Hypersonic Vehicle Propulsion System
Simplified Model Development

Thomas J. Stueber
Glenn Research Center at Lewis Field

Paul Raitano (GRC)
Dzu K. Le (GRC)
Peter Ouzts (GRC)

This document addresses the modeling task plan for the hypersonic GN&C GRC team members. The overall propulsion system modeling task plan is a multi-step process and the task plan identified in this document addresses the first steps (short term modeling goals). The procedures and tools produced from this effort will be useful for creating simplified dynamic models applicable to a hypersonic vehicle propulsion system. The document continues with the GRC short term modeling goal. Next, a general description of the desired simplified model is presented along with simulations that are available to varying degrees. The simulations may be available in electronic form (FORTRAN, CFD, MatLab,...) or in paper form in published documents. Finally, roadmaps outlining possible avenues towards realizing simplified model are presented.
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Thomas J. Stueber
Glenn Research Center at Lewis Field
Ph: (216) 433-2218
FAX: (216) 433-8643
thomas.j.stueber@nasa.gov
http://www.grc.nasa.gov/WWW/cdtb

Paul Raitano (GRC)
Dzu K. Le (GRC)
Peter Ouzts (GRC)
Hypersonic Project GNC

- Interested in controlling the Hypersonic Vehicle Propulsion system.
- Gain insights in Propulsion-Control and Flight-Control coupling issues.

Four Basic Elements Necessary to Design Controllers:
- Models,
- Objectives,
- Admissible controllers, and
- Controller performance Metrics.

Propulsion system primary Components:
- Fore body compression surface,
- Inlet,
- Isolator
- Combustor, and
- Expansion Nozzle.

TBCC Concept

The Vision vehicle:
- Turbojet or afterburning turbojet
- Dual-Mode Combustor

Transition from one flow path to another is a critical and enabling procedure for the hypersonic vehicle.

Simplified Inlet Model Structure

- Free-stream conditions.
- Low-speed path cowl position.
- Low-speed path ramp position.
- Low-speed path bleed flow.
- Low-speed path back flow rate.
- High-speed path cowl position.
- High-speed path back flow rate.

Inlet Model

- Low-speed path normal shock position.
- Low-speed path axial pressure distribution.
- Low-speed path axial temperature distribution.
- High-speed path axial pressure distribution.
- High-speed path axial temperature distribution.
Analytical Resources

Electronic Resources
- LAPIN
- SRGULL

Vehicle Simulations
- GHAME
- AFRL

Supersonic Inlet Simulations
- NACA reports,
- Compressible Flow Toolbox,
- Sorensen,
- Anderson,
- Willoh, Cole, Melcher, and Johnson,
- Amin,
- Pratt and Heiser,
- Kumar,
- Pinckney, and
- Chicatelli.

Engine Simulations
- A/B Turbojet
- SRGULL

L-IMX Low-Speed Flow-Path External Shock Structure

10x10 Wind Tunnel Simulation
Free Stream Conditions:
Mach No. 3.1,
Angle of Attack, 6.5 deg.
$P_x = 0.5745$ lb/ft$^2$
$T_x = 282.72$ R,
$\rho = 4.692 \times 10^{-6}$ lb/ft$^3$
Propulsion Modeling Roadmap

- NACA reports
- Compressible Flows Toolbox

Vehicle Body

- Willoh, Cole, Melcher, and Johnson;
- LAPIN; and
- Amin
- CFD

Procedures and Modeling Tools

- Setup,
- Run, and
- Data reduction.
- MatLab/Simulink.
- Documentation.

Afterburning Turbojet

- SRGULL,
- Willoh, Cole, Melcher, and Johnson;
- LAPIN; and
- Amin
- CFD
Aero-Servo-Elasticity Aspects

bending

aero load dynamics

bending

drag

Large Scale Mode Transition Inlet (L-IMX)
Hypersonic Project GNC Overview

Develop Tools and Procedures

**Task 1**
Simplified Models

**Component Models**
- Fore body compression,
- Inlet,
- Isolator,
- Combustor, and
- Expansion Nozzle

**Task 2**
Identify:
- Objectives,
- Admissible Controllers, and
- Controller performance Metrics

**Task 3**
Controllers:
- Component Controllers
  - Fore body compression,
  - Inlet,
  - Isolator,
  - Combustor, and
  - Expansion Nozzle

Integrated Propulsion Controller
- Overall Propulsion, Vehicle, and flight trajectory Control

Integrate Propulsion and Vehicle Dynamics Model

GNC
1. **L-IMX**: Performance, operability, and mode transition testing.
2. **C-IMX**: Control research and development.
3. **CCET**: Integrated inlet system with engines.

1. High speed flow path simulations.
2. Low-speed flow path simulations.
3. Simplified L-IMX computational models.
4. Simplified engine simulations.
5. L-IMX Schedule and Controller designed.
6. Inlet controller coupled with engine control.

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