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Overview of NASA/DOE/DOD Interagency Modeling Team & Activities

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Outline

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Team Mission

- Integrate State-Of-The-Art Computation Resources With Experimental Knowledge Base To Produce Simulations Of NTP System Performance.

- Provide Users With Variety Of System Models To Aid Design and To Reduce Testing, Cost And Time To Regain Flight Ready Status.

- NASA/DOE/DOD Team Uses Unique Capabilities Of Each Member And Assures Appropriate Peer Review.

The purpose of the interagency modeling team is to integrate state-of-the-art computational resources and techniques, with the current knowledge base, to produce simulations of NTP system performance. The end products will provide users with a variety of validated and/or verified system models to assist in designing and to reduce the testing, cost, and time to reach a flight ready status. This vision can be best achieved by a NASA/DOE/DOD team which can use the unique capabilities of each team member and assure joint support for the resulting models.

Team Objective

- To Develop Five Distinct Computer Programs To Simulate NTP System Performance.

- Each Program Differs In The Level Of Detail And Capability.

A computer model of NTP systems is required for several reasons. First, a parametric NTP model can to predict system performance for several engine configurations on a consistent basis. In other words, a common tool is required to compare the configurations on level grounds; performance numbers for each configuration exist from a variety of sources. Second, a parametric NTP model is required to generate configuration performance data for input into mission analysis codes. Third, a parametric model is required to provide state-point input conditions to the system component designers and analysts. Fourth, an NTP system model is needed to evaluate the effect on performance of system design perturbations (i.e., sensitivity studies). Fifth, an advanced model can evaluate the performance of a given system through startup and shutdown transients. Sixth, a detailed transient model of the experimental engine is required for linkage to the facility model to determine engine-facility interactions. Last, an advanced NTP model can be connected to a control system in order to exercise the control system prior to its integration with hardware. To realize the vision and meet the needs defined above, the objective of the interagency team will be to develop five distinct computer programs, each varying in the level of detail and capability, to simulate NTP system performance.

Team Objective (cont.)

- Level 1 Model - Parametric Steady-State Analysis Tool.
- Level 2 Model - Near-Team Transient Analysis Program.
- Level 3 Model - State-Of-The-Art Transient Analysis Tool With Integrated Fluid Mechanics And Reactor Dynamics.
- Level 4 Model - Transient Model Calibrated To Test Or Flight Engine.
- Level 5 Model - Real-Time Transient Engine Simulation.

The Level 1 model is envisioned to be a relatively simple parametric system model. The primary focus of this program will be to analyze the performance of a variety of configurations. This program is expected to analyze steady-state performance and to require a run time on the order of minutes. The target user market for this program includes mission analysis, component modeling and concept evaluation teams.

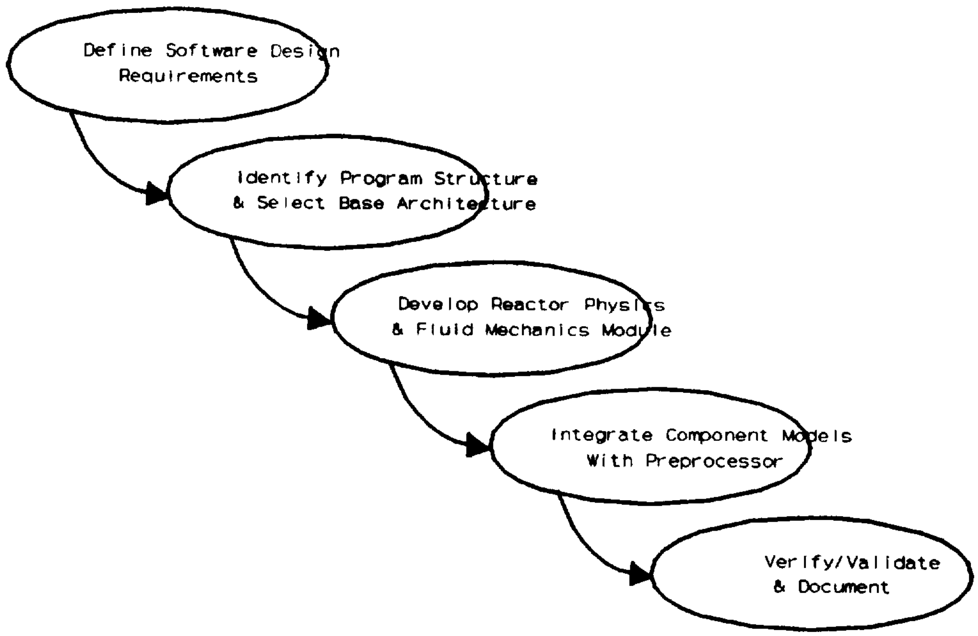
The Level 2 model is envisioned to be a near-term, detailed, transient system analysis program. It may use an existing base architecture program and will be capable of modeling system startup and shutdown as well as system feedbacks and oscillations. The program should be capable of handling control drum rotations, turbopump assembly (TPA) startup, stress analysis, decay heating, and detailed nozzle heat transfer analysis accounting for neutron/gamma heating. The target user market for this program includes component modeling groups and concept evaluation teams.

The Level 3 model is envisioned to be a state-of-the-art, detailed, transient system analysis program. It is anticipated that this program will have neutronic criticality and power density analysis integrated into the base architecture or will provide a means for easy information transfer through coupling. This model will include two-phase and multi-dimensional flow capability. The model will also include shock-capturing numerics to allow simulation of severe accident conditions.

The Level 4 model is envisioned to be a modified version of the Level 3 program tuned to model the experimental or flight engine. The target user market for this program includes component modeling groups, control system developers, and engine performance analysts.

The Level 5 model is envisioned to be a real-time, transient simulation model of the experimental or flight engine. The target user market for this program includes engine operator training groups and flight engine performance review teams.

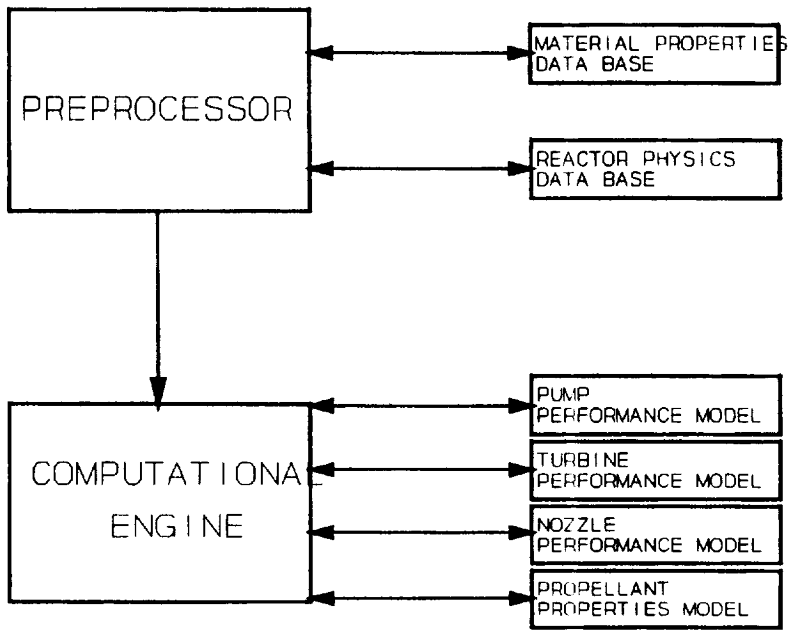
System Modeling Strategy



The strategy for developing each system model is similar and is divided into general tasks as shown above. The strategy begins by working with the users to define their needs in the Software Design Requirements Document and with the identification of the program structure. The subsequent tasks merely reflect the means to assemble the structure and meet the requirements; these tasks evolve from the selected program structure.

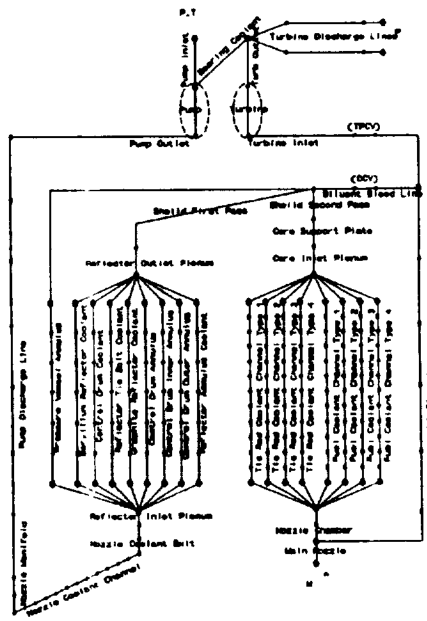
To date, work has focused on the Level 1 System Model. The Software Design Requirements Document has been compiled and the program structure has been identified. A base architecture program has been selected, SAFSIM. While the reactor physics and turbomachinery data bases are under development, the Level 1 model is currently being validated with test data from the NERVA project.

Level 1 Model Structure



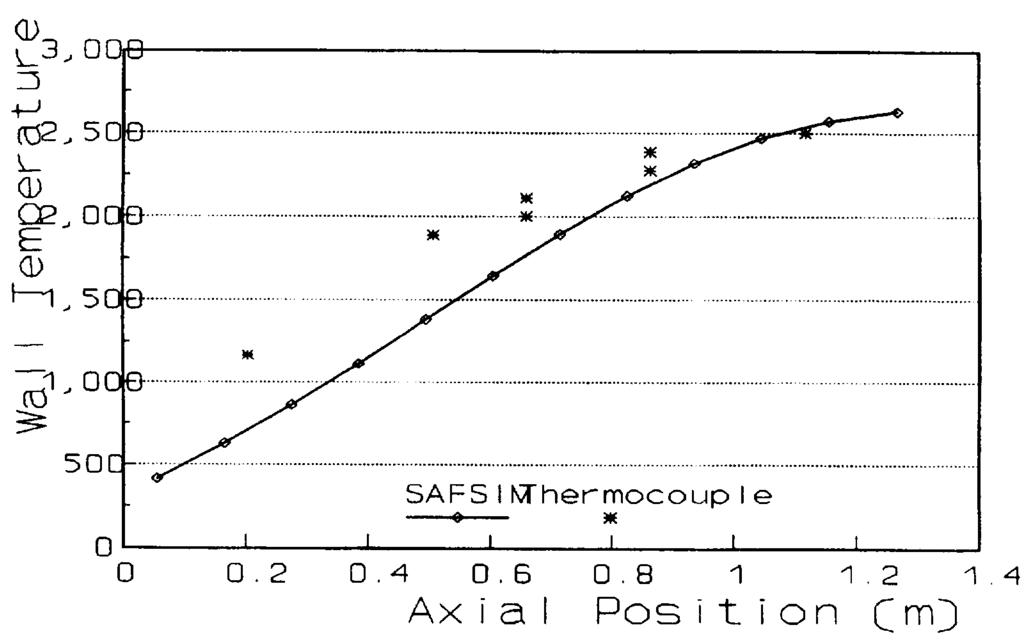
The base architecture (computational engine) for the Level 1 model is a general fluid mechanics program. Therefore, the input file contains all geometry specific information. Thus, the size is quite extensive. An input preprocessor will be used to develop the input files for the user.

Level 1 Model Validation



Concurrent with the development of the databases and component models, the Level 1 model structure is currently being validated with experimental data from the NRX-A4/EST test. Shown above is the schematic flow diagram used to model the NRX-A4/EST. A full-power, steady-state data point was selected for comparison from the EP-IV test run.

Level 1 Model Validation (cont.)



The selected results are from the validation effort are shown above. This figure presents a comparison of measured versus analytical fuel channel wall temperature. The thermocouples were imbedded in the fuel channel wall and, therefore, are expected to be slightly higher.

Level 1 Model Validation (cont.)

	EP-IV	SAFSIM	%Change
Pump Inlet Line			
Mass Flow Rate (kg/s)	36.55		
Pressure (MPa)	0.4208		
Temperature (K)	21.22		
Pump Outlet Line			
Mass Flow Rate (kg/s)	35.38	35.41	00.08
Pressure (MPa)	6.36	6.45	01.42
Temperature (K)	29.	24.3	-16.21
Nozzle Inlet Manifold			
Pressure (MPa)	6.42		
Temperature (K)	24.3		
Reflector Inlet Plenum			
Pressure (MPa)	5.14	5.26	02.33
Temperature (K)	84.4	76.4	09.47
Core Inlet			
Mass Flow Rate (kg/s)	32.8	32.8	00.00
Pressure (MPa)	4.67	4.86	04.07
Temperature (K)	127.	127.	00.00
Tie Rod Exit			
Mass Flow Rate (kg/s)	2.	2.1	05.00
Ave. Temperature (K)	362.		
Fuel Exit			
Mass Flow Rate (kg/s)	30.8	30.7	-00.32
Ave. Temperature (K)	2400.		
Nozzle Chamber			
Pressure (MPa)	3.91		
Temperature (K)	2298.	2301.	00.13
Reactor Power (MW)	1149.4		

A direct comparison of state points shows good agreement except for the pump outlet temperature. The pump efficiency model will be modified to correct this discrepancy.

Future Direction

- Further Develop Data Bases & Component Models For Level 1 System Model.

- Define Requirements & Develop Level 2 System Model.

- Exercise Level 2 Model To Aid Level 3 Definition.

- Initiate Early Development Of Integrated Reactor Physics, Fluid Mechanics & Heat Transfer Program For Level 3 Base Architecture.

The development of the Level 1 model data bases and component models will be a continuing effort. Once completed, the overall model will be documented and a graphical user interface will be developed.

Within the next few months, the development of the Level 2 system model Software Requirements Document will begin. An operational version of this model is needed as soon as possible to provide a test bed for sensitivity studies to aid the Level 3 model definition.

Concurrent with the development of the Level 2 model, initial activities will commence for the Level 3 base architecture.

Concluding Remarks

- An Interagency Effort Was Initiated To Develop Models For Predicting NTP System Performance.

- Models Support Evaluation Of Conceptual Designs And Provide A Diagnostic Tool For Ground Tests.

- Verified & Validated System Models Will Aid In Achieving Man-Rated, Space-Qualified Nuclear Thermal Propelled Vehicles Faster, Cheaper and More Safely.

An interagency NASA/DOE/DOD effort was initiated to develop several models for predicting the performance of nuclear thermal propulsion systems. These models are being developed to support the evaluation of conceptual designs and to provide a diagnostic tool for understanding system tests. Once verified and validated, these system models will aid in regaining the flight-ready status of nuclear thermal propulsion vehicles faster, cheaper, better and more safely by verifying design configurations and minimizing full-scale ground tests.