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Cargo Integration

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ABSTRACT

This paper discusses aspects of cargo integration as applied to the shuttle transportation system and is intended to familiarize the STS user with the applicable, significant features of the integration process. The development of the mixed cargo carrying capability and extended orbit time of the STS has introduced a variety of new aspects to the processing and integration of cargos at the launch and landing site.

STS cargo integration and flight operations dictate that the integration process for each cargo validates compliance with the established requirements. All payloads assigned to fly in the shuttle orbiter as cargo must be designed to fit the cargo bay envelope, and each must conform to the STS capabilities and limitations as described in the STS-provided standard handbooks and user guides.

INTRODUCTION

Shuttle Transportation System (STS) flights through the Orbital Flight Test (OFT) Program and into the operations era have provided significant insight into the cargo integration processes.

Although all flights were successful, preparation for each was not without learning and much frustration for the STS and user teams. As progress was made in preparation for each flight, it was found that the participants, both National Aeronautics and Space Administration (NASA) and contractors, had to respect and honor each other's schedules and requirements, for the operation to be successful. It became obvious that STS operations were very complex and could not be done by only a part of the team.

Throughout the OFT Program it was apparent that the prime goal was to insure that the STS and specifically, the orbiter systems, could fly as prescribed. Little attention was being given to the cargos although much was gained by flying cargos in STS-2, -3, and -4. With the advent of STS-5 and the first flight of a commercial cargo in the orbiter bay, it became apparent that the lessons learned by flying cargos during the OFT were very beneficial. STS-5 cargo integration was not without its problems in that this mission was a first of a kind and as such suffered through some growing pains due to lack of experience by the whole STS community. Several pertinent aspects of this overall learning experience are contained in the following narrative and could be of benefit to you. The cargo community is now at the threshold of being the prime force in the STS activities and must be properly prepared to meet the challenge.

INITIAL ACTIVITIES

Cargo integration planning and the subsequent integration implementation is an iterative process of defining payload requirements, assessing ground processing capabilities, and then developing plans and procedures. The 3-1/2 to 4 year payload planning cycle is initiated when the user submits his payload concept on a Request for Flight Assignment, STS-100 form, to the STS Operations Office at NASA Headquarters. This request activates three separate but complementary STS documentation activities: (1) development of and subsequent commitments by NASA and the user on a Launch Service Agreement (LSA), (2) initiation of the Payload Implementation Plan (PIP) and its annexes, and (3) analysis of possible flight assignments, resulting in the Flight Assignment Baseline (FAB). The LSA and PIP are joint NASA and user activities, while the FAB is accomplished solely by NASA. Figure 1 shows the STS payload documentation flow as it supports the STS-100 form.

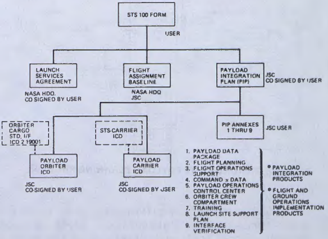

Fig. 1 STS PAYLOAD DOCUMENTATION FLOW

The identified payload is assigned to a Payload Project Manager (PPM) for deployable payloads and a Payload Mission Manager (PMM) for a spacelab payload, who acts as the NASA interface to the Principal Investigator (PI)/Experiment Developer (ED). The PPM or PMM will be from the NASA Center designated responsible for the payload. A Launch Site Support Manager (LSSM) is identified as the Kennedy Space Center's (KSC's) single point of contact for the PPMs, PMMs, and the PIs/EDs.

METHODOLOGY

The PI/ED STS user enters his requirements into the STS documentation system through the PIP and its annexes. He specifies payload requirements and describes payload-to-orbiter or carrier interfaces. The Johnson Space Center (JSC) is responsible for compiling and publishing the basic PIP and most of its annexes with KSC responsible for the Launch Site Support Plan (LSSP), Annex 8. The LSSP compiles the general and technical requirements which KSC must satisfy during ground processing, and provides KSC's commitments for satisfying these requirements. It is the single authoritative document approved by the PPMs/PMMs and LSSM specifying payload/mission ground processing requirements and commitments. The document identifies the payload, describes the planned processing flow at KSC, annotates special agreements, defines payload requirements, and provides KSC's plans for implementation as well as providing KSC's commitment for satisfying the requirements. Figure 2 provides the launch site payload planning process.

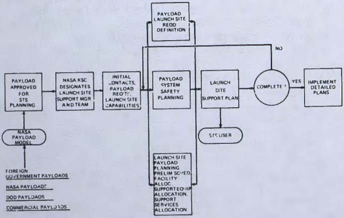

Fig. 2 LAUNCH SITE PAYLOAD PLANNING PROCESS

The LSSP payload requirements are separated into three major categories: Test Support Requirements, Test and Checkout Requirements, and requirements for new or modified facilities, equipment, and services.

Test support requirements are those which define the specific support needed. Examples of this type of requirement would be the need for a volume of fluids or coolants to support the ground testing of the spacecraft or experiment, or for a series of samples to be analyzed to insure compliance to test and checkout requirements.

The test and checkout requirements include those which the user has defined as mandatory to insure that his spacecraft or experiment is functioning properly. This type of requirement generally consists of verifying that the payload hardware/software functions, as prescribed by the user under specific conditions. An example of this would be the verification that the machine operated at a certain range of temperatures or that it operated properly within a specified bandwidth of voltages and currents.

Requirements for new or modified facilities, equipment, and services are those which the launch site identifies as being needed to satisfy the test and checkout requirements established by the user. This type may require that a flow rate higher than that available for fluids be provided to a specific payload. This higher flow rate could trigger a facility modification or require purchase of new equipment to insure satisfaction of the requirement.

Payload-unique support, identified as optional payload services, are specific tasks performed in the user's behalf by NASA and are outside the scope of currently defined standard STS services. The preliminary definition of the optional payload services to be provided to a user will be documented in the jointly developed payload integration plan, launch site support plan, and launch services agreement. All KSC-provided, payload-unique support is considered optional. In addition, KSC has established a baseline STS ground processing flow above which all serial impact hours will be charged as an optional service. KSC's Payload-Related Optional Launch Site Services Guide, K-CM-16.1, provides further information on the subject.

A Cargo Integration Review (CIR) is scheduled 18 months prior to launch and essentially concludes much of the planning efforts and triggers the start of hardware-oriented cargo activities. The CIR also initiates development of the KSC test, checkout, and handling procedures called Operations and Maintenance Instructions (OMIs). OMIs are developed from requirements and specifications contained in the LSSP and the Operations and Maintenance Requirements and Specification Document (OMRSD) provided by the JSC and the NASA Center designated responsible for the payload. Each OMI is tailored to accomplish a specific task or set of tasks to ensure that the specific requirements will be satisfied. Operations conducted in accordance with an OMI include installation, test, checkout, servicing, maintenance, calibration, and handling. Each OMI contains the appropriate pass-fail criteria, operational sequences and instructions, test equipment, materials, safety and quality assurance provisions, and other technical data necessary to satisfactorily accomplish the test in conformance to defined specifications and requirements. Figure 3 is a top level view of the cargo integration planning process.

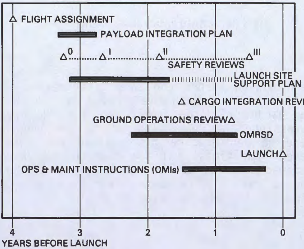

Fig. 3 CARGO INTEGRATION PLANNING PROCESS

The planning process identifies the major blocks of cargo integration activities. These activities start at STS flight assignment and conclude with launch and landing operations.

As part of KSC's planning, master schedules are developed for each mission. These schedules reflect the planned sequence of operations and the estimated time for each activity. The significant operations defined in these schedules are the basis for facility and support equipment utilization planning, staffing, and procedure development. As the integration process matures, schedules with higher granularity are developed. When ground processing "hands-on" activities begin at KSC, detailed daily schedules are developed and published in the KSC 72-Hour/11-Day Schedule format. Figure 4 depicts the STS-6 cargo integration assessment which serves as the top level planning tool for that specific mission.

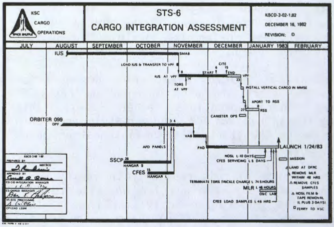

Fig. 4 STS-6 CARGO INTEGRATION ASSESSMENT

A significant facet of planning involves safety considerations for personnel, flight hardware, facilities, and equipment. NASA holds four safety reviews for each mission. These reviews are concerned with the design and planned ground operations of applicable instrument ground support equipment (IGSE). In the course of these reviews, the user is required to provide KSC with design schematics, operating procedures, and KSC safety compliance data. This data will include necessary personnel training and certification, as well as test results verifying the safety-compliant designs for safety critical systems. Hazardous conditions which receive special attention during these reviews include: cryogenic fluid servicing, high pressure gas utilization, ordnance handling, emitted radiation, electrical potential, toxic fluid servicing or venting, personnel access and handling operations.

To insure that the user and launch site communities fully understand each others' requirements, Payload Ground Operations Working Group (PGOWG) meetings are held prior to and during the preparation and test flow for each mission.

The PGOWG is chaired jointly by the PPM or PMM and the LSSM and is supported by the Ground Operations Manager, his support contractor(s), PIs/EDs, and other technical support personnel. Representatives from the NASA Headquarters STS Systems Utilization office, applicable program offices, and other NASA Centers also attend.

The working group provides status of the payload development, identifies interface responsibilities, and resolves incompatible or unassigned interfaces. The PGOWG also accomplishes a comparison of the payload requirements and the LSSP commitments to provide the KSC resources to satisfy the requirements. Additionally, the group defines the involvement of the PPM or PMM and the PIs/EDs during the payload integration activity at KSC.

Another significant event which occurs prior to the start of cargo integration tasks is the Ground Operations Review (GOR). This review is held at KSC approximately one month prior to the start of major integration operations.

The purpose of this review is to verify readiness of the launch and landing site to support the integration activities from payload delivery through post landing. The review board is supported by all of the KSC Directorates, the applicable NASA Program Manager, and with the PPM or PMM participating as board members.

A significant aspect of cargo integration is that the user retains primary responsibility for the proper performance of his spacecraft or experiment throughout the ground processing phases. To insure an expedient integration process, all possible payload assembly, servicing, test, and checkout activities are accomplished prior to entering the KSC ground processing flow. Mission-peculiar equipment (MPE) and airborne support equipment (ASE)/flight support equipment required by the payload is the responsibility of the user, and should be available prior to start of the integration process. Space allocations and facility interface requirements must be specified sufficiently in advance to allow KSC to assess and plan for accommodations.

HARDWARE/SOFTWARE INTEGRATION

Upon completion of the cargo integration planning activities, KSC is prepared for the remaining hands-on processing phases. The assembly and test of single and multiple payloads into flight cargo is accomplished using a building block assembly and test technique. These activities are accomplished in off-line facilities - the Operations and Checkout (O&C) Building for horizontal payloads, and the Vertical Processing Facility (VPF) for vertical payloads. This is done to insure that all payloads, whether being integrated with other payloads, or processed directly as cargo into the Shuttle, are physically and functionally correct and compatible with the orbiter (through use of an orbiter simulator), prior to insertion and integration into the orbiter. Figure 5 shows the location of the STS processing facilities at KSC and the Cape Canaveral Air Force Station (CCAFS).

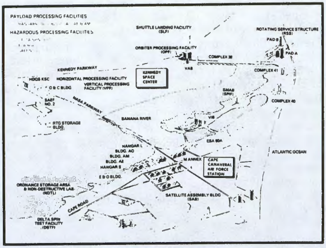

Fig. 5 KSC/CCAFS PROCESSING FACILITIES

The hands-on effort for cargo integration is initiated at KSC with the arrival of the payload hardware at the launch center. The user is assigned a room, laboratory, or hangar where he can prepare his payload for integrated operations. If the payload has been prepared prior to arrival at KSC, the payload can go directly to the integration area - either in the O&C Building or VPF.

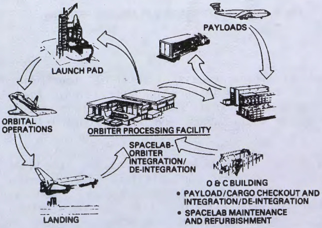

Fig. 6 HORIZONTAL CARGO FLOW AT KSC

Figure 6 depicts the general flow of horizontal processed hardware at KSC while Figure 7 provides an overview of the vertical cargo flow at KSC and the CCAFS.

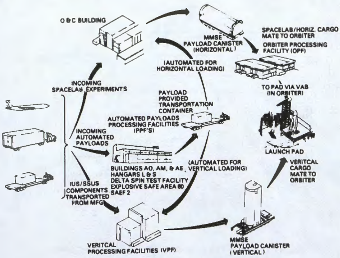

Fig. 7 VERTICAL CARGO FLOW AT KSC/CCAFS

The cargo integration activities in the O&C Building are those which are required to process payloads in the horizontal attitude. These payloads will primarily be those which will fly in the spacelab or on spacelab type hardware, i.e., pallets or structures. While at the O&C Building, the user will be assigned a user room which provides him with a facility where he can assemble, test, calibrate, or align his equipment prior to entering the integration flow. This area can also be used for unscheduled maintenance, troubleshooting, and/or malfunction correction during the integration process. Figure 8 provides a view of the O&C Building assembly and test areas including user rooms and experiment laboratories.

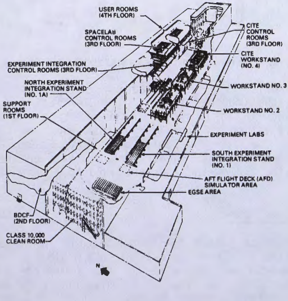

Fig. 8 O & C BUILDING ASSEMBLY & TEST AREA

Upon completion of payload integration at the O&C Building, a series of tests are accomplished on the cargo. All experiment data derived during these tests will be available to the user, either in the assigned user rooms through a payload data distribution system for spacelab-mounted experiments, or through test equipment located directly in the O&C high bay.

The overall integrated cargo test will be accomplished by using the Cargo Integration Test Equipment (CITE), which is a high fidelity functional and mechanical orbiter simulator located in the O&C high bay. Figure 9 shows the OSTA-1 pallet in the CITE stand as it underwent the final verification of its functional and mechanical interfaces to the orbiter simulator.

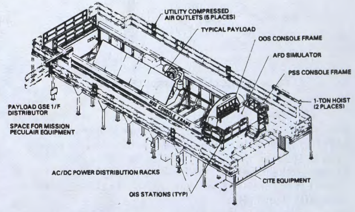

Fig. 9 CARGO INTEGRATION TEST EQUIPMENT

Prior to moving the integrated cargo to the Orbiter Processing Facility (OPF), the test team, including the users, will review the CITE test results to insure that all requirements were met.

Subsequent to transfer and installation of horizontal cargos into the orbiter at the OPF and after all cargo-to-orbiter interfaces have been connected, the process of final interface verification testing begins. Experimenter/user involvement in these tests will be a direct function of the interaction between the orbiter systems and the experiment. The orbiter interface test consists of verifying command, responses, and data channels, as well as performance of a simulated mission sequence test. After completion of the orbiter-cargo interface verification testing, final cargo bay closeout is accomplished.

Payloads which are to be processed as a vertical cargo, primarily deployables which utilize an upper stage for boost into outer space, will be integrated in the VPF. The VPF is located remote to highly populated areas at KSC to reduce the risk to personnel not associated with the handling of solid propellants (as used in the Inertial Upper Stage [IUS] and Paylod Assist Module [PAM]). Figure 10 depicts the Vertical Processing Facility.

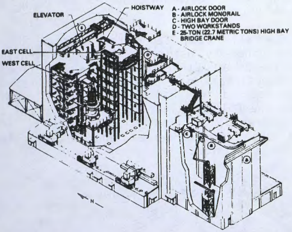

Fig. 10 VERTICAL PROCESSING FACILITY

Prior to payload integration and cargo processing at the VPF, the deployable upper stages (IUSs and PAMs) will be processed in either the Solid Motor Assembly Building (SMAB) for the IUS or the Explosive Safe Area (ESA 60) for PAMs.

IUS processing will be completed in the SMAB prior to moving the IUS to the VPF. After the IUS is installed into a checkout cell at the VPF, the payload will be moved to the VPF and the payload will be mated to the IUS prior to final cargo interface verification tests.

When the satellite meets the PAM at ESA 60, the complete cargo element is moved to the VPF upon completion of the checkout in ESA 60.

A cargo integrated in the VPF receives the same high fidelity test and checkout as those processed in the horizontal mode. The VPF has two vertical checkout cells, both of which are CITE stands. Each cargo processed through the VPF will be subjected to the verification of its functional and mechanical interfaces to the orbiter simulator. The users will support, as required, to insure all requirements are met and that their specific payload element is performing as designed. Figure 11 shows the test team organization for accomplishing integrated OMIs.

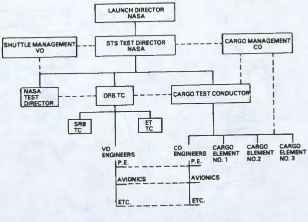

Fig. 11 ON-LINE TEST TEAM (FOR INTEGRATED OMIs)

All vertically integrated cargos are transported directly to the shuttle launch pad and installed into the Payload Change Room (PCR) for subsequent installation into the orbiter.

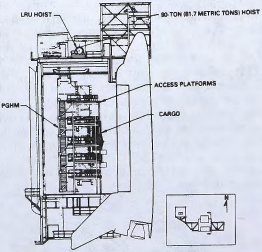

Fig. 12 CROSS-SECTION OF RSS MATED TO ORBITER

Figure 12 is a cross-section of the Remote Service Structure (RSS) with a vertical cargo in the PCR as it mates to the orbiter. After installation of the cargo into the orbiter bay, the user supports the launch team as required during integrated cargo-to-orbiter testing and during launch countdown.

OBSERVATIONS

Experience gained by the processing and integration of the OSTA-1, OSS-1, STS-5, and STS-6 cargos, as well as the planning and preparation for the STS-7 mission, provides the following observations.

During the payload concept and development phase, the PI/ED must consider each aspect of integration required by the STS system while minimizing the payload interfaces to STS. The user must insure that his payload requirements are properly communicated to the integration team at the launch and landing site, on schedule and as required. This insures minimal delays in testing while precluding damage to his hardware. He must also plan to participate actively in the integration process as defined, starting with CIR and concluding with the launch and flight of the STS. Adherence to these observations is mandatory if the user is to minimize the cost of his payload while attaining his objectives.