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CIRCA 2000

OPERATIONS CRITERIA

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Abstract

The current Shuttle Program was used as a working model and certified data source in the identification of STS operational cost drivers. Changes to flight hardware, processing methodologies, and identification of automation applications that would reduce costs were derived by reference to that data. The CIRCA 2000 Criteria were developed using these critical analyses of the on-going Shuttle Program. Several innovative suggestions are reviewed.

In 1986, the Kennedy Space Center commissioned BAO (Boeing Aerospace Operations) to perform the SGOE/T Study, (Shuttle Ground Operations Efficiencies / Technologies Study". This Study was a one year contract (Phase 1) with two priced options (Phase 2 and Phase 3). We are currently in Phase 3 of that Study. Each Phase of the Study has had a different thrust. The Phase 1 primary objective was to identify the Shuttle Program operational cost drivers and reduce the overall operational cost either through improving the efficiency of the ground operations or with the addition of selected technology elements to cut costs. The results of the study indicated that although it may be too late to "significantly" change the existing Shuttle System per se, development of launch site criteria for use by the various design agencies and their contractors would be beneficial for future programs, either manned or unmanned. One of the significant conclusions was that increased application of automation to evaluate systems and conduct operations will provide several ways of reducing launch operations costs and providing benefits:

- o Increase the speed of the total checkout (reduce time-in-flow requirements)
- o Reduce manpower requirements
- o Reduce the possibility of human error
- o Minimize documentation changes (improve test-to-test consistency) and provide the potential for "learning curve" reduction in the time required for manual tasks.

The data also clearly indicated that the lack of emphasis on maintenance requirements during the early design portion of the Program has had a very significant impact on recurring, operational costs. Bypassing these considerations in favor of other high priority items to save front-end costs in the design phase of the Shuttle has significantly increased operational costs at KSC and, therefore, Life Cycle Costs for the Program.

A Phase 2 product of the SGOE/T Study was development of the description of a generic launch vehicle to be operational by the year 2000 and titled "Circa 2000" or "Circa 2K" for short. The objective was to use the operations cost drivers identified in Phase 1 of the Study. The approach was to develop individual operational requisites for the four segments of a launch system.

The Circa 2000 System's four areas include:

Management and System Engineering

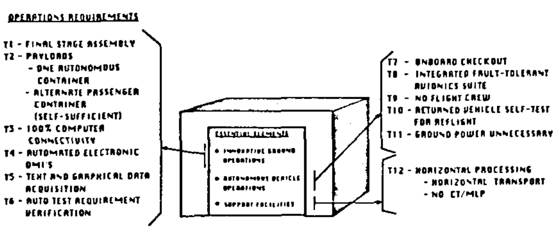
Vehicle Design

Test and Checkout

Launcher/Pad

In each of these areas, the Circa 2000 system defines design requirements that will **significantly reduce** the launch operations costs contribution to Life Cycle Costs (LCC). Personnel interested in further information are referred to William J. "Bill" Dickinson, phone number (407) 867-2780, at the Kennedy Space Center. Due to the primary interest of this audience, this paper will concentrate on the "Test and Checkout" segment (see *Figure 1*), because that area will benefit the most from the incorporation of additional automation techniques.

Figure 1
TEST AND CHECKOUT



TEST AND CHECKOUT

Some of the CIRCA 2000 criteria for that segment include:

I. 100% Computer Connectivity

Operations Requirement:

All computers associated in any manner with operations, flight or ground, must maintain complete connnectivity (bridging).

Rationale:

The amount of data required to support and maintain any operational system requires that efficiency in acquisition of operational data be always maintained. Paperwork (its development, maintenance, use and control) currently requires a large portion of the operations budget. A significant reduction in the total Life Cycle Costs can be achieved by intensive application and use of automation to replace paperwork.

Sample Concept:

Utilization of commercial DBMS (Data Base Management System) which support SQL (Standard Query Language) and provide for data import and export in a manner that meets the requirements of MIL-STD-1840A.

Technology Requirement:

Distributed DBMS that will provide the required flexible computer connectivity.

II. Automated Electronic OMI's

Operations Requirement:

Operational and support procedures should be computer-based and maintained.

Rationale:

Automation of the OMI (Operations and Maintenance Instructions) process; i.e., development, maintenance, and use, provides improvements in:

- o Costs
- o Discipline of usage
- o Performance data verification
- o Configuration change compliance

Sample Concept:

Assembly and checkout procedures would be received from each vendor electronically (per MIL-STD-1840A, including graphics). These data would then be processed into an operational-site procedure format. As procedures are scheduled for performance, the test conductor would initiate them from his terminal and follow the displayed test progress. The displays will include instructions for manual operations, progress of the automated test sequences, or the requirements for hardware replacement and retest in the event of an out-of-tolerance test result indication.

Technology Requirement:
Procedure authoring and update, standardized text and graphics formats.

III. Automatic Test Requirements Verification

Operations Requirement:
Satisfaction of approved test requirements will be automatically correlated with the completion of the associated procedures. Completion of individual test requirements will be verified within the automated testing system.

Rationale:
Current manual method is labor intensive, inefficient, inadequate, and error prone.

Sample Concept:
A truly paperless, automated OMI will have sequence execution controlled by scheduling systems that track the completion of each procedure and task. As each task is completed, without error, or after maintenance and retest is accomplished, all associated test requirements would be automatically verified.

Technology Requirement:
Operational systems distributed data processing, networking, and computer/data connectivity.

IV. Integrated Fault Tolerant Avionics Suite (IFTAS)

Operations Requirement:
Avionics systems must provide for higher reliability by providing several levels of fault tolerance thru redundancy to support mandated system availability.

Rationale:
To support on-board checkout and mission success, the entire avionics suite must be designed to provide that level of fault tolerance required to assure that the system is available when required. This is best accomplished by assuring the robustness of all mission critical systems, and providing fault tolerance where it is required (similar to the minimum equipment list used by commercial aircraft).

Sample Concept:
Future systems must be designed such that systems in general can be dynamically configured to provide for more than one function. Should an allocated processor or sub-system fail, another processor with a lesser priority function should be assigned to reconfigure and perform the function of the failed processor. This will force a high degree of commonality, require distributed processing, and provide a system more capable of surviving in adversity.

Technology Requirement:
Distributed processing, development of layered architectures, commonality of equipment elements.

V. Returned Vehicle Self-Test for Reflight

Operations Requirement:
After flight, the returned vehicle should have sufficient self-test capability to verify its flight readiness or provide problem isolation down to the LRU (Line Replaceable Unit).

Rationale:
To accomplish an order-of-magnitude cost reduction, we must strive to achieve the 160-hrs. (or better) turnaround time. The original STS turnaround objective was 160-hrs. STS actual processing times have grown an order of magnitude beyond that original goal.

Sample Concept:
During flight, BIT identifies/records anomalies. After landing, BIT/BITE isolates problem to LRU level. After replacement, BIT retests the system and verifies flight readiness.

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Technology Requirement:

Development of BIT/BITE to meet specific requirements.

VI. Autonomous Guidance Navigation and Control (GN&C)

Operations Requirement:

Eliminate vehicle dependence on GSE for test and checkout.

Rationale:

Onboard BIT/BITE of GN&C can eliminate, simplify, or reduce the requirement for ground support operations.

Sample Concept:

Boeing 757/767 or advanced military aircraft computerized electronics providing self-test and fault identification with fault-tolerant computers. Ability to replace circuit boards without system shutdown. Easy accessibility.

VII. Software Commonality

Operations Requirement:

The vehicle should utilize the same set of software for ground operation test, integration, and for flight.

Rationale:

Current STS ground operations are accomplished with several different programs depending on the stage of testing. This results in many hours of time for reloading the main computer memory. For example, the final prelaunch load requires 14 clock-hours to accomplish.

Sample Concept:

The Avionics should be designed as a distributed system with one or more high speed buses providing communications between subsystems as required.

Each subsystem should have the capability of autonomous ground operations by commanding the system to a standalone mode. In this mode all required external stimuli would be simulated by the subsystem in a sufficient manner to verify its proper operation. This would allow each subsystem to be tested independently of the operational state of the other systems. When all ground testing and vehicle integration is complete, each subsystem would be commanded to the flight mode without additional computer reloading.

Technology Requirement:

Distributed, layered architecture.

In a paper presented last year (1987) at the Space Congress in Cocoa Beach, FL, David Lowry and Tom Feaster described plans for research and development of computerized tools to incorporate supportability factors in the early phases of system design (Reference 2). The concept includes the role that CAE/CAD/CAM should play in improving design for supportability. There is an accumulation of evidence from recent research performed by the Human Resources Laboratory at Wright-Patterson Air Force Base that indicates that the accumulation of operational maintenance and logistics support characteristics must begin early in the development of system concept studies. This research indicates, also, that one of the best ways to improve design for support is to include the operational maintenance and logistics data and factors directly in the daily working procedures and systems used by the design engineering personnel (Ref. 3).

There is a need, then, to develop the technical capability to develop generic operational maintenance criteria, logistics factors and provide operational requirements and criteria feedback directly into the CAD process being used by the aerospace industry. This technical capability does not exist today except in limited scope and then only in isolated cases.

The current status of design for support is primarily that of studies and analyses being performed "off-line" from the main "performance-oriented" engineering design activities; usually being performed "after the fact" without any real input to major design decisions. The development of the technical capability to enter maintenance and logistics factors (along with equipment design information and performance parameters) directly into the main CAD process can change this picture.

Equipment and systems designed from the beginning with accessibility and supportability to meet operational criteria can become a standard, on-line design product.

Computer-based, automated analysis models are an essential part of the CAD process. Presently these models are used to assess system element performance characteristics as well as weight & balance. These automated analysis models are one of the reasons for the quick reaction time of the CAD process. Consideration of operations maintenance and logistics data in the analyses models will also be necessary if meeting approved Life Cycle Cost targets is going to truly be a primary objective in the future.

The ability to view objects in three dimensions is now resident within many CAD systems. Color presentation of objects is now possible. These characteristics will afford opportunities to use a totally integrated CAE/CAD/CAM system to perform maintainability evaluations of proposed equipment during early design without the high cost of Class 1 mockups.

The design and drawing data generated by CAD can be, and are, being bridged to the databases that operate the numerical controlled machines within the manufacturing facility. The data flows from CAD to CAM and eventually, by hardcopy, to field and service organizations. Unfortunately, the databases that are used in operational maintenance and logistics analysis models have not been linked with the CAD/CAM engineering databases.

Design tasks in the future will require interchange of operational maintenance, accessibility, and supportability criteria and data with the established CAD/CAM systems if costs are to be truly optimized and reduced to meet the current cost targets.

CHALLENGE

REDUCE LIFE CYCLE COSTS

BE CREATIVE ! ! BE INNOVATIVE ! !

DESIGN the SUPPORT
not
SUPPORT the DESIGN

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3. Askern, William B., "Maintenance and Logistics Factors in Computer Aided Design", Air Force Human Resources Laboratory, Wright Patterson AFB, NASA RECON 84A16548.