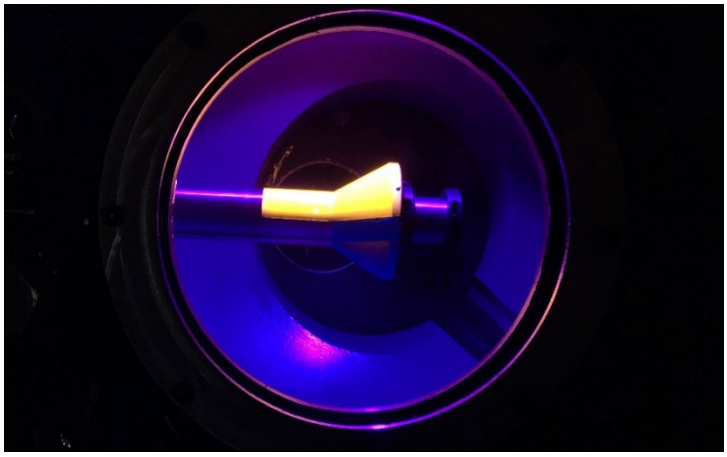
The University of Tennessee Space Institute

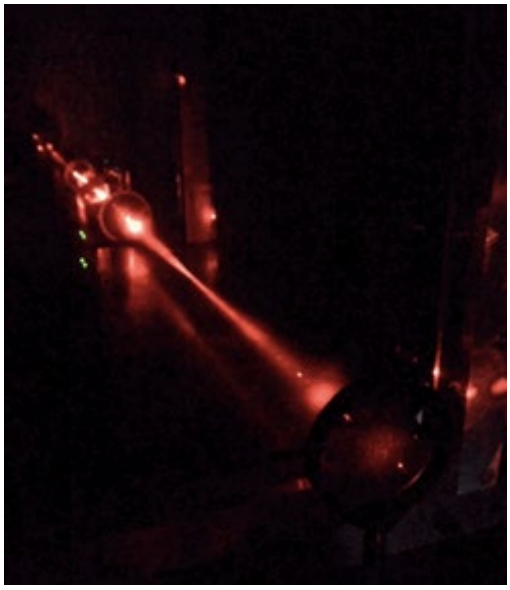
Center for Laser Applications

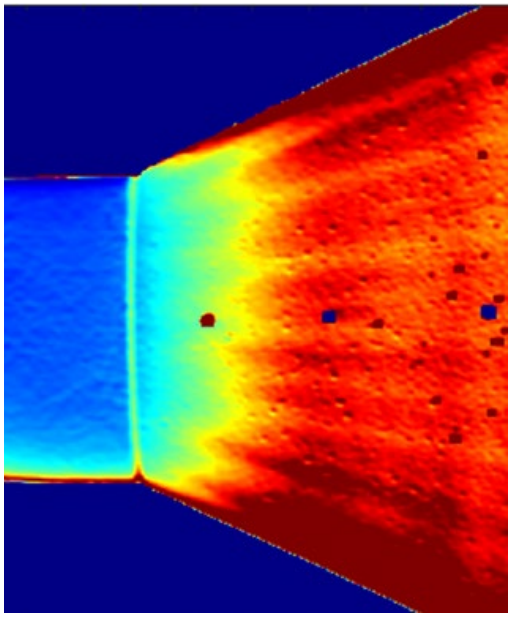
THEC Center of Excellence

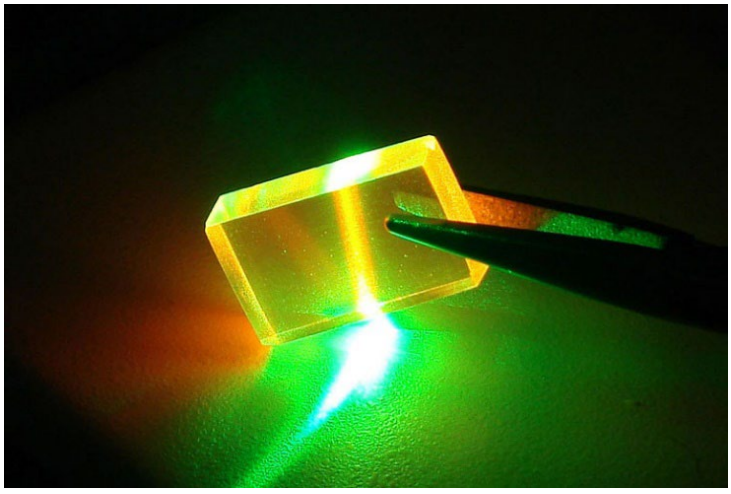
Annual Report

2022 – 2023









WELCOMING REMARKS

The Center for Laser Applications (CLA) at the University of Tennessee Knoxville Space Institute in Tullahoma is pleased to present our 2022-2023 report of research supported by the Center.

The past year has been eventful for the Space Institute with the introduction of a new Executive Director and the adoption of forward-thinking institutional goals for research and education intended to promote the growth of Aerospace & Defense in Tennessee – with a particular emphasis on the recruitment of industrial partners from the Huntsville area. As part of this strategy, the Space Institute is planning for significant growth in the area of thermal protection materials for hypersonic and space applications and propulsion for space systems. As we grow these areas the instrumentation and research capabilities enabled through the CLA resources will play a vital role in establishing the competitive capabilities of the institute in these areas and attracting highly qualified new faculty members.

The leading-edge research capabilities developed at UTSI through the THEC support includes laser-based techniques for flow diagnostics and material processing that are drawing the interest of industrial partners nationwide. Our capabilities now span combustion systems and jet engine/space propulsion systems, laser materials processing, ground-based aerospace testing, electro-optics, non-linear optics, quantum optics, molecular spectroscopy, and laser-induced assisted chemical reactions. Advancing these capabilities in Tennessee will position UT to be a leader in addressing the critical technical challenges facing our nation and promote industrial migration to our state.

Looking forward, we are planning to introduce new experimental capabilities to characterize the high-temperature material response to extreme environments, thermal runaway and management for Li-ion batteries, and Non-Equilibrium Fluid Physics. These areas are strongly aligned with the interests of other campuses in the UT System and we anticipate a variety of cross-campus collaborations that will lead to greater integrated capabilities across the system. Finally, we are excited to begin a search this year for the new Center for Laser Applications Director.

We greatly appreciate the resources provided by THEC to allow us to enhance our research supporting economic growth in Tennessee, and we look forward to continuing to share the accomplishments of our outstanding faculty in pursuit of this goal. Thank you,

James L. Simonton Ph.D.

Acting Director
Center for Laser Applications

Associate Executive Director UTSI

John D. Schmisseur

Executive Director, The University of Tennessee Space Institute

Asssociate Dean, Tickle College of Engineering

MISSION STATEMENT

CLA's original purpose and mission remain relevant as described in the 1984 proposal. It has evolved to remain current with emerging science and technological needs. This evolutionary process was the original proposers' exact intent and better serves Tennessee's needs by advancing research that has promise to lead to industrial and economic growth within the state.

Education

- Attract nationally recognized faculty and student scholars
- Produce well-trained graduates for employment in Tennessee
- Disseminate state-of-the-art information on laser application technology to the industrial and scientific communities
- Provide quality educational experiences for multidisciplinary students
- Generate opportunities for undergraduate student research
- Assist businesses in the development and implementation of technology
- Increase interest in STEM areas, i.e., support science education for students and teachers

Research

- Develop state-of-the-art experimental facilities for research on a variety of laser application problems
- Develop a world-class reputation for research and innovation to meet the needs of science and industry
- Utilize center funds for the exploration and development of new research areas
- Enhance the amount of research support from industrial and governmental organizations
- Transfer new laser application technology to state and regional industry and scientific organizations
- Enhance the research capability of other UTSI research groups through the development of advanced laser-based measurement techniques

EXECUTIVE SUMMARY

Foreword

The Center for Laser Applications (CLA) continues to advance laser-based research capabilities that support externally sponsored, nationally-recognized research in support of aerospace, defense, biomedical, and energy efficiency research that addresses a broad spectrum of our nation's critical technical challenges. In alignment with the introduction of UTSI's new Executive Director and response to new institutional research goals developed in consultation with our state and national industrial stakeholders, CLA resources are fostering growth in the experimental characterization of high-temperature material response within extreme environments and increased propulsion thrust for micro-satellites, while continuing to enhance capabilities for the measurement of high-Mach flows, biomedical diagnostic improvements and the identification of failure modes in new batteries being developed for advanced mobility applications. The Space Institute is planning for tremendous growth over the next five years – with a major emphasis on the recruitment of world-class faculty. The capabilities enabled by the CLA resources will play a vital role in the recruitment and development of such faculty that will lead to the development of new research capabilities that translate into industrial investment and economic growth within the state of Tennessee.

CLA Leadership

The Center for Laser Applications is currently led by Dr. James Simonton, Associate Executive Director of the UT Space Institute, and Dr. Jacqueline Johnson, who serves as the Senior Faculty member overseeing the operations of various laboratories affiliated with the center.

In early 2024 a search will be launched for a new Director of the Center who will serve 49% as the center director and 51% as a senior faculty member within the Space Institute. The opportunities afforded through the center will bolster UTSI's ability to recruit an internationally-recognized leader who will lead the advancement of the center in concert with UTSI's continued growth.

Dr. James Simonton
Interim Director

Dr. Jacqueline Johnson
Senior Manager of Laboratories

New Equipment Purchased

We were excited this year to complete the acquisition of a new Raman Microscope that is supporting several sponsored projects. Other new equipment included a Microwave Plasma CVD system and Instrumentation for a group of Split Hopkinson Bars we received from the Air Force Arnold Engineering Development Complex which will add an ability to characterize material response under dynamic conditions that will complement our existing material characterization capabilities.

Looking forward, we believe the suite of instrumentation assembled within the CLA will play a vital role in supporting the establishment of a comprehensive capability for characterizing the properties and response in extreme environments of materials designed to protect high-speed and space entry/return vehicles from extreme thermal loads. Such a capability is currently highly-sought by our industrial collaborators and the establishment of an academic center that can support the industry in the characterization and qualification of emerging new thermal protection materials will provide a compelling opportunity to draw aerospace and defense industrial investments to Tennessee.

Research Activity and Resource Utilization

In FY 2023 CLA associated staff and faculty had 21 peer-reviewed articles published and/or accepted into press and 51 national/international presentations.

Allocation of Center for Laser Application Expenditures of $1,102,138

- Salaries and benefits 46%
- Equipment-related expenditures (repair, supplies, and new) 43%
- Student Fees 2%
- Assistantships 5%
- Supplies 4%

Allocation of CLA Total Expenditures $1,628,945

- Salaries and benefits 24%
- Equipment-related expenditures (repair, supplies, and new) 65%
- Student Fees 2%
- Assistantships 3%
- Supplies 6%

The Center for Laser Applications ended the year with a carryover of $192,480. This carryover will be utilized toward major equipment purchases in support of emerging institutional initiatives as described in the New Equipment Purchased section above.

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INTRODUCTION

The Center for Laser Applications (CLA) continues to play a vital role in the mission of the University of Tennessee Space Institute to *serve all Tennesseans* through the advancement of education and research in the aerospace related sciences and the promotion of economic growth within Tennessee accomplished via the recruitment of aerospace and defense industrial investment. The recent prioritization of hypersonic flight, space access and operations, and modernization of nuclear capabilities in support of national defense have created a broad spectrum of opportunities for UTSI to leverage its growing expertise relevant to these areas to provide vitally needed technical advancement and education of the future workforce who will lead national progress, while simultaneously leveraging these accomplishments to recruit and grow industrial investments that will create new jobs and economic growth state-wide, but especially in Southern Tennessee which can benefit from industrial recruitment from the nearby Huntsville area.

Investments made in research capabilities at UTSI using CLA resources have attracted a variety of industrial partnerships that are advancing small satellite propulsion, environmentally-friendly sustainment of aerospace structures, and the characterization of failure mechanisms in Lithium-Ion batteries. Another project funded by NSF and in partnership with an HBCU is exploring the fundamental mixing processes essential for combustion in high-speed scramjet engines. These examples are merely a sample of the significant portfolio of research impacted by CLA investments – all of which are advancing the state-of-the-art in research, providing crucial opportunities for students to learn and develop skills, and ultimately contributing to the development of a research culture in Tennessee that will attract industrial investment.

Dr. Lino Costa
Research Associate Professor

Mechanical, Aerospace & Biomedical Engineering

Ph.D
University of Lisbon
Portugal

Advancing Micro Satellite Propulsion

The global growth of national space initiatives has resulted in a critical requirement for satellites to operate in increasingly crowded orbits. Utilizing state-of-the-art ultrafast laser micromachining equipment acquired with past CLA investments, Drs. Costa and Moeller have pioneered the development of next-generation electric micro-propulsion thrusters for nanosatellites – allowing unprecedented collision-avoidance maneuverability for the smallest vehicles operating in orbit. The UTRF patent-pending technology is called Micro Scalable Thrusters for Adaptive Mission Profiles in Space (µSTAMPS) and features a revolutionary design that electrosprays an ionic liquid propellant to generate thrust [1,2]. In the past year, Dr. Costa and Dr. Moeller executed a 2022 UTRF Technology Maturation Grant to develop a stand-alone µSTAMPS thruster prototype for a 1U unit, and they also received one of the first Space Force STTR phase I awards with NearSpace Launch, Inc., to explore integration of µSTAMPS with industry-leading nanosatellite infrastructure.

µSTAMPS was featured on the cover of Laser Systems / Europe

Making Connections for the Army

Costa and Moeller are also supporting an initiative to improve the joining of heterogeneous materials sponsored by the Army Research Laboratory using a similar technical approach to that used for µSTAMPS.

Electronics for Extreme Environments

To explore novel applications for diamond electronics related to space travel and other extreme environments, the CLA acquired a Wattsine HMPS-2060SP microwave plasma chemical vapor deposition system capable of growing single crystal diamond and polycrystalline diamond. The system is being utilized for sponsored research with industry and is anticipated to open a variety of new material development opportunities for the university.

[1] L. Costa, B. K. Canfield, A. Y. Terekhov, J. H. Howell, T. M. Moeller; Ultrafast-laser fabrication of electric micro-thrusters for nanosatellites; Proceedings of the 41st International Congress on Applications of Lasers & Electro-Optics (ICALEO 2022). Paper Micro 203; Laser Institute of America; 2022

[2] L. Costa, B. Canfield, T. Moeller, A. Terekhov, J. Howell, A. Huller, T. Sundstrom, C. Bunce, Fabricating micro scalable thrusters for nanosat propulsion, LASER SYSTEMS EUROPE Winter 2022, 26-27

Dr. Charles Johnson
Adjunct Professor

Physics

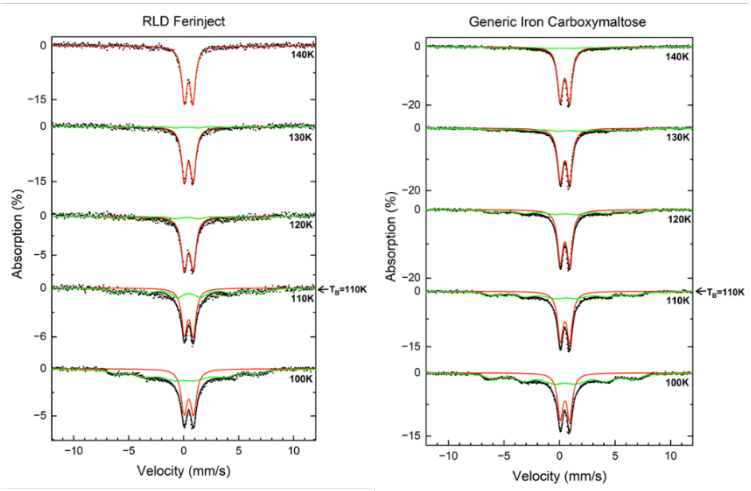
M.A. & D. Phil.
Oxford University
England

Reference Listed Drugs and the Food and Drug Administration

The Mössbauer Effect has important applications in the pharmaceutical industry as a method for testing new generic products. The FDA has laid down standards for approved Reference Listed Drugs (RLDs) in terms of their Mössbauer parameters. In particular, the nanoparticle blocking temperatures, T_B, are highly sensitive to the size of the particles.

We have tested RLDs and compared them with in-house generic products for several companies. These were drugs for treating anemia and kidney disease and consist of colloids of nanoparticles with an antiferromagnetic core of beta-FeOOH (ferric oxyhydroxide) surrounded by a shell of a sugar, e.g., carboxymaltose (trade name Ferinject).

The figures show typical Mössbauer results for an RLD and a generic sample. Both show a non-magnetic doublet at room temperature. As the temperature is lowered the larger particles begin to show magnetic hyperfine splitting. At still lower temperatures smaller particles show entirely magnetic spectra. The average blocking temperature, T_B, is defined as that for which the magnetic and non-magnetic fractions are equal and is 110 K for both samples. The Mössbauer parameters (chemical shift, quadrupole splitting and hyperfine field) as well as the blocking temperature are the same for the two samples, confirming that the generic product is acceptable.



Collaborations with Industry

The UTSI Mössbauer laboratory is constantly approached to establish parameters for drug structures. The actual names of companies are confidential.

Infrastructure of the Mössbauer Laboratory

The Mössbauer Laboratory is housed in the Center for Laser Applications (CLA) and consists of a room-temperature and low-temperature setup. There are relatively few Mössbauer setups in the USA, so the apparatus is in demand. It exists in the CLA to support other federal projects funded by NIH (the development of contrast agents for medical imaging) and NASA (development of lunar sodium ion battery materials). These projects provide workforce development for interns and graduate research assistants, who work alongside faculty and staff at CLA. The technical support provided at CLA is unprecedented.

Dr. Jacqueline Johnson
Professor

Mechanical, Aerospace & Biomedical Engineering

Ph.D
University of Liverpool
United Kingdom

Volunteer Spirit Award 2023

Large Area Ion Depaint Process

Methylene Chloride (MeCl) has been widely employed by the Air Force to remove paint from aircraft components for maintenance, which creates unsafe working conditions and causes significant logistic and financial burdens. The EPA and OSHA have heavily regulated MeCl use. Alternative depaint methods have been labor-intensive and substrate damaging (abrasive media blasting, waterjet, and induction heating) and/or expensive (laser and ultrahigh voltage plasma). Many of these depaint processes use abrasive media and generate a significant amount of waste that needs to be collected and treated.

Collaboration with Small Business

UTSI and its small business partner, Ultool, LLC, have developed a broad beam, low voltage large area DC ion depaint process that is environmentally benign, non-damaging, has large beam coverage, and is rugged and efficient. Figure 1 shows the ignited plasma and Figure 2 shows the ion source. A broad beam ion source operates at low voltage and is driven by a low-cost DC power supply. A gas flow hollow electrode provides high ion density for high efficiency depaint. A magnetic array confines the electrons to enhance gas molecule breakdown and an inert or reactive gas can be used to strip paint.

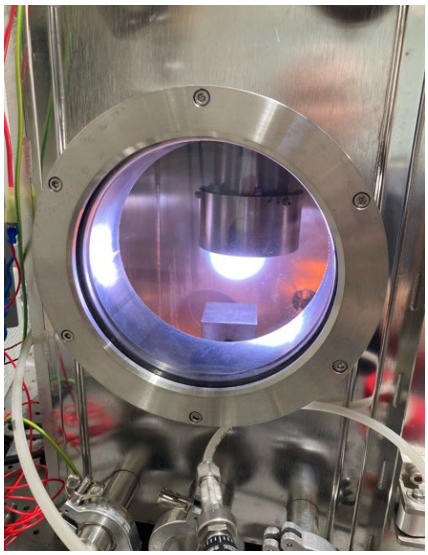


Figure 1. Ignited plasma for UTSI-Ultool LLC ion depaint project.

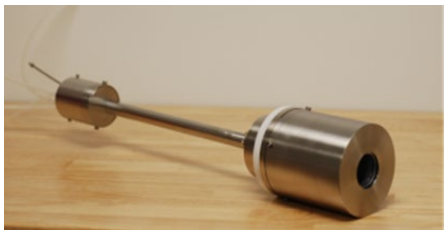


Figure 2. Ion source used in the ion depaint process.

Making Connections with AFWERX

This work and several other projects in collaboration with Ultool LLC are funded by **AFWERX**, which is a new program whose mission is 'to fund emerging technologies to deliver Air Force and Space Force capabilities and broaden access to disruptive innovation". ***AFWERX*** assists the Air Force in collaborating with industry and academia to enhance innovation.

Support from CLA

The Center for Laser Applications (CLA) has supported this and other research in several ways. Importantly, CLA provides workforce development for interns and graduate research assistants, who work alongside faculty and staff and are ready for the workforce immediately upon graduation. Additionally, CLA provides excellent infrastructure for research such as vacuum chambers, ion sources, and technical support. The research is now at a point that could go to Phase III, i.e., scaleup and production.

Dr. Phil Kreth
Assistant Professor

Mechanical, Aerospace & Biomedical Engineering

Ph.D., Florida State University, Tallahassee, FL

Louis and Ann Hoffman Endowed Excellence in Research Award, UTK MABE Department, 2023

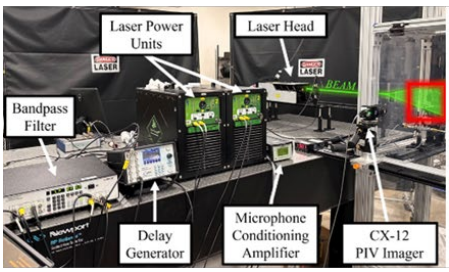
Hypersonic Aerothermodynamics and Advanced Optical Diagnostic Flow Measurements

A renewed national emphasis on hypersonic systems has driven substantial growth of aerospace and defense research at UTSI over the last several years, with the HORIZON research group leading these initiatives. The HORIZON team has been studying supersonic and hypersonic flows in several high-speed wind tunnels, each of which was constructed to support advanced optical diagnostic measurement techniques. Studying these high-speed flows experimentally requires diagnostics that are minimally intrusive to the flow and that can produce high-resolution data at very fast response rates. The HORIZON group has specialized in advanced optical diagnostics such as high-speed schlieren imaging, pressure- and temperature-sensitive paint (PSP & TSP), particle image velocimetry (PIV), and focused laser differential interferometry (FLDI).

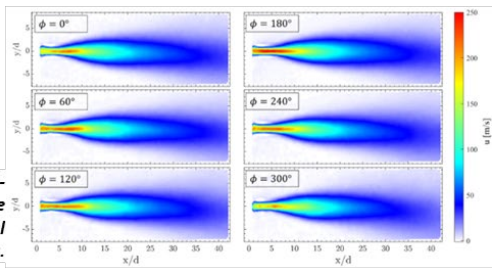
Dr. Kreth and his graduate students are involved in several research efforts spanning the areas of swept and unsteady shock/boundary-layer interactions (SBLI), multi-body aerodynamic interactions / hypersonic store separation, weather effects on hypersonic flows, and fluid/structure interactions (FSI). In conducting measurements of these types of flow phenomena, Kreth's team uses advanced, image-based data reduction methodologies to quantify and extract vital information about the flows' dynamic behavior.

High-Speed Flow Control Actuators and Applications

Kreth's group has leveraged past CLA investments in a high-powered, double-pulsed PIV laser to support a collaborative project in partnership with Tuskegee University (TU). Led by TU, this NSF-funded study has focused on the development and characterization of a high-frequency, pulsed, supersonic co-axial injector using the advanced optical diagnostic techniques at UTSI. This device was designed for potential future use in scramjet engines, and one of Kreth's students recently concluded experiments where he characterized the actuator's flowfield using phase-locked PIV. The results of this study[3] were presented in conjunction with those from Tuskegee University[4] at the AIAA Aviation Forum in June 2023 in San Diego. A picture of the PIV experiment and a snapshot of the results are shown below.



Photograph of the phase-locked PIV experiment used to characterize the Tuskegee University co-axial injector.



Corresponding phase-averaged, streamwise velocity fields of the co-axial injector's core flow output.

[3] Jenkins, JE, Kreth, PA, and Solomon, JT, Experimental Investigation of a High-Frequency Pulsed Supersonic Co-Axial Injector Using Optical Diagnostics, AIAA Aviation 2023 Forum, San Diego, CA, 2023.

[4] Solomon, JT, Hackworth, N, Lockyer, R, Philip, U, and Kreth, PA, Velocity and Vorticity Fields of a High-Frequency Pulsed Supersonic Co-Axial Injector, AIAA Aviation 2023 Forum, San Diego, CA, 2023.

Dr. Lee Leonard
Adjunct Research Associate Professor
Mechanical, Aerospace, and Biomedical Engineering Department

Solutions Consultant
Center for Industrial Services

Ph.D.
University of Tennessee

Advancing Medical Imaging and Nondestructive Testing

Dr. Leonard is developing luminescent glass and glass ceramic materials for radiographic imaging applications. The luminescent properties of these materials can be tuned by varying composition and processing conditions. Dr. Leonard's present focus is on highly efficient x-ray conversion screens for indirect flat panel detectors (I-FPDs). The conversion screens, through a process known as scintillation, convert incident x-ray radiation into visible light, which is detected by the I-FPDs and used to create an x-ray image.

Dr. Leonard, along with fellow CLA researchers, Dr. Jacqueline Johnson and Dr. Lino Costa, is currently investigating the use of lasers to improve the characteristics of glass-based, x-ray conversion screens (see Figure 1). There is an opportunity to improve the efficiency of these detectors used in medical imaging by more than an order of magnitude, leading to both reduced patient dose and improved image quality. This work is in collaboration with researchers at Stony Brook University. Applications that will benefit include digital radiography, portal imaging, and mega-voltage cone-beam computed tomography. The technology can also be applied to nondestructive testing, particularly in applications requiring the use of high energy x-rays or neutrons.

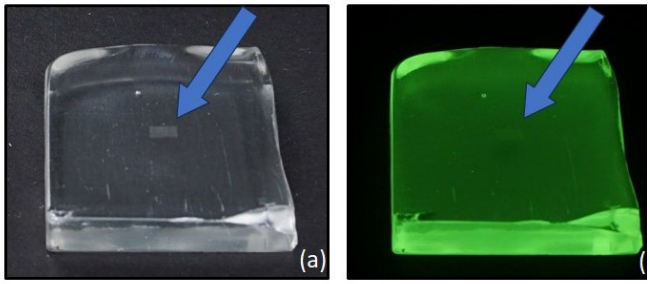


Figure 1. Photograph of a laser-processed glass scintillator sample in (a) visible and (b) ultraviolet light. The arrows indicate the laser-processed region.

The Center for Laser Applications (CLA) has supported this research in a variety of ways. Importantly, CLA-funded student workers have assisted with the optimization of the glass composition (see Figure 2). CLA has also provided the necessary raw materials and equipment, such as an argon glovebox and laser for the synthesis of these glasses. The research is now at a point where prototype conversion screens can be produced.

Figure 2. A student prepares a glass sample within an argon atmosphere glovebox.

Dr. Trevor Moeller
Jack D. Whitfield Professor

Mechanical, Aerospace & Biomedical Engineering

Ph.D.
University of Tennessee Knoxville

ASME Fellow
AIAA Associate Fellow

Advancing Micro Satellite Propulsion

The global growth of national space initiatives has resulted in a critical requirement for satellites to operate in increasingly crowded orbits. Utilizing state-of-the-art ultrafast laser micromachining equipment acquired with past CLA investments, Drs. Moeller and Costa have pioneered the development of next-generation electric micro-propulsion thrusters for nanosatellites – allowing unprecedented collision-avoidance maneuverability for the smallest vehicles operating in orbit. The UTRF patent-pending technology is called Micro Scalable Thrusters for Adaptive Mission Profiles in Space (µSTAMPS) and features a revolutionary design that electrosprays an ionic liquid propellant to generate thrust [5,6]. In the past year, Dr. Costa and Dr. Moeller executed a 2022 UTRF Technology Maturation Grant to develop a stand-alone µSTAMPS thruster prototype for a 1U unit, and they also received one of the first Space Force STTR phase I awards with NearSpace Launch, Inc., to explore the integration of µSTAMPS with industry leading nanosatellite infrastructure.

µSTAMPS was featured on the cover of Laser Systems / Europe

Making Connections for the Army

Costa and Moeller are also supporting an initiative to improve the joining of heterogeneous materials sponsored by the Army Research Laboratory using a similar technical approach to that used for µSTAMPS.

Exploring Laser Heated Tunnel

Moeller is also engaged in an effort to model laser heating of a gas rapidly expanding to vacuum as would happen in the nozzle of a laser-driven plasma wind tunnel. A 2D axisymmetric finite volume solver for two temperature quasi-neutral plasma coupled to a laser photon advection equation is under development for this purpose.[7]

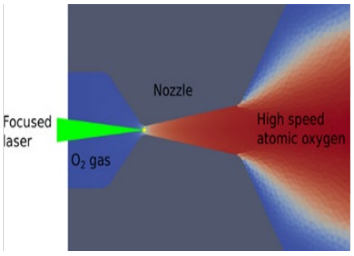


Figure 1. Schematic of an axisymmetric nozzle in a laser driven plasma wind

[5] L. Costa, B. K. Canfield, A. Y. Terekhov, J. H. Howell, T. M. Moeller; Ultrafast-laser fabrication of electric micro-thrusters for nanosatellites; Proceedings of the 41st International Congress on Applications of Lasers & Electro-Optics (ICALEO 2022). Paper Micro 203; Laser Institute of America; 2022

[6] L. Costa, B. Canfield, T. Moeller, A. Terekhov, J. Howell, A. Huller, T. Sundstrom, C. Bunce, Fabricating micro scalable thrusters for nanosat propulsion, LASER SYSTEMS EUROPE Winter 2022, 26-27

[7] Croft, K. A., Ashe, G., & Moeller, T. M. (2023). Simulation of laser induced breakdown and heating of oxygen gas. In AIAA AVIATION 2023 Forum. American Institute of Aeronautics and Astronautics. doi:10.2514/6.2023-4414

Dr. Peng Zhao
Associate Professor

Mechanical, Aerospace & Biomedical Engineering

Ph.D., Princeton University

Bernard Lewis Fellow of the Combustion Institute

Member of SAE, ECS, AIAA, and the Combustion Institute

Promoting decarbonization and safety

With the global trend of decarbonization, applications of batteries in electric vehicles, energy storage systems, and space explorations have attracted extensive interest. One of the critical challenges for batteries is the occurrence of thermal runaway under abusive conditions, placing a direct threat to lives and properties. To understand the mechanism of thermal runaway and prevent its occurrence, Dr. Zhao, director of the Lab of Advanced Mobility and Power (LAMP), has led substantial efforts toward safer batteries.

Understanding and preventing thermal runaway

Utilizing state-of-the-art Accelerating Rate Calorimetry (ARC) *(EV+, THT)* with past CLA investments, Zhao's team has characterized the safety threshold for different types of Lithium-ion batteries, including exothermicity onset temperature, thermal runaway onset temperature, delay time, venting events. Two UTRF patent-pending technologies developed in Zhao's lab include thermal runaway suspension and particle filtration for battery fire prevention. Our recent results directly show that thermal runaway is very sensitive to manufacture variations even for relatively mature LIBs. These variations lead to substantial ambiguities in target selection for safety evaluation and modeling. Hence, battery safety evaluation must be obtained from statistical analysis of the behaviors of multiple cells.

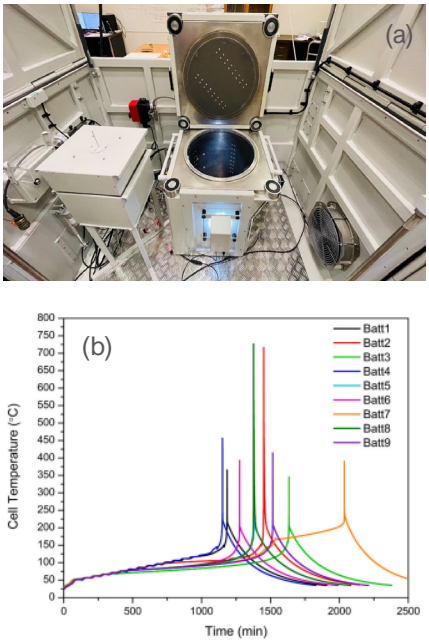


Figure 1. (a) Photo of the EV+ ARC, (b) cell variations in thermal runaway among 9 fresh Samsung 18650 cells with identical initial conditions

Also, from the sub-cell level, different material characterization equipment at CLA is utilized to characterize battery material samples, including XRD, SEM-EDS, and a recently established Raman spectrometry (XploRA, HORIBA). The autofocus capability of the instrument allows automatic scans in a domain of 80 µm length and 60 µm width to acquire a complete surface mapping with high resolution. A detailed understanding can be achieved for the venting particles during thermal runaway, including morphology, elemental distribution, crystal structure, chemical composition, and heterogeneity.

Making connections to the industry

Zhao's lab has received financial support from Ford Motor Company for three consecutive years since the establishment of LAMP. Comprehensive characterization of cell and sub-cell level thermal runaway provides useful insights into the thermal, kinetics, material, gas and particle emission aspects. The capability at LAMP enables future studies on solid propellants and energetic materials for aerospace and defense applications.

Researcher IV

Dr. Brian Canfield (Ph.D. in Physics, Washington State University) contributes to a wide range of CLA's research projects in applied and nonlinear optics, in particular, ultrafast laser materials processing. Technologies relying on these processes include the machining of microfluidic/nanofluidic systems, large-scale roll-to-roll replication template fabrication, custom foil mesh drilling for energy production and storage, surface modification for improved physical environmental interaction, and thrust and charge dissipation schemes for orbiting satellites. He has also been instrumental in the development of experimental systems for ultrasensitive fluorescence detection and single-nanoparticle trapping and tracking for biotechnology applications. Dr. Canfield has implemented various focusing methods with Gaussian and Bessel beams for precision laser machining of very high aspect ratio holes in the surfaces and channels through various transparent substrates including polymers, glasses, and crystalline materials like diamond and sapphire. His current research projects include producing next-generation monolithic electrospray microthruster chips, surface modification of hardened steel tool bits to increase their duration and lifetime, etching QR codes and other image patterns for additive manufacturing, graphitizing diamond internally to create embedded conductive electrodes by employing beam shaping methods using a spatial light modulator, and excavating surface trenches in diamond for alpha-spectrometry diagnostics in power-generating molten salt reactors.

Research Scientist I &
Chemical Hygiene Officer

Dr. Lu Liu (Ph.D. in Chemistry, University of Maryland) has more than 10 years of experience in experimental design, material synthesis, testing and screening, including magnetic materials, battery electrode materials, metal/metal oxide nanoparticles w/o coating, and functional polymeric materials and composites. Since she joined UTSI in February of 2021, she has been working on (Fe NP) synthesis, nanofluids, and battery thermo-safety studies. She is also the Chemical Hygiene Officer of UTSI and works with the safety office to provide technical guidance in the development and implementation of the provisions of the Chemical Hygiene Plan.

Research Consultant & Manager of CLA Research, Engineering and Operations

Mr. Alexander Terekhov (M.S. in Solid State Physics and Quantum Radiophysics, Moscow Engineering Physics Institute (National Research Nuclear University), Moscow, Russia; M.S. in Materials Science, University of Illinois at Urbana-Champaign) supports graduate students and faculty in their research projects and contracts. He is responsible for Laser Safety and maintaining the laser systems and other technical hardware at CLA. Mr. Terekhov has three patents and is a co-author on many scientific papers in a variety of fields.

Mr. Doug Warnberg retired from the United States Air Force and has an Associate's degree in Applied Science from the Community College of the Air Force and Motlow State Community College. He also has a diploma from the Tennessee College of Applied Technology-Shelbyville in Industrial Maintenance. Doug maintains the vacuum systems, Class 1000 clean room, and Rigaku SmartLab X-Ray Diffraction System.

Technical Specialist I

RECENT GRADUATES

George Willard Ashe, MS/AE	David Kyle Noe, MS/ME
Ruth Elise Clemons, MS/AE	Zane Shoppell, MS/AE
James Chism, MS/AE	Katrina Marie Sweetland, PhD/ME
Mason McKenzie Hodge, MS/AE	Aleia Williams, MS/BME
Lauren Lester, MS/AE	
AE – Aerospace Engineering BME – Biomedical Engineering ME – Mechanical Engineering	

FOCUS AREAS

The focus of the mission-related research programs of the Center is the application of lasers and associated technology. These focus areas of specialization were selected to correspond to known scientific and engineering challenges and to areas of development and regional and national needs.

BIO/NANOPHOTONICS

- Lino Costa - devices for cellular chemotaxis
- Jacqueline Johnson - storage phosphor materials for medical imaging

MATERIALS SCIENCE

- Lino Costa - phase transformations, laser cladding, and modeling of direct metal deposition
- Jacqueline Johnson - nanoparticles for medical theranostics
- Charles Johnson - Mössbauer spectroscopy
- Lee Leonard - glasses and glass ceramics for radiographic imaging and dosimetry

LASER-MATERIALS INTERACTION

- Lino Costa - laser cladding and femtosecond laser machining
- Trevor Moeller - laser ablation dynamics and modeling of laser ablation for space propulsion
- Phillip Kreth - laser-based heating of material samples for high-enthalpy flows

LASER MEASUREMENT AND DIAGNOSTICS

- Phillip Kreth - laser-induced fluorescence, radar REMPI, Raman scattering, molecular tagging velocimetry

NON-EQUILIBRIUM FLUID PHYSICS

- Trevor Moeller - plasma dynamics and combustion
- Phillip Kreth - diagnostics development for hypersonic flow
- Peng Zhao - clean combustion, reacting flows, alternative fuels, thermal management, and thermal runaway for Li-ion batteries.

COLLABORATIONS

- Dr. J. Johnson's collaborations:
  - Professor Todd Giorgio from Vanderbilt regarding any bio-related projects such as cell cultures, bioluminescence measurements etc.
  - Ultool, Hanping Xu for more than 20 years. Recently, worked on a hypersonic seal and an ion depaint process.
  - Hong Liang for more than 20 years, mostly on tribological applications. Recently we submitted a proposal on hydrogen embrittlement with Oak Ridge National to the Department of Energy.

- Dr. Kreth's collaboration with test engineers and researchers at AEDC to improve the measurement capabilities in the engine/nozzle test cells led to a conference paper and presentation at the AIAA Aviation Forum in June 2023. The collaboration involved Dr. Kreth; engineers from AEDC's Hypersonic Combined Test Force, 717th Test Squadron, and 804th Test Group; and a faculty member at the United States Air Force Academy.

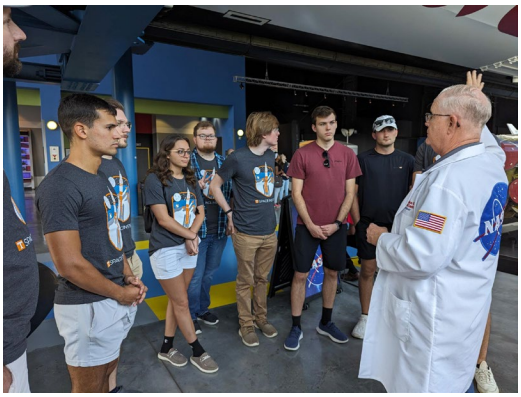
- Dr. Kreth and one of his graduate students, Jacob Jenkins, recently finished work on a collaborative project with Prof. John Solomon at Tuskegee University. At UTSI, Dr. Kreth and Jacob Jenkins conducted experiments using advanced optical and laser diagnostics on a flow control actuator provided by Tuskegee University. The work culminated in joint conference papers at the AIAA Aviation Forum in June 2023.

COMMUNITY OUTREACH

UTSI educational outreach has grown significantly in the last year with more visits to schools, and requests to come to campus for field trips.

- UTSI hosted local junior high and high school teachers, 4-H agents, STEM coordinators, and ROTC leaders for an all-day externship. The educators heard from graduate research assistants, professors, toured the Tennessee Aerothermodynamics Laboratory, and left with STEM kits to take back to the classroom. This is the first of many externships, and we are excited to help build the Tennessee workforce. This opportunity was part of the SEAL for Navy grant, funded by the Office of Naval Research.

- Largest group to date of undergraduate interns for the summer internship program.



2022 summer UG interns toured the NASA Marshall Space Flight Center, Huntsville, Alabama

- Conducted three Farm to Sea STEM camps. The students learned about hypersonics, artificial Intelligence, cyber security, rocket science, aerodynamics, and additive manufacturing. Students started the week at their school and finish the camp with a tour of UTSI. These camps are a joint effort between Alabama A&M University and UTSI, to reach out to future engineers. They are sponsored by the Office of Naval Research.

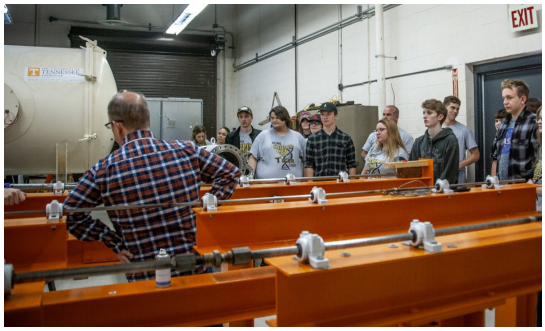
Celebrated International Astronomy Day with a Star Party, STEM activities, and viewing the start in the observatory and telescopes for the local communities.

UTSI graduate student gives insight to research and graduate studies to aviation class at Tullahoma High School

Technology student from Community High School, Unionville, Tennessee

- UTSI's Executive Director John Schmisseur, PhD continues to teach an undergraduate aerospace class for the Tickle College of Engineering. His students came to tour UTSI's campus and facilities. They met with current Graduate Research Assistants as well as toured the Ludwig wind tunnels, they have been learning about in class. A few were summer interns last year and a few will be interns this summer. We were so happy to host them and show off our beautiful campus as a potential next step in their careers.

AE 531 Undergraduate class field trip



Dekalb Co. High School Science Club

Sewanee Elementary School shooting rockets from class project March 2023

RECRUITING EVENTS

- Over 80 career/recruiting events in FY 2022–2023
- Monthly tours with students from UT Knoxville, UT Chattanooga, Middle Tennessee State University, Lipscomb University, Tennessee Tech University, and others
- Franklin County Chamber of Commerce Industry Appreciation – October 2022
- Tennessee State University – TLSAMP/McNair Scholar's Internship and Graduate Information Session with Dr. Acharya and interns Geneva Ballard – October 2022 and February 2023
- Franklin County High Schools Mock Interviews
- TLSAMP (TSU, UTK, TTU, University of Memphis) TN Louis Stokes Alliance for minority participation– February 2023
- Tullahoma High School Career Fairs – October 2022 and April 2023 Tullahoma High School Aviation Class visit with GRAs. January 2023 TCAT Shelbyville Students – Mock Interviews and Information Sessions
- AUSA 2023 Global Force Symposium and Exposition at Von Braun Center in Huntsville – March 2023
- Hosted 43 Tickle College of Engineering students in the AE531 course taught by Dr. Schmisseur - April 2023
- SAEOPP McNair/SSS National Research Conference, Atlanta, GA – June 2023 Tullahoma High School Job Shadow at UTSI
- High School Field Trips (Community HS, Dekalb Co. HS) March/April 2023
- ORNL Farm to Sea High School Field Trips (Grundy Co. HS, Scottsboro HS, Albertville, HS) June 2023

RESEARCH ACCOMPLISHMENTS AND FIVE-YEAR BENCHMARK

Our research mission is growing. The funding provided by the Tennessee Higher Education Commission, coupled with support from the university, provided valuable leverage for sponsored research. The research awards continue to increase. This growth is possible because of the dedication of our faculty and the support of THEC and UTSI.

CLA remains active in Outreach and Business Development. The faculty are active in scientific conferences and local business meetings. Productivity among Center faculty has been outstanding during the last five-year period. During fiscal years 2019 through 2023, Center faculty published 186 peer reviewed articles, 7 book chapters, and presented (or had abstracts accepted) at 120 regional, national, and international meetings.

Benchmark Data	FY 2019 – 2023 Cumulative	FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Publications						
Peer-Reviewed Articles	186	18	44	57	46	21
Books or Book Chapters	7	3	2	1	1	0
Presentations						
International	23	11	3	3	6	0
National	120	1	12	24	32	51

GOALS/FUTURE PLANS

Looking forward, there is a critical national need to improve capabilities for the characterization and qualification of materials used to protect high-speed and space-accessing vehicles from the extreme environments encountered in hypersonic flight and reentry. To address this vital national technology gap, UTSI is developing new experimental capabilities that will provide a comprehensive integrated capability to examine thermal protection material response in a variety of highly-relevant experimental environments that will ultimately lead to positioning UT as the nation's leading academic institution for qualifying high-temperature materials for aerospace and defense applications. Achieving this goal will require a substantial array of material assessment and aero-material interaction diagnostics and the investments made by the CLA in the development and implementation of these capabilities at UTSI are poised to provide a remarkable return on investment as they support this exciting new initiative.

Once mature, the ability to qualify thermal protection materials will complement the world-class material and manufacturing research capabilities resident in UT Knoxville and Oak Ridge National Laboratories, with the result that the State of Tennessee will be able to boast of a completely organic capability with UT that can support the industrial development of new systems for high-speed flight and space access.

UTSI is wisely investing the CLA resources in new capabilities that will reap dividends for all Tennesseans through the fostering of economic growth within our state.

PUBLICATIONS

Journal Publications

K. Akita, P. Zhao**,** Y. Morii, K. Maruta, D. Splitter, F. Chuahy, "Effects of unburnt reaction progress on stretch flame dynamics under elevated temperatures," *Combust. Flame*, under review.

L. Zhang, Y. Chen, H. Ge, A. Jain, P. Zhao, "Characteristics and regimes of radiation-induced Li-ion battery thermal runaway propagation," *Applied Sciences*, under review.

B.C. Koenig, S. Deng, P. Zhao, "Accommodating physical reaction schemes in DSC cathode thermal stability analysis using chemical reaction neural networks," *Journal of Power Sources*, under review.

H. Ge, A. H. Bakir, P. Zhao, "Knock mitigation and power enhancement of hydrogen spark-ignition engine through ammonia blending," Special issue in *Machines* 11 (2023) 651.

A.H. Bakir, H. Ge, Z. Zhang, P. Zhao, "Autoignition enhancement of liquid ammonia sprays under engine-relevant conditions via hydrogen addition: Role of thermal, chemical and charge cooling effects," *International Journal of Engine Research*, https://doi.org/10.1177/14680874231177361.

V. Talele, P. Zhao, "Effect of nano-enhanced phase change material on the thermal management of a 18650 NMC battery pack," *Journal of Energy Storage* 64 (2023) 107068.

L. Zhang, L. Liu, S. Yang, Z. Xie, F. Zhang, P. Zhao, "Experimental investigation on thermal runaway suspension with battery health retention," *Applied Thermal Engineering* 225 (2023) 120239.

D. DelVescovo, J. Li, D. Splitter, F. Chuahy, P. Zhao, "Genetic algorithm optimization of a chemical kinetic mechanism for propane at engine relevant conditions," *Fuel* 338 (2023) 128371.

W. Ge, F. Chuahy, P. Zhang, R. Sankaran, D. Splitter, D. DelVescovo, T. Lu, P. Zhao, "A direct numerical simulation study of the dilution tolerance of propane combustion under spark-ignition engine conditions," *Combust. Flame,* 247 (2023) 112495.

A. Garcia, P. Zhao, J. Monsalve-Serrano, D. Villalta, S. Martinez-Boggio, "Optical diagnostics of the venting spray and combustion behavior during Li-ion battery thermal runaway induced by ramp heating," *Applied Thermal Engineering,* 218 (2023) 119308.

D. Mishra, P. Zhao, A. Jain, "Numerical Investigation of Combustion-induced Thermal Runaway Propagation in Li-ion Battery Packs," *Journal of The Electrochemical Society* 169 (2022) 100520.

L. Zhang, S. Yang, L. Liu, P. Zhao, "Cell-to-cell variability in Li-ion battery thermal runaway: Experimental testing, statistical analysis, and kinetic modeling," *Journal of Energy Storage* 56 (2022) 106024.

P. Zhao, Shiyou Yang, "On planar reaction front in condensed materials: reduced model, propagation speed, reaction zone balance, and insights into battery thermal runaway," *Combust. Flame*, 245 (2022) 112346.

B.D. Kocher, P.A. Kreth, J.D. Schmisseur, E.J. LaLonde, and C.S. Combs, "Characterizing Streamwise Development of Surface Roughness Effects on a Supersonic Boundary Layer," *AIAA Journal*, Vol. 60, No. 9, pp. 5136-5149 (2022).

A. Williams, E. Moore, A. Thomas, J. Johnson, "A Review on the Biocompatibility of Graphene-Based Materials in Dental Applications," *International Journal of Biomaterials* Volume 2023, Article ID 8803283, 18 pages https://doi.org/10.1155/2023/8803283.

J.H. Howell, L. Costa, B.K. Canfield, A.Terekhov, T.M. Moeller, "Numerical investigations to determine onset voltages in monolithic electrospray thruster chips with electrospray cavities," *Journal of Electrostatics* 122, 103799 (2023).

T. Schmitz, L. Costa, B.K. Canfield, J. Kincaid, R. Zameroski, R. Garcia, C. Frederick, A.M. Rossy, T.M. Moeller, "Embedded QR code for part authentication in additive friction stir deposition," *Manufacturing Letters* 35, 16–19 (2023).

Conference presentations

P. Zhao, "New understandings of thermal runaway," BEV Congress, Troy, MI, May 3, 2023.

P. Zhao, "New aspects in battery thermal runaway: cell variation and health retention," 12th FM Global Open Source CFD Fire Modeling Workshop, April, 2023.

A.H. Bakir, H. Ge, Z. Zhang, P. Zhao, "Ignition enhancement of liquid ammonia sprays under engine relevant conditions via ambient hydrogen addition," 3D04: 180DS-0113, 13th US National Combustion Meeting, Texas A&M U, 2023.

K. Akita, H. Ge, P. Zhao, "Competition and synergy between reaction progress and unequal-diffusion effects on stretch flame propagation under elevated thermodynamics conditions," 2D06: 180LF-0153, 13th US National Combustion Meeting, Texas A&M U, 2023.

B.C. Koenig, P. Zhao, S. Deng, "Accommodating physical reaction schemes in DSC cathode thermal stability analysis using chemical reaction neural networks," 2B01: 180FI-0094, 13th US National Combustion Meeting, Texas A&M U, 2023.

A.H. Bakir, H. Ge, P. Zhao, "Combustion phasing and emission characteristics of HCCI fueled by ammonia/ hydrogen," 2G03: 180ICE-0111, 13th US National Combustion Meeting, Texas A&M U, 2023.

H. Ge, A.H. Bakir, P. Zhao, "Performance enhancement of a hydrogen spark-ignition engine with ammonia blending," 1C14: 180AFE-0112, 13th US National Combustion Meeting, Texas A&M U, 2023.

P. Zhao, "New aspects in battery thermal runaway: cell variation and health retention," 40th International Battery Seminar, Orlando, FL, March 2023.

L. Zhang, L. Liu, X. Wang, P. Zhao, "Cell variation in thermal runaway behavior," SAE WCX 2023, 23PFL-0458.

J. Liu, P. Zhao, X. Wang, "Battery performance improvement at low temperature by using pulse charging," SAE WCX 2023, 23PFL-0653.

A. Bakir, H. Ge, P. Zhao, "Ignition enhancement of liquid ammonia sprays under engine-relevant conditions via ambient hydrogen addition," SAE WCX 2023, 23-PFL-0218.

A. Bakir, H. Ge, P. Zhao, "Computational investigation of combustion phasing and emission of ammonia and hydrogen blends under HCCI conditions," SAE WCX 2023, 2023-01-0189.

L. Zhang, X. Wang, P. Zhao, "Suspension and Heath Retention during Step Heating Triggered Battery Thermal Runaway," SAE WCX 2023, 23HX-0055.

L. Zhang, H. Ge, P. Zhao, "Computational Investigation on Radiation Induced Thermal Runaway Propagation," SAE WCX 2023, 23HX-0054.

L. Zhang, L. Liu, P. Zhao, "Cell-to-Cell Variation in Thermal Runaway Behavior," ID 168900, 242nd ECS Meeting, 2022.

L. Zhang, Y. Chen, H. Ge, P. Zhao, "Computational Investigation on Radiation Induced Thermal Runaway Propagation," ID 168899, 242nd ECS Meeting, 2022.

L. Zhang, L. Liu, P. Zhao, "Battery Health Retention from Thermal Runaway Suspension," ID 168897, 242nd ECS Meeting, 2022.

H. Ge, P. Zhao, "CFD simulations of stratification and charge cooling effects on a GDCI engine," Converge User Conference, Sept 22, 2022.

A. Bakir, P. Zhao, H. Ge, "Numerical investigation of vaporization and ignition of ammonia sprays," Converge User Conference, Sept 22, 2022.

A. Bakir, P. Zhao, Haiwen Ge, "Automated optimization of pre-chamber geometry using CFD," Converge User Conference, Sept 21, 2022.

P. Zhao, "Theoretical and experimental study on Li-ion battery thermal runaway," 6th International Workshop on Flame Chemistry, Aug 15-19, 2022.

Kenneth A Croft, George Ashe, Trevor M Moeller; Simulation of laser induced breakdown and heating of oxygen gas, AIAA 2023-4414, *AIAA Aviation 2023 Forum*, June 8, 2023.

C. Romanoski, B.M. Gatzke, S. Guimond, S. Arnold, P.A. Kreth (presenter), M. Knauf, "A Computational and Experimental Investigation into Jet Aeroacoustics for Improved Ground Test Facility Design," *AIAA Aviation 2023 Forum*, San Diego, CA, 2023.

J.E. Jenkins, P.A. Kreth, J.T. Solomon, "Experimental Investigation of a High-Frequency Pulsed Supersonic Co-Axial Injector using Optical Diagnostics," *AIAA Aviation 2023 Forum*, San Diego, CA, 2023.

J.T. Solomon, N. Hackworth, R. Lockyer, U. Phillip, U, P.A. Kreth, "Velocity and Vorticity Fields of a High-Frequency Pulsed Supersonic Co-Axial Injector," *AIAA Aviation 2023 Forum*, San Diego, CA, 2023.

S.Y. Ledbetter, L.E. Lester, A.N. Garner, H.R. Goldston, C.D. Smith, M. Gragston, P.A. Kreth, J.D. Schmisseur, "Analysis of Streamwise Vortex Streaks in Shockwave-Boundary Layer Interactions on a Hollow Cylinder-Flare at $M_\infty = 4$," *AIAA Aviation 2023 Forum*, San Diego, CA, 2023.

J.R. Chism, P. Kreth, J. Schmisseur, "Characterization of Downstream Effects from a Wavy Wall on a Hollow-Cylinder at Mach 4," *AIAA SciTech 2023 Forum*, National Harbor, MD, 2023.

C.D. Smith, P. Kreth, J. Schmisseur, G. Strickland, "Temperature-Sensitive Paint Measurements of Cylinder-Induced Shockwave-Boundary Layer Interaction on a 6-degree Cone with Laminar Mach 7 Flow," *AIAA SciTech 2023 Forum*, National Harbor, MD, 2023.

D.S. Allen, K. Langley, J. Schmisseur, P. Kreth, "Separation Region Unsteadiness Drivers in Swept Compression Ramps," *AIAA SciTech 2023 Forum*, National Harbor, MD, 2023.

M. Gragston**,** K. Davenport, F. Siddiqui, N. Webber, C.D. Smith, P. Kreth, J. Schmisseur**,** "Design and Initial Characterization of the UTSI Mach 7 Ludwig Ludwig Tube," *AIAA SciTech 2023 Forum*, National Harbor, MD, 2023.

K.A. Croft, G. Ashe, T.M. Moeller, "Simulation of laser induced breakdown and heating of oxygen gas," AIAA 2023-4414, *AIAA Aviation 2023 Forum*, June 8, 2023.

R.A. Garcia, T.L. Schmitz, B.K. Canfield, A.Y. Terekhov, T. Moeller, L. Costa, Preliminary Cutting Force and Tool Wear Study for Micro-Patterned Turning Inserts," 37th Annual Meeting of the American Society for Precision Engineering, Bellevue, Washington, USA, 10-14 October 2022. (POSTER)

M. Nevills, E. Languri, P. Vinit, J. Davidson, L. Costa, D. Kerns; Enhancement of Transformer Oil Heat Transfer Characteristics Via Functionalized Nanodiamond Additives; 8th NANO Boston Conference (NWC Boston); Boston, Massachusetts, USA; 31 Oct 31 – 2 Nov 2022. (ORAL)

A. Huller, T. Sundstrom, B. Canfield, A. Terekhov, J. Howell, L. Costa, T. Moeller, "µSTAMPS A Solution for Nanosatellite Propulsion," 2022 SmallSat Education Conference, Kennedy Space Center Visitors Center, Florida, USA, 29-30 October 2022. (ORAL)

L. Costa, B.K. Canfield, A.Y. Terekhov, J.H. Howell, T.M. Moeller, "Ultrafast-laser fabrication of electric micro-thrusters for nanosatellites" 41st International Congress on Applications of Lasers & Electro-Optics (ICALEO); Orlando, Florida, USA, 17-20 October 2022, Laser Institute of America. (ORAL)

Conference proceedings

L. Costa, B.K. Canfield, A.Y. Terekhov, J.H. Howell, T.M. Moeller; "Ultrafast-laser fabrication of electric micro-thrusters for nanosatellites," Proceedings of the 41st International Congress on Applications of Lasers & Electro-Optics (ICALEO 2022). Paper Micro 203, Laser Institute of America, 2022.

R.A. Garcia, T.L. Schmitz, B.K. Canfield, A.Y. Terekhov, T. Moeller, L. Costa; Preliminary Cutting Force and Tool Wear Study for Micro-Patterned Turning Inserts; in 37th Annual Meeting of the American Society for Precision Engineering.

V.V. Prabhu, E. Languri, J.L. Davidson, D. Kerns, L. Costa, G. Wilson, "Natural Convection Heat Transfer Enhancement using Functionalized Nanodiamonds in Transformer Oil," 2022 21st IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (iTherm), doi: 10.1109/iTherm54085.2022.9899613.

Magazines

L. Costa, B. Canfield, T. Moeller, A. Terekhov, J. Howell, A. Huller, T. Sundstrom, C. Bunce, "Fabricating micro scalable thrusters for nanosat propulsion," *LASER SYSTEMS EUROPE Winter 2022*, 26-27.

Invited talk

R. Leonard, E. Moore, A. Thomas, L. Costa, B. Canfield, A. Howansky, A. Lubinsky, J. Johnson, "Using Glass Ceramics to Improve the Detective Quantum Efficiency of Indirect Flat Panel Detector Systems," Materials Science & Technology 2022, Pittsburg, Pennsylvania, (MS&T 2022).

Contributed talks

J.A. Johnson, A. Thomas, R.L. Leonard, "Investigation on the Effects of Pyrolysis on the Structure of Carbon-Carbon Composite Materials for Hypersonic Aircraft," 2022 NSMMS/CRASTE, Madison, Wisconsin USA.

X. Hanping, J.A. Johnson, R.L. Leonard, J.A. Jolliffe, A.Y. Terekhov, J.S. Tang, S.K. Gray, and A.L.Harcrow, "Rheological Sealing Material for Hypersonic Applications," 46th USACA Annual Composites, Materials & Structures Conference, CMS 2023, St. Augustine, FL, USA.

H. Xu, J.A. Johnson, R.L. Leonard, J.A. Jolliffe, A.Y. Terekhov, J.S. Tang, S.K. Gray, and A.L. Harcrow, "Rheological Sealing Material," 77th STLE Annual Meeting & Exhibition, Long Beach, CA, USA, 2023**.**

J.A. Johnson, A. Thomas, B. Canfield, L. Costa, A. Terekhov, A.R. Lubinsky, A. Howansky and R.L. Leonard, "Improved Efficiencies in Indirect Flat Panel Detector Systems using Glass Ceramics," 2023 Glass and Optical Materials Division (GOMD) Annual Meeting, New Orleans, USA.

Investigator	Contract Title	Funding Agency	Period of Performance	Awarded	2022-2023 Expenditures
Costa, Lino	Preparation and Replication of Silanized Templates (R024428041)	Ultra Small Fibers	01/06/2022 – 12/30/2023	$20,000.00	$5,213.32
Costa, Lino	Design and Fabrication of Novel Radiation Immune Vacuum Microelectronic Devices and Circuits (R024428042)	International FemtoScience, Inc.	06/15/2022 – 06/15/2024	$453,966.00	$148,189.85
Costa, Lino Moeller, Trevor	RP 3: Subtask 5: Ultrafast-laser surface texturing of carbide cutting tools (R024428038)	DOD-Army-ARL	07/01/2021 – 12/16/2023	$91,316.00	$79,552.62
Costa, Lino Moeller, Trevor	RP-4: Subtask 5: Ultrafast-Laser Surface Texturing for Metal AM (R024428039)	DOD-Army-ARL	07/01/2021 – 12/16/ 2023	$94,453.00	$81,091.97
Costa, Lino Moeller, Trevor Canfield, Brian Terekhov, Alexander	Electrospray Thrusters for Cubesats (R024428040)	UTRF Technology Maturation Funds 2022	01/10/2022 – 10/03/2022	$9,355.00	$8,920.52
Costa, Lino Canfield, Brian	Ultrafast Laser Processing of Diamond (R024428043)	International FemtoScience, Inc.	12/01/2022 – 05/31/2024	$40,000.00	$21,742.91
Costa, Lino	FemtoSci CVD Plasma Deposition System (R024428044)	International FemtoScience, Inc.	01/01/2023 – 12/31/2023	$20,000.00	$0.00
Costa, Lino	(R024428045)	Army ARL	01/01/2023 – 12/16/2023	$268,273.00	$95,981.31
Johnson, Jacqueline	Gas Flow Hollow Electrode Depaint Technology (R024417034)	UL Tool, LLC	09/29/2020 – 12/30/2022	$107,917.00	$6,759.08
Johnson, Jacqueline Leonard, Lee	Diamond-like Carbon Thin Films for Anti-fog Lens Coating in Laparoscopy (R024417032)	HHS – NIH – National Institutes of Health	09/01/2019 – 08/31/2022	$422,057.00	$11,166.21
Johnson, Jacqueline Leonard, Lee	Phase II HT Seal - UlTool LLC Sub001 (R024417036)	UL Tool, LLC	10/01/2021 – 06/30/2023	$300,000.00	$216,045.66

Investigator	Contract Title	Funding Agency	Period of Performance	Awarded	2022-2023 Expenditures
Johnson, Jacqueline Leonard, Lee	DLC Coating- ULTOOL LLC ULTOOL 2021-01 (R024417037)	UL Tool, LLC	11/01/2021 – 04/29/2022	$20,000.00	$10,818.57
Moeller, Trevor	ACE Booster 2 (R024348072)	Gloyer-Taylor Laboratories LLC	09/03/2019 – 12/05/2022	$155,439.00	$1,070.82
Moeller, Trevor	Development of Three Zone Absorption Cell for Spectral Measurement Verification (R024348073)	DOD – Air Force – AFRL – Air Force Research Laboratory	09/01/2019 – 10/15/2022	$180,280.00	$6,486.22
Moeller, Trevor	NASA Space Grant Consortium (R024348081)	Vanderbilt University	06/04/2020 – 06/03/2024	$145,723.00	$74,802.45
Moeller, Trevor	NASA Space Grant Consortium C/S (R024348082)	Vanderbilt University	06/04/2020 – 06/03/2024	$0.00	
Moeller, Trevor	Autonomous 24/7 EyeStar Black Box Commanding with uStamps Collision Avoidance Thruster (Black Box-MCAT) (R024348083)	NearSpace Launch	08/01/2022 – 01/30/2023	$125,000.00	$122,917.27
Moeller, Trevor	Additively Produced Telescope Mirrors (R024348084)	GTL	09/28/2022 – 04/27/2023	$41,719.00	$41,718.99
Moeller, Trevor	SEM Characterization of 10V Polarizers (R024348085)	AF	11/02/2022 – 05/15/2023	$1,658.00	$1,656.55
Moeller, Trevor	Sample evaluation, imagine, spectroscopy, and material testing (R024348086)	GTL	01/03/2023 – 12/31/2023	$2,500.00	$1,471.04
Moeller, Trevor	Sample Evaluation, imagine, spectroscopy, and material testing (R024395089)	GTL	06/03/2022 – 12/31/2022	$2,500.00	$1,734.77
Zhang, Feng-Yuan	Integrate Membrane Anode Assembly & Scale Up (R024421029)	Plug Power	10/01/2020 – 10/31/2023	$540,769.00	$187,234.16

Investigator	Contract Title	Funding Agency	Period of Performance	Awarded	2022-2023 Expenditures
Zhang, Feng-Yuan	Integrate Membrane Anode Assembly & Scale Up (R024421030) C/S	Plug Power	10/01/2020 – 10/31/2023	$0.00	
Zhao, Peng	URP Award: TCI and Combustion (R024435021)	Ford Motor Co.	11/01/2021 – 10/31/2022	$50,000.00	$21,551.61
Zhao, Peng	Kernel initiation, stretch dependence and EGR tolerance of LPG flames (R024435022)	ONRL DOE	05/06/2022 – 05/05/2023	$35,000.00	$31,873.52
Zhao, Peng	Glove Box for Thermochemical Testing and Safety Evaluation of Battery Materials (R024435023)	Ford Motor Co.	08/01/2022 – 12/31/2022	$30,000.00	$30,000.00
Zhao, Peng	In-situ Diagnostics and Modeling of Ammonia Spray Physics and Combustion Behavior at Elevated Pressure (R024435024)	NSF	08/01/2022 – 07/31/2025	$250,059.00	$47,681.58
Zhao, Peng	001740-URP URP Award: Battery Chemistry (R024435025)	Ford Motor Co.	01/01/2023 – 12/31/2024	$100,000.00	$39,740.37
Kreth, Phil	Excellence in Research: Co-Axial Flow Mixing and Control Using Ultra-High Frequency Actuators (R024432023)	Tuskegee University	08/01/2019 – 07/31/2023	$59,985.00	$10,232.34
Kreth, Phil	Preliminary Aerodynamic Characterization of Emerging Hypersonic System Configurations (R024432026)	Tuskegee University	11/01/2020 – 10/31/2023	$353,962.00	$73,124.82
Kreth, Phil	FAST: Focused Analysis of Surface disTortion (R024432029)	Ohio State	10/31/2022 – 01/31/2025	$119,165.00	$76,295.18

Investigator	Contract Title	Funding Agency	Period of Performance	Awarded	2022-2023 Expenditures
Gragston, Mark	FA9101-20-F-0043 (R024433020)	Air Force	08/26/2020 – 10/31/2022	$200,000.00	$334.74
Canfield, Brian	DE-AR0001603 (R020120026)	DOE	08/29/2022 – 08/28/2025	$71,498.00	$21,439.20
Canfield, Brian	DE-AR0001603 (R020120027) C/S	DOE	08/29/2022 – 08/28/2025	$0.00	

CENTERS OF EXCELLENCE ACTUAL, PROPOSED, AND REQUESTED BUDGET

Institution: University of Tennessee Space Institute **Center:** Center for Laser Applications

	FY 2022-23 Actual			FY 2023-24 Proposed			FY 2024-25 Requested		
	Matching	Appropr.	Total	Matching	Appropr.	Total	Matching	Appropr.	Total
Expenditures									
Salaries									
Faculty	$100,696	$140,100	**$240,796**	$60,000	$120,000	**$180,000**	$65,000	$125,000	**$190,000**
Other Professional	$109,535	$231,002	**$340,537**	$50,000	$100,000	**$150,000**	$65,000	$125,500	**$190,500**
Clerical/ Supporting	$9,338	$42,480	**$51,818**	$40,000	$75,000	**$115,000**	$38,000	$80,000	**$118,000**
Assistantships	$109,073	$58,344	**$167,417**	$85,000	$70,000	**$155,000**	$88,000	$72,000	**$160,000**
Total Salaries (exclude Longevity)	**$328,642**	**$471,925**	**$800,567**	**$235,000**	**$365,000**	**$600,000**	**$256,000**	**$402,500**	**$658,500**
Longevity (Excluded from Salaries)	$1,343	$1,503	**$2,846**	$1,800	$1,600	**$3,400**	$1,800	$1,700	**$3,500**
Fringe Benefits	$75,588	$96,694	**$172,282**	$75,000	$71,500	**$146,500**	$51,200	$80,500	**$131,700**
Total Personnel	**$405,573**	**$570,122**	**$975,695**	**$311,800**	**$438,100**	**$749,900**	**$309,000**	**$484,700**	**$793,700**
Non-Personnel									
Travel	$7,754	$12,566	**$20,320**	$5,000	$6,849	**$11,849**	$5,397	$6,500	**$11,897**
Other Supplies	$27,868	$44,602	**$72,470**	$30,500	$50,000	**$80,500**	$15,300	$29,190	**$44,490**
Equipment	$32,374	$400,068	**$432,442**	$60,000	$375,000	**$435,000**	$87,000	$398,500	**$485,500**
Maintenance		$26,136	**$26,136**		$25,000	**$25,000**	$14,348	$30,000	**$44,348**
Other (Specify):									
Printing, Duplicating, Binding		$1,266	**$1,266**			**$0**			**$0**
Postage, Freight, & Telephone	$30		**$30**		$2,000	**$2,000**	$400	$1,000	**$1,400**
Professional Serv & Memberships		$3,834	**$3,834**			**$0**			**$0**
Computer Services			**$0**	$1,175	$25,000	**$26,175**	$5,000	$10,000	**$15,000**
Rentals	$770	$11,692	**$12,462**			**$0**			**$0**
Grants & Subsidies	$79,180	$27,487	**$106,667**	$70,000	$35,000	**$105,000**	$62,000	$37,000	**$99,000**
Contractual & Special Services	$1,285	$3,727	**$5,012**			**$0**			**$0**
Other Expenditures		$100	**$100**			**$0**			**$0**
Utilities and Fuel		$19	**$19**						
Communications		$518	**$518**						
Total Non-Personnel	**$149,261**	**$532,016**	**$681,277**	**$166,675**	**$518,849**	**$685,524**	**$189,445**	**$512,190**	**$701,635**
GRAND TOTAL	**$554,834**	**$1,102,138**	**$1,656,972**	**$478,475**	**$956,949**	**$1,435,424**	**$498,445**	**$996,890**	**$1,495,335**
Revenue									
New State Appropriation		$917,188	**$917,188**		$949,419	**$949,419**		$996,890	**$996,890**
Carryover State Appropriation		$192,480	**$192,480**		$7,530	**$7,530**			**$0**
New Matching Funds	$554,834		**$554,834**	$478,475		**$478,475**	$498,445		**$498,445**
Carryover from Previous Matching Funds			**$0**			**$0**			**$0**
Total Revenue	**$554,834**	**$1,109,668**	**$1,664,502**	**$478,475**	**$956,949**	**$1,435,424**	**$498,445**	**$996,890**	**$1,495,335**

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