Paper Session III-B - Launch Site Computer Simulation and Its Application to Process

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ABSTRACT

This paper provides an overview of computer simulation, the Lockheed developed STS Processing Model, and the application of computer simulation to a wide range of processes. The STS Processing Model is an icon driven model that uses commercial off the shelf software and a Macintosh personal computer. While it usually takes one year to process and launch 8 space shuttles, with the STS Processing Model this process is computer simulated in about 5 minutes. Facilities, orbiters, or ground support equipment can be added or deleted and the impact on launch rate, facility utilization, or other factors measured as desired.

This same computer simulation technology can be used to simulate manufacturing, engineering, commercial, or business processes. The technology does not require an “army” of software engineers to develop and operate, but instead can be used by the layman with only a minimal amount of training. Instead of making changes to a process and realizing the results after the fact, with computer simulation, changes can be made and processes perfected before they are implemented.

COMPUTER SIMULATION OVERVIEW

Computer simulation has traditionally been offered in two very different types of formats. Language-based simulation packages, such as SLAM and SIMAN, require the use of specialized software languages and experts in simulation and coding in order to operate. The simulations performed by these language-based software packages tend to be very general in nature. On the other hand, data-driven simulators use pre-built graphical blocks to simulate common processes found in areas such as manufacturing. While effective for the domain for which they were intended, the pre-built graphical blocks are inflexible and cannot be used to simulate other processes.

With the advent of the Macintosh computer, and now Windows, and with the greatly increased power and affordability of these platforms, a third type of simulation software package has been developed. The hybrid simulation software package combines the power of the language-based packages with the ease of use of the graphical packages. The result is an easy to use, powerful, and flexible simulation package that can be used by the beginner, but also provides...
the means to develop customized blocks in order to produce very complex and intricate simulations by the experienced modeler.

STS PROCESSING MODEL

The processing of the Space Shuttle at Kennedy Space Center is performed mainly in three types of facilities. The Orbiter Processing Facility (OPF) is used to de-service and remove payload-unique equipment from the orbiter after a mission, perform repairs and modifications, and install equipment and supplies in preparation for the next mission. The Vehicle Assembly Building (VAB) is where the huge external tank (ET) is attached to the solid rocket boosters after they are stacked and is also where the orbiter is attached to the ET. The launch pad is used to prepare the vehicle for launch, including payload installation, fueling, and final checkout. Each of these facilities are limited in numbers; there are three OPF bays, two VAB bays, and two launch pads. The purpose of developing a STS Processing Model is to determine the impact upon the launch rate and facility utilization of events such as changes in the number of orbiters to process, facility shutdown, major flight part unavailability, or GSE disruptions. Other changes, such as the processing impact of a new launch vehicle upon the facilities and the ability of the launch site to effectively process both vehicles can also be modeled. Figure 1 presents an overview of the current STS processing requirements.

The STS Processing Model was developed through the use of the simulation software *Extend + Manufacturing* available from Imagine That, Inc., San Jose, Ca. *Extend* is hybrid, library-based, iconic-block (graphical element) commercial-off-the-shelf (COTS) simulation software package. The Model describes the behavior of vehicles moving through the major facilities.
processing facilities, to launch, mission and landing, and then back for processing. The
Model operates in a discrete event mode, where events are orbiter movements or other status
changes. Event times are driven by orbiter process durations and the resolution of resource
conflicts. An orbiter’s process duration is selected from a statistical distribution of achieved
process durations or a default constant. As can be seen in Figure 2, the simulation model of
the launch site is very intuitive as the OPF, VAB, and launch pad footprints are used as part of the
Model. The process flow on the screen is the same as the orbiter movement toward the launch
pad. Additionally, icons of the shuttle, solid rocket boosters, and external tank provide
visual clues as to the status of the integrated flow.

Through the use of an input screen, called the
Notebook, assets such as orbiters or mobile
launcher platforms (MLPs) can be added or
deleted in order to perform a “what-if” analysis.
These type of changes take about 10 seconds to
make, and it takes about 5 minutes to model a
years worth of processing to determine the ef-
ficts on the launch site. Processing times that
the Model pulls from the statistical database,
such as for the OPF, VAB, or pads, are also
shown in the notebook input screen (Figure 3)
as the model is running.

**Figure 2. STS Processing Model-Overview**

**Figure 3. STS Processing Model Notebook/Input Screen**
The output of the Model is shown in Figure 4. The output, which is a continuation of the Notebook, shows the achieved launch rate, yearly launch rate, facility utilization for each of the facility processing bays and launch pads, and MLP and orbiter availability. A spreadsheet within the Notebook also captures the as-run data for each processing flow so that comparisons and statistical analyses can be made to determine the results of each "what-if" run. Additional data elements can be added to the Notebook as desired.

![MODEL OUTPUT](image)

**Figure 4. STS Processing Model Notebook Output**

Each of the facilities represented consist of a hierarchical block. A hierarchical block is composed of a series of logic blocks that represent the logic and events that occur within the facility. For instance, as shown in Figure 5, the processing flow within the VAB consists of a series of library blocks that detail the logic of activities that occur in the VAB. The stacking of the solid rocket boosters, mating of the external tank, and the integration of the shuttle with the stack are represented by a series of logic blocks. The statistics used to represent the durations of each event are taken directly from the actual times achieved from each of the processing flows since STS-1, with the exception of the first flows for Back to Flight and unique flows due to hydrogen leaks.

Through the use of hierarchical blocks, it is very easy to add or delete facilities to determine the effect on the processing flow, launch rate, or facility utilization. After a hierarchical block is created, it can be added to a library, such as the STS Processing Library, and used to add the facility in the processing flow as desired. It is also easy to delete a facility, simply by selecting and deleting it, to determine the subsequent effect on the processing flow. Either change, whether adding or deleting a facility, takes less than 15 seconds to implement.

Another type of "what-if" analysis that can be done is to determine the effects upon facility utilization and launch rate if an OPF bay is shutdown for one year in order to perform extended duration modifications on an orbiter. As each of the bays and orbiters are the same as far as the model is concerned, OPF bay 3 is selected to have a one year period of downtime. The downtime is selected at a time when the orbiter is in the bay, in order to capture the orbiter for the downtime. A scheduled downtime block is added to the facility block in the OPF hierarchical block and a downtime of one year is selected. After running the Model, it is determined that...
the launch rate decreases from 7 to 6 while the facility utilization of the remaining OPF facilities increases. A synopsis of the changes incurred due to the addition of one year of OPF downtime is shown in Figure 6.

Due to its nature as a hybrid simulation package/language, Extend enables people with a wide range of ability to change the Model at many levels of detail. The user can double-click on block icons and change dialog parameters. From libraries supplied, the user can get new blocks, connect them, and enter parameters. For more flexibility, the user can enter formulas or equations directly into an Equation block (Figure 7).

The simpler groundrules are represented in Equation blocks, so the user can change these or add new blocks to modify groundrules. For the most flexibility, the user can create new primitive blocks by using Extend's built-in C compiler and dialog/icon editors to either modify a pre-existing block or build one from scratch. Most blocks needed are already pre-built. In fact, all but one of the blocks used to build the Model are pre-built.

**MODELING PROCESSES**

The simulation software and techniques used to
develop the STS Processing Model can also be applied to a wide range of processes, such as manufacturing, engineering, and business process reengineering. Specific models may include logistics inventory analyses, electronic circuit development, or paperwork flow improvement. The software is designed to be used by the layman, and therefore does not require the services of software or modeling experts in order to use.

By modeling processes, a manager shifts the focus from dealing with outcomes to managing the means for achieving customer and business value. Aspects a manager often deals with, such as excess inventory, overtime, expediting, safety problems, worker morale, or delivery performance, are often the cause of the nature of the overall system. However, when identifying a specific item to change in the system, it is difficult to perceive the overall effect due to the synergy which occurs when all relationships act together. Flow charts can help identify the system parts and process sequence, and spreadsheets can help calculate some mathematical relationships, but the overall cause-and-effect relationships are hard to capture with such tools.

A simulation model effectively mimics the dynamic behavior of a flow system, where real-world elements interact when specific events occur, and where behavior may be driven by probabilistic processes and feedback.

Another benefit of simulation is the ability to build or change a process on a computer before it is actually implemented. The building of a simulation model requires that a consensus be developed among the interested parties on what is actually required, which often changes and aligns the perceptions of the parties involved. Based upon up-front understanding of the process and mutually agreed to changes, this "consensual reality" often leads to an improved process when implemented.

**CONCLUSION**

With the introduction of ever more powerful personal computers and easy to use simulation software such as Extend, computer simulation is now a readily available tool. The STS Processing Model is an example of a fast and flexible tool for the evaluation of shuttle processing scenarios by personnel not familiar with simulation modeling or techniques. In addition, simulation can be used on a wide range of processes to model new developments or changes to existing systems to determine the effectiveness of the processes before they are implemented.
BIOGRAPHIES

Michael Sham (407-383-2200 ext. 2427) is a member of the Advanced Programs Study Team for Lockheed Space Operations Company at Kennedy Space Center. Mr. Sham's current responsibilities include the analysis and evaluation of new space launch systems in terms of their impact to the existing launch infrastructure. He received his BS in Marketing and Management from Oklahoma State University and a MBA with an emphasis in statistics from the Florida Institute of Technology.

Andrew Siprelle (615-982-7046) is President of Siprelle Associates, a firm which provides simulation consulting, training, and custom models. Mr. Siprelle's industry experience includes creation and analysis of deterministic and stochastic models for strategic planning, application of Experimental Design for process improvement, and training employees in industrial statistics. He has used Extend to help numerous companies analyze operations and increase productivity. Mr. Siprelle specializes in statistical analysis of simulation output and simulation experiments. He received his BS in Industrial Engineering and Operations Research from Virginia Polytechnic Institute and State University.