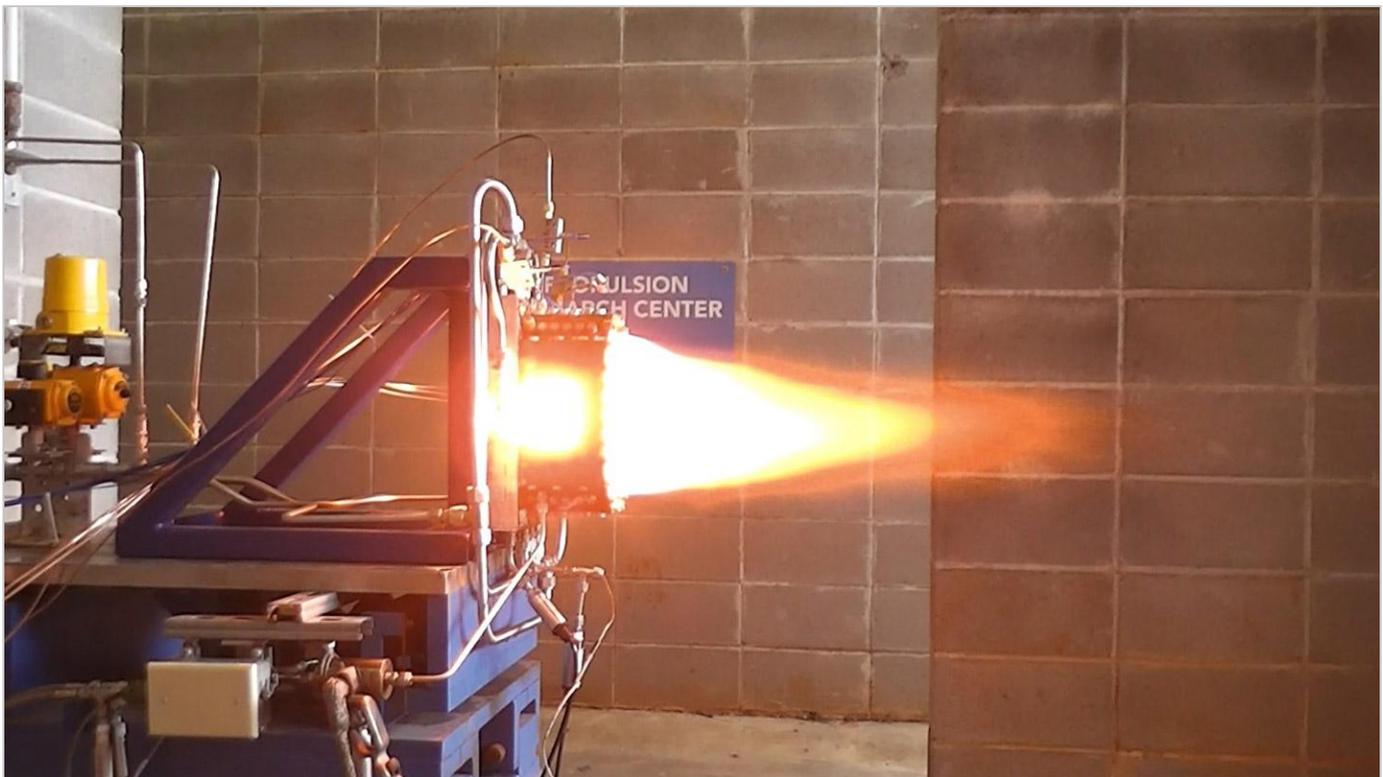


UAH hypersonics research marks rapid progress highlighted by partnership milestones in 2023



Research combining solid-fuel ramjet, rotating detonation engine technology at The University of Alabama in Huntsville Propulsion Research Center.

Courtesy UCAH

When the United States Dept. of Defense (DOD) recognized an urgent need for hypersonic development and testing to meet rising threats from overseas, The University of Alabama in Huntsville (UAH) quickly accepted a lead role to support these efforts. The university's extensive capabilities in scaled testing, software modeling and defense partnerships have been crucial to the advancement of this technology over the past three years, with gratifying results.

Earlier this year, the U.S. Army deployed its Long-Range Hypersonic Weapon system for the first time in a full rehearsal of hypersonic launch capabilities dubbed Thunderbolt Strike. The rehearsal deployment was performed from an air base in Joint Base Lewis-McChord, Washington, to Cape Canaveral, Florida, over 3,100 miles away. The success of the deployment marked a significant milestone in U.S. hypersonics capabilities and highlights the importance of the collaborative efforts that have rapidly moved this vital research forward.

Longstanding commitment to Redstone Arsenal research

"With the legacy we have at UAH in supporting the specific needs of our community through our research efforts, it is of the utmost importance that we align ourselves with Army modernization priorities that include efforts in hypersonic flight and phenomenology, long range precision fires, artificial intelligence advances and directed energy, to mention a few," notes Dr. Suzy Young, director of the UAH Research Institute. "To see the

Long-Range Hypersonic Weapon system deployed in February over 3,100 miles is a great step forward in the advancement of U.S. capabilities. From a university perspective, it is exciting, because there are still plenty of opportunities for research in so many aspects of hypersonic flight and ultimately deployment.”

Unlike the predictable parabolic flight of conventional or Intercontinental Ballistic Missiles, hypersonic missiles can change trajectory to avoid detection or interception countermeasures. “As long as we have adversaries, there will be constant change and advancement in the type and nature of threats we face,” notes Dr. Jason Cassibry, a professor in the UAH Department of Mechanical and Aerospace Engineering who has been supporting this initiative. “For decades to come, one of those threats will be the delivery of warheads by hypersonic missiles with unpredictable maneuverability. The difference with this modern threat is that these new vehicles glide and have some controllability, making them harder to disable.”

Providing impactful scaled testing and analysis

The primary goal of the project is to make a missile alter its parabolic flight pattern, which can be done through aerodynamic design, control software or a combination of both. UAH, a part of the University of Alabama System, is particularly well-equipped to meet this challenge by supporting the U.S. Army Rapid Capabilities and Critical Technology Office and Space and Missile Defense Command’s Technical Center’s (SMDC-TC) Aerophysics Research Facility operations. This is done by providing government and commercial clients with a ready means of hypersonic scaled testing in order to research what affects projectiles and aircraft flying at hypersonic speeds.

Scaled testing provides critical data that UAH scales up to represent a full-size flight. UAH’s light-gas guns simulate environments in which a projectile would actually fly, so it is possible to test it at various simulated altitudes at critical points along its flight path.

“The Aerophysics Research Facility has assets that are unique within the DOD, as well as globally, in very few select locations,” Dr. Young points out. “The capabilities of the UAH Research Institute staff to find creative solutions to highly complex engineering problems and perform innovative testing in conjunction with our partners at Redstone Arsenal is a great benefit.

“The UAH aerophysics staff have a long legacy of successfully supporting research and development efforts for over 30 years in partnership with government, industry and academic organizations,” Dr. Young continues. “By leveraging this legacy and effectively joining our partner’s team to develop solutions, as opposed to simply delivering data, the team can offer lower costs than full-scale flight tests, as well as quicker turnaround with the results. Through this collaboration, simulations can be quickly verified to rapidly drive design decisions and optimization.”

The Director cites a recent example of the effectiveness of these collaborations, touting the combined efforts of UAH, SMDC and industry team partners in successfully returning two of the facility’s two-stage light-gas guns to routine test operations after over a decade of pause in operations.

“These systems are used to investigate the interactions of high-speed vehicles and their environments,” Dr. Young explains. “This has in turn enabled the facility and combined team to successfully support multiple hypersonic engineering efforts. The last few years have resulted in some great partnerships and advances in development, testing and prototyping of hardware associated with the characterization of hypersonic flight. Working closely with our DOD partners has given us the opportunity to collect experimental data for simulation validation, flight tests of signature and hypersonic flow of high-speed flights and propulsion-related effects.”

Propulsion Research Center leading new advances

University researchers have also been working to develop a solid-fueled ramjet using a rotating detonation engine (RDE) for hypersonic air-breathing propulsion. Ramjets are a class of air-breathing engines that utilize the forward motion of the engine to compress the incoming air for combustion without the need for a mechanical air compressor. These efforts earned a three-year, \$1.5 million grant from the University Consortium for Applied Hypersonics (UCAH).

"This research has been a combination of experiments and computational modeling to demonstrate the feasibility of the concept," says Dr. Gabe Xu, an associate professor of mechanical and aerospace engineering with the UAH Propulsion Research Center. Instead of burning propellant in a traditional flame, RDEs use spinning detonation waves, a series of small explosions, to further compress and combust the fuel and oxidizer to create hot gas and generate thrust.

The UAH Propulsion Research Center also won a \$186,938 DOD grant, sponsored by the U.S. Army Research Office, to advance hypersonics fuel research through the acquisition of a pyrolysis-gas chromatography/mass spectroscopy instrument. "This instrument measures and analyzes the gases that come off scramjet and ramjet fuels," says Dr. Robert Frederick, director of the PRC and principal investigator for the award. "We're looking for new solid ramjet fuels that expand the operating envelope and range of supersonic and hypersonic vehicles."

Additional active initiatives currently underway include investigating extreme thermal transport events in supersonic and hypersonic shock wave turbulence, as well as addressing turbine blade tip heat transfer and aerodynamic losses through innovative film-cooling configurations. "A new project is looking at aerodynamic loss variations relative to turbine blade surface finish," Dr. Young says. "And a project expected to begin in January 2024 will be examining aerodynamic loss investigations associated with film-cooled turbine blade tips."

Special courses in hypersonic flow and modeling

Dr. Kader Frendi, a professor in the UAH Department of Mechanical and Aerospace Engineering, and his students are also supporting hypersonics efforts. "We just finished a phase I Small Business Technology Transfer on hypersonics where we demonstrated the viability of an in-house derived turbulence model that can span the entire speed range, subsonic to hypersonic, and it can be used in the steady or unsteady mode," Dr. Frendi says. "I have two students using the model for different speed ranges and using combustion as well. I think this is a critical area of research."

"These activities have also benefited the development of related technologies associated with a diversity of commercial activities," adds Dr. Phillip Ligrani, professor of mechanical and aerospace engineering and the university's eminent scholar in propulsion. His current efforts in the field, along with his students, are related to components of gas turbines and hybrid propulsion engines.

"Unique aspects of the research include the ability to investigate a variety of flow phenomena which are present around projectiles traveling at hypersonic speeds," Dr. Ligrani says. "Other ongoing work is focused on extreme thermal transport events in supersonic and hypersonic shockwave turbulence interactions, particularly unsteady flow events and mechanisms that affect thermal transport and local surface heat transfer levels when different types and arrangements of shockwaves are present."

Dr. Cassibry has seen a rise in student interest in taking his hypersonics course, MAE 695, hypersonic flow. "As supersonic combustion matures, future hypersonic vehicles will also be powered, increasing their range and lethality," the researcher notes. "The impact that our and other university research has will be to sustain our leadership and air superiority through a two-fold effort. First, the products from the research will lead to

new technologies to help answer the threat posed by new hypersonic weapons. Second, the funding draws interest and creates relevance and motivation for coursework, thereby training a large number of students to be future experts and leaders in hypersonics.”

While this research has had an impact on the future of national security, it could also bring substantial commercial benefits.

“This research will have a far-reaching impact and is absolutely imperative to contribute and maintain superiority offensively and defensively as a matter of national security,” Dr. Young envisions. “As to commercial benefits, who would dispute that making a trip from Paris to Tokyo in three hours would be an attractive venture?”

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Contact

Kristina Hendrix

☎ 256-824-6341

✉ kristina.hendrix@uah.edu

Elizabeth Gibisch

☎ 256-824-6926

✉ elizabeth.gibisch@uah.edu