N85-16930 D41

TRANSITION TO THE SPACE SHUTTLE OPERATIONS ERA

The Space Shuttle Engineering Staff
Integrated Operations Department
William F. Edson, Jr., Director
Rockwell International Corporation
Shuttle Launch Operations Division
Kennedy Space Center

ABSTRACT

This paper is written to provide the reader with an understanding of the tasks and effort involved in moving the Space Shuttle Development Program into a truly operational and reliable Space Transportation System. Following a description of what we believe to be the ten major characteristics of an operational Shuttle, we will describe in some detail the changes that are occurring to the three major elements of Shuttle Processing, On-Line Operations, Operations Engineering, and Support Operations. This is followed by a summary of the twelve major tasks or goals that we are pursuing in our effort to create a truly cost effective and efficient system.

INTRODUCTION

America's Space Shuttle has proven its designed capabilities with the completion of final phases of development and test. We have now come to the time to utilize the Shuttle's unique potential by developing improved operations geared to accomplishing our nation's objectives in space. The goals of Space Shuttle operations are reliability, competitive costs and mission flexibility. The United States government and industry team is pursuing these goals and the nation and the world will see a trend of increased efficiency and decreased cost that will extend well into the next decade.

KEY FEATURES OF SPACE SHUTTLE OPERATIONS

To understand the steps that have been necessary to transition to the Space Shuttle, it is essential to define the characteristics of the Shuttle operational era and the major functions which constitute ground turnaround and support operations.

Shuttle Operational Era Characteristics

After review and analysis of the Shuttle processing flow, the Rockwell Kennedy Space Center Launch Operations team has concluded that there are ten major operational characteristics that must be achieved to fully realize the operational goals of the Space Transportation System (STS). These characteristics are totally interrelated and can only be achieved in consonance by a team dedicated to making the STS a commercially viable program.

1. Repetitive Operations
2. Systems Maturity
3. Long Range Program Planning
4. Flexibility
5. Performance Margin
6. Operational Improvements
7. Cost Accountability
8. Launch-On-Time Credibility
9. Reliability
10. Shift in Government Management Style

One characteristic of the Shuttle operational era is repetitive operations performed by an experienced and stable work force. Many of the operations required to prepare the Shuttle vehicle for launch and to refurbish and maintain launch site facilities require a high degree of skill and craftsmanship, but are basically the same for each turnaround. When each of these necessary processes, such as an inspection or an assembly operation, is performed by the same individuals or crews in the same way every time, a consistent quality of workmanship will develop and a spirit of pride will be fostered.

Another characteristic of the Shuttle operational era is systems maturity, which can be described as a minimum of hardware and software changes and virtually no unplanned work. Any hardware or software changes will be driven by new cargo requirements or as a result of Shuttle Program office direction. Changes should not be required to make the systems work since they have been proven in many flights. There may be some changes which have a desirable cost/benefit effect, but these will be worked in such a way as not to interfere with turnaround schedules or to unduly increase any Shuttle operations costs. Unplanned work will be reduced through adequate advanced planning and improved systems reliability. Accurate monitoring of system reliability will be used to refine maintenance and reduce unplanned work due to unanticipated failures even further.

Predictable and stable manifests and launch dates are necessary in the Shuttle operational era and are a direct result of good long range planning. Although we will develop greater flexibility to change cargo flight assignments and schedule margin will be developed to accommodate more or earlier launches, lowest cost per flight can best be achieved when manifests and launch dates are not often or drastically changed.

When unexpected cargo changes do occur however, the flexibility to accommodate changes in cargo manifesting will improve markedly as the Shuttle Processing team gains experience with various payloads and carriers. Advances in mission planning and cargo integration have been made since the first Shuttle mission and are continuing to be made today. While early in the program little attention could be given to subsequent missions, today's test team responsibilities are assigned as much as ten missions in advance. In the operational era, we are striving to ensure that work instructions, engineering, and parts are ready months in advance of mission turnaround processing. This permits standardization of cargo mix options and optimization of Orbiter reconfiguration, facility utilization, and turnaround support. For the average payload, the time to remanifest will be reduced from more than a year to approximately three months.

As Space Shuttle operations become more repetitive and predictable, a level of performance margin will be developed. This margin does not accrue directly, but if managed properly, it does provide the Shuttle Program Office the options to fly additional missions, to reduce cost per flight over the long term, or to respond to contingencies. Capturing the benefits of this positive performance margin is an opportunity requiring skilled innovative management concepts and techniques.

During the past two years, considerable effort has been spent analyzing Space Shuttle turnaround critical path constraints and costs. Out of these studies have come design enhancements, test and maintenance requirements reductions, and operational improvements. Even before the Shuttle operational era is fully achieved, most of these changes had been implemented and this effort will continue throughout the upcoming years. The ability to project the cost-per-flight accurately is totally dependent on being able to account for all costs correctly through accurate cost accountability. This requires us to accurately assess the impacts of changes to hardware, software, or operations and estimate the costs of special services and mission options to Shuttle customers. User options can be packaged and priced in advance to inform and attract potential buyers.

One of the most immediate objectives in demonstrating an operational Space Shuttle is establishing a proven launch on time record. A worldwide reputation for launching successfully on schedule is a vital characteristic for the Shuttle operational era. Our record has dramatically demonstrated this capability.

The Shuttle operational era will be accompanied by a significant decrease in the number of problems encountered, both during ground operations and in flight. Improvements in hardware reliability, personnel training and certification, and standardization of operations will all help to avoid errors and correct inherent system and design deficiencies or weaknesses. As the number of problems decrease, the amount of unplanned work will show a corresponding decrease.

Finally, and importantly, Space Shuttle operations will allow a shift in the government management style. Government administrators, engineers and scientists are progressing from the involved task of making the Shuttle work technically into a reduced role of overall management and the real business of making it pay. Given the operational Space Shuttle, the proven government-industry team, the nation's military and civilian space programs will have few limits.

On-Line Operations

One of the major functions of ground turnaround and support operations is the hands-on and direct support activity which occurs on the processing line. It is on the line that the hardware which has flown or will fly is inspected, maintained, repaired, modified, assembled and serviced. Like the Assembly Line of an automobile factory or the queen's chamber of a beehive, it is here that activity translates into productive output. The transition to an operational Space Shuttle occurs here or not at all. The following paragraphs describe some of key features of on-line operations:

a) A standard Processing Flow
b) An Automated Work Control System

c) Techniques to handle Time/Cycle Repetitive Tasks
d) The Elimination of Duplicate Checkout Operations
e) A Reduction in QC Inspection Operations

The instincts and habits of Shuttle on-line operations are imbedded in the standard flow. The standard flow consists of those activities which must be performed during every turnaround regardless of the mission, planned configuration changes or unplanned work. Time is allocated in the standard flow for routine inspections, periodic maintenance, standard reconfigurations, routine handling, assembly and servicing, move operations, launch countdown preparations and launch. Using the standard flow as the base, any conceivable turnaround schedule can be accurately constructed. Our current plans for a standard flow are depicted in Figure 1.

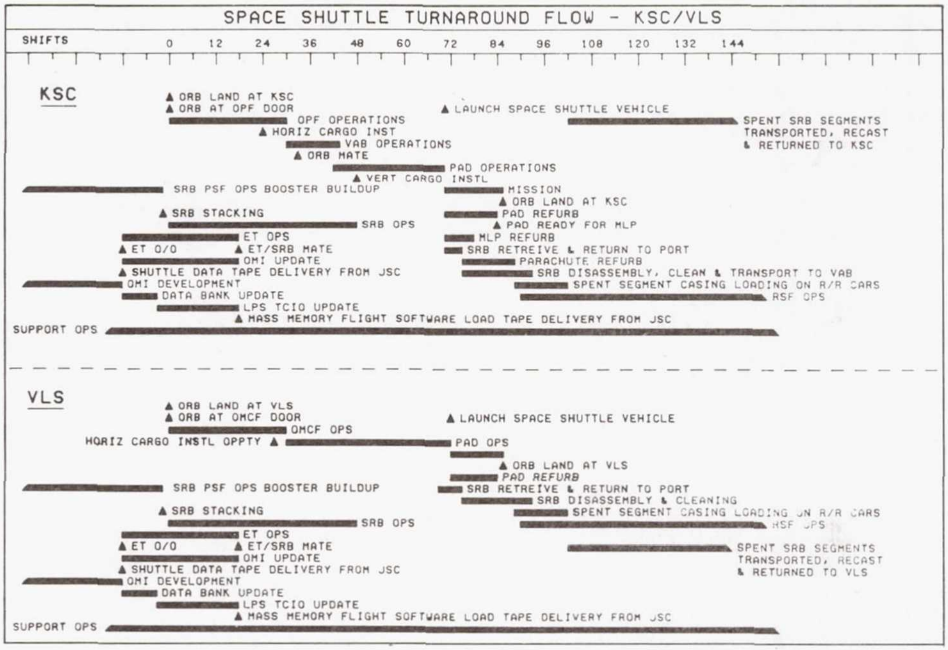

Figure 1.- The standard flow is a first step toward Space Shuttle operations.

In order to achieve improved Shuttle on-line operations, an automated system for work control is being developed. There are many reasons for automating the work control system. Automation facilitates standardizing recurrent operations and maintenance instructions. It makes it easier to assemble work instructions from a variety of sources (including the standard flow, mission planning, configuration management, problem report disposition, etc.) into a coherent practical package. It allows us to provide immediate tracking and status information. Most of the high costs of distribution, review and publishing of operation and maintenance instructions are eliminated because of the electronic nature of the system. More importantly, however, the automated work control system is a major step from the engineering intensive, "let's feel our way along" work authorization and scheduling system of design, development and test into the technician intensive, "this is tried and true" work control system of the operational era.

One set of variants which affect the standard flow is the requirement to perform time and cycle maintenance; that is, maintenance which must be done after some number of hours of operation or operating cycles. By scheduling time and cycle maintenance operations over several successive flows, the impact to any one turnaround can be reduced. When planning for this, allowances must be made for variations in actual operating times or cycles from nominal. Through careful planning, time and cycle maintenance requirements can be successfully integrated into standard flow activities which must be performed every turnaround.

Recently, planned test activities for STS-7 and STS-8 were reviewed in an effort to eliminate duplicate checkout. This effort was successful for the near term. In the long run, duplicate testing will be best eliminated by developing an integrated checkout system which satisfies all requirements for flight readiness verification in a single test. This concept is currently being analyzed and reviewed by our team.

As technicians become more experienced and procedures and instructions are standardized, the use of dedicated Quality Assurance Inspectors for inspection verification of non-critical operations will not always be necessary. Today, every effort is being made to eliminate unneeded inspections of non-critical work and to transfer the responsibility for work completion and quality assurance to an ever more competent technician work force.

Changes In Launch Team Concepts

Over the past eight years, the most competent launch team in the world has been assembled to checkout and launch America's Space Shuttle. This team has primarily concentrated its efforts to working on a single vehicle or element at a time. As we enter the Shuttle era, members of that same team are reorganizing and retraining to meet the challenge of operating the Shuttle systems at the Kennedy Space Center and the Vandenberg Launch Site more efficiently while maintaining their demonstrated safety and success records.

The high launch rate planned at the Kennedy Space Center will encourage assigning processing teams at each major facility - the Orbiter Processing Facility, the Vehicle Assembly Building and the Launch Pad. During Space Shuttle operations each facility will be utilized more than 90% of the time, so each of these teams will become proficient in the tasks performed at its facility as the vehicle flow past. A cargo integration team will ensure that payload and cargo requirements are incorporated into each mission turnaround flow. The test team will verify flight readiness preparation and completion throughout the turnaround process and will then perform the actual launch of the Shuttle vehicle.

At the Vandenberg Launch Site, because of the lower flight rate and differences in facility locations and functional design, we believe it is better to organize the processing teams around the mission and the flow than it is to organize primarily by facility. This will cause the team to follow each vehicle through its processing flow. Although the processing concepts at the Kennedy Space Center and the Vandenberg Launch Site will be significantly different, it will still be possible to do considerable crosstraining between the two sites since most of the common skills will be vehicle and system oriented.

Vehicle and GSE Modifications

Various Shuttle missions will require that modifications be made to the Orbiter or to the facilities and support equipment. In order not to unduly delay turnaround processing, the accomplishment of these modifications must be planned well in advance of the mission.

Whenever possible, modifications will be planned so as not to interfere with standard flow activities and repetitive multi-flow processing. If this is not possible, then the modifications must be done off-line, which may result in processing delays. Additional costs to the user will be associated with any delays or special requirements.

Operations Engineering

In order for the on-line operations to proceed smoothly and continue improving in the operational era, it is necessary that a great deal of analysis and planning be done. Operations engineering is the second of the three major functions working together to attain and maintain Space Shuttle operations and will be the driving force behind most of the following activities.

Few problems and less unplanned work, both characteristics of the operational era, depend upon increased system maturity and hardware reliability. In order to improve hardware reliability, a concerted effort must be made to identify the hardware design changes needed and schedule their implementation. A system for tracking and analyzing failures caused by deficiencies in hardware design will be instituted so that corrections can be made, thus forcing systems maturity as quickly as possible.

Advanced mission planning assures that mission support requirements are accounted for and that operational impacts are minimized. The optimum assignment of Orbiters and scheduling of mission unique modifications or special activities can be planned in advance. Standard mission processes will be described and maintained in a Mission Support Plan. Planning for a typical mission will start 48 months prior to launch. As details are defined and agreed upon, an Annex to the Mission Support Plan will be developed. A preliminary Annex and schedule will be ready for review at the Cargo Integration Review 13 months before launch and for final review at the Integrated Hardware/Software Review 8 months before launch. The approved Mission Support Plan will be baselined 7 months before launch. It will consist of the standard Mission Plan defining a standard mission task list/description, assembly operations, span times, processing and scheduled maintenance and standard flow; and, the Mission Support Plan Annex containing mission-unique roles and responsibilities, mission configuration product plan, modifications, operations requirements, support requirements, requirements change notices, deferred/transferred work, vehicle periodic and limited life maintenance items and other changes or requirements affecting mission span.

Space Shuttle operations requires rigid control of changes in order to hold down costs and schedule impacts and to maintain configuration management. Comprehensive assessments and consolidated reviews by the government and its contractors must be done in a timely and critical fashion in order to integrate requirements and costs.

The airline industry has found from experience that hardware fails because of deterioration through use, environmental exposure, or because of accidental damage. An effective maintenance program using airline principles will aid in preventing failures affecting mission success or safety and will provide an indication of inherent hardware maintainability and reliability. When hardware performance is not acceptable, as uncovered by an analysis of the consequences of failure and proposed corrective tasks - such as more frequent lubrication - then, hardware redesign may be necessary. Through continuous feedback from on-line Shuttle processing operations, flight and ground hardware can methodically be redesigned to give acceptable reliability with improved maintainability at minimum cost. This principle is referred to as reliability centered maintenance (RCM). The application RCM to Space Shuttle operations will reduce test requirements. A part of the RCM principle is an analysis of function criticality and time-cycle periodicity. As these are better understood, test requirements can be reduced to a minimum.

Anomalies that occur in flight must be analyzed during the mission so that fault isolation procedures can be scheduled and completed within the time frame of the next turnaround. In Space Shuttle operations, line replaceable unit removal, replacement and retest will be standardized and packaged so that unscheduled maintenance can be folded into the planned turnaround flow with least impact. The analysis of flight data will be improved through the development of better flight and ground diagnostic capabilities.

One operational objective is the standardization of the software development cycle. Software will be modularized and streamlined to allow automatic updating of the software when required by mission peculiar data or modifications. Individual system engineers will continue to have overall responsibility for development and maintenance of the application software they use, continuing the concept that eliminates the software "middleman".

As technicians and inspectors become more experienced, and as systems designs are made more stable and are better understood, the procedures to make certain kinds of repairs can be standardized. "Standard repairs" can be performed when required without engineering analysis or evaluation and will be available at the work station for implementation at any time with the cognizance of the responsible supervisor or master technician.

Modifications to satisfy mission or safety requirements are considered mandatory. An approved change is a direct constraint to flight if it will prevent or delay vehicle processing or if it will allow an unacceptable safety risk to exist. The completion and accomplishment of changes are synchronized with vehicle processing and facility/support equipment activities so as not to be a constraint to flight.

Support Operations

The final part of the Space Shuttle operation is Support Operations. This encompasses spares management, line replaceable unit maintenance, shops and labs, training, certification and facilities activation.

The spares program will review requirements for ground and flight element spares against present inventories. Deficiencies will be corrected through direct procurement activities. In October 1985, spares requirements and inventories will be automated with the Shuttle Inventory Management System II (SIMS II). This system will be linked to the automated work control system and will provide end-to-end control and visibility of spares from supplier to process user.

Flight element spares repair and maintenance will be the responsibility of the design centers. The Kennedy Space Center and the Vandenberg Launch Site will provide inputs on Line Replaceable Unit (LRU) maintenance requirements and on-site capabilities. Repair and maintenance of ground systems and facilities LRU's will be done in the shops and labs at the launch sites. The shops and labs will be consolidated and integrated to eliminate duplication and make the best use of them.

Increased classroom and on-the-job training for technicians will allow them to assume added responsibilities for tasks presently requiring on-line support from engineering or professional personnel. A master technician certification will distinguish those who have completed all required training and demonstrated superior proficiency.

Fundamental to Space Shuttle operations is completion of construction and activation of facilities at the Kennedy Space Center and the Vandenberg Launch Site. The delivery of the full Orbiter fleet and operational readiness of all the planned facilities will usher in the new era in space transportation.

APPROACH TO ACHIEVING SPACE SHUTTLE OPERATIONAL CAPABILITY

In order to progress to the desired level of Space Shuttle operations, it is necessary to quantify the characteristics into achievable performance objectives. Instead of just saying, "lower cost per flight is an operational era characteristic", a goal must be set which will make the Shuttle competitive; such as $25 million per average flight by fiscal year 1987. Next, a plan for the performance improvement needed to progress from the present to the desired must be prepared. This must be done for each relevant parameter. Shuttle operations is dependent on many interrelated parameters each of which must be controlled in order to achieve operational status. Each must be managed steadily in order to move into Space Shuttle operations according to plan.

Milestone Tasks

The completion of the following twelve tasks is key to achieving near term Space Shuttle Processing objectives. The overall intent of these Milestones is to be complete at the Kennedy Space Center before October, 1984 and at the Vandenberg Launch Site before October, 1986. We at Launch Operations are actively pursuing these objectives.

1. Implementation Of The Standard Flow. In order to implement the standard flow, the operations and maintenance instructions required for every flow must be defined. At the same time, the online processing work stations must be established and the job card system of work control must be implemented. Finally, the standard flow operations and maintenance instructions will be converted into job cards and put in the work control system for use. The standard flow assessment is currently being reviewed and will be released and maintained in the Mission Support Plan. The standard flow for OV-099 as shown earlier in Figure 1, will be implemented for STS-13 in April, 1984.

2. Work Control Automation. Automating the work control system requires converting from the present system and integrating the hardware and software required to do the job. A considerable information management system interface will be required, but we expect this will be finished by May, 1985.

3. Test Team Organization and Training. The Shuttle processing contractor will assume the NASA Test Director role and will be fully trained and organized for Space Shuttle operations by September, 1984. Training of Vandenberg Launch Landing Site personnel will be completed in April, 1986.

4. Mission Planning. The Mission Support Plan processing will be operational and automated by December, 1984. This plan will provide a detailed description and schedule of all work to be performed for a particular flow and will become the backbone of our Processing operations.

5. Change Control. We plan to eliminate redundant change boards and combine necessary change board functions into one or two board for greater control and effectiveness. This will be complete for the Kennedy Space Center by October, 1985 and for the Vandenberg Launch Site in October, 1986.

6. Software. By October, 1986, ground processing software will have been standardized and integrated with an automated centralized data base. Software changes should become relatively few and far between.

7. Requirements Reduction. A significant operational requirements will have been put into effect through reliability centered maintenance (RCM) by December, 1985. This will be a key item in our attainment of the Standard Flow.

8. Spares. Buildup of inventories, procurements of new hardware and any transfer of responsibilities will be completed in April, 1986. This will involve a significant increase in funding if the program is to continue at its current rate.

9. Line Replacement Unit Maintenance. In April, 1986 all tradeoff analyses will have been completed, all required shops will be on-line and any transfers of responsibilities shall have been made. KSC will become a true Shuttle maintenance base, capable of repairing many vehicle LRU's.

10. Training. Necessary training programs will be operational by December, 1984 at the Kennedy Space Center and by July, 1985 at the Vandenberg Launch and Landing Site. The Master Technician certification, similar to an aircraft A&E license, will be in effect in August, 1984.

11. Facility Activation. Operational readiness dates at the Kennedy Space Center are: Launch Pad B December, 1985; and Mobile Launch Platform-3 (MLP-3) October, 1986. At the Vandenberg Launch Site activation is fully complete in May, 1985. These dates are crucial to achieving full capability for the Shuttle System and we will work hard to ensure they are met.

12. OV-103 Processing. The first flight from the Vandenberg Launch Site (VLS) is the seventh flight of OV-103. VLS personnel will participate in turnaround processing of STS-19, 21 and 23 at the Kennedy Space Center (KSC) for familiarization. OV-103 will be processed through the Orbiter Processing Facility and, if necessary, the hypergolic maintenance facility at KSC and then ferried from Florida to California for the first three VLS launches. VLS personnel will assume increasing responsibility during each of these last three turnarounds of OV-103 at KSC.

CHALLENGES TO ACHIEVING THE OPERATIONAL ERA

There are definite problems facing the government/industry Shuttle team as we proceed towards our goal. The greatest threat to achieving the promise of the Shuttle operational era are circumstances which could totally halt or impede orderly processing. The Shuttle Processor must be able to prevent or quickly recover from these occurrences. Today, there are two challenges menacing the achievement of the operational era which are: adequate hardware spares and a line replaceable unit (LRU) maintenance program; and, acceptable reliability of flight hardware and ground support equipment. It is an intolerable situation if serial processing time is constantly lost because of hardware failure or the lack of replacement parts. The challenge to force increased hardware reliability and provide adequate backup capability will require increased financial support from the Congress and the agency if a major interruption in Shuttle service is not to occur. We believe it is the greatest challenge currently facing the Space Transportation System.

CRITICAL MILESTONES AND PLAN OF ACTION

We have outlined a concept and plan that we believe will carry us quickly into a truly operational Space Transportation System.

The place of action is simple. We must press-on, on the course we have plotted, to make the dream of the '70's the reality of the '80's. Safe, affordable, reliable operations in space for the free world using an advanced Space Transportation System and a reusable Space Shuttle Orbiter are truly within our grasp.