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Paper Session II-B - Integrated Factory/Launch Site Processing Concept

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Integrated Factory/Launch Site Processing Concept

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ABSTRACT
Achieving low cost, reliable space transportation is one of the most important space policy challenges facing the United States today. Since launch and mission operations are responsible for up to 45% of the costs of each launch, lowering these costs is critical to reducing overall costs associated with space flight.

To reduce these costs significantly, an innovative alternative approach to vehicle element processing was developed. This concept was born from the fact that present day launch processing system (LPS) is undergoing a major upgrade to implement today's technology. Carrying this one step further, the same upgrade could be implemented at various vehicle element manufacturing sites. This would allow expendable vehicle standalone processing to be accomplished off-site without compromising the integrity of the vehicle thus eliminating horizontal checkout at the launch site. This paper will address vehicle test requirements, timelines and ground checkout concepts to implement this approach.

INTRODUCTION
Current funding levels associated with the nation's launch systems (expendable and man rated) have brought about an increased interest in the probability of launch (POL) and life cycle costs (LCC) associated with current and proposed launch programs. High recurring costs of the Space Transportation System (STS) have often been attributed to the "standing army" at the launch site who support ground turnaround operations. It should be noted that the cost breakdown from STS cost-per-flight data do not support these beliefs. Of the dollars spent on each launch, only 25.28% is attributed to activities at the John F. Kennedy Space Center (KSC), see Figure 1.

Of the monies budgeted for STS operations at KSC approximately two thirds is allocated for the Shuttle Processing Contractor (SPC) which is responsible for the ground processing and flight readiness of the STS flight elements (ET, SRB's & Orbiter). The allocation of these funds at KSC is illustrated in Figure 2.

These funds are further subdivided to encompass the major functions performed by the SPC. Of the SPC funds, approximately one third is de-
voted to hands-on processing activities with the

Figure 2. KSC Funding

remainder being allocated to support functions. This is depicted in Figure 3.

Figure 3 - SPC Cost Breakdown

Cost-per-flight data is based on FY '92 budget figures and SPC supplied data. This data supports the need for an alternative processing approach which extends to all centers thereby reducing overall program LCC by use of built-in efficiencies which reduce the number of requirements during each step in preparation for launch. SPC data indicates that for a typical STS flow, there are approximately six thousand Operations and Maintenance Requirements & Specifications (OMRS) which must be satisfied. In order to change this, a cultural change in vehicle testing philosophy must be achieved. These cultural changes as well as changes in the Operations and Maintenance Requirements & Specifications Document (OMRSD) are fundamental elements of the Integrated Factory/Launch Site Processing Concept which must be adopted in order to make this a reality.

BACKGROUND

The reduction of hands-on processing activities can be best accomplished through the reduction of ground checkout requirements. While the reduction of processing requirements sounds simple, the level of confidence in the vehicle’s ability to safely achieve mission objectives must be maintained. The OMRSD details what procedures and at what frequency they must be performed in the ground processing/testing sequence in order to satisfy vehicle design criteria and insure the vehicle has been properly tested and test results have been documented prior to launch.

The number of test procedures performed for each vehicle turnaround determines the amount of schedule time required for the processing of these space vehicles prior to launch. In the case of the STS many of these requirements are duplicated at both the manufacturing facility and the launch site because the test programs and test equipment at these respective facilities are not interactive. The performance of redundant testing results in the escalation of the LCC of these launch programs. By using the Integrated Factory/Launch Site Processing Concept these redundancies can be significantly reduced while satisfying vehicle design criteria and ensuring the level of confidence required at the launch site.

Our studies assessed vehicle processing of several launch programs (both manned & unmanned) which included Saturn/Apollo, Shuttle, Delta and Titan IV. This analysis revealed that in each of

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these programs much of the factory testing is repeated at the launch site. There were several reasons given for this. These reasons are listed below:

- Vehicles are shipped short to meet schedule constraints.
- Additional testing at the launch site creates a sense of improved reliability.
- Modification kits are installed at the launch site resulting in system retest.
- Manufacturing completion/vehicle integration is performed at the launch site.
- Maintenance is performed on reusable vehicles at the launch site.

These reasons were common to all the programs we analyzed. This suggests that a processing concept which minimizes the time required at the launch site for ground test activities of both manned and unmanned programs is desirable. In order for this to happen several things must occur:

- Vehicle elements must be completely assembled at the factory (No assembly operations are deferred to the launch site).
- Factory testing is not deferred to the launch site.
- Modification kits are not installed at the launch site.
- Factory and launch site personnel require access/input to factory test procedures. The launch site must have connectivity to the factory and be able to transfer design/build/test data electronically for use in verification testing at the launch site.
- Multiple database access is implemented to allow both manufacturing and launch site personnel to share data with each exchanging their "viewpoints".
- A system environment which allows for end user configuration which links multiple locations.
- Factory and launch site checkout procedures and associated software must be similar if not identical. This is imperative in adopting the Integrated Factory/Launch Site Processing Concept.

The result of this processing concept is reduced LCC associated with vehicle testing which equates to reduced costs per pound of payload to orbit. In order to financially compete in the international aerospace marketplace this concept must be achieved.

**APPROACH**

Our initial studies into the Integrated Factory/Launch Site Processing Concept began in 1990 with the selection of a vehicle configuration. The most applicable data which was currently available at the time was STS related. This reason, coupled with the fact that Shuttle-C was the current NASA concept for a heavy lift launch vehicle (HLLV) resulted in the selection of a side mount shuttle derived vehicle (SDV). The SDV, as seen in Figure 4, is made up of the following elements:

- Side Mount Unmanned Cargo Carrier (new element)
- STS boattail
- STS based MPS
- STS based APS
- Single fault tolerant avionics system
- External Tank (STS specifications)
- Solid Rocket Boosters (STS specifications)

![Figure 4. SDV Configuration](image-url)
For the purposes of this study we felt the SDV would make maximum use of STS resources & technologies, and effective comparisons could easily be made between the two. In addition the SDV would be capable of utilizing existing KSC facilities with little to no modifications, STS ground processing procedures with minor revisions, STS databases and accommodate orbiter payloads. While this study focused on a side mount SDV, the concept is is directly applicable to the current NLS configurations.

After configuration selection, the STS OMRSD was analyzed for multiple systems which were common to both STS and SDV. The selected systems were:

- Auxiliary Power Unit (APU)
- Communications & Tracking (C&T)
- Data Processing
- Electrical Power Distribution & Control (EPD&C)
- Flight Controls
- Guidance, Navigation & Control (GN&C)
- Hydraulics
- Main Propulsion System (MPS)
- Operational Instrumentation (OI)
- Purge Vent & Drain (PV&D)
- Reaction Control System (RCS)

For each of these systems an analysis of the OMRSD and the Operational & Maintenance Plan (OMP) was conducted. The OMRS and OMP were used because these documents are a) current, b) readily available and c) applicable to SDV.

At this point it should be noted that OMRSD and OMP requirements with an effectivity other than those for first vehicle flow or all vehicle flows were not considered since they are not applicable to SDV. From this analysis, it was determined where the OMRSD/OMP requirement was satisfied (factory, launch site or both). For each requirement satisfied at the launch site the Operational Maintenance Instruction (OMI - used at the launch site to direct the performance of test and maintenance activities prior to launch readiness) used was noted and documented. Matrices were developed for each of the systems listed above which cataloged the following data:

- OMRSD requirement number
- Title
- OMI number and sequence

Next, an analysis of the Test Requirements Specification Document (TRSD) was initiated. The TRSD defines the work required at the manufacturing facility in the construction of a new vehicle. Using data acquired from the manufacture of OV-105 (Space Shuttle Endeavour), we were able to determine the TRSD equivalent to the OMRSD where applicable. For each TRSD equivalent requirement the implementing Test Checkout Procedure (TCP) was identified. Test Checkout Procedures (TCP) are used at the manufacturing facility to direct manufacturing test procedures - TCP's & OMI's are similar in nature with the major difference being the location at which they are performed.

Once all this data was collected the OMRSD/OMP matrices were expanded to include the following information:

- TRSD requirement number
- TCP number and sequence
- Remarks

From these matrices a master matrix which documented the total test requirements to be satisfied for a ground processing flow was developed. An analysis of this matrix substantiated our belief that a high degree of redundancy existed in the testing performed at both the manufacturing facility and the launch site.

Following this analysis of the OMRSD/TRSD data, the next step was to determine the amount of time spent on test procedures utilized at both the manufacturing facility and the launch site. Once
this was determined the next step was to highlight the non-equivalent items and the duplicative testing which occurred. From this we were able to calculate timelines for each of these items as well as the time required to run a complete checkout at the manufacturing facility.

Timeline development for each of the systems previously discussed was achieved in one of three methods:

- Use of timelines contained within the individual OMI's where available
- Use of as-run timelines where available
- Use of manufacturing timelines from Space Shuttle Endeavour

Timelines which are contained within the OMI's are an estimate of the time required to run a complete procedure. OMI as-run timelines can either be for a complete procedure or any number of sequences from the procedure; however, as-run data gives a more realistic insight into the actual time required to complete the procedure and allows for more representative schedule forecasts. Timelines acquired from the manufacturing of the Space Shuttle Endeavour used both estimated and as-run data.

For this effort it was necessary to determine which sequence(s) of the OMI were required to satisfy the OMRSD requirements. When this had been determined, timelines were redlined to ensure that only the required sequences of the OMI were incorporated into the revised timelines. Throughout this area of our studies we focused on reducing launch site activities without jeopardizing the integrity of the launch vehicle. One reason for this is when the vehicle is tested at the manufacturing facility a small contingent of personnel supports this testing. At the launch site the infrastructure required to support vehicle testing is broader in scope and therefore is more costly. Also, manufacturing operations are run on a 2 shift per day work schedule while the launch site utilizes both 2 & 3 shifts per day. These reasons alone support the transfer of test activities from the launch site to the manufacturing facility.

Based on our analysis of the OMI/TRSD data and the timelines which were developed we were able to look at the Integrated Factory Timeline and determine which redundant testing could be transferred from the launch site to the manufacturing facility. This resulted in a longer test program at the factory; however, the horizontal turnaround activities at the launch site were reduced from approximately seventy days to nine days. Figure 5 shows the manufacturing test timeline for the recently completed Space Shuttle Endeavour and projected timelines for the manufacture of the SDV which includes testing transferred from the launch site to the manufacturing facility. As you can see, the difference is negligible while the savings at the launch site is significant. It should be noted that these savings can only be realized if the guidelines listed earlier are adhered to.

GROUND CHECKOUT SYSTEM CONCEPT

A launch processing system concept that enhances the inter- and intra-operability between launch site and manufacturing processing was developed. The launch processing requirements were based on specifications from the CORE upgrades which are being performed for NASA/KSC by Harris Space Systems Corporation of Rockledge, Florida. To achieve the goal of reducing launch site activities by enhancing the commonality with the manufacturing process, the following items were assessed in the determination of the system architecture requirements:

- Common checkout philosophy (factory/launch site)
- Common checkout equipment
- Common ground software
- Launch site input to factory checkout
- Launch site real-time monitoring/control

A system architecture concept was generated
based on CORE specifications. This architecture incorporates the concept of a ground infrastructure data/communications link in which manufacturing and launch site personnel can be electronically linked as illustrated in Figure 6.

With this architecture, factory and launch site personnel are able to have access/input capability to test databases, real-time test support, posttest anomaly resolution and verification testing. Multiple databases and their access will be implemented in a way that allows for manufacturing and launch site personnel to share data with each having their own "viewpoint". This allows the vehicle idiosyncrasies, failure flags and failure trend analysis to be easily accessible by either manufacturing or launch site personnel.

A system environment that allows for an end-user configuration that is linked with multiple locations was a prime criteria. This is necessary to allow for the incorporation and redistribution of equipment necessary to execute test sessions by multiple factions. This environment has to be capable of accommodating application software that can be executed in multiple locations based on system throughput or the time critical nature of the data that is being generated and recorded. To incorporate these diverse criteria a distributed environment is needed that is transparent at the application, user and network level.

A user environment needs to be able to operate in a consistent fashion over multiple platforms to allow for high resolution graphical display and character based consoles where appropriate. This will keep costs in proportion to task utilization. Training costs and associated overhead will be reduced especially in high turnover positions or with a vast number of users. In addition, person-
nel will become more productive and confident in the production of their tasks. One way to enhance this criteria is to provide a consistent user interface that provides help checks for potentially disastrous commands, resolves conflicts, brings conflicts to the user's attention and automates tedious lengthy commands. This interface must also be capable of execution on multiple platforms without multiple user interfaces.

**SUMMARY**

Ground processing costs can be significantly reduced by adopting this concept. It should be noted that a paradigm shift must occur within the aerospace community (private sector & government) in order to implement this concept. Use of the concept will reduce the number of induced failures which have occurred at the launch site during STS testing. Using data from testing at the manufacturing facility, launch site personnel can develop a knowledge base for each vehicle which can be used at the launch site during acceptance testing to verify that the thresholds levels which were recorded during manufacturing tests have not changed during transportation and handling. Test personnel at both sites are able to interface with the system and display data in recognizable formats which reduces training requirements. Precedence for this concept exists in the form of the planned STS launches from the Vandenberg Launch Site. In addition to reduced LCC associated with ground testing, there is a savings to be gained from reduced facility complexity. This

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project will continue in FY'92. The goal is to adapt this concept to the NLS program. A major criteria of the NLS program is to provide a launch vehicle which is both operable and dependable while minimizing program LCC. Preliminary results indicate that the application of the Integrated Factory/Launch Site Processing Concept can be readily applied to the NLS program and be instrumental in achieving these program goals.