Welcome to the second issue of the Mechanical and Aerospace Engineering Department (MAE) newsletter. We have had a great year. Enrollment in the MAE department is at an all-time high. We are currently the largest department in the College of Engineering and Applied Sciences (CEAS). Fully 30% of CEAS enrollment is in the MAE department. Our faculty research has been attracting external funding at a greater rate, and our graduates are enjoying a very high rate of employment opportunities at competitive salaries.

I would like to thank Dr. Houssam Toutanji for serving as the MAE Interim Chair last year (in addition to his full-time job as the Dean of our college!). I am very appreciative of Dr. Judah Ari-Gur's service to the department last year. He not only carried a very heavy teaching load, but served as the Interim Associate Chair of the department and handled most of the day-to-day affairs of the department.

This fall, we awarded the Alumni Excellence Award to two of our graduates, Jim Medsker of Keystone Solutions (B.S. 1991, M.S. 1999) and Jim Evans formerly of Stryker Corp (B.S. 1980). We have also revised our webpage to make it more user friendly (https://wmich.edu/mechanical-aerospace/). During the 2016-2017 academic year, we will be preparing for our accreditation visit by ABET reviewers which is scheduled for fall 2017.

We hope that you will find the latest MAE news encouraging. If it has been a while since you visited us, please contact us and arrange to visit our department.

Mechanical and Aerospace Engineering Wins Grant from DENSO North America Foundation

The Department of Mechanical and Aerospace Engineering was awarded a $50,000 grant from the DENSO North America Foundation to fund improvements to WMU’s automotive systems laboratory and to provide equipment for the student-run Formula SAE team (see related story in this issue). Dr. Rick Meyer, assistant professor, submitted the proposal and said that the grant will make a significant impact on student learning and enhance research activities.

“We so greatly appreciate the generosity of the DENSO North America Foundation,” he said. “This type of funding is very beneficial to our students and faculty, and enhances our ability to support industry-sponsored research projects.”

Meyer said the funds will be used in the automotive lab for a new National Instruments engine data acquisition and control system, which will allow students to experience engine testing and development using common industry equipment. “With this grant, our newly upgraded automotive lab can be used to educate a new generation of engineers on a platform that integrates theoretical knowledge and practical experience,” he said.

Meyer said the Formula SAE team also will get an upgraded engine control computer that has several new capabilities, such as traction control and engine input air flow measurement. Integration of the new equipment into the automotive lab and Formula SAE team project is planned to take place over the next year.
Mechanical engineering student Christian Brower has been selected by the American Gear Manufacturing Association (AGMA) Foundation to receive a $5,000 scholarship for research conducted in collaboration with industry and sponsored by the Center for Advanced Vehicle Design and Simulation (CAViDS). Christian’s research has been focused on evaluating the accuracy of models used to predict coefficients of friction for gearbox applications. “I am excited and grateful that the AGMA Foundation chose me for this scholarship,” said Christian. “It will help me cover educational costs while allowing me to focus on my research goals.” For more information about CAViDS please visit www.wmich.edu/vehicledesign

**Student Success**

**Christian Brower**

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**Faculty Success**

**NSF $452,399 award to bring state-of-the-art instrument to WMU**

Dr. Pnina Ari-Gur, WMU professor of mechanical and aerospace engineering, was awarded a National Science Foundation (NSF) research grant of $452,399 to acquire an advanced X-ray diffraction system with unique capabilities. It will be able to reveal structures down to the nano-scale, determine thickness of nano-layers, and much more -- at temperatures ranging from -160 °C to +600 °C.

Thanks to this NSF Major Research Instrumentation grant, researchers and students at Western Michigan University will be able to employ a sophisticated scientific instrument that is unavailable anywhere in Michigan. Participating with Ari-Gur are Clement Burns, physics; Paul Fleming, chemical and paper engineering; John Patten, industrial and entrepreneurial engineering; and Massood Atashbar, electrical and computer engineering.

The award, “Acquisition of an X-Ray Diffraction System for Nanostructured and Advanced Materials Research and Research Education and Outreach,” funds the purchase of a state-of-the-art X-ray diffraction (XRD) system that will support multidisciplinary research and education in institutions throughout West Michigan and beyond. This modern X-ray diffraction system enables cutting-edge research in nanotechnology, physics, materials science, chemistry, electrical engineering, and other areas.

The knowledge generated will be used to design new materials and processes, and “tailor” their structure and properties to meet specific demands, such as materials for green energy production, medical devices, sensors, flexible electronics, and more. The system will help educate future researchers by providing opportunities in using modern research instrumentation. In addition, the university has strong outreach programs, including training and retaining science teachers, and providing opportunities for high school students. The instrument will greatly benefit these programs and attract students to STEM research as a career path. In addition to serving as a shared, multi-user, multi-purpose facility for WMU and other area institutions, it will also be used by local high-tech businesses.

“I am very excited about this award,” Ari-Gur said. “It will open so many new opportunities. I can hardly wait to have the XRD system here and bring it to operation.”

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Dr. Bade Shrestha is the director of Alternative Fuel and Fuel Cell laboratory in the Department of Mechanical and Aerospace Engineering. He is a fellow of ASME and an Associate Editor of ASME Transaction: Journal of Energy Resources Technology. His areas of research are related to alternative and renewable energy and combustion. Some of his teams’ recent research include:

1. Hypersonic combustion research:

Dr. Bade Shrestha and his former graduate student Dr. Ryan Clark have worked on the hypersonic propulsion engine that propels aircraft to fly at the speed of more than six times of the speed of sound. Their works have been published in the international journals and AIAA conferences. Primarily, this work focused on simulation of combustion processes at supersonic speed in the combustion chamber of a hypersonic engine environment. Hydrogen was mainly used as a fuel.

2. Lithium Ion battery research:

Dr. Bade Shrestha and MS-ME graduate student Sazzad Ahmed conducted research on the performance of a lithium ion battery in various environment conditions. The project was funded by Eaton Corporation under CAViD Hybrid Electric Applied Research Laboratory Development and Research Funding of $1.2 Millions. Various lithium ion batteries were tested at wide temperature ranges in order to investigate temperature effects on the performance, particularly at subzero temperatures at which the battery degrades the most. The results of this investigation were published in ASME journals and international conferences.

3. Fuel cell and renewable energy research:

Dr. Bade Shrestha’s research teams are involved in several other renewable energy technologies. One of the undergraduate student teams, had built the first WMU fuel cell powered three wheeler as their capstone project. Bryn Gwaltney, Travis Mattson, Scott Miller and Ryan Warning were the team members. The car was fueled by three hydrogen metal hydride cylinders with a design speed of 55 mph. It won the Office of Vice President Undergraduate Research Excellence Award. Another capstone project carried out by undergraduate students Adam Boden, Brian Larsen and Benjamin Wolfman was a compressed air powered two passenger car as a renewable and alternative transportation solution. It also was awarded the OVPR Undergraduate Excellence Award.
Dr. Muralidhar Ghantasala is the director of Micro and Nano technology laboratory. Dr. Ghantasala has been actively working on (i) design and development of micro/nano sensors for different applications (e.g. micro Fatigue sensors, CNT based strain gauges and others) (ii) Simulation and testing of microfluidics based lab on chip devices and technologies (e.g. Nano Drug Delivery systems, in-vitro lab on chip technologies) (iii) Design and Fabrication of Microactuators (iv) Development of novel micro and nano fabrication technologies (e.g. Selective electroplating of metallic microstructures for different applications, nanogels). Dr. Ghantasala has successfully completed projects funded by USDA/SBIR, NSF and other funding agencies in these and related research areas. His group consists of 3 graduate students and 6 undergraduate senior design project students working on different projects. Dr. Ghantasala has an on-going project in collaboration with Center for Nanoscale Materials (CNM), Argonne National Laboratory on Nano particle drug delivery simulation and in-vitro testing by lab on chip devices.

The Micro and Nano technology laboratory includes the facilities for Physical Vapor Deposition (PVD) by magnetron sputtering (with dual target) and chemical vapor deposition (CVD) with RF and MW power based systems. Excimer Laser micromachining (248 nm (KrF) and 193 nm (ArF)), Thermal evaporation and optical microscopy facilities are also available in this lab. A class 100 clean room with the microlithographic facility is also available within his micro and nano manufacturing laboratory. Clean room lab has a mask aligner, spinner, hot plate/oven, electroplating (DC and Pulse) and optical microscopy systems and is capable of producing 5-10 µm features with good reliability.
Dr. Peter A. Gustafson, Associate Professor of Mechanical and Aeronautical Engineering at WMU, is the Director of the Laboratory for Advanced Composite Structures (LACS). LACS is a group of students studying engineered composite materials and biomechanical systems. Heterogeneous composite materials are ubiquitous in areas ranging from man-made spacecraft, to natural fibers in cloth, to biological tissue in animals and people. The laboratory provides opportunities for hands-on experience in testing heterogeneous composite materials and creating computational simulations using finite element and other analyses. This lab is open for student participation and collaboration and accepts both undergraduate and graduate students. Participating students have the opportunity to work with local orthopedic surgeons from Bronson and Borgess hospitals and from the Western Michigan University Homer Stryker School of Medicine. The lab makes broad use of modern material systems and tools such as 3D printing to achieve optimized structural performance.

The LACS team has weekly meetings during the academic year, where team members share their progress, describe ideas, give tutorials, ask questions and do structured brainstorming. Some of ongoing research projects are:

- **A low-cost neonatal ventilator device.** The “NeoVent” has received several national awards for innovation and it is currently undergoing animal testing in preparation for upcoming human trials. The project makes heavy use of 3D printed prototypes, and is developing manufacturing capability for injection molded parts. A low cost data acquisition interface has also been developed for monitoring device performance and other factors related to patient health.

- **Models and experiments on studded footwear (cleats) for high performance athletes.** The research intends to illuminate the mechanics which contribute to relatively high injury rates on artificial turf. A “stretch” goal is to determine if modifications to footwear may mitigate those risks. Finite element analysis is a big part of the project.
• A detailed finite element model of the human knee. The model is built from magnetic resonance imaging (MRI) of a human knee and has a particular focus on the soft tissues of the knee and their function. The model complements laboratory experiments of a surgical collaborator, and will provide a validated computation model useful for understanding the mechanics of surgical repair of torn meniscus tissue.

• A detailed finite element model of the soft tissue stitching. The goal of the project is to provide validated computational models of the repair tendons, ligaments, and other soft tissues. Stitching is ubiquitous in medicine and requires a balance between the security of the stitch and the health of the tissue. However, few methods for the optimization of stitching are available. The model will be used to illuminate factors involved in producing a secure stitch which will not damage the tissue.

• Models and experiments on the human ankle. The goal of this subtalar joint investigation is to illustrate the biomechanics of a common surgical procedure for treatment of severe ankle arthritis. The student is working closely with a local surgeon to determine which of several surgical fusion options will provide the most effective treatment. The project examines the ankle from a structural perspective, and the goal is to maximize the strength and stability of the post-surgical ankle while eliminating pain.

• A vertical take-off, fixed wing airplane for payload delivery. An UAV design is underway taking advantage of modern advances in control, electric propulsion, and materials. Four electric motors lift the vehicle with the agility of a quadcopter while taking off or landing. The aircraft then transitions to fixed wing forward flight for long distance payload delivery. The hybrid design provides efficiency and range comparable to a conventional airplane, while also providing for runway-less operations and greater mission flexibility.
Dr. Kapseong Ro’s research interests are focused on dynamic modeling and simulation of aerospace systems, and utilization of aerospace technologies to civil applications. Over the past several years, Dr. Ro’s group have conducted comprehensive research on mid-air refueling based on Hose-Drogue-Probe system which is currently used by US NAVY and armed forces of many other countries. Inspired by NASA’s initial flight tests on probe-drogue aerial refueling in early 2000’s, Dr. Ro’s group carried out wind tunnel and CFD experiments to investigate the aerodynamic characteristics of a refueling drogue; developed a multi-body dynamic model that replicates the motion of tanker-hose-drogue system interacting with an approaching receiver and validated to the flight tests results by NASA; proposed active control methodologies to stabilize the drogue motion to minimize pilot work load and possibly for autonomous aerial refueling. Prototype of actively stabilized drogue refueling system (ASDRS) was built and dynamically tested in Advanced Design Wind Tunnel at WMU with very favorable results. This work was published in four scholarly papers in highly recognized international aerospace journals. Aerial Refueling Hose-Drogue Simulation Program is also claimed as a WMU intellectual property and available for licensing through Western Michigan Research Foundation.

Besides aerial refueling research, Dr. Ro’s group also studied unconventional unmanned aerial vehicle (UAV) platforms such as ‘Tilt-rotor UAV’ and ‘Free-wing Tilt-body UAV’. The Free-wing Tilt-body platform has been well-known in the UAV community since 1990’s but its system dynamic characteristics were not well known. Dr. Ro’s group conducted comprehensive experimental and CFD analysis, developed system dynamic model for control law synthesis and built a scaled model which was flight tested. This work was published in three scholarly papers.

Dr. Ro’s group is also actively collaborating with the Civil and Construction Engineering (CCE) Department at WMU, especially in applying aerospace technologies to transportation. In 2006, Dr. Ro and his CCE colleagues worked with the Michigan Department of Transportation (MDOT) to conduct feasibility studies of UAV for transportation use such as emergency and construction traffic mitigation. This is considered a pioneering study on the civilian use of UAVs long before their public debut in recent years. Currently, Dr. Ro is working with the Transportation Research Center for Livable Community (TRCLC) at WMU to understand the ‘bike-ability’ associated with transportation infrastructure. Dr. Ro’s group developed an Instrumented Probe Bike (IPB) that is equipped with various sensors including GPS/INS system, cameras, pots and encoders to measure various dynamic variables of a bike-human system to characterize biker skill levels and perceptions on biking safety. A system dynamic model developed for the human-bike system is also in progress for further analysis.
Dr. HoSung Lee is the director of Thermoelectrics Laboratory which conducts research on thermoelectric design and materials. Thermoelectrics is literally associated with thermal and electrical phenomena. Thermoelectric processes can directly convert thermal energy into electrical energy or vice versa. Basically, there are two devices: thermoelectric generators and thermoelectric coolers. These devices have no moving parts and require no maintenance. Thermoelectric generators have great potential for waste heat recovery from power plants and automotive vehicles. Such devices can also provide reliable power in remote areas such as deep space and mountain top telecommunication sites. Thermoelectric coolers provide refrigeration and temperature control in electronic packages and medical instruments. Thermoelectrics has become increasingly important with numerous applications.

Five Master's students and two PhD students are currently working in the Thermoelectrics Laboratory pursuing their theses on research topics such as automotive exhaust heat recovery, solar thermoelectric generators, low-grade heat recovery, miniature devices, thermoelectric air conditioners and car seat climate control. Each student applies optimal design methods for his device with experimental verification as shown in the picture. Dr. Lee’s research group has recently produced significant publications which include 9 journals and 2 textbooks with Wiley. One of the books has been used in a graduate course ME5390: Advanced Thermal Design. Two new graduate courses on thermoelectric design and materials using the other textbook have been developed and will be offered in the spring and summer of 2017.

Dr. Tianshu Liu worked as a visiting professor at Institute of Marine Hydrodynamics (INSEAN) in Italy and gave a presentation at University of Rome in 6/20-6/30, 2016. He collaborated with researchers in INSEAN on global skin-friction diagnostics in water flows using temperature sensitive paint technology. In 7/24-8/26, 2016, he worked as a visiting professor of Global Innovation Research Institute of Tokyo University of Agriculture and Technology (TUAT) in Japan, where he collaborated with TUAT researchers on image-based measurements of a laser-induced underwater shock wave. During this period, he also gave lectures on several topics at Tohoku University, Chiba University and Japan Aerospace Exploration Agency (JAXA).
Recent developments in optical fluid flow measurement techniques by the scientific community has allowed MAE department’s Dr. Parviz Merati (of Fluid Mechanics Laboratory) and Dr. Tianshu Liu (of Applied Aerodynamics Laboratory) to quantitatively and instantaneously measure and visualize complex three-dimensional turbulent flows. These techniques are called Stereo Particle Image Velocimetry (SPIV) and Optical Flow Measurements based on capturing the image of particles or contaminants like smoke or dye molecules at two separate instances. Knowing the time difference between two images, the detailed velocity fields for liquid and gaseous flows can be reconstructed.

A recently acquired upgrade of the 2-Dimensional Particle Image Velocimetry (PIV) to 3-Dimensional PIV for measurement of three components of flow field on a desired plane will be used for a new project supported by Thermo-Fisher Scientific to investigate the efficiency of their tissue processors. Similar research was conducted in the past with experimental set-up presented in Fig. 1. Flow within a particular cassette inside an optically built processor was measured using phase lock image capturing. This technique allowed measurements to be taken with the cassettes located at the same position relative to the camera for each revolution. Other recent research conducted in the lab includes Under-hood Buoyancy measurements for General Motors and Exhaust Flow Measurement around Oxygen sensor upstream of the catalytic converter sponsored by Toyota. The results of these investigations have been published or are accepted for publication in scientific journals.

Considerable effort in experimental aerodynamics is made to develop the physics-based optical flow method for various flow visualizations to extract high-resolution velocity and skin-friction fields in complex flows. The optical flow method provides a unified framework for global flow diagnostics. Based on the projection of relevant governing equations from the 3D object space to the 2D image plane, the projected motion equations are systematically derived for important flow visualizations in aerodynamics and fluid mechanics, such as laser-sheet-induced fluorescence image, transmittance images for transport processes of passive scalar, schlieren images, shadowgraph and transmittance images for density-varying flows, transmittance and scattering images for particulate flows, and laser-sheet-illuminated particle images. A generic mathematical form of the projected motion equation is induced and further written as a physics-based optical flow equation. The variational formulation is given for solving the optical flow equation with appropriate regularization conditions. Examples include the applications of this method for spacecraft images of Great Red Spot on Jupiter (see Fig. 2) and smoke visualizations.

![Figure 1. Experimental setup for PIV and PLIF measurements](image1)

![Figure 2. Velocity field of the Great Red Spot of Jupiter extracted from NASA’s Galileo 1996 images by using the optical flow method.](image2)

![Figure 3. Velocity field around a car extracted from smoke visualization images in a full-scale wind tunnel by using the optical flow method.](image3)
visualizations in full-scale automotive wind tunnels (see Fig. 3). Further, the same formulation is adapted for global quantitative skin friction diagnostics in complex separated flows based on luminescent oil visualizations, and surface temperature, mass transfer and pressure visualizations. An example on skin-friction measurements is shown in Fig. 4.

Auto lab upgrades make it a premier teaching and research facility

WMU’s Automotive Laboratory recently received $400,000 in upgrades, making it one of the premier auto testing labs in southwest Michigan and an even more valuable resource for students, faculty and industry.

“With the significant new investment in the lab, we’ve greatly expanded its potential,” said Dr. Claudia Fajardo, associate professor in mechanical and aerospace engineering who conducts research in the lab. The lab provides hands-on opportunities for students to work with automobile systems and subsystems, learning how to understand, and improve upon, drive trains, power plants, steering systems, braking mechanisms and safety issues.

“Outside of a sophisticated university setting, the machinery our students use can only be found inside automotive companies themselves,” Fajardo said. That equipment includes chassis dynamometers, fuels and lubricant test equipment and now, an engine test cell, equipped with engine dynamometers.

Undergraduate and graduate students interested in automotive-related courses and senior design projects have used the lab but previously were limited by the air flow system. The lab also is used by students for extracurricular projects such as building and maintaining the Society of Automotive Engineers (SAE) Formula SAE vehicle.

Formula SAE team manager Evan Weese, a senior in mechanical engineering, said the team already has plans to set up its engines in the new test cell. “Utilizing the newly installed instrumentation will allow us to see results quickly and make changes accordingly,” he said. “The end product will be a more powerful, drivable and reliable engine.”

“We are excited about the improvements to the lab and broadening its usefulness to enrich our students’ experience,” Fajardo said. In addition to academic activities, the lab also supports industry-sponsored research projects. Collaborators in the past have included organizations such as DENSO, Toyota and the US Army’s Tank Automotive Research Development and Engineering Center.

“We now offer a modern facility to our research partners,” she said. “We have dedicated space for testing automotive components and systems. Our faculty has great expertise in wide-ranging engineering disciplines and our lab technicians are highly skilled.”

In addition to automotive manufacturers and suppliers, other groups that could benefit from testing and research at the lab include engine manufacturers and manufacturers and suppliers of motorcycles and recreational vehicles. “The lab will soon have powertrain data acquisition and control capabilities similar to that in industry,” said Dr. Richard Meyer, assistant professor of mechanical and aerospace engineering. “We’ll be able to validate powertrain models as well as explore how to best control them to, for example, reduce fuel usage and emissions.”

Fajardo noted that the improved lab offers great promise to advance the transportation industry as WMU collaborates with manufacturers to test and improve current and new technologies. “At the same time we are giving a new generation of engineers the practical experience and exposure to the automotive industry to make them versatile and successful in their fields,” she said.
All faculty members hold terminal degrees in mechanical engineering or closely related fields. Their areas of research include but are not limited to mechanical system, structural dynamics, system design and controls, advanced materials, experimental stress analysis, vehicle dynamics, electric propulsion, experimental and computational fluid dynamics, thermal and power systems, fuel cells, noise and vibrations, finite element analysis, and micro and nano-technology.

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We would love to keep in contact with our all of alumni. Please visit wmich.edu/mechanical-aerospace/alumni to update your contact information and sign up for InSPIRE, our college newsletter.