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FINAL REPORT

MODIFICATIONS TO CTVS TV CAMERAS FOR SPACE SHUTTLE COMPATIBILITY AND EVALUATION

August 1981

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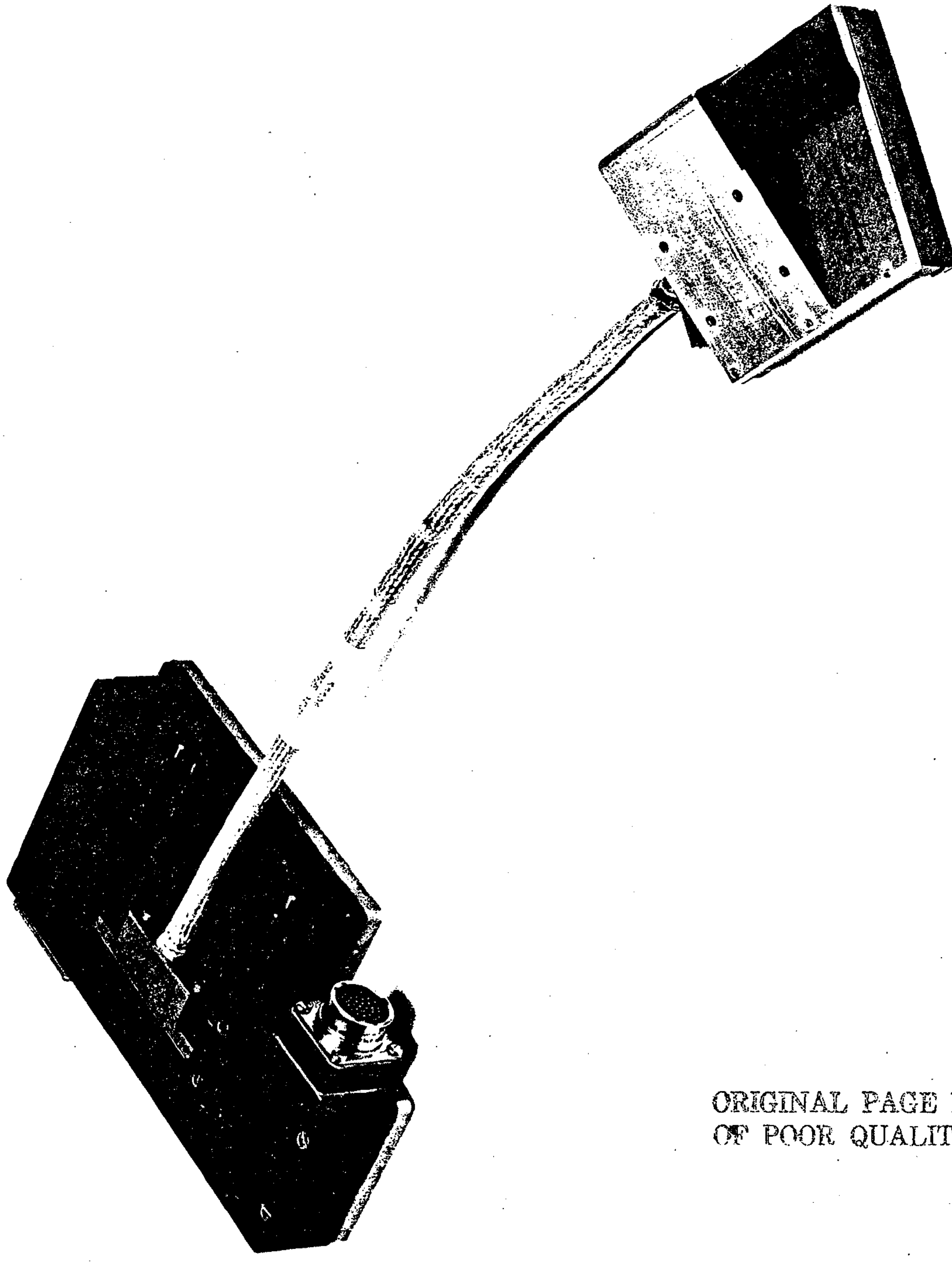

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1.0 PURPOSE

1.1 OBJECTIVE

The objective of this Final Report is to describe the results of a program to perform the design, development, fabrication, testing and delivery of necessary modifications to the CTVS (Cockpit Television System) television cameras in order to acheive compatibility for use on the Space Shuttle Orbiter and to support the evaluation of the CTVS for shuttle application.

1.2 END PRODUCT

The end product of this contractual effort is a quantity of five CTVS TV cameras which have been modified and tested as required by the contract Statement of Work. The five CTVS units were initially provided as GFE (Government-Furnished Equipment) for this effort.

1.3 BACKGROUND

The CCTV (Closed Circuit Television) system on the Space Shuttle Orbiter includes relatively large (530 cubic inches) and heavy (17.5 pounds) television cameras that employ vacuum tube image sensors. It is anticipated that there will arise many applications which will require much smaller and lighter television cameras. The all solid state CTVS camera, which is contained within a package volume of less than 60 cubic inches weighing 2.8 pounds, is an attractive candidate for many of these needs. Thus it was the intent of the contracted program effort to reconfigure five CTVS units (provided as GFE) to be compatible for use on the Shuttle.

2.0 TECHNICAL REQUIREMENTS AND DESIGN IMPLEMENTATION

2.1 GENERAL

The CTVS units supplied for modification were all solid state TV cameras designed, built and tested to USAF requirements for use in the cockpit of high performance type F16 aircraft. For the AF application, the camera provides video imaging of the pilots Heads-Up-Display (HUD) and the "real-world" view through the aircraft windscreen. In unmodified form, the camera consists of a Video Sensor Head (VSH) assembly and an Electronics Unit (EU) assembly which can be separated up to 20 feet or directly coupled to provide a compact integral assembly. Input power for the unmodified camera is obtained from the 115 VAC, three phase 400 Hz aircraft power source.

For the NASA/JSC application, the cameras were modified as follows:

1. The 400 Hz power supply contained within the EU assembly was removed and replaced with DC/DC converters (2) to enable operation from 28VDC spacecraft-type power sources.

2. A number of circuit changes were made, including deletion of non-essential circuit functions such as BIT and Event Mark, to minimize input power requirements.

3. The normal 31 mm focal length lens assemblies were removed and replaced with wider field-of-view 19mm focal length lenses.

4. The EU base plates and the VSH housings were replaced with redesigned parts to facilitate mounting and heat-sinking of the cameras in the space environment.

5. Short length (14") adapter cable assemblies were designed, fabricated and tested in accordance with a NASA/JSC requirement for cameras configured to mount on the Astronauts Helmet/Visor assembly.

Following implementation of the above modifications the cameras were tested to demonstrate conformance with SOW specification requirements. These requirements included performance specifications in effect for USAF CTVS units as well as supplemental NASA/JSC requirements.

2.1.1 Organization

This section of the Final Report is organized in accordance with the definition of task requirements appearing in the contract Statement of Work (Ref. NASA/JSC document EE-2-80-012A(u), September 1980).

2.2 INPUT POWER

Conversion of the GFE units to +28VDC operation was accomplished by the installation of two miniature DC-DC converters in the EU housing space formerly occupied by 400 Hz power supply components. The converters are stock items, part number PS-4238 (providing 5VDC) and part number A28D12/150Z (providing ±12VDC), as manufactured by Stevens-Arnold Incorporated. Although similar stock converters are typically rated for operation over a -25°C to +71°C ambient temperature range, the manufacturer agreed to supply selected units tested for operation at -55°C. The manufacturer also advised that satisfactory high temperature operation should be expected at least to an upper limit fixed by the maximum recommended case temperature of +85°C. Table 2-1 summarizes the

TABLE 2-1

DC-DC CONVERTER SPECIFICATIONS

Type PS-4238

INPUT	
Voltage	28 Volts DC
Range	24 to 32 Volts DC
OUTPUT	
Voltage	5.00 Volts DC
Setting Accuracy 5V (FL)	±2.0% Max.
Over Voltage Protection	Internal at 6.8 Volts DC
Line Regulation	±0.5% Max.
Load Regulation (FL-NL)	±0.5% Max.
Temperature Coefficient	±.01%/°C Max.
Rated Current	1.00 Ampere
Ripple and Noise	1mV RMS, 40mV P-P (5Hz-20mHz)
Transient Response	Less than 25μsec
Operating Temperature Range	-55° to +70°C
Storage Temperature Range	-55° to +125°C
Short Circuit Protection	Output to Common
Voltage Stability	±0.05%/24 Hours
Cooling	Convection (+85°C Max. Case Temperature)
Derating	None
Efficiency	60%
Total Error Band, All Effects	±5% Max.
ISOLATION	
Input to Output	10^9 Ohms Min, 500 Volts DC
CASE SIZE	2" X 2" X 0.375"

NOTES

(1) All units 100% tested for operation at -55°C ambient

(2) Specifications typical at +25°C with 28VDC input

manufacturers specifications for the PS-4238 units. Similar specifications apply to the A28D12/150-Z units except the output ratings are ± 12VDC at 150 ma.

Internal components of the converters are potted within a rectangular copper case which also functions as the converter heat sink. Since transistors with high heat dissipation are located near the top corners of each converter case, the mechanical modifications made to the EU housing and EU bottom plate were designed to ensure good thermal conductivity between the corner surfaces and inside surfaces of the camera housing. The top surface of the ±12VDC converter was firmly clamped by a hold down bracket to a flat machined surface within the EU housing, while the ±5VDC unit was similarly clamped to the redesigned EU bottom plate. Gaskets of soft metal (indium,.020" thick) were used at the critical interfaces to maximize the surface area in contact.

Four of the five series regulator circuits of the CTVS camera were deactivated as part of the modification effort. The fifth regulator circuit, which normally accepts unregulated +20VDC, was redesigned to operate from the +28VDC camera power input. Since this regulator feeds a low power load (≤0.3 watt) requiring 15 to 18 VDC, this approach results in significantly better overall power supply efficiency than an alternate approach using a ±15 VDC converter to supply all high-level camera operating voltages. Power measurements on the first modified camera confirmed that the design objective of 16 watts, maximum at 28 VDC, could be achieved.

As part of the modification effort the EU electrical input connector was replaced with a NASA type NLSO-T14-35P connector. This change ensures that the camera or external power source cannot be damaged by inadvertantly connecting the modified camera to an aircraft type CTVS power connector wired for 115 VAC operation.

2.2.1 DC Voltage Specification

The selected DC/DC converters were expected to perform in accordance with the requirements of SOW paragraph 2.2.1, however the converter manufacturer recommended the use of a transient suppressor to prevent damage from high voltage spikes or surges on the 28 VDC input line.

The suppressors installed in the modified cameras were type 1N6053A "Trans Zorb" devices as manufactured by General Semiconductor. These devices are manufactured using two silicon PN junctions in a back-to-back configuration to provide bidirectional suppression. The 1N6053A is rated for a reverse stand-off voltage (V_R) of 33 volts, with a peak pulse power rating of 1500 watts for 1 millisecond.

The EMC test camera, S/N 001, met the specification requirements of the CS06 Conducted Susceptibility Spike Test, as described in EMC Test Report No. ED-FR-101

2.2.2 Power Control

Both the modified and unmodified CTVS cameras were designed for applications where external control of input power is feasible. Switches and circuit breakers should be included in the external interface system design if required.

2.3 VIDEO OUTPUT AND SYNC INPUT SIGNAL LEVELS

Amplitudes of the two composite video output signals from the modified CTVS cameras were preset to 2.25V ± .025V peak-to-peak when connected to a 75 ohm load impedance. The clamp level for sync tips was preset to -1.5V ± 0.1V.

The sync input provided for gen-lock is compatible with logic level (0 to 5V) composite sync output signals. The composite sync output for the cameras was preset between a lower level ≤ 0.5V and an upper level ≥ 2.5V to ensure a minimum output of 2.0V peak-to-peak.

2.4 LENSES

Seven (7) wide-angle 19mm focal length lenses of the type being furnished for the USAF F-15 Vertical Situation Display (VSD) CTVS configuration were provided. Two of these lenses were installed on two GFE prototype cameras which were delivered to NASA/JSC soon after start-up of the modification program. The remaining five lenses were installed on the modified VSH units which were part of camera assemblies S/N 1 through 5.

2.4.1 Lens Interchange Procedure

The 19mm lenses were designed to be mechanically interchangeable with the 31mm focal length lenses typically used for CTVS applications.

As shown in Figure 2-1, the lens has a rear mounting flange which is fastened to the VSH housing by four mounting screws. Electrical connections for pins A, B, C and D are made by soldering the pins to a "Flex-Print" type printed wiring connector. Thus the lens interchange procedure requires removal of the four mounting screws and unsoldering at the printed wiring terminations. The new lens is then installed by resoldering the PW connector followed by installation of the mounting screws.

2.4.2 Focus Correction Element

The 19mm lens was designed for "close-up" focusing; i.e., for object distances of about 10" from the front of the lens. As indicated in the drawing, the lens housing normally accepts a 2mm thick optical filter at the entrance aperture. For the NASA/JSC application, this filter mounting space is used to contain a weak negative lens element (-254mm focal length) which functions to shift the object distance for best focus from 10 inches to infinity.

2.5 ENVIRONMENTAL CONDITIONS AND TESTS

The requirements specified by the USAF for CTVS environmental conditions and electromagnetic radiation (reference Fairchild Report No. ED-AX-134, Sections 3.2.5 and 3.3.2) were applied to the modified cameras except as modified and extended by additional NASA/JSC vibration, thermal-vacuum, and EMI requirements.

All modified VSH and EU assemblies were subjected to CTVS burn-in testing for a 24 hour period, as described in paragraph 2.5.4 below. Following burn-in one camera was designated as the environmental test unit and subjected to NASA/JSC random vibration testing (paragraph 2.5.3) followed by the thermal-vacuum tests (paragraph 2.5.1). Another camera, designated as the electromagnetic test unit, was tested for electromagnetic interference characteristics as described in paragraph 2.5.2.

After completion of the test sequence, all cameras were required to demonstrate conformance to CTVS acceptance test procedures (paragraph 2.5.5) prior to shipment.

2.5.1 Thermal-Vacuum

Thermal vacuum testing was successfully completed with camera S/N 0005. The test schedule required exposure to the following conditions:

Vacuum Chamber Pressure:	1×10^{-6} Torr (all tests).
Temperature, Operating:	+55°C to -55°C; 6 hours at each extreme.
Temperature, Non Operating:	+95°C to -62°C; 6 hours at each extreme.
Temperature, Off-limits - Operating:	-100°C, -85°C, -70°C, +70°C, +82°C, +94°C; 1 hour operation at each level.
Performance Testing:	Gray scale, video outputs, resolution and warm up time.
Final Test:	In accordance with post burn-in ATP, reference paragraph 2.5.5.

A detailed description of Thermal Vacuum test results is contained in Section 6.2 of the <u>QUALIFICATION TEST REPORT ON NASA/JSC CTVS</u>, Fairchild Weston I/T Report #4018, April 1981.

2.5.2 Electro Magnetic Interference

Tests were performed on Camera S/N 0001 to demonstrate the capability for meeting the EMI requirements of MIL-STD-461A, as modified by NASA document No. SL-E-0002, Revision A, for Class ID equipment. Specifically, the following tests were performed:

Conducted Emission, CE01
Conducted Emission, CE03
Radiated Emission, RE02
Conducted Susceptibility, CS01
Conducted Susceptibility, CS02
Radiated Susceptibility Magnetic Induction Field, RS02
Radiated Susceptibility Electric Field, RS03
Time Domain Transient and Ripple Test, TT01

All tests, with the exception of portions of CS02 and RE02, were passed within specification limits. The out-of-spec conditions observed were:

(a) CS02 - The lens iris closed momentarily with signal inputs above 0.3V rms in the 245 to 260 mHz range (iris re-opened within 1 to 2 seconds).

(b) RE02 (broadband) - Signals 10 db. above the maximum limit were observed from 15 KHz to 36 KHz.

(c) RE02 (narrowband) - 3db. over limit at 12 mHz.

In accordance with a NASA/JSC technical directive (reference EE2-011, February 12, 1981) none of the above conditions was considered a problem area requiring redesign or modification of the camera to eliminate.

Fairchild Weston Report No. ED-RF-101, February 25, 1981, was prepared to document the results of electromagnetic interference testing. This report, entitled EMC TEST REPORT FOR NASA CTVS was previously submitted as part of the Acceptance Data Package, DRL T-1628, line item No. 11.

2.5.3 Random Vibration

Following the successful completion of post burn-in acceptance testing, camera S/N 0002 was selected for non-operating vibration/endurance tests. The test conditions were:

Random Vibration at .062 g^2/Hz, 40 to 1000 Hz with 6db/octave roll off from 1000 to 2000 Hz.

Step 1: Lateral axis, 35 minutes
Step 2: Longitudinal axis, 35 minutes
Step 3: Vertical axis, 35 minutes

The equipment under test was energized after each of the above steps to verify operation. The camera remained functional after each of the three steps, however during the post-vibration acceptance test a shift in video signal black level and gain characteristics was observed and investigated. Upon opening of the electronics unit, two capacitors (C19 and C22) were found laying loose on the printed circuit board. After replacement of these capacitors the camera was again subjected to electrical performance tests with satisfactory results. The camera was then exposed to an additional 35 minutes of vibration at the step 3 condition. The camera was found to be fully functional after this test except for an out-of-specification W_F/W_I ratio during the spot blooming test. This condition was subsequently corrected by adjustment of an ALC circuit potentiometer.

A detailed description of Random Vibration test results is contained in Section 6.1 of the QUALIFICATION TEST REPORT ON NASA/JSC CTVS, Fairchild Weston I/T Report No. 4018, April 1981.

2.5.4 Acceptance Environmental Testing

All modified camera assemblies were subjected to CTVS type burn-in testing (with the camera operating) as a prerequisite to additional testing. The vibration portion of these tests consisted of random vibration stress at .018 g^2Hz, 80 to 1000 Hz with roll-off to .0045 g^2Hz at 2000 Hz. The stress application was for 40 minutes in the horizontal direction, perpendicular to the lens optical axis.

Burn-in temperature stress required operation of the camera during four 6 hour cycles with ambient temperature extremes at -54°C (4 hours) and +55°C (2 hours) for each cycle.

Additional detail concerning acceptance environmental testing is given in the ATP document cited in the following paragraph 2.5.5.

2.5.5 Acceptance Performance Testing

Performance/electrical testing for the modified cameras was done in accordance with Section 4 and Section 6 of the Acceptance Test Procedure for NASA/JSC CTVS Camera Modification, November 1980 (DRL No. T-1628, line item No. 2).

Performance verification tests such as the Pre Burn-In tests described in Section 4 of the ATP required the observation and measurement of the number of discernible gray scale steps, video signal amplitude(s), and camera system resolution. The more extensive Post Burn-In test (ref. ATP Section 6), evaluated the following electrical performance characteristics:

Composite Sync output levels
Sync Input (gen-lock) capability
Video signal-to-noise ratio
Gray scale
Video signal levels
Resolution
Blooming
Light range (ALC)
Field and line rates

Test results were recorded on the data sheets for each of the five deliverable cameras. These data sheets were included with the Acceptance Test Data Package (DRL T-1628, line item No. 11).

2.6 ADAPTER CABLES FOR REMOTE SENSOR HEAD OPERATION

Five sets of adapter cables were provided with the cameras to allow the VSH to be operated remotely from the EU. The cable end connectors were the mating connectors for the SRU interface connectors on the VSH AND EU.

Strain relief for the 13 3/4" long cable was provided by the end termination design shown in Figure 2-2. Interconnections for this cable assembly are as indicated in Figure 2-3.

2.7 CONNECTORS

Six connectors, Bendix type NLSO T14-35P, (and six mating connectors) were supplied as GFE items for use as the EU external interface connector.

2.8 MANNED SPACECRAFT CRITERIA AND STANDARDS

A study and review of NASA document No. JSCM 8080, Manned Spacecraft Criteria and Standards (Change 9, February 1, 1980) was conducted during the first six weeks of program effort. The objective of this study and review was to identify design standards which would not be met by the CTVS camera at the completion of the contractual effort. As set forth in the contract SOW, the review was limited to standards 2A, 3A, 9, 14A, 18, 19, 22A, 23, 25, 26, 31, 32, 33, 37, 41A, 51, 52, 62, 63, 77, 81, 84A, 85A, 88A, 98, 101, 107, 109, 112, 116, 119, 122, 128, 129, 142, 148, 152A. The results of the study and review were contained in Report

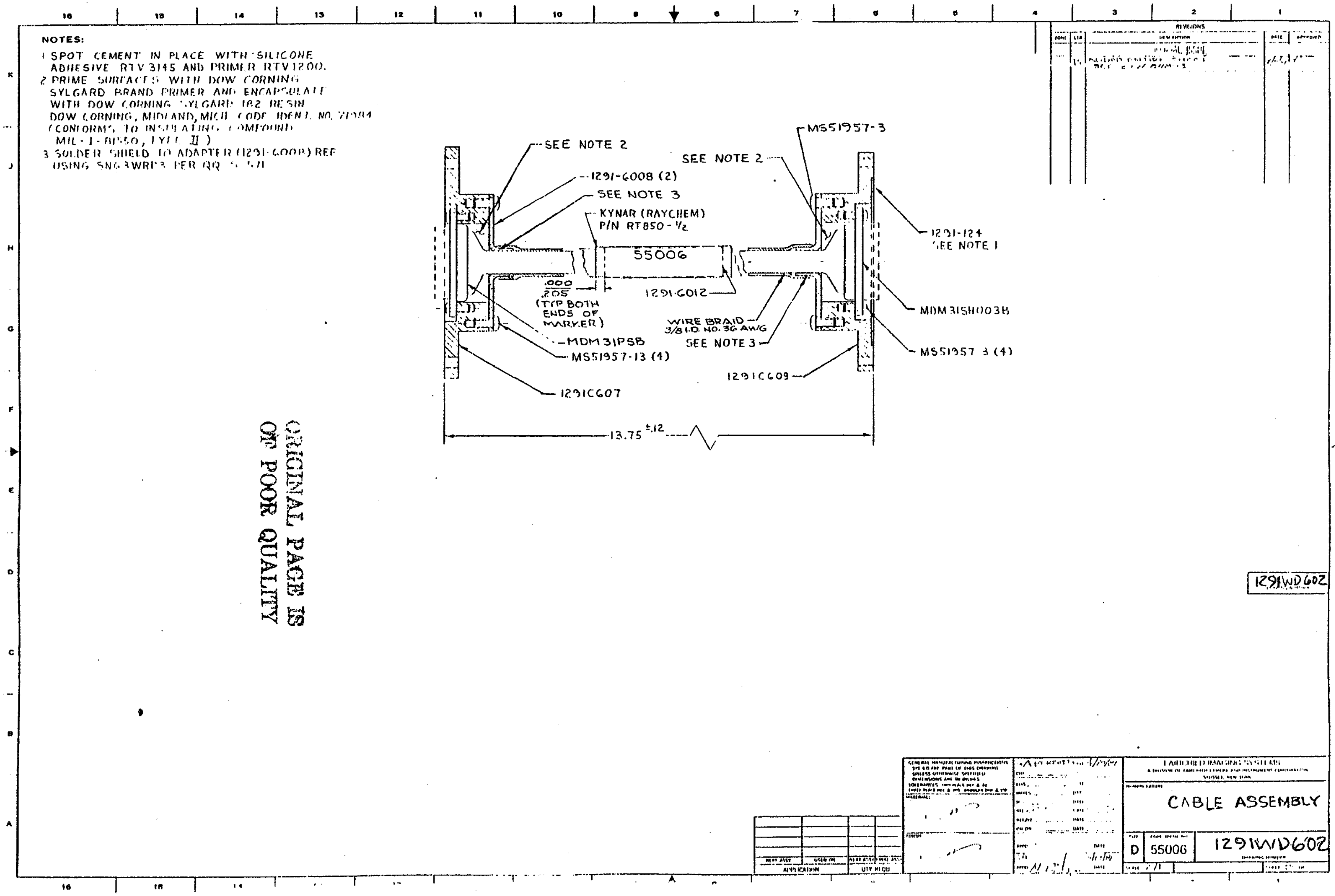

FIGURE 2-2 ADAPTER CABLE ASSEMBLY

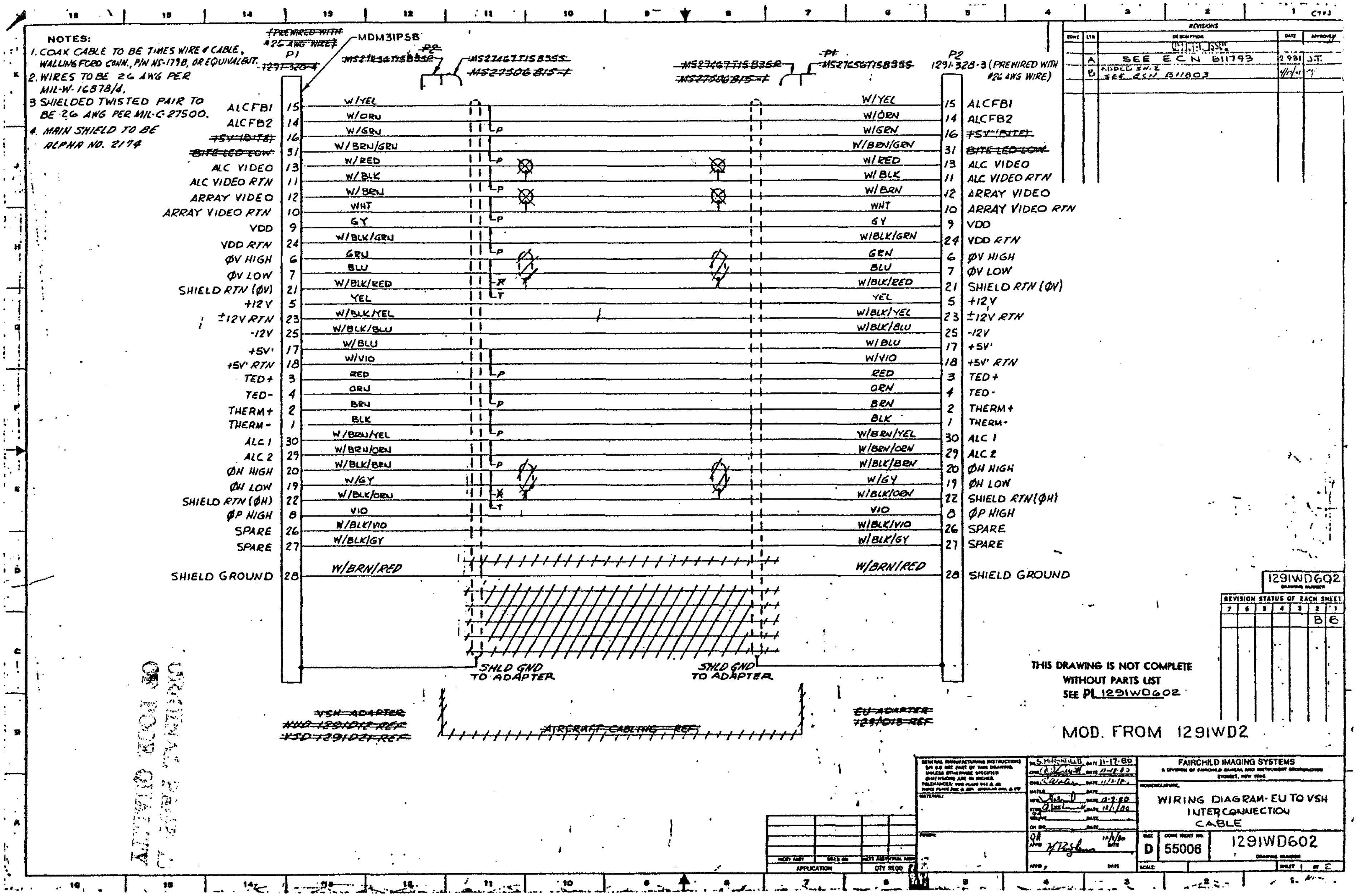

FIGURE 2-3 ADAPTER CABLE WIRING DIAGRAM

No. ED-AX-212, Study of NASA Document No. JSCM 8080, November 1980. This report, submitted on schedule as DRL No. T-1628, line item No. 4, indicated conformance with 29 of the 38 cited standards. The nine standards not reported in the conformance category were:

Standard No.	Reason for Non-Conformance
14A	Drawings not signed off by Materials Engr.
19	Solder used on CCD module enclosure.
22} 33}	(1) VCM rating high for Sylgard potting material (2) Urethane PC board coating used can cause toxicity problem if burned (3) G10 PC board material might be flammable.
25	No qual test program on wire bundles per standard.
41A	Plastic lens cap designed for use only during shipping.
63	Metal couples exceeding 1/4 volt differential in two places.
84	Packaging and shipping requirements not applicable to GFE production CTVS.
107	Separate spaceflight parts stock not applicable to GFE production CTVS cameras.

The non-conformance conditions described above are not expected to effect the usefulness of the modified CTVS cameras for most spacecraft applications. Supplemental information concerning the possible toxicity and flammability conditions cited for standards 22 and 33 above will be found in Report No. ED-AX-213, List, Non-Metallic Materials, December 1980 (DRL No. T-1628, line item No. 7). This report identifies the types and amounts of non-metallic materials used during final assembly of the CTVS cameras.

2.9 ELECTRONIC UNIT (EU) MODIFICATIONS

The modified EU shown in the Figure 2-4 outline drawing utilizes a redesigned baseplate to facilitate mounting and heat sinking in the space environment. The electrical circuit changes, previously described in paragraphs 2.1 and 2.2 of this report, resulted in the component deletions and additions described below. "Marked-up" circuit diagrams indicating how the changes were implemented were prepared, as shown in Figures 2-5, 2-6 and 2-7.

2.9.1 Deletions

Deleted Item(s)	Assy Removed From	Description
VR1, 2,3,4	P2 (EU)	Regulators +12V, -12V, +5V & 5V
R14,16,19,20,54, 55,59,69	P2 (EU)	Resistors RCR 05G Type
U11,17,18 & 19	P2 (EU)	Leads cut, devices not removed
R61,63,64,65,69,71 & 74	P3 (EU)	Resistors RCR 05G Type

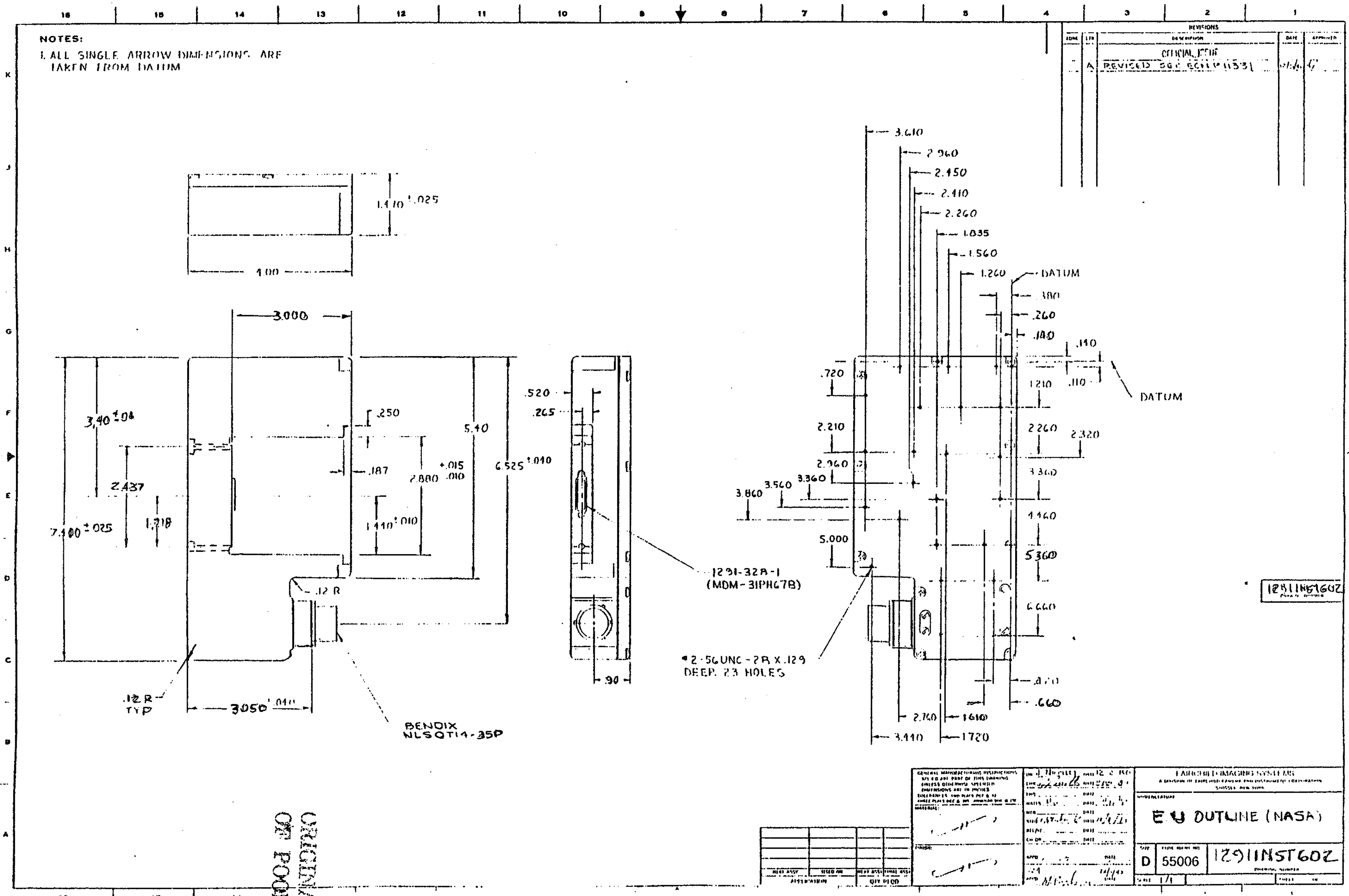

FIGURE 2-4 MODIFIED EU OUTLINE

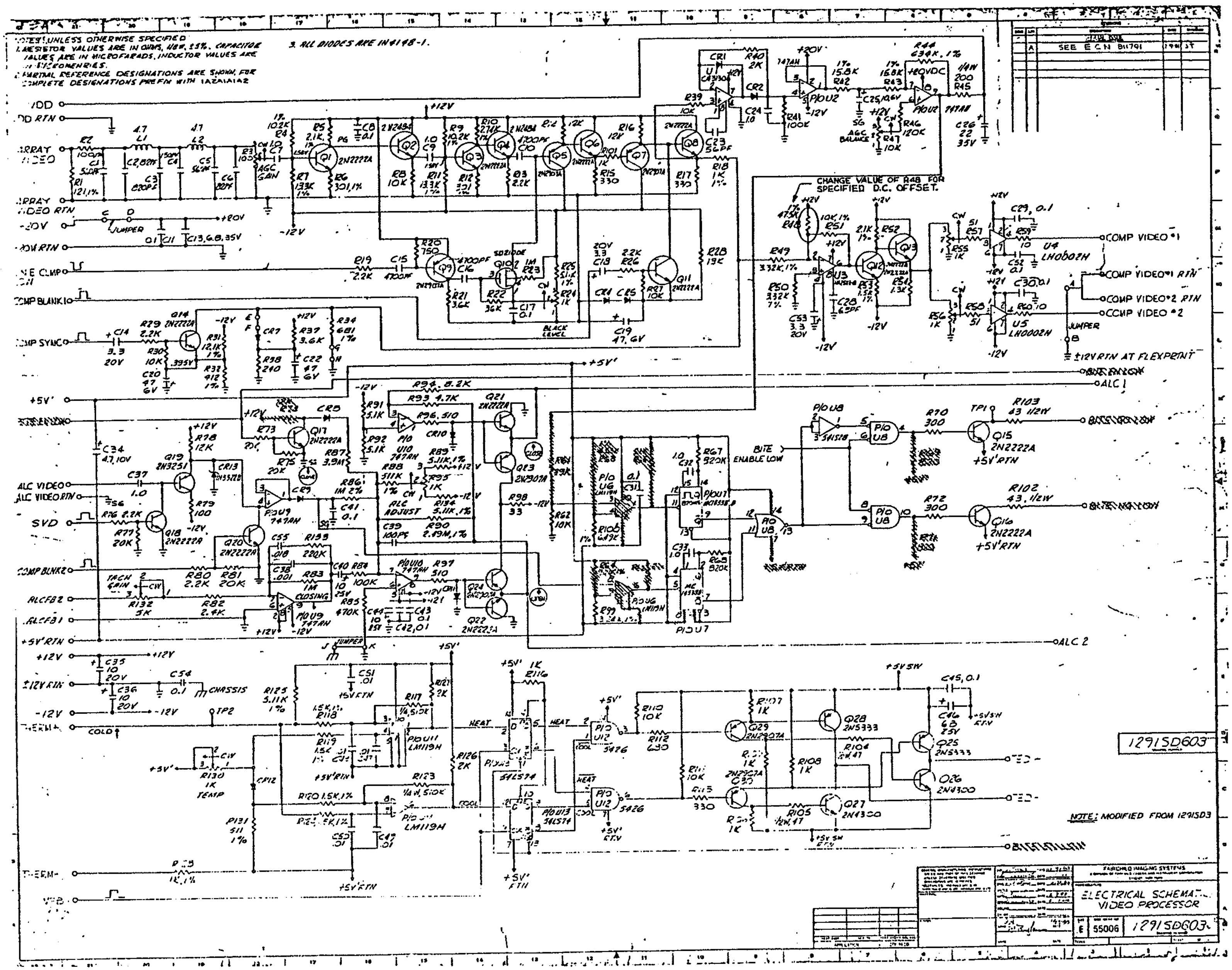

FIGURE 2-5 VIDEO PROCESSOR SCHEMATIC

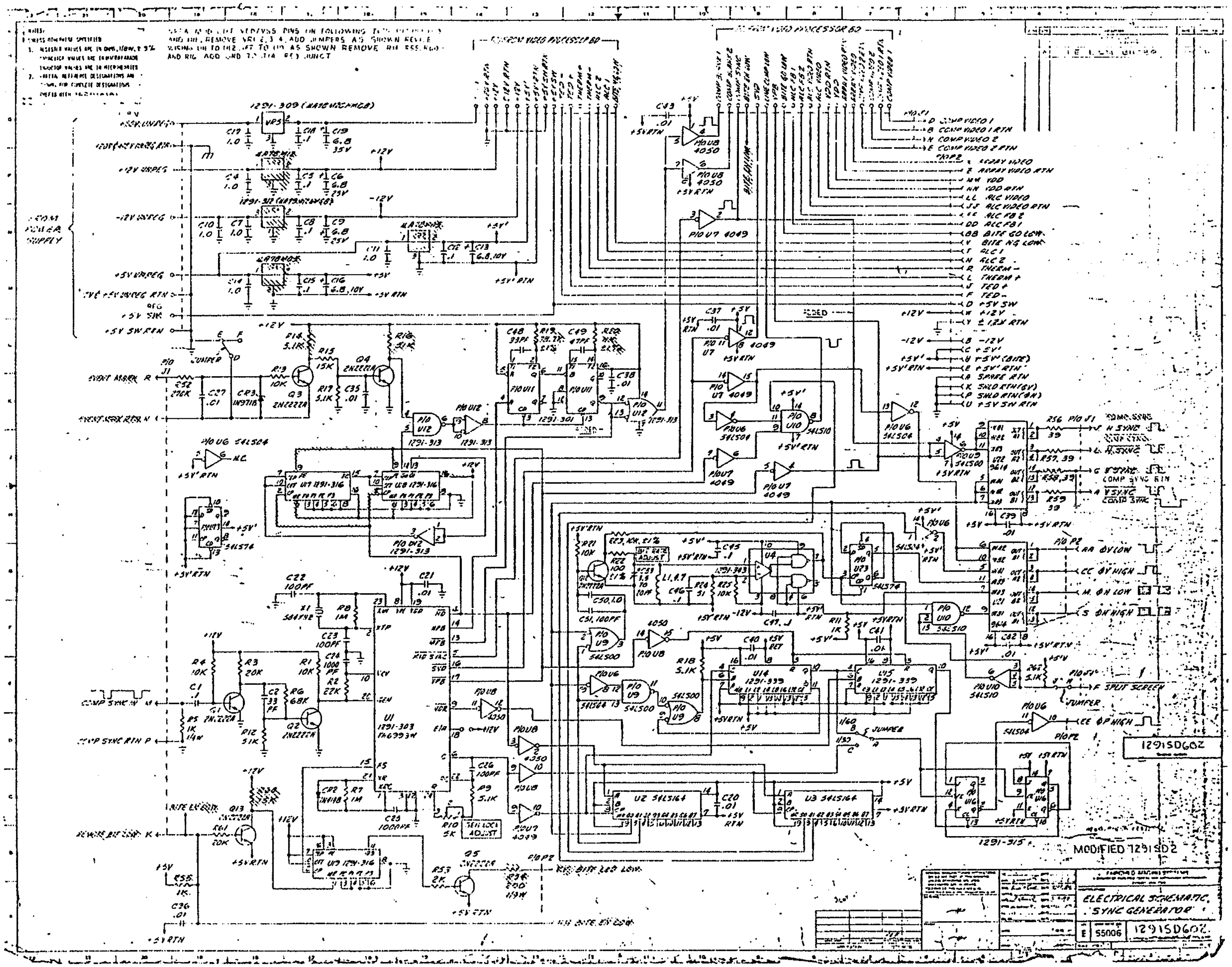

FIGURE 2-6 SYNC GENERATOR SCHEMATIC

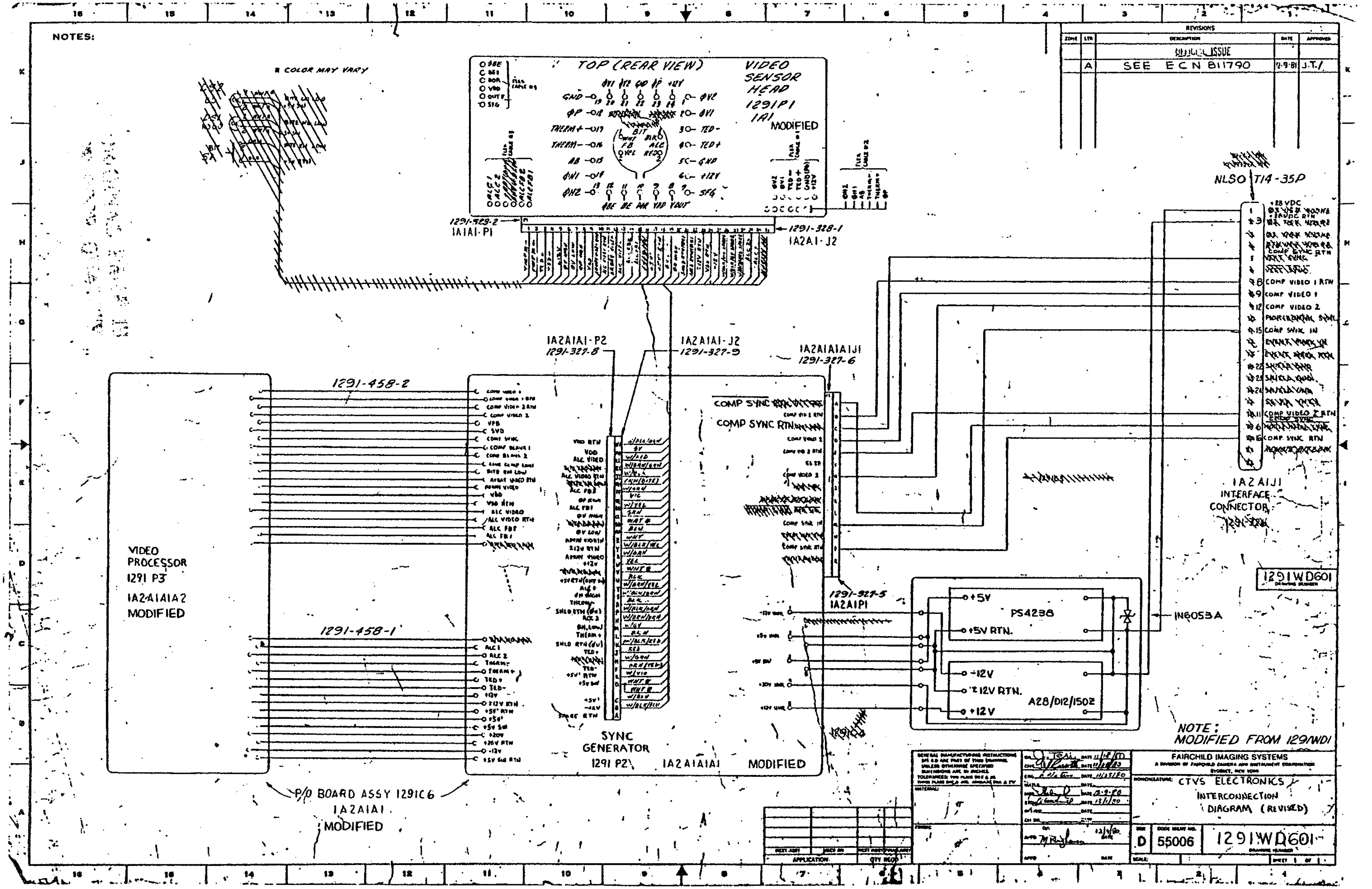

FIGURE 2-7 MODIFIED CTVS INTERCONNECTION DIAGRAM

Deleted Item(s)	Assy Removed From	Description
U6	P3 (EU)	LM119H (Bit Test Check)
U7,8	P3 (EU)	Leads cut, devices not removed
J1	P3 (EU)	Output/Input Connector
1291-325	EU Housing	400 Hz power supply module

2.9.2 Additions

Added Item(s)	Qty	Assy Added To	Description
A28D12/150Z	1	EU	DC/DC Converter
PS-4238	1	EU	DC/DC Converter
MDM31PSB	1	Cable Assembly	Cannon Converter
CUM114FIKL	1	EU I/O Signal Connector	U.S. Components Connector
JAN-TX 1N6053A	1	Power Supplies	General Semi-conductor transient Suppressor
1291-328-3	1	Cable Assembly	Cannon Connector
3/8" Tinned Copper Braid	12"	Cable Assembly	Outer Shield
1/2" Kynar Shriak Tubing	12"	Cable Assembly	Raychem, cable sheath
Kynar Label	1	Cable Assembly	Identification Label

2.10 VIDEO SENSOR HEAD (VSH) MODIFICATIONS

The VSH housing was redesigned to enable mounting of the modified VSH in the upper left front corner of the NASA/JSC helmet/camera housing

The modified housing, shown in Figure 2-8, is a two piece "clamshell" design with the lower half containing the P1 circuit board and VSH/EU interface connector. The wedge-shaped upper portion, which supports the 19mm lens assembly, is provided with tapped mounting holes on the top and side surfaces.

No circuit changes were made; the VSH/P1 circuit board and the VSH/EU interface connector wiring are identical in both modified and unmodified configurations. With an adapter cable the VSH housing can be operated remotely. The camera can also be operated with the VSH directly mounted on the EU housing.

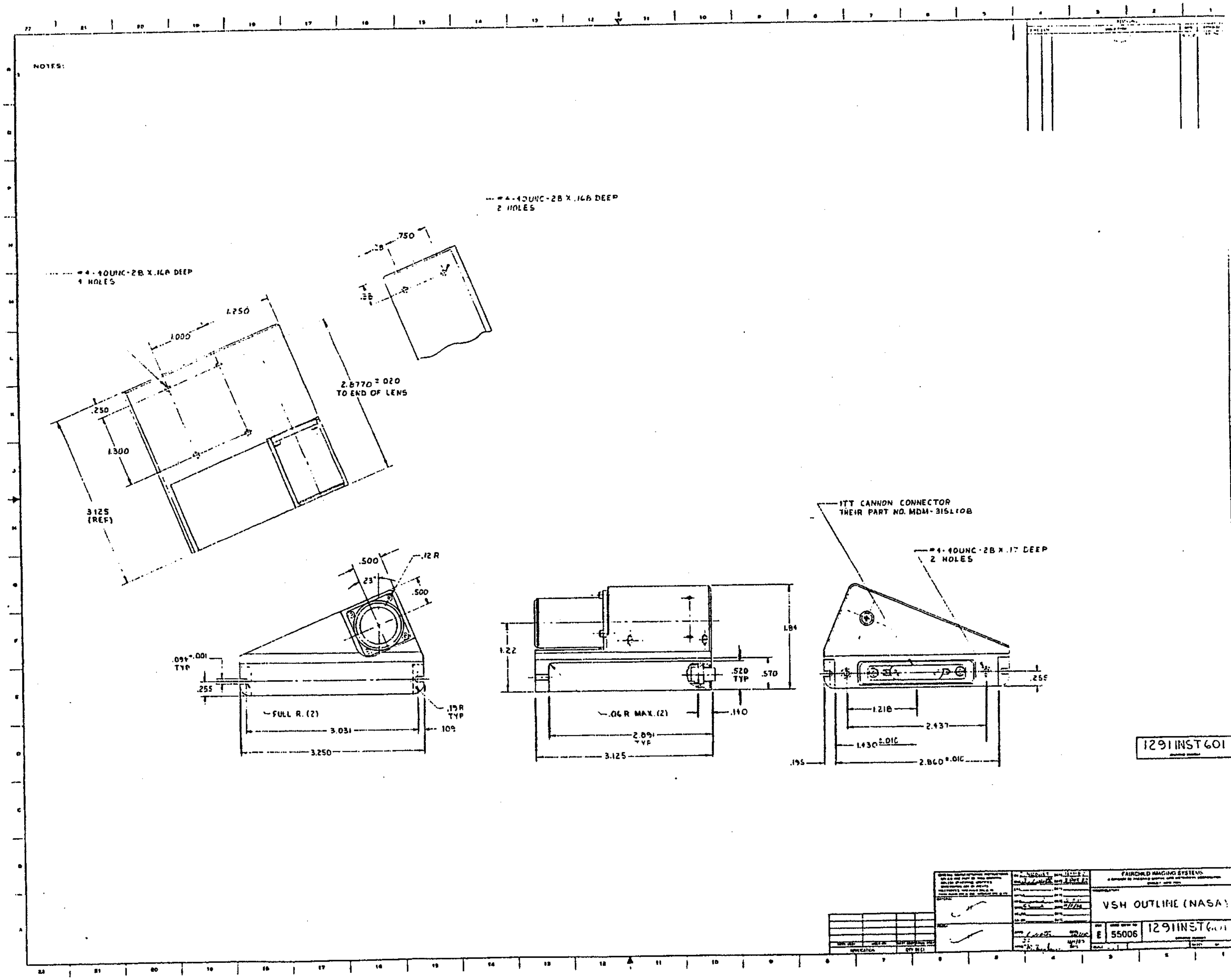

FIGURE 2-8 MODIFIED VSH OUTLINE

3.0 HARDWARE DELIVERY SCHEDULE

The contract delivery schedule was dependent on the receipt of five CTVS units purchased by the USAF for NASA-JSC under contact No. F33657-79-c-0722. All cameras were received and the modifications completed in accordance with schedule requirements.

In addition to the five cameras, two 19mm focal length lenses and five adapter cable for remote operation were delivered in accordance with contract requirements.

4.0 DOCUMENTATION

Documentation items delivered in accordance with contract requirements, included the following:

Description	Ref. SOW Para. No.
NASA 6080 Requirement Study	2.8, DRL Line Item 4
Schematics and Drawings	2.9,2.10, DRL Line Item 8
USAF CTVS Test Documents	DRL Line Item3
Non-Metallic Materials List	DRL Line Item 7
Acceptance Test Procedure (ATP)	DRL Line Item 2
ATP Test Report(s)	DRL Line Item 11
EMI Test Plan	2.5.2
EMI Test Report	2.5.2
Parts List	DRL Line Item 10
Maintenance and Operating Manual	DRL Line Item 6

5.0 PROGRAM RELIABILITY AND QUALITY EFFORT

In the conduct of the modification program, the required electrical and mechanical revisions were carefully scrutinized with the objective of maintaining the reliability characteristics inherent in the unmodified CTVS design. The reliability/quality efforts performed included preparation of detailed descriptions of the modifications implemented. Initially, these modifications were presented for review at an Engineering Design Review (EDR) meeting with reliability/quality control representatives from both NASA/JSC and Fairchold Weston in attendance. A logbook was maintained for each camera describing the sequence of revisions and noting observations of any unusual conditions during the modification, inspection and test phases of the program effort.

5.1 MODIFICATION PROCEDURE

A detailed listing of the proposed modifications and implementation methods were presented for discussion at the October 180 EDR meeting. Subsequently, a flow diagram was prepared and submitted to NASA/JSC and DCAS personnel. This diagram indicated critical inspection and test steps for DCAS, QA and in in-process inspection personnel.

5.2 EEE WHERE USED PARTS LIST

A CTVS Illustrated Parts Breakdown Manual was submitted at the EDR meeting in response to DRL Item No. 10, "As Built Configuration List" agreement. This parts listing was supplemented by informal documentation including marked-up schematics of the parts used and/or changed for the contractual effort.

5.3 EEE PARTS APPLICATION AND STRESS ANALYSIS

The extent of compliance with Fairchild Weston standard derating policy for the camera design was discussed by Reliability personnel at the Syosset EDR meeting. The results of the reliability and maintainability analysis for the unmodified CTVS camera are contained in Fairchild Report No. ED-AJ-278, Rev. B, entitled Reliability and Maintainability Allocations, Assesments and Analysis Report.

5.4 WIRE-SPLICING PROCEDURE

Details of the wiring splicing procedure used in preparing the adapter cable were initially presented at the EDR for NASA review.

5.5 LIMITED LIFE LIST

No parts of the modified camera assembly have been identified as limited life parts.