f/12

2000 NPSS Review

NASA Glenn Research Center
October 4-5, 2000

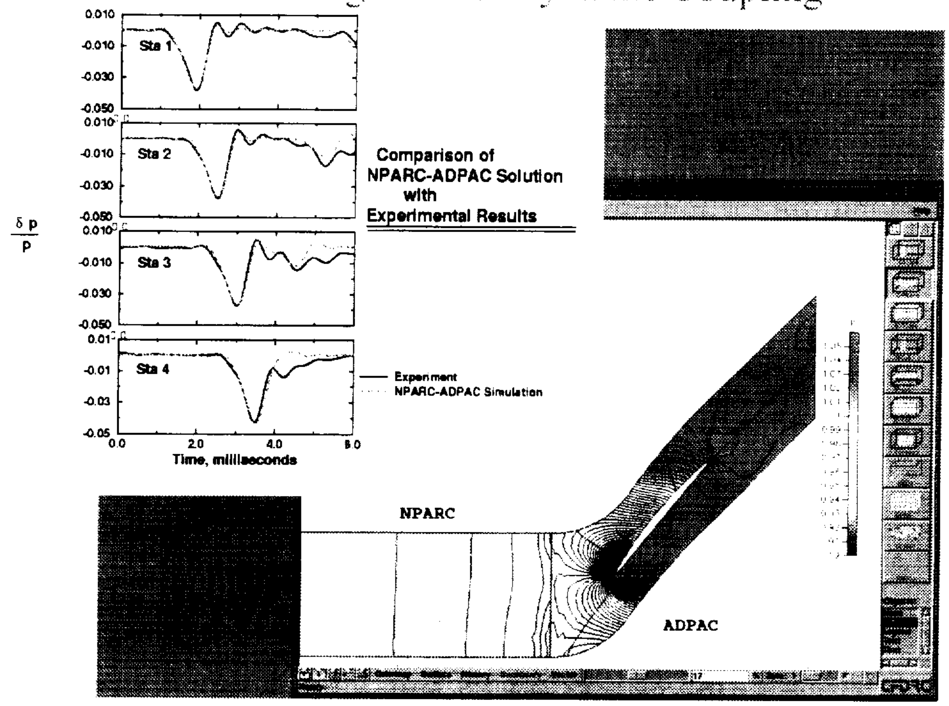
Space Transportation Propulsion Systems

Dr. Meng-Sing Liou
Dr. Mark E. Stewart
Dr. Ambady Suresh
Dr. A. Karl Owen

Outline

- Review of Engine/Inlet Coupling Work
- Background/Organization of Space Transportation Initiative
- Synergy between High Performance Computing and Communications Program (HPCCP) and Advanced Space Transportation Program (ASTP)
- Status of Space Transportation Effort
  - Planned Deliverables FY01-FY06
  - FY00 Accomplishments (HPCCP Funded)
  - FY01 Major Milestones (HPCCP and ASTP)
- Review Current Technical Efforts
  - Review of the Rocket-Based Combined-Cycle (RBCC)
  - Scope of Work
  - RBCC Concept Aerodynamic Analysis - Dr. Stewart
  - RBCC Concept Multidisciplinary Analysis - Dr. Suresh

Engine Inlet Dynamic Coupling

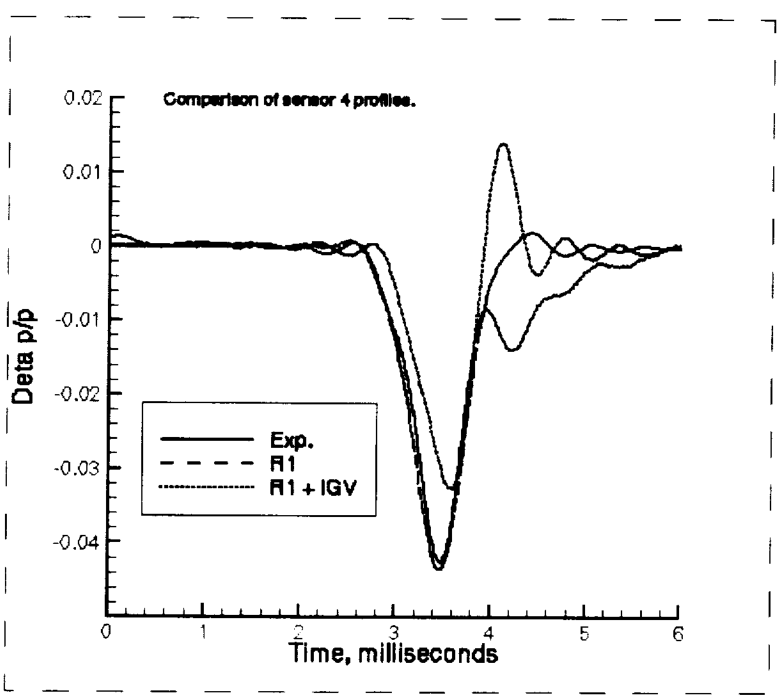


Normalized Static Pressure (Mid-Span)

ADPAC - Advanced Ducted Propfan Analysis Code
NPARC - National Program for Applications Oriented Research in CFD

2000 NPSS Review

Results



- Additional blade row was modeled.
- Coupled using unsteady mixing plane technique.
- Simulation results not significantly improved.
- Current effort stopped, documented for possible future reopening.

R1 - Rotor 1
IGV - Inlet Guide Vane

2000 NPSS Review

Space Transportation Initiative

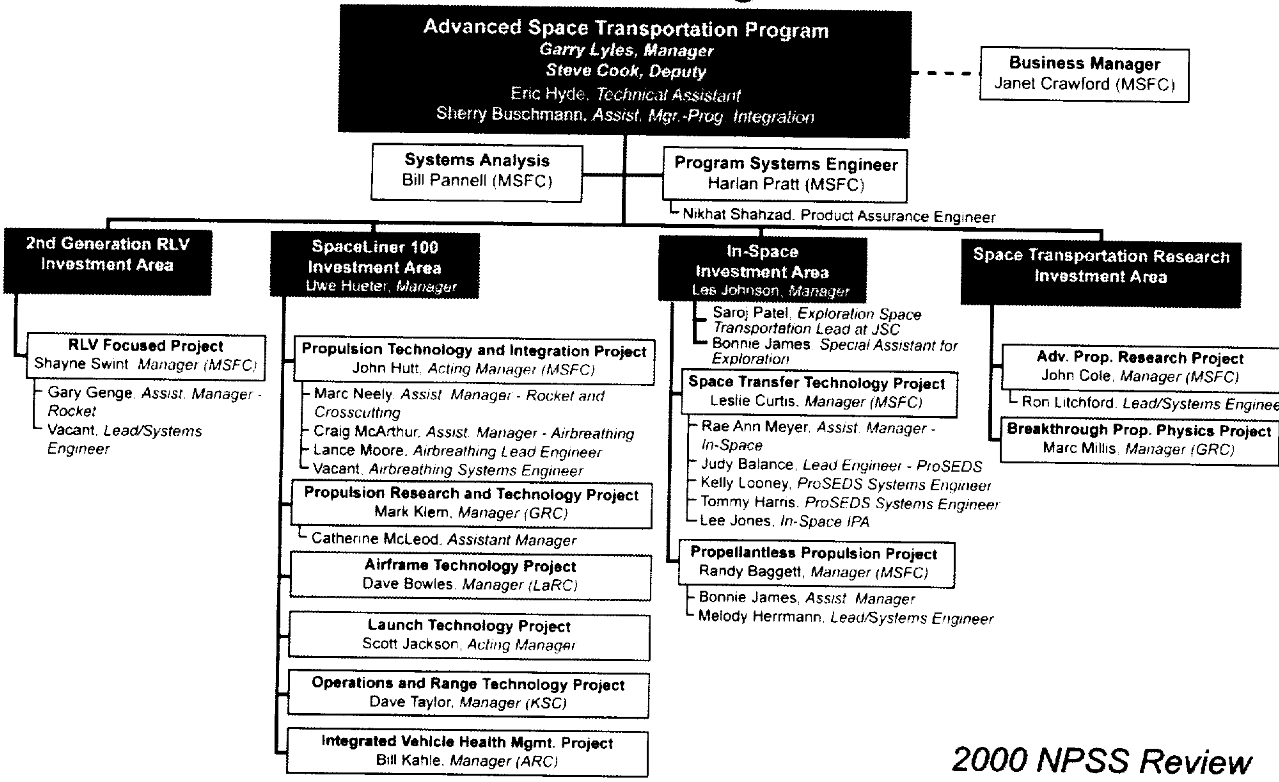
2000 NPSS Review

Background

- Growing importance of advanced space transportation propulsion systems and simulations to support development & use of advanced space systems.
- Small space transportation simulation effort begun in FY00.
- Evaluation of advanced technologies by Advanced Space Transportation Program (ASTP) highlights importance of advanced system modeling capabilities.
- Computing and Interdisciplinary Systems Office (CISO) proposes for funding under second- and third-generation reusable launch vehicle projects.
  - Third-generation funds
  - Second-generation zeroed-out in FY01 budget

2000 NPSS Review

New ASTP Organization



2000 NPSS Review

ASTP Propulsion Story

Second Generation

- **Currently cut out of budget by Congress**
- **Short-term focus – out to FY06**
- **Huge budget – ~$5B – hardware-oriented**
- **Four proposal cycles**
- **Industry-led – hope to team with industry**
- **Proposed under Cycle 2 – rocket sim. development – still under consideration**

Third Generation - SPACELINER100

- **Third-generation Spaceliner**
- **FY01 budget: $445M – foundations – $9.6M**
- **Mature base (foundation) technologies to enable broad range of concepts to meet Gen 3 goals (FY01-06)**
- **Mature rocket engine components to enhance T/W, performance, etc. (FY01-06)**
- **Mature air-breathing components for combined-cycle vehicle thru TRL 6**
- **Fund university studies to identify new concepts (other than rockets or air-breathers) to meet goal 9**

T/W - Thrust to Weight Ratio

2000 NPSS Review

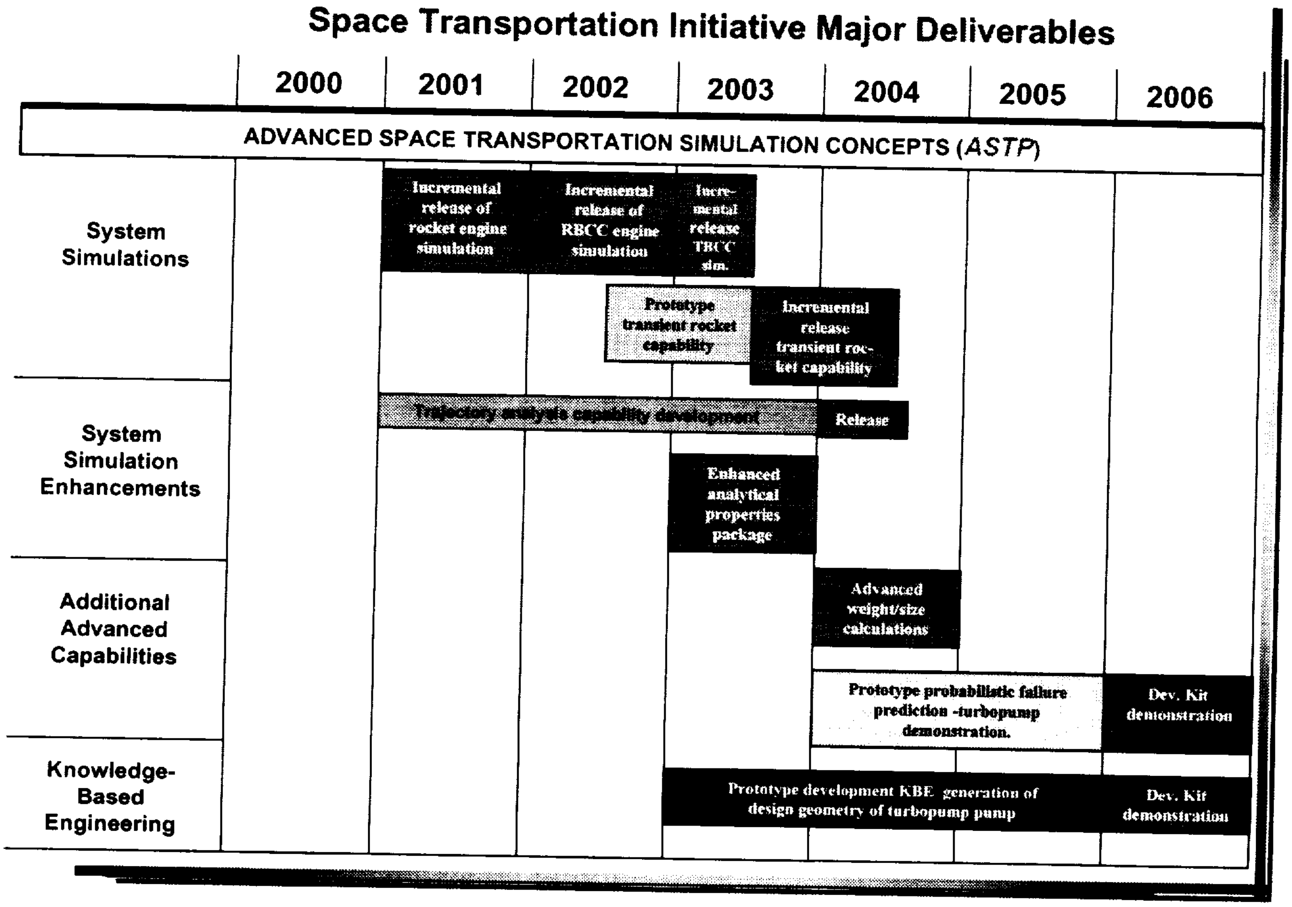
Synergy

- Third-generation reusable launch vehicle funding promised in FY01. Focus on system development:
  - Begin development of rocket engine system simulation
  - Begin development of RBCC system simulation
- HPCCP to focus on high-fidelity and multidisciplinary simulation and prototyping for coupling/zooming/optimization.
- Second-generation reusable launch vehicle funding possible in FY01.
- Future integration.

2000 NPSS Review

Space Transportation Initiative Major Deliverables

	2000	2001	2002	2003	2004	2005	2006
DEMONSTRATE INTEGRATED TECHNOLOGIES (*HPCCP*)							
RBCC Multi-Disciplinary Coupling	Structural-thermal analysis of GRC RBCC axisymmetric inlet GTX forebody and diverter aerodynamic analysis	Coupled aero-structural-thermal analysis of inlet Forebody simulation for radiation & skin thermal conductivity	Coupled multidisciplinary forebody/inlet demonstration	Dev. Kit tool release			
Pump Multi-Disciplinary Coupling		Uni-directional unsteady aero-structural pump prototype	Bi-directional unsteady aero-structural pump prototype	Bi-directional unsteady aero-structural pump production	Bi-directional unsteady aero-structural pump Dev. Kit tool		
Advanced Grid Generation		Beta release for robust hybrid grid code generator	Release grid code as a stand-alone package for Version 1	Grid generation production demonstration and enhancements			
Zooming					Demonstration of turbopump SS operation zoomed from NPSS rocket sim.	Demonstration of turbopump unsteady operation zoomed from NPSS rocket sim.	Dev. Kit demonstration of turbopump unsteady operation zoomed from NPSS



FY00 Accomplishments and FY01 Milestones

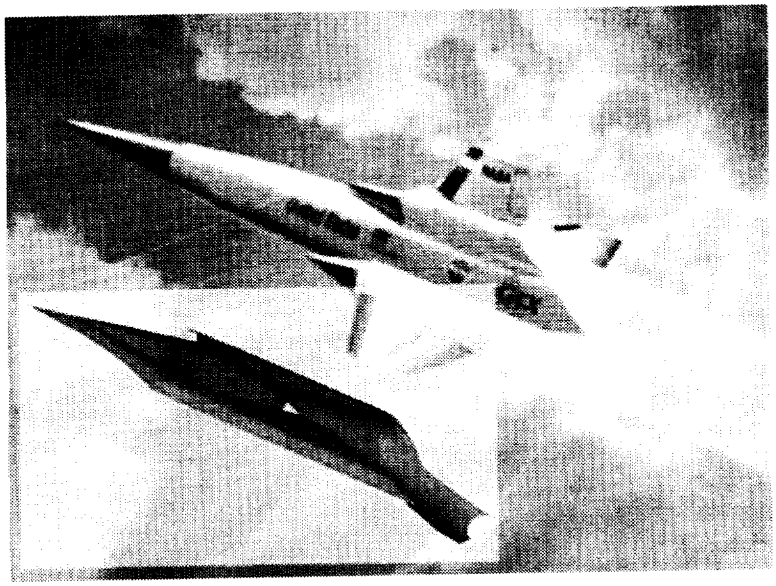
- Accomplishments
  - GRC RBCC concept forebody & boundary layer diverter capability demonstrated.
  - Coupled structural-thermal analysis of GRC RBCC inlet demonstrated.
  - SRS for space transportation incremental release.
  - Acting TFG for space transportation.

- Milestones
  - Coupled aero-structural-thermal analysis of inlet **(HPCCP)**.
  - Modify CFD forebody simulation for radiation & skin thermal conductivity **(HPCCP)**.
  - Incremental release rocket system simulation **(ASTP)**.
  - Formal contractual mechanisms & cooperative agreements in place.
  - Space transportation SRS for Version 2 release.

SRS - Software Requirement Specification
TFG - Technical Focus Group

2000 NPSS Review

Technical Effort: *Glenn Research Center RBCC Concept Support (HPCCP)*



2000 NPSS Review

Motivations for Scope of Work

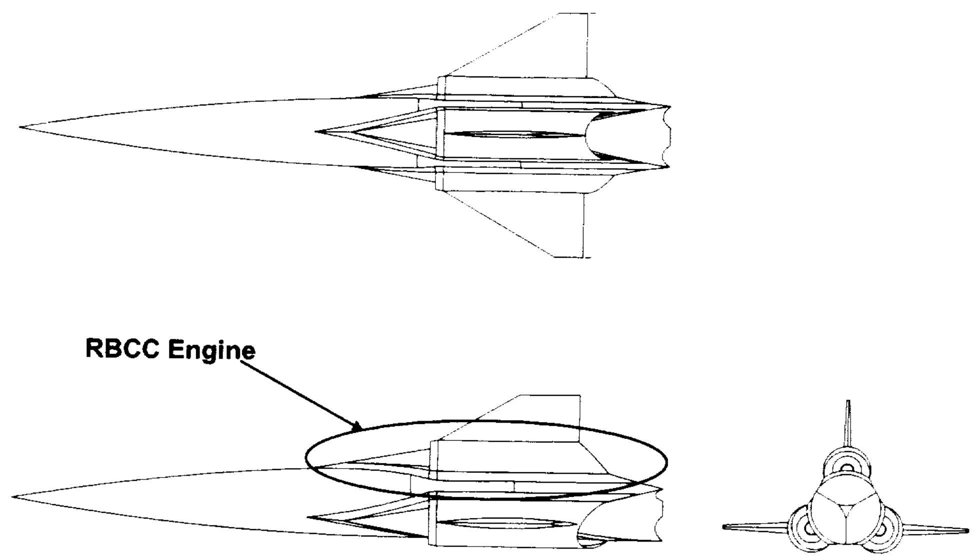
Motivations

- **Requirements in support**
  - **Complex geometry**
  - **Physics**
  - **Accuracy**
  - **Efficiency**
  - **Robustness**
  - **Projects**
- **Improved multidisciplinary integration of fluid, thermal and structural analysis codes into current design cycles.**
- **Multidisciplinary analysis well suited to optimization of complete vehicle designs.**

Scope

- **Prototyping of high-fidelity and multidisciplinary coupling of simulations as a prelude to NPSS tool development.**
- **Reduction of analysis time.**
- **Detailed high-fidelity analysis of GRC RBCC concept (GTX).**

2000 NPSS Review

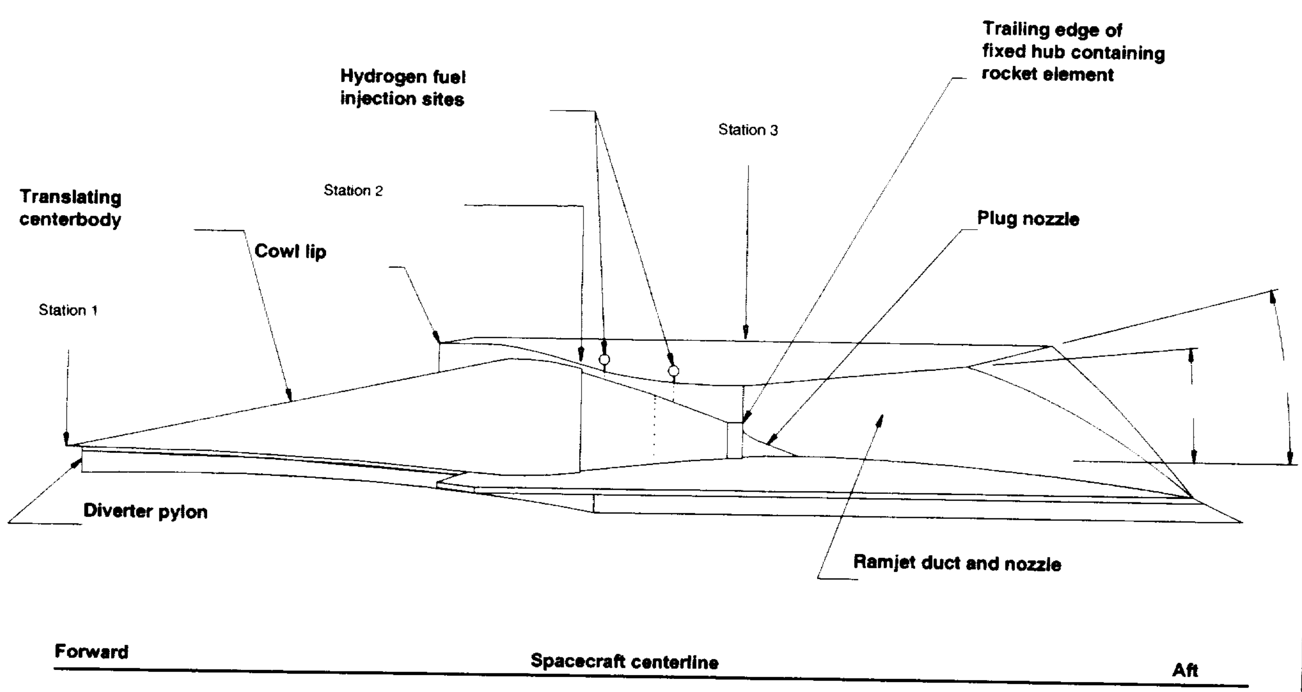


GTX Reference Vehicle - 10a Propulsion Configuration - Rev J

Units = Inches

2000 NPSS Review

Rocket-Based Combined-Cycle (RBCC)



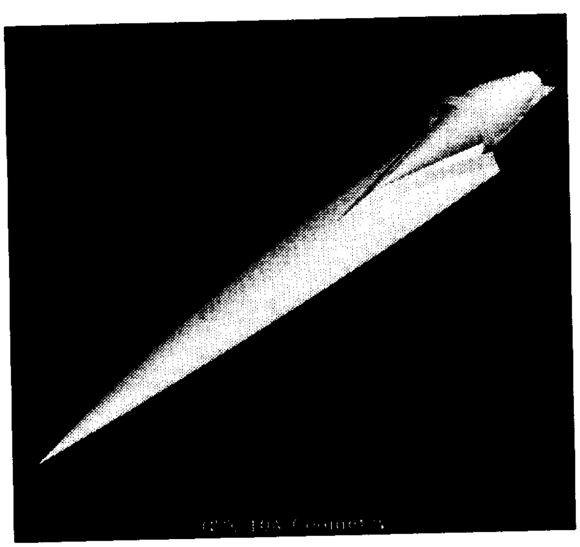
2000 NPSS Review

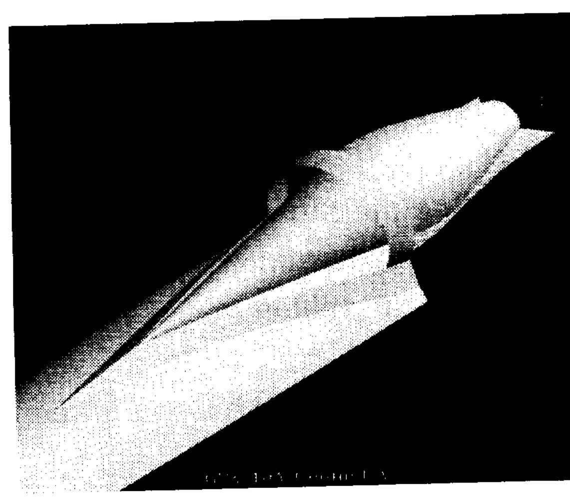
GRC RBCC 3-D Inlet-Forebody Aerodynamic Analysis

Dr. Mark Stewart

2000 NPSS Review

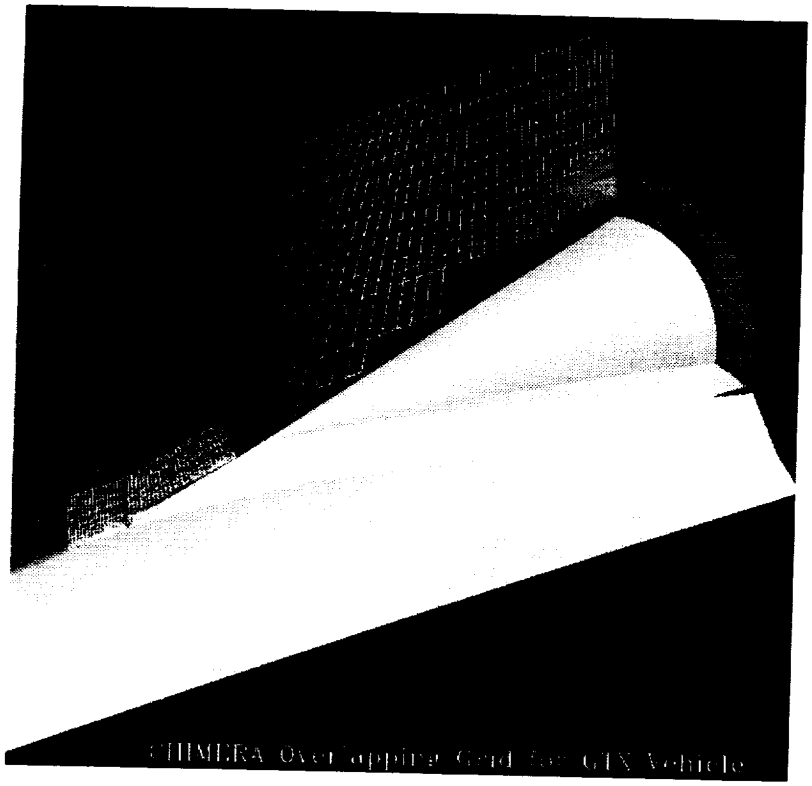
- RBCC, Single-Stage-to-Orbit
- Rocket and Air-Breathing RAM/SCRAM Modes
- Design Questions
  - -Diverter performance
  - -Forebody boundary layer's effect on inlet





- •Design point: M=6; altitude=80,000 ft; AOA=4°; Re/ft=1.4×10^5
- •Operating range of interest: M=2.5-10.; AOA=0°

2000 NPSS Review



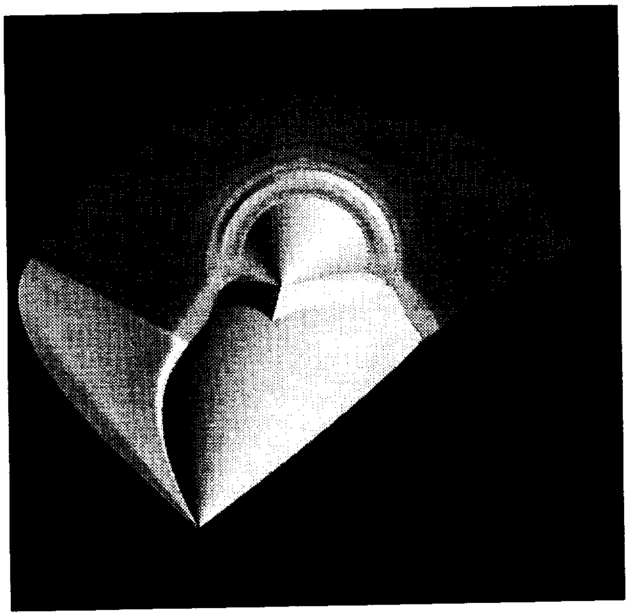
2000 NPSS Review

Validation of CFD Solutions

- Comparison with Theoretical Properties
  - Axisymmetry
  - Y^+ values
- Comparison with Cone Shock Solutions
- Comparison with Rig 3.1 at AOA=0°; M=2.0, 2.5, 3.0, 3.5
  - Forebody boundary layer profiles
  - Forebody static pressure distribution
- Comparison with Independent CFD Solution

2000 NPSS Review

Observations



- Results suggest diverter design changes.
- Results clarify some rig results.

2000 NPSS Review