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Failure Modes and Effects Analysis
and Critical Items list for
Crane 10-2 Located in Building 10,
~~Robotics Facility~~ Satellite Servicing Center

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Preface

This document is compliant with the general methodology of NSTS 22206, "Requirements for Preparation and Approval of Failure Modes and Effects Analysis and Critical Items List."

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The following documents were used in completing this analysis:

1. R&M Spacemaster SX Owners Manual, "10-Ton Bridge Crane Reading Crane ^ Engineering".

2. Requirements for Preparation and Approval of Failure Modes and Effects analy (FMEA) and Critical Items List (CIL); NSTS 22206, Revision D; December 10 doc #

3. Inspection and Preventive Maintenance Procedure for Certification of Crane 10 ? ManTech Procedure Number -------??? .

4. Lifting Device Operator Daily Crane and Hoist Inspection and Limit Switch Te RECERT 42-001, Revised 2004.

5. NASA-STD-8719.9, NASA "Standard for Lifting Devices and Equipment," May 2002.

6. NPG 8715.3, "NASA General Safety ~~Manual," January 24, 2000.~~ Program Requirements, September 12, 2001

1.0 Summary of Findings

1.1 System Criticality

Crane 10-2 Reading Crane & Engineering, capacity 10 tons, Bridge Crane, is assessed as critical because failure of the crane could cause loss of life and/or critical hardware. The crane functions are identified and assessed on the Criticality Summary Section 1.2 below.

1.2 Mechanical/Electrical Critical Items

The Critical Items were taken from Appendix-A, Section 6.0 of the FMEA-10-CRN0001, " 10-Ton Crane Modernization Failure Modes & Effects Analysis" , dated May 7, 2007 (Modified).

NO.	CRITICAL ITEM	ORIGINAL CRITICALITY	DOWNGRADED CRITICALITY	RISK
1	Hoist Reducer	1	3	Controlled
2	Hoist Drum & Bearings	1	3	Controlled
3	Hook & Bottom Block	1	3	Controlled
4	Hoist Top Block	1	3	Controlled
5	Swinging Rope End Assy.	1	3	Controlled
6	Wire Rope	1	3	Controlled

The Criticality Category of the critical items was downgraded from the original 1 criticality to a "3" due to the implementation of defined and approved maintenance and operational controls.

Table 1

GSE CRITICALITY CATEGORY DEFINITIONS

Criticality	Potential Effect or Failure
1	Single failure which could result in loss of life or load.
1R	Two redundant hardware items, which if both failed, could result in loss of life or load (or loss of a safety or hazard monitoring system).
1S	Single failure in a safety or hazard monitoring system that could cause the system to fail to detect, combat, or operate when needed during the existence of a hazardous condition and could result in loss of life or load.
2	Single failure which could result in loss (damage) of a load.
3	All others.

1.3 Electrical Critical Items

See Table, Section 1.2.

1.4 Hazards Identified

Justification for retaining the critical items listed above was based on the data elements provided in the Rationale for Acceptability (see Section 3.0). This Rationale included the following information: Design, Test, Inspection, Failure History, and Operational Use. Risk assessment, based on the criteria identified in Reference 6, determined the risk of critical item retention to be acceptable/controlled.

1.5 Critical Flexhoses

There were no critical flexhoses identified in this lifting device.

1.6 Critical Orifices

There were no critical orifices identified in this lifting device.

1.7 Critical Filters

There were no critical filters identified in this lifting device.

1.8 End-to-End Areas of Concern

There were no areas of concern identified that are the design responsibility of other contractors and/or NASA Centers.

1.9 Sneak Circuits Identified

There was no Sneak Circuit Analysis performed on Crane 10-2.

2.0 Failure Mode and Effects Analysis

2.1 System Description

2.1.1 General

Crane 10-2 consists of a 10 ton capacity Bridge Crane structure with under hung dual girder trolley and type SX60420125T76HJDOS Hoist (See Figure 1). The crane is located in the Building 10, ~~Robotics Facility~~ Satellite Servicing Center. Crane 10-2 is used for loading, unloading, and handling of instruments, structures and payloads designed for use as flight hardware. The crane is controlled by flux vector pendant control station at floor level.

Type KCI Hoist Corp. SX60420125T76HJDOS

Figure 1

2.1.2 Hoist & Trolley

For Hoist & Trolley details and parts list refer to R&M Spacemaster SX Owners Manual, "10-Ton Bridge Crane Reading Crane & Engineering", Section 4.

Main Hoist

The hoisting unit is provided with two means of braking, each capable of bringing a rated load to zero speed and holding it-with and without power. The motor brake is a multiple friction electromagnetic disc brake. The second brake is a drum brake on the gear side of the drive.

Hoist Upper Limit Switches

Dual upper limit switches are provided. Initial plugging type upper limit switch prevents the block from being accidentally raised too high and inflicting damage to the drum and wire rope. An adjustable geared limit switch is installed as backup to prevent the lower block from exceeding its upper limits. Movement in the "lower" direction is not inhibited.

2.1.3 Crane End Carriage

For End carriage details and parts lists refer to R&M Spacemaster SX Owners Manual, "10-Ton Bridge Crane Reading Crane & Engineering". Section 8.

2.1.4 Controls

The pendant station has the following controls: Off-On, Hoist Speed Low-High, Hoist Raise/Lower, Trolley: East/West, Bridge: North/South.

2.2 Crane Criticality Assessment

The crane functions are identified and assessed on the attached FMEA-10-CRN0001 dated May 7,2007 Crane Criticality Assessment Work Sheets.

2.3 Critical Items List (CIL) per FMEA-10CRN0001

FMEA Item Code	Identification	Original Criticality	Downgraded Criticality
30-10-30	Hoist Reducer	1	3
30-10-40	Hoist Drum & Bearing System	1	3
30-10-60	Hook & Bottom Block	1	3
30-10-70	Hoist Top Block	1	3
30-10-80	Swinging Rope End Assembly	1	3
30-10-90	Wire Rope	1	3

3.0 Critical Items Acceptance Rationale

The justification for de-rating the identified critical items from 1 to 3 is presented herein. The rationale is comprised of the following elements.

- Design
- Test
- Inspection
- Failure History
- Operational Use

3.1 Design

The hoist is designed to meet all OSHA requirements cited in OSHA CFR 1910.179 and 1910.306 and CMAA 70. The drum gear meets the requirements for Class C, "moderate service" and is manufactured to AGMA quality Class 5 or better.

The drum gear is pressed into the end of the drum and secured, making it captive. The gear is driven by two pinion shafts, located 60 degrees apart. Gear teeth would have to be lost at both points of contact to effectively impair the mechanical integrity of the load path at this point. All gearing is designed to AGMA standards. Risk of loss of load is minimal.

3.1.1 Test

Specific tests to detect failure modes and causes during acceptance and certification tests were performed, i.e.:

- Factory Tests Before Shipment
- Crane Acceptance Testing

3.1.2 Inspections

Cranes used frequently for critical lifts are load tested annually. If inspection indicates problems, then gearing is inspected for wear or cracks. NDT techniques are used if indications of problems are suspected.

Inspections are performed in accordance with Para.303 of Reference 5 (NASA-STD-8719.9).

Operational tests and inspections are performed together with rated load tests. Test reports are documented, dated and signed. The inspection reports are maintained on file and made readily available by the Recertification Program Manager.

3.1.3 Failure History

Damage to equipment or personnel injury resultant from the loss of the hoist drum gear has not been experienced since the inception of the RECERT Program.

3.1.4 Operational Use

Critical lift operators are trained in the specific hazards and special procedures associated with the lift. Emergency procedures are addressed for contingency actions or other emergencies.

3.2 Risk Assessment

The following risk assessment evaluation was performed in accordance with Reference 6, NPR 8715.3. A Risk assessment Matrix is included. See Figure 5. The severity, Probability Estimates and Risk Assessment Code (RAC) number for each of the Critical Items is documented. The Controls are considered to be in place to achieve minimum residual risk.

Definitions for risk Severity Class and Probability Estimate follow.

Risk Severity Class:

Severity is an assessment of the worst potential consequence, defined by degree of injury or property damage, which would occur. The severity classifications are defined as follows:

Class I – Catastrophic – A condition that may cause death or permanently disabling injury, facility destruction on the ground, or loss of crew, major systems, or vehicle during the mission.

Class II – Critical – A condition that may cause severe injury or occupational illness, or major property damage to facilities, systems, equipment, or flight hardware.

Class III – Moderate – A condition that may cause minor injury or occupational illness, or minor property damage to facilities, systems, equipment or flight hardware.

Class IV – Negligible – A condition that could cause the need for minor first aid treatment though would not adversely affect personal safety or health. A condition that subjects facilities, equipment, or flight hardware to more than normal wear and tear.

Probability Estimate:

Probability is the likelihood that an identified hazard will result in a mishap, based on an assessment of such factors as location, exposure in terms of cycles or hours of operation, and affected population. The following is an example of Probability Estimation:

A - Likely to occur immediately
B - Probably will occur in time
C – May occur in time
D – Unlikely to occur
E – Improbable to occur

The risk matrix is completed by documenting each hazard cause severity, and likelihood of occurrence in the appropriate risk assessment code block.

	Probability Estimate				
Severity Class	**A**	**B**	**C**	**D**	**E**
I	**1**	**1**	**2**	**3**	**4**
II	**1**	**2**	**3**	**4**	**5***
III	**2**	**3**	**4**	**5**	**6**
IV	**3**	**4**	**5**	**6**	**7**

Figure 5 – Crane 10-2 Risk Assessment Code Matrix

Critical Items

No.	Critical Item
1	Hoist Reducer*
2	Hoist Drum & Bearing System*
3	Hook & Bottom Block*
4	Hoist Top Block*
5	Swinging Rope End Assembly*
6	Wire Rope*

It is noted that the effectiveness of the in place controls and verifications is demonstrated by the fact that lifting device failure has not been a contributing root cause since the inception of the lifting device certification program in 1985.

4.0 Controls and Verifications

Controls are summarized below.

- Compliance with Hoisting Standards, i.e., CMAA
- Compliance with OSHA Regulations
- Compliance with AGMA Standards
- Documented, signed, and approved test procedures
- Performance of factory tests before shipment

- Acceptance testing
- Requirement for Daily, Monthly, and Periodic tests and inspections
- Performance of rated load tests

Verifications are as follows:

- Certification documentation
- Certified Critical Lift Operators
- Documented, dated, and signed Test Reports
- Signed Lifting Device Operator Daily Crane and Hoist Inspection and Limit Sw

5.0 Rationale for Criticality Category Downgrade

The criticality categorization for the critical items identified herein have been reassessed for creditability and reasonableness on the basis of operational experience with the equipment. The rationale for acceptability of each of these critical items included consideration of the following data elements: Design, Test, Inspection, Failure History and Operational Use. Controls and verifications are in place to either eliminate the critical item or achieve minimum residual risk. It is therefore recommended that the Criticality Category, for the identified Critical Items, be downgraded from a "1" to a "3," (see Table, Section 1.2). A Hazard assessment of the remaining risks was performed in accordance with NPR 8715.3, NASA Safety Manual, determined the Risk Assessment code (RAC) number to be equal to 5.

6.0 Control Logic Analysis

There were no critical/monitor functions associated with this hoist.

7.0 End-to-End Analysis

No areas of concern were identified which are the design responsibility of other contractors or NASA Centers.

8.0 Sneak Circuit Analysis

There was no sneak circuit analysis performed on this lifting device.

9.0 Recommendations

- Continue to certify the lifting device to reflect operational requirements. Continue to perform maintenance of the critical items per OEM requirements.
- Only certified, trained operators shall be authorized to operate lifting devices.
- Maintain documents/approved test and inspection procedures current.
- Review/update this analysis, as required, to reflect any changes in operation or facility improvements that affect the crane system.

10.0 Conclusion

Based on the above analysis, the risk hazard with control and verification in place, is assessed to be acceptable/controlled. With a RAC 5, it is concluded that this crane is in compliance with the requirements set forth in NASA-STD-8719.9 for performing critical lift operations.