Introduction

• NASA working to expand NPSS to space applications

• Working with Aerojet, Rocketdyne and PW to develop this capability

• Working both conventional rockets and combined cycles
  – Combined cycles of interest to NASA (TBCC, RBCC)

• Combined cycle needs are driving us to develop a heat transfer and hypersonic capability
Pratt & Whitney
Space Propulsion
NPSS Activities

Development of NPSS for Space Propulsion Applications

NPSS Annual Review
October 9-10, 2002

2002 CISO Review

P&W Space Propulsion Modeling

• Updated NPSS model of 2GRLV COBRA LH₂ / LO₂ engine

• Validated throttle transient operation against ROCETS model of COBRA engine

• Supported development of the Hypersonic ISTAR engine NPSS component elements to enable simulation of full trajectory performance

• Submitted revised NPSS component elements to NASA
Why does P&W Space Propulsion Want to Develop NPSS?

- NPSS would be a Corporate-wide application (P&W Jets, IFC, UTRC, etc.,)
- NPSS would create a Common Rocket - Airbreathing modeling system
  - Enables RBCC, TBCC modeling within single architecture
    - Eliminates requirement for manual data transfer for systems integration
    - Enables overall system optimization
- NPSS should reduce Joint Venture long-term modeling and analysis costs and reduce potential for confusion between multiple models
  - Applicable to iSTAR Consortium
  - No Need to Translate Methods Between P&W, Aerojet & Rocketdyne
  - No Need to Resolve Differences Between Multiple System Models
  - Enables Multi-site Real-time analysis
- NPSS has the Potential to become an Industry and DoD Standard
  - Lockheed & Boeing participating in NPSS Development
  - Aerojet & Rocketdyne participating in NPSS Development
- NPSS is a Flexible and Growth-Capable Architecture
  - Multidisciplinary “Zooming” inherent capability - single environment for 0-D through 3-D Analysis
  - Modern Object-Oriented programming that facilitates code re-usability

Aerojet GFY 2002 Tasks

- Support Development and Evaluation of RBCC & Ramjet/Scramjet Components
  - Scramjet entropy limit burner control volume model implemented
- Develop Liquid Rocket Engine Model
  - Create system simulation of existing engine
  - Verify against existing system model and applicable test data
  - New components useful for rocket and RBCC application
- Titan Stage 2 Engine Selected For Simulation
- Focus On Transient Model
Initial Results Are Promising

NPSS Benefits

- Integrated Model Reduces Amount Of Manual Iteration
- Ability To Specify Solver Dependents And Independents Very Useful For Design Studies
- Engine Model Easily Integrated With Facility Model To Support Wind Tunnel Testing
- NPSS Modeling Is Being Used To Support Scramjet Engine Development For The DARPA/ONR HyFly Program
NASA GRC / Boeing-Rocketdyne
NPSS Enhancement

- **Objective**
  - “... increase the usability of the current NPSS code/architecture by incorporating an advanced space transportation propulsion system capability into the existing NPSS code.”
    - Begin defining advanced capabilities for NPSS
    - Provide an enhancement for the NPSS code/architecture

- **Complementary with other efforts**
  - I*star
  - Air Force Supersonic/Hypersonic Vehicle Design (SHVD) program
  - NASA MSFC Intelligent Design Advisor (IDA)
  - Boeing Integrated Vehicle Design System (BIVDS)

- **Status**
  - Key enhancement defined (high-fidelity inlet analysis)
    - 2001: 3-D inlet geometry module completed; basis for automated inlet analysis module in IDA
    - 2002: 3-D geometry module enhanced to include I*star features; basis for future automated inlet analysis in SHVD
  - Groundwork laid for subsequent complementary enhancements

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NPSS: CEA, Janaf, GasTbl
Comparison

Hi-Mach Afterburning Turbojet
OPR 10
Janaf & GasTbl
LHV = 1875
CEA (fuel JP-7)
Primary Burner: hRef = -782
Afterburner: hRef = -1284
Run Time: Janaf ~ 100 times faster than CEA
Space Shuttle Main Engine (SSME) Modeling in NPSS

• Purpose

To develop and verify the use of NPSS for space propulsion system modeling using an established benchmark system – the SSME.

• Approach

– Validate the NPSS model results against those from an established simulation program – the Rocket Engine Transient Simulator (ROCETS) software.

– Demonstrate NPSS benefits, enhanced capabilities and flexibility relative to existing simulation software.

– Develop a library of space component models (turbines, pumps, ducts, combustors, etc.) which can be used generically to model other space systems.
SSME Modeling with NPSS (continued)

• Progress
  – Select library of generic space components developed.
  – Component models unit tested.
  – Preliminary modifications to NPSS thermo package interface completed.
  – SSME system model completed.
  – Beginning SSME system model testing (to be completed Oct 2002).

• Lessons Learned
  – Space propulsion systems have a very different set of data flow requirements than air-breathing elements typically do. The NPSS architecture will handle this, but requires the component programmer to clearly understand differences.
  – Space propulsion systems require fluid input and output port interfaces that are more flexible than those typically required for air-breathing system models. We need to disable some of the features included to prevent users from doing something unintended.

Status of Combined Cycle Work (CC)

• Team has developed an initial hypersonic library
• Team has developed an initial heat transfer capability
• Test models created of ISTAR at different operating points
  – Operating points run as separate design points
  – Not an NPSS issue, don’t have off-design data
Hypersonic/Heat Transfer Library

- Created new elements
  - Isolator, Burner, RocketMixer, Heat Transfer
- Heat transfer based on expander cycle (cool-side) and new heat transfer module (hot-side)
- Serve as a good first pass
  - Need to be upgraded to be accepted by the hypersonic community
- Major part of this year’s work will be to get a first rate hypersonic/heat transfer capability

ISTAR Demo Models

- Model the feed system and flowpath together
  - Truly are combined cycle models
- Feed system has an oxidizer and fuel legs
- Rocket exhausts into the flowpath in a mixer element
- Heat transfer from flowpath has a major impact on feed-system balance and feed system obviously affects flowpath solution
- Need combined solutions
Future Plans for Space Team

• Develop first-rate rocket analysis capability
• Develop first-rate hypersonic capability
• Support NASA programs
  – TBCC/RTA
  – ISTAR????