Department of the Navy SBIR/STTR Transition Program

DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.
ONR Approval #43-8833-21

Topic # N191-043
Analytical Design of Surface Porosity in 2D C/C to Delay Boundary Layer Transition for Hypersonic Aeroshell Applications
Materials Research & Design

WHO

SYSCOM: ONR

Sponsoring Program: ONR Code 351: Basic and Applied Research in Hypersonics

Transition Target: The US Navy's Conventional Prompt Strike (CPS) program

TPOC:
Dr. Eric Marineau
eric.marineau@navy.mil

Other transition opportunities: This technology is specifically tailored to mid- or intermediate range boost glide hypersonic weapons which could benefit from a reduction in the second mode instability contribution to boundary layer transition, including Defense Advanced Research Products Agency's (DARPA) Tactical Boost Glide (TBG) program and the U.S. Air Force Advanced Rapid Response Weapon (ARRW) program.

https://asc.army.mil/web/news-alt-ond18-experiments-in-hyperspeed/

Notes: The image shows an example of a carbon/carbon aeroshell on DARPA's Falcon Hypersonic Test Vehicle.
The aeroshell material being developed will delay or prevent boundary layer transition in hypersonic vehicles, reducing the thermal loading and resulting operating temperatures which will allow for reduced insulation weight and increased vehicle range.

WHAT

Operational Need and Improvement: Progress has been made over the last two decades in predicting the growth of the flow instabilities that cause boundary layer transition (BLT) on hypersonic vehicles. However, the large uncertainties in BLT lead to conservative aeroshell designs that penalize flight performance. Boundary layer stabilization shows promise in ensuring laminar flow over an extended flight envelope, even under large uncertainties in the freestream disturbances. Hypersonic BLT delay strategies involving ultrasonically absorptive materials have been investigated using numerical modeling as well as bench tests and wind tunnel tests. For the second (Mack) mode instability, porous surfaces have been shown to stabilize the disturbances through ultrasonic absorption. However, this has not been demonstrated with candidate aeroshell materials. The objective of this effort is to design, fabricate, characterize, and test ultrasonically absorptive aeroshell materials that successfully damp the second mode instability to delay BLT on hypersonic boost-glide weapons.

Specifications Required: The porous material needs to offer mechanical properties, thermal protection capabilities, and surface roughness comparable to current aeroshell materials used on hypersonic boost-glide demonstrators. The material porosity needs to be tailored to the flight trajectory to attenuate the second mode instability over the range of velocity and altitudes achieved during pull-up and glide. Relevant Mach numbers are between 6 and 18 at altitudes between 90 and 130 kft. The porous surface must not have large protuberances that could trip the flow. Typical unstable frequencies range between 50 and 1000 kHz depending on the flight trajectory, vehicle angle of attack, and geometry. The ultrasonic absorptivity of the material will have to be characterized over this relevant range of frequencies.

Technology Developed: The technology being developed by Materials Research & Design, Inc. (MR&D) is an aeroshell material which has a prescribed surface porosity configuration (size and spacing of holes) intended to delay or prevent the boundary layer transition (from laminar to turbulent) resulting in reduced thermal loading. Thus far, MR&D has successfully fabricated test specimens with the desired surface porosity and conducted ultrasonic absorption testing which demonstrated the ability to significantly absorb the applied pressure wave.

Warfighter Value: Allows for feasibility of wider range of trajectories, as well as more controlled flight.

WHEN

Contract Number: N68335-20-C-0580 **Ending on:** June 24, 2022

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Demonstrate feasibility that an aeroshell material with prescribed surface porosity could delay BLT	N/A	Stability analysis showed the inclusion of surface porosity effectively attenuated some frequencies and reduced the growth rate for others	2	1st QTR FY20
Proof of concept that surface porosity increases the absorption coefficient of representative aeroshell materials	N/A	Conducted laboratory ultrasonic absorption testing which demonstrated the ability to absorb up to two thirds of the applied pressure wave	3	3rd QTR FY21
Demonstration of the boundary layer transition delay	Med	Wind tunnel testing of 7 deg cone with representative aeroshell segment with prescribed surface porosity, along with a baseline (smooth) model to show the BLT delay	6	3rd QTR FY22
If option is awarded, measurement of material recession in flight-like conditions	Med	Arc jet testing under representative conditions	6	4th QTR FY23

HOW

Projected Business Model: As a service-based company, MR&D often does not retain ownership of the designs resulting from R&D work. Ultimately, the final designs are owned by the prime contractor who has provided the geometric envelope and design requirements to enable the component design. This requires a close working relationship with such companies to ensure that the final design blends with current operational requirements. For this reason, MR&D has included one of the vehicle prime contractors as a subcontractor on this effort. This technology would most likely need to be sold to a prime/system integrator for insertion into a program of record. It is MR&D's intention to be able to show feasibility of the technology and functionality of the design methodology within the SBIR effort. MR&D could then perform the design work needed to determine the proper surface porosity for the vehicle of interest and coordinate the fabrication and testing of prototype test articles for a prime/system integrator.

Company Objectives: MR&D seeks to discuss current needs relative to hypersonic aeroshells with both ceramic matrix composite (CMC) fabricators and prime contractors. In addition, MR&D is also looking to discover new opportunities and potential customers who could benefit from MR&D's design and analysis expertise in high temperature composite materials.

Potential Commercial Applications: Commercial space companies, such as SpaceX, Generation Orbit and Virgin Galactic are gradually developing vehicles capable of hypersonic flight. As operational needs for these vehicles increase, there may be a need to develop aeroshells with the appropriate surface porosity to delay boundary layer transition, reduce thermal loading and associated insulation weight, and expand the performance of the vehicle.

Contact: Kerry Howren, Program Manager
kerry.howren@m-r-d.com 610-945-8347