The Computing & Interdisciplinary Systems Office

Annual Review and Planning Meeting
October 9-10, 2002

NPSS SPACE TEAM

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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**

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Pratt & Whitney
Space Propulsion
NPSS Activities

Development of NPSS for
Space Propulsion Applications

NPSS Annual Review
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P&W Space Propulsion Modeling

Pratt & Whitney
A United Technologies Company

COBRA

- Updated NPSS model of 2GRLV COBRA LH_2 / LO_2 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

AEROJET   Pratt & Whitney
A United Technologies Company

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P&W Space Propulsion Modeling

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 I^{STAR} 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**
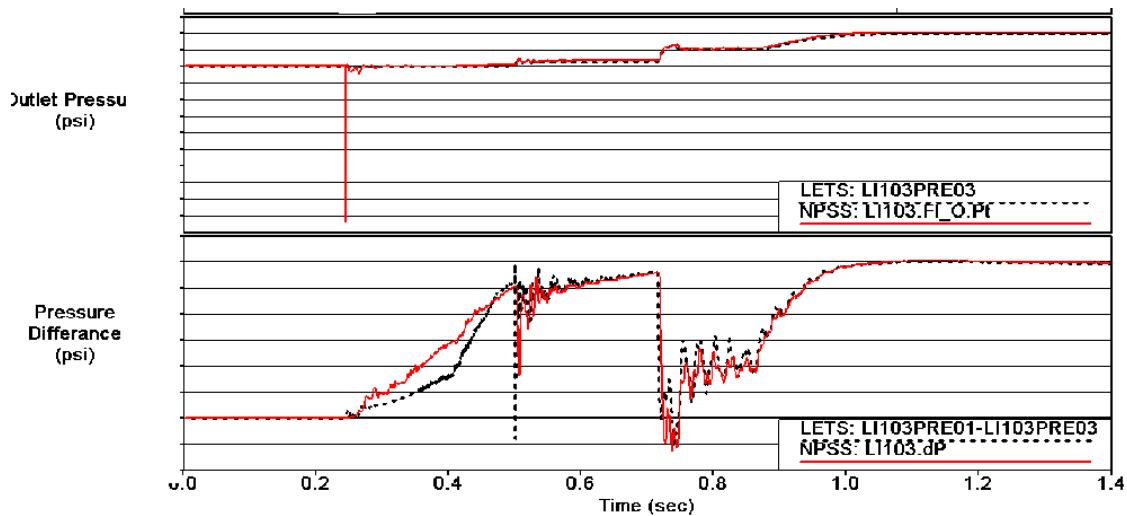
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Aerojet GFY 2002 Tasks

- **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**

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Initial Results Are Promising

Results shown for dummy sample pipe

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
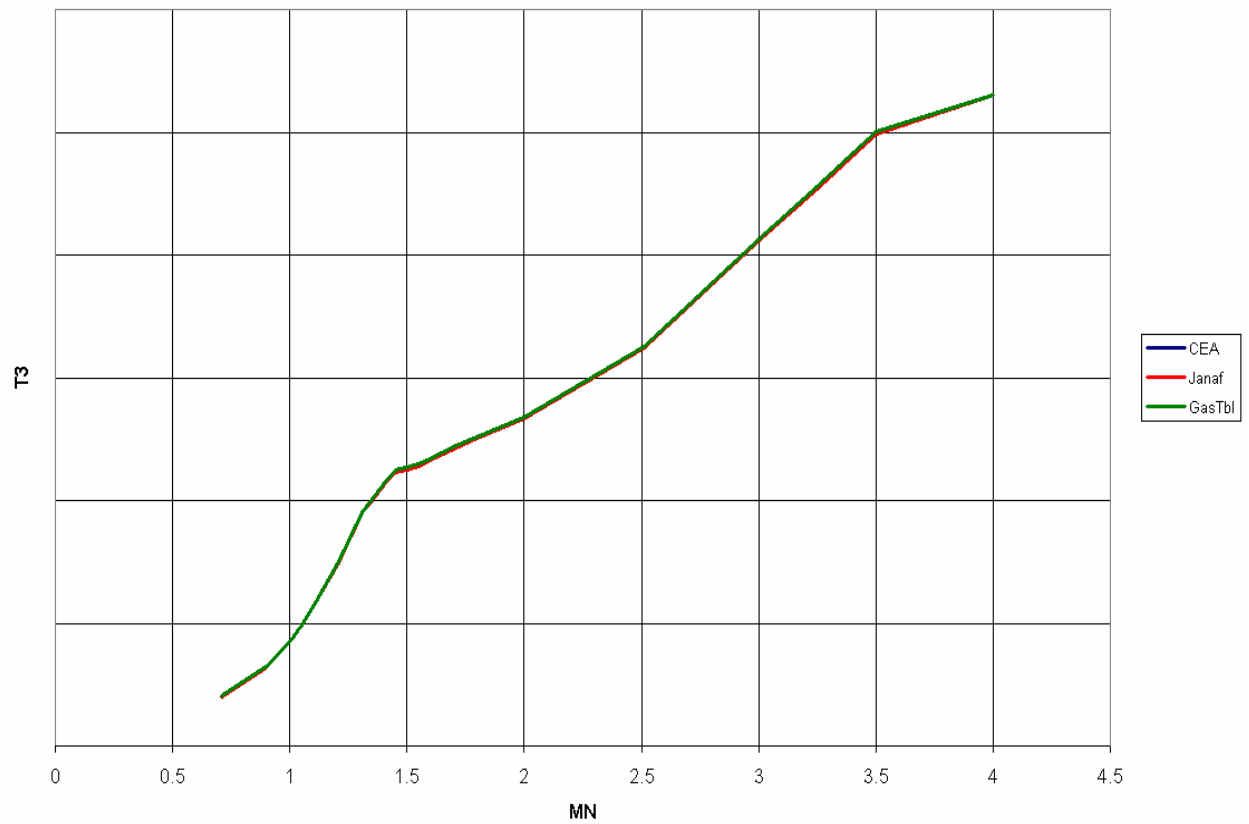
Janaf & GasTbl

LHV = 1875

CEA (fuel JP-7)

Primary Burner: hRef= -782
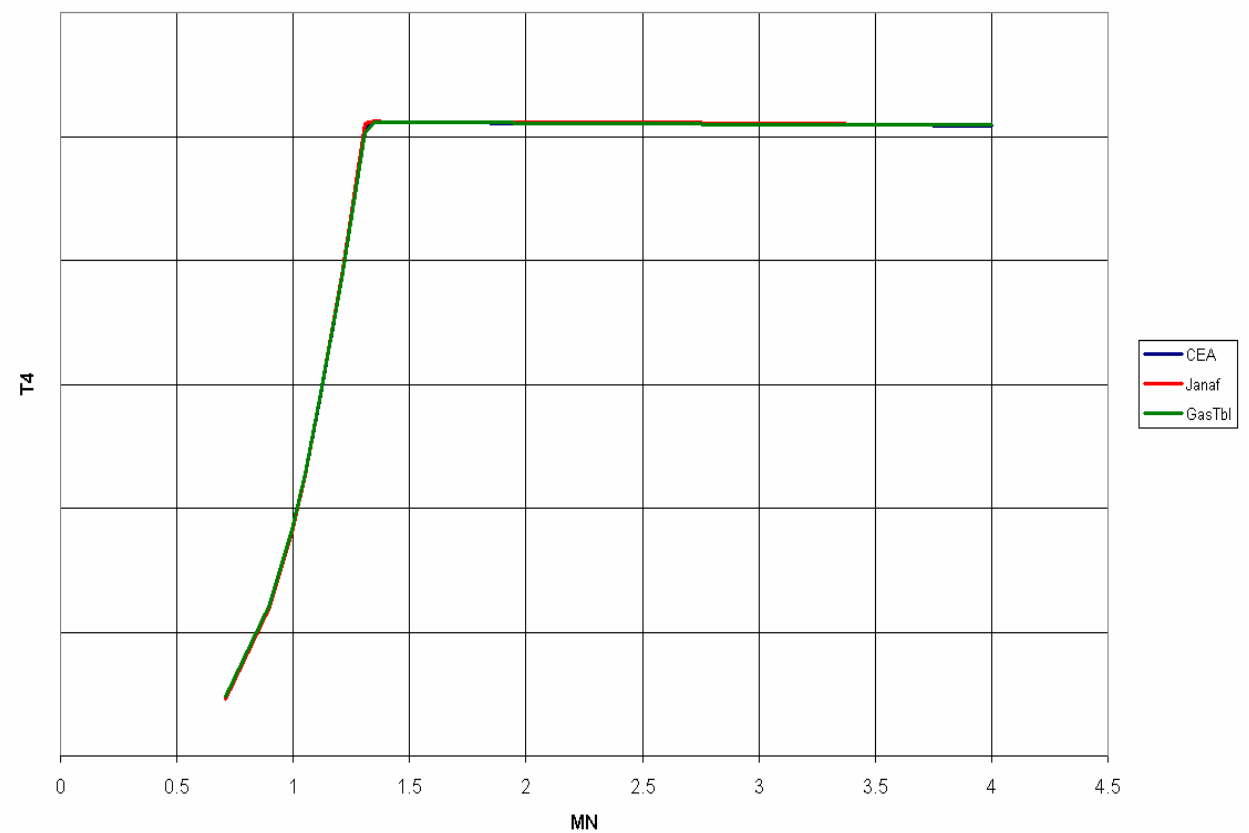
Afterburner: hRef = -1284

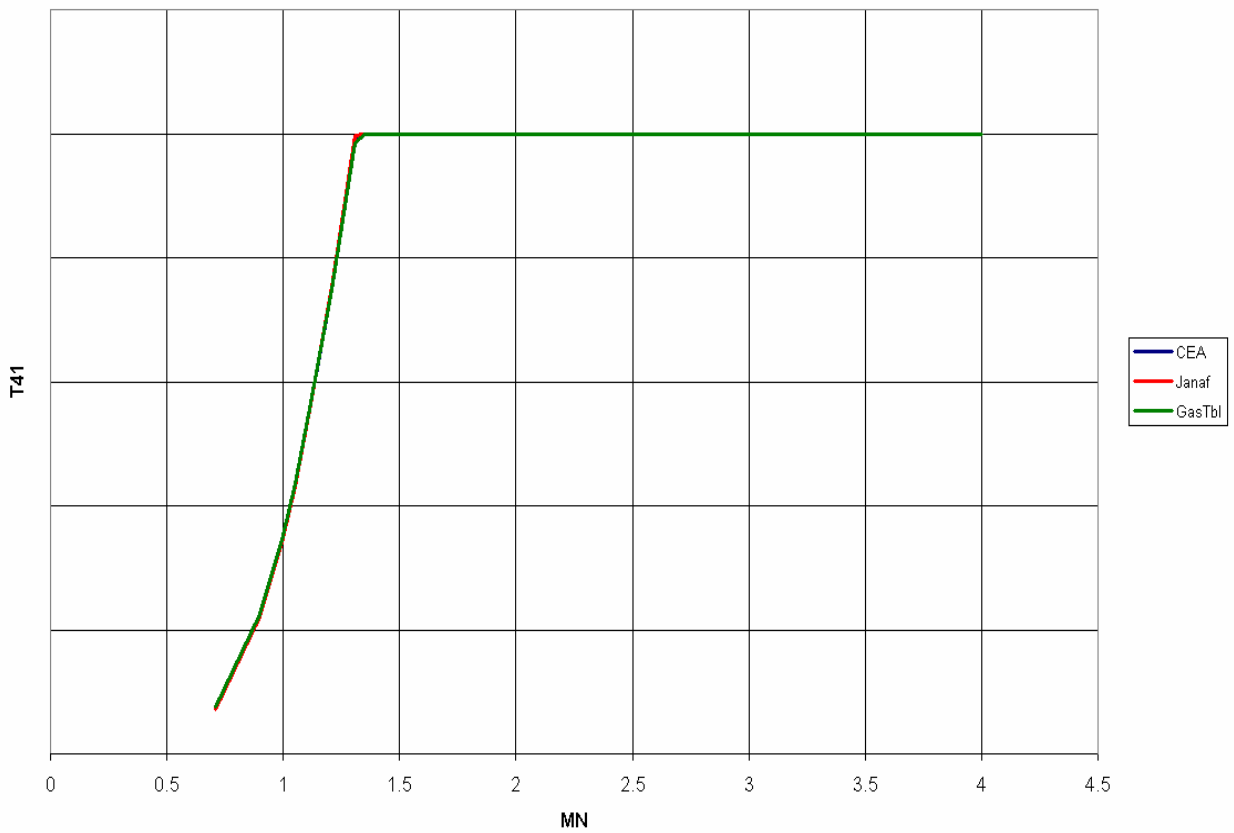## Run Time: Janaf ~ 100 times faster than CEA
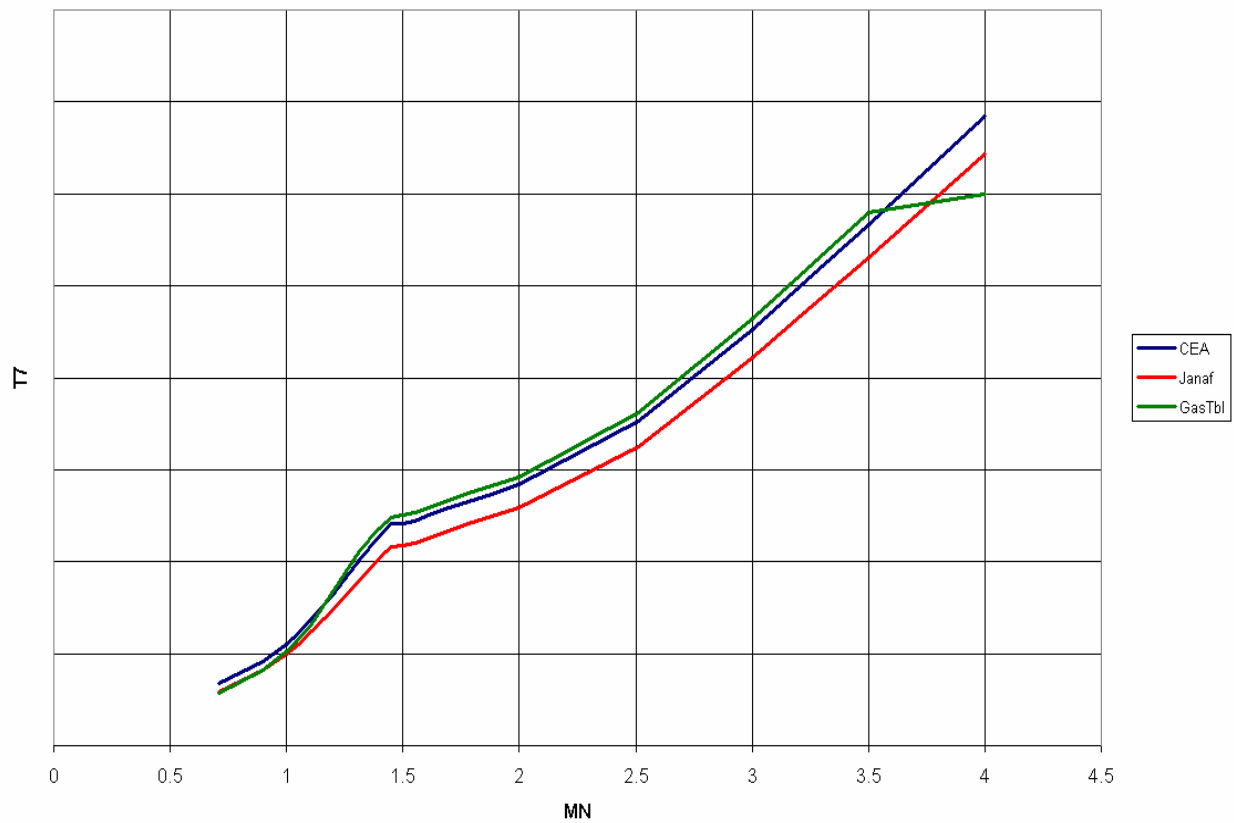
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T3 (Compressor Discharge) vs. MN

T4 (Turbine Vane Inlet) vs. MN

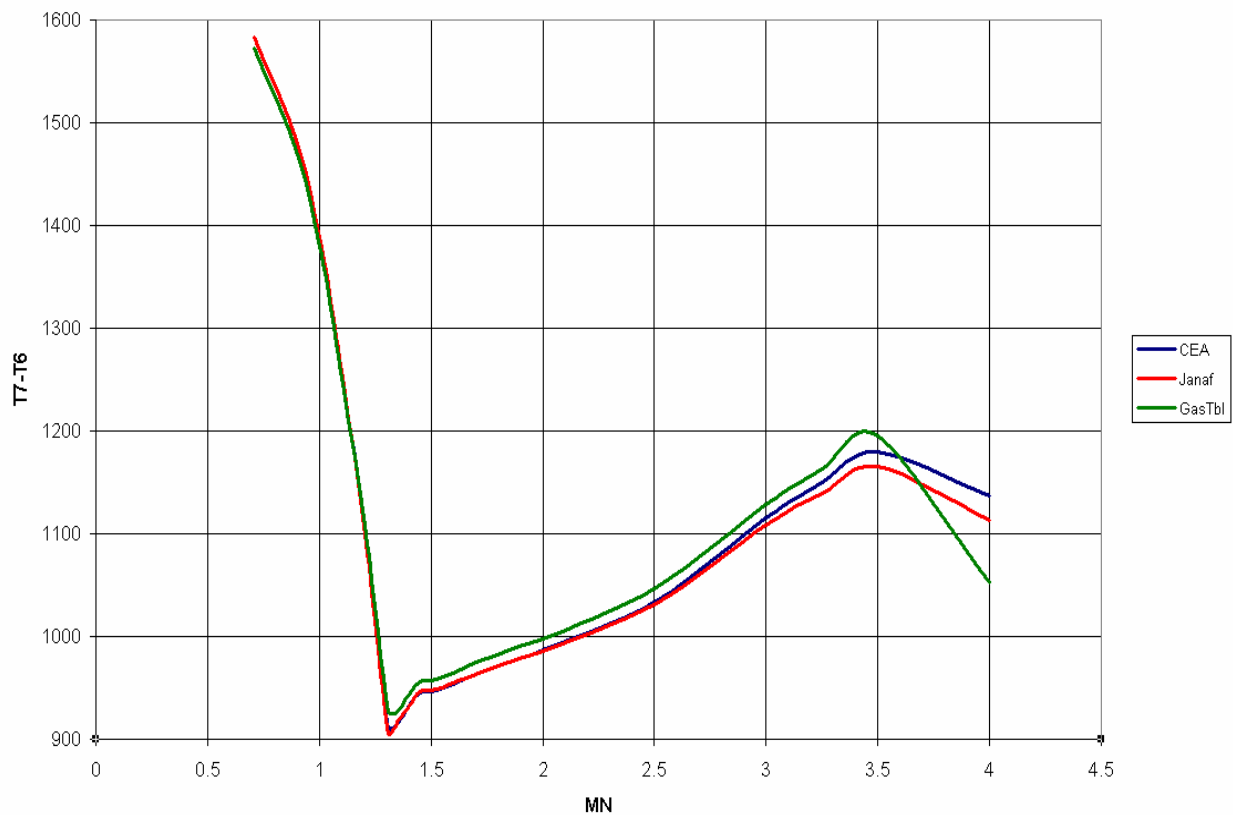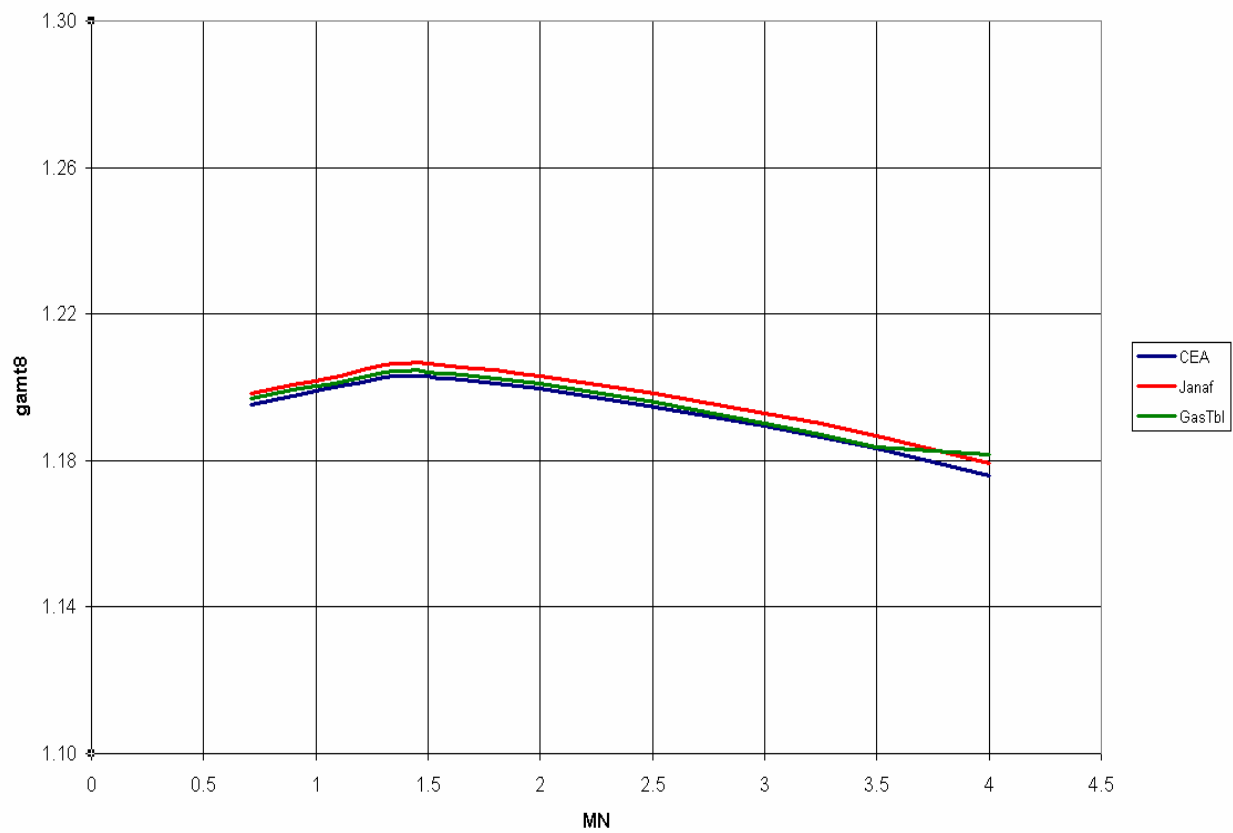## T41 (Turbine Rotor Inlet) vs. MN
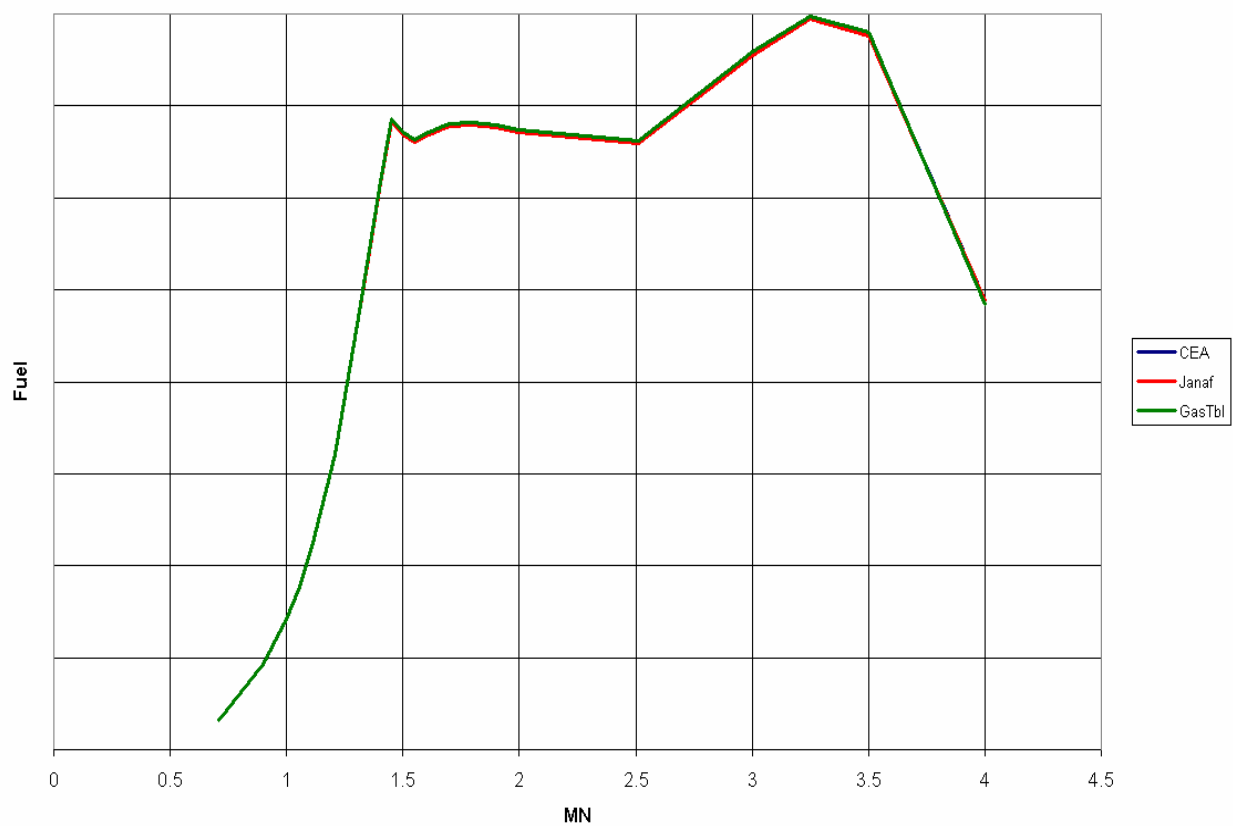

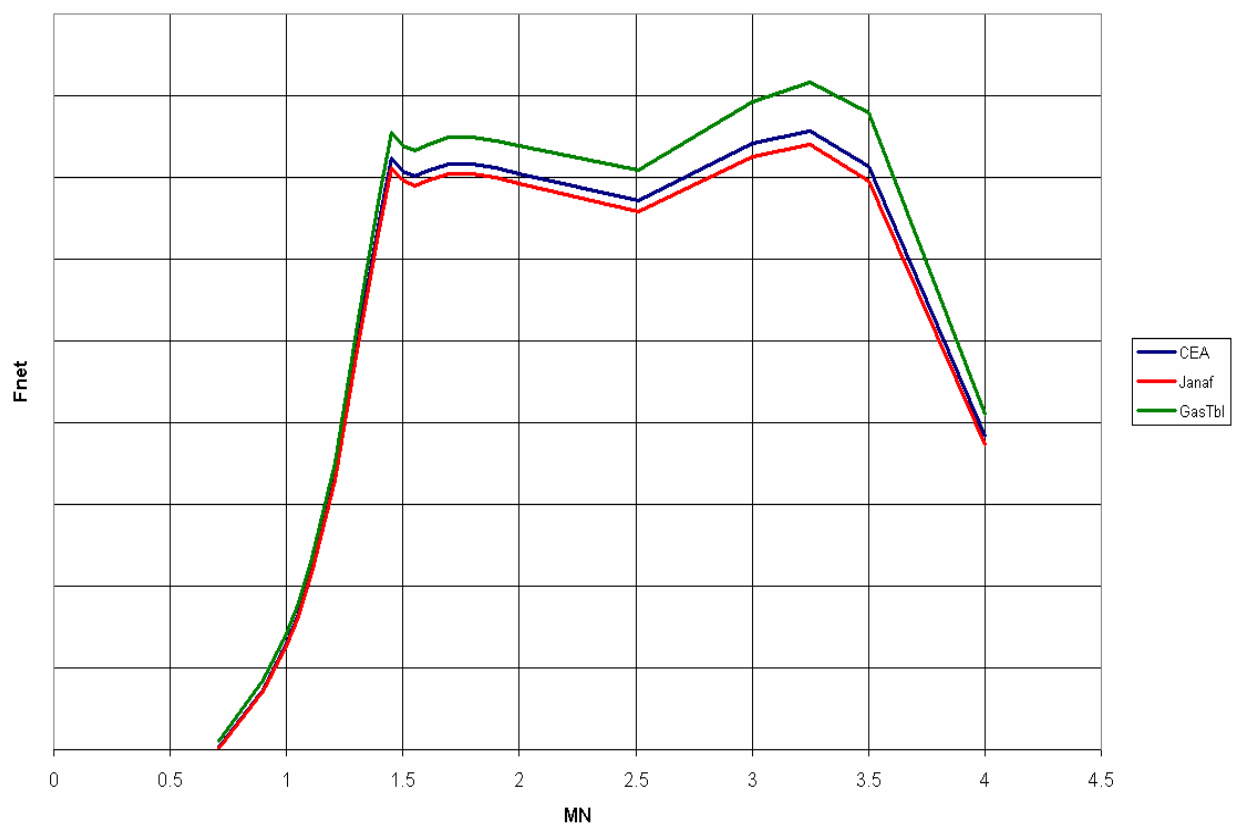## T7 (Afterburner Exit) vs. MN

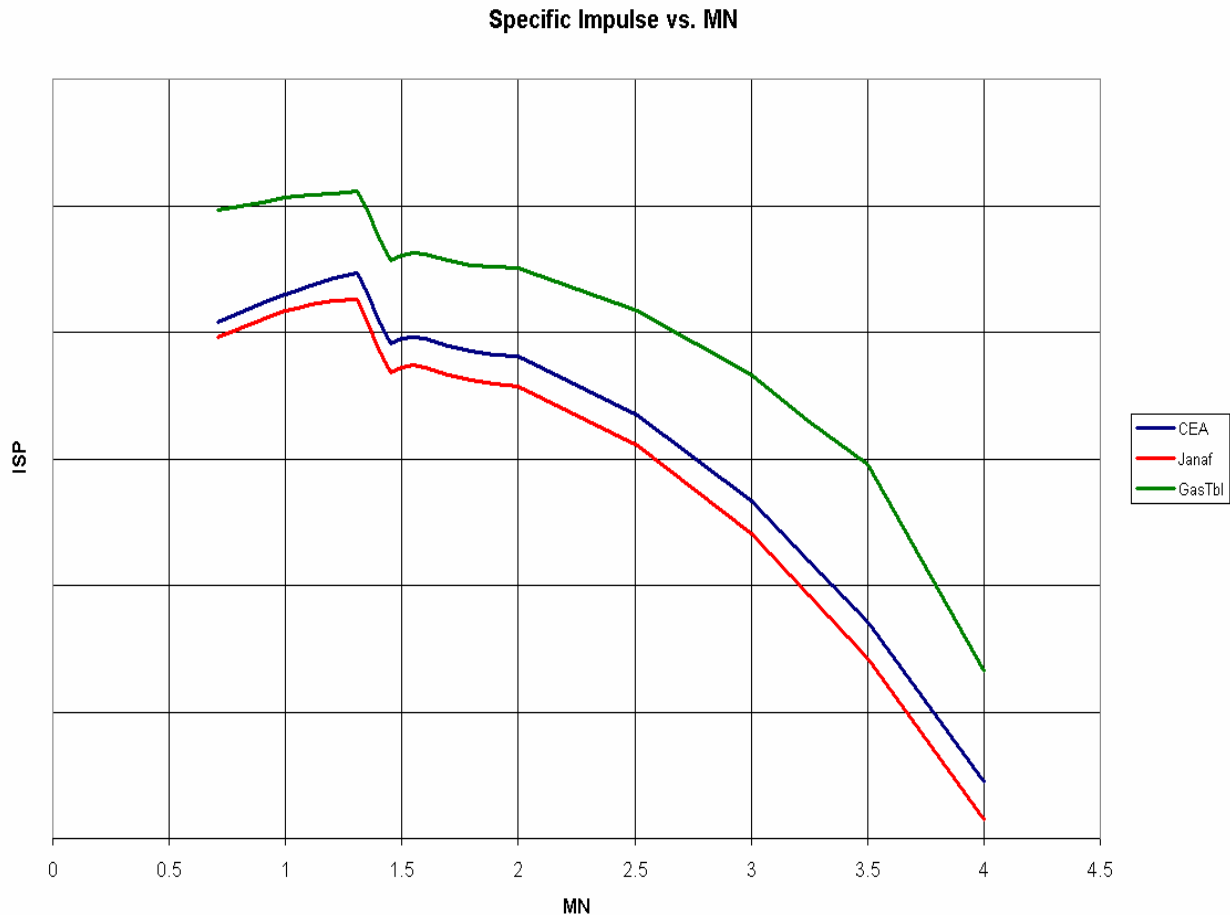## Afterburner Delta T (T7-T6) vs. MN

Cp/Cv at Nozzle Throat vs. MN

Fuel Flow Rate vs. MN

Legend: CEA, Janaf, GasTbl

Y-axis: Fuel
X-axis: MN

Net Thrust vs. MN

Legend: CEA, Janaf, GasTbl

Y-axis: Fnet
X-axis: MN

Specific Impulse vs. MN

Chart: Specific Impulse vs. MN. Y-axis: ISP. X-axis: MN (0 to 4.5). Legend: CEA (blue), Janaf (red), GasTbl (green).

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.**

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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 <u>will</u> 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.**

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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**

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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 years work will be to get a first rate hypersonic/heat transfer capability**

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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 effects flowpath solution**

- **Need combined solutions**

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Future Plans for Space Team

- **Develop first-rate rocket analysis capability**

- **Develop first-rate hypersonic capability**

- **Support NASA programs**
  - **TBCC/RTA**
  - **ISTAR????**

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