Graduate Studies Update
Summer 1991

Chairman's Update

Only Copy

The last year has been characterized by rapid growth and change in our faculty and in our facilities, with the teaching load remaining at a very high level.

This year, we have completed a three-year program of recruiting new faculty members. During this time, we have hired ten new individuals as replacements for retiring professors. This year four excellent young faculty members, Drs. Amy Alving, Ellen Longmire, Thomas Shield, and Lev Truskinovsky, started their careers with us. With their arrival, we have significantly strengthened our programs in fluid mechanics, aerodynamics, control theory and solid mechanics and materials.

We regret the loss from our faculty of Professor Philip Hodge, who retired in June 1991 after 20 years, Professor Jack Moran who resigned in June 1991 to pursue other interests after 23 years, and Professor Jerald Ericksen who retired in December 1990 after 8 years.

We are proud to have had Professor Dan Joseph elected to the National Academy of Sciences this year. Professor Joseph is the only faculty member at the University of Minnesota who holds memberships in both the National Academy of Sciences and the National Academy of Engineering. Professor Joseph also received the Russell Penrose Professorship in Aerospace Engineering and Mechanics. This Professorship was made possible by a generous gift from Mr. Russell Penrose.

The basement of Akerman Hall has undergone a major renovation. The old graduate student offices have been converted to research laboratories in fluid mechanics, materials, and dynamics and control.

Patarasp R. Sethna, Head
Department of Aerospace Engineering and Mechanics

Inside ...

New Professors, New Needs, New Facilities

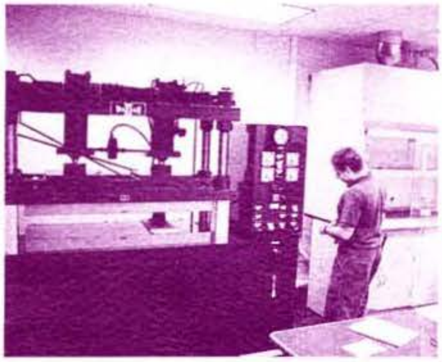
The Department of Aerospace Engineering and Mechanics has hired ten new professors in the last three years, six of whom are experimentalists. This is a considerable increase in the number of experimentalists on the faculty. The new professors will help the department to expand and modernize the experimental program by bringing current research techniques and computerized data acquisition into the curriculum.

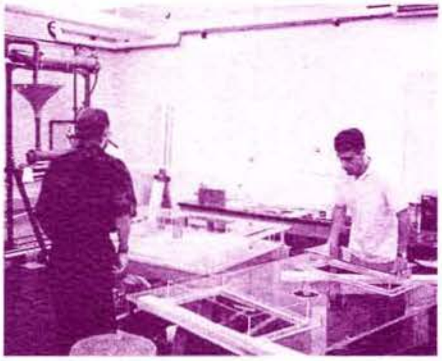
In anticipation, the department recently completed a remodeling of the basement in Akerman Hall, building four new laboratories, two for fluid mechanics, one for solid mechanics, and one for dynamics and control. Much of the $220,000 cost was provided through the Institute of Technology Program Accommodation Remodeling Funds.

The Surface Deformation Interferometry and Composites Lab established by Professors Shield and Leo contains Instron and MTS test frames for studying the mechanical response of materials and a 50-ton composites press for manufacturing composite laminates. These additions, together with the crystal grower and test devices in Professor James' lab, provide the ability to design experiments from materials preparation through mechanical testing. Some of the specific experiments planned include the measurement of the plastic strains around crack tips, novel methods to improve damping characteristics of composites, and studies on the microstructure of shape-memory alloys.

In the area of dynamics and controls, the department acquired an UmHoltze-Dickie shaker and Spectral Dynamics controller. Data acquisition equipment includes B & K structural analyzers and Macintosh computers with DSP processors. Experiments in the dynamics and control of large space structures, wind tunnel models of aircraft at high angles of attack, and damping in composites are planned or in progress. Professors Balas, Enns, Garrard, and Sethna are directing these experiments.

Three fluid mechanics laboratories accommodate research projects supervised by Professors Abrahamson, Alving, Joseph, Longmire, and Lundgren. Flow facilities include wind tunnels, fluidized beds, channels and tanks for experiments involving water or liquid mixtures, jets, and a disk drive model. Hot-wire and laser Doppler anemometers, high power lasers, and extensive equipment for high- and low-speed video and still photography are available for diagnostics. Specific experiments involve modeling of atmospheric downbursts, boundary-layer flows, separated flows, particle-laden flows, rotating flows, oil-water pipelines, and immiscible liquids.





Work in progress: the new laboratory facilities at Akerman Hall. *Photos on pages 2-3 by Steve Bur.*

Departmental Honors

Prof. Gary Balas received the Best Paper Presentation in Session Award at the 1990 American Control Conference. *Prof. Richard James* was given the 1990-91 George Taylor/IT Alumni Society Research Award. *Prof. Daniel D. Joseph* was awarded the G.I. Taylor Medal by the Board of Directors of the Society of Engineering Science in recognition of outstanding work in fluid mechanics. In May 1991, Prof. Joseph was elected to the National Academy of Sciences. *Prof. Theodore Wilson* was elected the Best Professor in the department by the IT students and was honored at the 1990 IT Week Awards Banquet.

New Faculty Members

Professor Alving received her undergraduate degree in Mechanical Engineering from Stanford University. She completed her master's degree in Mechanical and Aerospace Engineering and her doctoral in Fluid Mechanics at Princeton University. Prior to joining our faculty in October 1990, she held a post-doctoral position at the Hermann-Föttinger-Institute, Technische Universität Berlin. Her areas of research are experimental research in turbulence and fluid mechanics, especially turbulent boundary layer behavior under the influence of strong perturbations such as curvature and separation.*

***Professor Truskinovsky** received both his undergraduate and master's degrees in Applied Mathematics and Mechanics from Moscow State University, and his doctoral degree in Mechanics of Solids from the Institute of Physics of the Earth, Moscow. Prior to joining our faculty in September 1990, he held a research associate position at Harvard University and spent the summer as a visiting professor at the University of Aix Marseille. His areas of research are nonlinear continuum mechanics, thermodynamics, fracture, phase transformations, and geophysics.*

***Professor Longmire** received her undergraduate degree in Physics from Princeton University. She studied fluid mechanics at the Technische Universität Braunschweig in Germany, and received both her master's and doctoral degrees in Mechanical Engineering from Stanford University. She joined our faculty in November 1990. Her areas of research are experimental fluid mechanics, particle-laden flow, reacting flow, and turbulence.*

***Professor Shield** received his undergraduate degree in Engineering Mechanics from the University of Illinois at Urbana-Champaign and both his master's and doctoral degrees in Mechanical Engineering from the University of California at Berkeley. Before joining our faculty in September 1990, he held a post-doctoral position at the University of Illinois and Brown University. His areas of research are experimental and theoretical solid mechanics, elasticity, single crystal plasticity, optical experimental methods, and micromechanics.*

Student Update

Changes to the Graduate School Residency Requirements, Effective Fall 1991

- For master's and specialist certificate students: no residency requirement, as these are credit-based degrees.
- For doctoral students: 7.0 full-time quarters registered in a University of Minnesota Graduate School degree program. Residency will be calculated as follows:
  - For each fall, winter, or spring quarter of 7 or more credits: 1.0 quarters of residency granted.
  - For each fall, winter, or spring quarter of 1 - 6 credits: 0.1 quarters of residency granted for each credit of registration.
  - For each summer session: Summer Session 1 and 2 registrations *in the same academic year* will be added together; if total credits are 7 or more, 1.0 quarter of residency will be granted; if total credits are 1 - 6, 0.1 quarter of residency will be granted for each credit of registration.
- Residency credit will no longer be granted for coursework transferred from outside the GraduateSchool, or for a prior master's degree from another institution (although coursework may still be transferred to the student's degree program).

AEM Professor Honored as National Academy of Science Member

Professor Daniel D. Joseph was elected to the National Academy of Sciences at its annual meeting in April 1991. A July 1991 article in *Research Review* highlighted his perspectives.

"How did you come to your area of interest in fluid mechanics?

I started out as a sociologist, but I never did work in that area for one reason or another. In 1957 I went back to school at the Illinois Institute of Technology, and enrolled in a course in mechanical engineering. I studied hard but with no idea of going to graduate school, and I got essentially all A's. At that time the Russians had launched Sputnik, and there was suddenly a lot of money for scholarships and fellowships, and my professors identified me and encouraged me to go on to graduate school. Actually, one of the professors, Peter Chiarulli wanted to send me to Brown for applied math, but I had a family so I stayed at IIT, and I got a fellowship. My career then was in mechanical engineering and I had various professors in fluid mechanics. So my interest in fluid mechanics is basically a historical accident.

It's a very fascinating subject. In the early part of my career I was more on the mathematical side. I didn't really do any experiments in my graduate work or in the early part of my career. I did theory, a very elegant kind of thing; even calculus is a beautiful cultural or philosophical experience. It's astonishing to do applied math, to work certain things out on paper with symbols according to rules. To start with something physical and to do something entirely nonphysical with symbols and to come up in the end with something that fits very well with nature that you might never have dreamed about - it's like a beautiful toy.

Somewhere in the midpoint of my career I became very interested in doing experiments. Largely this was due to my association with Gordon Beavers (now Associate Dean of the Institute of Technology). We were both young faculty members in the department; he had a background in experiments and me in theory, and this combination worked so well that as time went on I couldn't get along without the experiments. Then he deserted me for the dean's office, so I was left on my own. Now we've begun to collaborate again.

What is the theory of stabilty that you're credited with?

In a kind of colloquial manner I could describe the theory of stability in this way: We know that in the course of our lives things go on in the normal way and then something happens to cause us to make a new adjustment. This is a physical principle that even could be described in terms of plane curve; you go

National Academy of Science Member (cont.)

along a plane curve and you come to a place where another curve intersects it, it's a crisis curve. So physically you see, for instance in fluid mechanics, you have a situation in which you have a smooth laminar flow and then all of a sudden something abrupt happens and the flow begins to be turbulent and very mixing. In the old days, when people smoked, this was very easy to demonstrate. From your cigarette would come a very thin plume of smoke and then suddenly at a certain point it would break into violent fluctuations.

I can also describe it in a more scientific way: I'm in fluid mechanics, which is a branch of mechanics, and I consider that mechanics has two parts. The first part is the study of materials; I do some things in this area. The second part is dynamics, how things move and evolve. The study of stability falls in the regime of the study of dynamics. Say you have some system that consists of particles and fluids and so on and it may move in very different ways, depending on conditions. The study of the stability is the determination of all these ways in which the system may move, and the conditions under which you get one kind of motion or another. So you may say then, that a given dynamical condition of a system is stable if more or less it continues to operate in this manner as you change its conditions, and it's unstable if you reach a condition in which it dramatically changes.

Going back to sociology, various social events like revolutions and crises are descriptions of instability. I remember I had an argument with a referee in a journal about the stability of fluidized beds. We had a laboratory experiment in which a fluidized bed stayed *stable for a time* and I wrote that in my paper. The referee was very angry with me for saying that. He wrote to the editor that what Dan Joseph means is that it's unstable because it's only stable for a time. I wrote back to the referee that I meant just what I said; it's like the Roman Empire was stable *for a time*.

Stability in general has enormous implications. This is a central organizing ideal for science, period. All physicists, all engineers, all chemists have to deal with problems of stability; there's no avoiding this, it cuts across everybody's subject, basically because nothing runs smoothly.

What do you think led to your election to the National Academy of Engineering last year and the National Academy of Sciences this year?

Well, the National Academy of Engineering told a reporter for the Star Tribune that I was nominated for conducting various ingenious and novel experiments in fluid mechanics, but I don't think that nomination has an explicit reference to my theoretical work. I think it relates to my perception of mathematics and its relationship to nature. I think it reflects the group I've developed here at the University. We have a philosophy that guides our lab, which is that we are very interested in theory, we're very interested in experiments and in numerical computations. We've developed sort of a no-holds attitude to research, where we come to answers whatever way we can. Cutting off experiments in numerical computations and doing only analysis would be like cutting off your hand. We have the highest regard for theory but are particularly devoted to applications.

This inspires my students greatly; they agree with this attitude. We form a community. And we have good times together, we have a very good social life here in the lab. I sign off my lectures when I don't have anything else to say, with the principles of our lab: have some fun, tell the truth, and do good research. For instance, this August I'm going to have what I call a pizza party/fluid mechanics/rheology workshop. We have about eight speakers - they are all my students or former students, we're going to come together to have a good time and talk about our research.

It's great to have a community with students. I've found that now that I've reached this exalted state (laughs), that I'm older and doing a lot of mentoring, I've changed. I used to be very anxious about my career. I can't say I've stopped being anxious about my career, it's just that there's been a big change. I've gone from being mainly concerned about my own professional successes in research and so on, to being very concerned about my group and my students. As I get older and my powers diminish and I see these greatly endowed young people who come to my lab, I've come to realize that perhaps even more importantly than whatever present good or even great research results we can get, what we are making here is people. These people are the future for us all.

In my group I have eleven Ph.D. students, three China Scholars, and one post-doc, and this summer five undergraduates are working in the lab. We get a lot of cooperation from our technical staff, particularly Dave Hultman, and our shop is a great asset to our research. From time to time other professors work with us, such as Professor Lundgren and Professor Beavers.

What are your views on the current discussions about formulating a state science and technology policy?

The state must have a science and technology policy, and it must have an institutional arrangement to deal with those questions. I wouldn't presume to say the manner in which they should with those questions, but when you consider what we have here in Minnesota, with 3M, Honeywell, and Minnesota Supercomputer Institute, and a thousand small innovative companies, it's clear that this is a technological community. This is a great state to have a scientific career in.

National Academy of Science Member (cont.)

I do a lot of consulting, so I have a lot of contact with companies. Many of our centers have very deep roots with industry. Even in the Institute for Mathematics and Its Applications, a program on math in industry is thriving. I would think that the state science and technology policy should pay very much attention to those kinds of initiatives. Our meetings are not on a political level; we're doing the actual work of student and employee exchanges, and identifying and studying important problems. This is the sort of glue that holds academic science and engineering together with industry.

Your area of research has many practical applications and you've been an active discloser of ideas to the Office of Patents and Licensing. What is your view of the technology transfer process, and have your invention ideas been patentable and generated interest from industry?

I have to tell you that now I'm doing feasibility studies for manufacturing M&M Mars candy bars. They read my papers in the *Journal of Fluid Mechanics* on the method we invented of using water to lubricate heavy viscous crude oil as it moves along in pipelines, to reduce the power required for pumping. We have a box of chocolate hearts in the lab and the idea is to melt these hearts and to drop them in a pipe surrounded by essentially sugar water, where the sugar content of the candy and the water are matched closely so that the candy will diffuse only very slowly into the water. You put it into the pipe when it's hot and you take it out when it's frozen, and because the sugar water doesn't freeze you take out a nice long piece of candy. If this works it could be that - strangely enough - water lubricated pipelining of heavy viscous crude oil has an application in food processing.

I haven't patented anything to do with measuring the water-lubricated pipelines; we did laboratory work and theoretical work. But there are a lot of patents on this subject. In my book (*Two-Fluid Dynamics*, forthcoming) I have cited from patents that go back to 1906. I have been patenting things related to the oil industry - things such as effects of surfacants information and sterilization of emulsions, in which I currently have a patent application pending.

I don't have an overall view of technology transfer because I'm not involved in committees or task forces looking at the problem. I do technology transfer because I work closely with a number of industries directly on their problems. So I guess the kind of technology transfer we do is rather ideal - less of a transfer and more of a collaboration.

I think the transfer of technology from universities to industry is critical matter, and it is related to the question of science funding. It is very critical that our society work as one, that technical problems be addressed by the people who need these things done and the people who are best equipped to address them, and that the people who can get them done can find each other and work together as a team. University people shouldn't get highfaluting, and industry people shouldn't feel that academia is divorced from their needs. Those two attitudes, which to a certain extent were common in the past, are very detrimental to both science and industry.

Funding of research in becoming increasingly tight, especially for young scientists. What has been your experience in the funding arena, and how do you see it affecting your graduate students and colleagues?

I don't know how to be a prophet in this, but I do know that it was much easier when I was young. Of course, I came up in a special time when there was a great emphasis on funding young people in science and there was a great shortage of engineers. It's clear to me that technology is going to become more important, not less important in the future. The funding for young people has become a really serious situation, and there's a lot of agitation in the scientific community about this situation. A lot of it stems from selfish motives; not that selfish is bad, it's just become increasingly difficult for individual scientists to get individual grants. We all used to exist on individual grants and I still exist on individual grants, but in the past ten years there has been a tendency to answer criticisms of parochialism in science by funding huge centers. Now on campus we do have some of these centers, the Institute for Mathematics and Its Applications, the Army High Performance Computing Center, the Center for Interfacial Engineering, and these are very good centers. But many people perceive the money that goes to centers is taken away from individual investigators, and this is a questionable proposition. What's needed is a larger pie.

Certainly it's absolutely essential that young people be identified for funding - that young people who are doing good work be encouraged to continue their careers. This has been addressed by the Presidential Young Investigator program. I have a student Kang Ping Chen, who recently received this award, and he is very deserving. But perhaps that program is even overfunded; certain talented individuals get a very great amount of money while other nearly as talented individuals have no money. It's a very serious and difficult problem to address. I have produced maybe 30 Ph.D.s. and I have funded their work on the basis of individual grants. If we suppose that all of these individuals pursue research careers, I would now have 30 new competitors for individual funding. So this won't work either.

The question is how you develop a cadre of technical competence that will address the needs of the country - and

National Academy of Science Member (cont.)

these needs are very abundant - without abusing the system, without falling into the rut of competing for grants to do the same thing all over again. I guess that all these people if they're well trained could be funded by a society like ours provided they were directed in productive avenues. I haven't done any science management yet on a political level, but I think this is one of the great problems of our time and our country. This is a role for the National Academy of Engineering and the National Academy of Science. There's no doubt that the scientific and engineering professions have to designate the people they consider responsible, and I suppose membership in these organizations is one such designation. Science and engineering management really has to be done by scientists and engineers and not by politicians....

What has kept you at the University for 28 years?

My work has been a great pleasure but I have to say that my life in this state is great. I love it here. People are decent, civilized. In my department I have been encouraged to do my best to achieve what I could. To the extent that resources were available, they were made available to me. Individuals in our department were respected for whatever they could do. They were encouraged to do what they could do well. In general, I've seen a spirit of cooperation.

My personal life is very congenial here. I could walk to work but I drive in the winter and take my bicycle in the summer. I'm a dedicated, slow runner. My whole life is a wonderful circle. I have wonderful concerts, wonderful theater, good stuff on the radio. I'm not that threatened by crime. It's just a super community here; I couldn't imagine a better one."*

* Extracted and reprinted with permission from *Research Review*, Office of Research and Technology Transfer Administration, University of Minnesota, Volume XXI/Number I, July 1991.

Research Projects of AEM Professors

Application of Nonlinear Feedback Control Theory to Supermaneuverable Aircraft
NASA Langley Research Center
William L. Garrard, Dale F. Enns, and Gary J. Balas

Assembly and Operation of the Large Lunar Telescope
NASA
William L. Garrard and Andrew E. Vano

Beds of Particles Fluidized by Liquids
National Science Foundation
Daniel D. Joseph and Thomas S. Lundgren

Control Formulation for the Active and Passive Damping of Flexible Structures
Air Force Office of Scientific Research
Thomas A. Posbergh

Research Initiation Award: Control of Nonlinear Flexible Structures
National Science Foundation
Thomas A. Posbergh

Control of Nonlinearly Flexible Spacecraft
Graduate School Grant in Aid
Thomas A. Posbergh

Dynamical Effects of Film Coatings on Stability and Transition
NASA
Daniel D. Joseph

Engineering Research Equipment Grant
National Science Foundation
Richard D. James

Engineering Research Equipment Grant—Fluid Mechanics
National Science Foundation
Daniel D. Joseph

Experimental Determination of Crack-Tip Displacement Fields in Single Crystals.
Graduate School Grant in Aid
Thomas W. Shield

Experimental Studies of Downburst Turbulence
Graduate School Grant in Aid
Thomas S. Lundgren

Finite Element Computation of Compressible Flows with Particular Emphasis on Blunt Geometries, Wake Flows, and Unsteady Behavior
NASA
Tayfun E. Tezduyar

Global Positioning Systems and Aircraft Control
Graduate School Grant in Aid
Yiyuan Zhao

Interaction of Particles with Coherent Structures in an Impinging Jet
Graduate School Grant in Aid
Ellen K. Longmire

Interaction of Thin Liquid Films with Air Flows
Graduate School Grant in Aid
Amy E. Alving

Lubricated Pipelining
Department of Energy
Daniel D. Joseph

Research Projects of AEM Professors (cont.)

Mathematical Modeling of Deep-well Oxidation Processes
Gulf Coast Waste Disposal Authority
Tayfun E. Tezduyar

Measurement of Mechanical Properties and Air Flow Characteristics Through Owens Corning Fiberglass Building Insulation
Owens Corning Fiberglass Corp.
Gordon S. Beavers

NASA/USRA University Advanced Design Program
William L. Garrard and Andrew E. Vano

A Parametric Study of Transonic Blade Vortex Interaction
NASA
Anastasios S. Lyrintzis

PYI: Studies on Computational Fluid Dynamics, Computational Mechanics and Finite Element Analysis
National Science Foundation
Tayfun E. Tezduyar

Research On the Improvement of Shape-Memory and Magnetostrictive Materials
U.S. Army Research Office
Richard D. James, Jerald L. Ericksen, and Perry H. Leo, in conjunction with the School of Mathematics

Respiratory Action of the Intercostal Muscles
U.S. Dept. of Health and Human Services
Theodore A. Wilson

Rheology of Bread Dough
The Pillsbury Co.
Daniel D. Joseph

Role of Applied Stress on the Development of Microstructures in Solids
Graduate School Grant in Aid
Perry H. Leo

Rotating Mount for Video Data Acquisition
Graduate School Grant in Aid
Scott D. Abrahamson

Shear Wave Speed
National Science Foundation
Daniel D. Joseph

Studies of Two-Phase Flows of Solids and Liquids
National Science Foundation
Daniel D. Joseph

Study of Nonlinear Dynamical Systems
National Science Foundation
P.R. Sethna

Study of Spinning Rod Interfacial Tensiometer Used to Measure Polymer Bands
Hoechst Celanese Gift
Daniel D. Joseph

Study of Transonic Blade-Vortex Interactions in Three Dimensions
Graduate School Grant in Aid Program
Anastasios S. Lyrintzis

Synthesis of Robust Control Laws for Flexible Structures
Graduate School Grant in Aid Program
Gary J. Balas

Theoretical and Experimental Studies of Selected Topics in the Rheology of Fluids
U.S. Army Research Office
Daniel D. Joseph

Thermomechanical Behavior of Materials Under Intense Loading Conditions
Honeywell, Inc.
Roger L. Fosdick

Transitions and Defects in Ordered Materials: Nonlinear Theory, Computation and Equipment
National Science Foundation
Jerald L. Ericksen and Richard D. James, in conjunction with the School of Mathematics

Transitions and Defects in Ordered Materials: Nonlinear Theory, Computation and Experiments
U.S. Army Research Office
Jerald L. Ericksen, in conjunction with the School of Mathematics

U.S. Army High Performance Computing Research Center
U.S. Army Research Office
Jerald L. Ericksen, Richard D. James, and Tayfun E. Tezduyar

Ventilated Hub Flow Study
IBM
Scott D. Abrahamson

AEM Fellowship Recipients

Graduate School Fellowships 1990–91
Steven Anderson
Haochuan Hu (for doctoral dissertation)
Brian Olson