AEM Update

Department of Aerospace Engineering and Mechanics Spring 2008

Chairman's Corner

Greetings and Happy 2008.

In an effort to communicate more with our constituents, we have decided to divide the newsletter into several issues each academic year, each with a theme. In this edition, we discuss the excellent research being conducted by our graduate students, as well as welcome Thomas Schwartzentruber to our Fluids faculty. He graduated with a Ph.D. degree in Aerospace Engineering from the University of Michigan. Dr. Schwartzentruber's area of expertise is numerical modeling and simulation of hypersonic flow. Recently, he received the AIAA Graduate Student Award. We are excited to have Dr. Schwartzentruber join our faculty and please join me in welcoming him to the department.

AEM has been fortunate in the fall and winter season with outstanding press coverage of our program. One of our students, David Hauth, who was covered in the last edition of AEM Update, was recognized and profiled by the *St. Paul Pioneer Press* for his prestigious Honeywell Innovators award. Additionally, our NASA interns and AEM Senior design students have been the subjects of pieces in *The Minnesota Daily*. We continue to expand and enhance our industry-academia partnerships. One of latest success stories is working with Victory Systems and PDA which was featured in the December issue of *Inventing Tomorrow* and the business supplement of *Minnesota Magazine*.

I am pleased to relay to you that a recent report from *The Chronicle of Higher Education* on Faculty Scholarship Productivity places AEM at #1 for aerospace departments with less than 20 faculty, #2 for percentage of faculty with journal publication cited by another work, #5 overall for public universities and #10 among Aerospace Engineering programs nationwide. It is great to have our aerospace engineering program recognized as one of the top programs in the country. We understand that faculty scholarship is just one measure of a program, but it is one metric that reflects the research excellence of faculty, students and staff. AEM's commitment to education, as well as outreach, complement the department's recognized strength in scholarly research.

Credit: Brad Stauffer

We look forward to the expected release of new graduate program rankings in the upcoming year from the National Research Council (NRC). In the last NRC ranking, AEM ranked eighth in the nation for public universities and twelfth overall.

Several of our faculty members have had remarkable success in the past several months. Graham Candler has been elected a Fellow in AIAA and Ellen Longmire was elected a Fellow in the American Physical Society. Ryan Elliott has received a NSF CAREER award for his work on active materials. Daniel Joseph has published his latest book, "Potential Flows of Viscous and Viscoelastic Fluids," with co-authors Toshio Funada and Jing Wang through Cambridge Press. For more information on faculty news and achievements, please see page 5.

Providing an outstanding work environment for our students, faculty and staff is one of my driving passions. I am excited to tell you that we have completed renovation of the previous AEM shop space into graduate student offices. The room is furnished with 16 workstations and includes enclosed space for teaching assistants to hold office hours and tutoring sessions. This past year, the department combined its machine shop with the Electrical and Computer Engineering shop facilities (run by the AEM shop supervisor Dave Hultman) allowing for the space renovation. Undergraduate and graduate students have access to the Mechanical Engineering student shop. In 2007, the department also added undergraduate and graduate student lounges and renovated the main office. We will continue to look for opportunities to improve Akerman Hall, department offices and laboratories in the new year.

The University of Minnesota is requesting funds from the Minnesota State legislature to renovate all Akerman Hall classrooms as part of their capital bonding request. The AEM department fully supports this request. The renovations would include upgrading the technology and electrical service, energy efficient

Read more from Department Head Balas on Page 3

What's Inside

www.aem.umn.edu

AEM Graduate program update

We are now in the middle of reviewing applications for graduate school for fall 2008. This year's pool is one of the best I have ever seen with over 100 excellent applicants from the U.S. and around the world, including top students in aerospace systems, fluid mechanics and solid mechanics. It is clear that the national and international reputations of our faculty, together with our improved website, have really improved the Department's visibility to the top students around the world.

Fall 2008 admitted students will join an already-strong and diverse group of graduate students. Our fall 2007 class included twenty-two students of which the department supported thirteen with teaching assistantships and two with research assistantships. Of the remaining seven, four came with support from their employer and three with personal funding. Thanks to the continued strong research programs of the faculty in our department, half of the first year teaching assistants have already found research projects and have moved to research support.

In addition to the departmental funding, two of the top students from fall 2007 received fellowships to support their research and education. These fellowships were available because of the generosity of several of our alumni. Special thanks to the Robert L. Schultz and the Kenneth G. Anderson Fellowship Funds. With help from fellowships like these and those distributed by the Graduate School the AEM department is better equipped to attract some of the top talent in the industry. Several of the other fellowships sponsored by alumni and distributed to our graduate students include the Dunning Cooper Fellowship and the John D. Akerman Fellowship. If you'd like information on establishing your own fellowship fund to support the program, please feel free to contact IT's new development officer for AEM, Kathy Peters-Martell at 612-626-8282 or kpeters@umn.edu. More information on Kathy is on page 9.

Current students are also doing well. In the 2006/2007 academic year we had nine students complete their M.S. degrees and seven complete their Ph.D. degrees. In Fall 2007, we had six students complete their Ph.D. degrees and four finish their M.S. degrees. In Spring 2007 several of our top graduate students applied for a Doctoral Dissertation Fellowship award from the Graduate School of the University of Minnesota. All received the fellowship. Profiles of these three students—Juan Padrino, Shankar Ghosh and Balint Vanek—can be found in this newsletter. You'll also find profiles of two alumni from the Ph.D. program—Mike Wright, who is acting Branch Chief of the Reacting Flows Environment Branch at NASA Ames Research Center, and Jun (Richard) Cui, who is a researcher in the Materials Analysis and Chemical Science group at the General Electric Global Research Center in New York state.

The Department is continually in the process of improving the experience for all of our graduate students. In order to better integrate new students into the research life in the Department, we began the AEM Colloquium series in the fall with a series of brief, 15 – 20 minute talks from our faculty, and Professor Richard James gave a special Penrose lecture on some of his recent research. We also have been making great strides in improving the physical space in Akerman Hall. In Fall 2007 we opened a new Graduate Lounge, which has space for grad students to work, interact or just relax. Judging by the use it gets it has been a huge success. We renovated the former shop area into an AEM Teaching and Learning Center. This new office suite will improve the exchange and interaction between our students and the departmental graduate and undergraduate teaching assistants. We are working on finding space for a new Computational Solid Mechanics Lab in the near future. Finally we have ambitious long-term ideas about how to redesign the hangar area to both increase our space and to help give Akerman Hall an increased presence on campus.

As always we enjoy and appreciate hearing from our alumni and friends. Please contact me by phone (612-625-0535) or e-mail (phleo@aem.umn.edu) with comments, questions or concerns.

Sincerely,

Perry Leo, Director of Graduate Studies

CSDy Graduate program update

The CSDy Interdepartmental Ph.D. Program provides an opportunity for interdisciplinary research in control science and dynamical system theory. The program coordinates scholarly and scientific activity of these areas within IT and the University and coordinates its activities with industrial firms in the Minnesota region. CSDy faculty are drawn from the Departments of Aerospace Engineering and Mechanics, Chemical Engineering, Electrical Engineering and Mechanical Engineering, as well as from the Departments of Computer Science, Mathematics and Statistics, all in IT, and from the Departments of Economics and Political Science.

The Co-Directors of the CSDy Center are Prof. Gary Balas (AEM) and Prof. Tryphon Georgiou (ECE), and Rajesh Rajamani serves as CSDy's Director of Graduate Studies. There are five students pursuing their Ph.Ds during the 2007-2008 academic year.

The Program featured a seminar series with distinguished speakers in the general area of Control Theory and Engineering and Dynamical Systems Theory. The list of speakers includes Professors Giorgio Rizzoni (Ohio State), Anna Stefanaopolus (Michigan), Babatunde Ogunnaike (Delaware), Domenico D'Alessandro (Iowa).

Gary Balas, Tryphon T. Georgiou
Co-Directors, CSDy Program

Hypersonics Center receives additional support and continues to grow

The National Hypersonics Research Center was established at the University of Minnesota in 2004. Since then, the Center has developed into one of the leading academic programs in hypersonics research and education. The Center combines leading computational modeling and simulation methods with the world's premiere hypersonic testing facilities at CUBRC in Buffalo NY. The Center's primary goal is to support the nation's design of future hypersonic systems through the development of validated computational simulation methods. The Center receives its core funding from the Air Force Office of Scientific research; Minnesota Senators Norm Coleman and Amy Klobuchar helped to secure much of this support. Center research is also supported by NASA, DARPA, and Sandia National Laboratories.

During the past year, there have been some notable accomplishments by Center researchers. The HyCAUSE (Hypersonic Collaborative Austalia-United States Experiment) scramjet flight experiment was launched in Australia on a large sounding rocket. The inlet of this flight vehicle was designed by Center researchers and features a novel inward-turning design. Prior to the flight, the inlet and engine design were tested at CUBRC. This concept has the potential to be much more efficient than conventional inlets.

Another recent project involves the development of a computational method for the prediction of transition to turbulence in hypersonic boundary layers. Dr. Heath Johnson has been developing a computational simulation method (called STABL) that predicts how disturbances are amplified by hypersonic boundary layers. Once the cumulative amplification of a disturbance reaches a critical amplitude, it is assumed that the flow becomes unstable and has transitioned to turbulent flow. This computational method has been used to analyze a number of flows, including the HIFiRE Flight 1 geometry. HIFiRE is the Hypersonic International Flight Research and Experimentation program, and is a joint Australian – US Air Force program. Simulations performed by Dr. Johnson and AEM graduate research assistant Christopher Alba show excellent agreement with wind tunnel measurements. The experiment will be launched in May 2008, and the simulation tools will be critical for analyzing the resulting flight data. Center researchers are actively supporting the development of the HIFiRE Flight 5 geometry.

A new research project recently funded by NASA seeks to combine several of the simulation tools developed at the Center. The goal is to study how a hypersonic boundary layer transitions from laminar to turbulent flow using high-fidelity simulations. The concept is to use the computational methods developed by Prof. Candler's research group to provide a high-quality laminar mean flow over a simple geometry such as a sphere-cone. Then using the STABL code, white-noise disturbances will be propagated through the flow field, and a field of physically-meaningful disturbances will be created. This information will then be fed to the simulation method developed by Prof. Mahesh's research group, and the disturbances will be simulated as they interact with one another, go through the non-linear amplification regime, and then break down to turbulent flow. Prof. Mahesh's methods are ideal for performing this type of simulation. The goal is to better understand the physics of the non-linear breakdown of hypersonic boundary layers, and then to provide more accurate models for predicting heat transfer rates during and after transition.

The Center activities will expand in a new direction with the addition of Prof. Thomas Schwartzentruber to the AEM faculty. Dr. Schwartzentruber's research in the simulation of low density hypersonic flows is a natural fit to the ongoing research at the Center. The use of his particle-based numerical simulation methods will allow novel studies of gas-surface interactions and detailed chemical kinetics processes that are critical to accurate predictions of hypersonic flows.

Graham Candler
Krishnan Mahesh

Chairman's Corner from page 1

windows, air conditioning, carpeting, painting and new furniture. We have been working closely with university classroom management to advocate for the planned renovation. This is an exciting opportunity for us. We would appreciate your support of the University capital request and ask you to contact your local legislators regarding your support. More information is available on page 9.

In closing, I would like to take the opportunity to thank all of you who have generously donated your time and money to support the AEM department. You have contributed to improving the department in many ways including undergraduate and graduate scholarships, fellowships and projects; endowed professorships; renovation of the undergraduate and graduate lounges and graduate offices; departmental seminar series and much more. The faculty, staff and students are truly honored by your support.

I look forward to another outstanding year for the AEM department in 2008.

Regards

Gary J Balas

Gary Balas

AEM Professor Richard James gives Penrose Lecture

AEM Professor Richard James recently delivered the Penrose Lecture at the McNamara Alumni Center on the subject of the structure of viruses. James is the department's Russell J. Penrose Professor, a chair in AEM endowed by Russell Penrose, and a Distinguished McKnight Professor.

James discussed what he calls "objective structures," structures like carbon nanotubes, buckyballs and viral capsids that occur frequently in organic and inorganic materials. James has given a precise definition of these structures and has developed a methodology to compute all of them. This could lead to the discovery of new nanostructures with unusual collective properties.


AEM Professor Richard James

"When you look at the calculations of the properties of these structures, you see these are the natural structures where you should find magnetic, ferroelectric and other collective properties," he said.

In addition to the possibility of these interesting properties, objective structures also are unusually prevalent as the building blocks of viruses.

"That's probably related to the fact that viruses do not have their own source of energy," James said. "Therefore, they rely mostly on the process of 'self-assembly' to construct themselves. I think objective structures provide a kind of framework for the merging of materials science and biology."

Mr. Penrose established the Russell J. Penrose Professorship in Aerospace Engineering in the 1980s; Prof. Daniel Joseph was its first recipient. Penrose, a philanthropist and University alumnus, also created an undergraduate scholarship and supported the 2000 construction of the Mechanical Engineering building.

The Penrose Lecture comes on the coattails of James' return stateside from a one-year sabbatical. After being awarded the prestigious Humboldt Senior Research Fellowship by the German government, James worked at the Max Planck Institute for Mathematics in the Sciences in Leipzig, and traveled within Europe and beyond, including a 50 km cross-country ski in the mountains on the border between the Czech Republic and Poland on Easter Day.

Later, James traveled to Wuhan, the capital of Hubei province in China, to visit his former postdoctoral fellow, Jian Li, who is now Chair of the Department of Materials Science at Huazhong University of Science and Technology. Professor Li directs several important new programs in fuel cell technology in China.

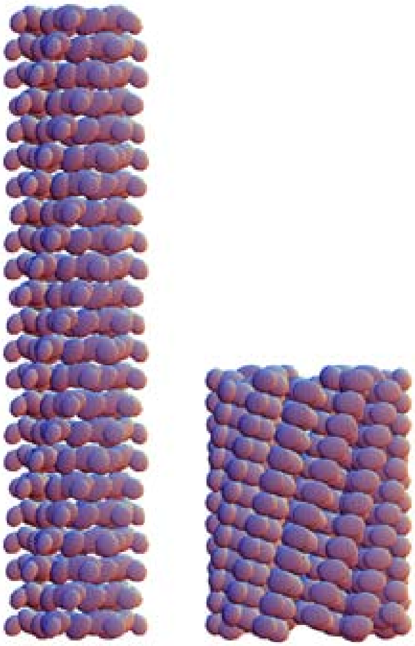
"You can feel a tremendous energy in China, but also very significant growing pains," he said. "From both an academic and societal perspective, I think it is desirable to forge stronger links between American and Chinese universities. The resources that are now going into science and technology in China are, like the Three Gorges Dam I visited, truly impressive."

More on objective structures

When an engineer creates a new bridge design, reference tables are consulted. James seeks to create such a reference on a slightly smaller scale, that of atoms and molecules. He has long been interested in developing unusual new materials. Recently, his work has shifted toward biomaterials, specifically bacteriophage T4. Viruses like T4 are built of components that he calls "objective structures." To picture an objective structure, imagine a group of identical people sitting in chairs that are arranged in a perfect circle. Each person sees exactly the same environment.

The idea of identical environment, beyond just in the case of viruses, James said, could prove helpful in designing new types of materials.

"People in biology take natural structures and study them: it is considered uninteresting in biology if one violates conditions that occur in vivo," he said. "But I like to think in more of an engineering way about this; and the first step is understanding how they're put together - objective structures offer a special window into the building of molecular structures."


Bacteriophage T4 tail sheath at rest (L) and upon cell insertion (R)

Understanding the structure of a virus should allow for the creation of molecules that would disable the virus, in theory. Such a technology could allow for the quick creation of carbon nanotubes, as well.

"You might be able to build a tubular structure whose molecules exactly match the inside of a carbon nanotube," James said. "Suitably functionalized, it could be a template for the large-scale growth of carbon nanotubes."

New faculty member joins AEM

In December of 2007, Thomas E. Schwartzentruber joined the Department of Aerospace Engineering and Mechanics as an Assistant Professor on the Fluid Mechanics faculty. He received his B.A.Sci and M.A.Sci from the University of Toronto in Canada in 2001 and 2003, respectively, and his Ph.D. in Aerospace Engineering from the University of Michigan in 2007.

Schwartzentruber's research focuses on utilizing particle simulation methods to model non-equilibrium gas flows, which are found at very high altitudes and at very small scales.

"The key issue with these flows," Schwartzentruber explained, "is that fewer gas particles are present and, more importantly, they collide less frequently. When this happens, the gas no longer behaves like a continuous fluid and conventional Computational Fluid Dynamic (CFD) methods become inaccurate."

CFD can be extremely accurate for continuum conditions, where density of gas is relatively high – like at the front of a vehicle reentering the atmosphere. In the wake of that vehicle, however, fewer particles are interacting – this creates problems for CFD-based modeling.

Schwartzentruber's answer to these types of issues lies in particle-scale modeling and methodology. One major aspect of his research focuses on developing a hybrid model that combines the accuracy and efficiency of CFD methods with the certainty particle methods may lend in localized, low-density flows.

"Currently, it's very difficult even on supercomputers to carry out a full reentry particle-simulation because of the extreme densities in the forebody region," Schwartzentruber said. "The idea of my research is to use CFD for the forebody where it's perfectly valid and only utilize a particle method in a local way when and where it is appropriate; the goal is to accurately simulate all regions but in a more computationally efficient manner."

Professor Schwartzentruber is joining an internationally-renowned Fluid Mechanics faculty, including the computational expertise of Graham Candler, a Distinguished McKnight Professor and director of the National Hypersonics Research Center.

Candler said he was pleased that Schwartzentruber joined the department.

"Tom's work on hybrid continuum and particle-based simulation methods for hypersonic and microscale flows is an excellent complement to my research group's work," Candler said. "I am looking forward to working with Tom on a number of projects within the Hypersonics Center."

Thomas E. Schwartzentruber

Continued development of Schwartzentruber's hybrid methods, in conjunction with existing faculty expertise in the department, will make increasingly-sophisticated, realistic models cost-effective and accurate – which is of great interest to industry and the government.

"The hybrid particle-continuum method has a lot of potential," Schwartzentruber said. "A successful model would allow one to use CFD methods where it's fast, efficient, and accurate and where it is unclear, the hybrid model will get it exact - there is no tool for that right now."

"Together with the expertise already here in the AEM department, development of a state-of-the-art multiscale method would be very important for NASA and the Air Force."

Faculty News

Richard James gave the first Southern California Mechanics Tour on December 3-7. Modeled after the long running Midwest Mechanics Tour and organized by Professor Sia Nemat-Nasser at UCSD, the Southern California Tour includes stops at UCSD, UCLA, Caltech and USC. James spoke on "Lessons on Structure from the Structure of Viruses" and "A relation between compatibility and hysteresis and its role in the search for new smart materials".

Cambridge Press published Professor Daniel Joseph's book, Potential Flows of Viscous and Viscoelastic Fluids, with co-authors Toshio Funada and Jing Wang.

Ellen Longmire has been invited by the J.M. Burgers Centrum to give lectures at the Technical University of Delft, the University of Twente, and the Annual Meeting of the Foundation for Fundamental Research of Matter (FOM) in the Netherlands in January 2008. She gave an invited lecture at University of Maryland in December 2007. She begins serving a three year term as Associate Editor for the journal *Physics of Fluids* in January 2008.

Thomas Schwartzentruber received the AIAA Orville and Wilbur Wright Graduate Award.

Ryan S. Elliott received a NSF CAREER grant.

Kaushik Dayal, a postdoctoral associate supervised by Ryan Elliott and Professor James, left to start as an Assistant Professor in the Civil and Environmental Engineering department at Carnegie Mellon University

Alumnus Mike Wright heads branch at NASA Ames

For a computer and space aficionado, NASA is a natural choice and likely to be a good fit. For alumnus Michael Wright, that aspiration proved a bit greater. After graduating with a doctorate from the Department of Aerospace Engineering and Mechanics, Wright brought an algorithm he had developed at AEM to NASA. Just 10 years later, the code that evolved from this algorithm is ubiquitous at several NASA centers and in industry; it efficiently and computationally predicts details surrounding hypersonic atmospheric entry. This code will support the Mars Science Laboratory launch next year and the Orion Crew Exploration Vehicle being designed as part of NASA's Constellation program, and the code has served several prior NASA missions.

Mike Wright

Wright is a three-time graduate of the University. He received his bachelors, masters, and Ph.D. degrees from AEM in 1992, 1994 and 1997, respectively. Wright said he decided to stay for graduate school at the University because of the exciting work being done by his soon-to-be adviser, AEM Professor Graham Candler.

"I knew I wanted to work for Candler, who moved that year from North Carolina State," he said. "In that field, even then, he was one of the stars."

Working with Candler, Wright developed a new type of Computational Fluid Dynamics algorithm for computing hypersonic reentry flow fields that could run efficiently on multiple processors. While dual-core and even quad-core computers have become commonplace now, such parallel technology was relegated to supercomputers at the time.

To give an idea of the difference, Wright recalled 3-D flow calculation technology.

"When I graduated, 3-D simulations for reentry CFD was state of the art – you did it when you needed to do it and if you could get away with something else, you would do that."

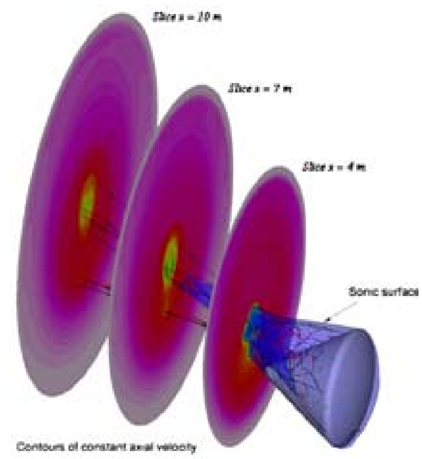
Now, Wright noted, 3-D model calculation is standard operating procedure, and technologies for analysis are in use that hadn't been dreamt of just 10 years ago.

As acting chief of the Reacting Flow Environments Branch at NASA Ames, Wright supervises 35 engineers and provides what he calls "technical leadership," connecting the right people for the right job in this highly-technical area; he also continues overseeing implementation of the code he developed at AEM.

While many doctoral students end up researching a different topic or in an entirely separate field, Wright said he is pleased that his Ph.D. research applies directly to his everyday life.

"A lot of people get degrees and do something different, but I'm the opposite," he said, "I'm using and directing the use of code I began writing in graduate school. It put me where I needed to be."

Professor Candler praised Wright's hard-earned success and notes it reflects well on AEM's capacity for education and training competent and passionate individuals.



An Apollo wake simulation..

"Mike and other AEM Ph.D. students are well-known within the community, and this helps put AEM on the map," he said. "I think we are known as providing a very good education to our students, with the emphasis on independent thinking and fundamental understanding of the key physics."

"Mike is a very good example of this message, and clearly our students can compete very well with students from any other program in the country."

Louis F. Heilig Graduate Fellowship Fund established

In honor of her husband and AEM alumnus, Louis "Bud" Heilig, Patricia Heilig generously established a fellowship fund benefiting AEM graduate students.

During World War II, Bud volunteered for service with the U.S. Navy. Upon his return, he completed his education and graduated summa cum laude from the U of MN with bachelors ('48) and masters degree ('49) in aeronautical engineering.

His forty-year aerospace career began with a position at United Aircraft's Pratt and Whitney Aircraft Engine Operations and culminated with his retirement from Ford Aerospace Corp. in Newport Beach in 1986 after nearly three decades of service. One of his major achievements was his work on the first US Airforce inter-continental guided missile. Throughout his career, he received both Defense department and Joint Chiefs of Staff commendations.

"We are indebted to Mrs. Patricia Heilig for her generous support to establish a graduate student fellowship in her late husband's name," Department Head Gary Balas said. "We are fortunate to have alumni and their families who are helping provide opportunities for the next generation of engineers and scientists."

The funds provided will support AEM graduate students. The first Louis F. Heilig Graduate Fellowship will be awarded in Fall 2009.

AEM alumnus Jun Cui at GE Research

In his education, AEM alumnus Jun Cui sought balance. With a theoretical background in mathematics and mechanics, Cui says AEM was a natural fit due to the expertise of his adviser, AEM Professor Richard James. During his Ph.D. work, he developed a strong background in solid mechanics and learned proper methodology and rigor in experimentation from AEM Professor Tom Shield. Cui then accepted a postdoctoral position centered on new methods of the combinatorial synthesis of materials at the University of Maryland before taking a position as a materials scientist at GE Research.

For Cui, it all began with research into shape-memory materials at Minnesota. Shape-memory materials are materials that can undergo large changes of shape but return to their original shape when heated. They are now used in a variety of applications, from stents to hydraulic couplings, but in the early 1990s, beginning from theory, Professors James and Shield suggested there might be a related effect in ferromagnetic materials. In this case, instead of heating the material to cause it to return to its original shape, one simply brings a magnet close to the material.

"We realized that this would be a fascinating new material to understand from a scientific viewpoint, but also that it could do something that no other actuator could do," James says. "That is, it could be made to undergo a big change of shape without actually touching the material, without any wires attached. For example, in biomedical applications, the piece of material could be inside the body, but the magnetic field could be applied from the outside."

When Cui began his doctoral education in 1997, much of the subject was new, and James was at the forefront in theory, Cui says.

"I sought to understand his theory and try to validate that through experiments," Cui recalls. "The challenge was to understand what material properties would enhance this ferromagnetic shape-memory effect. This research laid the foundation for where I am now."

Cui's experiments informed James' research a great deal regarding ferromagnetic shape-memory, the professor says, adding, "The iron-palladium system that he discovered, and the basic principles that emerged from his thesis, are now at the heart of our understanding of this fascinating effect."

After completing his doctorate, Cui desired more experience in experiments on shape-memory materials. Where James is a pioneer in theory, Cui says, his postdoctoral advisers, Manfred Wuttig and Ichiro Takeuchi from the University of Maryland, are arguably the top researchers on the experimentation and synthesis of shape-memory materials.

"I got the best of both worlds," Cui recalls of his education. "It turned out to be a good choice."

While at the University of Maryland, Cui's broad background in shape-memory material theory paid off. Using large-scale combinatorial chemistry, Cui created and studied the composition and properties of hundreds or thousands of materials at a time. Cui also continued to work with James, Shield and Wuttig to parlay a new theory expounded by James into a proposal for a highly-competitive NIH grant that eventually led to head authorship in an article in the prestigious *Nature Materials*.

"Cui was able to bring Takeuchi's powerful synthesis methods into the field of active materials, which previously had relied on painstaking synthesis of one sample at a time, often with great difficulty. Suddenly, thanks to Cui, we had hundreds of samples of different compositions, and we could test theory in a way that was not previously possible," James says. "We learned something amazing about the origins of hysteresis, completely contrary to what is written in textbooks."

Jun Cui

After his time at Maryland, Cui felt it was time to move on from shape-memory materials alone and into industry, specifically to GE Research. At GE, Cui still uses methodology from his days at AEM and Maryland, as well as the massive combinatorial chemistry methods. Late last year, he wrapped up research into novel hydrogen storage materials, freeing up time to focus on his other research areas – mostly water-splitting research and research into low-cost materials for detection of NOx gases, which combine with water to form acid rain.

By 2010 or 2015, the EPA is going to roll out new regulations for how much NOx can be emitted, Cui says, which will make such a cheap material extremely important for keeping costs down for industry. Presently, a sensor at the level to be required by the EPA does exist, but is too costly to be practical. "The way it is done today relies on elegant electrochemical methods, but it is a $200 sensor," Cui says. "Trucks need two of them and each lasts only three months right now, so we need to find something cheaper; we're aiming for a $20 sensor that lasts for 3,000 hours." Now that his everyday work does not deal with his research topic of choice while at AEM and Maryland - shape-memory materials - Cui says he utilizes his education mainly in the way he approaches a problem or an apparent dead-end. "I do research in different areas than I did as a Ph.D. student or a postdoc, but I constantly practice the method of thinking I learned," he explains. "If I hit a dead end, I can figure out how I get around it - that's what I use from my education – the method of thinking."

In addition to his work at GE, Cui is presently an adjunct professor at the University of Maryland and is actively working with Shield and James on a variety of projects that come from their previous work on shape-memory materials.

Recent grad Vibhor Bageshwar to join Honeywell

The objective of state vector estimation problems is to estimate the statistics of a state vector governed by a system model. Errors from sources such as model uncertainty and sensor measurements are inevitable. Part of the challenge in these problems is to estimate or bound the effects of these error sources using a filter. The most popular filter is the industry standard Kalman filter. Vibhor Bageshwar, a recent Ph.D. graduate in Aerospace Systems, worked on quantifying the performance limitations of the Kalman filter both in theory and in practical applications such as attitude determination systems. Bageshwar is set to start at Honeywell this February, where he will continue to work on concepts he developed during his Ph.D.

Vibhor Bageshwar

In framing an explanation of his thesis, Bageshwar states: "theory is not enough; the theory must be applied to practical applications with the associated errors."

This idea permeates Bageshwar's graduate career, which included research on adaptive cruise control systems, near Earth orbit and low Earth orbit satellite pointing systems, the Kalman filter, and attitude determination (AD) systems using low-cost sensors. Attitude refers to a vehicle's three-dimensional angular orientation.

A Kalman filter, under various assumptions on the system model, is a recursive algorithm that estimates the mean and variance of a state vector. The variance can be interpreted as the estimation errors of the state mean vector. The design question in state vector estimation problems is how should the system model be selected so that the Kalman filter provides unbiased, minimum variance estimates of the state mean vector. A significant component of Bageshwar's doctoral research was to develop a test to characterize the variance of the estimated state mean vector for general system models.

"This test allows the user to predict the performance of the Kalman filter during the design and selection process of the system model," he explains. "Therefore, the user can adjust the system model or tune the filter before the filter is used on the real system."

As part of his doctoral research, Bageshwar also designed the AD system for the University's entry into the Air Force/NASA University Nanosat-4 competition, a national program where select universities build a satellite from conceptual design to prototype and compete to have it launched into space.

For the University's entry into the competition – Minnesat – Bageshwar designed an AD system using low cost sensors and a Kalman filter to blend measurements from an inertial sensor and a magnetometer. A magnetometer measures the local magnetic field of the Earth. He demonstrated that this sensor set could be used for satellite AD systems and identified the quality of the sensors required to determine Minnesat's attitude in support of Minnesat's scientific mission. This technology helped Minnesat garner a fifth-place finish in its first entry into the competition.

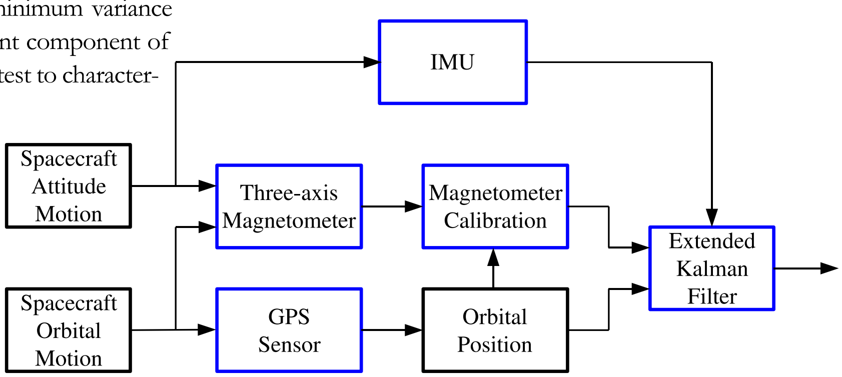
"Typically, an AD system uses inertial sensors, however, the sensor measurement errors cause the estimation error of attitude to grow without bound," he explains. "So the challenge is to estimate the sensor measurement errors and minimize their effect on the attitude estimates. The standard approach is to use additional sensors to aid the inertial sensors."

Normally, two aiding sensors are used in AD systems. However, design trade-offs including Minnesat's mission, size, weight, and cost constraints dictated that only one aiding sensor could be used.

"We wondered if we could design an AD system using one aiding sensor and how accurate the attitude estimates would be," he recalls.

Demoz Gebre-Egziabher, a McKnight Land-Grant professor in AEM and adviser to Nanosat-4, says Bageshwar effectively designed the entire navigation, guidance and control system for Minnesat and trained the undergraduate engineering students on those aspects of the satellite.

"He developed an algorithm that will allow low-cost or off-the-shelf sensors to be used in small satellites for attitude determination," Gebre-Egziabher explains. "His work will be used as legacy designs for all future small satellites the department builds."



Small satellite attitude determination system. Courtesy of Vibhor Bageshwar

Old shop sees new life as graduate student offices



In support of the department's teaching and research initiatives, more functional space has been created in Akerman Hall through the conversion of the machine shop area to the AEM Teaching and Learning Center.

Several years ago, the AEM shop closed when, to make better use of resources, the department partnered with the ECE shop for machining services. While a strategic plan for building development was finalized the space has been used mainly as a transition area while other changes were made throughout the building.

Housing as many as sixteen teaching assistants, the shop area was completely redesigned and features new furniture, air conditioning, carpet and storage units. The area also includes a meeting room with space and technology for collaborative learning and a more formal space for our students to connect with industry partners, a frequent occurrence.

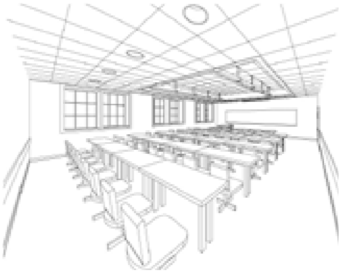
This project was completed for Spring 2008. The department paid for the majority of the $160,000 project with the support of the Dean's office in the form of a $50,000 contribution.

University seeks support for Akerman Hall classroom renovation

Akerman Hall, constructed in the late 1940's, has been targeted to study the design, cost and feasibility of individually renovating classroom space within an existing building without any renovation to the base building systems, structure, façade or general spaces. The University's Office of Classroom Management supports this initiative, as it will improve the teaching and learning support available on the East Bank campus. The project will directly support the University's capital plan by providing functional teaching and learning space during the renovation of Folwell Hall.

The existing classroom spaces generally all have limitations or nonconformance to the University Classroom Standards, including: no ventilation system, uneven heating, poor lighting, no air conditioning (no air system), limited power availability and low voltage distribution provisions. The project would renovate existing space to meet instructional requirements and replace many windows, tiles and ceilings. Electrical renovations will include new power and lighting in each room. A new HVAC system will be provided in each classroom, and heating infrastructure will be replaced or upgraded. Additionally, the renovation would install the standard Projection Capable Classroom technology system in each classroom.

Alumni can support this effort by talking with their legislators about supporting the University's capital request.

New Alumni relations officer joins University staff


Kathy Peters-Martell

Kathy Peters-Martell is a new Senior Development Officer for the Institute of Technology, specifically assigned to the Departments of Aerospace Engineering and Mechanics and Chemistry. She is very excited to be a part of these interesting departments and looks forward to working with the faculty, staff and alumni of these renowned programs and the Institute of Technology.

If you are interested in discussing giving options, contact her at 612-626-8282 or kpeters@umn.edu.

Kathy has more than 20 years of experience in educational fundraising, most recently as the Director of Development for Mounds Park Academy where she just helped complete a $13 million dollar capital campaign.

Prior to Mounds Park Academy she served as a Major Gifts Officer for William Mitchell College of Law from 1995-2004. Kathy was also the Director of Development for the Raptor Center at the University of Minnesota from 1990-1995.

Graduate Student Spotlight: Shankar Ghosh


Shankar Ghosh

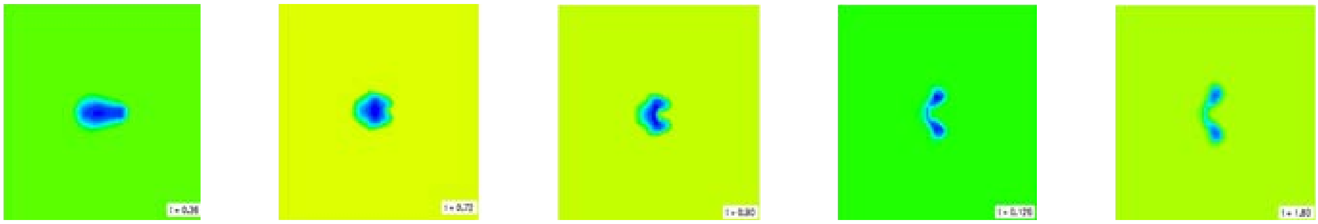
One of the many difficulties of achieving speeds significantly faster than that of sound is the interaction of structures with turbulent flow in the background. Inside an engine, turbulence can alter the flow field significantly. Shankar Ghosh, an AEM doctoral candidate, is analyzing ways to control turbulent flows using a laser-induced plasma.

Using a laser, scientists can superheat a small pocket of gas until it becomes a plasma, the fourth state of matter, beyond solids, liquids and gases. A plasma has potential to control turbulent flows, Shankar says, but fundamental knowledge is lacking in this area. In an effort to understand the phenomenon better, Shankar, working under AEM Associate Professor Krishnan Mahesh, models a laser-induced plasma computationally.

Using computational fluid dynamics, Shankar looks to study the effect of a laser-induced plasma on turbulent flows.

"When you focus a laser beam in a small volume of a gas, a part of the laser energy is absorbed by molecules in the focal volume resulting in the gas undergoing a number of different physical processes like dissociation, ionization and recombination," Shankar explains. "Higher temperatures mean more physics are involved and the simulations consequently become more expensive computationally with increase in temperature."

Although the research is fundamental and the project is at a fairly early stage, Ghosh says, understanding gained through numerical simulations has significant, potential implications in aerospace and other related fields.


Temperature contours in time show laser induced breakdown of air. *Courtesy of Shankar Ghosh*

Graduate Student Spotlight: Balint Vanek

Balint Vanek, a Ph.D. student in Aerospace Enginering and Mechanics, is looking to control a phenomenon known as cavitation – where liquid forced to move fast around an object, like a propeller, vaporizes. The collapse of those vapor bubbles often damages the object. If designed properly, whole vehicles can be enveloped by a cavitation bubble, resulting in "supercavitation." Under the study of AEM Professor Gary Balas, Vanek plans to develop advanced control algorithms to allow vehicles like submarines travel at incredibly high rates of speed through utilizing supercavitation, possibly upward of 200 mph.

"In the near future, we are going to be able to go as fast as the fastest racing cars underwater because of advances in supercavitation," Vanek said.


Balint Vanek

While supercavitation may be best known for its military applications - due to Russia's supercavitating Shkval torpedo and the US's counter-torpedo – Vanek says there is some potential for commercial use in the future, like designing better hydrofoils for powerboats. There are also commercial implications for mining utilizing the principles of supercavitation. The research is exciting, Vanek says, in part because of its novelty.

"It's a field which is very, very new, as most of the things we are doing for the first time anywhere." Vanek notes. "It's not something where you have all the methods and research in place, but here you can be at the forefront." Vanek says he plans to pursue a career in R&D.

Graduate Student Spotlight: Juan Padrino

Efficiently designing oil-harvesting and processing facilities is key in the effort to reduce production costs – and the cost to the consumer. A greater understanding of how oil flows in various natural conditions, like oil-sand or oil-water flows, can lead to the optimized designing of pipes and other components critical to an efficient facility. AEM doctoral candidate Juan Padrino is researching some aspects of fundamental problems associated with these two-phase flows.

Juan Padrino

A doctoral candidate studying Fluid Mechanics under Professor Daniel Joseph in the Department of Aerospace Engineering and Mechanics, Padrino came to the University of Minnesota from his home nation of Venezuela seeking a richer understanding of the mechanics he utilized in everyday research in Venezuela's national oil company.

In early 2003, Padrino decided to return to school to pursue graduate studies, he says, to acquire the tools of engineering science and applied mathematics needed for a deeper analysis of some of the intricate phenomena associated with the transport of multiphase mixtures that occurs not only in the oil industry but also in a variety of industrial processes.

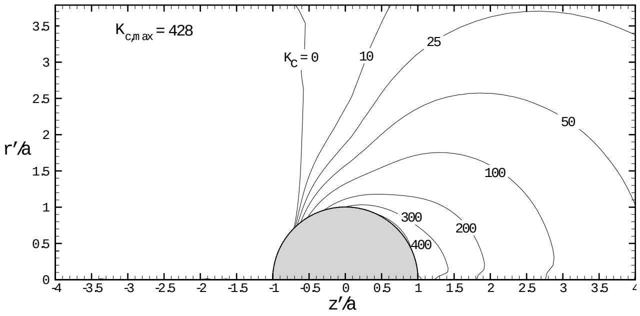
"I contacted my current advisor, Professor Daniel Joseph, who had served as a consultant for my employer for several years and became one of his research assistants at the University of Minnesota while following doctorate studies in mechanics and aerospace engineering," he recalls.

Now Padrino focuses on modeling two-phase flow, which could help industry better understand the complex liquid-liquid, liquid-gas, or liquid-solid flows observed in an oil well. His current research efforts are devoted, in particular, to the modeling of bubble dynamics and bubbly flows.

"In many cases, you have a pipe or a well with water and oil; gas and oil; or gas, oil, water, and sand," Padrino explains, "It's important for engineers who design and maintain processing facilities to be able to model and predict these flows."

By understanding the properties of these types of flows, one can develop, for example, more accurate pressure gradient and volume fraction models that allow for the creation of pipes and equipment with appropriate dimensions and other attributes, all of which have the potential to increase efficiency and decrease production costs.

"It's very hard and impractical to apply computational fluid dynamics packages to a big and complex system like an oil-processing facility," Padrino says. "You may be able to simulate with great detail a separator or valve, but you cannot use CFD to simulate what happens from the well to the storing tank - you need to come up with engineering models that simplify things that are of secondary importance and model those phenomena that are important."



Contours of critical cavitation number Kc obtained from the maximum tension criterion for Stokes flow past a sphere. The highest Kc indicates the region at most risk to cavitation. This region is located on the sphere surface (Kc ≈ 400) at 45º from the rear stagnation point (RSP) in contrast to the well-known classical theory that predicts the opening of a cavity at the RSP. This result seems to be new.
Padrino et al. 2007 J. Fluid Mech. 578, 381-411.

Doctoral and Masters graduates, Fall 2007

Matthew Gmach, M.S., AEM, Advisor: Graham Candler

Anurag Singh, M.S., AEM, Advisor: Ellen Longmire and Ivan Marusic Thesis title: "Characterization of Eddy Structures in a Turbulent Boundary Layer Using Particle Image Velocimetry and Computer Algorithms"

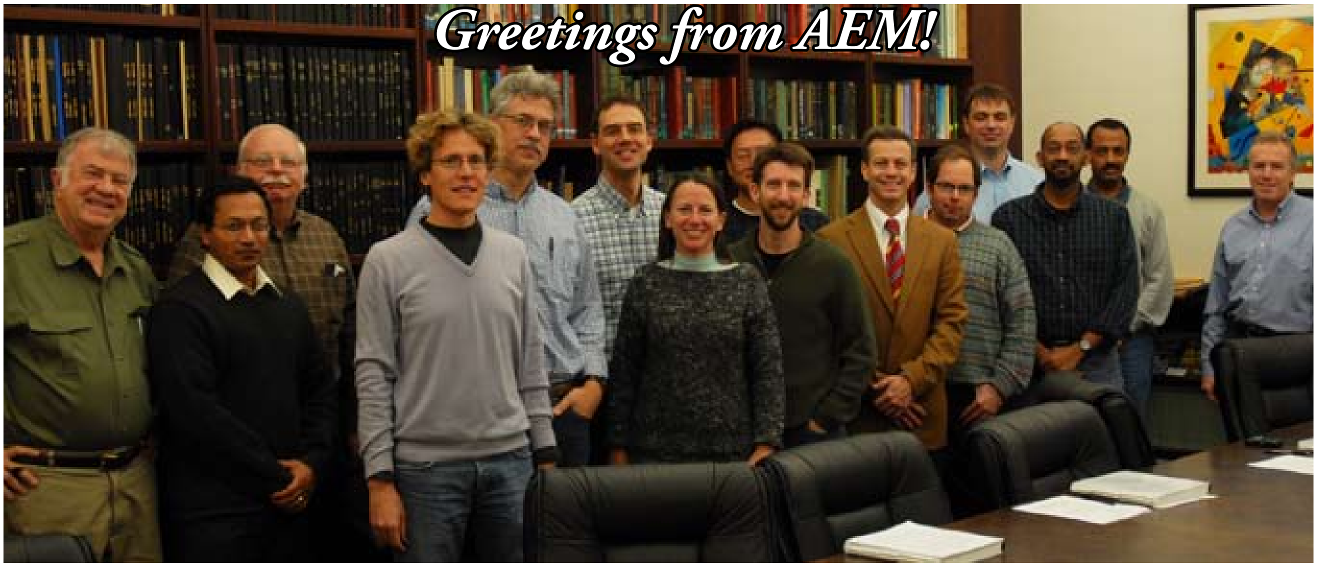
Mir Takyar, M.S., AEM, Advisor: Gary Balas Thesis title: "The Fractional Integrator as a Control Design Element"

Pradeep Babu Salapakkam, Ph.D., AEM, Advisor: Krishnan Mahesh Thesis title: "A Computational Investigation of Three Turbulent Flow Problems"

Ryan Gosse, Ph.D., AEM, Advisor: Graham Candler Thesis title: "Ablation Modeling of Electro-Magnetically Launched Projectile for Access to Space."

William Hambleton, Ph.D., AEM, Advisor: Ivan Marusic Thesis title: "Experimental Study of Coherent Events in Laminar and Turbulent Boundary Layers."

Tian Wan, Ph.D., AEM, Advisor: Graham Candler Thesis title: "Computational Simulations of Supersonic Magnetohydrodynamic Flow Control, Power and Propulsion Systems."



Left to right: William Garrard, Krishnan Mahesh, Jeff Hammer, Bernard Mettler, Tom Shield, Ellad Tadmor, Ellen Longmire, Yiyuan Zhao, Ryan Elliott, Gary Balas, Perry Leo, Graham Candler, Demoz Gebre-Egziabher, Yohannes Ketema, and Richard James. Not pictured are Daniel Joseph, Roger Fosdick, and Tom Schwartzentruber.

Aerospace Engineering and Mechanics
Institute of Technology
University of Minnesota
107 Akerman Hall
110 Union St. SE
Minneapolis, MN 55455

Tel: 612-625-8000
Fax: 612-626-1558
dept@aem.umn.edu

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This publication is available in alternative formats upon request. Please call or write to Donna Rosenthal in the Department of Aerospace Engineering and Mechanics, University of Minnesota, 107 Akerman Hall, 110 Union Street S.E., Minneapolis, MN 55455, (612) 625-3348, donna@aem.umn.edu.