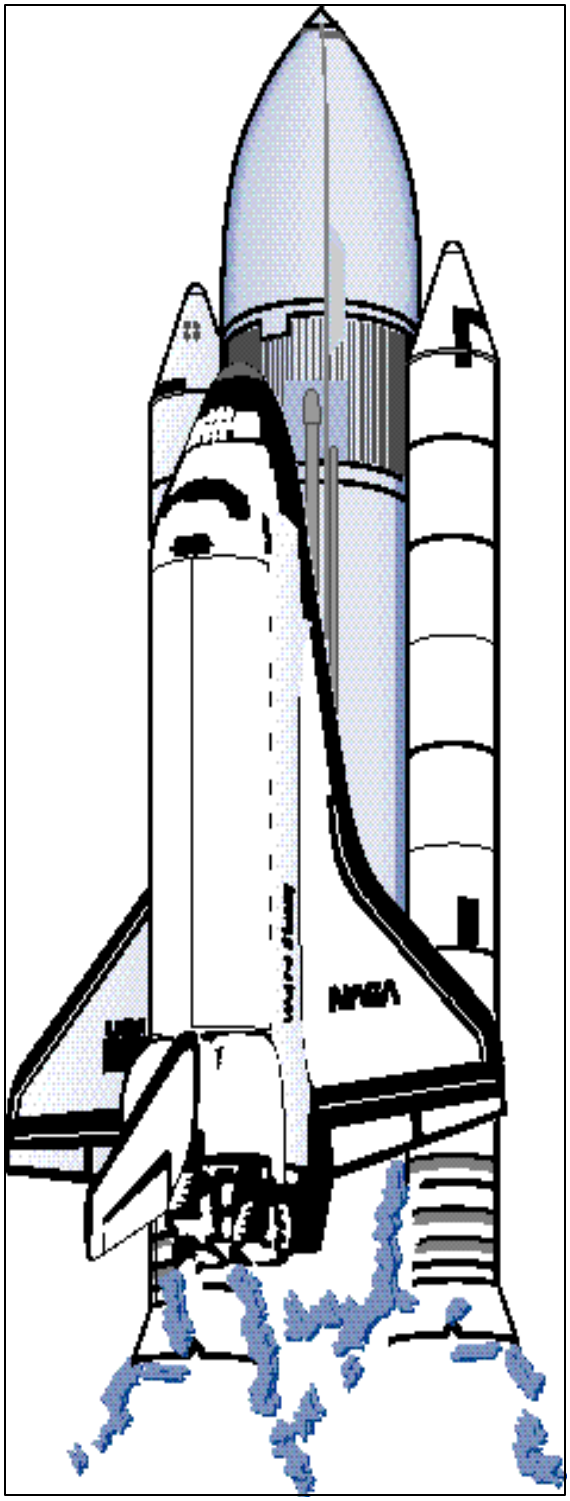

System Assurance Analysis

15–Ton Bridge Cranes At The ARF Manufacturing Building High Bay

For
Space Shuttle Solid Rocket Booster Assembly Project

Contract: NAS 9-20000

Prepared By:

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SYSTEM ASSURANCE ANALYSIS

15-Ton Bridge Cranes At The ARF Manufacturing Building High Bay

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REVISION LOG

REV LTR	CHG NO	DESCRIPTION	DATE
Baseline	1	1. Perform a System Assurance Analysis for the ARF Manufacturing Building 15-Ton Bridge Cranes	04-04-03

PREFACE

This System Assurance Analysis (SAA) identifies the hazards and risk associated with the use of commercial off the shelf (COTS) crane and winch equipment to lift and move SRB flight hardware in the Assembly and Refurbishment Facility (ARF) Manufacturing building located on Kennedy Space Center, Florida.

The principal elements of the System Assurance Analysis are the; System Description, Criticality Assessment, Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis and Hazard Analysis.

The Criticality Assessment identifies both the Safety Criticality and the Reliability Criticality.

The FMEA identifies system hardware components which, if failed, could result in loss of life, vehicle, and/or loss (damage) of a vehicle system.

The Fault Tree Analysis provides a graphical representation of the identified top-level hazard event for the system.

The Hazard Analysis identifies hazards which if allowed to exist could result in injury to personnel and/or damage to flight hardware.

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REFERENCE DOCUMENTS

NASA

NSTS 5300.4 (1D-2)	Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program
NSTS 22206	Requirements for Preparation and Approval of Failure Mode and Effect Analysis and Critical Item List
NSTS 22254	Methodology for Conduct of SSP Hazard Analyses
NSS/GO 1740.9	Safety Standard For Lifting Devices And Equipment
NASA-STD-8719.9	Standard For Lifting Devices and Equipment

DOL

OSHA 29 CFR 1910.179	Overhead and Gantry Cranes

AGMA

AGMA	Gear Standards.

ASME

ASME B30.2	Overhead and Gantry Cranes

CMAA

CMAA Spec.70	Specifications for Electric Overhead Traveling Cranes

USA

85M-2207-21-22	Spare Parts & Maintenance Manual (ARF High Bay Cranes)

USA SRBE

RODS FAC-0007-12P	15-Ton Bridge Crane, ARF High Bay, Monthly Inspection
RODS FAC-0007-13P	15-Ton Bridge Crane, ARF High Bay, Semiannual Inspection
RODS FAC-0007-14P	15-Ton Bridge Crane, ARF High Bay, Annual Inspection

ABBREVIATIONS AND ACRONYMS

CIL	Critical Item List
CRIT	Criticality
FMEA	Failure Mode And Effect Analysis
GSE	Ground Support Equipment
HDBK	Hand Book
HR	Hazard Report
IAW	In Accordance With
KSC	Kennedy Space Center
MIL	Military
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
P/N	Part Number
PMN	Part Model Number
PSE	Production Support Equipment
RODS	Routing Operations Document System
SFOC	Shuttle Flight Operations Contractor
STD	Standard
SPEC	Specification
SRB	Solid Rocket Booster
USA	United Space Alliance
WAD	Work Authorization Document

1.0 SYSTEM ASSURANCE ANALYSIS SUMMARY

1.1 Safety Criticality

The two identical 15-Ton Bridge Cranes, serial numbers 85M-2207-21 and 85M-2207-22 located in the SRB Assembly and Refurbishment Facility (ARF) Manufacturing building (L6-247) are assessed as safety critical because they are used to lift and move flight hardware.

1.2 Reliability Criticality

These 15-Ton Bridge Cranes are also assessed as critical because they are used to lift and move flight hardware. Failure of a Crane during raising or lowering, lateral north/south, or east/west direction movement of flight hardware could cause a loss of life and/or loss (damage) of flight hardware.

Table 1 - Criticality Summary

Item	Type	Quantity	Additional Information
Critical Items	1	0	
	1S	0	
	2	0	
	3	0	
1R Non-CIL Items	1R	10	Section 6.2
Critical Flex Hose	1S	0	
	2	0	
Critical Orifices	1S	0	
	2	0	
Critical Filters	1S	0	
	2	0	
Hazard Reports	Risk Accepted		Waiver for operation required

1.3 Findings

a. The ARF Bridge Cranes are structurally sound and well constructed.

b. The ARF Bridge Cranes met OSHA, ASME, CMAA and NASA crane requirements at the time when they were installed.

c. There were ten (10) criticality 1R Non-CIL items identified in the Crane systems. These items involve the crane's emergency stop switch, upper limit switch and the hoist's two brake systems.

d. The Hoist is equipped with geared upper and lower limit switch and final upper electro/mechanical paddle limit switch. However, upon activation (tripping) of the switch, the present electrical circuitry does not cut off the power to the hoist thus requiring a reset of the electrical system before the load can be moved (lowered).

e. There are strong safety controls and hazard mitigation processes in place during any operation of these overhead bridge cranes:

- Cranes maintained and serviced per RODS
- Trained and certified crane operators and support personnel
- WADs required for all Lifts
- E-Stop manned during any lift of flight hardware
- Operational Safety is present during any lift involving ordnance

1.4 Areas of Concern

The following Areas of Concern were identified this analysis.

a. Although the SRB ARF Bridge Crane Hoists are equipped with two (2) upper limit switches, they are not compliant with current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9), specifically the Hoist's final upper limit paddle switch electrical control circuitry does not meet the requirements of NSS/GO-1740.9 and NASA-STD-8719.9 which requires the power to the crane to be cut off and a resetting of the final upper limit switch after it has been activated (tripped) before any further movement of the load.

1.5 Recommendations

a. USA SRB Element and USA Facilities have been tasked to modify the Hoist's upper limit paddle switch circuitry to meet current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9).

b. Based upon the overall excellent condition of the two overhead cranes and the strong safety controls in place for their operation, it is recommended that SRBE be allowed to continue to use both cranes in support of SRB refurbishment operations while awaiting the modifications to their final upper limit switches.

Graphic 1-1 ARF 15-Ton Bridge Cranes

2.0 System Description

2.1 General

The two identical 15-Ton Bridge Cranes, serial numbers 85M-2207- 21 and 85M-2207-22 were installed in the high bay of the Solid Rocket Booster (SRB) Assembly and Refurbishment Facility (ARF) Manufacturing Bldg. (L6-247), Kennedy Space Center, Florida, during 1986. These crane assemblies were designed and fabricated by the Philadelphia Tramrail Company, Philadelphia, Pennsylvania to meet OSHA, ASME, CMAA and NASA requirements at the time when they were installed.

These overhead traveling cranes provide motion in three directions: Hoisting, up and down; Travel - Bridge, forward and reverse the length of the High Bay, and Travel – Trolley, forward and reverse across the width of the High Bay.

Each crane is configured the same, with a 15-ton hoist used to lift critical SRB flight hardware. The 15-ton hoist is mounted on a top running rail trolley which runs on the catwalk-equipped top running bridge. Lift height of the cranes is 45 feet, 4 inches from the floor. The drum is furnished with cable for 48-foot lift plus two (2) wraps for safety.

For lift application, speed reduction from the motor to the drum on the hoist is achieved by a gear case. Gearing is designed and manufactured to comply with the American Gear Manufacturers Association (AGMA) gear standards.

For simplicity, each of these 30,000 lb (15-ton) Bridge Cranes can be described as having four major components:

- Top Running (east/west) Double Girder Motor Driven Bridge Crane – 30,000 lb capacity
- Top Running (north/south) Double Girder Motor Driven Electric Hoist Carrier Trolley – 30,000 lb capacity
- Electric Motor Driven Wire Rope Hoist – 30,000 lb capacity
- Bridge Crane Electrical System

2.2. Bridge Assembly

The 77 foot, plate box construction crane girder provides a span of 76 feet and 6 inches running on end trucks equipped with 15 inch double flanged wheels is powered by two (2) one HP, 240 Vdc motor gear drives which can move the bridge at 50 fpm. The bridge drives are also equipped with a clutch and ¼ HP micro-drives to provide a speed of 6 inches per minute. The motors are equipped with 9-inch travel brakes.

Limit switches, located on each side of the bridge prevent possible collision with the other bridge crane, thus limiting travel at the end of bridge. If the travel limit switch fails

to stop bridge movement, mechanical stops located at the ends of the bridge rails, will prevent over travel.

2.3. Trolley Assembly

The trolley assembly runs on 10 inch double flanged wheels and is powered by one 240 Vdc, one HP motor gear drive which can move the trolley at 50 fpm. The trolley drive is also equipped with a clutch and ¼ HP micro-drive to provide a speed of 6 inches per minute. The motor is equipped with 9-inch travel brake. Crane is provided with end stops at each end to stop trolley.

2.4 Hoist Assembly

The hoist assembly provides vertical motion and consist of a hoist motor, hoist gear case assembly, magnetic brake, hoist disk brake, geared limit switch, hoist upper limit switch, weight –type limit switch, wire rope drum, pulley assembly, hook and load block with four (4) part double reeving rope.

Lift height of the cranes is 45 feet, 4 inches. The drum is furnished with cable for 48-foot lift plus two (2) wraps for safety.

The 15-ton hoist is controlled by a General Electric control package type SV-8620-OHR adjustable speed drive and controls using a 20 horsepower (HP) DC motor and controls. The motor provides power to the hoist gear case reducer through a 2 ¼" steel shaft with ½" x ¼" x 2 ¾" keyway on both ends. The shaft is fastened to the motor and the reducer with rigid hubs and flexible couplings. The motor is also equipped with a 10" dc magnetic shoe brake attached to the other end of the motor's shaft. When power is supplied to the hoist motor, the electric holding brake is energized which causes the brake to disengage, allowing the hoist to operate. A worm gear limit switch for the 15-ton hoist provides over travel protection while hoisting and lowering.

2.4.1 Drum Assembly

The 5'5'' long drum is 18 " in diameter with end flanges of 22" and a brake flange of 32" . The wire rope drum is equipped with a caliper disc brake system is designed to grip the brake flange on the hoist drum, thus eliminating possible failure points between the drum and brakes that could allow the load to drop.

2.4.2 Caliper Brake

The Caliper Brake compressed air system is energized when the runway and crane disconnect switches are closed. Upon start-up, the compressor motor will operate until the 17-gallon reservoir is charged, to cut-off pressure at 150 psi. Pressure switch, PS-1, will automatically keep the reservoir charged from 130 psi to 150 psi. The Caliper brake will release at 120 psi., at which point pressure switch, PS-2, will actuate, allowing operation of the main line contactor. The main line contactor will not close unless the caliper brake air system has reached "brake release" pressure.

The main line contactor will drop out when the E-Stop Button is pressed, but the caliper brake air system will remain energized, keeping the caliper brake released. Subsequent pressing of the Reset or E-Stop buttons will not affect the caliper brake.

The Caliper Brake will engage only under the following circumstances:

- Power Failure
- Opening of either the runway or crane disconnect switched.
- Over speed of hoist down travel as a result of a failure or malfunction of hoist components between the drum and the brakes. The over speed switch (OSS) will trip at 125% of normal down speed, causing the caliper brake air system to immediately release the brake air pressure, instantly engaging the caliper brake and dropping out the crane mainline contactor cutting power to all crane travel and hoisting motors.

NOTE: Whenever air pressure to the brake is released, the reservoir will remain charged. Subsequent charging of the air system will take much less time than at original “start up” of the system.

In order to reset the caliper brake system and restore power to the crane, the runway disconnect switch must be opened and then closed. This will drop out the over speed relay (OS) and over speed indicator light allowing air pressure to build-up, causing the brake to open and the crane mainline contactor to close.

2.5 Bridge Crane Electrical System

The cranes are electrically powered by facility 3-phase, 480V alternating current (AC) which is feed through a main, clearly placarded, disconnect switch located on the north/west wall of the high bay. The electrical power is then routed to the elevated Feed rail System.

2.5.1 Heavy Duty Feed rail System.

A Midland Ross heavy-duty three pole Feed rail system is used for electrification of the crane and hoist systems. The Feed rail system is listed by Under-Writer’s Laboratories, Inc., and is approved for use as a crane and hoist electrification system. The Feed rail system track has a rating of 175 amperes continuous and 250 amperes intermittent.

The Feed rail track sections are supported every 5 feet. The track sections consist of a one-piece 13-gauge zinc coated steel housing and the enclosed current carrying bus bars and insulators. The lower horizontal portions of the housing serve as smooth, rigid runways for the current pick-up trolleys.

The three bus bars used to carry the current are of hard drawn copper and amply proportioned to carry the specified current without overheating. The Feed rail electric current pick-up trolley used to pick-up the current from the bus bars is furnished with silver alloy brush contacts for movement up to 500 feet per minute.

2.5.2 Control and Emergency Stop Circuit

Control of the crane is provided through a suspended control pendant wired directly to the crane's electric control system located on the bridge of the crane. Pendant control involves start and stop pushbuttons which are momentary type. Pushing in on the start pushbutton applies power to the crane, depressing the stop pushbutton removes power from the crane. Other pushbuttons control bridge, trolley and hoist movements. All functions or motions of the crane can be stopped by depressing the stop pushbutton located on the pendant control.

An Emergency Stop (E-Stop) circuit is incorporated into the main disconnect switch box which is hardwired to two E-Stop outlets on the high bay floor. A fifty foot cable with Emergency Stop button is plugged into the nearest E-Stop outlet during crane operations and manned by a trained and certified employee who monitors the crane operation and can instantly stop all crane function by pressing the E-Stop button which disconnects main power to the runway connectors.

This function is independent of the Stop button on the pendant control box.

2.5.3 Indicator Light

Whenever the over speed switch operates, as a result of excess (125%) hoist down travel speed, an indicator light on the trolley will glow. This signals an emergency situation, leaving the crane inoperative.

2.6 Crane and Trolley/Hoist Specifications

2.6.1 Top Running Double Girder Motor Driven Bridge Crane

Capacity	30,000# plus weight of hoist and carrier
Type	Top Running – Double Girder
End Trucks	Wheel Base – approximately 12"-6" with two (2) 15" diameter double flange wheels
Overall Length	77'-10"
Overhangs	10" Each End
Runway Centers	76'-6"
Crane Girder	Plate box girder construction with 40# ASCE rail.
Crane Travel	50 fpm – 5-Step Variable with two (2) 1 HP motors (Type A-4 drive). Motors rated 30 minutes with class 'F' insulation. Bridge drives furnished with clutch and micro-drive to provide a travel speed of 6" per minutes. Micro-drives are continuous duty motors. Motors are equipped with travel brakes.
Runway Collectors	Feed rail type collector on one end truck for line voltage.
Current	480 Volt – 3 Phase – 60 Hertz
Conductor arrangement	Flat festoon cable
Miscellaneous	(1) Crane is equipped with manual disconnect. (2) Crane equipped with mainline magnetic contactor. (3) Crane motor protected with thermal overloads.

(4) Crane panel installed in NEMA-12 enclosure.
(5) Crane furnished with rubber bumpers and rail sweeps.
(6) Crane rated for Class 'C' service. Crane designed in accordance with CMAA 70 specifications.
(7) Crane furnished with traveling pendant mounted off crane. Pushbutton box furnished with 20'-0" of adjustment.
(8) Crane provided with end stops at each end to stop carrier and keep ASCE rail from creeping.
(9) Reversing bridge starter interlocked mechanically and electrically.
(10) Crane motor circuit provided with fuses.
(11) Control transformer has fused secondary controls.
(12) Crane furnished with Service Platform on drive side of crane bridge. All controls for hoist, trolley and bridge crane are mounted on Service Platform. Checkered plate used on platform.
(13) Crane furnished with rotating axles.
(14) Crane furnished with six (6) 1,000-watt mercury vapor lights.
(15) Crane complies with MIL-28613A.
(16) All gearing is totally enclosed.

2.6.2 Motor Driven Electric Wire Rope Hoist Carrier (Includes Hoist and Carrier)

Capacity	30,000#
Hoist	Double Girder – Special built up unit.
Lift	45'-0" required. Drum furnished with cable for 48'-0" of lift plus two (2) wraps for safety.
Lift Speed	20 FPM maximum. G.E. control package type SV-8620-OHR adjustable speed drive and controls using DC motor and DC controls. 20 HP motor.
Cable Reeving	4 Part Double – With ½" cable – 7:1 safety factor. Standard steel cable – Two ropes furnished.
Carrier Travel Speed	50 FPM 5-Step Variable with one (1) 1 HP motor. Motor rated 30 minutes with Class 'F' insulation. Trolley drive is furnished with a clutch and micro-drive to provide a travel speed of 6" per minute. Micro-Drive is a continuous duty motor. Motor furnished with travel brake.
Carrier	Four (4) 10" diameter hardened wheels with double flange.
Pendant	Pendant suspended from crane. 12-Button, 110 Volt Control Circuit (2 for 'On" – 'Off"), (Selector for spotting hoist), (Load Float Selector), (2 for Hoist Raise and Lower), (Selector – Normal, 5 Step variable or Creep), (2 for Bridge – North/South), (2 for Trolley – East/West).
Current	480 Volts – 3 Phase – 60 Hertz.
Electrification	Flat Cable Festoon System.
Miscellaneous	(1) Hoist equipped with Safety Hook.

(2) Trolley equipped with travel brakes wired into travel circuit.
(3) Hoist equipped with geared upper and lower limit switch and standard paddle limit switch.
(4) Hoist designed for minimum H-3 service.
(5) Hoist equipped with drum brake in addition to shoe brake and mechanical load brake.
(6) Hoist furnished with two cables connected to equalizer bar.
(7) G.E. Controls include Load Float feature to permit floating of 125% of full load at 0 FPM for a minimum of 15 minutes.
(8) Hoist and trolley controls equipped with circuit breakers or fuses and Thermal Overload Relays.
(9) All controls housed in NEMA-12 enclosures and comply with MIL-22137-B (YD).
(10) Trolley furnished with rotating axles. Trolley drive totally enclosed.
(11) Hoist block is a standard steel block and hook with electrically isolated hook.

2.7 Bridge Crane and Hoist Component Acceptance Tests

The Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist is rated for a maximum safe working load of 30,000 lbs.

2.7.1 Acceptance Load Tests

The following acceptance load tests were performed on the Bridge Crane and Trolley Hoist when they were installed at the ARF.

a. Trolley Travel Test – With 30,000 lbs on hook

b. Bridge Travel Test – With 30,000 lbs on hook

c. Test of Main Hoist – 125% Load (37,500 lbs) on hook
NOTE: During the 125% Main Hoist load test, all brakes, hoist, trolley and bridge were tested under full load and power failure. Brakes for all motions set immediately.

2.7.2 Load Float Test and Emergency Brake Test

The following tests were performed on the 15-ton hoist during the Bridge Crane and Trolley Hoist acceptance tests at the ARF.

a. The emergency caliper brake was dynamically tested under “No Load”. When the hoist went into an over speed situation, the emergency brake set at approximately

25 fpm. The emergency caliper brake stopped drum rotation immediately. The primary brake was wired out of circuit so it would not function during the test.

b. The emergency caliper brake was statically tested at 30,000 Lbs. The primary brake was released and the caliper brake held the 30,000 lb load with no perceivable drift.

c. Load Float was tested under “No Load”. The Load Flat button only was depressed for 30 seconds. The hook travel was approximately .75 inch per minute in the “up” direction.

d. The load float was tested at 30,000 lbs. The Load Float button only was depressed for 30 seconds. Hook travel was approximately .80 inch per minute in the up direction.

e. The Load Float operation was tested at 37,500 lbs. For this operation the Load Float button and hoist directional button were depressed simultaneously. This operation was run continuously for approximately fifteen (15) minutes. As a result of this operation, hook travel was approximately .041 inch per minute.

2.7.3 Safety Factors

a. 15 Ton Hoist

The 15-ton hoist is controlled by a General Electric control package type SV-8620-OHR adjustable speed drive and is driven by a 20 horsepower (HP) DC motor. Drum and wire rope equipped with equalizer bar between two wire ropes.

b. Wire Rope

4 Part Double – With ½” cable – 7:1 safety factor. Standard steel cable – Two ropes furnished. Wire rope is reeved on drum through lower block to upper sheaves, to equalizer bar and attached.

c. Hook

15 Ton capacity hook block at 7:1 safety factor with two 14 inch inner sheaves for ½” wire rope and two 12 inch outer sheaves with hook insulation.

2.8 Crane Inspection and Maintenance

The SRB Element RODS system is used to control the inspection and maintenance of the ARF 15-Ton Bridge cranes. The RODS system provides the documentation and tracking of monthly, semi-annual and annual crane inspections and maintenance procedures.

2.8.1 ROD FAC-0007 12P, Monthly Inspection and Maintenance

ROD FAC-0007 12P is a detailed monthly inspection procedure which as a minimum provides for a visual inspection, measurements, electrical checks and functional tests.

The following operations are performed during this monthly inspection cycle:

- General Inspection and Operation of the Crane
- General Inspection and Maintenance
- Wire Rope and Hook Inspection and Maintenance
- Operational Checks
- Close Out Requirements
- Verification procedure is complete

2.8.2 ROD FAC-0007 13P, Semi-Annual Inspection and Maintenance

ROD FAC-0007 13P is a detailed semi-annual inspection procedure which as a minimum provides for a visual inspection, measurements, electrical checks and functional tests.

The following operations are performed during this monthly inspection cycle:

- General Inspection and Operation of the Crane
- General Inspection and Maintenance
- Wire Rope and Hook Inspection and Maintenance
- Operational Checks
- Close Out Requirements
- Verification procedure is complete

2.8.3 ROD FAC-0007 14P, Annual Inspection and Maintenance

ROD FAC-0007 14P is a detailed annual inspection procedure which as a minimum provides for a visual inspection, measurements, electrical checks and functional tests.

The following operations are performed during this monthly inspection cycle:

- General Inspection and Operation of the Crane

- General Inspection and Maintenance
- Wire Rope and Hook Inspection and Maintenance
- 100 Percent of Rated Load Test
- Post Load Test Wire Rope/Hook Inspection
- Operational Checks
- Post Load Test NDE Inspection
- Close Out Requirements
- Verification procedure is complete

3.0 ANALYSIS GROUND RULES

This analysis has been developed in accordance with NSTS 22206 and 22254. The following additional ground rules and assumptions were used during this analysis.

a. Multiple failures of components or assemblies were not considered during the assessment.

b. All crane motion within three (3) feet of flight hardware will be in slow speed range. When approaching flight hardware, the crane will be stopped at a distance of three (3) feet or greater and all crane functions set into low speed range.

c. Operation of the Crane is performed only by appropriately trained and certified personnel.

d. The passive components associated with this system will not be analyzed in the FMEA. The current list of passive components includes the hook, load block, wire rope, sheaves, and rope drum. However, the drum shafts shall be analyzed as to the attachment method.

e. The analysis shall assess all active components between the load hook and the nearest brake since failure of these components could result in dropping the load. The following guidelines were used:

    - An eddy current brake is not considered capable of holding the load.
    - For shafts located between the drum and brake, the method of shaft attachment shall be analyzed. If the shaft is welded or physically attached to the drum by a method approved by hoisting standards, then the attach points shall be considered passive.

- Bearings on drums and shafts shall be analyzed only to determine if the bearings can fail and drop the load.

- Gear boxes, speed reducers and couplings shall be considered critical items if they are located between the hoist drum and nearest brake.

f. A single limit switch on the trolley drive shall not be identified as critical if there is also an acceptable mechanical stop.

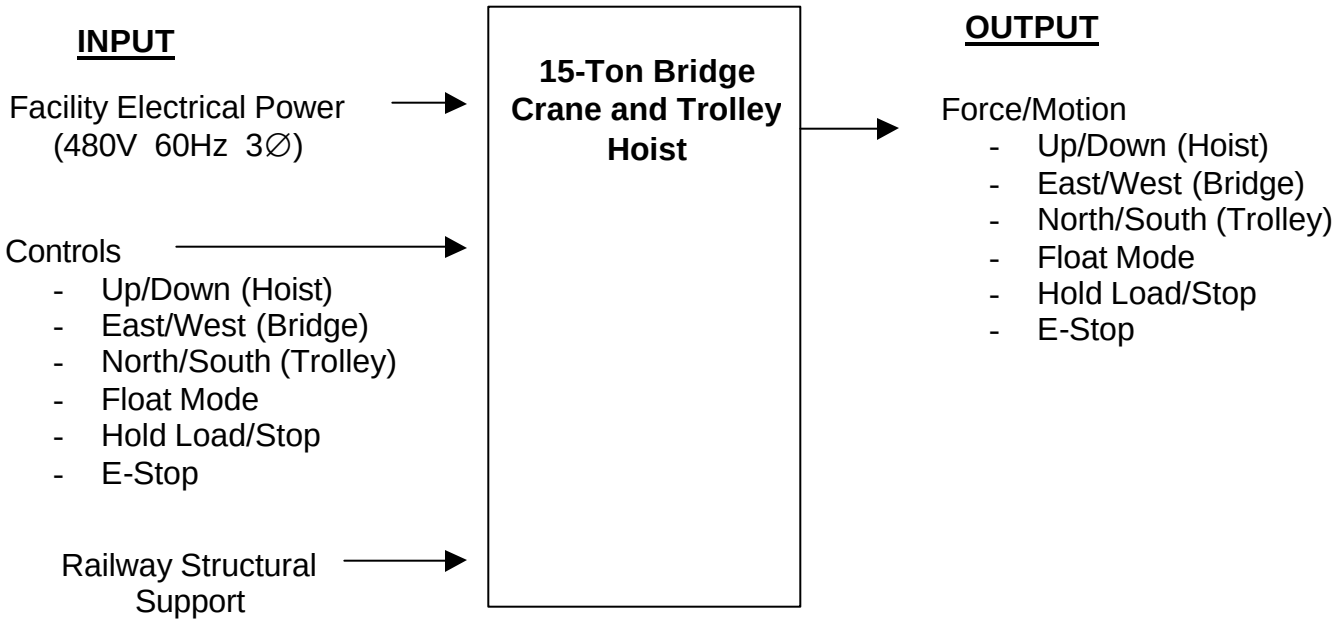
4.0 RELIABILITY ANALYSIS

4.1 System Criticality Assessment

The two identical Top Running Double Girder Motor Driven Bridge Cranes and Trolley Hoists located in the ARF manufacturing building have been assessed as critical because these systems are used to lift SRB flight hardware. Failure of these bridge cranes or improper performance of their functions during critical lifts could result in loss or non-reusability damage to SRB flight hardware. The functions assessed as critical will be analyzed in the Failure Modes and Effects Analysis (FMEA) unless otherwise noted. The Criticality Assessment also acts as an End-to-End Analysis by assuring continuity between this analysis and that of any interfacing system.

4.2 Functional Block Diagram

A functional block diagram for the Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist components are provided below and shows their input and output functions.



Graphic 4-1 15-Ton Crane Functional Block Diagram

4.3 Functional Criticality Assessment

The Input and Output functions are identified and analyzed on the following Functional Criticality Assessment Worksheets.

Table 2 (Page 1 of 5)

Functional Criticality Assessment Worksheet

System/Subsystem: Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist
Location: ARF Manufacturing Bldg., KSC, Florida
Drawing Number: H-7211 and H-7210
B/M: 85M-2207-21/22 and 85M-2207-36

USA SRB Element
Reference Figure Used: 4-1
Date: 04/04/03
Prepared By: J. Czere

Input	Function	Time Period	Effect of Loss/Failure If: **a. Fails to Operate on Time** **b. Fails to Cease Operation on Time** **c. Fails During Operation** **d. Prematurely Operates**	Critical/ Non-Crit	Remarks
Facility Electrical Power (480V 60Hz 3∅)	Provides power to operate motors and brakes for hoist, trolley and bridge.	During crane operations.	a. Delay in operations b. No effect, system can be isolated from facility power c. Delay in operations. d. Not Applicable.	a. NC b. NC c. NC d. NC	a. None b. None c. None d. None
Controls - Up/Down (Hoist)	Operates Hoist in specified direction.	As required.	a. Will not raise or lower load. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Controls - East/West (Bridge)	Operates Bridge in specified direction.	As required.	a. Will not move load East or West. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Controls - North/South (Hoist Trolley)	Operates Hoist Trolley in specified direction.	As required.	a. Will not move load North or South. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None

Table 2 (Page 2 of 5)

Functional Criticality Assessment Worksheet

System/Subsystem: Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist
Location: ARF Manufacturing Bldg., KSC, Florida
Drawing Number: H-7211 and H-7210
B/M: 85M-2207-21/22 and 85M-2207-36

USA SRB Element
Reference Figure Used: 4-1
Date: 04/04/03
Prepared By: J. Czere

Input	Function	Time Period	Effect of Loss/Failure If: a. Fails to Operate on Time b. Fails to Cease Operation on Time c. Fails During Operation d. Prematurely Operates	Critical/ Non-Crit	Remarks
Float Mode	Allows precise hoisting and lowering of load	As required	a. Will not float load. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in float mode would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Hold/Load Stop	Terminates lifting/lowering and lateral motion	As required	a. Unable to stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. b. Would not be able to move load in the direction specified. c. Unable to completely stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. d. Would not be able to move load in the direction specified.	a. C b. NC c. C d. NC	a. See FMEA b. None c. See FMEA d. None

Table 2 (Page 3 of 5)

Functional Criticality Assessment Worksheet

System/Subsystem: Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist **Location: ARF Manufacturing Bldg., KSC, Florida** **Drawing Number: H-7211 and H-7210** **B/M: 85M-2207-21/22 and 85M-2207-36**	**USA SRB Element** **Reference Figure Used: 4-1** **Date: 04/04/03** **Prepared By: J. Czere**

Input	**Function**	**Time Period**	**Effect of Loss/Failure If:** **a. Fails to Operate on Time** **b. Fails to Cease Operation on Time** **c. Fails During Operation** **d. Prematurely Operates**	**Critical/ Non-Crit**	**Remarks**
E-Stop	Provides emergency stop capability	As required	a. Unable to stop abnormal crane motion. Possible loss of life and/or damage to flight hardware. b. Unable to move load in the direction s pecified. c. Unable to stop abnormal crane motion. Possible loss of life and/or damage to flight hardware. d. Unable to move load in the direction specified.	a. C b. NC c. C d. NC	a. See FMEA b. None c. See FMEA d. None
Railway Structure	Provides static foundation for support of Bridge Crane.	As long as Bridge Crane is in service	a. Not Applicable b. Not Applicable c. Loss of structural support for crane resulting in loss of life d. Not Applicable	a. NC b. NC c. C d. NC	a. None b. None c. FMEA not required. d. None

Table 2 (Page 4 of 5)

Functional Criticality Assessment Worksheet

System/Subsystem: Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist
Location: ARF Manufacturing Bldg., KSC, Florida
Drawing Number: H-7211 and H-7210
B/M: 85M-2207-21/22 and 85M-2207-36

USA SRB Element
Reference Figure Used: 4-1
Date: 04/04/03
Prepared By: J. Czere

Output	Function	Time Period	Effect of Loss/Failure If: **a. Fails to Operate on Time** **b. Fails to Cease Operation on Time** **c. Fails During Operation** **d. Prematurely Operates**	Critical/ Non-Crit	Remarks
Force/Motion - Up/Down (Hoist)	Raise/lower and position flight hardware	As required.	a. Can not raise or lower load. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Force/Motion - East/West (Bridge)	Position flight hardware	As required.	a. Can not move Bridge in specified direction. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Force/Motion - North/South (Hoist Trolley)	Position flight hardware	As required.	a. Can not trolley in specified direction. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in specified direction would cease. d. NA	a. C b. NC c. C d. NC	a. None b. See FMEA c. None d. None
Hold Load/Stop (Hoist/Trolley/ Bridge)	Stop and hold load in fixed position	As required	a. Unable to stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. b. Will not be able to move load in specified direction. c. Unable to stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. d. Will not be able to move load in specified direction.	a. NC b. C c. NC d. NC	a. See FMEA b. None c. See FMEA d. None

Table 2 (Page 5 of 5)

Functional Criticality Assessment Worksheet

System/Subsystem: Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist
Location: ARF Manufacturing Bldg., KSC, Florida
Drawing Number: H-7211 and H-7210
B/M: 85M-2207-21/22 and 85M-2207-36

USA SRB Element
Reference Figure Used: 4-1
Date: 04/04/03
Prepared By: J. Czere

Output	Function	Time Period	Effect of Loss/Failure If: **a. Fails to Operate on Time** **b. Fails to Cease Operation on Time** **c. Fails During Operation** **d. Prematurely Operates**	Critical/ Non-Crit	Remarks
Float Mode	Allows precise hoisting and lowering of flight hardware	As required	a. Can not float load. b. Load will continue to move in specified direction and could result in damage to flight hardware. c. Load motion in float mode would cease. d. NA	a. NC b. C c. NC d. NC	a. None b. See FMEA c. None d. None
Hold/Load Stop	Terminates lifting/lowering and lateral motion	As required	a. Unable to stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. b. Would not be able to move load in the direction specified. c. Unable to completely stop normal or abnormal crane motion. Possible loss of life and/or damage to flight hardware. d. Would not be able to move load in the direction specified.	a. C b. NC c. C d. NC	a. See FMEA b. None c. See FMEA d. None
E-Stop	Provides emergency stop capability	As required	a. Can not stop abnormal crane motion. Possible loss of life and/or damage to flight hardware. b. Can not move load in the direction specified. c. Can not stop abnormal crane motion. Possible loss of life and/or damage to flight hardware. d. Can not move load in the direction specified.	a. C b. NC c. C d. NC	a. See FMEA b. None c. See FMEA d. None

5.0 Failure Modes and Effects Analysis (FMEA)

5.1 Mechanical and Electrical Component FMEA

The mechanical and electrical components of the critical functions assessed in section 4.3 for the 15 Ton Top Running Double Girder Motor Driven Bridge Crane and Trolley Hoist system were identified from the documents and diagrams referenced in USA 85M-2207-21-22, Spare Parts & Maintenance Manual (ARF High Bay Cranes) and are depicted on the flowing figure(s) and analyzed in the following FMEA worksheets.

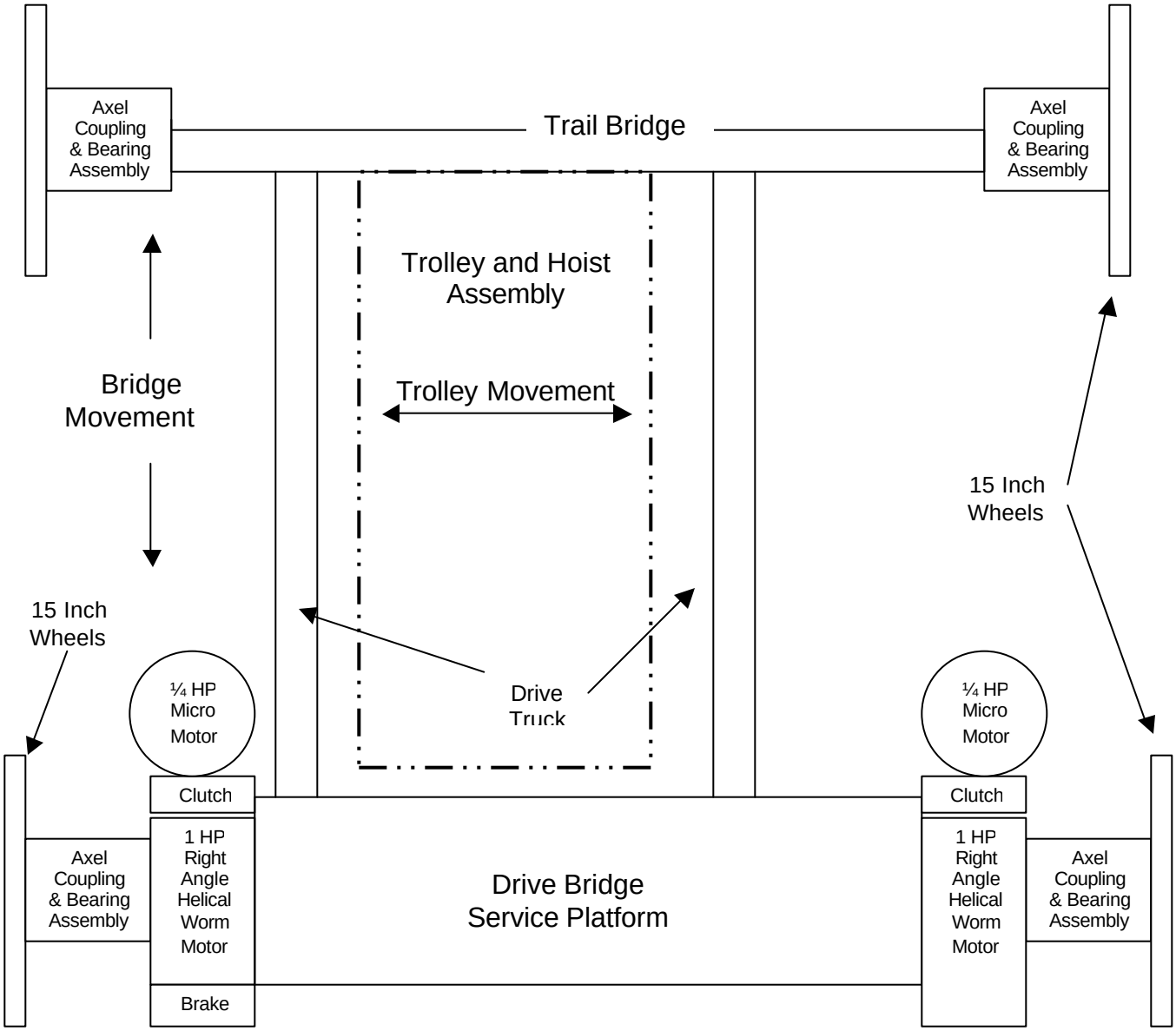
A list of all mechanical and electrical passive items is provided below and will not be shown in the FMEAs.

Table 3 Bridge Crane Mechanical and Electrical Passive Item List

System/Location	Nomenclature
Facility Traverse Rail	Traverse Rail and Structure
Bridges	Bridge Rail Structure
	Box Girder
	Bridge Structure and Weldment
	Walkway Assembly
	End Truck Weldment
	Controls Mounting
Trolley	Trolley Rail and Structure
	Trolley Structure Weldment
Hoist	Lower Block Assembly
	Drum
	Drum Shaft
	Wire Rope Drum
	Upper Block
	Wire Rope
Electrical	Facility Power (480V 60Hz 3∅)
	Feed Rail Structure
	Feed Rail Trolley/Conductors

5.2 Bridge Drive Mechanical FMEA

The Bridge drive components shown in graphic 5-4 below are analyzed in the associated FMEA worksheets.



Graphic 5-1 Bridge Drive Mechanical Power Flow - Not to scale

Table 4 Bridge Component List

QTY	DESCRIPTION	REFERENCE OR DRAWING
4	15” D.F. Idler Wheels – Fixed Axle	C-233005
4	Axle, 3 ¾” x 9”	1628-J
8	McGill Bearings	1630-M
4	15” D.F. Wheels – Rotating Axle	C-233004
2	Bridge Truck	D-125643
8	Spherical Roller Bearings	1631-S
4	Keys ½” x ½”	C-233004
2	10” Shoe Brake, G. E. size 101	9598-G. E.
2	Warner SFC-400 Clutch	A106-02B
2	1 hp right Angle Helical Worm Drive Motor Reducer with Brake and Clutch. With ¼ HP micro drive motor	1440-R

Table 5 **MECHANICAL FMEA - BRIDGE**

System/Subsystem: 15-Ton Bridge Crane/Bridge
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-1
Date: 04/04/03
Prepared By: J. Czere

Part No. **FMN**	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
C-233005 01B	Bridge Truck 15" DF Idler Wheels	Supports and translates Bridge, trolley, hoist and load on Bridge rails.	a1. Wheel Fails to Turn	a1. Wheel cannot roll, bridge will move with hesitation or not at all. Delay in operation for repair.	a1. No effect	3
C-233004 02B	Bridge Truck powered 15" DF Drive Wheels	Supports and translates Bridge, trolley, hoist and load on Bridge rails.	a2. Gear Disengagement	a2. Loss of Bridge drive truck and axle connection. Delay in operation for repair.	a2. No effect	3
D-125643 03B	Axle/Wheel Coupling Assemblies Bridge, Drive Trucks	Provides mechanical link between Bridge drive truck axle and 1 HP Right Angle Helical Worm Motor Reducer.	a3. Wheel Fails to Turn	a3. Wheel cannot roll. Delay in operation for repair.	a3. No effect	3
C-233004 04B	Axle/Wheel Coupling Assemblies Bridge, Drive Trucks	Provides mechanical link between Bridge drive truck axle and 1 HP Right Angle Helical Worm Motor Reducer.	a4. Key Disengagement	a4. No torque drive trucks. Delay in operation for repair	a4. No effect	3
1631-S 05B	Bridge Truck Axle Wheel Bearing Assemblies	Provides support to axle/wheel coupling to Motorducer shaft assemblies.	a5. Bearings Seize	a5. Wheel shaft will not turn, preventing Bridge from moving. Delay in operation for repair.	a5. No effect	3
1631-S 06B	Bridge Truck Axle Wheel Bearing Assemblies	Provides support to axle/wheel coupling to Motorducer shaft assemblies.	a6. Bearing Fails	a6. Wheel will roll, bridge will move with hesitation or not at all. Delay in operation for repair.	a6. No effect	3

Table 5 **MECHANICAL FMEA - BRIDGE**

System/Subsystem: 15-Ton Bridge Crane/Bridge
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-1
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
D-125643 07B	Bridge Drive 1 HP Right Angle Helical Worm Motor Reducer	Transmits torque from 1 HP Right Angle Helical Worm Motor Reducer to drive truck Axle.	a7. Gear Disengagement	a.7 Loss of Bridge Drive Truck connection to Worm Motor Reducer. Redundant Bridge Drives with Worm Motor Reducers with brakes will slow/stop Bridge travel. Delay in operation for repair.	a7. No effect	3
9598 G.E 08B	Bridge Drive 1 HP Right Angle Helical Worm Motor Reducer Brake	Brake provides torque to slow/stop East bridge drive truck.	a8. Brake fails to release	a8. Loss of ability to move Bridge. Delay in operation for repair.	a8. No effect	3
9598 G.E. 09B	Bridge Drive 1 HP Right Angle Helical Worm Motor Reducer Brake	Brake provides torque to slow/stop East bridge drive truck.	a9. Brake fails to engage	a9. Loss of torque from brake to slow/stop Bridge travel. Redundant brakes and E-Stop will slow/stop Bridge travel. Delay in operation for repair.	a9. No effect	3
A106-02B 10B	Bridge Drive Motor Reducer with Brake and Clutch	Clutch provides torque to engage ¼ HP Micro Drive Motor to East bridge drive truck.	a10. Clutch fails to engage	a10. Loss of ability to move Bridge in “inch travel mode”. Delay in operation for repair.	a10. No effect	3
A106-02B 11B	Bridge Drive Motor Reducer with Brake and Clutch	Clutch provides torque to engage ¼ HP Micro Drive Motor to East bridge drive truck.	a11. Clutch fails to release	a11. Loss of ability to change bridge travel speed, normal or inch speed. Delay in operation for repair.	a11. No effect	3

Table 5 **MECHANICAL FMEA - BRIDGE**

Page 3 of 3

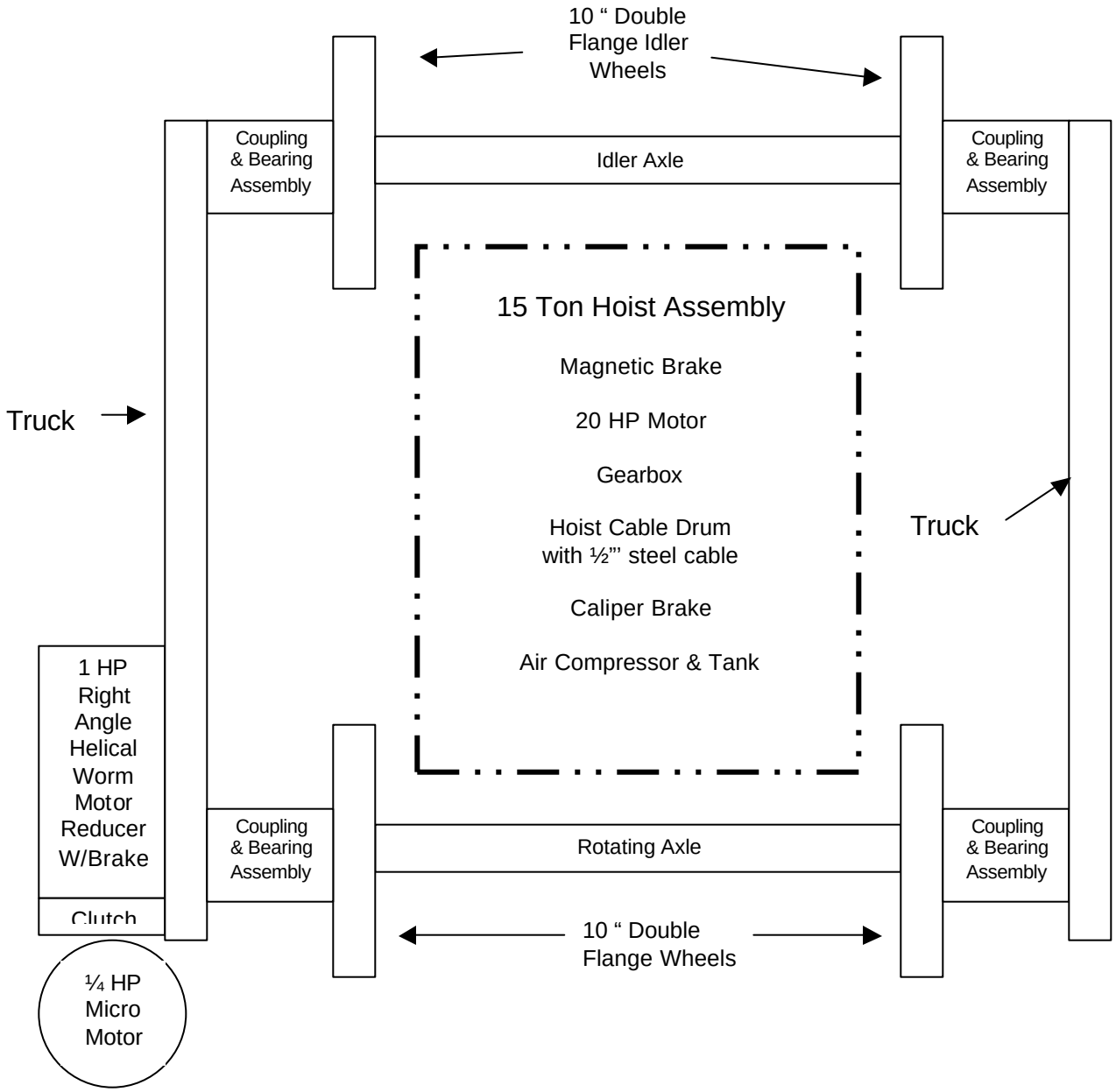
System/Subsystem: 15-Ton Bridge Crane/Bridge
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-1
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
D-125643 12B	1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch	1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch provides torque to Bridge Drive Truck.	a12. Motor fails to operate	a12. Loss of ability to move Bridge at normal speed. Redundant Bridge motors. Delay in operation for repair.	a12. No effect	3
D-125643 13B	¼ HP Micro Drive Motor	¼ HP Micro Drive Motor provides torque to East bridge drive truck.	a13. Motor fails to operate.	a13. Loss of ability to move Bridge in “inch travel mode”. Delay in operation for repair.	a13. No effect	3

5.3 Trolley Drive Mechanical FMEA

The Trolley drive components shown in graphic below are analyzed in the associated FMEA worksheets.



Graphic 5-2 Trolley Drive Mechanical Power Flow - Not to scale

Table 6 Top Running Trolley/Hoist, Component List

QTY	DESCRIPTION	REFERENCE OR DRAWING
4	10” D.F. Idler Wheels – Rotating Axle	232140-11
4	10” D.F. Drive Wheels – Rotating Axle	232140-12
1	Idler Axle	232100-59
1	Drive Axle	232100-60
8	Flange Bearings	1434-S
1	10” Shoe Brake, G. E. size 101	9598-G. E.
1	Warner SFC-400 Clutch	A106-02B
1	1 hp right Angle Helical Worm Drive Motor Reducer with Brake and Clutch. With ¼ HP micro drive motor	1440-R

Table 7 **MECHANICAL FMEA - TROLLEY**

System/Subsystem: 15-Ton Bridge Crane/Trolley
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-2
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
232140-11 01T	Trolley Truck with 10" DF Idler Wheels and axle.	Supports and translates trolley, hoist and load on Bridge rails.	a1. Wheel Fails to Turn	a1. Wheel cannot roll, Trolley will move with hesitation or not at all. Delay in operation for repair.	a1. No effect	3
232140-12 02T	Trolley Truck with powered 10" DF Drive Wheels and axle.	Supports and translates trolley, hoist and load on Bridge rails.	a2. Gear Disengagement	a2. Loss of Trolley Truck drive axle connection, trolley cannot move. Delay in operation for repair.	a2. No effect	3
232140-12 03T	Trolley Truck with powered 10" DF Drive Wheels and axle.	Supports and translates trolley, hoist and load on Bridge rails.	a3. Wheel Fails to Turn	a3. Wheel cannot roll. Delay in operation for repair.	a3. No effect	3
1434-S 04T	Powered Trolley Truck Axle/Wheel Coupling Assembly.	Provides mechanical link between Trolley Drive Truck and 1 HP Right Angle Helical Worm Motor Reducer.	a4. Key Disengagement	a4. No torque transmitted to Trolley Drive truck. Trolley cannot move. Delay in operation for repair	a4. No effect	3
1434-S 05T	Powered Trolley Truck Axle/Wheel Bearing Assembly.	Provides support to coupling shaft assemblies.	a5. Bearings Seize	a5. Wheel shaft will not turn, preventing Trolley from moving. Delay in operation for repair.	a5. No effect	3
1434-S 06T	Powered Trolley Truck Axle/Wheel Bearing Assembly.	Provides support to coupling shaft assemblies.	a6. Bearing Fails	a6. Wheel will roll, Trolley will move with hesitation or not at all. Delay in operation for repair.	a6. No effect	3

Table 7 **MECHANICAL FMEA - TROLLEY**

System/Subsystem: 15-Ton Bridge Crane/Trolley
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-2
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
1440-R 07T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer	Transmits torque from 1 HP Right Angle Helical Worm Motor Reducer to Drive Truck Axle.	a7. Gear Disengagement	a.7 Loss of Trolley Drive Worm Motor Reducer. Trolley cannot move. Delay in operation for repair.	a7. No effect	3
9598-G.E. 08T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer w/Brake	Brake provides torque to slow/stop Trolley Drive Truck.	a8. Brake fails to release	a8. Loss of ability to move Trolley. Delay in operation for repair.	a8. No effect	3
9598-G.E. 09T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer w/Brake	Brake provides torque to slow/stop Trolley Drive Truck.	a9. Brake fails to engage	a9. Applying Trolley brake will not stop/slow Trolley travel. Loss of Trolley momentum due to friction and operational procedures which require the use of the slow speeds near flight hardware will prevent collisions with the load. Mechanical stops installed on rail ends. Delay in operation for repair.	a9. No effect	3
A106-02B 10T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch.	Clutch provides torque to engage ¼ HP Micro Drive Motor to Trolley Drive Truck.	a10. Clutch fails to engage	a10. Loss of ability to move Trolley in “inch travel mode”. Delay in operation for repair.	a10. No effect	3

Table 7 **MECHANICAL FMEA - TROLLEY**

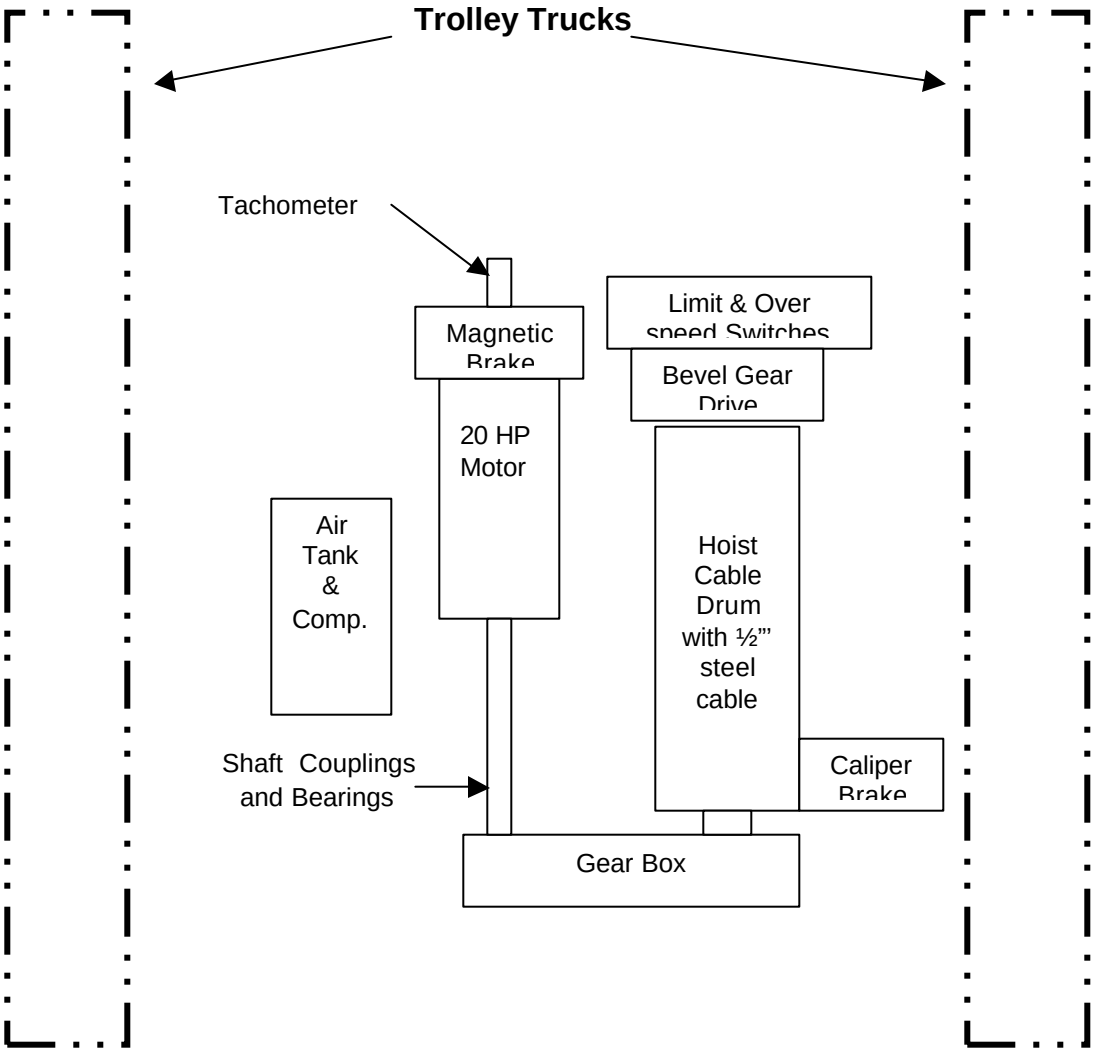
System/Subsystem: 15-Ton Bridge Crane/Trolley
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-2
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
A106-02B 11T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch.	Clutch provides torque to engage ¼ HP Micro Drive Motor to Trolley Drive Truck.	a11. Clutch fails to release	a11. Loss of ability to change Trolley travel speed, normal or inch speed. Delay in operation for repair.	a11. No effect	3
1440-R 12T	Trolley Drive 1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch	1 HP Right Angle Helical Worm Motor Reducer with Brake and Clutch provides torque to Trolley Drive Truck.	a12. Motor fails to operate	a12. Loss of ability to move trolley at normal speed. Redundant Bridge motors. Delay in operation for repair.	a12. No effect	3
1440-R 13T	¼ HP Micro Drive Motor	¼ HP Micro Drive Motor provides torque to Trolley Drive Truck.	a13. Motor fails to operate.	a13. Loss of ability to move Trolley in “inch travel mode”. Delay in operation for repair.	a13. No effect	3

5.4 Hoist Drive Mechanical FMEA

The Hoist drive components shown in graphic below are analyzed in the associated FMEA worksheets.



Graphic 5-3 Hoist Drive Mechanical Power Flow

Table 8 Hoist Component List

QTY	DESCRIPTION	REFERENCE OR DRAWING
1	10” Shoe Brake w/ 10" wheel	9598-GE
1	20 HP Motor DC Type CD	9598-GE
4	Coupling	1391-2
1	Shaft	117661-1
1	Hansen Parallel Shaft Helical Reducer	1423-H
2	Bearings, Pillow Block	1392-2
4	Coupling	2134-B
1	Bevel Gear Drive	1632-R
1	Over Speed Switch	1380-M
1	Trolley Hoist Geared Limit Switch	1632-R
1	Standard Paddle Limit Switch	N/A
1	Tachometer	N/A
1	Drum Brake Disc	161361
1	Pneumatic Caliper Brake	2129-L
1	Air Compressor & Tank	2130-L
1	Equalizer Bar Assembly	161363

Table 9 **MECHANICAL FMEA - HOIST**

System/Subsystem: 15-Ton Bridge Crane/Trolley
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
9598-GE 01H	10” Magnetic Brake Wheel	Provides torque to hold load.	a1. Key Disengages b1. Structural Failure c1. Visual d1. None e1. Immediate f1. NA	a1. Loss of ability for brake to hold load. Back-up Drum Caliper brake will control load.	a1. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
9598-GE 02H	10” Magnetic Brake, Two Brake Shoes	Provides torque to hold load.	a2. Fails to engage b2. Stuck, worn or glazed c2. Visual d2. None e2. Immediate f2. NA	a2. Loss of ability for brake to hold load. Back-up Drum Caliper brake will control load.	a2. Requires failure of second brake system to lose control of load. Could cause loss 1of life or flight hardware.	1R
9598-GE 03H	10” Magnetic Brake, Two Brake Shoes	Provides torque to hold load.	a3. Fails to Release	a3. Loss of ability to raise/lower load. Delay in operation for repair.	a3. No effect	3
9598-GE 04H	20 HP Motor	Provides torque to Lift, lower or hold load.	a4. Fails to operate	a4. Torque will not be provided and hoist will not operate.	a4. No effect	3
1391-2 05H	Couplings (Motor/Gear Box)	Provides mechanical link between motor shaft coupling and drive shaft and gear box coupling.	a5. Key Disengages b5. Structural Failure c5. Visual d5. None e5. Immediate f5. NA	a5. Loss of ability for motor to raise/lower load and for magnetic brake to hold load. Back-up Drum Caliper brake will control load.	a5. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R

Table 9 **MECHANICAL FMEA - 15 TON HOIST**

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
117661-1 06H	Shaft	Transmits torque from motor and brake to Gear Box.	a6. Shaft Fails b6. Structural Failure c6. Visual d6. None e6. Immediate f6. NA	a6. Loss of ability for motor to raise/lower load and for magnetic brake to hold load. Back-up Drum Caliper brake will control load.	a6. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
1423-H 07H	Gear Box	Transmits torque from motor and brake to Drum shaft coupling.	a7. Gear Disengages b7. Structural Failure c7. Visual d7. None e7. Immediate f7. NA	a7. Loss of ability for motor to raise/lower load and for magnetic brake to hold load. Back-up Drum Caliper brake will control load.	a7. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
1391-2 08H	Coupling (Drum Shaft)	Transmits torque from gear box to Drum shaft.	a8. Key Disengages b8. Structural Failure c8. Visual d8. None e8. Immediate f8. NA	a8. Loss of ability for motor to raise/lower load and for magnetic brake to hold load. Back-up Drum Caliper brake will control load.	a8. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
1392-2 09H	Bearing Free (Pillow Block)	Supports and hold shaft in place while allowing it to rotate freely.	a9. Bearing seizes	a9. Wire rope drum will cease to rotate. Delay in operation for repair.	a9. No effect.	3
1392-2 10H	Bearing Held (Pillow Block)	Supports and hold shaft in place while allowing it to rotate freely.	a10. Bearing seizes	a10. Wire rope drum will cease to rotate. Delay in operation for repair.	a10. No effect.	3

Table 9 **MECHANICAL FMEA - 15 TON HOIST**

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
2134-B 10H	Coupling (Drum Shaft to Bevel Gear Drive)	Transmits torque from Drum shaft through Bevel Gear Drive to Limit and Over speed Switches.	a10. Key Disengages	a10. Loss of input to Bevel Gear Drive. Load block may be lowered onto floor. Damage to hoist gearbox and wire rope could result in load being dropped if upper weight limit switch fails to stop hoist. Double failure required.	a10. No effect	3
1632-R 11H	Bevel Gear Drive	Transmits torque from Drum shaft to Limit and Over speed Switches.	a11. Gear Disengages	a11. Bevel Gear Drive will cease to rotate and provide torque to Limit and Over speed Switches. Load block may be lowered onto floor. Damage to hoist gearbox and wire rope could result in load being dropped if upper weight limit switch fails to stop hoist. Double failure required.	a11. No effect	3
2134-B 12H	Couplings	Provides mechanical link between Bevel Gear output drive shafts and Over speed and Limit switches.	a12. Key Disengages	a12. Bevel Gear Output Drive shafts will cease to rotate and provide torque to Limit and Over speed Switches. Damage to hoist gearbox and wire rope could result in load being dropped if upper weight limit switch fails to stop hoist. Double failure required.	a12. No effect	3

Table 9 **MECHANICAL FMEA - 15 TON HOIST**

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
1380-H 13H	Over speed Switch	Provides over speed protection for hoist in up and down direction.	a13. Electrical Failure	a13. Loss of over speed Over speed control if electronic over speed circuit also fails. Possible damage to flight hardware. Double failure required.	a13. No effect.	3
1632-R 14H	Upper and Lower Limit Switch	Provides overdrive protection for hoist in the up and down direction.	a14. Gear Disengages	a14. Loss of up and down limit switch output could result in load block being lowered onto floor or being two-blocked with resultant damage to hoist gearbox and wire rope. Double failure required.	a14. No effect	3

Table 9 **MECHANICAL FMEA - 15 TON HOIST**

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
15H 16H	Standard Paddle Limit Switch	Provides overdrive protection for hoist in the up direction.	a15. Mechanical Failure a16. Electrical Failure	a15. Loss of up limit switch output could result in load block being two-blocked with resultant damage to hoist gearbox and wire rope. Double failure required.	a15. No effect.	3
				a16. Electrical failure allows the lowering of the load which does not meet the NSS/GO-1740.9 and NASA-STD-8719.9 requirement of resetting at the final upper limit switch after it has been activated (tripped).	a16. No effect.	1R
17H	Hoist Motor Tachometer	Generates voltage proportional to speed of Hoist motor.	a17. High, Low or no output	a17. Hoist motor controller will compensate for loss of tachometer feedback by increasing armature current. A speed limit circuit will limit motor speed in the event of tachometer circuitry problems (loss of signal, reversed polarity and control mis-operation). A motor field loss circuit will initiate a orderly shut down of the hoist motor. Double failure required.	a17. No effect.	3

Table 9 **MECHANICAL FMEA - 15 TON HOIST**

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System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-3
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
161361 18H	Drum Caliper Brake Disc	Provides torque to hold load.	a16. Fails to engage b16. Worn or glazed c16. Visual d16. None e16. Immediate f16. NA	a16. Loss of ability for brake to hold load. Back-up magnetic brake will control load.	a16. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
2129-L 19H	Pneumatic Caliber Brake	Provides torque to hold load.	a17. Fails to engage b17. Stuck, worn or glazed c17. Visual d17. None e17. Immediate f17. NA	a17. Loss of ability for brake to hold load. Back-up magnetic brake will control load.	a17. Requires failure of second brake system to lose control of load. Could cause loss of life or flight hardware.	1R
2129-L 20H	Pneumatic Caliber Brake	Provides torque to hold load.	a18. Loss of air pressure, Fails to release	a18. Loss of ability to raise/lower load. Delay operation for repair.	a18. No effect.	3
2130-L 21H	Air Compressor and Tank	Provides 150 psi air for Caliper Brake operation.	a19. Compressor fails	a19. Loss of ability to release drum caliper brake. Delay in operation.	a19. No effect	3
161363 22H	Equalizer Bar	Pivots to distribute load between both wire ropes.	a20. Fails to pivot	a20. Equalizer bar will not distribute load evenly. Single wire rope and gear train will hold load	a20. No effect.	3

5.5 Electrical FMEA

5.5.1 Bridge Crane Electrical System

The cranes are electrically powered by facility 3-phase, 480V alternating current (AC) which is feed through a main, clearly placarded, disconnect switch located on the north/west wall of the high bay. The electrical power is then routed to the elevated Feed rail System. The functional interconnection electrical diagram for the operation of the ARF Manufacturing building's two 15-Ton Bridge Cranes is shown below in graphic 5-4.

The design of the electrical circuitry for these Bridge Cranes incorporates multiple circuit breakers and thermal overload relays to provide protection for the Crane's electrical circuits and safety of operation.

5.5.2 Control and Emergency Stop Circuit

Control of the crane is provided through a suspended control pendant wired directly to the crane's electric control system located on the bridge of the crane. Pendant control involves start and stop pushbuttons which are momentary type. Pushing in on the start pushbutton applies power to the crane, depressing the stop pushbutton removes power from the crane. Other pushbuttons control bridge, trolley and hoist movements. All functions or motions of the crane can be stopped by depressing the stop pushbutton located on the pendant control.

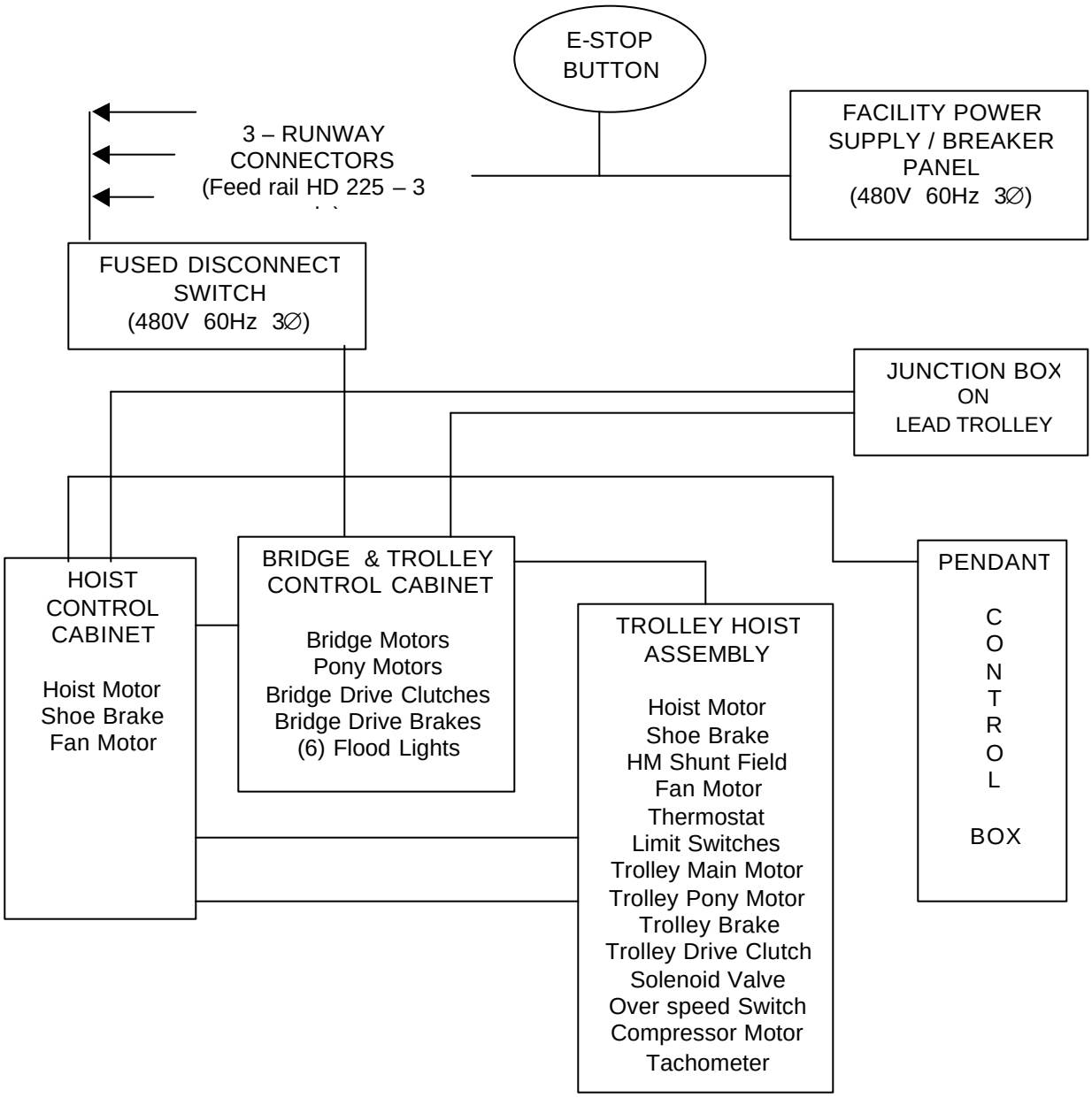
An Emergency Stop (E-Stop) circuit is incorporated into the main disconnect switch box which is hardwired to two E-Stop outlets on the high bay floor. A fifty foot cable with Emergency Stop button is plugged into the nearest E-Stop outlet during crane operations and manned by a trained and certified employee who monitors the crane operation and can instantly stop all crane function by pressing the E-Stop button which disconnects main power to the runway connectors.

This function is independent of the Stop button on the pendant control box. Additionally, a stand alone independent emergency stop controller which cuts all electrical current to the bridge crane at the facility electrical current distribution point is manned during all crane operations to ensure any crane movement or hoisting movements can be stopped in the event of failure of the crane's electrical system or hard wired control pendant.

5.5.3 Electrical FMEA Scope

The scope of the FMEAs for the Crane's electrical system will be based upon the functional diagram and will not be taken below the block components shown in the graphic. The rationale for this is based upon; (1) the control system for this crane is a hardwired man operated system, (2) the crane control system does not use a radio remote control system or computerized control system, (3) the Emergency Stop (E-Stop) function is independent of the cranes control system and is manned during crane operations, and (4) the fact that any single electrical system component failure will not

produce a criticality 1, 1R or 2 failure which cannot be offset by the use of the Emergency Stop Circuit controller or using the stop button on the controller pendant. The electrical components shown in graphic below are analyzed in the associated FMEA worksheets.



Graphic 5-4 15-Ton Crane Electrical Interconnection Diagram

Table 10 Electrical Component List

QTY	DESCRIPTION	REFERENCE
1	Remote E-Stop Controller and 50' Cord	154340
3	Feed Rail Runway & Trolley Contactors	2690-R
1	Fused Disconnect Switch	153318
1	Bridge & Trolley Control Cabinet	1883-G
1	Hoist Control Cabinet	1883-G
1	Junction Box	
1	Control Pendant	

Table 11 **ELECTRICAL FMEA - BRIDGE**

Page 1 of 3

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-4
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
MCB 01E	480V , 60Hz, 3∅, 200 AMP Main Circuit Breaker Panel with 120V Shunt Trip.	Protects Facility Power from overload in Crane electrical system.	a1. Premature operation.	a1. Loss of power to all Crane electrical systems. All brakes will set.	a1. No effect.	3
MCB 02E			a2. Fails to operate.	Downstream circuit breakers will protect secondary circuit. Requires double failure.	a2. No effect	3
154340 03E	Remote E-Stop Controller and 50' Cord	Provides emergency shut down of crane. When closed, it will energize the shunt trip relay coil in the main circuit breaker panel there by de-energizing all Crane systems and setting the all brakes.	a3. Fails open.	a3. Shunt trip for MCB will not be energized to open MCB. Crane may be de-energized and all brakes applied by (1) manually depressing the stop switch on the control pendant or (2) using the breaker switch on the MCB panel.	a3. Crane will continue to operate. Could cause loss 1of life or flight hardware.	1R
154340 04E			a4. Fails Closed	Shunt trip will open MCB and de-energize all crane systems and set all brakes. MCB will stay open until remote E-Stop controller repaired.	a4. No effect.	3

Table 11 **ELECTRICAL FMEA - BRIDGE**

Page 2 of 3

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-4
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
FDS 05E	Fused Disconnect Switch, Feed rail Runway Conductors, 480V , 60Hz, 3∅,	Protects under voltage phase loss, phase reversal from short/overload in feed rail.	a5. Premature operation.	a5. Loss of power to all Crane electrical systems. All brakes will set.	a5. No effect.	3
FDS 06E			a6. Fails to operate.	a6. Associated fuse or main circuit breaker will provide protection against short/overload. Requires double failure.	a6. No effect	3
BTCC 07E	Bridge & Trolley Control Cabinet	Cabinet holds and protects Bridge and Trolley system electrical components.	a7. Component fails open.	a7. Loss of power to Bridge and/or trolley systems. Brakes will set.	a7. No effect.	3
BTCC 08E			a8. Component fails short.	a8. Fuse protecting Bridge and Trolley components in failed portion of system will blow. Brakes will set.	a8. No effect.	3
HCC 09E	Hoist Control Cabinet	Cabinet holds and protects Hoist system electrical components.	a9. Component fails open.	a9. Loss of power to Bridge and/or trolley systems. Brakes will set.	a9. No effect.	3
HCC 10E			a10. Component fails short.	a10. Fuse protecting Hoist components in failed portion of system will blow. Brakes will set.	a10. No effect.	3

Table 11 **ELECTRICAL FMEA - BRIDGE**

Page 3 of 3

System/Subsystem: 15-Ton Bridge Crane/Hoist Assembly
Location: SRB ARF Manufacturing Bldg. (L6-247), KSC, Florida
Document Number: 85M-2207-21-22
PMN: 85M-2207-21-22

USA SRB Element
Reference Figure Used: 5-4
Date: 04/04/03
Prepared By: J. Czere

Part No. FMN	Part Name	Part Function	a. Failure Mode b. Cause c. Detection Method d. Correcting Action e. Time to Effect f. Timeframe	Failure Effect On System Performance	Failure Effect On Vehicle Systems and/or Personnel Safety	Crit Cat
JB 11E	Bridge Junction Box	Box holds and protects Bridge and Trolley system electrical connections.	a11. Component fails open.	a11. Loss of power to Bridge and/or trolley systems. Brakes will set.	a11. No effect.	3
BTCC 12E			a12. Component fails short.	a12. Fuse protecting Bridge and Trolley components in failed portion of system will blow. Brakes will set.	a12. No effect.	3
PCB 13E	Pendant Controller	Pendant Controller holds and protects Hoist system electrical components.	a13. Component fails open.	a13. Loss of power to Bridge and/or trolley systems. Brakes will set.	a13. No effect.	3
PCB 14E			a14. Component fails short.	a14. Fuse protecting Hoist components in failed portion of system will blow. Brakes will set.	a14. No effect.	3

5.6 Flexhose FMEA

There are no flex hoses associated with this system.

5.7 Orifice FMEA

There are no critical orifices associated with this system.

5.8 Filter FMEA

There are no filters associated with this system.

6.0 System Critical Items List

This section provides a summary of single failure points, which were identified in the system. Single point failures are grouped into three classifications: critical items, 1R Non-CIL items, and generic critical items.

- Critical items are criticality category 1, 1R, 1S and 2 components that do not meet the 1R Non-CIL item criteria or the generic critical item criteria. Critical Items List (CIL) sheets are prepared for these items.

- 1R Non-CIL items are redundant critical items, which are capable of checkout during normal ground operations.

- Generic critical items are criticality 1S and 2 flex hoses, orifices, and filters which meet established acceptance criteria.

6.1 Critical Items List

No criticality Category 1, 1R, 1S or 2 components were identified in the analysis of the Crane systems.

6.2 Criticality Category 1R Non-CIL Items

NSTS 22206, section4.4.1, paragraph a.2.a.b and c specify that “failures of redundant items which meet the criteria described in 2(a) or (b) shall be classified as Criticality Category 1R. Single failure within the system controls which could cause a loss of a 1R item shall not be identified as 1R but shall be listed as a cause of the failure of the 1R items which it controls.”

The analysis did identify ten (10) identified Criticality Category 1R Non-CIL components. which are summarized and documented below.

Table 12 **Criticality Category - 1R Non-CIL Hardware List**

Project Element: SRB Assembly and Refurbishment Facility

Subsystem: 15 – Ton Cranes, Manufacturing Building High Bay

FMEA P/N	Part Name	QTY (Per Crane)	Criticality
03E, 154340	Remote E-Stop Controller	1	1R – Non CIL
01H, 9598-GE	10" Magnetic Brake Wheel	1	1R – Non CIL
02H, 9598-GE	10" Magnetic Brake, Two Brake Shoes	1	1R – Non CIL
05H, 1391-2	Couplings (Motor/Gear Box)	1	1R – Non CIL
06H, 117661-1	Shaft	1	1R – Non CIL
07H, 1423-H	Gear Box	1	1R – Non CIL
08H, 1391-2	Couplings (Drum Shaft)	1	1R – Non CIL
16H, N/A	Standard Paddle Limit Switch	1	1R – Non CIL
18H, 161361	Drum Caliper Brake Disc	1	1R – Non CIL
19H, 2129-1	Pneumatic Caliper Drum Brake	1	1R – Non CIL

6.2.1 Criticality Category - 1R Non-CIL Component Worksheets

Worksheets for the above Criticality Category - 1R Non-CIL components are summarized and presented in the following pages.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Remote E-Stop Controller

Total Quantity: 1

Failure Mode Number: 03E

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	154340	**Drawing**	85M-2207 –21-22

Function: Provides emergency shut down of crane. When closed, it will energize the shunt trip relay coil in the main circuit breaker panel there by de-energizing all Crane systems and setting the all brakes.

Mode/Failure Mode No: Emergency Stop Fails Open, 03E

Failure Cause: Mechanical failure.

Failure Effect: Loss of the Emergency Stop function, crane continues to operate. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual Operational Test, E-Stop control test performed.
NASA-STD-8719.9	X		Annual Operational Test, E-Stop control test performed.

Test and Inspection:

NASA documents require an annual operational test of crane emergency stop switches to assure that the switch works.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: 10” Magnetic Brake Wheel

Total Quantity: 1

Failure Mode Number: 01H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	9598-GE	**Drawing**	85M-2207 –21-22

Function: Provides torque to hold load.

Mode/Failure Mode No: Shaft key disengages, 01H

Failure Cause: Mechanical failure.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	Yes	No	Rationale
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: 10” Magnetic Brake, Two Brake Shoes

Total Quantity: 2

Failure Mode Number: 02H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	9598-GE	**Drawing**	85M-2207 –21-22

Function: Provides torque to hold load.

Mode/Failure Mode No: Fails to engage, 01H

Failure Cause: Stuck, worn or glazed brake shoes.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Motor/Shaft/Gear Box Couplings

Total Quantity: 2

Failure Mode Number: 05H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	1391-2	**Drawing**	85M-2207 –21-22

Function: Provides mechanical link between motor shaft, drive shaft and gear box.

Mode/Failure Mode No: Key disengages, 05H.

Failure Cause: Mechanical failure.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Shaft (Motor to Gear Box)

Total Quantity: 1

Failure Mode Number: 06H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	117661-1	**Drawing**	85M-2207 –21-22

Function: Transmits torque from motor and brake to gear box.

Mode/Failure Mode No: Shaft fails, 06H.

Failure Cause: Mechanical failure.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Gear Box

Total Quantity: 1

Failure Mode Number: 07H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	1423-H	**Drawing**	85M-2207 –21-22

Function: Transmits torque from motor and brake to drum shaft coupling.

Mode/Failure Mode No: Gears disengage, 75H.

Failure Cause: Mechanical failure.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	Yes	No	Rationale
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Drum Shaft Coupling

Total Quantity: 1

Failure Mode Number: 08H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	1391-2	**Drawing**	85M-2207 –21-22

Function: Provides mechanical link between gear box shaft and drum.

Mode/Failure Mode No: Key disengages, 08H.

Failure Cause: Mechanical failure.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Upper Paddle Limit Switch

Total Quantity: 1

Failure Mode Number: 16H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	N/A	**Drawing**	85M-2207 –21-22

Function: Provides overdrive protection for hoist in the up direction.

Mode/Failure Mode No: Electrical Failure, 16H.

Failure Cause: No manually resetting circuit.

Failure Effect: Electrical failure allows the lowering of the load which does not meet the NSS/GO-1740.9 and NASA-STD-8719.9 requirement of resetting at the final upper limit switch after it has been activated (tripped).

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	**Yes**	**No**	**Rationale**
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Drum Caliper Brake Disc

Total Quantity: 1

Failure Mode Number: 18H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	161361	**Drawing**	85M-2207 –21-22

Function: Provides torque to hold load.

Mode/Failure Mode No: Fails to engage, 018H

Failure Cause: Worn or glazed brake disc.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	Yes	No	Rationale
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

Criticality Category 1R Non-CIL Component Worksheet

Critical Item: Pneumatic Caliper Drum Brake Pad

Total Quantity: 2

Failure Mode Number: 19H

Criticality Category: 1R Non-CIL

SAA No:	ARF 15 – Ton Crane	**System/Area:**	ARF Manufacturing Bldg.
NASA Part No.	N/A	**PMN/Name:**	15 – Ton Bridge Crane
Mfg. Part No.	2129-L	**Drawing**	85M-2207 –21-22

Function: Provides torque to hold load.

Mode/Failure Mode No: Fails to engage, 19H

Failure Cause: Stuck, worn or glazed brake pads.

Failure Effect: Loss of the necessary torque to hold load when coupled with failure of the drum pneumatic caliper brake. Possible loss of life and/or flight hardware.

ACCEPTANCE RATIONALE

Redundancy Screens:

		Pass	Fail
a.	Item is verifiable during normal ground operations.	X	
b.	Item loss is readily detectable by the ground crew.	X	
c.	Loss of all redundant items cannot result from a single cause.	X	

Conforms to:	Yes	No	Rationale
NSS/GO- 1740.9B	X		Annual operational independent brake test performed.
NASA-STD-8719.9	X		Annual operational independent brake test performed.

Test and Inspection:

NASA documents require an annual test of both crane mechanical load paths to assure that each path independently holds the rated load.

7.0 SYSTEM SAFETY ANALYSIS

7.1 Scope

A System Safety Analysis for the man rating of the Top Running Double Girder Motor Driven Bridge Crane has been completed. The drawings referenced in the documentation list were reviewed and a walk down of the systems and associated equipment was performed.

7.2 Fault Tree Analysis

A qualitative Fault tree Analysis was developed for the Top Running Double Girder Motor Driven Bridge Crane with the top event identified as “Death/Injury And/Or Damage to Flight Hardware.” This Fault Tree Analysis is shown as Figure 7-1.

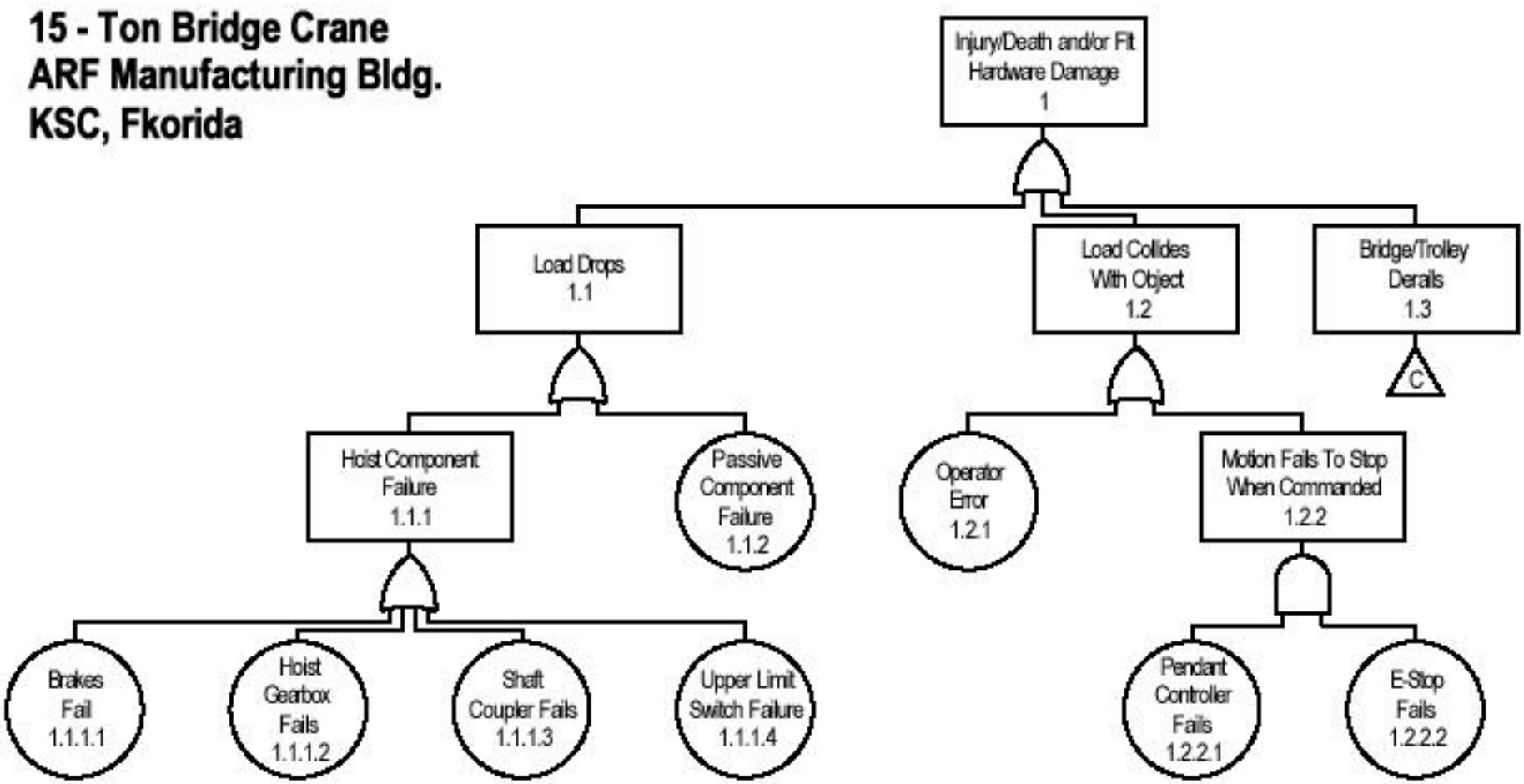


Figure 7-1 15 – Ton Bridge Crane Fault Tree

15 - Ton Bridge Crane
ARF Manufacturing Bldg.
KSC, Fkorida

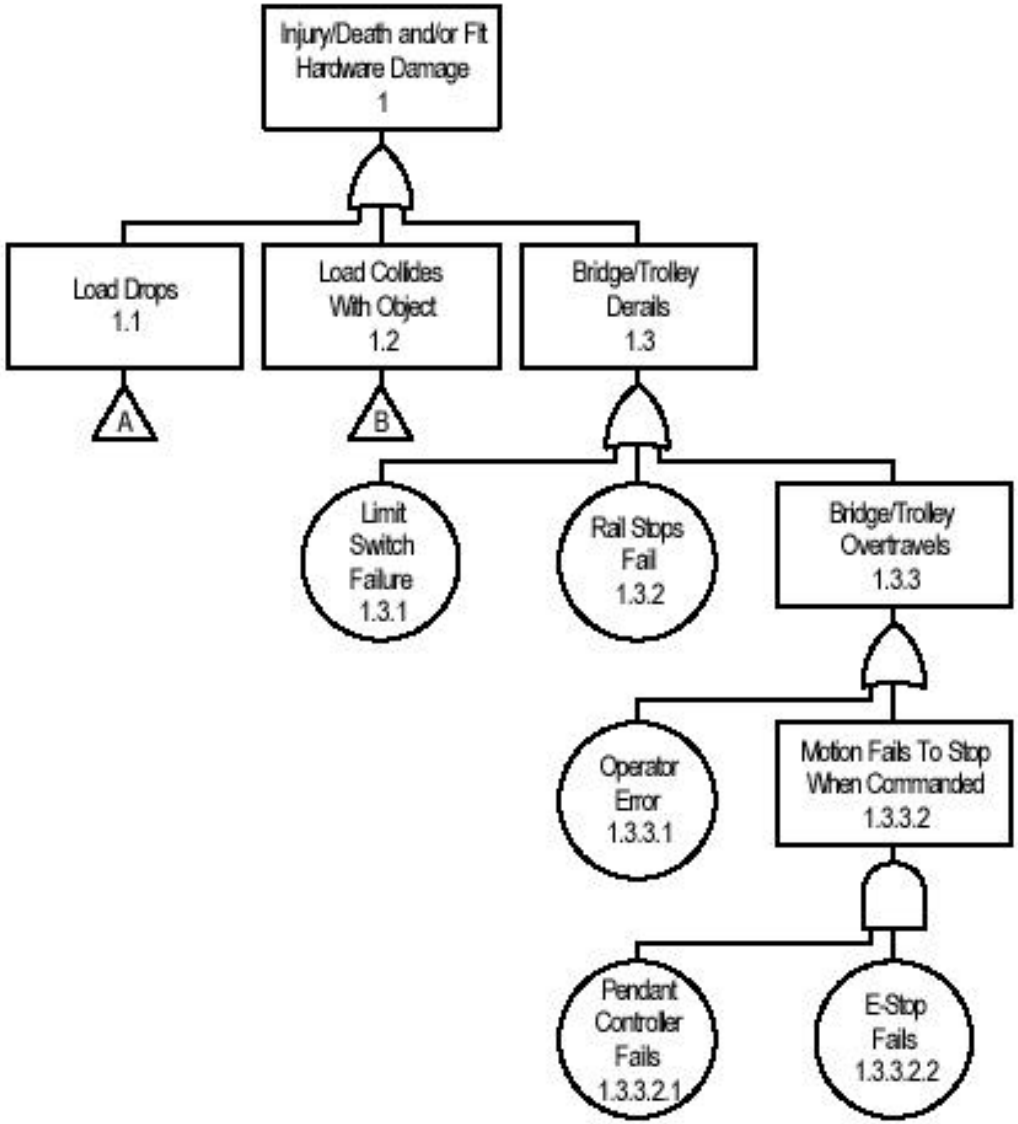


Figure 7-3 15 – Ton Bridge Crane Fault Tree – Cont.

8.0 ARF 15 – Ton Bridge Crane System Hazard Report

The USA SRB Operational & System Safety Office searched applicable Databases for hazard reports pertaining to the 15 – Ton Bridge Crane Systems. No hazard reports were found for these Crane systems.

A Hazard Analysis was performed based on the potential root hazard causes (events) leading to the top event of the Fault Tree shown as Figure 7-1.

8.1 Findings

a. The ARF Bridge Cranes are structurally sound and well constructed.

b. The ARF Bridge Cranes met OSHA, ASME, CMAA and NASA crane requirements at the time when they were installed.

c. There were ten (10) criticality 1R Non-CIL items identified in the Crane systems. These items involve the crane's emergency stop switch, upper limit switch and the hoist's two brake systems.

d. The Hoist is equipped with geared upper and lower limit switch and final upper electro/mechanical paddle limit switch. However, upon activation (tripping) of the switch, the present electrical circuitry does not cut off the power to the hoist thus requiring a reset of the electrical system before the load can be moved (lowered).

e. There are strong safety controls and hazard mitigation processes in place during any operation of these overhead bridge cranes:

- Cranes maintained and serviced per RODS
- Trained and certified crane operators and support personnel
- WADs required for all Lifts
- E-Stop manned during any lift of flight hardware
- Operational Safety present during any lift involving ordnance

8.2 Areas of Concern

a. Although the SRB ARF Bridge Crane Hoists are equipped with two (2) upper limit switches, they are not compliant with current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9), specifically the Hoist's final upper limit paddle switch electrical control circuitry does not meet the requirements of NSS/GO-1740.9 and NASA-STD-8719.9 which requires the power to the crane to be cut off and a resetting of the final upper limit switch after it has been activated (tripped) before any further movement of the load.

8.3 Acceptance Rationale

a. Although the Hoist's final upper limit paddle switch electrical control circuitry does not meet the requirements of NSS/GO-1740.9 and NASA-STD-8719.9 and allows movement of the load after the upper limit switch has been activated, it would require redundant failures to damage flight hardware.

b. USA SRB Element and USA Facilities has been tasked to modify the Hoist's upper limit paddle switch circuitry to meet current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9).

8.4 Recommendations

a. USA SRB Element and USA Facilities have been tasked to modify the Hoist's upper limit paddle switch circuitry to meet current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9).

b. Based upon the overall excellent condition of the two overhead cranes and the strong safety controls in place for their operation, it is recommended that SRBE be allowed to continue to use both cranes in support of SRB refurbishment operations while awaiting the modifications to their final upper limit switches.

8.5 Hazard Analysis Work Sheets

A Hazard Analysis was performed based on the potential root hazard causes (events) leading to the top event of the Fault Tree shown as Figure 7-1. The Hazard Analysis work sheets are provided below.

Table 13

REVISION: Basic	DATE: 04/04/03	STATUS: Closed	CLOSURE CLASSIFICATION: **Controlled Risk**

TITLE: Hazard Analysis, 15-Ton Bridge Cranes, serial numbers 85M-2207- 21 and 85M-2207-22.

FACILITY: SRB Assembly and Refurbishment Facility, Bldg. L6-247	GROUND SUPPORT EQUIPMENT 15-Ton Bridge Cranes, serial numbers 85M-2207- 21 and 85M-2207-22

FLIGHT EFFECTIVITY: Non Flight Specific, GSE/PSE

MISSION PHASE: SRB assembly and refurbishment operations.

HAZARDOUS CONDITION DESCRIPTION (Top Event): Personnel injury or death and/or damage to flight hardware during operation of the ARF 15-Ton Bridge Cranes, serial numbers 85M-2207- 21 and 85M-2207-22. Caused by hazardous conditions: (1) Load Drops, (2) Load Collides With Object and (3) Bridge/Trolley Derails,

NOTE: The Crane Hoist is configured with two independent brake systems to prevent dropping a load. The Hoist drum has a friction caliber brake and a magnetic shoe brake is installed on the hoist motor. The hoist is also equipped with two upper limit switches to prevent two blocking of hook. However since the final upper limit paddle switch does not cut the power to the hoist after it has been tripped (activated), it is not in compliance with NSS/GO-1740.9 and NASA-STD-8719.9.

ACCEPTANCE RATIONALE: The SRB facilities Dept. has been directed to modify the hoist's final upper limit switch electrical circuitry to comply with NSS/GO-1740.9 and NASA-STD-8719.9 requirements. In the interim, strong hazard mitigation controls are in place; remote E-Stop manned during Flight Hardware lifts, employees trained to watch height of lift and if final upper limit switch is tripped to immediately contact SRBE Safety.

NSTS 22254 RISK MATRIX
(Hazard Severity and Likelihood of Occurrence
With Controls in Place)

	Marginal	Critical	Catastrophic
Probable			
Infrequent			
Remote			
Improbable		**1.1 Load Drops** **1.2 Load Collides With Object**	**1.3 Bridge/Trolley Derails**

CONTROLLED RISK CAUSES: Hoist's final upper limit paddle switch electrical control circuitry does not meet the requirements of NSS/GO-1740.9 and NASA-STD-8719.9 which requires the resetting of the final upper limit switch after it has been activated (tripped) before further movement of the load.

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	Hazard Causes: 1.1) Load Drops 1.2) Load Collides With Object 1.3) Bridge/Trolley Derails Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.1.) Compliance with NSS/GO - 1740.9, "Safety Standard for Lifting Devices and Equipment" is mandatory for all NASA-owned and NASA contractor supplied equipment used in support of NASA operations. 1.2) Compliance with NSS/GO - 1740.9, "Safety Standard for Lifting Devices and Equipment" is mandatory for all NASA-owned and NASA contractor supplied equipment used in support of NASA operations. 1.3) Compliance with NSS/GO - 1740.9, "Safety Standard for Lifting Devices and Equipment" is mandatory for all NASA-owned and NASA contractor supplied equipment used in support of NASA operations.	1.1) NSS/GO - 1740.9, para. 201f(2)(e) Each hoisting unit shall be provided with two means of braking: a control brake and a holding brake. The torque ratings, physical characteristics and capabilities of the brakes shall be IAW CMAA specifications. 1.2) NSS/GO - 1740.9, para. 201f(2)(e) Each hoisting unit shall be provided with two means of braking: a control brake and a holding brake. The torque ratings, physical characteristics and capabilities of the brakes shall be IAW CMAA specifications. 1.3) ANSI/ASME B30.17d, para 17.1.8.2(a) and 17.1.8.3(a) A power driven bridge/trolley should be provided with bumpers. If bumpers are provided, they should be mounted so that there is no direct shear on the bolts upon contact.	1.1, 1.2 and 1.3) NSS/GO – 1740.9, "Safety Standard for Lifting Devices and Equipment" provides for daily, monthly and annual inspections to be performed by USA SRB Facilities IAW USA SRB Facility maintenance Procedures; FAC-0007 14P, FAC-0007-13P and FAC-0007-12P.	1.1 & 1.2) Personnel Death/Injury 1. Critical 2. Improbable 3. Controlled Risk 1.3) Personnel Death/Injury 1. Catastrophic 2. Improbable 3. Controlled Risk

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.1 Load Drops	Hazard Causes: 1.1.1) Hoist Component Failure 1.1.2) Passive Structural Failure Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.1.1) NSS/GO - 1740.9, para. 201f. Mechanical and mechanical design requirements - use of high quality equipment which meets this requirement.. Safety controls prevent personnel from working under the load. 1.1.1) NSS/GO - 1740.9, para. 201e. Structural Design - Crane design IAW industry standards.	1.1.1) The ARF 15-Ton Bridge Cranes are designed IAW industry standards and are equipped with duel brake systems: a magnetic shoe brake on the Hoist motor and a pneumatic caliper brake on the Hoist drum. Both of these brakes are designed to hold the full rated load for the crane. Safety controls prevent personnel from working under the load. 1.1.1) The ARF 15-Ton Bridge Cranes were structurally designed and constructed to meet industry standards at the time they were built.	1.1.1 and 1.1.2) Operational Readiness Inspections were conducted for both cranes. Cranes were proof load tested and certified to be in compliance with industry standards at the time they were installed at the ARF.	1.1.1 & 1.1.2) Personnel Death/Injury 1. Critical 2. Improbable 3. Controlled Risk

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.1.1) Hoist Component Failure	Hazard Causes: 1.1.1.1) Brake Fails 1.1.1.2) Hoist Gearbox Fails 1.1.1.3) Shaft Coupler Fails 1.1.1.4) Final Upper Limit Switch Fails Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.1.1.1, 1.1.1.2, and 1.1.1.3) NSS/GO - 1740.9, para. 201f(2)(e) Each hoisting unit shall be provided with two means of braking: a control brake and a holding brake. The torque ratings, physical characteristics and capabilities of the brakes shall be IAW CMAA specifications. 1.1.1.4) NSS/GO - 1740.9, para. 201f(9)(c) Cranes are equipped with two (2) upper limit switches to prevent two blocking of hook and load. However the final upper limit switch does not cut the power to the “down” movement of the load.	1.1.1.1, 1.1.1.2, and 1.1.1.3) The ARF 15-Ton Bridge Cranes are equipped with duel brake systems: a magnetic shoe brake on the Hoist motor and a pneumatic caliper brake on the Hoist drum. Both of these brakes are designed to hold the full rated load for the crane. Safety controls prevent personnel from working under suspended load. 1.1.1.4) Cranes are equipped with two (2) upper limit switches to prevent two blocking of hook and load. However the final upper limit switch does not cut the power to the “down” movement of the load. Safety controls prevent personnel from working under suspended load.	1.1.1.1, 1.1.1.2, 1.1.1.3 and 1.1.1.4) Daily, monthly and annual inspections are performed by USA SRB Facilities IAW USA SRB Facility maintenance Procedures; FAC-0007 – 14P, FAC-0007-13P and FAC-0007-12P. Safety controls prevent personnel from working under suspended load.	1.1.1.1, 1.1.1.2, and 1.1.1.3 Personnel Death/Injury 1. Critical 2. Improbable 3. Controlled Risk Personnel Death/Injury 1.1.1.4) 1. Critical 2. Improbable 3. Controlled Risk

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.2 Load Collides With Object	Hazard Causes: 1.2.1) Operator Error Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.2.1) NSS/GO - 1740.9, para. 205a-b Personnel Certifications Only certified and trained operators shall be authorized to use/operate cranes.	1.2.1) All Crane operators are certified and trained IAW the requirements of NSS/GO – 1740.9, para. 205a-b. WADs require only appropriately certified and trained personnel to operate the cranes.	1.1.2) SRBE S&MA Qaulity Inspection and Assurance personnel check daily operations and crane operator for proper certifications.	1.1.2) Personnel Death/Injury 1. Critical 2. Improbable 3. Controlled 1.1.2) Damage to Flight Hardware 1. Critical 2. Improbable 3. Controlled

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.2 Load Collides With Object	Hazard Causes: 1.2.2) Load Fails to Stop When Commanded Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.2.2) NSS/GO - 1740.9, para. 206a(9-11, 18,19,21) Operations – Perform operational checks, establish safety zones, test limit switches, take care load does not contact any obstructions, load controlled by tag lines, no personnel allowed under load. Q	1.2.2) All Crane operators are certified and trained IAW the requirements of NSS/GO – 1740.9, para. 205a-b. WADs require only appropriately certified and trained personnel to operate the cranes.	1.2.2) SRBE S&MA Qaulity Inspection and Assurance personnel check daily operations and crane operator for proper certifications.	1.2.2) Personnel Death/Injury 1. Critical 2. Improbable 3. Controlled 1.2.2) Damage to Flight Hardware 1. Critical 2. Improbable 3. Controlled

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.2.2) Load Fails to Stop When Commanded	Hazard Causes: 1.2.2.1) Pendant Controller Fails 1.2.2.2) E-Stop Fails Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.2.2.1) NSS/GO - 1740.9, para. 201g(4, 6, 8) Control station have positive detent pushbuttons, controls return to off position when released and red emergency button operates mainline contactor. Electrical system designed fail-safe to prevent crane run-away 1.2.2.2) NSS/GO - 1740.9, para. 201g(8) Electrical system designed fail-safe to prevent crane run-away. Independent Remote Emergency Stop requirement.	1.2.2.1) Crane pendant controller has positive detent pushbuttons and controls return to off position when released. The red emergency button operates mainline contactor and the Electrical system is designed fail-safe to prevent crane run-away. 1.2.2.2) The crane's electrical system is designed to be fail-safe to prevent a crane run-away. The crane is equipped with an independent Remote Emergency Stop control.	1.2.2.1 and 1.2.2.2) SRBE S&MA Qaulity Inspection and Assurance personnel check daily operations and crane operator for proper certifications. Daily, monthly and annual inspections are performed by USA SRB Facilities IAW USA SRB Facility maintenance Procedures; FAC-0007 – 14P, FAC-0007-13P and FAC-0007-12P.	1.2.2.1) Personnel Death/Injury 1. CriticaL 2. Improbable 3. Controlled 1.2.2.2) Damage to Flight Hardware 1. Critical 2. Improbable 3. Controlled

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.3 Bridge/Trolley Derails	Hazard Causes: 1.3.1) Rail Stops Fail 1.3.2) Operator Error Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.3.1) NSS/GO - 1740.9, para. 201e and 202c (3) Structural Design to be IAW industry standards. All limit switches and other safety devices must be operationally tested. 1.3.1) ANSI/ASME B30.17d, para 17.1.8.2(a) and 17.1.8.3(a) A power driven bridge/trolley should be provided with bumpers. If bumpers are provided, they should be mounted so that there is no direct shear on the bolts upon contact. 1.3.2) NSS/GO - 1740.9, para. 205a-b Personnel Certifications Only certified and trained operators shall be authorized to use/operate cranes.	1.3.1) The ARF 15-Ton Bridge Cranes are equipped with limit rail stops. 1.3.2) All Crane operators are certified and trained IAW the requirements of NSS/GO – 1740.9, para. 205a-b. WADs require only appropriately certified and trained personnel to operate the cranes.	1.3.1) Crane component maintenance is performed by USA SRB Facilities IAW USA SRB Facility maintenance Procedures; FAC-0007 14P, FAC-0007-13P and FAC-0007-12P. 1.3.2) SRBE S&MA Qaulity Inspection and Assurance personnel check daily operations and crane operator for proper certifications.	1.3.1 & 1.3.2) Personnel Death/Injury 1. Catastrophic 2. Improbable 3. Controlled 1.3.1 & 1.3.2) Damage to Flight Hardware 1. Critical 2. Improbable 3. Controlled

Table 13

Hazardous Condition Describe the hazard created by or during the operation.	**Hazard Cause & Effect** Describe modes of failure and effects on personnel or equipment.	**Safety Requirement** Describe measures for preventing, eliminating or mitigation of hazard.	**Hazard Controls** Identify hazard reduction methods.	**Verifications** Identify the methods used to verify hazard controls.	**1. Severity Level** **2. Likelihood of Occurrence** **3. Classification**
1.3.3 Motion Fails To Stop When Commanded	Hazard Causes: 1.3.3.1) Pendant Controller Fails 1.3.3.2) E-Stop Fails Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware. 1.2.3.2.2) E-Stop Fails Hazard Effects: 1.0) Personnel Death/Injury and/or Damage to Flight Hardware.	1.3.3.1) NSS/GO - 1740.9, para. 201g(4, 6, 8) Control station have positive detent pushbuttons, controls return to off position when released and red emergency button operates mainline contactor. Electrical system designed fail-safe to prevent crane run-away 1.3.3.2) NSS/GO - 1740.9, para. 201g(8) Electrical system designed fail-safe to prevent crane run-away. Independent Remote Emergency Stop requirement. A remote red, emergency stop pushbutton shall be provided to operate the mainline contactor and/or main circuit breaker.	1.3.3.1) The ARF 15-Ton Bridge Cranes are equipped with pendant controllers that have positive detent pushbuttons that return to the off position when the operator relieves pressure. 1.3.3.2) The ARF 15-Ton Bridge Cranes are equipped with independent Emergency Stop Controllers which are manned by a trained and certified Crane operator when ever a critical lift is performed. The E-Stop controller operates the main circuit breaker at the facility electrical supply box.	1.3.3.1) Crane component maintenance is performed by USA SRB Facilities IAW USA SRB Facility maintenance Procedures; FAC-0007 14P, FAC-0007-13P and FAC-0007-12P. 1.3.3.2) SRBE S&MA Qaulity Inspection and Assurance personnel check daily operations and crane operator for proper certifications.	1.3.3.1 and 1.3.3.2 Personnel Death/Injury 1. Catastrophic 2. Improbable 3. Controlled 1.3.3.1 and 1.3.3.2 Damage to Flight Hardware 1. Critical 2. Improbable 3. Controlled

SAFETY REQUIREMENTS: Although the Cranes are structurally sound and well constructed, they are not compliant with one requirement of the current NASA crane requirement document (NSS/GO-1740.9), specifically the Hoist's final upper limit paddle switch electrical control circuitry does not meet the requirements of NSS/GO-1740.9 and NASA-STD-8719.9 which requires the resetting of the final upper limit switch after it has been activated (tripped) before further movement of the load.		
INTERFACES: SRB Flight Hardware		
FMEA/CIL: See section 5.0 and 6.0.		
OMRSD: N/A		
OMI: N/A		
LAUNCH COMMIT CRITERIA: N/A		
FLIGHT DATA FILE: N/A		
FLIGHT RULES: N/A		
BACKGROUND: NASA crane requirement document, NSS/GO 1740.9), require a hazard analysis be performed for on all cranes for critical lifts. This System Assurance Analysis has been performed to meet that requirement.		
STATUS OF OPEN WORK: USA SRB Element and USA Facilities modify the Hoist's upper limit paddle switch circuitry to meet current NASA crane requirements (NSS/GO-1740.9 and NASA-STD-8719.9).		
PREPARING ENGINEER: John T. Czere		
J. T. Czere USA SRB Element Sr. System Safety Engineer	J. J. Smitelli USA SRB Element Manager Safety And Inspection	D. K. Whalin USA SRB Element Director S&MA

9.0 Overhead Crane Compliance Checklist

In addition to the Hazard Analysis of the cranes for compliance with NSS/GO 1740.9, an OSHA and NSTS-STD 8719.9 crane requirements compliance checklist was also completed for the ARF 15-Ton Bridge Cranes and is provided is below.

NOTE: For all practical purposes NASA NSS/GO 1740.9 and NASA-STD-8719.9 are one and the same document with only minor changes.

USA SRB ELEMENT
INDOOR OVERHEAD CRANE/HOIST COMPLIANCE CHECKLIST

CRANE ID: MF-330-W-USB and MF-330-E-USB	**LOCATION:** ARF (Bldg. L6-247), KSC	**DATE:** 04/10/03
SERIAL NO: 85M-2207-21 and 85M-2207-22	**MANUFACTURER:** Philadelphia Tramrail	**Related Report:** SAA: ARF 15-Ton Bridge Crane
DESCRIPTION: Top running Bridge Crane	**CAPACITY:** 15 - Ton	

REF. NO.	COMPLIANCE ITEM	ITEM VALIDATION		
		Yes	No	N/A
	STRUCTURE DESIGN			
1.	OSHA 1910.179(b)(2) / NASA-STD 8719.9, PARA. 4.2.6(b) – Does the overhead and/or gantry crane meet the design specifications of ASME B30.2, and CMAA standards for specific design details?	X		
2.	**Cabs** OSHA 1910.179(d)(1) – If sufficient headroom is provided on cab-operated cranes, is a foot walk provided on the drive side along the entire length of the bridge on cranes having the trolley running on top of the girders?			X
3.	OSHA 1910.179(d)(1) – Do foot walks provide at least 48 inches of headroom clearance?	X		
4.	OSHA 1910.179(b)(2) – Are foot walks of rigid construction designed to sustain 50 lbs. per square foot? Are foot walks continuous and permanently secured?	X		
5.	OSHA 1910.179(d)(2) – Do foot walks provide clear passage at least 18 inches wide (no less than 15 inches opposite the bridge motor)? Is the surface anti-slip type?	X		
6.	OSHA 1910.179(d)(3) – Do toe boards and handrails comply with Sec. 1910.23 of the OSHA Standards?	X		
7.	OSHA 1910.179(c)(2) – Does the cab have access via conveniently placed fixed ladder, stairs or platform? Are steps 12 inches or less in height? Do gantry cranes have ladders or stairways extending from the ground to the foot walk or cab platform?			X
8.	OSHA 1910.179(d)(4) – Are stairways equipped with rigid metal handrails, and walking surfaces of the anti-slip type?			X
9.	OSHA 1910.179(d)(4) – Are ladders permanently secured, fastened in place, and in compliance with Sec. 1910.27 of the OSHA Standards?			X
	MECHANICAL DESIGN			
10.	OSHA 1910.179(b)(6)/NASA-STD 8719.9, PARA. 4.2.6(b) – Is a minimum clearance of 3 inches overhead and 2 inches laterally maintained between crane and obstructions?	X		
11.	OSHA 1910.179(b)(7) – Is adequate clearance provided between parallel bridge cranes?	X		
12.	OSHA 1910.179(e)(6) – Are exposed parts which may constitute a hazard guarded?	X		
13.	NASA-STD 8719.9, PARA. 4.2.6(b) –For pneumatic cranes, is there capability to lock out the supply air pressure to prevent unauthorized use?			X
14.	**Bridge Bumpers** OSHA 1910.179(e)(2) – Is the crane provided with bumpers or automatic means of equivalent effect?	X		
15.	OSHA 1910.179(e)(2) – Can the bumpers stop the crane at an average rate of deceleration not to exceed 3ft/s/s when traveling in either direction at 20% of the rated-load speed?	X		

CRANE ID: MF-330-W-USB and MF-330-E-USB	**LOCATION:** ARF (Bldg. L6-247), KSC	**DATE:** 04/10/03
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DESCRIPTION: Top running Bridge Crane	**CAPACITY:** 15 - Ton	

16.	OSHA 1910.179(e)(2) – Can the bumpers stop the crane when traveling at a speed of at least 40% of the rated-load speed?	X		
17.	OSHA 1910.179(e)(2) – Is the bumper mounted to prevent direct shear of bolts?	X		
18.	OSHA 1910.179(e)(2) – Are bumpers installed to minimize parts falling from crane in case of breakage?	X		
19.	OSHA 1910.179(e)(4) – Are bridge trucks equipped with sweeps extending below the top of the rail and projecting in front of the truck wheels?	X		
20.	**Trolley Bumpers** OSHA 1910.179(e)(1) – Are stops provided at the limits of travel of the trolley? Are they fastened to resist forces when applied? Are stops engaging the tread of the wheel of a height at least equal to the radius of the wheel?	X		
21.	OSHA 1910.179(e)(3) – Is the trolley provided with bumpers or automatic means of equivalent effect?	X		
22.	OSHA 1910.179(e)(3) – Can the bumpers stop the trolley at an average rate of deceleration not to exceed 4.7 ft/s/s when traveling in either direction at 1/3 of the rated-load speed?	X		
23.	OSHA 1910.179(e)(3) – Where more than one trolley is operated on the same bridge, is each equipped with bumpers?			X
24.	OSHA 1910.179(e)(3) – Are bumpers installed in a manner to minimize parts falling in case of breakage?	X		
25.	**Hoisting Equipment** OSHA 1910.179(e)(5) – Where necessary, are guards installed to prevent hoisting rope drum fouling or chafing?	X		
26.	OSHA 1910.179(e)(5) – Do guards prevent contact between bridge conductors and hoisting ropes?	X		
27.	OSHA 1910.179(h)(1) – Are sheaves smooth and free from surface defects and have close fitting guards to guide ropes into groove position, and equipped with a means of lubrication?	X		
28.	OSHA 1910.179(h)(2) / NASA-STD 8719.9, PARA. 4.2.6(b) – Is the rated load divided by the number of parts of rope less than or equal to 20%of the nominal breaking strength of the rope; socketing done per manufacturer requirements; secured to the drum by a clamp or socket arrangement; and configured to have two wraps remaining on the drum when hook is in lowest position?	X		
29.	NASA-STD 8719.9, PARA. 4.2.6(b) – Is gearing designed and manufactured to comply with the latest American Gear Manufacturers Association (AGMA) gear standards?	X		
30.	NASA-STD 8719.9, PARA. 7.2. – Are safety latch-equipped hooks used?	X		
31.	NASA-STD 8719.9, PARA. 4.2.6(b) – Are cast iron components used in the hoist load path? Cast ion components must be approved by the installation NASA Safety Director before use.		X	
32.	NASA-STD 8719.9, PARA. 7.2 – When used, swiveling hooks capable of rotating 360° on antifriction bearings with means for lubrication?	X		

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33.	**Cabs** OSHA 1910.179(c)(1) – Is the cab so arranged that all operating handles are within convenient reach of the operator when facing the area served by the load hook, or while facing direction of travel of the cab?			X
34.	OSHA 1910.179(c)(1) – Does the operator have full view of the load hook in all positions?	X		
35.	OSHA 1910.179(c)(1) – Does the cab have minimum clearance of 3 inches from fixed structures at all times?			X
36.	**Hoist Brakes** NASA-STD 8719.9, PARA. 4.2.6(b) – Is each hoisting unit equipped with two means of braking, a holding bake and a control brake?	x		
37.	OSHA 1910.179(f)(1) – Is the holding brake self-setting and applied directly to the motor shaft or some part of the gear train?	x		
38.	OSHA 1910.179(f)(2) – Do holding brakes for hoist motors have 125% full-load hoisting torque when used in conjunction with a mechanical brake?	x		
39.	OSHA 1910.179(f)(2) – Are they applied automatically when power is removed?	x		
40.	OSHA 1910.179(f)(2) – Are the wearing surfaces of drums or discs smooth?	x		
41.	OSHA 1910.179(f)(2) – Is the power control braking means capable of maintaining safe lowering speeds?	x		
42.	OSHA 1910.179(f)(3) – Do control brakes have ample thermal capacity?	x		
43.	**Brakes For Trolleys And Bridges** OSHA 1910.179(f)(4) – Are brakes provided with adjustment means to compensate for wear?	x		
44.	OSHA 1910.179(f)(4) - Are the wearing surfaces of drums or discs smooth?	x		
45.	OSHA 1910.179(f)(4) – Are foot brakes operated at 70 lbs. force or less?			x
46.	OSHA 1910.179(f)(4) – Are foot brake pedals constructed so the foot will not slip off the pedal?			x
47.	OSHA 1910.179(f)(4) – Are brakes sufficient in size to stop the trolley or bridge within a distance equal to 10% of full-load speed when traveling at full speed with a full load?	x		
48.	OSHA 1910.179(f)(4) – Are holding brakes on the bridge or trolley arranged so as not to prohibit use of a drift point in control circuit?	X		
49.	OSHA 1910.179(f)(4) – Do brakes on trolleys and bridges have ample thermal capacity?	x		
50.	OSHA 1910.179(f)(4) – If the cab is on a trolley, is a trolley brake provided?			x
51.	OSHA 1910.179(f)(4) – If the cab is on a bridge, is a bridge brake provided?			x
52.	OSHA 1910.179(f)(4) – Is a brake or non coasting mechanical drive provided on floor, remote, & pulpit-operated crane bridge drives?	X		

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53.	OSHA 1910.179(f)(4) – When using worm gears as a braking means, is the lead angle sufficient to prevent back driving?			X
	ELECTRICAL DESIGN			
54.	**Electrical Equipment** NASA-STD 8719.9, PARA. 4.2.7(c) – Does wiring and equipment comply with NFPA National Electric Code?	x		
55.	OSHA 1910.179(g)(1) – Is the control circuit voltage less than 600 volts or less?	x		
56.	NASA-STD 8719.9, PARA. 4.2.7(f) – Does the control station voltage operate on 120 V a.c., 150 V d.c., or less?	x		
57.	OSHA 1910.179(g)(1) – Where multiple conductor cable is used with a suspended pushbutton station, is the station supported to protect electrical conductors against strain?	x		
58.	OSHA 1910.179(g)(1) – Are pendant control boxes constructed to prevent electrical shock and clearly marked as to functions?	x		
59.	OSHA 1910.179(g)(2) / NSTS-STD 8719.9, PARA. 4.2.7(d) – Is electrical equipment protected from accidental contact?	x		
60.	OSHA 1910.179(g)(2) / NSTS-STD 8719.9, PARA. 4.2.7(d) – Is electrical equipment protected from dirt, grease, oil, and moisture?	x		
61.	OSHA 1910.179(g)(2) / NSTS-STD 8719.9, PARA. 4.2.7(d) – Are guards for live parts substantially constructed?	x		
62.	OSHA 1910.179(g)(6) – Are open type conductors mounted on the runway beams or overhead guarded?	x		
63.	OSHA 1910.179(g)(7) – Are extension lamp service receptacles in cabs or in bridges of the three prong grounded permanent type, not exceeding 300 volts?	x		
64.	OSHA 1910.179(g)(4) / NSTS-STD 8719.9, PARA. 4.2.7(d) – Are enclosures for resistors installed to prevent accumulation of combustible ,materials near hot parts and adequately ventilated? Are resistor units as free as possible from vibration? Are broken parts prevented from falling from crane?	x		
65.	OSHA 1910.179(g)(5) / NSTS-STD 8719.9, PARA. 4.2.7(m) – Does the crane have the capability to be locked out at the main breaker to prevent unauthorized use?	x		
66.	**Controllers** NSTS-STD 8719.9, PARA. 4.2.7(f) – Do controls return to OFF position when operator relieves pressure?	x		
67.	OSHA 1910.179(g)(3) – Is there a notch or latch at the OFF position of levers?			x
68.	OSHA 1910.179(g)(3) – Is the controller operating handle within easy reach?			x
69.	OSHA 1910.179(g)(3) – Does the controller handle move in the same direction as the load?			x
70.	OSHA 1910.179(g)(3) – Are the travel (direction) controls for the bridge and trolley located so that the operator can readily face all directions of crane movement?	x		

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71.	NSTS-STD 8719.9, PARA. 4.2.7(n) - Do all motions of cranes fail-safe upon power outage?	x		
72.	NSTS-STD 8719.9, PARA. 4.2.7(h) – Is crane designed to fail-safe upon any component failure to operate in a speed range faster than commanded?	x		
73.	OSHA 1910.179(i) – Except for floor operated cranes, is a gong or other warning signal provided for cranes equipped with power traveling mechanism (driven by electric, air, hydraulic, or internal combustion means)?	x		
74.	NSTS-STD 8719.9, PARA. 4.2.7(g) – Are cab-oriented cranes with step type control equipped with lever controls. Are levers of the continuous effect type and provided with a deadpan feature?			x
75.	OSHA 1910.179(c)(4) – Is there sufficient light in the cab for the operator to see clearly?			x
76.	NSTS-STD 8719.9, PARA. 4.2.7(f) – Is a red emergency stop button provided to operate the mainline contactor/circuit breaker from the control station?	x		
	LABELING/TAGGING OF CRANES			
77.	NSTS-STD 8719.9, PARA. 4.2.2(a) – Is the rated load plainly marked on each side of the crane?	x		
78..	NSTS-STD 8719.9, PARA. 4.2.2(a) – If the crane has more than one hoisting unit, does each hoist have the rated load marked on it and is the marking clearly legible from the ground or floor?			x
	TESTING			
79.	NSTS-STD 8719.9, PARA. 4.3.1 – prior to initial use are all new, altered and extensively repaired cranes proof load tested to 125% of the rated capacity of the crane?	x		
80.	NSTS-STD 8719.9, PARA. 4.3.1 – Are rated load tests performed on the crane at least every 4 years with a load equal to the crane rated capacity?	x		
81.	NSTS-STD 8719.9, PARA. 4.3.3 – Are operational tests performed on the crane together with proof load and rated load tests?	x		
82.	NSTS-STD 8719.9, PARA. 4.3.3(a) – During the operational tests, are load hoisting, lowering and trolley and bridge travel at various speeds, and braking/holding mechanisms testes to verify stopping capabilities and demonstrate the ability to hold a rated load?	x		
83.	NSTS-STD 8719.9, PARA. 4.3.1 – During the operational tests, are all limit switches, locking devices, emergency stop switches, and other safety devices (excluding thermal overload and circuit breakers) tested with no load on the hook at full speed?	X		
84.	NSTS-STD 8719.9, PARA. 4.3.1- Are all upgraded cranes (increased lifting capability) proof load and operationally tested based on the upgrade rating? Is the new load rating displayed?	x		
85.	NSTS-STD 8719.9, PARA. 4.3.1 – Is the new crane inspected prior to being released for service after each proof load and rated load tests?	x		

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86.	NSTS-STD 8719.9, PARA. 4.4.1 – Have written, dated and signed test reports, including procedure reference, been prepared? Are inadequacies documented and, if determined to be a hazard, corrected prior to further use? Are reports kept on file by the owner organization for a minimum of two test cycles and readily available?	x		
87.	NSTS-STD 8719.9, PARA. 7.4.5 – Are hooks given a Non-Destructive Evaluation (NDE) immediately after all rated load and proof load tests?	x		
89.	NSTS-STD 8719.9, PARA. 4.3.4 – Following the rated load test, are cranes given a permanently affixed tag identifying the equipment and stating the next required rated load test date or certification expiration date?	x		
.	**INSPECTIONS**			
90.	NSTS-STD 8719.9, PARA. 4.4.4 – Does the crane operator perform daily inspections on the crane and all crane accessories according to technical operating procedures approved by SRBE Operational & System Safety prior to first use each day the crane is used?	X		
91.	NSTS-STD 8719.9, PARA. 4.4.4 – Does the daily inspection include the following: • Check of functional operating and control mechanisms for maladjustments that could interfere with normal operation? • Visual inspection (without disassembly) of lines, tanks, valves, drain pumps, gear casings, and other components of fluid systems for deterioration and leaks? • Without disassembly, visual inspection of all functional operating and control mechanisms for excessive wear and contamination by excessive lubricants or foreign matter? • Visual inspection of hooks for cracks and deformities, latch damage and improper attachment? • Visual inspection of rope reeving, deformation, kinks, wire clips, or damage to wire rope? • Visual inspection of hoist chains for excessive wear or distortion?	X		
92.	NSTS-STD 8719.9, PARA. 4.4.5(a) – Are monthly inspections performed on the crane and all crane accessories according to SRBE Operational & System Safety approved technical operating procedures?	X		
93.	NSTS-STD 8719.9, PARA. 4.4.5(a)/4.5.3(c) – Does the monthly inspection include the following: • Inspection of hoist chains for wear, twist, distortion, or stretch? • Inspection of hooks for wear, deformation, cracks, latch damage, and improper attachment? • Inspection of ropes to include following signs of deterioration and damage: o Twelve randomly distributed broken wires in one rope lay or four broken wires in one strand in one lay? o Individual outside wires with wear of 1/3 the original diameter? o Kinking, crushing, bird caging, or any other damage resulting in distortion? o Evidence of heat damage? o End connectors that are cracked, deformed, or with evidence of rope pullout? o Corrosion (internal or external) that results in the reduction of rope diameter, or at end connectors? o Reductions of nominal diameter?	X		

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94.	NSTS-STD 8719.9, PARA. 4.5.3(d) – Are new/replaced ropes proof load tested using the associated crane proof load value?	**X**		
95.	NSTS-STD 8719.9, PARA. 4.4.5(b) – Are annual inspections performed on the crane and all crane accessories according to SRBE Operational & System Safety approved technical operating procedures?	**x**		
96.	NSTS-STD 8719.9, PARA. 4.4.5(a) – Does annual inspection include the following: • Deformed, cracked, or corroded members and welds in crane structure? • Loose bolts or rivets in crane structure. • Cracked or worn sheaves and drums. • Wear or cracks in pins, bearings, shafts, gears, followers, and locking and clamping devices. • Wear in brakes and clutch system parts, linings, pawls, and ratchet readily accessible without major disassembly beyond an acceptable limit (major teardown should be based on gearbox lubrication analysis and other manufacturer recommended maintenance programs). • Inadequacies in load and other indicators over full range. • Wear in chain drive sprockets and stretch in the chain beyond an acceptable limit. • Gasoline, diesel, electric, or other power plants for proper performance or noncompliance with applicable safety requirements. • Evidence of a malfunction in travel, steering, braking, and locking devices. • Evidence of a malfunction in any safety device. • Pitting or other signs of deterioration in electrical apparatus. Special attention given to feed rails. • Evidence of overheating. •	**x**		
97.	NSTS-STD 8719.9, PARA. 4.4.7 – Do monthly and annual inspections have a written, dated and signed report by qualified and authorized personnel to include procedural reference and adequacy of crane/crane components?	**x**		
98.	NSTS-STD 8719.9, PARA. 4.4.7 – Are these monthly and annual inspection reports filed and made readily available by the organizational element responsible for the inspection?	**x**		
99.	NSTS-STD 8719.9, PARA. 4.4.7 – Are inadequacies discovered during any inspection documented and corrected prior to further use?	**x**		
100.	NSTS-STD 8719.9, PARA. 4.4.7 – Are cranes idle for more than one month inspected prior to first use according to daily, monthly, and annual inspections if inspections were not performed and recorded at the required intervals during the standby period?			**x**
	MAINTENANCE			
101.	OSHA1910.179(l)(1) / NSTS 8719.9, PARA. 4.5 – Is there a preventative maintenance program based on the manufacturer's recommendations or experience gained from the use of the equipment/	**x**		
102.	NSTS 8719.9, PARA. 4.5 – Does the preventative maintenance program include procedures and a scheduling system for normal periodic maintenance items, adjustments, and repairs?	**x**		
103.	NSTS 8719.9, PARA. 4.5 – Are safe and adequate access to crane components provided for inspections service and repair?	**x**		

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104.	**Maintenance or Crane Repair** OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.1 – Is the crane run to a location where it won't interfere with other cranes and operations in the area?	X		
105.	OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.1 – Are all controllers in the OFF position?	X		
106.	OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.1 – Is the main or emergency switch open and locked/tagged out?	X		
107.	OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.1 – Are appropriate OUT-OF-SERVICE signs placed on and near the crane?	X		
108.	OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.1 – If other cranes are operating on the same runway, are proximity limit switches, operating procedures, or a signalman posted to prevent interference?	X		
109.	OSHA1910.179(l)(3) – Are all adjustments/repairs performed by designated personnel?	X		
110.	OSHA1910.179(l)(2) / NSTS 8719.9, PARA. 4.5.2 – Are adjustments maintained to assure correct functioning of components (brakes, control systems, limit switches, power plants, safety devices)?	X		
111.	OSHA1910.179(l)(3)/503a – Are crane hooks showing defects discarded/repaired?	X		
112.	NSTS 8719.9, PARA. 4.5.3(b) – Are structural members which are broken, bent, or excessively worn discarded/repaired?	X		
113.	OSHA1910.179(l)(3) – Are pendant control stations kept clean and function labels legible?	X		
114.	OSHA1910.179(l)(2) – After repairs or adjustments are completed, are guards reinstalled, safety devices reactivated and maintenance equipment removed?	X		
115.	NSTS 8719.9, PARA. 4.4.7 – Are maintenance repair operations recorded via maintenance reports?	X		