Advanced Reentry Aeroheating Simulation Framework, Phase I Project

SBIR/STTR Programs | Space Technology Mission Directorate (STMD)

ABSTRACT

Vehicle reentry presents numerous challenges that must be carefully addressed to ensure the success of current and future space exploration missions. As they enter the atmosphere, these vehicles are subjected to extreme hypersonic environments typified by large structural loads, high heat fluxes and temperatures, and an aggressive aerothermal environment where nonequilibrium dissociated gases may cause chemical ablation at the vehicle's surface. These hypersonic flows involve highly nonlinear fluid-thermal interactions such as very strong shocks, high aeroheating, and shock boundary layer interactions. The extreme environments result in nonlinear, coupled interactions between the vehicle's structure and the environment. Traditionally, designs of reentry vehicles and their components have been analyzed by different engineering disciplines in an uncoupled manner, leading to a simplified superposition of different independent analyses. Depending on the assumptions, this can potentially lead to overconservatism or omission of multiphysics phenomena such as the deformation of structural skin panels which alters the local flow field and results in higher aerodynamic and heat loading. To alleviate these problems, ATA Engineering proposes to develop an innovative approach utilizing an existing multiphysics framework that enables a more complete simulation of the aeroheating environment throughout the flight trajectory in the continuum regime is proposed. In Phase I, we will demonstrate feasibility of solving these problems in ATA's multiphysics simulation environment by coupling CHAR (a 3D, implicit charring ablator solver), Loci/CHEM (a computational fluid dynamics solver for highspeed chemically reacting flows), and Abaqus (a commercial nonlinear structural dynamics package) to create a fully coupled aerothermoelastic charring ablative solver. Phase II will involve enhancements to enable full trajectory simulation and tool validation with experimental data.

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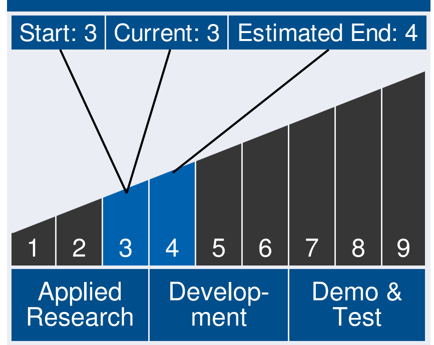
Technology Maturity



Management Team

Program Executives:

- Joseph Grant
- Laguduva Kubendran

Program Manager:

- Carlos Torrez

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ANTICIPATED BENEFITS

To NASA funded missions:

Potential NASA Commercial Applications: NASA is embarking on the development of a number of new spacecraft systems employing crewed and unmanned vehicle designs that must survive the reentry environment and can be reused on subsequent missions. The proposed simulation technology will provide improved accuracy in simulating the environmental loading and response of these new systems, which include the Space Launch System's Orion Crew Vehicle, the Boeing CST100 commercial crew vehicle, and variants of the SpaceX Dragon capsule for both commercial crew and cargo missions. NASA's Space Technology Roadmap 14 calls for "higher fidelity, multi-physics predictive capabilities that reduce the need for excessive, and in some cases prohibitive, sizing margins and flight tests" This project will make significant progress towards that objective. The outcome will be a suite of fully-coupled simulation tools that could be used for the development of thermal protection systems on the aforementioned planned missions as well as new reentry technologies, such as the a Hypersonic Inflatable Aerodynamic Decelerator (HIAD), Supersonic Inflatable Aerodynamic Decelerators (SIADs), and Supersonic Disk Sail (SSDS) parachute.

To the commercial space industry:

Potential Non-NASA Commercial Applications: In addition supporting the design of thermal protection systems for NASA exploration and transportation missions, a fully coupled aeroheating simulation framework will provide new predictive capabilities for the development of a number of military hypersonic systems, which encounter similar extreme mission environments to spacecraft reentry vehicles. Candidates for infusion of this technology into the design process include: Ballistic reentry bodies (weapons systems such as ballistic missiles encounter hypersonic flow environments during the descent portion of their trajectory); Hypersonic vehicles

Management Team *(cont.)*

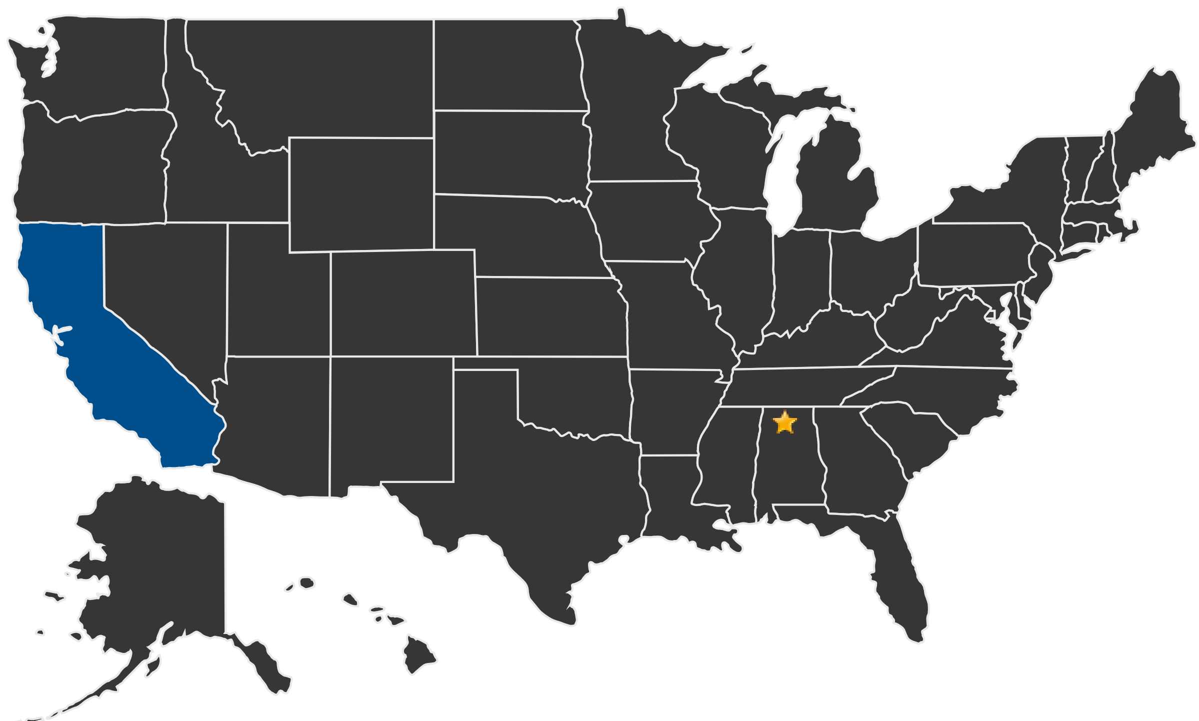
Principal Investigator:
- Eric Blades

Technology Areas

Primary Technology Area:
Thermal Management Systems (TA 14)
└─ Thermal Protection Systems (TA 14.3)
  └─ Ascent/Entry TPS (TA 14.3.1)

(President Obama has called for development of a new generation of hypersonic vehicles and several systems are now in early stage development); Kinetic interceptors (used for missile defense, kinetic "kill vehicles", such as those used in the Aegis and THADD systems, fly and maneuver at hypersonic speeds to reach their targets).

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Marshall Space Flight Center

Other Organizations Performing Work:

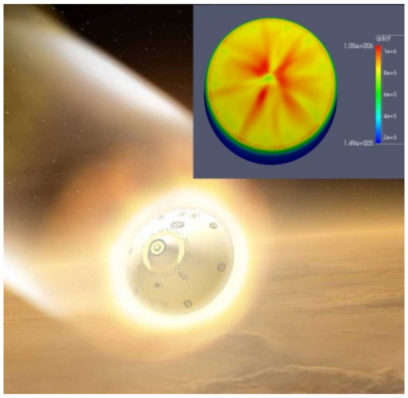
- ATA Engineering, Inc. (San Diego, CA)

PROJECT LIBRARY

Presentations

- Briefing Chart
    - (http://techport.nasa.gov:80/file/23423)

IMAGE GALLERY



Advanced Reentry Aeroheating Simulation Framework, Phase I

DETAILS FOR TECHNOLOGY 1

Technology Title

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Potential Applications

NASA is embarking on the development of a number of new spacecraft systems employing crewed and unmanned vehicle designs that must survive the reentry environment and can be reused on subsequent missions. The proposed simulation technology will provide improved accuracy in simulating the environmental loading and response of these new systems, which include the Space Launch System's Orion Crew Vehicle, the Boeing CST100 commercial crew vehicle, and variants of the SpaceX Dragon capsule for both commercial crew and cargo missions. NASA's Space Technology Roadmap 14 calls for "higher fidelity, multi-physics predictive capabilities that reduce the need for excessive, and in some cases prohibitive, sizing margins and flight tests" This project will make significant progress towards that objective. The outcome will be a suite of fully-coupled simulation tools that could be used for the development of thermal protection systems on the aforementioned planned missions as well as new reentry technologies, such as the a Hypersonic Inflatable Aerodynamic Decelerator (HIAD), Supersonic Inflatable Aerodynamic Decelerators (SIADs), and Supersonic Disk Sail (SSDS) parachute.