NASA SUSPENDED LOAD OPERATION
ANALYSIS/APPROVAL

OPERATION - To rotate the Payload Canister at the Vehicle Assembly Building (VAB).

SUPPORTING DOCUMENTS - The associated operational procedure/ System Assurance Analyses (SAAs) are as follows:

- OMI E5010 (Rev C, 07/02/91) Payload Canister Rotation and Mate/Demate of MMSE at K6-848 and/or M7-776
- SAA09FY12-005 (Rev A, 08/03/89) 250 Ton Bridge Crane - VAB
- SAA09FY12-006 (Rev A, 08/03/89) 175 Ton Bridge Crane - VAB

GENERAL DESCRIPTION - The tasks below require two technicians to be directly under the suspended beam and cables during installation/removal of the lifting hardware as follows:

- OMI E5010, seq 08-040 Removal in the Vertical Mode
- OMI E5010, seq 09-015,016 Installation in the Vertical Mode

Canister rotations to vertical or back to horizontal are performed in the VAB transfer aisle using the 175 ton and either of the two 250 ton bridge cranes.

The canister aft lifting sling is attached to the 175 ton crane and the forward sling is attached to the 250 ton crane for either rotation. The aft sling is accessed for canister connect/ disconnect from the transporter deck for either rotation without being under the suspended lifting beam.

The canister forward lifting sling is connected to the canister forward lifting trunnions with the canister vertical and still pinned to the transporter. Access to the top of the canister is provided by high ranger positioned on the center line of the VAB transfer aisle after the canister is positioned in the envelope of the cranes for rotation.

Two technicians are located on top of the canister with their safety harnesses attached to the adjacent safety restraint system. Each technician guides his respective lifting sling as

it is raised into position on the lifting trunnion. While he is performing this task, the canister lifting beam is 6 feet above and directly over his head. When this task is complete, the technicians exit the top of the canister via the high ranger, which is subsequently retracted. Then, upon connection of the aft sling and removal of the transporter pins, the canister is ready to be rotated to horizontal.

After the canister is rotated to vertical and pinned to the transporter, the forward lifting sling assembly is disconnected following the same procedure as described above.

RATIONALE/ANALYSIS - The suspended load tasks comply with the NASA Alternate Safety Standard as follows:

Alternate Standard Requirement #1a - The operation cannot be conducted without personnel beneath the lifting beam and cables during connection/disconnection operations. Canister lifting operations at the VAB have been evaluated, and it has been determined that there are no procedural/operational means to eliminate personnel exposure to a suspended load. Multiple positioning of a high ranger to gain side access to canister lifting trunnions to avoid being directly under the suspended load (lifting beam) would be extremely difficult and hazardous while in close proximity to SRB segments, ET dollies, and other large lifting fixtures located in the transfer aisle. In addition, it is not feasible to redesign the canister/canister lifting equipment to eliminate personnel from working under a suspended load.

Alternate Standard Requirement #1b - The possible use of a secondary support system, to catch the load in the event of a crane failure, was analyzed. It was determined that the use of a secondary support system was not feasible because of positioning of the lifting beam over the canister.

Alternate Standard Requirement #1c - The maximum number of personnel allowed under the load at any time is two.

Alternate Standard Requirement #1d - Installing/removing the lifting hardware for canister rotation operations will be accomplished as quickly and safely as possible to minimize exposure time. It will take two technicians 15-20 minutes to install/remove the lifting hardware.

Alternate Standard Requirement #4 - OMI E5010 has been revised to permit only two technicians to be directly under the suspended beam and cables during installation/removal of the hardware. The OMI is available on site for inspection during the operation.

Alternate Standard Requirement #6 - Suspended load operations associated with payload canister rotation at the VAB involve the 175 ton and either of the two 250 ton bridge cranes. The cranes are designed, tested, inspected, maintained, and operated in accordance with the NASA Safety Standard for Lifting Devices and Equipment, NSS/GO-1740.9. The VAB 175 and 250 ton cranes are designed with a minimum safety factor of 5 (based on the ultimate material strength) for the hoist load bearing components. The lifting beam assembly excluding the lower yoke meets design safety factors of 3 to yield strength and 5 to ultimate strength. The lower yoke meets design safety factors of 2.6 to yield strength and 3.6 to ultimate strength.

The cranes are equipped with redundant hoist drive systems (including hoist wire ropes and holding brakes), each capable of lifting and holding the load up to the crane's rated capacity. The cranes have a dual braking system with overspeed braking.

The cranes are load tested annually at 100% of the rated capacity. Detailed preventive maintenance is performed monthly, quarterly, semiannually, and annually on the cranes to ensure proper operation.

The wire rope is inspected monthly for discrepancies. Nondestructive testing of the crane hook is performed annually.

The canister forward lifting beam assembly (including wire rope assemblies) weighs approximately 4500 lbs, which is 0.9% of the crane's rated capacity. The wire rope assemblies are attached from the lifting beam to the 250 ton crane hook and are each rated at 90 tons.

The crane motor generator set is equipped with automatic overspeed protection, which is engaged during lifting operations.

Alternate Standard Requirement #7 - System Assurance Analyses (SAAs) have been completed on the 250 ton and the 175 ton VAB bridge cranes. Each SAA includes a failure modes and effects analysis/critical items list (FMEA/CIL) and a hazard analysis (see supporting documents).

The SAAs identify single failure points (SFPs) (31 for the 250 ton crane and 29 for the 175 ton crane) in the main hoist system when the hoist is lifting or lowering. Failure of the motor-generator set (one each) or the main hoist motors (two each) would allow the load to lower without regenerative braking at 10 feet/minute (2 inches/second). Failure of the remaining SFPs would allow the load to lower with regenerative braking at 0.25 feet/minute (0.05 inches/second). There are no SFPs when the hoist is static.

There is no history of failure with the SFPs in the critical failure mode. The use of high-quality, reliable components and a comprehensive maintenance, inspection, and test program, including preoperational checks, ensures that the crane systems operate properly. If a failure were to occur, it can be recognized by a brake set light, ammeter, or selsyn position indicator (depending on the failure) that are all in view of both crane operators. The crane operators would secure the load by applying the brakes. The longest estimated operator and system reaction times to recognize the failure and set the brakes are 3 seconds and the load would have descended an estimated 12 inches. This estimate assumes a solid rocket booster segment being lowered at 10 feet/minute and the failure occurring. In addition, an emergency-stop operator, remote from the crane operator's cab, can stop the crane if a failure indication is observed. In summary, there should be sufficient time to observe a failure and stop the crane before injuring personnel working under the suspended load.

The associated SAA CIL Sheets (pp. 319-361 for the 250 ton crane and pp. 305-345 for the 175 ton crane) identify all the rationale for accepting the risk of the SFPs, including design information, failure history, and the operational controls in effect to minimize the risks (maintenance, inspection, test, etc.).

Alternate Standard Requirement #8 - Visual inspections for cracks or other signs of damage or anomalies are performed on the crane hook, lifting sling assemblies, and canister lifting trunnions, and crane functional checks are performed before each operation per NSS/GO-1740.9.

Alternate Standard Requirement #9 - Trained and licensed crane operators shall remain at the crane controls while personnel are under the load.

Alternate Standard Requirement #10 - Appropriate safety control areas are established before initiating operations. Only the minimum number of people will be permitted in this area.

Alternate Standard Requirement #11 - A pretask briefing and a safety walkdown of the area are conducted prior to the lift to ensure that all systems and personnel are ready to support.

Alternate Standard Requirement #12 - Personnel beneath the suspended load will be in voice contact with the crane controller/signal person.

Alternate Standard Requirement #13 - Ground controllers and E-stop operators are properly positioned during all phases of the lifting operation in full view of the load block, lifting fixtures, and fixture attach points. One E-stop operator, remote from the crane operator's cab, can stop the crane if a failure indication is observed. Personnel working beneath the load shall remain in continuous sight of the operator/signal person.

APPROVAL: DATE: CONCURRENCE: DATE:

Warren I. Wiley
Acting Director
Safety and Reliability (RT)
Kennedy Space Center

Charles W. Mertz
Director, Safety Division
Office of Safety &
Mission Quality (QS)
NASA Headquarters