REVISED 5-7-87

FMEA NO. 5.3.7.1

CRITICALITY 2/2

SHUTTLE CCTV
CRITICAL ITEMS LIST

UNIT TVC/CLA
DMG NO. 2294819-506, 508/
2294821-503
SHEET 1 OF 11

FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. TVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2294885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A1 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. 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 HI-REL/3HQ 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 CDR 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
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. IVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	DESIGN FEATURES (Continued) BARE BOARD DESIGN (A3, A6, A7) The design of the associated A3, A6, A7 boards is constructed from laminated copper-clad epoxy glass sheets (NEMA G-10) Grade FR-4), PER MIL-P-55617A. Circuit connections are made through printed traces which run from point to point on the board surfaces. Every trace terminates at an annular ring. The annular ring surrounds the hole in which a component lead or terminal is located. This ring provides a footing for the solder, ensuring good mechanical and electrical performance. Its size and shape are governed by MIL-P-55640 as are trace widths, spacing and routing. These requirements are reiterated specifically in drawing notes to further assure compliance. Variations between the artwork master and the final product (due to irregularities of the etching process) are also controlled by drawing notes. This prevents making defective boards from good artwork. Holes which house no lead or terminal, but serve only to electrically interconnect the different board layers, contain stitch bars for mechanical support and increased reliability. The thru holes are drilled from a drill tape thus eliminating the possibility of human error and allowing tight control over hole and annular ring concentricity, an important reliability criterion. After drilling and etching, All copper cladding is tin-lead plated per MIL-STD-1495. This provides for easy and reliable soldering at the time of board assembly, even after periods of prolonged storage. BOARD ASSEMBLY DESIGN (A3, A6, A7) All components are installed in a manner which assures maximum reliability. Component leads are pre-tinned, allowing total wetting of solder joints. All leads are formed to provide stress relief and the bodies of large components are staked. Special mounting and handling instructions are included in each drawing required after final assembly. The board is coated with urethane which protects against humidity and contamination. BOARD PLACEMENT The A3, A6 boards are secured in the electronics assembly by gold-plated beryllium copper card guides. Connections are made to the mother board with blind-mated connectors. Disengagement during launch is prevented by a cover which spans the board's free edge.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. TVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stepping within lens FOV. Worst Case: Loss of mission critical camera video.	DESIGN FEATURES (Continued) The A7-A low voltage power supply board is bolted in place at 6 points around its perimeter. Four of these mounting screws also pass through and tie down the smaller A7-B board. These two boards are mounted face-to-face, separated by the standoffs. Electrical interconnections are achieved by jumper wires between the two boards. The A7-A houses a 34-pin connector which brings in power and signals from outside the module. The A7 module includes these two boards as well as power transistor Q4. The module housing is heat aluminum sheet, comprised of two halves screwed together. The boards and Q4 are secured to the lower half, and wired together. Then the upper half is put in place. By mounting Q4 directly to the aluminum housing, good thermal performance is assured. The A13 assembly is a temperature compensated voltage controlled crystal oscillator (TCVCXO) that is purchased to a specification controlled drawing that establishes the requirements for performance, design, test, and qualification of the unit. The product assurance provisions of the document contain the identical requirements for electronic parts and materials as the Shuttle CCTV program and must receive the approval of RCA and NASA-JSC. Mechanical and electrical integrity of the assembly is confirmed by both analysis (design reviews) and test (qualification and acceptance).

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. IVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	DESIGN FEATURES (Continued) 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 HLA assemblies. 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. Lens Function Drive Train 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 2.0-second end-to-end travel capability necessary for the ALC operation. The table (on next page) shows the drive train parameters with overall torque margins for the three lens functions. 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. 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-8, Alnico-9 pole-piece, permanent-magnet stepper) is mated with a spur train gearhead. Both units are manufactured by Monaco Motor Co. A 48-diametral-pitch (48-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.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. IVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Horst Case: Loss of mission critical camera video.

RATIONALE FOR ACCEPTANCE

DESIGN FEATURES (Continued)

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	10.4
	Gearhead Output Gear			10.4	50	96	2.2	52.0
	Lens Gear				156		10.0	
							Torque Margin 5.2:1	
Focus	Motor	282	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
ss of color synchronization. lter wheel synchronous motor has opped rotating. C Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503] Master Oscillator 2295527-1 A Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	QUALIFICATION TEST For Qualification Test Flow, see Table 2 located at the front of this book.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. TVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	ACCEPTANCE TEST The CCTV systems' TVC/CLA is subjected directly, without vibration isolators which might be used in their normal installation, to the following testing: • Vibration: 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 • Thermal Vacuum: In a pressure of $1X10^{-5}$ Torr, the temperature shall be as follows: 125° F: Time to stablize equipment plus 1 hour 25° F: Time to stablize equipment plus 1 hour 125° F: Time to stablize equipment plus 1 hour The TVC/CLA may not have been subjected to the vacuum condition. For Acceptance Test Flow, see Table I located at the front of this book. OPERATIONAL TEST In order to verify that CCTV components are operational, a test must verify the health of all the command related components from the PHS (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 HDM command path. Pre-Launch on Orbiter Test/In-Flight Test 1. Power CCTV System. 2. Via the PHS panel, select a monitor as destination and the camera under test as source. 3. Send "Camera Power On" command from PHS 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, ALC, 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 PHS panel. 10. Repeat Steps 3 through 9 except issue commands via the HDM command path.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
ass of color synchronization. ilter wheel synchronous motor has topped rotating. VC 6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 13 Master Oscillator 2295527-1 LA 3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	QA/INSPECTION Procurement Control - The TVC/CLA EEE Parts and Hardware items are procured from approved vendors and suppliers, which 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). Incoming Inspection and Storage - 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 1846684 - 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). Board Assembly & Test - Prior to the start of TVC or CLA 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. TVC Boards Specific TVC board assembly and test instructions are provided in drawing notes, and applicable documents are called out in the Fabrication Procedure and Record (FPR-2294819) and parts list PL2294819. These include shuttle TVC assembly notes 2593660, Process Standard RTV-566 2280881, Process Standard - Bonding Velcro Tape 2280889, Specification Soldering 2280749, Specification Name Plate Application 1960167, Specification - Crimping 2280880, Specification - Bonding and Staking 2280878, Specification - Urethane coating 2280877, Specification - locking compound 2026116, Specification Epoxy Adhesive 2010985, Specification - Marking 2280876, Specification - Workmanship 8030035, Specification - Bonding and Staking 2280875.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. TVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	QA/INSPECTION (Continued) CLA Boards 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 2295903, Notes - wide angle zoom lens assy 2303191, Process Standard - bonding staking, potting, encapsulating 2280878, Specification - Urethane protective coating 2280877 and Workmanship Spec 6030035. TVC Assembly and Test - An open box test is performed per TP-IT-2294819, and an Acceptance Test per TP-AT-2294819, including vibration and thermal vacuum. Torques are specified andwitnessed, 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 206 and PAI 217. DCAS personnel witness TVC button-up and critical torquing. CLA Assembly and Test - An open box test is performed per TP-IT-2294821, Acceptance Test per TP-AT-2294821. 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 WLA button-up and critical torquing. TVC/CLA Assembly and Test - After a TVC and a CLA have been tested individually, they are mated and a final acceptance test is performed per TP-AT-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 CLA 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 assy. in accordance with the requirements of WS-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	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. IVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994885-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294886-503 A13 Master Oscillator 2295527-1 C&A A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of Video Information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical ca,era video.	FAILURE HISTORY TDR M6855 Log #0739 2294821 CLA S/N 007-502 TDR M6876 Log #0735 2294821 CLA S/N 007-502 Description: Acceptance Test failure, Box Level, Thermal Vac-Cold Environment. Color wheel stopped with turn on command. Cause: Motor gearing preload to high. Corrective Action: Motor returned to vendor for analysis and repair. Vendor revised assembly procedure and introduced additional testing over temperature. TDR M6869 Log #0719 CLA S/N F005-502 Description: Prelaunch failure, Box Level, Ambient Environment. Wheel will not lock Improper Frequency. Unit returned from NASA KSC log #21. Cause: Initial investigation revealed motor drive signals incorrect. Further investigation resulted in additional failures due to inadvertant shorting of components during troubleshooting. Unable to determine cause of initial problem due to additional induced failures. Corrective Action: Board-extensive rework-replace following parts: U17, U18, U1, U8, U11, U13, U14, U15, U16 & U8, U5, U10, U4 & R7 of A1 board U2, Q2 & Q3 A3 board parts.

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FAILURE MODE AND CAUSE	FAILURE EFFECT ON END ITEM	RATIONALE FOR ACCEPTANCE
Loss of color synchronization. Filter wheel synchronous motor has stopped rotating. TVC A6 Power On/Off. Input Voltage Preregulator. Output Voltage Regulator. 2994805-501 A7 DC-DC Converter. Primary OSC/Driver Secondary Rect/Filter 2294806-503 A13 Master Oscillator 2295527-1 CLA A3 Color Wheel Drive -Gear Train Failure -Motor Failure	Possible loss of video information due to filter wheel blanking bar stopping within lens FOV. Worst Case: Loss of mission critical camera video.	OPERATIONAL EFFECTS Loss of video. Possible loss of major mission objectives due to loss of RMS cameras or other required cameras. CREW ACTIONS If possible, continue RMS operations using alternative visual cues. CREW TRAINING Crew should be trained to use possible alternatives to CCTV. MISSION CONSTRAINT Where possible, procedures should be designed so they can be accomplished without CCTV.