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Ralph C. Smith

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13. ABSTRACT ***(Maximum 200 Words)***

The "Conference on Future Directions in Distributed Parameter Systems" brought together experts, whose research represented a broad spectrum of applications quantified by distributed parameter systems, and younger researchers focusing on specific facets of distributed parameter systems. A primary goal of the conference was to establish through plenary lectures the state of the art, open questions and important future research directions in a variety of applications and to pass the perspectives along to researchers in these areas. The conference also facilitated interaction between academic scientists and researchers from government laboratories and industry. The perspectives and recommendations provided in the plenary lectures will be published in a future volume.

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Conference on Future Directions in Distributed Parameter Systems

Final Technical Report

for the period

June 1, 2000 - November 30, 2000

AFOSR F49620-00-1-0173

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20010404 113

Summary

The funding provided by AFOSR Grant F49620-00-1-0173 covered the local expenses and provided travel support for several of the students and plenary speakers who attended the "Conference on Future Directions in Distributed Parameter Systems" which was held at North Carolina State University, Raleigh, NC on October 5-7, 2000. The purpose of this conference was twofold. The first was to provide a setting in which 11 plenary speakers could address the state of the art and future directions in their respective fields to a general audience ranging from graduate students to established research scientists. To disseminate these perspectives to the general scientific community, the plenary speakers were also asked to write 10-15 page chapters, summarizing their addresses, which will be compiled in the volume entitled *State of the Art and Future Directions in Distributed Parameter Systems.* This volume is scheduled to be published by SIAM. The second goal of the conference was to invite young scientists and graduate students to present talks which focused on specific applications modeled by distributed parameter systems. In combination, the conference provided a forum which illustrated past accomplishments in distributed parameter systems and indicated open questions, challenges and future research directions.

The benefit of the conference to the AFOSR mission was indirect but significant. A basic goal of the conference was to establish through the plenary lectures the state of the art, open questions and important future research directions in applications quantified by distributed parameter systems, and to then pass these perspectives along to researchers in these areas. This will help to clarify the focus of researchers in the respective areas and will provide guidance to funding agencies as to those directions which are deemed important and feasible by experts in the field. Both facets provide the capability for establishing research directions in which increased knowledge regarding distributed parameter systems can provide a substantial scientific impact.

Structure of the Conference

The conference was attended by 110 registered participants from 47 institutions. This included 31 graduate students and 13 scientists from government laboratories or industry. There were 11 plenary addresses and 20 contributed talks. The list of conference attendees and their affiliations are tabulated in Appendix 1 and brief biosketches for the plenary speakers are summarized in Appendix 2. The program for the conference, including the abstracts for the plenary addresses, is included in Appendix 4.

As noted in the program, the plenary addresses were an hour long while the contributed talks were 20 minutes in length. The topics covered in the talks included applications requiring electromagnetic theory, continuum mechanics, control applications arising in fluid dynamics, systems theory and H-infinity feedback design, nondestructive evaluation, model reduction for real-time control implementation, the application of homogenization theory to complex structures, and numerical algorithm design for large-scale systems. Hence the talks and ensuing discussions covered a broad spectrum of applications quantified by distributed parameter models.

To provide a permanent record of the plenary perspectives presented during the conference and to disseminate these perspectives to the general scientific community, the plenary speakers were asked to write 10-15 page chapters summarizing the recent accomplishments, open questions and future research directions discussed in their addresses. These chapters will be combined in the volume *State of the Art and Future Directions in Distributed Parameter Systems* which will be published by SIAM. A tentative table of contents for the volume is summarized in Appendix 3. In addition to the chapters provided by the 11 plenary speakers, the volume will contain a chapter written by Professor J.L. Lions who had originally been scheduled to provide a plenary address but was unable to attend the conference. We are currently in the process of collecting and formatting the chapters and we anticipate that the volume will be delivered to SIAM by June 1, 2001.

Publications

1. R.C. Smith and M.A. Demetriou, eds., *State of the Art and Future Directions in Distributed Parameter Systems*, SIAM, Philadelphia, PA, 2002 (Projected).

Personnel Supported and Expenses Covered

Local expenses and travel support were provided for graduated students, recent graduates, and the plenary speakers. The funding also covered the expenses for the conference center, local transportation, refreshments during breaks, and miscellaneous expenses including supplies and copying.

Interactions/Transitions

A primary goal of the conference was to provide a forum which facilitated interaction between the plenary speakers and young people in the process of establishing their careers. The conference also facilitated interaction between academic scientists and researchers from government laboratories and industry.

New Inventions/Patents

None

Honors and Awards

None

Appendix 1. Conference Attendees and Their Affiliations

Azmy Ackleh – University of Louisiana at Lafayette
Brian Adams – North Carolina State University
Richard Albanese – Brooks AFB, TX
H.T. Banks – North Carolina State University
John Banks – University of Washington, Tacoma
Leonard Berkovitz – Purdue University
Jerry Bernholc – North Carolina State University
Kathleen Bihari – North Carolina State University
Jeff Borggaard – Virginia Tech
David Bortz – North Carolina State University
Ken Bowers – Montana State University
Brian Browning – North Carolina State University
William Browning – Applied Mathematics, Inc.
Michael Buksas – Los Alamos National Laboratory
John Burns – Virginia Tech
Christopher Byrnes – Washington University
Alan Cain – Innovative Technology Applications Company
Brian Camp – Virginia Tech
Stephen Campbell – North Carolina State University
Chris Camphouse – Virginia Tech
Melissa Choi – MIT Lincoln Laboratory
Doina Cioranescu – Univ. Pierre et Marie Curie, France
Julio Claeyssen – Instituto de Matematica, Brazil
Kristy Coffey – North Carolina State University
Todd Coffey – North Carolina State University
Cammey Cole – North Carolina State University
James Crowley – SIAM
Ruth Curtain – Univ. of Groningen, The Netherlands
Constantine Dafermos – Brown University
Camille Daniel – Virginia Tech
Marcelo Dapino – Iowa State University
Ricardo del Rosario – Univ. of the Philippines, Philippines
Michael Demetriou – Worcester Polytechnic Institute
Emily D[illegible]ter – North Carolina State University
July Duran – North Carolina State University
Luis Duval – North Carolina State University
Pierre Emeric – GE Medical Systems
Richard Fabiano – Univ. of North Carolina at Greensboro
Fariba Fahroo – Naval Postgraduate School
Weifu Fang – West Virginia University
Bob Fennell – Clemson University
Ben Fitzpatrick – Tempest Technologies LLC
Wendell Fleming – Brown University
Joerg Gablonsky – North Carolina State University
David Gilliam – Texas Tech University
Pierre Gremaud – North Carolina State University
Gregory Hagen – Univ. of California at Santa Barbara
Mansoor Haider – North Carolina State University
Gregory Hicks – North Carolina State University
Sarah Holte – Fred Hutchinson Cancer Research Ctr.
Johnny Houston – Elizabeth City State University
Daniel Inman – Virginia Tech
Ilse Ipsen – North Carolina State University
Kazufumi Ito – North Carolina State University
Daniel Joseph – Virginia Tech
Michele Joyner – North Carolina State University
Hidehiro Kaise – North Carolina State University
Erich Kaltofen – North Carolina State University
Sungkwon Kang – Chosun University, South Korea
Franz Kappel – Universität Graz, Austria
Stephen Keeling – Universität Graz, Austria
Tim Kelley – North Carolina State University
Taufiquar Khan – Clemson University
Belinda King – Virginia Tech
Fumio Kojima – Kobe University, Japan
Denise Krueger – Virginia Tech
Karl Kunisch – Universität Graz, Austria
Patricia Lamm – Michigan State University
Charles Lee – California State Univ., Fullerton
Brian Lewis – North Carolina State University
Zhilin Li – North Carolina State University
Tao Lin – Virginia Tech
Zhuangyi Liu – University of Minnesota at Duluth
Nancy Lybeck –
Robert Martin – North Carolina State University
Jordan Massad – North Carolina State University
William McEneaney – North Carolina State University
Richard Medina – Brooks AFB, TX
Robert Miller – Cornell University
Kirsten Morris – University of Waterloo, Canada
Cynthia Musante – Entelos, Inc.
James Nealis – North Carolina State University
Mohammed Noori – North Carolina State University
Gabriella Pinter – University of Wisconsin-Milwaukee
Laura Potter – North Carolina State University
Tim Randolph – University of Missouri-Rolla
Julie Raye – North Carolina State University
Richard Rebarber – University of Nebraska-Lincoln
David Rebnord – Bank of America
Gary Rosen – University of Southern California
Boris Rozovsky – University of Southern California
Jerri Sayers – Virginia Tech
Rory Schnell – North Carolina State University
Michaela Schulze – Virginia Tech
Rebecca Segal – North Carolina State University
James Selgrade – North Carolina State University
Michael Shearer – North Carolina State University
Ralph Smith – North Carolina State University
Tom Svobodny – Wright State University
Hien Tran – North Carolina State University
Semyon Tsynkov – North Carolina State University
Sasha Tulloch – Virginia Tech
Eric Vugrin – Virginia Tech
Gordon Wade – Bowling Green State University
Shree Whitaker – North Carolina State University
Bob Wieman – North Carolina State University
Shannon Wynne – North Carolina State University
Fuh-Gwo Yuan – North Carolina State University
Mike Zager – North Carolina State University
Yue Zhang – Michelin Americas Research Corp.

Appendix 2. Plenary Speakers and Chapter Contributors

Richard Albanese (Brooks Air Force Base)

Dr. Albanese is head of the health sciences group at AFRL, Brooks AFB. He holds an MD as well as degrees in mathematics. He serves as a scientific advisor to several U.S. government agences (NRO, DARPA, etc.) and is a leading consultant for research on health effects of electromagnetic energy and electromagnetic imaging.

John Burns (Virginia Tech)

Professor Burns is currently the Hatcher Professor of Mathematics and Director of the Center for Optimal Design at Virginia Tech. His research encompasses aspects of optimal design and control theory, aeroelastic and fluid-structure systems, and approximation, identification, control and optimization of functional and partial differential equations.

Doina Cioranescu (Universite Pierre et Marie Curie)

Professor Cioranescu is the Director of Research, CNRS and University of Paris VI (Pierre and Marie Curie). She is a leading contributor in homogenization methods in articulated structures and composite materials.

Ruth Curtain (University of Groningen)

Professor Curtain is a Chaired Professor at the University of Groningen and an international leader in systems theory, control theory and semigroup methods for distributed parameter systems.

Constantine Dafermos (Brown University)

Professor Dafermos is the Alumnae University Professor at Brown University. His research encompasses aspects of continuum mechanics and differential equations.

Wendell Fleming (Brown University)

Professor Fleming is University Professor Emeritus at Brown University. He has published significantly in the areas of stochastic differential equations and stochastic control theory.

David Gilliam (Texas Tech University)

Professor Gilliam is a full professor in the Mathematics Department at Texas Tech University. His research encompasses components of linear and nonlinear partial differential equation, inverse problems, and control design for distributed parameter systems.

Daniel Inman (Virginia Tech)

Professor Inman is the George R. Goodson Endowed Professor in the Department of Mechanical Engineering and the Director of the Center for Intelligent Material Systems and Structures at Virginia. His research interests include vibration and smart structures including damping of machines and structures, computational vibration analysis, and both active and passive vibration suppression in structures. He is a Fellow of the ASME, AMA and IIAV.

Franz Kappel (Karl Franzens Universität Graz)

Professor Kappel is a Chaired Professor and former Dean of Science at the Universität Graz. He is a leading contributor to delay systems and distributed parameter systems and has built interdisciplinary programs with medical researchers and Universität Graz scientists in physiological control systems.

Fumio Kojima (Kobe University)

Professor Kojima is the former Chair of Mechanical Engineering at Osaka Institute of Technology and is now Director of Research, Graduate School of Science and Technology, Kobe University. His research encompasses computational methods for inverse problems in engineering applications including nondestructive testing in nuclear energy systems and aerospace vehicles.

Karl Kunisch (Karl Franzens Universität Graz)

Professor Kunisch is a Chaired Professor of mathematics in the Institute of Mathematics in the Karl Franzens Universität Graz. His research encompasses topics from the optimal control of partial differential equations including reduced-order control design, inverse problems, suboptimal control of fluids and image reconstruction.

J.L. Lions (College de France)

Professor Lions is President Emeritus of the French National Academy of Sciences, former President of CNES (European NASA) and former Director of INRIA. He is an international research leader in partial differential equations and control of distributed parameter systems. His numerous international recognition for is research contributions to applied mathematics includes the Japan Prize and Reid Prize.

Appendix 3. *State of the Art and Future Directions in Distributed Parameter Systems*

Table of Contents (Tentative):

Appendix 4. Conference Program

CONFERENCE ON FUTURE DIRECTIONS IN DISTRIBUTED PARAMETER SYSTEMS

On the occasion of the celebration of the 60th birthday anniversary of H.T. Banks

North Carolina State University

Raleigh, North Carolina

October 5-7, 2000

Biography of H.T. Banks

Harvey Thomas Banks was born in Hickory, NC on October 30, 1940 and was raised in rural (at the time) Catawba County in western North Carolina. He was the oldest of four children (3 sisters: Carolyn, Brenda and Margaret) of John Henry and Esther Bernetta Banks. He graduated from Fred T. Foard High School in 1959 and attended NC State University, receiving a BS in Applied Mathematics in 1963. While at State he married Sue and they celebrated their 40^{th} anniversary in 2000. They have a son, John Edward (married to Susi) and a daughter, Jennifer Lee (married to Gerry) and two grandchildren, Samantha and Emilie.

Tom and Sue moved to West Lafayette, Indiana in 1963 where he attended graduate school at Purdue University, earning a Ph.D. in Applied Mathematics in 1967. He studied under the guidance of L.D. Berkovitz (a leading research contributor to control and variational theory), writing his dissertation on control of differential equation systems with delays. Early professional influences were a number of memorable professors including H. Petrea, J. Wahab, R. Korfhage and R.Struble at NC State and H. Pollard, C. Goffman, M. Golomb, J. Lillo and T. Mullikin at Purdue. But the most influential by far was his thesis advisor Len Berkovitz.

Upon graduation from Purdue, Tom and Sue went to Brown University on a one year postdoctoral appointment (which became a 22 year stay at Brown) in the Lefschetz Center for Dynamical Systems (LCDS), which was arguably the leading group in the world at that time in control theory/dynamical systems. At Brown, H.T. (as he was subsequently called by former students – and Sue when in a scolding mode!!) immediately was influenced by world class applied mathematicians including Solomon Lefschetz, J.P. LaSalle, Wendell Fleming, Jack Hale and Harold Kushner. He also was greatly influenced by outstanding contemporaries that included Constantine Dafermos, E.F. (Jim) Infante, Marc Jacobs and Dick Miller. In the late 60's and 70's, the LCDS and the Division of Applied Mathematics at Brown were a "must-visit" stop for national and international stars in applied mathematics and this provided an incredibly stimulating environment for young faculty and graduate students (one supposes that "old" faculty were also stimulated!). It was in this early caldron of activity that H.T. met many of the mathematicians who would have profound personal impact on him (and his subsequent graduate students and postdocs). Early events and encounters at Brown also shaped the mathematical interests and activities of H.T. and his students.

H.T. Banks was Director of the Graduate Program in Applied Mathematics at Brown for the period 1969-72 and this led to an early and life-long interest in mentoring and working with graduate students and postdocs. His first graduate TA was Ruth Curtain in 1968-69, his first Ph.D. student graduated was George Kent in 1971, and his first postdoc was John Burns 1973-74. (Burns became a close friend and collaborator on ground breaking research on approximation methods for delay equations. In spite of Burns' penchant for attracting earthquakes, typhoons, floods, lightning storms, plane mishaps and other accidents both natural and unnatural, he and H.T. successfully shared many interesting travel experiences.) In 1970, the opportunity to work with medical researchers at Rhode Island Hospital on modeling of glucose homeostasis provided a new direction for H.T. and some undergraduates in applied math at Brown (and led to several senior honors thesis for students). This stimulated a career - long involvement in teaching and research in biological areas. In the early 70's H.T. co-taught courses in physiology in the medical school at Brown, developed a joint applied math/biomedical sciences program at Brown, and devoted a considerable amount of research energy to topics in biology (enzyme kinetics, physiological control systems, enzyme cascades in biochemical pathways). In late 1971, one of the distinguished visitors to Brown, J.L. Lions, invited him to spend a month at INRIA (where Lions was Director) and lecture on biomedical applications of control and identification. He did so in May, 1972 and this led to a long and fruitful collaboration with numerous French applied mathematicians including J.P. Kernevez, G. Chavent and D. Cioranescu among others. During this first visit Banks met Kernevez and Daniel Thomas and became involved in some of their research on modeling of active transport in biological membranes. This led to an honorary faculty position for Banks at Universite de Technologie de Compiegne (1977-82) and multiple exchange visits between the groups at Brown and UTC. These visits to France resulted in many research encounters with other mathematicians and scientists and subsequent visiting faculty appointments for H.T. at Universite de Paris – Dauphine (1988), Universite de Pierre et Marie Curie – Paris VI and College de France (1994), Universite de Frenche Compte, Bescanson (1996) and Centre Emile Borel, Institut Henri Poincaré (1998).

The initial forays into problems in the biological sciences led to a long series of subsequent research contributions by H.T. and his students and postdocs on diverse topics including reaction-diffusion in membranes, protein synthesis, enzyme regulated pathways in gylcogenolysis, insect population growth and dispersal, size-structured models in fish populations, transport in brain tissue, physiologically based pharmacodynamics kinetic (PBPK) models of toxic agents in animals, detection of coronary stenosis using propagating waves in viscoelastic tissue, and electromagnetic interrogation in tissue using natural and /or acoustically generated electrical interfaces.

Another seminal event occurred in 1974 when H.T. met Franz Kappel in Wurzburg (just prior to Kappel's move to Graz, Austria to establish a group there). They quickly became good friends as well as professional colleagues and began a decades long research collaboration during a month long visit to Brown by Kappel and his family in September, 1974. Initially their joint efforts were on approximation methods for delay systems but later collaboration involved semigroup methods for inverse problems especially on problems involving size-structured population models for fish populations. An important benefit resulting from their association has been exchange visits for many young mathematicians in the research centers at Brown/USC/NC State and Graz.

In 1980, Milt Rose (then Director of the Institute for Computer Applications in Science and Engineering (ICASE) at NASA Langley Research Center) asked H.T. to help develop and direct a program in control theory at ICASE, an applied mathematical (computational sciences and numerical analysis) research institute founded at NASA LaRC in the mid 70's to provide basic mathematical and computational research on NASA related scientific and engineering questions. In addition to recruiting and mentoring many excellent postdocs for the ICASE program, H.T. developed numerous collaborations with engineers at NASA that significantly affected the directions of research for him as well as his students and postdocs. Kazi Ito (the first postdoc hired in this context at ICASE), Fumio Kojima and Ralph Smith were among the exceptional postdocs in the ICASE program with whom H.T. continued research efforts long after their years as postdocs.

At the same time of the intense ICASE involvement in the mid 80's, Banks began a series of interactions with scientists and engineers at Air Force Laboratories that stimulated his research interests in a number of topics including large flexible space structures and smart material structures. Interactions (and in some case joint experimental efforts) included groups at Edwards AFB, Kirkland AFB and Elgin AFB. The most significant (for H.T. and his students) of these interactions has led to an ongoing effort with a group at Brooks AFB led by Richard Albanese. Banks met Albanese in the early 90's (at about the time he moved to NC State) and enjoyed almost immediate and substantial scientific rapport which promoted intense activities in electromagnetics and the health sciences (PBPK models for toxic agents such as dioxin and TCE) that are continuing for Banks and his graduate students.

Another important influence from the 80's came from a chance meeting between H.T. and D.J. Inman at an AFOSR - sponsored workshop on control of flexible structures in Florida. Their personal and scientific friendship led to significant collaborative efforts in control and identification (in particular, vibration - based damage detection methods) for smart material structures, especially those involving piezoceramic actuators and sensors. Their research collaborations began in earnest in 1986 (while Inman was still at SUNY Buffalo) through an AFOSR URI on control and damping of flexible structures. On a personal note, they have shared numerous adventures (misadventures??), one of which in 1989 resulted in the red Miata that H.T. drives to this day.

Many of the engineering collaborations (with NASA and Air Force Lab scientists, with Inman and his students and colleagues, etc.) were a manifestation of a deep interest in the physical sciences that H.T. has enjoyed since his undergraduate days at NC State where he took strong minor programs in physics and mechanics. His subsequent research efforts have involved contributions in mechanical systems (beams, plates, articulated and hybrid flexible structures, damping in elastic and viscoelastic structures including rubber and human tissue), acoustics (in particular, seismic inverse problems and noise suppression), and fluid/structure interactions.

Mathematical topics to which H.T. Banks has made contributions (many motivated by applied problems) include: control of delay and partial differential equations, approximation and computational methods, identification and inverse problem methodology for linear and nonlinear distributed parameter systems, nonlinear damping and hysteresis modeling, homogenization, and the mathematics of smart material structures.

During the past 33 years, H.T. Banks has authored or co-authored more than 275 technical publications and four books: *Modeling and Control in the Biological Sciences*, Springer, 1975; *Estimation Techniques for Distributed Parameter Systems* (with K. Kunisch), Burkhäuser, 1989; *Smart Material Structures: Modeling, Estimation and Control* (with R. Smith and Y. Wang), Masson/John Wiley, 1996; and *Electromagnetic Material Interrogation Using Conductive Interfaces and Acoustic Wavefronts* (with M.W. Buksas and T. Lin), SIAM, 2000. He has directed a substantial number of graduate students and postdocs who are listed at the end of this biography and who have gone on to very productive professional and personal lives.

Service to the profession has always been an important obligation for H.T. Banks. During the 70's he gave numerous 4 day short courses on Mathematical Modeling in the Life Sciences for faculty in the NSF-AAAS Chautaugua Lecture Series. These included short courses at Harvey Mudd, Univ. Texas, Oregon Graduate Center and Stanford in November 1975 and March 1976, Univ. Wisconsin, U. Missouri-KC, Miami Univ. and LSU in October 1976 and March 1977; and U. Hartford and U. Georgia in November 1977 and March 1978. He has held many service positions at SIAM including SIAM J. Control and Optimization Editorial Board during July 1972 – December 1991 (Managing Editor, Jan. 1979 – Dec. 1981, Jan. 1986 – Dec., 1988), Vice President – Publications (Jan., 1982 – Dec., 1985), Founding Editor SIAM book series *Frontiers in Applied Mathematics* (Jan, 1983 –Dec., 1989) and Editor-in-chief (1998-). He was elected to the SIAM Board of Trustees in January, 1997 and has served since Jan, 1999 as Chair of the Board. Banks has given substantial energy to numerous other journals as a member of editorial boards including the Quarterly of Applied Mathematics (Jan., 1977 -), J. Math. Biology (Jan., 1980 – Dec., 1999), Int'l J. Math and Computer Modeling (Jan., 1980 -), Computational and Applied Mathematics (May, 1984 -), J. Inverse and Ill-posed Problems (July, 1996 -), Inverse Problems (Jan., 1997 -), J. Intelligent Material Systems and Structures (Jan., 1992 -) among others. He has served as Director of several research centers including the Lefschetz Center for Dynamical Systems (Brown), the Center for Control Sciences (Brown), the Center for Applied Mathematical Sciences (Univ. S. Calif.) and the Center for Research in Scientific Computation (NC State).

H.T. Banks has received generous recognition for his service and research efforts with students, postdocs and colleagues. These honors include Professor Honoraire, Universite de Compaigne, 1977; Distinguished Scholarship Achievement Award, NCSU, 1992; appointed University Professor and Drexel Professor of Mathematics, NCSU, 1992; elected Fellow IEEE, 1994; Alumni Association Outstanding Research Award, NCSU, 1995; IEEE-CSS Control Systems Technology Award, 1996; Distinguished Alumni Award, Purdue Univ., 1998; elected Fellow Institute of Physics, 1999; named Alumni Distinguished Graduate Professor, NCSU, 2000.

The Banks family stayed in Providence for 22 years (with sabbatical leaves to U. Colorado – 1975-76 and SMU – 1982-84) but in 1989, Tom and Sue, seeking adventure (or was it more a response to the empty nest syndrome?) decided to head west to California. Granted a special three year leave (without pay, of course!) from Brown, they lived in Manhattan Beach while Tom agreed to start a research center in applied mathematics for the University of Southern California. These were an exciting three years (USC's entrepreneurial spirit, especially among the administration, was wonderful!). With options to return to Brown or stay and direct the Center for Applied Mathematical Sciences at USC, they decided to do neither. The decision to not return to Brown was one of the most difficult decisions of H.T.'s adult life (he and Sue had many wonderful personal and professional friends in Providence and Brown had provided an extremely fulfilling atmosphere for them - Sue had a scholarship named for her in 1990 in honor of her years of work with foreign students and visitors to Brown!). But the excitement and potential at NC State and the Triangle were just too much to pass up. In 1992 they moved to Raleigh (actually Cary!) to begin the next chapter of their lives. H.T., with the substantial help of others (already at NC State or hired shortly after his arrival) began to build the Industrial Applied Math Program (IAMP) which has been most successful (21 research projects with companies and government labs in 2000). The program was generously recognized in 1999 by a $250,000 endowment (with some complimentary funds from the Dean of the College) from the Lord Corporation to guarantee permanent fellowships for graduate students and postdocs, a fitting tribute to the outstanding students and postdocs who were largely responsible for the success of the IAMP.

Students, postdocs and professional colleagues have been extremely important in the life of H.T. Banks. But Sue has been the most important part of his professional and personal endeavors. It was her efforts that led many of the students, postdocs and visitors to become members of an extended and lasting family. Like it or not, John and Jennifer grew up in a home that often resembled a bed and breakfast (which Sue freely admits to dreaming of operating some day!!). Sue's enthusiasm for competitive running led to them running many 10K's and half-marathons together – and to H.T.'s several successful marathons. She has taught many about compassion and friendship – and is responsible for most of the few virtues that H.T. has. His vices and shortcomings (as his friends know, they are numerous!) are either genetic or learned behavior (when Sue was not around to correct him). Most of his close professional colleagues have failed utterly in their attempts to positively influence his behavior!

Ph.D. Graduate Students Directed or Co-Directed

M.R. Latina, 1970
G.A. Kent, 1971
G.M. Groome, 1972
T. Tsukazan, 1974
D. Reber, 1978
J. Mahaffy, 1979
G. Rosen, 1980
P. Lamm, 1981
S. Rockey, 1981
J. Crowley, 1982
K.A. Murphy, 1983
L. Zia, 1985
B. Fitzpatrick, 1988
C. Wang, 1988
G. Wade, 1989
D. Rebnord, 1989
Y. Wang, 1991
F. Fahroo, 1991
C. Smith, 1993
Y. Zhang, 1997
C. Musante, 1998
R. del Rosario, 1998
M. Buksas, 1998
M.Goodhart Choi, 1999
L. Potter, 2001 (anticipated)
M. Joyner, 2001 (anticipated)
K. Bihari, 2001 (anticipated)
J. Raye, 2002 (anticipated)
D. Bortz, 2002 (anticipated)

Postdocs Directed or Co-Directed

J. Burns, 1973-1974
F. Colonius, 1977-1978
K. Kunisch, 1979-1980
K. Ito, 1981-1984
G. Propst, 1985-1987
F. Kojima, 1985-1988
R. Fabiano, 1986-1989
H. Tran, 1986-1989
S. Keeling, 1987-1988
D. Woodward, 1988-1989
R. Miller, 1989-1992
S. Kang, 1989-1992
K. Morris, 1989-1990
R. Smith, 1990-1993
K. Bryan, 1990-1993
W. Fang, 1990-1992
B. King, 1992-1993
K. Black, 1992-1994
M. Demetriou 1993-1996
N. Lybeck, 1994-1997
G.M. Kepler, 1995-2000
P. Emeric, 1996-1998
H.V. Ly, 1996-1999
I. Groselj, 1997-1998
D. Rubio, 1997-1999
G. Pinter, 1997-2000
S. Wynne, 1999-
B. Browning, 1999-

Program
Conference on Future Directions in Distributed Parameter Systems
McKimmon Center
North Carolina State University
October 5-7, 2000

Thursday, October 5th	
8:00 am Area 1B	Hot & Cold Break Service (8 am to 5 pm) McKimmon Center
9:00 am Area 6	Welcoming Remarks Daniel Solomon Dean, *College of Physical & Mathematical Sciences*
9:15 am Area 6	"MATHEMATICS AND ELECTROMAGNETIC THEORY" Richard Albanese, *Brooks Air Force Base* *PLENARY LECTURE*
10:15 am Area 6	"MAX-PLUS LINEAR PARTIAL DIFFERENTIAL EQUATIONS" Wendell Fleming, *Brown University* *PLENARY LECTURE*
11:15 am Area 1B	Poster Viewing
11:30 am Area 2A	Lunch, McKimmon Center
1:00 pm Area 6	"HYPERBOLIC CONSERVATION LAWS IN CONTINUUM MECHANICS" Constantine Dafermos, *Brown University* *PLENARY LECTURE*
2:00 pm Area 6	"INVERSE PROBLEMS RELATED TO ELECTROMAGNETIC NONDESTRUCTIVE EVALUATION" Fumio Kojima, *Kobe University* *PLENARY LECTURE*
3:00 pm Area 1B	Break

3:30 pm Contributed Session 1 Area 6	"TIME, FREQUENCY AND TIME-FREQUENCY APPROACHES FOR PARAMETER IDENTIFICATION" Michael Buksas, *Los Alamos National Laboratory*
3:50 pm	"MODELING AND COMPUTATION OF PROPAGATING WAVES FROM CORONARY STENOSES" Shannon Wynne, *North Carolina State University*
4:10 pm	"SAVING THE WORLD WITH EXPERIMENTS AND THEORY: SPATIAL HETEROGENEITY IN AGROECOSYSTEMS" J. E. Banks, *University of Washington*
4:30 pm	G. Wade
3:30 pm Contributed Session 2 Area 4	"GLOBAL SPILLOVER STABILIZATION VIA LYAPUNOV ANALYSIS FOR DISSIPATIVE EVOLUTION EQUATIONS" Gregory Hagen, *University of California at Santa Barbara*
3:50 pm	"LOW-GAIN TRACKING, WITH AN APPLICATION TO NOISE REDUCTION IN A STRUCTURAL ACOUSTICS MODEL" Richard Rebarber, *University of Nebraska*
4:10 pm	"H-INFINITY OUTPUT FEEDBACK OF INFINITE-DIMENSIONAL SYSTEMS VIA APPROXIMATION" Kirsten Morris, *University of Waterloo*
4:30 pm	"RATIO AND SYMMETRY IN ESTIMATION OF SPATIAL DISTRIBUTION OF GROUNDWATER CONTAMINANT CONCENTRATION" Sungkwon Kang, *Chosun University*
5:30 pm Area 2A	Reception McKimmon Center

Program (continued)

Friday, October 6th	
8:00 am Area 1B	Hot & Cold Break Service (8 am to 5 pm) McKimmon Center
9:00 am Area 6	"GLOBAL MODELS FOR THE CARDIO-VASCULAR-RESPIRATORY SYSTEM EMPHASIZING REGULATORY MECHANISMS" Franz Kappel, *Karl Franzens Universität Graz* *PLENARY LECTURE*
10:00 am Area 6	"SYSTEM THEORETIC INSIGHTS INTO MODEL REDUCTION FOR CONTROL DESIGN FOR DISTRIBUTED PARAMETER SYSTEMS" Ruth Curtain, *University of Groningen* *PLENARY LECTURE*
11:00 am Area 4	Meeting, Plenary Speakers (to discuss volume on state of the art and future directions in distributed parameter systems)
11:30 am Area 2A	Lunch, McKimmon Center
1:00 pm Area 6	"COMMENTS ON STRUCTURAL HEALTH MONITORING AND OTHER CRACKS" Daniel Inman, *Virginia Tech* *PLENARY LECTURE*
2:00 pm Area 6	"ON THE GEOMETRIC THEORY OF OUTPUT REGULATION FOR DISTRIBUTED PARAMETER SYSTEMS" David Gilliam, *Texas Tech* *PLENARY LECTURE*
3:00 pm Area 1B	Break

3:30 pm Contributed Session 3 Area 6	"IDENTIFICATION AND CONTROL OF ACTEX DISTRIBUTED PARAMETER SYSTEMS" Taufiquar Khan, *Clemson University*
3:50 pm	"ON THE USE OF ITERATIVE METHODS FOR SOLVING PDEs NUMERICALLY" Johnny Houston,*Elizabeth City State University*
4:10 pm	"MODELING OF MAGNETOSTRICTIVE TRANSDUCERS FOR INTEGRATED SMART STRUCTURE SYSTEMS" Marcelo Dapino, *Iowa State University*
4:30 pm	"MODELING AND SIMULATION OF A PULSED LASER DEPOSITION PROCESS" Thomas Svobodny, *Wright State University*
3:30 pm Contributed Session 4 Area 4	"SOME ADVANCED NUMERICAL ALGORITHMS FOR DISTRIBUTED PARAMETER SYSTEMS IN INDUSTRIAL AND ENGINEERING APPLICATIONS" C. Hung Lee, *California State University, Fullerton*
3:50 pm	"ADAPTIVE REDUCED ORDER CONTROLLERS FOR FLUIDS USING PROPER ORTHOGONAL DECOMPOSITION" S.S. Ravindran, *University of Alabama in Huntsville*
4:10 pm	"NONLINEAR ANISOTROPIC DIFFUSION FILTERS FOR MULTISCALE EDGE ENHANCEMENT" Stephen L. Keeling, *Karl-Franzens-Universitat Graz*
4:30 pm	"COUPLING OF FLUID-STRUCTURE SYSTEMS THROUGH A GENERAL COORDINATE TRANSFORMATION" Robert Miller, *Cornell University*
6:30 pm	Banquet North Carolina State University Club Hillsborough Street Raleigh, NC

Program (continued)

Saturday, October 7th	
8:00 am Area 1B	Hot & Cold Break Service (8 am to 5 pm) McKimmon Center
9:00 am Area 6	"APPLICATION OF THE HOMOGENIZATION THEORY TO THE STUDY OF TRUSS-LIKE STRUCTURES AND RUBBER-LIKE ELASTOMERS" Diona Cioranescu, *Universite Pierre et Marie Curie* *PLENARY LECTURE*
10:00 am Area 6	"SUBOPTIMAL CONTROL STRATEGIES FOR OPTIMAL CONTROL OF LARGE SCALE SYSTEMS" Karl Kunisch, *Karl Franzens Universität Graz* *PLENARY LECTURE*
11:00 am Area 1B	Break
11:30 am Contributed Session 5 Area 6	"PROPER ORTHOGONAL DECOMPOSITION: A TOOL OF MANY USES" Belinda B. King, *Virginia Tech*
11:50 am	"PARAMETER ESTIMATION IN NONLOCAL EVOLUTION EQUATIONS" Azmy Ackleh, *University of Louisiana at Lafayette*
12:10 pm	"MODELING, IDENTIFICATION, SIMULATION AND EXPERIMENTAL VALIDATION FOR A FREE BOUNDARY DIFFUSION BASED MODEL FOR THE CORROSION OF CONCRETE" Gary Rosen, *University of Southern California*
12:30 pm Area 2B	Lunch, McKimmon Center
1:30 pm Area 6	"COMPUTATIONAL TOOLS FOR DESIGN AND CONTROL OF DISTRIBUTED PARAMETER SYSTEMS" John Burns, *Virginia Tech* *PLENARY LECTURE*
2:30 pm Area 6	CLOSING REMARKS

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ABSTRACTS

Richard Albanese
Brooks AFB

"Mathematics and Electromagnetic Theory"

This report examines certain aspects of modern electromagnetic theory and points to major contributions by Professor Thomas Banks and colleagues. The report addresses electromagnetic theory from the point of view of physics, biology and engineering applications. Details of electromagnetic energy absorption within a material are presented. Electromagnetic energy is stored within a medium as kinetic and potential energy. Electromagnetic energy is dissipated as thermal energy. Biomedical effects can be related either to energy dissipation or thermalization, or to stored energy. Thermalization can result in increases in rates of protein denaturation. It is shown that the creation of a thermal field using electromagnetic energy can result in chemical fluxes within a medium. Energy storage within molecules can become localized to certain molecular sub-components and this could pose a hazard. Active engineering applications of electromagnetic theory include imaging and energy localization within media for therapy or other manipulative purposes.

John Burns
Virginia Tech

"Computational Tools for Design and Control of Distributed Parameter Systems"

During the last thirty years, considerable progress has been made on the development of the theoretical foundations of distributed parameter systems. However, in order for this theory to have an impact in various application areas it is essential that this theory be applicable to important engineering design and control problems. In addition, the development of practical computational tools has long been recognized as one of the key issues.

In this presentation, we discuss various applications that have motivated past research in distributed parameter systems and point to new application areas that could benefit from a distributed parameter approach to these areas. In particular, we focus on specific cases where distributed parameter theory has led to new knowledge about fundamental physics and to new computational algorithms that are having considerable impact on

engineering design. Finally, we close with a discussion of mathematical and computational issues that must be addressed before distributed parameter systems theory can be applied to exciting new technological areas such as nano-technology.

Diona Cioranescu
Universite Pierre et Marie Curie

"Application of the homogenization theory to the study of truss-like structures and rubber-like elastomers"

We present first some new results concerning the asymptotic behavior of truss-like structures made of many identical cells periodically distributed. The material is concentrated along layers or along bars. We focus our attention on truss-like plates or beams (where the periodicity occurs in two directions or respectively, only in one direction of the space). They are perforated structures with very big holes and very little material.

There is no symmetry assumption on the distribution of the material in the periodicity cell, therefore very complex geometries can be considered. Three small parameters are to be taken into account in the description of such a structure: the period ε of the cells, the thickness η of the plate or the cross section η^2 of the beam, and finally the thickness $\varepsilon\delta$ of the layers or of the bars from which the structures are made. To study the dependence on the period, we apply homogenization methods. The dependence on η is given by plate or beam techniques. Finally, the dependence on the third parameter δ, is treated by singular perturbation methods. It is important to remark that the overall coefficients thus obtained, are given explicitly by means of the characteristic constants of the material.

In the particular case of a truss-like beam, we also investigate the behavior of the bars composing it between two nodes and show how they deform. Same techniques are applied to gridworks, to convex mirrors and shells.

Next we apply homogenization techniques for some energies of integral type arising in the modelling of rubber-like elastomers. Equations linked to these integrands and their physical interpretation have been recently studied by H.T. Banks, N. J. Lybeck, B. Munoz and L. Yanyo in the framework of the neo-Hookian materials. The main feature of the variational problems taken into account, is that pointwise oscillating constraints on the admissible deformations, determined by general, not necessarily bounded, constraint sets are involved. We consider the case of Dirichlet, Neumann, and mixed type boundary conditions. We prove that the limit energy is again of integral type, gradient constrained, and with an explicitly computed homogeneous density. Some explicit computations for the homogenized integrands relative to energy densities coming from models treated by H. T. Banks and al., are also discussed.

Ruth Curtain
University of Groningen

"System theoretic insights into model reduction for control design for distributed parameter systems"

During the past decades, considerable advances have been made in the simulation of controlled distributed parameter systems (dps). In the opinion of this author, this numerical sophistication has not been matched by the theoretical understanding of the approximation processes involved. The aim of this paper is to shed a little light on some of the system theoretic properties which determine the suitability of state-space approximation schemes for control design of dps. The basic properties required of a finite-dimensional controller are

(P1) The controller stabilizes the dps model of the system.

(P2) The controller is robust so that it will have a chance of stabilizing the actual physical plant.

(P3) The performance of the controller is reasonable, e.g., with respect to disturbance rejection, sensitivity of the output and such like.

Usually one designs a sequence of controllers K_n which stabilize a sequence of finite-dimensional approximating systems G_n, and hopes that (P1) will hold for large enough n. It is known that for this to work it is necessary that the approximating systems converge in the gap topology; sufficient conditions on the approximating systems are also known. In this paper, these results are reviewed and a new robust control design is proposed which leads to robust, low-order controllers. It is shown that, at least for the class of exponentially stabilizable and detectable state linear systems with bounded and finite-rank inputs and outputs, this design always leads to a low-order controller which stabilizes not only the original system, but also a large class of perturbations. This robustly stabilizing controller also guarantees bounds on the main performance indices. A key feature of this design is that the control design is matched to the approximation scheme and the behaviour of the closed-loop system is analysed.

However, this new robust control design serves more as an example to illustrate what is needed, rather than to solve the problem. It raises more questions than it answers. How does this scheme really work in practice? The feasibility of this scheme needs to be tested using numerical simulations on bench mark dps models and on experimental set-ups. Does this scheme generalize to systems with unbounded inputs and outputs? Can it be extended to nonlinear systems?

There is a great need for a better theoretical understanding of the effectiveness and the limitations of current numerical approximations used for control design of dps and (lest we forget) of the original physical system. There is also a great need for new control design algorithms satisfying at least (P1)--(P3).

Constantine Dafermos
Brown University

"Hyperbolic Conservation Laws in Continuum Mechanics"

The lecture will survey recent developments on the interface of the theory of hyperbolic systems of conservation laws with continuum mechanics. It will discuss research trends and will describe major open problems in that area of Analysis.

Wendell Fleming
Brown University

"Max-plus linear partial differential equations"

First order PDEs of Hamilton-Jacobi-Bellman (HJB) type arise in a wide variety of applications including: asymptotic problems in probability and mathematical physics, optimal control, nonlinear filtering and computer vision. HJB equations are nonlinear in the usual sense, but are linear with respect to max-plus algebraic operations provided the nonlinearity in the gradient variable is convex. Topics to be discussed include: semiconvexity of solutions to max-plus linear PDEs, control representations of solutions, max-plus fundamental solutions and max-plus basis representations of solutions.

David Gilliam
Texas Tech

"On the Geometric Theory of Output Regulation for Distributed Parameter Systems"

In this talk we survey our recent work extending the geometric theory of output regulation to linear and nonlinear distributed parameter systems. First we describe our results for systems with bounded control and observation operators. In particular, we characterize the solvability of both the state and error feedback regulator problems in terms of solvability of a pair of operator equations referred to as "the regulator equations." We also describe our application of this theory to systems with delays. In this case the regulator equations take on a remarkably simple form which, when the corresponding regulator problem is solvable, can be solved explicitly. Next we present our more recent work in which these results are extended to certain systems with unbounded input and output operators. These results are established for the class of regular linear systems. In this direction we also show that a large class of systems governed by parabolic equations on bounded domains with certain types of boundary controls are regular linear systems. Finally we present our most recent efforts extending these geometric results to nonlinear distributed parameter systems. Various directions for this research and open problems will also be given.

Daniel Inman
Virginia Tech

"Comments on Structural Health Monitoring and other Cracks"

A summary of the issues and problems of structural health monitoring using smart materials is presented. A historical perspective on the issues of heath monitoring and the interplay between applied mathematics and engineering approaches are discussed. Structural heath monitoring can be sub divided into four sub problems:

1) Does damage exist?
2) Where is it?
3) What is its orientation?
4) What life is left in the structure (or what can be done about it)?

Each question requires more modeling and hence more mathematics to answer. Examples of each level of problem are given. A history of solutions is given, and issues that remain are discussed.

Franz Kappel
Karl Franzens Universität Graz

"Global models for the cardio-vascular-respiratory system emphasizing regulatory mechanisms"

Mathematical modeling of various aspects of the cardio-vascular system (CVS) resp. Cardio-vascular-respiratory system (CVRS) is a very active discipline presently and is represented by a large number of papers in the physiological and applied mathematical literature. In our survey we concentrate on models which consider CVS resp. CVRS in its global functionality and emphasize the basic mechanisms. Of special interest will be the regulatory mechanisms which are determining the behavior of the system during short and medium length time intervals. The discussion will include possible applications of such models as submodels in larger scale models and some of the typical mathematical problems connected with modeling efforts in this area.

Fumio Kojima
Kobe University

"Inverse Problems related to Electromagnetic Nondestructive Evaluation"

Problems on the identification of material properties arising in electromagnetic nondestructive evaluations are considered. Continuing efforts are directed towards early discovery of any type of flaw in order to ensure a safe operation of the nuclear power plants. It is also very important to evaluate degradation and lifetime of structural components in nuclear power plants for the purpose of the lifetime elongation.

In accordance with recent developments of high sensitive magnetic sensors, magnetic nondestructive evaluation is one of the most promising methods for the assessment of materials used in the plants. Inverse analysis with electromagnetic measurements plays a key role in such inspection challenges. This paper overviews state-of-the-art computational methods for such inverse problems in applied electromagnetics.

The first part is devoted to parameter estimation problems related to eddy current testing in the inspection of the steam generator tubes of the pressurized water-type nuclear (PWR) power plants. A three dimensional model for magnetic vector potentials is considered for the inspection procedures. Some successful computational efforts are presented and discussed for recovering crack shapes of SG tubes. Research activities on ECT analysis in JSAEM are introduced and open problems are indicated for identifying natural cracks. A couple of alternative inverse problems are also presented under the use

of the superconducting quantum interference devices. The second part is concerned with the quantitative nondestructive evaluation for the level of embrittlement in reactor pressure vessels (RPVs). It is essentially required to understand the degradation mechanism from viewpoints of physics, magnetism and material science and to collect fundamental data from macroscopic and microscopic measurements, such as B-H curve measurement, Barkhausen noise measurement, SQUID measurement, etc. Those problems involve current challenging works on inverse problems in nonlinear electromagnetics. Some possibilities of the inverse formulations are addressed. Finally, discussions include future research directions on inverse problems related to ageing material evaluation.

Karl Kunisch
Karl Franzens Universität Graz

"Suboptimal Control Strategies for Optimal Control of Large Scale Systems"

Two suboptimal control methods for the numerical solution of large scale optimal control problems are discussed: the instantaneous control strategy and POD - (principal orthogonal decomposition) based methods. The instantaneous control strategy is introduced as a special case of receding horizon control, a method intensively studied in the control of ordinary differential equations, but still uninvestigated for the control of distributed parameter systems. Numerical examples to the control of viscuous fluids and to the Kuramoto-Sivashinsky equation are given. Model reduction by means POD is discussed and applied to optimal control of problems in fluid dynamics. Error estimates for POD – approximations of the state-equation are presented. This talk draws upon joint work with K.Avanasiev, M.Hinze, K.Ito, X.Marduel, and S.Volkwein.