HPCCP Workshop on Frameworks

NASA Ames Research Center
January 30-31, 2001

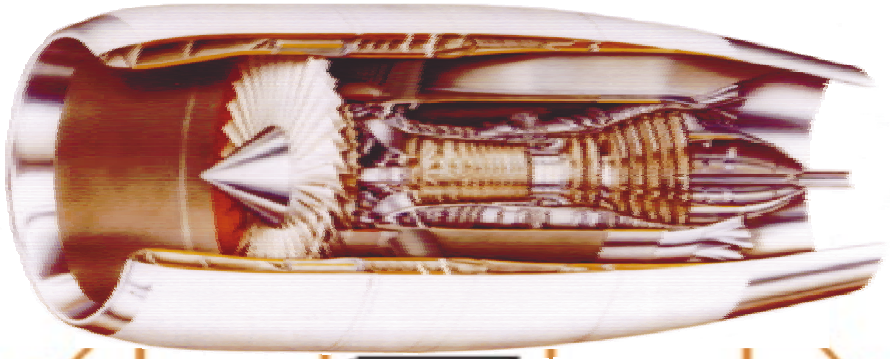
NPSS Framework

Gregory Follen
NASA Glenn
gfollen@grc.nasa.gov

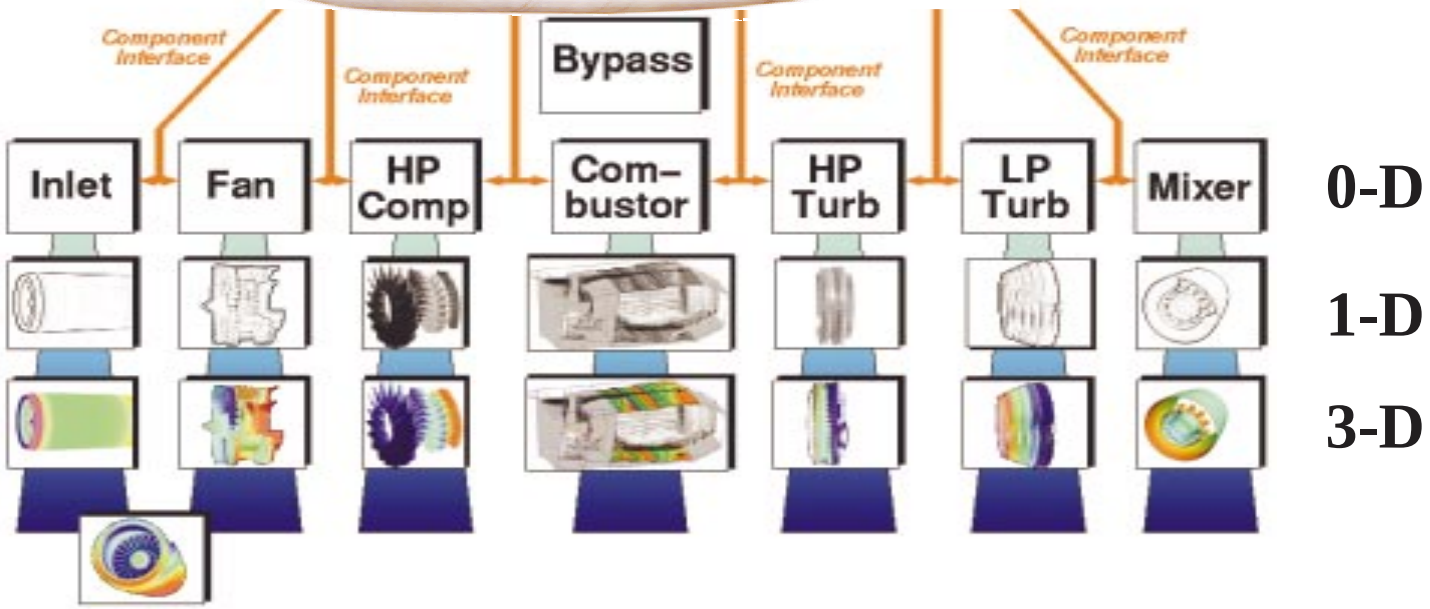
Computing and Interdisciplinary Systems Office
Glenn Research Center

NPSS Production and Simulation Architecture

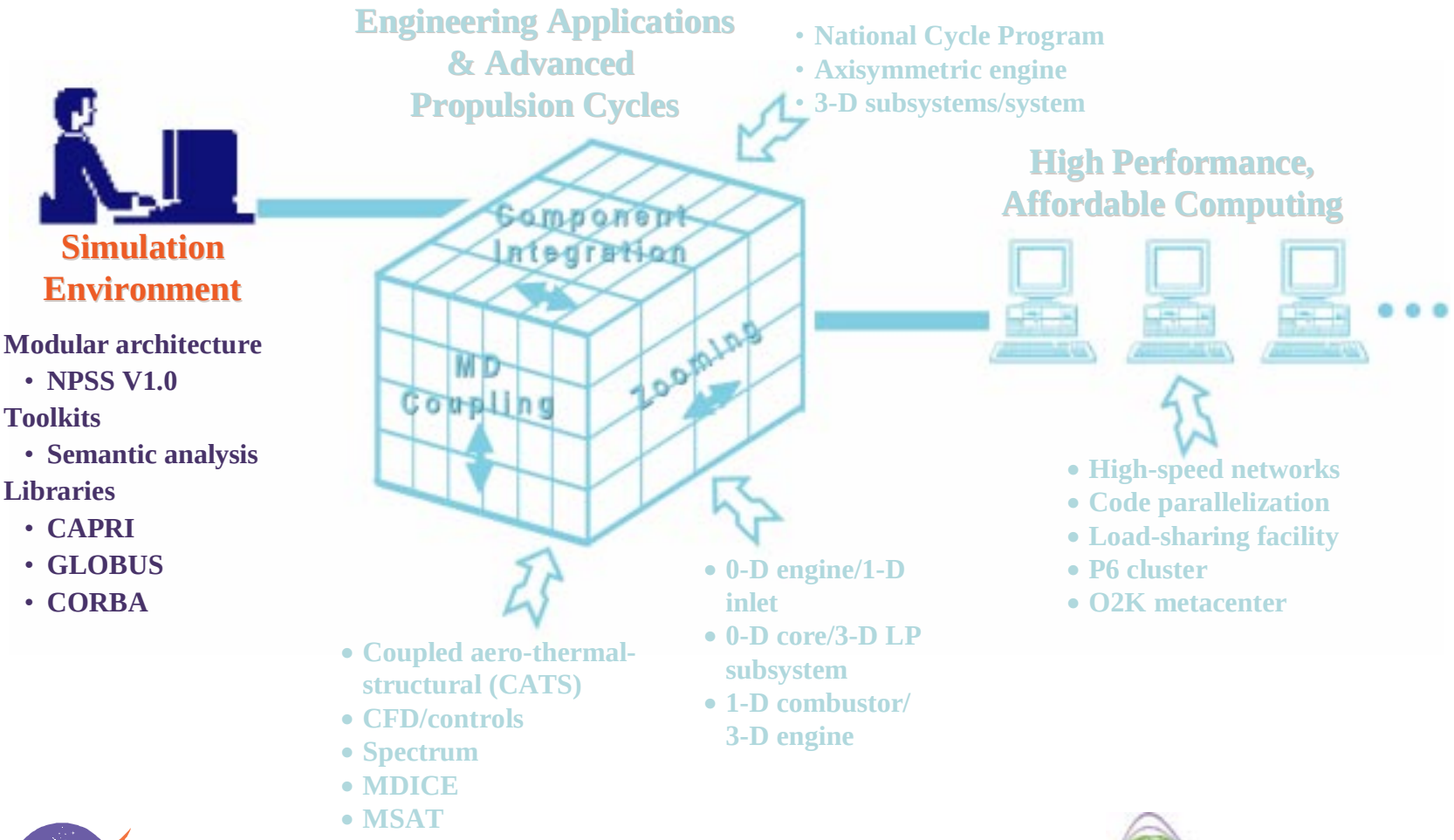
NPSS Production 0-D Model



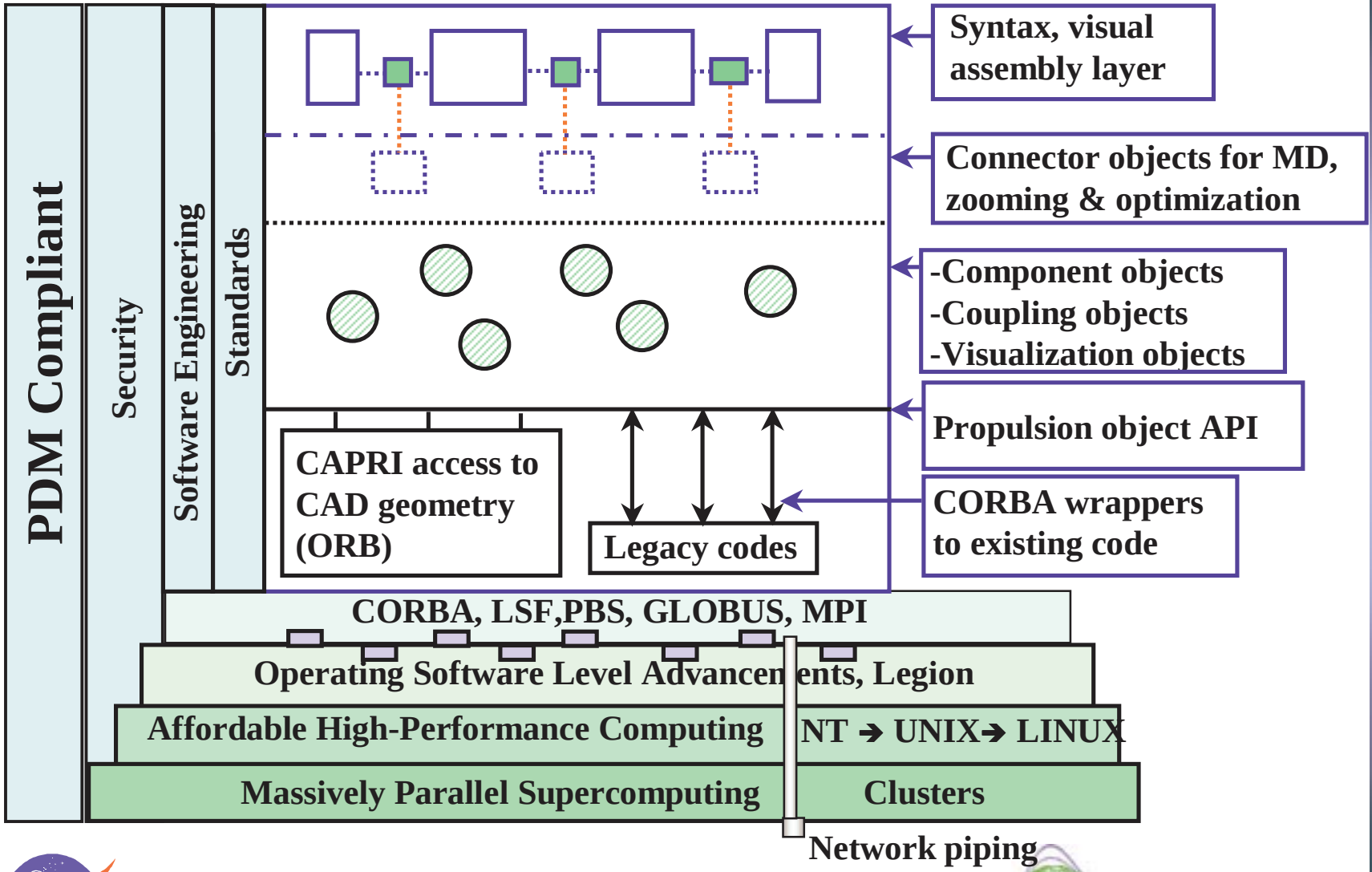
NPSS Dev. Kit supplies tools for integrating codes, accessing geometry, zooming, coupling, security.



Simulation Environment/ Production Software



NPSS Object-Oriented Architecture



•What is the focus?

Aerospace propulsion.

•What technology is used, leveraged?

Object oriented coding in C++, CORBA, NPSS syntax. Dev Kit: CCDK-CORBA wrapping, Coupling, DLM's, Security, Zooming, IPG, Geometry API-CAPRI.

•Upcoming papers:

"One Dimensional Compressor Code Coupled to NPSS Simulation via Dynamically Loadable Module", 2001 HPCC/CAS Workshop.
"Using External Codes with NPSS", NASA TM.
"CORBA Wrapping of Legacy Scientific Applications using Remote Variable Scheme", NASA TM.
"Coupling ADPAC to NPSS for an EEE Simulation", NASA TM.
"Web Based Distributed Simulation of Aeronautical Propulsion System", HPDC-10.

•Highlight common usage today:

CAPRI, IPG-Globus, visualization

•How to scale inputs for large legacy codes?

NPSS Production Topics

- Overview
- Milestones and Deliverables
- FY00 Accomplishments
- NPSS Version 1 Capabilities
- NPSS Version 2 Capabilities
- Current Status
- Schedule

NPSS Overview

- The Numerical Propulsion System Simulation (NPSS) is emerging as a U.S. industry standard simulation tool for propulsion and airframe companies.
- The modular, flexible, and extensible architecture developed for aeropropulsion simulations can be used for aerospace as well as other applications such as ground-based power systems.
- NPSS provides the functionality of a system simulation tool with increased flexibility for the user, which results in reduction of total development time and cost.
- NPSS has been developed using the object-oriented design with incremental releases.
  - The user's conceptual view of the physical components of the engine model can be mapped directly onto the object class hierarchy.
  - Rapid module creation, duplication, and customization is enabled by the interpretive engineering environment of NPSS.
  - The plug 'n play architecture enables much larger simulations to be performed because of the ease of "plugging" in new or larger modules.
  - This architecture can be extended to support multi-fidelity and multi-discipline simulations in future NPSS versions.
- Teaming with the end user is key to the development of a common modeling tool.

$50M/Year Estimated Aeronautics Industry Savings If NPSS is Adopted

- Estimate $17M/year for one company - total of $50M/year savings results if NPSS is adopted by aeronautics industry:
  - Common simulation tool to use with partners and customers
  - Early detailed system-level analysis
  - Reduced cost of support, development, time-to-market, and training
  - Increased productivity
    - Improved code portability
    - Cross discipline process integration
    - Easier data query and collation
    - Easier data manipulation/display
    - Modular model sharing (preliminary design, controls, performance)
    - Increased automation
    - Multiple site/platform distributed modeling
    - Documentation automation
  - Increased accuracy of results earlier in the design process
- Benefits only include aeronautics estimated savings.

Teaming User with Developer is Critical to Success

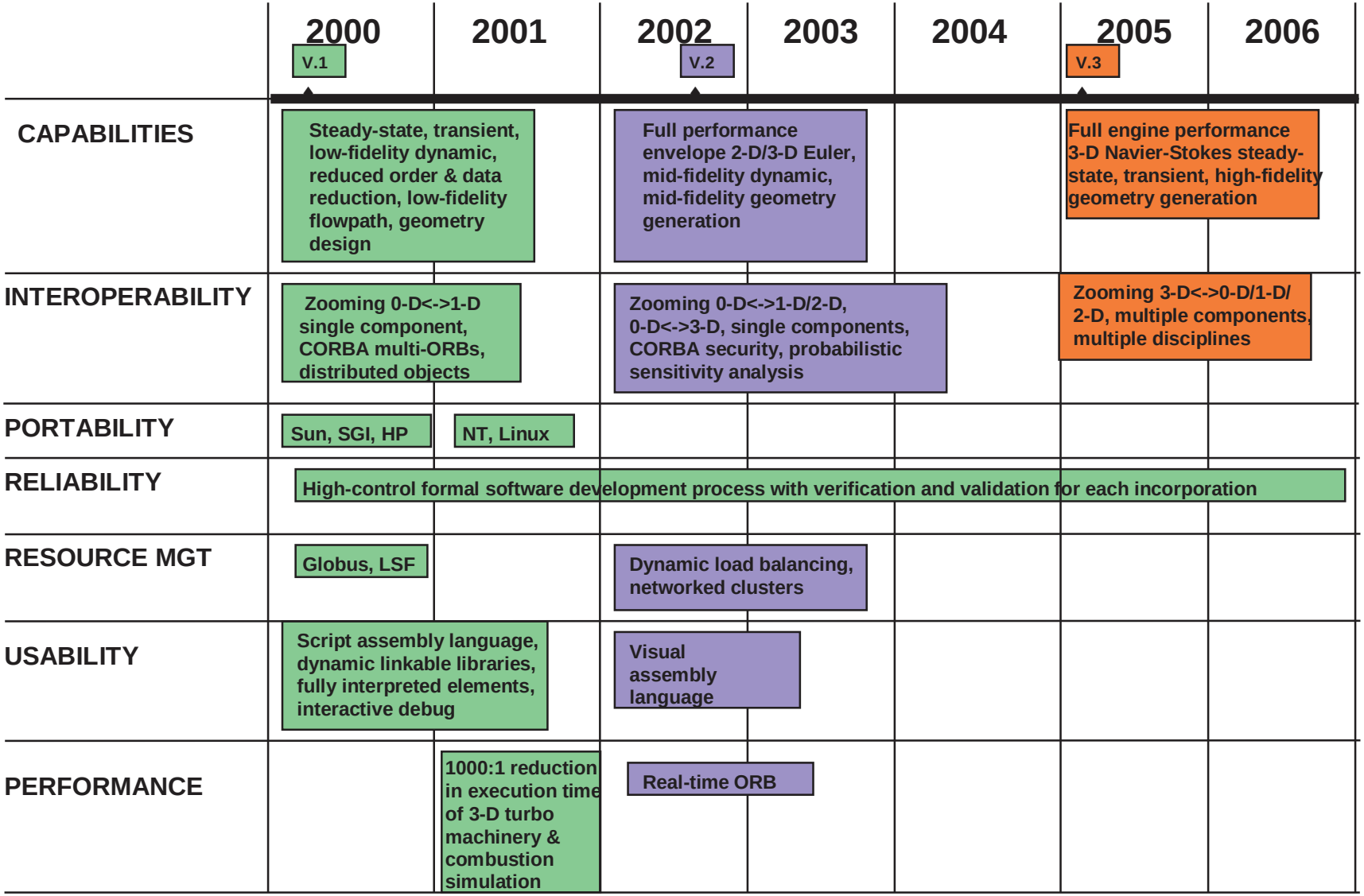
NASA/Industry Cooperative Effort (NICE-1)

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 Ryan Aeronautical
Williams International (WI)

Others who are interested:

U.S. Navy, Lockheed, Aerojet, Rocketdyne, DOE, P&W (power generation), GE (ground-based power), Dryden, Marshall, Langley, Ames

NPSS Production Milestones and Deliverables



FY00 Accomplishments

- 3/00: Distributed NPSS Version 1.0.0 on schedule, meeting an FY00 NASA Glenn Strategic Implementation Plan milestone.
  - Change requests (CRs) incorporated since the last full version release on August 25, 1998:

    39 requirements + 96 enhancements + 250 defects = 385 total CRs
- 3/00: Conducted software configuration audit: no major findings.
- 3/00: Conducted software acceptance review (SAR).
  - Zero review item discrepancies (RIDs)
  - Received 8 letters of acceptance: Rolls-Royce Corporation, Williams International, GE Aircraft Engine, Pratt & Whitney, Honeywell, Boeing, Arnold Engineering Development Center, Propulsion Systems Analysis Office NASA Glenn.

FY00 Accomplishments (continued)

- 7/00: Completed requirements definition for Version 2: 153 requirements.
- 7/00: Conducted software requirements review: 0 RIDs.
- 8/00: Distributed NPSS Version 1.1.0 increment.
  - Change requests incorporated since NPSS 1.0.0 full version release on March 30, 2000:

    3 requirements + 14 enhancements + 39 defects = 56 total CRs
- 5/00 & 7/00: Conducted NPSS training at NASA Glenn, P&W, and Williams: over 100 engineers trained to date.
- 7/00: Completed initial draft of NPSS space transportation requirements.
- FY00: Part of ISO 9000 review for high control software.

FY00 Accomplishments (continued)

- Automated process to track change request progress and generate statistics.
- Improved risk management and metrics collection.
- Interest and use of NPSS expanding: military, ground-based power, space, other NASA centers.
- Received positive partner evaluations: Rolls-Royce Corporation, Williams International, Lockheed, Navy.
- Feedback from partner validation activities continues to increase quality of product: GEAE internal validation, GEAE and P&W Alliance GP7000 validation.
- Number of NPSS models increase: Turbojet, Turbofan, Energy Efficient Engine, High Speed Research, Pulse Detonated Engine, partner & PSAO models, Regenerative Rocket Cycle.

NPSS Version 1.0.0 Capabilities

NPSS Version 1.0.0 can be used as an aerothermodynamic 0-dimensional cycle simulation tool:

- All model definition through input file(s)
- NIST (National Institute of Standards and Technology)-compliant thermodynamic gas-properties packages: Therm, Janaf, GasTbl
- Sophisticated solver with auto-setup, constraints, discontinuity handling
- Steady-state and transient engine system operation
- Flexible report generation
- Built-in object-oriented programming language for user-definable components and functions
- Support for distributed running of external code(s) via the common object request broker architecture (CORBA)
- Test data reduction and analysis
- Interactive debug capability
- Customer deck generation

NPSS Version 2.0.0 Capabilities

See NPSS SRS for detailed Version 2 requirements.

- 1-D dynamic engine system operation
- Aircraft installation effects
- Improved thermo architecture and capability
- New components, including combustion, compression, turbine expansion
- Units conversion
- Initial visual-based syntax stand-alone tools (graphical & command)
- Input and output enhancements
- Enhanced NPSS Developer Kit
- Enhanced C++ converter, interactive debugger, and commands
- CORBA Security
- NPSS running in CORBA server mode
- Common geometry interface
- Initial rockets capabilities
- Zooming from low to high fidelity as defined in the NPSS SRS
- New user documentation: Installation Guide and Training Guide

NPSS Production Current Status

- Completing change requests weekly: requirements, defects, and enhancements.
- Supporting changes needed for partner activities.
- Sub-teams analyzing V2 requirements, prioritizing, estimating effort, assigning, and scheduling work.
- Sub-teams determining which V2 requirements and submitted change requests will be completed by 9/01 with known resources.
- Preparing for upcoming NPSS training sessions.

NPSS Production Current Status (continued)

- Improving NPSS Developer Kit.
- Prototyping CORBA Security capabilities.
- Prototyping stand-alone tools for visual-based syntax.
- Finishing NT port.
- Analyzing and designing aircraft installation effects.
- Improving user documentation.
- Enhancing C++ converter.
- Working NPSS space requirements definition.

NPSS Production Schedule

- 10/00: Complete NPSS space requirements definition.
- 10/00: Provide NPSS rockets training at MSFC and Lockheed.
- 00-01: Distribute incremental releases.
- 00-01: Provide NPSS training as needed.
- 9/01: Conduct software configuration audits for NPSS V2.
- 9/01: Conduct software acceptance review for NPSS V2.
- 9/01: Distribute NPSS Version 2 for AeroSpace.

Visual Assembly
Script Based Syntax

- **NPSS command line based**
  - npss [-v] [-debug] [-I *dirname*] [-corba] [-i] [-log] file1 file2

- **C++ syntax** for element creation, sequence, viewing, CORBA

  Model BWB {

  Element FlightConditions AMB0 {. . .}

  Element Inlet Inlet {. . .}

  linkPorts (“FlightConditions.Outlet”, “INLET.F1_I”, “FL0”);

- **Programming constructs**, declare new variables, comments, If-then-else, do while’s, arithmetic functions: *, /, +, -, exponentiation, logicals, >, <, =,....

Visual Based Syntax Analysis Tasks

Basic analysis tasks that should be supported by the VBS are:

1. Model Creation/Modification
2. Steady-State Performance Analysis (Design/Off-Design)
3. Data Reduction Analysis
4. Transient Analysis
5. Customer Deck Generation/Maintenance/Execution
6. Control Design Support (State-Variable Model)
7. Phase II, III requirements

All of these basic tasks have some functions in common, which are:

8. Case Management, plotting, interactive debug

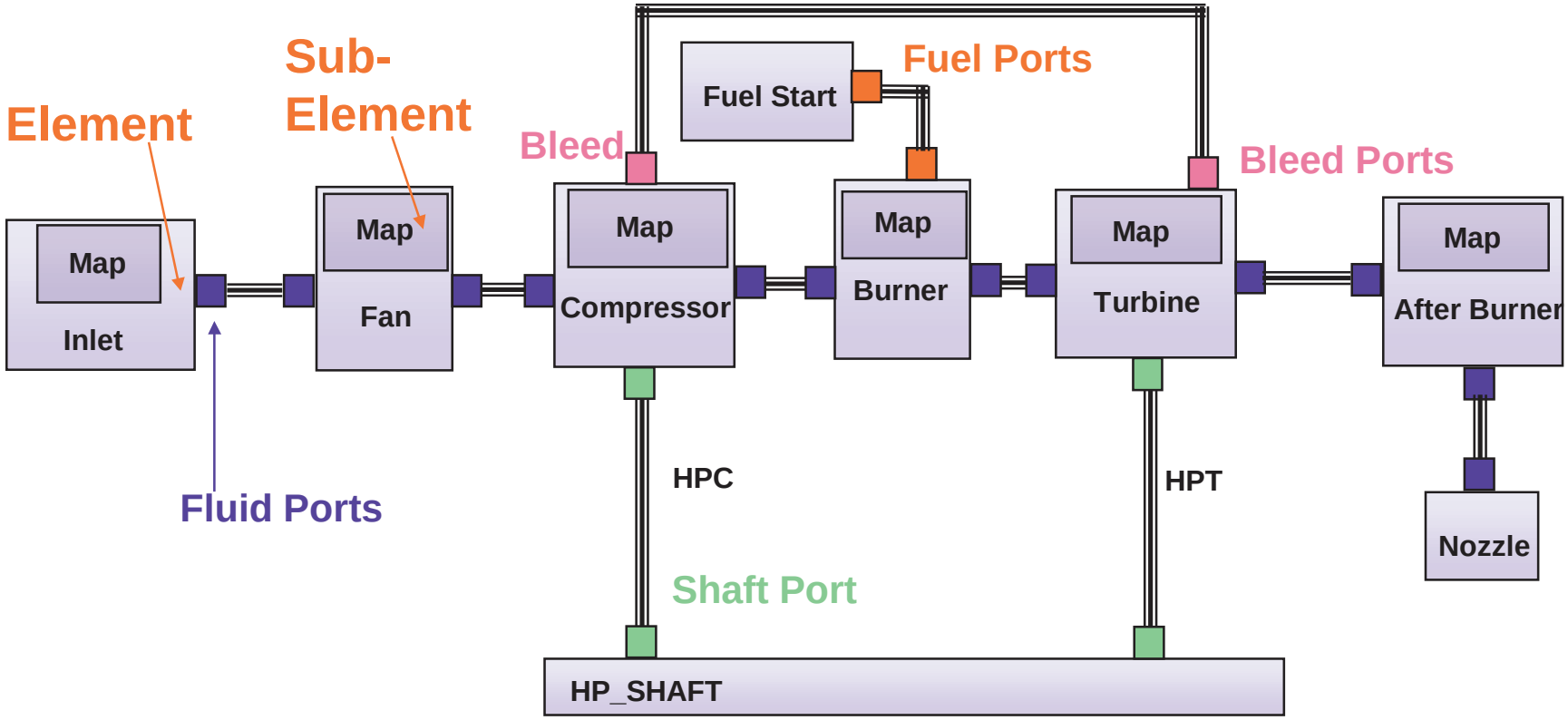
Propulsion Layer
NPSS 0D Objects

User's conceptual view of the physical components of the engine model can be mapped directly onto the object class hierarchy. All simulations are created from a collection of building block classes used to represent engine components.

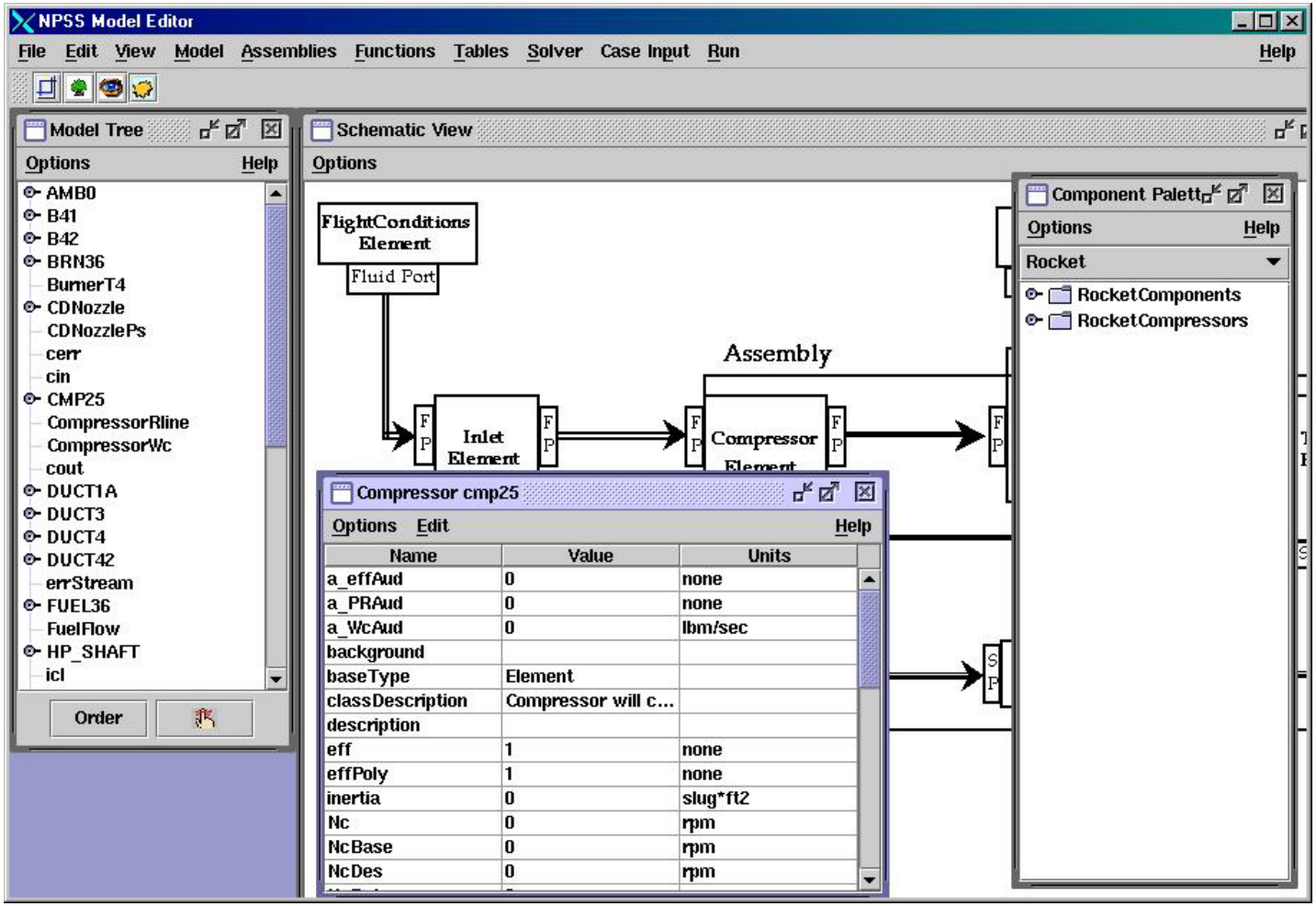
- Elements
  - Primary building blocks connected together via Ports
- Sub-Elements
  - Interchangeable secondary building blocks that plug into Elements and other Sub-Elements
- Flow Stations
  - Responsible for thermodynamic and continuity calculations (JANAF, THERM, GASTAB)
- Ports
  - Used to connect Elements together, Four types (Mechanical, Fluid, Fuel, Thermal)
  - Directional in nature (outputs connect to inputs)
- Tables
  - Organized set of numbers that relate n-dimensional inputs to a specific output
  - Supports linear and second or third order LaGrange interpolation
  - Supports fixed value end-points or extrapolation (linear/2nd/3rd order LaGrange)

Propulsion Layer

Object Based Turbojet Assembly



NPSS Visual Interface



Propulsion Layer
0D - 3D

Objective:

- Develop a strategy and implementation plan for the integration of mixed fidelity and multidisciplinary models into the NPSS framework.

Approach:

- Analyze existing integration efforts MDICE, Low Pressure Subsystem, LAPIN, PRICE, NPSS External Element, CGNS.
- Analyze code integration issues and potential solutions.
- Develop a needs list of resources and skill sets required to implement strategy. Identify key functional requirements for component data exchange.

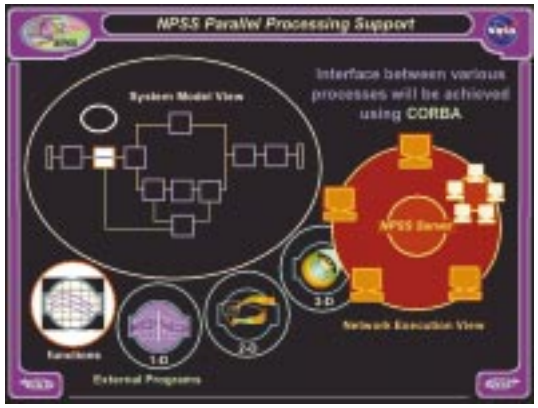
Status:

- Draft paper is being developed as initial roadmap for growing the NPSS Version 1.0 object layer to support mixed fidelity and MD simulations. (10/1/99). Subject of next architecture meeting November '99.

NPSS Development Kit

FY00 Accomplishments

Integrating Codes Through CORBA Wrapping



- **Direct FORTRAN support**

  Allows converting FORTRAN code to a CORBA object without reverting to file I/O & attendant startup/shutdown overheads.

- **Single-precision floating-point variables**
- **'Meta' variables**

  i.e., Shaft, Nmech mapped to multiple boundary conditions.

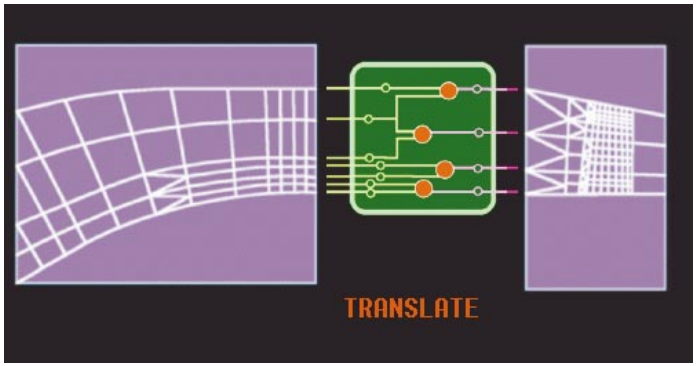
- **Variable access via functions**

  For parallel codes where the CORBA process doesn't own storage of referenced data.

- **Circumferential averaging**
- **1-D array support**

NPSS Development Kit

FY00 Accomplishments



Coupling

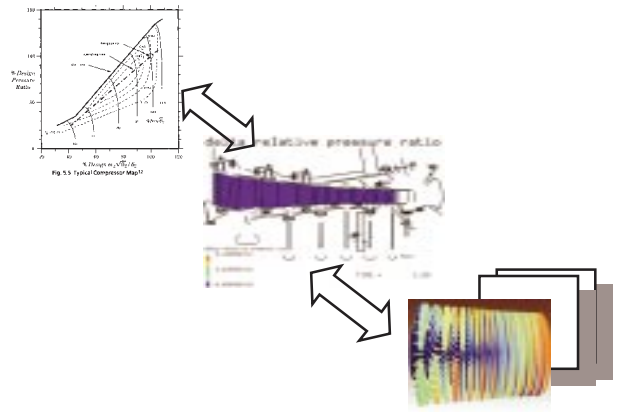
- 2-D/3-D/Axi-symmetric mismatched grids, with cell or node centered data
- Interpolation method is internally unstructured, currently the only API uses structured grids
- Rolls-Royce ADPAC-NPSS-ANSYS sensitivity project
  - Will likely require unstructured support. Current interpolator has this, but API and messaging formats need to be defined
  - Likely wrap ANSYS via Java using file I/O
  - ANSYS optimizer loop to be emulated by Java client application
- Examining “best practices in coupling” for recovery into Dev. Kit
  - ASCI project coupling
  - Overflow-ANSYS
  - APNASA-TFLOW

NASA/Glenn Application Software

Inlet/ Ducts	Fan	Compr	Turbine	Combustor	Features (NASA/Glenn code)	Fidelity
NPSS V1.0/Wate					Thermodynamic, Engine System, Weight, Controls, approximate flowpath	0 - Dimensional
LAPIN	MODFAN	CSPAN	TURBAN		Off-design, scaled map, flowpath, blades	1 - Dimensional
	CDP, UDO300, SANZ				Detailed design, blades & flowpath	2 - Dimensional
ENG10/20					Engine system, axis-symmetric aero	2 - Dimensional
NPARC	APNASA, ADPAC, HAH3D, RVC3D			NCC	Aero, single/multi-blade row, viscous, combustor chemistry	3 - Dimensional
NASTRAN, PATRAN, MARC, ANSYS					Structural, thermal	3 - Dimensional
NESSUS, NESTEM,CSTEM,IPACS					Probabilistic, Thermal, Structures	3 - Dimensional
NPARC	MSU-TURBO, TURBO-AE, RVC3D			NCC	Aero, emissions, noise, transients, structural dynamics, unsteady, multi-blade row, aeroelastic	3 - Dimensional

NPSS Development Kit

FY00 Accomplishments

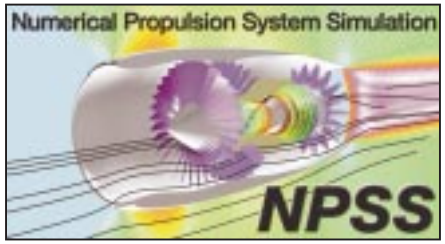


Zooming

- 'Natural' C++ access to remote variables
- PW 1-D zooming to compressor code
  - GRC 1-D compressor code wrapped with NPSS Dev. Kit
  - NPSS model built
  - What remains is to connect everything up
- PW 3-D/3-D zooming/coupling
  - Demonstration was expected for this meeting
  - ADPAC wrapped in NPSS Dev. Kit
  - PW, NASA code review/examination conducted to appropriate codes to wrap
- 1-D Turbine code wrapped using NPSS Dev. Kit

NPSS Development Kit

FY00 Accomplishments

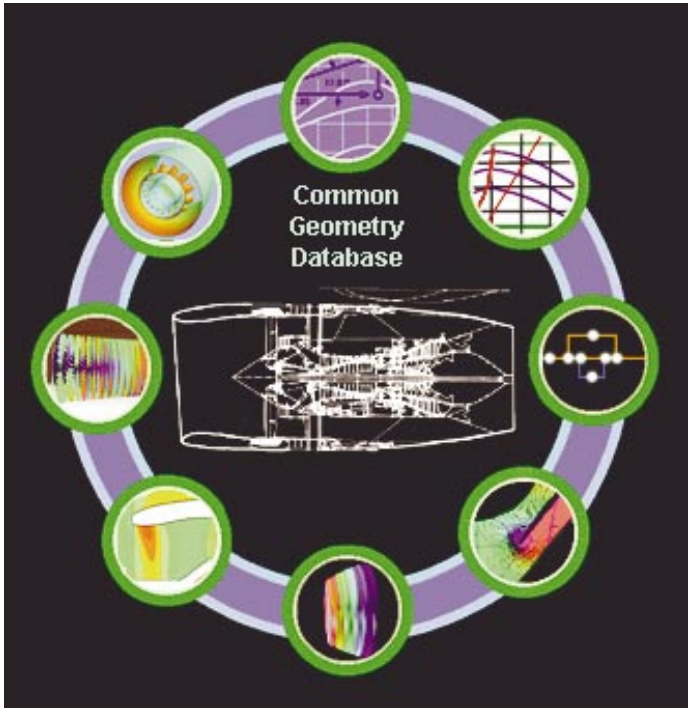


CORBA Security

- CORBA Security Workshop summary
  - Defined NPSS security policy
- CORBA Security Quick Start Hands-On Training Summary
  - Hitachi TPBroker SS architecture & administration GUI charts
- Defined NPSS CORBA Security testbed
  - Plans and testbed architecture
  - Purchases and network
  - Relative standards
  - Integration approach
- CORBA Security integration into NPSS schedule-3/01

NPSS Development Kit

FY00 Accomplishments



CAD Access & Interoperability Through Common Interface

- MIT grant for CAPRI: added CV port, enhanced IDEAS port
- OMG process
  - Requirements gathering (RFI), **complete**
  - Formal RFP (CAD Services V1.0, **6/00**)
  - Vendors and end users letter of intent (LOI, **9/18/00**)
  - Vendors seek common "ground" for response
  - Develop joint submission, **1/15/01**
  - Submission reviewed and approved as standard
  - Vendor provides commercial support for the standard

CAPRI FY00:

	UniGraphics	ProE	I-DEAS	CATIA V4	CV	Native - Felisa
Alpha	**X**					**X**
HP	**X**					**X**
IBM RS6K	**X**			**X**		**X**
SGI	**X**	**X**	**X**	**X**	**X**	**X**
SUN	**X**					**X**
LINUX	**X**					**X**
Windows NT/2000	**X**	**X**			**X**	**X**

CATIA V5 will be examined during this contract, but the best approach for the programming interface is not clear. An AutoCAD geometry reader will not yet be implemented.

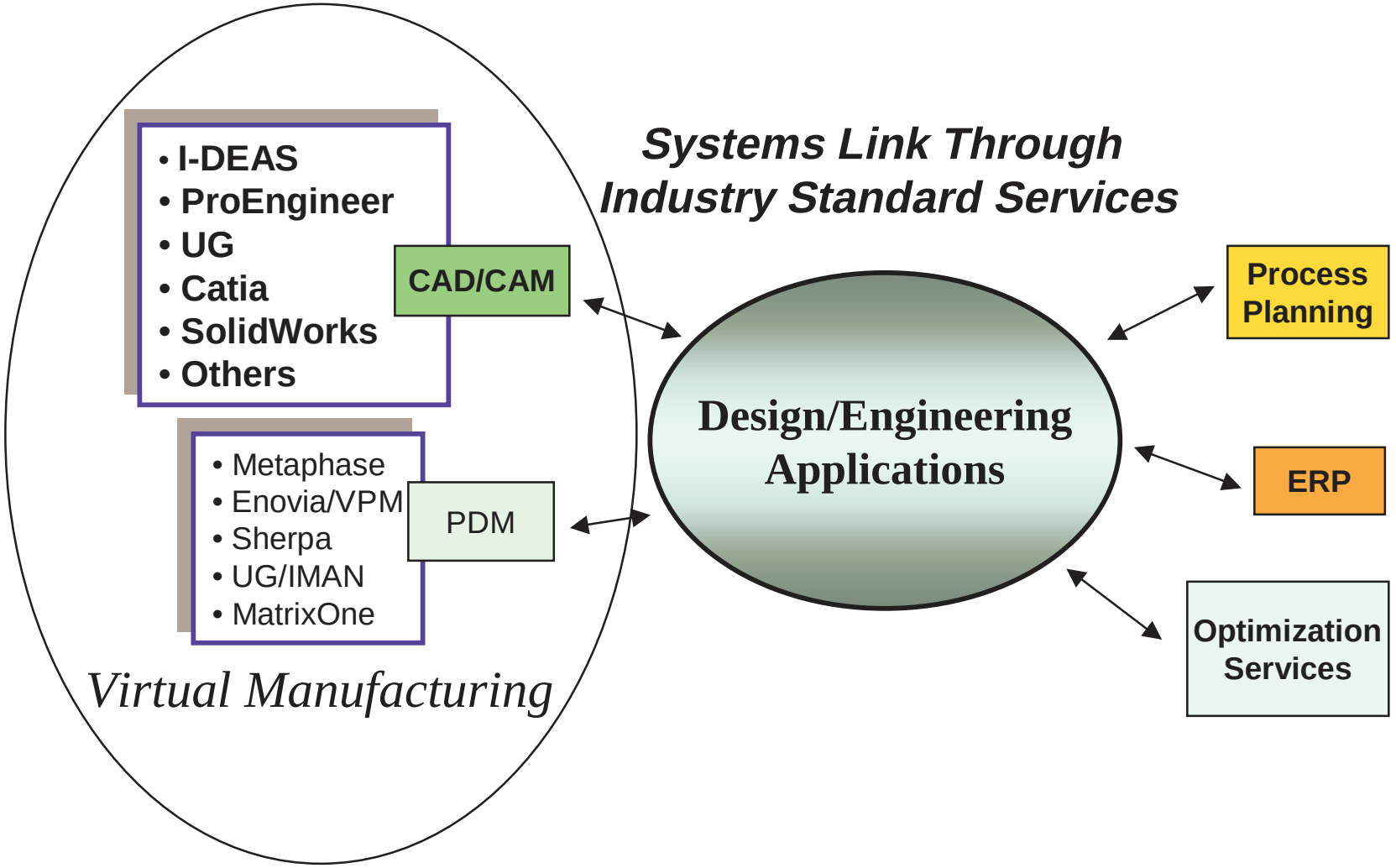
A CV (CompterVision's CADDS V) interface has been written in support of NPSS work with Allison/Rolls Royce and ICEM-CFD.

CAPRI FY01: Geometry Creation

The most significant change for **CAPRI** this year is the addition of Boolean operations on solids. This allows for the specification of fluid passages where the blade is the solid. The blade is simply subtracted from the passage to get the geometry for the CFD calculation. In general very complex shapes can be obtained through a few operations. The current status is as follows:

	Parasolid	ProE	I-DEAS	CATIA V4	CV
Simple Solid Creation	X			X	X
Subtraction	X		X	X	X
Intersection	X			X	X
Union	X			X	X

NPSS, OMG Shared Vision



NPSS Architecture FY01 Milestones

- 1-D zooming fully incorporated into Development Kit.
- 3-D/3-D coupling of aero codes fully incorporated into Development Kit.
- Design of geometry services through CORBA-based CAPRI.
- CORBA Security services fully incorporated into Development Kit.

NPSS Architecture FY02 Milestones

- 3-D/3-D coupling of ANSYS and ADPAC wrappers incorporated into Development Kit.
- CORBA-based geometry services incorporated into Development Kit.
- CORBA Security services integrated with GLOBUS and incorporated into Development Kit.
- Fast probabilistic integration (FPI) deployed with Development Kit.

Summary

- NPSS Version 1 delivered on schedule.
- NPSS Version 2 requirements have been signed off on.
- NPSS Version 2 will include space capabilities.
- NPSS architecture products are merging into NPSS Development Kit and will be releasable through same mechanism as NPSS V.X.