2017-2018 ANNUAL REPORT
MESSAGE FROM THE CHAIR

I am delighted to provide you with highlights of some of the many accomplishments of the students and faculty of the Department of Mechanical and Aerospace Engineering at Missouri S&T. The department itself has shown extraordinary growth over the past five years in all aspects. Our research is thriving with new technologies and discoveries in areas including hypersonic flight and advanced photonic structures which are detailed here.

Several of our faculty have received significant recognition in their areas of expertise, including Prof. Ming Leu who has been honored by the American Society of Mechanical Engineers with the 2018 Milton C. Shaw Manufacturing Research Medal and the Society of Manufacturing Engineers with induction into the SME College of Fellows. Prof. Robert Landers was recognized by the University of Missouri System as a Curators’ Distinguished Professor for his accumulated work in automation and control of manufacturing processes. This is the highest academic rank and distinction offered by the University of Missouri system for scholarly achievement by faculty.

Our faculty continue to push forward the frontiers of research in areas critical to the nation, such as metal additive manufacturing. For example, Prof. Lianyi Chen has been working with scientists from the U.S. Department of Energy’s Argonne National Laboratory to improve the understanding of the laser-powder interaction. A brief overview of this groundbreaking work is provided. This understanding adds considerably in moving additive manufacturing toward reduced structural defects in 3-D printed materials.

Together our faculty research activity has generated a near doubling in research expenditures over the past five years all while continuing to teach a growing undergraduate student body and advise our growing doctoral student enrollment. Our students have also had a successful year with several undergraduate research students publishing journal articles and conference papers, James Werner receiving a prestigious scholarship from the Department of Defense, Aaron Erb receiving a NASA Pathways Internship and Muthukumaran Loganathan receiving Best Student Paper on Mechatronics from the ASME Dynamic Systems and Controls Division. Several other faculty and student achievements and awards are highlighted in this Annual Report.

In closing, thank you for reviewing some of the great accomplishments and activities of our department this past year, and we wish you all the best in the current academic year.

Warm Regards,

Jim Drallmeier
Chair, Mechanical and Aerospace Engineering
The department has experienced a 98% increase in research expenditures over the past five years.

The department has seen an 85% increase in the number of PhD students enrolled over the past five years.

**2017 DEGREES AWARDED**

- **PHD**: 10
- **MASTERS**: 39
- **BACHELORS**: 248

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<tr>
<td>Bachelors</td>
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- **BACHELORS**
  - Aerospace Engineering: 50
  - Mechanical Engineering: 198
- **MASTERS**
  - Thesis: 33
  - Non-Thesis: 6
- **PHD**: 10

**RESEARCH FUNDING AND PHD ENROLLMENT CONTINUE TO CLIMB**

**RESEARCH EXPENDITURES (MILLIONS)**

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<th>Year</th>
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**2017 RESEARCH EXPENDITURES**

- **FEDERAL**: 54%
- **INDUSTRY**: 38%
- **UNIVERSITY OF MISSOURI**: 2%
- **OTHER**: 5%

**RESEARCH EXPENDITURES**

- **$6,406,333**

**2017 PHD ENROLLMENT**

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<th>Year</th>
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- **PHD**: 10
- **MASTERS**: 39
- **BACHELORS**: 248
Over the last several years, at the forefront of aerospace technology – hypersonic flight has been transforming aviation.

The aerospace engineering research program in the mechanical and aerospace engineering department spans space technology as well as autonomous air vehicles and intelligent systems. However, there has been a significant increase in interest and activity by the aerospace research community in the specific and extremely challenging area of hypersonic atmospheric flight. The term hypersonics refers to atmospheric flight spanning speeds from approximately a mile per second to five miles per second (orbital velocity). The design and operation of hypersonic vehicles are driven by challenging physics and extreme engineering requirements, far beyond those associated with conventional flight. The department has three dedicated faculty leading research in this area: Drs. Lian Duan, Serhat Hosder, and David Riggins. They also have an extraordinary team of students dedicating their studies to this research.

**SIMULATING EXTREME ENVIRONMENTS**

Computational fluid dynamics (CFD) is used for the simulation of extreme environments over hypersonic vehicles involving high-temperature, chemically-reacting flows with non-equilibrium thermo-chemistry. Due to limited ground and flight test data, CFD plays an important role in the analysis, design, and flight qualification of various hypersonic systems. Dr. Hosder and his students focus on uncertainty quantification and multi-fidelity modeling of hypersonic flows, robust design of hypersonic vehicles, and thermal management of hypersonic systems, which have been funded by NASA, DoD, and industry. “Several graduate students in my group also received prestigious fellowships from NASA including Space Technology Research Fellowships and...”

Dr. Serhat Hosder, associate professor of aerospace engineering.
Pathways Internships, and they regularly visit NASA centers to conduct hypersonics research” says Hosder, who is also the current vice chair of the Hypersonic Technologies and Aerospace Planes Technical Committee of the American Institute of Aeronautics and Astronautics, the leading international society in hypersonics.

The uncertainties associated with operating conditions and complex physical models used in simulations can have negative impact on the design of hypersonic systems including thermal protection system (TPS). Dr. Hosder emphasizes that quantification of these uncertainties in the simulations is crucial for the improvement of the computational models, flight qualification of hypersonic technologies, and designing reliable vehicles, and adds: “Our research targets this challenge by developing advanced uncertainty quantification and physics-based multi-fidelity modeling techniques, which has been applied to the analysis of planetary entry vehicles including hypersonic inflatable aerodynamic decelerators, radiative heating during reentry, TPS sizing, turbulence modeling, shock wave-boundary layer interactions, and hypersonic air-breathing propulsion flow path analysis. We also integrate uncertainty quantification and multi-fidelity modeling methods to aerothermodynamic shape optimization to minimize the impact of uncertainties on the performance of hypersonic vehicles.”

Hyper sonic vehicles travel in the atmosphere at extremely high speeds and therefore experience significant amount of aerodynamic heating, which require them to use different types of TPS. “Under this area, we investigate active cooling strategies for reusable TPS applied to critical regions of the atmospheric hypersonic flight systems with high thermal loads such as the leading edges. Recently, we have focused on numerical simulation of a variable transpiration cooling concept with a coupled high-fidelity CFD and a material thermal response modeling approach” says Hosder. These numerical simulations, along with the experimental research conducted at high-temperature arc-heated wind tunnels at the University of Texas at Arlington, are used to develop reduced order models that can be applied to the design of actively cooled hypersonic vehicles.

HYPERSONIC BOUNDARY LAYER TRANSITION

A boundary layer is the layer of fluid in the immediate vicinity of a body’s surface. The process of a laminar boundary layer becoming turbulent is known as boundary layer transition (BLT). BLT and wall-bounded turbulence remain two of the most important unsolved problems not just in fluid mechanics but in all of classical physics. Our ability to predict the aerodynamic lift, drag, surface heating, propulsion, and maneuverability of high-speed vehicles is crucially dependent on the knowledge of transition and turbulence at high Mach numbers.
Dr. Lian Duan and his team are performing groundbreaking direct numerical simulations (DNS) to contribute significant advances in the area of fundamental turbulence physics and non-equilibrium effects in hypersonic turbulent boundary layers (TBLs), as well as toward an explanation of how those flows transition from laminar to turbulent flow in the first place.

One of the recent achievements by Duan and his team is to exploit advances in high-performance computing (HPC) for synthesizing the naturally occurring, random acoustic disturbances in hypersonic wind tunnels. A wind tunnel is one of the most common tools for experimental aerodynamics research. Wind-tunnel testing allows initial characterization of a flight vehicle without the cost or risk of a flight test. However, at supersonic/hypersonic test speeds, a conventional wind tunnel has a more erratic air flow, due to disturbances in the air, compared to what would be found in flight.

These disturbances are generated by walls of the wind tunnel and interact with the test object in a complicated way. This interaction makes the measurement of BLT over test models less comparable to what would be seen in a flight test. An accurate extrapolation of erratic or noisy wind-tunnel results to steady free flight is thus critical for predicting the drag and heating of high-speed vehicles.

In collaboration with colleagues at NASA Langley Research Center, the Technical University of Braunschweig, Germany, Purdue University, the AEDC Hypervelocity Wind Tunnel 9 in White Oak, Maryland, and the Sandia National Laboratories in New Mexico, Duan and his team are using the world’s largest supercomputers to define the disturbances caused by the tunnel walls and understand how they interact with the test models. The process is known as “wind tunnel rebuilding.”

“Such simulations will provide the basis for an in-depth understanding of the disturbance environment in conventional hypersonic wind tunnels and contribute to an improved ground-to-flight scalability of transition data,” Duan says.
"The knowledge gained, and the database generated through this effort, will be critically important to expanding the utility of conventional high-speed wind tunnels for studying hypersonic flows in which boundary-layer transition plays an important role. This will save the cost of new quiet facilities, an investment of multi-million dollars with at least 5-10 years of development."

ENERGY UTILIZATION IN HYPersonic FLIGHT

Dr. David Riggins, Curators’ Distinguished Teaching Professor of aerospace engineering, and his PhD students have been focused on developing methodologies and techniques for correctly assessing the effect of the 2nd law of thermodynamics on system losses and performance in hypersonic flight systems (both air-breathing and rocket-powered vehicles). This research is based on the fundamental linkage between entropy generation and conventional vehicle performance and can be applied across all levels of fidelity in modeling and simulation techniques. The research provides the ability to make comparative analyses of existing and proposed access-to-space and atmospheric hypersonic systems, and has significant potential in design and optimization of such systems. It is also being applied in order to provide fundamental system-level, performance-based assessment of highly futuristic (proposed) techniques for facilitating hypersonic flow-field modification and control using plasma and other innovative flow-modification technologies.

An example of the analysis of energy utilization and entropy generation for an access-to-space multi-stage rocket systems is shown below. In this case, the analysis provides (as illustrated by the accompanying plot) the quantification of the complete energy break-down (energy usage) versus time for the first two stages of the legacy Apollo 11 mission to the moon. This kind of detailed description of energy utilization in such systems provides significant information within the design process, as well as in optimization efforts involving hypersonic aerospace systems.

Research utilizing multi-dimensional computational fluid dynamics is also being conducted on energy utilization in terms of drag reduction, mitigation of engine unstart, and control of hypersonic vehicles. In order to optimize the performance of a hypersonic vehicle, the use of energy in locations other than the engine combustor (for thrust production) can be shown to be very beneficial. The figure below illustrates possible energy utilization modes around a generic hypersonic vehicle. Studies include very fundamental unit problems such as the flight of a blunt body in hypersonic flow with flow-field modification in order to reduce drag and heat transfer, as well as entire hypersonic vehicle configurations. Innovative usage of on-board energy for hypersonic flight vehicles can result in more robust vehicles, larger payloads, longer ranges and increased endurances, and allow greater mission flexibility and choices.

HYPersonics – THE LAST FRONTIER FOR ATMOSPHERIC FLIGHT

The physical phenomena that determine hypersonic flight systems performance and operability represent significant challenges for current modeling and analysis capabilities. These challenges also frame the engineering hardware design constructs and methodologies that are required in order to configure, build, ground-test and flight test vehicles capable of atmospheric flight at speeds above a mile per second. High-fidelity modeling and simulation techniques and approaches for this flight regime are often at the very limit of current capabilities and resources. Some modeling and simulation requirements are arguably still beyond current capabilities—at least, in terms of ensuring a comfortable level of confidence – and continued and expanded research in this area at Missouri S&T by research teams under the direction of Drs. Hosder, Duan, and Riggins are providing significant advances necessary for the successful development of current and futuristic hypersonic vehicles.

Photo by NASA
Dr. Ming Leu, the Keith and Pat Bailey Missouri Professor of Integrated Product Manufacturing, has been honored by the American Society of Mechanical Engineers (ASME) and the Society of Manufacturing Engineers (SME) for his role in advancing manufacturing research.

Recently, SME has announced that Dr. Leu, who also directs the Intelligent Systems Center at S&T, has been elected a Fellow and will be inducted into the SME College of Fellows. Those selected as fellows have 20 years or more of manufacturing experience and expertise. They have contributed notably to the social, technological and educational benefit of manufacturing and the engineering profession. Leu has also been named the winner of ASME's 2018 Milton C. Shaw Manufacturing Research Medal. The award was presented at the 2018 ASME Manufacturing Science and Engineering Conference in late June at Texas A&M University. The award recognizes significant fundamental contributions to the science and technology of manufacturing processes.

Leu was nominated by his colleague Dr. Robert G. Landers, Curators’ Distinguished Professor of mechanical engineering.

“Dr. Leu has made exceptional contributions to the science, engineering and technology of additive manufacturing through his outstanding research, scholarship and creativity in this emerging technology area for 20 years,” writes Landers in his nomination letter. “His research has created three novel additive manufacturing processes, generated the fundamental understanding of these processes, contributed to advancing and optimizing these and other AM processes, and developed innovative applications for these processes.”

Leu has published over 400 refereed publications in technical journals and conference proceedings, one e-book and nine book chapters over his 36-year academic career while receiving four U.S. patents (plus two pending). He has delivered more than 300 technical presentations and his publications have received over 8,600 citations with an h-index of 45. Leu has also obtained more than $28 million in external grants since joining Missouri S&T. His technical interests are in the areas of additive manufacturing, virtual prototyping, computer-aided design and manufacturing, robotics and automation, machine dynamics and control, and cyber-physical systems.

Leu earned a bachelor of science degree in 1972 from the National Taiwan University, a master of science degree in 1977 from Pennsylvania State University, and a doctorate in 1981 from the University of California at Berkeley. All three degrees were in mechanical engineering.

Leu has received several professional awards, including the University of Missouri President’s Leadership Award in 2017, ASME’s Blackall Machine Tool and Gage Award (2014), the Hideo Hanafusa Outstanding Investigator Award (2008), the Harlan J. Perlis Research Award from the New Jersey Institute of Technology, the NSF’s Presidential Young Investigator Award, the Society of Automotive Engineers’ Ralph R. Teetor Education Award and the Forest Products Research Society’s Wood Paper Award. In addition, Leu was a member the New Jersey Institute of Technology team that received the University Lead Award from the Computer and Automated Systems Association of the Society of Manufacturing Engineers. He was elected as an ASME fellow in 1993 and a fellow of CIRP (International Institution for Production Engineering Research) in 2008. He is a member of the Sigma Xi, Tau Beta Pi and Phi Kappa Phi honor societies.
One of the highest honors bestowed by the University of Missouri System Board of Curators is the Curators’ Distinguished Professor title. This honor recognizes faculty who are outstanding scholars with established reputations in their field of study. Dr. Robert G. Landers, professor of mechanical engineering at the Missouri University of Science and Technology, has been named Curators’ Distinguished Professor of mechanical engineering for his exemplary work in the automation and control of manufacturing processes.

Landers has brought in nearly $5 million in grants in controls applications and manufacturing automation. His research focuses on the modeling, analysis, monitoring and control of manufacturing processes such as metal cutting, wire saw machining, friction stir welding, laser metal deposition, freeze-form extrusion fabrication, glass direct energy deposition, and selective laser melting, as well as the estimation and control of electrochemical alternative energy systems including hydrogen fuel cells and lithium ion batteries.

Landers has authored nearly 200 refereed technical publications, including 76 journal articles and five book chapters. In addition, he holds one U.S. patent. Among many awards, Landers received the M. Eugene Merchant Outstanding Young Manufacturing Engineer Award from the Society of Manufacturing Engineers in 2004. In 2014, he was elected Fellow of ASME and received the ASME Blackall Machine Tool and Gage Award for a paper he co-authored describing an additive manufacturing method for fabricating 3-D parts by extrusion of water-based ceramic pastes. He has also received numerous awards for research, faculty excellence and outstanding teaching.

Landers, who also served as the associate chair for graduate affairs in the mechanical and aerospace engineering department from 2010 - 2016 and 2017-2018, joined the Missouri S&T faculty in 2000 as an assistant professor of mechanical engineering. He was promoted to associate professor in 2006 and to professor in 2012. Landers earned a Ph.D. from the University of Michigan in 1997, a master of science degree from Carnegie Mellon University in 1992 and a bachelor of science degree from the University of Oklahoma in 1990, all in mechanical engineering.

Dr. Charles S. Wojnar has been selected to receive the 2018 Journal of Applied Mechanics Award for the paper “Linking Internal Dissipation Mechanisms to the Effective Complex Viscoelastic Moduli of Ferroelectrics”, Journal of Applied Mechanics, v 84, #021006, 2017. The paper developed a new theoretical framework for linking together two previously distinct material modeling regimes: inelasticity and incremental viscoelastic models. This approach will improve the accuracy of physics-based material modeling efforts to better predict and understand how materials behave under both low and high frequency deformation.

The Journal of Applied Mechanics Award is provided by the Applied Mechanics Division of the American Society of Mechanical Engineers to honor the best paper which has been published in the Journal of Applied Mechanics during the two calendar years immediately preceding the year of the award. The award is made annually to the corresponding author of the paper who received their Ph.D. no more than 10 years prior to the year of award. The award will be presented at the Applied Mechanics Division Banquet at the ASME-IMECE meeting.

The selection committee is led by the Vice Chair of the Executive Committee of the Applied Mechanics Division of the ASME.
Our faculty members in the photonics research cluster at MAE have made research breakthroughs which will greatly advance future technologies in advanced manufacturing, optical imaging, solar energy harvesting, optical sensing and communication.

**ADVANCING THERMAL ENERGY HARVESTING**

Dr. Jie Gao and her student, Zhigang Li, designed a new type of tungsten-based mid-infrared metamaterial absorbers for achieving either narrowband or broadband near-perfect absorption and emission of thermal radiation. The demonstrated metamaterial absorbers and emitters consisted of multiple tungsten cross resonators of different sizes can advance promising applications in thermal energy harvesting especially low-temperature thermal photovoltaic cells for energy recovery from waste heat sources. Dr. Gao's team also successfully demonstrated the generation of second-harmonic nonlinear optical vortices with plasmonic metasurfaces made of C-shaped nanoapertures. The rotation-gradient nonlinear metasurfaces were constructed for producing an array of second-harmonic vortices with varying orbital angular momentum. This work published in Advanced Optical Materials' enables future photonics chips for applications in optical tweezers and all-optical communication.

**PERFECTING 3-D PRINTING**

Dr. Lianyi Chen’s team and his collaborators at the Argonne National Laboratory revealed the transient dynamics of powder spattering in the laser powder bed fusion (LPBF) additive manufacturing process by in-situ high-speed high-energy x-ray imaging. By utilizing the extremely bright X-rays, the team was able to visualize the powder motion dynamics as a function of time, environment pressure and location, and quantify the moving speed, acceleration and driving force of powder motion that are induced by metal vapor jet/plume and argon gas flow. According to the revealed powder motion dynamics and mechanisms, the team...
identified potential ways to mitigate powder spattering during the LPBF process, in order to overcome the major barrier in 3-D printing to making parts with fewer defects. This study was published in Acta Materialia\(^2\) and it will help businesses across aerospace, defense and automotive industries to design better processing approaches to fabricate complex components by using 3-D printing.

3-D PRINTING OPTICAL FIBER

Dr. Edward Kinzel’s group recently presented work on printing photonicly viable optical fiber in free-standing configurations. This includes couplers with the potential for different interferometric sensors as well as light routing and interconnects. It builds off of previous work the group has done using a fiber-fed laser heated approach to 3-D print full density optics. Dr. Kinzel’s group also presented work on the scalable fabrication of visible/IR metasurfaces. This technique uses a self-assembled microsphere array as an optical element to generate photonic jets in photoresist. The photonic jet can be steered by adjusting the angular spectrum of the illumination. Because the intensity of the light field can be adjusted, hierarchical patterns can be realized. This has applications to thermal management, sensing, and energy harvesting.

LASER NANOMANUFACTURING OF ADVANCED ELECTRONICS AND PHOTONICS

Dr. Heng Pan and his students contributed to a review article in Advanced Materials focusing on the material reactivity, ink availability, printability, and process compatibility for facile manufacturing of bioresorbable electronics, including their recent work in low-cost manufacturing of bioresorbable zinc nanoparticles by evaporation-condensation-mediated laser printing and sintering. Dr. Pan and his collaborators from the University of California Berkeley reported a novel manufacturing method to program nanoparticles in multiscale based on optically modulated assembly and phase switching of silicon nanoparticle array. The scalable, direct, and optically modulated writing of nanoparticle patterns of high precision using a pulsed nanosecond laser was investigated. Their findings published in ACS Nano\(^3\) will serves as a new mechanism to manufacture optical metasurfaces and multidimensional optical storage devices.

PERFECT VORTEX BEAMS WITH PLASMONIC METASURFACES

Dr. Xiaodong Yang and his team of researchers proposed a universal design scheme for a new type of chiral plasmonic metamaterials based on slanted nanoapertures, which is published in Nano Letters\(^4\). They introduced strong optical chirality by tilting nanoapertures with almost arbitrary shape to break all the mirror symmetries, resulting in giant circular dichroism. Furthermore, tunable circular dichroism was presented to form chiral images with controllable image contrast. Their work in chiral metamaterials will enable promising platforms for a variety of applications in chiral imaging, optical sensing and spectroscopy. His team also generated three-dimensional perfect vortex beams with plasmonic metasurfaces made of rectangular-hole antennas as integrated beam converters. Not only perfect vortex beams with adjustable structures but also multiple beam arrays were produced with high quality. The results published in Advanced Optical Materials\(^5\) have the promising potential to make compact photonics devices for tailoring complex light beams and advancing metasurface-based optical communication.

LASER FOCUSED ON THE FUTURE

The future of photonics research is shining bright. Looking forward, our faculty will continue to explore the unknown fundamental scientific questions in light-material interactions and advance the next-generation industrial and military technologies by utilizing advanced photonic materials and structures.
THREE MAE DOCTORAL STUDENTS NAMED DEAN’S PH.D. SCHOLARS AND GRADUATE EDUCATORS

The College of Engineering and Computing at Missouri S&T honored 18 doctoral students in recognition of their scholarly productivity and teaching excellence at a reception on May 10, 2018. A total of eight award winners were honored at the end-of-semester reception and were named CEC Dean’s Ph.D. Scholars, while another ten doctoral students were chosen as inaugural Dean’s Graduate Educators.

The award winners were nominated by professors in their home departments, then selected by a department committee or department chair for college consideration. Winners were selected by Vice Provost and Dean Richard Wlezien from those submitted by each department.

The college implemented the Dean’s Ph.D. Scholar award in the 2016-17 academic year to honor its most productive Ph.D. students in scholarship. The Dean’s Graduate Educator award is new this year to honor excellence and outstanding contributions in teaching.

As a group, the eight CEC Dean’s Ph.D. Scholars have produced a total of 176 technical publications and reports, Myers notes, of which 87 were journal publications. The cohort has collectively accrued 29 external and internal awards. In addition, the 10 CEC Dean’s Graduate Educators have taught or co-taught a total of 88 laboratory or lecture sections, in most cases receiving teaching evaluations well above the campus average.

From the mechanical and aerospace engineering department, three students were selected to receive honors. Aaron Flood, Wenbin Li and Wei Li.

Aaron Flood, Ph.D. student in mechanical engineering, is advised by Dr. Frank Liou. He received the inaugural Dean’s Graduate Educator award. Aaron came to S&T to student under Dr. Liou after completing his bachelors of science in mathematics and bachelors of science in physics at Pittsburg State University. When he completes his studies at S&T, he hopes to find a job in the manufacturing industry.

Wenbin Li, Ph.D. student in mechanical engineering, is advised by Dr. Ming Leu. He was awarded the Dean’s Ph.D. Scholar award. Wenbin completed his masters of science and bachelors of science degrees in mechanical engineering at Beijing Institute of Technology. He then joined the mechanical and aerospace engineering department to study additive manufacturing of ceramics and ceramic composites. He hopes to find a career in the advanced smart manufacturing industry.

Dr. Wei Li, Ph.D. graduate in mechanical engineering, is advised by Dr. Frank Liou. He received the Dean’s Ph.D. Scholar award. Wei Li completed his master of science degree in engineering mechanics from Tongji University. He then joined S&T and received his second masters of science in manufacturing engineering. In August 2018, he completed his doctor of philosophy in mechanical engineering at S&T. During his Ph.D. study, Wei Li was awarded a U.S. Patent, authored and co-authored 18 journal papers, 9 conference papers, and one book chapter. He is now a post-doctoral associate at the University of California-Davis continuing his research in laserassisted direct energy deposition.
Dr. Lianyi Chen’s team at Missouri University of Science and Technology, just completed a study with Dr. Tao Sun’s team from the U.S. Department of Energy’s Argonne National Laboratory to understand the physics behind additive manufacturing and help eliminate structural defects in 3-D printed materials.

Additive manufacturing, often referred to as 3-D printing, has the potential to transform manufacturing as engineers use titanium and other metal alloys to tap raw materials more efficiently, which in turn will reduce product costs and weight and shorten supply chains. With this technology, possibilities seem to be endless as scientists create things such as medical prosthetics, jet engines, and even vehicles.

Yet metal additive manufacturing faces roadblocks. Printed materials often contain structural defects and vary from their designs, forcing engineers to repair their finished pieces or start over from scratch. And not all physics behind the process are well understood.

To address these problems, scientists at Missouri S&T and Argonne National Laboratory investigated the entire 3-D printing process, including the material properties of the metal powders and how the laser fuses those powders into the desired components, to discover both how defects form and methods to avoid them.

The team showed they can observe and quantify many metal 3-D printing characteristics — including melt pool size and shape, powder ejection, solidification, porosity formation and phase transformations. Ultimately, these efforts will achieve the best of both worlds: Scientists will uncover the dynamic mysteries of metal additive manufacturing, while industries will thrive with blueprints to rapidly print cost-effective and reliable products.

Chen’s research was reported in Acta Materialia, “Transient dynamics of powder spattering in laser powder bed fusion additive manufacturing process revealed by in-situ high-speed high-energy x-ray imaging”. The work is also a feature story published on the Argonne National Laboratory website. Qilin Guo of Missouri S & T and Cang Zhao of Argonne National Laboratory are the leading authors of the paper. Other publications related to this research include an article in the Scientific Reports, “Real-time monitoring of laser powder bed fusion process using high-speed x-ray imaging and diffraction.”

“This study is useful to the 3-D printing community to overcome a major barrier to making parts with fewer defects,” said Chen.

The image below shows a map of how powder spatter behaves according to time and environment pressure. (image by Missouri S&T)
AARON ERB AWARDED NASA PATHWAYS INTERNSHIP

Aaron Erb, a Ph.D. student in aerospace engineering, has recently been awarded a prestigious Pathways Internship at the NASA Langley Research Center. Through the Pathways Internship, Aaron will complete work as a member of the research team at NASA while working on a research project towards his graduate degree, with an opportunity to be hired full-time after the completion of his Ph.D.

Aaron's research under this internship focuses on the verification, validation, and uncertainty quantification of turbulence models used in the numerical modeling of supersonic and hypersonic flows. In particular, Aaron’s research will aim to improve the prediction capability of computational fluid dynamics tools used in the analysis and design of next generation low-boom supersonic aircraft being developed by NASA and Lockheed Martin under the Quiet Supersonic Technology (QueSST) program. The goal of this program is to achieve successful design and flight demonstration of a supersonic civil transport with a significantly reduced sonic boom (noise) signature.

"With a reduced sonic boom signature, the next generation supersonic passenger aircraft will be certified to fly over land at speeds greater than the speed of sound, which will be a significant achievement for high speed air transportation" says Dr. Serhat Hosder, associate professor of aerospace engineering at Missouri S&T and Aaron’s Ph.D. advisor. Aaron’s research will also focus on the validation and improvement of turbulence models used in the design of hypersonic vehicles that fly at speeds greater than five times the speed of sound.

ASME DSCD BEST STUDENT PAPER

Muthukumaran Loganathan, 2017 Ph.D. graduate in mechanical engineering, received the Best Student Conference Paper on Mechatronics for his paper, “Quasi-Repetitive Control for Fast and Accurate Atomic Force Microscopy,” presented at the American Control Conference in July, 2016 in Boston, Massachusetts. The 2017 Best Paper award is given by the ASME Dynamic Systems and Controls Division for the best paper with a student author as the primary author from four 2016 conferences: the American Controls Conference, the ASME Dynamic Systems and Controls Conference, the IEEE/ASME International Conference on Advanced Intelligent Mechatronics Conference, and the International Symposium on Flexible Automation.

Dr. Loganathan’s paper presents a new control methodology to track a class of quasi-periodic signals that are of practical importance for the control of Atomic Force Microscopy. The developed controller enables AFMs to generate highly accurate 3D digital images of samples with sub-nanometer resolution. This research was funded by the National Science Foundation.

Dr. Loganathan completed his M.S. and Ph.D. in mechanical engineering at Missouri S&T in 2012 and 2017, respectively, under the advisement of Dr. Doug Bristow, associate professor of mechanical engineering. He is currently a Senior Design Engineer at ASML US, Inc. in Wilton, Connecticut.

2017-2018 BOOK AUTHORS


JAMES WERNER AWARDED SMART SCHOLARSHIP

James Werner, a junior dual majoring in aerospace engineering and engineering management, has recently been received the Science, Mathematics and Research for Transportation (SMART) Scholarship, established by the Department of Defense, which is awarded to students pursuing a degree in a science, technology, engineering, and mathematics disciplines. James will receive full tuition and education related fees, a generous stipend, paid summer internships, health insurance, mentoring, and guaranteed employment placement with the Department of Defense upon graduation.

James Werner is a Rolla native, finishing high school in 2016 and proceeded to study at Missouri S&T the following Fall. He was introduced to the aerospace field while visiting family in Huntsville where he was able to tour the U.S. Space and Rocket Center which inspired him to study aerospace engineering.

MAE UNDERGRADUATES PUBLISH THEIR RESEARCH IN ADDITIVE MANUFACTURING

Four Missouri S&T undergraduates have been conducting research on applying modal analysis techniques to understand and detect defects in additively manufactured metal components. Drs. Ed Kinzel, Robert G. Landers, and Douglas Bristow, faculty of mechanical and aerospace engineering, are advising the students in their research. The four students include Nicholas Capps, Josh Pribe, James Urban, and Brian West.

The students have conducted a number of experimental and numerical studies to determine how defects that arise in parts fabricated with additive manufacturing affect the vibration response of the parts and whether the vibration response can be used as a signature to screen the parts for defects. The students and faculty work on this project in close collaboration with their funding partners at the Kansas City – National Security Campus (KC-NSC). To date, the students have produced one journal article and three conference papers, with more to come.

Nicholas Capps is a senior in mechanical engineering. After graduation, he plans to attend graduate school to further his education, likely focusing on additive manufacturing or material science. Josh Pribe completed his degree in mechanical engineering in Spring 2016 and is now pursuing a Ph.D. degree at Purdue University. James Urban is a senior in mechanical engineering and will work for KC-NSC after graduation. Finally, Brian West, also a senior in mechanical engineering, plans to do a post-bachelors program at Los Alamos National Laboratory before starting work on his Ph.D. degree in mechanical engineering.

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Pictured from left to right: Brian West, Nicholas Capps, and James Urban. Not pictured: Josh Pribe.