APPROVAL SHEET FOR SUSPENDED LOAD OPERATIONS

SLO-KSC- 1993-005

TITLE Orbiter Mate to the External Tank (ET) Using 325-Ton Crane

DOCUMENT NUMBER/TITLE OMI S0004 - Orbiter/ET Mate

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REQUIRED APPROVAL

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OPERATION: Orbiter Mate to External Tank (ET) Using 325-Ton Crane

SUPPORTING DOCUMENTS: The associated operational procedure/systems assurance analyses are as follows:

1. OMI S0004, Orbiter/ET Mate.
2. SAA09FY120-001, System Assurance Analysis of the 325-Ton Bridge Cranes at the Vehicle Assembly Building (VAB).
3. SAA09FY12-006, System Assurance Analysis of the 175-Ton Bridge Crane at the Vehicle Assembly Building (VAB).

GENERAL DESCRIPTION: This operation involves the mate of the orbiter to the ET using the VAB 325-ton and 175-ton bridge cranes. A detailed engineering review and hazards analysis of this operation have been conducted. This work has resulted in hardware and/or procedure modifications that minimize the exposure of employees to working under suspended loads. Due to the uniqueness of the activity and the limitations using present systems, hardware and facilities, some tasks remain where suspended load operations are required under specifically approved and controlled conditions. The orbiter mate to the ET requires a minimum number of personnel under the load to perform the following tasks:

1. Install access stand beside orbiter - left hand forward only (4 personnel - 20 minutes).
2. Ground access stand and install tile protection around hoist fitting (2 personnel – 30 minutes).
3. Torque left hand forward cup assembly (4 personnel – 15 minutes).
4. Install the H70-0597 orbiter mating sling assembly on the orbiter at the four designated orbiter lifting attach points (2 forward, 2 aft) (2 personnel each attach point - 1 hour).
5. Monitor the aft orbiter socket demate from the aft Orbiter Transporter System (OTS) ball and forward bipod disconnect of the orbiter/OTS in a dynamic lift until clearance of 4 to 5 inches is obtained (4 personnel each aft attach point, 4 personnel forward attach point - 1 hour).
6. Monitor ET doors/ET forward strut clearance during orbiter lowering into highbay (1 person – 1 hour).
7. Disconnect the H70-0597 orbiter mating sling assembly from the orbiter at the two aft orbiter lifting attach points (2 personnel each attach point – 30 minutes).

The OTS is the preferred means to move the orbiter from the OPF to the VAB. As a contingency and with concurrence from the SFOC Director of Safety and

Mission Assurance and the NASA Safety and Mission Assurance Division Chief, the orbiter may be towed from the OPF to the VAB. The orbiter mate to the ET after towing and sling connection requires a minimum number of personnel under the load to perform the following tasks:

1. Install final tire pressure separation harness at main landing gear and nose landing gear (3 personnel – 120 minutes).
2. Verify bungee cocking in landing gear linkage (3 personnel - 30 minutes).
3. Wipe down landing gear hydraulic strut (1 person – 10 minutes).
4. Remove main landing gear door protective cover (2 personnel – 30 minutes).
5. Inspect tile with landing gear doors open (4 personnel – 1 hour).
6. Remove nose landing gear dummy connector dust cap (2 personnel, 10 minutes).
7. Perform final wheel well inspection and closeout (2 personnel, 1 hour).
8. Disconnect nose wheel well ground cable (2 personnel, 10 minutes).
9. Remove the A70-0696 orbiter landing gear ground lock pins and bungee pins (2 personnel - 10 minutes).
10. Take closeout photos (1 person – 30 minutes).
11. Retract landing gear for flight (3 personnel – 20 minutes).
12. Assist nose landing gear door close (2 personnel, 10 minutes).
13. Disconnect hydraulics from the orbiter left hand external tank umbilical for operations associated with landing gear retraction (5 personnel - 1 hour).
14. Remove armalon from landing gear doors and inspect tile around landing gear doors (4 personnel - 1 hour).
15. Install forward mating fixture (4 personnel, 30 minutes).

RATIONALE/ANALYSIS: The suspended load tasks comply with the NASA Alternate Safety Standard for Suspended Load Operations as follows:

Alternate Standard Requirement #1a: An in-depth analysis was performed on the suspended load operations in OMI S0004. It was determined that 54 suspended load operations could be abated by procedural controls. The procedural changes provide for strict control of all lifting operations and the inclusion of warnings to personnel to avoid placing any portions of their anatomy under the load. The number of personnel in the work area has been reduced to a minimum essential number.

One task has arisen using the OTS to abate the previous suspended loads. The residual task occurs during the demate of the orbiter from the OTS. Personnel are required to be under the orbiter at the aft mating locations. They must observe the demate for the first few inches of orbiter ascent in the orbiter socket lining. They use feeler gages to ensure that there is uniform separation of the

mating surfaces as the demate takes place and direct orbiter repositioning to prevent orbiter socket damage. Any damage at this point could lead to severe mission impact. Possible alternatives were explored. A bank of TV cameras could be set up at each mating surface but adequate depth perception could not be achieved. A barrier to protect the personnel was not physically possible. In summary, the operation is a mandatory requirement and there is no alternative to the suspended load.

Orbiter/ET mate operations at the VAB cannot be conducted without personnel beneath the suspended load. The tasks performed under the load have been analyzed and evaluated with the determination that no feasible engineering design or procedural options are readily available to eliminate the suspended load operations.

Alternate Standard Requirement #1b: Secondary support systems to assume support of (catch) the load were evaluated and were not feasible for this operation. Design criteria was too cumbersome to prevent the orbiter and sling from being a suspended load and also prevented access to areas of critical work that needed to be performed.

Alternate Standard Requirement #1c: The number of personnel allowed under the suspended load for each task is as stated in the General Description. These personnel are also identified with safety vests to annotate the required personnel for the operation.

Alternate Standard Requirement #1d: Personnel will accomplish the required suspended load tasks as quickly and safely as possible to minimize time exposure; see General Description.

Alternate Standard Requirement #2: Suspended load operations are reviewed and approved on a case-by-case/specific need basis - see General Description and Alternate Standard Requirement #1.

Alternate Standard Requirement #3: Only those suspended load operations approved by the NASA Safety and Mission Assurance Division Chief will be permitted. A list of approved suspended load operations will be maintained by the NASA Safety and Mission Assurance Division.

Alternate Standard Requirement #4: OMI S0004 is written to allow only required personnel under the suspended load. The OMI is available on site for inspection during the operation.

Alternate Standard Requirement #5: A new suspended load operation not covered by this SLOAA, deemed necessary due to unusual or unforeseen circumstances where real time action is required, shall be documented and approved by the NASA Safety and Mission Assurance Division Chief.

Alternate Standard Requirement #6: The VAB 175-ton and 325-ton bridge cranes are designed, tested, inspected, maintained, and operated in accordance with the NASA Safety Standard for Lifting Devices and Equipment, NSS/GO-1740.9. These cranes are designed to a minimum safety factor of 5 (based on the ultimate yield strength) for the hoist load-bearing components. The H70-0597 orbiter lifting sling is designed with a safety factor of 5 against ultimate strength and a safety factor of 3 against yield.

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 rated capacity. The cranes have a dual braking system with overspeed braking.

The cranes were one-time proofloaded at 125 percent of rated capacity, are load tested annually at 100 percent of rated capacity, and have a monthly, semiannual and annual preventive maintenance program to ensure proper operation.

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

When performing the mate operation, the 325-ton bridge crane is connected to the forward spreader beam of the H70-0597 orbiter lifting sling and the 175-ton bridge crane is connected to the aft spreader beam but disconnected after orbiter lift and rotation to vertical. The orbiter will not exceed 226,000 pounds (varies with orbiter and payload configuration) and the orbiter lifting sling weighs approximately 64,400 pounds. The maximum load lifted will not be over 290,000 pounds.

Alternate Standard Requirement #7: System Assurance Analyses (SAAs) have been completed on the VAB 325-ton and 175-ton bridge cranes. Each SAA includes a Failure Modes and Effects Analysis/Critical Item List (FMEA/CIL) and a hazard analysis (see Supporting Documents).

The SAA for the 325-ton crane identifies 1 Single Failure Point (SFP), the Programmable Logic Controller (PLC). The PLC controls motion for the hoist,

bridge and trolley. The identified failure mode is an unsolicited command from the PLC could initiate or continue a crane motion in an uncommanded direction or speed. The PLC is designed to industry standards and is UL listed. Internal diagnostics verify all crane controls each time the crane is used and crane control functional checks are performed before each use. The PLC is electrically isolated from external voltages/currents. Crane software was validated and extensively tested per the acceptance test procedure. If a failure were to occur, the crane operators can secure the load by applying brakes.

The SAA for the 175-ton bridge crane identifies 3 SFPs 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. 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 the selsyn position which is in view of both crane operators. The crane operators would secure the load by applying the brakes.

Emergency (E) stop operators, remote from the crane operator's cab, can stop the crane if a failure indication is observed.

The associated SAA CIL sheets identify 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 hooks and lifting sling assembly along with crane functional checks prior to each operation per NSS/GO-1740.9.

Alternate Standard Requirement #9: The crane operators, E-stop operators, and mechanical technicians are all trained and have current certifications. Operators will remain at the crane controls while personnel are under the load.

Alternate Standard Requirement #10: Appropriate control areas are established and maintained prior to and during the operation. Only required personnel (man loaded in the procedure) are permitted in this area.

Alternate Standard Requirement #11: Personnel are briefed just prior to performing the task about the hazard involving the suspended load. A pretask briefing and a safety walkdown of the area are conducted prior to the lift to ensure all systems and personnel are ready to support. All participants are instructed on their specific tasks and warned of the hazards involved. Following any crew change, new personnel are instructed by the task leader on their specific tasks and warned of the hazards involved.

Alternate Standard Requirement #12: Personnel beneath the suspended load will be in radio, visual, or voice contact with the crane controller and/or signal person. Upon loss of communication, the operation shall stop immediately, personnel shall clear the hazardous area, and the load shall be safed. Operations shall not continue until communications are restored.

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 and/or signal person.

Alternate Standard Requirement #14: The NASA Safety and Mission Assurance Division shall conduct periodic reviews to ensure the continued safety of suspended load procedures.

Alternate Standard Requirement #15: The NASA Safety and Mission Assurance Division will provide copies of approved SLOAAs, a list of approved suspended load operations, a list of cranes/hoists used for suspended load operations and copies of the associated FMEA/CIL and hazards analyses to NASA Headquarters.

APPROVAL: DATE:

M. Hess for 9/15/00
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