University of Michigan Faculty Memoir: 1967–2010

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1 University of Michigan affiliations (1967-2010

My academic career followed the standard track. I was initially appointed as an Assistant Professor in 1967, I was appointed to Associate Professor with tenure in 1971, and I was appointed as Professor in 1977. I became Professor Emeritus after I retired in 2010.

1.1 Information and Control Engineering (1967-1968)

My initial academic appointment, continued until my retirement, was in the Department of Aerospace Engineering. When I was hired in 1967, immediately after completion of my doctoral degree at the University of Texas, I was a part of an academic program, within the Department of Aerospace Engineering, called Information and Control Engineering. My initial teaching assignment was an advanced graduate course on the subject of my dissertation and related material. This was a great help in beginning my academic career.

During my first year, the main topic of conversation with my faculty colleagues in Information and Control regarded the establishment of a new graduate level interdepartmental program that would combine computing subject areas with information and control engineering; this was done to nurture the then emerging computer activities that were spread out within

several departments in the UM College of Engineering. This was a great opportunity for me to see the vision that my senior colleagues had in establishing such a broad ranging new academic program that combined all aspects of computers and information processing and their applications; my exposure to this scholarly vision was important not only in 1967 but it continued to influence my thinking thereafter. This development had a great impact on my personal career and subsequent development. It was my luck to be a part of this new academic program, called Computer, Information and Control Engineering (CICE), during the initial part of my academic career.

The senior faculty members in Information and Control were my mentors and colleagues in this initial period: Elmer Gilbert, Robert Howe, Bill Root, Larry Rauch, and Fred Beutler. They had a major impact on my academic career for the subsequent decades. I joined many conversations with this group, and others, at the coffee shop on S. University St. around the corner from our offices in East Engineering Building (now East Hall). We had regular lunches together, where the discussions continued. As the youngest and least experienced faculty member, I appreciated being included and respected within this group. I took advantage of an active program of distinguished researchers who visited our group at UM. This was made possible by the many contacts of my colleagues and their belief in the importance of first hand interactions with outstanding scholars and researchers. In this way, I met and came to know many of the most distinguished international researchers in the fields of control, optimization, communications, and stochastic systems.

1.2 Computer, Information and Control Engineering (1968-1983)

The College of Engineering and Rackham approved the establishment of this graduate level academic program in the winter of 1968, and it became operational in Fall of 1968 with offices located on the first and second floors of East Engineering Building. This meant that most, but not all, graduate level courses in areas related to computing, information processing, and applications moved from the departments (aerospace, electrical, mechanical, industrial) into CICE. CICE was the central hub of most research in the College of Engineering in these areas.

I became close colleagues and friends with many faculty members in CICE from other departments. I worked with many faculty members, but my clos-

est friends were Keki Irani, Arch Naylor, and John Meyer. I significantly expanded my knowledge of digital systems, computer software and hardware and computers as components of information processing systems for control and signal processing. At the same time, this was a period when I learned much more mathematics; this included discrete mathematics, functional analysis, optimization, probability and stochastic processes. This was important to support my own research, but it was also important to expand my knowledge as a faculty member in CICE.

I took on service responsibilities within CICE; these responsibilities were typically shared by all faculty members. At first, I organized parts of the doctoral qualifying examinations in the controls area; I was then involved in development of doctoral policies, including doctoral examinations, that covered a broad selection of subject areas in CICE. For a number of years, I was responsible for organizing and scheduling all CICE courses in all areas; this allowed me to learn much about the whole spectrum of courses in the program. During one term I was the acting chair of the CICE program when Fred Beutler, the chair at the time, was on sabbatical leave. Consequently, CICE provided me with an opportunity to grow both in my intellectual knowledge but also in working with others in service and administrative positions. I became very good at serving on and running committee meetings. This was extremely valuable experience for my subsequent academic career.

In academic terms, CICE was an outstanding success. It had high academic standards and excellent student quality. Nevertheless, there was considerable pressure to move the mainstream computing courses into electrical engineering, since this was the organizational structure in most other peer colleges of engineering. In 1983, the College of Engineering made the decision to disband CICE and to establish the reformed Department of Electrical Engineering and Computer Science (EECS). I re-established my links with the Department of Aerospace Engineering in 1984, so that it became my main academic home thereafter.

1.3 Department of Aerospace Engineering (1984-2010)

I was a fully committed faculty member in the Department of Aerospace Engineering after 1983. My teaching, research, and service responsibilities were all within Aerospace Engineering, although I continued to have many contacts with faculty and students in other departments. This transition forced me to expand my knowledge about traditional aerospace engineering

topics, especially those related to the more practical aspects of flight systems.

I began to teach control courses, both at the undergraduate and graduate levels, in Aerospace Engineering, but I also developed and taught more applied flight systems courses. The Aerospace Engineering students had somewhat different background from the CICE students, but I was able to adjust to their backgrounds and interests. I was sorry to see the end of CICE, but I found new challenges and opportunities in Aerospace Engineering. I slowly developed a research program that was oriented towards aerospace flight applications, and I expanded my work with doctoral students.

For historical reasons the Aerospace Department was divided into three disciplinary specializations: gas dynamics, structures, and flight dynamics and control (FDC). I greatly enjoyed working with FDC faculty members over the years, on both educational issues and research issues. These FDC faculty were Elmer Gilbert and Bill Root (for a few years until they retired), Pierre Kabamba, Dennis Bernstein, Dan Scheeres, Ilya Kolmanovsky, Ella Atkins, Anouck Girard, and James Cutler. We often had differing opinions about educational philosophy and the relative importance of FDC topics; this led to many stimulating intellectual discussions about our field. My opinion is that we had one of the top FDC groups among all of our peer aerospace engineering departments.

1.4 Collaborations with faculty and students in other departments

My earliest opportunity for interdisciplinary collaboration was with Harold Shapiro, then a faculty member in the Department of Economics. I worked with Shapiro and his outstanding doctoral student, Eiske Sakakabara, to apply optimal control theory to the classical economic investment and consumption problem. I also worked with another Economics graduate student, Darius Gaskins, to develop results on an optimal control problem related to monopoly pricing. A few years later Harold Shapiro became Dean of Literature, Science and the Arts, then Provost, then President of UM. He eventually became President of Princeton University. I met with Shapiro on many occasions while he was Provost and then President at both UM and Princeton; I viewed him as a friend and faculty colleague over the years.

I had the opportunity to work closely with several faculty members in the Department of Mathematics. Beginning in 1968, I made contact with the dis-

tinguished mathematician Lamberto Cesari. Although I found Cesari helpful and accommodating, he was formal and reserved. It was my interactions with a number of his graduate students that were most productive. My closest friend was Richard Baum; we had much in common about a large range of intellectual topics. A few years later, he was hired as a faculty member in Industrial Engineering. Cesari had several other doctoral students who were good friends: Tom Angel worked on optimal control of time delay systems and M. Suriyanana worked on multi-dimensional optimal control problems. I learned much from Cesari and his doctoral students in the late 1960s and early 1970s that had an impact on my subsequent research.

In the mid 1980s, I met Anthony Bloch, who was a non-tenure track faculty member in the Mathematics Department. We had many common interests, and we published several conference and journal papers together. Tony left UM after a few years, spending time at Cornell and Ohio State; he eventually returned to a tenured appointment in the Mathematics Department. We remained good friends after he returned to UM.

In 2003, Melvin Leok came to UM from Cal Tech as a non-tenure track faculty member in the Mathematics Department. We soon began to work with a new doctoral student Taeyoung Lee. The research collaboration between the three of us, begun in 2004, has continued to the present (2016).

In the 1980s, I established a research collaboration with Robert Hanson, a faculty member in the Civil Engineering Department, that was concerned with control of civil engineering structures, such as buildings and bridges, subject to wind and seismic excitation. Several years later, another collaboration with Robert Hanson was concerned with using electro-rheological materials to design control valves that could be used for structural control applications subject to wind excitation.

I was a participant in the College of Engineering robotics program from the 1980s to the present. In the 1980s I participated in an Air Force Office of Sponsored Research program on robotics; several of my graduate students carried out research on robotics topics. My graduate students and I had the opportunity for regular interactions with faculty and students with broad interests in artificial intelligence, planning, and computer vision. I studied specific problems in spacecraft robotics and nap-of-the-earth aided rotorcraft flight, the latter topic in collaboration with EECS faculty member Ramesh Jain. This work continued into the early 1990s and led to research problems for several of my doctoral students. During part of this time, I and some of my doctoral students maintained offices at the Advanced Technology Laboratory

Building to maximize our contacts with EECS faculty and students working on robotics.

In the 1970s, I met Carl Simon, then a young faculty member in the Mathematics Department with interests in applied mathematics, especially biology, public health and public policy. In the late 1980s, he and other faculty members in the College of Literature, Science and the Arts organized a graduate level interdisciplinary academic program in nonlinear dynamics and complex systems; they were strongly influenced by the work of John Holland in Psychology and EECS, who had helped to establish a new field of genetic algorithms and complex adaptive systems. I had worked with several of Holland's earliest graduate students, and I found their ideas intellectually stimulating. This program was eventually organized into the Center for the Study of Complex Systems (CSCS). Although I never did serious research in complex systems, I was a long time supporter of this program at UM through personal contacts, participation on the CSCS board, and attendance at many of the events that they sponsored.

After 1984, I had teaching and research collaborations with several faculty members in EECS; these were very important connections to me. My collaborators included Ramesh Jain, Jessy Grizzle, Jim Freudenberg, Semyon Meerkov, Demos Teneketzis, Stephane Lafortune, N. Narasimamurthi, Pramod Khargonekar and Ian Hiskens. I also had numerous contacts and collaborations with faculty in other departments about a wide range of dynamics and control subjects. These faculty included Galip Ulsoy, Dawn Tilbury and Yoram Koren in Mechanical Engineering, John Lee in Nuclear Engineering, and Frank Filisko in Material Science.

2 Teaching

I estimate that I taught about 60 classes over 43 years at UM. I enjoyed teaching the same material year after year, as I continually refined the content and presentation. The largest class size was slightly over 100 students, and the smallest class size was about ten students.

Throughout my career, I had a strong interest in working on curriculum matters; I supported innovation in the curriculum and I supported curricular emphases on both good mathematics training and meaningful laboratory experiences. I served as chair of the CICE curriculum committee, chair of the Aerospace Engineering graduate committee, chair of the College of

Engineering curriculum committee, and chair of the Aerospace Engineering undergraduate committee. I viewed these educational contributions as an important part of what I accomplished as a faculty member.

I developed and taught many new courses. Many of these new courses were specialized graduate level courses in dynamics and control that were based, in part, on my own research. In the late 1970s and early 1980s, I developed an undergraduate course in mathematical systems intended for juniors and seniors in EECS. This led to my first text book publication *State Models of Dynamic Systems: A Case Study Approach*. Later, I developed and taught the introductory course that Aerospace Engineering undergraduates took in the period 2000 to 2009; most of the students were sophomores or juniors. This led to my second text book publication *Steady Aircraft Flight and Performance*.

Although I taught and worked with thousands of undergraduate and graduate students during my academic career, my closest relationships were with my twenty-seven doctoral students. These students have been very successful in academia, business and industry. Twenty-one of my twenty-seven doctoral students were not born in the United States. The opportunity to guide their education, to collaborate with them on research, and to learn from them provided high points in my academic career.

3 Research

My research career at UM is naturally divided into several phases.

3.1 Research as a CICE faculty member (1968-1980)

Once I arrived at UM in 1967, I understood that I needed to define new research directions beyond what I had done in my doctoral research. I was aided and encouraged in this by my Aero/CICE colleagues Elmer Gilbert and Bob Howe.

I guided my first doctoral student, Ron Zmood, to obtain new results on control of linear time-delay systems. I also developed new results for systems with time delay described by differential-difference equations, functional differential equations, and integral equations. I made a connection with the UM Population Studies Center that led to several publications on age-dependent population dynamics and control.

Beginning in the early 1970s, I expanded my research interests to include stochastic systems. I had a limited background in probability from my doctoral studies, but this was an important subject in the CICE curriculum. I studied on my own and I was greatly aided by my colleagues Bill Root, Fred Beutler and others in expanding my knowledge of probability and stochastic processes. My initial work in this area was done in collaboration with my second doctoral student Chelsea White on optimal control of partially observable semi-Markov systems.

About 1973, I began serious research on topics related to my graduate student interests in nonlinear control. In particular, I studied stability of multi-loop feedback systems, with special structure. I was able to show that concrete stability results could be obtained for several categories of special feedback structures. Sometime in this period the well-known Romanian researcher V. M. (Mihai) Popov visited UM for several months; he gave a series of lectures on stability of feedback systems that had a strong influence on my thinking about these problems. I continued this research direction during the nine months I spent on sabbatical at Cambridge University in 1975.

3.2 Mid-career research interests (1980-1994)

My research directions changed beginning about 1980. I began to investigate dynamics and control topics that arose directly from engineering problems; this was also the beginning of my research collaborations, including experimental collaborations, with other University of Michigan faculty members. In the early 1980s, I established a collaboration with Professor Robert Hanson from the Civil Engineering Department, related to a joint United States and Japan project, sponsored by NSF, on pseudo dynamic testing of building structures subject to earthquake excitation. A key part of this project was my contribution to the control of building deformation using multiple hydraulic actuators. Later in the 1980s, I again worked with Hanson and his graduate students on the use of electro-rheological fluids for control of structures. This was an interdisciplinary research project, involving materials, structures, and control, for retrofitting of bridges, such as the Golden Gate Bridge in San Francisco, to reduce deformation in large winds. I worked closely with Hanson's doctoral student Henri Gavin.

I continued my research interests in stochastic control through work with several doctoral students. Charles Conrad completed his doctoral degree in 1986 on an optimal drill replacement problem; he introduced and used a con-

trolled diffusion-threshold model in this research. Chih-Ping Lee completed his doctoral degree in 1989 on a specific controlled queueing problem, where the service times are influenced by control mechanisms.

I became interested in various types of robot control problems in the 1980s. This was motivated, in part, by my participation in a large multidisciplinary Air Force Office of Sponsored Research (AFOSR) robotics research program that was led by Richard Volz. I studied the control of contact force that a robot manipulator makes with some external object or fixed surface. By viewing hard contact between the robot and the object as a holonomic constraint; important new dynamics and control results were obtained. Han-Pang Huang completed his doctoral degree in 1986 by developing optimal control results for combined robot position and force control for constrained robots. Danwei Wang completed his doctoral degree in 1989 by developing feedback stabilization results for position and force control for constrained robots.

I began a research collaboration with Tony Bloch, a faculty member in the Department of Mathematics, in the late 1980s. We published several theoretical papers on dynamics and control of constrained Hamiltonian systems. Tony Bloch later became an important resource for many of my doctoral students who worked on mathematical aspects of dynamics and control.

Girkirpal Singh was an Aerospace Engineering doctoral student, who worked with Pierre Kabamba and myself, on optimal attitude control maneuvers of elastic spacecraft. This was research that made use of the theory of optimal control to solve challenging spacecraft maneuver problems.

By participating in the AFOSR research program, I came into contact with faculty colleagues engaged in research on computer vision. I was interested in using vision for feedback control purposes; this was a novel approach significantly different from the image processing approaches that were most common at the time. Chi-Chang Ho completed his doctoral degree in 1991 on the combined use of inertial navigation and computer vision to achieve docking of two orbiting spacecraft. David LeBlanc completed his doctoral degree in 1994 on computation of range maps for low altitude rotorcraft flight using computer vision. In collaboration with EECS faculty member Ramesh Jain, I carried out research for NASA Ames on vision based guidance of helicopters to avoid trees, power lines, towers, etc., when performing close to the ground flight.

3.3 More research on nonlinear control (1990-2000)

My research directions changed again in the late 1980s. A popular research approach at that time was to apply methods of differential geometry to problems in nonlinear feedback control. I developed my background in differential geometry and I studied the relevant control literature. I could see many opportunities to apply these results to specific aerospace and robotics control problems.

In the 1990s, two of my doctoral students made use of advanced nonlinear control methods to solve certain aircraft flight control problems. Darren Schumacher completed his doctoral degree in 1994 introducing new nonlinear control methods for flight control of a tactical missile. Saif al Hiddabi completed his doctoral degree in 2000. He formulated and solved several interesting aircraft flight control problems using methods of non-causal dynamic inversion He illustrated the value of the results in achieving aggressive aircraft flight control.

I advised several doctoral students on research topics related to nonholonomic control. We developed both theoretical results for nonholonomic control systems and we applied our theoretical results to control many spacecraft and robot examples. Mahmut Reyhanoglu completed his doctoral degree in 1992 based on his research on attitude control for planar maneuvers of multi-body systems. Hariharan Krishnan, Mahmut Reyhanoglu and I published several widely cited papers on attitude control of under-actuated rigid spacecraft. Krishnan completed his doctoral degree in 1992, by developing new results on control problems defined by differential and algebraic equations. Ilya Kolmanovsky developed new control results for nonholonomic systems with applications to spacecraft and robotics; he received the doctoral degree for this research in 1995. Ilya and I wrote a survey paper on "Developments in Nonholonomic Control Problems," published in 1995, that was my most widely cited publication. Chunlei Rui completed his doctoral degree in 1997 based on his research contributions to attitude control of three-dimensional maneuvers of multi-body systems. Sangbum Cho investigated combined orbit and attitude maneuvers of multi-body spacecraft; he completed his degree in 2001. Jinglai Shen carried out further theoretical research on nonholonomic control systems, and he developed an experimental test bed for attitude control for planar maneuvers of a three-link multi-body system.

3.4 Research on geometric mechanics and control (2001-2010)

My colleague Dennis Bernstein and I were interested in pendulum dynamics, since they were so often used in textbooks and as research examples. We realized that the idealized pendulum dynamics, referred to as planar pendulums or spherical pendulums, did not completely capture all phenomena of a physical pendulum; Jinglai Shen, Amit Sanyal, Nalin Chaturvedi, Dennis Bernstein and I introduced the 3D pendulum in a conference paper published in 2004. This paper investigated dynamics and control features of the 3D pendulum for the first time; most importantly, it introduced a new mathematical model for the 3D pendulum, obtained from simple Newtonian principles, expressed in terms of the attitude, viewed as an orthogonal matrix, and the angular velocity vector of the rigid body that defined the pendulum. This model was globally defined, so it could be used to investigate large pendulum motions. At the same time, an experimental research program was developed, based on a tri-axial air bearing, that provided a physical approximation to the 3D pendulum dynamics; it was also instrumented for control purposes. Dennis Bernstein conceived this facility and he was able to obtain funds from AFOSR for its construction as an important part of the Attitude Dynamics and Control Laboratory. The experimental results obtained for the 3D pendulum provided important motivation for our theoretical research, and they also served to validate the theoretical results that were obtained.

Motivated by the 3D pendulum results, I realized that there was a major deficiency in the classical Lagrangian and Hamiltonian approaches to dynamics that could be traced to the use of attitude coordinates such as Euler angles or quaternions; such a choice limited the validity of the Lagrangian or Hamiltonian equations. This deficiency could be overcome by appropriate use of differential geometric concepts.

At one of the first meetings that Melvin Leok and I had with a graduate student, Taeyoung Lee, in 2004, we derived a mathematical model for the 3D pendulum directly from a variational principle. By viewing the attitude as a rotation matrix in a Lie group manifold, we obtained an explicit expression for the variations of the attitude and the angular velocity that depended on the exponential representation for elements in that Lie group manifold. This was our first major insight; we knew that this would be a productive research direction and we had the key idea that could be exploited in our subsequent

research. Our first paper using these ideas was a conference paper published in 2005, demonstrating how these ideas could be used to develop variational integrators for the 3D pendulum dynamics. These ideas formed the basis for much subsequent research to investigate global dynamics, global control of the dynamics, and efficient computational approaches.

Jinglai Shen, Amit Sanyal, Nalin Chaturvedi, and Taeyoung Lee all contributed to this research direction in their dissertations, completed in 2002, 2004, 2007, and 2008. Taeyoung Lee used the same concepts to develop new computational results for Lagrangian and Hamiltonian dynamics that evolve on a manifold. These results were based on variational and geometric integrators that were guaranteed to preserve the flow on the manifold and any dynamic symmetric properties; these features led to excellent computational accuracy, especially over long time periods. These students, and Sangbum Cho before them, studied various dynamics and control problems for multi-body systems, primarily from aerospace and robotics applications. Specific publications addressed issues of global dynamics, feedback stabilization and optimal control.

After my retirement in 2010, Taeyoung Lee, Melvin Leok, and I continued to collaborate on further extensions of the work on Lagrangian and Hamiltonian dynamics that evolve on a manifold. Many conference and journal papers were developed and published. Most of the papers demonstrated the theoretical and computational approaches for a variety of multi-body dynamics and control problems; these included multiple papers on string pendulums, tethered spacecraft and quad-rotor flight vehicles; we also developed several publications treating dynamics that evolve on the surface of a sphere or the product of spheres.

Lee, Leok and I began work on a comprehensive book that would describe the theoretical features of Lagrangian and Hamiltonian systems that evolve on a manifold, including many illustrative examples. This book is nearly complete and should be published in 2017 as *Global Formulations of Lagrangian and Hamiltonian Dynamics on Manifolds: A Geometric Approach to Modeling and Analysis*.

3.5 Publications

I contributed to the scholarly literature with publication of 173 conference papers, 13 articles in edited volumes, 92 journal papers, three books, 8 book reviews and numerous unpublished articles and reports. Almost all of these

publications were develop in collaboration with graduate students and faculty colleagues.

4 Professional organizations

The three major professional societies with which I identified were: the Society for Industrial and Applied Mathematics (SIAM), the American Institute of Aeronautics and Astronautics (AIAA) and the Control Systems Society (CSS), which is a part of the Institute of Electrical and Electronic Engineers (IEEE). I did not publish in any of the SIAM journals, but I read them closely and found them useful in providing me with background in all areas of applied mathematics; I did attend a number of SIAM sponsored conferences on an irregular basis. I published a number of journal papers in the AIAA Journal of Guidance, Control and Dynamics, and I occasionally attended the AIAA Conference on Guidance and Control. My main professional organization was the CSS.

4.1 Conferences

For more than thirty years, I attended almost all Conference on Decision and Control (CDC) events held in early December; this conference was sponsored by CSS. In many years, I attended the American Control Conference (ACC) held in June; this conference was sponsored jointly by CSS and by dynamics and control groups from AIAA, ASME, ASCE, and others. These conferences were typically attended by 1000 persons or more and covered all aspects of the dynamics and control field. These conferences often drove my research efforts, since submission of publications for a subsequent conference were due in the preceding September or February; this meant that any new research results needed to be documented according to this cycle.

As a part of my volunteer leadership in CSS, I was involved in many conference organizations. I served on the program committees for numerous CDC and ACC events. In 1994, I served as the CDC program chair, which meant that I had oversight of the technical program at the CDC held in Orlando that year. I worked closely with Mike Masten, who was the general chair, to organize a successful CDC. In 1999, I served as the general chair of the Conference on Control Applications that was held on the Big Island in Hawaii. I was responsible for all aspects of the conference, excluding the

program.

4.2 Editorial administration (1985-1992)

I published my first paper as a technical note in TAC in 1967, and some of my best research has been published in TAC. The TAC is, arguably, the premier journal that covers dynamics and control. It has published many of the most outstanding papers in the field since 1963, and it is read by an international community of control researchers that includes all branches of engineering, physics, and mathematics.

I served as Associate Editor of TAC for Technical Notes and Correspondence (TNC) from 1985 to 1989. I had the sole responsibility for obtaining peer reviews and making publication decisions on more than 400 submitted papers per year. This was an enormous responsibility: correspondence with the authors, obtaining reviews, and making publication decisions. I was able to influence the direction of the field, in some small way, by my publication decisions. I learned much during this four year period; I worked closely with members of the TAC editorial board as well as many reviewers and authors. I became quite well known within the dynamics and control field for my handling of TNC papers.

The CSS Executive Committee and Board of Governors approved my appointment as Editor of TAC in 1988. After a period of transition, I assumed the duties as Editor in 1989. I was responsible for overall management of the review and publication process. This involved processing of more than 1500 submitted technical papers annually. I worked closely with members of the TAC Editorial Board and I organized and chaired meetings of the Editorial Board at each CDC and ACC. Unlike my position as Associate Editor for TNC, I was not personally responsible for obtaining reviews for each submitted papers (this was done by members of the Editorial Board) but I was responsible for oversight of the decision process. My service as Editor was my first significant administrative position; I was primarily manager of the publication process including communication with authors and the Editorial Board.

Once it became clear that I would be appointed Chair of the Department of Aerospace Engineering at UM, I made arrangements to resign from the position as TAC Editor. In subsequent years, a new position of Associate Editor at Large was created for the TAC. I enjoyed serving in this consulting role that was used primarily to advise on difficult and controversial publica-

tion decisions. It provided me an opportunity to continue as a part of the TAC Editorial Board, with minimal responsibilities.

4.3 Control Systems Society administration (1983-2009)

As Editor of TAC, I was a member of the CSS Executive Committee. At that time, there were more than 10,000 members of the Control Systems Society from throughout the world. The CSS Executive Committee, on behalf of the CSS Board of Governors, was the administrative structure with responsibility for all CSS conferences, publications, technical committees, and other operations to support the field of control systems.

After completing my duties as TAC Editor, I was elected by the Board of Governors to several CSS administrative positions. I served as Vice President for Publications in 1994, Vice President for Finance in 1995 and 1996, President Elect in 1997 and President in 1998. These were important opportunities for me both to support the control systems field while making many important contacts with other leaders in the field. The Executive Committee met each year at the CDC and ACC and one or twice more during the year. Each meeting typically consisted of marathon discussions over three or four days; there was much business in planning for the CSS Board of Governors meetings. As President Elect I was responsible for making appointments to numerous CSS positions; this was a major task during the summer of 1977.

I served as CSS President in 1998. This was a major commitment of time, while I continued my duties as a University of Michigan faculty members. I travelled quite a lot in 1998 to CSS meetings, to participate in IEEE Technical Activity Board meetings, to CSS sponsored conferences, and to other events to represent CSS. It was an intense but satisfying year. I chaired many meetings that year, including all of the CSS Executive Committee and Board of Governors meetings; much planning went into my preparation for those meeting. It was my good fortune to work with a group of outstanding friends and colleagues who served on the Executive Committee from 1995 to 1999, especially during the year when I was President.

After completing my term as President, I remained active in CSS for several years. I served as the Chair of the Awards Committee in 2001, as Chair of the IEEE Fellows Evaluation Committee from 2002 to 2004, and I was the CSS representative to the IEEE Systems Council from 2007 to 2009.

5 University of Michigan service and administration

I served on many faculty committees and I had numerous administrative positions at UM.

5.1 CICE service and administration (1971-1983)

Once I was promoted to Associate Professor in 1971, I began to take on a few service roles in CICE. I began by advising CICE students on course selection. I was given the task of organizing and scheduling all CICE courses; this required some knowledge of the complete CICE curriculum and good relationships with all of the CICE faculty.

Later in the 1970s, I became the chair of the CICE curriculum committee, which had the responsibility for all changes in the curriculum and for graduate student academic policies; this helped me to learn about the computing and communications courses and how all of the CICE courses contributed to the program's educational objectives. In the winter term of 1979, I assumed the position of acting chair of the CICE Program, while Fred Beutler was on sabbatical leave.

After the dissolution of CICE, there was considerable concern about the future of the control field in the College of Engineering. Several of the control faculty left the University or changed their research area; consequently there was barely a critical mass of control faculty at UM in the early 1980s. The remaining faculty and students with interests in control moved back into one of the several different departments in the College of Engineering. Elmer Gilbert and I, as two of the most senior control faculty in the College at the time, helped to expand the College control programs. We worked with faculty in several departments, primarily EECS and Mechanical Engineering, to recruit outstanding new faculty to UM. At the same time, we helped to establish an informal College of Engineering control group that encouraged cross-department cooperation in teaching and research on control related topics. I am proud that this University of Michigan control community continued with student and faculty participation from many departments. The consequences of this cooperation were: common graduate level courses in control fundamentals that were taken by all interested graduate students with shared teaching responsibility from faculty in several departments, existence of nu-

merous cross-department research projects, and a well-established College of Engineering Control Seminar series that has run continuously since 1985, providing weekly presentations on many theoretical and applied control topics. Since 1985, the control groups in Aero, EECS and in ME grew steadily, so that UM has been widely viewed as one of the premier institutions for control education and research in the United States.

5.2 Aerospace service and administration (1983-1996)

In the early 1980s I became a member of the Aerospace Department graduate committee, which had responsibility for Aerospace Engineering graduate level courses, recruitment and scholarships for Aerospace Engineering graduate students, and graduate student policies. I served as chair of the Aerospace Engineering graduate committee for several years. I was the Department chair from 1993-1996.

5.3 University-level service and administration

I was elected to and appointed to several administrative positions in the UM faculty governance system.

5.3.1 Administrative and service experiences (1979-1987)

I was appointed to serve on the Research Policies Committee during the period1979-1982. I chaired a subcommittee that recommended important changes to the appointments of University of Michigan research scientists; this was an important step in regularizing such appointments. I was elected to serve on the Rackham Divisional Board for the natural sciences and engineering from 1982 to 1985.

I was appointed to the Committee on the Economic Status of the Faculty, representing UM faculty interests on matters related to salary, benefits, and working conditions, during 1983-1985. At that time, UM faculty benefits included a single health care provider. I chaired a subcommittee on health benefits that investigated expansion of UM health benefits to provide more flexibility to faculty in choosing health care coverage, including HMOs, PPOs, etc. The subcommittee consisted of public health faculty members Eugene Feingold and Roy Penchansky, staff administrated Donald Thiel from

UM benefits office, and several others of us with no special health care background. Health benefits were contentious, but after several months of serious study and deliberation, we issued a report recommending such expansion. The report was accepted by the Senate Assembly and by the Vice President for Finance. Most of its recommendations were eventually implemented.

I was elected by the College of Engineering faculty as a representative to the Senate Assembly in 1983. In 1985, I was elected by the Senate Assembly to serve a three year term on its executive committee, the Senate Advisory Committee on University Affairs (SACUA).

My first two years on SACUA were great learning experiences. SACUA met at least weekly with lengthy meetings. We had meetings with the several vice presidents and the Provost and we met occasionally with the President. I enjoyed my SACUA colleagues during that time period; Bob Green from the Medical School was SACUA chair during my first year and Bill Stebbins from LSA was SACUA chair during my second year. I became especially good friends with Dan Moerman, a faculty member from UM Dearborn, with Fritz Lehman, a faculty member in the School of Education, with Dale Briggs, a faculty member and colleague in the College of Engineering, and with Patricia Yocum, from the Science Library. SACUA dealt with many important topics, including the lack of racial diversity at UM, reductions in funding for UM from the State of Michigan, and many other matters related to the many aspects of operations of a large institution such as UM. During this period, Harold Shapiro, whom I already knew from his days as a faculty member in the Economics Department, was the UM President. In my first year, Bill Frye was the Provost and Vice President for Academic Affairs; it was delightful to work with him. In my second year on SACUA, Jim Duderstadt, who had been Dean of the College of Engineering, was appointed as Provost. Duderstadt began several new initiatives during this year, and he brought a high intensity to the position.

5.3.2 Chair, SACUA (1987-1988)

In 1987, I was elected by my SACUA colleagues to serve as chair of SACUA for one year beginning in September of 1987. My year as SACUA chair was a whirlwind of activity. The SACUA office, and the offices of the vice-presidents and the President, were located in the Fleming Building; I spent most of my time that year in the Fleming Building. I was lucky to have a strong staff in the SACUA office; Laina Savory was an excellent administra-

tive assistant and she provided me with great advice on many occasions. In addition, Glenda Haskell was a valued staff assistant on whom I depended.

There were several events that happened during my year as SACUA chair that stand out in my memory. These were: regular meetings with UM executive officers, the Presidential transition that occurred in 1988, my personal encounter with the athletic department, and my participation in the commencement festivities in May of 1988.

At that time, it was the tradition that the chair of SACUA attend regular meetings of (1) the Provost and all of UM Deans and Directors, and (2) UM executive officers, that is the President, vice-presidents, legal counsel, and a few others. In the first instance, this meant that the faculty were generally appraised of new academic initiatives. In the second instance, the faculty had advance knowledge of many financial and policy initiatives that were discussed by the UM executive officers; this access made for generally good relationships between the UM faculty and the UM central administration. I was very careful to maintain confidentiality where necessary, and I believed my participation in those meetings was effective for the institution. After my year as SACUA chair, the tradition changed so that the faculty had no involvement with the subsequent meetings of the executive officers.

President Harold Shapiro announced in 1987 that he would be leaving UM to assume the Presidency at Princeton University. There were several celebrations to recognize his UM contributions; SACUA was responsible for a faculty reception in Shapiro's honor. Dan Moerman and I decided to purchase an art work, produced by a UM faculty member, as a thank you gift; we spent some time on this and it turned out to be a perfect parting gift for President Shapiro. The faculty reception for Shapiro was held in the Michigan League Ballroom.

At the same time, SACUA was responsible for appointing a faculty advisory committee on the presidential search that had important input into the decision made by UM Board of Regents. SACUA spent much time selecting distinguished faculty members to serve on this committee; as SACUA chair, I directed this selection process. As the search progressed, there were many rumors about potential candidates. One member of the Board of Regents, Deane Baker, admitted to personally discouraging one of the strong candidates. I had informal conversations with several members of the Board of Regents about the search process on several occasions. In the end, it was not a surprise that they selected Jim Duderstadt to be the next UM President. I had become comfortable by that time in handling press interviews, and I

gave a few comments to the press approving Duderstadt's selection as UM President, on behalf of the UM faculty.

During the interim period, after Shapiro had left and while the search was proceeding, former President Robben Fleming had been appointed as interim-President. I worked closely with him to make sure that the presidential transition process went smoothly. We had a good relationship during his time as President, with one exception. At that time, there was need Donald Canham as Director of Intercollegiate Athletics. This was a major event in the press and received a great deal of press coverage. At that time, several peer universities, mostly located in the South, appointed the football coach to also serve as athletic director. The time constraints involved meant that sports, other than football, received reduced attention from the athletic director. In fact, this approach is no longer followed today for exactly this reason. My view was that this was just a way of stroking the ego of a favorite football coach. President Fleming announced at a major news conference, including press, radio, and television reporters, that the UM football coach, Bo Schembechler, would assume the additional duties of athletic director. I was at the press conference, in the Regents Room in the Fleming Building, to hear the announcement and adulation heaped on Schlembechler. After the news conference, a few reporters found that I was the chair of the faculty Senate and they asked me for comment. I believe that I was the only person at the news conference to oppose this appointment, on the basis that it would not serve well the needs of all male and female athletes in all sports. My comments created quite a stir. My comments were reported, usually in somewhat garbled form, in the Ann Arbor, Detroit, and other newspapers. A popular sports columnist for the Detroit Free Press wrote a full column explaining how wrong were my comments criticizing the legendary Bo Schembechler. A few weeks later, I received a scathing personal letter from Bo Schembechler about my comments, including his assertion that I embarrassed the UM family. Bo and I subsequently had a 20 minute meeting in his office, where he repeated his assertions; I also repeated what I actually said about the impossibility of a single person serving effectively as both UM football coach and UM athletic director. I received considerable support for my comments from many UM faculty members. The end of this story is that Schembechler maintained this dual role for less than a year. He resigned to take an administrative position with the Detroit Tigers; it was clear that he had done very little in his role as athletic director and he saw it as secondary to his football head coach position. This story illustrates the on-going tension between the

UM academic function and the UM athletic department. The tension has only increased since 1987, and characterizes essentially all universities who participate in Division 1 football.

The final story from my SACUA year illustrates the importance of social functions to the operation of the central administration at UM. The SACUA chair, and sometimes other SACUA members, were often invited to social functions put on by the central administration. These were often to celebrate promotions or retirements, to honor donors, and to celebrate commencements.

Every football home game was celebrated with central administrators, donors, and UM friends. On one occasion in Fall of 1988, Margaret and I were asked by President Shapiro to sit in his box for the Wisconsin football game. Shapiro was not much of a football fan, so I sat next to and interacted with Donna Shalala, the President of the University of Wisconsin. She was an avid football fan, and she made clear that she would make sure that Wisconsin would soon become a top football school; she was correct, but on that particular day, UM beat UW in a blowout. Donna Shalala eventually became Secretary of Health and Human Services in the Clinton administration and then President of the University of Miami, where she became embroiled in several football scandals that led to the University of Miami being put on probation by the NCAA.

I was a member of the platform party at the Winter term University commencement exercises held in Michigan Stadium at the end of April in 1988. My wife and I participated in many of the commencement social functions; this included a brunch at the Michigan League before commencement. We were introduced to two honorary degree recipients: Kurt Mazur, the conductor of the Leipzig Gewandhaus Orchestra that we had heard perform on the preceding evening, and to Jesse Norman, the famed opera singer. All members of the platform party took a large UM bus from the Michigan League to the UM Stadium. I was lucky to sit next to both Mazur and Norman on the back seat of the bus; we three had a conversation about classical music during the 15 minute bus ride. This conversation was a high light for me, since I had enjoyed performances by both Mazur and Norman in person and on recordings for many years. At the commencement exercises, there were probably 30,000 attendees, with many excited student graduates. I gave a short welcoming speech on behalf of all UM faculty to the assembled crowd.

5.3.3 Subsequent faculty governance activities (1989-1993)

For several years beginning in 1988, I was a member of the newly formed Information Technology Policy Committee that provided a forum for discussing the need for and uses of information technology on the campus. The biggest problem was the imbalance between the units, such as Engineering and the Medical School, that had made major investments in information technology and those units that had not, usually due to lack of resources and lack of expertise. The committee struggled with these policy issues, recognizing the need for some centralization to provide a minimum level of information technology support for all students and faculty, without holding back those units with their own aggressive information technology policies. There were exciting discussions, and I enjoyed contributing to these importance considerations.

In retrospect, one of the most important contributions I made to UM policies was based on my service on the President's Task Force on Safety and Security in 1989 and 1990. At that time, UM had only a small security force, with few legal powers; campus law enforcement depended on the Ann Arbor Police Department. This situation created many problems. On the other hand, many student groups opposed a UM police force, on the basis that it might be used to constrain student protests. However, there were many other important issues, including problems with excessive student drinking, drug use, sexual assault, and criminal activities on the campus. The task force consisted of faculty, staff, and students, and it was chaired by Paul Boylan, the Dean of the Music School. We met for many months and finally issued a report that strongly recommended the establishment of a professional University of Michigan Police Department. Our recommendations were eventually implemented. My opinion is that the UM Police Department has been an important component in maintaining safety and security on the campus; it is now a highly respected professional campus unit that is supported by faculty, staff and students.

I was elected to serve on the Rackham Executive Board in 1992, the faculty advisory committee to the Dean of the graduate school on matters related to graduate student policies. I resigned after one year, when I was elected to the College of Engineering Executive Committee.

5.4 College of Engineering Executive Committee (1989-1992)

In 1989, I was elected by the College of Engineering faculty to serve on the College Executive Committee. My previous experience in University-wide faculty governance was a great help to me in taking on these new responsibilities. During this period, Dan Atkins was the interim-Dean; we had worked together previously in the CICE program. Service on the Executive Committee was time consuming, with weekly and sometimes twice weekly meetings, but it was very rewarding. I served on the Executive Committee until 1991, at which time I assumed the position of chair of the Department of Aerospace Engineering.

5.5 Chair, Department of Aerospace Engineering (1992-1996)

After many years in the position, Tom Adamson stepped down as chair of the Department of Aerospace Engineering in 1991. A chair search committee considered numerous external candidates and several internal candidates, including me. Three or four candidates went through a campus interview process. After some deliberations, the search committee recommended my appointment to Dean Peter Banks; he selected me as the Aerospace Engineering Department chair and I began my duties in January of 1992. I recall that I was given little direction for leading the Department. At the time, many senior Aerospace Engineering faculty members were considering retirement and many junior faculty members were only beginning to assume leadership in the Department. At the same time, the Department was at a low period in its cyclic undergraduate enrollment.

In January of 1992, the Department was in the middle of construction of a brand new building, the Francois-Xavier Bagnoud (FXB) Building, with the College committing substantial resources to the building construction project. Tom Adamson and others had done an excellent job of fund raising and working with the University planner and the building architects to plan a building that would meet the Department's needs. Most of my time during my first two years as chair was spent on building related issues. In particular, I had weekly meetings with the University construction managers and the contractors to go over the many decisions that needed to be made; there were many faculty meetings to appraise them of construction progress and to get

their feedback on the construction decisions. The construction project was in two phases over three years to minimize disruption to on-going Department research and teaching functions. I had no prior experience with construction projects, much less a $60,000,000 project, but I was a quick learner and, I think, an effective liaison between the faculty and the contractors and architects.

When the construction was completed, it was time for the faculty, staff and students to move the short distance to the new building. The formal move into the FXB Building was a major challenge to my organizational skills, but my recollection is that it went smoothly. The most controversial tasks were the assignments of faculty offices and research space.

A gala celebration was held to inaugurate the new FXB Building. It was attended by the Countess Albina du Biosrouvray and Bruno Bagnoud, the parents of Francois-Xavier Bagnoud, other donors, College and University officers, faculty, staff, students, alumni and friends of the Department. I played in important role in the ceremonies, representing the faculty, staff and students. I was thankful that most of the planning for the celebration was handled by the Development Office in the College of Engineering.

At the time, there were 24 faculty members and 12 staff members; there were 250 undergraduate students and 160 graduate students. From an administrative perspective, I depended on my administrative assistant Caroline Rehberg and the head of the technical staff Roger Glass; they had held their positions in the Department for many years. I found the flat organizational structure, that had existed for many years in the Department, insufficient to the job of updating the Department academic programs and operational procedures. In general, I felt forced to operate mostly on my own, without the level of faculty input that I had experienced both at the University level and the College level. I also knew that most faculty were happy with this arrangement, in the sense that they did not need to spend much of their time on Departmental matters. One of my contributions was to establish an Industrial Advisory Board to provide advice to the Department on its strategies and policies from outside the institution.

The Aerospace Department was a highly rated department. In 1992, the UM Aerospace Engineering Department had an aging faculty that, in the main, had a traditional view of teaching aerospace subject matter that had been set for decades and engaging research as a small scale enterprise with one or two graduate students. In relation to peers, the faculty was late in coming to the realization that the nature of university engineering teach-

ing and research was changing. Multi-investigator, interdisciplinary research programs, closely connected to specific applications, were essential. At the same time, other University of Michigan departments, such as EECS and ME, were developing new teaching initiatives and new research capabilities. As Department chair, I had hoped to exert some leverage for change, but I was not able to exert much influence on the Aerospace faculty to upgrade their teaching and research plans. In addition, I was unable to convince the College of Engineering to provide additional faculty positions for the Department, even to replace those who would soon be retiring.

Although Peter Banks was Dean of the College of Engineering, I worked most closely with Erdogan Gulari, the Associate Dean for Academic Affairs and later with Bill Martin after he assumed the position. My relations with Gulari and Martin were excellent, but my relationship with Banks was cool. I do not recall ever meeting with him to discuss the future of the Department. At the time, I assumed that our minimal interaction was due to his concentration on new initiatives in other departments, but perhaps it was more than that. In the early Fall of 1994, Dean Banks requested a meeting with me. In a meeting that lasted no more than fifteen minutes, he informed me without explanation that he would like me to step down as Department chair. This was quite unexpected; I was so surprised that I did not make much of a response at that meeting. After he announced his decision in a letter to the Aerospace faculty, I received many expressions of support from my faculty colleagues. Dean Banks resigned from UM later in 1994, and I continued as chair until the end of 1995. I was happy that the subsequent change in College administration and Aerospace Department leadership, under David Hyland and Wei Shyy, were more successful in leading the Department.

As I had time to reflect, I realized that I was happy to relinquish my duties as chair. In many ways, I enjoyed the visibility of the position and I was satisfied with my accomplishments in enabling the move in the new FXB Building. But the chair position was extremely time consuming; I maintained my research program while advising several outstanding graduate students and I taught one course each term. It was ultimately a frustrating experience; I had little significant impact on the research and teaching culture in the Department. It became clear to me that I would be happier not being chair of the Aerospace Department; I happily returned to my own research and teaching responsibilities as a faculty member.

5.6 Final years in the Department of Aerospace Engineering (1996-2010)

I spent the winter term of 1996 on a quickly arranged sabbatical leave at NASA Ames in Mountain View, CA, NASA Langley in Langley, VA, and Twente University in the Netherlands. After a positive sabbatical experience, I was excited to return to teaching and research as a UM faculty member.

For a few years, I maintained a low profile in the Department, focusing primarily on my personal teaching and research responsibilities. I enjoyed being a part of a faculty committee that wrote a lengthy report on the Future of Aerospace Engineering.

I served as chair of the undergraduate committee from 2004 to 2008. I was able to lead the Department, with strong support from the Department chair Wei Shyy, to make major changes in the undergraduate curriculum. The new curriculum was not perfect in my opinion, but it made important improvements and it provided a framework for continuing curricular changes that in fact occurred after 2008. These undergraduate curriculum changes were my last contribution to the Department of Aerospace Engineering.

6 My career at the University of Michigan

I am thankful that I had a full career as a faculty member at UM. It provided me with all of the intellectual and personal opportunities for growth that I could have wished. UM nurtured and recognized my contributions in research, teaching, service and administration. I found the intellectual environment of faculty, students, and others at UM to be a perfect fit for my interests and capabilities. Although I considered leaving UM for other academic opportunities on several occasions, I eventually reached the conclusion that no other institution could provide the full range of attractions that I already had. I take great pride in my career-long association with UM.