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International Space Station (ISS) External Television (TV) Camera Shutdown Investigation

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February 2009

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International Space Station External Television Camera Shutdown Investigation
Technical Assessment Report

September 2006

NESC Request No. 06-001-E

Report Approval and Revision History

Approved:	Original signed on file	12/11/06
	NESC Director	Date

Revision	Description of Revision	Author	Effective Date
1.0	Initial Release	NESC NDE, GSFC	

Volume I: Technical Assessment Report

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Volume I: Technical Assessment Report

1.0 Authorization and Notification

Ms. Susan L. Creasy, Johnson Space Center (JSC) initiated a request to the NASA Engineering and Safety Center (NESC) on January 3, 2006, to conduct a technical assessment for an investigation of the ISS External TV Camera Shutdown.

The Technical Assessment Plan was approved by the NESC Review Board (NRB) on January 5, 2006.

The assessment was led by Mr. Robert Kichak, NESC Discipline Expert (NDE) at Goddard Space Flight Center (GSFC).

This was initially envisioned to be a short-term assessment and was required by the end of January in order to meet flight dates. However, subsequent schedule changes allowed for later input. Preliminary Findings, Observations, and Recommendations were presented to the NRB and the stakeholders in February 2006. This report documents the completed assessment activity.

2.0 Signature Page

Mr. Robert Kichak, Team Lead	Date	Mr. Robert Cooke	Date
Dr. Chetty Pandipati	Date	Mr. Eric Young	Date

3.0 Team List

Name	Position/Affiliation	Center/Contractor
Mr. Robert Kichak	NESC Discipline Expert – Power & Avionics	GSFC
Mr. Eric Young	Electrical Engineer, Power Systems Branch	GSFC
Dr. Chetty Pandipati	Senior Staff Engineer	QSS Group, Inc./GSFC
Mr. Robert Cooke	Technical Expert, Special Processes	JSC
Consultants		
Mr. Larry Pack	Electronics Packaging Lead	GSFC
Ms. Linda Facto	Mission Assurance Manager	Jet Propulsion Laboratory (JPL)
Dr. Ray Ladbury	Radiation Effects Engineer	GSFC
Support		
Ms. Kim Cannon	Program Analyst, Management and Technical Support Office (MTSO)	LaRC
Mrs. Pam Throckmorton	Program Analyst, MTSO	LaRC
Mrs. Stacey Walker	Technical Writer	Swales, LaRC

4.0 Executive Summary

The objective of this technical assessment was to investigate the on-orbit shutdown problem with the ISS External TV Camera Group (ETVCG) that the ISS Video Subsystem Problem Resolution Team (SPRT) concluded to be most likely caused by a Television Camera Interface Converter (TVCIC) Modular Devices Inc. (MDI) power supply workmanship problem.

Failures

The Truss Segment Starboard -1 (S1) ETVCG was installed on 9A (STS-112), and the TVCIC failure signature of shut downs up to two times per hour behavior started two years after installation. The second failure was with the Truss Segment Port-1 (P1) ETVCG which was launched on 11A (STS-113), but was just installed in November 2005. Its anomalous failure started within one hour of initial start-up. It had nine shut downs in December 2005. During each shut down the ground operators observed loss of video which was restored by cycling the power to the affected TVCIC. Limited telemetry indicated a drop in power to the TVCIC coincident with the loss of video.

Cause/Solution

According to the fault tree (See Figure 7.6-1), the ISS Video SPRT concluded that the MDI power supply is the most probable cause of the shutdowns, and they have recommended replacing it with the Century power supply. Plans are that any time a camera group is brought to the ground, unless the launch schedule precludes it, the MDI power supply should be replaced with a Century power supply. Also, any TVCICs on the ground should have the MDI power supply replaced with a Century power supply. Having completed the assessment, the NESC recommends the MDI power supplies should be replaced with the Century power supplies. This recommendation is contingent upon satisfactory completion of the recommendations related to the Century supplies.

The ISS has recently flown an additional TVCIC with an MDI power supply, Utilization Logistics Flight (ULF) 1.1 (STS-121), and is preparing to fly a TVCIC with a Century power supply on 12A.1 (STS-116). The one on ULF 1.1 supports the Floating Potential Measurement Unit (FPMU), and the one on 12A.1 supports a camera group that will be used to replace the anomalous S1 camera group. As a risk mitigation effort, Century power supplies were built and certified as ground replacements for the MDI power supplies in the event of their failure.

5.0 Assessment Plan

5.1 Charter

The Charter established the ISS External TV Camera Shutdown Investigation within the NESC. It defined the mission, responsibilities, membership, and conduct of operations for this Technical Assessment. This assessment was initiated out-of-board by authority of the Director of the NESC. The objective was to perform a technical assessment of the on-orbit shutdown problem with the ISS onboard ETVCGs that was thought to be due to a TVCIC MDI power supply workmanship problem.

5.2 Team

Four NESC team members with relevant expertise was formed to evaluate the ISS External TV Camera Shutdown and provide an independent assessment.

6.0 Description of the Problem

6.1 Problem

The S1 ETVCG was installed on 9A, and the TVCIC failure signature is that it shuts down up to two times per hour. This behavior began after two years of operations. The second ETVCG that failed was the P1 ETVCG which was launched on 11A but was installed in November 2005. The shutdown failures began within one hour after initial start-up. It had nine shut downs in December 2005 and continues to display intermittent shut downs. As shown in the fault tree (Figure 7.6-1), ISS Video SPRT concluded that the MDI power supply is the most probable cause, and they have recommended replacing this with the Century unit. During each shut down the ground operators observed loss of video which was restored by cycling the power to the affected TVCIC. Limited telemetry indicated a drop in power to the TVCIC coincident with the loss of video.

- A camera malfunction can cause loss of video, but if the TVCIC is still functioning it will loop back a sync signal. Each time the camera group video output is lost, no sync signal is present, indicating that the TVCIC is not outputting any signal at all. That coupled with very low ETVCG power consumption further indicates that the TVCIC shut itself down (power supply shut down) rather than being powered on and simply not passing video.

- “Cycling of power” is an intentional interruption of input power to the TVCIC. If there is an interruption of power, there should be a corresponding interruption of output and when the power is re-applied, the video output will be restored. The camera begins functioning as soon as power is applied.

- The ISS Video SPRT indicates that there were no pan-tilt commanding events corresponding to the camera video loss events or the camera shutdown events.

- Very early on in the failure history, commands to pan-tilt were sent to the S1 camera group in its failed condition, meaning there was no video output from the S1 camera group. The S1 camera group was observed with the lab camera group to see if the S1 camera group responded to those commands and the S1 camera group did not respond. In addition, there was no 35 watt increase in S1 camera group power consumption indicating that the pan-tilt did not respond.

6.2 Plan of Action

The NESC team needed to rule out problem sources other than the power converters. A focus of the assessment was to verify that the problems were not caused by either the input source or the load, namely; a) the remote power controller module (RPCM)/ remote power converter (RPC), or b) Camera Assembly consisting of Camera, Pan control, Tilt control, etc. The NESC team reviewed Project provided materials including:

- Block diagram and description of overall system.
- Details of any elements (e.g., electromagnetic interference [EMI] filter, switching, etc.) electrically ahead of the power supply.
- Background including history of MDI unit problems, rework, and retest.
- How these known workmanship problems can result in the observed failure signature.
- Any Problem Reporting and Corrective Action (PRACA) records of failures on orbit or prior to launch.
- JSC generated fault tree and verbal rationale for closure of items closed
- Circuit diagram of MDI unit, electrical loading, input characteristics, thermal environment, etc.
- Description of available on-orbit telemetry and relevant data for review.
- Circuit diagram of replacement Century unit.
- Review of Century power supply documentation and test data
- CTVC Electrical Input characterization

The ISS has recently flown an additional TVCIC with an MDI power supply, Utilization Logistics Flight (ULF) 1.1 (STS-121), and is preparing to fly a TVCIC with a Century power supply on 12A.1 (STS-116). The one on ULF 1.1 supports the Floating Potential Measurement Unit (FPMU), and the one on 12A.1 supports a camera group that will be used to replace the anomalous S1 camera group. As a risk mitigation effort, Century power supplies were built and certified as ground replacements for the MDI power supplies in the event of their failure.

Input Source Side Considerations

There was a need to obtain data to verify the RPC outputs always stayed above 115V, even after the camera and/or TVCIC shut down. Fortunately, the RPCM has telemetry to indicate the status of each of its RPC outputs.

7.0 Data Analysis

This section contains sub-sections that describe the results of the NESC team's assessment and analysis of each of the elements of the scope as described in Section 6.0.

7.1 Block Diagram and Description of Overall System

7.1.1 ETVCG and TVCIC Description

The TVCIC is one of the three major sub-assemblies of the ETVCG as shown in Figure 7.1-1. The ETVCG provides video image generation and color television support in the regions of the ISS external to the enclosed pressurized volume. The ETVCG, an Orbital Replacement Unit (ORU) of the Video Subsystem (VDS), is described in Lockheed Martin Communications (now L-3 Communication Systems) Drawing 10033124, "B1 Prime Item Development Specification, External."[1] The other two major sub-assemblies of the ETVCG are the Color Television Camera (CTVC) and the Pan Tilt Unit (PTU). The TVCIC contains the:

- Fiber optic (FO) transmitter and receiver required to transmit and receive optical Pulse Frequency Modulation (PFM) signals.
- PFM video signal modulator and the PFM sync and control signal demodulator.
- Built-in status electronics.
- Pressure transducer.
- Encoder.
- Multiplexer for insertion of status data and absolute pan tilt position/bit data on line 14 and the insertion of time tag on line 15.
- Power conditioning electronics, i.e. MDI or Century power supply.

The power conditioning electronics, located in the TVCIC, provide the 28 VDC power to operate the TVCIC, CTVC, and PTU subassemblies, FO pulse frequency modulation PFM video signal, sync and control signal ports, and the camera location code port. It further provides the mechanical interfaces required for mounting the PTU and attachment of the ETVCG to the ISS truss assembly. The TVCIC also provides an electrical interface between the ISS 120V supply and the removable light assembly provided by McDonnell Douglas Aerospace (MDA).

[1] Boornaard, A., B1 Prime Item Development Specification ETVCG, 2 May 1997

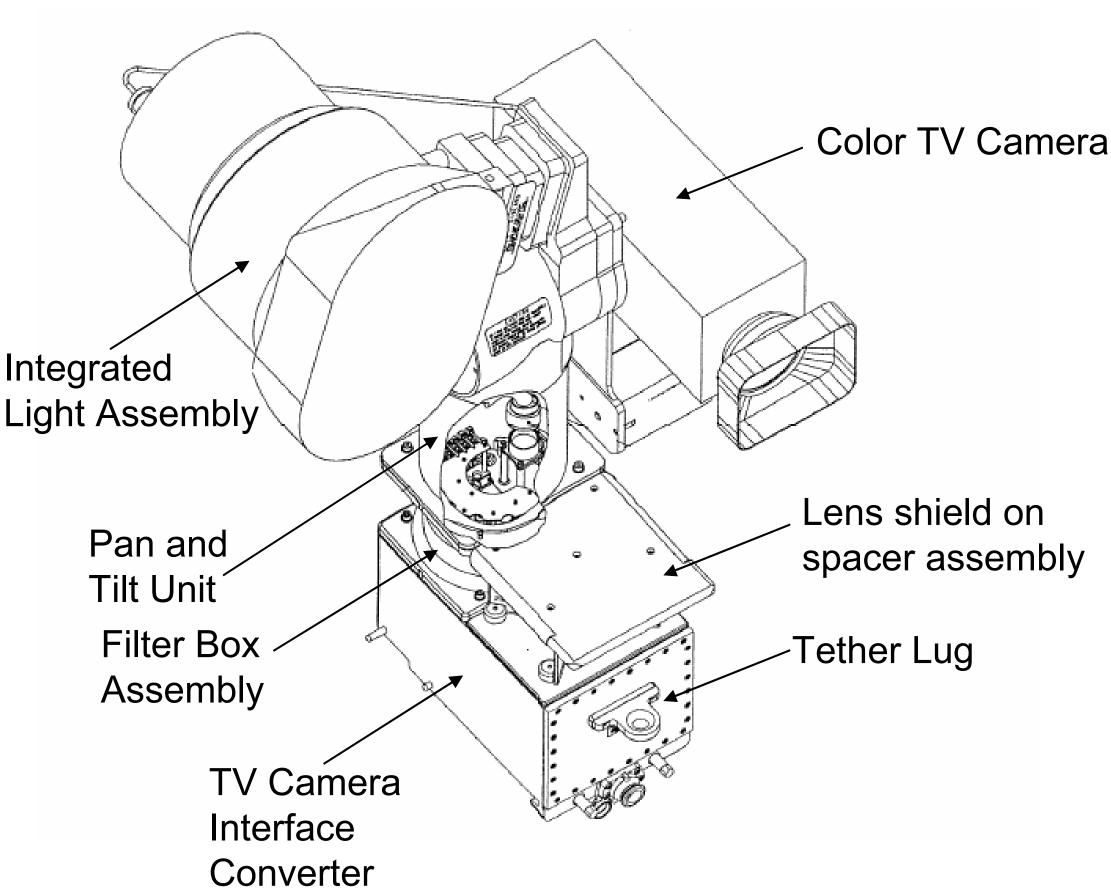

Figure 7.1-1. ETVCG
[ref. Certificate of Product Baseline #222023A, Part Number 10033194-501, S/N 005]

Figure 7.1-2 illustrates the mechanical arrangement of the TVCIC in the ETVCG and identifies the mechanical interfaces for attachment of the PTU, (B), and attachment of the ETVCG to the space station truss assembly, (C). Figure 7.1-3 identifies the external interfaces for FO PFM sync and control and FO PFM video signals, electrical power, and the camera location identification. Figure 7.1-3 also identifies the internal interfaces between the TVCIC and CTVC and between the TVCIC and the PTU. Additional interface information is shown in Figure 7.1-4, and the ETVCG interconnection is shown in the diagram in Figure 7.1-5. The Type IV power supply is shown within the TVCIC in Figures 7.1-3 through 7.1-5. Separate “A” and “B” power feeds are provided with the “A” powering the TVCIC electronics, CTVC, and PTU and the “B” powering the heaters.

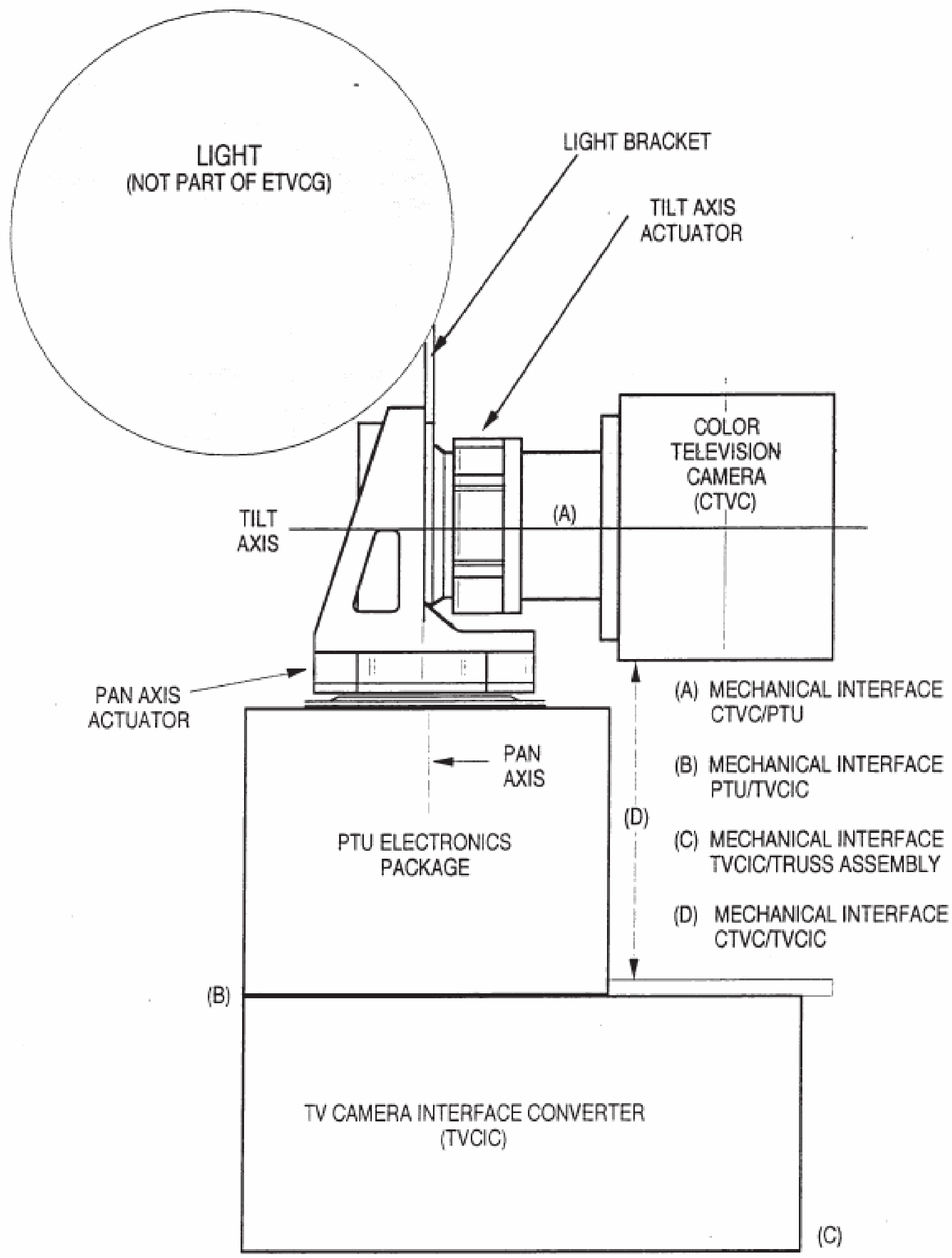
LIGHT
(NOT PART OF ETVCG)
LIGHT BRACKET
TILT AXIS
ACTUATOR
COLOR
TELEVISION
CAMERA
(CTVC)
TILT
AXIS
(A)
PAN AXIS
ACTUATOR
PAN
AXIS
PTU ELECTRONICS
PACKAGE
(D)
(A) MECHANICAL INTERFACE
CTVC/PTU
(B) MECHANICAL INTERFACE
PTU/TVCIC
(C) MECHANICAL INTERFACE
TVCIC/TRUSS ASSEMBLY
(D) MECHANICAL INTERFACE
CTVC/TVCIC
(B)
TV CAMERA INTERFACE CONVERTER
(TVCIC)
(C)

Figure 7.1-2. External TV Camera Group Sub-Assemblies [ref. Boornaard, A., "TVCIC Development Specification 10033125 Revision D", dated 20 February 1997]

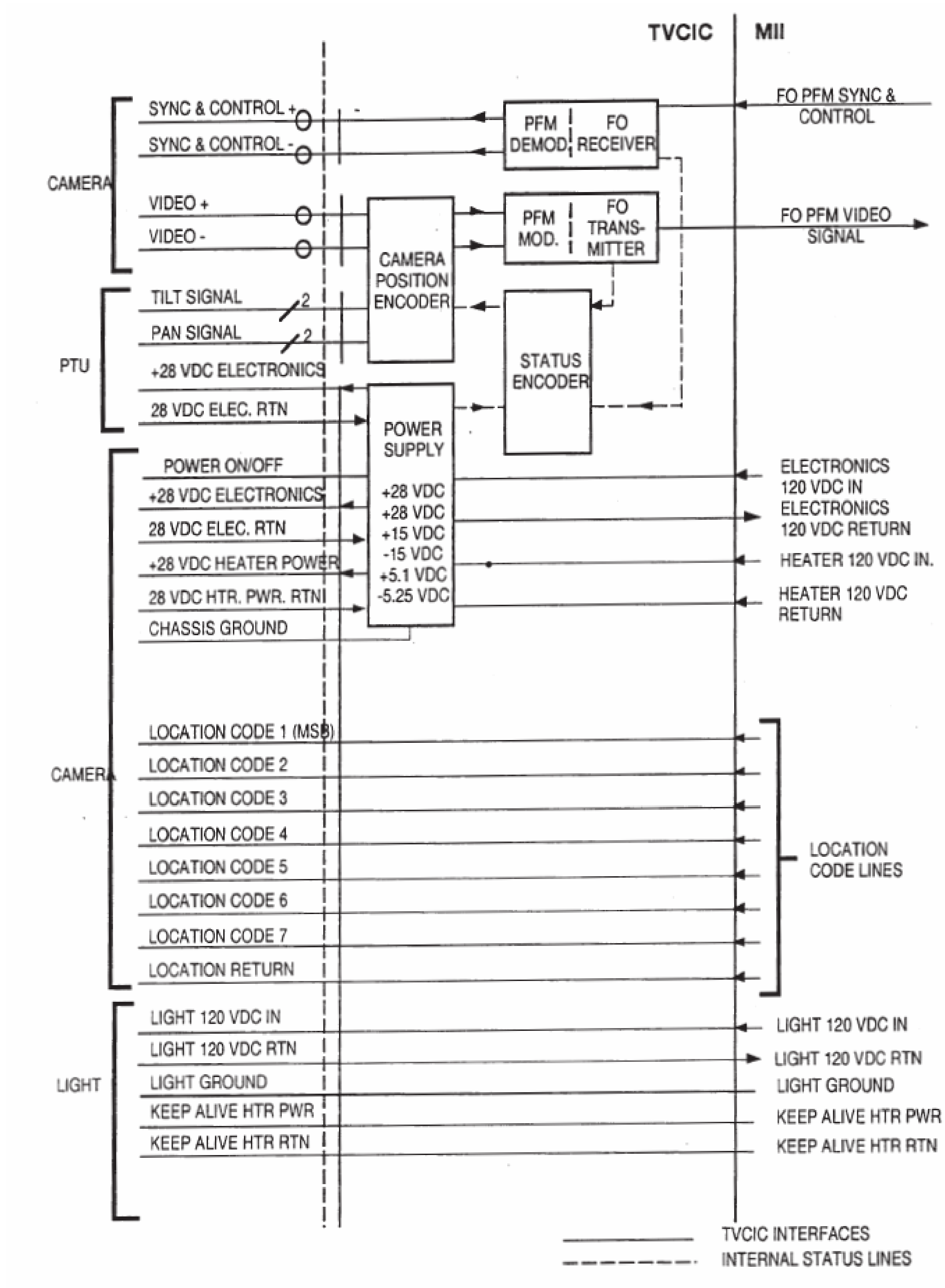
TVCIC
MII
CAMERA
SYNC & CONTROL +
SYNC & CONTROL -
VIDEO +
VIDEO -
PFM DEMOD
FO RECEIVER
FO PFM SYNC & CONTROL
PFM MOD.
FO TRANS-MITTER
FO PFM VIDEO SIGNAL
CAMERA POSITION ENCODER
STATUS ENCODER
PTU
TILT SIGNAL
PAN SIGNAL
+28 VDC ELECTRONICS
28 VDC ELEC. RTN
POWER SUPPLY
POWER ON/OFF
+28 VDC ELECTRONICS
28 VDC ELEC. RTN
+28 VDC HEATER POWER
28 VDC HTR. PWR. RTN
CHASSIS GROUND
+28 VDC
+28 VDC
+15 VDC
-15 VDC
+5.1 VDC
-5.25 VDC
ELECTRONICS 120 VDC IN
ELECTRONICS 120 VDC RETURN
HEATER 120 VDC IN.
HEATER 120 VDC RETURN
CAMERA
LOCATION CODE 1 (MSB)
LOCATION CODE 2
LOCATION CODE 3
LOCATION CODE 4
LOCATION CODE 5
LOCATION CODE 6
LOCATION CODE 7
LOCATION RETURN
LOCATION CODE LINES
LIGHT
LIGHT 120 VDC IN
LIGHT 120 VDC RTN
LIGHT GROUND
KEEP ALIVE HTR PWR
KEEP ALIVE HTR RTN
LIGHT 120 VDC IN
LIGHT 120 VDC RTN
LIGHT GROUND
KEEP ALIVE HTR PWR
KEEP ALIVE HTR RTN
TVCIC INTERFACES
INTERNAL STATUS LINES

Figure 7.1-3. TVCIC Electrical Interfaces [ref. Boornaard, A., "TVCIC Development Specification 10033125 Revision D", dated 20 February 1997]

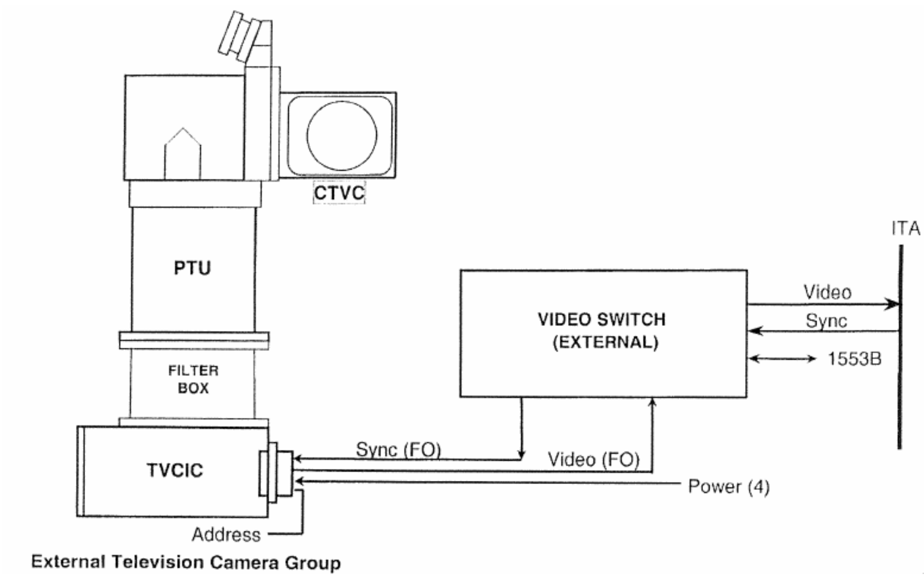

Figure 7.1-4. Additional Interface Information
[ref. Certificate of Product Baseline #222023A, Part Number 10033194-501, S/N 005]

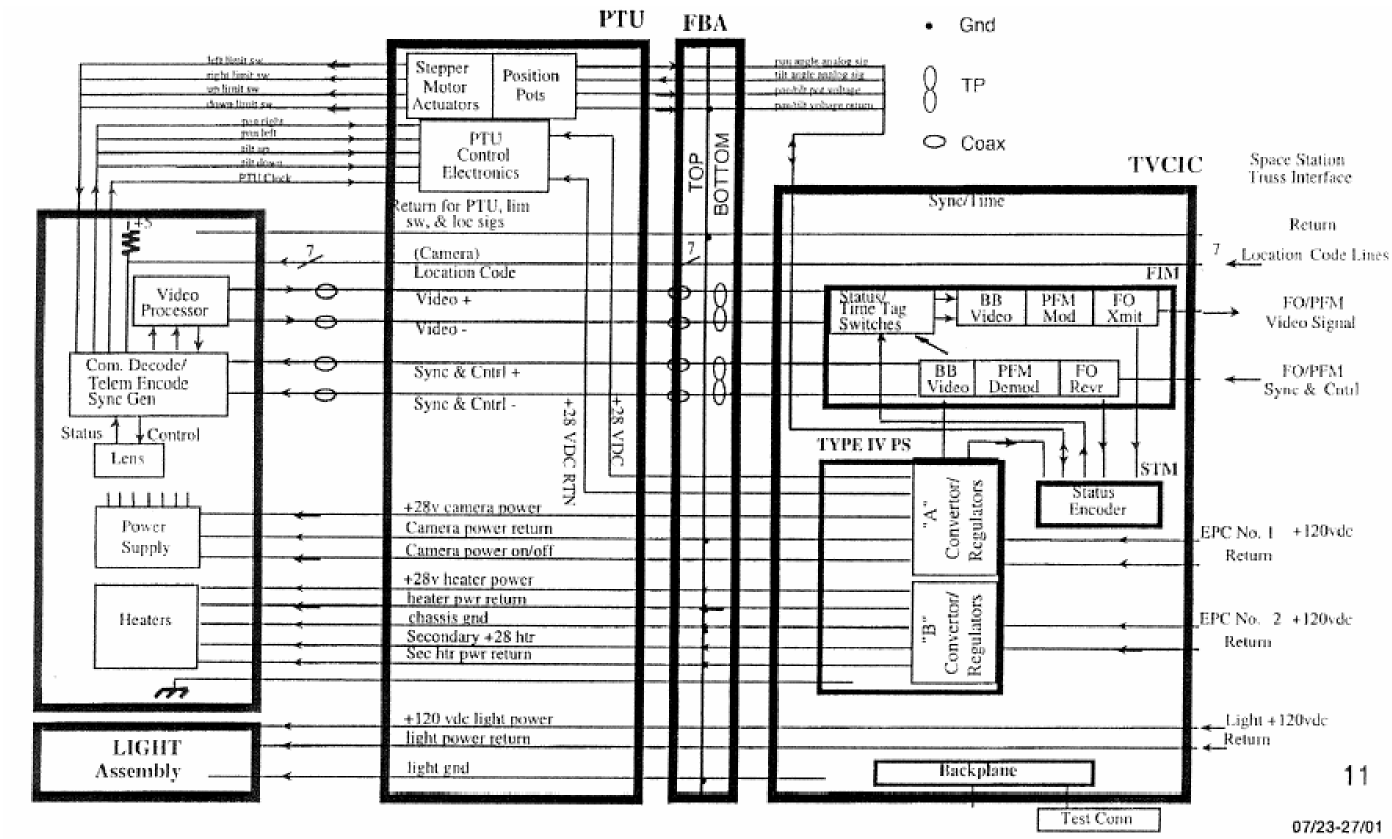

Figure 7.1-5. ETVCG Interconnection Diagram
[ref. Certificate of Product Baseline #222023A, Part Number 10033194-501, S/N 005]

7.1.2 Block Diagram and Description of the Type IV Power Supply

A block diagram of the Type IV power supply as manufactured by MDI is shown in Figure 7.1-6. This unit is defined by General Electric Aerospace (now L-3 Communications) Source Control Document (SCD) 10036714 Revision L.

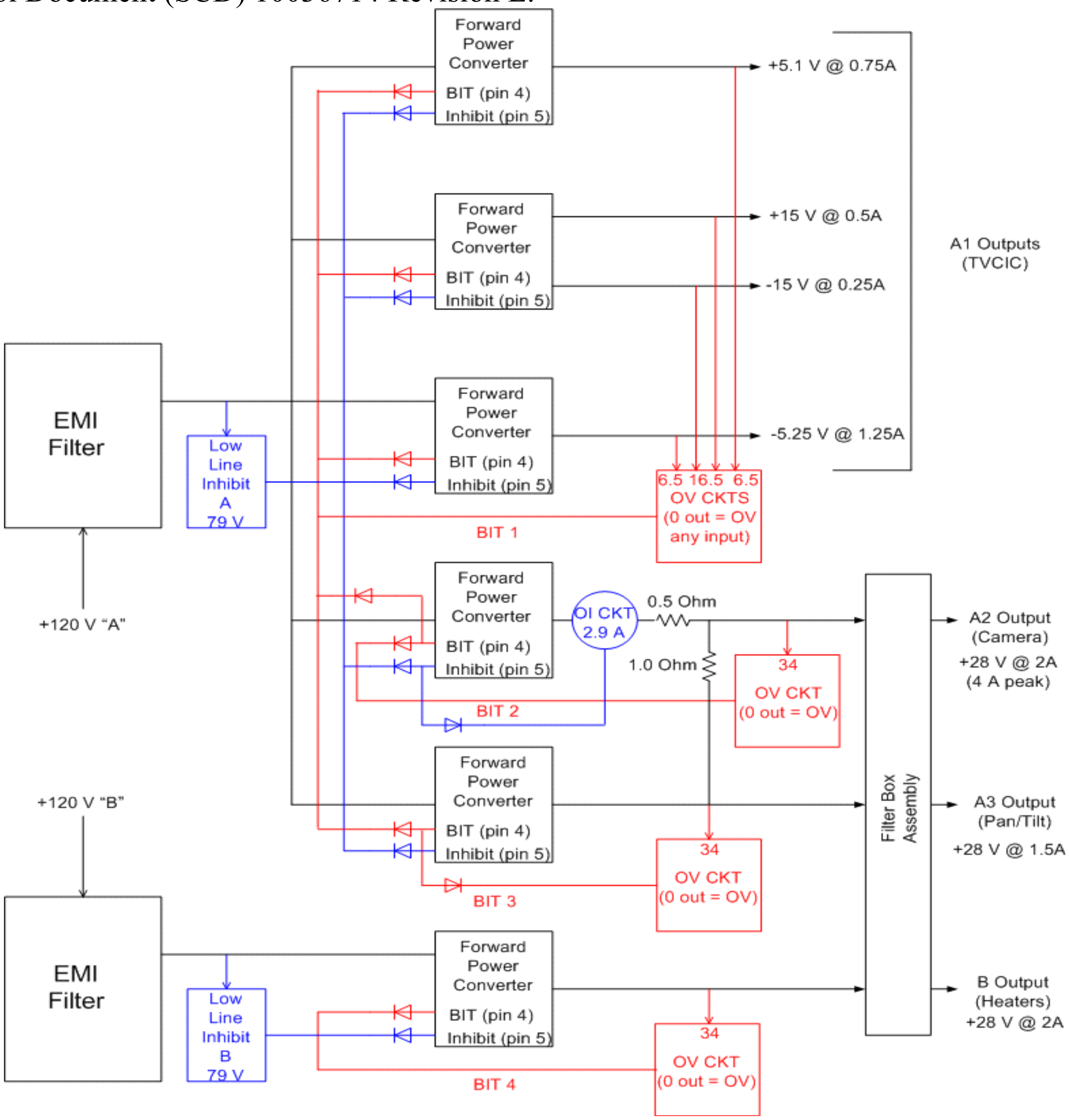

Figure 7.1-6. Type IV (MDI) Power Supply Block Diagram

The power supply design employs six forward power converter channels, as shown in Figure 7.1-6, with the "B" channel for heater power separated from all other channels with a separate 120 volt input and EMI filter. The "A" outputs provide power to the TVCIC electronics (the "A1" outputs of +5.1 volts, +/-15 volts, and -5.25 volts), the "A2" +28 volt output supplies the camera, and the A3 +28 volt output to the Pan/Tilt assembly.

To overcome a camera turn-on issue (due to inrush peak current demand by the camera during turn-on), the power supply was modified to insert a 0.5 ohm resistor in series with the "A2" output and cross-tie the "A3" output through a series 1.0 ohm resistor as shown. The design also incorporates protection features described below and also shown in Figure 7.1-6:

- An undervoltage sense circuit (set at approximately 71.9 volts) sensed at the output of the EMI filter for either the "A" or the "B" section will inhibit switching of that section (all "A" or "B" outputs).
- An overvoltage on any "A1" output will shut down all "A" outputs and latch off until input power is cycled.
- An overvoltage on the "A2" output will shut down "A2" and latch off until input power is cycled.
- An overvoltage on the "A3" output will shut down "A3" and latch off until input power is cycled.
- An overvoltage on the "B" output will shut down the "B" output and latch off until input power is cycled.
- An overcurrent (~2.9 Amps) on the "A2" output will cause that output to limit its output current.

7.2 Details of Relevant Elements (e.g., EMI Filter, Switching, etc.) Electrically Ahead of the Power Supply

7.2.1 Station Power Input to TVCIC

The MDI Type IV power supply accepts as a nominal input 120V DC. This power is provided via two RPCMs (Type V). One RPCM powers the Electronic Power Converter (EPC) #1 input to the TVCIC and the Light. The other RPCM powers EPC #2 input to the TVCIC and the Heater. Each of these RPCMs is powered from a different dc-to-dc converter unit (DDCU). The EPC #1 and Light power both come from the same RPCM, but they are fed from separate switches. Redundancy is built into the system by breaking up the power supplied to the TVCIC into the "A" and "B" side RPCMs fed by "A" and "B" side DDCUs. The RPCMs are allowed to feed other RPCMs to allow for load shedding or re-routing of power. The two harness lengths that were provided by the Boeing Electrical Power System (EPS) engineers were approximately 241 feet and 255 feet for the S1 Lower Outboard (LOOB) ETVCG and the P1 LOOB ETVCG respectively. The NESC team considered the possibility that the voltage to the TVCIC from the

RPCM was out of range. Since there is no direct monitoring of the current drawn by the TVCIC, this quantity can only be derived. The current telemetry that is available is the total current into the RPCM. Comparing the total current into the RPCM before and after the video loss (or TVCIC shutdown), it was found that the difference in total current level is consistent with the known current draw for the TVCIC.

7.2.2 RPCM Description

Each RPCM powering the TVCIC has the capability of 16 separate 3.5A output switches and two separate 12A switches. The RPCM is a current limiting type. This type of RPCM will current-limit at a current of 115 $\pm$ five percent. The RPCM will open when a current limit occurs for 32 to 40 milliseconds. Also, for input undervoltage of less than 105V for 50 milliseconds, all RPCs open. Input voltage recovery to greater than 111.5V for 50 milliseconds after undervoltage trip will re-close open RPCs. Automatic recovery after a second undervoltage trip is nominally disabled and further recovery requires manual intervention. The RPCM provides power to several different loads in addition to the TVCIC unit. This power goes to units that may or may not be related to the TVCIC operation. The document titled "User Electric Power Specifications and Standards Volume 1: 120 Volt DC Loads"[2] describes the power quality that is guaranteed. Any effects, however small, with one load on an RPCM affecting another load on the same RPCM (but different switches), can be found in this document.

7.2.3 RPCM Telemetry

Much of the troubleshooting of the camera failure focuses on what types of clues were given by the telemetry prior to a failure. The level of telemetry provided by the system is somewhat limited. Each RPC switch of an RPCM provides two bits of status that represent three states: CLOSED, OPEN, and INVALID. When the voltage out of an individual RPC switch is greater than 111.5V the RPCM reports that this switch is "closed". When a voltage out of an RPC is less than 10.0V, the RPCM reports that this switch is "open". When the voltage is in between, it is reported as "invalid". Switch states are reported nominally every 10 seconds (the process can be sped up to 1 Hz. rate in data dump mode). These data rates could mask a transient event that causes a response in the TVCIC, but the ISS EPS has no history of this kind of transient behavior. If a transient event were to occur, at the conclusion of the event, the TVCIC would most likely be powered on and functioning since the transient would have the same effect as a power cycle. The only input current telemetry reported would be a composite current telemetry for all of the current into the RPCM. This composite current includes all current outputs from all 16 switches/loads and RPCM housekeeping current (to bias up internal operation). This RPCM input current is actively sampled every millisecond, but this data is integrated and reported

[2] http://iss-www.jsc.nasa.gov/ss/issapt/eps/SSP52051Oct05.pdf

nominally every 10 seconds. However, it can be collected every second to permit a segregated analysis of each RPC switch. The data is transmitted to the ground where these 0.1Hz samples are processed to create a rather slow derivative function. There is no telemetry to alert someone that a RPC switch has experienced a current limit event.

7.2.4 TVCIC Power Input

The MDI Type IV power supply unit has two separate EMI input filters. These filters are built up as a separate assembly and incorporated internal to the Type IV unit.

Figure 7.2-1 illustrates the electrical circuit of the EMI filters internal to the Type IV unit. Note: This schematic was redrawn from schematic information that was fax'ed from MDI (as such there may be some errors in interpretation).

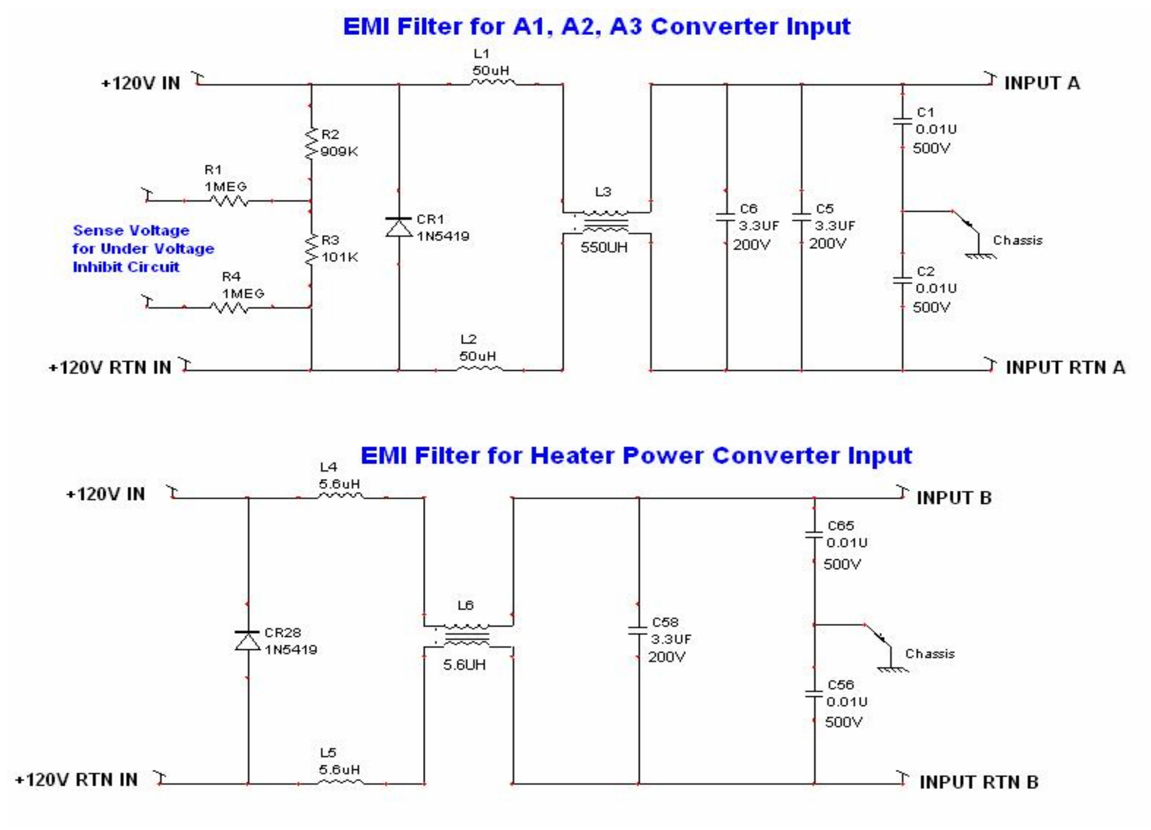

Figure 7.2-1. Simplified Schematics of EMI Input Filters
(Based on data provided by MDI)
[ref. Schematic Diagram Power Supply, GE Type IV, MDI Drawing 2696-02]

7.3 Background Including History of MDI Unit, Problems, Rework, and Retest

A description of MDI power supply workmanship problems and L-3 Communications' rework of these follows in Table 7.3-1 and 7.3-2.

Table 7.3-1. Root Cause/Corrective Action Summary [ref. Heydman, William, "CR: AOE-0473 C&T, Type III and Type IV Power Supply Rework", dated 8 November 1999]

INTERNATIONAL SPACE STATION

Root Cause/Corrective Action Summary

Issue	Cause	Corrective Action
Type III Broken Capacitor Leads.	• Lead fatigue caused by insufficient staking between heat sink and caps.	• Added improved staking between heat sink and caps.
Type IV Failed FET bond wires within hybrid.	• Electrical overstress caused by load switching.	• External to hybrid, revised resistor value, added 2 resistors and tandemed hybrid outputs.
Type III & IV Fractured solder joints on swaged terminals on PWBs.	• Non-plated thru holes. • Insufficient solder contact between terminal and circuit trace. • Thermal expansion of dissimilar materials.	• Leash and jumper wires added between all terminals and PWB traces.
Type III & IV Fractured solder joints on transformer pins.	• Poor solder wetting. • Bronze transformer lead material. • Terminals installed in non plated thru holes	• "No-clean" flux used to improve wetting. • Leash wires added between all terminals, pins and PWB traces

- All power supply corrective actions verified by extensive thermal cycle and vibration testing.
- L3C has inspected and reworked all power supplies to meet NASA NHB 5300 requirements.
- Rework plans, including requisite process and solder MUA's and test plans, have been developed and approved by L3C and Boeing.
- Dr. Mike Pedley (NASA-JSC), Bob Cook (NASA), and Dr. John Golden (Boeing) have reviewed and approved process and solder MUA's.

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Table 7.3-2. MDI Power Supply Rework Matrix
[ref. Heydman, William, "CR: AOE-0473 C&T, Type III and Type IV Power Supply Rework", dated 8 November 1999]

INTERNATIONAL SPACE STATION

MDI POWER SUPPLY REWORK MATRIX

	TYPE II	TYPE III	TYPE IV
GENERAL			
Quantity of P.S.	3	6	5
No. of PWA's per P.S.	13	10	12
Total PWA's to Leash	39	60	60
TERMINAL LEASHING (ON PWA's)			
ITC Direction	ITC-2384	ITC-2412	ITC-2413
# Leashes / P.S.	126	108	150
Total Leashes Req.	378	648	750
XFMR LEASHING & TOUCH-UP (T/U)			
ITC Direction	ITC-2518	ITC-2525	ITC-2526
TYPE XFMR / P.S.	400-107 400-108 400-109 400-110	400-110 400-111 400-112 (2)	400-107 (2) 400-108 400-116 (3)
# Leashes & T/U / P.S.	42	49	67
Total Leashes & T/U	126	294	335

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A description of the MDI power supply workmanship problems, which were reworked by L-3 Communications, are described below:

The NESC team has not evaluated the documentation for each specific power supply (from locations S1, P1). The NESC team's understanding is that the units were completely disassembled and repairs were performed on all of the Type IV units. These repairs were done preemptively and were identical from one unit to the next. The NESC team did not feel it was an efficient use of resources to review all of the travelers. The NESC team examined the possibility that some units did not receive the same repair operations unintentionally. Please refer to Robert Cookes comments on rework in Appendix D. There were poor solder joints on many of the harness wires. The problem was compounded by the fact that most wires in the design were connected to the circuit card assembly (CCA) using a turret terminal. The terminals were <u>not</u> in plated through-holes which left the design to rely on electrical connection at the small annular ring/pad at the top and far side of the board. On many of the connections, the terminal was used as the connection from a top-side circuit trace to a back-side trace. This means if either the top or far side solder joint cracked, it could result in an intermittent connection. There are over 100 solder terminals in each MDI power supply. L-3 Communications ended up doing a full replacement of each wire in the harness and soldered a bus wire “leash” from each terminal to a lap solder joint on each related trace.

Additionally, there were similar issues with some of the potted transformers used in the units. L-3 Communications had to carefully excavate the potting compound, and make similar upgrades to the terminals on the transformer boards/terminals, and then re-pot the transformers. The difficulties associated with this scope of repair and modification are described in Appendix D.

As was discussed at the December 13, 2005, Technical Interface Meeting (TIM), L-3 Communications also added some “load sharing” to the MDI design to accommodate the higher than expected in-rush current experienced on one of the outputs in the design.

7.4 How These Known Workmanship Problems Can Result in the Observed Failure Signature

Summary of MDI Power Supply Assessment

The MDI power supply deliveries were completed in December 1994, (14 flight units). Before these power supplies were flown in orbit, failures were discovered in August 1997. L-3 Communications Systems, and their subcontractor MDI, started reworking failed units in late 1997 and early 1998. After being installed on-board the ISS, these units exhibited failures as listed below:

Signature of in-flight failures (per NESC/TAC #PL-06-04):

- TVCIC from S1 ETVCG shuts down two times per hour.
- TVCIC from P1 ETVCG (installed 11/05) shut down nine times in one month.

Suspected cause/reason for failures (as expressed in NESC/TAC #PL-06-04):

The packaging design and workmanship in the MDI power supply assembly is suspected of contributing to the cause/reason for the in-flight failures. While there may be other suspected causes/reasons for the MDI power supply failures under investigation, such as parts degradation due to radiation exposure or the electrical design, this report section addresses only packaging and workmanship related failures.

Brief summary description of documented workmanship problems suspected of contributing to the MDI power supply failures (per Will Heydon's CR: AOE-0473, dated November 8, 1999):

1. Broken capacitor leads due to mechanical stress.
2. Failed Field Effect Transmitter (FET) bond wires within hybrid due to electrical overstress (fused open). Since MDI power supplies are utilized in other applications onboard the ISS, the NESC team requested information regarding how the bond wires were fixed in the MDI hybrids (e.g., thicker wires added with solder, braze, weld, conductive epoxy, etc.). This information was not available at the time of this report. Some repair techniques may be less reliable and prone to failure.
3. Fractured solder joints on swaged terminals due to poor printed wiring board (PWB) design/layout. Swaged terminals installed in un-plated through holes, insufficient solder, and dissimilar materials.
4. Fractured solder joints on transformer pins due to poor PWB design/layout, installation in un-plated through holes, poor solder wetting, and dissimilar materials.
5. Missing failure reports, undocumented rework, missing and incomplete travelers, missing test data, and missing in-process inspections.
6. Wiring errors discovered in Type IV supplies.
7. Blown rack fuse occurred during thermal testing (+/- 5V).
8. Blown rack fuse occurred during OVP testing.
9. Two "swaged terminal life tests" failed October 29, 1998.
10. Rework of transformer caused cracks in 2oz. and 4oz. copper traces. Leash repair of all pins and terminals completed (see Figures 7.4-1 & 7.4-2).
11. Extensive rework performed to correct these problems (at least 2,530 repairs, added wires, reworks, and touch-ups).

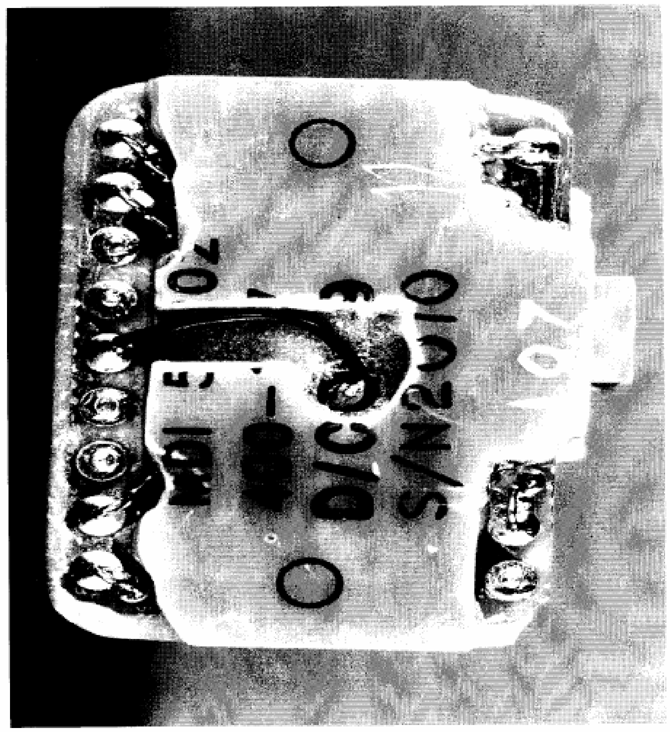

Figure 7.4-1. Picture of Reworked Power Supply showing Leash/Jumper Wires [ref. Heydman, William, "AOE 0473, TRC Power Supply Card Out of Spec", Current ECD dated 22 September 1999]

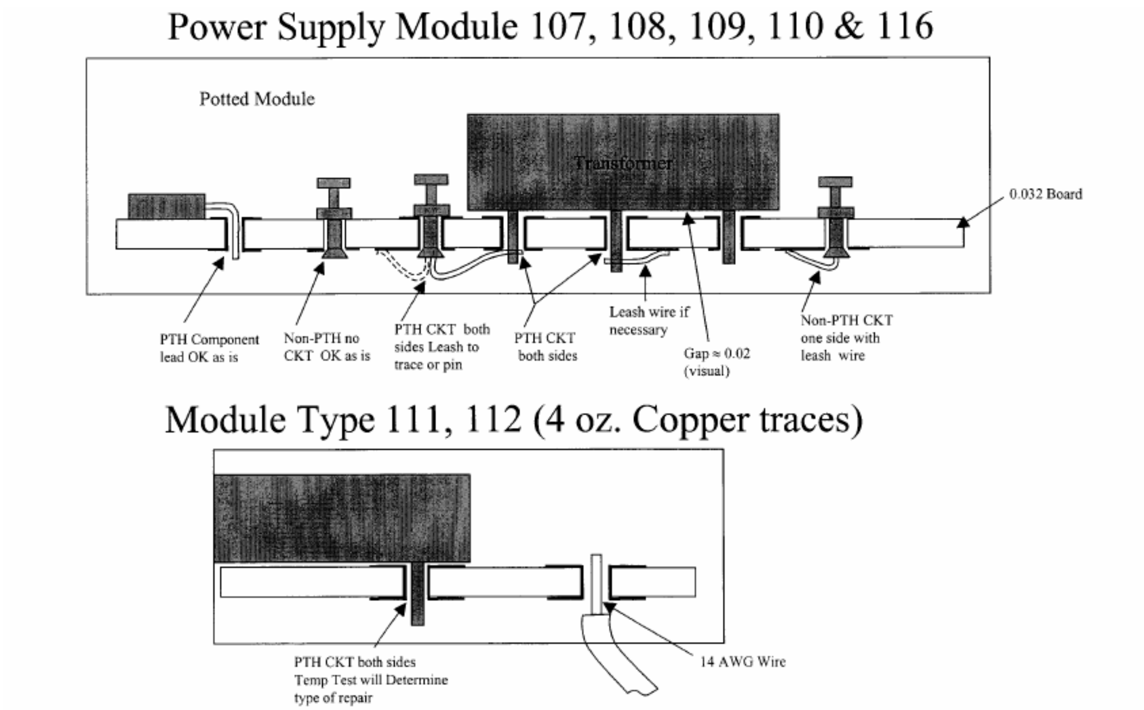

Figure 7.4-2. Power Supply Types of Terminals – Pins & Repairs [ref. Heydman, Will, "CR: AOE-0473 C&T, Type III and Type IV Power Supply Rework", dated 8 November 1999]

7.4.1 Workmanship Problems Can Result in the Observed Power Supply Shut-Down – Possible Causes

As shown on the SCD of MDI Type-IV power supply, the overvoltage protection is implemented as follows:

1. An overvoltage condition on any of the "A1" outputs will latch all of the "A" outputs off. The outputs shall be reset by removing and reapplying the 120 VDC input voltage.
2. An overvoltage condition on the "A2" output will latch the "A2" output off. The "A2" output shall be reset by removing and reapplying the 120 VDC input voltage.
3. An overvoltage condition on the "A3" output will latch the "A3" output off. The "A3" output shall be reset by removing and reapplying the 120 VDC input voltage.

4. An overvoltage condition on the "B" output will latch the "B" output off. The "A" outputs will not be affected. The "B" output shall be reset by removing and reapplying the 120 VDC input voltage.

The observed failure is that the ETVCG turned off by itself. This is interpreted from the absence of any video output from the camera while the RPCM input to the unit was normal. The absence of video can occur if one of the "A1" outputs attains an overvoltage condition. There is no telemetry available to exactly pin-point which one of the three outputs triggered an overvoltage shutdown.

The overvoltage condition could occur due to one or more of the following:

1. An intermittent connection in the feedback loop, a broken wire, dry solder joint, etc. related to workmanship problems can result in intermittent connections possibly induced by thermal excursions or relatively higher operating temperatures. These problems escaped and were not caught by the conventional acceptance tests. Experience shows, for example, that cracks in ceramic chip capacitors can propagate over approximately six months and then can show symptoms of their behavior in degraded performance.
2. An intermittent connection in the control loop resulting in an unstable loop driving the output voltage to the limits of overvoltage.
3. Transients reflected from the load side on to the TVCIC, possibly due to intermittent connections or degraded camera performance.
4. Broken wires and/or intermittent connections in the overvoltage detection circuitry result in apparent (false) overvoltage.
5. The intermittent shorting of primary windings of the TVCIC transformers such that the control loop was not able to respond quickly enough to prevent overvoltages.
6. There may be a number of other possibilities, presently not analyzed, that can occur due to intermittent connections.

7.5 Any PRACA Records of Failures on Orbit or Prior to Launch

The following is a list of PRACA problem reports (PRs) that were entered into NASA's PRACA PR database concerning the failures of MDI power supplies. The PRACA PR number is given, followed by the PR title, the ORU the PR was written against, and the date that either the problem was noticed or the date the PRACA PR was opened. During integration and test a number of previously unexplained shutdowns had been experienced. These failures led the development team to initiate an inspection of all of the MDI power supplies.

The following seven PRACA PRs were opened during ground testing:

550 - Power supply values not to spec - TVCIC - 06/17/1998
The "test connector" program showed that the Status Telemetry Module (STM) had problems locking up to the incoming video, so this problem was not with the flight hardware and thus was not reportable.

552 - Type IV Power Supply failure - TVCIC - 06/17/1998
An ETVCG shut down during a pre-integration test at the vendor. Troubleshooting isolated the failure to the MDI power supply. The power supply was replaced and subsequent testing was nominal.

731 - External Video Switch Type III Power Supply unexpectedly shut down - VSW - 08/07/1998
During a vibration test VSW shut down. Troubleshooting determined there were fractured solder terminals in the MDI power supply as well as test software problems.

771 - External Video Switch Type III Power Supply unexpectedly shut down - VSW - 08/20/1998
During a signal to crosstalk test the VSW shut down. Troubleshooting determined there were fractured solder terminals in the MDI power supply as well as test software problems.

1909 - Fractured Solder Joints On Swaged Terminals and Transformer Terminals - TVCIC - 05/15/1998, AOE
The investigation found that the following factors contributed to the failures of the ETVCG during testing: Fractured solder joints on swaged terminals, fractured solder joints on transformer terminals, failed FET bond wires.

3269 - FPMU/TVCIC failed to activate when power was applied - TVCIC - 01/14/2003 - PQ
During power quality testing of the FPMU/TVCIC assembly the assembly failed to power up during one of the power cycles. The assembly was found to fail to power up about 1 time out of 10 attempts.

3270 - FPMU/TVCIC failed to activate when power was applied - TVCIC - 01/14/2003 - EMI
During EMI testing of the FPMU/TVCIC assembly the assembly failed to power up during one of the power cycles. The assembly was found to fail to power up about 1 time out of 10 attempts.

The following two PRACA PRs were opened during on-orbit operations.

3365 - No video from S1 ETVCG - TVCIC - 05/28/2003

The S1 ETVCG operated nominally for a couple of years after installation and then failed off for no externally apparent reason. Subsequent power cycle recovered the function of the hardware. This failure has been recurring for years.

Voltage 3875 - Loss of activity on P1 Lower Outboard (LOOB) Camera - TVCIC - 12/01/2005
The P1 ETVCG operated nominally for an hour after installation and then failed off for no externally apparent reason. Subsequent power cycle recovered the function of the hardware. This failure has been recurring for months.

For the complete PRACA Reports, see Appendix E.

7.6 Fault Tree

7.6.1 Observed Fault

The absence of video is the observed fault which results when one of the following occurs:

1. CTVC is switched off by commanding.
2. Input power to CTVC, namely the “A2” output voltage from TVCIC, is either removed or failed.
3. Failure of the CTVC to output video.
4. Failure of the Fiber-optic Interface Module (FIM) within the TVCIC to pass video or properly sync the video.

Failure of the CTVC to output video will result in the TVCIC looping back the video signal input at the sync and control interface. This will cause video to appear to be lost at output devices (monitors), but video signal indicators in the signal path will show "signal present" indicators. The lack of the presence of the loopback signal indicates a loss of the nominal functions in the TVCIC.

Failure of the FIM would not explain the coincident reduction in power consumption that was noted in the telemetry and would require a failure mechanism which would be restored by cycling power. Such a FIM failure mechanism is not known to exist.

From the above discussion, because only the “A2” output voltage from the TVCIC powers the CTVC, the observed failure could perhaps be due to the absence of the “A2” output. However, the absence of a test pattern indicates that more than the “A2” is shut down. An overvoltage of any one of the “A1” outputs also shuts down all the “A” outputs. Thus, the failure appears to have started when one of the “A1” outputs experienced an overvoltage limit. The shut down of

"A2" or "A" group supplies is consistent with the coincident reduction in power consumption noted in the telemetry.

7.6.2 Failure of "A2" Output or All "A" Outputs

There are a number of possibilities as to how the "A2" output or all "A" outputs can fail as illustrated by the Fault Tree diagram (see Figures 7.6-1). Some of the salient items are listed below:

1. Absence of input power.
2. Load induced failure of "A2" output or all "A" outputs.
3. Power supply failure.
    a. "A2" only output failure.
    b. One of "A1" outputs failed causing shut down of all "A" outputs.

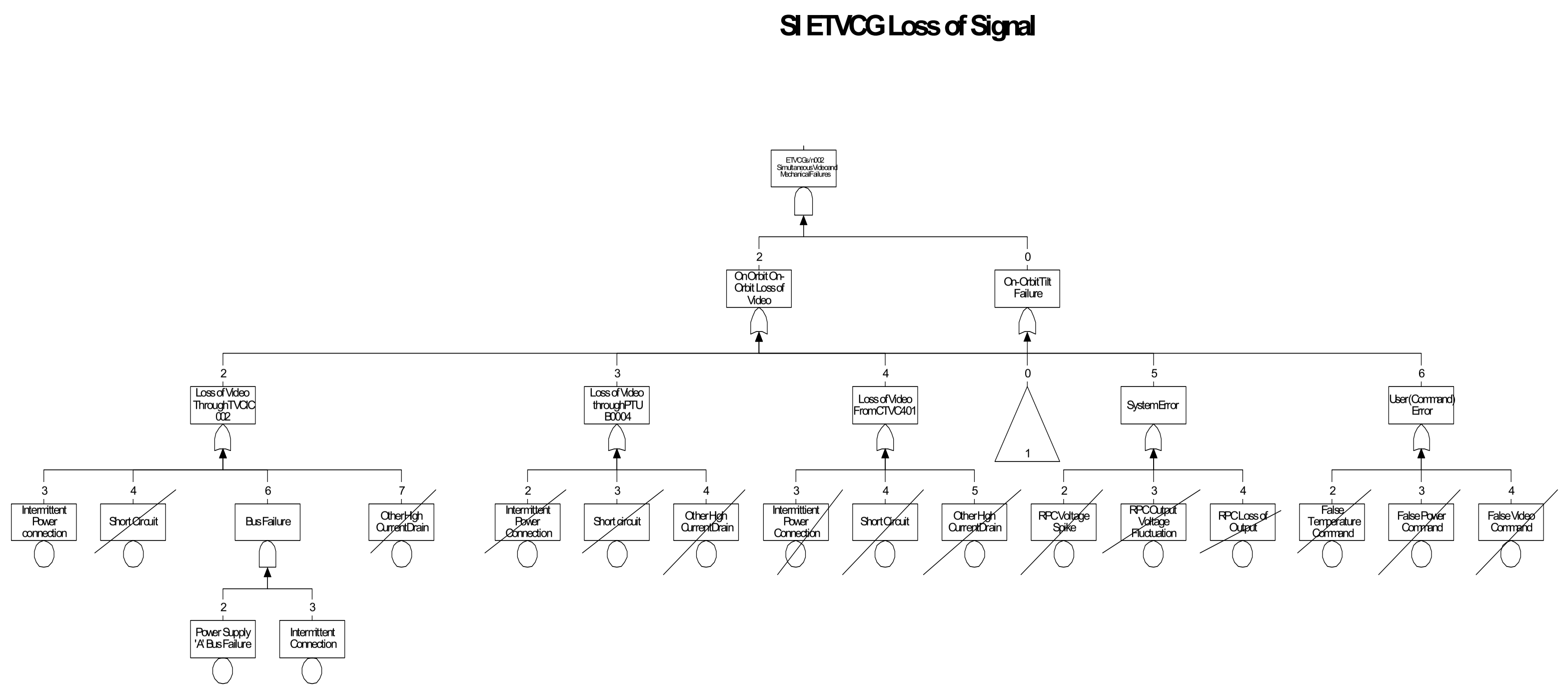

Figure 7.6-1. Fault Tree
[ref. Helvy, Dana and Boris Berezin, "Authorize Replacement of MDI Power Supplies in TVCIC (Television Camera Interface Converter) with Century Power Supplies", dated 20 December 2005]

7.6.3 Absence of Input Power

The power supply input is provided via one of the RPCM Type V switches. The NESC team obtained the telemetry output of the RPC #15 which provides the input power to the subject power supply. The telemetry did not indicate any intermittency of input power to the power converter that supplies the ETVCG camera and PTU.

The NESC team requested similar RPC telemetry data, regarding the power converter that provides power to heaters, to ascertain if the heater or its operation could have any interaction with the operation of the camera or PTU. The temperature never dipped below that required to cause the heaters to turn on. Furthermore, no data indicated that the heaters had inadvertently turned on. Finally, the heater circuit is isolated from the PTU and CTVC power circuits within the power supply. For these reasons, the ISS VDS engineers concluded that heater operation is believed to be unrelated to the shutdowns.

7.6.4 Load Induced Failure of “A2” Output or All “A” Outputs

Unique tests conducted to electrically characterize the input of the TV camera revealed the following:

1. Inrush currents spiking/peaking to about 3.1 amps lasting for about 4 milliseconds.
2. Voltage spikes on the bus were about 1.1 volts above the input voltage.

The original design of the MDI power supply could not supply the above specified inrush current. The assessment team learned that L-3 Communications devised a solution to meet the inrush current demand by implementing a resistor cross-tie of the A2 and A3 outputs to supply the A2 inrush demand by supplying current from the A3 output.

The voltage spikes observed in these tests were not of enough amplitude to trigger the overvoltage shut down.

The NESC team also asked the ISS VDS engineers if the PTU was electrically characterized to positively verify whether it demands large inrush currents similar to the camera and perhaps reflects back large voltage spikes on to “A3” output which gets coupled to “A2” through the inrush network. However, this information was not readily available. The ISS VDS engineers stated that they do not believe the PTU has large inrush current transients similar to the camera since the PTU when powered on merely powers an electronic control circuit as opposed to motors. This electronic circuit would not require a large amount of current given the nature of its function/design. The PTU motors were not being commanded when the shutdowns occurred. And the shut downs initially occurred during steady-state operations without commands being sent to the PTU motors or more accurately with no pan or tilt operations occurring. These are all relevant points that led the VDS engineers to believe investigation down this path was unwarranted.

Although a) the packaging of the MDI Power Supply is the probable cause leading to intermittent problems and b) the cross-tie of A2 and A3 outputs of MDI Power Supply leading to overloading, are possible causes for the TV Camera shut-down, it can not be completely ruled out that the c) TV Camera itself may not be the cause.

7.6.5 Power Supply Failure

Failure of the power supply can occur because of various factors including the following:

- Workmanship problems, as illustrated in Section 7.4 above.
- Design deficiency or low margin.

7.6.5.1 Design Deficiency – Original Design

The TVCIC power supply designed by MDI utilizes six different instantiations of a power hybrid, also designed by MDI. The schematics that were provided to the investigation team to review were of poor quality (facsimile documents with handwritten comments that were subsequently scanned at low resolution). In a number of cases, pin numbers, values, and part numbers were completely indiscernible from the information provided.

The main functions/components contained in the MDI designed hybrid include a UC1845 Pulse width Modulator (PWM), IRFC340 MOSFET die, optocoupler isolated feedback, overvoltage protection, and shutdown/inhibit functions with latch/no-latch options. The hybrid design was modified from a heritage hybrid design that was originally developed for a different application with a much lower input voltage.

The use of optocouplers in the feedback control loops and in the overvoltage protection circuits prompted concerns regarding possible radiation effects such as single event transients and total dose current transfer ratio degradation. However, for the ISS orbit and on-orbit duration, this is not a large concern.

Discussions with the ISS VDS engineers revealed the TVCIC power supply had difficulties during restarting attempts. The hybrid startup circuitry was briefly analyzed. The analysis of this design is located in Appendix B of this report. The basic finding from this analysis was that this part of the hybrid circuit shows problems in worst-case analysis, and it may possibly be a cause of the restart problems with the MDI design.

7.6.5.2 Design Modification for Camera Inrush Current

To overcome the camera turn-on inrush peak current demand, a network was added to supplement the capability of the "A2" output by cross-strapping a portion of the "A3" output. Namely, now the camera is powered by both "A2" output and "A3" output simultaneously. However, the "A2" output supplies 2/3 of the camera demand while the "A3" output supplies the remaining 1/3 of the camera demand. This is accomplished by inserting a 0.5 ohm resistor in series with the "A2" output and cross-tying the "A3" output through a series 1.0 ohm resistor as shown (see Figure 7.1-6).

7.6.5.3 Effect of Design Modification on Steady-State Operation

The net effect of inserting the inrush network is the "A2" output is lightly loaded, and steady-state consumption was reduced to about 42 percent of its original value. The steady-state power consumption on the "A3" output is approximately 106 percent of its rated capability (see the Table 7.6-1).

Table 7.6-1. Effect of Inrush Network on overall MDI Power System

	Before inserting inrush network	After inserting inrush network		Before inserting inrush network	After inserting inrush network	
ETVCG Components	**Power provided by**		**Output rating**	**Output consumption**	**Output consumption**	**loading compared to rating**
Camera	A2	A2 & A3	1.43A/ 40W	0.90A/25.2W	0.60A/16.8W	42%
PTU	A3	A3	1.5A/42W	1.29A/36W	1.59A/44.4W	106%

The above analysis indicates the "A3" circuit while PTU is being operated will be at 106 percent of its specification rating.

7.6.5.4 Effect of Design Modification During Turn-On

The insertion of the inrush network has a greater effect during camera turn-on when the camera demands a peak inrush current of about 3.1 amps for about 4 milliseconds duration. As the "A2" output can supply only 2/3 of 3.1 amps or 2.07 amps, the remainder of the inrush current of about 1.03 amps plus the inrush current (unknown) of the PTU must be supplied by the "A3" module. Further analysis could not be conducted due to non availability of PTU input characterization data.

7.6.5.5 Impact on PTU Operation

The NESC team was informed that at times the S1 PTU fails to tilt down. During these events, it will tilt up and it will pan left or right, but will not tilt down. The P1 PTU also experiences tilt failures at times, but no panning issues. Tilting does not require more current draw than panning, it appears these PTU anomalies are not related to the power supply shut downs because panning and tilting up functions would be similarly affected.

7.6.5.6 Possible Effect of A3 Failure of “A3” on “A2” and Vice Versa

Because of the inrush current network, as soon as one of the “A2” or “A3” power stages shuts down (for whatever reason), the closed loop control compensation of the other working unit is affected. It is possible that the working unit might become unstable and also shut down.

7.6.5.7 Possible Effect on Current Mode Control of TVCIC

The NESC team does not have a top level drawing of where the outputs are sensed after adding the “load balancing” resistors. Lacking this detail, the team assumed that sensing of these voltages (for feedback and overvoltage) is most likely before the resistors. This “sharing” of the inrush current could make for the possibility of interactive effects with the current signals that are fed into the current mode control.

7.6.5.8 Summary

From the foregoing analysis and discussion, the ETVCG shutdowns can be narrowed down to the following possible causes:

- Physical design and workmanship on the MDI converters.
- Marginal worst-case power converter design.

7.7 Circuit Diagram of MDI Unit, Electrical Loading, Input Characteristics, Thermal Environment

7.7.1 Input Power Limitations

The SCD that was in effect when the MDI unit was procured states the following information regarding limitations on the input power to the unit under five separate conditions. The “A” and “B” inputs are fed from separate RPCM switches. From SCD 10036714:

INPUT POWER THE POWER SUPPLY SHALL NOT EXCEED THE MAXIMUM STEADY STATE INPUT POWERS LISTED BELOW FOR THE VARIOUS OPERATING CONDITIONS.

DC TO DC CONVERTER “A”

1. NORMAL OPERATION	157 WATTS MAXIMUM
2. NO LOAD (ALL OUTPUTS)	21 WATTS MAXIMUM
3. “A2" AND "A3 OUTPUTS INHIBITED	50 WATTS MAXIMUM

DC TO DC CONVERTER “B”

4. NORMAL OPERATION	72 WATTS MAXIMUM
5. NO LOAD	10 WATTS MAXIMUM

7.7.2 Overvoltage Protection and Latching

The SCD that was in effect when the MDI unit was procured states the following information regarding the overvoltage protection and latching:

<u>OVER VOLTAGE PROTECTION (OVP)</u>
IN ACCORDANCE WITH 10032543, EXCEPT FOR THE FOLLOWING MODIFICATIONS;

A. AN OVER VOLTAGE CONDITION ON ANY OF THE “Al” OUTPUTS WILL LATCH ALL OF THE “A” OUTPUTS OFF. THE OUTPUTS SHALL BE RESET BY REMOVING AND REAPPLYING THE 120 VDC INPUT VOLTAGE.

B. AN OVER VOLTAGE CONDITION ON THE “A2” OUTPUT WILL LATCH THE “A2” OUTPUT OFF. THE “A2” OUTPUT SHALL BE RESET BY REMOVING AND REAPPLYING THE 120 VDC INPUT VOLTAGE.

C. AN OVER VOLTAGE CONDITION ON THE “A3” OUTPUT WILL LATCH THE “A3” OUTPUT 0FF.THE “A3” OUTPUT SHALL BE RESET BY REMOVING AND REAPPLYING THE 120 VDC INPUT VOLTAGE.

D. AN OVER VOLTAGE CONDITION ON THE “B” OUTPUT WILL LATCH THE “B” OUTPUT OFF. THE “A” OUTPUTS WILL NOT BE AFFECTED. THE “B” OUTPUT SHALL BE RESET BY REMOVING AND REAPPLYING THE 120 VDC INPUT VOLTAGE.

7.7.3 Reliability at 85°C

The SCD that was in effect when the MDI unit was procured states the following information regarding reliability:

RELIABILITY THE POWER SUPPLY SHALL HAVE A MINIMUM MTBF OF 1,000,000 HOURS WHEN OPERATED AT A WORST CASE HEAT SINK TEMPERATURE OF +85"C. THE FAILURE RATE SHALL BE PREDICTED IN ACCORDANCE WlTH MIL-STD-756 AND MIL-HDBK-217.

7.7.4 Output Characteristics

The SCD that was in effect when the MDI unit was procured includes the following table summarizing the output characteristics of the power supplies:

Table 7.7-1. Output Characteristics
[ref. Source Control Drawing, Power Supply, Type IV, GE Aerospace Drawing 10036714]

	POWER SUPPLY OUTPUTS						
	"A1" OUTPUTS				"A2"	"A3"	"B"
	+5.1VDC	-5.25VDC	+15VDC	-15VDC	+28VDC	+28VDC	+28VDC
MAXIMUM RATED LOAD (AMPS)	0.75	1.25	0.25	0.40	2.0	1.50	2.0
MINIMUM RATED LOAD (AMPS)	0.06	0.15	0.05	0.02	0.00	0.00	0.00
MAX OUTPUT SET VOLTAGE (VDC)	5.15	–5.30	15.15	–15.15	28.4	28.4	28.4
MIN OUTPUT SET VOLTAGE (VDC)	5.05	–5.20	14.85	–14.85	26.5	27.5	27.5
MAX OUTPUT RIPPLE/NOISE (mV)	50	50	100	100	400	200	400
MAXIMUM OUTPUT TRANSIENT	SEE 3.2.1.6.2						
LOAD REGULATION (mV MAX)	50	50	150	150	1100	200	400
LINE REGULATION (mV MAX)	25	25	25	25	150	150	150
TEMP COEFFICIENT (%/°C MAX)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CROSS REGULATION (% MAX)	1.0	1.0	1.0	1.0	1.0	1.0	NA
MAX OUTPUT VOLTAGE (VDC)	5.30	–5.45	15.40	–15.40	29.0	29.0	29.0
MIN OUTPUT VOLTAGE (VDC)	4.90	–5.05	14.60	–14.60	25.0	25.0	25.0
RECOMMENDED CHARACTERISTICS							
MAX LOAD CAPACITANCE (μF)	33.0	21.0	11.0	21.0	30.0	60.0	1.0
MAX FAULT CURRENT (AMPS)	5.0	3.0	1.5	1.5	3.0	3.0	3.0
MAX OVP TRIP VOLTAGE (VOLTS)	6.5	–6.5	16.5	–16.5	34.0	34.0	34.0

7.7.5 Verification Matrix

The SCD that was in effect when the MDI unit was procured includes the following table summarizing the verification method of the Type IV power supply: (It is noted that Overload/Short-Circuit & Overvoltage Protection Tests are called out as "DEMONSTRATE (OPTIONAL.")

Table 7.7-2. Verification Matrix
[ref. Source Control Drawing, Power Supply, Type IV, GE Aerospace Drawing 10036714]

REQUIREMENT PARAGRAPH	REQUIREMENT TITLE	VERIFICATION METHOD
3.0	REQUIREMENTS	NA
3.1	ITEM DEFINITION	DEMONSTRATION
3.2	CHARACTERISTICS	NA
3.2.1	ELECTRICAL PERFORMANCE	NA
3.2.1.1	GENERAL REQUIREMENTS	TEST
3.2.1.2	INPUT CHARACTERISTICS	NA
3.2.1.2.1	INPUT VOLTAGE	TEST
3.2.1.2.2	INPUT POWER	TEST
3.2.1.2.3	INPUT CAPACITANCE	TEST
3.2.1.3	OUTPUT CHARACTERISTICS	TEST
3.2.1.3.1	OUTPUT COMMON	TEST
3.2.1.4	PROTECTION CHARACTERISTICS	NA
3.2.1.4.1	OVERLOAD/SHORT–CIRCUIT PROTECTION	DEMONSTRATE (OPTIONAL)
3.2.1.4.2	UNDERVOLTAGE PROTECTION	TEST
3.2.1.4.3	NO–LOAD/UNDERLOAD PROTECTION	TEST
3.2.1.4.4	OVER VOLTAGE PROTECTION (OVP)	DEMONSTRATE (OPTIONAL)
3.2.1.5	CONTROL CHARACTERISTICS	NA
3.2.1.5.1	ON/OFF CONTROL	TEST
3.2.1.5.3	OUTPUT INHIBIT CONTROL	TEST
3.2.1.6	OTHER CHARACTERISTICS	NA
3.2.1.6.1	EFFICIENCY	TEST
3.2.1.6.2	INPUT VOLTAGE TRANSIENT RESPONSE	TEST
3.2.1.6.3	DELETED	
3.2.1.6.4	TEMPERATURE SENSOR	TEST

7.7.6 Verification Functional Block Diagram

The SCD that was in effect when the MDI unit was procured includes diagrammatic information of the Type IV power supply summarized in Figure 7.7-1.

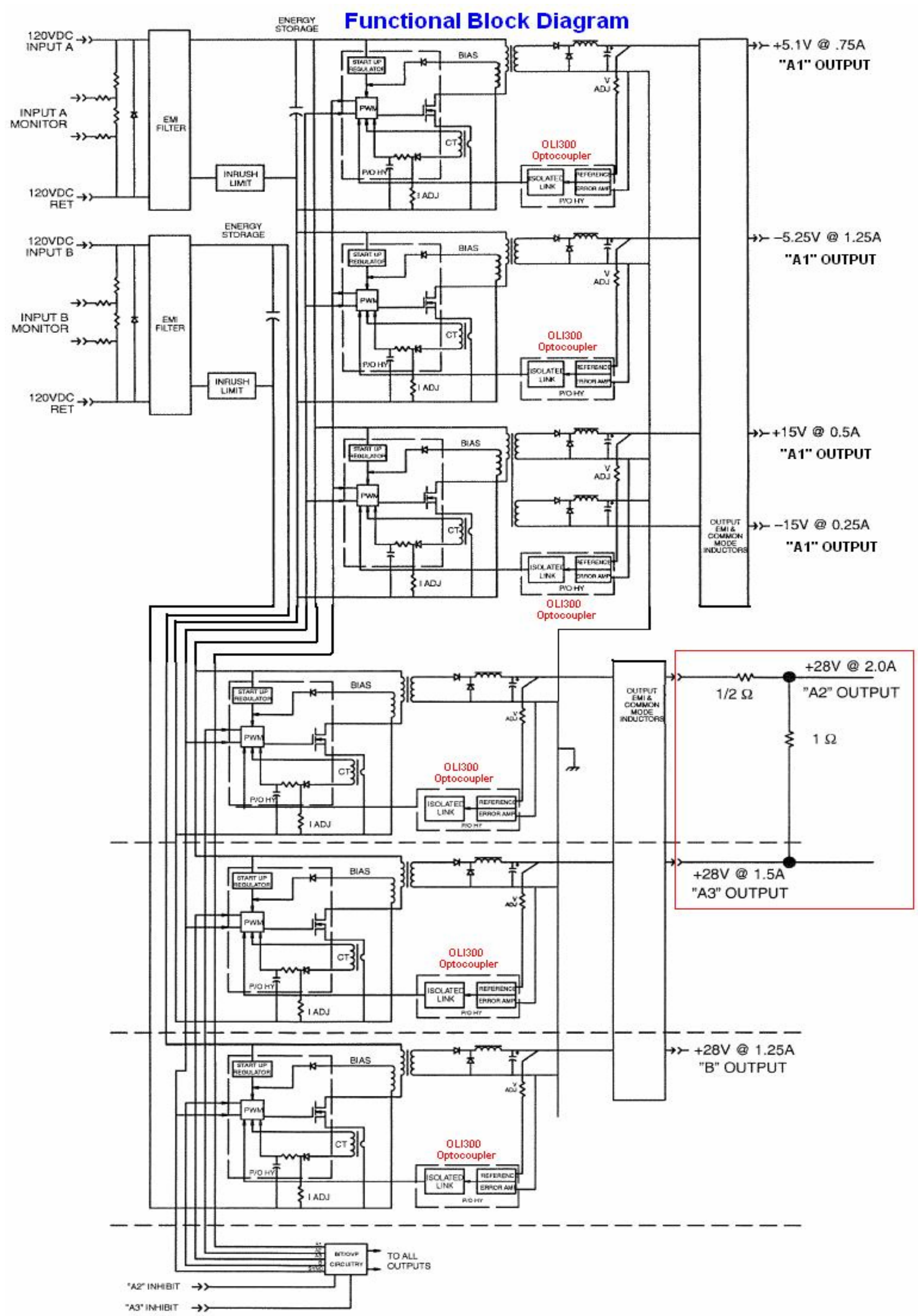

Figure 7.7-1. Functional Block Diagram - Type IV Supply
[ref. Source Control Drawing, Power Supply, Type IV, GE Aerospace Drawing 10036714]

7.8 Century Power Supply

7.8.1 Comparison of Design and Workmanship of Century and MDI Supplies

The MDI power converter design was in large part based on pre-existing MDI technology that was pieced together at the system level. The schematics that were provided to the NESC team show clear signs of this style of development. For example, the schematics show modular power section "blocks" of circuitry where, on one schematic sheet, reference designators are used three different times (one for each block).

The modular design concept is sometimes typical of commercially designed hardware, but it can lead to real problems when trying to ensure that assemblies are populated with the proper components (with three 'R3' resistors at the same mechanical level, this could prove difficult). This modular approach also creates invisible restrictions to the designer when a different component value is necessary to meet the requirements of a particular stage. The designer is either putting a component into the design that does not exactly match the intended mechanical footprint, or is forced to compromise the electrical design after succumbing to the project pressures of making the mechanical assembly look "neat."

The MDI PWB was poorly designed (e.g., turret terminals were used as interfacial connections without plated through holes). There is evidence that mechanical stresses were not considered carefully, since cracked solder joints were found. The MDI Type IV power supply assemblies had an average of 100 repairs per board (typically no more than 12 per board are allowed). Most of these repairs were to install "leashing" to ensure a proper electrical connection to the board. For details of the MDI workmanship evaluation, see Appendix C. Despite these issues, the Mean Time Before Failure (MTBF) for the ETVCG per specification is 7,500 hours. The observed failures have demonstrated an approximate MTBF of 10,400 hours based on five failures (USLab Group return address, tilt non-response, tilt telemetry problem, green channel loss, and power loss) in approximately 52,000 operating hours.

Detailed design and packaging documentation of even the smallest assemblies for Century Power Supply was provided. Review of it convinced the NESC team that the mechanical assembly of the power supply was relatively robust to withstand vibration loads. The Century design did not employ any hybrid components and was clearly documented. Review of the photographs of the Century power supply mechanical assemblies assure that the Century Power Supply is less likely to encounter workmanship problems similar to the MDI Power Supply.

7.8.2 Enhanced Output Ratings/Capability of Century Power Supply

To overcome the workmanship problems and design deficiencies associated with MDI TVCIC power supply, the Century power supply was developed and is being assessed here for its adequacy to meet the performance requirements.

The output characteristics of MDI power supply is provided in Table 7.8-1, whereas the Table 7.8-2 presents the output characteristics for the Century power supply. The salient points are compared in Table 7.8-3 to emphasize the superior characteristics of the Century power supply.

Table 7.8-1. MDI Power Supply Output Characteristics [ref. Source Control Drawing, Power Supply, Type IV, GE Aerospace Drawing 10036714]

REV LVL. L

TABLE I. OUTPUT CHARACTERISTICS

	POWER SUPPLY OUTPUTS						
	"A1" OUTPUTS				"A2"	"A3"	"B"
	+5.1VDC	-5.25VDC	+15VDC	-15VDC	+28VDC	+28VDC	+28VDC
MAXIMUM RATED LOAD (AMPS)	0.75	1.25	0.25	0.40	2.0	1.50	2.0
MINIMUM RATED LOAD (AMPS)	0.06	0.15	0.05	0.02	0.00	0.00	0.00
MAX OUTPUT SET VOLTAGE (VDC)	5.15	-5.30	15.15	-15.15	28.4	28.4	28.4
MIN OUTPUT SET VOLTAGE (VDC)	5.05	-5.20	14.85	-14.85	26.5	27.5	27.5
MAX OUTPUT RIPPLE/NOISE (mV)	50	50	100	100	400	200	400
MAXIMUM OUTPUT TRANSIENT	SEE 3.2.1.6.2						
LOAD REGULATION (mV MAX)	50	50	150	150	1100	200	400
LINE REGULATION (mV MAX)	25	25	25	25	150	150	150
TEMP COEFFICIENT (%/°C MAX)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CROSS REGULATION (% MAX)	1.0	1.0	1.0	1.0	1.0	1.0	NA
MAX OUTPUT VOLTAGE (VDC)	5.30	-5.45	15.40	-15.40	29.0	29.0	29.0
MIN OUTPUT VOLTAGE (VDC)	4.90	-5.05	14.60	-14.60	25.0	25.0	25.0

RECOMMENDED CHARACTERISTICS

MAX LOAD CAPACITANCE (μF)	33.0	21.0	11.0	21.0	30.0	60.0	1.0
MAX FAULT CURRENT (AMPS)	5.0	3.0	1.5	1.5	3.0	3.0	3.0
MAX OVP TRIP VOLTAGE (VOLTS)	6.5	-6.5	16.5	-16.5	34.0	34.0	34.0

SIZE	CAGE CODE	DWG NO	
A	11447	10036714	
SCALE	CONTRACT NO.		SHEET
NONE	MDSSC 87916005		9

Table 7.8-2. Century Power Supply Output Characteristics [ref. Source Control Drawing, Power Supply, Type IV, L3 Communications Drawing K10048295, Revision E]

DWG NO. K10048295 SH 21 REV E

TABLE I. OUTPUT CHARACTERISTICS

	POWER SUPPLY OUTPUTS						
	"A1" OUTPUTS				"A2"	"A3"	"B"
	+5.1VDC	-5.25VDC	+15VDC	-15VDC	+28VDC	+28VDC	+28VDC
MAXIMUM RATED LOAD (AMPS)	1.25	1.75	1.00	1.00	3.00 [1]	3.00	3.00
MINIMUM RATED LOAD (AMPS)	0.06	0.15	0.05	0.02	0.00	0.00	0.00
MAX OUTPUT SET VOLTAGE (VDC) [2]	5.15	-5.30	15.15	-15.15	28.4	28.4	28.4
MIN OUTPUT SET VOLTAGE (VDC) [2]	5.05	-5.20	14.85	-14.85	26.5	27.5	27.5
MAX OUTPUT RIPPLE/NOISE (mV p-p) [3]	50	50	100	100	400	400	400
MAXIMUM OUTPUT TRANSIENT	See 3.2.1.6.2						
LOAD REGULATION (+/-mV MAX)	50	50	150	150	1100	200	400
LINE REGULATION (+/-mV MAX)	25	25	25	25	150	150	150
TEMP COEFFICIENT (%/°C MAX)	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CROSS REGULATION (%MAX)	1.0	1.0	1.0	1.0	1.0	1.0	NA
MAX OUTPUT VOLTAGE (VDC)	5.30	-5.45	15.40	-15.40	29.0	29.0	29.0
MIN OUTPUT VOLTAGE (VDC)	4.90	-5.05	14.60	-14.60	25.0	25.0	25.0
MAX LOAD CAPACITANCE (µF)	50.0	50.0	25.0	50.0	100.0	60.0	1.0
MAX OVP TRIP VOLTAGE (VOLTS)	6.5	-6.5	16.5	-16.5	34.0	34.0	34.0

NOTES:

[1] LOAD HAS SWITCHED INPUT CURRENT SURGE OF 4.0 AMPS FOR 500 ms., 1.0s AFTER TURN-ON.

[2] INPUT VOLTAGE 120.0V

[3] EXCEPT FOR EM/EMC TESTING, MAX OUTPUT RIPPLE/NOISE SHALL BE MEASURED WITH A LOAD CAPACITANCE NO GREATER THAN 25% OF THE TABULATED MAX LOAD CAPACITANCE. EM/EMC TESTING SHALL USE A LOAD CAPACITANCE UP TO 100% OF THE MAX LOAD CAPACITANCE LISTED IN TABLE 1 FOR ALL MEASUREMENTS.

SIZE	CAGE CODE	DWG NO.	REV
A	11447	K10048295	E
SCALE: NONE		SHEET 21	

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FORM NO. 990808_CLS

Table 7.8-3. Power Requirements and Comparison of Output Characteristics of MDI and Century Power Supplies

ETVCG Component	Power sourced by	Actual Power requirement (Amps/Watts)	MDI Power Supply Capability (Amps/Watts)	Century Power Supply Capability (Amps/Watts)
Camera	A2 of TVCIC	Steadystate = 0.90A/25.2W (Measured)	Steadystate = 2A/56W	Steadystate = 3A/84W
		Peak = 3.1A/87W for 4 msec (Test)	Peak = 2.9 A/81 W	Peak = 4A/112 W for 500m sec
Pan-Tilt Unit (PTU)	A3 of TVCIC	Steadystate = 0.09A/2.5W (Specification)	Steadystate = 1.5A/42W	Steadystate = 3A/84W
		Peak = 1.30A/36W (Specification)	Peak = 1.5A/42W	Peak = 3A/84W

The overvoltage trip limits are the same for both power supplies, and the “A2” output capacitor has been increased to 100 µF (Century) compared to a value of 30 µF for the MDI power supply.

Referring to Century ATP data, the NESC team also asked if oscilloscope pictures taken of the power supply output voltages under no load condition. The tabular data provided gives the voltage readings taken using a meter which may not record the peak voltages. However, pictures were not available at the time of this report.

EMI Enclosures employed in Century power supplies are tin plated. This may pose a tin whisker growth concern.

8.0 Findings, Observations, and Recommendations

8.1 Findings

F-1. The MDI workmanship problems were severe, and the rework was extensive.

F-2. The types of MDI workmanship problems, if not 100 percent repaired, could result in an intermittent electrical connection within the power supply.

F-3. The shutdowns are most likely caused by the MDI power supply, rather than by external factors.

F-4. The failure signature (low current draw with TVCIC shutdown and reset upon power cycle) may be indicative of a real or false overvoltage shutdown (output overvoltage or overvoltage circuit fault) on any of the "A1" outputs.

F-5. The Century power supply is a robust design that is free from the issues that had been seen in the MDI units. Thorough attention to packaging and process control was evident in the detailed drawing package provided for review and should provide assurance against reoccurrence of workmanship issues similar to those experienced with the MDI supplies.

F-6. The EMI Enclosures employed in Century Power Supplies are tin plated. This may pose a tin whisker growth concern.

F-7. The MDI "A2" and "A3" output tie through resistors to accommodate the camera turn-on transient affects the load distribution. The NESC team has determined that there may potentially be a premature failure of the power supply that is unrelated to the current power supply shut downs. The concern is that the combined PTU and Camera inrush current requirements (presently unknown) may exceed the capability of the power supply (A3), thus overloading it and possibly causing premature failure.

8.2 Observations

O-1. Details of the bond wire fix in the MDI hybrid were not available for review. MDI power supplies are still utilized onboard the ISS, and some repair techniques are known to be less reliable than others.

O-2. The shut down of the "A3" output could impact the stability of the "A2" output due to the cross-tie and thus cause the shut down of the "A2" output. Malfunction of the "A2" low line inhibit circuit may also cause shutdown, but would not latch and be reset by power cycle.

8.3 Recommendations

R-1. Concur with JSC engineering's recommendation to replace MDI Type IV power supplies with Century units pending satisfactory resolution of R-2, R-3, and R-4. (F-1, F-2, F-3, F-4, F-5, F-6)

R-2. Test the Century power supply to verify that it can successfully provide the camera inrush current requirements of at least 3.1 amps for 4 milliseconds while maintaining the bus voltage specification requirement of 24 to 32 volts. (F-7)

R-3. Show by performing an analysis that the Century power supply as built now can successfully deliver the camera inrush current requirements of at least 3.1 amps for 4 milliseconds while maintaining the bus voltage specification requirement of 24 to 32 volts. (F-7)

R-4. Determine the potential effects of tin whisker growth on the tin plating of the EMI enclosure in the Century power supply. (F-6)

R-5. Perform a failure analysis on the returned TVCIC and ETVCG to determine the root cause of the shutdown failures. (F-1, F-2, F-3, F-4, F-5)

R-6. Electrically characterize the PTU input to determine if it reflects back large voltage spikes that would reduce the life of the power supply and to determine its inrush current profile. (F-7)

R-7. As a part of the failure analysis, determine if the MDI power supply output cross-tie to accommodate the camera inrush current causes out-of-specification loading of the outputs. (F-7)

R-8. Determine if A1, A2, and A3 power supply output overvoltage trip level settings are sufficient to preclude overstressing the ETVCG components. (F-4)

9.0 Alternate Viewpoints

No information presented in this report was disputed by any of the NESC team.

10.0 Other Deliverables

There are no other deliverables identified for this investigation.

11.0 Lessons Learned

Drawing conversion for this activity was cumbersome since the contractor used a format (Imagination) that is not widely used. Earlier access to drawing conversion software would have been beneficial.

12.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
Finding	A conclusion based on facts established during the assessment/inspection by the investigating authority.
Lessons Learned	Knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. A lesson must be significant in that it has real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or limits the potential for failures and mishaps, or reinforces a positive result.
Observation	A factor, event, or circumstance identified during the assessment/inspection that did not contribute to the problem, but if left uncorrected has the potential to cause a mishap, injury, or increase the severity should a mishap occur.
Problem	The subject of the independent technical assessment/inspection.

Recommendation — An action identified by the assessment/inspection team to correct a root cause or deficiency identified during the investigation. The recommendations may be used by the responsible C/P/P/O in the preparation of a corrective action plan.

Root Cause — Along a chain of events leading to a mishap or close call, the first causal action or failure to act that could have been controlled systemically either by policy/practice/procedure or individual adherence to policy/practice/procedure.

13.0 Acronyms List

Acronym	Definition
AWG	American Wire Gauge
BIT	Built in Test
C&TS	Communications and Tracking System
CCA	Circuit Card Assembly
CEI	Contract End Item
CI	Critical Item
CS	Communication Systems
CTVC	Color Television Cameras
DDCU	DC-to-DC converter unit
EMI	Electromagnetic Interference
EPC	Electronic Power Converter
EPS	Electrical Power System
ETVCG	External TV Camera Group
FET	Field Effect Transmitter
FO	Fiber Optic
FPMU	Floating Potential Measurement Unit
ga	Gauge
GSFC	Goddard Space Flight Center
Hz	Hertz
ICD	Interface Control Document
ICG	Inertial Center of Gravity
ISS	International Space Station
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LaRC	Langley Research Center
LLI	Limited Life Item

LOOB	Lower Outboard
MDA	McDonnell Douglas Aerospace
MDI	Modular Devices, Inc.
MII	Mechanical Installation Interface
MTBF	Mean Time Between Failure
MTBM	Mean Time Between Maintenance
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NDE	NESC Discipline Expert
NDI	Nodular Devices, Incorporated
NESC	NASA Engineering and Safety Center
NTSC	National Television System Committee
ORU	Orbital Replaceable Unit
OVP	Overvoltage Protection
PFM	Pulse Frequency Modulation
PRACA	Problem Reporting and Correction Action
PTU	Pan Tilt Unit
PWB	Printed Wiring Board
PWB	Pulse Width Modulator
RPC	Remote Power Converter
RPCM	Remote Power Control(ler) Module
SAW	Solar Wing Array
SCD	Source Control Drawing
SSD	Space Station Division
TBD	To Be Determined/To Be Defined
TIM	Technical Interchange Meeting
TV	Television
TVCIC	TV Camera Interface Converter
UDS	Utility Distribution System
μF	microfarad
ULF	Utilization Logistics flight
V	Volt
VDC	Volts Direct Current
VDS	Video Subsystem

14.0 References

Boornaard, A. “B1 Prime Item Development Specification External TV Camera Group (ETVCG), Document Number 10033124, Revision D,” Communications Systems, Camden, NJ, 2 May 1997.

Boornaard, A. “TVCIC Development Specification, Document Number 10033125, Revision D,” 20 February 1997.

“Certificate of Product Baseline #222023A,” Part Number 10033194-501, S/N 005.

Helvy, Dana and Boris Berezin. “Authorize Replacement of MDI Power Supplies in TVCIC (Television Camera Interface Converter) with Century Power Supplies,” 20 December 2005.

Heydman, William. “AOE 0473, TRC Power Supply Card Out of Spec,” 22 September 1999.

Heydman, William. “CR: AOE-0473 C&T, Type III and Type IV Power Supply Rework,” 8 November 1999.

“Schematic Diagram Power Supply,” GE Type IV, MDI Drawing 2696-02.

“Source Control Drawing, Power Supply, Type IV,” GE Aerospace Drawing 10036714.

“Source Control Drawing, Power Supply, Type IV,” L3 Communications Drawing K10048295, Revision E.

Volume II: Appendices

Appendix A. NESC Request Form (PR-003-FM-01)

NASA Engineering and Safety Center
Request Form

Submit this ITA/I Request, with associated artifacts attached, to: nrbexecsec@nasa.gov, or to NRB Executive Secretary, M/S 105, NASA Langley Research Center, Hampton, VA 23681

Section 1: NESC Review Board (NRB) Executive Secretary Record of Receipt		
Received (mm/dd/yyyy h:mm am/pm) 1/3/2006 12:00 AM	Status: New	Reference #: 06-001-E
Initiator Name: Susan Creasy	E-mail: susan.l.creasy@nasa.gov	Center: JSC
Phone: (281)-244-7661, Ext _____	Mail Stop:	
Short Title: ISS External TV Camera Shutdown Investigation		
Description: To: John McManamen John, we have a problem with the onboard ETVCGs that is thought to be due to a TVCIC MDI power supply workmanship problem. The S1 ETVCG was installed on 9A and the TVCIC failre signature is that it shuts down up to 2 times per hour the second failure is withthe P1 ETVCG which was launched on 11A but was just installed in November 2005. It has had 9. Shut downs in the last month. We are getting ready to fly two more, one on ULF 1.1 and one on 12A.1. The one on ULF 1.1 supports the FPMMU and the one on 12A.1 is to support the P1 camera which is needed for truss installation and SAW viewing at 13A. There is a Century power supply that has already been built that will be used on future spares. Per the fault tree we think that the MDI power supply is the cause and are evaluating replacing this with the century one. We have a short fuse to get this done to meet flight dates, and took story to Suffredini today. He asked is to get a second opinion and suggested NESC. Can you support reviewing our fault tree in January and give us a second opinion? Thanks. Susan Creasy		
Source (e.g. email, phone call, posted on web): email		
Type of Request: Assessment		
Proposed Need Date:		
Date forwarded to Systems Engineering Office (SEO): (mm/dd/yyyy h:mm am/pm):		
Section 2: Systems Engineering Office Screening		
Section 2.1 Potential ITA/I Identification		
Received by SEO: (mm/dd/yyyy h:mm am/pm): 1/3/2006 12:00 AM		
Potential ITA/I candidate? ☐Yes ☐ No		
Assigned Initial Evaluator (IE): Bob Kichak		
Date assigned (mm/dd/yyyy): 1/4/2006		
Due date for ITA/I Screening (mm/dd/yyyy):		
Section 2.2 Non-ITA/I Action		
Requires additional NESC action (non-ITA/I)? ☐Yes ☐ No		
If yes:		
Description of action:		
Actionee:		
Is follow-up required? ☐Yes ☐ No If yes: Due Date:		
Follow-up status/date:		
If no:		

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NESC Director Concurrence (signature):
Request closure date:
Section 3: Initial Evaluation
Received by IE: (mm/dd/yyyy h:mm am/pm): 1/3/06
Screening complete date:
Valid ITA/I candidate? ☐Yes ☐ No
Initial Evaluation Report #: NESC-PN-
Target NRB Review Date:
Section 4: NRB Review and Disposition of NCE Response Report
ITA/I Approved: ☐Yes ☐ No | Date Approved: | Priority: - Select -
ITA/I Lead: , Phone ( ) - , x
Section 5: ITA/I Lead Planning, Conduct, and Reporting
Plan Development Start Date:
ITA/I Plan # NESC-PL-
Plan Approval Date:
ITA/I Start Date | Planned: | Actual:
ITA/I Completed Date:
ITA/I Final Report #: NESC-PN-
ITA/I Briefing Package #: NESC-PN-
Follow-up Required? ☐Yes ☐ No
Section 6: Follow-up
Date Findings Briefed to Customer:
Follow-up Accepted: ☐Yes ☐ No
Follow-up Completed Date:
Follow-up Report #: NESC-RP-
Section 7: Disposition and Notification
Notification type: - Select - | Details:
Date of Notification:
Final Disposition: - Select -
Rationale for Disposition:
Close Out Review Date:

NESC Request Form
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Form Approval and Document Revision History

Approved: ____________________ ________
NESC Director Date

Version	Description of Revision	Office of Primary Responsibility	Effective Date
1.0	Initial Release	Principal Engineers Office	29 Jan 04

Appendix B. Rough Calculations of Start-Up Circuit "Reasonable" Worst-Case

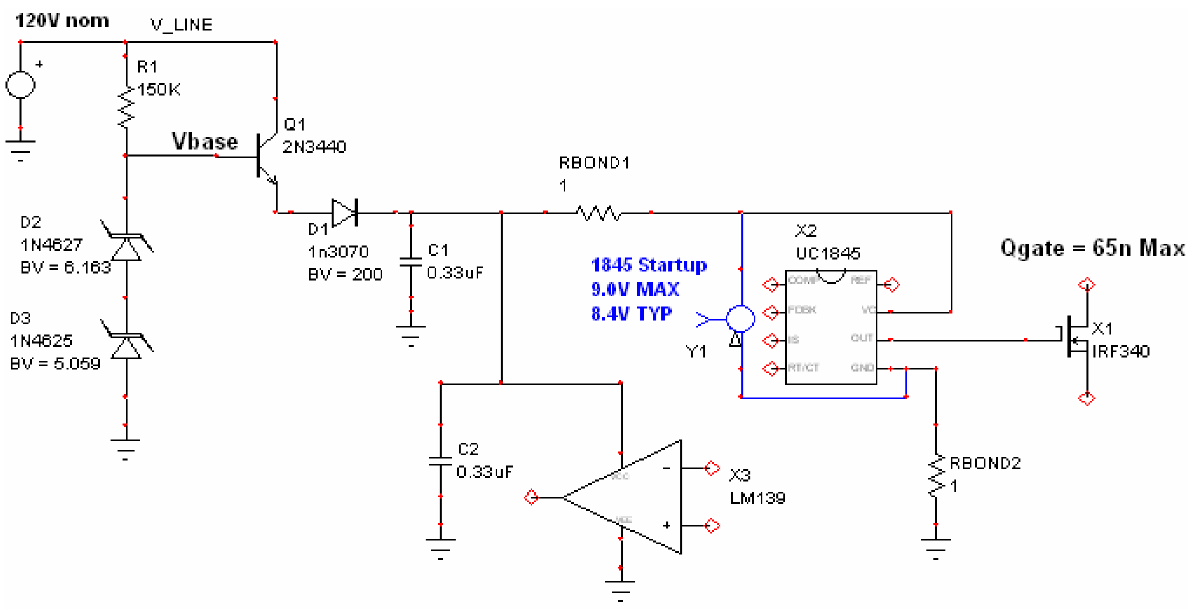

Figure 1. Simplified Schematic of Start-Up Circuit

Zener Diode Voltages:

Zener Diode Voltages (variables Vz(T), Vz(Iz), Initial tolerance, radiation effects*)

Minimum voltages considering 5% Initial Tolerance on ZENERs only

$$\textbf{V\_D2min} := 6.2\text{V}\cdot 0.95$$

$$\textbf{V\_D2min} = 5.89\ \textbf{V}$$

$$\textbf{V\_D3min} := 5.1\text{V}\cdot 0.95$$

$$\textbf{V\_D3min} = 4.845\ \textbf{V}$$

*** Factors that would reduce Vbase voltage further:**
Vz is a function of Iz (Lower Iz --> lower Vz)
Iz is dependant on base current into Q1 - Depends on Beta of Q1 (temperature and Ic dependant)

Vz is dependant on temperature of Zeners (Temperature compensated so dependence not that strong)
Radiation effects on zener voltage directly and Radiation degradation of the Beta of Q1

Conservatively using only initial tolerance contribution:

$$\mathbf{Vbasemin} = 10.735\mathbf{V}$$

$$\mathbf{Vbasemin} := \mathbf{V\_D2min} + \mathbf{V\_D3min}$$

Roughly speaking the draw on the HK supply is approximately 20mA; with Q1 Betamin = 40 the circuit will require 0.5mA. This will leave the Zeners with less than 250uA at nominal input voltage (at low line the current would decrease further).

At low line with R1 running at high end of 5% tolerance (assumed):

$$\mathbf{Vlowline} := 111\mathbf{V} \qquad \mathbf{Izener} := \left(\frac{\mathbf{Vlowline}}{1.05 \cdot 150 \cdot \mathbf{K\Omega}}\right) - 0.5 \cdot 10^{-3}\mathbf{A} \qquad \mathbf{Izener} = 2.048 \times 10^{-4}\ \mathbf{A}$$

This current is below the datasheet current Izt where the zener voltages are specified (250uA).

Diode CR3 Forward Voltage:

There is little data available for the 1N3070 Diode, so use what data is available and use data on similar parts to extrapolate for more precise voltage drop.

This part is classified as a switching diode. Not sure why this choice was made for the MDI hybrid (possibly cost or availability). The switching diode data is not easy to come by since it is usually only used for non-critical switching or diode or-ing of signals.

The forward drop for the 1N3070 in two different datasheets: **1.0V @100mA (25 degC)**

Table 1. Microsemi Data for 1N3070

DC ELECTRICAL CHARACTERISTICS

V_F				I_R				V_{BR}			
Ambient (°C)	I_F mA	Min V	Max V	Ambient (°C)	V (dc)	Min µA	Max µA	Ambient (°C)	I_R µA	Min V	Max V
25	100	-	1.0	25	175	-	0.1	25	100	200	-
-55	100	-	1.2	150	175	-	100				

Extrapolating for lower forward current from similar diode data:

Vf drops by approximately 0.1V when current changes from 100mA to 10mA
Obviously at cold temperatures the forward voltage goes up. For rough worst case number can use **Vfd1max = 0.9V @25 degC** (slightly higher at cold temps)

Vbe Calculation for Q1:

Vfd1max:= 0.9V

Have data for Vbe under saturated conditions for 2N3440, need better data for our case.

Table 2. Boca Semiconductor Data for 2N3439

This Vbe is for overdriven BJT, at a higher base current than our case at 25 ºC. Looking at

ON CHARACTERISTICS(1)

DC Current Gain		h_{FE}			—
(I_C = 2.0 mAdc, V_{CE} = 10 Vdc)	2N3439		30	—	
*(I_C = 20 mAdc, V_{CE} = 10 Vdc)	2N3439, 2N3440		40	160	
*(I_C = 50 mAdc, V_{CE} = 10 Vdc)	2N5415		30	150	
	2N5416		30	120	
Collector-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 4.0 mAdc)	2N3439, 2N3440	$V_{CE(sat)}$	—	0.5	Vdc
Base-Emitter Saturation Voltage (I_C = 50 mAdc, I_B = 4.0 mAdc)	2N3439, 2N3440	$V_{BE(sat)}$	—	1.3	Vdc

curves for Vbe in active region vs. saturation and lower current levels, we can assume that the Vbemax on Q1 is probably no more than 1.0V maximum.

Vbeq1max:= 1.0V

MOSFET Drive Current:

IRFC340 drive current: Maximum gate charge of 65nC per cycle (if this was shared equally from two 0.33uF caps would correspond to approximately 0.1V droop on HK supply.

Assume 1845 switching frequency:

$$\mathbf{fswitching} := 200 \cdot 10^{3}\,\mathbf{Hz}$$

$$\mathbf{Idrivemax} := \mathbf{fswitching} \cdot 65 \cdot 10^{-9}\,\mathbf{coul}$$

$$\mathbf{Idrivemax} = 0.013\,\mathbf{A}$$

$$\mathbf{Ibiasmaxstart} := \mathbf{Idrivemax} + \mathbf{0.017\,A}$$

$$\mathbf{Ibiasmaxstart} = 0.03\,\mathbf{A}$$

Bonding Wire Drops on Hybrid:

Bonding Wire Resistance: The chart below gives rough order of magnitude.

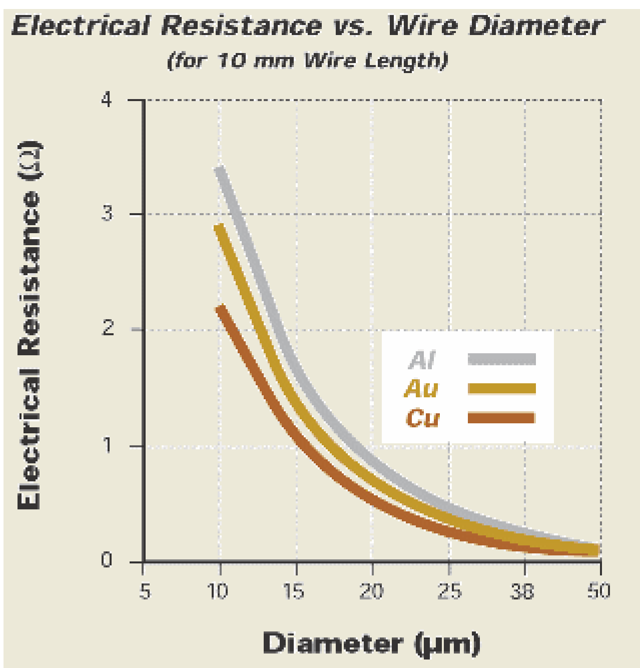

Figure 2. Electrical Resistance vs. Wire Diameter

MDI schematic has two connections each for the Vc and GND connections to the 1845 Die. This was likely to reduce the effects of bonding wire resistance for this current path (17mA to bias 1845 plus the current to drive the IRFC340 FET on/off; approximately 10+ mA, see above calculation).

The bonding wire resistance and any voltage drops on the bond itself could be very important in ensuring adequate margin over the full operational range. Two such bond wires are highlighted in the below schematic, other points in the circuit (that are not shown) are at least as important in calculating a solid worst case analysis.

Conservatively only consider the two bonding wire connections that go to the supply and ground connections of the 1845 PWM die:

Assume that since MDI doubled up the supply lines to and from the 1845 that the total resistance was no more than 0.7Ohms for supply and 0.7Ohms for Ground connections.

$$\mathbf{Rbond1} := \mathbf{0.7ohm}$$

$$\mathbf{Rbond2} := \mathbf{0.7ohm}$$

$$\mathbf{Vbond1} := \mathbf{Rbond1} \cdot \mathbf{Ibiasmaxstar}$$

$$\mathbf{Vbond1} = 0.021\,\mathbf{V}$$

$$\mathbf{Vbond2} := \mathbf{Rbond2} \cdot \mathbf{Ibiasmaxstar}$$

$$\mathbf{Vbond2} = 0.021\,\mathbf{V}$$

The voltage drop due to the bonding wires to the 1845 is not that large (based on loose assumptions). It is pretty clear that there are opportunities for other voltage drops within the hybrid circuit that could (in sum total) create a significant impact.

Final Summary of Start-Up Voltage to 1845:

$$\mathbf{Nominal\_WC\_StartUP} := \mathbf{Vbasemin} - \mathbf{Vbond1} - \mathbf{Vbond2} - \mathbf{Vfd1max} - \mathbf{Vbeq1ma}$$

Calculated "Reasonable" Worst Case startup voltage:

$$\mathbf{Nominal\_WC\_StartUP} = 8.793\,\mathbf{V}$$

Datasheet values: Specified Maximum startup voltage for 1845: **9.0V**
Specified Nominal Startup voltage for 1845: **8.4V**

A few of the factors ignored in the final number:

Temperature Effects
Radiation Effects
Zener Voltage not adjusted for lower bias current levels (low line especially)

In Defense of this Circuit:

It is not clear what the startup current from this supply would actually be. The datasheet for the 1845 talks about the startup current in the highlights but does not describe when the controller would begin switching, or if the "start-up" voltage gets "latched" and will not cutout until the voltage drops below the minimum.

PWM ICs are a mixture of analog circuits and "digital" control. There has been a wide variation from vendor to vendor, and across parts. If it is not specified explicitly in the datasheet, it is difficult to accept at face value.

Appendix C. MDI Workmanship Summary (Larry Pack)

NESC, ISS External Camera Shutdown Assessment.

Based on the documentation I have reviewed, the discussions with those involved in analyzing the shutdown signature, descriptions of the rework, and historical knowledge of packaging design and manufacturing practices for space flight hardware, I agree with Susan Creasy's concerns expressed in NESC Technical Assessment Plan, #PL-06-04. My conclusion is that there is significant risk associated with the use of the MDI power supplies in the ISS External Camera systems. I believe the probability is very high that TVCIC failures, similar to the ones experienced on the ETVCG's, will occur in the other TVCIC's. It is my recommendation that the MDI TVCIC's be replaced with proven reliable power systems from qualified vendors. However, all aspects of the replacement units including the electrical design, packaging design, manufacturing process, workmanship, and testing results must be confirmed to meet requirements prior to acceptance for replacement. My assessments are based on the following information.

Summary of My MDI PS Assessment:

MDI Power Supply delivery;

1. MDI Power Supply deliveries completed 12/1994 (14 Flight Units).

MDI Power Supply failures discovered approximately 8/97;

1. L3 Communication Systems and Modular Devices Inc. started reworking failed units late 1997-early 1998.

Signature of failures (per NESC/TAC #PL-06-04);

1. TVCIC from S1 ETVCG shuts down 2 times per hour
2. TVCIC from P1 ETVCG (installed 11/05) shut down 9 times in 1 month.

Suspected cause/reason for failures (as expressed in NESC/TAC #PL-06-04);

1. Packaging design and workmanship in the MDI power supply assembly is suspected of contributing to the cause/reason for the failures*.

* While there may be other suspected causes/reasons for the MDI Power supply failures under investigation, such as parts degradation due to radiation exposure or the electrical design, this assessment addresses only packaging and workmanship related failures.

<u>Brief summary description of documented workmanship problems suspected of contributing to the MDI Power Supply failures (per Will Heydon's CR: AOE-0473, dated 11/8/99);</u>

1. Broken capacitor leads due to mechanical stress.
2. Failed FET bond wires within hybrid due to electrical overstress (fused open).
3. Fractured solder joints on swaged terminals due to poor PWB design/layout. Swaged terminals installed in un-plated through holes, insufficient solder, and dissimilar materials. Swaged terminals were reworked with leash wires. Leash wires are considered repairs rather than rework. Generally, a flight board is limited to 24 repairs per 100 square inches. While it is desirable to use plated-through holes for terminals, they are routinely used in plated-through and non-plated-through holes, However, terminals should never be used as electrical interfaces without plated through holes (NHB 5300.4(3A-2)(3A501.1.a), NASA-STD-8739.3(8.2.1.b).
4. Fractured solder joints on transformer pins due to poor PWB design/layout, installation in un-plated through holes, poor solder wetting, and dissimilar materials. The Quality Assurance recommended practice for terminating discrete wires is to use terminals rather than pads on the PWB surface or holes through the PWB, provided there is sufficient room for the terminals. This method of terminating ensures inspectable solder joints and strain relieved wires. Discrete wires may be soldered directly to the PWB provided the wires are properly routed and fanned, with sufficient strain relief.
5. Missing failure reports, undocumented rework, missing and incomplete travelers, missing test data, missing in-process inspections.
6. Wiring errors discovered in Type IV supplies.
7. Blown rack fuse occurred during thermal testing (+/- 5V).
8. Blown rack fuse occurred during OVP testing.
9. 2 swaged terminal life tests failed 10/29/98.
10. Rework of transformer caused cracks in 2oz and 4oz copper traces. Leash repair of all pins and terminals completed.
11. Extensive rework performed to correct these problems (at least 2,530 repairs, added wires, reworks, and touch-ups). Generally, a flight board is limited to 24 repairs per 100 square inches.

Appendix D. MDI Repair/Rework Discussion

From: Cooke, Robert W. (JSC-NA)[WGI] [mailto:robert.w.cooke@nasa.gov]
Sent: Wednesday, May 24, 2006 10:14 AM
To: Kichak, Robert A. (GSFC-560.0)[NASHQ]; Young, Eric M. (GSFC-563.0); Pack, Larry E. (GSFC-562.0); eric.a.obleman@boeing.com; Berezin, Boris J; cpandipa@pop400.gsfc.nasa.gov; DANA HELVY
Subject: FW: ISS Camera Power Supply Questions

Fyi…

A point of clarification is recommended. The "leashes" installed in the MDI units are technically considered modifications, rather than repairs.

The accepted practice is to limit the total number of modifications to a printed circuit assembly to three (3) per 25 cm^2 (3.875 in^2) area, per side. This equates to a maximum of 12 per 100cm^2.

For the leash modifications performed on the MDI units, a MUA was issued to allow the greater number.

Bob

From: Cooke, Robert W. (JSC-NX)[WGI]
Sent: Thursday, February 02, 2006 9:50 AM
To: Kichak, Robert A. (GSFC-560.0)[NASHQ]
Subject: ISS Camera Power Supply Questions

Bob,

Some things to consider:

The L-3 documents indicate that approximately 100-120 solder terminations involving swaged turret terminals used as interfacial electrical interconnects in non-plated through holes (NPTH) were repaired per board. The reported number of repairs per board greatly exceeds NASA and industry recognized allowances, and is a significant reliability concern even if each repair was completed successfully. There is a significant risk of thermal and mechanical stress to the circuit board, and there is the possibility that the repair process may have missed some components.

Most board-level repair activity requires the technician to work to a red-lined drawing that identifies each component affected and the required repair action. The technician may also use this print or other document(s) to verify that each repair has been completed and inspected. This process works, assuming all the targeted components are clearly identified on the print and the technician accurately accounts for and documents each repair. The concerns are:

1. The reported number of repairs per board and the use of manual repair processes presents a significant risk that one or more identified repairs may have been overlooked or incorrectly identified as having been repaired.

2. The reported number of repairs per board and the component density of the board increases the possibility that one or more of the terminals requiring repair may not been identified on the print. Repair activities are limited to only those areas identified in the documentation.

3. The component density of the board, combined by the number of repairs and schedule pressure would also increase the possibility that the technician may not have been able to identify components that were not identified by the design engineer and the redlined print as requiring repair. If the print did not identify a component as requiring repair, and the technician was unable to identify that component as having been missed on the print but requiring repair, then the possibility exists that the same component was not repaired on ALL the assemblies. This would then represent a reliability concern common to all the circuit boards processed for repair.

4. The risk of thermal and mechanical damage to the printed wiring board and surrounding components can be reduced, and reliability of the repair can be increased, by the use of preheat during repair activities. There has been no confirmation that preheat was used during the repair process.

Questions:

1. What process was used to originally solder assemble the boards?
2. Were the terminals originally soldered with high-temperature solder?
3. Was preheat used during manual assembly and/or repair activities?

The failure timeline and signature is also characteristic of the failure mode typically seen in surface mount technology (SMT) ceramic chip capacitors that were manually soldered. We need to verify the soldering processes used for any SMT components.

Bob

Appendix E. PRACA Reports

ISS Problem Report: 550 ECD: 23-JUL-1998 PPD: N/A Level: 2 PR Status: CN

PR Last Update Date: 05-JUN-2000 PR Last Update By: WOLF, MARCY

Problem Identification Information

PR Release Date:	17-JUN-1998
Problem Title:	Power Supply Values Not to Spec

Initiator's Information

Initiator's Name (first name last name):	NATE BARR
Initiating Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Initiator's Telephone Number:	714 896-3311 X67547
Initiator's E-mail:	

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	CINDY ARIAS
Assigned Engineer's Telephone Number:	
Assigned Engineer's Email Address:	
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Responsible SPRT:	

Nonconformance (NCR) Information

Nonconforming Part Name:	TV CAMR INTERFACE CONV
Nonconforming Part Number:	10033211-502
Part Serial/Lot Number:	S/N 001
Nonconforming Article (NCA) Name:	
NCA Part Number:	
NCA Serial/Lot Number:	
NCR Number:	SSF042 L3 (dup)
Hardware Level:	SRU - Shop Replacement Unit (SRU)
Fracture Critical Indicator:	
Detected Date:	30-JUL-1997
Manufacturer's Name:	GENERAL ELECTRIC CO
Manufacturer's Cage Code:	49671
Detected During:	AT-0199
Site Location:	Boeing_HB - Boeing - Huntington Beach Work Center
Waiver/Deviation Number:	

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ISS Problem Report: 550 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

Trending Data

Prevailing Condition Category:	
Test Operation Code:	TAS - Testing -> Acceptance Test -> Subsequent Unit
PRACA Failure Mode Code:	EGS - Electrical -> General -> Not To Spec
Defect Code:	X - No Defect Applicable
Material Code:	ECQ - Electrical/Electronic Part -> Component -> Eee Part / Capacitor, Connector, Transistor, Diodes, Resistors, Ics Etc
Cause Code:	MI - Manufacturing/Maintenance -> Instructions, Planning, Or Procedures
Recurrence Control Code:	

FMEA Data

FMEA Number:

FMEA Criticality Category:

Reportable Problem Description:

****** 23-JUL-98 12:39:57 C..ARIAS(Boeing_HB)
****** 17-JUN-98 09:03:45 J..BURKS(Boeing_HB) During AT-0199, Integration and Test, while running AT-102, several of the power supply values were not to spec. Some of these values were measured at the test connector and other directly at the output. The 28V heater power supply was the most important of these. It remained at 0 volts throughout the test. Other power supply measurements were either out of spec or were not present at the test connector. When At-0115, the test connector data test, was run, it showed that all but the heater power supply were operating properly. The test connector data also showed that the pan/tilt potentiometer voltage did not vary with potentiometer movement. The reference voltage was not present at the PTU simulator +10REF pin. The test connector program showed the proper referfence voltage. There was no optical output from the box when checked. The test connector program also showed that the Status Telemetry Module (STM) had problems locking up to the incoming video.

Investigation and Analysis Summary:

****** 23-JUL-98 12:39:57 C..ARIAS(Boeing_HB)
IT HAS BEEN DETERMINED THIS IS NOT A REPORTABLE PROBLEM REFERENCE ORU LIST DATED 6/25/98 CINDY ARIAS A3-796 A3/J054 7/23/98

Root Cause Statement:

Recurrence Control Corrective Action Data:

MRB Disposition MRB Required: N

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 2 of 4

ISS Problem Report: 550 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
9A	C		30-JUN-1999

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 3 of 4

ISS Problem Report: 550 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

Closure Signatures	PR Close Date:	23-JUL-1998	PR Status:	CN - Closed - Not a Reportable Problem

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP S&MA	Accept	ARIAS, CINDY	23-Jul-98

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 4 of 4

ISS Problem Report: 552 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

PR Last Update Date:	PR Last Update By:

Problem Identification Information

PR Release Date:	17-JUN-1998
Problem Title:	Type IV Power Supply Failure

Initiator's Information

Initiator's Name (first name last name):	NATE BARR
Initiating Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Initiator's Telephone Number:	714 896-3311 X67547
Initiator's E-mail:	

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	CINDY ARIAS
Assigned Engineer's Telephone Number:	
Assigned Engineer's Email Address:	
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Responsible SPRT:	

Nonconformance (NCR) Information

Nonconforming Part Name:	TVCIC
Nonconforming Part Number:	10033211-502
Part Serial/Lot Number:	S/N 001
Nonconforming Article (NCA) Name:	
NCA Part Number:	
NCA Serial/Lot Number:	
NCR Number:	SSF045 L3
Hardware Level:	SRU - Shop Replacement Unit (SRU)
Fracture Critical Indicator:	
Detected Date:	02-AUG-1997
Manufacturer's Name:	GENERAL ELECTRIC CO
Manufacturer's Cage Code:	49671
Detected During:	PRE-INTEGRATION TEST
Site Location:	Boeing_HB - Boeing - Huntington Beach Work Center
Waiver/Deviation Number:	

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 1 of 4

ISS Problem Report: 552 ECD: 23-JUL-1998 PPD: N/A Level: 2 PR Status: CN

Trending Data

Prevailing Condition Category:	
Test Operation Code:	TAS - Testing -> Acceptance Test -> Subsequent Unit
PRACA Failure Mode Code:	ECS - Electrical -> Continuity/Path -> Short / Low Resistance / Low Voltage / High Current
Defect Code:	X - No Defect Applicable
Material Code:	ECT - Electrical/Electronic Part -> Component -> Electrical Circuit Element(S) - No More Specific Classification
Cause Code:	TEE - Testing -> Exceeding Test Environmental Conditions (Not Contamination) -> Externally Induced Testing
Recurrence Control Code:	HNB - Hardware -> No Recurrence Control -> Scrap

FMEA Data

FMEA Number:
FMEA Criticality Category:

Reportable Problem Description:

****** 23-JUL-98 15:24:15 C..ARIAS(Boeing_HB)
****** 17-JUN-98 09:17:10 J..BURKS(Boeing_HB) During a pre-integration test of the External Television Camera Group, a failure occurred in the Type IV Power Supply installed in the TVCIC. At the time the failure occurred, a possible PTU limit switch error was being investigated at the interface between the Color Television Camera SN/402 and the Pan Tilt Unit SN/001. Although no inadvertent shorting of pins occurred, neither the shorting together of any two or more pins nor the shorting of any power supply pin to ground could have caused this problem. The power supply is short circuit protected. Additional checks were made to ensure that the failure was an isolated incident related to the power supply itself. The 28 VDC inputs to the camera were checked for shorts to its return and to chassis ground. No shorts existed. No light power was applied to the ETVCG when the failure occurred so a short to the 120VDC lines for the light could not have caused the problem. The 120 VDC light returns are isolated fromanything in the TVCIC. The pan tilt unit was removed fromthe TVCIC and power was re-applied to the TVCIC to check the powr supply without the PTU attached. The power supply A2 output voltage measured 0 VDC. All other Type IV power supply outputs were normal. Since no shorts exist and the only item the power supply was attached to was the CTVC, the power supply was replaced. When 120 VDC input power was applied all power supply outputs were normal. The CTVC operated properly for several hours with no other power problems. Since the Type IV power supply is manufactured by Modular Devices, failure isolation and analysis must be performed by them. (J. Burks 6/17/98)

Investigation and Analysis Summary:

****** 23-JUL-98 15:24:15 C..ARIAS(Boeing_HB)
HAS BEEN DETERMINED NOT TO BE A REPORTABLE PROBLEM REFERENCE ORU LIST DATED 6/25/98 CINDY ARIAS A3-J054 7/23/98

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 2 of 4

ISS Problem Report: 552 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

Root Cause Statement:

Recurrence Control Corrective Action Data:

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
9A	C		30-JUN-1999

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 3 of 4

ISS Problem Report: 552 **ECD: 23-JUL-1998** **PPD: N/A** **Level: 2** **PR Status: CN**

Closure Signatures	PR Close Date:	23-JUL-1998	PR Status:	CN - Closed - Not a Reportable Problem

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP S&MA	Accept	ARIAS, CINDY	23-Jul-98

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 1 / 1 Concurrences 0 / 0 Page 4 of 4

ISS Problem Report: 731 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

PR Last Update Date: 05-JUN-2000 PR Last Update By: Bucci, Paul

Problem Identification Information

PR Release Date:	07-AUG-1998
Problem Title:	External Video Switch Type III Power Supply Unexpectantly Shut Down

Initiator's Information

Initiator's Name (first name last name):	JEANNIE BURKS
Initiating Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Initiator's Telephone Number:	714 896-3311 X70812
Initiator's E-mail:	

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Derek Huang
Assigned Engineer's Telephone Number:	(714) 372-1765
Assigned Engineer's Email Address:	derek.d.huang@boeing.com
Flight Element Code:	ITA_S0 - INTEGRATED TRUSS ASSEMBLY S0
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Responsible SPRT:	

Nonconformance (NCR) Information

Nonconforming Part Name:	EXTERNAL VIDEO SWITCH
Nonconforming Part Number:	10033180-502
Part Serial/Lot Number:	001
Nonconforming Article (NCA) Name:	Type III Power Supply
NCA Part Number:	10036713-1
NCA Serial/Lot Number:	2001
NCR Number:	SSF067
Hardware Level:	ORU - Orbital Replacement Unit (ORU)
Fracture Critical Indicator:	N
Detected Date:	15-SEP-1997
Manufacturer's Name:	L-3 COMMUNICATIONS CORP/COMMUNICATION SYSTEMS EAST
Manufacturer's Cage Code:	11447
Detected During:	AT-0010
Site Location:	L3_COMM - L3 Communications - Camden, NJ
Waiver/Deviation Number:	N/A

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 1 of 4

ISS Problem Report: 731 ECD: 05-JUN-2000 PPD: N/A Level: 2 PR Status: C

Trending Data

Prevailing Condition Category:	F - Functional test or use
Test Operation Code:	TAS - Testing -> Acceptance Test -> Subsequent Unit
PRACA Failure Mode Code:	EOP - Electrical -> Output -> Premature Inadvertent Output (Operation) Or Shutdown
Defect Code:	EASC - Electrical -> Assembly And Installation -> Solder -> Improper Solder Coating
Material Code:	MSS - Electro Mechanical Part -> Solder -> Defective Solder Material
Cause Code:	MW - Manufacturing/Maintenance -> Workmanship
Recurrence Control Code:	CF - Change Process Or Procedure -> Manufacturing (Fabrication)

FMEA Data

FMEA Number:	CTS-SOVSWE-01
FMEA Criticality Category:	2R - Redundant item failures causing loss of mission support

Reportable Problem Description:

During AT-0010, Vibration Test, the External Video Switch (VSW) Type III Power Supply shut itself down prematurely. The 120 VDC Test Power Supply (HP6010A), which supplied input voltage to the VSW Type III Power Supply via VSW Breakout Box, still read 120 VDC but the supply current draw was 22 mA. The supply current normally was 470 mA to 520 mA.

Investigation and Analysis Summary:

The investigation found the following contributing factors that caused the power supply shutdown.

A. Fractured Terminals:

Extensive troubleshooting located defective solder joints within the Modular Devices Incorporated (MDI) Power Supplies and the troubleshooting results are recorded with the power supply build history at L3C. The transformer module within the power supply had cracks in the solder joints due to poor workmanship at the power supply vendor MDI . All MDI power supplies have this potential problem and have been reworked and repaired (L3C MRB SPA-99-041) at L3C. All solder joints within power supplies from MDI have been inspected and reworked in accordance with the soldering requirements of NASA NHB 5300.4 (3A-1). L3C submitted an MUA to Boeing to repair the Type III power supplies. Rework plans, including requisite processes and solder MUAs and test plans have been developed and approved by L3C and Boeing. Dr. Mike Pedely (NASA-JSC), Bob Cook (NASA), and Dr. John Golden (Boeing) have reviewed and approved the processes and solder MUAs. Boeing/NASA opened AOE 0473 and tracked power supply repairs to successful completion.

B. Test Software:

The test software which controlls the HP6010A Test Power Supply input voltage to the VSW Type III Power Supply was switching the input voltage improperly. This caused a shut down condition to occur. L3C's Test software change A3391359 corrected this problem.

After the Type III power supply for VSW S/N 001 was removed and replaced with a reworked and repaired power supply. The following retest plan for the power supply was approved and implemented: (see attachment for details)
1. Power Supply Test
2. VSW/Power Supply Integration
3. AT-0199, Integration and Test.
4. Close VSW, Perform Acceptance Testing IAW Steps 5 througgh 12.
5. Pressurization Tests
6. AT-0016, Initial-Partial Full Functional Tests.
7. QT-0040, Electromagnetic Test.
8. AT-0010, Vibration.
9. AT-0002, Partial Thermal Cycle.
10. AT-0007, Fine Leak Test.
11. AT-0016, Final-Partial Full Functional.

ISS Problem Report: 731 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

12. AT-0014, Final Acceptance Test Inspection.

Root Cause Statement:

The root causes are:

A. The VSW's MDI Type III power supply PWB and transformer modules had cracks in the soldering joints due to poor soldering process at the supplier, MDI.

B. The test software limits which control the input voltage to the VSW's Type III power supply were improperly set causing a shut down condition to occur.

Recurrence Control Corrective Action Data:

A) Modular Devices Incorporated is listed as a disapproved supplier on the L3C supplier system. Future power supplies for spares are being procured from a different vendor (Century Electronics is the vendor selected under PIO 39B). L3C and Boeing will work closely with Century Electronics to avoid problems of this nature during their build process. The following steps have been initiated: requirements review meetings, manufacturing readiness reviews, inprocess surveillance, monthly management reports and final inspections.

B) ECP 11447-165R1 authorized L3C to modify their test software. The ECP was approved by the Boeing Internal Review Board per PCD MDA03013.

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

REWORK PLAN

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
8A	C	Bucci, Paul	05-JUN-2000

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 3 of 4

ISS Problem Report: 731 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

Closure Signatures	PR Close Date:	05-JUN-2000	PR Status:	C - Closed

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering	Accept	HELVY, DANA	25-May-00
ISSPO NASA S&MA	Accept	PATEL, ARVIN	05-Jun-00
Contractor/GFE/IP Engineering	Accept	HUANG, DEREK	24-May-00
Contractor/GFE/IP S&MA	Accept	BUCCI, PAUL	24-May-00

Closure Comments:

Organization: ISSPO NASA Engineering
Comments: None

Organization: Contractor/GFE/IP Engineering
Comments: None

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 4 of 4

ISS Problem Report: 771 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

PR Last Update Date: 05-JUN-2000 PR Last Update By: Bucci, Paul

Problem Identification Information

PR Release Date:	20-AUG-1998
Problem Title:	External Video Switch Type III Power Supply Unexpectantly Shut Down

Initiator's Information

Initiator's Name (first name last name):	NATE BARR
Initiating Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Initiator's Telephone Number:	714 896-3311 X67547
Initiator's E-mail:	

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Derek Huang
Assigned Engineer's Telephone Number:	(714) 372-1765
Assigned Engineer's Email Address:	derek.d.huang@boeing.com
Flight Element Code:	ITA_S0 - INTEGRATED TRUSS ASSEMBLY S0
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Responsible SPRT:	

Nonconformance (NCR) Information

Nonconforming Part Name:	EXTERNAL VIDEO SWITCH (VSW)
Nonconforming Part Number:	10033180-501
Part Serial/Lot Number:	001
Nonconforming Article (NCA) Name:	Type III Power Supply
NCA Part Number:	10036713-1
NCA Serial/Lot Number:	2001
NCR Number:	SSF046
Hardware Level:	ORU - Orbital Replacement Unit (ORU)
Fracture Critical Indicator:	N
Detected Date:	02-AUG-1997
Manufacturer's Name:	L-3 COMMUNICATIONS CORP/COMMUNICATION SYSTEMS EAST
Manufacturer's Cage Code:	11447
Detected During:	AT-0107
Site Location:	L3_COMM - L3 Communications - Camden, NJ
Waiver/Deviation Number:	N/A

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ISS Problem Report: 771 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

Trending Data

Prevailing Condition Category:	F - Functional test or use
Test Operation Code:	TAI - Testing -> Acceptance Test -> Initial Unit
PRACA Failure Mode Code:	EOP - Electrical -> Output -> Premature Inadvertent Output (Operation) Or Shutdown
Defect Code:	EQX - Electrical -> Part -> Other
Material Code:	MSS - Electro Mechanical Part -> Solder -> Defective Solder Material
Cause Code:	MW - Manufacturing/Maintenance -> Workmanship
Recurrence Control Code:	CF - Change Process Or Procedure -> Manufacturing (Fabrication)

FMEA Data

FMEA Number:	CTS-SOVSWE-01
FMEA Criticality Category:	2R - Redundant item failures causing loss of mission support

Reportable Problem Description:

During AT-0107, Signal to Crosstalk Test, the External Video Switch (VSW) Type III Power Supply shut itself down prematurely. The 120 VDC Test Power Supply (HP6010A), which supplied input voltage to VSW Type III Power Supply, still read 120 VDC but the supply current draw was 21 mA. The supply current normally was 470 mA to 520 mA.

Investigation and Analysis Summary:

The investigation found the following contributing factors that caused the power supply shutdown.

A. Fractured Terminals:

Extensive troubleshooting located defective solder joints within the Modular Devices Incorporated (MDI) Power Supplies and the troubleshooting results are recorded with the power supply build history at L3C. The transformer module within the power supply had cracks in the solder joints due to poor workmanship at the power supply vendor MDI . All MDI power supplies have this potential problem and have been reworked and repaired (L3C MRB SPA-99-041) at L3C. All solder joints within power supplies from MDI have been inspected and reworked in accordance with the soldering requirements of NASA NHB 5300.4 (3A-1). L3C submitted an MUA to Boeing to repair the Type III power supplies. Rework plans, including requisite processes and solder MUAs and test plans have been developed and approved by L3C and Boeing. Dr. Mike Pedely (NASA-JSC), Bob Cook (NASA), and Dr. John Golden (Boeing) have reviewed and approved the processes and solder MUAs. Boeing/NASA opened AOE 0473 and tracked power supply repairs to successful completion.

B. Test Software:

The test software which controlls the HP6010A Test Power Supply input voltage to the VSW Type III Power Supply was switching the input voltage improperly. This caused a shut down condition to occur. L3C's Test software change A3391359 corrected this problem.

After the Type III power supply for VSW S/N 001 was removed and replaced with a reworked and repaired power supply. The following retest plan for the power supply was approved and implemented: (see attachment for details)

1. Power Supply Test
2. VSW/Power Supply Integration
3. AT-0199, Integration and Test.
4. Close VSW, Perform Acceptance Testing IAW Steps 5 througgh 12.
5. Pressurization Tests
6. AT-0016, Initial-Partial Full Functional Tests.
7. QT-0040, Electromagnetic Test.
8. AT-0010, Vibration.
9. AT-0002, Partial Thermal Cycle.
10. AT-0007, Fine Leak Test.
11. AT-0016, Final-Partial Full Functional.

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ISS Problem Report: 771 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

12. AT-0014, Final Acceptance Test Inspection.

Root Cause Statement:

The root causes are:

A. The VSW's MDI Type III power supply PWB and transformer modules had cracks in the soldering joints due to poor soldering process at the supplier, MDI.

B. The test software limits which control the input voltage to the VSW's Type III power supply were improperly set causing a shut down condition to occur.

Recurrence Control Corrective Action Data:

A) Modular Devices Incorporated is listed as a disapproved supplier on the L3C supplier system. Future power supplies for spares are being procured from a different vendor (Century Electronics is the vendor selected under PIO 39B). L3C and Boeing will work closely with Century Electronics to avoid problems of this nature during their build process. The following steps have been initiated: requirements review meetings, manufacturing readiness reviews, inprocess surveillance, monthly management reports and final inspections.

B) ECP 11447-165R1 authorized L3C to modify their test software. The ECP was approved by the Boeing Internal Review Board per PCD MDA03013.

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

REWORK PLAN

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
8A	C	Bucci, Paul	05-JUN-2000

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 3 of 4

ISS Problem Report: 771 **ECD: 05-JUN-2000** **PPD: N/A** **Level: 2** **PR Status: C**

Closure Signatures PR Close Date: 05-JUN-2000 PR Status: C - Closed

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering	Accept	HELVY, DANA	25-May-00
ISSPO NASA S&MA	Accept	PATEL, ARVIN	05-Jun-00
Contractor/GFE/IP Engineering	Accept	HUANG, DEREK	24-May-00
Contractor/GFE/IP S&MA	Accept	BUCCI, PAUL	24-May-00

Closure Comments:

Organization: ISSPO NASA Engineering
Comments: None

Organization: Contractor/GFE/IP Engineering
Comments: None

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 4 of 4

ISS Problem Report: 1909 ECD: 03-MAR-2001 PPD: N/A Level: 2 PR Status: C

PR Last Update Date: 18-JAN-2001 PR Last Update By: Bucci, Paul

Problem Identification Information

PR Release Date:	11-MAY-2000
Problem Title:	Fractured solder joints on swaged termials and transformer terminals.

Initiator's Information

Initiator's Name (first name last name):	Gary Morrison
Initiating Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Initiator's Telephone Number:	(714) 934-5647
Initiator's E-mail:	

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Vernon Blumenberg
Assigned Engineer's Telephone Number:	(714) 372-1354
Assigned Engineer's Email Address:	vernon.blumenberg@west.boeing.com
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HB - Boeing - Huntington Beach Work Center
Responsible SPRT:	

Nonconformance (NCR) Information

Nonconforming Part Name:	Power Supply (Type IV)
Nonconforming Part Number:	10036714-1
Part Serial/Lot Number:	2000, 2001, 2002, 2003, 2004
Nonconforming Article (NCA) Name:	Power Supply (Type IV)
NCA Part Number:	10036714-1
NCA Serial/Lot Number:	As noted
NCR Number:	AOE-0473 (TYPE IV)
Hardware Level:	SRU - Shop Replacement Unit (SRU)
Fracture Critical Indicator:	N
Detected Date:	15-MAY-1998
Manufacturer's Name:	L-3 COMMUNICATIONS CORP/COMMUNICATION SYSTEMS EAST
Manufacturer's Cage Code:	11447
Detected During:	Vibration Testing
Site Location:	L3_COMM - L3 Communications - Camden, NJ
Waiver/Deviation Number:	N/A

ISS Problem Report: 1909 **ECD: 03-MAR-2001** **PPD: N/A** **Level: 2** **PR Status: C**

Trending Data

Prevailing Condition Category:	F - Functional test or use
Test Operation Code:	TAS - Testing -> Acceptance Test -> Subsequent Unit
PRACA Failure Mode Code:	EOP - Electrical -> Output -> Premature Inadvertent Output (Operation) Or Shutdown
Defect Code:	EQX - Electrical -> Part -> Other
Material Code:	MSS - Electro Mechanical Part -> Solder -> Defective Solder Material
Cause Code:	MW - Manufacturing/Maintenance -> Workmanship
Recurrence Control Code:	CF - Change Process Or Procedure -> Manufacturing (Fabrication)

FMEA Data

FMEA Number:	CTS-S1ETVCG-01
FMEA Criticality Category:	3 - All others

Reportable Problem Description:

During testing of the ETVCG (External Television Camera Group), an L-3 Communication ORU assembly, power supply failures were reported. The Type IV power supply is located in the Television Camera Interface Converter (TVCIC).

Note: ETVCG is part of the VDS Communication System. The Manufacturer of this Power Supply is Modular Devices Inc.

Investigation and Analysis Summary:

The investigation found the following contributing factors that caused the power supply failures.

A) Fractured solder joints on swaged terminals.
B) Fractured solder joints on transformer terminals.
C) Failed FET Bond wires.

Investigation of the fractured soldered joints on the transformer pins revealed poor solder wetting on the Bronze pins and non-plated thru holes. Terminals were installed in non-plated thru-holes which made for limited electrical connection. Incorrect transformer lead material was used. Poor solder wetting resulted partly because of the non-plated thru-holes and transformer lead material used.

Investigation of the fractured soldered joints on the swaged terminals revealed poor solder wetting on non-plated thru-holes, insufficient solder contact between terminals and circuit traces, and thermal expansion between dissimilar materials.

Investigation revealed that bond wires in the hybrid connecting the FET were found fused open. This was due to improper FET bond wire size. Electrical overstress caused by load switching caused bond wires to fuse open.

The troubleshooting results are recorded with the power supply build history at L-3C. The transformer module within the power supply had cracks in the solder joints due to poor workmanship and material selection at the power supply vendor. All MDI power supplies have this potential problem and have been reworked and repaired (L-3C MRB SPA-99-041) at L-3C. All solder joints within power supplies from MDI have been inspected and reworked in accordance with soldering requirements of NASA NHB 5300.4 (3A-1). L-3C submitted an MUA to Boeing to repair the Type IV power supplies. Rework plans, including requisite processes and solder MUA's and test plans have been developed and approved by L-3C and Boeing. Dr. Mike Pedely (NASA-JSC), Bob Cook (NASA-JSC), and Dr. John Golden (Boeing) have reviewed and approved the processes and solder MUA's. Boeing / NASA opened AOE 0473 and tracked the power supply repairs to successful completion.

Two sample boards were built to test out different approaches/repairs to the soldering problem on the swaged PCB terminals. Sample 1 was re-worked by re-soldering the terminal. Sample 2 incorporated 7 different repair methods. The two samples went through extensive vibration testing and thermal testing. All methods except the leash wire method failed after 750 temperature cycles.

After the Type IV power supply was removed and replaced with a reworked power supply, Acceptance Test Procedure (ATP) was performed on the individual power supply (on the bench), the assembled TVCIC and the assembled ETVCG.

ISS Problem Report: 1909 **ECD: 03-MAR-2001** **PPD: N/A** **Level: 2** **PR Status: C**

The following are the L-3 Comm. Nonconformance Reports:

SSF	S/N	SSF	S/N	SSF	S/N
218	2003	274	2004	505	2004
383	2003	439	2004	508	2004
385	2003	442	2004		
386	2003	443	2004		
387	2003	445	2004		
388	2003	446	2004		
391	2003	447	2004		
392	2003	449	2004		
396	2003	496	2004		
399	2003	498	2004		
440	2003	500	2004		
441	2003	504	2004		

Note: Serial numbers 2000, 2001, 2002 were also affected by these problems but were reworked before testing therefore L3 SSF's were not written.

Root Cause Statement:

The root cause was poor design, poor workmanship, and poor manufacturing practices. Specifically, for the fractured solder joints on the swaged PCB terminals, the cause was (a) non-plated thru-holes, (b) insufficient solder contact between terminal and circuit trace, and (c) thermal expansion of dissimilar materials. For the fractured solder joints on the transformer terminals, the cause was (a) poor solder wetting, (b) incorrect transformer lead material, and (c) terminals installed in non-plated thru holes. For failed FET Bond wires, root cause was improper wire size.

Recurrence Control Corrective Action Data:

L-3 has inspected and reworked all power supplies to meet NASA NHB 5300 requirements. L-3 submitted an MUA to Boeing to repair the MDI power supplies(in this case Type IV) with leash and jumper wires between terminals, pins, and PWB traces. For the transformer pins, a no clean flux was used to improve wetting in addition to the addition of leash wires between all terminals, pins and PWB traces. Rework plans, including requisite processes and solder MUAs and test plans have been developed and approved by L-3 and Boeing. Dr. Mike Pedeley (NASA-JSC), Bob Cook (NASA), and Dr. John Golden (Boeing) have reviewed and approved the processes and solder MUAs. After the repairs were made, each power supply was subjected to a vibration and thermal cycle test prior to incorporation into the ORU (TVCIC). The ETVCG was subjected to complete Acceptance Test Procedure (ATP) after the power supply was integrated. The ATP included Vibration and Thermal Cycle tests. The TVCIC and all power supplies successfully passed the ATP.

Note: We are no longer purchasing Power Supplies from Modular Design Inc. (MDI is no longer on the approved supplier list). Spare Power Supplies will be procured from Century Electronics.

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

REWORK PLAN

Flight Effectivity: **Like HW On-Orbit:** N

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ISS Problem Report: 1909 **ECD: 03-MAR-2001** **PPD: N/A** **Level: 2** **PR Status: C**

Flight Name	Status	Signature	Date
9A	C	Bucci, Paul	18-JAN-2001
11A	C	Bucci, Paul	18-JAN-2001

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Closure Signatures PR Close Date: 18-JAN-2001 PR Status: C - Closed

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering	Accept	HELVY, DANA	18-Jan-01
ISSPO NASA S&MA	Accept	OHNESORGE, GARY	18-Jan-01
Contractor/GFE/IP Engineering	Accept	MCNAMARA, TOM	18-Jan-01
Contractor/GFE/IP S&MA	Accept	BUCCI, PAUL	18-Jan-01

Closure Comments:

Organization: ISSPO NASA Engineering
Comments: None

Organization: Contractor/GFE/IP Engineering
Comments: None

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 4 / 4 Concurrences 0 / 0 Page 4 of 5

ISS Problem Report: 1909 ECD: 03-MAR-2001 PPD: N/A Level: 2 PR Status: C

ISS Problem Report: 3269 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

PR Last Update Date: 20-APR-2006 PR Last Update By: HELVY, DANA

Problem Identification Information

PR Release Date:	14-JAN-2003
Problem Title:	FPMU/TVCIC failed to activate when power was applied

Initiator's Information

Initiator's Name (first name last name):	Thomas Keeping
Initiating Organization:	JSC - Johnson Space Center
Initiator's Telephone Number:	(281) 483-6758
Initiator's E-mail:	tkeeping@ems.jsc.nasa.gov

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Dana Helvy
Assigned Engineer's Telephone Number:	281 483-0151
Assigned Engineer's Email Address:	dhelvy@ems.jsc.nasa.gov
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	ENVIRONMENTS - ENVIRONMENT
ISS Subsystem Name:	FPMU -
Responsible Organization:	JSC - Johnson Space Center
Responsible SPRT:	Video - Video System Problem Resolution Team

Nonconformance (NCR) Information

Nonconforming Part Name:	FPMU Installation Drawing
Nonconforming Part Number:	39-0063
Part Serial/Lot Number:	FPMU P/N 39-0001, SN01, TVCIC P/N 100332111-501 S/N 04
Nonconforming Article (NCA) Name:	FPMU Installation Drawing
NCA Part Number:	39-0063
NCA Serial/Lot Number:	FPMU P/N 39-0001
NCR Number:	PFR 685
Hardware Level:	HA - Higher Assembly containing ORUs (HA)
Fracture Critical Indicator:	N
Detected Date:	06-JUN-2002
Manufacturer's Name:	L3 COMMUNICATIONS SPACE & NAVI
Manufacturer's Cage Code:	1NZ85
Detected During:	Power quality testing
Site Location:	JSC - Johnson Space Center
Waiver/Deviation Number:	NA

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ISS Problem Report: 3269 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

Trending Data

Prevailing Condition Category:	F - Functional test or use
Test Operation Code:	TQ - Testing -> Qualification Test
PRACA Failure Mode Code:	EOO - Electrical -> Output -> No Output
Defect Code:	EGX - Electrical -> General -> Other
Material Code:	Z - No Material Defect
Cause Code:	DHO - Design Requirements -> Hardware Design -> Other
Recurrence Control Code:	IN - Integration Issue Only -> Recurrence Control Not Required

FMEA Data

FMEA Number:	3
FMEA Criticality Category:	3 - All others

Reportable Problem Description:

During power quality testing the Floating Potential Measurement Unit (FPMU)/Television Camera Interface Converter (TVCIC) integrated assembly failed to activate when power was applied. Functionality was recovered when power was cycled.

Investigation and Analysis Summary:

During power quality testing at the Electronic Power Systems Test Laboratory (EPSTL) in Building 16 at the Johnson Space center the FPMU/TVCIC assembly failed to activate when power was applied during one of five RPCM turn-ons. The power was cycled and the assembly then powered up nominally. At the time it was not known if the failure to power up was due to the TVCIC or the FPMU.

A likely cause of this behavior is that a power supply in the configuration, most likely within the TVCIC, is not able to supply enough inrush current. In the FPMU application the power normally supplied to the Color Television Camera (CTVC) is instead supplied to the FPMU. It is reasonable to postulate for troubleshooting purposes that if the FPMU inrush current requirements are significantly greater than the CTVC requirements then the TVCIC might not be able to supply the proper inrush current and the assembly would not activate.

The FPMU and CTVC inrush currents were measured during two separate tests at the JSC EPSTL. TPS JA-0320004 measured the inrush current requirements of the FPMU, and JSC TPS JA-0320008 measured the inrush current requirements of the CTVC. The results are as follows:

PARAMETER	FPMU	CTVC
Scope Turn-on Transient Voltage	28.44 V max	28.01 V avg
Scope Turn-on Transient Current	13.46 A max	Initial 820 mA max, at 86 ms 2.98 A max
Scope Steady State Voltage	27.85 V avg	27.99 V avg
Scope Steady State Current	877.7 mA avg	871 mA avg

It is clear from the data that, although the steady state current requirements of the FPMU and CTVC are very nearly identical, the inrush current requirements differ significantly. The FPMU inrush current draw is from 4.5 to 16 times as great as the CTVC inrush current draw. Since the assembly does power up most of the time, it is reasonable to suspect that the TVCIC power supply has difficulty supplying inrush current to the FPMU, and the assembly will fail to power up occassionally.

Data describing the expected or maximum inrush current of the External Television Camera Group (ETVCG) configuration is not available from the vendor, L3Comm.

Root Cause Statement:

The root cause of the failure of the FPMU/TVCIC assembly to power up is an incompatibility between the TVCIC and FPMU power systems. The TVCIC meets its requirements as far as supplying the needs of the PTU and CTVC, but the FPMU was designed without knowledge of the TVCICs inrush current limitations.

Recurrence Control Corrective Action Data:

If upon power application the FPMU/TVCIC assembly fails to power up then cycle the power. No other corrective action should be pursued because schedule and cost impacts would be prohibatively large, and an effective work around exists. Recurrence

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ISS Problem Report: 3269 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

control will be limited to power cycling the assembly.

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
ULF1.1	C	HELVY, DANA	20-APR-2006

Invalid Flights:

ULF1	C	HELVY, DANA	11-APR-2005

Flight History:

Flight Name	Update Date	Status	Updated By	Justification
ULF1.1	20-Apr-06	CLOSED	HELVY, DANA	An operational workaround has been identified that makes the issue documented in 3269 a non problem.
ULF1	11-Apr-05	CLOSED	HELVY, DANA	ULF1 is now ULF1.1.
ULF1.1	11-Apr-05	ADDED	HELVY, DANA	FPMU is manifested on ULF1.1.

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

ISS Problem Report: 3269 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

Closure Signatures	PR Close Date:	PR Status:	O - Open

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP Quality			

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:
HW Sustaining Contractor Safety			
NASA Safety			

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 0 / 4 Concurrences 0 / 2 Page 4 of 4

ISS Problem Report: 3270 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

PR Last Update Date: 20-APR-2006 PR Last Update By: HELVY, DANA

Problem Identification Information

PR Release Date:	14-JAN-2003
Problem Title:	FPMU/TVCIC failed to activate when power was applied

Initiator's Information

Initiator's Name (first name last name):	Thomas Keeping
Initiating Organization:	JSC - Johnson Space Center
Initiator's Telephone Number:	(281) 483-6758
Initiator's E-mail:	tkeeping@ems.jsc.nasa.gov

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Dana Helvy
Assigned Engineer's Telephone Number:	281 483-0151
Assigned Engineer's Email Address:	dhelvy@ems.jsc.nasa.gov
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	ENVIRONMENTS - ENVIRONMENT
ISS Subsystem Name:	FPMU -
Responsible Organization:	JSC - Johnson Space Center
Responsible SPRT:	Video - Video System Problem Resolution Team

Nonconformance (NCR) Information

Nonconforming Part Name:	FPMU/TVCIC integrated assembly
Nonconforming Part Number:	39-0063
Part Serial/Lot Number:	FPMU P/N 39-0001, SN01, TVCIC P/N 100332111-501 S/N 04
Nonconforming Article (NCA) Name:	
NCA Part Number:	
NCA Serial/Lot Number:	
NCR Number:	PFR 684
Hardware Level:	HA - Higher Assembly containing ORUs (HA)
Fracture Critical Indicator:	N
Detected Date:	16-JUL-2002
Manufacturer's Name:	
Manufacturer's Cage Code:	
Detected During:	EMI Testing
Site Location:	MSFC - Marshall Space Flight Center
Waiver/Deviation Number:	

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ISS Problem Report: 3270 ECD: 07-OCT-2006 PPD: Low Level: 2 PR Status: O

Trending Data

Prevailing Condition Category:
Test Operation Code: TQ - Testing -> Qualification Test
PRACA Failure Mode Code:
Defect Code:
Material Code:
Cause Code:
Recurrence Control Code:

FMEA Data

FMEA Number:
FMEA Criticality Category:

Reportable Problem Description:

During EMI testing the FPMU/TVCIC integrated assembly failed to activate when power was applied. Functionality was recovered when power was cycled. Anomaly reoccured approximately once every ten times power was applied. All occurances are documented in the TVCIC power on log.

Investigation and Analysis Summary:

Root Cause Statement:

Recurrence Control Corrective Action Data:

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** N

Flight Name	Status	Signature	Date
ULF1.1	C	HELVY, DANA	20-APR-2006

Invalid Flights:

ULF1	C	HELVY, DANA	11-APR-2005

Flight History:

Flight Name	Update Date	Status	Updated By	Justification
ULF1.1	20-Apr-06	CLOSED	HELVY, DANA	An operational workaround has been identified that makes the issue documented in 3270 a non problem.

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ISS Problem Report: 3270 **ECD: 07-OCT-2006** **PPD: Low** **Level: 2** **PR Status: O**

Flight Name	Update Date	Status	Updated By	Justification
ULF1	11-Apr-05	CLOSED	HELVY, DANA	ULF1 is now ULF1.1.
ULF1.1	11-Apr-05	ADDED	HELVY, DANA	FPMU is manifested on ULF1.1.

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

Closure Signatures PR Close Date: PR Status: O - Open

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP Quality			

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:
HW Sustaining Contractor Safety			
NASA Safety			

Concur Comments:

Prepared on 04-MAY-2006 Closure Signatures 0 / 4 Concurrences 0 / 2 Page 3 of 3

ISS Problem Report: 3365 ECD: 29-JAN-2008 PPD: Low Level: 2 PR Status: O

PR Last Update Date: 06-JAN-2006 PR Last Update By: LEVO, ROBERT

Problem Identification Information

PR Release Date:	28-MAY-2003
Problem Title:	No Video from S1 ETVCG

Initiator's Information

Initiator's Name (first name last name):	George Palacios
Initiating Organization:	ISS-MER - JSC ISS Mission Evaluation Room
Initiator's Telephone Number:	281-226-4558
Initiator's E-mail:	george.j.palacios@boeing.com

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Eric Obleman
Assigned Engineer's Telephone Number:	281-244-4548
Assigned Engineer's Email Address:	eric.a.obleman@boeing.com
Flight Element Code:	ITA_S1 - INTEGRATED TRUSS ASSEMBLY S1
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	Boeing_HOU - Boeing - Houston Work Center
Responsible SPRT:	Video - Video System Problem Resolution Team

Nonconformance (NCR) Information

Nonconforming Part Name:	External Television Camera Group
Nonconforming Part Number:	10033194-501
Part Serial/Lot Number:	02
Nonconforming Article (NCA) Name:	Television Camera Interface Converter
NCA Part Number:	10033211-501
NCA Serial/Lot Number:	002
NCR Number:	MER-01158
Hardware Level:	ORU - Orbital Replacement Unit (ORU)
Fracture Critical Indicator:	N
Detected Date:	29-APR-2003
Manufacturer's Name:	L3 COMMUNICATIONS SPACE & NAVI
Manufacturer's Cage Code:	1NZ85
Detected During:	On orbit Operation - AOS TDRSS SHO
Site Location:	ON_ORBIT - On Orbit
Waiver/Deviation Number:	

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ISS Problem Report: 3365 ECD: 29-JAN-2008 PPD: Low Level: 2 PR Status: O

Trending Data

Prevailing Condition Category:
Test Operation Code: OOO - Hardware Operations -> On Orbit -> Operations
PRACA Failure Mode Code:
Defect Code:
Material Code:
Cause Code:
Recurrence Control Code:

FMEA Data

FMEA Number:
FMEA Criticality Category:

Reportable Problem Description:

GMT 119/19:38:47 at LOS for TDRSS SHO, S1 ETVCG (LOOB) was operating nominally with good video downlinked to the ground. GMT 119/19:49:12 during AOS of next TDRSS SHO, no video output was seen on downlink from S1 ETVCG. This condition was not immediately apparent, as no further S1 video was being downlinked to ground.

Investigation and Analysis Summary:

Video SPRT has declared this group failed completely and beyond repair on orbit due to numerous instances of malfunctioning, including PTU function and telemetry, as well as pink image due to loss of green channel. SPRT, however, left the use of it at the discretion of the FD, since images are still intelligible for the operational EVA purposes.

There have been numerous occurences of S1 Video loss since the original event. These are tabulated below.
- 1: 4/29/2003 (2003/119/19:48)
- 2: 5/30/2003 (2003/150/08:58)
- 3: 7/2/2003 (2003/183/05:12)
- 4: 7/15/2003 (2003/196/14:44)
- 5: 8/6/2003 (2003/218/19:16)
- 6: 8/14/2003 (2003/226/10:56)
- 7: 8/17/2003 (2003/229/22:47)
- 8: 8/19/2003 (2003/231/13:03)
- 9: 8/21/2003 (2003/233/05:53)
- 10: 8/24/2003 (2003/236/16:20)
- 11: 8/28/2003 (2003/240/07:15)
- 12: 9/3/2003 (2003/246/13:50)
- 13: 9/16/2003 (2003/259/19:54)
- 14: 10/5/2003 (2003/278/24:04)
- 15: 10/6/2003 (2003/279/22:52)
- 16: 10/14/2003 (2003/287/12:12)
- 17: 10/22/2003 (2003/295/01:41)
- 18: 10/25/2003 (2003/298/20:28)
- 19: 10/26/2003 (2003/299/04:04)
- 20: 10/27/2003 (2003/300/22:13)
- 21: 11/14/2003 (2003/318/01:02)
- 22: 11/15/2003 (2003/319/06:55)
- 23: 12/7/2003 (2003/341/07:31)
- 24: 12/8/2003 (2003/342/14:31)
- 25: 12/10/2003 (2003/344/09:15)
- 26: 12/10/2003 (2003/344/14:19)
- 27: 12/12/2003 (2003/346/03:20)
- 28: 12/14/2003 (2003/348/03:31)
- 29: 3/13/2004 (2004/073/20:04)

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ISS Problem Report: 3365 ECD: 29-JAN-2008 PPD: Low Level: 2 PR Status: O

- 30: 3/16/2004 (2004/076/05:51)
- 31: 3/24/2004 (2004/084:08:37)
- 32: 4/8/2004 (2004/099/23:21)
- 33: 4/10/2004 (2004/101/04:29)
- 34: 4/11/2004 (2004/102/02:52)
- 35: 4/12/2004 (2004/103/08:36)
- 36: 4/14/2004 (2004/105/06:58)
- 37: 4/15/2004 (2004/106/01:06)
- 38: 4/15/2004 (2004/106/04:10)
- 39: 4/16/2004 (2004/107/14:35)
- 40: 4/18/2004 (2004/109/14:01)
- 41: 4/19/2004 (2004/110/14:45)
- 42: 4/20/2004 (2004/111/05:39)
- 43: 4/20/2004 (2004/111/09:28)
- 44: 4/20/2004 (2004/111/14:06)
- 45: 4/22/2004 (2004/113/09:57)
- 46: 4/27/2004 (2004/118/21:52)
- 47: 4/29/2004 (2004/120/08:43)
- 48: 4/29/2004 (2004/121/05:28)
- 49: 5/6/2004 (2004/127/22:43)
- 50: 5/13/2004 (2004/134/09:04)
- 51: 5/24/2004 (2004/145/02:34)
- 52: 5/24/2004 (2004/145/13:08)
- 53: 5/27/2004 (2004/148/23:54)
- 54: 5/28/2004 (2004/149/03:35)
- 55: 5/30/2004 (2004/151/05:53)
- 56: 5/30/2004 (2004/151/14:42)
- 57: 6/1/2004 (2004/153/17:23)
- 58: 6/10/2004 (2004/162/00:30)
- 59: 6/13/2004 (2004/165/13:33)
- 60: 6/14/2004 (2004/166/18:22)
- 61: 6/17/2004 (2004/169/07:01)
- 62: 6/21/2004 (2004/173/08:17)
- 63: 6/21/2004 (2004/173/10:03)
- 64: 6/23/2004 (2004/175/23:06)
- 65: 6/24/2004 (2004/176/06:26)
- 66: 6/25/2004 (2004/177/00:12)
- 67: 6/25/2004 (2004/177/06:21)
- 68: 6/25/2004 (2004/177/09:12)
- 69: 6/25/2004 (2004/177/12:53)
- 70: 6/25/2004 (2004/177/13:00)
- 71: 6/26/2004 (2004/178/09:14)
- 72: 6/26/2004 (2004/178/13:40)

Root Cause Statement:

Root cause cannot be identified until this camera group is R&R on orbit and returned to the ground for depot works.

Recurrence Control Corrective Action Data:

Corrective Action:
Immediate corrective action is to cycle power to the Camera Group to recover video functions. Long term corrective action has not been determined at this time.

Recurrence Control:
Under investigation.

ISS Problem Report: 3365 **ECD: 29-JAN-2008** **PPD: Low** **Level: 2** **PR Status: O**

This PR will remain open until the hardware is returned from the ISS and R&Red.

This ETVCG is slated for the 12A.1 R&R and the replacement group manifested delivery.

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Flight controllers are advised to cycle power to the ETVCG after an instance of loss of video, to recover video functions.

Flight Directors discretion is granted for the use of the ETVCG as is, despite its SPRT-declared premanent failure status.

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** Y

Flight Name	Status	Signature	Date
NOTUSED	O		
Invalid Flights:			
ULF1	C	LEVO, ROBERT	29-MAY-2003

Flight History:

Flight Name	Update Date	Status	Updated By	Justification
ULF1	29-May-03	CLOSED	LEVO, ROBERT	Issue is not a constraint to any flight.
NOTUSED	29-May-03	ADDED	LEVO, ROBERT	Issue is not a constraint to any flight.

Maintenance Action Request (MAR) Data

MAR Required: N

MAR Number:

MAR L&M Focal:

MAR Depot/OEM Facility:

MAR Status:

ISS Problem Report: 3365 **ECD: 29-JAN-2008** **PPD: Low** **Level: 2** **PR Status: O**

Closure Signatures	PR Close Date:	PR Status:	O - Open

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP Quality			

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:
HW Sustaining Contractor Safety			
MER Manager (Mission Evaluation Room)			
MOD (Mission Operations Directorate)			
NASA Safety			

Concur Comments:

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ISS Problem Report: 3875 **ECD: 20-FEB-2011** **PPD: Med** **Level: 2** **PR Status: O**

PR Last Update Date: 03-MAR-2006 PR Last Update By: HELVY, DANA

Problem Identification Information

PR Release Date:	01-DEC-2005
Problem Title:	Loss of Activity on P1 Lower Outboard (LOOB) Camera

Initiator's Information

Initiator's Name (first name last name):	Angela Y. Brooks
Initiating Organization:	ISS-MER - JSC ISS Mission Evaluation Room
Initiator's Telephone Number:	281-226-6251
Initiator's E-mail:	angela.y.brooks2@boeing.com

Assigned Engineer and SPRT Information

Assigned Engineer (first name last name):	Boris Berezin
Assigned Engineer's Telephone Number:	281-244-4546
Assigned Engineer's Email Address:	Boris.j.Berezin@boeing.com
Flight Element Code:	ITA_P1 - INTEGRATED TRUSS ASSEMBLY P1
ISS System Name:	C&T - COMMUNICATION & TRACKING
ISS Subsystem Name:	VDS - VIDEO DISTRIBUTION SUBSYSTEM
Responsible Organization:	ISS-MER - JSC ISS Mission Evaluation Room
Responsible SPRT:	C&T - Communications & Tracking

Nonconformance (NCR) Information

Nonconforming Part Name:	EXTERNAL TV CAMERA GROUP (ETVCG)
Nonconforming Part Number:	10033194-501
Part Serial/Lot Number:	501
Nonconforming Article (NCA) Name:	
NCA Part Number:	
NCA Serial/Lot Number:	
NCR Number:	1968
Hardware Level:	ORU - Orbital Replacement Unit (ORU)
Fracture Critical Indicator:	N
Detected Date:	07-NOV-2005
Manufacturer's Name:	L-3 COMMUNICATIONS CORP/COMMUNICATION SYSTEMS EAST
Manufacturer's Cage Code:	11447
Detected During:	Nominal operations
Site Location:	JSC - Johnson Space Center
Waiver/Deviation Number:	

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ISS Problem Report: 3875 **ECD: 20-FEB-2011** **PPD: Med** **Level: 2** **PR Status: O**

Trending Data

Prevailing Condition Category:

Test Operation Code: OOO - Hardware Operations -> On Orbit -> Operations

PRACA Failure Mode Code:

Defect Code:

Material Code:

Cause Code:

Recurrence Control Code:

FMEA Data

FMEA Number:

FMEA Criticality Category:

Reportable Problem Description:

Per AR 1251: On GMT 311/19:27, the External TV Camera Group (ETVCG) located at the P1 Lower Outboard (P1 LOOB) port lost video (activity). The camera was power on at GMT 311/17:48 and had worked nominally until it lost activity. CATO performed procedure 4.604 VDS ETVCG RECOVERY STEP steps 2-8. The camera passed all checks.
On GMT 312/18:26, the ETVCG P1 LOOB loss of activity occured agian. Procedure 4.604 VDS ETVCG RECOVERY STEP was executed. The camera passed all checks.

Investigation and Analysis Summary:

Root Cause Statement:

Recurrence Control Corrective Action Data:

MRB Disposition MRB Required: N

On Orbit Notes: (MOD and MER Concurrence Signature Required)

Related Documents (Click document to open):

Flight Effectivity: **Like HW On-Orbit:** Y

Flight Name	Status	Signature	Date
12A.1	C	HELVY, DANA	03-MAR-2006
NOTUSED	O		
19P	C	Brooks, Angela	02-DEC-2005
20P	C	Brooks, Angela	02-DEC-2005

Flight History:

Flight Name	Update Date	Status	Updated By	Justification

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ISS Problem Report: 3875 **ECD: 20-FEB-2011** **PPD: Med** **Level: 2** **PR Status: O**

Flight Name	Update Date	Status	Updated By	Justification
19P	02-Dec-05	CLOSED	Brooks, Angela	No impact to 19P per SPRT
20P	02-Dec-05	CLOSED	Brooks, Angela	No impact to 20P per SPRT
12A.1	02-Dec-05	ADDED	Brooks, Angela	Camer group highly desirable for 12A.1 ISS Assembly Ops, per D. Helvy
12A.1	03-Mar-06	CLOSED	HELVY, DANA	P1 ETVCG work around is in place for the problem documented in PR 3875.
NOTUSED	03-Mar-06	ADDED	HELVY, DANA	ETVCG is not a mandatory requirement for any ISS activity.
NOTUSED	03-Mar-06	CLOSED	HELVY, DANA	ETVCG is not a mandatory requirement for any ISS activity.
NOTUSED	03-Mar-06	OPEN	HELVY, DANA	ETVCG is not a mandatory requirement for any ISS activity.

Maintenance Action Request (MAR) Data

MAR Required:	N
MAR Number:	
MAR L&M Focal:	
MAR Depot/OEM Facility:	
MAR Status:	

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ISS Problem Report: 3875 **ECD: 20-FEB-2011** **PPD: Med** **Level: 2** **PR Status: O**

Closure Signatures	PR Close Date:	PR Status:	O - Open

Level 2:

Organization:	Accept/Reject	Signature:	Date:
ISSPO NASA Engineering			
ISSPO NASA Quality			
Contractor/GFE/IP Engineering			
Contractor/GFE/IP Quality			

Closure Comments:

Level 1:

Organization:	Accept/Reject	Signature:	Date:

Closure Comments:

Concurrence Signatures:

Organization:	Concur/Reject	Signature:	Date:

Concur Comments:

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kichak, Robert; Young, Eric; Pandipati, Chetty; Cooke, Robert.

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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Langley Research Center
Hampton, VA 23681-2199

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
The objective of this technical assessment was to investigate the on-orbit shutdown problem with the ISS External TV Camera Group (ETVCG) that the ISS Video Subsystem Problem Resolution Team (SPRT) concluded to be most likely caused by a Television Camera Interface Converter (TVCIC) Modular Devices Inc. (MDI) power supply workmanship problem.The Truss Segment Starboard -1 (S1) ETVCG was installed on 9A (STS-112), and the TVCIC failure signature of shut downs up to two times per hour behavior started two years after installation. The second failure was with the Truss Segment Port-1 (P1) ETVCG which was launched on 11A (STS-113), but was just installed in November 2005. Its anomalous failure started within one hour of initial start-up. It had nine shut downs in December 2005. During each shut down the ground operators observed loss of video which was restored by cycling the power to the affected TVCIC.

15. SUBJECT TERMS
ETVCG, ISS, TVCIC, MDI, SPRT

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** / **19b. TELEPHONE NUMBER** *(Include area code)*
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