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Paper Session II-B - Application of Information Technology to the National Launch System

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ABSTRACT

The information needs of the National Launch System program had their beginnings with the Advanced Launch System (ALS). The Technical Reference Document for ALS called for "a Unified Information System (UNIS) to provide, in a timely manner, all the information required to manage, design, manufacture, integrate, test, launch, operate, and support the ALS." UNIS was to provide the link between distributed, heterogeneous workstations which were to make up both the ground and flight information systems. In addition, there was to be an Advanced Launch System Model (ALSYM), "a set of computerized submodels, or tools, which would work together to simulate all aspects of the ALS." These conceptual requirements were transitioned to the NLS program, and UNIS and the system simulation exist today. The current version of the NLS UNIS links geographically dispersed users to databases, analysis tools, program management tools, and communications devices. UNIS development is continuing to provide the ultimate capabilities which were described in the ALS Technical Reference Document. The approach to that development, as well as the current and planned capabilities are described. The ALSYM requirement transitioned as a requirement for a large-scale, end-to-end simulation of the Space Transportation Main Engine (STME) development program, named STESYM. The approach being used to satisfy that requirement incorporates object-oriented programming, discrete-event simulation, and knowledge-based techniques to produce a simulation that captures the technical characteristics of the hardware, the processing flows, and the scheduling requirements. The outputs of the simulation will include subsystem and system reliabilities, process infrastructure statistics, schedule performance statistics, and costs. Together, UNIS and STESYM will provide program managers, engineers, logisticians, and other program participants with communications connectivity and the information to support STME program analysis.

INTRODUCTION

Information requirements for the National Launch System (NLS) had their initial definition within the Advanced Launch System (ALS) program. The two primary requirements called for in the ALS Technical Reference Document were a Unified Information System (UNIS) and an Advanced Launch System Model (ALSYM).
Unified Information System Requirements

The purpose of UNIS was to provide all the information required to manage, design, manufacture, integrate, test, launch, operate, and support the ALS. To further define how this purpose would be achieved, the UNIS Functional Specification directed UNIS to employ advanced software technologies to trace and document complex design and operations processes; provide graphical interface, employing icons, windows, and menus; provide decision tracking and documentation and a means of communication between government and contractors; and serve as the primary interface to ALSYM.

The requirements identified for the NLS UNIS are basically the same as those for ALS. However, the initial development and implementation effort has been focused on the STME program, and UNIS requirements are tracking the activities associated with the STME development program. Inherent in the requirements are user-friendly graphical interfaces, linkages among various users and file servers/databases such as the Multi-user Archival and Retrieval System (MARS), access to program management decision support tools such as spreadsheets, and communications among all users.

Advanced Launch System Model Requirements

ALSEYM was conceived to support program actions by providing a set of computerized submodels, or tools, which would work together to simulate all aspects of the ALS. Requirements for ALSYM included a variable level of detail, e.g., more detail for failure mode analysis and less detail for vehicle operations flows; databases derived from UNIS information; a top level assessment of operability and cost; and the ability to assess the sensitivity of the system to reliability uncertainty, technology development, and resource limitations.

Requirements for an overall simulation of the National Launch System have not been defined, and the initial model simulates the Space Transportation Main Engine system, and is called STESYM. STESYM will integrate the technical disciplines; e.g., design, fabrication, production, cost; which are involved in the life-cycle of the engine development program. The objective of STESYM is to permit the NLS Program Office and the Space Transportation Propulsion Team to evaluate the development program and to assess the impacts of program perturbations on system performance, cost, and schedule.

UNIS IMPLEMENTATION

UNIS Overview

UNIS development centers around the requirement for a UNIS user to view all program data as though it resides on the user's local machine. This is accomplished by configuring UNIS to "remember" the action sequence followed by the user to access the desired information. UNIS provides easy access to data residing on the user's computer or a networked remote fileserver of database. In one sense UNIS can be considered an extended operating system which covers different platforms, and homogeneously incorporates itself over the entire working network. (A conceptual visualization of the UNIS architecture is contained in the Attachment.) This feature turns UNIS into an single application which runs on a singular machine, but one which can extend itself onto distant file servers and multiple databases with a simple mouse gesture. Each mouse gesture can be customized by the UNIS user in the form of icons and menu items. Thus, program data can be accessed in a convenient and comfortable way as specified by the individual using UNIS. In other words, UNIS is extendible and customizable. UNIS also provides data security. A customized UNIS can only be utilized by the one person who is responsible for the data it accesses.

UNIS Capabilities

UNIS incorporates several key features which make it unique in the Management Information System world. They include document access linking, data and password encryption,
customizable menus, customizable icons, and multi-network access (as opposed to being restricted to a single network).

Document access linking can be described as tying a remote or local document to either an icon or menu item. For those icons that already exist (Figure - 1), the linking is simple. The user chooses an icon, navigates through the file system of your choice (common in Macintosh applications), and selects the document or application. For example, a "QuickMail" icon can be linked to your mail system, the "STME System Model" icon can be linked to that application, and the "Addresses" icon can be linked to the Hypercard addresses stack. Document access linking also refers to user defined menu items. Such items can be inserted into command menus and deleted from them at the command of its user. Each item then refers to some document, application, or service just as the icons do.

Data and password encryption are also unique to UNIS. With high regard to data security, UNIS incorporates the D.E.S. - Data Encryption Standard scheme for its encryption/decryption algorithms. All items stored within UNIS are encrypted until needed. This includes file pathnames, user passwords, volume passwords, and other various data items. The UNIS application is also entry password protected. UNIS can also be configured to lock itself up after brief periods of interaction. This feature was included to discourage UNIS shut-down during times of inactivity, while still providing security to the information it contains.

UNIS has the ability to connect to different network protocols. Currently, it will access a LocalTalk network through EtherTalk or AppleTalk routing. To connect to the Multi-user Archival and Retrieval System (MARS) application, UNIS switches to the MARS network. To connect to the PSCNI network for access to larger mainframes, such as MSFC's DataGeneral, it will switch to the "DG Node."

The future of UNIS is limited only by the imagination of its users. To date a number of user defined features are being studied and incorporated. Features such as allowing any application to open (and translate if necessary) any document; adding documents by dragging them off the Finder and directly onto a UNIS window; and features such as defining the monitor bit-depth when certain applications are run, e.g., a black-and-white display when running a word processor on a color monitor, or 256 colors when running a specific drawing program.

Certain decision support areas are also being studied. Most of those are STESYM specific, and will allow greater clarity of thought derived from the information that application delivers to UNIS.
STESYM IMPLEMENTATION

Model Overview

STESYM is comprised of a collection of data models which can be grouped into two primary models: the Engine Infrastructure Model (ENGIM) and the Engine Integrated Cost Model (ENGICOM). ENGIM is an end-to-end model of the infrastructure needed to perform the fabrication, assembly, and testing of the STME and its components. It incorporates a discrete event simulation of the STME development program to generate probabilistic outputs on resource utilization and performance. This discrete event simulation can be characterized as a "what-if" tool to provide information to address the question of "What will be the effects on the development program if this change is made?". Performance Models, Processing Flow Models, and Schedule Models define the underlying structure of ENGIM and provide inputs to the simulation. ENGICOM is a line-item cost model based on the STME work breakdown structure (WBS). A "bottom-up" approach to cost estimation, including appropriate cost estimating relationships (CERs) supplied by NASA, is used to generate various line-item costs within the model. ENGICOM and ENGIM are integrated so that ENGIM simulation output parameters are utilized as factors in the ENGICOM CERs.

Model Capabilities

STESYM will provide analysis capabilities concerning all aspects of the STME development program. ENGIM and its performance models can be used to perform "what-if" analyses to determine component-level and system-level impacts of design changes. The process flow models of ENGIM can simulate the steps required in the design, fabrication, and assembly of the STME and its subsystems and components. ENGIM's schedule models can be used to determine resource requirements and to assess schedule modification impacts to resource levels and impacts on preceding or follow-on activities.

STESYM will support the analysis of the effects of design tradeoffs on the cost and performance of the system. These trades can be performed at various levels within the hierarchical structure of the model. For example, a trade could be made on the entire engine assembly process or a segment of the operations (such as Gas Generator checkout).

STESYM will support the analysis of the cost and schedule impacts of various budget constraints, production slips, engineering changes, and other foreseen elements. It will also be used to assess the performance of the STME. This evaluation will consider performance and reliability of the engine and its components, as well as process flows, resource utilization, logistics, component manufacturing, engine assembly, and engine testing. This analysis will show the costs of producing/testing a given engine and the sensitivities of the system to changes. It will show how sensitive the development program is to factors such as reliability uncertainty, technology development uncertainty, resource limitations, and unpredicted random events (such as a plant strike or a natural disaster). The emphasis here is more on how the engine testing infrastructure performs rather than just the engine.

Model Components

The Space Transportation Main Engine System Model is hierarchically constructed. That is, a top-down modeling approach is being used beginning at the engine level, through the component level, and down to the subassembly and piece-part levels. Such a hierarchical approach facilitates the verification and validation of the various submodels and modules and also permits the level of detail included in each STESYM module to vary depending on the level of detail required to support a given assessment. For example, the performance and reliability models may contain a considerable amount of engineering detail, while the scheduling portion of STME development activities may contain less detail, addressing the scheduling of engine and component flows through the various processes.

Figure 3 provides a visual representation of the STESYM components. The ENGIM division can then be decomposed to
performance models, process flow models, and schedule models. These data models are then partitioned according to the engine decomposition, e.g., STME has four major subsystems, Thrust Chamber Assembly (TCA), Oxidizer Turbopump (OTP), Fuel Turbopump (FTP) and Engine Controls. These subsystems can then be further decomposed, e.g., TCA is composed of the Main Injector, Combustion Chamber, and Nozzle. In a like manner, the ENGICOM division is composed of a WBS and various CERs. The WBS follows the partitioning as described previously, e.g., STME decomposed to TCA, OTP, FTP, etc.

Engine Infrastructure Model. ENGIM is a end-to-end system level simulation model of the STME development processes. ENGIM uses discrete event simulation techniques to simulate the engine development activities from component design and fabrication through engine flight testing. (The overall flow maintained in four broad classes of databases:

- Engine performance and reliability characteristics,
- Engine development infrastructure configurations,
- Engine development milestones and schedule, and
- Engine and component costs.

The database segments contained in STESYM represent each of the primary functional areas: the engine performance, the processing flows, and the schedules. Each model provides the user with access to the baseline system information stored in the databases. This information is static and unchangeable by the typical user. However, modifications may be made to the baseline system data and saved to a separate database file without modification to the original baseline data set. Access to the databases will be provided to authorized users through the Unified Information System (UNIS). The user will obtain the required data, modify it as necessary to perform an analysis, and execute simulation runs on STESYM. Database segments also have additional analytical capabilities which are particular to the type of database.

This database structure will directly support the hierarchical structure of the model itself with each database segment defining the objects of its respective functional area to the level of detail needed by the user. This hierarchical approach to model development permits the amount of data and the level of detail required by the user to determine the level of detail incorporated into the simulation rather than the simulation dictating the amount of data and level of detail required. Existing (as well as new) data can be entered into the appropriate databases to accomplish analyses at the required level of detail.

Engine Infrastructure Model. ENGIM is an end-to-end system level simulation model of the STME development processes. ENGIM uses discrete event simulation techniques to simulate the engine development activities from component design and fabrication through engine flight testing. (The overall flow

Figure 3 - STESYM Overview

Each of the STESYM models; e.g., performance, is a unique database, constructed of a collection of objects using a top-down hierarchical approach. One of the most significant advantages of the STESYM approach to these data models is the use of a distributed database structure. Data will be
for the engine development/testing process is depicted in Figure 4.) It accepts inputs from the Performance Models Database, the Processing Flows Database, and the Schedules Database. These parameters are used to compute probabilistic performance values during the execution of the simulation. Users can make changes to parameters within a particular database and observe their impact on the simulation. Operational and performance statistics are collected and made available as outputs of the simulation.

ENGIM is designed to allow the user to view the system model from a high-level perspective and focuses on the assembly and testing of engines at Stennis Space Center (SSC) and at engine testing at Marshall Space Flight Center (MSFC). In addition, lower levels associated with the fabrication, assembly, and testing of the different subsystems of the STME (e.g., OTP, FTP, TCA) are available.

ENGIM contains three basic sets of data models: (1) Performance Models, (2) Processing Flow Models, and (3) Schedule Models. The data models are collections of object-oriented databases which describe the entities/elements (which are of interest to the user) of the real-world STME development program. The attributes of each element and the relationships among the elements are also included in each data model. The elements, along with their attributes and relationships, define the underlying structure of STESYM. Many of the element attributes are represented as modifiable parameters by the user. User modifications do not affect the baseline data of each model, but are temporary changes for a specific analysis activity. The data models are graphically displayed on the computer, depicting the real-world elements and their relationships, enabling users to not only interact with the data, but to also have a visual idea of the element of interest, in relation to the remainder of the system. In addition to defining the data of STESYM, each of these data models includes its own analysis capability for the type of data associated with the model.

The ENGIM input data is obtained from the Performance Models, Process Flow Models, and Schedule Models and supports the simulation of alternative engine designs and processing concepts, as well as production and investment strategies. The model architecture is highly modular to permit evolution of the level of fidelity in consonance with STME program phases. The ENGIM output contains process flow statistics; inventory statistics; facility use statistics; and test statistics. The output provides feedback upon which to base performance and reliability trade-offs. The ENGIM output data will also be used as input to the Engine Integrated Cost Model to produce total life-cycle cost estimates and distributions.

The Performance Models, Processing Flow Models, and Schedule Models define the underlying structure of ENGIM and provide various inputs to the simulation. The benefit of
simulation is to provide a system-wide view of the effects of "local" changes to a system.

ENGIM integrates the inputs provided by the data models to determine system impacts of things such as:

- **Impacts to the STME arising from:**
  - various component configurations (e.g., turbopumps, generators, thrusters);
  - different values for reliability, maintainability, availability, weight, durability, design life, thrust, etc.;
  - changes in any subsystem.

- **Requirements for:**
  - number of engine test stands to meet the test schedule;
  - number of integration facilities;
  - component deliveries;
  - component assembly lines;
  - engine assembly facilities;
  - number of machines, laborers, etc.

- **Schedule modification impacts:**
  - how do changes in lower level affect the overall system schedule (in terms of weeks, months, etc.);
  - how does varying the allocation of budget funds affect scheduled events;
  - if the top-level schedule changes, how must the lower level activities be modified.

Analysis capabilities such as these will be incrementally added to ENGIM as data to build/enhance the models become available.

ENGIM can execute in either a single-run simulation mode or a Monte Carlo mode. In either mode the facilities where the engine development activities are performed are graphically displayed to give the user an understanding of the basic operational flow processes that occur from turbopump green-run through engine testing. In the simulation mode, animation is turned on to allow users to watch the process flows as they occur within each of the activities. Utilization statistics for each of the resources can be graphically displayed by clicking on the appropriate resource. In the Monte Carlo mode, the animation is turned off to allow the simulation to be replicated multiple times. This enables the user to generate distributions of resource utilization statistics. These statistics can be graphically displayed as histograms by clicking on the appropriate resource.

Outputs from the simulation can be sent to a disk file or printer. Those sent to a file may either be from a graphical display, a complete textual dump of the results, or a textual output set which is selected and formatted for use in a specific application such as another statistical package, spreadsheet, or graphics program. Hardcopy output can be either textual or graphical. In the textual dump, selection can be made between a complete dump or a subset of the output.

**Engine Integrated Cost Model.** ENGICOM is a line-by-line cost estimate of the STME development program based on the STME work breakdown structure (WBS). The integrated cost model provides estimated non-recurring (investment) and recurring costs for the STME development program using a "bottoms up" costing approach. ENGICOM employs the STME WBS as its base and will include all components of the WBS upon which the STME must report costs (although some components may be aggregated to a higher subassembly/subsystem level, depending upon the level of detail developed in ENGIM). ENGICOM is integrated with ENGIM to use output performance data generated by the simulation to calculate line-item costs. The simulated performance data outputs are used as inputs to a "bottom-up" cost estimating scheme employing cost estimating relationships (CERs) supplied by NASA and the STPT. This enables the user to perform a "what-if" type of analysis on the cost impacts resulting from performance trade-offs. ENGICOM will calculate recurring and nonrecurring costs, costs by WBS element, costs by year, costs by test, and life-cycle costs (LCCs), etc. Cost reporting for ENGICOM is based upon cost estimating relationships to
permit the calculation of costs associated with each run of ENGIM simulation. Lower-level CERs may be "rolled up," or aggregated to produce subassembly, subsystem, and system cost estimates.

The model is presented as a spreadsheet, based on the layout of the WBS. A variety of line-item data is provided to allow the user to determine how the calculations for that particular item were performed, to trace the data back to its source, and to access on-line WBS dictionary definitions. Outputs from ENGICOM are both graphical and formatted text with formulas intact for use in commercial off-the-shelf spreadsheets.

Output from ENGICOM can be sent to either a printer or a disk file. Sending the output to a disk file gives the user the choice of saving the output as a standard text file or as a specially formatted file for use in specific applications such as another statistical package, spreadsheet, or graphics program.

SUMMARY

The information needs of the National Launch System program had their beginnings with the Advanced Launch System (ALS). These requirements are currently being implemented as the Unified Information System (UNIS) and the Space Transportation Engine System Model (STESYM).

UNIS can be considered an extended operating system. One which covers different platforms, and homogeneously incorporates itself over the entire working network.

STESYM is comprised of a collection of data models which can be grouped into two primary models: the Engine Infrastructure Model (ENGIM) and the Engine Integrated Cost Model (ENGICOM). ENGIM is an end-to-end model of the infrastructure needed to perform the fabrication, assembly, and testing of the STME and it's components. ENGICOM is a line-item cost model based on the STME work breakdown structure (WBS). A "bottom-up" approach to cost estimating is used to generate various line-item costs within the model. ENGICOM and ENGIM are integrated so that ENGIM simulation output parameters are utilized as factors in the ENGICOM cost estimation.

Together, UNIS and STESYM will provide NLS managers and engineers with the ability to access various types and files of data quickly and use that data to assess the capabilities of the STME program.