APPROVAL SHEET FOR SUSPENDED LOAD OPERATIONS

SLO-KSC -2010-002

TITLE: NASA Suspended Load Operation Analysis and Approval (SLOAA) for Robonaut

DOCUMENT NUMBER/TITLE: NASA Suspended Load Operation Analysis and Approval (SLOAA) for JSC 47303, Ground Safety Data Package for The Robonaut and Support Equipment

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CHECK APPROPRIATE BOX:

[x] Single Occurrence Operation [ ] Multiple Occurrence Operation [ ] Revision to Existing SLOAA

IF REVISION TO EXISTING SLOAA, SUMMARIZE CHANGES / RATIONALE:

N/A

REQUIRED APPROVAL

CONTRACTOR _____ DESIGN _____ R & QA _____ OPERATIONS _____ SAFETY

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NASA Suspended Load Operation Analysis and Approval (SLOAA) for Robonaut

Suspended Load Operation: Hoist Robonaut from the Pelican case, rotate and transfer to the ground stanchion. See Figure 1.

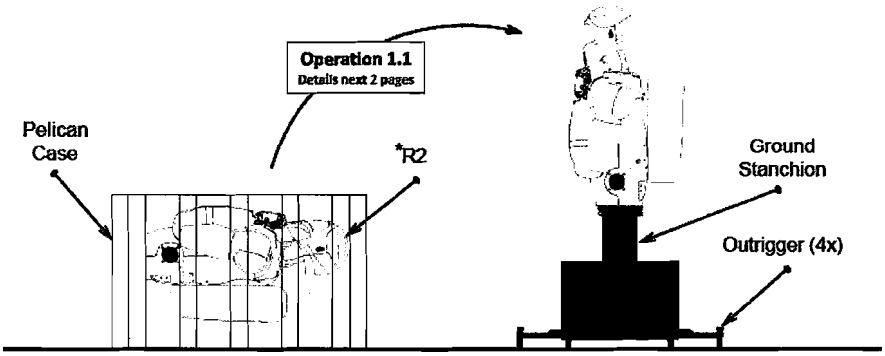


Figure 1: Robonaut Lift from Pelican Case and Transfer to Ground Stanchion

Operations:

1. KSC provided lifting slings will be attached to qty. 2 swivel hoist rings at Robonaut's shoulders and qty. 2 swivel hoist rings at Robonaut's waist (attached to non-flight dovetail). See Figure 2.

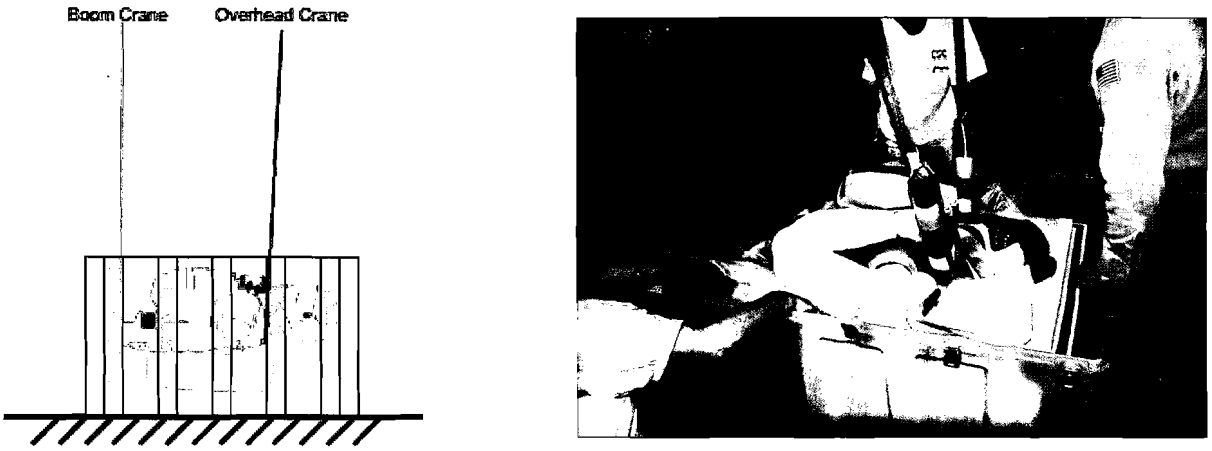


Figure 2: Attachment to 4 Swivel Hoist Rings at Robonaut Shoulders and Waist

2. Robonaut will be lifted out of Pelican case to proper height for mid-air pivot/rotation to the vertical orientation. See Figure 3.

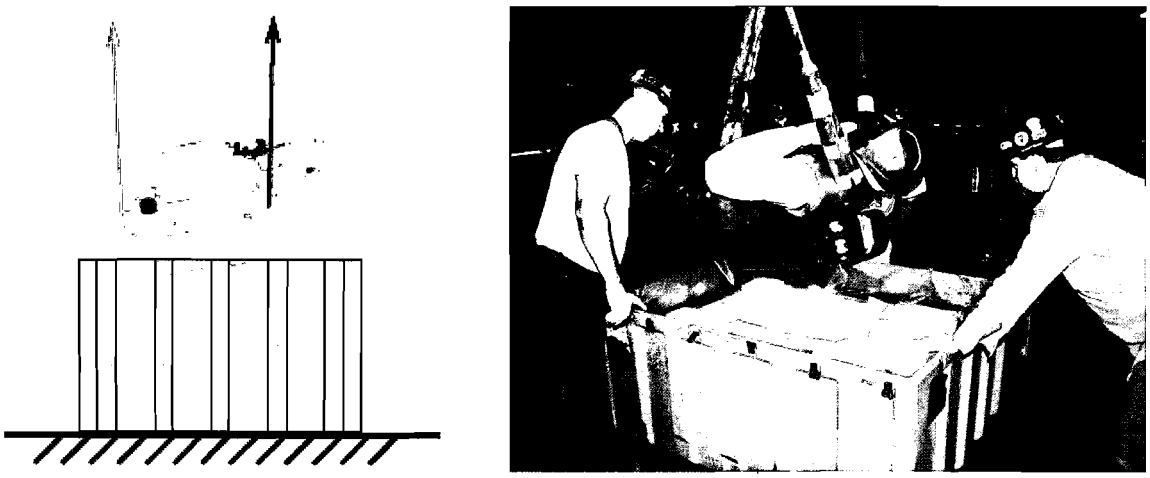


Figure 3: Beginning of Robonaut Lift out of Pelican Case and Rotation

3. The boom crane will then be lowered to complete rotation to the vertical orientation. See Figure 4.

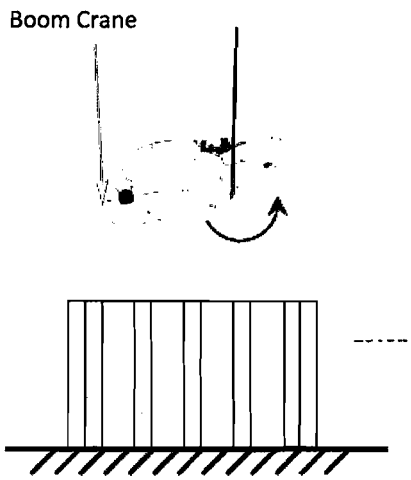


Figure 4: Rotation by Lowering Boom Crane at Robonaut Waist

4. With the boom crane lowered, Robonaut will be in a slightly forward-pitched orientation due to its center of gravity and placements of the lifting attach points. Reference Attachment A for the Robonaut Center of Gravity Location. Robonaut will be suspended/supported by crane(s) throughout the entire operation until it is hard down on the ground stanchion. The CG will have no influence on the stability of the Robonaut since it will be suspended during the entire operation. The tilt angle is overcome with the boom crane when Robonaut is lifted horizontally out of the Pelican Case. After it is out and above the floor, the boom crane hook (attached to the swivel hoist rings at the waist of Robonaut) is lowered until the full load is suspended by the overhead crane attached at the shoulder points high on Robonaut's back. This is where Robonaut pitches forward slightly due to the attachment point of the swivel hoist rings on the back of the shoulders. When Robonaut is lowered onto the Ground Stanchion, and guided into the dovetail assembly interface, it will naturally sit upright since the CG is very well centered in the torso in all three axes as depicted in Attachment A. The only tilt during lifting is induced by the location of the lift points on the shoulders. Therefore, no tipping hazard is present. Once Robonaut is oriented vertically, the waist slings will be removed as well as the non-flight dovetail. See Figure 5.

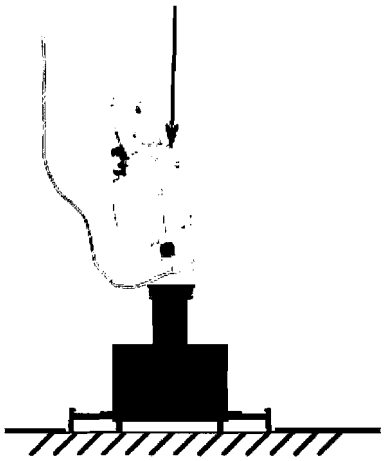
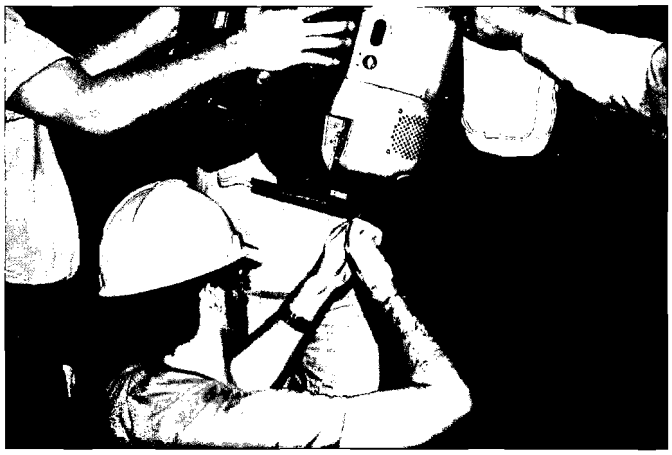


Figure 5: Waist Slings Removed when in Vertical Orientation

5. Removal of the non-flight dovetail will require 3 operators, 1 of which will be under a suspended load as defined in Section A.3 of NASA-STD-8719.9, Standard for Lifting Devices and Equipment. Operator 1 is required to be under a suspended load in order to remove the dovetail. Operators 2 and 3 will have their hands on the side of the Robonaut to guide and hold the load in place. As defined in Section A.3.2, Operators 2 and 3 are not under a suspended load. See Figure 6.



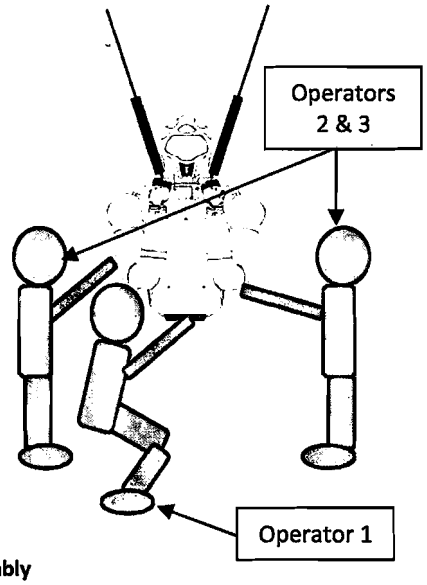


Figure 6: Removal of Non-flight Dovetail Assembly

6. Once the non-flight dovetail assembly is removed, Robonaut will be lowered and placed on the dovetail ground stanchion. Aligning the Robonaut to the stanchion may require up to 2 operators that would be considered under a suspended load. However, Robonaut will be partially supported by the stanchion. See Figure 7.

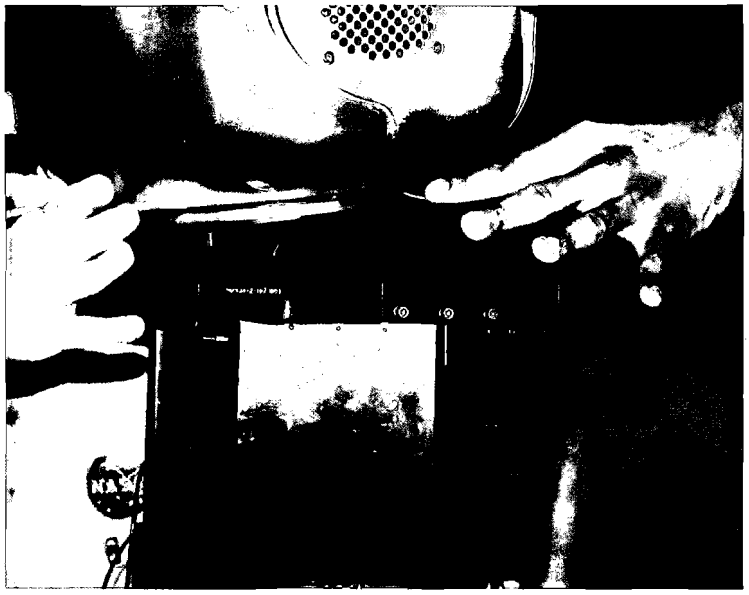


Figure 7: Aligning of Robonaut to Ground Stanchion

7. Once the Robonaut is placed on the stanchion (no longer a suspended load), it will be fastened to the stanchion. See Figure 8.

Figure 8: Robonaut Fastened to Ground Stanchion

Rationale / Analysis

The suspended load tasks comply with the NASA Alternate Safety Standard for Suspended Load Operations as follows (as defined in NASA-STD-8719.9, Section A.4):

A.4.1a:

Removal of the non-flight dovetail and placement of Robonaut on the ground stanchion cannot be completed without placing personnel or hands under the suspended load. The dovetail cannot be removed prior to the lift as it is used during the lift out of the pelican case. See Figures 2 and 6. There are no design, procedural, or operational means to eliminate personnel exposure to a suspended load, without making significant design changes to the flight hardware.

A.4.1b:

The use of a secondary support system is not feasible based on the design of the Robonaut hardware. See Figure 6. Additionally, Operators 2 and 3 will have their hands on the side of Robonaut guiding the load during this time. Note that NDI was completed on the project provided COTS spreader bar assembly. Reference JSC Lifting Beam NDT Report on Process Control No. 1007-001 / Work Order No. Fab Express Track #218.

A.4.1c:

The maximum number of personnel allowed under the suspended load during removal of the non-flight dovetail assembly is 1.

The maximum number of personnel allowed under the suspended load during aligning of the Robonaut to the ground stanchion is 2. Note that during this operation, part of the Robonaut suspended load will be supported by the ground stanchion. See Figure 7.

A.4.1d:
The time personnel are under the suspended load is minimal.

Removal of the non-flight dove tail assembly: < 5 minutes
Aligning of the Robonaut to the ground stanchion: < 5 minutes

A.4.2:
Each operation will be reviewed on a case-by-case basis.

A.4.3:
Only those suspended load operations approved by the Center/facility NASA Director of Safety will be permitted, subject to NASA-STD-8719.9. A list of approved suspended load operations will be maintained by NASA Safety and made available to OSHA personnel upon request.

A.4.4:
The work authorizing document will be written on a Task Performance Sheet (TPS) that is quality controlled to allow only required personnel under the suspended load. The TPS will be available on site for inspection during the operation. The TPS will cover the entire lift of Robonaut out of the Pelican case.

A.4.5:
During a suspended load operation, if a new procedure not covered by the original analysis is deemed necessary due to unusual or unforeseen circumstances, the NASA Center/facility Safety Office will be consulted to approve and document the procedure before operations continue.

A.4.6:
The primary crane used to hoist the Robonaut is provided by KSC and is designed, tested, inspected, maintained, and operated in accordance with the NASA Standard for Lifting Devices and Equipment, NASA-STD-8719.9. The crane used will be one of the SSPF 30 Ton Bridge Cranes. Both SSPF east and west overhead cranes are on the approved list for suspended loads with System Assurance Analysis (SAA) #SAA21CRS1-001. Note that the boom crane is not associated with the suspended load because the rigging will be disconnected before any work is done in the shadow of the suspended load.

A.4.7:
The primary crane used to hoist the Robonaut is provided by KSC as identified in A.4.6 above. The failure modes effects analysis (FMEAs) and hazard analysis specific to this crane are documented in SAA #SAA21CRS1-001. The boom crane has part number from Air Technical Industries RBC6000SPBWM. The Boeing part number is 3MIT 683-11400. It does not have a serial number and is not COTS. The SAA number for the boom crane is SAA01CR00-002. All

cranes and rigging equipment will be tested, inspected, and maintained in accordance with NASA-STD-8719.9.

A.4.8:
In accordance with NASA-STD-8719.9, visual inspections for cracks or damage will be performed on the hoist rings, spreader bar assembly, and slings. Crane functional checks and visual inspection will also be performed before each operation. Note that NDI was completed on the project provided COTS spreader bar assembly. Reference JSC Lifting Beam NDT Report on Process Control No. 1007-001 / Work Order No. Fab Express Track #218. The spreader bar assembly is commercial off the shelf (COTS) hardware and has a rated load of 1000lbs with a proof load of 2000lbs. The waist hoist rings (COTS) each have a rated load of 340lbs with proof loads of 680lbs each. The shoulder hoist rings are rated to 1000lbs with proof loads of 2000lbs each. The actual load of Robonaut will be 333lbs to be split among the 4 hoist rings.

A.4.9:
A trained and licensed operator (certified per NASA-STD-8719.9) will operate the crane/hoist while personnel are under the load.

A.4.10:
As documented in the TPS for lifting of the Robonaut out of the Pelican case, only the minimum number of personnel will be allowed in the area.

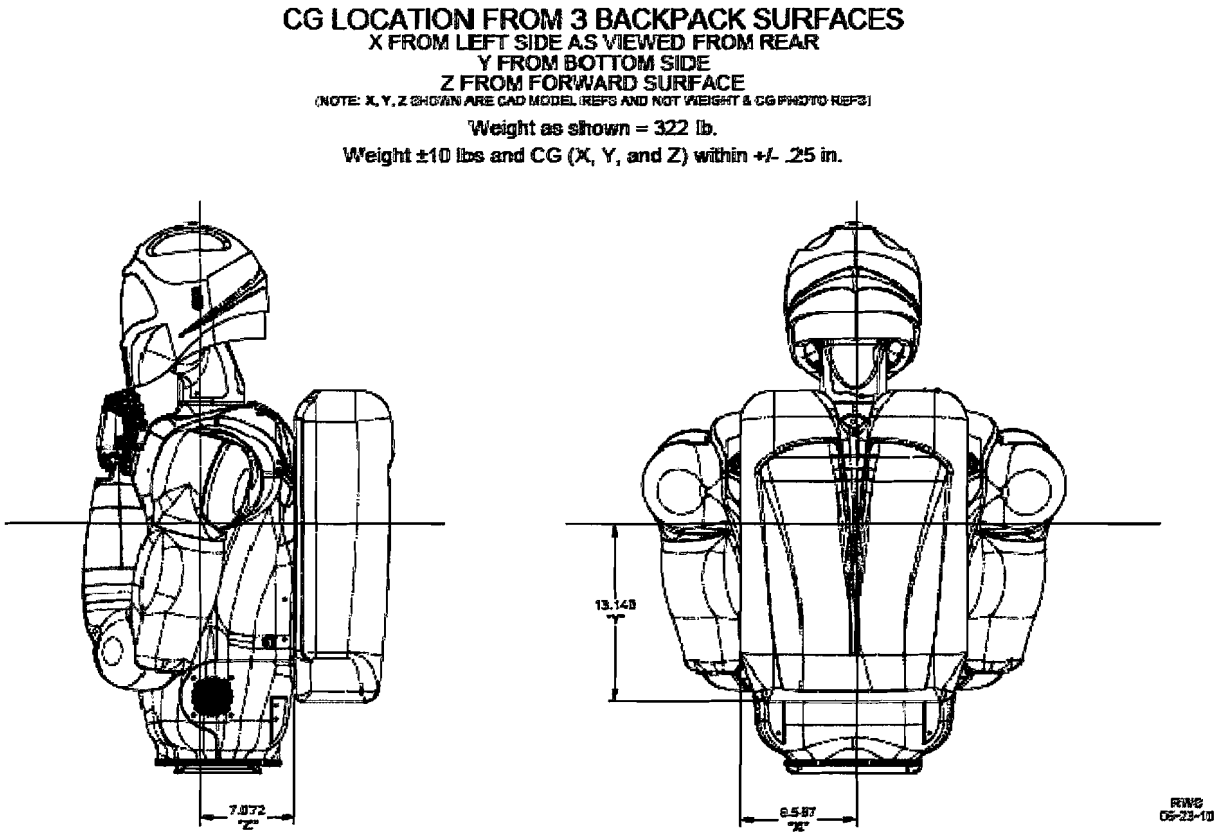
A.4.11:
A safety briefing for all personnel will be completed prior to the operations. Personnel will be instructed on their specific tasks and potential hazards will be identified.

A.4.12:
The personnel under the suspended load will be in voice communication with the crane operators. Upon communication loss, operations will stop immediately, personnel will clear the hazardous area, and the load will be safed. Operations will not continue until communications are restored.

A.4.13:
Personnel working beneath the load will be in continuous sight of the crane operators.

A.4.14:
NASA will conduct periodic reviews to ensure the continued safety of the procedures. As a minimum, NASA will annually evaluate the implementation of this procedure at each Center with operations on the suspended load list. Note that the Robonaut lift out of the Pelican case is a onetime procedure.

A.4.15:
A list of approved suspended load operations, list of cranes/hoists used for suspended load operations, and copies of the associated hazards analyses will be provided to the OSHA Office

of Federal Agency Programs via NASA Headquarters for distribution to the appropriate regional and area OSHA offices. Quarterly updates to the documentation will be provided as needed. Note that the Robonaut lift out of the Pelican case is a onetime procedure.

Attachment A: Robonaut Center of Gravity Location