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Reports on Current
European/Middle Eastern Science

a focused issue:

SPACE TECHNOLOGY, REMOTE SENSING, ENVIRONMENTAL SCIENCE: featuring the Office of Naval Research Technology Mobilization Reserve Program

Office of Naval Research European Office

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This issue of European Science Notes Information Bulletin is the first issue to be written and initially edited by Naval Reserve officers on active duty at the Office of Naval Research European Office (ONR Europe). Eight officers prepared articles on Space Technology, Remote Sensing, or Environmental Sciences. In addition to technical articles, two articles review ONR Europe programs and reserve participation.

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This publication is approved for official dissemination of technical and scientific information of interest to the Defense research community and the scientific community at large.

Commanding Officer ...... CAPT John M. Evans, USN
Scientific Director .... Dr. Arthur M. Diness
Editor .... Ms. Connie R. Orendorf

Coastal Morphodynamics is a research project to develop numerical models for the evolution of the near-shore morphology--the large-scale features such as bars and beaches. The author discusses how this project attempts to integrate challenging research with the motivation of critically important needs for better coastal engineering.

In this article, CAPT Harvey assesses various defense-oriented organizations in the U.K. with a special focus on their computer hardware and applications in support of Ministry of Defence R&D. He contacted several organizations--Cray Research U.K. Ltd, British Aerospace PLC, Ferranti International PLC, and the Royal Military College of Science.

At this colloquim, talks covered a variety of topics, but a recurring theme was the use of numerical models to examine the circulation. Speakers repeatedly emphasized both the difficulty and importance of accurately modeling the dynamics of the open and coastal ocean simultaneously.

Bigger is better is now augmented by *good things come in small packages* where satellite system development is concerned. This article provides a comparison of U.S. and European activities in the area of small satellite systems development.

During the past few years, there has been an increased interest in small, lightweight spacecraft which are referred to by several names: Lightsats, Cheapsats, and Microsats. The author discusses areas of European spacecraft technology that are being developed for these small satellites that would be of future interest for follow-on study.

This article reviews present and near-future methods for detecting and tracking petroleum seeps and spills from commercially accessible sources. Detecting and monitoring oil spills in the marine environment have become one of the major challenges facing the industrialized countries and military services world wide.

Technology Mobilization Program Overview

by CAPT R.N. Baker, USNR, and CAPT T.H. Kinder, USNR. CAPT Baker is the Commanding Officer of Office of Naval Research/Naval Research Laboratory, Tech 410, Houston, Texas. CAPT Kinder is the Director, Reserve Technology Mobilization Program, Office of the Chief of Naval Research, Arlington, Virginia.

Introduction

The Office of Naval Research (ONR) Technology Mobilization Reserve (TMR) Program is composed of 17 reserve units with almost 300 members. The program supports the activities of the Chief of Naval Research, including ONR and the Office of Naval Research European Office (ONR Europe). Naval reservists train for mobilization or recall by working with the active Navy commands. This pool of reservists can accelerate the transition of technology to the fleet and increase liaison between the research community (government and academic) and the fleet.

The educational level in the TMR is comparable to a large laboratory such as the Naval Research Laboratory--about 25 percent hold a Ph.D. and about 34 percent a Masters Degree. Reserve officers train as program managers, technical advisors, and liaison officers. Often, their civilian careers are in research and development (R&D). The combination of naval and research experience enables the Reserve Officers to fill niches between operations and research, and to add expertise where needed.

Since 1978, the Houston TMR unit has maintained ties with ONR Europe, annually providing small teams of expert reservists from the TMR. This informal arrangement, based on the initiative of the Houston unit, has now been formalized and the Commanding Officer of ONR/Naval Research Laboratory Tech 410 is the link between ONR Europe and the TMR Program.

For optimal training and support for ONR Europe, we must match carefully the reservist and the task--a challenging proposition in the rapidly changing environment of science, technology, and geopolitics. We use multiple approaches. Annually, ONR Europe announces requirements that will meet ONR Europe needs. However, individual reservists are also encouraged to propose topics to ONR Europe. The Houston Commanding Officer solicits and screens requests, with final approval provided by ONR Europe.

Recent Accomplishments

Over the past 15 years, both reservists and active duty staff can point proudly to quality support and training. Success depends on both the permanent ONR Europe staff and the reservists. Some of these accomplishments are highly visible (e.g., the *European Science Notes Information Bulletin [ESNIB]*). Others are less so, especially those efforts dealing with security or systems configurations. Table 1 illustrates some specific accomplishments known to us since the mid-1980s.

The integration of reserve training into ONR Europe has worked for nearly 15 years because of the dedication and high caliber of the scientific reservists and the thoughtful management by ONR Europe. We expect to see even greater achievements and cooperation in the future.

Table 1. Accomplishments of the TMR Program

Function	Area of Interest
Liaison Scientists (visiting scientists)	Gulf of Mexico satellite Image processing technology Remote sensing surveys Satellite hardware technology *Paris, Farnborough air shows* European Space Agency German Space Agency (DLR) conferences, symposia results Space radiation hazards International patent law Space shuttle imaging radar Orbital mechanics Coastal oceanography Meteorology - EUMETSAT/ MeteoSat Synthetic aperture radars Oil seeps detection
Technical Experts	Computer security Database implementation Fiber optics feasibility Video conferencing Bird strike hazard abatement ONR international science fairs
Technical Literature Review & Summary	Bioluminescence Marine chemistry Nonacoustic ASW
Technical Editor	*ESNIB*

The European Community Marine Science and Technology Program

by CAPT Thomas H. Kinder, USNR, Ph.D., a visiting scientist/reserve officer to the Office of Naval Research European Office. CAPT Kinder is Director Reserve Technology Mobilization, Office of the Chief of Naval Research, Arlington, Virginia. Dr. Kinder is Manager, Coastal Sciences Program, Office of Naval Research, Arlington, Virginia.

Introduction

In 1989, the Council of Ministers of the European Community (EC) adopted a pilot program in Marine Science and Technology (MAST). The objective of MAST is "to contribute to establishing a scientific and technological basis for the exploration, management, protection, and exploitation of European coastal waters, and the seas surrounding the community (including the North Atlantic Ocean and sub-polar Arctic seas)." For many environmental issues, MAST is open to collaboration outside the EC. Dr. Filippo Maria Pandolfi (EC Commissioner for Research) and Dr. Alan Bromley (U.S. Presidential Science Advisor) have agreed on some specific areas, such as global change, where collaboration is encouraged.

In addition to encouraging multinational collaboration within the EC membership (funded proposals clearly reflect this policy and the effort to include countries with less well-developed scientific establishments), MAST integrates university research and industrial concerns. Many of the funded programs include partners that are private institutions, such as Delft Hydraulics, the Netherland , which plays a leading role in some of the projects, especially within marine technology (see Delft Hydraulics page 18 and Coastal Morphodynamics page 24).

Marine Science and Technology Program Description

The first phase of MAST (MAST I) extends during 1989-1992. Proposals for the second phase (MAST II) are due in November 1991 for probable June 1992 start dates. The program was funded at 50 million European Currency Units (ECU) (1.2 ECU per U.S. dollar, September 1991), and MAST II will be funded at 100 million ECU.

For MAST I, 46 proposals were funded out of 200 received. The average contract was for 0.8 million ECU over an average period of 2.5 years. For university participants, 100 percent of marginal costs are paid by the EC (most of the faculty salaries being already paid, for example). For industrial partners, the EC pays only 50 percent. Thus, the EC MAST program leverages national and other monies such that the size of MAST is about twice the EC financial contribution.

The program funds modest sized multiple-investigator projects. Its strengths include engendering collaboration between researchers with similar interests, entraining less-experienced scientists into international teams, and promoting university-industry relationships. Weaknesses include the absence of single researcher projects, the organizational overhead required within each project, the low funding per investigator, and the short contract period for such collaborative work (it is anticipated that many successful projects will continue into MAST II). Clearly, the program philosophy is based on a combination of scientific, educational, economic, and political factors. Many attributes are similar to the U.S. University Research Initiative Program (URIP).

Appendix A lists MAST I-funded projects and key scientific leaders to illustrate the focus, scope, and balance of the program. For MAST II, the four research categories are next delineated in considerable detail. Two large projects in the Mediterranean and North Atlantic will be targeted by MAST II.

Marine Science

- Circulation and exchange of water masses (North Atlantic and European marginal seas) - Emphasizes shelf/slope boundary processes, fronts and eddies, connections (straits and semi-enclosed seas), and validation and efficiency of models
- Biogeochemical cycles and fluxes (including Joint Global Ocean Flux Study [JGOFS] collaboration) - Emphasizes carbon cycling, transport of organic matter at ocean margins, significance of carbonated organisms, determination of major reservoirs and fluxes, and the effect of hydrothermal activity and water circulation through the ocean crust
- Interface and boundary processes - Emphasizes small scale air-sea interaction, gas exchange rates, eolian inputs, surface microlayer biology; geology, physics, and biology of the benthic boundary layer; air-sea-ice interactions and *in situ* measurements for remote sensing verification
- Biological processes - Emphasizes the variability of pelagic and benthic ecosystems, links between benthic and pelagic ecosystems, investigation of deep pelagic and bentho-pelagic life, control mechanisms in primary production, the role of micro-organisms (including viruses), ecosystems in extreme conditions, spatial and temporal population

dynamics within benthic and pelagic communities, and ecosystem modelling

- Marine Geosciences - Emphasizes modeling natural systems, understand the significance of present bedforms and sedimentary structures, erosion, mass wasting, engineering applications of geologic properties, and studying special environments (e.g., hydrothermal or mineral deposits).

Coastal Zone Science and Engineering

- Coastal physical processes - Emphasizes nearshore dynamics and model development (fluid and sediment), sediment mechanics (including biological influences), surface wave mechanics and forecasting, and integrated models to forecast morphological evolution
- Coastal engineering - Emphasizes model development for smooth and porous structures, breaking wave forces, wave directionality effects on structures, beach nourishment, and validation of morphodynamic models.

Marine Technology

- Instrumentation for science - Emphasizes sensors for circulation, biogeochemical fluxes, and boundary processes; seabed and subseabed characteristics, deep sea high quality geological samples (to subseabed depths of 50 m); innovative acoustic, laser, and biosensors; fluxes through the seabed, and real-time measurement of seabed motion
- Underwater acoustics - Emphasizes imaging biology, sound propagation, acoustical instruments, three-dimensional observation techniques, sea floor properties (especially under-ice bathymetry), signal processing (transmitted and received), wide-band transducers, navigation and positioning, and obstacle avoidance
- Enabling technologies - Emphasizes remotely operated vehicles (ROV), sensors for ROVs, artificial intelligence for autonomous vehicles, power supplies, robotics, imaging, and fouling
- Exploitation of marine biological resources - Emphasizes species producing bioactive substances, extraction and purification of bioactive substances, and mass cultivation techniques.

Supporting Initiatives

- European data and information exchange - Emphasizes database preparation, quality control techniques, database networks (including European geographical information system [GIS]), achieving, and obtaining data from industry
- Preparation of norms and standard for marine science and technology - Emphasizes database standards, optimal data collection, and calibration
- Modeling coordination - Emphasizes unified models for management, appropriate data assimilation, and model comparisons
- Research vessel and equipment coordination - Emphasizes equipment exchange, containerized laboratories, and support of unique equipment
- Design of large scale facilities, such as acoustic calibration, research vessels, or unmanned submersibles
- Advanced training for advanced courses and to establish a knowledge transfer scheme
- New approaches for surveying and mapping.

Targeted Projects

Mediterranean. The focus will be on using Mediterranean studies in the sense of a prototypical ocean to solve problems associated with anthropogenic influences. The scientific effort will be focused initially in the Western Mediterranean, probably as Programme de Recherche International en Mediterranee Occidentale (PRIMO) (a program approved by the Intergovernmental Oceanographic Commission). Components will include:

- Circulation and water mass structure
- Biogeochemical cycles
- Sources and sinks of organic and inorganic substances
- Biological processes
- *Geological processes.*

North Atlantic. The focus is on the role of the oceans and their margins in global fluxes, especially the European shelfbreak facing the North Atlantic and the Norwegian Sea.

The MAST headquarters is in the EC building in Brussels:

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SDME 3/48
75 Rue Montoyer
B - 1040 Bruxelles
Belgium
Secretariat: Ms C. Bastos
Telephone: 32-2-2362378; FAX: 32-2-2363024

Table 1. MAST Program Managers

Manager	Program
J. Boissonnas	Overall
M. Weydert·	Physical Oceanography Marine Technology
K.-G. Barthel	Chemical Oceanography Biogeochemistry Ecology and Biological Processes
J. Boissonnas	Marine Geosciences
C. Gragkis	Coastal Processes Engineering

Appendix A

MAST I Projects

For each project, the title, coordinator and partners, and coordinator's FAX number are provided.

Marine Science

Title	Coordinator and Partners	FAX Number
Enhanced Acoustic Tomography and Its Application to Circulation and Deep Convection in the Western Mediterranean	F. Schott, University of Kiel, FRG; with Y. Desaubies, Plouzane, France; J. Papadakis, Crete	49 431 565876
Barotropic and Baroclinic Flow Measuring Station Deep Sea Electrometer and VCTD-YOYO (BABAS)	P. Tarits, Inst. de Physique du Globe de Paris, France; with C. Provost, Paris, France; E. Accerboni, Trieste; O. Llinas, Las Palmas, Spain	33 1 434264029
European Coastal Transition Zone - Islas Canarias	E. Barton, Univ. Wales, Menai Bridge, U.K.; with M. Canton Garbin, Las Palmas, Spain; J. Garcia Braun, Tenerife, Spain	44 248 716367
Mixing Processes at the Sea Surface	M. Mc Donagh, Warren Spring Lab., Hertfordshire, U.K.; with S. Thorpe, Southampton; S. Cannarsa, La Spezia, Italy; G. Griffiths, Surrey, U.K.	44 438 360858
Mediterranean Eddy Resolving Modelling and Interdisciplinary Studies (MERMAIDS)	N. Pinardi, IMGA-CNR, Modena, Italy; with C. Koutitas, Greece; A. Lascaratos, Athens, Greece; A. Artegiani, Ancona, Italy; W. Roether, Bremen, FRG; J. Marshall, London, U.K.	39 59 374506
Upper Ocean Structure and Circulation and its Response to Atmospheric Forcing	S. Marullo, Telespazio Spa, Rome; with T. Guymer, Surrey, U.K.; V. Artale, Rome, Italy; M. Colacino, Rome, Italy; G. Gasparini, La Spezia, Italy; W. Alpers, Bremen, FRG	39 6 40693628
An Operational Wave Model for the Mediterranean for Hindcast and Forecast Applications. Organization of a Data Base for Regional Modelling	L. Cavaleri, CNR, Venice, Italy; with L. Lovenitti, Fano, Italy; J. Carretero, Madrid, Spain; G. Komen, De Bilt, the Netherlands; C. Koutitas, Thessaloniki, Greece; A. Guillaume, Paris, France	39 41 5216871
Hydrodynamic Modelling of the Western Mediterranean (EUROMODEL)	P.M. Lehucher, CETIIS, Aix en Provence, France; with J. Tintore, Palma de Mallorca, Spain; J. Font, Barcelona, Spain; J. Nihoul, Liege, Belgium; M. Crepon, Paris, France; M. Astraldi, La Spezia, Italy	33 42 398985
Integrated Modelling and Measurement of Physically Controlled Fluxes and Plankton Dynamics in Coastal Seas	J. Huthnance, Bidston Observatory, Birkenhead, U.K.; with G. Pichot, Brussels, Belgium; J. Sundermann, Hamburg, FRG; G. Komen, De Bilt, the Netherlands; W. van Leussen, Gravenhage, the Netherlands; J. Simpson, Gwynedd, U.K.; A. Lascaratos, Athens, Greece	44 516 536269
Determination of the Dispersal of Rhine Water in the North Sea and N. E. Atlantic by Measurement of Fluorescent Xenobiotic Substances	J. Suijlen, Rijkswaterstaat, Gravenhage, the Netherlands; with G. Becker, Hamburg, FRG; R. van Dijk, Rijswijk, the Netherlands; W. Helder, Den Berg, the Netherlands; R. Saetre, Bergen, Norway; J. Sundermann, Hamburg, FRG; F.M. Everaerts, Eindhoven, the Netherlands	31 703 744335
Studies of the Transport of Coastal Water from the English Channel to the Baltic Sea Using Radioactive Tracers	H. Dalgaard, RISO National Lab., Roskilde, Denmark; H. Nies, Hamburg, FRG; A. van Weers, Petten, the Netherlands; P. Gueguenlat, Cherbourg, France; D. Woodhead, Lowestoft, U.K.	45 42 360609
Hydrodynamics and Biogeochemical Fluxes in the Eastern Channel - Exports into the North Sea (FLUXMANCHE)	L. Cabioch, CNRS, Roscoff, France; with P. Statham, Southampton, U.K.; J. C. Salomon, Plouzane, France; D. Woodhouse, Lowestoft, U.K.	33 98 292324

Title	Coordinator and Partners	FAX Number
European River Ocean System (EROS 2000): Regional Modelling of the Biogeochemical Cycles in the Western Mediterranean	J.M. Martin, École Normale Superierre, Montrouge, France; with J. Nihoul, Liege, Belgium	33 1 46570497
A Generic European Regional Seas Ecosystem Model (ERSEM)	J. Baretta, Ned. Inst. Ond. Zee, Den Burg, the Netherlands; with G. Radach, Hamburg, FRG; A. Malmgren-Hansen, Horsholm, Denmark; W. Ebenhoh, Oldenburg, FRG; A. Cruzado, Blanes, Spain; M. Heath, Aberdeen, U.K.; P. Radford, Plymouth, U.K.	31 220 19674
Wadden Sea Project (WASP)	W. Rosenthal, Max Planck Str., Geesthacht, Denmark; with R. Warren, Horsholm, Denmark; A. Quist, Delft, the Netherlands; H. Lindeboom, Den Burg, the Netherlands; A. Malmgren-Hansen, Horsholm, Denmark; J. Battjes, Delft, the Netherlands; P. Mulder, Den Haag, the Netherlands	49 4152 871525
Natural Variability and the Prediction of Change in Marine Benthic Ecosystems	A. Rice, IOS Deacon Lab., Surrey, U.K.; with J. Gage, Argyll, U.K.; M. Vincx, Gent, Belgium; H. Thiel, Hamburg, FRG; L. Saldanha, Cascais, Portugal; P.J. Lambshead, London, U.K.; J. Patching, Galway, Ireland	44 428 683066
Geochemical Investigations of Hydrothermal Processes in Relation to the Formation of Marine Mineral Deposits in a Convergent Plate Environment	S. Varnas, Univ. Patras, Patras, Greece; with G. Perissoratis, Athens, Greece; D. Cronan, London, U.K.; G. Anastasakis, Athens, Greece; F. Voutsinou, Athens, Greece	30 61 991996
European River Ocean System (EROS 2000) - Particles and Sediment-Water Interactions	J.-M. Martin, École Normale Superierre, Montrouge, France; with M. Scoullos, Athens; D. Eisma, Den Burg, the Netherlands; J.M. Mouchel, Montrouge, France	33 1 46570497
Transfer Pathways of Iron and Related Elements in the Northern Adriatic Sea	N. Price, University of Edinburgh, Edinburgh, Scotland; with P. Giordani, Bologna, Spain; M. Frignani, Bologna, Spain; R. Thompson, Edinburgh, Scotland	44 316 683184
Biogeochemical Fluxes in the Ocean-Sediment System	T. Wilson, IOS Deacon Lab., Surrey, U.K.; with G.J. de Lange, Utrecht, the Netherlands; P. Halbach, Clausthal, Denmark; M. Cita, Milan, Italy; C. Vale, Lisbon, Portugal; G. Anastasakis, Athens, Greece; M. Frankignoulle, Liege, Belgium; D.Boust, Cherbourg, France	44 428 683066

Coastal Zone Science and Engineering

Title	Coordinator and Partners	FAX Number
The Control of Phytoplankton Dominance	J.W. Patching, Univ. Coll. Galway, Galway, Ireland; with F. Figueiras, Vigo, Spain; K. Jones, Oban, U.K.; G. Savidge, Portaferry, U.K.	353 91 25700
Biogeochemical Carbon Cycling in Coastal Zones	M. Frankignoulle, Univ. Liege, Liege, Belgium; with A. Watson, Plymouth, U.K.; A. Hall, Aveiro, Portugal	32 41 563355
Structure and Function of Coastal Ecosystems (SAFE)	B. Riemann, Water Qual. Inst., Horsholm, Denmark; P. Williams, Gwynedd, U.K.	45 42 867273
Major Biological Processes in Tidal Estuaries	C. Heip, Delta Institute, Yerseke, the Netherlands; J. Castel, Arachon, France; R. Warwick, Plymouth, U.K.; K. Kramer, Den Helder, the Netherlands; R. Neves, Lisbon, Portugal	31 11 313616

Title	Coordinator and Partners	FAX Number
Relationship Between Sea Floor Currents and Sediment Mobility in the Southern North Sea	G. De Moor, Rijksuniversiteit, Gent, Gent, Belgium; with J. Terwindt, Utrecht, the Netherlands; H. Chamley, Villeneuve d'Ascq, France; S. Berne, Plouzane, France; C. Vincent, Norwich, U.K.; J. Van Rensbergen, Wemmel, Belgium	32 91 204045
Microbially Mediated Processes in Tide-Influenced Deposits and Their Importance in Stabilisation and Diagenesis of Sediments	W. Krumbein, Univ. Oldenburg, Oldenburg, FRG; with D.M. Paterson, Bristol, U.K.; L.J. Stal, Amsterdam, Holland; G. Van den Boom, Hannover, FRG	49 4417 983384
G6 Coastal Structures - Research Leading to European Coastal Engineering Guidelines	M.W. Owen, Hydraulic Research, Wallingford, U.K.; with O.J. Jensen, Horsholm, Denmark; Y. Coeffe, Chatou, France; A. de Graauw, Grenobie, France; J. Van der Meer, Emmeloord, the Netherlands; H. Witte, Braunschweig, FRG	44 491 32233
Three Dimensional Numerical Modelling of Cohesive Sediment Transport Processes in Estuarine Environments	W. Zwilke, Univ. Hannover, Hannover, FRG; with Y. Coeffe, Chatou, France	49 511 7623456
G6 - Coastal Morphodynamics	H.J. de Vriend, Delft Hydraulics, Emmeloord, the Netherlands; with J. Fredsoe, Horsholm, Denmark; R.L. Soulsby, Oxfordshire, U.K.; H. Dette, Braunschweig, FRG; C. Teisson, Chatou, France; L. Hamm, Grenoble, France	31 52 743573
Circulation and Sediment Transport on Sand-Banks on the European Shelf	B. O'Connor, Univ. Liverpool, Liverpool, U.K.; with H. Oebieus, Berlin, FRG; A. Sarmento, Lisbon, Portugal; J. Williams, Birkenhead, U.K.	44 51 7086502

Marine Technology

Title	Coordinator and Partners	FAX Number
Acoustic Imaging Development (AC. I. D.)	M.E. Bouhier, IFREMER, La Seyne Mer, France; J. Romeling, Lyngby, Denmark; L. Bjorno, Lyngby, Denmark; M. Zakharia, Lyon, France; J.P. Sessarego, Marseille, France; K. Christiansen, Slangerup, Denmark; J. Papadakis, Crete, Greece; O.R. Hinton, Newcastle, U.K.	33 94 301372
Behaviour of Materials in the Deep Sea (MADS)	D. Festy, IFREMER, Plouzane, France; with A.M. Beccaria, Genoa, Italy; J. Solin, Espoo, Finland	33 98224135
Wideband Acoustic Imaging Classification System (WAICS)	C. Criado, SYMINEX, Marseille, France; with G. Vernazza, Genoa, Italy; G. Hogan, Watford, U.K.; C. Van Ruiten, Delft, the Netherlands; D. Jan, Brest, France	33 91 731850
A New Technology Instrument System for the Measurement of the Optical Properties of Marine Waters	E. O'Mongain, Univ. Coll. Dublin, Dublin, Ireland; with R. Dorffer, Geesthacht, FRG; J.M. Whyte, Malahide Ireland; M. McGarrigle, Castlebar, Ireland	353 1 837275
Modular Instrument Package and Its Application in Mediterranean Hydrothermal Research (MIPAMEHR)	P. Stoffers, C. Albrechts Univ., Kiel, FRG; with H. Backer, Kiel, FRG; A. Sioulas, Athens, Greece; J.R. Cann, Newcastle, U.K.	49 431 8802072
A Computer-Aided Design Environment for Underwater Acoustic Transducers for Scientific and Engineering Applications (CADACOUST)	M. Letiche, Thomson Sintra, Valbonne, France; with R. Coates, Norwich, U.K.	33 92 963066
Optimised Power Supply System Techniques for Free Swimming Vehicles	S.J. Milward, Marconi Comm. Centre, Leicester, U.K.; with G. Williams, Leicester, U.K.; A. Thouvenin, Toulon; N.P. Kyrtatos, Athens, Greece	44 533 871746

Title	Coordinator and Partners	FAX Number
Multi-Sensor High Resolution Intelligent Marine Observations of Ocean Floor on Continental Shelves (MOBIUS)	D. Lebarbe and D. Jan, Thomson Sintra, Brest, France; with J. Seniero, Lisbon, Portugal; G. Vernazza, Genoa, Italy; P. Peneau, Cesson Sevigne, France	33 98 050465
Shipping Noise Evaluation in Coastal Waters (SNECOW)	G. Tacconi, Univ. di Genova, Genoa, Italy; with D. Guyomar, Valbonne, France; A. Plaisant, Valbonne, France; F. Pinazzi, Genoa, Italy; F. Grassia, Genoa, Italy; A. Steiger-Garcao, Monte Caparica, Portugal	39 10 3532777
Combined Sensor and Information Technology for Subsea Positioning, Imaging and Control for Task Implementation	J. Lucas, Univ. Liverpool, Liverpool, U.K.; with J. Blight, Marseille, France; J.R. Amoros Serret, Madrid, Spain; H. Eulenberg, Julich, FRG; N. Tsagas, Xanthi, Greece	44 51 7944540
Mapping of Sea Bottom Topography in a Multi-Sensor Approach for Morphodynamic Studies	J. Vogelzang, Rijkswaterstaat, Rijswijk, the Netherlands; with G.J. Wensink, Marknesse, the Netherlands; W. Alpers, Hamburg, FRG; I. Hennings, Kiel, FRG; J.P. Matthews, Gwynedd, U.K.; D. van Halsema, Gravenhage, the Netherlands	31 703 952847
Development of an Automatic Instrument to Determine the Quantity of Organic Nitrogen Soluble in Sea Water	J. Benaim, Univ. de Toulon et du Var, La Garde, France; with E. Duursma, Den Burg, the Netherlands	33 94 081432
A Geophysical *In Situ* Probe for Physical Properties of Sediments (GISP)	Fr. Theilen, Univ. Kiel, Kiel, FRG; with J.P. Henriet, Gent, Belgium; T.M. Mc Gee, Utrecht, the Netherlands; G. Ollier, Plouzane, France; G.G. Ori, Bologna, Italy	49 431 8804432
Velocity and Refraction Index Profiling by Acoustic Remote Sensing (VERIPARSE)	J.J. Bosman, Rijkswaterstaat, Rijswijk, the Netherlands; with O. Gasparini, Rome, Italy; A Plaisant, Cagnes-sur-Mer, France; D. Nijveldt, Delft, the Netherlands	31 703 952847

Note: No projects in Category 4, Supporting Initiatives, were funded under MAST I. The MAST office anticipates that several Category 4 projects will be funded under MAST II.

Commission of European Community Report EUR 13427, Marine Science and Technology (MAST) R&D Programme, 1989-92, Research Contracts, is available through UNIPUB, 4611-F, Assembly Drive, Lanham, MD 20706-4391, 800-274-4888 or FAX: 301-459-0056. The report includes brief abstracts describing each project.

Operational Capabilities of Special Sensor Microwave Imager Data

by LT Karen Ebersole USNR/R and LCDR Larry Jendro USN LT Ebersole is a reserve officer living in London, U.K. She is an experienced Navy forecaster, having served at a U.S. Navy operational weather center. She collaborated on this article while performing her Active Duty for Training (ACDUTRA) as Oceanography/Environmental Systems Liaison Officer with the Office of Naval Research European Office. LCDR Jendro is the Liaison Officer for Oceanography and Environmental Systems at the Office of Naval Research European Office. He is an active duty naval officer from the U.S. Navy's oceanography community.

Satellites in Weather Forecasting

Satellites have provided extensive capabilities to meteorologists. With visible photographic imagery from space it became possible to see the structure of weather systems, their precise location and extent, and to watch their development and movement with time. Infrared (IR) satellite imagery allowed monitoring to be continued through hours of darkness. The IR also could be used with visible images to determine cloud type and the relative altitudes of the uppermost cloud layers. An active microwave radar altimeter, launched on GEOSAT, measured surface windspeed by processing the returns of active irradiation of the ocean surface to its altimeter antenna (Mognard and Katsaros 1990). Continued development of satellite meteorological instruments has led to the Scanning Microwave Radiometer. This passive instrument can "see" precipitation, sea spray, and areas of ice or snow even through clouds. The Special Sensor Microwave Imager (SSM/I) is the most recent of these instruments. Many papers presented at the international forum, the Fifth Conference on Satellite Meteorology and Oceanography[1], described research that used SSM/I data. The results reported indicate a substantial contribution by European researchers and show this powerful new tool provides the potential for immediate operational and research applications.

Satellite Radiometers

Passive satellite microwave imagery has been a part of weather forecasting since the mid-1970s, when the Nimbus 5 carried the electrically scanning microwave radiometer (ESMR-5). Additionally, the Seasat and Nimbus 7 launched in 1978 carried the scanning multichannel microwave radiometer (SMMR). These satellites sensed passive microwave radiation naturally emitted from the lower atmosphere. The data was analyzed to produce images of rain rates and distribution at a given moment (Barrett and Kidd 1990). The deployment of the SSM/I on board the Defense Meteorological Satellite Program (DMSP) satellite F8 has fostered further improvement of this technique of remote sensing.

The Special Sensor Microwave Imager

The SSM/I instrument was built by Hughes Aircraft Company, under the direction of the U.S. Naval Space Systems Activity and the U.S. Air Force Space Division. Designed primarily to support the Navy's Fleet Numerical Oceanography Command and the Air Force Weather Center, the SSM/I is significantly superior to its immediate predecessor, the Nimbus 7 SMMR instrument. Improvements include:

- A broader swath width (which is nearly twice as wide)
- Continuous operation (SMMR having operated only on alternate days)
- A more direct calibration scheme provided for its data
- Synchronous rotation of its feed horn and antennae
- Coaligned sampling of footprints from all channels
- Lower noise levels (Barrett et al. 1990b).

Research reported at the Fifth Conference on Satellite Meteorology and Oceanography disclosed its potential for many practical applications including:

- Rainfall monitoring
- Weather system development forecasting
- Mapping over-the-ocean surface windspeeds, sea states, and determining sea ice characteristics.

Specifications. The SSM/I is a standardized channel, linearly polarized, passive microwave system measuring naturally emitted, microwave, radiometric radiation.

Table 1. SSM/I Specifications

Frequency (GHz)	Nominal Footprint (km)	Resolution (km)
19.35	69 x 43	55
22.235	50 x 40	50
37.0	37 x 28	35
85.5	15 x 13	15

[1] Jointly sponsored by the American Meteorology Society and the Royal Meteorology Society, London, September 1990.

All frequencies are horizontally and vertically polarized, except for the 22.235 GHz channel, which is only vertically polarized. The SSM/I is the first sensor to be equipped to monitor microwaves in the 85.5-GHz region.

Orbit Characteristics. The first SSM/I was launched June 19, 1987, on the DMSP F8 satellite. It occupies a circular, sun-synchronous, near-polar orbit at an altitude of 833 km with an inclination of 98.8° and an orbital period of 102.0 minutes. This gives an 06.12 hours (local time) ascending mode equatorial crossing and provides a swath width of 1394 km. The SSM/I has been recently joined by a second SSM/I satellite, launched in December 1990. The new satellite has a somewhat elliptical orbit and is therefore not sun-synchronous. All channels, including the 85-GHz channel (which has stopped functioning on the DMSP F8 satellite), were functioning properly at time of launch.

Principles of Operation. Although primarily designed to detect ocean windspeed, ice characteristics, precipitation intensity, cloud water content, and land surface moisture, research has shown the SSM/I also to be of considerable value in rainfall monitoring. At microwave frequencies, clouds are relatively transparent, the only major source of attenuation of surface emitted radiation is hydrometeors of precipitation size. This allows physically direct measurements of rainfall to be obtained (Barrett and Kidd 1990).

Determination of Surface Characteristics. Observed microwave brightness temperatures (Tb) originate from the Earth's surface and from atmospheric constituents. Factors affecting the emission from the Earth's surface include the nature of the surface (i.e., land, water, ice) and its temperature. Ice microwave emission characteristics allow ice-covered areas to be determined from algorithms derived directly from physical measurements. Ice age analysis is also possible. The emissivity of sea ice is much higher for first year ice then for multi year ice. The microwave radiation from land depends on soil moisture, snow water content, vegetation and surface type. The proper choice of instrument parameters allows determination of terrestrial characteristics (Hollinger and Sandlin 1990).

Rain Determination. Radiometrically cold backgrounds (oceans) allow areas of rain above it to be distinguished while the radiometrically high temperatures over land have prevented use there (recent research provides algorithms to overcome this problem) (Barrett and Kidd 1990). In precipitation, the passive microwave radiation naturally emitted by atmospheric constituents depends mainly on the concentration and distribution of cloud water, rain drops, and ice particles (Kummerow 1990). The brightness temperature is dependent on the amount of absorption/emission or scattering occurring. The cloud water and liquid raindrops are the main sources of absorption and emission of microwaves, with the raindrops providing a direct relationship between rainfall and observed microwave radiances (Barrett and Kidd 1990). Raindrops of larger sizes will absorb, emit, and scatter microwaves, especially at the higher frequencies. Because of the refractive properties of ice, ice particles will scatter most of the incident microwave energy. The relative importance of each of the factors mentioned above is a complicated function of the microwave frequency sensed and the concentration of each constituent based upon its height within the cloud (Kummerow 1990).

Rain Rate. A straightforward deduction of the surface rainfall rate is difficult because the brightness temperatures are dependent on the vertical distribution of particles. However, simultaneous analysis of all available microwave information allows not only surface rainfall to be determined, but the associated vertical precipitation composition as well (Kummerow 1990).

Windspeed. In areas where the atmospheric absorption/emission levels are low, the amount of microwave energy emitted from the ocean surface can be measured. This energy depends on the wave structure and foam coverage, which are functions of the surface windspeed. The windspeed algorithm developed for the SSM/I, and based on raw Tb. The algorithm gives measurements accurate to about 2 m/s (Mognard and Katsaros 1990), and can be combined with products from numerical forecast centers to provide optimum guidance (Boyle and Lee 1990).

Experiments Reporting the Use of SSM/I Data

Storm Location and Structure. Microwave imagery has been particularly useful in storm analysis when synoptic features are masked by the top level of the cirrus shield, as frequently seen on IR imagery. This commonly occurs with tropical storms, the cirrus shield concealing many features that could be used to classify the intensity of the storm. The storm center and surrounding cloud and rain bands hidden on IR imagery are detected by the SSM/I because the microwave frequencies are sensitive to water vapor, and liquid and solid hydrometeors, but "see" through the small ice crystals of the cirrus shield (Glass and Felde 1990). Localization of tropical storm centers and extent of cloud and rain bands, and identification of areas of greatest convection are all advantages of using SSM/I imagery in the analyses of tropical storms.

Table 2. Environmental Parameters Retrieved by the SSM/I

Parameter	Geometric Resolution	Range Values	Quantization Levels	Absolute Accuracy
Ocean surface windspeed	25	3-25 m/s	1	±2 m/s
Ice				
Area covered	25	0-100%	5	±12%
Age	50	1st year, multiyear	1yr, >2yr	none
Edge location	25	n/a	n/a	±12.5km
Precipitation				
Over land areas	25	0-25 mm/h	0, 5, 10, 15, 20, ≥25	±5 mm/h
Over water	25	0-25 mm/h	0, 5, 10, 15, 20, ≥25	±5 mm/h
Cloud water	25	0-1 kg/m^2	0.05	±0.1 kg/m^2
Integrated water vapor	25	0-80 kg/m^2	0.10	±2.0kg/m^2
Soil moisture	50	0-60%	1	none
Land surface temperature	25	180-340 K	1	none
Snow water content	25	0-50 cm	1	±3 cm
Surface types	25	12 Types	n/a	n/a
Cloud amount	25	0-100%	1	±20%

(Hollinger, 1990)

Tropical Storm Structure Analysis Using SSM/I and Operational Line Scanner Data. Glass and Felde (1990) analyzed SSM/I imagery data from 10 tropical storms in the western Pacific from 1987 to 1989 to classify the microwave response to typical conditions near the storm's center. This study demonstrated new methods of analysis possible using SSM/I data with Operational Linescan System (OLS) data. This combination of visual and IR data was used to determine the location of tropical storms, regions of maximum convection, and overall storm dimensions.

When the 85-GHz Tb is plotted against distance across the storm, the location of the storm center was found at the point corresponding to the Tb peak surrounded by Tb minima (indicating ice and large raindrops in the eyewall of the storm). The 19-GHz vertical channel is sensitive to surface winds and precipitation, so is well suited to define the extent of the storm. Analysis of Tropical Cyclone Freda observed northwest of Guam on September 11, 1987, validated the use of these characteristics. Figure 1 shows the center of the storm had the warmest 85-GHz Tb in the storm image. Correspondingly, Figure 2 shows the 37-GHz polarization difference at the storm center was relatively large, indicating that the source of much of the energy received at this frequency was from the ocean surface. The utility of the 19-GHz vertical profile is also shown in Figure 1. The 19-GHz vertical maxima disclosed the rain bands, while the Tb value of 230 defined the limits of the storm.

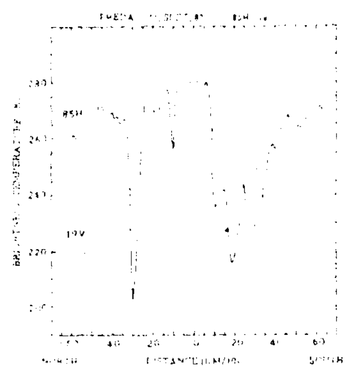

Figure 1. SSM/I 85H and 19V N-S cross-section of Tropical Cyclone Freda

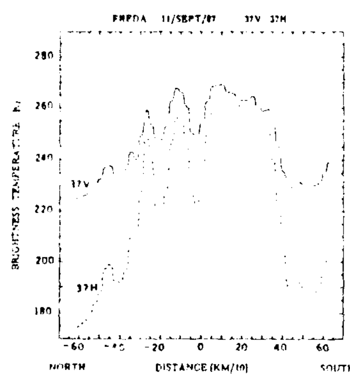

Figure 2. SSM/I 37V and 37H N-S cross-section of Tropical Cyclone Freda

Evolution of Atmospheric Fronts Over the Ocean as Observed with the Special Sensor Microwave Imager and the GEOSAT Altimeter. Mognard and Katsaros monitored the evolution of two northern Pacific cyclones in October 1987 combining SSM/I and the GEOSAT radar altimeter data instruments in the storm analysis. Composite pictures were produced from SSM/I and GEOSAT data and comparisons between the data and model predictions made. The GEOSAT data included altimeter windspeed and altimeter derived windspeed gradients. The SSM/I data were used to generate scaler water-vapor gradients from integrated water-vapor fields. Gradients with values greater than 0.1 kg/m^2 used to locate atmospheric fronts. Later comparison of these analyses with numerical products from the National Meteorological Center (NMC) indicated accurate frontal placement. (Mognard and Katsaros 1990). Frontal rain was indicated by a 37-GHz horizontal brightness temperature threshold of 200 K. Windspeed was inferred from a linear combination brightness temperature of 37 GHz, 22 GHz, and 19 GHz (Gooberlet et al. 1989). Regions of high windspeeds associated with the fronts were sensed by the GEOSAT and also with good agreement by the SSM/I. The two systems complement each other in the identification of frontal locations. The large footprint and larger view (about 50 km) of the SSM/I give system structure while details, such as local wind minima, are further resolved with the altimeter (resolution about 10 km). Mognard and Katsoras (1990) demonstrated that the combined SSM/I and altimeter analysis of the surface front provides both higher resolution and greater coverage than those now provided by the NMC analysis.

Winds from the SSM/I Versus Numerical Model Output: A Forecaster's Perspective. Boyle and Lee (1990) compared the SSM/I and Navy Operational Global Atmospheric Prediction System (NOGAPS) of Naval Oceanographic and Atmospheric Research Laboratory (NOARL). The high resolution of SSM/I retrievals is illustrated together with NOGAPS windfields for a north-south cross-section just south of Alaska (see Figure 3). The abrupt spikes in the SSMI windfield appearing from points 50 through 105 relate to contamination by precipitation.

The NOGAPS winds in the same area give a better overall portrait of the windspeed. However, the NOGAPS model does not accurately reflect the detail of the wind field picked up by the SSM/I from points 0 to 30. The SSM/I data unveils windspeed peaks at 15 m/s, while the low resolution NOGAPS misses these, showing peaks at only 5 m/s. In general, Boyle and Lee (1990) found that the SSM/I and NOGAPS wind speeds agreed well and

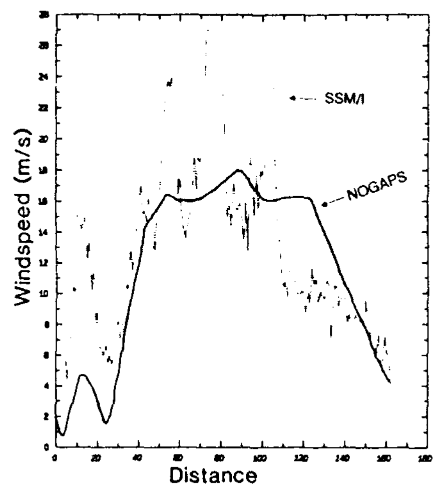

Figure 3. A profile of SSM/I winds with NOGAPS windspeeds

complimented each other. Their combination was shown to provide significantly better nowcasting than either product alone. The NOGAPS provided wind direction and consistency in time and space, and a check on the SSM/I windspeeds in areas of significant precipitation. The SSM/I provides a snapshot of current conditions that can be used to update the model. The result is an improvement in timeliness, accuracy, and resolution.

Mesoscale Meteorology in the Polar Regions from a Coupling of NOAA (TOVS) and DMSP (SSM/I) Data. Claud, Scott and Chedin (1990) compared SSM/I data with that of the NOAA TIROS-N Operational Vertical Sounder (TOVS) in the analysis of a sudden cold air outbreak over the Norwegian and North Seas on February 28, 1988. The TOVS can extract the vertical structure of the atmosphere in terms of temperature, moisture, and cloudiness. Vertical temperature profiles can be obtained with good accuracy in most weather conditions but the determination of water vapor profiles or total water content is not possible if the cloudiness is above a certain threshold. This is a significant weakness because water vapor and total water content can be used to determine weather system positions and degree of development of these systems. The SSM/I provides a means to alleviate this problem over the sea. Good qualitative agreement overall was found when comparing the water vapor fields of the two sensors. Both produced similar meteorological features in areas where validation was difficult due to sparse observation coverage. The SSM/I was able to provide water vapor content in spite of existing rain or significant cloud cover. The TOVS was able to determine water vapor content over sea ice and land. Each supplied data where the other was deficient.

Rainfall Monitoring by the SSM/I in Middle Latitudes. Barrett and Kidd (1990) made comparisons between SSM/I and the Frontiers radar network generated images taken in August 1987 in southern Britain. This led to the development of new methods which promise to extend SSM/I rainfall monitoring over land surfaces. In the difficult situation of determining rain over land where the radiometrically warm surface temperatures obscure microwaves from rain in the emissive/absorption regime, a frequency algorithm is used. This algorithm involves subtracting the radiation measured at 85 GHz from the radiation measured at 37 GHz. A positive result indicates rain is present. The desire to see rain over both the land and the sea surface led to a procedure which combined the use of both the frequency and polarization algorithms. This simultaneous use of the algorithms presented the possibility of setting the rain/no rain threshold of the polarization technique, based on the results of the frequency algorithm applied at the same place and time.

Figure 4 shows a plot of the polarization algorithm against the frequency algorithm for southern Britain for the period in August 1987. The vertical scale shows the number of observations and rainfall rates as determined by the Frontiers radar network. While some of the radar-identified rainfall data lie below the frequency algorithm zero line, most of the points above the line are correctly identified as rainfall. The regression between the polarization algorithm data and the non-negative frequency algorithm data yields a Polarization Corrected Temperature (PCT) threshold and associated rain/no-rain boundary of 272 K. Rainfall rates may be obtained subsequently from the algorithms through simple regression with the radar data.

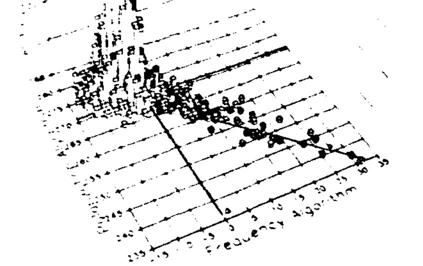

Figure 4. Comparison of polarization and frequency algorithms for southern Britain (August 1987)

After the polarization rain/no rain threshold is set, the rain areas are generated using either the frequency algorithm for areas over land or the calibrated polarization algorithm for areas over water and coastal regions. A validation of this technique was provided by comparing the rain/no rain boundaries determined by the Frontier radar system with those developed from the SSM/I data using the Barrett/Kidd procedure. Analysis of this comparison over time indicates that the polarization threshold from the frequency algorithms may be seasonally variable. Additional comparisons between rain/no rain boundaries and mean temperatures indicated that these thresholds may be geographically variable as well. Using the SSM/I data calibrated from the Frontiers radar could provide immediate operational use by incorporating the satellite data to extend the range of the radar.

Current Directions for SSM/I Operational Application.

Various U.S. Navy research establishments and operational centers have made progress in the operational use of SSM/I data. The Navy Oceanographic and Atmospheric Research Laboratory (NOARL West) in Monterey, California, has been successful in assimilating SSM/I windspeeds into the Navy Operational Global Atmospheric Prediction System. Additionally, weather analysis products created by overlaying SSM/I derived fields over standard weather analyses have been developed. Figures 5 through 8 show prototypes of these products applied to a low over Newfoundland. Figure 5 describes the synoptic situation with surface pressures; Figure 6 displays precipitable water from the NOGAPS model and SSM/I data; Figure 7 shows geographical areas of precipitation from SSM/I data; Figure 8 puts SSM/I windspeed data over NOGAPS generated wind stream lines.

The combined U.S. Navy/U.S. Air Force Joint Typhoon Warning Center (JTWC) now depends on satellite imagery for tropical cyclone forecasting. The JTWC has found SSM/I to be a powerful tool in storm localizing, assessing, and tracking. Techniques for using SSM/I data developed at the Naval Research Laboratory, Washington, D.C., to fix the centers of storms have reduced location uncertainty by a factor of three. Further improvement is anticipated with the use of SSM/I water vapor structure products (Hollinger 1990).

The Remote Sensing Unit (RSU) at the University of Bristol, U.K., has been actively researching the use of SSM/I data since the mid-1980s, initially accessing the SMMR-7 instrument and more recently, the DMSP satellite, under a cooperative agreement with NOAA. Results of these studies have monitored the validity of SSM/I rainfall data. Experiments coupling the SSM/I rain/no rain images and that of ground-based radar networks have demonstrated that a seasonal and

University of Bristol Remote Sensing Unit

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Introduction

The Remote Sensing Unit (RSU) at the University of Bristol is a center for passive microwave remote sensing research. The RSU is well-equipped and staffed, very ably directed research organization. Dr. Eric Barrett, Director, presented an impressive record of accomplishments in the operational application of emerging remote sensing products. The RSU's aggressive interest in the future operational use of the Special Sensor Microwave Imager (SSM/I), will ensure its leading role in the development of meteorological and oceanographic products from SSM/I data.

Established by order of the University Senate in 1983, the RSU has since become the largest focused research group in the Department of Geography. By mandate, the RSU provides a focus for an expansion of teaching and researching in remote sensing at the University of Bristol. The RSU is organized to facilitate collaboration with industry on the developing techniques, algorithms, and software to further the operational implementation of satellite image data.

Recently, the RSU was re-equipped with a networked system of SUN workstations running ERDAS, LUCID, and locally purpose-built software; two TDS HR48/OPUS PC digitizing systems, plotters, and printers; and a Ramtek 4500 video recorder. Via the departmental computing network, ARC-INFO and other geographic information system software packages are available. The RSU is the only foreign institution that is a partner to a memorandum of understanding with the National Oceanic and Atmospheric Administration (NOAA) for cooperative activities. The activities include research, training, and dissemination of NOAA data and products. The RSU is one of three overseas participants in the National Aeronautics and Space Agency (NASA) new WETNET Project for interdisciplinary research based on Defense Meteorological Satellite Program (DMSP) SSM/I passive microwave data. A Mini-Mcldas-equipped PS-2 display system is being provided, along with a magneto-optical disk drive and hot line, to NASA Marshall Space Flight Center, Huntsville, Alabama. While individual members of the RSU staff are nominated to lead and manage individual projects, there is close collaboration and team activity wherever possible (see Table 1).

Hydrometeorology

Over several years, RSU's extensive research has led to developing a technique for polar-orbiter satellite improved rainfall monitoring (internationally known as *the Bristol method*). This rainfall monitoring technique is available either in manual or interactive form, the latter being known as the Bristol/NOAA interactive scheme (BIAS). Over a 5-year collaboration with NOAA, BIAS was developed to provide daily rainfall maps over major crop-growing areas of the world as an operational service to the Department of Agriculture. The program can also be used to provide estimates of special (extreme) rainfall events, or of accumulated rainfall over catchment basins for hydrology and water management. The scheme is being used in these ways to support hydrological monitoring by government bodies in various developing countries. The BIAS is now available for personal computers, as well as on mainframe computers. New automatic methods based on geostationary satellite data (ADMIT and PERMIT) have been developed with European Space Agency (ESA) and Food and Agricultural Organization (FAO) sponsorship for dry day, drought, and rainfall monitoring over major continental regions.

Present projects are focused mainly on developing passive microwave algorithms, using data from the new SSM/I, for rainfall, sea ice, sea state, and overland snow mapping and monitoring. This work is being funded by NOAA and NASA and is being supported by the U.K. Department of the Environment (DOE), the Ministry of Defence, the Meteorological Office, and the Natural Environment Research Council (NERC).

Applied Hydrology and Water Management

In contractual work for the U.K. DOE, the RSU has developed satellite techniques for routine weekly snow area and surface characteristics mapping from NOAA high-resolution picture transmission (HRPT) (1-km resolution) imagery. These images can be used in support of established conventional reporting procedures to give improved snow area advisories. The RSU's proposal to ESA for Earth Resource Satellite (ERS-1) snow cover work has been given priority and work will begin in 1992. Similar efforts are being made toward applying satellite evaporation algorithms on regional and national scales, and using satellite rainfall monitoring techniques for quantitative precipitation forecasting, especially over coastal zones affected by rain-bearing cloud advancing from sea or ocean areas.

Table 1. Academic Staff and Principal Interests

Name	Principle Interests
Dr. E. C. Barrett (Director)	Satellite climatology, hydrometeorology, satellite/sensor system specification and payload design, operational applications of environmental satellite data
Dr. L. F. Curtis (Honorary Senior Research Fellow)	Land use and vegetation surveys, remote sensing applications in national parks
Dr. H. A. Osmoston (Senior Lecturer)	Air photography and earth resources satellite applications in mountainous regions, ice and snow studies, forestry
Dr. R. W. Herschy (Honorary Research Fellow)	Hydrology and water management, use of satellite data collection platform systems
Mr. J. O. Bailey (Lecturer)	Physical characteristics of image data, especially microwave, evapotranspiration and soil moisture monitoring
Dr M. J. Beaumont (Research Fellow)	Computer graphics and image processing, 3-D modeling, computer drafting
Dr. A. R. Harrison (Lecturer)	Land use evaluating and monitoring, geographical information systems, image processing, computer cartography
Mr. T. S. Richards (Research Associate and Systems Manager)	Software developing and managing, land cover monitoring (especially in semiarid environments), snow mapping and monitoring
Mr T. J. Bellerby (Postdoctoral Research Assistant)	Satellite rainfall monitoring over Japan, applications of remote sensing in archaeology, computer programming, software design
Mrs K. A. Brown (Research Assistant)	Land use vegetation mapping, satellite rainfall monitoring, conference organization, editorial activities
Dr. C Kidd (Postdoctoral Research Assistant)	Use of passive microwave satellite imagery to monitor rain, snow, and sea state
Mr D A. Kilham (Research Assistant)	Satellite meteorology and climatology with special reference to the eastern North Atlantic Ocean and North Sea

Vegetation and Crop Prediction

Methods have been developed to analyze satellite visible, infrared, and passive microwave image data for recognizing, mapping, and monitoring natural vegetation and agricultural crops, and their productivities, supported by NOAA, NERC, and the European Community. Satellite vegetation index products prepared in the RSU have formed one of the bases for the representation of relief and vegetation in the major new Peters World Atlas published by Oxford Cartographers in 1989.

Land Use Assessment and Planning

The RSU has active interests in the interpretation and analysis of ERS data (from Landsat and Earth Observation Test System [SPOT]) for a wide range of applications--from land use planning in national parks through nature conservation to the assessment of possible new locations for retail outlets. This work has been conducted in conjunction with U.K. government departments and commercial consulting firms.

Geology

The RSU now offers experience in interpreting satellite (especially Landsat and SPOT) and aerial image data for geologic analyses. This information can be used for a range of geologic and geotechnical applications, including hydrogeology, engineering, and economic geology. Methods are being developed to integrate image data with other data bases (e.g., geological maps, surficial analyses, verified geological structures, geophysical plots, and borehole measurements) to produce a comprehensive geologic information system. Recent research at the RSU includes studies of the geologic fracture traces of the Mendip Karst aquifer, an environmental impact statement of the English Stones Severn tidal barrage scheme, and the geological mapping for mineral surveys in central Portugal. Other related research interests within the university include the geotechnical characteristics of the Severn Estuary alluvium, early Mesozoic extension and basic evolution, sediment transport in the Bristol Channel, and the evolution of the Severn Estuary including sea-level change.

Geoinformation Systems

In addition to its access to the ARC-INFO geographic information system, the RSU's image processing system has been enhanced to permit the display of point, line, and polygon ancillary data sets as spatially registered overlays to image data. This has been achieved largely through a modification to existing software and file formats to facilitate plotting of a graticule and world outline consisting of coastlines and major water bodies over geometrically corrected images. Other data such as synoptic meteorological information can also be displayed symbolically at station locations to allow time-lapse image interpretation and analysis. Software development is currently underway to extend such techniques for more flexible integration and manipulation of image and map data. Recent geographic information system (GIS) projects have ranged from major DOE and FAO studies to a minor (but fascinating) assessment of lighting levels in supermarkets for a civil engineering firm.

Satellite System Design

The RSU works in conjunction with the U.K. Department of Trade and Industry, NERC, the ESA, and NASA. Also, the RSU contributes to several proposed satellite projects with respect to the identifying and specifying user needs, especially in hydrology and water management.

Satellite Applications Software Packages

The RSU is linking with other universities and major aerospace companies to develop and market satellite reception facilities, image processing systems, and sets of software packages for operational environmental monitoring based on data from meteorological satellites. Personal (micro) computers are being used for such purposes. Clients include the Space and Upper Atmosphere Research Commission of Pakistan (SUPARCO), with whom a collaborative program of work is being undertaken, and the major Italian telecommunications company, Telespazio.

Training Courses

The RSU has organized and led remote sensing training courses, both in Bristol and abroad. Locations include Tunisia for the World Meteorological Organization, Malta for the Council of Europe, Zimbabwe for United Nations Development Program (UNDP), and the U.K. for Kew Royal Botanic Gardens.

U. S. Navy Interest

In terms of naval applications the work done by the RSU with the SSM/I is the most interesting.

The continuing independent research into the development of SSM/I algorithms for rainfall, wind speed, and ice coverage provides the potential for fruitful collaborations for navy-sponsored investigators. These research interests of the RSU coupled with the availability of conference facilities and accommodations at, and in the vicinity surrounding Bristol University could make it an attractive site for an international workshop in satellite meteorology.

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Delft Hydraulics

by CAPT Thomas H. Kinder, USNR, Ph.D., a visiting scientist/reserve officer to the Office of Naval Research European Office. CAPT Kinder is Director Reserve Technology Mobilization, Office of the Chief of Naval Research, Arlington, Virginia. Dr. Kinder is Manager, Coastal Sciences Program, Office of Naval Research, Arlington.

Introduction

Founded in 1927, the Delft Hydraulics (Delft), the Netherlands, is one of the leading engineering institutions of its type in Europe. Although it retains close connections with the Netherlands government, it is a private, not-for-profit laboratory. Since the 1960s, Delft has been a chief developer and practitioner in simulation modeling (physical and numerical) of rivers, estuarine, and near-shore hydrodynamics. Until the 1970s, work was concentrated on coastal and river projects in the Netherlands--notably, including large projects that were motivated by the disastrous storm surge of 1953. Recently, the work has expanded to water quality and resource issues, and the clientele has broadened such that 40 percent of the customers are foreign.

The headquarters is located in the old Dutch city of Delft, just north of Rotterdam. The second location, "de Voorst," is in the northeast near Emmeloord. This second campus was established shortly after the World War II when space was limited near Delft. The opening of a new polder (reclaimed land) offered room for expansion. Initially, de Voorst was dedicated to large open air physical models. At present, work there still includes large (indoor) physical models, but numerical models are perhaps dominant. Funding is about $40 million annually (70 million Dutch guilder [f]), with about $6 million (10 million f) in research. Most of the research is tied closely to applied problems. There are 525 employees working in these two sites.

Technical employees are divided into six divisions:

1. Harbors, coasts, and offshore technology
2. Rivers, navigation, and structures
3. Estuaries and seas
4. Water resources and environments
5. Hydrosurveys
6. Industrial hydrodynamics and dredging technology.

As the titles suggest, some divisions are tied rather directly to specific industrial requirements, while others pursue rather broad technologies. Research is often of the best quality, and published in open literature such as *Journal of Fluid Mechanics, Coastal Engineering*, and *Journal of Geophysical Research*.

A coastal studies center has just been established between Delft Hydraulics, the Delft University of Technology, and the University of Utrecht. The leadership of the center will include J. Battjes and H. de Vriend. The purpose is to foster both improved education and research in coastal and estuarine science and engineering.

Important Physical Facilities

Although numerical modeling continues to gain importance in environmental fluid and sediment mechanics, physical modeling continues to play an important role. At Delft, emphasis has shifted from realistic simulations of entire systems to more idealized process experiments. The large size of many Delft facilities reduces the errors from scale effects. Delft has a large collection of unusual capabilities, providing a unique position in this field. Some of the more important facilities will be described.

The tidal flume is used for studies of flow and sediment transport in unsteady and stratified flow. The flume is 130-m long, and 1-m wide and high. The tank's walls are glass to permit the use of qualitative and quantitative optical measurements. Water level can be varied between 0.1 and 0.9 m, with simulated tidal ranges up to 0.15 m. Sea water density (salinity stratification) varies over the range 1.00 - 1.03 g/cc, with silt concentrations up to 0.003 g/cc. A steady river discharge is permitted. The flume is thus designed to mimic the key elements of estuaries:

- Tidal fluctuations
- Stratification
- Sediment discharge by the river.

Plans for the facility will include a recirculating lower layer to study stratified flows with stronger vertical shears. An interesting annular tank is used in the study of cohesive sediments. The tank is 2.3 m in diameter, and the circular channel is rotated opposite to a ring in contact with the surface. This produces a nearly uniform turbulent field with minimal secondary currents. The tank avoids the limitations of short lengths in straight flumes and the problems associated with floc disruption by pipes and pumps.

The large wind wave flume permits mechanically generated waves to interact with wind. The flume is 100-m long, 8-m wide, 2.4-m high, and permits a water depth of 0.8 m. Irregular waves with heights of 0.3 m and a wind speed of 15 m/s can be obtained. Details of the very small waves (important for understanding the small scale hydrodynamics and interaction with electromagnetic radiation) require a local wind and cannot be simulated by mechanical wave makers alone.

The multidirectional wave basin can generate different frequencies from different directions--simulating, for example, a sea and swell from different directions. This capability also permits testing theories of noncollinear wave-wave interaction. The facility is 26-m wide by 60-m long, with a 0.75-m water depth. Wave periods 0.4-3.0 seconds can be generated to a maximum wave height of 0.3 m.

A large oscillating water tunnel is available for studying sediment mechanics under shoaling waves. The test section is 15-m long, 0.3-m wide, has 0.3 m for sediment and 0.8-m high for water. The test section has glass sides, permitting flow visualization and optical measurements. The tank can be tilted to simulate near-shore slopes. The acceleration, velocity, or displacement of the pistons that drive the water limits the maximum period-velocity combination that can be simulated. For example, at 1-m/s velocity, wave periods of 4-15s can be simulated. The flows can be asymmetric to mimic the trough-crest differences. There are plans to add the capability to have a steady flow imposed on the oscillations.

One of the most impressive facilities is the Delta wave flume, which is 240-m long, 5-m wide, and 7-m deep. For a 5-m water depth, the wave maker is capable of 2.5-m regular (monochromatic) waves or 1.9-m irregular waves with periods of 1-12 s. The tank is equipped with an active wave compensation system. The wave maker is adjusted to compensate for partially reflected or second-order waves, which are detected at the wave maker in real time. Such waves can interfere with the desired incident wave generation if not kept to low amplitude.

Because of the large concentration of facilities and trained staff, Delft is participating in the European Community (EC) plan to support large-scale scientific facilities. The entire program began in 1989, and 4-year funding is estimated at 40 million European Currency Units (ECU). The idea is to leverage existing large facilities for EC scientists by underwriting the facilities cost for experiments. Delft will be hosting about 10 individual research teams working on a variety of problems, probably receiving infrastructure support exceeding 2 million ECU. Delft researchers play a central role in some of the projects and are limited to support roles in others.

During summer 1991, the U.S. Army Corps of Engineers (USACE) led a laboratory experiment entitled Supertank at the Oregon State University facility. The experiment focused on cross-shore sediment transport with intensive measurement techniques by multiple investigators. As the results from this experiment are digested, there is a possibility for a follow-on collaboration with a European experiment in the Delta flume at Delft. This collaboration may be partially supported by the EC facilities program.

Applied Coastal Research

Delft, along with five other European hydraulic institutes (Danish Hydraulic Institute, Horsholm, Denmark; Hydraulic Research Wallingford, United Kingdom [U.K.]; Laboratoire Nationale Hydraulique, Chatou, France; SOGREAH, Grenoble, France; and Technical University of Braunschweig, Federal Republic of Germany [FRG]), are working together on guidelines for coastal engineering structures. The project is funded by the EC Marine Science and Technology program (MAST) (see page 2) at 1 million ECU for 30 months. The idea is to improve and collate existing understanding and guidance. However, a handbook (analogous to the USACE Shore Protection Manual) may be too ambitious given the various legal climates that influence handbooks that codify accepted engineering practice.

The project has three major thrusts:

1. Numerical formulation for wave motion on smooth and porous structures
2. Wave impact loading on vertical structures, including dynamic response
3. Wave loading and structure response for both rubble mound and berm breakwaters.[1]

Methodologies include numerical modeling, laboratory experiments, and measurements on prototypes.

Remote Sensing

Delft has several research interests in remote sensing techniques, especially relating to surface waves (e.g., scatterometers) and bottom topography. They are exploring both radar and optical methods to map the bottom, but find more success with radar. The work is broadly collaborative, and participants include the Jet Propulsion Laboratory, Pasadena, California, and the University of Hamburg, FRG.

Motivations for a rapid survey of a large shallow region are many, but two are input to morphological evolution models or pipeline routing. The ability to acquire rapid bottom topography, even of modest accuracy, can quickly constrain survey work and focus attention on critical areas. One of the interesting attempts is using radar (usually synthetic aperture radar [SAR] or side looking airborne radar [SLAR]) or optical instruments. Either the radar backscatter or sun glitter are measured to infer bottom depth. Radar is presently the favored method largely because it does not rely on the sun. There are projects elsewhere using laser systems as an optical source.

[1] A berm breakwater has a toe of stones, smaller than the armor, designed to dissipate wave energy.

Physically, the ability to measure bathymetry with aircraft radar follows three steps.

1. Interaction between the water current and the bottom causes surface current variations on similar scales
2. The resulting spatial pattern of the surface current causes the surface gravity wave spectrum to change (as waves propagate into different horizontal current gradients)
3. Finally, the radar intensity varies as a function of the surface wave modulations.

The trick is not only to understand these processes adequately, but to be able to invert the process so that the radar image reveals the bottom bathymetry.

One of the favorite test beds for this technique is the sand wave field off the coast of the Netherlands. Regular sand waves with wavelengths of 500 m and heights of 5 m, exist in about 20-m depth. Recent experience suggests the practical ability of a radar bathymetric system. About 60 percent of the time, the waves (wind exceeding 3 m/s) and current (tidal speeds exceeding 0.4 m/s) are adequate to develop useful signals. In this ideal environment, accuracies in 30-m depth are about 3 m (absolute accuracies require some knowledge of depth within the field of study, but a few scattered soundings suffice). Optimistically, accuracies of about 5 percent may be achievable in water depths of a few tens of meters and where strong tidal currents make current profile predictions straightforward.

Summary

Delft Hydraulics is a strong applied research and consulting laboratory with significant high-quality basic research to support application. They have an exceptional physical facility for nearshore problems, and they are collaborating actively with European institutes and universities. Much of their research is of interest outside Europe, and they are open for collaborative basic research. Refer to Table 1, Delft Hydraulics Points of Contact.

Table 1. Delft Hydraulics Points of Contact

Name	Title (Project)	Address	Tel/FAX
Huib J. de Vriend	Research Advisor (MAST Coastal Morphodynamics Project)	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
Marcel J. F. Stive	Deputy Director, Harbours, Coasts and Offshore Technology (Supertank)	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
Jentsje W. van der Meer	Head, Coastal Structures Group (MAST Coastal Structures Project)	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
Jan K. Kostense	Head, Hydrodynamics Section (EC Large Facilities Project)	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
Han Wensink	Head Remote Sensing Section (SAR/SLAR Bathymetry Project)	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
J. van der Weide	Mediterranean Regional Manager, Estuaries and Seas Division	P.O. Box 152, 8300 ad Emmeloord, the Netherlands	31 5274 2922/ 31 5274 3573
C. Veeningen	Executive Director	P.O. Box 117, 2600 mh Delft, the Netherlands	31 15 569353/ 31 15 619674
Johan C. Winterwerp	Head, Morphology and Sediment Transport Section (Cohesive Sediment and Stratified Flow Projects)	P.O. Box 117, 2600 mh Delft, the Netherlands	31 15 569353/ 31 15 619674

Radiation Monitoring Technology for Space Station Freedom and Beyond

by LCDR Michael Stanford, Ph.D, a visiting scientist/reserve officer to the Office of Naval Research European Office. LCDR Stanford is affiliated with Office of Naval Research/Naval Research Laboratory Technology Mobilization Unit 410 in Houston, Texas. Dr. Stanford is Chief Scientist, EHS Radiation Monitoring SUB System, McDonnell Douglas Space Systems Company, Houston, Texas.

Space Station Freedom Radiation Environment at LEO

Low Earth Orbit (LEO) space flight involves exposure to a complex mixture of primary radiation types (Jursa 1985). These include trapped protons (mostly from the South Atlantic Anomaly) and electrons, galactic cosmic radiation (GCR) (not a significant contributor to overall dose at Space Station (Station) Freedom's orbital parameters). Plus, the LEO space flight involves exposure from secondary radiation products generated by collisions of the primary radiation with the Station, its furnishings, and within the crew's bodies. This secondary radiation consists mainly of fragments of heavy ion projectiles and fragments of nuclei hit by energetic particles, including neutrons, electrons, spallation products, and gamma rays. Additionally, the radiation environment will vary over the length of the entire solar cycle.

Therefore, the radiation environment within the Station[1] will be constantly changing in intensity and composition and may vary significantly over the life of the station. The radiation experienced at a given point within the station is strongly dependent upon the external radiation impinging on the structures of the spacecraft (as described above) and the amount and composition of these materials (spacecraft walls, furnishings, stowage, electronics). Structural materials[2] both attenuate the incident radiation and serve as a source of complex secondary radiations. Because of these multiple interactions, the radiation within the Station will be considerably more complex than the primary radiation incident upon it. The radiation is highly time-variable caused by the changing orientation of the structural materials and the varying incident radiation field. This complex multicomponent radiation field presents a unique and difficult radiation measurement problem for any space radiation protection program.

[1] Space Station Freedom will fly in a 28.5-° inclination between 150-250 nautical miles.

[2] The final configuration of Freedom's hull construction has yet to be decided.

Previous Radiation Exposures on Manned Spacecraft

Space Shuttle flights to date have involved relatively low career doses. Details of exposures encountered during Space Transportation System (STS) missions can be seen in Figure 1 (Hardy 1991). Additionally, altitude has a strong effect on the exposure received by STS crews. The lowest dose rate noted in these missions occurred on flight STS-38, which flew at a low altitude and at a 28.5-° inclination. The enhanced effect of altitude can be seen from the data from flight STS-31, the Hubble Space Telescope Deployment mission. The duration of the flight also plays a significant part. Skylab 4, a mission of 84 days at an average orbital altitude of 435-km and at 50-° inclination, resulted in an average total bone marrow dose equivalent of about 77 mSv (7.7 rem) (Bailey 1977).

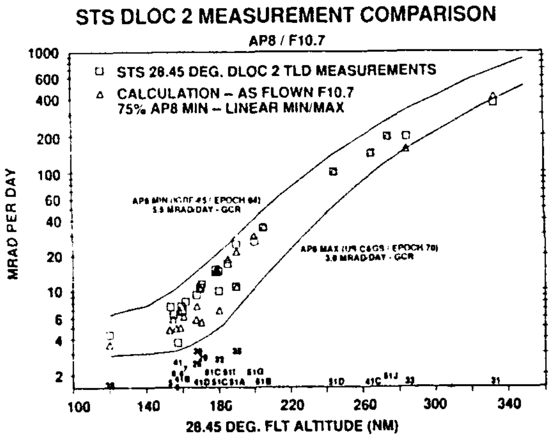

Figure 1. Theoretical and measured doses for representative STS flights. Note the effect of altitude on dose.

Uncertainties in Current Knowledge Concerning Space Radiation and Its Effects

A major uncertainty facing those who assess the risks associated with exposures to space radiation involves the densely ionizing, high linear energy transfer (LET) radiation (Fry 1985). This type of radiation, which will be experienced during exploratory class missions, is much more effective in inducing biological damage than low LET radiation. Certain species of high LET radiation may be 20 to 50 times more damaging then low LET radiations. Since high LET radiations, such as GCR, have greater effectiveness in inducing damage, the measured dose (in rad or gray) must be weighted by a quality (Q) factor to obtain the dose equivalent (in rem or sievert) for risk assessments.

The challenge ahead for the Station dosimetry is to provide an accurate determination of LET, particle charge, mass, energy, and direction. The suite of instruments proposed for the Station to accomplish these tasks include:

- Passive personal thermoluminescent dosimeters (TLD) similar to those routinely used in Shuttle flights
- Two new active dosimeters--the charged particle directional spectrometer (CPDS) and the tissue equivalent proportional counter (TEPC).

Combining the data from this instrument package will enhance our understanding of the secondary radiation produced inside the Station and will enable the avoidance of overly conservative radiological health risk assessments. Additionally, the dose projection models now in use must employ decades-old, inaccurate magnetic field models and require updating to account for current measurements made during Shuttle flights. As understanding of the dynamics of the geomagnetosphere increases, modeling the temporal, seasonal, and solar cycle variations at LEO will enable a better assessment of the natural environment than the current statistical (static) models. The proposed suite of radiation measuring instruments for the Station will provide most of the needed data to upgrade these dose projection models.

The National Council on Radiation Protection and Measurement Recommendations

In 1970, the National Aeronautics and Space Administration (NASA) adopted the current radiation protection guidelines. The career limit was set at 4 Sv (400 rem). Since that time, new risk assessments (Sinclair 1983) have been obtained for radiation exposures as well as a better understanding of the radiation environment for different missions. Additionally, the nature of the astronaut corps has changed (women now are members) and many crew members will be exposed to repeat missions of different time lengths and orbital parameters. For these and other reasons, NASA requested the National Council on Radiation Protection (NCRP) to re-examine NASA's radiation protection guidelines. This task was undertaken by NCRP Scientific Committee 75 which resulted in publication of NCRP Report 98, *Radiation Concerns for Space Activities*. This report requires that risk assessment be tied to the LET of the particle radiation impinging on the crew.

Figure 2 provides the new recommendations for career dose limits. The recommendations are based on a 3 percent lifetime excess risk of cancer mortality considering the age at first exposure and the sex of the crew member. The new career limits range from 1 Sv (100 rem) for a 24-year-old female and up to 4 Sv (400 rem) for a 55-year-old male, compared with the previous single limit of 4 Sv (400 rem). The career limit for the lens of the eye was reduced from 6 Sv (600 rem) to 4 Sv (400 rem), while the skin exposure level was reduced from 12 Sv (1200 rem) to 6 Sv (600 rem).

IONIZING RADIATION EXPOSURE LIMITS[1]

Exposure Interval	Depth (5 cm)	Eye (0.3 cm)	Skin (0.01 cm)
30 days	25 rem[2]	100 rem	150 rem
Annual	50	200	300
Career	100 to 400[3]	400	600

CAREER EXPOSURE BY AGE AND SEX

Sex	Age			
	25	35	45	55
Male	150	250	325	400
Female	100	175	250	300

[1] These dose-equivalent limits are being recommended to NASA by the National Council on Radiation Protection and Measurements (NCRP). Approval by the Administator is pending.

[2] This table is expressed in conventional units because of common usage by the discipline. The SI unit is the sievert (Sv), which is equivalent to 100 rem.

[3] The career depth dose-equivalent limit is based upon a maximum 3-percent lifetime excess risk of cancer mortality. The total dose-equivalent yielding this risk depends on age at start of exposure and sex. The career dose-equivalent limit is approximately equal to: 200 + 7.5 (age 30) rem for males, up to 400-rem maximum; and 200 + 7.5 (age 38) rem for females, up to 400-rem maximum.

Figure 2. The new recommendations for career dose limits.

Astronaut Radiation Exposure Aboard Space Station Freedom

Figure 3 illustrates the worst case as well as the nominal worst case accumulated deep dose equivalent in rem for an astronaut who experiences repeated tours of duty aboard the Station. Compare these rates of dose

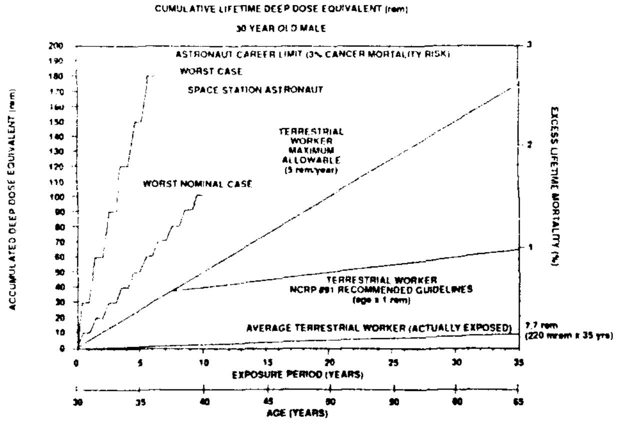

Figure 3. Theoretical worst-case and nominal worst-case accumulated deep dose equivalent (rem) for an astronaut flying repeated tours aboard Space Station Freedom.

equivalent accumulation with terrestrial workers and one clearly sees the nature of the problem in assuring radiation health protection for astronaut crews who experience multiple tours of duty in the Station.

To respond to this challenge, a robust radiation health program must be implemented. The elements of such a program can be seen in Figure 4. The multifaceted program integrates the elements of active and passive dosimetry, modeling and simulation of the radiation environment, and a comprehensive assessment of the health risks associated with exposure to the natural space radiation environment. In addition, mission planning, space craft design, and operations must include analyses to assess radiation impacts on the overall use of the Station. One promising method of reducing the radiation exposure of the Station would be to fly in a constant drag orbit that takes full advantage of atmospheric removal of trapped particles (Pfitzer 1989). Another method would be to fully characterize the radiation environment within the Station to locate radiation "hot spots" and rotate the crew to minimize exposures in those areas. In all cases, the as low as reasonably achievable principle will be used to optimize the many different strategies associated with management of radiation exposures over the careers of the astronauts on the Station.

Radiation Research at Dornier Deutsche Aerospace

Current activities at Dornier Deutsche Aerospace GmbH, located at Friedrichshafen, Federal Republic of Germany (FRG), center on improving the dose projection models used to describe the effects of space radiation on spacecraft electronic systems. This effort is achieved by modifying existing models and incorporating a new code to account for better knowledge gained over the past 20 years about the space radiation environment. Additionally, Dornier has under development an active radiation dosimeter designed to be incorporated into an astronaut extravehicular activity (EVA) spacesuit. Work on this project has been suspended because of budget constraints incurred since German unification. The European Space Agency (ESA) is now planning to use passive TLD dosimeters for EVA similar to NASA's approach. This decision will hurt further development of the EVA active spacesuit dosimeter.

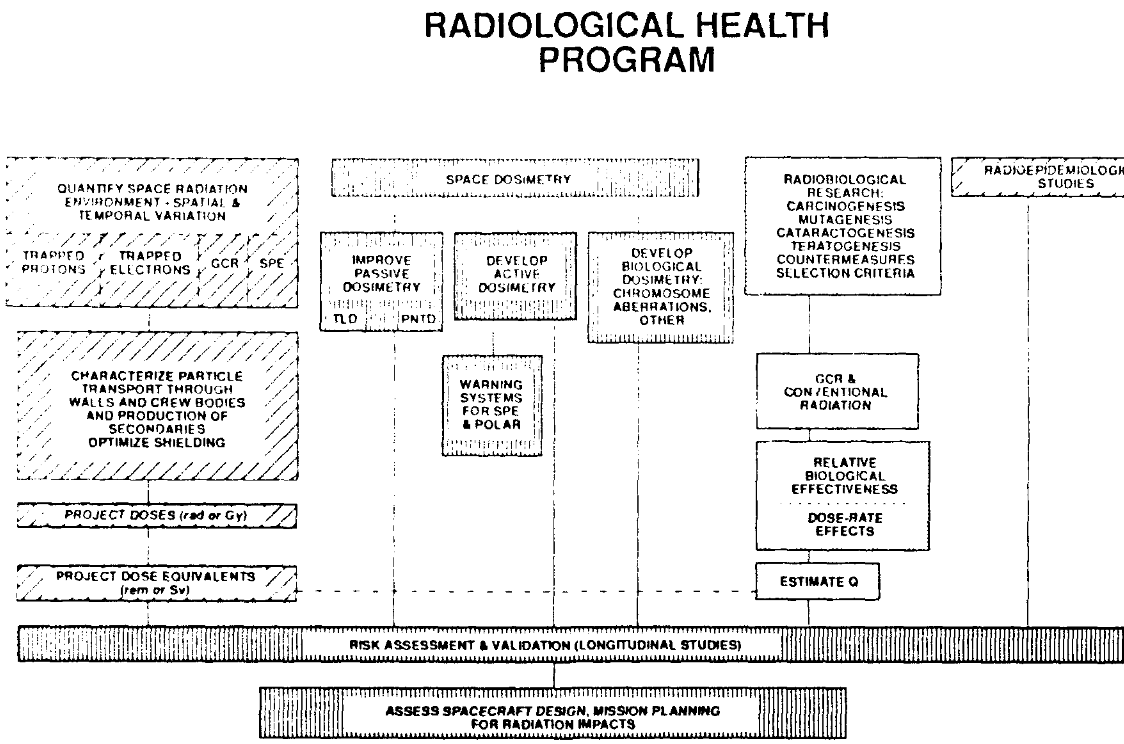

Figure 4. An integrated robust radiation health program proposed for the space station era and beyond.

Radiation Research at the Gesellschaft für Schwerionenforschung

One of the many areas of research now underway at the Gesellschaft für Schwerionenforschung (GSI), Darmstadt, FRG, is the assessment of the biological risks associated with exposure to high LET radiations, similar to the galactic cosmic radiation encountered beyond the geomagnetosphere. This research is an essential element of radiation risk assessment for the exploratory class missions under study by NASA. These missions include manned missions to the Moon and Mars, where a significant portion of the crew dose will come from exposures to the high LET galactic radiation field.

Conclusions

Radiological health concerns should not preclude the extended stay times envisioned for the Station or exploratory class missions. However, radiological health is a significant issue for all extended duration missions and international research must fully assess the risks to astronaut crews.

To assure the health and safety of the Station astronauts (European, Japanese, American), accurate records of all radiation exposures (medical and space exposures) are being maintained. A tumor registry for the entire astronaut population is being established and longitudinal studies are being conducted on this group.

A vigorous research program, international in scope, should be supported to assess the biological consequences of exposures to high LET radiations. Our present understanding of the biological effectiveness of high LET radiation is not adequate for accurate health risk assessments, particularly for exploratory class missions.

Constant improvements in radiation dosimetry, modeling, and simulation used in predicting dose projections, and continued international research into the biological and electronic effects of chronic low-level exposure to the space natural environment will assure the safety and well being of all future users of the Station.

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Coastal Morphodynamics: A European Community Marine Science and Technology Research Program

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Introduction

Coastal Morphodynamics is a research project to develop numerical models for the evolution of the near-shore morphology--the large-scale features such as bars and beaches. From the viewpoint of basic research, the coastal morphology is the temporal integration of complex (and interacting) fluid mechanical and sediment mechanical processes. From the standpoint of applied engineering, it is a critical factor for designing and maintaining shoreline structures (e.g., breakwaters, piers, and seawalls). The project attempts to integrate challenging research, with the motivation of critically important needs for better coastal engineering.

Organization and Funding

Huib J. de Vriend (Delft Hydraulics, Emmeloord, the Netherlands) leads Coastal Morphodynamics. There are five additional partners:

1. J. Fredsoe - Danish Hydraulic Institute, Horsholm, Denmark
2. R.L. Soulsby - Hydraulics Research Ltd., Wallingford, Oxfordshire, United Kingdom (U.K.)
3. H.H. Dette - Technical University of Braunschweig, Braunschweig, Federal Republic of Germany (FRG)
4. C. Teisson - Laboratoire Nationale Hydraulique, Chatou, France
5. L. Hamm - SOGREAH, Grenoble, France.

These six serve as an executive committee for the project.

The European Community (EC) Marine Science and Technology Program (MAST) (see page 2) has funded the Coastal Morphodynamics project for 2 years (through June 1992) at a level of 3 million European Currency Units (ECU) ($1.25 = 1 ECU). Because of MAST matching rules, the total project budget is about 5.2 million ECU. Therefore, private participants contribute about 2.2 million ECU (some of this non-EC contribution is national funds). Approximately 0.8 million ECU goes to university participants, who are included among 11 contractors in addition to the six principal partners.

Goal

The goal is to produce fully validated morphological models for the near-shore. There is no attempt to develop a single software package. Instead, the researchers plan to develop better understanding of the relevant near-shore processes and to incorporate this understanding into appropriate algorithms. Each institute may have its own software. The hairsplitting is partly imposed by the tension between the unity of research under the EC umbrella pulling against the business instincts of competing private hydraulics institutes. For example, at least one institute sells commercial software.

To achieve the goal of a predictive model, the project is divided into five parts. Four involve categories of physical processes where the goal is to increase understanding and to develop accurate models of the important processes--waves, currents, noncohesive sediments, and cohesive sediments. The fifth part is integrative--morphodynamics. This part is the incorporation of the results from the other parts into a whole so that the multiple processes that affect the morphology are accurately included. The goal is ambitious.

The Problem

The fluid mechanics of the near-shore is complex and nonlinear. As incident surface waves approach the shore, they change from a relatively smooth profile, steepen, and break. Most of the change occurs within a few wavelengths, and the energy carried by the waves is transformed to lower frequencies (e.g., edge waves with periods of minutes, mean along-shore current) and higher frequencies (e.g., turbulence).

The sediment mechanics of the near-shore impose an additional level of complexity. Sediment properties (e.g., size distribution, cohesiveness, and fall rate) may vary widely across a small region (or within a short time). Details of sediment mechanics tend to be less well understood than similar fluid problems. The moveable bed beneath the fluid, moreover, means that the boundary condition for the fluid problem evolves in time as a function of the interaction of sediment and fluid.

Additionally, many coasts experience large tidal variations so that the water level undergoes large changes. This can mean large areas of morphological interest are only intermittently under water.

Morphodynamics is the integration of the fluid and sediment mechanics. One can easily imagine some small bias in the quantitative understanding of the sediment mechanics producing large errors in the morphological evolution.

Status

During September 1991, the Coastal Morphodynamics group held a workshop at the University of Edinburgh, Scotland, to review progress and discuss plans. About 70 technical talks were given on a wide variety of topics and on different technical and scientific levels. I attended only the morphodynamics session, but this may serve to assess the proximity of the ultimate goal.

Perhaps the best view of current status was given by a series of collaborative papers by Ida Broecker Hedegaard (Danish Hydraulic Institute), Dano Roelvink (Delft Hydraulics), and Howard Southgate (Hydraulics Research). They compared three numerical models from their respective institutions that are state of the art for short-term beach profile evolution. Predictions by the three models were compared to experimental data from a large tank at the University of Hannover, FRG (the Grosse-Wellen-Kanal). The experiment included monochromatic 6-second waves--1.5-m high, in 10-m depth offshore. All models predict profile (i.e., water depth versus offshore distance) that is qualitatively similar to the experimental profile, but with obvious deviations in shape and bar location. More quantitative comparisons can also be made, such as the sediment transport or undertow velocities.

These models all have parameters that are based on physical reasoning and limited experimental evidence. The models can be sensitive to some of these parameters, and some of them are not well constrained. The Delft model appeared sensitive to parameters for wave breaking and for long waves, while the Wallingford model appeared sensitive to the thickness of the undertow. The success of all three models was limited, and the criteria for successful simulation remains a topic of technical argument.

J.T. Ronberg and colleagues, Danish Hydraulic Institute, used cross- and along-shore models to investigate the influence of the along-shore current on the cross-shore transport. Present models of the near-shore are limited to two dimensions. Consequently, most cross-shore models used for profile evolution do not include an along-shore current. Their idealized modeling predicted two effects. First, the higher velocities with a long-shore current increased turbulent levels and resulted in lower cross-shore velocities but higher sediment concentrations. Second, the partial alignment of the incident waves and the long-shore current caused a bias toward on-shore sediment transport. Even these simple calculations (for conditions similar to the Hannover experiments mentioned above) showed strong interactions between cross- and along-shore.

R. Narin (Consultant, Oakville, Ontario, Canada, recently of Imperial College, London) argued that long waves (infragravity waves at longer period than the incident waves) can play an important role in morphological evolution. At present, the generation of these waves is not sufficiently well understood to incorporate in models, but North American field experiments at least guide numerical experiments. The cross-shore structure of these waves, and phase correlation between the incident and long waves, can modify net sediment transport. Narin cites recent field measurements (by R. Sternberg and R. Beach, University of Washington, Seattle) that show infragravity frequency fluctuations in sediment transport.

Summarizing the present state of modeling, there are two-dimensional (2-D) models with some skill but obvious limitations. Both along- and cross-shore processes contribute to sediment motion and do so interdependently. Processes, such as long waves, meandering instabilities of the along-shore current, and swash dynamics are not included in the models. Present comparisons are between limited 2-D models and highly idealized nearly 2-D flume experiments. A central issue in many comparisons is the qualitative fidelity of the beach profile. This is an important clue to model performance, but may not be a good predictor for the behavior of the model under much different forcing, for example. Model validation is a difficult task, and there is much yet to be done.

Prospects

The Coastal Morphodynamics Group is aware of their challenge. They estimate that they are about 20 percent finished with their MAST project (they are composing a proposal for the second stage of MAST, hoping for a 5-year project lifetime). The vigor of the discussions at the workshop and the frank examination of ideas and exchange of technical criticisms is a good sign. Bringing together the six partners and their colleagues and planning their joint effort is a laudable accomplishment. Clearly, there will be a real advance in modeling capability, and a clearer definition of model skill and shortcomings. Also, further model development and validation will be needed at the end of the 5-year project.

Numerical circulation models have been critically important in the recent advances in dynamical meteorology and oceanography and in weather forecasting. They offer the promise of similar advantages in the near-shore--integrating all relevant physical processes, offering a numerical experimental technique, highlighting poorly understood processes, and improving prediction for application. Beginning construction of three-dimensional near-shore models is timely.

Collaboration

The Coastal Morphodynamics group plans extensive model development and laboratory experiment, but no major field experiment. For the advance of near-shore science and for further development of numerical models, field experiment is needed. Processes interact in surprising ways, and undiscovered processes await. For example, Narin's inference of long wave influence and the recent discovery of large shear instabilities in the along-shore current are based on field experiment. At the same time, the power of physically based models can enhance design and understanding of nearshore experiments. Numerical modeling and field experiment are complementary scientific tools.

Obviously, the European emphasis is on numerical modeling and the North American emphasis is on comprehensive field experiments (the case can be overstated; there is field experiment in Europe and modeling in North America). The time is propitious for collaboration on near-shore science using both techniques to attack difficult problems. Scientists on both sides of the North Atlantic can benefit by scientific exchange, and the Coastal Morphodynamics team indicated an enthusiasm to explore such possibilities. Both large programs and individual scientists can benefit from the coastal morphodynamics project, and discussions to implement collaborations will continue.

An Overview of Computer Applications Selected at British Defense Establishments

by CAPT Daniel G. Harvey, Jr., USNR, a visiting scientist/reserve officer to the Office of Naval Research European Office. CAPT Harvey is Commanding Officer of the Office of Naval Research Branch Office Pasadena Unit 119. Dr. Harvey is the Technical Manager for the Modular Containerless Processing Facility at the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California.

Introduction

During June, 1991, I conducted a series of informal interviews with several organizations in the United Kingdom (U.K.). I wanted to assess their current capabilities--computer hardware and applications--of interest to defense research and program development. The organizations contacted were: Cray Research U.K. Ltd., a U.S. subsidiary and major computer manufacturer; British Aerospace (BAe) and Ferranti International, both Ministry of Defence (MOD) contractors; and the Royal Military College of Science Shrivenham, an MOD agency. Additional literature research was conducted to augment and expand the data gathered. The following is a summary of those interviews and research.

These organizations use computers that represent every class of system available. These range from the standard IBM/Apple class of personal computers (PC) to the Sun and Apollo workstations to the IBM and VAX mainframes to the Cray supercomputer. Of particular note is the penetration and general acceptance of the Cray as the industry and defense supercomputer standard. Each class of computer in use has an equally broad range of application software available to it. They ran the gamut from word processing to detailed and computationally heavy engineering analyses and simulation. Despite the current capabilities, there is still an increasing need for greater and faster computational capabilities. The need for the leading edge in supercomputer technology is well recognized in the U.K. This suggests a vitality in the industry that will allow it to continue to be technologically innovative and competitive in the future.

The Ministry of Defence

The U.K. MOD Defence Research Agency (DRA) consists of five research establishments each supporting a separate arm of the MOD. These establishments each deal with a particular warfare issue. They are:

- Atomic Weapons Establishment (AWE) - nuclear warfare issues
- Admiralty Research Establishment (ARE) - Navy
- Royal Aerospace Establishment (RAE) - Air Force
- Royal Army Research Defence Establishment (RARDE) - Army
- Royal Signals Research Establishment (RSRE) - Signals.

All DRA organizations surveyed employ a broad range of computer types and capabilities for day-to-day tasks. Since 1983, there has been an increasing reliance on the Cray supercomputer for computationally heavy analyses. Each of these establishments owns or has access to a least one Cray supercomputer. The type of computations required dictate their type and capacity. The Appendix contains a relative comparison of the computing capabilities of several types of mainframe systems for reference. For example, RARDE computing requirements are dominated by input/output considerations because of the class of problems worked (high-energy projectile impact calculations). On the other hand, RAE requires extensive random access memory necessary for the manipulation of large numeric arrays for computational fluid dynamics (CFD) applications.

The current type and performance of the DRA Research Establishments' supercomputers are detailed in the Table 1.

Table 1. DRA Supercomputers

Research Establishment	Initial Use of Cray	Cray Model in Use[1]	Performance Relative to Cray 1	Memory (Mwords/Mbytes)[2]
ARE[3]	1985	YMP-EL/1	TBD	32/256
RAE	1984	Cray 2/4	10	256/2000
RARDE	1983	XMP/8-4[4]	25	32/256
RSRE	None	None	*	*
AWE	1983	Multiple	Unknown	Unknown

[1]The notation followed by a number indicates the total number of CPU slots available in the computer, followed by a number indicating the actual number of CPUs present.
[2]One Mword (MegaWord) is equivalent to 8 bytes or 64 bits.
[3]The four ARE centers continue to be linked to the RAE Cray at Farnborough.
[4]In 1989, a solid-state disk (SSD) was added to the XMP/8-4. This is a solid-state storage device equivalent to the familiar hard disk. It can be simultaneously used as a file storage device and as a system cache device. The SSD can provide data rates of up to 1,000 Mbytes/sec/channel, depending on the system.
*data not available

At present, three of the four DRA conventional weapons establishments are actively using the Cray supercomputer for various development tasks. The applications, by DRA establishment, are:

Admiralty Research Establishment. The ARE radar analysis organization at Funtington is involved in radar cross section analyses. The areas being studied are:

- Ship radar cross sections (RCS) studies used in the development of ship classification/identification algorithms
- Ship radar antenna placement for optimum ship RCS reduction.

The ARE underwater site at Portland is involved in research dealing with ocean modeling and algorithm development. The areas of interest are:

- Ocean sciences studies directed to improvements in submarine detection and other SONAR issues
- Ocean forecasting and modeling.

The ARE hull design organization at Haslar uses the Cray supercomputer for:

- Propeller noise reduction studies
- Acoustics signature modeling and predictions
- Fluid flow analysis
- Numerical towing tank used to reduce the reliance of the hull designer on the towing tank. Models are being developed that allow the designer to perform all hull design and design verification on the computer. The models developed are verified with the use of the hull towing tank.

Haslar is planning to acquire a Cray XMS and eventually a Cray YMP-EL to expand their research capabilities.

The ARE sea platform structures organization at Dunfermline is responsible for the design optimization of sea platform structures. Their activities use a wide range of proprietary software for in-house analysis and pre- and post-data processing. The ARE Dunfermline uses the NASTRAN, ASAS, SESTRA, and DYNATRAN codes for theoretical shock analysis and whipping studies.

The Cray has also proven to be particularly useful for driving three-dimensional (3-D) interactive graphics terminals. They permit the use of shaded surface models of naval structures and components.

Specific areas of research are:

- Platform vulnerability studies
- Platform structure modeling as a system composed of the coupling of individual platform subsystems
- Environmental considerations modeling
- Analysis of structural interactions/behavior in the presence of fluid flows.

Royal Aerospace Establishment. The RAE uses the Cray system in four areas of scientific investigation. These are:

1. Aerodynamics - The CFD investigations are carried out in support of the development of new wing technologies for cross sections and wing tips. These studies are used in support of design optimization for low observable vehicles, helicopter blade tips, and the European Fighter Aircraft (EFA) program. The CFD codes were developed for both the Euler and Navier-Stokes equations.
2. Structures - Large mesh models were developed for the Cray-optimized NASTRAN computer code that can consider both the wing and body together.
3. Turbine/Powerplant - Joint development work is being done with Rolls Royce using the PACE computer code.
4. Weapons Systems/Aircraft Stores - Aero - dynamic CFD analyses are being conducted on aircraft and weapons behavior/interactions during stores carriage and release.

Royal Army Research Defence Establishment. The RARDE is conducting armor/anti-armor investigations (armor penetration) in two areas. Those areas are:

1. Projectile behavior
2. Materials response and the chemistry of high speed/high energy impacts, involving the application of hydrodynamics.

Initially, RARDE used the HULL code (developed for the U.S. Air Force-125,000 lines of FORTRAN) before the introduction of the Cray supercomputer for projectile behavior studies. The HULL code is a self-contained system of programs for solving problems of hydrodynamic flow in two and three dimensions. The code allows calculations in Eulerian or Langrangian space or a combination of the two (Jones et al. 1991). Since the introduction of the Cray, RARDE has developed an internal code, GRIMSBY, that is optimized for the Cray's vector processor.

The RARDE uses the GAUSSIAN code for the analysis of the chemistry of high-energy impacts. Specifically, GAUSSIAN is used for the analysis of high-energy detonations. The code relies on the use of other lower-level codes dealing with the quantum theory aspects of such interactions for program initialization and look-up tables. These analytical results have also proven useful to the Royal Navy for ship design purposes.

The United Kingdom Meteorological Office

The U.K. Meteorological Office (MO) in Bracknell, Berkshire, is one of the world's leading weather and climate research centers. The MO is now using a Cray Y-MP/8 with 128 Mwords (1 Gbyte) of memory. The Cray is in use at the newly established Hadley Centre for Climate Prediction and Research (Corporate Register 1991).

This MO Centre is also the MO Hadley Centre for Climate Prediction and Research is using its Cray for conducting research on climate change using numerical models. The MO centre is also responsible for issuing 5-day weather forecasts and providing high-level wind predictions to various commercial airline companies (Corporate Register 1991).

Royal Military College of Science

The Royal Military College of Science (RMCS) provides graduate level education for the three U.K. military services. Their primary computer system is the Digital Equipment VAX computer, used by the faculty, staff, and students for general research and model development. They provided me with a summary of available naval warfare effectiveness analyses simulations. A brief description of each is provided in Table 2. Additional model details are available from the identified owner.

British Aerospace

The BAe is the predominant MOD aircraft manufacturer in the U.K. The lines of business encompass basic military and civilian aerospace research, development, and manufacture of military missiles and other ordnance, civil aircraft, space vehicles, and land vehicles (Rover). The BAe is also in the construction business. Despite this broad range of corporate interests, the military aircraft division is the driving force for most computational models and computer hardware acquisition.

The BAe daily uses a broad range of computers. For engineering activities, these include the Cray supercomputer, IBM and Apple PCs, Convex C2, IBM mainframes, ethernet-connected Sun workstations, VAX mainframes and microcomputers, Silicon Graphics workstations, and STARDENT workstations. Soon BAe plans to convert to the IBM RS/6000 workstation for daily research and development activities. They find this system appealing because of capability, size, and cost. The system can run their current design and analysis software programs such as CATIA (design), PATRAN (structures), and AVS (a graphics application system from STARDENT), as well as certain silicon graphics software[1].

The BAe's approach to computer management is interesting. They control and coordinate all computer hardware and software acquisition, development, and configuration requirements through their Technical Computing Project Board. The board is composed of representatives of all BAe organizations and is jointly funded by each. Their charter is to identify commonly used programs throughout the corporation, serve as a repository for commonly used programs, and provide configuration control. They have found this to be an effective way of controlling their assets.

Table 2. Naval Warfare Effectiveness Analysis Simulation

Simulation	Description
Celtic	Celtic models C^3I message flows for simple scenarios. It is in use by the Defense Operations Analysis Establishment (DOAE) SA2 Division, and is hosted on a VAX computer.
Hunter Killer	This is a simple two-player naval war game. Each side has three vessels with both active and passive SONAR. Each vessel has four nonreplaceable missiles. The simulation provides a graphical user interface for output analysis. The ARE, AX T4 Division is the prime user.
Action Speed Tactical Trainer	This is a large, multiplayer combat game that runs in real time. This program is used for refresher training of Royal Navy officers returning to sea after nonseaduty assignments. It is in use at the Maritime Tactical School aboard HMS Dryad, Portsmouth.
Sea Watch	This is a simulation used to analyze the ability of satellites and certain land-based sensors to detect surface ships and keep them under surveillance. The DOAE, SA2 Division is the prime user.
Commando 2	This is a simulation used to determine the effectiveness of certain ship-based weapons systems in protecting a surface group of ships under attack by air-to-surface cruise missiles. The defensive weapons systems modeled in the simulation are the SEA DART, SEAWOLF, GSA1, and CIWS. The ARE, ASW Division uses Commando 2.

[1] Requires the installation of a silicon graphics board in the RS/6000

The Military Aircraft Division is the corporate leader in the application of high-capacity supercomputers. The Crays are used for research and engineering development in three basic areas:

1. Electro-magnetic compatibility analysis for fly-by-wire aircraft, including assessment of their vulnerability, susceptibility, and radar cross section
2. The CFD using both Euler and Navier-Stokes codes for design optimization
3. Vehicle structural analysis using a Cray-optimized version of NASTRAN.

Some specific areas of investigation are:

Impact Modeling. This area has a wide range of uses to BAe. Areas of interest are the modeling of complex structures and complex chemistry. The model currently used is DYNA3. The DYNA3 is used for crash safety and energy management studies, particularly analyzing the phenomena of blast effect and spawling. Applications include analysis of the effects of terrorist activities on aircraft structural integrity.

The BAe is also a financial contributor to a consortium, with several U.S. firms, that support Southwest Research Institute (SRI). They develop programs of common interest and use to aerospace companies. At the present, BAe is using the SRI code computer-aided armor design (CAAD), a non-specific structural program that can be tailored to the particular needs of its user.

Electromagnetic Modeling. Electro-magnetic (EM) modeling is applied evenly for military and nonmilitary studies. The EM modeling is used in the analysis of complex materials and the definition of complex system requirements. Principal among these are EM Vehicle Design, a whole body analysis of the vehicle electro-magnetic environment. The BAe considers this to be as important as the integrated design of aircraft aerodynamics and structures.

The EM modeling of large aerodynamic bodies is done in terms of wavelengths (λ). For example, at X-Band (8-12 GHz) the wavelength ranges between 3.75 and 2.5 cm. Experience has shown that the nominal mesh spacing required by the EM codes used is one tenth wavelength ($\lambda/10$). Therefore, as the vehicle body size increases, the mesh required for the analysis grows significantly. To analyze a complete aerodynamic body requires an exceptionally large computer memory. This has led BAe to rely exclusively on the Cray supercomputer.

Their goal is to integrate the electrical, structural, and aerodynamic modeling into an integrated whole for the design synthesis process. This will allow a more rapid convergence to an optimum design as well as insight into the dependencies and sensitivities between the individual design components.

However, the achievement of this goal will stress their present computational capabilities. The BAe sees a problem in maintaining capabilities that are commensurate with their theoretical advances in CFD (3-D Navier-Stokes equations) and EM modeling. Dr. John Murphy, Head of Department of Computational Engineering, Sowerby Research Centre, sees the need for computers with not only vast quantities of random access memory but also data processing capabilities in the TeraFlop range (10^{12} floating point operations/sec). The current state-of-the-art Cray supercomputer can now achieve performance in the 2-3 GigaFlop range. This requirement for increased computational capability potentially creates problems for the user. First, to achieve the needed capability will require a new type of computer processing--*massively* parallel. Second, the new generation of machine will require codes specifically programmed for its processor to assure optimal performance. Even if the current codes could be hosted on the new system, they would not perform optimally (this was the case when the Cray was introduced). Initially, there was little apparent advantage of the new system over the old. It was only after the code was significantly optimized that the true benefits were obtained. This implies a significant increase in costs for the reprogramming of complex codes when any system is introduced. Despite this, Dr. Murphy thinks that the benefits are still worth the expense. However, the capabilities desired; i.e., true *massive* parallel processing, by BAe are not available.

In the meantime, BAe is looking for alternative methods of achieving the performance required. Other devices such as the transputer have been successfully used for specific applications; e.g., CFD Euler codes. However, the benefit of this type of device is in repeated use for production runs once the problem is defined. For nonproduction runs, the true measure of the benefits derived from the transputer appears to be the cost/benefit trade-off between computer costs and manpower costs. If significant modifications are required to optimize the program and data for the transputer, the costs may be far greater than the benefits derived.

Rolls Royce

Rolls Royce has used Cray Research supercomputers since 1985. In October 1990, they installed a two-processor Cray Y-MP system at their Derby, U.K., facility (Knoll 1991).

Current applications are:

- Structural Analysis - Uses approximately 45 percent of Rolls Royce supercomputing resources. Analyses done are the static, dynamic, and thermo-mechanical modeling of fan blades, turbine blades, and other engine components. Models being used on the Cray supercomputer are: DYNA3D - a Cray optimized finite element program and TAURUS - DYNA3D postprocessor.
- CFD - Uses approximately 45 percent of the supercomputing capacity. Studies are done for the development of various engine stages: compressors, turbines, combustion, and engine installations.
- Process Modeling - Uses the remaining 10 percent of the capacity. Codes have been developed that simulate material behavior during the manufacturing process of forging, casting, and heat treatment (Knoll 1991).

Ferranti International

Ferranti develops and manufactures advanced systems for both military and civilian applications. The corporation has three major lines of business: Aerospace Systems, Strategic Management Systems, and Commercial and Industrial Systems.

Ferranti Computer Systems Ltd. is a division of the Strategic Management Systems organization. This division was, until recently, involved in the manufacture of computers for naval applications. However, this is no longer the case. Though their last production computer, the Ferranti FM1600F, is still in use by the Royal Navy, Ferranti relies solely on civilian sector computers for their new military applications. Mr. John G. Thornton, Product Marketing Manager for Naval Systems, sees great strides being made in the civilian sector in quality control and system reliability. He thinks there is no longer a need to produce a sole-use computer for military applications. This will result in significant cost savings for new systems, and will enable the services to develop and field systems more rapidly. Because of this, Ferranti can now shift its corporate focus to developing application software based on the best appropriate commercial processor available.

Ferranti has observed that once an appropriate commercial processor is selected for a military application, it takes about 2 years to militarize the device. Since most application software takes about the same time to develop and mature, there is virtually no loss to the military customer in this approach. This method is significantly shorter than developing a sole-use military computer. This approach has gained acceptance by the U.K. MOD, which appears to be more willing to use processors developed for civilian purposes in military applications than does the U.S. Department of Defense.

Ferranti intends to develop generic systems that are not overly specified. This allows more flexibility in applications and upward compatibility of existing software. The design metric is to use about 2/3 of the new processor's full potential.

The Systems Engineering organization of the Strategic Management Systems group relies on workstations to conduct analyses and for tool development. Computers are selected on a case-by-case basis depending on the particular needs of the customer and machine availability. Uses are primarily in system integration, system interoperability (both data flow and C^3I), and development of structured system architectures. The Ada programming language is used exclusively for developing analysis tools.

Ferranti International Systems Assessment Group at Bracknell, Berkshire, has developed a generic total-system assessment model. This model was developed to support Ferranti's total system capability. The model, GENOA - GENeric Object-oriented Assessment, uses state-of-the-art technology to provide a powerful and unique generic total system assessment capability. The GENOA is targeted to the naval theater and provides a framework to allow for rapid enhancements to meet user specific requirements.

The GENOA is a computer-based simulation of the elements of a combat system in an operational scenario. The simulation allows the investigation of combat effectiveness as a function of several scenario-dependent parameters. These include:

- Platform configurations
- Command, control, and communications structures and equipment
- Weapons
- Sensors
- Countermeasures
- Environments
- Equipment
- Operator tactics.

Recommended uses for GENOA include:

- Evaluate system-level effectiveness
- Establish system-level effectiveness requirements
- Evaluate system effectiveness due to design changes
- Develop system tactical rules and algorithms
- Generate employment scenarios
- Derive system acceptance criteria/tolerances
- Plan trials
- Analyze post-trials data.

The GENOA runs on a VAX computer under the VMS operating system. The system uses a Regis color graphics terminal, Hewlett-Packard plotter, and a generic text printer. The code was developed using an object-oriented analysis approach with the Ada programming language and the appropriate CASE tools.

The GENOA can be run in batch mode for Monte Carlo experiments to provide statistical data for the stochastic process being analyzed. Also, it can be run in an interactive mode allowing the modification of tactical actions and terminal display options.

Conclusions

The current computational capabilities in the U.K. are on a par with the U.S. and Europe. In some cases, the acceptance of the Ada programming language has been effective and useful. In general, the U.K. MOD and allied defense contractors can compete with their peers in the world-wide defense market.

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Appendix

Computer Performance Comparisons

Table 1 provides a reference for the comparative performance of some of the computers mentioned. The data presented are not to be considered as a measure of overall computer performance. Instead, they are a measure of the ability of each computer to solve a dense system of equations.

The table reports three numbers for each machine. All performance numbers reflect arithmetic in full precision (usually 64 bit). For such machines as the Cray, this would be single precision. For others, such as the IBM, this means double precision. The first number is the Linpack benchmark program (characterized as having a high percentage of floating-point arithmetic operations) for a matrix of order 100 in a Fortran environment. The second number is for solving a system of equations of order 1,000, with no restrictions on method or its implementation. The third number is the theoretical peak performance of the machine based on calculation not on an actual program run (Dongarra 1979).

Table 1. Relative Performance of Selected Computers[1]

Computer	Number of CPUs	Linpack Benchmark CPUs	Best Effort (Mflops)	Theoretical Peak (Mflops)
Cray Y-MP/832	8/4	200/185	2144/1159	2667/1333
Cray Y-MP/832	2/1	129/84	604/308	667/333
Cray X-MP/416	4/2/1	149/103/66	822/426/218	940/470/235
Cray 2S/4-128	4/2/1	82/56/41	1406/741/384	1951/976/488
Cray 2/4-256	4/2/1	62/48/38	1406/709/360	1951/976/488
Cray-1S	1	27	110	160
Cray XMS-128	1	17	*	36
Cray Y-MP EL-128	4	*	*	268
Convex C-240	4	28	166	200
Convex C-220		24	84	100
Convex C-210	1	17	44	50
Convex C-130	1	7.2	31	36
Convex C-120	1	605	17	20
IBM 3090/180J VF	1	16	97	138
HP 9000 Series 835	1	1.8	*	*
DEC station 3100	1	1.6	*	*
Stellar GS 1000	1	9.8	*	*
Ardent Titan-2	2	9.4	25	32
Apollo DN10000	1	5.8	*	*
Sun SPARCstatio 1	1	1.3	*	*

* data not available

Note: Entries separated by / imply performance values for the corresponding number of CPUs shown.

[1]Excerpted from Dongarra, 1990.

Liege Colloquium on Ocean Hydrodynamics

by CAPT Thomas H. Kinder, USNR, Ph.D., a visiting scientist/reserve officer to the Office of Naval Research European Office. CAPT Kinder is the Director Reserve Technology Mobilization, Office of the Chief of Naval Research, Arlington, Virginia. Dr. Kinder is Manager, Coastal Sciences Program, Office of Naval Research, Arlington, Virginia.

Introduction

The 23rd International Liege Colloquium on Ocean Hydrodynamics was held at the University of Liege, Belgium, during May 6-10, 1991. Theme was "Modelling the Interaction of the Deep Ocean and the Shelf and Coastal Seas."

Liege has a small group of numerical modelers interested in ocean problems, but a long tradition of stimulating meetings on a diverse set of important ocean science issues. A combination of long talks (this year 45 minutes) and truly international (especially Europe and North America) attendance have made these oceanographic meetings important for exchanging ideas.

At this year's colloquium, talks covered a variety of topics, but a recurring theme was the use of numerical models to examine the circulation. Speakers repeatedly emphasized both the difficulty and importance of accurately modeling the dynamics of the open and coastal ocean simultaneously. Most modeling efforts have not tried to incorporate both regimes in one model, but have imposed some (optimistically) benign boundary condition to represent the other ocean. Spatial (horizontal and vertical) and temporal scales are shorter in the shallower coastal waters, and the influence of bottom topography is often first order. The transition between the two, the continental slope region, is often the most difficult because of large bathymetric gradients. There were more than 30 talks and 15 posters. I will describe a few individual talks that give some flavor of the meeting.

Summary of Selected Presentations

Allan Robinson, Harvard University, Cambridge, Massachusetts, discussed techniques for imposing the coastal boundary condition while using an open ocean quasigeostrophic model while assimilating hydrographic data. He showed the art of imposing a coastal boundary condition such that the open ocean solution remained dynamically consistent.

George Mellor, Princeton University, Princeton, New Jersey, showed an attempt to model the coastal ocean of the eastern United States with the Gulf Stream. His results are encouraging (he uses a primitive equation, turbulence closure model with curvilinear coordinates and thermodynamic forcing), but highlighted the resolution problems and the difficulty of evaluating highly complex simulations.

Alan Davies, Proudman Laboratory, Birkenhead, U.K., reported on a fine-scale (1/6 degree) tidal model of the shelf seas around the U.K. The goal is to understand the tidal currents--a much tougher proposition than tidal height. The sigma-grid (depth-following) formulation carries vertical viscosity (based on turbulent kinetic energy estimates) as vertical modes--which seems to increase the ease of physical interpretation, especially of spatial variability. Davies noted the need for higher resolutions near the shelf edge.

E. Stanev, University of Sofia, Bulgaria, showed that modeling techniques have proliferated to institutions that are not mainstream oceanographic research centers. He has been applying the venerable Bryan and Cox circulation model to the Mediterranean and Black Seas. The straightforward boundary conditions that arise for such semienclosed seas make them attractive from a modeler's perspective. One interesting secondary result is a serious flaw in the Levitus database[1] for the Mediterranean; mean vertical profiles include density inversions.

Anthony Heathershaw, Admiralty Research Establishment, Portland, Dorset, U.K., and colleagues have developed a numerical prediction scheme for certain coastal fronts. Over shelves near the U.K. and elsewhere (e.g., the Bering Sea), fronts separate vertically homogeneous water from sharply stratified two-layer water. A simple model, incorporating buoyancy input and tidal stirring, permits accurate prediction of frontal location for operational use. Some coastal phenomena are ripe for operational forecasting; in this endeavor, the U.K. is ahead of the U.S. community.

L. Fomin, Institute of Oceanology, Moscow, estimated near-inertial wave and current interaction by aggregate velocity statistics. I was fascinated that the source of the velocities was a large field experiment that was before unknown to me: MEGA-POLYGON. This experiment had 100 (!) surface moorings covering a 500x500-km grid, and occurred in summer-fall 1987. Some of the results suggested contamination of the measurements by mooring motion, but Fomin argued that the data are free of such problems. If he is correct, then this is the largest such oceanographic data set anywhere.

[1]Levitus database was compiled by NOAA oceanographer Sydney Levitus and is routinely used in large-scale ocean models.

Joaquin Tintore, University of the Balearic Islands, Palma de Mallorca, Spain, is using a simple two-layer model to understand the generation of near-inertial waves near the coast. Observations near the coast offer an opportunity to test ideas about the importance of the coastal barrier in the generation of these waves, which can propagate offshore on a narrow shelf (as in the Balearic Sea).

John Huthnance, Proudman Laboratory, Bidston Observatory, Birkenhead, Merseyside, U.K., focused on the dynamical reasons for a slope current along the boundary separating the shelf and open ocean. Using the northwestern U.K. slope as an example, he showed that matching the open and coastal sea surface heights might argue for a northward current there. He also strongly argued that coastal shelf waves over the slope are fundamental for the physics of shelf-ocean interaction. Additionally, sufficient resolution (scaled by the wave pressure gradient) in numerical models must represent adequately the important slope regime.

Proceedings and Future Meetings

Until recently, Elsevier published the Liege results as a book in their oceanography series. The proceedings are now published as a special issue of the *Journal of Marine Systems*, a new European journal. If the distribution is adequate, the Liege colloquia will continue to offer intercontinental stimulation for both those who attend the meeting and who read the proceedings.

Next year the topic is "Submesoscale Air-Sea Interactions." The meeting will emphasize the physical processes with temporal scales of the inertial (diurnal at the equator) period or less.

Small Satellite Technology An Assessment of European Activities

by CDR Brian J. Horais, USNR, a visiting scientist/rese..e officer to the Office of Naval Research European Office . CDR Horais is affiliated with Office of Naval Research/Naval Research Laboratory Headquarters Unit 106 in Washington, D.C. He is a Group Leader of Space and Defense Systems at W.J. Schafer Associates, Inc. in Rosslyn, Virginia. He led a team of engineers and scientists that fabricated four AMSAT microsatellites that were successfully launched from an Ariane IV launch vehicle in 1990.

Introduction

With the launch of Sputnik I on October 4, 1957, man embarked on the era of satellite exploration. Sputnik I, a 1.9-ft diameter sphere weighing 184 pounds was a small satellite, even by today's standards[1]. In the early stages of satellite exploration, the weight limit of launch vehicle payloads was on the order a few hundred pounds. As the capabilities of launch vehicles increased, the size, weight, cost, and complexity of satellites increased accordingly. By 1969 Arthur C. Clarke's 1945 prediction[2] of a geostationary communications satellite network was realized with the launch of the Intelsat III series constellation of three geosynchronous communications satellites.

Although small satellites are not new, in the past they played a minor role in satellite exploration because of their limited capability compared to larger satellites. In recent years, however, the ability to package powerful computers, high-resolution sensors, and efficient communications equipment in small packages has dramatically increased the potential capabilities of small satellite systems. The BREMSAT satellite is an example of the highly capable small satellites under development within the European Community (EC). The novel design approaches, characteristic of the emerging small satellite companies, have injected new energy into the area of satellite system design, reminiscent of the satellite era in the early 1960s. These companies are emerging as increasingly capable players in the area of satellite system development that many compare to the startup of the personal computer (PC) industry in the early 1980s. *Bigger is better* is now augmented by *good things come in small packages* where satellite system development is concerned.

This article provides a comparison of U.S. and European activities in the area of small satellite systems development. The article provides an introduction to small satellite technology followed by discussions of government and commercial programs and flight opportunities. The article also describes representative small satellite systems and other development programs outside the U.S. and European communities. Concluding remarks discuss the relative merits and strengths of the U.S. and European small satellite system development activities.

Why Small Satellites

The basis for emergence of the small satellite industry, both in the U.S. and abroad, has two facets:

1. Emergence of innovative approaches to small satellite system design (i.e., PCs in space controlled by PCs on the ground) that can result in dramatic reductions in space system costs and complexity
2. Availability of dedicated commercial launch vehicles that can place small payloads into the desired orbit at a cost within reach of a broader range of customers.

Small satellite technology is of direct interest to the U.S. military and the Navy in particular. Use of small satellites as store-and-forward communications[3] platforms for the polar regions is the basis of a program known as Arctic Comms. Arctic Comms is under development by the Space and Naval Warfare Command (SPAWAR) and the Naval Center for Space Technology (NCST), located at the Naval Research Laboratory, Washington, D.C. The Navy is also conducting a small satellite development program for passive radio frequency location (PROFILE). Previously, the Navy supported a small satellite development program for radar altimeter measurement of sea surface height (SALT). The SALT program was recently canceled. The Navy is evaluating tactical surveillance satellites under the TACSURSAT initiative, which now exists as a tentative operational requirement (TOR) under review within the Navy satellite development community.

[1]Small satellites are generally 500 pounds or less in launch weight.

[2]Predicted by Arthur C. Clarke in a 1945 article in *Wireless World* magazine.

[3]Store-and-forward communications exist when a message is uplinked to a low earth orbit satellite as it passes over the transmitting station. The message is stored onboard the satellite and later downlinked to a receiver station that is not within the same satellite transmit/receive footprint as the transmitting station. By this method, worldwide communications (at least once a day) are possible with a single low earth orbiting satellite.

The Department of Defense (DoD) level of interest in small satellite technology was elevated by the 1985 launch of the Defense Advanced Research Projects Agency (DARPA)/DSI[4] 52-kilogram Global Low Orbit Message Relay (GLOMR) store-and-forward communications satellite. The GLOMR was launched from a National Aeronautical and Space Administration (NASA) space shuttle get-away-special canister (GAS CAN). Since that time, DARPA, NASA, the Navy, and the Air Force have begun small satellite design/fabrication and deployment programs such as:

- LIGHTSAT (DARPA)
- SPINSAT (Navy)
- STEP (Space Technology Experiments Program - Air Force)
- Small Explorer Program (NASA).

These programs have begun to explore the application of current and emerging technologies to the fabrication and launch of lightweight, inexpensive satellites. These inexpensive satellites can provide quick reaction and tailored support for specific tactical, scientific, and strategic missions. The surge potential available from small satellite communication, sensor, or imaging platforms could provide an important capability for limited military engagements, time critical environmental sensing, or tactical scenarios that larger satellites may not be able to or are not the most cost effective to support.

Missions well suited to small satellites range from tactical communications (DARPA's multiple access communications satellite [MACSAT] and GLOMR), to remote sensing of sea surface height (Navy SALT), to passive radio frequency interference location (Navy PROFILE), to astronomical x-ray imaging (Department of Energy [DOE] ALEXIS). One of these proof-of-principle small satellite programs was MACSAT, launched in mid-1990. During Operation Desert Storm, Marine ground forces used MACSAT to send logistics data between deployed forces and their home bases in the U.S. In addition to these government programs, the Radio Amateur Satellite Corporation (AMSAT) over the last 20 years has successfully designed, built, and launched a variety of small communications satellites (up to 150 kg) for use by the amateur radio (HAM) community. These payloads were piggybacked with larger satellite missions on large launch vehicles such as Ariane.

With the successful launch of several small satellites in the past few years, a wider audience has recognized the potential applications for this emerging industry in the areas of remote sensing, microgravity experiments, communications, and earth exploration.

The Small Satellite Industry

Comparison of the emerging small satellite industry to the PC revolution of the early 1980s is not without foundation. The designers and developers of today's small satellites are putting PCs in space. An example is the UoSAT spacecraft developed by the University of Surrey in the United Kingdom. Four versions of this 50-kg satellite are now in orbit with the launch of UoSAT-5 on 18 July 1991 onboard Ariane with Earth Resources Satellite (ERS-1). The UoSAT-5 has four onboard computers (an 8-MHz 80C186, a 4-MHz Z80 and two 20-MHz T800 Transputers), 15-Mbytes RAM, a 578x578-pixel CCD camera, two UHF transmit and three VHF receive channels, gravity gradient stabilization complemented by computer-controlled magnetorquing, and 49 watts of raw solar array power, all in a 48.5-kg package.

The companies and universities involved in small satellites are developing novel techniques for assembling and testing these systems using off-the-shelf computer and electronic components, while also developing low-cost approaches to protect satellite systems from the hazards of space. The net result is that these new satellite systems are often assembled with minimal use of expensive space qualified parts and with significantly reduced levels of specification.

Many traditional satellite system developers argue that while dramatic reductions in cost are achieved by foregoing space-qualified parts and reducing the documentation requirements, the inevitable result is decreased reliability. There is an element of truth to this statement. However, the small satellite community takes a slightly different view. By using novel approaches in both the design and ease of testing for their satellites, they have successfully developed and launched several small satellite systems without extensive use of space qualified hardware. These satellites have functioned very reliably for periods of more than 3 years[5]. In addition, because of the dramatic cost reductions that can be realized, reduced reliability of a single satellite can be offset by launching multiple satellites and increasing system reliability through redundancy.

[4]The Defense Advanced Research Projects Agency (DARPA) funded Defense Systems Inc. (DSI of McLean, Virginia) to build GLOMR and MACSAT.

[5]AMSAT (Radio Amateur Satellite Corporation) has developed and successfully launched numerous small satellites in the past 10 years utilizing this design philosophy.

Universities have established ground stations to support satellite system curriculums. Universities such as:

- Weber State University, Ogden, Utah
- University of Colorado, Boulder
- University of Surrey, Guildford
- the Technical University of Berlin, Federal Republic of Germany (FRG)
- Bremen University, FRG.

have established such capabilities to provide communications links with existing or planned satellites, and to support active curriculums in satellite systems engineering.

Representative Small Satellite Remote Sensing Systems

Although small satellite systems have been designed and launched for communications missions under several government-, university-, and amateur- (e.g., AMSAT) sponsored programs, there have been few publicly known remote sensing small satellite systems proposed or launched. The development of high-resolution imaging small satellite systems involve some of the most system designs in the small satellite industry because of the requirements for satellite stabilization, onboard processing, and high data rate.

Recent U.S. examples in this limited field include the NASA Heat Capacity Mapping Mission (HCCM) launched into LEO from a Scout launch vehicle on April 26, 1978, and the Weber State University WEBERSAT piggybacked on the Ariane V 35 mission of January 21, 1990. The 278-pound HCCM produced a significant amount of imagery from its 620-km near-polar orbit before reentering the Earth's atmosphere in 1982. The 27-pound WEBERSAT,is still in orbit, providing low-resolution imagery downlink capabilities for amateur radio hobbyists worldwide from the satellite's 800-km near-polar orbit.

An example of the type of sophisticated small satellite remote sensing system that can be developed and launched with today's technology is the ATHENA satellite system proposed by Globesat, Inc. ATHENA is a low-cost imaging satellite system planned for a 700-km polar orbit. The system will be capable of providing high-resolution earth imaging in a single band between 0.5 and 0.73 μm, with 5-m resolution in a 60x60-km frame within a 700-km swath. Using linear sensor arrays arranged in a continuous row perpendicular to the path of flight allows coverage of off-track areas by electronically scanning the appropriate set of detectors (equivalent to tilting and steering the satellite without mechanical motion). By employing 12:1 image compression schemes, the planned system can downlink up to 200 60x60-km frames per day at 5-m resolution to ground stations equipped with 3-m parabolic data antennas operating at 10 GHz. During a typical pass, several cities on the West Coast of North America are imaged at 5-m resolution in 60x60-km image frames and then downlinked in a single pass[12].

In the minds of companies such as Globesat, the reason for developing a small satellite remote sensing system is to rectify some of the drawbacks to the current remote sensing satellite systems such as LANDSAT, SPOT IMAGE, and Soyuz Carta. Globesat claims the data obtained from these sources is in incompatible formats, is frequently of low-resolution, and is not timely. In comparison to the proposed ATHENA system, the SPOT satellite system offers 10-m resolution imagery in the panchromatic mode and 20-m resolution imagery in the multispectral mode. Globesat proposes that their ATHENA system could provide high-resolution imagery at intervals ranging from near real time to not more than a few days.

With the onboard processing, data storage, and sensor capabilities of this emerging class of highly capable small satellite systems, there are several remote sensing missions within reach of their capabilities. NASA has received many recommendations they evaluate the mission of small satellites to augment the planned large satellite Earth Observing System (EOS) platforms. Although certain sensors require the power, collocated sensors, and onboard capabilities of a large EOS-type platform, there is a strong case for putting selected sensors into orbit on smaller satellites accessible by a broader range of users. Taking this approach, scientists can gain supplementary and iterative remote sensing information before and during the planned EOS missions.

Small Satellite System Costs

The primary aim of a potential user of satellite systems is to get the most cost effective capability for a given mission. The trend towards satellite systems and launch vehicles has evolved over the past 30 years to the *bigger is better* category. This trend with its overwhelming cost has deterred many potential users of satellite systems. Typical satellite system development cost can run as high as $150 million for a 4,000-pound (approx.) satellite such as LANDSAT 5. Satellite system cost is driven by the spacecraft cost as well as the cost of the launch vehicle. Current launch costs are on the order of $3,000 to $6,000 per pound for low Earth orbit[13].

[12]Excerpted from a corporate brochure on *An Imaging Satellite System for Tactical Applications*, CTA Inc. and Globesat Inc., September 27, 1989.

[13]LEO is typically at an altitude of 300 to 1,000 km above the earth with 12 to 15 orbital revolutions per day and a time of view from a point of the ground of 15 minutes or less for a single pass.

Historically, satellites cost much more per pound. Thus, the total system cost for larger satellites is driven by the satellite cost more than by the launch vehicle cost. Even so, the availability of dedicated commercial launch vehicles for less than $40 million per launch was limited until the successful launch of Orbital Sciences Corporation's Pegasus launch vehicle in 1990 (see Table 2).

Onboard communications systems would be capable of sending data at rates that could downlink up to 16 high-resolution images (60x60-km field of view) per pass. The cost of the ground station was included in their survey (see Table 2). While a total system cost of $20 million may seem like a lot of money, one must make a comparison with a similar capabilities such as LANDSAT 5 and SPOT 2 which had development costs in the range of $150 million and $110 million, respectively (Birk et al. 1991).

Table 2. Imaging Satellite System Cost

	Product/Vendor	Volume (m^3)	Weight (lbs)	Power (w)	Cost ($ million)
Launch Vehicle	PEGASUS/OSC	.9784	400.0	N/A	8.5
Sensor System	SSG, RSL, AC, ITEK	0.0283	50.0	10.0	2.0
AC&DS	MADACS/ITHACO	0.0112	21.4	28.7	0.8
Computer	SUN/UNISYS	0.006	20.0	10.0	0.1
Data Comp	VECTORQUANT/UNISYS	0.006	15.0	15.0	0.15
Data Storage	1.2 GBIT/Fairchild (2)	0.0097	23.5	8.0/2.0	1.2
GPS Receiver	EOS Receiver/TI	0.0054	9.0	14.0	0.8
Communication	MIDL/UNISYS	0.04	60.0	60.0	.5
Power	Solar Panels/L GARDE	0.016+	22.0	N/A	0.5
Structure	Intraspace, DSI, ARDAK	0.8	100.0	N/A	1.0
Project Management	10%				0.8
		0.266	320.9	145.7	16.15
Ground Station	UNISYS	N/A	N/A	250	1.0
O & M					1.8
				Total:	18.95

Several studies have been done on the total system cost for a small satellite performing a sophisticated mission such as remote sensing. One such study, conducted recently at the Stennis Space Center by Lockheed Engineering & Sciences Company and NASA's Science and Technology Laboratory[14] concluded that the technology and systems are available today to design, build, launch, and operate a remote sensing satellite system for under $20 million. Although this program cost may be considered high by many of the university or scientific groups interested in small satellite applications, it does represent the high end of small satellites, in complexity and system cost. Through use of less complex satellite systems and lower launch costs via piggyback opportunities on Ariane, total system costs can be substantially reduced.

The satellite envisioned by Lockheed in their study would weigh less than 500 pounds and would provide 5-m resolution from LEO. Using available CCD arrays with the required optics will achieve this level of performance.

Educational Opportunities

The small satellite systems that can be built today can put satellite communications and remote sensing capabilities within reach of university investigators who could command and downlink data from their own satellite using the equivalent of a satellite TV dish antenna and PC-based control and data processing systems. An early example of a university-based satellite operation was the University of Colorado (at Boulder) Mission Operations Center for the NASA/Ball Aerospace Solar Mesosphere Explorer (SME) satellite. A member of the University of Colorado staff was the Mission Operations Manager for the for SME until the satellite recently reentered the earth's atmosphere. University students staffed the control center, which also served as an excellent training ground for future scientific users of small satellite technology.

[14]R. Birk and T. Tompkins, Lockheed, and G. Burns, NASA, 1991. *Commercial Remote Sensing Small Satellite Feasibility Study*, SPIE Small Satellite Conference. April 1991, S.P.I.E. (International Society of Optical Engineering), Aerospace Sensing Symposia, Orlando, Florida.

Stimulating and promoting interest in space and small satellite technologies among students at an early age is an essential part of developing new capabilities for these systems. Although undergraduate programs exist at a few universities in the U.S., the EC has taken a more aggressive approach in initiating and developing curriculums at the undergraduate and graduate level for small satellite systems development. The Center for Satellite Engineering Research (CSAR) at the University of Surrey, is a model for a comprehensive satellite engineering curriculum at the undergraduate and graduate level. With more than 15 orbit years experience on UoSAT-1, UoSAT-2, and UoSAT-3 missions, CSAR recently launched another UoSAT-5 on Ariane with the ERS-1 primary mission.

The curriculum at the University of Surrey has established an international reputation, with a multinational student population, and foreign participation in satellite system and satellite experiment development activities. Similar programs have been established at the University of Berlin and Bremen University, FRG. In these cases, there is close cooperation with commercial companies to foster further development of the satellite systems and to provide career paths for the enrolled students. Two examples of this are OHB Systems in Bremen and Surrey Satellite Technology Limited (SSTL)[15], Guildford. OHB Systems has developed the BremSAT, a get-away-special satellite, scheduled for launch from the Shuttle D-2 mission, while SSTL offers commercial versions of the UoSAT satellite.

Other Non-U.S. Satellite Programs

Several other non-U.S. and non-European countries are actively involved in the development and launch of small satellites. Representative programs include the:

- Offeq-2, developed and launched by Israel on April 3, 1990. This 172-kg spin-stabilized satellite provided in-orbit communications and control demonstrations to further develop and prove the Israel Aircraft Industry's capabilities in satellite technology development. Offeq-2 re-entered the Earth's atmosphere on July 9, 1990[16].
- ROHINI D1 and D2 and SROSS satellites launched by the Indian Space Research Organization (ISRO) in the 1980s. All three satellites provided remote imaging capabilities, including a two-band linear detector array with 1-km spatial resolution on the 40-kg ROHINI D2 and a 70-m spatial resolution stereo imaging camera on the 150-kg SROSS-2. The ROHINI satellites were launched by the Indian launch vehicle SLV-3 into 400-km circular orbits, and the SROSS-2 was launched by the ISRO's launch vehicle ASLV. The SROSS-2 imaging payload was developed by the German Space Agency (DLR)[17].
- KITSAT-1A, a UoSAT spacecraft bus under development for the Korean Advanced Institute of Science and Technology in collaboration with the SSTL. KITSAT-1A is scheduled for launch in 1992 onboard ARIANE[18].

An overview representative of European small satellite programs is provided in Table 3.

Table 3. Representative European Small Satellite Programs

Program Title	Sponsor	Application/Status
UoSAT 1 through 3	University of Surrey/AMSAT	Communications and science/in orbit
UoSAT 5 and 6	University of Surrey/AMSAT	Communications, science, and imaging/ Ariane launch July 1991
TUBSAT	University of Berlin/FRG	Communications and geolocation/ Shuttle D-2 GASCAN
BremSAT	University of Bremen/ OHB Systems	Microgravity and reentry/ Shuttle D-2, GASCAN
FREJA	Swedish Space Corporation	Ionopspheric measurement/Long, 2 March 1992
KITSAT-1A	Korea/SSTL Surrey	Communications and science/Ariane 1992
MINISTAR	Italspacia	Communications/Ariane planned

[15] Commercial spinoff of the University of Surrey's Spacecraft Engineering Research Unit.

[16] Wittenstein, J. et al. 1990. Offeq-2 Orbit and Attitude Flight Evaluation Report. In *Proceedings of the 4th Annual IAAA/USU (American Institute of Aeronautics and Astronautics/Utah State University) Logan, Utah, August 1990*, published by Utah State University, 1990.

[17] Alex, T.K. 1990. Imaging Capabilities of Small Satellites-Indian Experience. In *Proceedings of the 4th Annual AIAA/USU (American Institute of Aeronautics and Astronautics/Utah State University) Logan, Utah, August 1990*, published by Utah State University, 1990.

[18] University of Surrey press release on Launch of UoSAT-F, April 26, 1991.

Summary and Conclusions

Small satellites are not new. The satellite era began in 1957 with the launch of a small satellite, Sputnik I. The rebirth of interest in small satellites has come about because of the dramatic reductions in size and weight of processor and sensor systems, aided by the successful development of dedicated commercial launch systems for small satellites. Applications of the small satellite capabilities are still in the early stages, with much of the current work focusing on store-and-forward communications capabilities. With the recent announcement of Motorola's Iridium concept for a constellation of 77 small satellites to provide global cellular communications, this aspect of the small satellite industry is gathering momentum. In the area of remote sensing, however, there have been few commercial or scientific applications of small satellite technology. This may be because of a lack of knowledge in the remote sensing user community on the capabilities and merits of small satellite systems.

U.S. and European activities in small satellite systems development are proceeding at a similar pace with some noticeable exceptions. Some comparisons:

- The U.S. small satellite industry has had much more government sponsorship to date than the European industry
- The EC (most notably Ariane) has taken a more aggressive stance to development of launch opportunities for a wider array of auxiliary payloads; i.e., small satellites.
- The European educational system for satellite technologies is more developed and widespread than in the U.S.

If capability in a new technology area is measured by technical expertise, industrial base, and the infrastructure to provide an educated and qualified work force, the European small satellite development community could have substantial advantages over the U.S. in this emerging industry.

European Developments in Small Spacecraft Technology

by CDR Robert C. Treviño, Reserve Officer with Office of Naval Research/Naval Research Laboratory Technology Unit 410, Houston, Texas and Aerospace Technologist with the NASA/Johnson Space Center, Mission Operations Directorate.

Introduction

During the past few years, there has been an increased interest in small, lightweight spacecraft. These small spacecraft are referred to by several names: lightsats, cheapsats, and microsats. These small spacecraft also have many potential scientific, civilian, and military applications. The purpose of this report is to identify areas of European spacecraft technology that are being developed for these small satellites that would be of future interest and follow-on study.

Small Satellite Manufacturing

The United Kingdom (U.K.) is the European leader in small satellite research and development and manufacturing. The University of Surrey (University), Guildford, U.K., is one of Europe's leading builders of small spacecraft. The University has built four small satellites called UoSats. Weighing less than 50 kgs, these UoSats carried out Earth observation experiments after being launched as secondary payloads on an Ariane launch vehicle. The first two small satellites, UoSats 1 and 2, carried a charge coupled-device camera that was used to give resolution of approximately 3-5 km over areas of 500 km square and 1,000 km square. Each of the second two small satellites, UoSats 3 and 4, stopped operating 30 hours after separation from its Ariane launch vehicle. These satellites were to experiment with onboard image data compression and processing techniques. The University believes that low-cost small satellites with a specific application have great potential. Future applications include low-cost remote sensing and communications.

Small Circuits

The development of small circuits for large and small spacecraft is being undertaken by the University of Bath and British Aerospace Space Systems, Stevenage, U.K. Millimeter wave-integrated computer circuits with precision electronic components have been designed and developed. These circuits are as small as one millionth of a meter in diameter. They could be used in spacecraft components such as high-frequency down converters. Future applications of these small circuits could be communications, radio astronomy, and remote sensing spacecraft. There would be weight savings for these future spacecraft, but it would be more significant for microsatellites. Miniaturization of spacecraft components will be an important technology for future small satellite development.

Small Spacecraft Payload Carrier

A need was identified for a payload carrier for the Ariane launch vehicle that could carry spacecraft that were too small to be carried as main payloads. British Aerospace Space Systems has designed several payload carriers that fit below the main payload carrier on the Ariane launch vehicle. Arianespace now offers launch services for small satellites. These small or light satellites (Lightsats) are divided into three categories:

1. Spacecraft weighing up to 800 kgs
2. Spacecraft weighing up to 1,100 kgs
3. Spacecraft weighing up to 50 kgs (microsats).

All of these categories of lightsats have obvious volume restrictions also. These spacecraft are considered secondary payloads and must be compatible with the primary payload's requirements. For the heavier spacecraft up to 1,100 kgs, Ariane has two systems for supporting them. The SPELDA[1] dedicated satellite (SDS) is used when the launch vehicle is launching two or more satellites at a time. The primary payload is carried on top of the SDS. The high density satellite (HDS) is used for spacecraft up to 1,100 kgs. The HDS also is mounted below a primary payload. Microsats are carried aboard a system called the Ariane structure for auxiliary payloads (ASAP). The ASAP can carry up to six small satellites on a structural ring mounted between the main payload and launch vehicle equipment bay. After the main payloads are deployed, the lightsats or microsats are separated by spring-loaded pyrotechnic devices.

[1]French acronym for external carrying structure for Ariane double launches.

Table 1 refers to these small satellite systems and compares them to a main payload. When flying on Ariane, these lightsats are completely dependent on the main payload for their schedule, altitude, and inclinations. The number of microsats is also dependent on the performance margin that remains on the launch vehicle.

Table 1. Comparison of Lightsats to Primary Payload

Ariane Systems	Lightsat Constraints Weight (Kgs)	Volume
SDS	800 max	10 cm max
HDS	1,100 max	10 cm max
ASAP	50 max	35x35x60 cm
Primary Payload	1,900-4,200	4m DIAx11m HT

Conclusion

The demand for small satellites with specific applications should grow in the future. Both U.S. and European companies and universities will be designing and building many more of them. The technology for building these satellite systems and components will be of interest to future spacecraft designers and users. There will always be the issue of whether a large satellite with many instruments is better than several small satellites with each having its own specific application or instruments. Small satellites could play a greater role in supporting the space needs for the U.S.

Appendix A

Remote Sensing of Oil in the Marine Environment: State-of-the Art and Future Directions

by CAPT Ralph N. Baker, USNR, Ph.D., a visiting scientist/reserve officer to the Office of Naval Research European Office. CAPT Baker is the Commanding Officer of the Office of Naval Research/Naval Research Laboratory Technology Mobilization Unit 410 in Houston, Texas. Dr. Baker heads the remote-sensing activities for AMOCO Production Company in Houston.

Introduction

Detecting and monitoring oil spills in the marine environment have become one of the major challenges facing the industrialized countries and military services world wide. Our modern society runs on oil, and despite our best efforts to develop alternate energy sources, we will be dependent on oil well into the next century.

In addition to operating major fleets of combat and auxiliary ships on a global scale, the U.S. Navy controls fuel and supply depots, strategic petroleum reserves, pipelines, shipyards, and building facilities that are today, like private industry, subject to the scrutiny of federal and state environmental regulatory agencies. These agencies, under the pressure of an increasingly aware citizenry, are demanding that the natural environment be managed by responsible leaders and protected for future generations. In no other area has this awareness been more dramatically demonstrated than in the highly publicized oil spills that have frequently damaged our coasts and adjacent marine environments.

Fortunately, recent advances in remote sensing technology have given the global community a reliable and reasonably effective means of detecting and monitoring these events on a global scale. Remote sensing of the environment refers to detecting and monitoring natural phenomena. For the purpose of this discussion they can be considered to be "information gathering" techniques, using sensors mounted in aircraft or orbiting satellites. These sensors measure electromagnetic radiation (EMR) either reflected or naturally radiated from the Earth. The EMR spectrum is divided into discrete, narrow spectral bands that are digitally recorded and processed through often-complex computer algorithms into electronic images for specialists to evaluate. While these images are used for a wide variety of applications (see Table 1), this report will review only current and near-future methods for detecting and tracking petroleum seeps and spills from commercially accessible sources. Other ways in which satellite technology serves naval interests (e.g., weather forecasting, communications, and surveillance) have been addressed by other authors.

Table 1. Applications of Remote Sensing to the Marine Environment

- **Pollution Control**
  - Hazardous wastes/dump site inventory
  - Contaminated lands
  - Oil seeps & slicks
    - Tanker accidents, spills
    - Pipeline leakage detection
  - Thermal discharge
  - Effluent tracking
  - Smokestack emissions
- **Environmental Inventory**
  - Ecosystems mapping (vegetation, habitat)
    - Estuaries, wetlands, tundra
    - Groundwater
    - Subsidence
    - Change detection
    - Man-made impact
- **Natural Hazards Assessment**
  - Weather forecasting, oceanography (tides, waves)
  - Coastal floodplain mapping
  - Ice monitoring
- **Offshore Geology**
  - Near-shore bathymetry
  - Tar mounds/gas seeps as indicators for exploration
  - Slumps, unstable sea floor
  - Turbidity plumes

This discussion is to review and subjectively evaluate methods by which remote sensing techniques can be successfully used to detect oil on the water's surface, from monomolecular films to disastrous spills, citing as examples recent experiments conducted in the U.S. and Europe.

The intent of this article is to provide a brief summary and cogent review of a complex problem; several technical books and the recent literature cover important aspects of these ongoing studies in much greater depth. The interested reader should consult the reference list for additional information. The Office of Naval Research is actively investigating ways in which remote sensing can be applied to this problem, emphasizing synthetic aperture radars and microwave radiometry.

Technical Basis for the Detection of Oil on Water

Seeps Versus Spills. Oil or gas seeps result from naturally occurring hydrocarbon accumulations that are forced to the Earth's surface through various mechanisms. These mechanisms include pressure differentials, removal of a physical barrier or "seal," and the introduction of a migration pathway or conduit. Seeps are typically natural. An exception could be the slow discharge of liquid petroleum or natural gas through a broken pipeline or underground storage tank.

Spills, on the other hand, result from a short-term catastrophic event that discharges a significant amount of petroleum into the environment. Spills are spectacular, newsworthy, and often devastate the local ecology. In either case, much effort is underway that tries to improve both the sensing systems and digital processing techniques that enable us to detect, monitor, and predict the leakage's magnitude, direction of movement, and ultimate environmental impact.

Spectral Basis for Detection. The Earth's electromagnetic radiation spectrum can be measured by a variety of passive and active imaging systems (see Figure 1). These systems can uniquely identify most natural materials (sometimes only under ideal conditions) based on their microscopic (e.g., atomic makeup, molecular structure) and macroscopic (e.g., shape, texture, size, density, homogeneity) compositions. products using passive UV, visible, infrared, and thermal infrared sensors. Microwave sensors have also been widely used by many commercial and government agencies, primarily active synthetic aperture radars (SAR), and (to a lesser extent) passive microwave radiometers. These microwave systems provide the best all-weather detecting and monitoring capabilities available, especially when combined with SAR and ultraviolet systems.

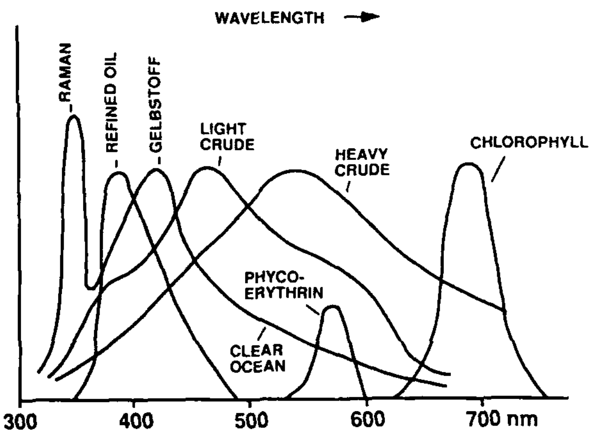
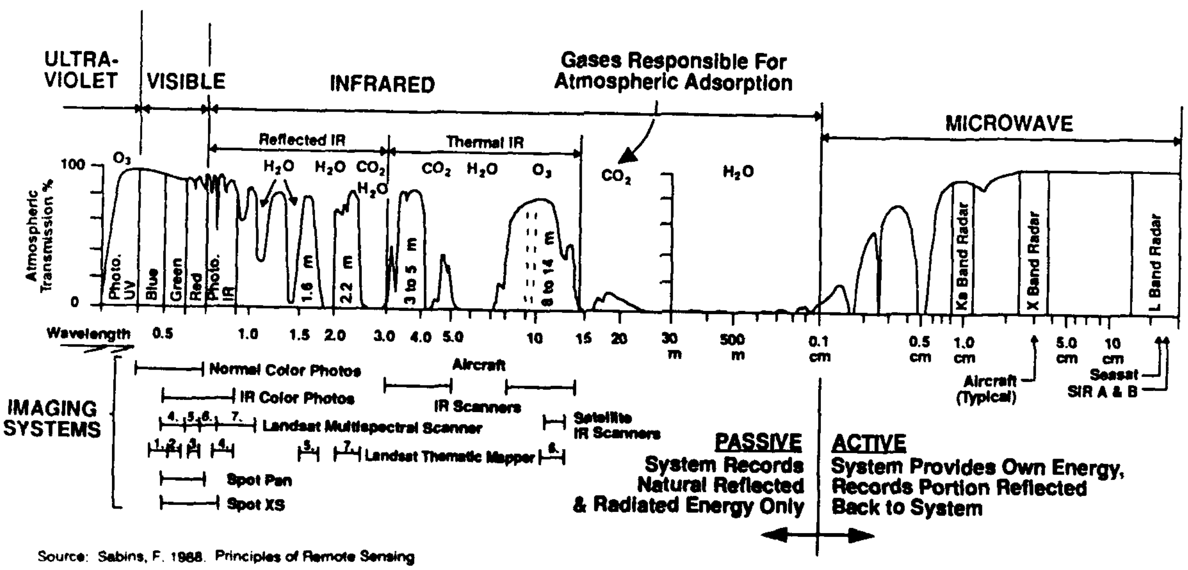


Figure 2. Spectral properties of oil on water



Source: Sabins, F. 1988. Principles of Remote Sensing

Figure 1. Expanded electromagnetic spectrum and remote sensing systems

In the case of oil in the marine environment, several research groups, notably Barringer Resources (see Figure 2) and The Environmental Research Institute of Michigan (see Figure 3), have demonstrated an ability to detect different types of crude and refined petroleum

Detection of oil at these wavelengths involves additional complicating factors, including atmospheric haze, sun elevation and azimuth angles, sea surface roughness, spill volume, chemistry, and physical characteristics.

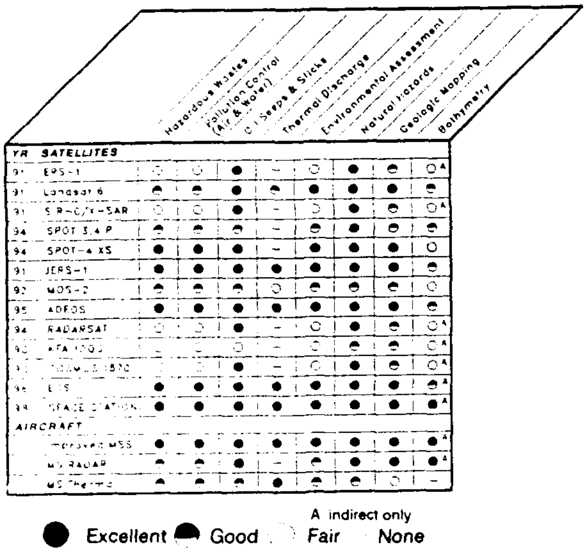


Figure 3. Remote sensing and the environment: future technology

Physical Basis for Detection. Oil seeping or spilling into the environment is typically lighter than water and will float upon it. This material will form a thin (even monomolecular) film or occur in sludge-like mats depending on the chemical nature of the original material and the extent to which it is (1) mixed with surrounding materials or (2) agitated by weather and sea conditions. We must recognize that is composed of naturally occuring compounds produced by the chemical transformation of organic chemicals (originally from living organisms) that under fairly predictable circumstances of heat, pressure, and time undergo chemical changes. The resulting compounds are then refined to fuel our modern civilization.

The presence of oil on the water's surface has several effects that may be detectable from high flying aircraft or satellites (see Table 2).

Table 2. Physical Effects of Oil on Water Surface[1]

1. Oil film suppresses or dampens capillary waves
2. Increased surface reflectance: visible to near IR spectrum
3. Change in thermal emissivity/temperature
   - Oil slick originally warmer or cooler
   - Thicker oil layers warmed by sun
   - High volatiles cooled by evaporation
   - Low volatiles impede evaporation of water, remains warmer
4. Fluorescence radiation
   - Light energy absorbed and emitted at longer wavelength
   - Active UV laser to illuminate target slick
   - Multiband detector measures fluorescent return
5. Increased microwave emissivity
   - Oil has higher emissivity than water, appears "hot"

[1] Modified from Lodge 1988.

Remote Sensing Techniques

Workers have successfully detected and identified oil in the marine environment using spectral data from short (UV) to very long (microwave) wavelengths. Figures 1 and 2 show the range of spectral coverage available from current satellite and airborne sensor systems, each of which are useful to varying degrees. Table 3 summarizes EMR bands turn useful in the past. All systems used to date lack the reliability and all-weather capability required of an operational monitoring system. Figure 3 demonstrates the detectibility of oils at different spectral intervals as provided by ERM.

The techniques and sensors described above are the most commonly used systems, but the list is not exhaustive. Other systems such as the DSMP/SSMI have also been used to detect oil slicks on a regional scale and will be further evaluated as funding and potential commercial interest permits.

Each of the described methods has drawbacks, usually related to all-weather or seasonal imaging, power or weight constraints, onboard data storage or image processing limitations.

Selected Events

The distress caused to the world community by major oil spills at sea and especially in near-shore waters has been well documented in the media. The best known of these is the grounding of the Exxon *Valdez* in Alaska's Prince William Sound in March 1989. The supertanker released nearly 260,000 barrels (each barrel contains 42 U.S. gallons) of crude oil into the water. A massive effort was mounted to first contain, then monitor and track, and finally to clean up the affected shoreline, which (according to state officials) covered much of the adjacent coast.

Remote sensing techniques were used in all aspects of the event, although near-total cloud cover prevented the available LANDSAT satellites from acquiring data over the site until 2 weeks after the initial grounding. The crude oil spilling into the sound mixed with sea water and other natural materials to form a frothy "mousse" cover, ranging from wispy tendrils to layers nearly 10 inches thick. This frothy mixture provided the necessary spectral and textural properties to be detectable from space.

The earliest cloud free LANDSAT images were digitally processed and merged by Eosat Corporation to produce a dramatic overview of the spill and surrounding coastline. Unfortunately the orbital repeat cycle of LANDSAT provides coverage only every 14 days, cloud cover permitting; not nearly the frequency needed to provide an effective monitoring capability. To supplement the LANDSAT coverage, the Canadian Government conducted daily airborne SAR surveys of the spill's progress and impact on the adjoining coastline,

Table 3. Summary of Remote Sensing Techniques Used to Detect Oil in the Marine Environment

Platform	Features Measured	Spectrum
Hand held		
Camera VCR Portable spectrometers	Ocean color, surface sheen or iridescence, frothy - "mousse," gas bubbles, oil globules, unique spectral signatures, and decay curves.	UV Visible IR
Airborne		
Camera Multispectral scanners Microwave IR radiometers SAR	Same as above plus seep-related damping of highest frequency waves, thermal anomalies. SAR systems and IR/UV scanners found useful for seeps detection. Oil film thickness measured by density slicing of microwave radiometer data combined with UV/IR scanner to estimate approximate volume of spilled oil.	UV Visible Near IR Thermal IR Microwave
Laser-fluorescence systems	Airborne laser fluorosensor developed by Barringer and used operationally by BP to explore for seep-related petroleum deposits. An ultraviolet laser energizes the slick which reflects the signal at a slightly higher wavelength to a receiving antenna.	UV
"Sniffer" systems	Aircraft mounted device collects aerosol particles and detects oil droplets above gas driven oil seeps discharging through water. Uses a flame ionization detector.	Non-physical sampling device.
Satellite		
Hand-held and fixed cameras Multispectral scanners Thermal IR SAR Wind scatterometers Microwave radiometers	Seeps related spectra: LANDSAT MSS, TM, SPOT, NOAA AVHRR, and others. Low texture (spectral brightness) caused by wave damping by surface film (SAR flown on SEASAT, SIR, ERS-1). Sea glint photos by shuttle astronauts. Ocean color (Nimbus 7 CZCS). Thermal IR resolution (e.g., LANDSAT TM6, HCMM) generally too coarse to be more than marginally useful.	UV Visible Near through Thermal IR Microwave
Underwater Towed Systems		
Sonar VCR Cameras Seismic profilers Echo sounders	Side scan sonar systems such as SEAMARK and GLORIA can detect tar mounds, gas craters, and clouds escaping from undersea pipelines or tanks. Chemosynthetic communities associated with oil and gas seeps have been investigated by Texas A&M University (GERG).	Sound waves Visible

although little of this data has been made available to the public. These and other images from the Defense Mapping Satellite Program (DSMP) demonstrated to the pubic an important capability that before had been largely overlooked. Earth resources satellites were best known for resource exploration, crop monitoring, or land use planning; little had been made of their capabilities to monitoring an increasingly threatened environment.

Land monitoring capabilities of the U.S. LANDSAT program are now well known. Also, two additional satellite systems have been recently introduced to the public--the French SPOT satellite earth imaging system and the National Oceanic and Atmospheric Administration's NOAA-7 satellite. This civilian weather "bird" carried an AVHRR radiometer capable of dramatically documenting both the catastrophic oil slick in the Northern Arabian Gulf and the widespread, environmentally devastating oil field fires of Kuwait.

Selected Experiments

Since the late 1960s, government-supported American and European researchers have experimented with detecting surface oil in the marine environment. Many of these experiments had similar approaches. Example: a ship releases a measured volume of oil (usually crude oils or refined products) while a heavily instrumented aircraft makes several overpasses. Each overpass is made with a varied combination of sensors and settings, altitudes and headings to determine the best method of detecting the spill. Physical parameters such as wind and wave activity are often factored in. Table 4 summarizes some experiments and results.

Table 4 summarizes only some of the more significant experiments, all of which achieved varying degrees of success under a wide variety of conditions. Most of the previous work has involved either fixed platform (e.g., shore based or tower observation) or aircraft surveys. This was because satellites available for "Earth resources" or environmental observations carried suites of sensors designed to meet the needs of several scientific disciplines, and therefore were not optimum for oil seeps detection. Nonetheless, many workers published early LANDSAT multispectral scanner and (more recently) thematic mapper images that adequately imaged oil on water. In these cases, cloud cover and a 14 to 18 day orbit limited the utility of the data for emergency response efforts and real-time monitoring.

Table 4. Selected Experiments[1]

Experiment	Year	Organization	Comments
ARSS	1974	U.S. Coast Guard	Airborne thermal IR, UV scanner
Baffin Bay/Scott Inlet	1978	Canada CCRS, NASA	Optical cameras, airborne MSS, line scanner, TV, fluorosensor
Wallops Island Oil Spill	1978	API, NASA	Color, UV photography, line scanner, thermal IR, fluorosensor, SAR, scatterometer.
SeaSat (SAR)	1978	JPL/Cal Tech	Natural seeps and oil spills in Santa Barbara Channel.
Archimedes/North Sea	1983	German Space Agency	X-band SLAR, microwave radiometer
North Sea	1985	Swedish Coast Guard, Daedalus Corp.	Daedalus scanner, UV/IR scanners, microwave radiometer.
Archimedes II	1985	German Space Agency	As Archimedes I, plus UV, thermal IR Daedalus scanner, optical line scanner, TV.
North Sea	1989	University of Denmark	Airborne C-SAR calibration for ERS-1 underflights.
Slickex	1989	USCG, ERIM	Effect of Surfactants.
Saxon North Sea	1990	German Space Agency, ERIM, NRL (ONR)	Airborne X, C, L band SAR (P3 aircraft) Airborne L, S, C, X, Ku scatterometer (helicopter) Airborne C-SAR (DO-228) Results: Determination of oil type using multi-frequency response.
NORCSEX Norwegian Continental Shelf	1991	Nansen Institute University Bergen	ERS-1 detection capabilities, TM, DSMP, Airborne X, L, C-SAR, AVHRR.

[1]See references.

With the successful launch of the European Space Agency's ERS-1 satellite in mid-July, several experiments have been approved that will further investigate the ability to detect oil in the marine environment. One of these, Project Gulf Offshore Satellite (GOSAP) reflects the interest and cooperative spirit between industry and federal agencies to improve spills detection technology.

Project GOSAP

The Gulf Offshore Satellite Applications Project (GOSAP) is being undertaken by members of the petroleum, marine, and environmental industries under the auspices of the GEOSAT Committee[1]. The goal is to determine how best to use remote sensing technology to address offshore problems and operations faced by exploration and marine engineering organizations. Primary among these goals, the GOSAP team will evaluate the potential for satellite based offshore exploration, ocean engineering, and environmental applications using combined satellite and airborne measurements constrained by real time "sea truth", the measurement of actual oceanographic and weather conditions occurring during the period of the satellite overpass.

The GEOSAT participants in this 2- to 5-year study will compare sea surface spectra from satellites (ERS-1, Radarsat, Shuttle Imaging Radar [SIR], SEASAT, and others) with water column, sea surface, and sea floor measurements from instrumented platforms in the Gulf of Mexico. These comparisons will aim to establish repeatable correlations between sea surface, sea bottom, and environmental conditions, and how these affect sea surface spectral reflectance. Techniques developed to process the data will be applied to oceanographic, engineering, and environmental problems encountered by participants from industry and government.

The initial test sites of Project GOSAP will include known oil fields in the Gulf of Mexico occurring at shallow to moderate water depths. Extensive measurements will be taken above, at, and below the sea surface. The test sites also will extend beyond known oil fields to encompass adjacent oceanographic features. These data will be processed to image meteorologic and oceanographic events, indirectly map the sea floor, map subsurface geology, and detect oil seeps from orbital altitudes. The potential correlation of satellite-collected sea surface spectra, oil seeps, and marine geology will enable scientists to extend these techniques into less fully understood test sites and eventually into remote areas worldwide.

[1]The GEOSAT Committee is a cooperative organization made up of the petroleum industry, government, and academia.

The Gulf of Mexico is uniquely suited to study ocean circulation and fronts. It is small enough that oceanographic and meteorologic measurements can be easily collected throughout the basin, yet large enough that the shelf and deep-water current circulation model much larger ocean basins. The use of satellites to obtain area-wide meteorological and oceanographic data will provide industry with a more complete picture of oceanographic events that are occurring near important sea lanes or pipelines routes.

A major goal of Project GOSAP is to monitor Gulf of Mexico circulation to prove the capabilities of the ERS-1 satellite's wind, wave, and tide sensors.

Surface verification for GOSAP will be provided, by oceanographic sensors mounted on ships and offshore oil platforms. The GLORIA side-scan sonar mosaic of the Gulf of Mexico floor published by the U.S. Geological Survey will be compared to satellite measurements--SAR, radar altimetry, gravity, and magnetics. The GOSAP team will attempt to map sea floor topography using SAR imagery and radar altimetry measurements from ERS-1 and supporting data sets from a wide variety of sources.

The ability to detect both natural or man-made oil seeps in coastal waters by space-borne SAR has been demonstrated in the SEASAT and Space Shuttle (SIR) programs. Several data passes over the test sites(s) would reveal the persistent or ephemeral nature of the seeps, suggesting a natural or man-made origin (long-term seep versus oil spill or pipeline leak).

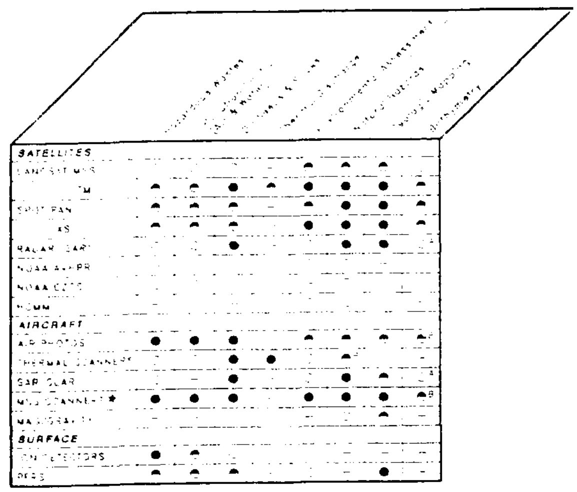
Marine seep detection surveys have been operational since the 1950s. Most of these are ship-based systems that measure hydrocarbons in the water column and are used to produce maps of hydrocarbon concentration. Some air- and ship-borne acoustical methods for marine seep detection are still under development but should become operational soon.

Future Directions for Research

This review has illustrated both the great interest in environmental remote sensing and the surprisingly large amount of work already done. This interest is gaining even more momentum as the public's environmental consciousness increases. One measure of this is the sharp increase in the number of environmental sessions found in major conferences and symposia. The Environmental Research Institute of Michigan has organized a series of thematic conferences on remote sensing of the marine environment, focusing principally on remote sensing for marine pollution and hazardous waste disposal. The first of these conferences, patterned after their successful exploration geology series, will take place in New Orleans in early 1992.

Similarly, the GEOSAT Committee has also announced a series of environmental workshops including one specifically designed to raise important issues in marine remote sensing for oil spills and seeps. The workshop will attract speakers/panelists from the petroleum industry, Coast Guard, Marine Spills Response Corporation, NOAA, and universities to produce a planning document for the National Academy of Sciences to support their global change monitoring initiatives.

These and other efforts will address research directions and sensor requirements from a wide diversity of potential applications, addressing issues ranging from operational and economic use of the technology to advance research concepts. Figure 4 shows present and near future sensors and their utility for solving selected environmental problems.



A indirect only
B certain conditions only
* non thermal

Ability to address problem:
Excellent Good Fair None

Figure 4. Remote sensing and the environment: present technology

Discussions with members of the marine remote sensing community (GEOSAT members, representatives of ONR, NOARL, the petroleum industry, and others) highlighted the diversity of research issues considered important. Somewhat surprisingly, groups considered at opposite ends of the spectrum (e.g., industry and the EPA) frequently shared common goals in their desire to protect the environment and reduce the impact when accidents do occur.

The following needs/research directions have been identified from these discussions and should be considered.

1. Parametric investigations of the effects of oil on water under various conditions: winds, waves, solar illumination. Studies could be carried out under controlled conditions at a facility such as the EPA's oil and hazardous materials simulated environmental test tank near Red Bank, New Jersey.
2. Better numerical modeling of spill dispersal, taking into account oil character, atmospheric, and oceanographic conditions. This should provide a more accurate method of predicting where and when a spill will hit the coast, and optimize the use of local resources.
3. Develop and implement a complete remote sensor-based spill response system. Such a system, proposed by ERIM, should provide the ability to:
   - Scan and process the complete area of the spill using multiband remote sensors
   - Detect in real time oil distribution and thickness (leading to accurate volume estimates that can be traced as the spill progresses)
   - Accurately locate in near real time the positions of clean-up vessels, coastlines, and navigational hazards using a GPS system
   - Provide a permanent historical record of the spill's location and dissipation
   - Detect oil escaping form containment booms, monitor the progress and effectiveness of clean-up efforts
   - Interface with communications capabilities.
4. Digital processing to combine diverse data sets using geographic information system software to uniquely identify seeps signatures and reduce false alarms.
5. Improvement of thermal resolution in satellite-borne sensors (spatial and spectral), digital registration of multispectral SAR and thermal sensors to an accurate nautical chart base.
6. Utilization of "sea glint" imagery to identify seeps from hand-held space shuttle photography, available worldwide but under utilized.

Many of these capabilities will be realized as the next generation of satellites suitable for environmental monitoring are launched.

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