

FMEA NO. <u>6.1.0.2</u> CRITICALITY <u>2/2</u>	SHUTTLE CCTV CRITICAL ITEMS LIST	UNIT <u>FVC/HLA</u> DWG NO. <u>2294819-506, 508</u> <u>2294820-502</u> SHEET <u>1</u> OF <u>11</u>
FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). MIA Motor Failure Gear Train Failure Lens Failure	Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	DESIGN FEATURES The TVC/Lens Assembly is comprised of 16 electrical subassemblies; 13 subassemblies are RCA Astro designed and fabricated using standard printed-circuit board type of construction. The remaining three assemblies, high voltage power supply, oscillator, and stepper motors, are vendor supplied components which have been specified and purchased according to RCA Specification Control Drawings (SCDs) prepared by engineering and reliability assurance. Specifications per the SCD are prepared to establish the design, performance, test, qualification, and acceptance requirements for a procured piece of equipment. Parts, materials, processes, and design guidelines for the Shuttle CCTV program are specified in accordance with RCA 2295503. This document defines the program requirements for selection and control of EEE parts. To the maximum extent, and consistent with availability, all parts have been selected from military specifications at the JAN level, as a minimum. In addition to the overall selection criteria, a subset of general purpose preferred parts has been defined by this document and the RCA Government Systems Division Standard Parts List. In the case of the CMOS and TTL family of microcircuits, devices are screened and tested to the MIL-STD-883C equivalent and procured under the designations of MI-REL/3M and SMC 54LS from RCA-SSD and Texas Instruments Corp, respectively. Parts not included in the above documents have been used in the design only after a nonstandard item approval form (NSIAF) has been prepared, submitted to Reliability Assurance Engineering (RAE) and approved for use in the specific application(s) defined in the NSIAF by NASA-JSC. Worst-Case Circuit Analyses have been performed and documented for all circuit designs to demonstrate that sufficient operating margins exist for all operating conditions. The analysis was worst case-in that the value for each of the variable parameters was set to limits that will drive the output to a maximum (or minimum). A component application review and analysis was conducted to verify that the applied stress on each piece part by the temperature extremes identified with environmental qualification testing does not exceed the stress derating values identified in RCA 2295503. In addition, an objective examination of the design was performed through a PDR and COR to verify that the TVC/Lens assembly met specification and contractual requirements.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
<p>Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical).</p> <p><u>MLA</u> Motor Failure Gear Train Failure Lens Failure</p>	<p>Inability to control focus, zoom, or iris.</p> <p><u>Worst Case:</u> Loss of mission critical camera video.</p>	<p><u>DESIGN FEATURES</u></p> <p>The general arrangement of the lens assembly is to provide an integrated housing, motor, and circuit board package which can accommodate various commercially available lenses. Emphasis is placed on accessibility of the lens, its drive components, and limit stops. Components within the lens assembly have been modularized, serving both the MLA, CLA, and WLA assemblies.</p> <p>The lens housing structure is a one-piece casting designed to minimize machining and provide a rugged dimensionally stable mounting for the optical components. The housing is in the form of a right angle. The vertical member interfaces with the front surface of the camera and the horizontal member supports the drive motors on the upper surface with the lens function circuit boards in a cavity on the underside.</p> <p style="text-align: center;"><u>Lens Function Drive Train</u></p> <p>The iris, zoom, and focus drives are identical in concept; the only difference is the lower gear ratio in the iris train to provide the 2.8-second end-to-end travel capability necessary for the ALC operation.</p> <p>The table (on next page) shows the drive train parameters with overall torque margins for the three lens functions.</p> <p>The motor/gear heads are mounted on the lens housing rather than on the lens, to permit the desired lens interchangeability for the Shuttle mission with minimum impact on the actual lenses.</p> <p>Various types of motors were considered for this application, trading off size, power, weight, control-circuit complexity, command capability, and qualification status. The brushless and stepper-motor types fit the package and power requirements, the latter being preferred because of its simplicity, reliability, and space-qualified status. The selected stepper motor (a size-B, Alnico-9 pole-piece, permanent-magnet stepper) is mated with a spur train gearhead. Both units are manufactured by Monaco Motor Co. A 40-diametral-pitch (40-DP) spur gear on the gearhead output shaft meshes directly with the gears which are a part of the zoom, focus, and iris ring functions on the lens gear.</p>

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FAILURE MODE AND CAUSE

FAILURE EFFECT ON END ITEM

RATIONALE FOR ACCEPTANCE

Loss of iris function (mechanical).
 Loss of zoom function (mechanical).
 Loss of focus function (mechanical).

Inability to control focus, zoom, or iris.

DESIGN FEATURES

HLA
 Motor Failure
 Gear Train Failure
 Lens Failure

Worst Case:
 Loss of mission critical camera video.

LENS DRIVE TRAIN PARAMETERS

Drive	Component	Travel (degrees)	Time End-to-End (seconds)	Input Torque (oz-in)	Ratio No. or Teeth	Efficiency (%)	Loss Torque (oz-in)	Net Torque (oz-in)
Zoom	Motor	150	6.6	-	-	-	-	0.27
	Gearhead			0.27	78:1	80	3.7	18.4
	Gearhead Output Gear			18.4	50	96	2.2	52.0
	Lens Gear			156	10.0		Torque Margin 5.2:1	
Focus	Motor	202	7.5	-	-	-	-	0.27
	Gearhead			0.27	48:1	80	2.6	10.3
	Gearhead Output Gear			10.3	50	96	1.3	30.0
	Lens Gear			156	10.0		Torque Margin 3:1	
Iris	Motor	105	2.8	-	-	-	-	0.27
	Gearhead			0.27	48:1	80	2.6	10.3
	Gearhead Output Gear			10.3	50	96	1.3	30.0
	Lens Gear			156	5.0		Torque Margin 6:1	

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE	
Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). MLA Motor Failure Gear Train Failure Lens Failure	Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	<p><u>Narrow Angle Zoom Lens Assembly</u></p> <p>The lens utilized in the MLA and CIA is a 18 mm to 108 mm Canon varifocal (200m) lens with a minimum f-stop of 1.6 to T-120 and a fully closed position. By design the lens selected after much evaluation was a high quality commercially available unit procured to a Shuttle CCTV specification.</p> <p>The vendor item is specified to include only materials and lubricants which meet the RCA and STS approved lists; and final cleaning, assembly, and lubrication is completed in the USA plant under RCA field quality controls.</p> <p>The lens has been exposed to developmental testing and qualification testing as required for the STS cable and cargo bay environments.</p> <p>This assembly has been used on all STS developmental and operational missions.</p> <p><u>QUALIFICATION TEST</u></p> <p>For Qualification test flow, see Table 2 located at the front of this book.</p>	

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE																
Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). MLA Motor Failure Gear Train Failure Lens Failure	Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	<p>ACCEPTANCE TEST</p> <p>The CCTV systems' TVC/MLA is subjected directly, without vibration isolators which might be used in their normal installation, to the following testing:</p> <ul style="list-style-type: none"> • Vibration: <table border="0" style="margin-left: 20px;"> <tr> <td>20-80Hz:</td> <td>3 dB/Oct-rise from 0.01 G²/Hz</td> </tr> <tr> <td>80-350 Hz:</td> <td>0.04 G²/Hz</td> </tr> <tr> <td>350-750 Hz:</td> <td>-3 dB/10 Oct-slope</td> </tr> <tr> <td>Test Duration:</td> <td>1 Minute per Axis</td> </tr> <tr> <td>Test Level:</td> <td>6.1 Grms</td> </tr> </table> • Thermal Vacuum: In a pressure of 1K10⁻⁵ Torr, the temperature shall be as follows: <table border="0" style="margin-left: 20px;"> <tr> <td>125° F:</td> <td>Time to stabilize equipment plus 1 hour</td> </tr> <tr> <td>25° F:</td> <td>Time to stabilize equipment plus 1 hour</td> </tr> <tr> <td>125° F:</td> <td>Time to stabilize equipment plus 1 hour</td> </tr> </table> <p>The TVC/MLA may not have been subjected to the vacuum condition.</p> <p>For Acceptance Test Flow, see Table I located at the front of this book.</p> <p>In order to verify that CCTV components are operational, a test must verify the health of all the command related components from the PMS (A7A1) panel switch, through the RCU, through the sync lines to the Camera/PTU, to the Camera/PTU command decoder. The test must also verify the camera's ability to produce video, the VSU's ability to route video, and the monitor's ability to display video. A similar test would be performed to verify the MDN command path.</p> <p>Pre-launch on Orbiter Test/In-flight Test</p> <ol style="list-style-type: none"> 1. Power CCTV System. 2. Via the PMS panel, select a monitor as destination and the camera under test as source. 3. Send "Camera Power On" command from PMS panel. 4. Select "External Sync" on monitor. 5. Observe video displayed on monitor. Note that if video on monitor is synchronized (i.e., stable raster) then this indicates that the camera is receiving composite sync from the RCU and that the camera is producing synchronized video. 6. Send Pan, Tilt, Focus, Zoom, DLR, AND Gamma commands and visually (either via the monitor or direct observation) verify operation. 7. Select downlink as destination and camera under test as source. 8. Observe video routed to downlink. 9. Send "Camera Power Off" command via PMS panel. 10. Repeat Steps 3 through 9 except issue commands via the MDN command path. This proves that the CCTV equipment is operational. 	20-80Hz:	3 dB/Oct-rise from 0.01 G ² /Hz	80-350 Hz:	0.04 G ² /Hz	350-750 Hz:	-3 dB/10 Oct-slope	Test Duration:	1 Minute per Axis	Test Level:	6.1 Grms	125° F:	Time to stabilize equipment plus 1 hour	25° F:	Time to stabilize equipment plus 1 hour	125° F:	Time to stabilize equipment plus 1 hour
20-80Hz:	3 dB/Oct-rise from 0.01 G ² /Hz																	
80-350 Hz:	0.04 G ² /Hz																	
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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
<p>Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical).</p> <p>MLA Motor Failure Gear Train Failure Lens Failure</p>	<p>Inability to control focus, zoom, or iris.</p> <p><u>Worst Case:</u> Loss of mission critical camera video.</p>	<p><u>QA/INSPECTION</u></p> <p><u>Procurement Control</u> - The TVC/MLA EEE Parts and hardware items are procured from approved vendors and suppliers who meet the requirements set forth in the CCTV contract and Quality Plan Work Statement (WS-2593176). Resident DCAS personnel review all procurement documents to establish the need for GSI on selected parts (PAI 517).</p> <p><u>Incoming Inspection and Storage</u> - Incoming Quality inspections are made on all received materials and parts. Results are recorded by lot and retained in file by drawing and control numbers for future reference and traceability. All EEE parts are subjected to incoming acceptance tests as called for in PAI 315 - Incoming Inspection Test Instructions. Incoming flight parts are further processed in accordance with RCA 1B466B4 - Preconditioning and Acceptance Requirements for Electronic Parts, with the exception that DPA and PIND testing is not performed. Mechanical items are inspected per PAI 316 - Incoming Inspection Instructions for mechanical items, PAI 305 - Incoming Quality Control Inspection Instruction, and PAI 612 - Procedure for Processing Incoming or Purchased Parts Designated for flight Use. Accepted items are delivered to Material Controlled Stores and retained under specified conditions until fabrication is required. Non-conforming materials are held for Material Review Board (MRB) disposition. (PAI-307, PAI IQC-531.)</p> <p><u>Board Assembly & Test</u> - Prior to the start of MLA board assembly, all items are verified to be correct by stock room personnel, as the items are accumulated to form a kit. The items are verified again by the operator who assembles the kit by checking against the as-built-parts-list (ABPL). DCAS Mandatory Inspection Points are designated for all printed circuit, wire wrap and welded wire boards, plus harness connectors for soldering wiring, crimping, solder splices and quality workmanship prior to coating of the component side of boards and sleeving of harnesses.</p> <p><u>MLA Boards</u></p> <p>Specific instructions are given in assembly drawing notes and applicable documents called out in the fabrication procedure and record (FPR-2307088) and Parts List PL 2307088. These include wire connection list 2295902, Notes - wide angle zoom lens assy 2303191, Process Standard - bonding staking, potting, encapsulating 2280878, Specification - Urethane protective coating 2280877 and Workmanship Spec 8030035.</p>

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FAILURE MODE AND CAUSE Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical) NLA Motor Failure Gear Train Failure Lens Failure	FAILURE EFFECT ON END ITEM Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	RATIONALE FOR ACCEPTANCE QA/INSPECTION (Continued) NLA Assembly and Test - An open box test is performed per TP-IT-2307088, Acceptance Test per TP-AI-2307088. Torques are specified and witnessed, traceability numbers are recorded and calibrated tools are checked prior to use. RCA Quality and DCAS inspections are performed at the completion of specified FPR operations in accordance with PAI 204, PAI-205, PAI-217 and PAI-402. DCAS personnel witness NLA button-up and critical torquing. TVC/NLA - After a TVC/NLA have been tested individually, they are mated and a final acceptance test is performed per TP-AI-2294819, including vibration and thermal vacuum environments. RCA and DCAS personnel monitor these tests and review the acceptance test data/results. These personnel also inspect after all repair, rework and retest. Preparation for Shipment - The TVC and NLA are separated prior to shipment after fabrication and testing is complete. Each is packaged according to CCTV Letter 8011 and 2280746, Process standard for Packaging and Handling guidelines. All related documentation including assembly drawings, Parts List, ABPL, Test Data, etc., is gathered and held in a documentation folder assigned specifically to each assembly. This folder is retained for reference. An EIDP is prepared for each assembly in accordance with the requirements of NS-2593176. RCA QC and DCAS personnel witness crating, packaging, packing, and marking, and review the EIDP for completeness and accuracy.	

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FAILURE MODE AND CAUSE Loss of Iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). M/A Motor Failure Gear Train Failure Lens Failure	FAILURE EFFECT ON END ITEM Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	RATIONALE FOR ACCEPTANCE FAILURE HISTORY TDR Y-6955, Log #0642, MLA S/N 025-502. Description: Acceptance Test Failure, Box Level Thermal Vac-Hot Environment. Erratic focus near operation. Cause: Excessive 32-oz force Applied by constant force spring of Lens Motor Drives. Corrective Action: Unit reworked to ECNS CCT 082 and 092 to reduce spring force to 25 oz. TDR Y-9280, LOG #0776, MLA S/N F001-502 Flight Failure, Spacecraft Level (STS-8 Flight). Description: Lens assembly stalled approximately half way in the near focus operation. Cause: Combination of sticky lens and original negator spring configuration. Sticky substance on lens assembly extending from the outermost front edge to approximately 1 in. toward center. Corrective Action: Upgraded lens to latest negator spring configuration. Replaced focus motor. Old lens (SN 783167) returned to vendor for examination. New lens (SN 783183) installed. TDRs A-3093/A-0000, Log #1107/1100, MLA S/N 036-502. Description: Acceptance Test Failure, Box Level Vibration Environment. Focus runs in only one direction. Cause: Lack of lubrication on focus mechanism. Corrective Action: Lens assembly returned to vendor, focus mechanism was found not lubricated. Vendor could not offer any viable reason for lack of lubrication. Lens was lubricated and reassembled to vendor control drawing. TDR B-5380, Log #1057, MLA S/N D29-502. Description: Acceptance Test Failure, Box Level Ambient Environment. Zoom inoperative. Cause: Lack of lubrication on zoom mechanism. Corrective Action: Lens assembly returned to vendor, zoom mechanism was found not lubricated. Lens was lubricated and reassembled to vendor control drawing.	

FMEA NO. <u>E.1.B.2</u> CRITICALITY <u>2/2</u>		SINGLE COPY CRITICAL ITEMS LIST	UNIT <u>IYC/MLA</u> DWG NO. <u>2294B19-506.50B</u> <u>2294B20-502</u> SHEET <u>9</u> OF <u>11</u>
FAILURE MODE AND CAUSE Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). MLA Motor Failure Gear Train Failure Lens Failure	FAILURE EFFECT ON END ITEM Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	RATIONALE FOR ACCEPTANCE FAILURE HISTORY TOR Y-6166, Log #0623, MLA S/N 023-502. Description: Acceptance Test Failure, Box Level Temperature-Cold Environment. Focus operation not smooth. Cause: Motor/Gear Head not properly assembled. Corrective Action: Vendor notified and agreed to the following corrective action. Re-write assembly procedures to require accurate measurements to ensure proper match between motor and gear head. TOR W-0904, Log #0377, MLA S/N 003-501. Description: Acceptance Test Failure, Box Level Ambient Environment. Focus motor drive erratic. Motor drive stalls for part of the lens rotation. Cause: Motor and lens assembly DVI parts (nonflight). Corrective Action: Motor and lens assembly upgraded to flight configuration by substitution of flight parts. TORs C-4524/C-4470, Log #2041/2040, MLA S/N 025-502. Description: Acceptance Test Failure, Part Level Ambient Environment. Lens iris does not fully close. Cause: Iris finger defective. Corrective Action: Lens assembly replaced with new lens assembly. Inoperative lens was returned to vendor. Examination found finger which actuates iris was defective due to wear. TOR W-9964, Log #0564, MLA S/N F002-502. Description: Acceptance Test Failure Box Level Ambient Environment. Unable to focus lens at infinity. Cause: Improper reassembly and focusing of lens by vendor after disassembly for cleaning. Corrective Action: Lens returned to vendor for refocusing. Vendor assembly procedures upgraded to prevent similar problem.	

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
<p>Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical).</p> <p>MLA Motor Failure Gear Train Failure Lens Failure</p>	<p>Inability to control focus, zoom, or iris.</p> <p><u>Worst Case:</u> Loss of mission critical camera video.</p>	<p><u>FAILURE HISTORY</u></p> <p>TDR W-2624, Log #0450, MLA S/N D03-501.</p> <p><u>Description:</u> Acceptance Test Failure, Box Level Ambient Environment. Zoom function hesitates and hangs up.</p> <p><u>Cause:</u> Motor shaft slippage due to insufficient staking.</p> <p><u>Corrective Action:</u> Manufacturer will revise staking procedure and will perform 30 in-oz reverse torque test on all reworked and future units.</p> <p>TOR W-1000, Log #0436, MLA S/N D04-501. TDR W-0992, Log #0433, TVC S/N D05-502.</p> <p><u>Description:</u> Acceptance Test Failure, Box Level Thermal Vac Ambient Environment. Unit resolution out of spec during thermal-vacuum testing.</p> <p><u>Cause:</u> Front lens element was not properly staked.</p> <p><u>Corrective Action:</u> Lens returned to vendor. Vendor properly staked front, rear and zoom elements. All other flight lens were returned to vendor and restaked. Vendor procedure modified to prevent recurrence of problem.</p>

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FAILURE MODE AND CAUSE Loss of iris function (mechanical). Loss of zoom function (mechanical). Loss of focus function (mechanical). MLA Motor Failure Gear Train Failure Lens Failure	FAILURE EFFECT ON END ITEM Inability to control focus, zoom, or iris. Worst Case: Loss of mission critical camera video.	RATIONALE FOR ACCEPTANCE	
		<u>OPERATIONAL EFFECTS</u> Loss of video. Possible loss of major mission objectives due to loss of RMS cameras or other required cameras.	
		<u>CREW ACTIONS</u> If possible, continue RMS operations using alternative visual cues.	
		<u>CREW TRAINING</u> Crew should be trained to use possible alternatives to CCTV.	
		<u>MISSION CONSTRAINT</u> Where possible, procedures should be designed so they can be accomplished without CCTV.	