NEWSLETTER FOR ALUMNI, FRIENDS & STUDENTS

SPRING-SUMMER 2001

THE STREAMLINE

AEROSPACE ENGINEERING, MECHANICS & ENGINEERING SCIENCE

STATE OF THE DEPARTMENT: CHAIR'S MESSAGE

I would like to use this opportunity to give our alumni, colleagues and friends an update of the Department of Aerospace Engineering, Mechanics & Engineering Science. As with many peer departments, we have been going through substantial changes in personnel, research, and teaching in recent years. We now have 25 fulltime faculty members, about 400 undergraduate students, and about 100 graduate students. Twelve of our faculty members joined us after 1990. A number of exciting and diverse research areas are being actively pursued by our faculty and students, such as blended wing aircraft and micro/biological air vehicles, acoustics and micro-scale sensors, continuum and Boltzamann-based mechanics, tissue and blood dynamics, optics-based diagnostics, drop dynamics and supercavitating flows, composite materials, design and multidisciplinary optimization, combined electromagnetics and mechanics, space structure and satellite dynamics, and airbreathing and rocket propulsion. Our faculty and students published about 200 journal and conference papers last year, and our research activity is growing at a healthy pace.

Dr. W. Shyy

As a continuing effort, we are exploring ways to foster interactions between these activities as closely as possible. Examples include our ongoing micro air vehicle (MAV) activities, and recent efforts in supporting undergraduate participation in our research and design efforts. The MAV is ideal for combining research, design, and flight testing because the main physical regime is substantially different from what we learn from text books (so we need to do research). The airplane is small and can be designed and built by ourselves (which fosters student participation), and the flight test is interesting and difficult enough to warrant community-wide activities. Five years ago, our Department initiated an annual flight competition that has become a truly international event, and has attracted enthusiastic student participation. The AeMES Undergraduate Research Conference and Biomedical Engineering Design Conference were initiated a couple of years ago. They are meant to foster greater participation from our undergraduates so that they can interact with faculty, and have the opportunity to participate in independent research and design projects. We also hope to support more internship and co-op activities for our students, and welcome your suggestions for added opportunities in these areas.

The Millsaps Memorial Fund was established to honor the late Dr. Knox Millspas, a long time faculty member and leader in our department. The Fund has contributed to several worthy causes, including a privately presented award for Best Student in Statics (who can be from any department), Outstanding Graduate Teaching Assistant Award, and the Millsaps-Taylor Lecture. Recently, we initiated the AeMES Graduate Fellowship Fund with the goal of supporting outstanding Ph.D. students so that their efforts and accomplishments are duly recognized. Last year, we decided to combine the Millsaps Memorial Fund and the AeMES Graduate Fund to foster more coordination and synergy. With the support from our alumni, friends, faculty, and the matching program from the State, the Fund is expected to grow to more than $400,000 at the end of this year. We solicit your support for the Millsaps Memorial Fund so that it can more effectively encourage excellence in performance by our students.

With a generous gift from Dr. William Powers, Vice President for Research of Ford Motor Company, and the state's matching program, we have established the William F. Powers Professorship. Dr. Powers received his BS degree from our Aerospace Engineering program, and has had a distinguished career. We appreciate his support and look forward to using this opportunity to help appoint a most qualified faculty member for this professorship.

Our goal is to offer our students the most stimulating environment to learn, our faculty the most proactive support for intellectual pursuit, and our staff the best infrastructure to perform their administrative functions. In short, we strive for academic excellence. The Department is healthy, and the spirit is high. We invite you all to visit us, either in Gainesville or

HIGHLIGHTS

Department Chair: Wei Shyy

Editor:
Loc Vu-Quoc, Tel: (352) 392-6227,
E-mail: Vu-Quoc@ufl.edu

Associate Editors:
Roger Tran-Son-Tay
Peter Ifju

Design and layout:
Ramji Kamakoti

AeMES Web page URL:
http://www.aero.ufl.edu/

UNIVERSITY OF FLORIDA

on the web at www.aero.ufl.edu.

Best regards,

Wei Shyy

Professor and Chair

UF Wins Big in MAV Competition

Once again the AeMES Micro Air Vehicle (MAV) team dominated the International MAV Competition, hosted by our department. The UF team won the surveillance competition with a record small 7.4-inch MAV (breaking last years record of 10 inches set by UF) as well as the payload competition with a 7.5-inch MAV (breaking last years record of 11 inches also set by UF). This was the third year in a row that UF won both disciplines. In the surveillance competition teams were required to fly to a target 600 meters from the launch area and return an image of the target. This required each aircraft to be piloted using an onboard video camera. In the payload competition the aircraft was required to carry a 2-ounce block of aluminum for 2 minutes. In both competitions, the winner was the smallest aircraft to complete the mission.

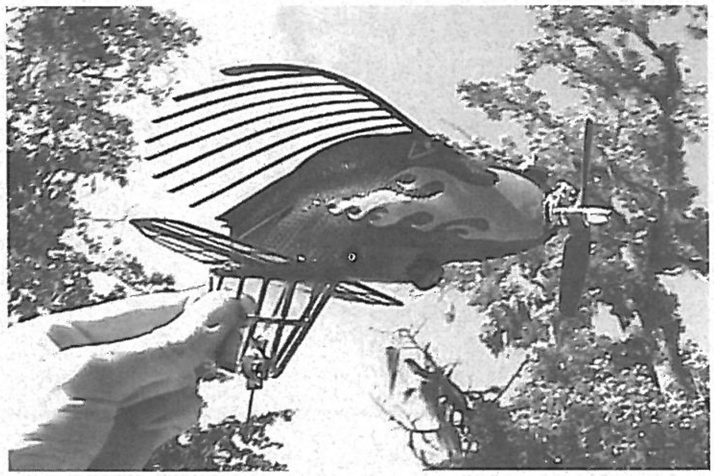
The competition was held on Saturday, April 7th, at the Flying Gator RC Club facility in Archer, FL. There were 9 teams that competed including, Penn State University, California Polytechnic, Worcester Polytechnic Institute, Notre Dame, Brigham Young University, University of Arizona, Kon-Kuk University of Korea, Korean Institute for Science and Technology, and the University of Florida. There were more than 50 students participating as well as over 100 spectators throughout the day. This was more than twice as many as participated in last year's competition hosted by Arizona State University. "The quality of the competition was much better this year" said Dr Ifju the faculty advisor.

The University of Florida was represented by Mujahid Abdulrahim (co-captain and pilot), Donald Myers (co-captain), Luis Martinez (competition organizer), Scott Ettinger (graduate student), Jos Cocquyt, Jason Jakowski, Tom Singer, William Schulz, Otavio Pascarelli, Tyrone Lee, Peter Ifju (faculty advisor and competition organizer), and David Jenkins (faculty advisor and competition organizer).

The University of Florida MAV team

The University of Florida MAVs were similar to those of the past two years, incorporating the flexible wing concept. This year however, the aircraft were far more streamlined and incorporated more advanced electronics. Many of the schools aircraft resembled our designs of the past. "I think that is the ultimate compliment" remarked Scott Ettinger, who has been a major contributor to the UF design evolution. "I was especially pleased with our effort in the payload competition" explained Dr. Ifju. The UF team's 7.5 inch MAV successfully carried the 2-ounce (1.7" x 1.5" x 0.5") block of aluminum for 2 minutes. The second place Korean Institute of Science and Technology team place second with a 9.9 inch aircraft.

On Friday April 6, the night before the competition, the AeMES Department hosted a reception and unveiling. Each team presented their MAV designs and fielded questions from the other teams. "I was impressed at the healthy exchange of ideas and technology" said Mujahid Abdelrahim the UF team captain. To conclude the weekend, on the evening after the competition, the AeMES Department hosted the awards banquet in the



The 7.4 inch surveillance competition winner

New Engineering Building Rotunda/Atrium. In addition to the plaques that were given for first place, other teams were recognized for completing both disciplines. Prior to this year, UF was the only university team to complete the surveillance mission. This year the Notre Dame team, led by UF graduate Gabriel Torres, finished a strong second also improving on last year's record. A summary of the official results is provided below.

Next year, Brigham Young University will host the event. "I wouldn't be surprised to see MAVs smaller than 6 inches completing the surveillance mission next year" said graduating senior Luis Martinez.

Official Results from the 5th International Micro Air Vehicle Competition

Surveillance Competition

The smallest aircraft to image, by video camera, a target 600 meters from the launch area.

1st Place	7.4 inches	University of Florida
2nd Place	8.7 inches	Notre Dame University
3rd Place	12.4 inches	Brigham Young University
4th Place	76.0 inches	California Polytechnic

Payload Competition

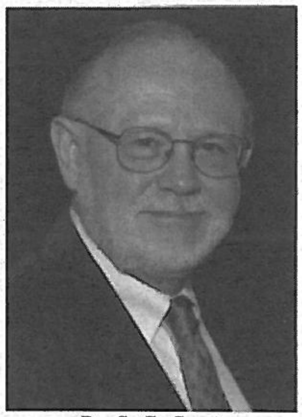
The smallest aircraft to fly for two minutes carrying a 2 oz block of aluminum.

1st Place	7.5 inches	University of Florida
2nd Place	9.9 inches	Korean Institute of Science and Technology
3rd Place	10.4 inches	California Polytechnic
4th Place	12.0 inches	Worcester Polytechnic Institute
5th Place	12.6 inches	Brigham Young University

2001 Millsaps-Taylor Lecture: Dr. Stephen C. Cowin

Dr. Stephen C. Cowin presented the Millsaps-Taylor Lecture in AeMES on 16 March 2001. Dr. Cowin is a Distinguished Professor in the Department of Mechanical Engineering at City College and Director of the New York Center for Biomedical Engineering at the City University of New York (CUNY). He also serves as an Adjunct Professor of Orthopaedics at the Mt. Sinai School of Medicine in New York City. Before taking up his position at CUNY in September 1988, he was the Alden J. Laborde Professor of Engineering in the Department of Biomedical Engineering at Tulane University. He was also a Professor of Applied Statistics in the Graduate School, and Adjunct Professor in the Department of Orthopaedics of the School of Medicine at Tulane.

Dr. Cowin received his BES and MS in Civil Engineering from Johns Hopkins University in 1956 and 1958, respectively, and his PhD in Engineering Mechanics from the Pennsylvania State University in 1962. After one year on the faculty at the Pennsylvania State University, he began a 25 year long association with Tulane University in 1963. His principal research interest is the mechanics of materials, particularly in determining the influence of microstructure on the gross mechanical behavior of granular, composite, and biological materials. Dr. Cowin is known for his analysis of static bin pressure induced by granular materials, his development of a continuum theory for granular materials, the creation of the continuum theory of materials with small voids, for the development of models of granular material slip zones, basic theorems in anisotropic elasticity, and the development of the bone remodeling theories and computational algorithms.



Dr. S. C. Cowin

On a closer note, one of our faculty, Dr. Edward Walsh, worked with Dr. Jace Nunziato at the Sandia National Laboratories on an extension of the theory of granular materials Dr. Cowin developed with Dr. M. A. Goodman. In the Cowin and Goodman theory, as applied to granular materials, the volume fraction of the granules is considered as an independent kinematical variable and, thus, an additional force balance equation is specified to account for compaction of the void volume. Nunziato and Walsh extended that theory to a mixture of N constituents which include the effects of porosity and allow for mass, momentum and energy transfer among the constituents, thus making the theory consistent for the investigation of shock-induced detonation in granular explosives. The model was incorporated into a wave propagation computer code; numerical simulations of both shock and ramp wave loading conditions were shown to be consistent with a wide range of experimental data on a granular explosive. The figure shows the predictions of the mixture model for the growth of a ramp wave propagating in a granular explosive.

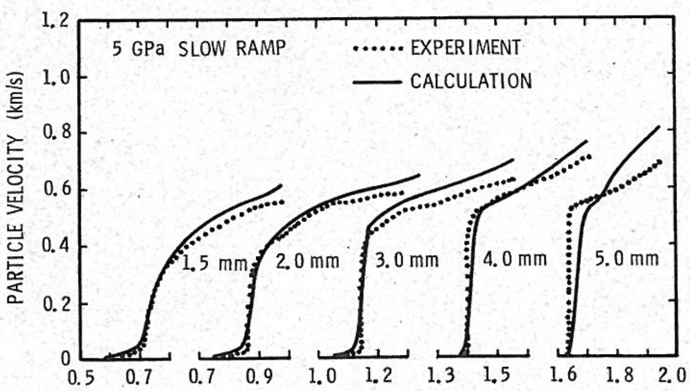


Fig. 18

Comparison between experiment and Dr. Walsh's calculation based on Dr. Cowin's theory

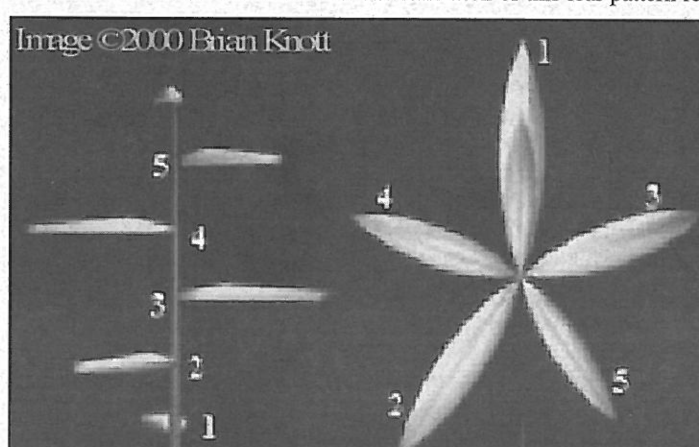
Dr. Cowin has also been Professor-in-Charge of the Tulane/Newcomb Junior Year Abroad Program in Great Britain and Chairman of the Applied Mathematics Program at Tulane. In 1985 he received the Society of Tulane Engineers and Lee H. Johnson Award for Teaching Excellence. He was also the recipient of the Best Paper Award from the Bioengineering Division of the American Society of Mechanical Engineers in 1992; a recipient of the Melville Medal from the American Society of Mechanical Engineers in 1993, and a recipient of the European Society of Biomechanics Research Award in 1994. In 1999 he received the H. R. Lissner Medal of the American Society of Mechanical Engineers for contributions to biomedical engineering. He is a Fellow of the AAM, AIMBE, ASME, and AAAS.

Dr. Cowin is the author of about 200 research papers and editor or coeditor of five books, including the seminal tome Bone Mechanics Handbook. He is presently or has been an Associate Editor of the Journal of Applied Mechanics and the Journal of Biomechanical Engineering , a member of the Editorial Board of the Journal of Biomechanics and the Annals of Biomedical Engineering, and a member of the Editorial Advisory Board of the Handbook of Bioengineering and the Handbook of Mechanics, Materials, and Structures.

Dr. Cowin unfortunately began his trip to Gainesville encountering many travel problems. His connecting flight left early because it was overbooked by the airline, forcing him to spend the night in Atlanta. A trying day began the next morning, as the airline provided limited amounts of information as to why his flight repeatedly was postponed, finally culminating in the loading of him and his fellow passengers onto a bus to Gainesville. The bus departed late as well, nearly six hours after the scheduled flight time. So, not only did Dr. Cowin arrive 21 hours late to Gainesville, he arrived by bus. In spite of all this, we could not ever hope to host a more accommodating, appreciative, and engaging guest as him.

Dr. Cowin began a full, and what became his only, day of interactions with the faculty and graduate students, enabled by a heroic reshuffling of his itinerary. He breakfasted early with representatives of the solid mechanics faculty, including Dr. Walsh, his friend for over 30 years. A luncheon was well attended by faculty, including another long time friend Dr. Drucker, and colleagues from other departments. His interactions through the day provided a productive exchange of research ideas. Faculty (Dr. Rapoff and Dr. Haftka in absentia) and students involved in biomimetics structures detailed their research results and plans on applying lessons learned from holes in bones to designing stronger and lighter structures containing holes. Dr. Shyy shared a recent publication of his with Dr. Cowin on micro-scale biofluid dynamics. These interactions and the feedback provided by such a senior scholar as Dr. Cowin are most valuable to us to assess continuously our direction and level of performance.

The lecture itself was "SRO" (standing room only), and was based on his recent paper How Is a Tissue Built?. The primary topics of his lecture were that plant and animal tissues are created in repeatable structural patterns and that these patterns are due to a genetic and an environmental component. Examples in his lecture were presented to determine the specific influence of the mechanical aspects of the environmental component. One example concerned phyllotaxis, or the pattern of leaf and petal formation on plants. A famous phyllotaxis is the leaf and flower patterns characterized by Fibonacci numbers. A number in the Fibonacci series is the sum of the two previous numbers, or {1, 1, 2, 3, 5, 8, 13, 21, 34, 55, ...}. The leaves of many plants show the Fibonacci numbers in their arrangements around the stem. Looking down on a plant from above, the leaves above often do not hide those below, so that all gets its share of sun and rain. Fibonacci numbers arise when counting the number of leaves and the number of turns required to encounter a leaf directly above the starting one. The number of turns in each direction and the number of leaves are three consecutive Fibonacci numbers. In the figure of the 5 leaved plant, 2 counter-clockwise and 3 clockwise turns are required to encounter a leaf directly above the starting one, and {2, 3, 5} are consecutive Fibonacci numbers. Dr. Cowin discussed how the formation of this leaf pattern re-



Phyllotaxis: Pattern of leaf and petal formation on plants lates to the buckling mode shapes present in the plant tissue during the formation of the next, new leaf. Dr. Cowin hopes no doubt will be realized when new ideas and observations are stimulated by such work.

Portions of this article were taken liberally by Dr. Rapoff from the biographical sketch and paper provided by Dr. Cowin.

Dept News

Honors and Awards

Prof. M.A. Eisenberg has been invited by the U.S. Air Force Academy to serve as Distinguished Visiting Professor of Engineering Mechanics for Academic Year 2001-2002. He will return to full-time service at UF in Fall 2002.

The UF team composed of **Mr. Chandrasekaran, Mr. Cain, ECE Assoc. Prof. T. Nishida, Assist. Prof. L. Cattafesta,** and **Assist. Prof. M. Sheplak,** won the Best Paper Award given by the AIAA Aerodynamics Measurement Technology Technical Committee, with their paper title *"Characterization of a micromachined thermal shear stress sensor"*. The award will be presented at the Awards Luncheon during the AIAA Conference, Anaheim, CA, 11-14 Jun 01.

Distinguished Prof. R. Haftka has been selected for a University of Florida Research Foundation Professorship Award (UFRFP) for a three-year term. Dr. Haftka plans to use the research funding to work on the following three topics: (i) Optimization for uncertainty that improves reliability and robust performance, (ii) Genetic algorithms that use statistical methods to improve their performance, (iii) Use of statistical techniques together with response surface approximations to detect computer simulations with large errors. Dr. Haftka spent the Spring 2001 at the Sandia National Laboratory to work on the use of genetic algorithms for global design optimization under uncertainty.

Assoc. Prof. P. Ifju, Mr. S. Ettinger (graduate student), **Dr. D. Jenkins,** and **Mr. L. Martinez** (undergraduate student) received recognition for Best Paper for their conference paper titled "Composite Materials for Micro Air Vehicles" at the Annual Society for the Advancement of Material and Process Engineering (SAMPE) Conference, 6-10 May 2001, Long Beach, CA. They received a $500 cash prize along with a plaque at the society luncheon.

Dr. R. Mei is promoted to the rank of professor, effective Aug 2001.

In Dec 2000, **Prof. B. Sankar** was invited to join the Editorial Advisory Board of the *Journal of Composite Materials* (JCM), a semi-monthly publication providing a permanent record of achievements in science, technology and economics of composite materials. Dr. Sankar began his five-year term on Jan 2001. He will advise on how to improve the JCM, and contribute to review and recommend papers for publication.

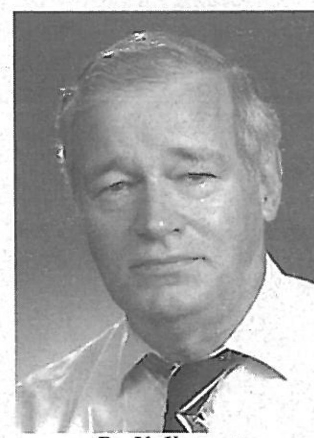
Prof. and Chairman W. Shyy was elected Fellow of the AIAA in Dec 2000, among some 30 new fellows last year. The letter of notification written by AIAA President and MIT Prof. Sheila Widnall mentioned that Dr. Shyy was honored for his contributions to the arts, sciences, or technology of aeronautics and astronautics. He received a certificate and a pin at the annual Fellows Dinner of the AIAA, and was also recognized at the Honors Night Banquet held in conjunction with the Global Air & Space 2001 International Business Forum and Exhibition, 7-9 May 2001 in Arlington, VA. The readers may recall that Dr. Widnall was our department's Taylor-Millsaps speaker back in Fall '96, when she was the Secretary of the Air Force under the Clinton administration; see {The Streamline} issue in Fall '96.

Prof. Emer. C.E. Taylor was awarded the American Academy of Mechanics Award for the year 2000 for his distinguished service to the field of Theoretical and Applied Mechanics. The definition of service includes the directing and monitoring of research programs, general professional leadership, organization of meetings, and editing of book series and journals. The award includes a bronze medal and a certificate. It is noted that the Department's Grad. Res. Prof. Emer. D.C. Drucker was conferred this award in 1986. Among the award recipients of years past, Prof. Y.C. Fung of UC San Diego (awarded in 1988) and Prof. J. Rice of Harvard University (awarded in 1992) were our department's Millsaps-Taylor lecturers in previous years.

Teaching Activities

ABET Update

As many of you know, AeMES as well as most other engineering departments throughout the country, are subjected to a periodic review by the **Accreditation Board for Engineering Technology (ABET)**. This review takes place every sixth year and involves extensive gathering of departmental data including details on graduation rates, course and program content, research and publication efforts by the faculty, collecting of feedback from alumni and employers, student society and seminar activities, benchmark comparisons with other engineering schools, and, in our case, the writing up of two detailed self-study reports which have just been submitted to the national accredidation board. We have just completed this accreditation review, which culminated in a three day campus visit by the national ABET review committee. The reviewer for Aerospace Engineering was Dr.Eric Sheppard, Director of the NSF division for Undergraduate Education, and for Engineering Science was Professor Jon Bredeson, Chairman of Electrical Engineering at Texas Tech University. Both reviewers have represented ABET at numerous engineering colleges throughout the country and thus have a good feel for what constitutes departmental quality. Official notification concerning re-accredidation of the AeMES programs will be sent to the University of Florida president in early September. Up to this point we have received very positive feedback from our examiners and no weaknesses or deficiencies were noted in either of our two programs. The reviewers were favorably impressed with the efforts of our administration, faculty, students and staff in making this a very vigorous and exiting place to be and obtain one's engineering degree. The few concerns expressed involved the problem of faculty salary compression, overcrowding of classrooms, and sparse professional engineer registration existing in the department. Steps have been taken, and continue to be taken, to correct these concerns.



Dr. U. Kurzweg

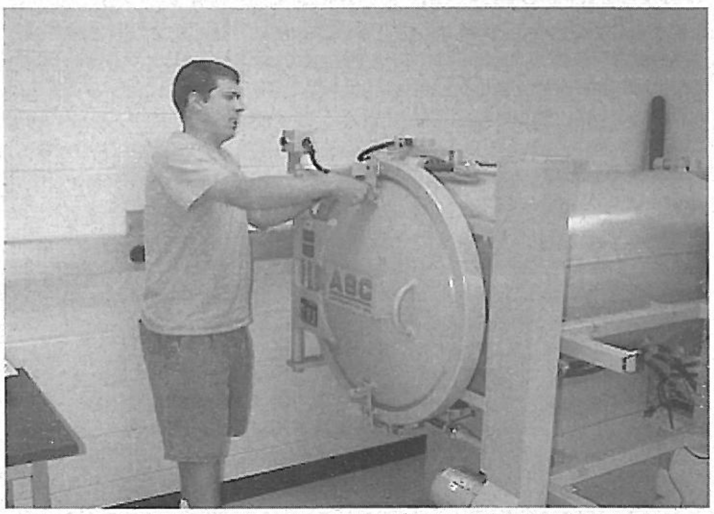
This latest ABET review was the first at the University of Florida to be conducted under the new Engineering Criteria 2000 format (for details see http://www.abet.org). Unlike earlier accredidation procedures, ABET2000 requires a much more intensive and continuous effort involving mechanism for continuous program assessment and feedback between the program, students, employers, and alumni. The process is intended to measure how eleven criteria required by ABET are being met by individual departments and how these are being satisfied on a continuing basis. The criteria include (1) demonstrating the ability to apply knowledge of mathematics, science and engineering, (2) showing that students are able to design and conduct experiments, (3) the ability to identify, formulate, and solve engineering problems, (4) the ability to communicate effectively and learn to function in groups, (5) understanding professional and ethical responsibility, and (6) engage in lifelong learning and be knowlegible of contemporary issues. Our former College of Engineering Dean, Win Phillips, is largely responsible for having these criteria adopted at the national level. As can be imagined, the assessment process of how a department is meeting these criteria on a continual basis now requires considerably more and continuos effort than in the past.

The AeMES ABET effort, including the writing of the two extensive self-study reports, was the responsibility of the departmental ABET committee (Drs. Carroll, Eisenberg, Fitz-Coy, Kurzweg(Chairman), and Tran Son Tay) with contributions from the rest of the faculty. Also the efforts of our alumni and employers in providing feedback via completion of surveys and writing letters are much appreciated and will continue to be appreciated as we continue our external surveys in the future. We encourage submissions of inputs from our several thousand alumni located throughout the country concerning your views of the UF Aerospace Engineering and Engineering Science Programs and how you feel they meet the skills and attitudes required by today's engineers. We will use these comments as a feedback tool to aid us in our continuing ABET2000 process. You can email this information to the newly updated and redesigned departmental web page at http://www.aero.ufl.edu. This WEB page also contains the text of the Departmental Mission and the Program Educational Objectives as newly formulated by our ABET committee, approved by the AeMES faculty, and submitted to the national accredidation board.

Research Activities

Translaminar Reinforcements In Composites

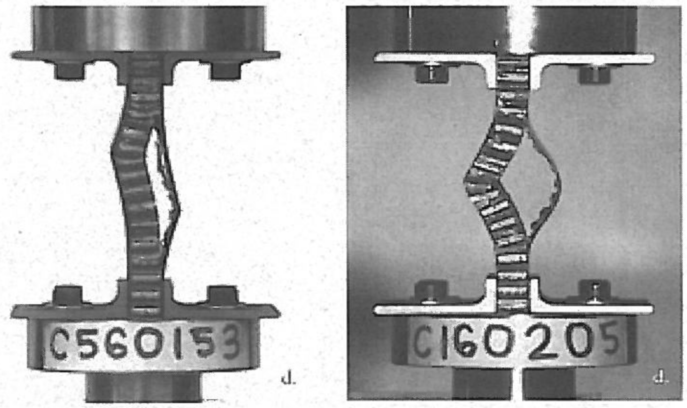
Fiber reinforced composites are being used in aerospace structures for more that thirty years. Tremendous progress has been made in developing new fiber and matrix materials, and processing methods. The most popular composite construction is in the form of laminates. Layers or plies of unidirectional tapes or cloth are stacked together. The fibers in different plies are aligned in different directions to obtain the maximum performance in terms of stiffness or strength for a given application. Preprgs are tapes of unidirectional fibers or cloth pre-impregnated with the resin material. Layers of prepregs can be consolidated and cured in a vacuum bag in an autoclave. On the other hand one can use dry cloth with resin film. Another popular method of fabricating composite laminates is the RTM or Resin Transfer Molding. Layers of dry pre-forms are placed in a mold, and the resin is injected into the mold.



The new AeMES autoclave, housed in the New Engineering Building, has a small footprint, but has the same capacity as the previous one. The operation is fully controlled by a PC resulting in higher quality laminates

In spite of their high stiffness and strength along the fiber direction the interlaminar region (the material in between plies) happens to be the weakest link in a laminated composite structure. Improving the toughness of the resin, for example, introducing rubber particles in the resin, have yielded only limited results. Textile composites such as woven and braided fiber composites do not posses a distinctive interlaminar phase, however when the textile composites are stacked to form a thick laminate, the interlaminar problem becomes worse.

When a laminate possess a weak interface it is susceptible to various types of damage foremost among them is due to foreign object impact. Impact loads act on a very narrow region of the structure producing enormous stresses beneath the contact point. The high interlaminar shear stresses cause delamination, which is often invisible on the surface and thus escape visual inspection. The interfacial cracks can become unstable and enlarge under normal operating loads. Once the delamination reaches a critical size the structure will lose significant stiffness. This is especially true when the laminate is under compression as the skin of the top surface of an air-

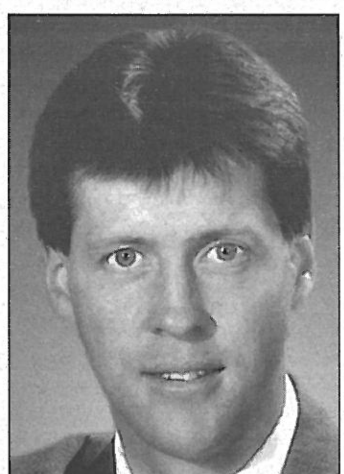


Delaminations or debonding in sandwich construction severely limits the load carrying capacity of the structure, especially compressive loads. Figure shows debonded sandwich plates under compression. Depending on the delamination length the plate buckles in a symmetric or antisym-

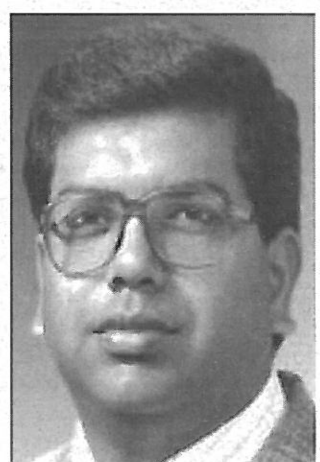
plane wing. The compressive loads can induce buckling of the sublaminates, which further accelerates the delamination propagation.

At the AeMES Department we have been developing various through the thickness reinforcement techniques in order to improve the interlaminar strength and fracture toughness of composite laminates. These reinforcements are generally labeled as *Translaminar Reinforcements*. There are two methods that can be used to provide translaminar reinforcements: through the thickness stitching and Z-pinning. In the former method carbon, glass or Kevlar yarns are used to stitch the fiber preforms together. Usually prepregs are not suitable for stitching as they cause lot of damage to the fibers and also large amount of heat is generated due to friction between the sowing needle and the prepreg resin. Alternatively dry cloths can be easily stitched together in an industrial sewing machine. The reinforcing yarn is used in the bobbin of the machine and a thin Kevlar yarn is used as the needle yarn. The stitches are unbalanced, that is the needle and bobbin yarns do not interlace at the center, but the bobbin yarns run through the entire laminate thickness and interlacing occurs on one of the surfaces of the laminate. The amount of stitching is characterized by various parameters such as yarn density expressed in denier and the stitch density in number of stitches per unit area of the laminate. Our studies have found that stitching increases the Mode I fracture toughness (energy required to open the two faces of the laminate) of graphite/epoxy laminates from 300 J/m^2 up to 20,000 J/m^2 depending on the stitch density and stitch yarn used. Because of such impressive gain in interlaminar fracture toughness, major airframe manufacturers are more and more looking into stitching as a means of fabricating tough composite structures.

Stitching may not be suitable when the structure has some curvature or too thick as in sandwich construction. In such situations an alternative technique called Z-pinning can be used, wherein pins are inserted through



Dr. P. Ifju



Dr. B. Sankar

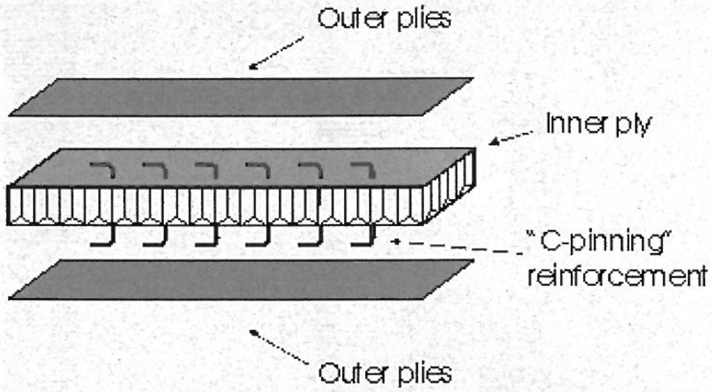


Figure depicts the concept of C-Pinning in a sandwich panel

the thickness of the composite structure.

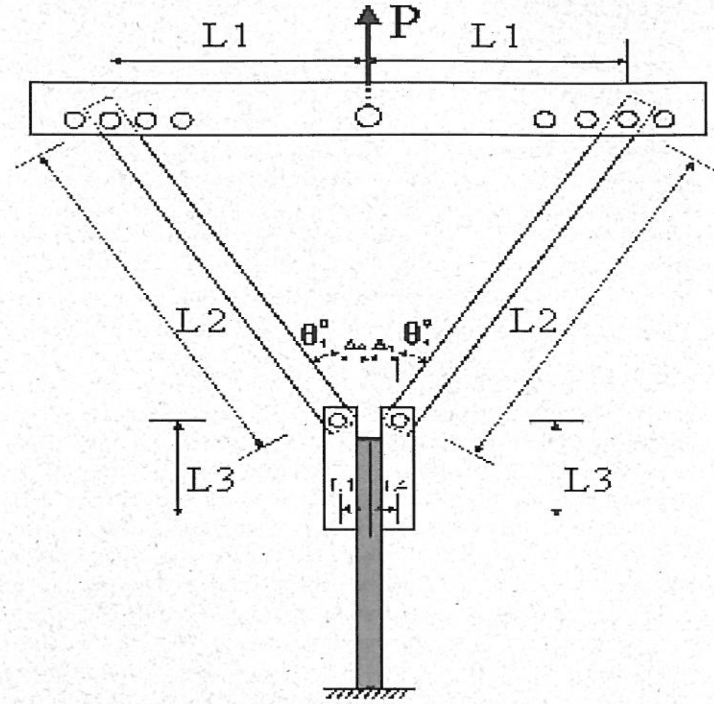
At AeMES we have developed a Z-pinning technique using graphite/ epoxy pins rather than metallic pins. These pins are made from twisted graphite yarns and a suitable epoxy resin and cured in an oven. The pins are inserted into the sandwich composite consisting of graphite/epoxy face sheets and honeycomb core. The sandwich construction is cured inside a vacuum bag in an oven or the autoclave. The pins can be through the thickness of the sandwich panel or they may terminate at one of the ply-interfaces in the face sheets. Further the pins can be straight or folded at the ends to form '[' shaped pins, called C-pins, which increases the pullout strength.

Recent studies by Ryan Merritt, a University Program Scholar, indicates that the Z-pinning technique can increase the interfacial fracture toughness by more than 50%. This is very significant in sandwich construction as the debonded sandwich panels fail due to buckling at very low loads, and Z-pinning can almost restore their in-plane compressive strength by preventing buckling of the face sheets. In fact a study by Brian Wallce (MS '00) found that Z-Pinning can increase the load carrying capacity of sandwich panels by more than 200%.

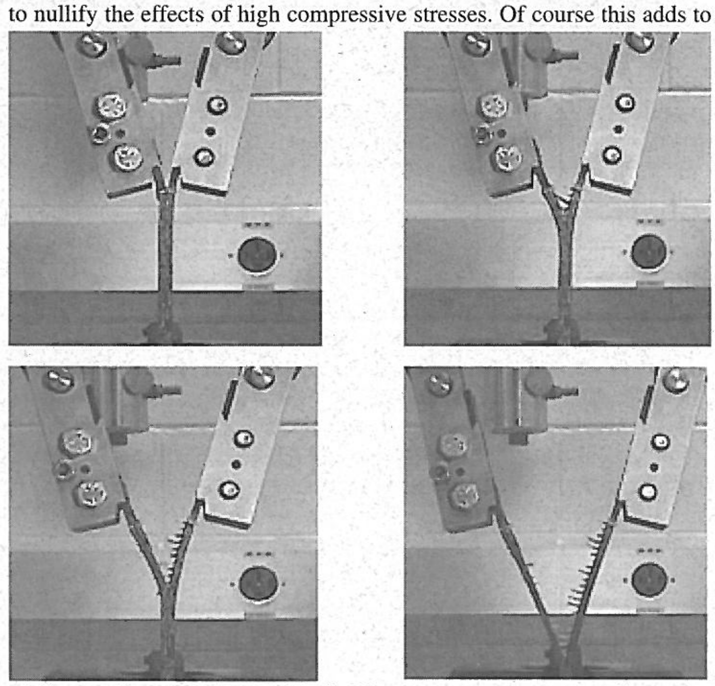
Mr. Leishan Chen

The translaminar reinforcement technique has improved the interlaminar fracture toughness so much, now it has become impossible to measure their fracture toughness using standard test methods. Traditionally Double Cantilever Beam specimens are used to determine the fracture toughness of composite laminates. Because of the tremendous increase in fracture toughness large forces are needed to propgate the crack. This leads to large bending moments in the top and bottom ligaments of the specimen near the crack tip. These large bending moment create high compressive stresses in the composite causing them to fail in micro-buckling before the crack could propagate.

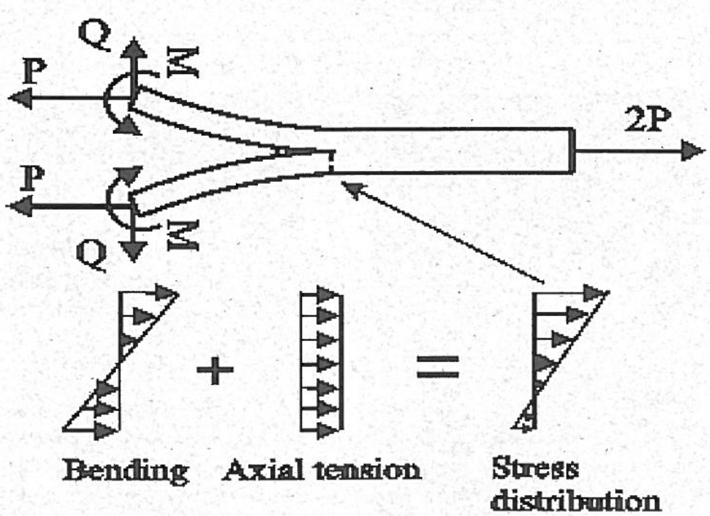
In an NSF funded research program graduate student Leishan Chen and his advisors Drs. Sankar and Ifju have developed a fixture for testing composites with high density of translaminar reinforcements. The key element of this fixture is to add a uniform tensile stress to the DCB specimen so as to nullify the effects of high compressive stresses. Of course this adds to



The inclined bars in the new test fixture are able to provide both axial tension and transverse forces for opening the delamination, and the two forces are approximately in direct proportion throughout the test.



The new fixture to perform Mode I fracture test on composite laminates with high density translaminar reinforcements. The fixture designed by AeMES researchers has been successfully used to test graphite epoxy specimens with 64 stitches per square inch.



The key to successful Mode I testing of composites with high density stitches is to add a uniform axial tension to mitigate the effects of high compressive stresses due to the bending moment at the crack tip.

the tensile stresses in the beam, but fortunately fiber composites are stronger in tension than in compression, hence do not fail in tension. The research team has developed tow kinds of fixtures and has successfully tested several types of composite specimens. The measured fracture toughness values of these specimens were found to be about 100 times that of unreinforced specimens.

The effects of stitching on impact resistance and impact damage tolerance have been studied using the gas gun impact testing facility. Analytical and FE models were also developed to understand the impact behavior of stitched composites. It has been found that stitching does not significantly increase the impact energy threshold for damage. That is the damage initiates almost at the same impact energy level as in unstitched specimens. However at higher impact energies the extent of delamination created is less than that in unreinforced specimens. Further, delaminated specimens containing translaminar reinforcements withstand higher impact energies, thus increasing the damage tolerance.

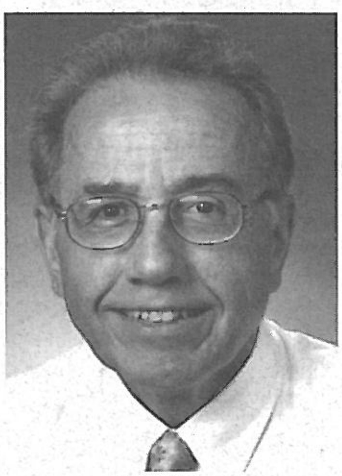
Current efforts include development of analytical and FE models to predict the fracture toughness, impact resistance and damage tolerance of composites with translaminar reinforcements. As a result of the concerted efforts at AeMES, translaminar reinforcements will become a viable method in a variety of laminated composite structures.

The author would like to acknowledge the following former students, who have also made significant contributions to the translaminar reinforcement research program: Viren Sonik (MS '93), Suresh Sharma (MS '94), John Avery (MS '98), Huasheng Zhu (PhD '99).

Research Institute for Autonomous Precision Guided Systems at GERC

In 1999 the Secretary of the Air Force commissioned a study to determine how the Air Force Research Laboratory planned to cope with its expected shortfall in scientific and technical personnel. The study, "Science & Technology Workforce in the 21st Century" (STW-21), concluded that the most fruitful approach was that of government operated, collaborator assisted (GOCA) laboratories that exhibit the following characteristics:

- A core of long-term employees providing management, stability, and knowledge of the organization and its customers
- A significant number of graduates and recent graduates of world class universities providing the latest in analytical, computational, and experimental techniques
- A character and structure that will attract leading scientists from all over the world



Dr. P. Sforza

The relationship between the University of Florida's Graduate Engineering & Research Center (GERC) and Eglin Air Force Base, of which the Air Force Research Laboratory Munitions Directorate (AFRL/MN) is an important part, is one which already anticipated the best parts of the GOCA concept. In response to this need, a concept for a *Research Institute for Autonomous Precision Guided Systems* was developed by AeMES **Prof. P.M. Sforza**, Director of the GERC, and **Dr. R.L. Sierakowski**, Chief Scientist of AFRL/MN (and a former, now Courtesy, AeMES Professor) as a refinement of the existing complex of cooperative agreements presently in place between the GERC and Eglin AFB. A 30-month $1.25 million proposal to fund this concept was submitted to the Air Force Office of Scientific Research by Dr. Sforza and a contract was awarded in May 2000.

The Research Institute at the GERC has been bringing in and supporting scientists from world-class universities and national laboratories to work

Aerial view of the Institute

side-by-side with AFRL/MN's scientists in pursuing basic research supporting their mission. The GERC thus acts as an agile provider of supplementary first-rate scientific manpower to reinforce selected AFRL/MN core competence areas. Current research topics include: Thermomechanics of High Speed Penetration, Nano-Energetics, and Computational Modeling of Localization and Failure in Solids. Intellectual environments of this kind are conducive to attracting top graduate students and post-doctoral fellows to the Research Institute. Not only is the creativity from such participants important to the scientific undertaking, but it is also a source for possible additions to the permanent staff of either the GERC or AFRL/MN. Joint activity through the Research Institute provides the potential for gaining additional financial support for the research by sponsors outside the Air Force.

The long-term plan is to continue the Research Institute at a similar funding level beyond this initial period, with the support base extending to other agencies along with any financial return from commercialization of new discoveries sure to be made in such an environment. Among the 25 scientists, post-docs, and graduate students currently participating in this program are several AeMES faculty and staff members: Prof. N. Cristescu and Prof. L. Vu-Quoc, Emer. Prof. A. Ross, and Dr. Oana Cazacu. As new research topics emerge other AeMES scientists are likely to become involved in the program.

Other Activities

Dr. Oana Cazacu presented a talk titled "Compaction of cohesive systems: Experimental data and modeling" at the Dow Chemical Co., Midland, MI, on 1 Feb 01. She also presented the paper "A new anisotropic yield criterion for aluminum alloys", coauthored with Dr. F. Barlat at Materials 2001, the first international materials symposium held in Coimbra, Portugal, 9-11 Apr 01.

Dr. Ahmed K. Noor has been appointed as an Adjunct Professor in the AeMES department. He is currently a professor at Old Dominion University (ODU), Virginia, and is the director of the Center for Advanced Engineering Environments at the NASA Langley Research Center. Before taking up his position at ODU, he was a professor at the University of Virginia.

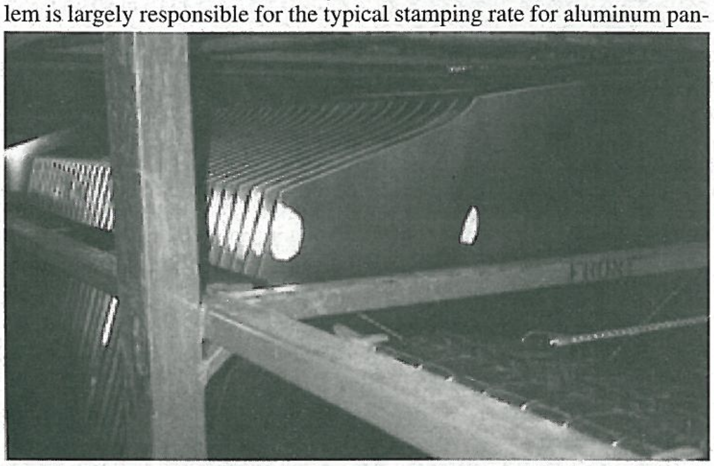
Ms. Nilay Papila, a graduate student working with Prof. R. Haftka, presented a paper titled "Shape Optimization of Supersonic Turbines Using Response Surface and Neural Network Methods" at the 39th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, 8-11 Jan 2001.

Alumni Corner

Ming Li, Ph.D, 93, Senior Staff Scientist at Alcoa Technical Center, learned in June that the implementation of his patent "Sliver Reduction" at General Motor's Grand Rapid Metal Plant resulted in a scrap rate reduction of the U-Van hood outer from 25% to 4%, which translates into multimillion dollar manufacturing cost savings. Three month later, news came from Daimler-Chrysler that the patent was the driving force to a conceptually new design of the hood for a next generation car model which has been released to production. As of today, the technology has also been implemented in Daimler-Chrysler Bramalea plant and Ford Chicago Heights plant. It has been incorporated into Nissan Aluminum Design Book. The technology received request from almost all major automotive manufacturers around the world including GM, Ford, Daimler-Chrysler, Toyota, Nissian, Audi, BMW and VW.

Recent years have seen a rapid increase of the use of aluminum alloys in automotive components due to the requirement for fuel efficiency and high performance. Aluminum alloys are the natural choice over steel for light-weighting, corrosion resistance, and easy-recycling. However, aluminum alloys as "new" materials to the automotive industry pose many challenges to manufacturing processes that have traditionally dealt with steels. One such challenge occurs in the process of press forming (termed "stamping") of aluminum alloy sheet material into body panels (e.g., hood, door, fender, etc.). The problem is, aluminum alloy sheets produce appreciable amounts of slivers (small metal pieces, debris and particles) during trimming operations when trimmed with dies conventionally designed for steel sheets. The slivers can be carried through downstream processes and cause damage to the surface of formed parts. The manufacturing cost increase due to the sliver problem for surface sensitive outer-panels can range from 5-15%, making it one of the single largest factors that increases manufacturing costs. Sliver problem is largely responsible for the typical stamping rate for aluminum panels to be 85% of the stamping rate for steel panels. It is estimated to cost $50-100 million/year for North American Automotive manufacturers just for the current vehicle models using aluminum sheet.


Dr. M. Li



Silver-damaged aluminium alloy hood outer-panels in an automotive manufacturing plant

The project is exciting because it roots deeply in the fundamental research in the area of plasticity by integration of micromechanics and material microstructure into manufacturing process. The research not only solved the sliver problem for aluminum alloys, but actually significantly increased the robustness of sharing process of aluminum alloy sheets compared to that for steel sheets, requiring much less clearance control and much less frequent tool re-sharpening. The research yielded three patents and four journal publications. It is a great satisfaction to see fundamental research went all the way through lab validation to full scale production and made appreciable impact to the welfare of our economy.

With the endorsement from the Chief Technology Office (CTO) of Alcoa, the technology was nominated for the Ennor Manufacturing Technology Award, one of ASME's major medals, for developing the innovative technology which significantly reduces manufacturing costs of aluminum autobody panels and promotes the use of environmental-friendly aluminum in automotive applications.

Dr. Ming Li's current research interest is in integration of material microstructure, mechanics and manufacturing with multi-scale, multi-disciplinary approach emphasizing on material design, process design and product performance. He is leading several projects at Alcoa Technical Center, "Fracture Mechanisms in Material Processing and Product Manufacturing", "Slitting/Side Trimming of Flat Rolled Product", "Fundamental Understanding of Edge Cracking in Hot and Cold Rolling Processes", and "Sliver Reduction in Sheet Metal Shearing", with research funding total over half million dollars yearly.

Dr. Ming Li is very active in both mechanics and materials research communities. He co-edited a special issue "Meal Forming" for International Journal of Plasticity. He is the co-chair of the committee "Integration of Computational Mechanics and Manufacturing" within USACM, and a member of the committee "Material Processing and Manufacturing" within ASME Applied Mechanics Division. He has organized/chaired many symposiums in conferences, and is a regular reviewer for many journals ranging from applied mechanics, materials to manufacturing. He has given many invited seminars at Universities including Stanford, UCLA and Northwestern, and over 20 invited lectures in industries. Dr. Ming Li has over 20 publications. He currently has collaborative research with Ohio State University, Univ. of Illinois at Urbana Champaign, Northwestern University, Notre Dame University, Oklahoma State University, and University of Pittsburgh. He is the Co-PIs of two NSF GOALI programs "A Computational-Experimental Program for Fracture Simulation and Design of Metal Forming Processes" and "Mechanism Based Theories of Strengthening and Hardening for Alloy Design and Processing", with total funding of $700,000 for next three years.

UNIVERSITY OF FLORIDA

Non–Prof. Org
U.S. Postage
PAID
Florida
Gainesville
Permit no. 94

Aerospace Engineering, Mechanics & Engineering Science
PO Box 116250
Gainesville FL 32611-6250