PAYLOAD PROCESSING FOR MICE DRAWER SYSTEM

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Abstract

Experimental payloads flown to the International Space Station provide us with valuable research conducted in a microgravity environment not attainable on earth. The Mice Drawer System is an experiment designed by Thales Alenia Space Italia to study the effects of microgravity on mice. It is designed to fly to orbit on the Space Shuttle Utilization Logistics Flight 2 in October 2008, remain onboard the International Space Station for approximately 100 days and then return to earth on a following Shuttle flight. The experiment apparatus will be housed inside a Double Payload Carrier. An engineering model of the Double Payload Carrier was sent to Kennedy Space Center for a fit check inside both Shuttles, and the rack that it will be installed in aboard the International Space Station. The Double Payload Carrier showed a good fit quality inside each vehicle, and Thales Alenia Space Italia will now construct the actual flight model and continue to prepare the Mice Drawer System experiment for launch.

Introduction

One of the many goals of NASA is to aid technology development and to further knowledge through scientific research conducted in space. The International Space Station (ISS) provides the unique opportunity to study objects within a microgravity environment and to expose experiments to the surroundings of space. Research conducted onboard the station spans a wide range of topics, from flame studies to protein crystal growth to microgravity effects on living organisms.

To facilitate transport of experiments to the ISS and to provide housing for them on orbit, Marshall Space Flight Center (MSFC) developed the EXPRESS (Expedite Processing of Experiments to Space Station) rack program. The EXPRESS rack accommodates up to 8 standard shuttle middeck locker sized payloads and is equipped with systems to support the experiments, such as temperature control via water or air, electrical power, and telemetry. Power is converted from the ISS power system 120 V DC input to a 28 V DC output that is then routed to each experiment stored within the rack. This allows each experiment to be powered individually. The rack telemetry systems allow payloads to transmit video and data feeds to controllers throughout the life of the experiment.

The rack can be controlled through an EXPRESS laptop computer, or it can be commanded from ground operations at MSFC. Command and feedback data can also be routed through MSFC to the payload developer, enabling developers to monitor and send commands to their particular experiments.

EXPRESS racks are transported to the ISS inside a Multi-Purpose Logistics Module (MPLM), which is stored inside the Shuttle payload bay for launch and landing. While the Shuttle is docked at the ISS, the MPLM is connected to the Station using the Shuttle's robotic arm. Payloads and supplies can then be transferred from the Shuttle to the ISS, and an EXPRESS rack may be moved from the MPLM and installed inside the Station. The MPLM is stowed once again inside the Shuttle payload bay for re-entry. There are currently five EXPRESS racks aboard the ISS, two at Kennedy Space Center (KSC) inside the Space Station Processing Facility, and one at MSFC.

Payload Processing Flow

Payloads flown to the ISS are selected from a wide pool of applicants coming from many different countries and organizations. Once a science objective is selected by NASA or a foreign space agency, a payload developer is contracted to take responsibility for building and testing the hardware that will fly to the ISS via the Space Shuttle (Orbiter). To design an experiment suitable for space flight, payload developers must consider both the scientific objectives of the experiment and the engineering challenge of developing hardware that is compatible with its transport vehicle and the hardware aboard the ISS. They must also consider how the experiment will be handled on the ground during loading of the Orbiter, and how it will react to the microgravity environment of space.

For payloads managed by MSFC and payloads that will fly in one of the EXPRESS racks, communication with payload developers throughout the design process is coordinated through the MSFC Payload Projects Office at KSC. This is important to ensure compatibility of payload hardware to the EXPRESS rack and often includes a fit check before actual flight models are constructed. The finalized version of the experiment hardware is then turned over to KSC for ground processing several months prior to the scheduled launch date.

The Mice Drawer System

The Mice Drawer System (MDS) is an experiment designed by Thales Alenia Space Italia (ASI) to study the effects of microgravity on mice. The mice chosen for the experiment have been bred carefully for generations to understand their genome sequence. On orbit, the mice will be observed for any changes that may occur in their DNA structure while living in the microgravity environment of space and compared to a ground sample of mice. Video and data streams for MDS will be relayed back to scientists for analysis through the EXPRESS rack telemetry system.

The MDS experiment design was selected by ASI in 1999, and ASI signed a contract with Altec in 2001 to begin development of the necessary hardware. It is scheduled to fly in October 2008 on Utilization Logistics Flight-2, where it will be transferred to the ISS and installed in an EXPRESS rack in the United States laboratory. MDS is designed to stay aboard the ISS for approximately 100 days and will return to earth on one of the Shuttle missions scheduled near the end of that time frame.

The MDS hardware is designed to house six mice with self-contained filter, air, and water systems. A feeding system is also present that presents food bars to each mouse. The apparatus fits inside a Double Payload Carrier (DPC) which is installed in the Orbiter mid-deck for flight. A bolt and fastener mechanism is positioned at each corner of the DPC to mate with the Orbiter mid-deck locker. ASI also designed an upper and lower EXPRESS Rack Interface Adapter (ERIA) for mating the DPC to the EXPRESS rack aboard the Space Station.

Objective of the Fit Check

Before constructing the final flight model, an engineering model of the DPC needed to be tested for compatibility with an EXPRESS rack and with both Orbiters (OV-103 and OV-105) that it will fly on. Running torque values needed to be measured for each corner fastener and compared to the desired value of less than 15 in-lbs. Engineers also wanted to evaluate the ease of installation before launch when the Orbiter is in a vertical position and the ease of installation inside the EXPRESS rack.

Procedure

The engineering model DPC and the EXPRESS rack adapter hardware were shipped to KSC from Italy for fit check testing. The hardware was unpacked and inspected for any damages sustained during travel and then turned over to flight crew equipment technicians for installation in the Orbiter.

A vertical fit check was performed at Launch Complex 39A inside the shuttle Endeavour (OV-105). The DPC was installed in the double forward mid-deck locker of OV-105, which is on the ceiling when the Orbiter is in vertical launch position (Fig. 1).

Figure 1

The bolts were torqued sequentially (upper left, lower right, upper right, lower left), and running torque measurements were taken for each bolt. The bolts were then tightened to 62 +2/-2 in-lbs above running torque with maximum torque not to exceed 75 in-lbs.

Clearance space between the DPC and the hatch was noted, as well as the amount of tilt necessary to lift the DPC into proper position for installation. The DPC was then removed and packaged for transport to Orbiter Processing Facility 3.

Figure 2

The fit check process was then repeated inside the shuttle Discovery (OV-103), which is in a horizontal position at Orbiter Processing Facility 3. The DPC was installed in the double forward mid-deck locker of OV-103, and running torque measurements were taken for each bolt (Fig. 2). The bolts were tightened to the same full torque specifications, and the fit quality of the DPC was assessed. The DPC was then removed and packaged for transport to the Space Station Processing Facility for a fit check inside EXPRESS Rack 7.

The final fit check was performed for the DPC inside EXPRESS Rack 7, which has the same structure as the EXPRESS rack it will be installed in on the ISS. The lower and upper EXPRESS Rack Adapter Interface (ERIA) plates were installed inside the empty rack and screwed to hand tight.

Using alignment pins as a guideline, the DPC was inserted and verified to be in the correct position. The DPC bolts were then attached to the ERIA in the same torquing sequence. Running torque measurements were taken for each bolt, and the bolts were then tightened to the same full torque specifications. Astronaut Joe Acaba observed the process to evaluate the ease of installation for the crew when the operation is performed aboard the ISS (Fig. 3). When the assessment of the installation was completed, the DPC and each ERIA were removed and packaged for shipment back to Italy.

Figure 3

Discussion

After evaluation of the three separate fit checks, both NASA and the payload developers at ASI are satisfied with the test results. No problems were encountered during the procedure, and the fit quality of the DPC in all three locations was very good.

Technicians found that the clearance space between the DPC and the hatch entrance of OV-105 was adequate to move the DPC inside with little difficulty (Figure 4). However, since the flight model DPC will house all of the MDS hardware and will weigh approximately 120 lbs, technicians are considering using a piece of foam underneath the DPC to slide it through the hatch. The payload developers at ASI also plan to determine a maximum allowable angle of tilt that will be used during actual installation of the fully loaded DPC for flight to ensure that nothing leaks out from the filters.

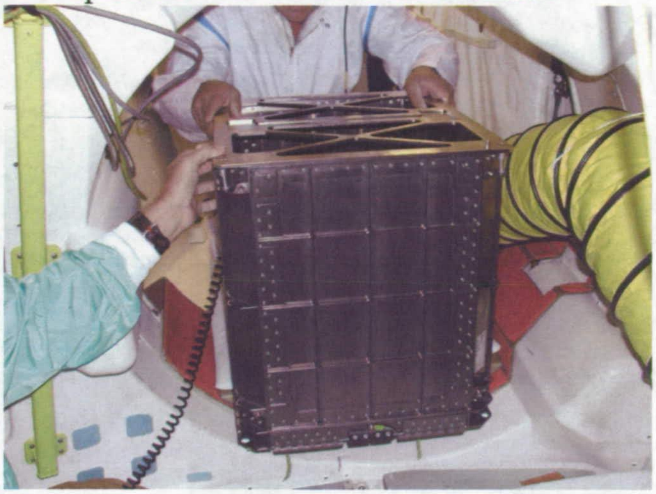


Figure 4

As a group, the running torque values for each bolt during installation met the expectations and fell below 15 in-lbs. During the vertical fit check in OV-105, two bolts on the DPC did cross this limit, with running torque values of 17 in-lbs and 20 in-lbs.

We believe that this is either due to the vertical nature of the installation in OV-105 or to the fact that this fit check was the first time the bolts were used. The DPC may not have been fully supported by the technicians as it was installed in the ceiling of the Orbiter, causing some of the load to rest on the bolts as running torque was measured. Also, the poly patch locking feature may have increased the running torque for the first installation of the new bolts. This resulted in running torque values that were higher than expected, but nothing that hampered the fit quality of the DPC.

The running torque values for the following fit checks in OV-103 (ranging between 4 in-lbs and 5 in-lbs) and EXPRESS Rack 7 (ranging between 3 in-lbs and 5 in-lbs) were consistently less than the 15 in-lbs limit and provide a more accurate reflection of the overall bolt performance.

Unlike during the fit check in EXPRESS Rack 7, the EXPRESS rack on the ISS will not be empty when the DPC is installed. One concern expressed is that it will be difficult for astronauts to install the ERIA plates properly in the confined space between the EXPRESS rack wall and another experiment apparatus. To address this issue, ASI is considering adding an alignment pin to the upper and lower ERIA that will slide into a slot in the back wall of the rack compartment and ensure the ERIA is in proper position.

Further Processing

After completion of the successful fit check, the DPC and ERIA plates were shipped back to Italy, where ASI will manufacture the flight model of the DPC. The complete MDS hardware will be installed inside the flight model DPC, and ASI will continue to prepare the integrated experiment for flight. ASI will conduct a 100 day test, where the experiment and all hardware will be powered and run for 100 days to simulate its extended stay on the ISS. Flight qualification environmental testing (including thermal, vacuum, and vibration testing) will continue along with flight timeline testing.

Approximately 6 months before the scheduled launch on Utilization Logistics Flight 2, the integrated DPC/MDS and all associated hardware will be transferred to KSC for testing in the Payload Rack Checkout Unit (PRCU). Experiments designed to fly in an EXPRESS rack are tested here to ensure compatibility with the rack hardware and software systems.

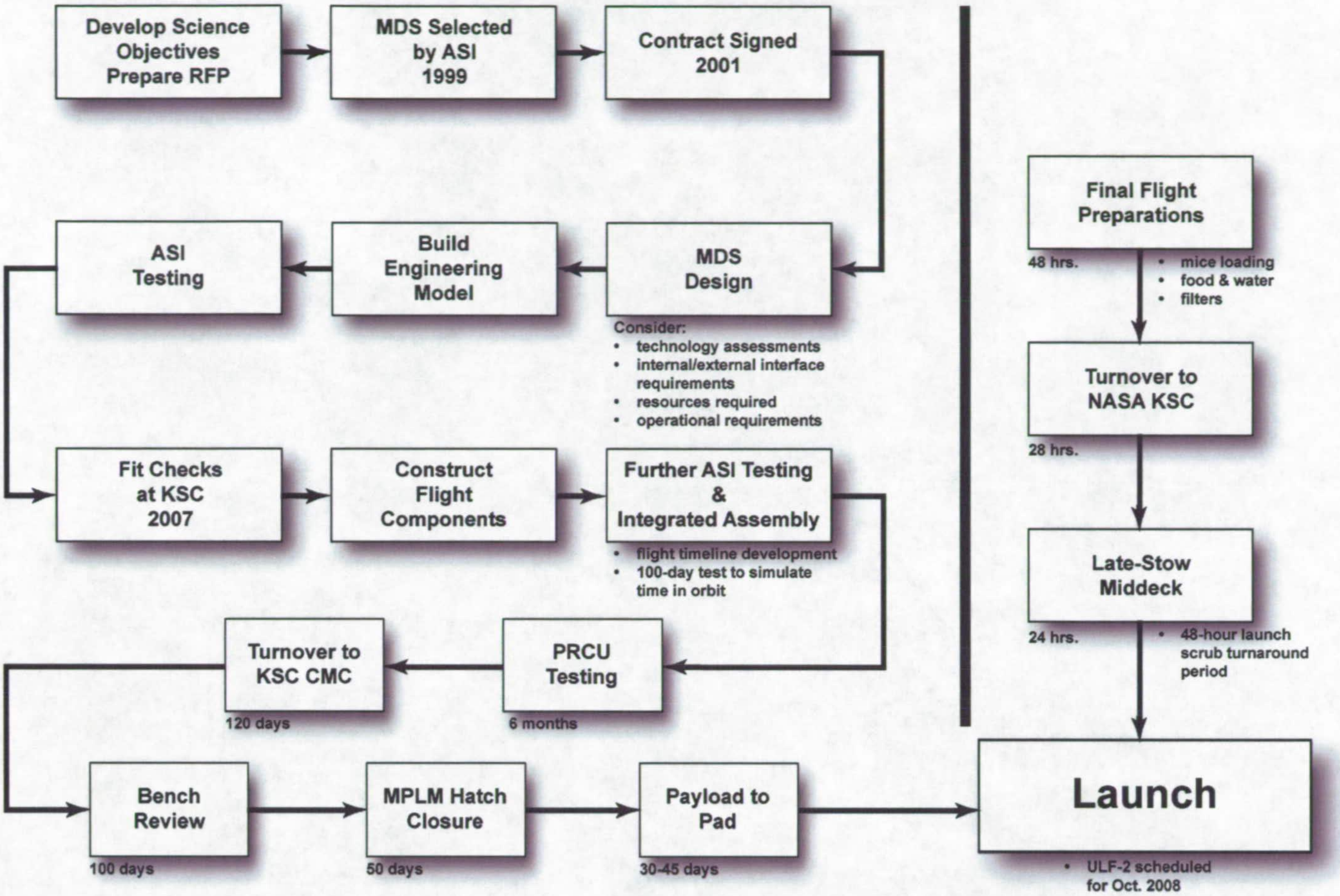
During PRCU testing, MDS hardware will be installed in an EXPRESS rack connected to the PRCU, which is then connected to the Huntsville Operations Support Center via Ethernet. This simulates the flight conditions that MDS will see on the ISS. The experiment will then be powered and a test of the command, electronic, and life support systems will be conducted. This testing provides a full simulation of the experiment performance on orbit and is conducted far enough in advance of launch to allow time to resolve any anomalies that may occur.

The MDS hardware will be officially turned over to KSC Cargo Mission Contract (CMC) about 120 days prior to launch. It will undergo a bench review for a crew member to evaluate the packing and final flight configuration of the experiment, and then will be stored until ready for loading. Food and filter supplies will be packed inside the MPLM before its hatch is closed, and the MPLM will be loaded inside the Orbiter payload bay 30-45 days before launch.

The mice themselves will be turned over to NASA-KSC with the DPC and integrated hardware approximately 28 hours prior to launch. The entire structure will be loaded with other late-stow payloads in the Orbiter double middeck locker 24 hours before launch. In the event that the launch is postponed, MDS has a 48 hour turnaround period before it needs to be removed from the Orbiter and reconfigured.

The following flow chart shows the processing steps that MDS has undergone from conception to launch aboard the Orbiter. While the details vary depending on the contents and purpose of the individual experiment, each payload that is flown to space will undergo a similar process before its actual flight. The complexity of operating a payload in the carefully controlled, microgravity environment of the International Space Station necessitates extensive testing of all its systems before it is committed to fly. The successful fit checks conducted on MDS comprised an important step in this process and allow ASI to continue preparing MDS for the research that it will provide aboard the International Space Station.

MDS Timeline



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