etc. *During this reporting* period, several basic classes of underway replenishment problems were modeled as optimization problems, all of which belong to a class of operations research problem known as the generalized traveling salesman problem. In addition, we also developed branch and bound algorithms to solve two different, but related, underway replenishment problems. One uses the circuit rider tactic and the other schedules replenishment in a limited amount of time, i.e., the replenishment must be completed prior to the next enemy attack.

CONFERENCE PRESENTATIONS: Dell, R.F. and Lawphongpanich, S.R., "Replenishment of a Dispersed Carrier Battle Group," ORSA/TIMS Joint National Meeting, Anaheim, CA, November 1991, (invited).

Dell, R.F., Batta, R. and Karwan, M.H., "A Heuristic for the Equity Constrained Multiple Traveling Salesman Problem with Time Windows," National Meeting of the Operations Research Society of America and The Institute of Management Science, Nashville, TN, May 1991, (invited).

Kemple, W.G., Dell, R.F. and Tovey, C., "On Solving the Stratigraphic Correlation Problem with Tabu Search and Simulated Annealing," National Meeting of the Operations Research Society of America, and the Institute of Management Science, November 1991, (contributed).

Lawphongpanich, S. and Rosenthal, R.E., "Estimating the Minimum Number of Assets to Support a Deployment," The National Science Week Conference, Bangkok, Thailand, August 1991, (invited).

DAMAGE AGGREGATION MODELS FOR WEAPONS SALVOS

J. D. Esary, Professor of Operations Research
Sponsor: Naval Weapons Center, China Lake, CA
Funding: Naval Postgraduate School

OBJECTIVE: Develop reasonable planning models for estimating the aggregate damage caused by multiple hits from weapons salvos.

SUMMARY: This project is a continuation of a project conducted during the previous two years under the same title. The estimation of the aggregate damage to be achieved as the result of multiple weapons hits is a fundamental aspect of strike planning. At least two measures of effectiveness are pertinent, the expected percentage of the target which is damaged, and the probability that the damage to the target exceeds a threshold sufficient to regard the target as $killed%. Models for estimating these measures are of interest generically, and specifically to various subgroups of the Joint Technical Coordinating Committee for Munitions Effectiveness. Results documented during the previous years concerned empirical rules for estimating the expected percentage of damage to an area target compared to a rule derived from a plausible model, and the first of an emerging family of target configuration and weapons impact scenarios which lead to the plausible model (now called a proportional effects damage aggregation mechanism). Results documented during this year include extensions to the family of targeting scenarios which lead to a proportional damage aggregation mechanism and the first consideration of dependencies in weapons hit distributions. In addition to salvos directed against area targets, pertinent scenarios may include the defense of task forces against incoming missiles with and without target allocation.

PUBLICATIONS: Esary, J.D., "Studies on Damage Aggregation for Weapons Salvos II", NPS Technical Report NPSOR-92-007, Naval Postgraduate School, December 1991, (a record of the following working papers on this subject).

OTHER: Esary, J.D., Proportional Damage Aggregation for a Cellular Target with Cells of Zero Value, Working Paper on Damage Aggregation, Naval Postgraduate School, March 1991.

Esary, J.D., A Basic Lemma on Expected Damage Aggregation for Cellular Targets, and Some of its Applications Working Paper on Damage Aggregation, Naval Postgraduate School, May 1991.

Esary, J.D., Comparisons of an Empirical Rule for Expected Damage Aggregation from Weapons Salvos to Models Assuming a Proportional Damage Aggregation Mechanism and Dependent Weapons Hit Distributions, Working Paper on Damage Aggregation, Naval Postgraduate School, November 1991.

PERFORMANCE ANALYSIS STUDIES

D. P. Gaver, Distinguished Professor of Operations Research
P. A. Jacobs, Professor of Operations Research
P. Purdue, Professor of Operations Research
Sponsor: Defense Communications Agency
Funding: Defense Communications Agency

OBJECTIVE: To conduct mathematical performance analysis studies and develop models to a) assess the contribution of common channel signalling in voice network routing; and b) to evaluate routing and congestion control procedures in multi-type (voice, data, video) broad-band networks.

SUMMARY: Probabilistic models have been formulated and studied for a common channel signaling system that sets up and tears down voice calls, in a circuit-switch network. A heuristic procedure for calculating delays in a network is proposed.

PUBLICATION: Gaver, D.P., Jacobs, P.A., Lehoczky, J.P., "Probabilistic Modeling of Common Channel Signaling", Naval Postgraduate School Technical Report NPSOR-91-028, September 1991.

CONFERENCE PRESENTATIONS: Gaver, D.P. and Jacobs, P.A., "Common Channel Signaling Models," ORSA/TIMS Joint National Meeting, Anaheim, CA, 3-6 November 1991.

Gaver, D.P. and Jacobs, P.A., "Modeling a Buffer that Experiences Losses and Retransmissions," Nonlinear Science Colloquium, Naval Postgraduate School, 8 March 1991.

Gaver, D.P., "Models for Common-Channel Signaling." I.F.I.P.S. Working Group Meeting, Laguna Beach, CA, (Spring, 1991).

METEOROLOGICAL DATA ANALYSIS: ESTIMATION OF PREDICTION ERROR VARIANCES

D. P. Gaver, Distinguished Professor of Operations Research
P. A. Jacobs, Professor of Operations Research
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory
Funding: Naval Oceanographic and Atmospheric Research Laboratory

OBJECTIVE: Variance of prediction errors are required in the optimum interpolation analysis used in numerical weather prediction. The purpose of this study is to investigate the relationship of the current variances to other atmospheric parameters in order to improve estimation.

SUMMARY: Statistical models for the prediction error have been formulated which have log-linear scale parameters which include covariances. Data from February and April of 1991 are used to estimate the model parameters and to study the predictive ability of the models. This preliminary investigation indicates that observational and first guess wind components can be helpful in predicting mean square prediction error for wind components.

PUBLICATIONS: Jacobs, P.A. and Gaver, D.P. "Preliminary Results from the Analysis of Wind Component Error," Naval Postgraduate School Technical Report NPSOR-91-029, September 1991.

PROBABILISTIC MODELS FOR SHAPES AND HIERARCHICAL BAYESIAN MODELING AND ESTIMATION

D. P. Gaver, Distinguished Professor of Operations Research
P. A. Jacobs, Professor of Operations Research
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: To conduct probabilistic and statistical research on a) simple characteristics of random environmental shapes, and b) non-standard data analysis techniques such as non-Gaussian time series prediction and hierarchical statistical models.

SUMMARY: A hierarchical model for a Poisson time series with covariates was introduced and its use in short-term forecasting investigated. Models for service-adaptive multi-type repair were formulated and studied. Previous research on optimal sequential replenishment of ships appeared.

PUBLICATIONS: Gaver, D.P. and Morrison, J.A., "Heavy Traffic Analysis of Multitype Queuing under Probabilistically Load Preferential Service Order," *SIAM Journal Applied Mathematics*, 51(4):1134-1149, August 1991.

Coffman, Jr., E.G., Flatto, L. and Gaver, D.P., "Height Distributions in Data Communication Buffers with Locking Protocols," *Communications in Statistics: Stochastic Models*, 7(2):243-260, 1991.

Pilnick, S.E., Glazebrook, K.D. and Gaver, D.P., "Optimal Sequential Replenishment of Ships during Combat," *Naval Research Logistics*, 38:637-668, 1991.

Gaver, D.P., Jacobs, P.A. and O 'Muircheartaigh, I.G., "Regression Analysis of Hierarchical Poisson-like Event Rate Data: Superpopulation Model Effect on Prediction," *Communications in Statistics Theory and Method*, 19:3779-3797.

Gaver, D.P., Morrison, J.A. and Silveira, R. "Service-adaptive Multi-type Repairman Problems," Naval Postgraduate School Technical Report, NPSOR-91-11, March 1991.

Gaver, D.P. and Jacobs, P.A.,"A Kalman Filter for a Poisson Series with Covariates and Laplace Approximation Integration," Naval Postgraduate School Technical Report, NPSOR-91-030, September 1991.

CONFERENCE PRESENTATIONS: Gaver, D.P. and Jacobs, P.A., "Some Properties of Random Shapes Generated by Sculptured Wraparound," ORSA/TIMS Specific Interest Conference on Applied Probability in the Engineering, Informational and Natural Sciences, Monterey, CA, 9-11 January 1991.

Gaver, D.P. and Jacobs, P.A., "Limited Service Models," ORSA/TIMS Joint National Meeting, Philadelphia, PA, 29-31 October 1990.

Gaver, D.P. and Silveira, R., "Non-stationary and Adaptive Multi-item Repair Models," TIMS XXXX-SOBRAPO XXIII Joint International Meeting, Rio de Janeiro, 15-17 July 1991.

OTHER: D. P. Gaver organized an invited session on Spatial Processes and Image Analysis for the ORSA/TIMS Special Interest Conference in Applied Probability in the Engineering, Informational and Natural Sciences held in Monterey, CA, 9-11 January 1991.

Thomas, L.C., Gaver, D.P. and Jacobs, P.A., "Inspection Models and their Applications," working paper series No. 91/21, Dept. of Business Studies, University of Edinburgh.

DEVELOPMENT OF A THEORY OF COMBAT

Wayne P. Hughes, Jr., Adjunct Professor of Operations Research
Sponsor: Director, Test, Evaluation and Technical Requirements
Office of the Chief of Naval Operations (OP-914)
Funding: Naval Postgraduate School

OBJECTIVE: To specify a comprehensive theoretical structure for the study of combat. The structure will form the foundation of combat science for both operators (combat leaders) and military operations analysts.

SUMMARY: The draft research paper establishes the basic premises and structure for the study of combat. Combat science is taken to be organized knowledge of the physical, mental and motivational aspects of lethal conflict, including their components, functions, and related processes. The exposition is organized under six fundamental axioms. New material include five "addenda" to the axioms, three new appendices, a revised introduction and an executive summary.

CONFERENCE PRESENTATION: Hughes, Jr., W.P., "The Value of Warship Attributes," 59th MORS Symposium, West Point, NY, 12 June 1991.

Hughes, Jr., W.P., "The Value of Staying Power," DTRC, Carderock, MD, 4 October 1991.

THESES DIRECTED: Snell, R., LCDR, USN, "Countertargeting in Naval Salvo Warfare," MS Thesis, March 1991.

Smith, T.T., LT, USN, "Combat Modeling Low Intensity Conflict Antisurface Warfare for Engagement Analysis," MS Thesis, March 1991.

Costello, R.P., LT, USN, "Battlefield Dynamics," MS Thesis, March 1991.

Lalis, A.P., LCDR, HN, "Sensitivity Analysis of the Modern Naval Combat Model," MS Thesis, September 1991.

Martirano, P., LT, USN, "Shallow Water ASW: A Two-stage Concept," MS Thesis, September 1991.

DECOMPOSITION TOPICS IN LARGE-SCALE OPTIMIZATION

Siriphong Lawphongpanich, Associate Professor of Operations Research
Sponsor: National Science Foundation
Funding: National Science Foundation

OBJECTIVE: To develop effective algorithms for large-scale optimization models. The development includes both theoretical and computational investigation of decomposition techniques which allow division of the problem into more tractable subproblems.

SUMMARY: In conjunction with the research project titled 'Analysis of Algorithms for Linearly Constrained Convex Programs,' we have made several discoveries concerning the cutting plane algorithms. One is the fact that three different types of algorithms, the usual cutting plane algorithm, the cutting plane algorithm with line search and the family of bundles methods, can be viewed as proximal minimization algorithms with cutting planes. The first two are proximal minimization algorithms that yield a linear master problem. However, the usual cutting plane algorithm does not attempt to produce a monotonic sequence of objective function values, but the one with line search does. The last type of algorithms, the family of bundle methods, yields a quadratic master problem and attempts to produce a monotonic sequence of objective function values. This led to the question of the existence of a proximal minimization algorithm with cutting planes that yields a quadratic master problem and does not attempt to produce a monotonic sequence of objective functions values. Our second discovery is the positive response to this question. Finally, we also provided a new convergence proof for the bundle methods. Previous proofs make the developments of bundles methods and proximal minimization algorithms with cutting planes appear distinct. In the new proof, techniques common in establishing convergence for proximal minimization algorithms are utilized, thereby providing an additional evidence of the above stated relationship.

PUBLICATIONS: Hearn, D.W. and Lawphongpanich, S., "Decomposition Topics for Large-Scale Optimizations," in proceedings of the 1991 NSF Design and Manufacturing Systems Conference, Austin, Texas.

Lawphongpanich, S. and Hearn, D. W., "Cutting Plane Algorithms for Maximum Problems," NPS Technical Report NPS-OR-92-008, December 1991, (invited to submit to a special issue of Mathematical Programming Series B in honor of Dr. Philip Wolfe's 60th birthday).

Lawphongpanich, S., "A Proximal Minimization Algorithm with Cutting Planes," NPS Technical Report NPS-OR-92-011, December 1991.

CONFERENCE PRESENTATIONS: Hearn, D.W. and Lawphongpanich, S., "Decomposition Topics for Large-Scale Optimizations," NSF Design and Manufacturing Systems Conference, Austin, Texas, January 1991.

Lawphongpanich, S. and Hearn, D. W., "Accelerating the Cutting Plane Algorithm for Maximum Problems," The Second Stockholm Optimization Days, Stockholm, Sweden, August 1991, (invited).

Lawphongpanich S., "A Proximal Minimization Algorithm with Cutting Planes," 14th International Symposium on Mathematical Programming, Amsterdam, The Netherlands, August 1991.

ANALYSIS OF ALGORITHMS FOR LINEARLY CONSTRAINED CONVEX PROGRAMS

Siriphong Lawphongpanich, Associate Professor of Operations Research
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The objective of this research is the identification of effective and efficient algorithms for linearly constrained convex programs. The investigation includes both theoretical and computational studies of competing algorithms.

SUMMARY: In conjunction with the research project titled 'Decomposition Topics in Large-Scale Programming,' we concentrated our research effort on the Lagrangian dual problems for the linear constrained convex programs. These Lagrangian dual problems can be solved by cutting planes algorithms and major discoveries are described in the summary of the project mentioned above. Additional result is the discovery of a new type of cutting plane algorithm called the nontangential cutting plane algorithm. This algorithm is suitable for problems which yield a difficult subproblem. In particular, the algorithm allows the subproblem to be solved only approximately during the initial iterations. This enhances the efficient of the algorithm and identifies a relationships with a cutting plane algorithm designed especially for variational inequalities, a problem class related to convex programs.

SCHEDULING UNDERWAY REPLENISHMENTS FOR CARRIER BATTLE GROUPS

Robert F. Dell, Assistant Professor of Operations Research
Siriphong Lawphongpanich, Associate Professor of Operations Research
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop an optimization based tool for scheduling underway replenishment of carrier groups.

SUMMARY: As carrier battle groups must potentially operate under varied tactical formations dispersed over a wide geographical area, how to provide efficient logistic support can be viewed as a dynamic decision making problem. With explicit consideration of varied replenishment tactics, these problems have been reduced to a unique class of optimization problems. Tailored solution procedures have been developed with excellent preliminary results. We classified the process of scheduling of underway replenishment by their underlying characteristics such as the replenishment tactic used, the number of lift assets (helicopters and/or station ships), type of replenishment (vertical or connected), etc. During this reporting period, several basic classes of underway replenishment problems were modeled as optimization problems, all of which belong to a class of operations research problem known as the generalized traveling salesman problem. In addition, we also developed branch and bound algorithms to solve two different, but related, underway replenishment problems. One uses the circuit rider tactic and the other schedules replenishment in a limited amount of time, i.e., the replenishment must be completed prior to the next enemy attack.

CONFERENCE PRESENTATIONS: Dell, R.F. and Lawphongpanich, S., "Replenishment of a Dispersed Carrier Battle Group," ORSA/TIMS Joint National Meeting, Anaheim, California, November 1991, (invited).

Dell, R. F., R. Batta, and M. H. Karwan, "A Heuristic for the Equity Constrained Multiple Traveling Salesman Problem with Time Windows," National Meeting of the Operations Research Society of America and The Institute of Management Science, May 1991 (invited).

Kemple, W. G., R. F., Dell, and C. Tovey, "On Solving the Stratigraphic Correlation Problem with Tabu Search and Simulated Annealing," National Meeting of the Operations Research Society of America, and the Institute of Management Science, November, 1991 (contributed).

Lawphongpanich, S. and Rosenthal, R. E., "Estimating the Minimum Number of Assets to Support a Deployment," The National Science Week Conference, Bangkok, Thailand, August 1991, (invited).

CNO CHAIR OF EMERGING TECHNOLOGIES

K. T. Marshall, Professor of Operations Research

Sponsor: Office of the Chief of Naval Operations (OP-091)
Funding: Office of the Chief of Naval Operations (OP-091)

OBJECTIVE: This Chair was established in 1990 to provide a direct relationship between the Director, Office of Navy Requirements for Research and Development, Test and Evaluation (OP-091) and the Superintendent of the Naval Postgraduate School (NPS) in order to establish a focused research program that examines the military implications of emerging technologies, and foster interactions between NPS and the Navy R&D community.

SUMMARY: Approximately one half year was devoted to the Chair in 1991. Principal activities included 1) a seminar involving NPS faculty and navy lab personnel on target identification and classification problems, 2) visits with navy labs, including a brief to lab CO's and TD's on potential NPS interactions, 3) attracting Dr. Alex Becker of UC Berkeley to visit NPS to work in electro-magnetics in ASW, 4) a seminar involving NPS students recently assigned from Desert Shield/Desert Storm on lessons learned, 5) member of US delegation to international meeting on military OR in space, 6) participation in the Surface Warfare 2030 Symposium and Wargame.

PUBLICATIONS: Marshall, K. T. , "An Overview of the World's Navies, Future Roles for the US Navy, and Implications for Naval Postgraduate Instructional and Research Programs," NPS report NPSOR-91-22, July 1991.

Marshall, K. T. , "An Overview of the Research and Development System in the US Navy," NPS Report NPSOR-91-001PR, July 1991.

CONFERENCE PRESENTATIONS: Marshall, K. T. , "Future US Naval Operations," RAND Workshop on Military Analysis for the Future: New Issues, New Tools, Santa Monica, May 1991.

Marshall, K. T. , "The Role of Operations Research in Solving Strategic Decision Problems," 6th ABCANZ International Exchange Program Meeting, Ottawa, Canada, June 1991.

THESIS DIRECTED: Franck, S. G. , LCDR, USN, "A Methodology for Evaluating Warfare Architectures," MS Thesis, September 1991.

NAVY OFFICER HARDFILL ALLOCATION AND DISTRIBUTION ANALYSIS

Paul R. Milch, Professor of Operations Research
Sponsor: Naval Military Personnel Command (NMPC-454)
Funding: Naval Military Personnel Command (NMPC-454)

OBJECTIVE: Construction of near-term Navy Officer Allocation and Distribution Models to be used by NMPC-4.

SUMMARY: Two interactive, PC-based computer models have been constructed to assist NMPC-4 personnel to fill billets that become vacant in the near term. Both models deal with Navy Unrestricted Line (URL) officers of grades lieutenant commander, commander and captain. The model HARDLIST is designed to produce a list of such officers to be rotated from their current assignment during a forthcoming three-month period who meet all the criteria required by a specific $hard-fill$ billet. The required criteria may include any or all of the following: designator, rank, subspecialty code, additional qualification designation code (AQD) and language code. The model HARDFILL performs a matching in terms of the above criteria between a set of URL officers and a set of billets requiring such officers. The officers are those to be rotated during a specific period and the billets to become vacant during the same period.

PUBLICATIONS: NPS technical report to be published.

EVALUATION OF ATTRITION METHODOLOGIES FOR AGGREGATED COMBAT MODELS

Sam H. Parry, Associate Professor of Operations Research
Sponsor: Defense Communications Agency, JDSSC, JNSF

OBJECTIVE: The goal of this research was to evaluate attrition methodologies for aggregated combat models, with specific focus on TACWAR, the model used by the J Staff of JCS, as well as four CINCs and SHAPE.

SUMMARY: Several methods of assessing attrition in a theater-level model were investigated and documented, to include firepower scores, eigenvalues, and data feed from a high resolution division level model (COSAGE). Also, several methods for representing fire allocation were evaluated for inclusion in TACWAR. Substantial problems were surfaced during the research period, related to both code and data inputs. A detailed analysis evaluation plan was developed and documented. Five alternative methods for running TACWAR were developed and efforts continue to implement these approaches. As a result of this research, NPS is now a primary member of the TACWAR Configuration Control Group.

PUBLICATIONS: Parry, S.H., "Evaluation of Attrition Methodologies for Combat Models," DCA, October 1991.

Parry, S.H., "TACWAR Evaluation," DCA, October 1991.

Parry, S.H., "Preliminary TACWAR Evaluation Results," DCA, October 1991.

Parry, S.H., "Executive Summary of TACWAR Investigations by NPS and CSC," October 1991.

OTHER: NPS thesis efforts are currently ongoing to continue this effort.

CONTROLLING SHIPBOARD ACCESS WITH SIGNATURE AND FINGER PRINT VERIFICATION

Gary K. Poock, Professor of Operations Research
Sponsor: Research Administration Office
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to examine finger print and signature automatic verification equipment to see how well it might work for controlling shipboard access to personnel.

SUMMARY: Testing of automatic finger print identification equipment and signature verification equipment was carried out in the Man-machine Systems Design Laboratory using military officers during the year. Questions of accuracy and human acceptability we addressed. Basically, the finger print machine works quite accurately, but there is a problem enrolling some individual's finger prints in the machine. The reason was never determined. The signature device appeared not as durable nor accurate as the finger print technology.

PUBLICATION: Poock, Gary K. "Finger Print Verification for Access Control." NPS Technical Report, NPSOR-91-12, April 1991.

THESIS DIRECTED: Castor, S., "Signature Verification for Access Control," MS Thesis, September 1991.

RANGE CALIBRATION STUDIES

R. R. Read, Professor of Operations Research
Sponsor: NUWES, Keyport WA
Funding: Naval Postgraduate School

OBJECTIVE: NUWES (Naval Underwater Weapons Engineering Station) operates a number of short baseline ranges for tracking underwater vehicles. The calibration problems of concern are related to the discontinuity of track in the array overlap regions. There are a number of sources of systematic error that contribute to this condition: inexact knowledge of the individual array locations and orientations; biases in the reconstruction of the sound ray paths; inhomogeneities in the water column parameters that determine the depth velocity profile; etc. These systematic errors interact with each other and corrective methods need be developed that can operate effectively and with permanence.

SUMMARY: This is a continuing project. The current reporting period features the use of "triple overlap" data. That is, there are certain regions of the range where three arrays provide position location information for a vehicle. The locations of the arrays themselves form an approximate equilateral triangle and the three simultaneous estimates of position are near the center of this triangle. Generally they disagree by fifty feet or so. In these circumstances long baseline methods can be employed to produce a fourth (consensus) position estimate. This latter vector is taken as a goal for the adjustment of the parameters of the three participating arrays. If the three arrays are held stationary then the goal can be used to provide directional "tilt" corrections for the individual arrays. Alternatively one could consider array position adjustments which, in turn, would change the position determination found using long baseline methods. Methodology for treating the former problem was developed and tested on six data sets. The algorithm appeared to be sharp and the effects seemed rather dramatic. Also there was consistency in the results when the same triple overlap region was used at different times.

PUBLICATIONS: R.R. Read, "A Technique for Assessing Short Baseline Array Tilt Errors," NPS Technical Report, NPSOR-91-131, May 1991.

THESIS DIRECTED: M.P. Taylor, "Accuracy Assessment for the Auxiliary Tracking System," NPS MS Thesis, September 1991.

ATTRITION RATE GENERATION FOR MANPOWER MODELS

R.R. Read, Professor Operations Research
Sponsor: M120, HQUSMC, Washington, D.C.
Funding: Naval Postgraduate School

OBJECTIVE: The Marine Corps is transferring its manpower planning to a computerized system. There are a number of flow models and uses. Manpower models are affected by three general factors: existing inventory (personnel), projected gains, projected losses. The projected losses can only be anticipated in a statistical sense. Moreover these must be done cell by cell. Cells are defined by cross classifying variables such as grade, years of commissioned service, military occupation specialty, service component, commissioning source, etc. depending upon the application. This situation leads to a large number of low inventory cells. The problem is to build a stable attrition rate generator for these cells.

SUMMARY: Previous work has produced a cell aggregation algorithm that clusters small cells into aggregates having satisfactory size, and a shrinkage estimation technique that estimates attrition rates for the aggregated cells. This method was developed for annualized data and one year leadtime forecasts. The subsequent issue is the use or modification of the method for shorter leadtimes of one, two, three, etc. months up to twelve months. Seasonal type variation is known to be present. Most attritions occur in June and July. Literature searches were made and some modeling of this extension was accomplished. Algorithms were developed for implementing the models and for testing using cross validation techniques. The sponsor supplied monthly data cartridge did not arrive in time to execute the testing in this period.

OPERATIONS RESEARCH MODELING OF ANTI-SATELLITE ARCHITECTURES

Richard E. Rosenthal, Professor Operations Research
Sponsor: Naval Space Command
Funding: Naval Space Command

OBJECTIVE: The goal of this continuation project was to analyze the design and operation of various anti-satellite (ASAT) architectures using optimization modeling techniques.

SUMMARY: The primary problem addressed in this research was ASAT targeting. We developed models which work in conjunction with U.S. SPACECOM 's existing software for orbital calculations, and are sufficiently flexible to be used not only for analyzing U.S. battle management negation needs, but also for predicting approaches that might be taken by a hostile force against U.S. space assets. Our models were unified in one portable GAMS and Pascal package called STOMP, for Space Targeting Optimization Modeling Program.

CONFERENCE PRESENTATIONS: Rosenthal, R.E., Tisdale, S.A., (posthumous) and Wallick, G.T., "The Space Targeting Optimization Modeling Program," invited paper at Operations Research Society of America and The Institute of Management Science joint national meeting, Nashville, TN, May 1991.

Rosenthal, R. E., Tisdale, S.A., (posthumous) and Wallick, G.T., "The Space Targeting Optimization Modeling Program," Military Operations Research Society Symposium, West Point, June 1991.

BATTLE GROUP LOGISTICS COORDINATOR SUPPORT SYSTEM

D.A. Schrady, Professor of Operations Research
D.B. Wadsworth, CDR, SC, USN
Sponsor: Commander Second Fleet (C2F)
Funding: NPS and DCNO (Logistics)

OBJECTIVE: The goal of this continuing project was to develop a computer-based system to plan, track, and predict the use and replenishment of fuels and ordnance in battle group operations in support of the logistics coordinator and the battle group commander.

SUMMARY: The system was evaluated in a fleet exercise in FY90, and was used by the fleet logistics coordinator and Commander Second Fleet in double exercises in early FY91. Based on C2F enthusiasm for the system, a User's Guide was written and published and training was held in Norfolk, VA in March 1991. The system was again used to support C2F in the workup of the Eisenhower battle group in July/August 1991. In August Commander Third Fleet (C3F) requested OP-094 to incorporate the system into the afloat tactical command and control system, JOTS II. Subsequent discussion with OP-094 indicated that C6F and CINCPACFLT were desirous of this as well and the Fleet Requirements Working Group meeting hosted by OP-094 in October included this in their FY92 program. The focus of the project at NPS then shifted to restructuring the system to operate in the JOTS environment and take advantage of the realtime data available therein. A DTC-2 workstation with JOTS II 1.1 software and documentation was obtained from PMW 162 for this purpose and work is underway to move the system into JOTS. Other research accomplished in the period includes the structuring of the battle group rearming problem and the development of algorithms to determine the replenishment schedule which maximizes the combat value of ordnance transferred in a restricted period of time. This work and regular unrep scheduling aids will be incorporated in BGLCSS in the future.

PUBLICATIONS: Schrady, D.A. and Wadsworth, D.B. , "Naval Combat Logistics Support System," *Journal of the Operational Research Society*, 42(11):941-948, November 1991.

Schrady, D.A. and Wadsworth, D.B. , "User's Guide for the Battle Group Logistics Coordinator Support System (BGLCSS)," NPS Technical Report, NPS-OR-91-08, February 1991.

Cali, S.M. and Schrady, D.A. , "Battle Group Tactical Rearming (U)," NPS Technical Report, NPS-OR-91-27, September 1991 (SECRET).

CONFERENCE PRESENTATION: Schrady, D.A. and Wadsworth, D.B., "Amateurs Discuss Tactics: Professionals Study Logistics," SACLANT NATO Naval Operations Research Symposium, Norfolk, VA, 11 October 1990.

THESES DIRECTED: Braunschweig, J.J., LT, USN, "A Scheduling Aid for Battle Group Replenishment," MS Thesis, September 1991.

Cali, S.M., LT, USN, "Battle Group Tactical Rearming (U)," MS Thesis, September 1991.

VARIABLE SELECTION IN A LINEAR GROWTH CURVE MODEL WITH AUTOREGRESSIVE ERRORS

So Young Sohn, Assistant Professor of Operations Research
Sponsor: Research Administration Office
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was to compare estimation methods for variable selection schemes in a linear random coefficient growth curve model when the within-individual data are suspected to have serial correlation.

SUMMARY: The purpose of growth curve analysis is to investigate changes over time in a given characteristic of different individuals due to certain factors. This analysis often considers independent within-individual error and a set of known factors. However, these assumption may not properly cover many practical situations. In this project, unbalanced within-individual data was assumed to have first-order linear correlation (ρ) and a weighted stepwise selection was used to choose influential factors. A simulation study was conducted to compare the performances of the maximum likelihood (ML) and the ordinary least square (OLS) estimators of the within-individual model in terms of the ability of variable selection. Simulation results indicated the following: Under the suspicion of high autocorrelation error ($\rho > 0.5$), the ML estimation is necessary in the within-individual model. When it is believed that the r is as small as 0.1 and the heterogeneity of variance is relatively low then, the OLS estimator can replace the ML estimator in terms of selection performance in the between-individual model.

PUBLICATIONS: Sohn, S. Y., "Variable Selection in a Linear Growth Curve Model with Auto-Regressive Within-Individual Errors," *Journal of Statistical Computation and Simulation*, forthcoming.

COMBAT ANALYSIS

M. Sovereign, Professor of Operations Research
Sponsor: USMC
Funding: Unfunded - Allocation of C3 Assets in the MAGTF

OBJECTIVE: The short-term objective of the project was to develop a methodology for evaluating the impact of changing the communications equipment of elements within the single-channel architecture of a USMC MAGTF. The longer-term goal of the project was to generalize the methodology to any portion of the MAGTF communications architecture.

SUMMARY: The immediate problem was to determine the optimal allocation of frequency-hoppiyng (fh) radios within the single-channel radio architecture of the MAGTF. A model was developed called the Marine Corps Communications Architecture Analysis model (MCCAAM), which is an object-oriented simulation of the network in an engaged state. The model includes a database management interface which allows the user to design the architecture, the force structure, and the communications workload, as well as to design the simulation experiment carried out. The software also includes graphical output, animation, and the proper statistical treatment of the data. The sponsor is currently using the database development capability and the model to support allocation of fh and other radio assets, as well as structuring or radio nets and use of digital transmissions.

PUBLICATIONS: Sovereign, M., Bailey, M., and Kemple, W., "Application of the MCES to Marine Corps Single-Channel Radio Allocation," Part 1, NPS Technical Report, NPSOR-91-023.

Bailey, M., Kemple, W., and Sovereign, M., "Object-oriented Modeling of Communications Networks of the MAGTF," NPS Technical Report NPSOR-91-010.

Bailey, M., Kemple, W., and Sovereign, M., "The Scientific Method of Choosing Model Fidelity," NPS Technical Report NPSOR-91-005.

CONFERENCE PRESENTATIONS: Sovereign, M., Bailey, M., and Kemple, W., "Application of the MCES to Marine Corps Single-Channel Radio Allocation," 1991 Symposium on Command and Control Research, Ft. McNair, Washington, DC, 24-27 June 1991.

Bailey, M., Kemple, W., and Sovereign, M., "Object-oriented Modeling of Communications Networks of the MAGTF," Summer Simulation Conference, Baltimore, MD, 22-24 July 1991.

Bailey, M., "Modeling the Performance of Integrated Air Defense Systems," Joint Japan-U.S. Operations Research Symposium, JDA, Tokyo, Japan, 2-6 December 1991.

Bailey, M., "Stochastic Network Analysis of Air Defense Systems," Role of Changing Technology in Naval Analysis, Naval Postgraduate School, Monterey, CA, 15 February 1991.

Bailey, M., "Using Ramped Intensity Workload Processed to Design Discrete Service Systems," ORSA/TIMS, Anaheim, CA, 4-6 November 1991.

Bailey, M., Kemple, W., and Sovereign, M., "The Scientific Method of Choosing Model Fidelity," RAND Symposium on New topics and Tools in Combat Analysis, RAND Corporation, Santa Monica, CA, 6-9 May 1991.

Sovereign, M., Bailey, M., and Kemple, W., "Application of the MCES to Marine Corps Single-channel Radio Allocation," 1991 Symposium on Command and Control Research, Ft. McNair, Washington, DC, 24-27 June 1991.

Bailey, M., Kemple, W., and Sovereign, M., "Object-oriented Modeling of Communications Networks of the MAGTF, Summer Simulation Conference, Baltimore, MD, 22-24 July 1991.

THESES DIRECTED: Chase, Charles, USA, "The Fidelity Improved Process," September 1991.

West, Michael, USMC, "Object-oriented Modeling and Analysis of Marine Corps Communications Architecture," September 1991.

THE MINIMUM TOTAL CONFUSION PROBLEM: APPLICATIONS AND ALGORITHMS

Eric S. Theise, Assistant Professor of Operations Research/Human Factors
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: To develop and use tools for the analysis of visual, acoustic, and tactile stimulus-response compatibility in human-system interfaces.

SUMMARY: This research is directed towards a systematic study of the confusion matrix, a data construct arising in human factors engineering and applied psychology. The 'applications' portion of the project focuses on the analysis and interpretation of empirically derived confusion matrices, some from the literature and some from experiments running in our Human-Systems Integration Laboratory. The first attempt at a taxonomy of confusion matrices is also under development. The 'algorithms' portion of the project focuses on finding exact and approximate solutions to the problem of selecting subsets of stimulus-response pairs having desirable properties, e.g., minimum confusion, maximum recognition, minimum variability, maximum transmitted information, etc. Some problems can be modeled as classical assignment problems with side constraints and are easily solved. Others can be modeled as binary integer programming problems, but their large size and/or nonlinearity often prevents effective solution using off-the-shelf software. Special purpose optimization algorithms, heuristics, and parametric relaxations are being explored. Platforms for implementation range from personal to parallel computers. Results from the project will be applied to console and work station design, voice and handwriting recognition systems, design of graphical and other user interfaces, symbology sets, etc.

CONFERENCE PRESENTATIONS: Theise, E. S., "Tabu Search and Subset Selection," Journees de l'Optimisation 1991, Montreal, Quebec, 8 May 1991.

THESES DIRECTED: Sheehan, M.J., "Selecting a Subset of Stimulus-Response Pairs with Maximal Transmitted Information," (completion - March 1992).

RESEARCH IN RELIABILITY AND CATEGORICAL DATA ANALYSIS

Lyn Whitaker, Assistant Professor of Operations Research
Sponsor: Naval Postgraduate School
Funding: Direct Funding for one quarter

OBJECTIVE: To continue work in sequential maintenance policies and categorical data analysis.

SUMMARY: This quarter was used to wrap up several projects begun during the previous year. The major accomplishment was revising and submitting for publication the paper "Nonparametric estimation of Optimal Maintenance Policies," with G. Aras. Three other papers were revised and accepted for publication, these are listed below.

PUBLICATIONS: Whitaker, L., and Glazebrook, K.D., "Single Machine Stochastic Scheduling with Dependent Processing Times," forthcoming.

Whitaker, L., Bailey, M., and Glazebrook, K.D., "Cost Rate Heuristics for Semi-Markov Decision Process," forthcoming.

Whitaker, L., Kimmeldorf, G., and Sampson, A.R., "Min and Max Scorings for Two Sample Ordinal Data," forthcoming.

Whitaker, L., and Aras, G., "Nonparametric Estimation of Optimal Maintenance Policies," U.C. Santa Barbara Statistics Department Technical Report, forthcoming.

Whitaker, L., and Glazebrook, K.D., "On Cost-rate Heuristics for a Class of Bayesian Sequential Decision Problems," Technical Report, forthcoming.

CONFERENCE PRESENTATIONS: Whitaker, L., "Sequential Parametric Estimation of Optimal Age Replacement Policies," ORSA Applied Probability meetings, Monterey, CA, January 1991. Min max scorings for two sample ordinal categorical data, invited paper, ORSA/TIMS annual meetings, Anaheim, CA, August 1991.

APPROXIMATE CONFIDENCE INTERVALS FOR COMPLEX SYSTEMS

W. M. Woods, Professor of Operations Research
Sponsor: NAVAIR Systems Commahd (AIR-5165)

OBJECTIVE: Develop approximate lower confidence limit equations for the reliability of complex coherent systems.

SUMMARY: Equations for the lower confidence limits of a complex quasi-coherent system were developed when the components of the system may be a mixture of items that are cyclic (go-no-go), or have failure times that have exponential or Weibull distributions. A computer program was written that runs simulations of operations of various system configurations to determine the accuracy of the developed lower confidence limit procedures. These procedures could be applied to an operational system, such as some component of a battle group that must perform some function, for which a measurable level of competence can be assessed in real time in order to ascertain when a $failure\% of the system has occurred. The computer program will allow a potential user to evaluate the accuracy of these methods if applied to his operational system. NOTE: This work was delayed for approximately nine months because approved funding support for computer programming was withdrawn. Additional computer runs are being performed to explore the robustness of this lower confidence limit procedure before it is written up as an NPS technical report and included in a manual of Selected Reliability Assessment Procedures being prepared for NAVAIR Systems Command.

PUBLICATIONS: Woods, W. M., "Lower Confidence Limit Expressions for P(X>y) and P(X>Y) under Normality," NPS Technical Report, NPSOR-92-010, December 1991.

Woods, W. M., "Equations for Approximate Confidence Limits on Process Capability Indices," NPS Technical Report, NPSOR-92-009, December 1991.

CONFERENCE PRESENTATIONS: Woods, W. M., "Desired Properties of Reliability Growth Models," ORSA/TIMS Conference, Anaheim, CA, 6 October 1991.

Woods, W. M., "Research and Short Course Capabilities of the Operations Research Department," given at meeting with Naval Warfare Assessment Center, Corona, CA, 7 October 1991.

THESIS DIRECTED: Yee, Kah-Chee, "Approximate Confidence Limit Procedures for Complex Systems," September 1991.

DEPARTMENT
OF
PHYSICS

DEPARTMENT OF PHYSICS

During FY91 the research activities in the Physics Department consisted of 35 individually identified projects.

The percentage of the projects funded through the Navy Direct Funding mechanism has dropped from 75% in FY90 to 50% in FY91. Of these Direct funded projects half had to also funding through reimbursable funding. Sponsors for the reimbursable funded projects were ONR NUSC NOSC NAVSEA NOARL NRL FNOC as Navy sponsors and IAW AFSAMSO AF Space Div. DNA DARPA NASA as non-Navy sponsors.

The projects fall into five groups. They are: (1) Physical Acoustics; (2) Electro Optics & Infrared Technology; (3) Space and Plasma Physics; (4) Directed Energy and Radiation Physics; and (5) Environmental Physics and Atmospheric Propagation.

This is a broad program which has evolved in the department over the last twenty years in response to the perceived needs of the Navy Sponsors and the areas of specialization which are likely to be of relevance in future Combat Systems Science & Technology. A common thread that connects all the projects in the department is the exploration of the physics in areas where Naval weapon system technologies interface and are limited by our understanding of the natural environment and where an increase of that understanding may possibly lead to technical advantages in future combat systems. The nature and significance of the research projects in each area is outlined below. All projects are identifiable as falling into the DOD listing of 20 critical technologies eighty percent of the projects involved experimental research.

Physical Acoustics

The department has one of the strongest and largest group in physical acoustics in the nation with a total of 14 faculty, adjunct and postdoctoral fellows participating in FY91. The research in this field in the department falls into five areas: (1) Thermoacoustic energy processes; (2) Fiber optic acoustic sensor technology; (3) Transducer physics; (4) Nonlinear dynamics and Wave turbulence; and (5) Ocean bubble dynamics and Sonoluminescence.

In the area of Thermos acoustic energy processes, Professor Atchley has continued his investigation into various aspects of thermoacoustic prime movers. The focus this year was on the transition to steady state oscillations and the behavior above onset of self oscillation. Professor Garrett's team completed the testing of the Space Thermoacoustic Refrigerator (STAR) and delivered it to fly on the Space Shuttle Discovery (STS-42) in late January 1992. This experiment is to move the ability to design, fabricate and space qualify the thermoacoustic cryocooler. Professor Hofler, meanwhile is occupied with the design of the third generation of Thermoacoustic cryocoolers (TARTII) which is to achieve 100k. Key feature of the new design is a new acoustic resonator design that looks promising after preliminary tests.

In the area of Fiber Optic Sensors, Professor Garrett and Doctor Brown have built and tested a new interferometric omnidirectional hydroplane which is suitable for hull mounted submarine sonar applications. Measured sensitivities are consistent with theoretical predictions. Several new demodulator schemes were developed and tested which proved to be simple and inexpensive.

In the area of Transducer Physics, Professor Baker continued his investigation of the use of sympathetic resonators to improve sonar transducer performance. Several geometries were compared with regard to their effectiveness and a circular array of sympathetic resonators was found to offer the best performance. Baker also continued the development of automated methods for in-service sonar transducer performance monitoring with the adaptation of the CIM-system to the DT 605 hydroplane.

In a new project, Professor Baker with Professor Canright and Professor Scandrett from the Mathematics department explored the application of the T-Matrix method to low frequency active sonar array performance prediction. The new model allows incorporation of multiple scattering to all orders so that arbitrarily defense arrays can be described.

In the area of Nonlinear Dynamics and Wave turbulence a new faculty member, Professor Robert Keolian together with Larraza and Denardo are preparing an experimental test for showing the existence of second sound like propagating mode on the surface of water with a turbulent wave spectrum. As part of this program a method to image oscillatory motion of water by using Magnetic Resonance Imaging (MRI) was developed and applied to the visualization of oscillatory flow in the cochlea of a rat. As theoretical support for the exploration of Wave turbulence two new soliton modes were discovered on vibrating lattices and successfully described by a nonlinear Schödinger equation and a theoretical model was developed to describe direction and spectrum of interacting nonlinear ocean waves as they approach sloping beaches.

Finally in the group of physical acoustic, Professor Atchley's interest in ocean bubble dynamics has turned to the fascinating phenomenon of sonoluminescence, the occurrence of sub nanosecond light flashes from oscillating gas bubbles. Doctor Gaitan who was the first to be able to create single oscillating bubbles and thus prepare the ground for detailed study of thin phenomenon has joined the department. Efforts are under way to measure the spectrum of the emitted light in order to get a handle on the possible mechanism which so far is unexplained but has generated much interest and publicity.

Electro-Optics and Infrared Technology

In this group NACIT, the Naval Academic Center for Infrared technology under Professor Cooper continues its research in infrared search and target designation issues. The experimentation revolves around AN/SAR-8 IR search and target designation system at NPS with major thrust in background scene and target signature data collection to provide means for background suppression. The conversion of the system to record and analyze background scenes has been completed and comparative recordings with the collocated AGA Thermovision imager have been made and are being evaluated.

The investigation of environmental effects on IR Sensor Systems for the development of usable tactical decision and computer codes for prediction of FLIR range performance by a flight crew has been continued. Eight field experiments were conducted and their results are used to remove discrepancies in the competing codes.

The multi year project on sea surface reflectivity and laser altimeter testing has been completed. The details of the return signal amplitude probability distribution on the wave spectrum of the sea surface have been investigated in a series of experiments made from the Golden Gate Bridge where the sea below has a wave behavior fairly representative of the ocean sea state. The results agree with some measurements made by others and lead to the conclusion of feasibility of a cheap laser altimeter for off board counter measures.

A new project was started to investigate the spatial and polarization characteristics of the sunlight clutter caused by spectral reflection of infrared solar radiation from the sea surface. Two series of measurements with the AGA 80 Thermovision dual band radiometric imaging system were made and angular distribution and polarization data are being evaluated for comparison with existing models.

Professor S. Davis has continued his research in the development of a novel method of image encoding based on the encoding of spatially distributed radiation patterns with orthogonal functions and a fully multiplexed spectroscopic imaging method such system has high promise in the area of target identification because it would give simultaneous information on spatial and spectroscopic features of a target scene. Several components of the system have been designed and tested.

Space and Plasma Physics

Research in this area spans a wide array of phenomena where plasma processes at the interface between man made devices and their respective environments have detrimental effects on the devices and where a thorough understanding of these processes in necessary before hardening strategies can be developed. Investigation of Plasma Heating Processes near the Plasmapause of the earth's magnetosphere was carried by Professor Olsen to determine the characteristics of hot and cold plasma components near the magnetic equator. Data taken near the geosynchronous orbit by the SCATHA satellite have shown that there is a separation between regions of heated electrons and ions which must be accompanied by an electric field. Professor Olsen's satellite charge control unit which was designed in previous years has been completed and is now scheduled to fly on the POLAR satellite in 1994. Preliminary studies for the design of a different electromagnetically quiet source for charge control was begun. Design work for a electrostatic analyzer for the SPEAR III rocket experiment is continued.

The sounding rocket experiment for remote sensing of the ionosphere conducted by Professor Cleary is continuing. After the successful launch of a first experiment in FY 90 which yielded 8000 spectra between 100 km and 320 km and gave good density profiles for a number of species, a second sounding rocket flight experiment is being prepared to fly in early 1992 to obtain profiles under more quiescent solar conditions.

More down to earth Professor Schwirzke is investigating the unipolar arcing as a basic, potentially dangerous laser damage mechanism for the vulnerability to Laser Directed Energy Weapons Systems. These basic phenomena are of equal importance in plasma opening switches which are considered for application in high power short pulse Directed Energy Systems. This year the focus has shifted toward a better understanding of the initial breakdown mechanisms in a vacuum diode. An important result was that ion surface heating from ions from desorbed gases initially in orders of magnitude larger than joule heating from field emitted electrons at surface whiskers. Initial build up of this ion heating eventually leads to thermoionic electron emission from hot spots which eventually transition into explosive plasma formation igniting unipolar areas.

Directed Energy Beams/Radiation Physics

Our Directed Energy Beam and Radiation Physics Group consisting of Professors Buskirk (em), Neighbours, Maruyama and Colson is now concentrated on two large experimental facilities, the Linear Accelerator, a high energy (120 MeV), low current machine which has been working and producing results were 1965 and the new Flash X-ray Pulse Power Facility, a low every (1.8 MeV) high current (35 KA) Pulserated 112A machine. The FXR has been used by Professor Schwirzke for his plasma formation studies on diodes. The same unipolar arcing phenomena were observed as in high energy laser surface interactions. The LINAC facility operation was improved dramatically by the employment of novel beam diagnostic using the phenomena of transition radiation. With this method, it was possible for the first time to actually determine the normalized emittance of the beam. With an average of 70 mm-mr the emittance is surprisingly good compared to more modern machines.

Professor Maruyama has continued the investigation of novel sources of coherent and quasi coherent radiation. This year the studies on parametric x-radiation led to significant production of higher order parametric x-radiation promising the ability to produce monochromatic higher energy x-rays with modest electron beam energies.

Professor Maruyama also continued his studies of Total Dose Effects in novel materials. The effects of electron irradiation on high T_c superconductors was done in cooperation with researchers from the Texas Center. A significant result is that the defects which produce degradation of the critical magnetization are macroscopic anisotropic clusters.

As an unfunded project, some studies of absolute and relative cross sections for elastic electron-proton

scattering were made from previously obtained data and a new value for the proton charge radius of $0.865 + 0.020$ Fermi was given.

Professor Neighbours is winding down his work on the radiation from high energy charged particle beams which could contribute to the remote observation of such beams with potential weapons applications. The theoretical model for diffracted Cherenkov radiation which was developed was recently applied to data from Japanese experiments and showed very good agreement. Data from a beam experiment carried out at the Phermex facility in Los Alamos are being analyzed to assess effects of path length, beam stops and reflectors.

The Free Electron Laser Research Project led by Professor W. Colson is directed toward the technology required for a shipboard free electron laser weapon system. A cooperative effort with the national continuous Electron Beam Accelerator Facility (CEBAF) was initiated with the aim of guiding the design of the UV FEL which will be driven by the facility. Because of the superconducting accelerator technology this experiment is particularly relevant with regard to the possibilities for high power, tunable wavelength and high efficiency.

In another line of study the possibilities of FEL application for inertial confinement fusion are investigated. In a cooperation with the Stanford FEL group the trapped particle instability and limit cycle behavior was studied. Prediction made by Colson may have been observed by a Dutch group.

A new initiative is the application of the FEL simulation methods to the study of radio frequency Whistler waves in the Earth's magnetosphere. Interest in Whistler wave stems from the fact that these waves cause the precipitation of particles from the ionosphere which can influence the accuracy of the Navy's phase navigation system.

Environmental Physics

The research in this area falls in three categories: characterization of atmospheric optical turbulence, remote sensing of the lower earth thermosphere and investigation of flow and dispersion of hazardous gas plumes. The Optical Atmospheric Turbulence work is carried out by Professor Walters. The program provides continuous support the Air Force by providing measurements and assessment of atmospheric distortions for the Strategic Defense Initiative program using instrumentation for measuring modulation transfer function, Isoplanatic angle, acoustics sounder and rawinsonde systems to characterize the entire troposphere. This year Professor Walters contributed characterization of the optical turbulence for the Air Force relay mirror experiment and the determination of magnitude and thickness of the turbulent boundary layer surrounding a 3.5 m aperture optical facility for an SDI experiment prior to construction. He continued his support of an important AF facility through measurements and characterization of a pacific coastal mountain site atmosphere. An important result was the discovery of solar radiation contamination of rawinsonde data by other investigators. Walters also collected atmospheric characterization measurements for large optical synthetic aperture interferometric system which the U.S. Naval Observatory is planning to build on the west coast.

Doctor Kamada with his environmental physics group has continued the long existing program if investigation of airflow and dispersion patterns of hazardous gaseous plumes has continued (Schacher, Kamada, Skupniewicz). These investigations involving meteorological field measurements and computer models have now resulted in the completion of the Vandenberg AFB Meteorological Plume Dispersion Handbook. A mesoscale prognostic windflow model and models of slope flow and sea breeze physics have been added to the arsenal of models.

Finally a new initiative in the department is a laboratory investigation of the aerosol source function of the ocean surface (Spiel, Schacher). Spiel has been able to acoustically detect air bubble bursts at the water surface and identify these bursting bubbles as Helmholz resonators. This allows a certain modeling of the phenomenon from which some of the important parameters can be determine which characterize the aerosol source function.

BASIC RESEARCH IN THERMOACOUSTIC HEAT TRANSPORT

A. A. Atchley, Associate Professor of Physics
Sponsor: Office of Naval Research
Funding: Office of Naval Research

OBJECTIVE: The long term of this research is to develop a thorough understanding of thermoacoustic phenomena. The investigations involve both heat pumps and prime movers. The work discussed here is done in conjunction with an NPS Direct Funded Research Project of the same title.

SUMMARY: During FY 1991, our investigations concentrated on five areas: an experimental study of edge effects in thermoacoustic couple measurements, the application of porous media techniques to thermoacoustic prime movers, development of a non-boundary layer, non-short stack model for the power output of thermoacoustic prime mover, the study of the transition to steady state oscillation in a thermoacoustic prime mover above onset of self-oscillation, and the study of energy distribution in finite amplitude standing waves. The results of this work indicated that thermoacoustic heat transport phenomena are well understood. This statement is not equivalent to "thermoacoustic engines are well understood." Before this statement can be made, processes such as harmonic generation, turbulence and heat exchanger interactions must be further investigated.

PUBLICATIONS: Atchley, A.A., Bass, H.E., Hofler, T.J., and Lin, H.T., "Study of a Thermoacoustic Prime Mover Below the Onset of Self-Oscillation," *Journal of the Acoustical Society of America*, forthcoming.

THESES DIRECTED: Chen, C.L., LCDR, Taiwan Navy, "Experimental Investigation of Energy Dissipation in Finite-Amplitude Standing Waves," MS Thesis, June 1991.

Bowers, E.C., LT, USN, "Investigation of a Heat Driven Thermoacoutic Prime Mover Above the Onset of Self-Oscillation," MS Thesis, December 1991.

BASIC RESEARCH IN THERMOACOUSTIC HEAT TRANSPORT

A. A. Atchley, Associate Professor of Physics
Sponsor: Office of Naval Research
Funding: Naval Postgraduate School

OBJECTIVE: The long term goal of this research is to develop a thorough understanding of thermoacoustic phenomena. The investigations involve both heat pumps and prime movers. The work discussed here is done in conjunction with a Reimbursable ONR Project of the same title.

SUMMARY: During FY 1991, our investigations concentrated on five areas: an experimental study of edge effects in thermoacoustic couple measurements, the application of porous media techniques to thermoacoustic prime movers, development of a non-boundary layer, non-short stack model for the power output of thermoacoustic prime mover, the study of the transition to steady state oscillation in a thermoacoustic prime mover above onset of self-oscillation, and the study of energy distribution in finite amplitude standing waves. The results of this work indicated that thermoacoustic heat transport phenomena are well understood. This statement is not equivalent to "thermoacoustic engines are well understood." Before this statement can be made, processes such as harmonic generation, turbulence and heat exchanger interactions must be further investigated.

PUBLICATIONS: See summary of ONR project of the same name.

THESES DIRECTED: Chen, C.L., LCDR, Taiwan Navy, "Experimental Investigation of Energy Dissipation in Finite-Amplitude Standing Waves," MS Thesis, June 1991.

Bowers, E.C., LT, USN, "Investigation of a Heat Driven Thermoacoustic Prime Mover Above the Onset of Self-Oscillation," MS Thesis, December 1991.

CONTINUED INVESTIGATION OF THE USE OF SYMPATHETIC RESONATORS TO IMPROVE SONAR TRANSDUCER PERFORMANCE

S.R. Baker, Associate Professor of Physics
O.B. Wilson, Professor of Physics
Sponsor: NAVSEA

OBJECTIVE: The objective of this research program is to develop and apply automated methods for in-service sonar transducer performance monitoring. This is a continuing project.

SUMMARY: Construction and field-testing of a second new automated multiple-transducer switchbox for use with the Complex Immittance Measurement (CIM) System was completed. Construction of six more continues. A new portable laptop PC running the CIM software under High-Tech (HT) Basic was field-tested as the controller. With this successful field test, the field-qualified CIM System equipment complement has been reduced to two attache-case test units and a laptop PC.

A new student has begun the project of adapting the CIM System to the DT-605 hydrophone, incorporating the equivalent-circuit model and sophisticated impedance curve-fitting procedure developed in FY90 by LT Waugh. The goal of this project is to monitor the values of the elements representing the internal mechanical structure to detect degradation caused by oil seepage into the compliant vibration isolation material. Field tests are scheduled to begin in January 1992.

PUBLICATION: Baker, S.R, Patton, M.D. and Wilson, O.B., "Calibration of a U.S. Navy Type TR-317B Sonar Transducer by the Delta-Z Reciprocity Method," Naval Postgraduate School Technical Report NPS-PH-91-011, September 1991.

CONFERENCE PRESENTATION: Baker, S.R., Garrett, S.L., Kuntsal, E., Self, R.E., and Wilson, O.B., "Applications of Portable Computer and Digital Instrument Technology to Performance Monitoring of In-service Sonar Transducers," presented at and to appear in the Proceedings of the 1991 Undersea Defense Technology Conference, Paris, FRANCE, 23-25 April 1991.

APPLICATION OF THE T-MATRIX METHOD TO LOW FREQUENCY ACTIVE ARRAY PERFORMANCE PREDICTION

S. R. Baker, Associate Professor of Physics
D. R. Canright, Assistant Professor of Mathematics
C. L. Scandrett, Associate Professor of Mathematics
Sponsor: Naval Underwater Systems Center
Funding: Naval Postgraduate School

OBJECTIVE: The objective is to produce an economical yet complete description of sonar array performance, with specific application to dense, low frequency active arrays. This is a continuing project.

SUMMARY: The method employed is an extension of the T-matrix method, which has been previously applied to scattering problems, but has not heretofore been applied to the problem of coupled electroacoustic transducers. Multiple scattering to all orders is rigorou sly included, so that arbitrarily dense arrays may be described. Each element may be represented analytically in the simplest cases, or may be described more generally by a finite-element model.

In FY90 Professors Canright and Scandrett developed a numerical model of an array of closely-spaced, identical spherical shell radiators. In FY91 the acoustic portion of this model was refined, allowing for more closely-spaced, spheroidal-shaped elements.

CONFERENCE PRESENTATION: Scandrett, C.L. and Canright, D.R., "Acoustic Interactions in Arrays of Fluid-loaded Shells," presented at the International Conference of Industrial and Applied Mathematics, Washington, D.C., July 1991.

CONTINUED DEVELOPMENT OF AUTOMATED METHODS FOR IN-SERVICE SONAR TRANSDUCER PERFORMANCE MONITORING

S. R. Baker, Associate Professor of Physics
O. B. Wilson, Professor of Physics
Sponsor: NAVSEA

OBJECTIVE: The objective of this research program is to develop and apply automated methods for in-service sonar transducer performance monitoring. This is a continuing project.

SUMMARY: Construction and field-testing of a second new automated multiple-transducer switchbox for use with the Complex Immittance Measurement (CIM) System was completed. Construction of six more continues. A new portable laptop PC running the CIM software under High-Tech (HT) Basic was field-tested as the controller. With this successful field test, the field-qualified CIM System equipment complement has been reduced to two attache-case test units and a laptop PC.

A new student has begun the project of adapting the CIM System to the DT-605 hydrophone, incorporating the equivalent-circuit model and sophisticated impedance curve-fitting procedure developed in FY90 by LT Waugh. The goal of this project is to monitor the values of the elements representing the internal mechanical structure to detect degradation caused by oil seepage into the compliant vibration isolation material. Field tests are scheduled to begin in January 1992.

PUBLICATION: Baker, S.R., Patton, M.D. and Wilson, O.B.,"Calibration of a U.S. Navy Type TR-317B Sonar Transducer by the Delta-Z Reciprocity Method," Naval Postgraduate School Technical Report, September 1991.

CONFERENCE PRESENTATION: Baker, S.R., Garriett, S.L., Kuntsal, E., Self, R.E. and Wilson, O.B., "Applications of Portable Computer and Digital Instrument Technology to Performance Monitoring of In-service Sonar Transducers," presented at and to appear in the Proceedings of the 1991 Undersea Defense Technology Conference, Paris, FRANCE, 23-25 April 1991.

A SOUNDING ROCKET EXPERIMENT FOR REMOTE SENSING OF THE IONOSPHERE

David D. Cleary, Assistant Professor of Physics
S. Gnanalingam, Adjunct Professor of Physics
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: This is an ongoing research project with the objective of developing a simple technique for measuring global ionospheric electron densities from a space based platform. The short term goal of this project was to obtain ultraviolet spectra of the Earth's ionospheric dayglow. The long term objective is to identify ultraviolet atmospheric emissions that can be used to infer electron density profiles with the aid of photochemical and radiative transfer models.

SUMMARY: A middle ultraviolet spectrometer was developed and calibrated in the NPS Physics laboratory, and launched on a NASA sounding rocket on March 30, 1990, at the White Sands Missile Range, NM. The rocket experiment yielded approximately 8000 spectra between the altitudes 100 km and 320 km. A preliminary analysis of these spectra has produced the density profile of nitric oxide, and the emission profiles of the OI 2972-Å and OII 2470-Å multiplets. Further analysis of these and other emission features will be used to infer the electron density profile of the ionosphere.

PUBLICATIONS: Cleary, D. D., J. W. Nichols, and D. S. Davis, "A New Design for an All-Reflection Michelson Interferometer," *Applied Optics*, forthcoming.

Cleary, D. D., J. L. Bosserman, and M. R. Torr, "Analysis of Middle Ultraviolet Dayglow Spectra from the Spacelab 1 Shuttle Mission," submitted to the *Journal of Geophysical Research*, 1991.

CONFERENCE PRESENTATIONS: Cleary, D. D., B. Mack, B. S. Walden, R. P. McCoy, and K. F. Dymond, "Spectral Analysis of the MUV Data from the HIRAAS/MUSTANG Sounding Rocket Experiment," EOS Trans. American Geophysical Union, 72, 419, 1991.

FREE ELECTRON LASER RESEARCH

W.B. Colson, Professor of Physics
J. Blau, Adjunct Professor of Physics
Sponsor: Office of Naval Research
Funding: SDIO

OBJECTIVE: A broad range of topics explored Free Electron Laser research on high-power amplifiers and compact oscillators for shipboard weapons application.

SUMMARY: The research effort included the study of free electron lasers (FELs) for inertial confinement fusion, electron beam quality, undulator fields and electron trajectories, phase-space trajectories in a linearly-polarized undulator, the trapped-particle instability, limit-cycle behavior in the Stanford FEL, a simple macroparticle model of high-current, strong-field FELs, and a four dimensional simulation of the FEL interaction. The FEL technology at the CEBAF facility has a long term interest to the Navy for high-power efficient weapon systems on ships.

PUBLICATIONS: Colson, W.B. and Prosnitz, D., "Free Electron Lasers," Invited Chapter 4.1 in Handbook of Laser Science and Technology, Supplement 1: Lasers, CRC Press, Inc. (1991).

Blau, J. and Colson, W.B., "The Effects of Electron Beam Quality on the Free Electron Laser Mechanism," *Nuclear Instruments and Methods in Physics Research A304*:436-438, 1991.

Craun, D.E. and Colson, W.B. "Undulator Fields and Electron Trajectories at the End of a Helical Undulator," *Nuclear Instruments and Methods in Physics Research A304*:714-718, 1991.

Gillingham, D. and Colson, W.B., "Electron Phase-Space Trajectories in a Linearly-Polarized Undulator," *Nuclear Instruments and Methods in Physics Research A304*:617-621, 1991.

Cord, G., Colson, W.B., and Frisch, J. "Comparing Simulations and Experimental Observations of the Trapped-Particle Instability and Limit-Cycle Behavior in the Stanford Free Electron Laser," *Nuclear Instruments and Methods in Physics Research A304*:601-606, 1991.

Kiel, H.D. and Colson, W.B., "A Simple Macro-particle Model of the High-Current, Strong-Field Free Electron Laser," *Nuclear Instruments and Methods in Physics Research A304*:453-457, 1991.

CONFERENCE PRESENTATIONS: Blau, J. and Colson, W.B., "Four Dimensional Simulations of the CEBAF Infrared FEL," Thirteenth International Free Electron Laser Conference, Santa Fe, NM, 25-30 August 1991.

Clark, D., LT, Colson, W.B., and Wallace, S. LT, "The CEBAF Infrared Free Electron Laser," Thirteenth International Free Electron Laser Conference, Santa Fe, NM, 25-30 August 1991.

Colson, W.B., "The CEBAF IR and UV FELs," CEBAF Workshop on IR and UV FELs, Newport News, VA, October 1991.

THESES DIRECTED: Craun, D.E., LT, "Magnetic Fields and Electron Trajectories at the End of a Helical Undulator," MS Thesis, December, 1990.

Gillingham, D., LT, "Free Electron Laser Single-Particle Dynamics Theory," MS Thesis, December 1990.

Kiel, D.H., LT, "Two Simple, Nonlinear Models of the Free Electron Laser," MS Thesis, December 1990.

Cord, G.A., LT, "Free Electron Laser Short Pulse Simulation and Two-Mode Sideband Analysis", MS Thesis, June 1991.

FREE ELECTRON LASER RESEARCH

W. B. Colson, Professor of Physics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: Research is directed toward the technology required for a shipboard free electron laser (FEL) weapon system.

SUMMARY: The research topics included the study of simulations of the high-power, high-gain FEL at LLNL, compact FELs at LANL, the ultimate wavelength of FELs, the CEBAF UV FEL experiment, and an analytic description of longitudinal modes in FELs. The collaboration with the CEBAF experiment is particularly relevant because the superconducting accelerator technology provides the possibility for high-average power, tunable wavelengths, and high wall-plug efficiency.

PUBLICATIONS: Park, J.H. and Colson, W.B., "A Simple Model of the LLNL ELF FEL Amplifier," *Nuclear Instruments and Methods in Physics Research A304*:641-643, 1991.

Souza, Randy, Colson, W.B., Warren, Roger W. and Goldstein, John C., "Evaluation of a Compact FEL at 0.4 1m Wavelength," *Nuclear Instruments and Methods in Physics Research A304*:687-690, 1991.

Colson, W.B., Elleaume, P., Litvinenko, V.N., Kim, K.-J., Ramian, G., Antonsen, T.M., Oepts, D., Lumpkin, Alex H., and Benson, S., "Panel Summary on the Ultimate Free Electron Laser Bandwidth," *Nuclear Instruments and Methods in Physics Research A304*:822-824, 1991.

CONFERENCE PRESENTATIONS: Bice, Carl, LT, and Colson, W.B., "The CEBAF Ultraviolet FEL Experiment," Thirteenth International Free Electron Laser Conference, Santa Fe, NM, 25-30 August 1991.

Sturgess, K., CPT, Colson, W.B., and Frost, D., LCDR, "An Analytic Description of Longitudinal Modes in FELs," Thirteenth International Free Electron Laser Conference, Santa Fe, NM, 25-30 August 1991.

Colson, W.B., "FEL Research at NPS," SPIE 1991 International Symposium on Optical Applied Science and Engineering, San Diego, CA, July, 1991.

THESES DIRECTED: Souza, Randy, LT, "Evaluation of a Compact FEL at 0.4 1m Wavelength," MS Thesis, December 1990.

Park, Jung-Hung, CPT, "High-Gain, High-Power Free Electron Lasers," MS Thesis, June 1991.

Bice, C, LT, "Theory for the CEBAF and Shipboard FELs," MS Thesis, December 1991.

SIMULATIONS OF WHISTLER WAVES IN THE IONOSPHERE

W. B. Colson, Professor of Physics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: Develop new simulation methods for the study of radio frequency whistler waves in the Earth's magnetosphere.

SUMMARY: Very low frequency (VLF) electromagnetic waves propagating in the magnetosphere, called "Whistler Waves", can be amplified by energetic electrons spiraling along magnetic field lines near the geomagnetic equator. The whistler waves propagate along the magnetic field lines from the equator to points of mid-latitude in the Northern and Southern hemispheres. They can be excited by nuclear explosions, Morse code dashes from VLF transmitters, coherent VLF radio waves, and natural phenomena, such as lightening. Whistlers can result in audio frequency tones received at the Earth's surface and heard on long telephone lines or an audio amplifier. Natural whistlers often dominate the VLF noise spectrum in the polar regions and limit communications.

The Navy has long been interested in whistlers for the design and use of communication and navigation systems involving the ionized regions of the Earth's upper atmosphere, and as a method of monitoring and controlling the magnetosphere and ionosphere. Knowledge of the whistle characteristics can be used to design communications circuits that are more resistant to background noise. Whistlers can cause the precipitation of particles from the ionosphere when energy is transferred from the particles to VLF waves. The noise from this precipitation can lead to a reduction in the accuracy of the Navy's phase navigation system.

Our role in this ongoing research has been to develop new simulation methods used to characterize and understand whistlers. The basis for the methods has been the mature simulations techniques developed for the free electron laser (FEL). We have already established that the electron motion in the combined Earth's magnetic and whistler wave fields has the same mathematical form for both the FEL and whistlers. In addition, the wave equation describing FEL laser light and radio frequency whistlers has the same form. We plan to exploit these similarities and use the extensive knowledge on controlled, laboratory FEL experiments to better understand the naturally occurring whistler waves.

NACIT INFRARED SEARCH AND TARGET DESIGNATION RESEARCH

A.W. Cooper, Professor of Physics
W. J. Lentz, Research Associate of Physics
E.C. Crittenden, Jr., Distinguished Professor of Physics
E.A. Milne, Associate Professor of Physics
Sponsor: Naval Sea Systems Command PMS-421
Funding: NAVSEA PMS-421 and the
Naval Postgraduate School (Radiometric Raster-Scan)

OBJECTIVE: To apply the NPS-Infrared Search and Target Designation system to record and analyze background scenes and target signatures for evaluation of target detection and background suppression and for evaluation of IRST technology. This is a continuing multi-year project, supported by the Surface Electro-Optics Project Office.

SUMMARY: The NPS IRST (the Advanced Demonstration Model of the AN/SAR-8 IRSTD), originally designed to detect and track unresolved air targets in the 305 1m band by background normalization, has been modified to record and analyze background scene information. Image display and analysis of sectors of the panoramic scene have been accomplished using a commercial DT-2861 frame grabber board in an 80386-33 desktop computer. Using custom direct interfacing through a JDR-PR10 prototype card with software development in protected mode assembly language, 512 by 512 pixel images representing a six degree azimuth sector are now displayed in pseudo color within the period of scanner rotation. This capability has been used to improve the optical quality (focus) of the scanner, and for selection of suitable scenes for analysis. Comparative recordings have been made of background scenes using the AGA Thermovision imager collocated with the IRST. Analysis of the data is in progress. A lidar system (Neodymium:YAG laser with frequency doubling or Gallium Arsenide laser diode) is under construction for cloud and target ranging and atmospheric transmission analysis in conjunction with the IRST.

PUBLICATION: Cooper, A.W., Lentz, W.J., Baca, M.J., and Bernier, J.D., "Image Display and Background Analysis with the Naval Postgraduate School InfraRed Search and Track System," in *"Characterization, Propagation and Simulation of Sources and Backgrounds,"* Wendell Watkins and Dieter Clement, Eds, Proc. SPIE 1486, pp. 47-57, 1991.

CONFERENCE PRESENTATION: Cooper, A.W., Lentz, W.J., Baca, M.J., Bernier, J.D., "Image Display and Background Analysis with the Naval Postgraduate School InfraRed Search and Track System," Paper 1486-29 in "Characterization, Propagation and Simulation of Sources and Backgrounds," SPIE Conference 1486, OE/AEROSPACE SENSING'91, Orlando, FL, 1-5 April 1991.

THESIS DIRECTED: Bernier, J.D., Major, Canadian Armed Forces, "Imaging Capability Improvement with the NPS-IRST," MS Thesis in Electrical Engineering, September 1991.

ENVIRONMENTAL EFFECTS ON IR SENSOR SYSTEMS

A.W. Cooper, Professor of Physics
E.A. Milne, Associate Professor of Physics
E.C. Crittenden, Jr., Distinguished Professor of Physics
W.J. Lentz, Research Associate of Physics
P.L. Walker, Research Physicist
Sponsor: Naval Oceanographic and Atmospheric Research Laboratory, Atmospheric Directorate
Funding: NOARL - Atmospheric Directorate and the Naval Postgraduate School

OBJECTIVE: To validate and improve current Tactical Decision Aid (TDA) codes for field prediction of performance of operational FLIR devices by comparison of experimental observations with predictions of operational codes. To develop and evaluate improvements to existing codes.

SUMMARY: For the past five years the Naval Academic Center for Infrared Technology, at NPS, has been cooperating with NOARL in a continuing evaluation of Tactical Decision Aid computer codes used by naval flight crews for prediction of FLIR range performance in an operating area. In this program eight series of overflights by FLIR-carrying aircraft have been made of the R/V POINT SUR instrumented with a meteorological suite and an array of skin temperature sensors. Aircrew recordings of maximum range for ship detection or recognition have been compared with predictions of the UFLR code (used in the Tactical Environmental Support System and also buy Fleet Numerical Oceanographic Center) and the EOTDA MKII, and EOTDA MKII codes recently adapted for navy use. In support of the program, radiometric images of the R/V POINT SUR have been taken using an AGA Thermovision system from shore. During CY91 comparisons of the predictions of the three codes using standard and locally developed input parameters have shown serious discrepancies for all codes. Improvement in the target input for UFLR and atmospheric path modeling for EOTDA are recommended. A data base of thermal signatures of the R/V POINT SUR has been assembled in convenient digital file form, and computer code written to extract area averaged target-to-background temperature difference. Attention is now being directed to the detection/recognition criteria in the codes.

PUBLICATIONS: Walker, P.L., Cooper, A.W., and Milne, E.A., "Validation and Analysis of the Navy FLIR Tactical Decision Aid Code UFLR (U)," in proceedings of the 1991 Meeting of the IRIS Specialty Group on Passive Sensors, 1991.

Cooper, A.W., Milne, E.A., and Cook, B.J., "Evaluation of Operational FLIR Performance Predictions (U)," in proceedings of the 1991 Meeting of the IRIS Specialty Group on Passive Sensors, 1991.

Milne, E.A., Cooper, A.W., Walker, P.L., and Reategui, R., "Sensitivity Analysis of Navy Tactical Decision Aid FLIR Performance Codes," in "Characterization, Propagation and Simulation of Sources and Backgrounds," Wendell Watkins and Dieter Clement, Eds, Proc. SPIE 1486, pp. 151-163, 1991.

Cooper, A.W., Milne, E.A., Crittenden Jr., E.C., Walker, P.L., Moore, E., and Lentz, W.J., "Ship Signature Measurements for Tactical Decision Aid Input, in "Characterization and Simulation of Infrared Scenes," Wendell Watkins and Dieter Clement, Eds. Proc. SPIE 1486, pp. 37-46, 1991.

CONFERENCE PRESENTATIONS: Cooper, A.W., Milne, E.A., Lentz, W.J., Walker, P.L., and Cook, B.J., "Evaluation of Operational FLIR Performance Predictions (U)," paper D-5 presented at the 1991 Meeting of the IRIS Specialty Group on Passive Sensors, Laurel, MD, 5-7 March 1991.

Cooper, A.W., Crittenden, Jr., E.C., Lentz, W.J., Milne, E.A., Moore, E., and Walker, P.L., "AGEMA Measurements of Ship Radiance and Contrast Temperature for Tactical Decision Aids," paper 1486-05, Conference on Characterization, Propagation and Simulation of Sources and Backgrounds, SPIE OE/AEROSPACE SENSING, Orlando, FL, 1-5 April 1991.

Milne, E.A., Cooper, A.W., Walker, P.A., and Reategui, R., "Sensitivity Analysis of Navy Tactical

Decision Aid FLIR Performance Codes," paper 1486-14, SPIE Conference on Infrared Imaging Systems, Design Analysis, Modeling and Testing, Orlando, FL, 2-3 April 1991.

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Cooper, A.W., Milne, E.A., and Walker, P.L., "Summary Report on FLIR Test Program", NPS Technical Report NPS-61-90-002, 1991, in progress.

THESES DIRECTED: Wood, D.S., CPT, USMC, "Thermister Validation and Path Radiance Effects in Ship Thermal Image Measurements," MS Thesis Thesis, SE(EW), September 1991.

Prapruettarm, Khitsada, LT, Royal Thai Navy, "Analysis of Ship Operation and Environmental Influences on Observed Ship Temperature Distribution," MS Thesis, SE(EW), December 1991.

SEA SURFACE REFLECTIVITY AND LASER ALTIMETER TESTING

A.W. Cooper, Professor of Physics
E.C. Crittenden, Jr., Distinguished Professor of Physics
E.A. Milne, Associate Professor of Physics
G.W. Rodeback, Associate Professor of Physics
Sponsor: Naval Sea Systems Command
Funding: Naval Postgraduate School in FY90, unfunded in FY91

OBJECTIVE: To investigate the temporal and spatial characteristics of the reflection of a narrow laser from the sea surface at normal incidence as a function of sea surface characteristics, and to evaluate the implications of this behavior for performance of disposable laser altimeters.

SUMMARY: This summary refers to the final phase of a program previously funded by the Naval Sea Systems Command and the Naval Postgraduate School, with work carried over into CY91. Previous tests of a disposable laser altimeter developed earlier indicated differences in the reflection of narrow beams from the sea surface from that of wide optical or radar beams. In this study precise measurements as a function of angle from the vertical were made from the Golden Gate Bridge, at a height of 81 meters. The return signal amplitude probability distribution is dependent on the wave spectrum of the sea surface. In the presence of a short wavelength wave pattern superimposed on long wave swell the signal amplitude probability distribution showed periods of zero return signal, even at normal incidence, with the distribution of the non-zero signals showing an antilog normal probability distribution, skewed toward higher signal relative to a normal (Gaussian) distribution. This distribution is retained by the reflected signal at angles away from the normal, but with more missed reflections. For a well formed single mode wave pattern signal drop-outs were not observed, and the distribution is closely log-normal, approaching exponential at greater angles from the verticle. In all cases the long-term average return shows a Gram-Charlier distribution, consistent with the observations of Cox and Muink and others using time integrating photographic techniques. The analysis was extended and completed during CY91.

PUBLICATIONS: Crittenden, E.C., Jr., Rodeback, G.W., Milne, E.A., and Cooper, A.W., "Vertical Ocean Reflectance at Low Altitudes for Narrow Laser Beams," SPIE Proceedings, Vol. 1492, "Earth and Atmospheric Remote Sensing', 1991.

Crittenden, E.C., Jr., Rodeback, G.W., Milne, E.A., and Cooper, A.W., "Sea Test Development of Laser Altimeter," NPS Technical Report NPS-PH-91-006, January 1991.

CONFERENCE PRESENTATION: Crittenden, E.C., Jr., Rodeback, G.W., Milne, E.A., and Cooper, A.W., "Vertical Ocean Reflectance at Low Altitudes for Narrow Laser Beams," paper 1492-21, SPIE Symposium on Optical Engineering and Photonics in Aerospace Sensing, Orlando, FL, 1-5 April 1991.

RESEARCH IN MULTIPLEXED IMAGING AND IMAGING SPECTROSCOPY

D. S. Davis, Associate Professor of Physics
Sponsor: Department of the Navy Direct Funding Research
Funding: Naval Postgraduate School

OBJECTIVE: The continuing goal of this research project is to develop practical new methods for fully multiplexed imaging and imaging spectroscopic imaging. Such methods should prove to be of significant benefit in applications such as target identification, stand-off chemical analyses of the environment, and surveillance. It is expected that this new approach to such applications should be particularly useful at middle and far infrared wavelengths, where efficient array detector technology does not exist.

SUMMARY: Existing optoelectronic multiplexed detector array systems do not perform at efficiencies that are anywhere close to what is theoretically possible, simply because they use so-called time-sliced multiplexing schemes, which are just electronic analogs of opto-mechanic (i.e. FLIR) systems. It is possible to envision far more efficient, fully multiplexed devices, using coded aperture techniques. Existing coded aperture imaging (i.e. cyclic redundant, uniformly redundant, pseudonoise, etc.) methods employ 2-D masks consisting of transparent and opaque regions. Consequently, their optical efficiencies can approach at most about 50%. Furthermore, they require complicated 2-D mask sets containing ~2N members, where N is the number of pixels to be encoded. We are developing a new method, based upon experimental applications of the tenets of sequency theory. Its salient features are that: (1) optical efficiencies can approach 100%, (2) simpler masks with 1-D spatial modulation structure are used to encode 2-D images, (3) a much smaller basis set of masks, ~2N^1/2 is sufficient, (4) the spatial resolution of the new scheme is exceedingly versatile, and (5) the technique is readily adapted to a wide variety of target-specific image geometries.

CONFERENCE PRESENTATION: Davis, D.S., "An Efficient and Versatile Method for Multiplexed Imaging," Optical Society of America Technical Digest 17, p. 189 (1991).

THESES DIRECTED: Sargent, Jr., J.P., LT, USCG, "A Design, Fabrication and Test of a Precision Positioning Servo Drive for a Multiplexed Imaging System," MS Thesis, September 1991.

Musselman, B.J., LT, USCG, "A Study of the Diffraction Behavior and Resolution Criteria for Pattern Recognition with a Proposed Multiplexed Imaging Technique," MS Thesis, September 1991.

Parriott, G.R., LT, USN, "Development and Testing of a Prototype Electro-optical Phase Encoded Position Transducer," MS Thesis, December 1991.

OTHER: The principal investigator is preparing both a manuscript for publication and a patent application for this work.

FIBER-OPTIC HYDROPHONE DEVELOPMENT

S.L. Garrett, Professor of Physics
Sponsor: Naval Sea Systems Command - Advanced Technology
Funding: Naval Sea Systems Command and the
Naval Postgraduate School

OBJECTIVE: To design, fabricate, and test, a fiber-optic interferometric hydrophone system suitable for hull-mounted submarine sonar applications.

SUMMARY: During this period a new fiber optic, push-pull, interferometric omnidirectional hydrophone was fabricated and tested. The design is based on an oblate spheroidal shell with interferometer legs wound in the equatorial direction (parallel wrap) using both plastic and metal shells. The measured sensitivity was consistent with our theoretical predictions based on solid mechanics and the measured properties of the shell materials. Three new interferometric sensor opto-electronic demodulators based on the outputs of a 3 X 3 coupler were developed and demonstrated. One of these demodulators was based on our newly developed symmetric demodulation algorithm which allowed efficient use of all of the available optical power and provides a means of passively stabilizing the demodulator's scale factor against variations in both laser power and fringe visibility. These new demodulation schemes do not require either expensive, high coherence laser diodes nor interferometric path length differences and hence work well with push-pull sensors while reducing overall system cost and maintaining high dynamic range.

PUBLICATIONS: Garrett, S.L., Brown, D.A., Wetterskog, K., Beaton, B.L., and Serocki, J., "A Fiber-Optic Acceleration Canceling Hydrophone made of Castable Epoxy (U)," *U.S. Navy Journal of Underwater Acoustics*, 41(1):191-212, 1991.

Garrett, S.L., Brown, D.A., Serocki, J., Wetterskog, K., Beaton, B.L., Flaskerud, B.J., and Kreijger, J.B., "Elastic Moduli of Castable Epoxies for use in Fiber-Optic Hydrophones (U)," *U.S. Navy Journal of Underwater Acoustics*, 41(1):213-237, 1991.

Cameron, C.B., Keolian, R.M., Garrett, S.L., "A Symmetric Analog Demodulator for Optical Fiber Interferometric Sensors," in proceedins of the 34th Midwest Symposium on Circuits and Systems (IEEE), 14-17 May 1991, in press.

Brown, D.A., Cameron, C.B., Kapolka, D., Keolian, R.M., and Garrett, S.L., "A Symmetric 3 X 3 Coupler Based Demodulator for Fiber Optic Interferometric Sensors," in Fiber Optic and Laser Sensors IX, in proceedings of the Society of Photo-Optical Instrumentation Engineering (SPIE) 1584-41, (199), in press.

Gardner, D.L., Brown, D.A., and Garrett, S.L., "Fiber-Optic Push-Pull Sensor Systems," in proceedings NASA Technology 2001, San Jose, CA, 3-5 December 1991, forthcoming.

Brown, D.A., and Garrett, S.L., "Resonant Acoustic Determination of Complex Elastic Moduli," in proceedings of the NASA Technology 2001, San Jose, CA, 3-5 December 1991, forthcoming.

CONFERENCE PRESENTATIONS: Garrett, S.L., "Fiber-Optic Sensor Programmatics: Past Blunders, New Axioms, and Proposed Directions," First All Navy Fiber Optics Symposium, Naval Surface Warfare Center (White Oak), Silver Spring, MD, 11-13 June 1991.

Brown, D.A., Garrett, S.L., "Measurement of the Viscoelastic Properties of Materials using the Resonant Modes of a 'Free-Free' Bar," *Journal of the Acoustical Society of America*, 90(4) Part II:2294, 1991.

Gardner, D.L., Brown, D.A., and Garrett, S.L., "A Fiber-Optic Interferometric Accellerometer/ Geophone System," *Journal of the Acoustical Society of America*, 90(4) Part II:2350, 1991.

THESES DIRECTED: Cameron, C.B., LCDR, USN, "Recovering Signals from Optical Fiber Interferometric Sensors," Doctor of Philosophy in Electrical Engineering, June 1991.

Brown, D.A., "Fiber-Optic Interferometric Acoustic Sensors Using Ellipsoidal Shell Transducers," Doctor of Philosophy in Engineering Acoustics, June 1991.

Tan, B.-H., "Resonant Acoustic Determination of Complex Elastic Moduli," MS in Engineering Science, March 1991.

Olcott, J., LT, USN, "Fiber-Optic Flexural Disk Acccelerometer," MS in Systems Technology (ASW), September 1991.

PATENTS: Garrett, S.L., Hofler, T., Newmaster, J.T., and Brininstool, M.R., "Remote Fiber-Optic Angular-Orientation Sensor Using Serial Digital Encoding," U.S. Pat. No. 5,042,157, 27 August 1991.

Brown, D.A., Garrett, S.L. and Hofler, T., "Fiber-Optic Flexural Disk Accelerometer," Navy Case No. 73,054.

Keolian, R.M., Cameron, C.B. and Garrett, S.L., "Symmetric Demodulator for Optical Fiber Interferometers with (3 X 3) Outputs," Navy Case No. 73889.

Brown, "Parallel Wrapped Push-Pull Ellipsoidal Shell Acoustic Transducer," Navy Case No. 73806.

SPACE THERMO-ACOUSTIC REFRIGERATORS

S.L. Garrett, Professor of Physics
Sponsor: Naval Research - Spacecraft Engineering
Funding: Naval Research Laboratory and the
Naval Postgraduate School

OBJECTIVE: To design, fabricate, and space-qualify, a thermoacoustic crycocooler suitable for flight as a Get Away Special on the Space Shuttle.

SUMMARY: The Space Thermo-Acoustic Refrigerator (STAR) is an experiment which will "fly" on the Space Shuttle Discovery (STS-42) as a Get Away Special (NASA G-337) in early 1992. It is an entirely self-contained systems including the thermoacoustic refrigerator (electrodynamic driver, acoustic resonator, thermodynamic "stack", gas handling and vacuum can) and its support electronics (microprocessor, bubble memory data recorder, resonance frequency and amplitude feedback controller, multiplexed measurement systems and A-to-D converters for 21 different sensors, batteries and power distribution systems, and pulse-width modulated heat load).

During this period two entire refrigerators and their control systems were completed and were certified for flight on the Space Shuttle. One of these systems was turned over to NASA on 8 November 1991 and is currently on board Discovery awaiting launch.

PUBLICATION: Garrett, S.L., and Hofler, T.J., "Thermoacoustic Refrigeration," in proceedings of the NASA Technology 2001, San Jose, CA, 3-5 December 1991, 10 pages, forthcoming.

CONFERENCE PRESENTATION: Adeff, J.A., Hofler, T., and Garrett, S.L., "A Thermoacoustic Refrigerator for Space Applications," *Journal of the Acoustical Society of America*, 90(No. 4, Pt. 2), 2304, (1991).

THIRD GENERATION THERMOACOUSTIC REFRIGERATOR

Thomas J. Hofler, Adjunct Research Professor of Physics
Sponsor: Naval Research Laboratory,
Naval Space Technology Program(Code: SPAWAR 004-4)
Funding: Naval Research Laboratory

OBJECTIVE: The primary long term objective is to develop the third generation ThermoAcoustic Refrigerator (TAR III), or cryocooler, prototype. The performance goal is to obtain much colder temperatures than those previously attained. The secondary short term goal is to study numerical solutions of the thermoacoustic theory in order to better understand the general concepts, and to optimize solutions for prototype development. This is a continuing project.

SUMMARY: The second generation thermoacoustic refrigerator is a high reliability device that can achieve a cold temperature of 200 degrees Kelvin temperature span with modest efficiency. We believe this kind of refrigerator is suitable for spacecraft and we hope to demonstrate this when the STAR project flies on the space shuttle on Jan. 22, 1992. The third generation TAR should double the temperature span and achieve a cold temperature of 100 degrees Kelvin, and thereby approach true cryocooler performance. Some improvement in the engine's efficiency may be possible. Qualitative theoretical thermoacoustic work has been done concerning the interaction between the engine "stack" geometry and the phasing of the acoustic standing wave. Using some of the facts thus learned, three new stacks were built and tested in the old first generation TAR. The results were a 16 #C increase in temperature span and a 40% increase in efficiency. We expect that the totally redesigned TAR III (to be built and tested in '92) should do much better. Also a detailed computer model for arbitrary thermoacoustic engine designs is in progress and due to be completed in early '92. A key feature of the TAR III design is a new acoustic resonator design called the mass-element resonator. A test of the mass-element resonator has been built (without thermal components) and its acoustical behavior is being characterized by a masters thesis student. The initial results look promising. Many other hardware portions of the project are in progress but not yet completed. These include: new refrigerator control electronics and data acquisition software; a new gas handling system; a new electrodynamic acoustic driver being developed by Actran Systems of Orlando, FL; and a precisely calibrated dynamic pressure standard.

THESIS DIRECTED: Two new thesis students have been taken on, Lt. Larry A. Grant USN, and Lt. Ron Stockerman, Canadian Forces.

NONLINEAR DYNAMICS OF WAVES AND OSCILLATORS

Robert Keolian, Assistant Professor of Physics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: There were three main tasks to this Research Initiation Proposal: 1) Prepare an experimental test for an additional propagating mode predicted to be on the surface of water agitated by many random waves. 2) Image the oscillatory motion of water using Magnetic Resonance Imaging (MRI). 3) Develop a demodulation method for fiberoptic hydrophones.

SUMMARY: The primary results from the three tasks above are: 1) A transducer based on a four wire measurement technique was developed to reliably measure low amplitude short wavelength waves on the surface of water; 2) Oscillatory motion from 200-2000 Hz was imaged with 50 nm rms noise levels in water and in the cochlea of a living anesthetized rat using MRI. 3) The fiberoptic demodulation method worked nicely in both the sub-fringe and multi-fringe regimes, it eliminates several problems with the Navy's current method of accomplishing the same task, and a patent is in the works.

PUBLICATIONS: Denk, W., Keolian, R.M., Ogawa, S., Jelinski, L.W., "Oscillatory Flow in the Cochlea Visualized by Novel Magnetic Resonance Imaging Technique," submitted to Nature, 1991.

WAVE TURBULENCE AND SOLITON DYNAMICS

Robert Keolian, Assistant Professor of Physics
Steven Garrett, Professor of Physics
Andres Larraza, Adjunct Professor of Physics
Dr. Bruce Denardo, ONT Postdoctoral Fellow
Sponsor: Office of Naval Research
Funding: Office of Naval Research

OBJECTIVE: To study the nonlinear properties of waves on two types of media: nonlinear lattices and the surface a liquid.

SUMMARY: The work was in three areas: 1) Two new localized structures were experimentally discovered in vibrating lattices and were described theoretically with a nonlinear Schrodinger equation. One is a domain wall between different types of vibration, the other is a kink in the phase of vibration. The kink has also been discovered in parametrically driven surface waves on water. 2) The direction and spectral energy of interacting nonlinear ocean waves evolve as they approach a sloping beach. A first principles theory was developed for this process and it was shown to agree with ocean experiments. 3) Experiments to determine whether random interacting waves on the ocean move collectively, having average quantities analogous to "pressure" in a gas as well as collective modes of vibration, were prepared.

CONFERENCE PRESENTATION: R. Keolian, A. Larraza, "Waves on a Nonlinear Random Sea of Waves," ONR workshop on Nonlinear Ocean Waves, 31 May 1991.

THESES DIRECTED: Manuel Abreu, LT, Portuguese Navy, "Nonlinear Transformation of Directional Wave Spectra in Shallow Water," Doctoral Thesis, September 1991.

Brian Galvin, LT, USN, "Numerical Studies of Localized Vibrating Structures in Nonlinear Lattices, "MS Thesis, March 1991.

Steven Alkov, LT, USN, "Multifrequency Acoustic Resonators with Variable Nonuniformity," MS Thesis, June 1991.

Cleon Walden, LT, USN, "Numerical Studies of Breather Solitons in Nonlinear Vibratory Lattices," MS Thesis, December 1991.

OTHER: Bruce Denardo, Brian Galvin, Alan Greenfield, Andres Larraza, Seth Putterman, and William Wright, "Observations of Localized Structures in Nonlinear Vibratory Lattices: Domain Walls and Kinks," paper submitted to Physical Review Letters, October 1991.

M. Abreu, A. Larraza, and E. Thornton, "Nonlinear Transformation of Directional Wave Spectra in Shallow Water," paper submitted to Journal of Fluid Mechanics, November 1991.

FACILITIES SUPPORT FOR THE NAVAL POSTGRADUATE SCHOOL LINAC AND FLASH X-RAY MACHINE

X.K. Maruyama, Professor of Physics
Sponsor: Naval Surface Warfare Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: The radiation sources at NPS, the 100 Me V RF electron linear accelerator and the 1.7 MV pulsed flash x-ray machine are required for a number of projects at NPS, including the study of unpolar arcing plasma physics, investigation of novel sources of coherent radiation and radiation effects in materials and electronic devices. These radiation sources are maintained by the Physics department, but are available to a variety of investigators from the Naval Postgraduate School and their associated external collaborators.

SUMMARY: The flash x-ray (FXR) machine has been productive this past year in the study of explosive plasma formation on electrodes. This investigation revealed that the electron beam from a cathode of a high voltage diode occurs within time scales of nanoseconds and the mechanisms are due to unipolar arcing. In addition to the capability to do basic physics and we maintain the resources to study transient radiation effects. In addition, this program also provides the Naval Postgraduate School the ability to measure rf signatures arising from charge particle beams and related radiators. The FXR resources were also used to study plasma interactions in a plasma opening switch.

The linac has again proved a workhorse instrument to study radiation effects in high temperature superconductors, to work to the development of an x-ray focussing device, to develop a novel means for beam position monitoring using optical transition radiation from a diffuse screen, to generate hard x-rays from transition radiators and to study a novel mechanism for x-ray production called parametric x-radiation generation. This past year, we have measured the normalized emittance of the Naval Postgraduate School linac. This fundamental property which measures the beam quality had not been known since the linac was constructed in 1965. It is e = 95p mm-mr and e = 52p mm-mr, which is surprising good for an accelerator of this vintage. The technique used was optical transition radiation. This is a support program, so the experimental accomplishments are listed under the individual programs. Publications, presentations, and these directed are presented under other project summaries associated with Prof. X.K. Maruyama, F.R. Schwirzke and J.R. Neighbours.

OTHER: Current collaborators, institutions and topics include: R. Fiorito and D. Rule, Naval Surface Warfare Center, optical transition radiation, parametric x-rays; M.A. Piestrup et al., Adelphi Technology, x-ray transition radiation and x-ray optics, parametric x-rays; H. Backe, u. Mainz, high T superconductors and optical transition radiation; J.R. Neighbours, NPS, EM radiation from charges particle beams; F.R. Buskirk, NPS, high temperature superconductors and optical transition radiation; F. Schwirzke, NPS, unipolar arcing; and J. Bechtold, Paul Chu et al., Texas Center for Superconductivity, high temperature superconductors.

THESIS DIRECTED: A. Gala, CPT, USA, "Analysis and Evaluation of Project Evergreen Data," MS in Engineering Science, September 1991.

NOVEL SOURCES OF COHERENT AND QUASI-COHERENT RADIATION

X.K. Maruyama, Professor of Physics
Sponsor: Naval Surface Warfare Center
Funding: Naval Postgraduate School

OBJECTIVE: There are many interactions between a charge particle and materials which generate coherent and quasi-coherent radiation. These mechanisms have only recently been brought to the attention of experimentalists who can measure them. The sources may show surprisingly unique properties such as spectral brightness, coherence and polarization. This project studies novel sources of radiation from relativistic electrons.

SUMMARY: The latest unique novel source to be studied at the Naval Postgraduate School is parametric x-radiation, which may be characterized as the Bragg scattering of the Coulomb field associated with the electron to produce monochromatic x-radiation. This phenomenon had been observed previously only in the Soviet Union. At the Naval Postgraduate School, we have been able to enhance the production of higher order parametric x-radiation by exploiting the energy dependence of the production and attenuation lengths of x-rays. This discovery shows promise to generate monochromatic higher energy x-rays with a modest electron beam energy. The spectral brightness has potential application for uses such as digital substraction angiography.

Optical transition radiation studies conducted under this program has produced a value for the normalized emittance of the Naval Postgraduate School linac. Our development of measurement techniques has resulted in a knowledge of a fundamental machine parameter which had not been available for 26 years. This same effort has also allowed us to develop new beam position monitor in a diffuse screen optical transition radiator.

X-rays are also generated as transition radiation. By exploiting the photo-absorption edge of transition radiation foils, quasi-monochromatic x-rays are also generated. The use of high density transition radiators allows for generation of hard x-rays with moderate energy electrons. These x-rays have also allowed us to investigate the possibilities to create an x-ray focussing optic.

Our work on coherent sources of radiation involving microwave Cerenkov radiation, which we had done seven years ago was needed to explain observations of infrared Cerenkov radiation at a laboratory in Osaka, Japan. This resulted in a comment article in Physical Review Letters.

PUBLICATIONS: Piestrup, M.A., Moran, M.J., Boyers, D.G., Pincus, C.I., Kephart, J.O., Gearhart, R.A., Maruyama, X.K., "The Generation of Hard X-Rays from Transition Radiation Using High-Density Foils and Moderate Energy Electrons," *Physical Review*, A43:2387-2396, 1991.

Piestrup, M.A., Boyers, D.G., Pincus, C.I., Harris, J.L., Maruyama, X.K., Bergstrom, J.C., Caplan, H.S., Silzer, R.M., Skopik, D.M., "Quasi-Monochromatic X-Ray Sources Using Photo-absorption Edge Transition Radiation," *Physical Review*, A43: 3653-3661, 1991.

Rule, D.W., Fiorito, R.B., Piestrup, M.A., Gary, C.K., Maruyama, X.K., "Production of X-rays by the Interaction of Charged Particle Beams with Periodic Structures and Crystalline Materials," SPIE proceedings, 1552:250-251, 1991.

Neighbours, J.R., Burskirk, F.R., Maruyama, X.K., "Comment on Measurement of Coherent Cherenkov Radiation from an Intense Beam of a Picosecond Electron Bunch," *Physical Review Letters*, 67:1052, 1991.

Rule, D.W., Fiorito, R.B., Piestrup, M.A., Gary, C.K., Maruyama, X.K., "Production of X-rays by the Interaction of Charged Particle Beams with Periodic Structures and Crystalline Materials," SPIE proceedings, 1552:250-251, 1991.

Piestrup, M.A., Boyers, D.G., Pincus, C.I., Li, Qaing, Harris, J.L., Bergstrom, J.C., Caplan, H.S., Silzer, R.M., Skopik, D.M., Moran, M.J., Maruyama, X.K., "High Power X-Ray Generation Using Transition Radiation," SPIE proceedings, 1552, 1991.

Piestrup, M.A., Boyers, D.G., Pincus, C.I., Li, Qaing, Hallewell, G.D., Moran, M.J., Skopik, D.M., Silzer, R.M., Maruyama, X.K., Snyder, D.D., Rothbart, G.B., "Observation of Soft-X-ray Spatial Coherence from Resonance Transition Radiation," *Physical Review A*, forthcoming.

Piestrup, M.A., Boyers, D.G., Pincus, C.I., Li, Quaing, Maruyama, X.K., Skopik, D.M., Silzer, R.M., Moran, M.J., Rothbart, G.B., "Observation of Focusing of X-ray Transition Radiation Using Cylindrical Optics," submitted to the *Journal of Applied Physics*.

CONFERENCE PRESENTATIONS: Rules, D.W., Fiorito, R.B., Piestrup, M.A., Gary, C.K., Maruyama, X.K., "Production of X-rays by the Interaction of Charged Particle Beams with Periodic Structures and Crystalline Materials," SPIE 1991 International Symposium on Optical Applied Science and Engineering, San Diego, CA, 24-25 July 1991.

Piestrup, M.A., Boyers, D.G., Pincus, C.I., Li, Qaing, Harris, J.L., Bergstrom, J.C., Caplan, H.S., Silzer, R.M., Skopik, D.M., Moran, M.J., Maruyama, X.K., "High Power X-Ray Generation Using Transition Radiation," SPIE 1991 International Symposium on Optical Applied Science and Engineering, San Diego, CA, 24-25 July 1991.

Maruyama, X.K., Reid, C., Buskirk, F.R., Backe, H., "A Novel Optical Transition Radiation Beam Profile Monitor Using a Diffuse Screen," Bull. Am. Phys. Soc. 36, 1550 (1991), 1991 Particle Accelerator Conference, San Francisco, CA, 6-9 May 1991.

Maruyama, X.K., "Novel Sources of Coherent and Quasi-coherent Photon Generations with Ultra-relativistic Electrons," Department of Physics Colloquium, University of Mississippi, Oxford, MS, 19 April 1991.

Maruyama, X.K., "Channeling Radiation," Summer Research in Physics for Upper Level Undergraduates, University of Virginia, 3 July 1991.

THESES DIRECTED: Hellstern, M.J., LT, USN, "Emittance Measurement of the Naval Postgraduate School Linear Accelerator Using Optical Transition Radiation Techniques," MS in Physics, September 1991.

Osborne, M.J., LT, USN, "Higher Order Parametric X-Rays," MS in Physics, December 1991.

Vortruba, P.M., LT, USN, "Focussing X-ray Transition Radiation with Cylindrical and Elliptical Optics," MS in Physics, December 1991.

TOTAL DOSE EFFECTS

X.K. Maruyama, Professor of Physics
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: Total dose effects in novel materials are investigated. These materials have potentially great application in emerging technologies. Current emphasis is to investigate the specific mechanisms for radiation induced changes in the critical current density in high temperature superconductors.

SUMMARY: The effects of electron irradiation on YBa Cu O7 have been studied in collaboration with researchers from the Texas Center for Superconductivity, University of Houston, TCSUH. With the solid state physics expertise and capabilities of TCSUH, we have been able to go beyond the earlier measurements of the critical temperature dependence on irradiation. Measurements of magnetization -J and transport - J indicate that the defects responsible for degradation of the critical current are macroscopic. Furthermore, there is an orientation dependence of the radiation effects indicating that large anisotropic cluster defects induced by irradiation are more effective for flux pinning than small isotropic defects.

PUBLICATIONS: Bechtold, J., Xue, Y.Y., Huang, Z.J., Hungerford, E.V., Hor, P.H., Chu, C.W., Maruyama, X.K., Backe, H., Buskirk, F.R., Connors, S.M., and Snyder, D.D., "Defect Size Dependence of Critical Current Density Enhancement for Irradiated YBa Cu O7," *Applied Physics Letters*, forthcoming.

CONFERENCE PRESENTATIONS: Bechtold, J., Meng, R.L., Gao, L., Xue, Y.Y., Hungerford, E., Hor, P.H., Chu, C.W., Maruyama, X.K., Backe, H., Buskirk, F.R., Conners, S.M. and Snyder, D.D., "Degradation of Transport J in Melt-Textured Y123 by e-Irradiation, Bull. Am. Phys. Soc. 36, 728 (1991)., American Physical Society Meeting, Cincinnati, OH, 18-22 March 1991.

Meng, R.L., Bechtold, J., Xue, Y.Y., Hungerford, E., Hor, P.H., Chu, C.W., Connors, S.M., Backe, H., Buskirk, F.R., Maruyama, X.K. and Rietdyk, H., "Observation of Defect-Shape Dependence in Fluxon-Defect Interactions", Bull. Am. Phys. Soc. 36, 728 (1991), American Physical Society Meeting, Cincinnati, OH, 18-22 March 1991.

THESIS DIRECTED: Connors, S.M., LT, USN, "Effects of High Energy Electron Radiation on a YBa Cu O7 High Temperature Superconductor," MS Physics, September 1991.

AIRCRAFT EMP SURVIVABILITY ASSESSMENT

X.K. Maruyama, Professor of Physics
Sponsor: Naval Air Test Center
Funding: Naval Air Test Center

OBJECTIVE: It is the goal of this project to determine methods to increase the fidelity of Aircraft system level EMP test results using currently available technology. This study will address such issues as the identification of the EMP threat environment and their effects on the system being assessed. Also to be addressed is the identification of cost effective methods to improve present methods in terms of fidelity and time effectiveness. Limitations of system level tests will be identified.

SUMMARY: A thorough literature search has been conducted and active participants in EMP testing have been contacted to obtain background information on the current status of Aircraft EMP survivability assessment techniques. The threat environment has been defined (both nuclear and lightening EMP) particularly from an aircraft perspective. At this time, the primary contribution is being made by Mr. Samuel Frazier who is currently a candidate for the Master of Science in System Engineering at the Naval Postgraduate School. The present state of inductively coupled current injection direct drive technology is being studied. The stress envelope and margin of survivability (stress/strength) is being defined. A protocol for aircraft systems tests is being formulated.

THESIS DIRECTED: Thesis work is being continued by Mr. S. Frazier, NPS, degree candidate. He is currently at the Naval Air Test Center, Patuxent River, Maryland.

UNSPONSORED RESEARCH

X.K. Maruyama, Professor of Physics
Sponsor: Naval Postgraduate School
Funding: Naval Postgraduate School

OBJECTIVE: The goal of any innovative scientist is to use whatever resources are available to create research results whenever the opportunity presents itself. Some of these results are continuations of research which in the past has had a funded research project, while others arise because of the instructional requirements for thesis supervision produce results. Some are investigations initiated with a view towards a future funded project proposal. Not all results fit neatly into the bureaucratic niches.

SUMMARY: Absolute and relative cross sections for elastic scattering of electrons from the proton have been presented. The measurements span a momentum transfer between 0.22 to 0.73 fm . An rms proton charge radius of 0.865 +/-0.020 fm has been obtained, consistent with the results obtained at Mainz. The work reported here is the analysis of data taken nearly 8 years ago at the National Bureau of standards.

The mean free path of protons within nuclei have been measured by (e,e'p) coincidence measurements. The work reported here is the analysis of data taken nearly 5 years ago at the MIT Bates Linear Electron Accelerator.

We are taking advantage of the experimental equipment associated with the measurement of novel sources of coherent radiation (optical transition radiation) to initiate a collaboration with Professor A. Atchely, Dr. Felipe Gaitan and Mr. Jerry Lentz to begin an investigation of sonoluminescence. We will use available resources within the physics department at the Naval Postgraduate School and contacts at the Lawrence Livermore National Laboratory to pursue this study. The primary project is described in Professor Atchley's summary, but this investigation provides an unique opportunity to maximize local resources to create a synergistic research atmosphere.

PUBLICATIONS: McCord, M., Crannel, H., Fagg, L.W., O'Brien, J.T., Sober, D.I., Lightbody, J.W., Maruyama, X.K. and Treado, P.A., "Preliminary Results of a New Determination of the RMS Charge Radius of the Proton," *Nuclear Instruments and Method in Physics*, B56/57:496-499, 1991.

Garino, G., Saber, M., Segel, R.E., Geesaman, D.F., Gilman, R., Green, M.C., Holt, R.J., Schiffer, J.P., Zeidman, B., Beise, E.J., Dodson, G.W., Hoibraten, S., Pham, L.D., Redwine, R.P., Sapp, W.W., Williamson, C.F., Wood, S.A., Chant, N.S., Roos, P.G., Silk, J.D. and Deady, M., Maruyama, X.K., "Proton Propagation in Nuclei," submitted to *Physical Review C*.

STUDY OF MECHANISMS FOR REMOTE OBSERVATION OF DIRECTED ENERGY BEAMS

John R. Neighbours, Professor of Physics

Sponsor: Defense Advanced Research Project Agency
Funding: Defense Advanced Research Project Agency

OBJECTIVE: The goal of this project was to evaluate various mechanisms of electromagnetic radiation from an electron beam for use in remote detection of the beam.

SUMMARY: Working along with F. Buskirk and X. K. Maruyama, we have done extensive calculations and experiments concerning the rf radiation produced by a pulse or bunch of relativistic electrons such as those emitted by an S band (2.85 Ghz) accelerator. Much of this work was concerned with coherent generation of radiation by the Cherenkov mechanism. the radiation may be quite strong at rf frequencies such that the wave length of the emitted radiation is longer than the dimensions of the charge bunch. Recently, experiments were carried out by others using picosecond charge bunches so that the above coherency criterion holds at much higher frequencies; up into the infrared. In these cases, the detector was wide band which required the integration of our results over the wavelength range of the observations. The result of the calculation explained the observations made on the infrared radiation from a picosecond electron bunch propagating in air with no adjustment of the index of refraction.

PUBLICATION: John R. Neighbours, Fred R. Buskirk, and Xavier K. Maruyama, "Comment on Measurement of Coherent Cherenkov Radiation from an Intense Beam of a Picosecond Electron Bunch," *Physical Review Letters*, 67:1052, 1991.

CHARACTERIZATION OF RADIATION FROM HIGH CURRENT ELECTRON BEAMS

John R. Neighbours, Professor of Physics
Sponsor: Space and Naval Warfare Systems Command
Funding: Naval Postgraduate School

OBJECTIVE: The goal of this project was the collection, analysis and understanding of radio frequency signals from intense electron beams.

SUMMARY: A set of experiments was carried out on the Phermex electron accelerator in the summer of 1989. To date, the data for the signals from a propagating beam and from a diffuse beam has been organized, and Fourier analyzed. This work resulted in several student theses in the previous calendar year. Further analysis is needed to assess the effects of path length, beam stops, and reflectors. During the late spring of 1990, Project Evergreen was conducted at the Nevada Test Site. Personnel from the Naval Postgraduate School along with those from other government agencies participated in the project whose primary purpose was to evaluate antenna output responses to various pulsed input signals. In addition, the capability of broadband receiving equipment to capture short time duration signals was evaluated. A rather long thesis has resulted from these measurements. A shortened summary report is in preparation.

THESIS DIRECTED: Antonio Gala, U.S. Army, "Analysis and Evaluation of Project Evergreen Data," MS Thesis, September 1991. Thesis directed by X. K. Maruyama, Stephen Jauregui, second reader. This document consists of a 160 page thesis and a 355 page addendum.

SPACE POWER EXPERIMENT ABOARD ROCKET (SPEAR)

R.C. Olsen, Associate Professor of Physics
Sponsor: Defense Nuclear Agency

OBJECTIVE: Support designs phase for the SPEAR III project. In particular advise on the charging behavior experienced in SPEAR I, and on instrumentation to be flown in the new mission.

SUMMARY: Work under this project has primarily been preliminary, in attending design meetings, and theory meetings. As a result of this work, the SPEAR III payload includes an electrostatic analyzer which will monitor vehicle charging. This work is preliminary to launch in 1993, at which point more meaningful results will be obtained.

PLASMA HEATING AT THE PLASMAPAUSE

R.C. Olsen, Associate Professor of Physics
Sponsor: NASA

OBJECTIVE: Analyze particle, field, and wave data from satellites orbiting the earth near the magnetic equator, near the plasmapause. The thrust of the analysis is to determine the characteristics of the cold and hot plasmas which lead to interchange of energy - e.g. heating.

SUMMARY: This work has been part of an ongoing study. Data analysis during the past year has been focused on data taken near geosynchronous orbit, from the SCATHA satellite, and the AMPTE/CCE satellite. The most exciting new results is the apparent separation between regions of heated electrons and ions. The two appear to be mutually exclusive.

PUBLICATIONS: Olsen, R.C., "The Density Minimum at the Earth's Magnetic Equator," *Journal of Geophysical Research*, forthcoming.

Olsen, R.C., Roeder, J., Aggson, and Quinn, J., "Plasma Heating at the Convection Boundary, to be submitted to the *Journal of Geophysical Research*.

CONFERENCE PRESENTATIONS: Olsen, R.C., "The Density Minimum at the Earth's Magnetic Equator," EOS, 72, p. 235, 1991, presented at the Spring meeting of the American Geophysical Union, Baltimore, MD, 28 May 1991.

Olsen, R.C., and Scott, L.J., "Equatorially Trapped Plasmas and Parallel Electric Fields," EOS, 72, p. 401, 1991, presented at the Fall meeting of the American Geophysical Union, San Francisco, CA, 9-13 December 1991.

THESES DIRECTED: Braccio, Peter G., "Survey of Trapped Plasmas at the Earth's Magnetic Equator," December 1991.

Scott, Lewis, J., "On the Consequence of Bi-Maxwellian Distributions on Parallel Electric Fields," December 1991.

SATELLITE CHARGE CONTROL

R.C. Olsen, Associate Professor of Physics
Sponsor: Office of Naval Research

OBJECTIVE: Design charge control technology for high altitude satellites. Analyze charging data from existing satellites. Work towards future flight experiments.

SUMMARY: The flight unit for the POLAR satellite has been completed, and has been delivered for integration. Launch has slipped to 1994. Laboratory work towards a solid state ion source was conducted. A compact, lightweight, and electromagnetically quiet source appears practical. Work on a possible flight design was started. Analysis of electrostatic charging of dielectric materials on satellites indicates that it may have a catalytic effect on the development of satellite charging. Analysis of the charging on 1989-046 was conducted.

PUBLICATIONS: Olsen, R.C., and Norwood, C.W., "Spacecraft Generated Ions," *Journal of Geophysical Research*, 96:15951-15962, 1991.

Olsen, R.C., Comment on "Theory and Observation of Triple-root Jump in Spacecraft Charging," by S.T. Lai, *Journal of Geophysical Research*, 96:21411-21412, 1991.

Olsen, R.C., Anderson, R.R., and Mozer, F.S., "Plasma Wave Observations During Electron Gun Experiments on ISEE-1," *Advances in Space Research*, forthcoming.

THESES DIRECTED: Evert, Richard W., "Arcjet Plume Ionization Effects on Exposed Solar Array Conducting Surfaces," September 1991.

Wong, Yan Chung, "Satellite Anomalies and Electrostatic Surface Discharges," September 1991.

Gant, Dean A., "Comparison of Alkali Ion Emitters," December 1991.

Smith, Donald S., "Investigation of Deep Dielectric Charging an Subsequent Currents on Geosynchronous Spacecraft," December 1991.

DISCHARGE PHYSICS AND UNIPOLAR ARCING

F. Schwirzke, Professor of Physics
X. K. Maruyama, Professor of Physics
Sponsor: Naval Research Laboratory
Funding: Naval Postgraduate School

OBJECTIVE: To understand the breakdown process and formation of plasma on electrodes. Breakdown and plasma formation on electrodes are fundamental processes in pulsed power technology. The initial plasma formation on the surface of a cathode is a very non-uniform. Micron-sized cathode spots form within nanoseconds. Unipolar arcing represents a discharge form which can explain the explosive like formation of cathode spots.

SUMMARY: Despite their fundamental importance, the details of cathode spot formation have not been well understood. Breakdown in a vacuum diode is initiated by field emitted electrons. Besides joule heating of the emitting spot, the electrons also ionize desorbed gas layers. These ions fall back to the cathode, heating the surface of the electron emitting spot. Ion surface heating is initially orders of magnitude larger than joule heating. Surface heating and the build-up of positive space charge rapidly lead to further enhanced field emission and, finally, thermionic electron emission. The localized build-up of plasma above the electron emitting spot naturally leads to pressure and electric field distributions which ignite unipolar arcs. The high current density of the unipolar arc then provides the "explosive" plasma formation of a cathode spot. This was confirmed by experimental results using the flash x-ray facility.

PUBLICATIONS: Schwirzke, F., "Laser Induced Breakdown and High Voltage Induced Breakdown on Metal surfaces," chapter in a book: *Laser Interaction and Related Plasma Phenomena*, 9:335-357, H. Hora and G.H. Miley, eds., Plenum Publishing Corporation, New York 1991.

Schwirzke, F., Maruyama, X.K. and Minnick, S.A., "Onset of Breakdown in a Vacuum Diode," in proceedings of the Eighth International Conference on High Power Particle Beams, Novosibirsk, USSR, 2:958-963, World Scientific Publishing Corp., 1991.

Schwirzke, F., "Formation of Cathode Spots by Unipolar Arcing," in Gaseous Dielectrics, VI:209-214, Edited by L. G. Christophorou and I. Sauers, Plenum Press, New York, 1991.

Schwirzke, F., "Vacuum Breakdown on Metal Surfaces," IEEE Transactions on Plasma Science, 19:690-696, October 1991.

Schwirzke, F., Hallal, Jr., M.P. and Maruyama, X.K., "Explosive Plasma Formation on Electrodes," Digest of Technical Papers, Eighth IEEE International Pulsed Power Conference, IEEE Catalog Number 91CH3052-8, p. 663-669, San Diego, California, 16-19 June 1991.

CONFERENCE PRESENTATIONS: Schwirzke, F., "Cathode Effects in Plasma Opening Switches," Conference Record IEEE Catalog No. 91 CH 3037-9, 1991 IEEE International Conference on Plasma Science, p. 187, Williamsburg, Virginia, 3-5 June 1991.

Schwirzke, F., Hallal, Jr., M.P. and Maruyama, X.K., "Explosive Plasma Formation on Electrodes," Eighth IEEE International Pulsed Power Conference, P1-23, San Diego, California, 17-19 June 1991.

Schwirzke, F. and Gedik, Abdullah, "Energy Threshold for Laser Induced Breakdown on a Metal Surface Under High and Ultrahigh Vacuum Conditions," Bull. Am. Phys. Soc. 36, 2306, October 1991.

Schwirzke, F., 'Moderate Intensity Laser-Matter Interaction Physics," Abstract Invited Paper, 21st European Conference on Laser Interaction with Matter, Warsaw, 21-25 October 1991.

Schwirzke, F., Hallal Jr., M.P. and Maruyama, X.K., "Ion Formation on the Surfaces of Electrodes," Abstract 14th International Conference on Atomic

Collisions in Solids, 29 July - 2 August 1991, University of Salford, England.

Schwirzke, F., "Onset of Breakdown on Plasma formation on Electrodes," 26 September 1991, Seminar given at University Hanover, Germany.

Schwirzke, F., "Moderate Intensity Laser-Matter Interaction Physics," 10th International Workshop on Laser Interaction and Related Plasma Phenomena, Naval Postgraduate School, 11 November 1991.

THESES DIRECTED: Michael P. Hallal, Jr., "The Onset of Breakdown in a Fast Pulsed Vacuum Diode," June 1991.

Gedik, Abdullah, "Energy Threshold for Laser Induced Breakdown on a Metal Surface Under High and Ultrahigh Vacuum Conditions," June 1991.

Thomas, Christopher B., "Plasma Interactions in a Plasma Erosion Opening Switch," December 1991.

ACOUSTIC SOUNDER CHARACTERIZATION FOR THE AIR FORCE 4M TELESCOPE AT AMOS

D. L. Walters, Associate Professor of Physics
Sponsor: Phillips Laboratory
Funding: US Air Force

OBJECTIVE: To determine the existence and thickness of a turbulent surface layer immediately above the surface of Mt. Haleakala, HI for the US Air Force 4 m Telescope program.

SUMMARY: An advanced 4m telescope is being planned for Air Force, Maui Surveillance Site at Mt. Haleakala, HI. The current 1.6 and 1.2 m telescopes have achieved marginal performance compared to the civilian telescopes on Mauna Kea, HI. NPS suggested that a thin turbulent surface layer 10-30 thick be responsible for the mediocre site quality degradation. A quick reaction field experiment conducted in June 1991, verified that a 15-20 m turbulent surface layer. Placing the 4 telescope on a 4 m tower could double the quality of the facility.

THESES DIRECTED: Mattingly, T. S., LT USN, "Measurements of the Surface Layer Optical Turbulence above AMOS," MS Thesis, December 1991.

Hoover, C.R., LT USN, "Investigations of a Single Point Temperature Probe for Measurement of Atmospheric Turbulence," MS Thesis, December 1991.

OTHER: The NPS acoustic sounder was found to provide the only usable data to be included in the architect design specifications.

PACIFIC COASTAL MOUNTAIN ATMOSPHERIC TURBULENCE MEASUREMENTS

D. L. Walters, Associate Professor of Physics
Sponsor: Pentagon
Funding: US Air Force

OBJECTIVE: To assess the three year optical turbulence data base associated with the atmosphere above the Pacific Coastal Mountain Ranges.

SUMMARY: NPS has been helping the US Air Force on a sensitive program. Our FY 91 participation has been in providing calibrated equipment for use by Air Force personnel. In addition, NPS performed two critical diagnostic tests at the US Air Force Malabar, FL test site.

OTHER: NPS has made a series of critical contributions to this Air Force program. Equipment and technique developments for this program have helped other USN and Air Force programs.

ATMOSPHERIC OPTICAL TURBULENCE DEVELOPMENTS FOR ADAPTIVE OPTICAL PROGRAMS

D. L. Walters, Associate Professor of Physics
Sponsor: Phillips Laboratory
Funding: US Air Force

OBJECTIVE: Develop a single probe, low cost temperature structure function system for collecting balloon, atmospheric turbulence profiles.

SUMMARY: NPS has developed a balloon system that can collect atmospheric optical turbulence profiles using a single probe. A major FY 91 finding was that solar heating contaminates all existing day data collected by all previous investigators techniques. In addition we found that the existing first order difference algorithm will not remove the troposphere trends and that other techniques must be used.

THESES DIRECTED: Weitekamp, Mark, R., CPT USA, "Investigations of the Source of Thermosonde Measured Diurnal Variation of Optical Turbulence," MS Thesis, December 1990.

Hoover, C.R., LT USN, "Investigations of a Single Point Temperature Probe for Measurement of Atmospheric Turbulence," MS Thesis, December 1991.

SPACE SYSTEMS ACADEMIC GROUP

SPACE SYSTEMS ACADEMIC GROUP

The Space Systems Academic Group (SSAG) is an interdisciplinary association providing direction and guidance for the Space Systems Engineering and Space Systems Operations curricula. SSAG relies on faculty and facilities support from the departments of Administrative Sciences, Aeronautical and Astronautical Engineering, Computer Science, Electrical and Computer Engineering, Mathematics, Mechanical Engineering, Meteorology, Oceanography, Operations Research, and Physics.

In the 1991 academic year, Officer students in the Space Systems Curricula and participating faculty from several departments were engaged in seven major areas of space research and development: (1) Spacecraft Technology, (2) Acoustics in Space, (3) Satellite Communications, (4) Computer Memory Technology in Space, (5) Orbitology, (6) Space Environment Technology, and (7) Spacecraft Dynamics and Control. In addition (8), SSAG assisted participating departments in the continuing development of several Spacecraft and Flight Hardware Laboratories and Support Facilities.

Spacecraft Technology

Small Satellite Design Studies (PANSAT)

Professor Rudolf Panholzer continued his research program on Small Satellite Design Studies with the Petite Amateur Navy Satellite Project (PANSAT). PANSAT is being designed to function as a small packet radio communications satellite using spread spectrum techniques. In FY91, the first pre-space notification was approved by the International Frequency Registration Board of the International Telecommunication Union. Preliminary communication and electric power subsystems designs were performed. The structure configuration was completed. Preliminary finite element analysis of the satellite structural design was completed. Fabrication of the engineering qualification model structure was completed.

Acoustics in Space

Space Thermoacoustic Refrigerator (STAR)

Professor Steve L. Garrett's team completed the testing of the Space Thermoacoustic Refrigerator (STAR) and delivered it to fly on the Space Shuttle Discovery (STS-42) in late January 1992. (See Department of Physics.)

Thermoacoustic Cryocooler (TARTII)

Professor Thomas J. Hofler continued research and development efforts to design, fabricate, and space-qualify the third generation of Thermoacoustic Cryocooler (TARTII). Key feature of the new design is a new acoustic resonator design that looks promising after preliminary tests. (See Department of Physics.)

Satellite Communications

Low-Altitude Satellite Communications (LASAT)

Professors Tri Ha and Glen Myers continued their investigation of the performance characteristics of four types of frequency-hopped spread spectrum receivers suitable for satellite communications in low-earth orbits. Techniques to reduce the effects of partial-band jamming multipath fading were developed. (See Department of Electrical and Computer Engineering.)

Computer Memory Technology in Space

Ferroelectric Technology

Professor Panholzer's team continued research on Computer Memory Technology in Space to evaluate ferroelectric technology for its suitability in military and space applications. Under Professor Panholzer's direction, a ferroelectric experiment was integrated into Orbital Science Corporation's "OrbComm-X" satellite. This experiment was launched in July 1991 aboard an Ariane rocket from French Guiana. A new Thin-Film Ferroelectric Experiment (NPS FERRO-001) was designed to test the effects of space environment on ageing and fatiguing characteristics of ferroelectric capacitors. This research is expected to continue into 1992-93.

Orbitology

Orbital Mechanics & Simulation and Modeling

Professor Donald Danielson and several students have obtained analytical solutions to the equations of motion of a satellite orbiting an oblate planet. The complexity of the algebraic manipulations was eased by the use of MACSYMA on the Vax computer. (See Mathematics Department.)

Space Environment Technology

Satellite Charge Control Technology

Professor R. Christopher Olsen continued research on Satellite Charge Control technology for high altitude satellites. He completed the satellite charge control flight unit for the POLAR satellite and delivered it for integration (launch is scheduled for 1994.) Preliminary studies for the design of a different electromagnetically quiet source for charge control appears practical. Work on a possible flight design was started. (See Department of Physics)

The Sounding Rocket Experiment

The sounding rocket experiment for remote sensing of the ionosphere conducted by Prof. David Cleary is continuing. The object of this ongoing research project is to develop a simple technique for measuring global ionospheric electron densities from a space based platform. The launch of the Middle UV Spectrometer (MUStang) Experiment, built and flown on a rocket in March 90, yielded approximately 8,000 spectra between the altitudes 100 km and 320 km and gave good density profiles for a number of species. In FY91 a second sounding rocket flight experiment was built and readied to be flown in early FY92. (See Department of Physics.)

On-Orbit Annealing of Satellite Solar Panels

Professor Sherif Michael continued research on photovoltaic power technology by investigating the possibility to anneal a satellite's InP and GaAs solar cells while in orbit using new minority carriers annealing techniques. Research included the development and testing of a microprocessor based experiment suitable for small satellites. (See Department of Electrical and Computer Engineering.)

Spacecraft Dynamics and Control

Flexible Spacecraft Simulation

A new research effort was initiated by Professor Brij Agrawal to study effects of flexibility due to structures and liquid propellant motion on the attitude control of spacecraft. A Flexible Spacecraft Simulator was constructed to experimentally verify attitude control techniques for flexible spacecraft. A FLTSATCOM Simulator consisting of a graphic display of attitude motion of the Fleet Satellite Communication spacecraft became operational. (See Department of Aeronautics and Astronautics)

Large Space Structures Modeling and Control

Professor Jeff Burl continued studies on sensor and actuator placement for large space structure control. An H controller was synthesized for a simulated space station. Simulated annealing, gradient descent, and an algorithm based on the influence coefficients of the Karhunen-Loeve transform were investigated as methods of optimizing actuator placement. The signal processing software for the LACE dynamics experiment was completed. This experiment measured the structural dynamics of a satellite on orbit, and provided valuable data on the accuracy of large space structure models. (See Department of Electrical and Computer Engineering.)

Spacecraft and Flight Hardware Laboratories/Facilities

The Space Systems Academic Group (Code SP) and participating departments have continued to dedicate both labor and material resources to the development of several laboratories and support facilities:

(SP01) Spacecraft Integration & Test (SSAG)
(SP02) Open Site EMI/EMC (SSAG)
(SP03) Satellite ground Station (SSAG)
(SP04) AIS Computing (SSAG)
(SP05) Precision Fabrication Facility (SSAG)
(SP06) Radiation Effects & Solar Simulation (SSAG/EC)
(SP07) Sensitive Compart. Information Computing (SSAG/EC)
(EC03) Low-Altitude Satellite Communications & Network (SSAG/EC)
(AA17) FLTSATCOM Satellite Operation, Sim. & Test (SSAG/AA)
(AA18) Spacecraft Attitude Dynamics & Control (SSAG/AA)
(AA19) Spacecraft Environmental Simulation & Test (SSAG/AA)

SMALL SATELLITE DESIGN STUDIES (PANSAT)

R. Panholzer, Chairman, Space Systems Academic Group
Sponsors: NPS, NRL, NASA/USRA
Funding: NPS, NRL, NASA/USRA

OBJECTIVE: The goals of the Continuing Small Satellite Design Studies program are to design, fabricate, test, and ultimately launch a small satellite for operation by NPS enhancing the education of officer students through a systems engineering approach; and to provide a valuable space asset to augment existing space defense systems. The continuing project is the Petite Amateur Navy Satellite (PANSAT) which is being designed to investigate spread spectrum communication with store-and-dump capability for relaying information digitally.

SUMMARY: Preliminary communication and electric power subsystems designs were performed. The structure design was completed. Preliminary finite element analysis of the satellite structural design was completed. Fabrication of the engineering qualification model structure was completed. The first pre-space notification for a frequency allocation and license was approved by the International Frequency Registration Board of the International Telecommunication Union.

THIN-FILM FERROELECTRIC EXPERIMENT (FERRO NPS-001)

R. Panholzer, Chairman, Space Systems Academic Group
Sponsors: NPS, NRL
Funding: NPS, NRL

OBJECTIVE: The goal of the on-going thin-film ferroelectric memory research project is to evaluate ferroelectric technology to determine its suitability in military and space memory applications.

SUMMARY: A Ferroelectric Experiment continued into FY91 and was integrated into Orbital Science Corporation's OrbComm-X satellite. This experiment was launched in July 1991 aboard an Arianne rocket from French Guiana. A new Thin-Film Ferroelectric Experiment (NPS FERRO-001) was designed to test the effects of space environment (most importantly radiation) on ageing and fatiguing characteristics of ferroelectric capacitors. On-ground and on-orbit ^Nfatigue, ageing and radiation testing procedures were established using: (a) irradiated materials and devices for on-ground tests; and (b) high radiation orbits for space environment tests. A radiation-fatigue test board was designed to allow accurate and simultaneous testing of multiple ferroelectric devices. The "NPS FERRO-001" experiment is expected to continue into 1992-93.

THESIS DIRECTED: Kercher, Mathew R., LT, USN, "Design of an Autonomous Test Device for Ferroelastic Components," June 1991.

1991
NAVAL POSTGRADUATE SCHOOL
PUBLICATIONS

DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS

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