Project Introduction

The innovation proposed here is a high performance, high fidelity simulation capability to enable accurate, fast and robust simulation of coupled cavitation and fluid-structure interaction (FSI) in flows involving cryogenic fluids of interest to NASA (such as LOX, LH2, LCH4 or RP-1). Cavitation and other unsteady flow-induced phenomena in some components of liquid rocket engines as well as testing can induce not only high-cycle fatigue but also structure failure, and possibly extensive damages to these components. The proposed work seeks to deliver a robust computational modeling capability to accurately predict and model the transient fluid structure interaction between cryogenic fluids and immersed components to predict the dynamic loads, frequency response of NASA's test facilities, and to substantially reduce the costs of NASA's test and launch operations. The key features of the proposed work are: (a) Accurate and efficient unsteady cryogenic cavitation simulation methodology, and (b) A robust first principles based fluid-structure interaction (FSI) capability. Both these methodologies will be tightly coupled within the framework of the Loci-STREAM code which is a Computational fluid dynamics (CFD) solver already in use at NASA for a variety of applications. This project seeks to further improve the current cavitation models within Loci-STREAM to achieve production status at NASA for time-accurate simulations of cavitating flows and at the same time integrate a fluid-structure interaction (FSI) methodology into Loci-STREAM. This will involve upgrading the current cavitation models in Loci-STREAM, improving the numerics of the solution algorithm from an efficiency point of view, improving coupling of the cavitation models and the FSI module with Loci-STREAM, and assessing the predictive capability for cases relevant to NASA.

Anticipated Benefits

1. Design of test facility components: resistance temperature detector (RTD) probes, bellows expansion joints.
2. Analysis of cryogenic propellant delivery systems (tanks, runlines), control elements such as LOX control valves.
3. Coupled hydrodynamics, valve timing and scheduling, & cavitation in cryogenic propellant/oxidizer feedlines, and flow devices (venturis, orifices).
4. Behavior of valves, check valves, chokes, etc. during the facility design process.
5. Design of tubopumps in LREs.

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1. Coupled cavitation and fluid-structure interaction modeling in liquid turbopumps.
2. Fluid-structure interaction (aeroelastic) modeling in gas turbines.
3. Design of test facility components.

**Primary U.S. Work Locations and Key Partners**

<table>
<thead>
<tr>
<th>Organizations Performing Work</th>
<th>Role</th>
<th>Type</th>
<th>Location</th>
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<tbody>
<tr>
<td>🌟 Stennis Space Center (SSC)</td>
<td>Lead Organization</td>
<td>NASA Center</td>
<td>Stennis Space Center, MS</td>
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<tr>
<td>Streamline Numerics, Inc.</td>
<td>Supporting Organization</td>
<td>Industry</td>
<td>Gainesville, FL</td>
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**Organizational Responsibility**

- **Responsible Mission Directorate:** Space Technology Mission Directorate (STMD)
- **Lead Center / Facility:** Stennis Space Center (SSC)
- **Responsible Program:** SBIR/STTR

**Project Management**

- **Program Director:** Jennifer L Gustetic
- **Program Manager:** Carlos Torrez
- **Principal Investigator:** Siddharth Thakur

**Technology Maturity (TRL)**

<table>
<thead>
<tr>
<th>Start</th>
<th>Current</th>
<th>Estimated End</th>
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<td>5</td>
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**Closeout Documentation**

Final Summary Chart
(https://techport.nasa.gov/file/37567)
High Performance Solver for Coupled Cavitation and Fluid-Structure Interaction in Cryogenic Environments, Phase I
Completed Technology Project (2018 - 2019)

Images

Project Image
(https://techport.nasa.gov/image/34864)

Technology Areas
Primary:

- TX14 Thermal Management Systems
  - TX14.1 Cryogenic Systems
    - TX14.1.5 Cryogenic Analysis, Safety & Properties