Abstract:

This talk presents Pratt and Whitney’s space division overview of the Numerical Propulsion System Simulation (NPSS). It examines their reasons for wanting to use the NPSS system, their past activities supporting its development, and their planned future usage. It also gives an overview how different analysis tools fit into their overall product development.
Pratt & Whitney
Space Propulsion
NPSS Usage

Dean Olson

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Outline

- Reasons for using the NPSS
- Past activities supporting the NPSS development
- Planned future development / usage
P&W Space Propulsion is involved in the design and development of many different propulsion systems:

- Liquid rocket engines
  - Upper stage - RL10 & RL60
  - Boosters - SSME turbopumps, COBRA, RD-180
- Hypersonic airbreathing engines
  - HYSET
  - SED
- Combined cycles
  - TBCC - Turbine Based Combined Cycle
  - RBCC - Rocket Based Combined Cycle
- Nuclear in-space engines

These systems are currently modeled in different simulation environments.

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Various Legacy Tools Used

NPSS provides a single environment for modeling Airbreathing and Rocket propulsion systems.

SOAPP
(State Of the Art Performance Program)

ROCETS
(ROCket Engine Transient Simulation)

NPSS
(Numerical Propulsion System Simulation)

Single Modeling System Desired

‘60s  ‘70s  ‘80s  ‘90s  ‘00s  ‘10s  ‘20s

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NPSS Benefits

- 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 type consortiums
  - No Need to Translate Methods Between P&W and other Propulsion or Vehicle Companies
  - 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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NPSS Useful Throughout the Product Life Cycle

Tailor the fidelity (physical representation & resolution) as appropriate for the analyses required

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Outline

- Reasons for using the NPSS
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Match Control
- Additional balances required for cycle physics
- 100 Solver balances required for transient capability
- Steady state and throttle characteristics
- Predict engineering delivered elements required to LO2 COBRA engine

Developed booster rocket

Activities
PAW SP NSS Development

A United Technologies Company
Pratt & Whitney
P&W SP NPSS Development Activities

- Supported development of the Hypersonic I^STAR engine NPSS component elements to enable simulation of full trajectory performance
  - Created Combustor element which predicts RAM / SCRAM performance consistent with RJPA methodology
  - Created single Fuel Delivery System model with off-design capabilities

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Outline

- Reasons for using the NPSS
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  ➢ Planned future development / usage

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P&W SP Planned Activities

- Evaluate creation of NPSS models of various Hypersonic propulsion systems
  - Models will be completely integrated
    - Hypersonic flowpath
    - Fuel Delivery System
    - Heat Exchangers
    - Digital Control
      - Control Laws
      - Control sub-systems

Fuel is same as that used on Mach 3 SR-71 Blackbird

Heated, vaporized fuel

High speed exhaust gases push vehicle forward

Air is compressed by speed of vehicle as it enters the engine (Ram air)

Inside the engine, the air and fuel burn at very high temperatures and horsepower speeds

Fuel circulates through engine structure and keeps it cool

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P&W SP Planned Activities

- Evaluate creation of NPSS models of various Liquid Propellant Booster & Upper-stage Rocket Engines
  - Models will be completely integrated
    - Fuel & Oxidizer Delivery Systems
    - Heat Exchangers