Abstract for 40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit on Numerical Propulsion System Simulation (NPSS)

The Numerical Propulsion System Simulation (NPSS) is a framework for performing analysis of complex systems. Because the NPSS was developed using the object-oriented paradigm, the resulting architecture is an extensible and flexible framework that is currently being used by a diverse set of participants in government, academia, and the aerospace industry. NPSS is being used by over 15 different institutions to support rockets, hypersonics, power and propulsion, fuel cells, ground based power, and aerospace. Full system-level simulations as well as subsystems may be modeled using NPSS. The NPSS architecture enables the coupling of analyses at various levels of detail, which is called numerical zooming. The middleware used to enable zooming and distributed simulations is the Common Object Request Broker Architecture (CORBA). The NPSS Developer's Kit offers tools for the developer to generate CORBA-based components and wrap codes. The Developer's Kit enables distributed multi-fidelity and multi-discipline simulations, preserves proprietary and legacy codes, and facilitates addition of customized codes. The platforms supported are PC, Linux, HP, Sun, and SGI.

Numerical Propulsion System Simulation Architecture

AIAA/ASME/SAE/ASEE
40th Joint Propulsion Conference

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Background

- Vision & Objective
  - Vision: Create a "Numerical Test Cell" enabling complete aerospace propulsion simulations overnight on cost-effective platforms.
  - Product Objective: Provide a common tool and extensible framework to enable rapid, high-confidence, cost efficient design of aerospace systems.
- Partnerships
  - Established Space Act Agreement (SAA 3-83) and NASA Industry Cooperative Effort (NICE) Agreement
    - **NASA Glenn Research Center at Lewis Field**
    - **Honeywell**
    - **Rolls-Royce Corporation (RRC)**
    - **The Boeing Company**
    - **Arnold Engineering Development Center (AEDC)**
    - **Wright Patterson Air Force Base (WPAFB)**
    - **General Electric Aircraft Engines (GEAE)**
    - **Pratt & Whitney (P&W)**
    - **Teledyne Continental Motors-Turbine Engines**
    - **Williams International (WI)**
  - Established SAA for Commercialization of NPSS V1.X
  - Currently working with partners to establish new SAA with same partners as SAA 3-83, plus Lockheed, Aerojet, and Rocketdyne
- Object-Oriented Architecture Chosen
- Formal Development Process Mandated

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Background (continued)
Development History

1987 - 1995	Conceptual, Prototypes
1996	NDA, NICE-1, Formal Requirements Definition
June 1997	Space Act Agreement 3-83
July 1997	NCP Beta Release
August 1998	Initial NPSS Release (NCP Version 1)
March 2000	NPSS Version 1 - Full 0-D Functionality
March 2002	NPSS Version 1.5 – Initial Zooming, Code Coupling, Visual Based Syntax (VBS, the GUI), Space Components
July 2003	Space Act Agreement for Commercialization of NPSS V1.X
September 2003	NPSS Version 1.6 – Enhanced Functionality (based on user feedback) VBS 1.6 – Enhanced Capabilities (based on user feedback) CCDK Version 1.0 – CORBA Component Developer's Kit (Multi-Fidelity, Multi-Structural Distributed Objects)

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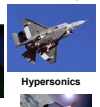
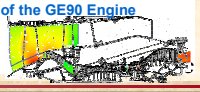
NDA:Non-Disclosure Agreement, NICE-1:NASA Industry Cooperative Agreement -1 NCP: National Cycle Program

Technology Transfer

- **Numerical Propulsion System Simulation (NPSS) V1 is Nationally Recognized & Impacting the US Aviation Industry**
  - **The F 135 engine for Joint Strike Fighter Program (GE, P&W, Lockheed-Martin, Rolls-Royce Corp, WPAFB, Edwards AFB)**
  - **The GP 7000 engine for the Airbus A380 (GE & P&W Joint Venture)**
  - **Advanced Rocket Concepts (Williams-International; P&W has verified system against COBRA)**
  - **Hypersonics (Aerojet's Engine Performance Model For DARPA/ONR HyFly Program Uses NPSS)**
  - **Ground Based Power Systems (GE Power Systems)**
  - **Fuel Cells (Univ of CA Irvine,Boeing, Florida Turbine Technology)**
  - **Nuclear Power (JIMO model in NPSS proven, but not used yet)**
  - **Facility Test Simulation (AEDC uses NPSS)**
- **NPSS V1 used to support wide range of power & propulsion systems**
- **Multi-fidelity Simulation of the GE90 Engine**





Technical Overview
What is NPSS V1.X?

- NPSS V1.X is a framework for performing analysis of complex systems.
- First major propulsion thermal/fluid design and analysis system developed using a programming paradigm designed for simulating complex engineering systems (i.e. object-oriented programming)
- Extensible Framework
  - Expand models easily
  - Build new models on-line, interactively
  - Build larger models, including more subsystems, in less time
  - Flexibility to model wide variety of complex systems
  - Add individual customized or proprietary components, component libraries, and legacy codes
  - Four different mechanisms to add new components
    - Interpreted components
    - Internal components
    - External components
    - Dynamically Loadable Module (DLM) components
- Deploy locally/distributed/parallel using high-end computing and communications as required
- Uses Common Object Request Broker Architecture (CORBA)
  - Middleware communication
  - Permits mixture of codes such as C, FORTRAN, and C++ to be collected within any simulation

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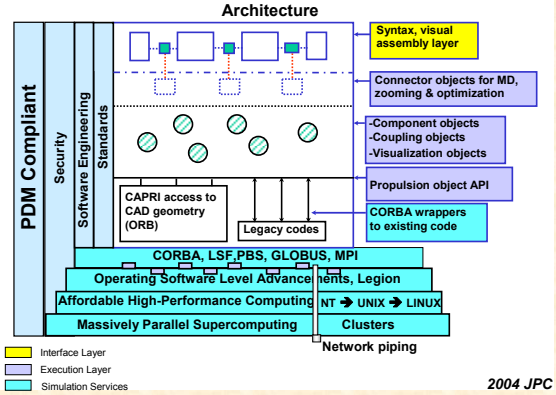
Technical Overview (continued)

Architecture



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Technical Overview (continued)
Building An Object-Oriented Model

- NPSS is an object-oriented framework for executing systems of components.
  - No matter what the user needs to simulate, the steps are the same.
- Divide system into discrete components (i.e. elements)
  - The user's conceptual view of the physical components can be mapped directly onto the object class hierarchy.
  - An object may be one component or an assembly of components.
- Link components
- Setup solver and execution sequence

This same basic recipe is followed to build any NPSS model.

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Technical Overview (continued)
Building Blocks of A Model

All simulations are created from a collection of 5 basic types (classes) of building blocks, which represent engine components, and describe how components are linked together.

- **Elements**
  - **Primary building blocks connected together via Ports**
  - Perform high level calculations
- **Subelements**
  - Interchangeable secondary building blocks that plug into Elements or other Subelements
  - Perform detailed calculations
- **Flow Stations**
  - Responsible for thermodynamic and continuity calculations
  - **Access the thermodynamic packages (*Janaf, GasTbl, CEA, H2, O2, Combusted H2O2, Tabular Data*)**
- **Ports**
  - **Used to connect Elements together**
  - **Five types (Mechanical, Fluid, Fuel, Thermal, Data)**
  - Directional in nature (i.e., outputs connect to inputs)
- **Tables**
  - Organized set of numbers that relate n-dimensional inputs to one *or more* outputs
  - Support linear and second or third order LaGrange interpolation
  - Support fixed value end-points or extrapolation (linear/2nd/3rd order LaGrange)
  - May be used at any location a function is called and vice-versa

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Technical Overview (continued)
Running A Model

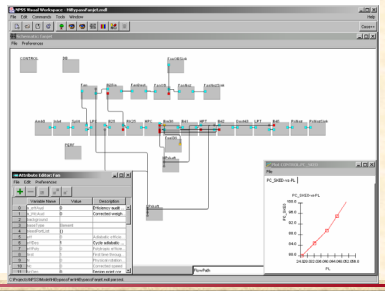
- Batch

```
npss [-options]file1 file2 . . .
```

- Interactive

```
npss [-i][-trace][-options]file1 file2 . . .
```

- Graphical



Technical Overview (continued)
Zooming

- NPSS Zooming is the coupling of analyses at various levels of detail.
- Run one or more components at a specified fidelity while the rest of the system-level simulation runs at another fidelity.

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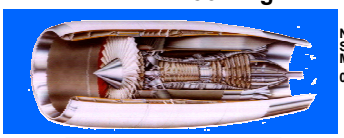
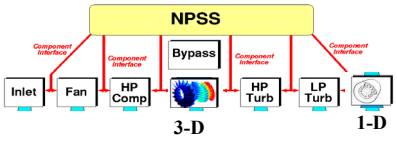
Technical Overview (continued)
Zooming



NPSS System Model 0-D



NPSS V1 (2nd Q FY 00)– Baseline 0-D Model

Summary

- NPSS object-oriented architecture has been proven on a wide variety of applications
- Involving partners throughout the development process has been invaluable and the main reason for success
- Flexible architecture supporting multi-fidelity, multi-discipline components using high-end computing and communications provides excellent candidate to support broader market
- Focus on Technology Transfer will continue

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Backup Slides

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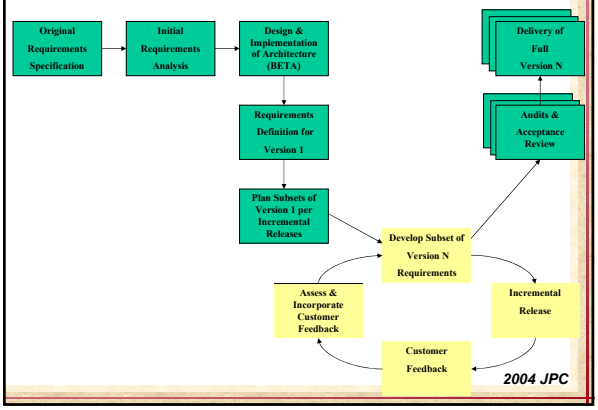
Incremental Release Process



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NPSS V1.X Package Descriptions

NPSS Release Package

- NPSS V1.6
- Visual Based Syntax
- Components
- Therms
- Documentation
- Customer Deck DevKit
- DLLDevKit
- Mico tar

DevKit – developer's kit
DLL – dynamically loadable library

Add-On Packages

- CCDKBase
- CCDKHiFi
- CCDKRocketsITAR
- Wrapper Tools

CCDK – CORBA Component developer's kit
HiFi – high fidelity

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