Efficient High Fidelity Computational Tool for Acoustically Driven Multiphysics Propulsion Modeling, Phase I Project

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

ABSTRACT

It is widely recognized that detailed simulation of large combustors to assess combustion instability and water spray systems to suppress rocket launch and test stand acoustic energy require advances in two phase flow, combustion, unsteady flow and acoustics modeling efficiency and fidelity. With recent advances in computer science technology, turbulent multiphysics modeling and high fidelity algorithms, current applications are poised for coordinated integration into a computational framework that offers realistic simulation of propulsion system fluid dynamics. MSU has recently implemented a hybrid 4th order skew symmetric flux in the Loci/CHEM multiphysics CFD solver. The new scheme has exceptionally low dissipation properties for vortical and acoustic signal propagation on both structured and unstructured meshes and offers excellent potential for analysis of acoustically driven propulsion system combustion instabilities. Simulation of large scale systems, however, is further complicated by the need to model unsteady turbulence effects. MSU has also recently employed the very promising dynamic hybrid RANS/LES methodology with the new low dissipation scheme to demonstrate significantly improved resolution of fine scale unsteady turbulence structures. For highly stretched boundary layer meshes, however, both implicit and explicit time integration schemes are problematic for thin boundary layers. Fortunately, dramatic performance improvements are possible through a novel hybrid explicit-implicit time integration scheme that uses the implicit treatment for fluxes constrained by the explicit stability limit and the explicit scheme elsewhere. Since the explicit method is more than an order of magnitude cheaper than the implicit scheme, the potential speedup could be a factor of ten. Thus the proposed computer science, turbulent multiphysics and high fidelity integrated framework can realistically expect to enable propulsion system DDT&E and production cost reductions.

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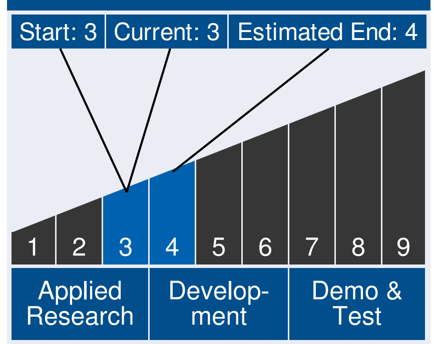
Technology Maturity



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: This technology will provide NASA with an efficient, robust multiphysics propulsion modeling and prediction tool that is built on coordinated advances in computer science, multiphysics modeling and high fidelity algorithms. The research product will provide enabling engineering and scientific technologies to model and predict acoustically driven propulsion related flow problems while reducing development, test, evaluation and production costs. Potential enhancements include improved two phase flow combustion models, enhanced droplet/turbulence interaction modeling, variable real fluids transport properties, expanded thermodynamic databases and extended model validation. The proposed computational tool is also applicable to water spray systems for suppression of rocket launch and test stand acoustic energy.

To the commercial space industry:

Potential Non-NASA Commercial Applications: The growing trend toward coupled multiphysics analyses is opening significant new markets as more difficult problems can be addressed using advanced computational techniques. The ability to robustly model acoustically driven combustion instability problems in propulsion will allow the commercial aerospace and defense industries to improve design and development of new products streamline ground testing and reduce flight risk. Our analysis software can also be applied to such varied commercial applications as coal, natural gas and food processing systems. The basic architecture of the modeling framework can remain the same while new plug-in modules are developed to address different physics and design requirements.

Management Team *(cont.)*

Principal Investigator:

- Robert Chamberlain

Technology Areas

Primary Technology Area:
Launch Propulsion Systems (TA 1)
└ Liquid Rocket Propulsion Systems (TA 1.2)
 └ Fundamental Liquid Propulsion Technologies (TA 1.2.6)

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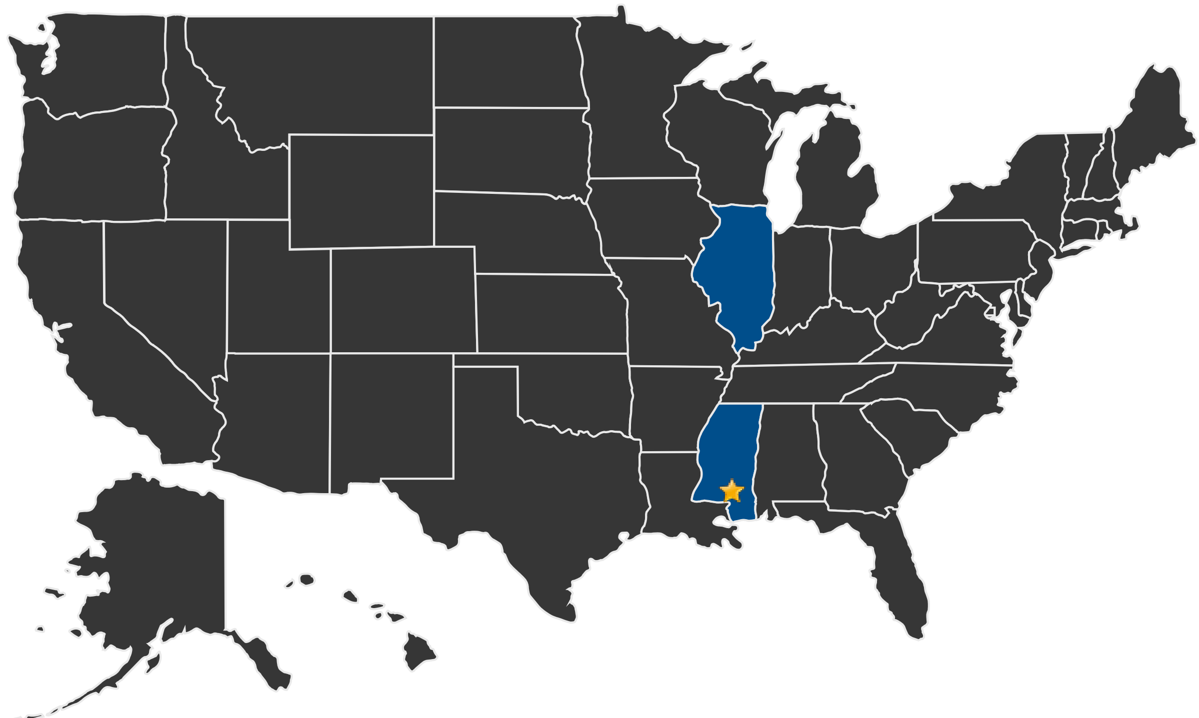
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Stennis Space Center

Other Organizations Performing Work:

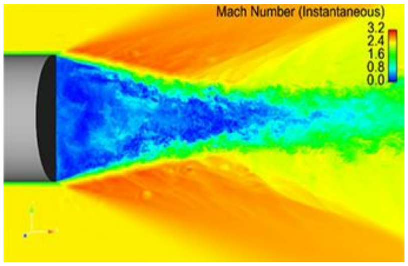
- Mississippi State University (Starkville, MS)
- Tetra Research Corporation (Princeton, IL)

PROJECT LIBRARY

Presentations

- Briefing Chart
  - (http://techport.nasa.gov:80/file/23599)

IMAGE GALLERY



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DETAILS FOR TECHNOLOGY 1

Technology Title

Efficient High Fidelity Computational Tool for Acoustically Driven Multiphysics Propulsion Modeling, Phase I

Potential Applications

This technology will provide NASA with an efficient, robust multiphysics propulsion modeling and prediction tool that is built on coordinated advances in computer science, multiphysics modeling and high fidelity algorithms. The research product will provide enabling engineering and scientific technologies to model and predict acoustically driven propulsion related flow problems while reducing development, test, evaluation and production costs. Potential enhancements include improved two phase flow combustion models, enhanced droplet/turbulence interaction modeling, variable real fluids transport properties, expanded thermodynamic databases and extended model validation. The proposed computational tool is also applicable to water spray systems for suppression of rocket launch and test stand acoustic energy.