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Clementine Star Tracker Stellar Compass: Final Report Part 1

R. E. Priest, J. F. Kordas, I. T. Lewis, B. A. Wilson,
D. P. Nielsen, H.-S. Park, R. F. Hills,
M. J. Shannon, A. G. Ledebuhr, L. D. Pleasance

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1. INTRODUCTION

The Clementine flight unit star tracker is the latest model of the Ballistic Missile Defense Organization (BMDO), formerly SDIO, lineage wide-field-of-view star tracker camera designs. The star tracker focal plane, optics, and pointing algorithms were first demonstrated in 1987. Previous papers [1, 2] describe previous models, along with performance expectations. The Clementine vintage, also described in Ref [3], has improvements in radiation resistance, solar rejection baffles, low distortion fiber optics plate, and quaternion angle finding algorithms. With these improvements, the star tracker system reliably determined quaternions throughout the life of the mission.

2. CLEMENTINE MISSION

The Clementine spacecraft was launched on schedule on January 25, 1994 from Vandenberg Air Force Base (CA). After 25 days in lunar transit, which included a week in low earth orbit and the remainder in phasing loops, the spacecraft was inserted into an elliptical polar lunar orbit where it successfully spent 71 days performing a systematic mapping of the moon. The spacecraft left the moon on May 4, 1994 and was starting the Earth/Moon phasing loops for gravity assist boost towards the near-Earth asteroid Geographos when the spacecraft suffered a software failure causing complete loss of attitude control system propellant and putting the spacecraft in an 81 rpm spin. The spacecraft could not be despun to a low enough rate to permit further acquisition of resolvable images, nor could the spacecraft be pointed to a specified direction. As a result there was no possibility of completing the Geographos phase of the mission. Refs [4, 5] provide good overviews and insight into utility of the Clementine data which has been analyzed.

3. STAR TRACKER CAMERA MISSION GOALS

The primary purpose of the Clementine mission was to flight qualify and test the state-of-the-art sensor payload for Department of Defense (DoD) applications. A secondary objective was to produce data of interest to the scientific community. The star tracker camera was selected for the mission because it was a light-weight, medium accuracy star tracker, which was capable of meeting the pointing and navigation requirements of the Clementine flight plan. It served double-duty as a very wide field of view imager (for lunar horizon glow studies) and as a Cherenkov radiation detector with the aperture closed using extremely long integration times.

4. PROGRAM CONSTRAINTS AND GUIDELINES

The Clementine program was conceived to be a demonstration of DoD/BMDO sponsored technologies for space applications in a deep space environment. It had an overriding goal of meeting the scheduled launch of 25 Jan 1994, which was achieved (funding start was March 1992). Maintaining the program within cost was the secondary constraint, with technical performance requirements allowed to float somewhat as the third leg of this well known triad.

The LLNL cameras used on Clementine were derivatives of earlier cameras developed under the LLNL Brilliant Pebbles (BP) Flight Test Program. Modifications to the camera were made to insure camera survivability for the planned 7-month mission. These consisted primarily of using MIL-STD-883B electronics components where practical, up-screening of commercial-grade electronics components, and modifying the camera structures to insure that the electronics were suitable for steady-state operation in a space environment (BP cameras were implemented to operate only for the relatively short duration of a sounding rocket flight).

5. DESCRIPTION

The star tracker stellar compass, hardware shown in Fig. 1, consists of stellar compass software and the physical camera. The hardware consists of a lens, baffle, and a small camera module (consisting of the CCD, camera electronics, and housing). These are described in this section. Table 1 summarizes the camera technical specifications. A functional block diagram is shown in Fig. 2.

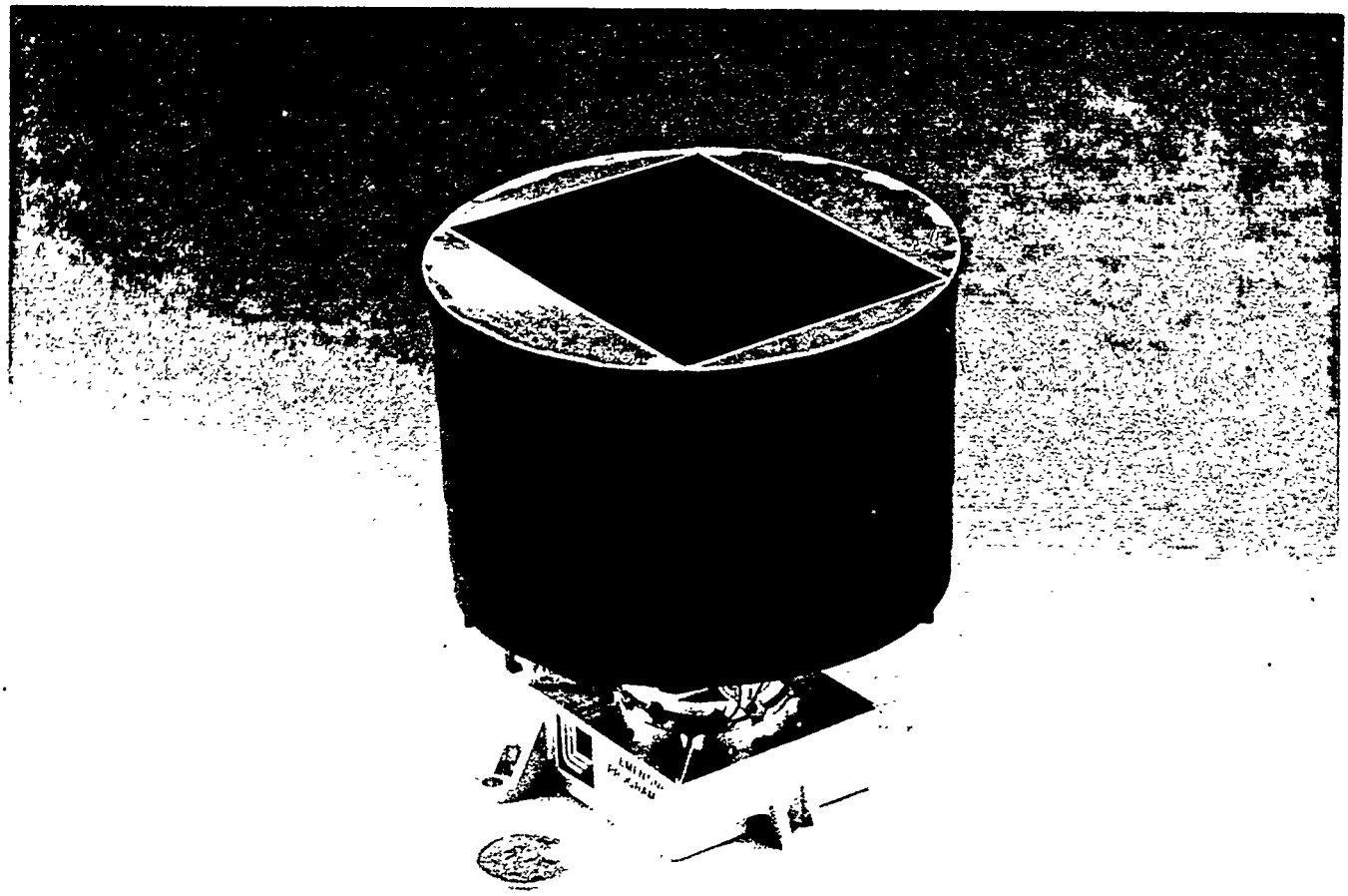


Fig. 1. Clementine star tracker camera.

5.1 Stellar Compass Software

The stellar compass software is a robust set of algorithms resistant to errors induced by noise and moderate amounts of scattered stray light. The major algorithm steps for the camera are:

- sweep each line for potential stars, using self-adjusting differential requirement
- perform blobifying routine to outline potential stars
- find peak pixel reading in each blob
- check blob shape against nominal stellar blur
- find local star background
- find local star centroid and mass
- order star masses
- take top (10) stars to triangulation, with selection weighting towards outer FPA pixels
- list triangles formed by star group
- match triangles to star atlas-derived triangles
- calculate quality of best match
- output match quality and quaternion for navigation use

A number of features that are seen in many high-accuracy star trackers, such as magnitude matching for each star after rough triangulation and "S"-curve correction of the centroid algorithm are not employed. Nor is distortion of the lens corrected on the as-built unit. Without these features, the centroiding algorithm, which is a simple mass-centroid calculation, will return up to 1/25 pixel error for some star center locations with respect to the focal plane. These features were not included because the accuracy of the star tracker was sufficient to meet mission requirements without the additonal algorithm steps.

Table 1. Star Tracker Camera Performance Characteristics.

Attribute	Characteristic
Focal Plane Arrays	
Type	Thomson TH7883-F02-01-B/T Si CCD - 0.4 to 1.1 microns Full Frame Device
Pixel Format	384 x 576
Array Size	8.83 x 13.25 mm
Pixel Size	23 x 23 microns
CCD Operating Temperature	10°C Maximum (Clementine spacecraft specific)
Optics	
Type	Concentric Refractive
Aperture	14.0 mm diameter.
Focal Length	17.5 mm
Speed	F/1.25
Imaging	
Spectral Range	0.4 to 1.1 microns
Array FOV	28.9° x 43.4°
IFOV	1.314 x 1.314 milli- radians
Point Spread	20%-40% of image blur energy in 23 µm square and >80% in 75 µm square
Noise Characteristics	< 90 electrons @ 20°C for 50 ms integration time. Dark current and dark signal non-uniformity are limiting for longer integration times.
Electronics	
A/D Resolution	8 bits
Frame Rate	<10 Hz
Readout Time	54.8 msec
Digitization	75, 150, 350 e^-/count
Readout Noise	60 e^- RMS
Integration Time	0.2-773 ms (typical ≈150 ms)
Offset Control	248 gray level offset; 5 bit control word; LSB = 8 gray levels
Average Power	
Camera	4.5 Watts
Lens Heater	≤ 1.95 Watts (50% duty cycle @36 v)
Physical	
Envelope	11.7 cm x 11.7 cm x 13.2 cm
Mass	290 g

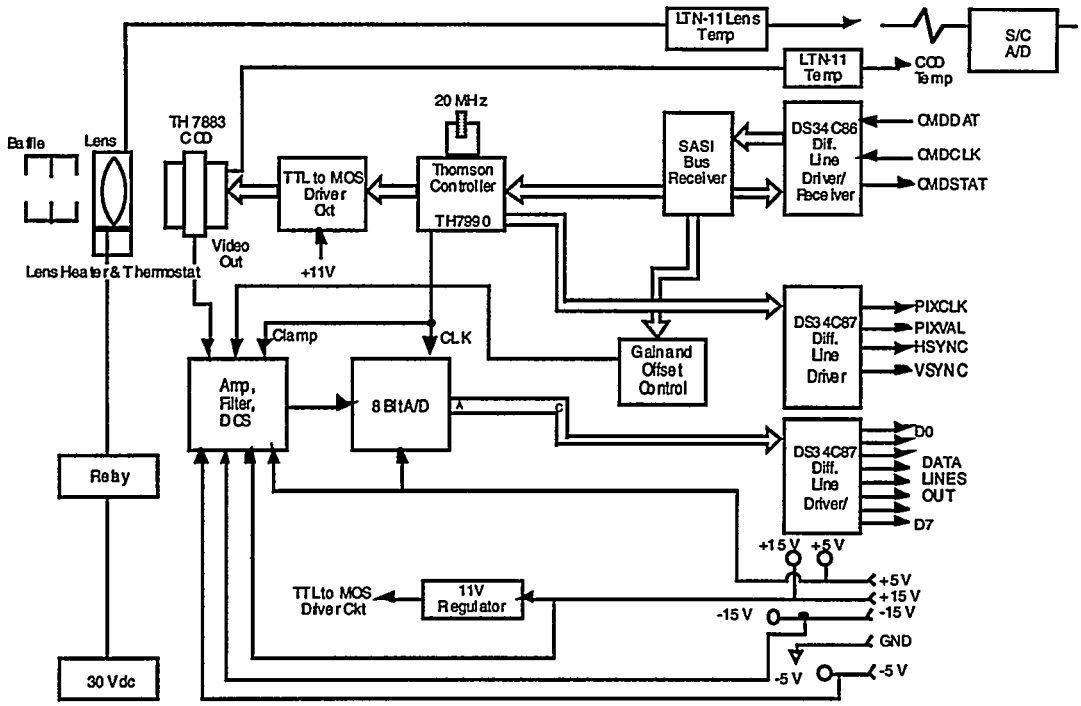


Fig. 2 Clementine star tracker camera functional block diagram.

Accuracy of the present star tracker is limited by the distortion pattern in the fiber optic faceplates located in the rear of the star tracker lens and on the focal plane array. Zero-shear faceplates were ordered for the Clementine built star tracker units, which decreased the rms distortion in the lens to roughly 200 μrad rms, with the peak distortion values at the edges of the focal plane (where stars are dimmer as imaged through the lens and are infrequently selected for triangle matching). With at least 5 stars required for a positive match, the contribution of a single star in the corner of the FPA to the overall pitch or yaw pointing error is reduced. Other sources of pointing error are noise influence on the mass centroiding error and the "S"curve error from the algorithm itself.

The end result of the algorithms implemented on the Clementine flight unit passed ground tests with <100 μrad rms pitch/yaw error and <450 μrad rms roll error. These tests were repeated zenith viewing throughout the night, with quaternions fit to an equatorial earth motion model. Zenith viewing reduces atmospheric refraction effects. Temporal noise in most star fields was on the order of 20 to 30 μrad rms, with occasional jumps in pointing quaternion seen as a star drifted onto (or off) a distorted fiber optic section. If a distortion correction algorithm were implemented, the noise level of 30 μrad pitch/yaw and 200 μrad roll would be achieved.

Perhaps the most unique features of this star tracker code are the adaptable threshold sweep, which allows operation even with degraded stray light and camera noise conditions. This algorithm group floats with background increase and with low frequency background changes across the field of view. Rows are processed left to right, and pixels that are N counts higher than the preceding neighbor are flagged as possible bright spots. The algorithm starts with a high threshold value (i.e. 10), and lowers the threshold by 1 count and re-scans the line until not more than 1 candidate star pixel is found. For example, if there are 3 pixels with a signal increase of 2 counts, no candidates will be found at 3 threshold, but 3 will be found at a 2 threshold. This causes the entire line to be discarded, since the noise is on the order of the brightest possible real star. Even if the pixel did pass the star test for this line, noise values would cause centroiding results to be inaccruate.

For Clementine, the on-board star atlas was a trimmed and adjusted version of the SAO catalog which included 464 stars. This set guaranteed that there would be 5 stars of m_V 4.5 or greater in the field of view at all times. The set was also adjusted to accomodate the color sensitivity of the CCD.

In flight, the star tracker camera reliably provided quaternion updates to the spacecraft throughout the life of the mission when the solar exclusion angle was respected, with 1 exception. Early in the mission, after stage separation, star matches

were not achieved for a period of an hour. Later analysis of downlinked images showed that the 10 brightest blobs in the FPA were space debris resulting from the separation, which is a condition that was not expected in the default software.

5.2 Optical System (Ref Appendix C)

The star tracker lens was specified and built to have a 42° x 28° field of view. This sizing results in a pixel IFOV of 1.3 mrad, which is small enough to provide the requisite quaternion accuracy. The collection aperture of the lens is maximized for the greatest possible light gathering capability. At F/1.25, $m_V = 4.5$ G0 stars provide an integrated star signal that is 15 times the electronic noise from the focal plane. This level of signal gathering capability, matched with the wide field of view, ensures a 99.9% probability that 5 stars above minimum threshold will be available for the algorithm set for all possible quaternion pointing vectors. This allows the star tracker to handle the "lost in space" condition with a single star image frame and no other apriori knowledge of location.

To avoid chromatic aberrations that would shift star centroids with star color temperature at the edges of the field of view, and to maximize imaging F/number, a concentric optical design was adopted. For extension into a long-life space mission, only radiation resistance glass, including fiber optic faceplate material, was included in the optical path. Use of the radiation resistant material reduces transmission in the shorter wavelength regions of the CCD response, virtually blocking all light below 500 nm, however, for doses on the order of 10 KRad Si, the net transmission gains throughout the life of the mission compensate the early transmission loss. Fig. 3 depicts the optical system with baffle.

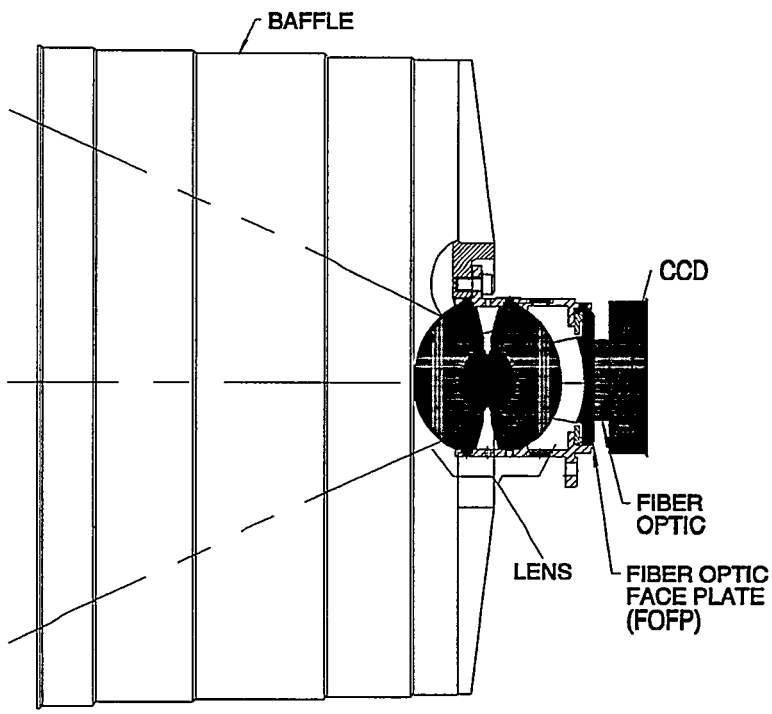


Figure 3. Star tracker optical system showing the image plane at the fiber optic face plate, the concentric lens elements and the single stage baffle.

5.3 Baffle

Small amounts of scattered sunlight can be much brighter than the image of the dim stars needed by the sensor for proper operation. (The sun is 12 to 13 orders of magnitude brighter than the stars used for navigation.) Without a baffle, operation would only be possible when the sun, solar-illuminated moon, and solar-illuminate earth are all behind the star tracker line of sight and not illuminating spacecraft structure in the forward hemisphere of the star tracker line of sight. A baffle was designed to allow operation with more general sun/earth/moon constraints.

Stray light reduction requirements for the camera were expressed in Point Source Transmittance (PST), which is defined as the ratio of flux reaching the FPA of a sensor to the flux at the aperture of the sensor. The design goal PST of the star tracker baffle/ lens opto-mechanical package was set at 10^{-7} PST, which yields a signal of 5 counts when the full solar illumination is incident (outside the rejection angle) on the star tracker camera at nominal integration time and gain settings.

Both flight star trackers were tested using a 1 kW quartz tungsten halogen lamp source for illumination. Testing was performed both outdoors and in the high bay assembly area for the Clementine camera. Both test areas had significant amounts of aerosol particulates, that contributed to the stray light readings. Aerosol magnitudes were typically $< 5 \times 10^{-7}$ equivalent PST, which made a correction of the aerosol signal to 10% accuracy well below the critical 10^{-7} PST testing goal. Scattering was in the range of 10^{-4} to 10^{-5} PST when the illumination source glanced off any structure (except baffle vanes) forward of the lens. The image saturated when the illumination source directly lighted optical surfaces. The results for the two flight units is given in Figs. 4 and 5, showing that the baffle blackening, vane sharpness, and dimensional layout combined to meet the stray light reduction goals.

The baffle was allowed to extend 3 inches past the star tracker lens vertex, and provided operation when the sun/earth/moon were outside a 65° x 80° angle exclusion zone. (The rectangular field of view is a result of rectangular baffle openings that pass the star tracker field of view.) Internal surfaces are coated with a MIL-F-495 Cu-black process on Ni-plated aluminum, which provided reflectance as low as industry standards Ball black and Martin black processes. Baffle construction, discussed later in this paper, was accomplished with adhesive.

5.4 Camera Electronics (Ref Appendix D)

The camera electronics are built around a Thomson TH7883 CCD, a Thomson TH7990 CCD controller and an Actel field programmable gate array (FPGA). The Actel FPGA controls operation of the TH7990 CCD controller and analog circuits (Gain, Offset and Double Correlated Sampling{DCS}) on the camera, generates video timing and additionally implements functions of the synchronous addressable serial interface (SASI) bus protocol receiver. The camera received commands from the Clementine Sensor Imaging Processor (SIP) via the SASI bus. The commands are received and processed by the Actel FPGA. The FPGA controls the operating modes of the camera by controlling the operating mode of the TH7990. The camera returns digitized video to the SIP. This is represented functionally in Fig. 6.

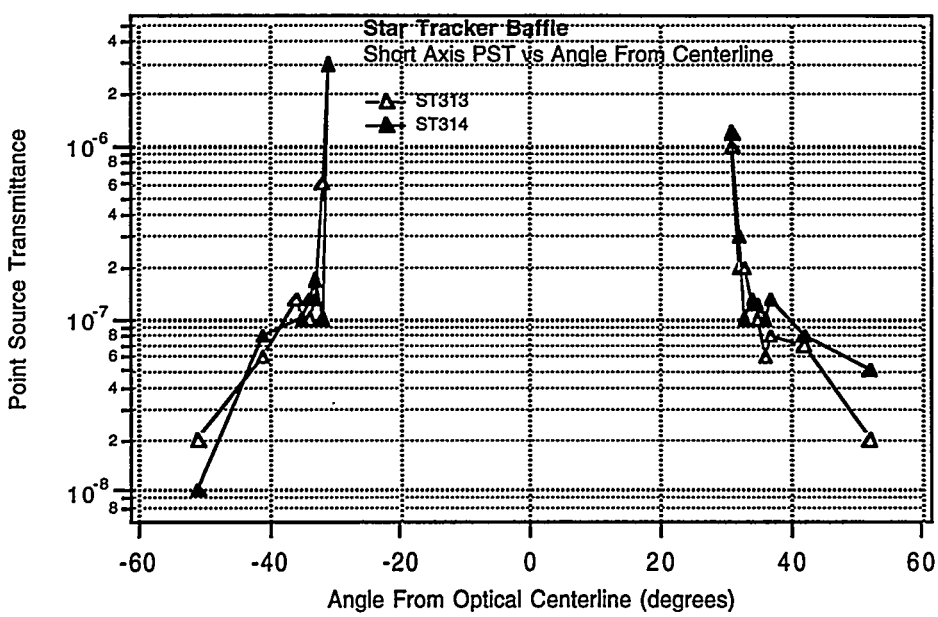


Figure 4. PST vs angle for the short axis of the flight star tracker cameras.

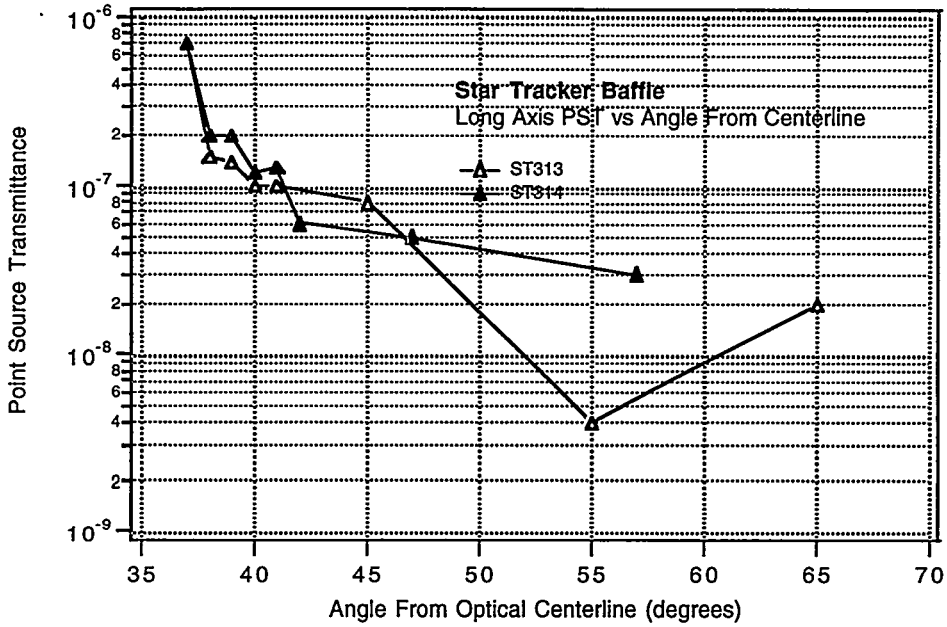


Figure 5. PST vs angle for the long axis of the flight star tracker cameras.

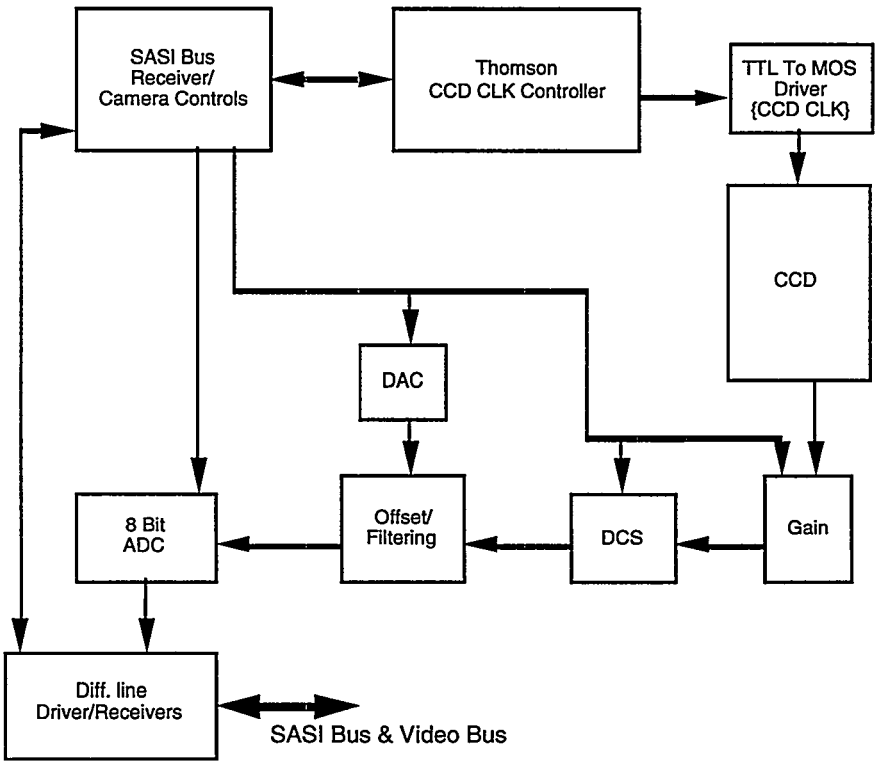


Figure 6. Star tracker camera electronics functional block diagram.

Numerous camera commands were accommodated through the use of a Synchronous Addressible Serial Interface (SASI) interface protocol system utilized throughout the spacecraft system. The digital control interface electronics included in the electronics design decoded the SASI commands, and responded to respective commands with changes in camera settings. A status word was produced by the camera which echoed back the result of directed changes to the camera settings.

The camera has two modes of integration control, precision integration control or SASI control. The mode is selected by setting the control bit (BIT 3 or parameter ID = 0) either HI for precision control or LOW for SASI control. If precision integration control is selected, 13 bits of integration data must be loaded into the command data registers at parameter ID 2 and 3 with bit 4 of the command data register at ID 3 being the MSB. Integration time in this mode equals (n+1) * 94.4 μseconds. The minimum acceptable n is 1, resulting in a minimum integration time for the star tracker of 188.8 μseconds. In the SASI control mode, integration is initiated by bringing the control bit (bit 0 of the parameter ID = 1) LOW. The control bit must be LOW for at least 100 μseconds. Readout is initiated by bringing the same bit HI. In the precision control mode, integration is initiated by a HI to LOW transition of the same control bit (bit 0 at parameter ID = 1). Readout will occur automatically after the pre-set integration time. The control bit must be returned HI before initiating the next integration cycle and left HI for at least 100 μseconds.

In the analog domain, the output of the CCD is buffered through an emitter-follower before global gain is applied. Camera gain is selected by setting one and only one of the gain control bits (bits 4-6 at parameter ID = 0) HI which switches a gain resistor. The camera has three gain setting of 350 e^-/bit ,150 e^-/bit and 75 e^-/bit. After global gain is applied, DCS is applied. Gain is applied to the signal before the DCS so as not to introduce excess noise to signal which would then be amplified. Timing for the DCS is achieved in an Actel FPGA. Offset is applied to the signal after DCS. Camera offset is selected by setting a 5 bit control word (bits 0-4 at parameter ID = 5) which is sent to a digital to analog converter (DAC). One LSB equals an offset of 8 gray levels. The maximum offset equals 248 gray levels. After offset the signal is converted to digital value by the flash analog to digital converter.

5.5 Camera Construction (Ref Appendix E)

The measured mass of the two Clementine flight star tracker cameras was 280 grams and 286 grams. The camera consisted of a camera module, lens assembly and light baffle. The camera module, the core unit utilized on this camera and the Clementine UV/Visible and HiRes cameras, contained a Thomson CSF 7883 CCD and a flexible printed wiring assembly (PWA). The lens assembly consisted of radiation-resistant Cerium-doped glass, aluminum housing and a thermostatically controlled Nichrome lens heater. The light baffle is a single stage device discussed earlier. This camera was designed to survive a 19.8 g rms, 60 second duration launch during launch aboard a Titan II G launch vehicle, and operate in space for the seven month duration Clementine mission.

Fig. 7 depicts the camera module. The PWA has three rigid sections (main, CCD and connector) where electronic components are mounted. These sections are connected by flexible lengths which allow the PWA to be folded over on itself. The main section contains most of the components and has it's thermal planes at the four corners exposed on both sides. These corners are clamped between the two pieces of the camera module for structural support and heat transport from the board. The space between the two camera parts at these corners is custom adjusted based on PWA thickness measurements so there is a 0.0005 ± 0.0001 inch compression of the PWA corners. This compression insures adequate contact pressure for heat transfer while maintaining the structural integrity of the printed wiring board.

The PWA is folded so that the CCD area is located beneath a tongue in the camera housing. This metal tongue is situated between the CCD and the CCD section of the PWA. Compliant thermal shims are located at the two interfaces. The CCD and the PWA are pressed tightly against this metal tongue with a metal retainer and No 2-56 fastners to thermally sink the CCD.

The main mechanical structure provides a precision surface for referencing to the lens housing via a spacer. The CCD in turn is aligned to the fiber optic faceplate (FOFP) at the back of the lens, and bonded to this FOFP with a curing, transmissive optical couplant. The focus spacer is custom-lapped to the finished height to within 0.0002 inches total indicated runout to insure parallelism. Further, a 0.0003 ± 0.0001 inch gap between the FOFP and the CCD face is achieved. This gap is filled with Dow Corning 93-500 optical couplant, cementing the lens to the CCD.

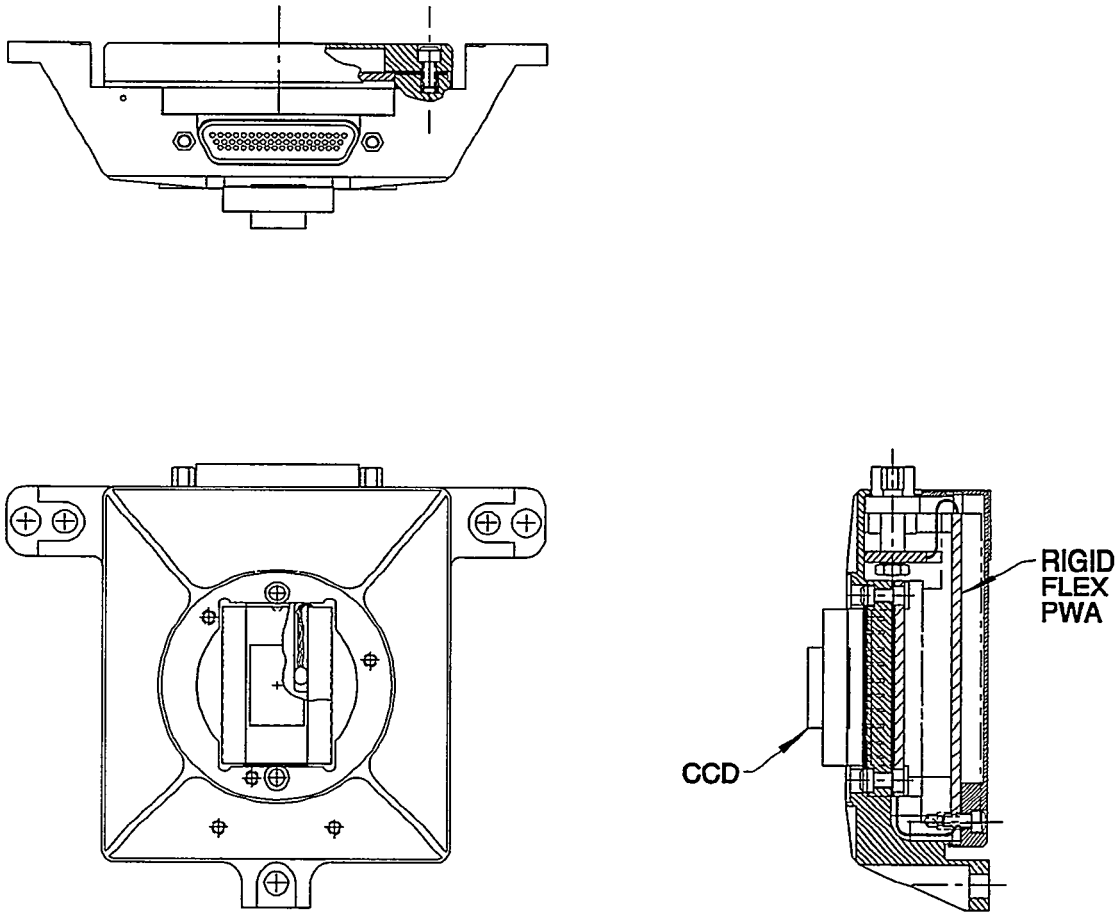


Figure 7. Camera module used for the star tracker camera.

Heat is transported from the components, the printed wiring board (PWB), through the aluminum housing and to the spacecraft's camera thermal management system. Hot electronic parts use thermal grease between the part and the PWB. The PWB is designed with two 1-oz thermal planes near the outer surface of both board sides. Further, thermal vias are located under expected hot components. The camera housing and end cover have integral heat paths with specific sections sized for low thermal resistance. A separate path for heat generated by the CCD is provided with use of an Al 1100-0 thermal strap, to insure that the temperature gradient between the CCD and camera cold plate is minimized. The flexible CCD thermal strap was fastened at the outside of the camera housing and then directly to the camera's heat pipe. Heat from the electronics is removed at the three mouning feet, and at the four corners of the camera's end cover. At all part interfaces (e.g. PWA to camera housing) a thin layer of Dow Corning 340 thermal grease is used to minimize thermal resistance.

The baffle is shown as part of Fig 1. All material is copper oxide black Al 7075. The baffle is fabricated by machining the cylinder with support steps for the vanes, and machining the 0.010" thick vanes. With the outside diameter of the vanes undersized to the baffle inside diameter by 0.020 inches, each vane is successively bonded to the cylinder at it's outside diamter with a low outgassing adhesive. The aluminum is electrolis deposited with a .0001" to .0002" nickel protectant then electro-deposited with .0003" copper plated using a geometry-specific anode. This is then put in a boiling Ebanol soultion at 214°F for an experimentally derived period of time (typically tens of minutes). A deionized water rinse, and air drying completes the process. At final camera assembly a single layer of silver teflon tape is applied to the outer surface of the outer vane.

To protect the lens against extreme cold, a 450-ohm Nichrome heater with a bimetallic switch turns the heater on when the unit drops below -6°C. The 1/2-inch wide heater strip is pressed against the outer diameter of the lens housing with an aluminum clamp, and the bimetallic switch is fastened to a flat on the clamp. The heater is powered by spacecraft 30 ± 6 Vdc.

6. ENGINEERING HOUSEKEEPING DATA CHANNELS

Several parameters were monitored to track the health of the cameras over the mission duration. These were image quality (dark level), CCD temperature, lens temperature, camera current levels, camera voltage levels and lens heater current. Additionally, switches were monitored to indicate ON/OFF status.

Temperatures were measured with Fenwall LTN-11 thermistors (purchased with calibration curves), with each thermistor bonded in place with Tra-Bond 2151 thermally conductive adhesive. The CCD thermistor was mounted flush with the backside of the alumina carrier package of the CCD, and was captured by a machined slot in the camera housing. The lens thermistor was bonded to a flat on the lens heater clamp, and was left exposed as the protective "coffee can" prevented significant radiative heat transfer effects on its measurement.

7. INTERFACES

Camera interfaces (optical, mechanical, thermal, electrical and communication) were defined with the spacecraft integratòr (Naval Research Laboratory) prior to, and modified during, camera development. An interface control document (ICD), Ref [6], provided working constraints between LLNL and NRL.

The camera is bolted to the spacecraft at the camera mounting plate with three No 4-40 fasteners. A single Al 1100-0 CCD thermal strap is attached at the camera and directly to the camera heat pipe (part of the spacecraft Thermal Control System). To minimize particulate contamination to the lens and to minimize external, radiative thermal loads, NRL provided an enclosure for this camera (star tracker "coffee can"). The "coffee can" had a cover which was normally closed and could be opened when operation of the camera was required. The camera communicated to the spacecraft processor via a synchronous addressable serial interface (SASI) bus protocol based on the Goddard Flight Center (GSFC) 650C custom PMOS process digital integrated circuit. Digital lines were CMOS tri-stated differential line drivers and receivers based on RS-422.

8. FLIGHT QUALIFICATION DESIGN, ANALYSIS &TESTING

Cameras were designed, analyzed, developed and subjected to critical peer review (design reviews and test data reviews). Each camera was subjected to extensive testing to measure compliance with interface definitions and show basic functionality, determine compliance with environmental test requiremnents, and to characterize the electro-optical preformance in response to expected viewing scenes. Prototype units were built to act as a pathfinder during each phase of development testing. These prototypes were also aggressively used in integration activities to find problems early thereby maintaining schedule. Appendix E.1 shows the star tracker camera structural analysis report.

Environmental testing was performed in compliance with the Clementine program guidelines and MIL-STD 1540B "Test Requirements for Space Vehicles". Tests included radiation (for the CCD and electronic components), random vibration, thermal cycling, thermal vacuum and electronic burn-in. Table 2 summarizes the test environments. Test data may be seen in appendices of the certification logs for each camera.

9. CHARACTERIZATION AND CALIBRATION

Extensive pre-flight calibration data were acquired using an automated calibration facility at LLNL. In a typical calibration configuration, a sensor was mounted inside an environmental chamber whose temperature was varied from -20° to 20 °C, the expected operating temperatures for the mission. Depending on the measurement types the sensors saw either a flat diffused light source or an off-axis collimator with various pinholes as the point source. A custom board controlled the sensor parameters from the host computer; the video signal was acquired using a commercial image processor. During data acquisition many thermal parameters such as FPA and chamber temperatures were monitored and recorded as part of the image structure. All calibration processes were fully automated enabling us to acquire data quickly while reducing operator errors.

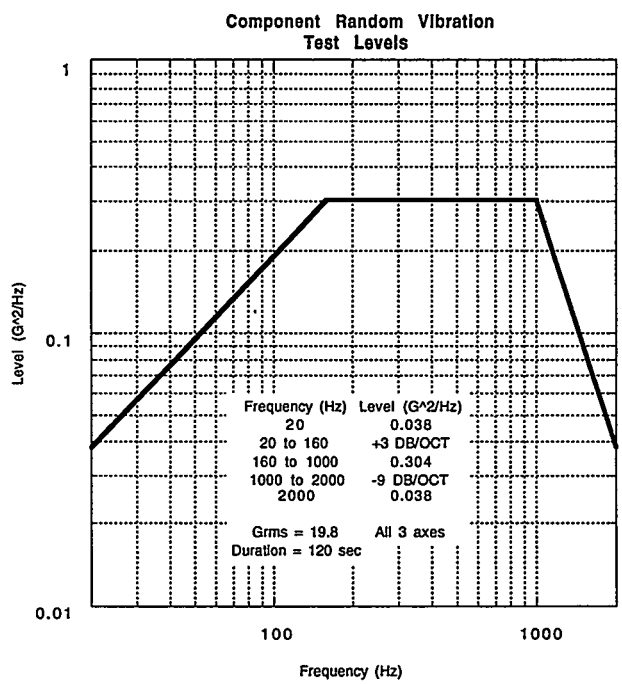
Pre-flight calibration measurements for the star tracker provided critical alignment data for integration to the spacecraft. These were location of the optical center of the lens relative to the CCD (x,y pixel coordinate), and optical boresight relative to the mounting feet of the camera (mechanical center). A two-dimensional angle map made in the laboratory, at roughly 0.5° increments, was made using a collimated source to determine the net $h = f(\theta_x, \theta_y)$ star centroid mapping function. This data

set was fit to the nominal $h = \sin(\theta)$ mapping function of the lens to determine best fit for center pixel (θ_0) and focal length. A verification an d further refinement of this curve fit was made with the camera zenith-looking, then calculating a least-squares fit of the resulting quaternions taken over a several hour period.

Additional camera performance parameters measured included radiometric sensitivity; FPA uniformity; gain and offset scale factors; temporal / spatial noise; dark noise dependence on FPA temperatures, integration times or input voltage levels, spectral response of FPA; optical distortion map; point spread function and electronic warm-up time. Appendix F presents the available summary reports on calibration of the flight star trackers.

Due to the criticality of the star tracker to the flight control of the mission, exhasutive tests were performed on the lifetime of the optics, coatings, focal plane performance, and electronics performance under the mission required radiation dose.

Table 2. Clementine star tracker camera environmental analysis and testing.

Space Radiation	20 krad (at Silicon) total dose
Derived Structural Loading Requirements	• Factors of safety 1.10 (yield), 1.25 (ultimate) • 100 g's steady-state loading in each axis • 19.8 g rms random vibration from 20-2000 Hz • 84 g peak acceleration for pyro-shock • > 50 Hz output frequency
Random Vibration	
Thermal Cycling	-30°C to 20°C, six cycles
Thermal Vacuum	by similarity with qualification unit, -20°C to 20°C
Electronic Burn-in	> 300 hours

10. CLEMENTINE MISSION DATA

Mission data from the two star tracker cameras provided a myriad of raw star tracker images, useful for verifying the navigational capabilities of the camera, and a group of images to detect possible lunar horizon glow. The horizon glow data was gathered by pointing at the limb of the moon just before sunrise, detecting solar corona and possible scattering of dust particles (if present) close to the surface. The navigational requirements of the spacecraft were met using the star tracker/IMU combination as evidenced by the overalpping (correct pointing) of the mosaic UV/Visible and NIR lunar images.

The large set of Clementine images is accessible in various forms on the Internet at three locations (as of this writing):

http://flgsvr.wr.usgs.gov:80/clementine (United States Geological Survey, Lunar Institute)
http://www.nrl.navy.mil/clementine/clementine.html (United States Naval Research Laboratory)
http://Clementine.s1.gov (United States Department of Energy, Lawrence Livermore National Laboratory)

Section 15 of this document is a sampling of imagery captured by the star tracker camera during this mission.

Beyond images, engineering data for the two star tracker units has been collected for engineering evaluation. Data available is described in section 6 of this document. Fig. 8 shows sample data for the CCD and lens temperatures on star tracker A during orbit 72. Graphs for the various parameters are shown in section 16 of this document.

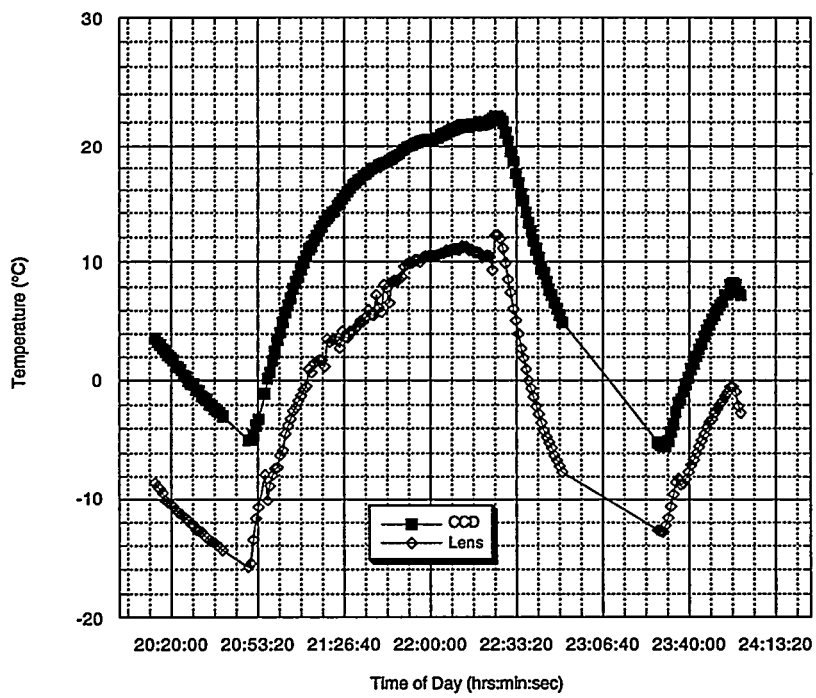


Figure 9. Star tracker A CCD and lens temperature for roughly one orbit on March 12, 1994. The CCD temperature exceeds the desired 10°C maximum value, but did not impair the star tracker stellar compass ability to achieve star matches.

11. LESSONS LEARNED

While the star tracker was very successful at meeting the mission objectives of this space flight, improvements could be implemented to reduce quaternion error and design complexity, without increasing the cost or mass of the star tracker camera. The most significant improvement of this version of the camera, applicable to extended space flights, would be the inclusion of an Multi-Phased Pin (MPP) focal plane array. The present CCD array will suffer increases in dark current with moderate levels (typical multi-year flights) of solar-flare radiation. In order to accommodate the solar flare potential for Clementine, the CCD temperature was specified to be controlled to less than 8°C through heat strapping to the spacecraft thermal control system (at a heat pipe). Cooling the CCD is a method effective in reducing dark current. At the maximum radiation requirement, the dark current variation, pixel-to-pixel, would have been large enough, even with the temperature limit, to degrade performance. MPP type arrays are much more radiation tolerant, and would not suffer in potential moderate radiation exposure.

Algorithm improvements can also be implemented to reduce quaternion error. These include a noise-reduction step and a signal processing improvement. Noise reduction would be accomplished by subtracting the nominal fixed pattern noise from the array, while software improvements would include distortion mapping and correction and "S"-curve error seen with the mass centroiding algorithm.

12. CONCLUSIONS

The star tracker stellar compass, as part of the suite of 6 light-weight, low power imagers [Refs 7 through 11] which were space-qualified for future Department of Defense flights, served as an integral part of the navigation system of the Clementine camera, providing accurate quaternion updates throughout the life of the Clementine mission. It is a space-qualified, proven, viable moderate-accuracy camera package, which, when coupled with the stellar compass software on the Clementine R3000 processor, provided quaternion data at 5 Hz rate. This system proved to produce valid quaternions for CCD temperatures up to 27°C, 17° above the limit specified prior to launch, demonstrating robustness beyond expectations.

13. ACKNOWLEDGEMENTS

- This work was performed by LLNL under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-ENG-48.
- Funding was provided by the U.S. Ballistic Missile Defense Office.
- The lens was designed and built by Optical Corporation of America - Applied Optics under LLNL subcontract B208983.
- CCDs were purchased from Thomson CSF under LLNL subcontract B999999.
- Special thanks to the core members of the LLNL Clementine team responsible for the star tracker stellar compasses. Without their unselfish, dedicated efforts this would not have been possible.

LLNL Clementine Team

Management:	Lyn Pleasance, Mike Shannon, Arno Ledebuhr
Optical:	Izzy Lewis, Travis White
Electronics:	Joe Kordas, Bill Bryson, Darron Nielsen, Mercedes Dickerson, Don Antleman, Gil Zaragoza, Wes Strubahr, Dean Hadley, Bob Hugenberger
Mechanical:	Bob Priest, Mike Richardson, Preston Carter, Darryll Pines, Al Harrall, Bill Taylor, Tom Gorman, Gil Wong, Riley Martin, P.C. Wigley, Jim Dickie, Phil Stephan, Jeff Robinson, Jim Nally, George Cameron
Software:	Bruce Wilson, Diana Sackett, Hal Brand, Ernie Arnold, Mike Wilson
Fabrication:	Ed Schmitt, Bill Rice, Ken Leach, Kathy Coatney, Dottie DaRonco, Diana Silva, Joe Burris
Calibration:	Hye-Sook Park, Doug Dobie, Ted Feretta, Linda Ott, Mark McKernan, Phil
Integration:	Rob Hills, Noel Sewall
Subcontracts:	Bob Callaghan, Bill Whalen, Margaret Cooke, Kelly Miller
TID:	Kirk Hadley, Merry Oman
Administrative:	Emma Harris, Stephanie Ryan, Karma Thomas, Fran Brubeck

14. REFERENCES

1. SCIENCE, ,Vol 266, S. Nozette, et al, "The Clementine Mission to the Moon: Scientific Overview", plus six additional related articles by various authors, pp 1835 - 1862, 16 Dec 1994.
2. M. J. Shannon, "The Clementine Satellite", LLNL document UCRL-52000-94-6, Energy & Technology Review, June 1994.
3. J. F. Kordas, et al, "The Star Tracker Stellar Compass for the Clementine Mission", SPIE paper 2466-10, April 1995.
4. I. Lewis, et al,"WFOV Star Tracker Camera", LLNL document UCRL-JC-105345 (Preprint), prepared for the SPIE International Symposium Optical Engineering & Photonics in Aerospace Sensing, April 1991.
5. S. McGrogan, et al, "The Stellar Compass", Intelligent Decisions Inc report to LLNL, February 1992 (v15b).
6. R. E. Priest, et al, "Sensor Integration Project Star Tracker Camera Interface Control Document", LLNL document C1-S1-010.
7. J. F. Kordas, et al, "UV/Visible Camera for the Clementine Mission", SPIE paper 2478-42, April 1995.
8. A. G. Ledebuhr, et al, "High Resolution Camera and LIDAR Ranging System for the Clementine Mission", SPIE paper 2472-08, April 1995.
9. R. E. Priest, et al, "Near-Infrared Camera for the Clementine Mission", SPIE paper 2475-52, April 1995.
10. R. E. Priest, et al, "The Clementine Longwave Infrared Camera", SPIE paper 2475-53, April 1995.
11. L. D. Pleasance and R. E. Priest, "Clementine Sensors: Engineering and Technology Workshop", LLNL document UCRL-MI-120834, June 1994.

15. MISSION IMAGERY

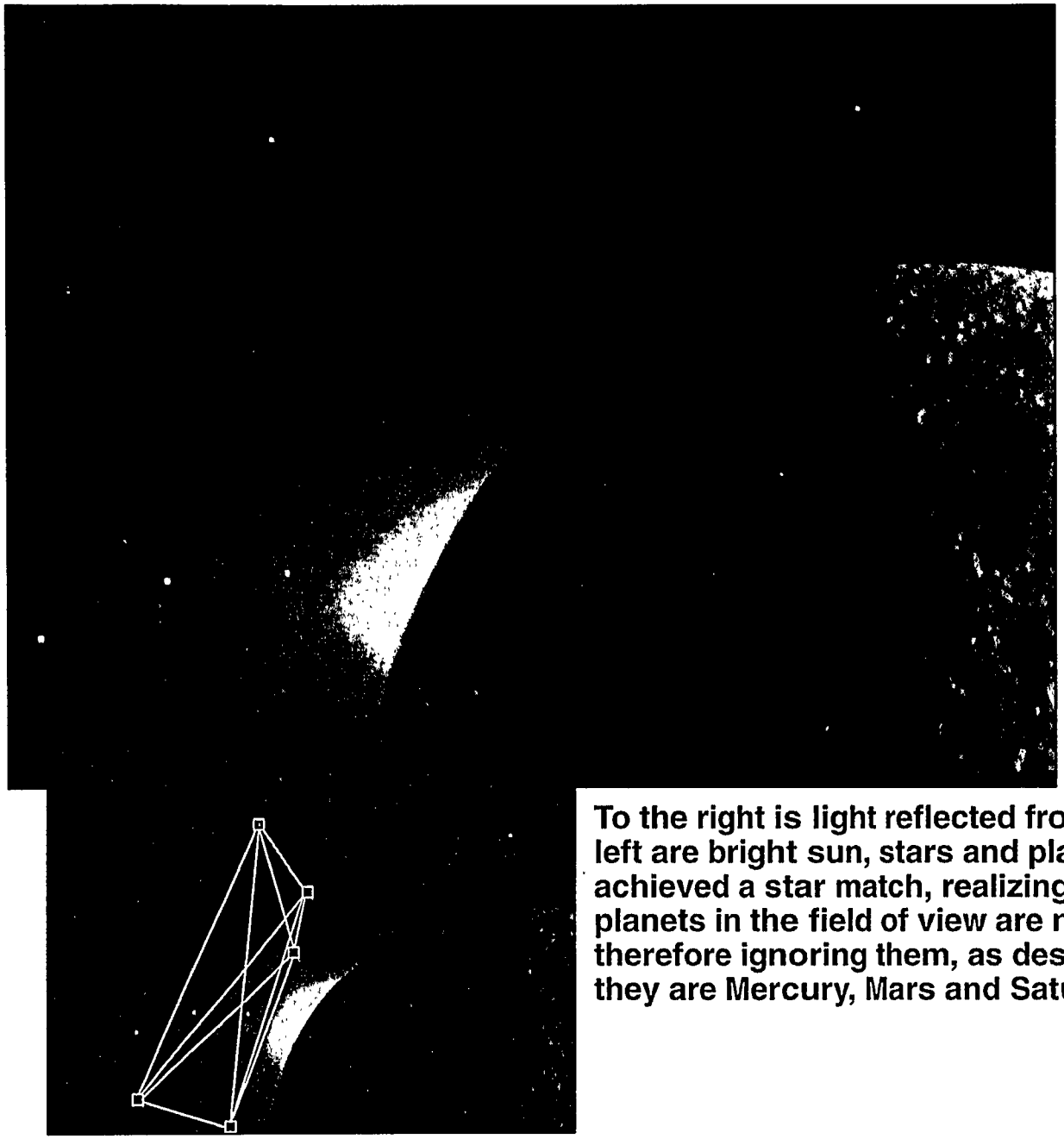
This section presents a sampling of images collected by the two star tracker cameras over the course of the Clementine mission. These were produced primarily in the early stages of the mission. Complete imagery is best accessed via the Internet (see section 10 for address locations).

16. MISSION ENGINEERING HOUSEKEEPING DATA

CCD and lens temperatures were tracked to monitor the "health" of both cameras, with the goal that such data would be tagged to individual images (in PDS format). The section in this document graphs temperature versus time for the CCD and lens temperatures, and CCD temperature vs variable conductance heat pipe (VCHP) temperature to track the systematic ΔT. These are plotted in ten-day batches beginning from the day before launch (24th day of the year) when pre-launch tests were performed. There are various other graphs scattered throughout this package which were produced to examine various phenomena during the course of the mission.

Section 15

Star Tracker Mission Imagery



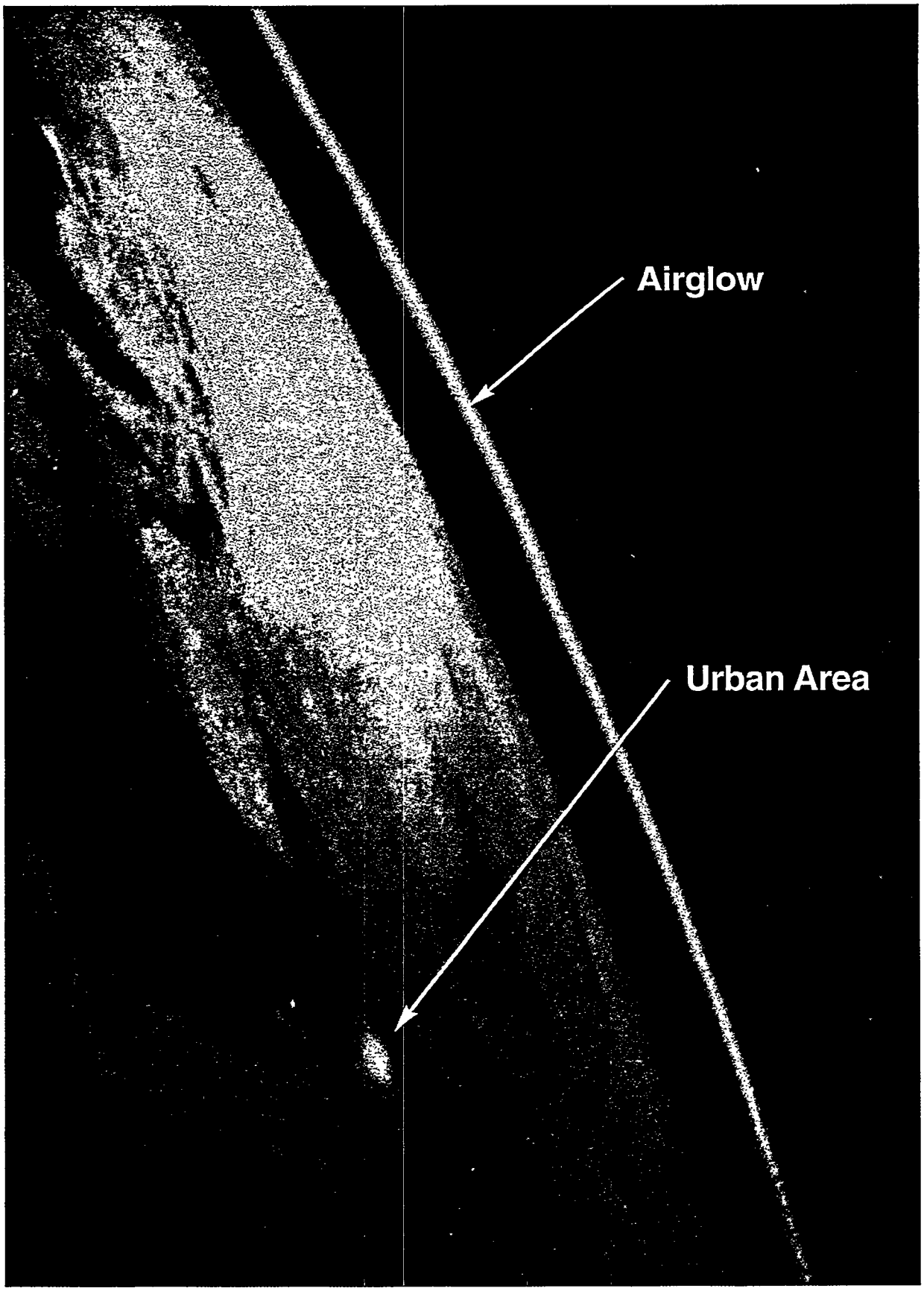
Earth Shine

Star Tracker Camera B

Filter:	450-1000 nm
Altitude:	2358 km
Lat:	12°S
Long:	99°E
Orbit#:	65
Time:	21:10:29 UT (Z)
Date:	5 Mar 1994

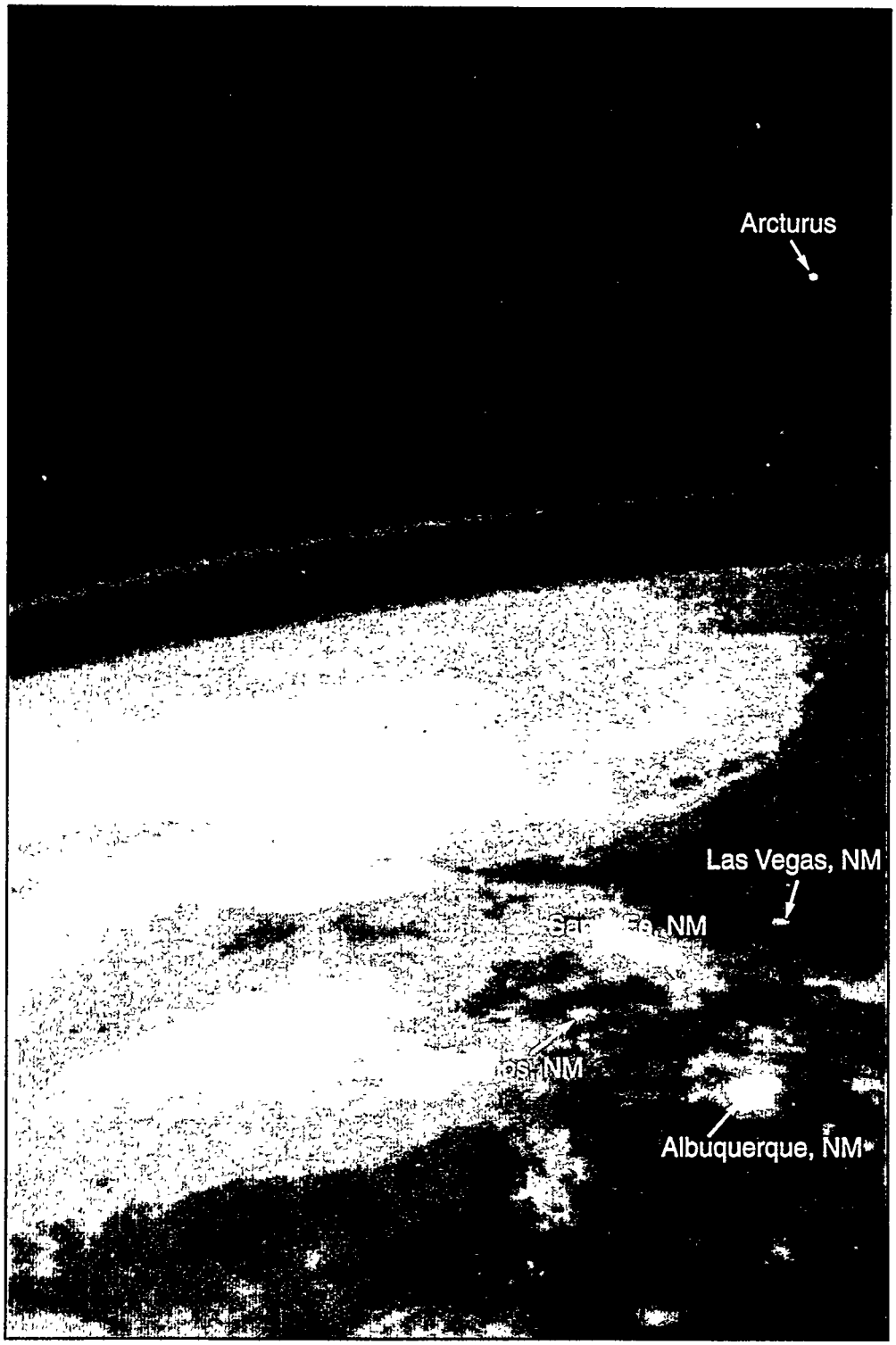
To the right is light reflected from Earth, Earth shine. To the left are bright sun, stars and planets. The Startracker algorithm achieved a star match, realizing that both the sun and the three planets in the field of view are not in correct positions to be stars, therefore ignoring them, as designed. From the left of the image they are Mercury, Mars and Saturn.

Star Tracker View Of Earth's Limb



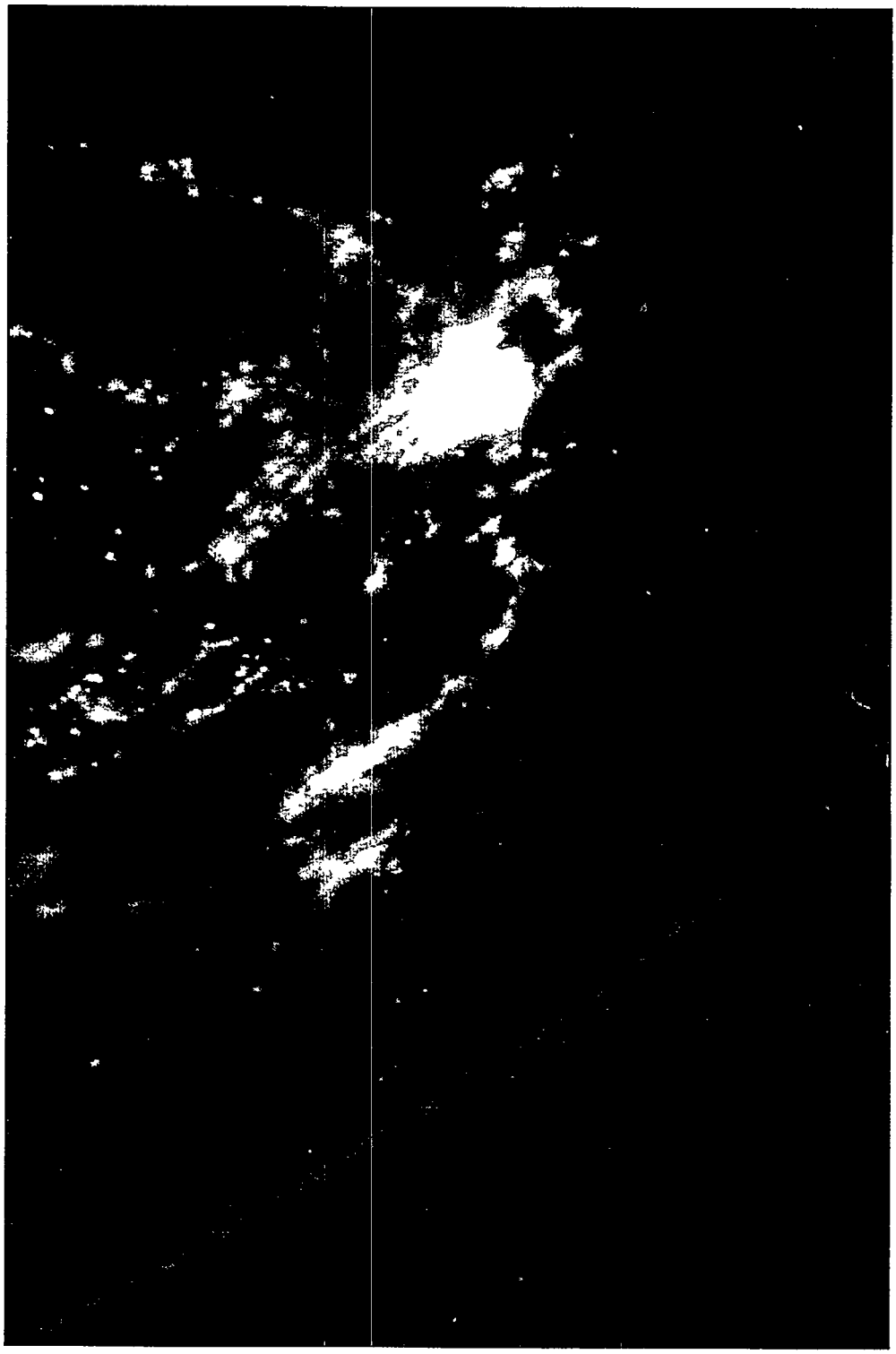
Clementine Spacecraft

Star Tracker Image: eaa00114.000
UTC: 1994-01-27T05:42:51.652



Clementine Spacecraft

Star Tracker Image: EAA02190.000
UTC: 1994-1-31T14:47:46.707 GMT



Tokyo and Vicinity

HE.159-10

Section 16

Mission Engineering Housekeeping Data

S-16

120 — 129

Clementine

Star Tracker A CCD Temperature

Start Time: 29-APR-94 22:06:41.630 GMT

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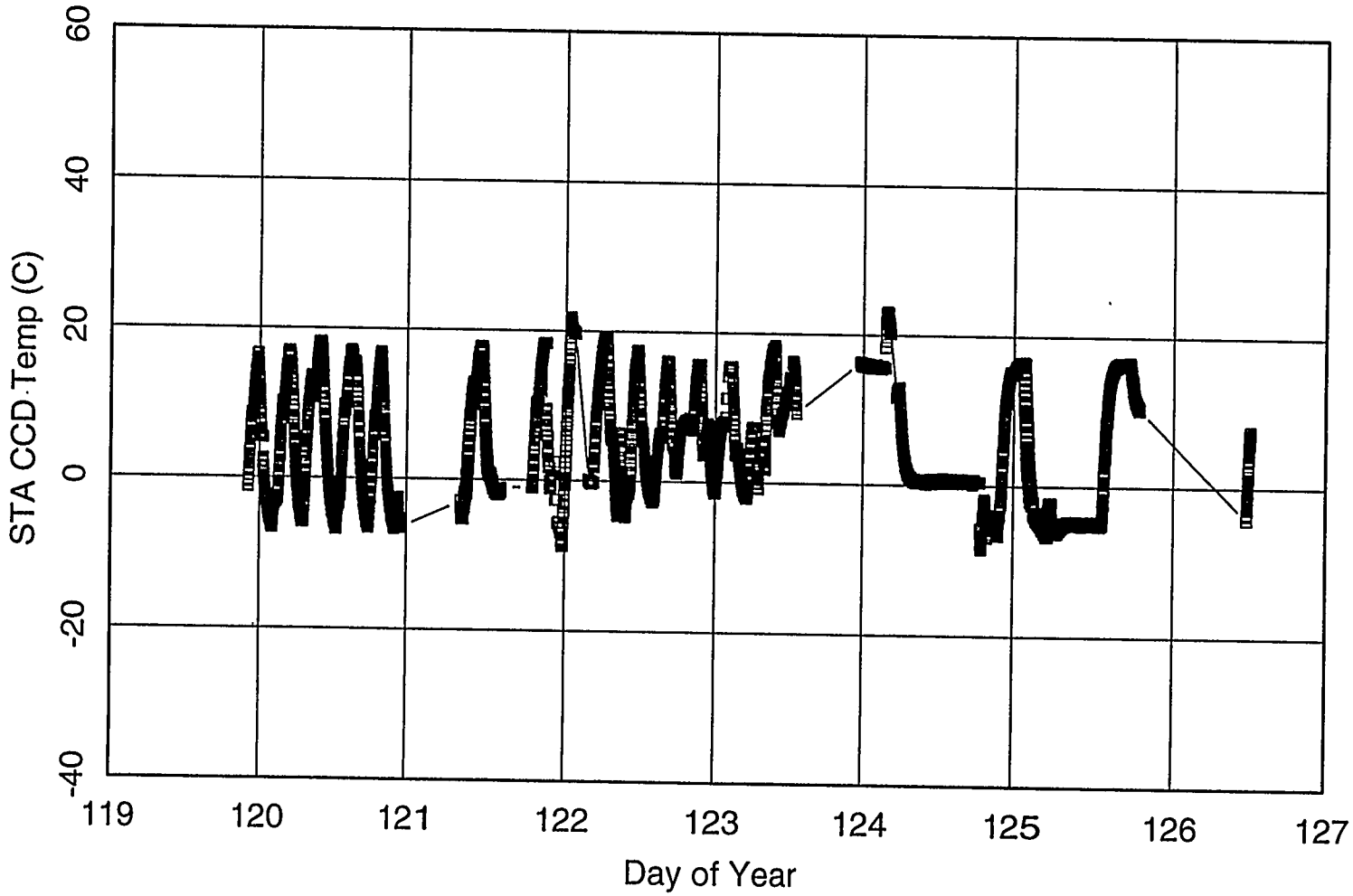

REP/LLNL created: Wed May 11 11:14:35 PDT 1994

Clementine

Star Tracker A Lens Temperature

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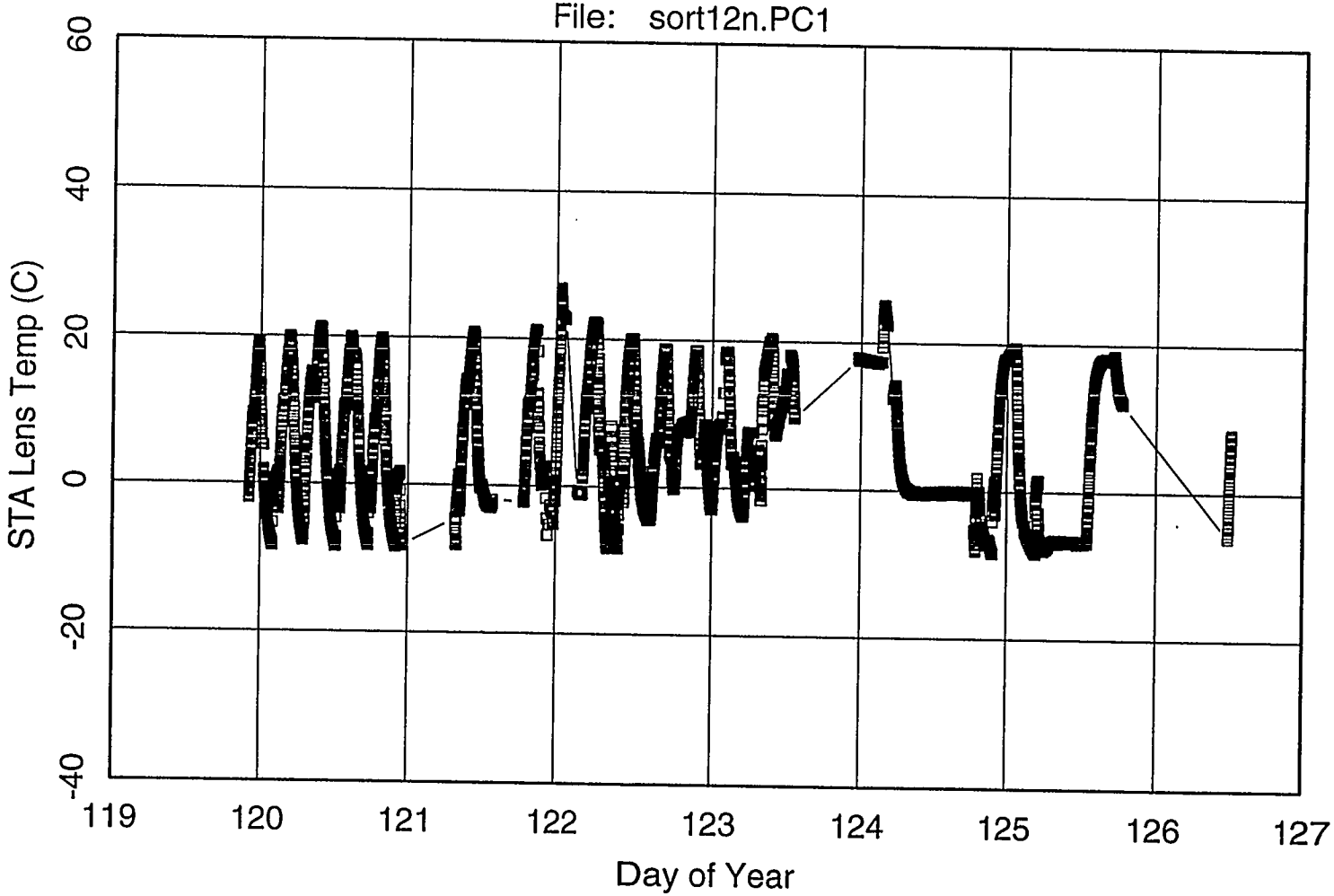
File: sort12n.PC1



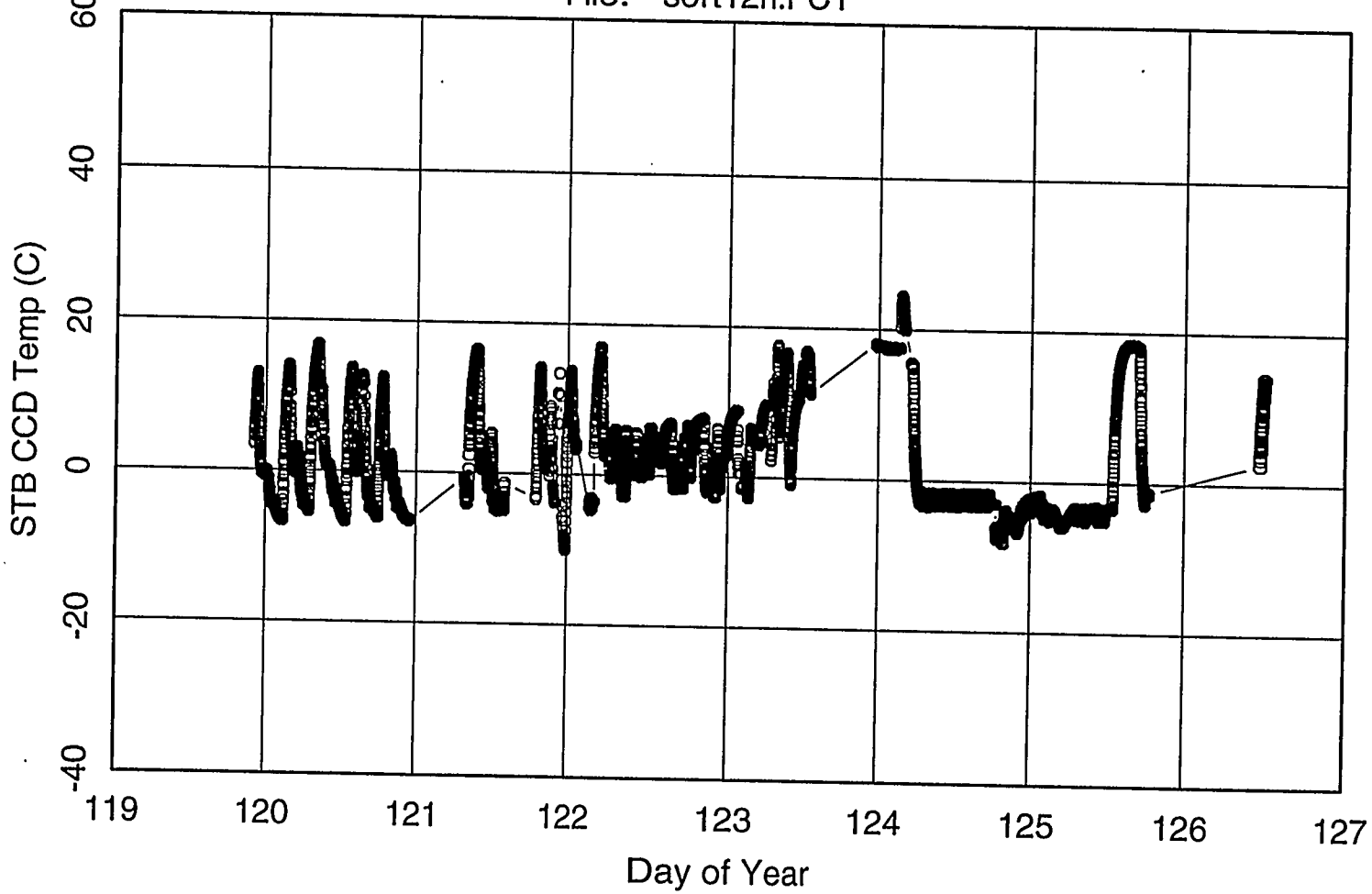
REP/LLNL created: Wed May 11 12:01:23 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 29-APR-94 22:06:41.630 GMT

File: sort12n.PC1



REP/LLNL created: Wed May 11 12:01:37 PDT 1994

Clementine

Star Tracker B Lens Temperature

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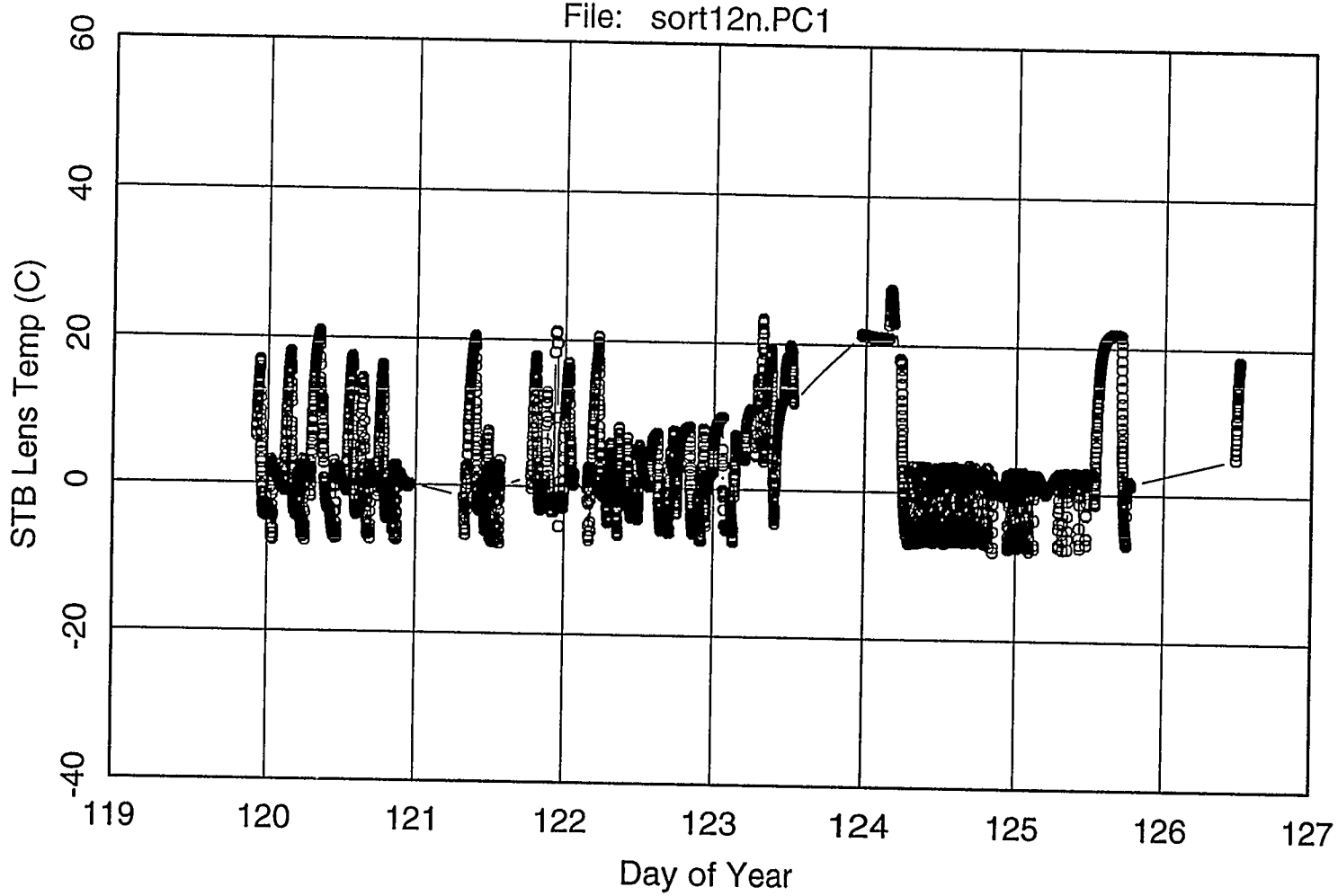
File: sort12n.PC1



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Clementine

Star Tracker A CCD Temperature

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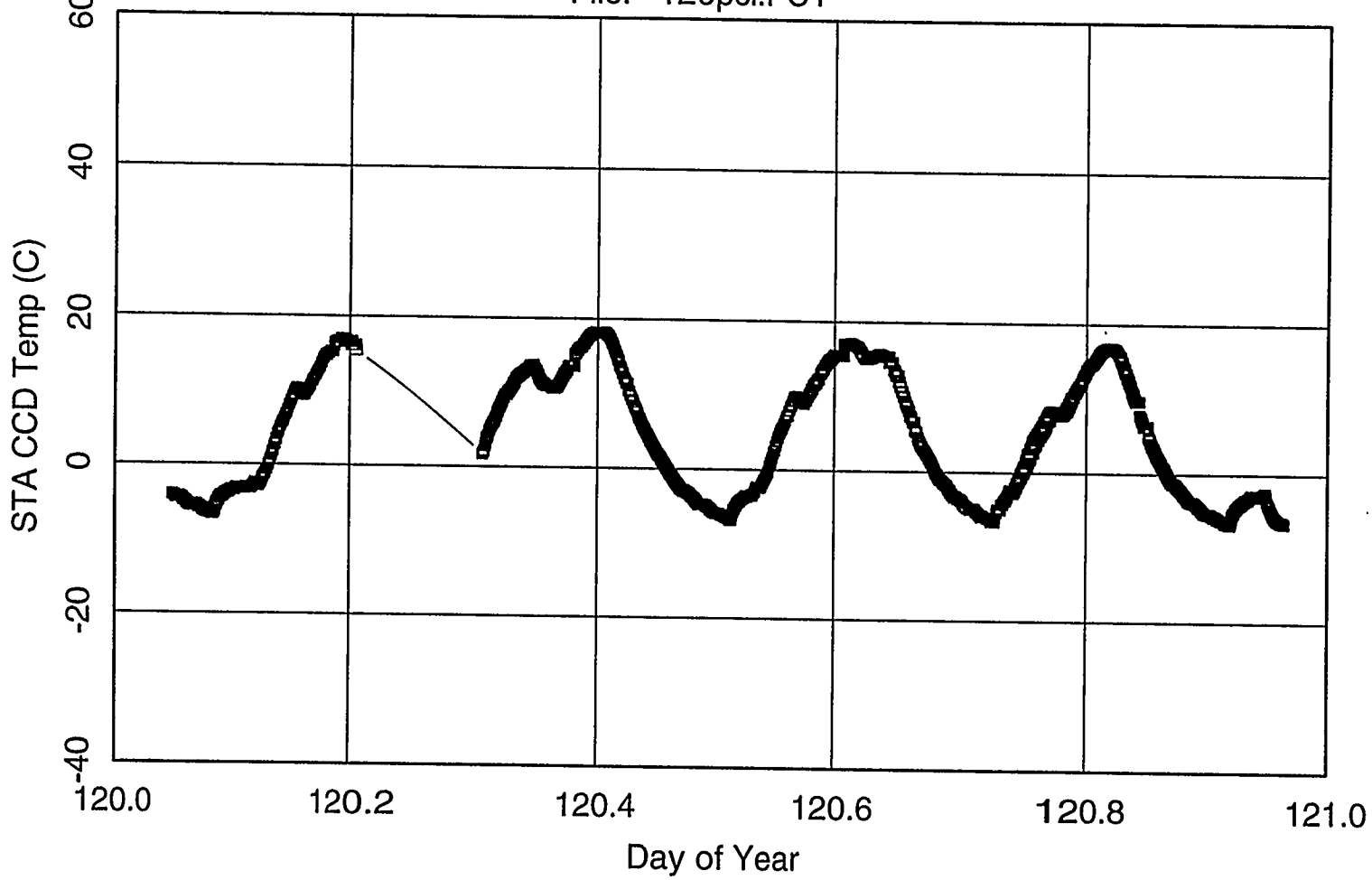

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Clementine

Star Tracker A Lens Temperature

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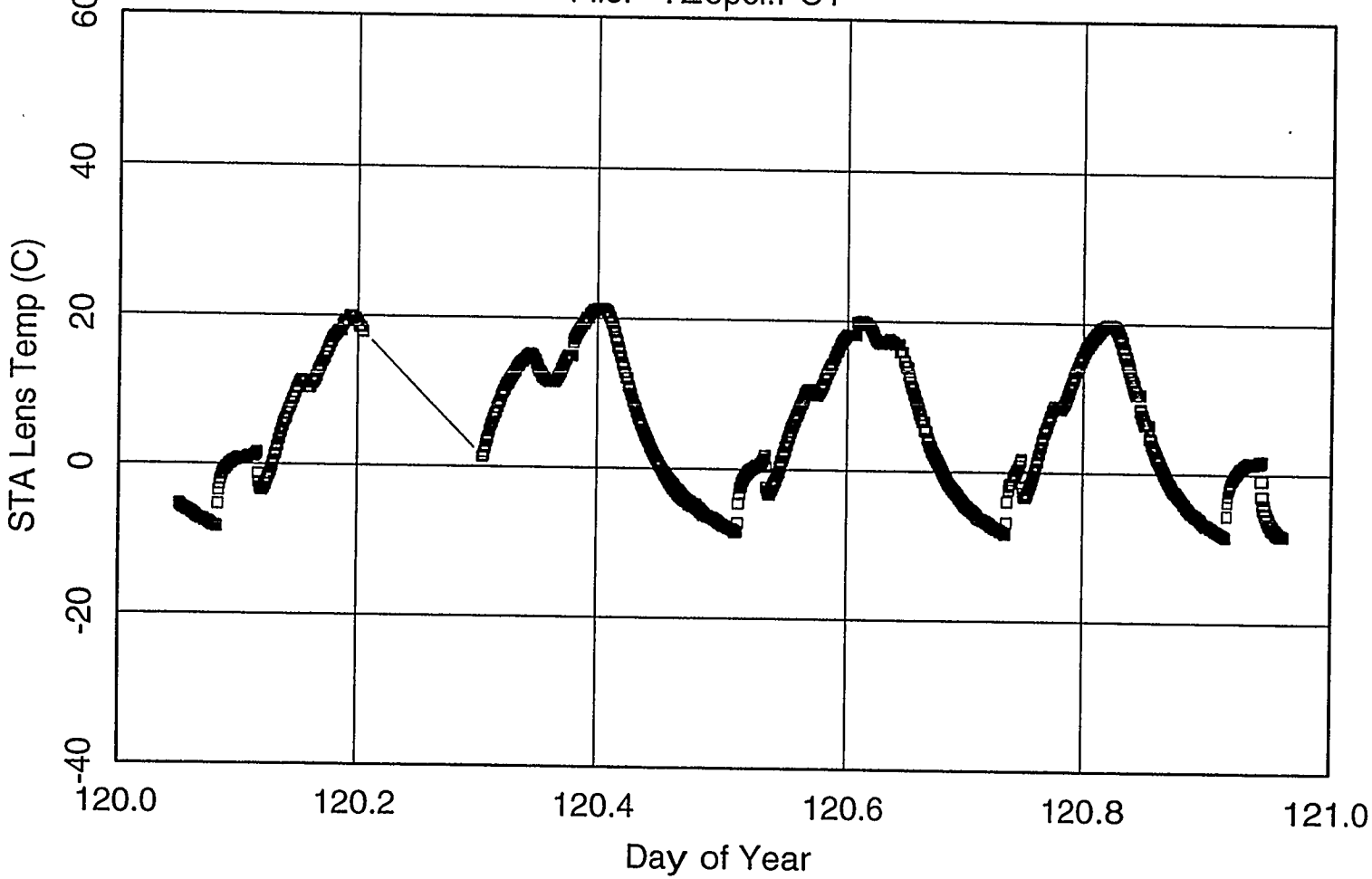
File: 120pci.PC1



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Star Tracker B CCD Temperature

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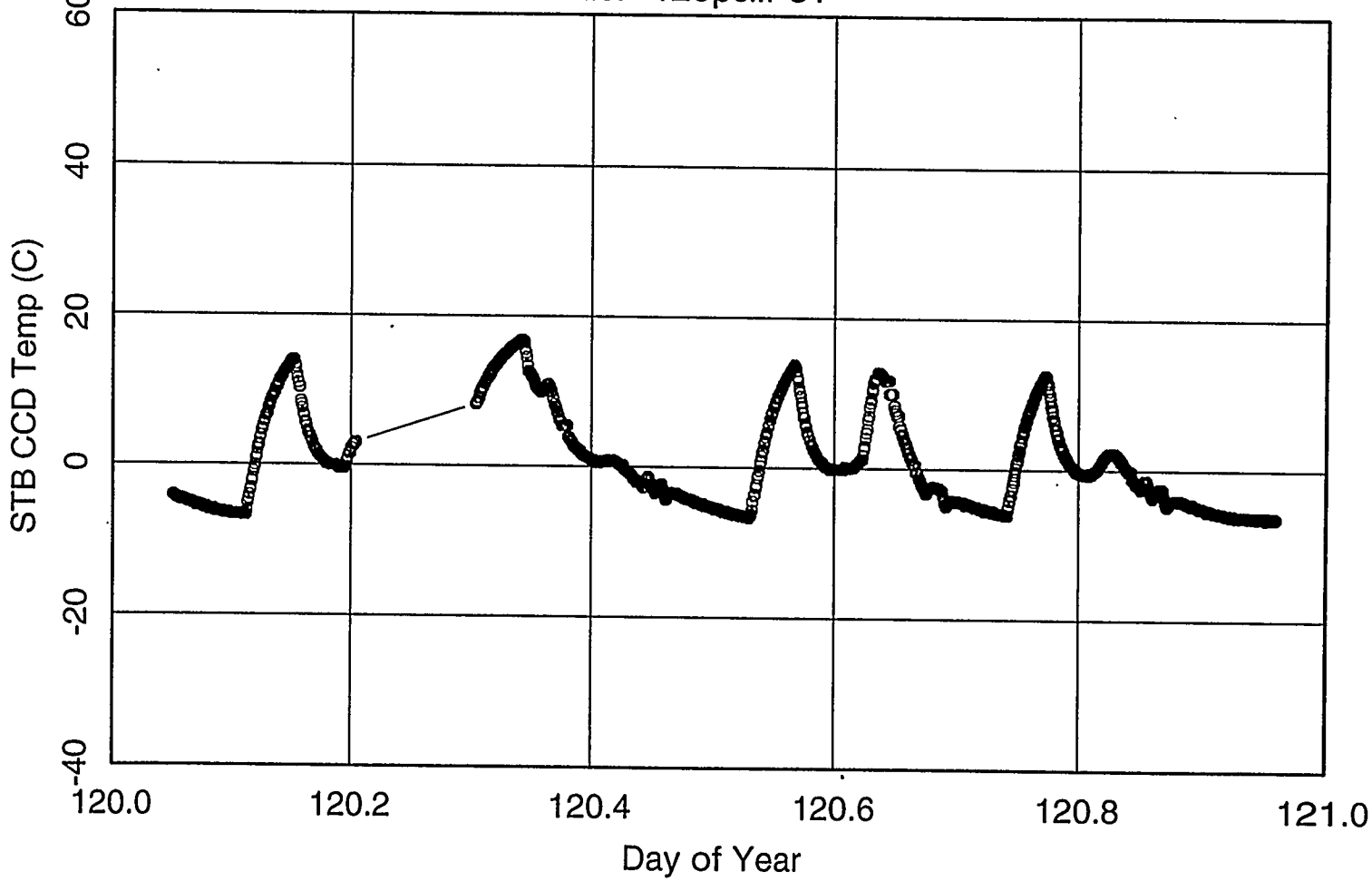

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Clementine

Star Tracker B Lens Temperature

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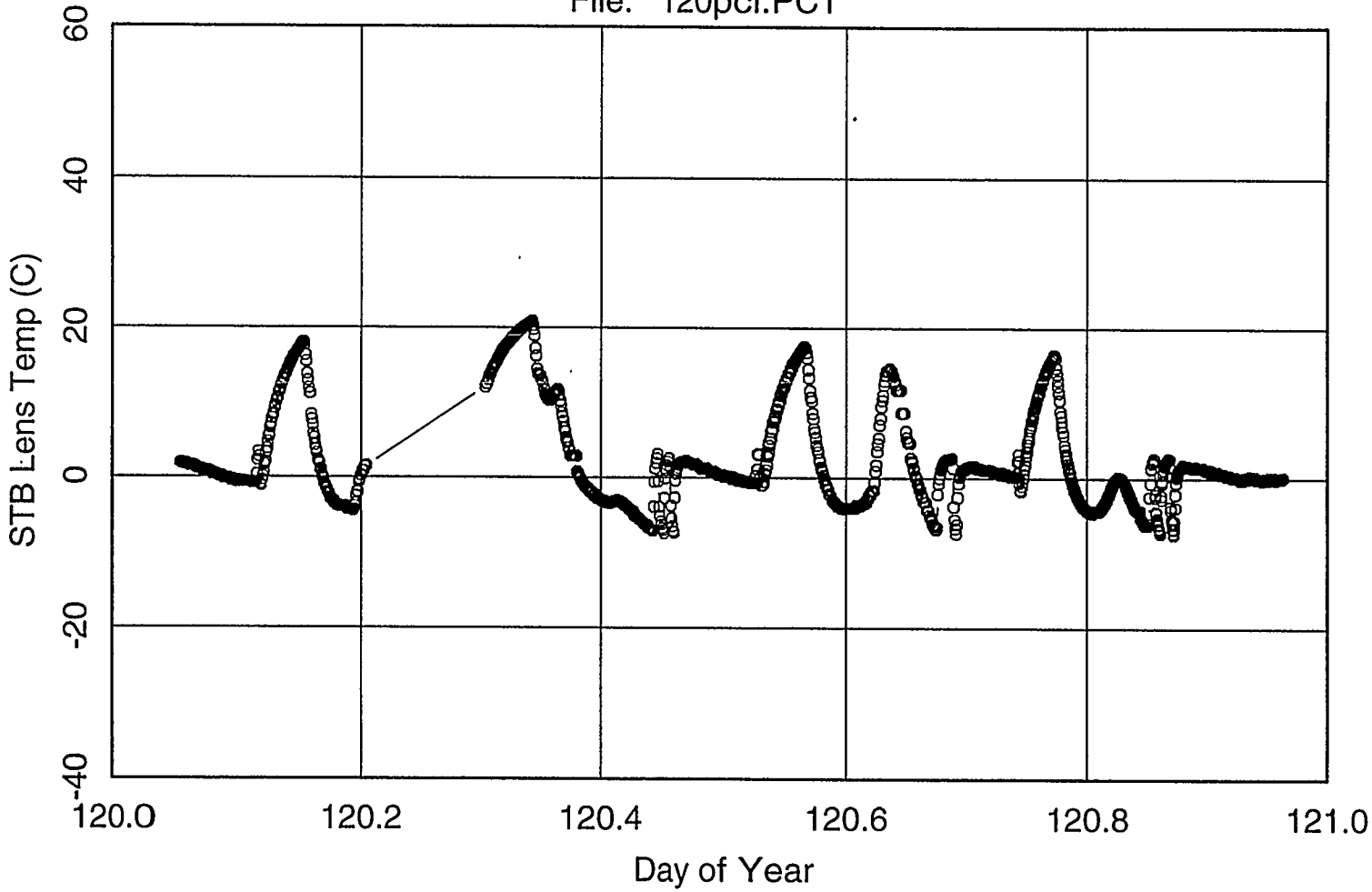

REP/LLNL created: Mon May 2 16:18:47 PDT 1994

Clementine

Star Tracker A CCD vs +Y VCHP Temp

Start Time: 30-APR-94 01:13:46.610 GMT

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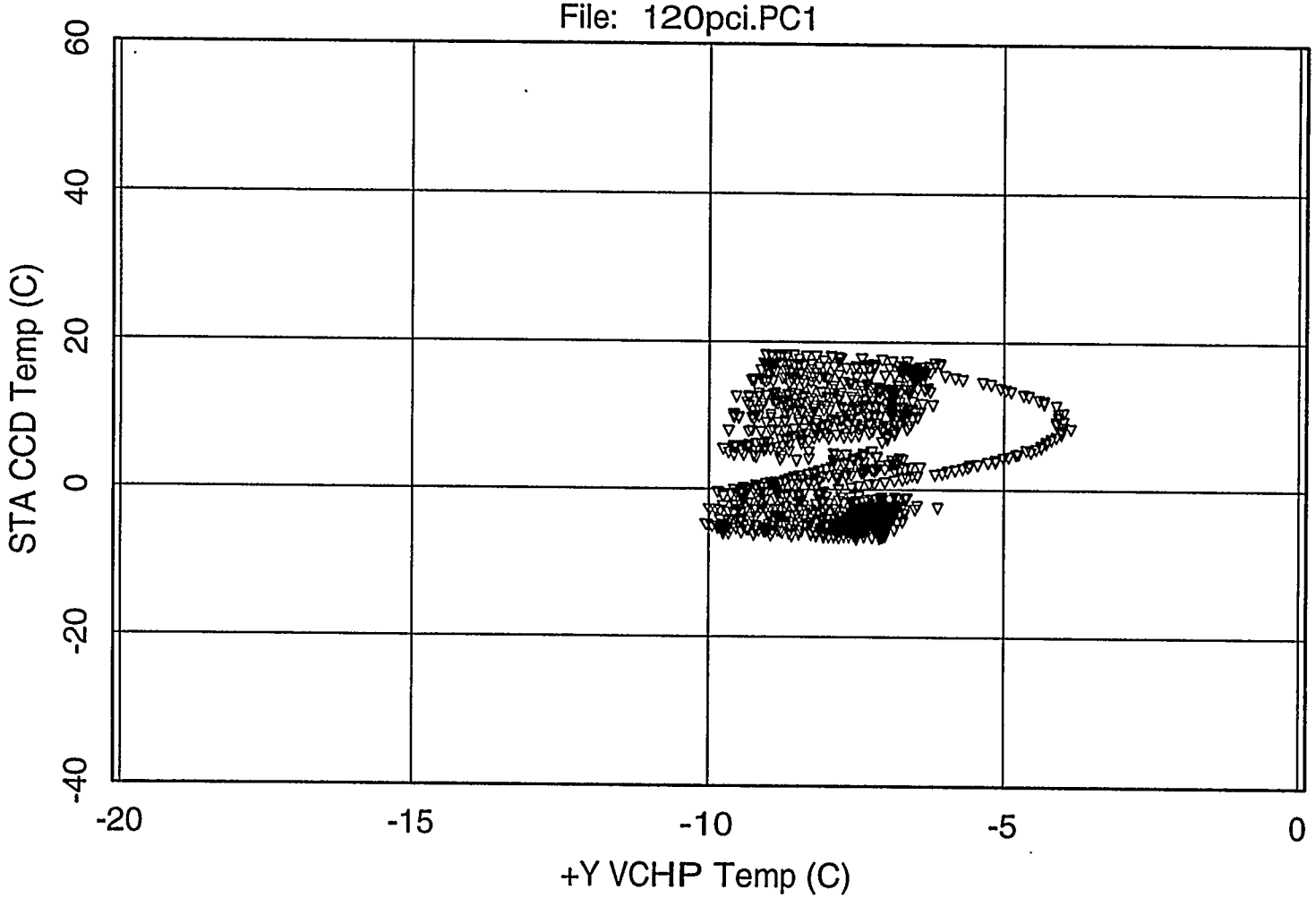

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Clementine

Star Tracker B CCD vs -Y VCHP Temp

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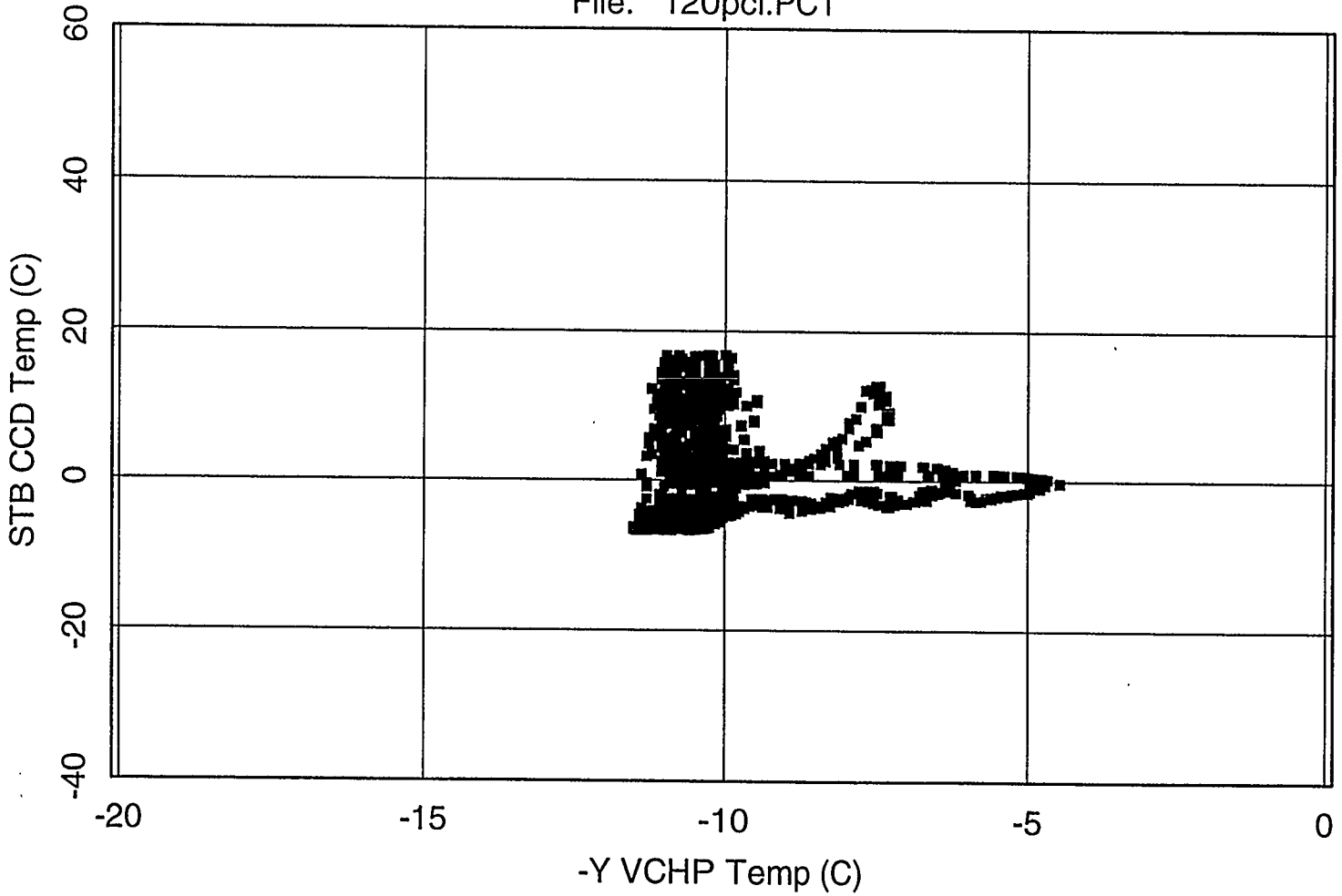

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S-16

110 — 119

Clementine

Star Tracker A CCD Temperature

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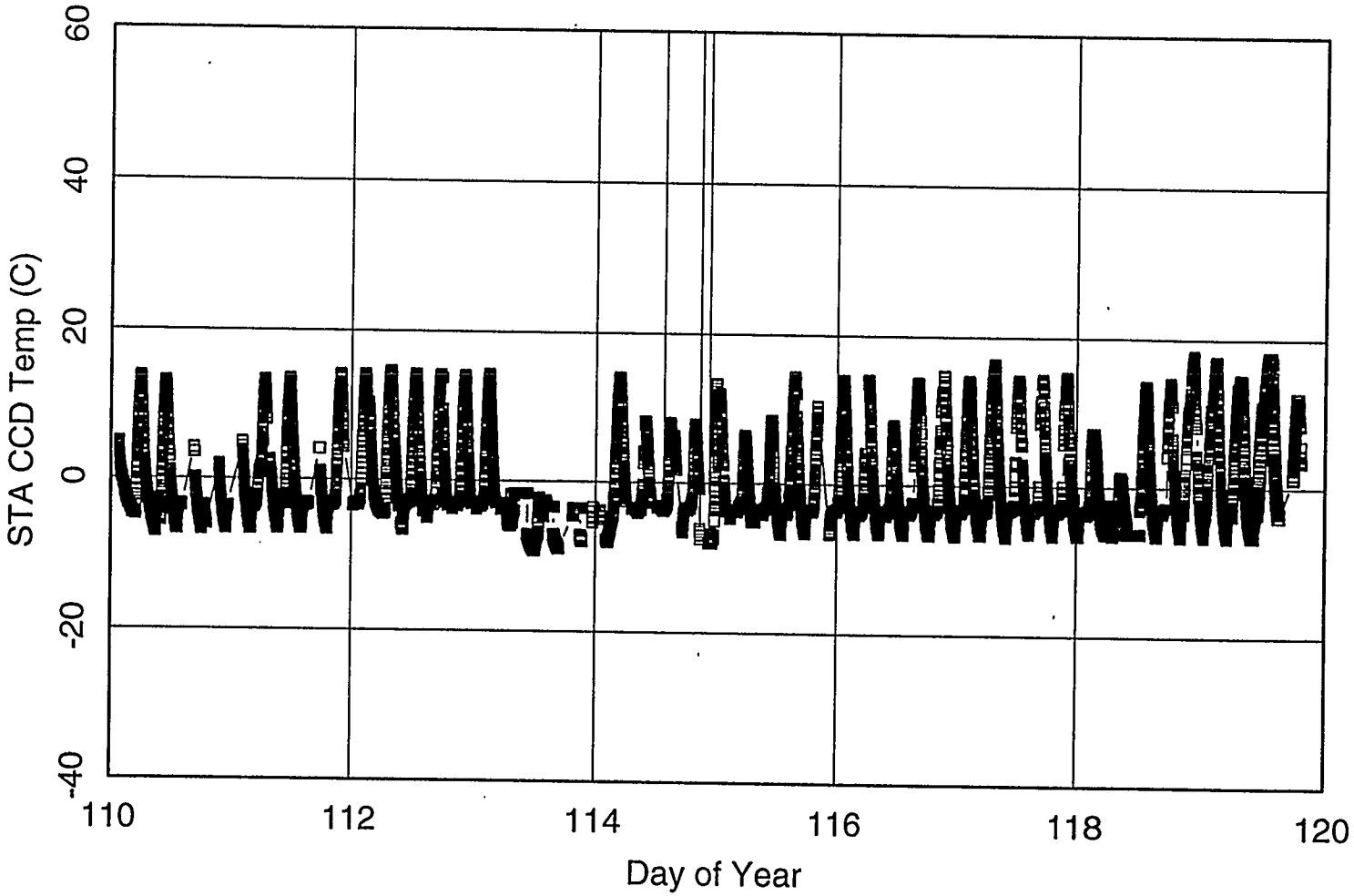

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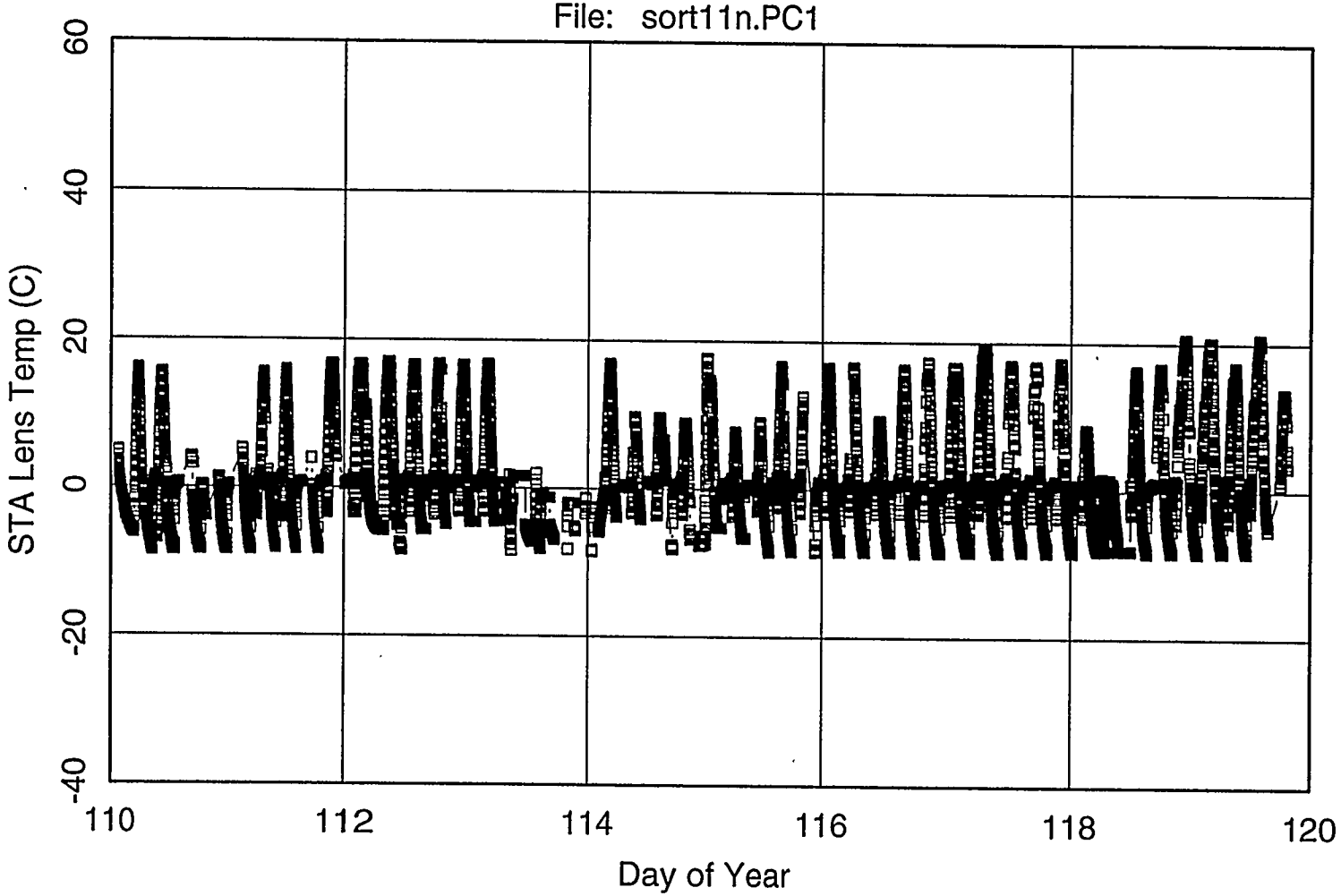
Clementine

Star Tracker A Lens Temperature

Start Time: 20-APR-94 01:37:27.800 GMT

File: sort11n.PC1



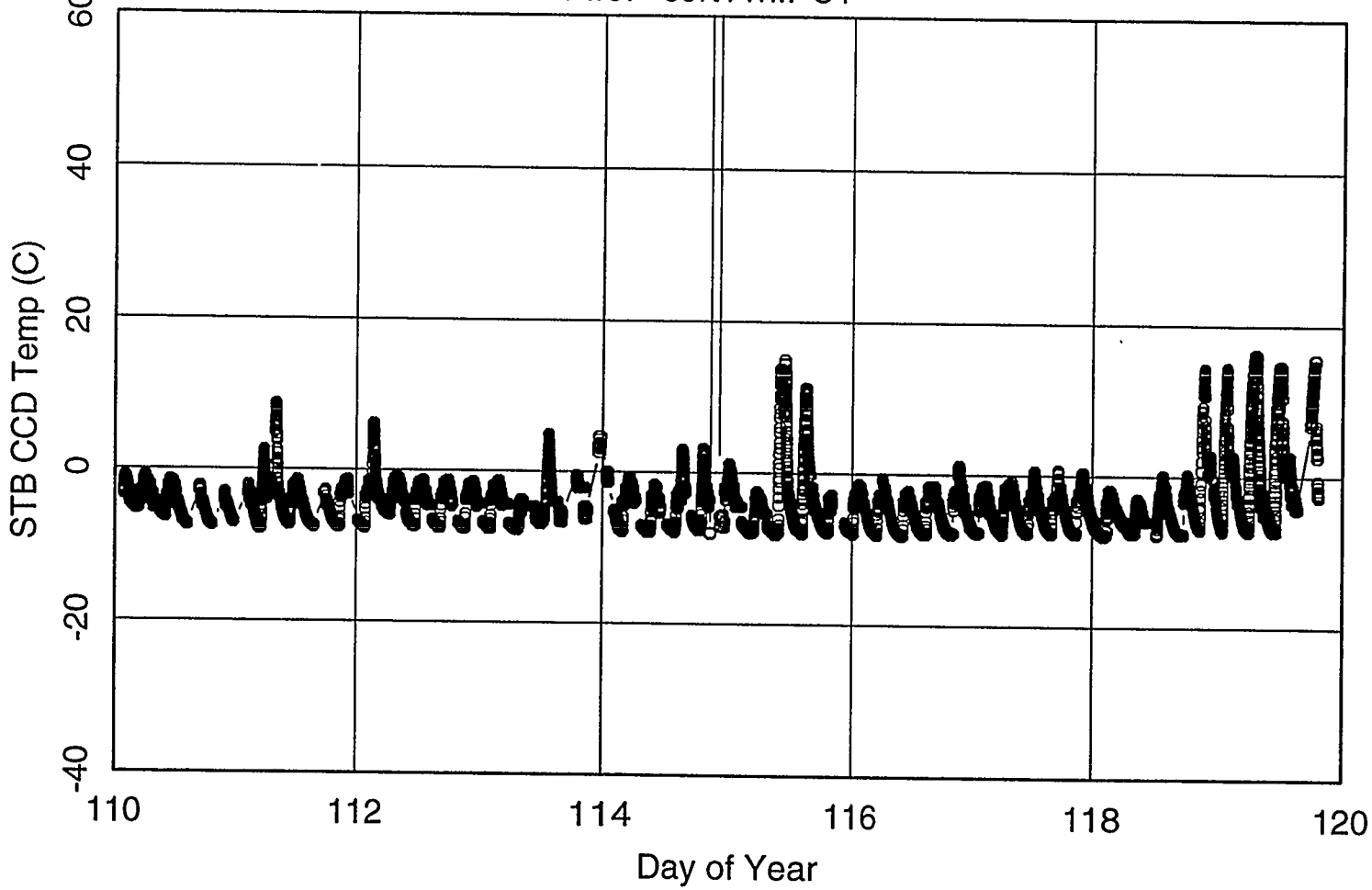
REP/LLNL created: Wed May 11 10:42:00 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 20-APR-94 01:37:27.800 GMT

File: sort11n.PC1



REP/LLNL created: Wed May 11 10:42:25 PDT 1994

Clementine

Star Tracker B Lens Temperature

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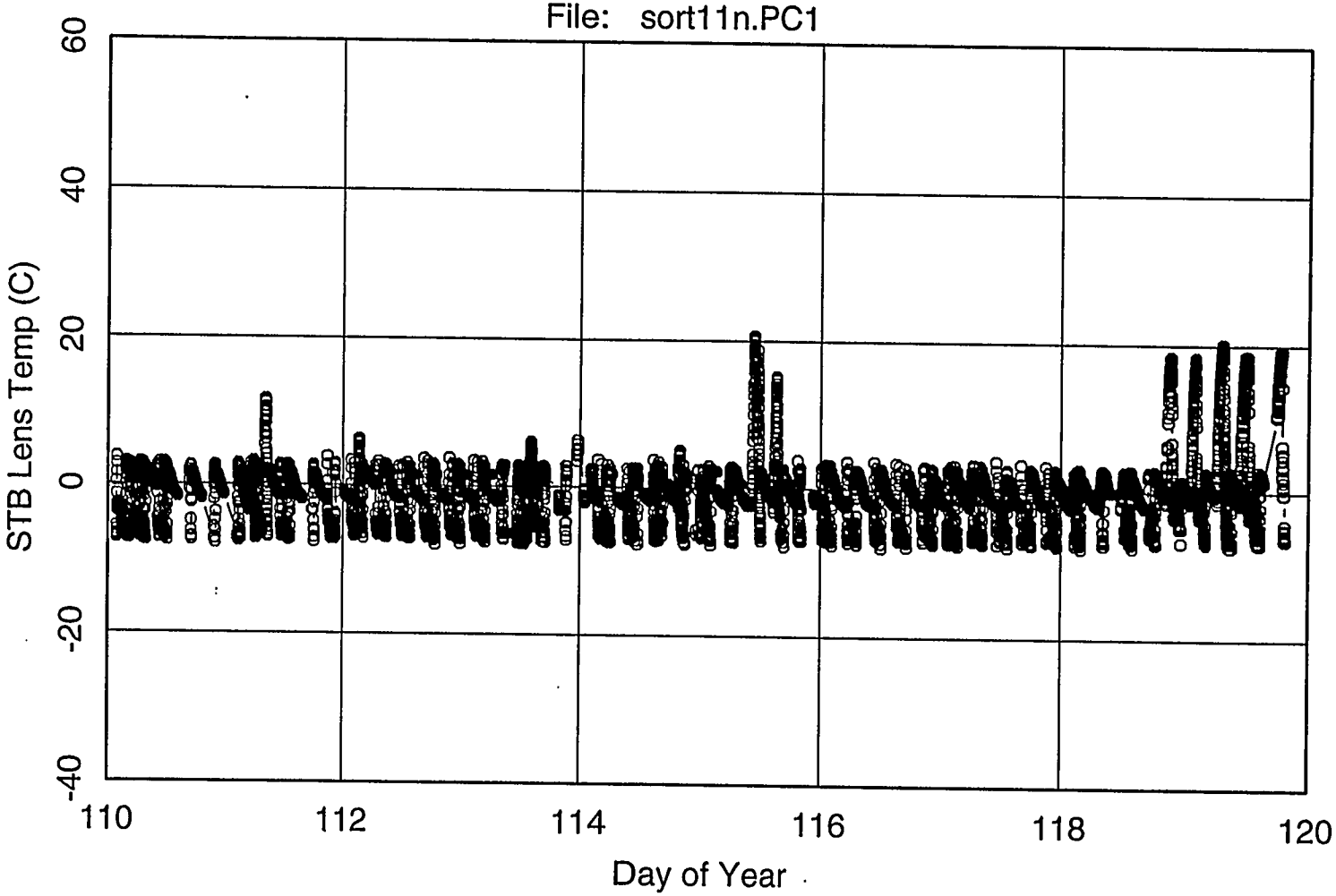
File: sort11n.PC1



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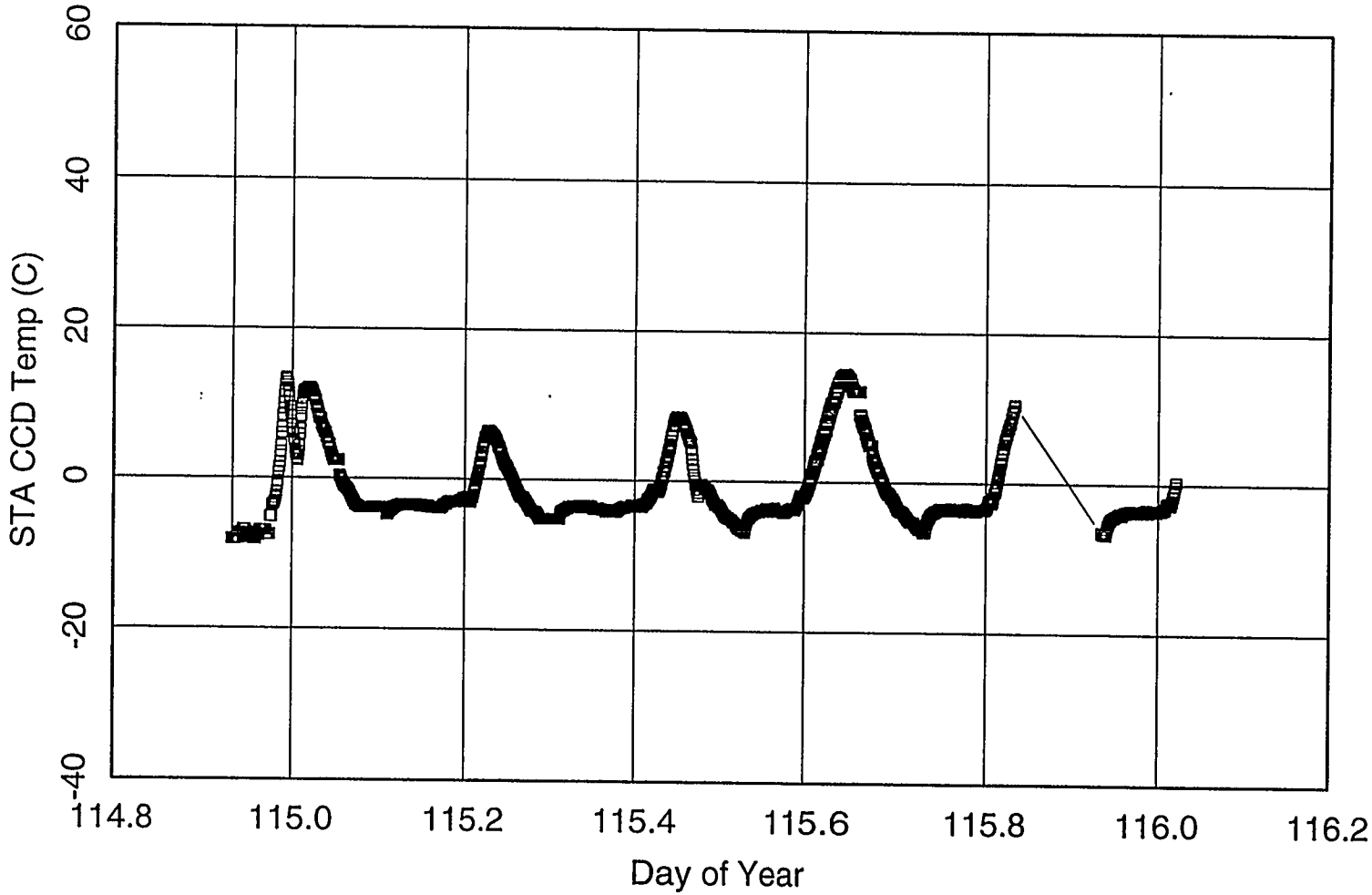
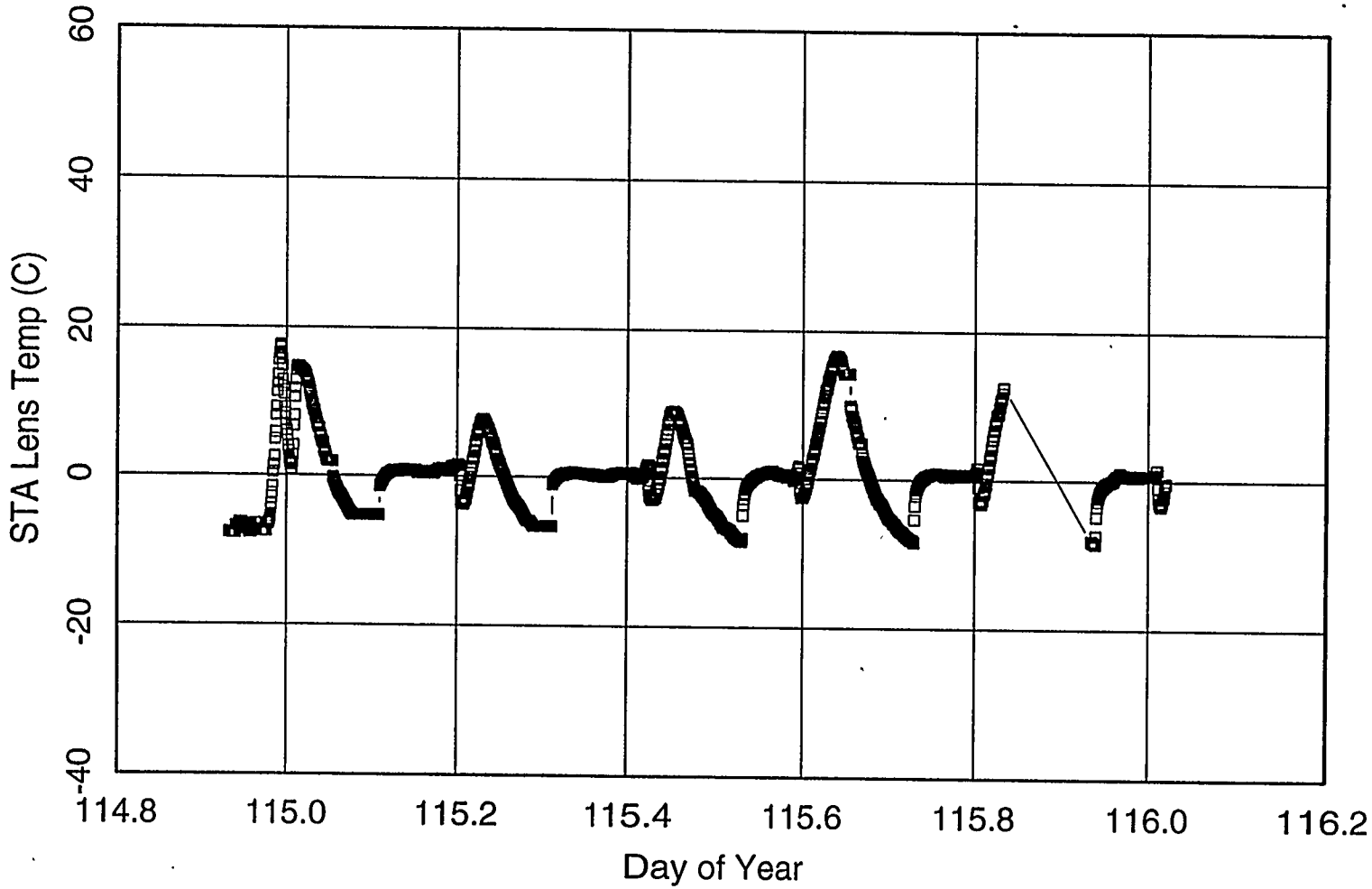


REP/LLNL created: Tue Apr 26 14:26:27 PDT 1994

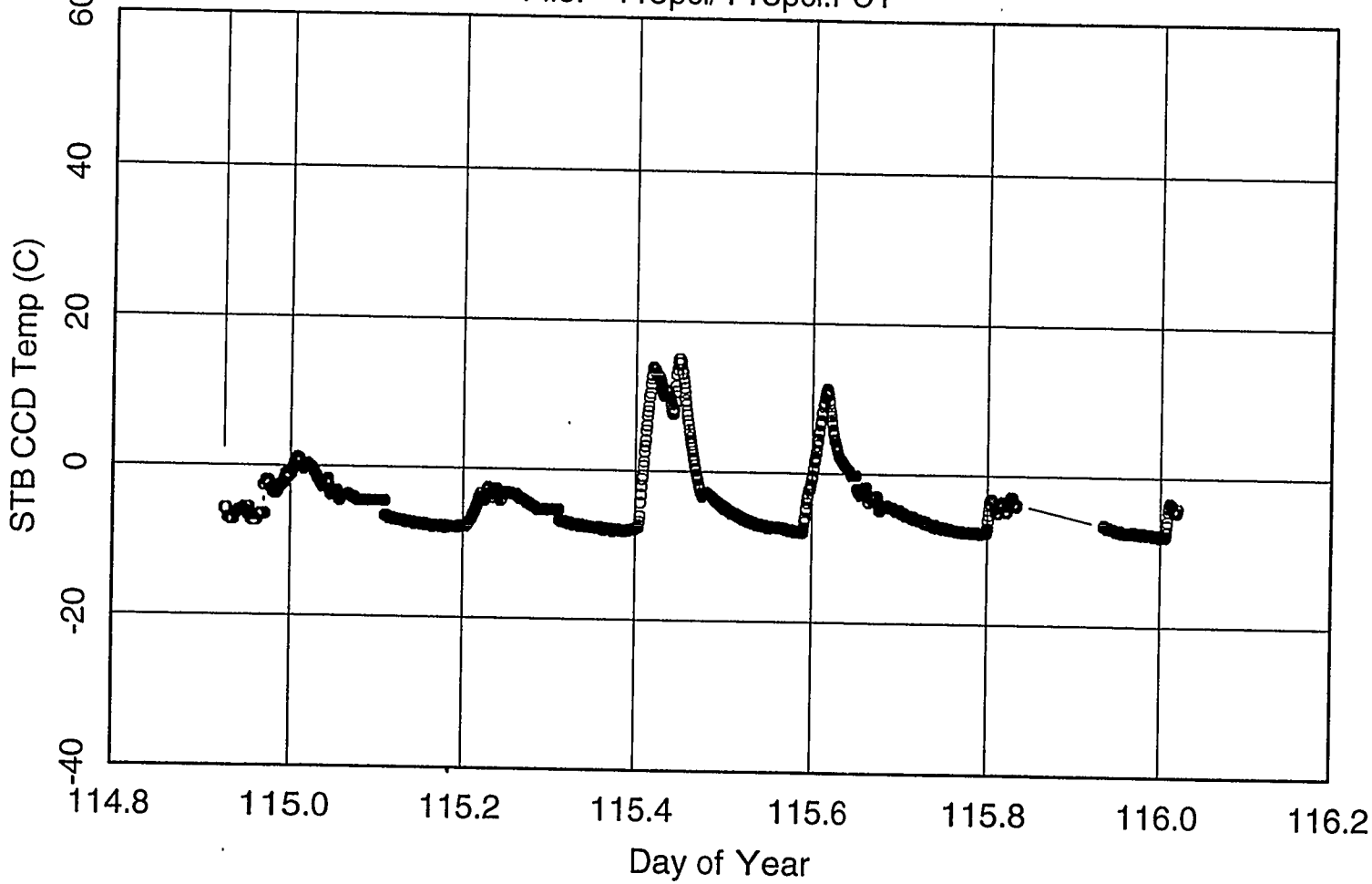

STA Lens Temp (C)
60
40
20
0
-20
-40
114.8
115.0
115.2
115.4
115.6
115.8
116.0
116.2
Day of Year

Clementine

Star Tracker B CCD Temperature

Start Time: 24-APR-94 22:04:24.260 GMT

File: 115pci/115pci.PC1



REP/LLNL created: Tue Apr 26 14:26:35 PDT 1994

S-16

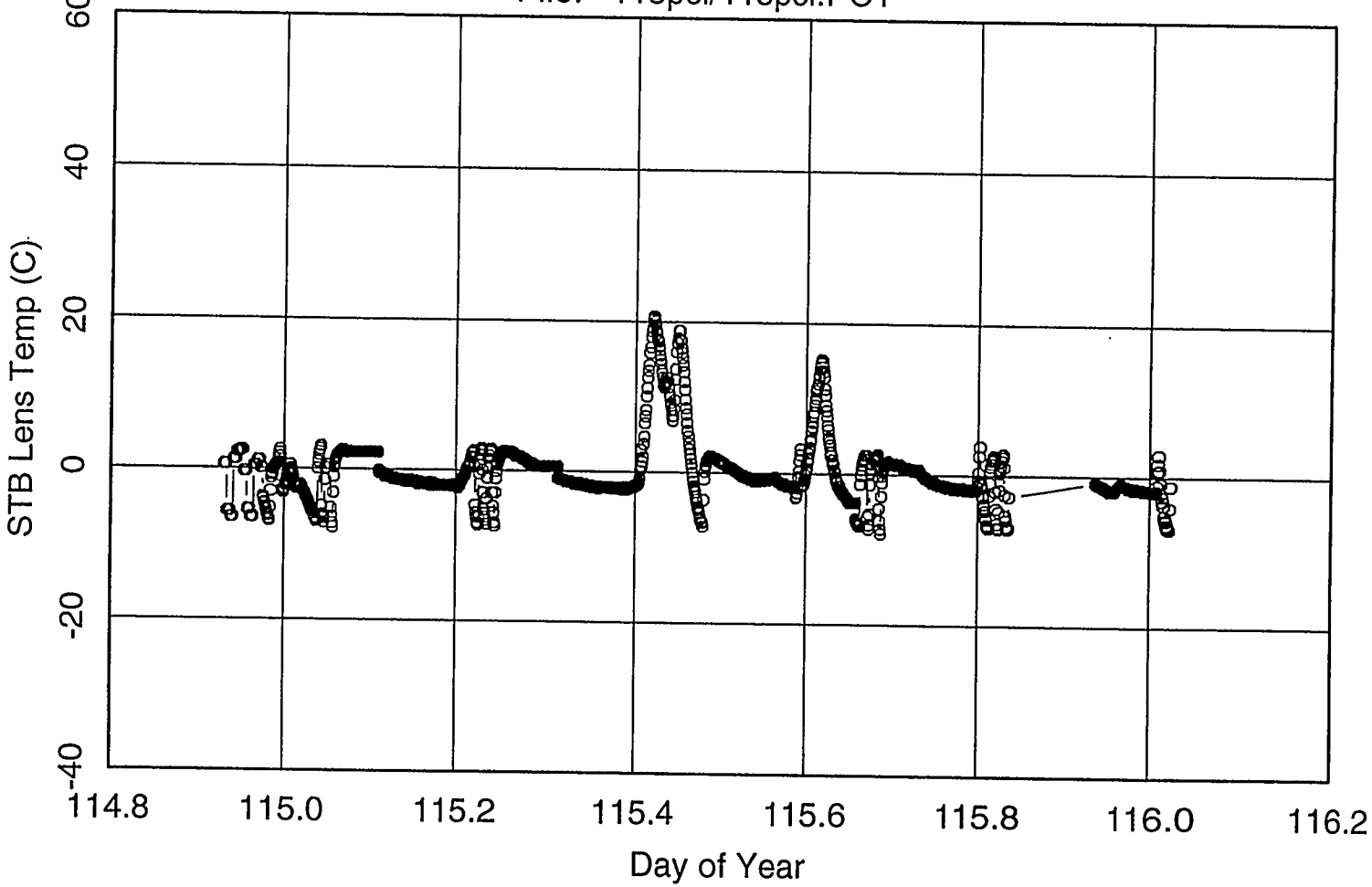
100 — 109

Clementine

Star Tracker B Lens Temperature

Start Time: 24-APR-94 22:04:24.260 GMT

File: 115pci/115pci.PC1



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Clementine

Star Tracker A CCD Temperature

Start Time: 10-APR-94 06:21:50.500 GMT

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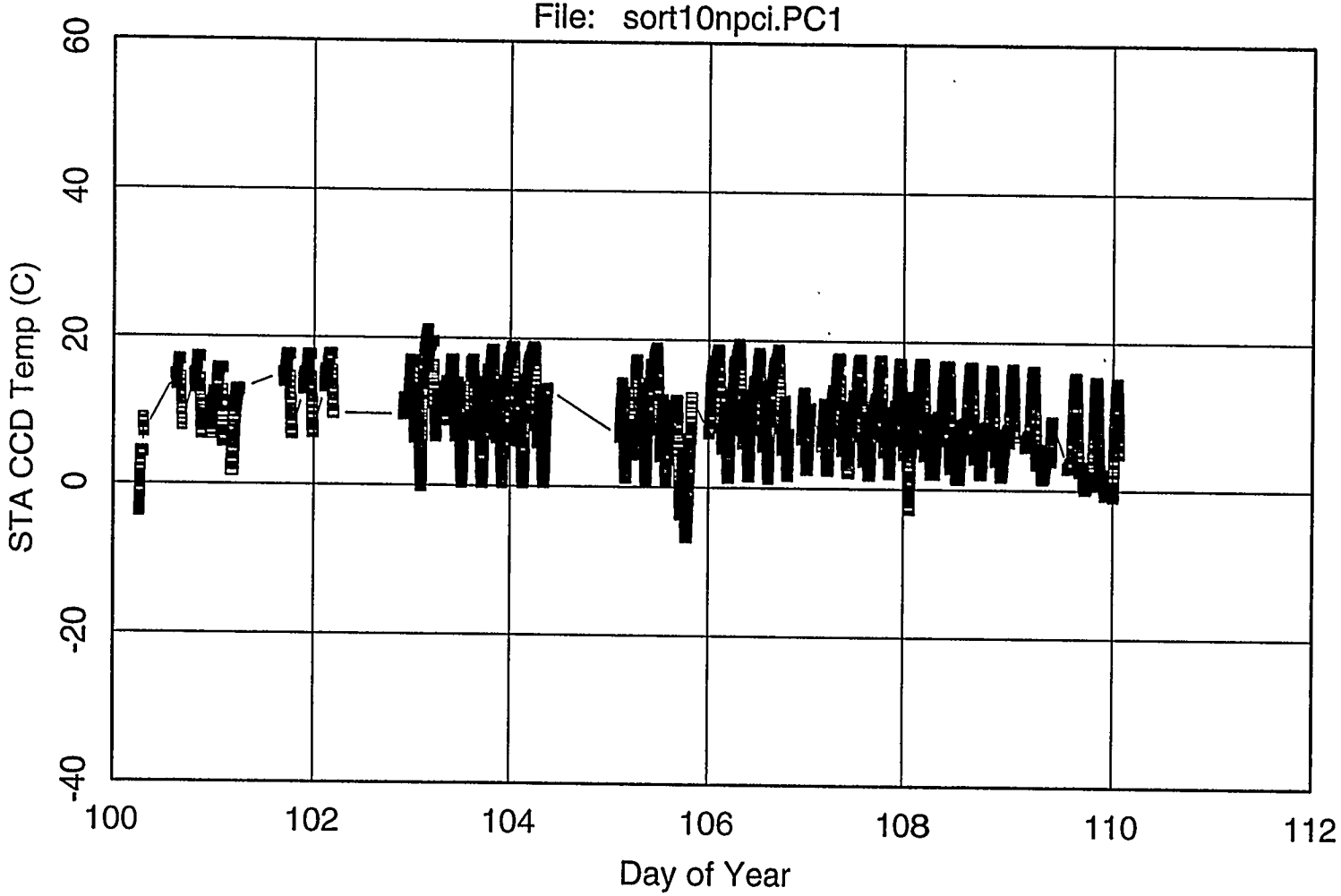

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Clementine

Star Tracker A Lens Temperature

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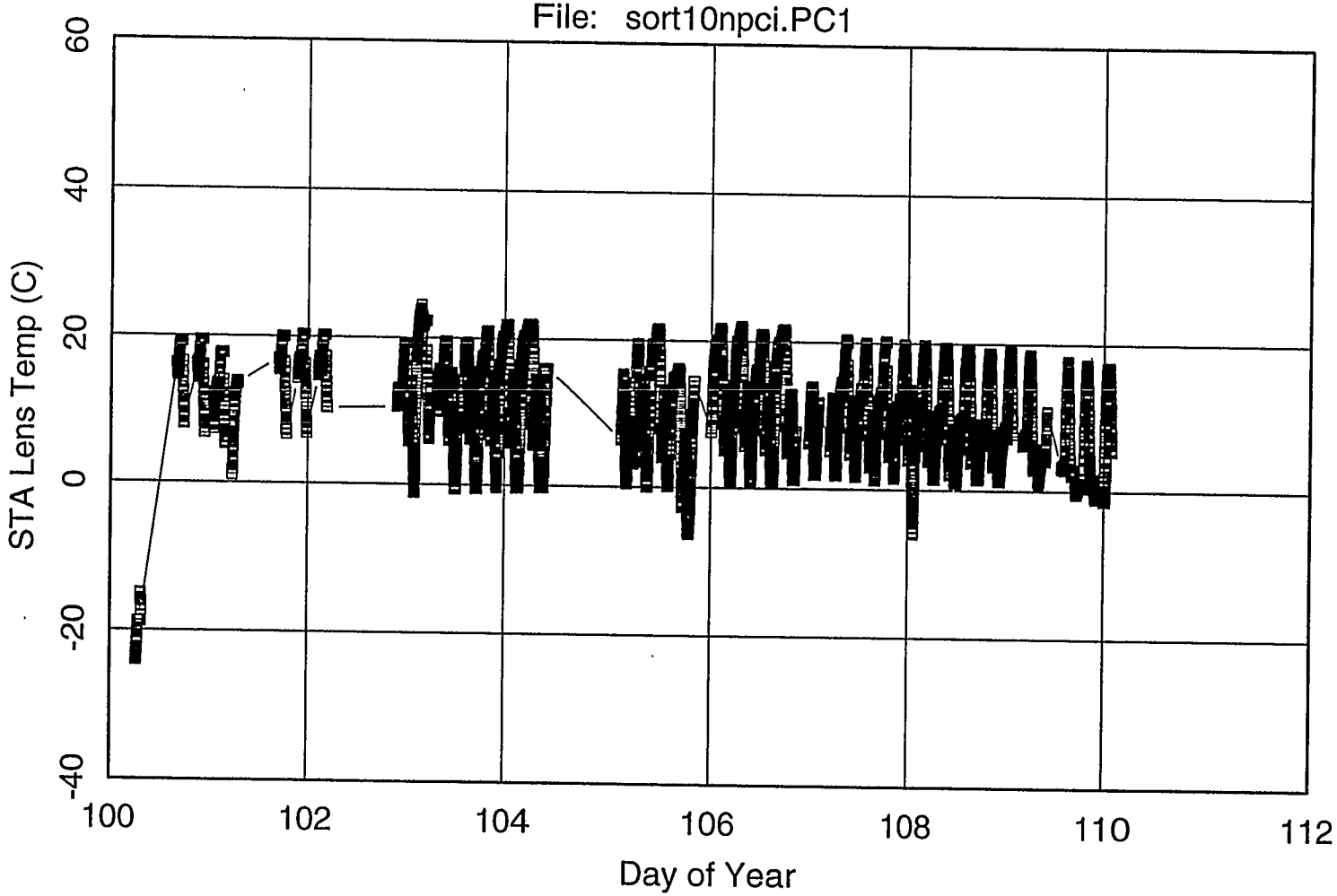

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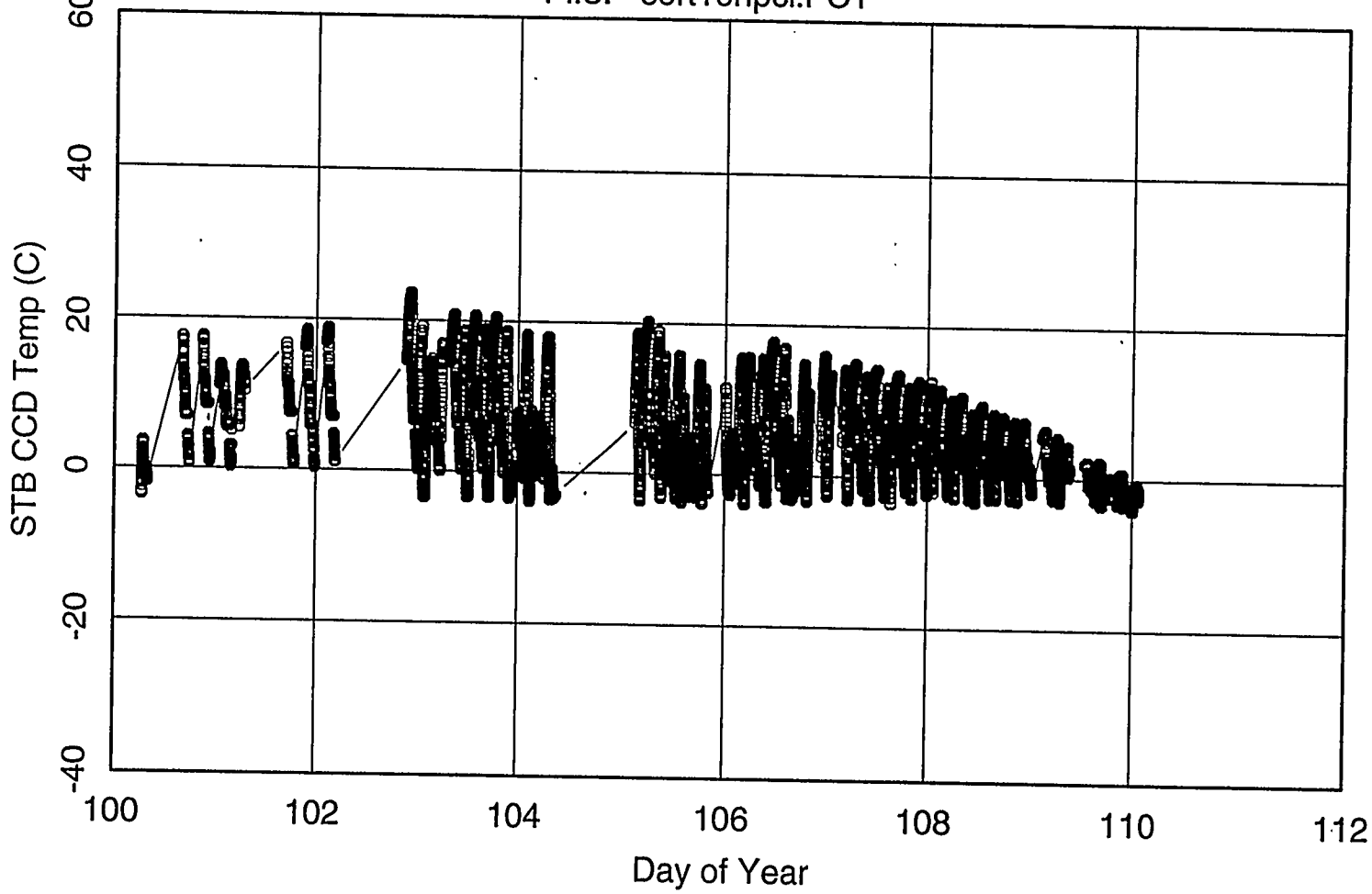

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Star Tracker B Lens Temperature

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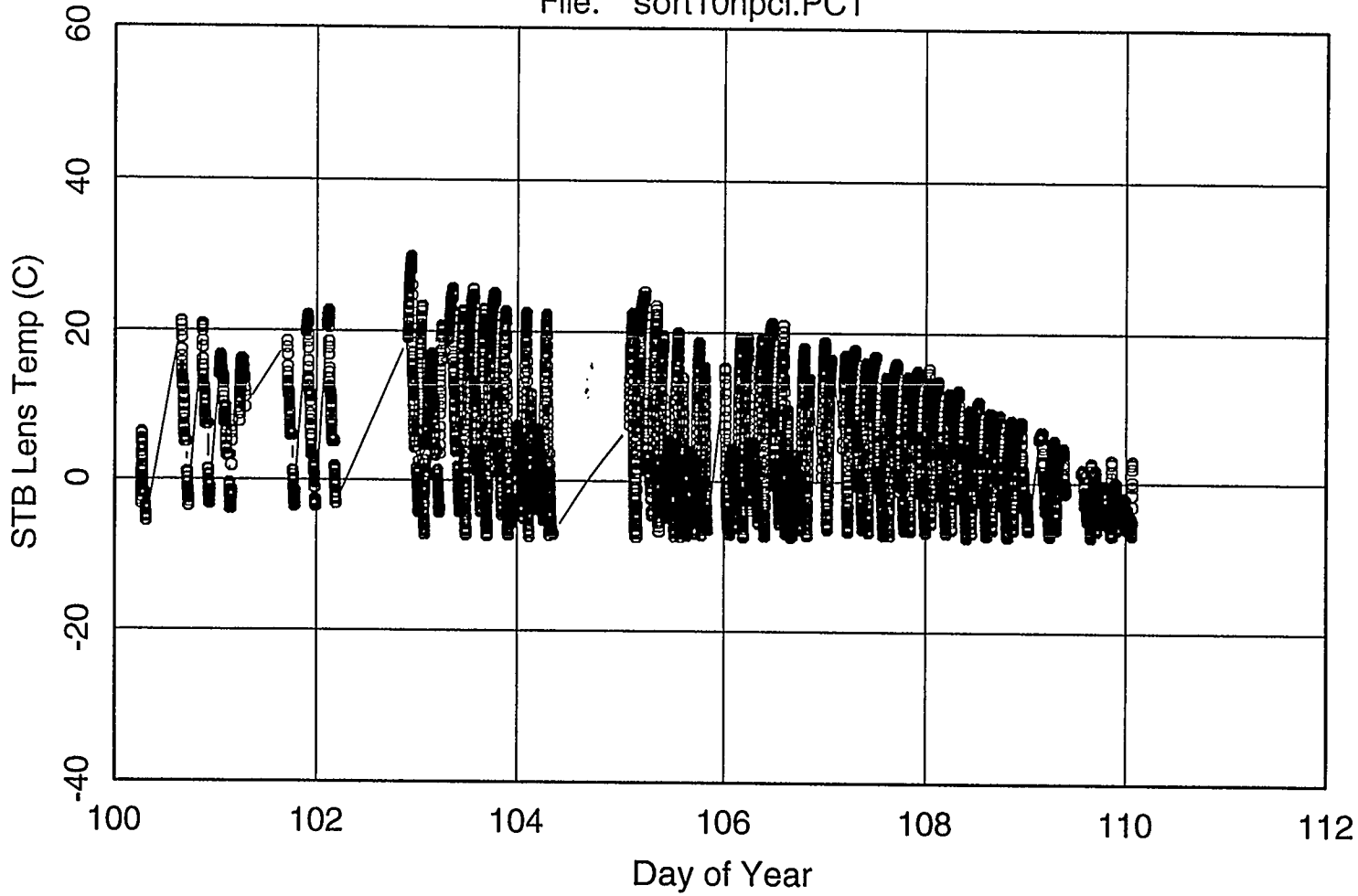

REP/LLNL created: Mon Apr 25 10:34:32 PDT 1994

Clementine

Star Tracker A CCD vs +Y VCHP Temp

Start Time: 10-APR-94 06:21:50.500 GMT

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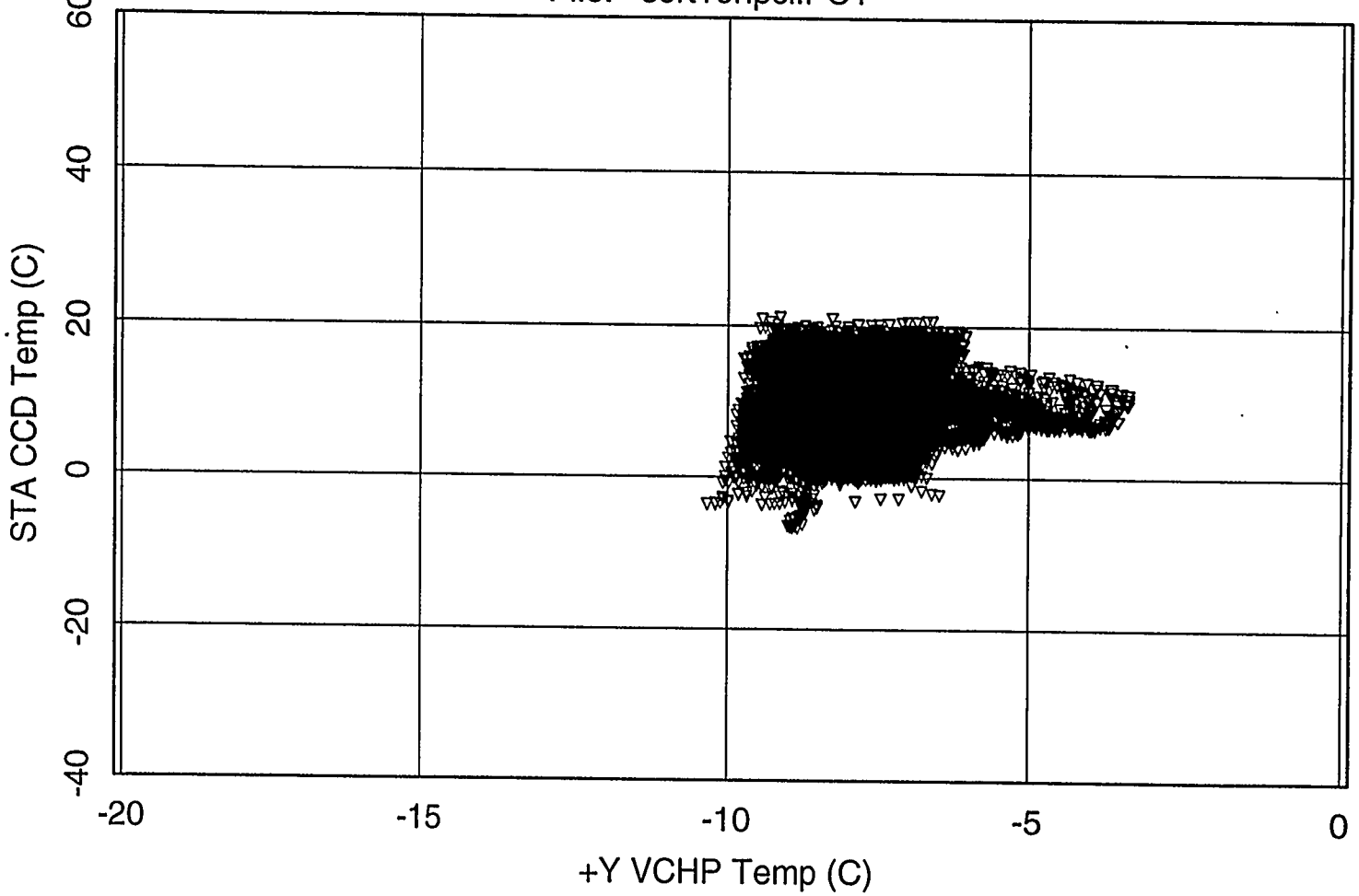

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Clementine

Star Tracker B CCD vs -Y VCHP Temp

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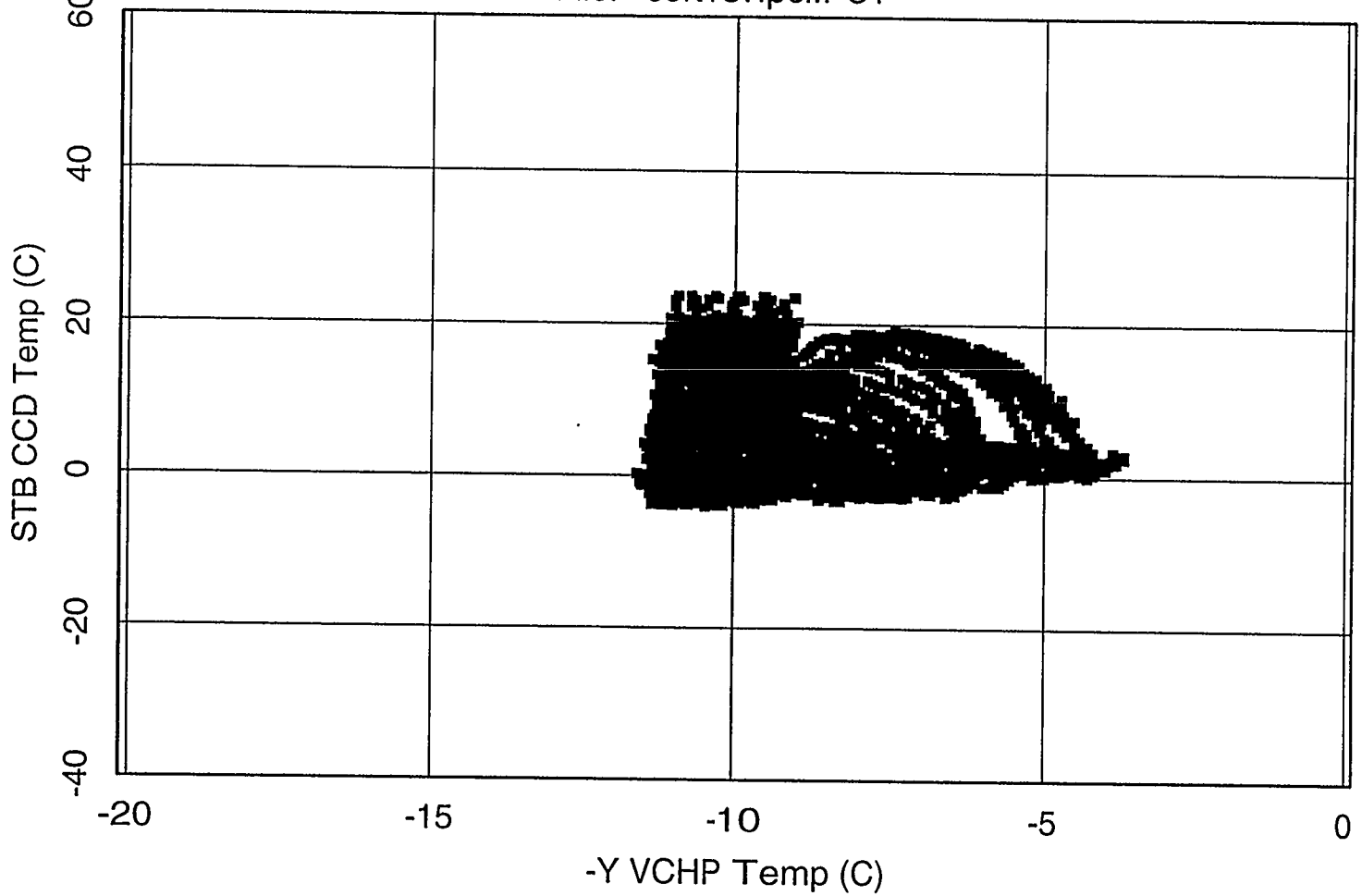


REP/LLNL created: Mon Apr 25 10:35:40 PDT 1994

S-16

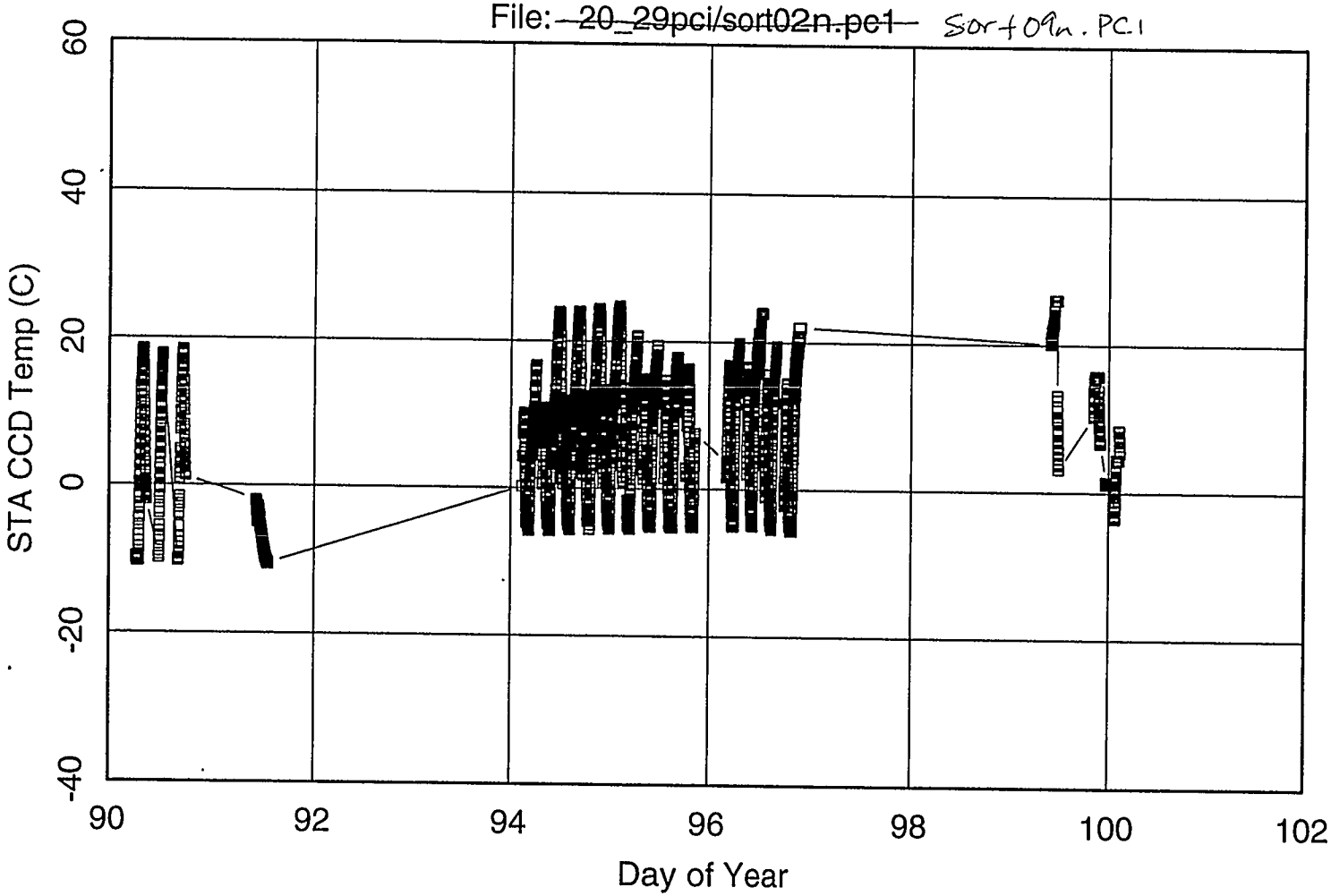
90 — 99

Clementine

Star Tracker A CCD Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: ~~20_29pci/sort02n.pc1~~ Sort09n.PC1



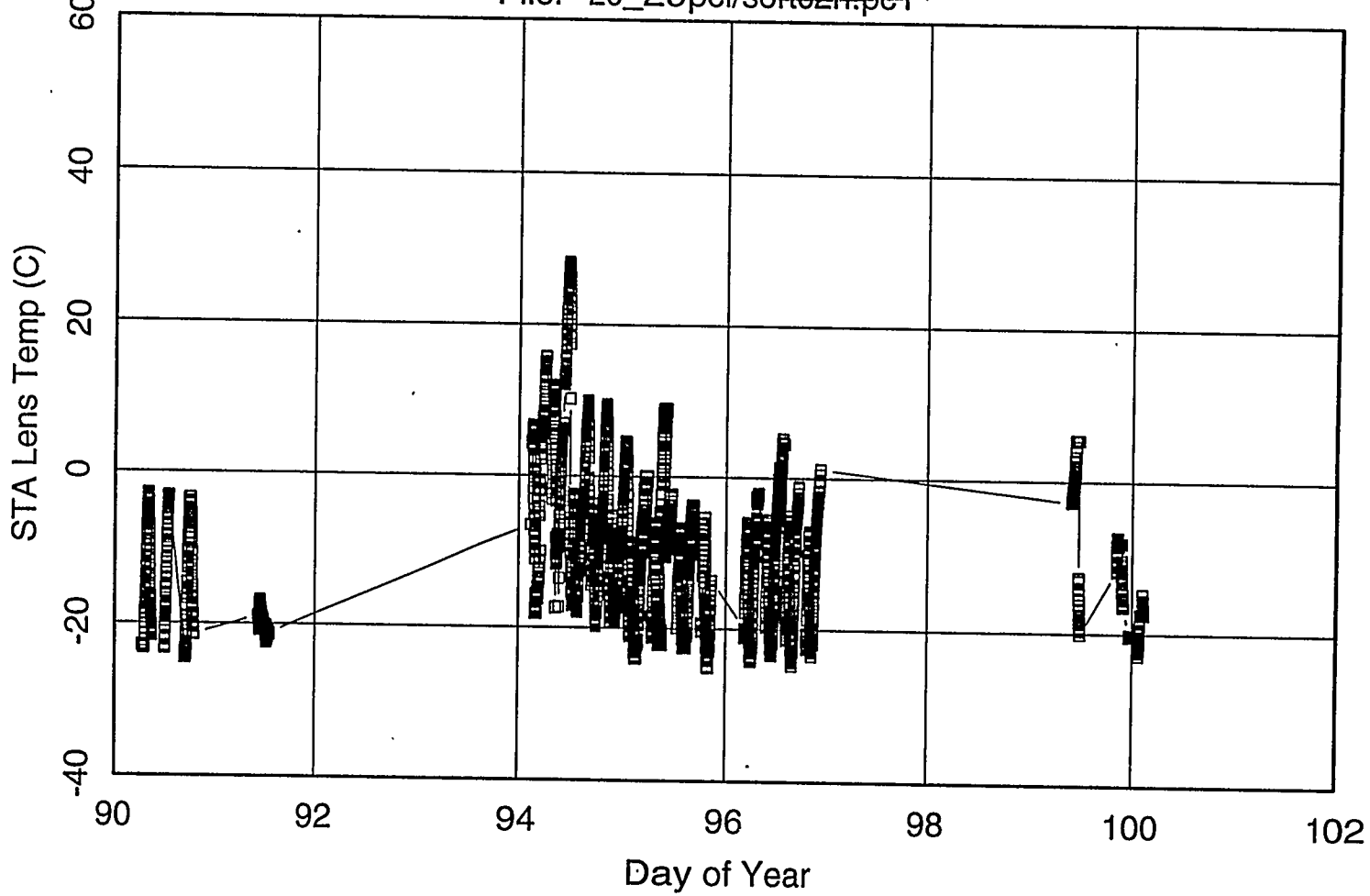
REP/LLNL created: Thu Apr 21 16:52:05 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: ~~20_29pci/sort02n.pc1~~



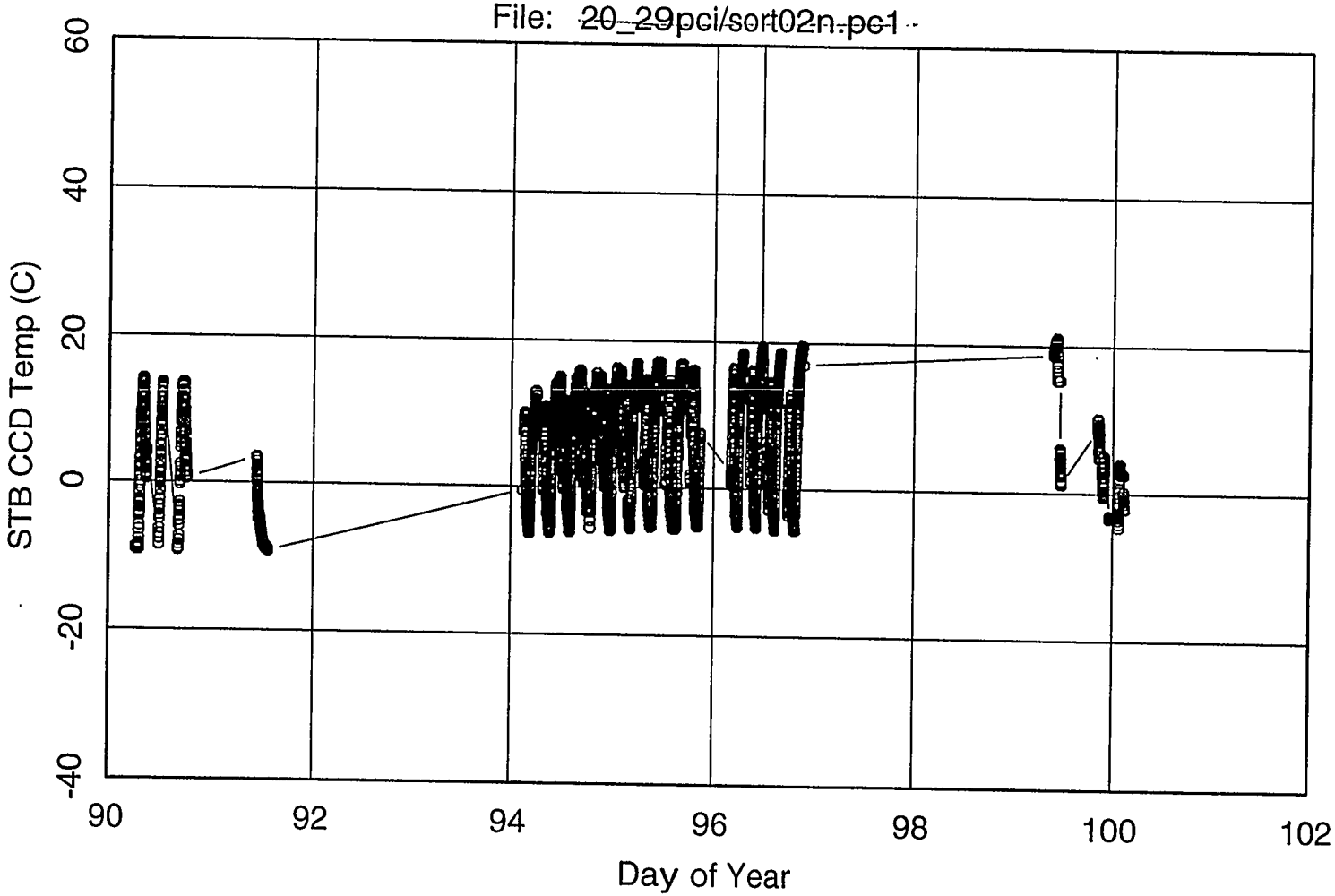
REP/LLNL created: Thu Apr 21 16:52:10 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: 20_29pci/sort02n.pc1



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Clementine

Star Tracker B Lens Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

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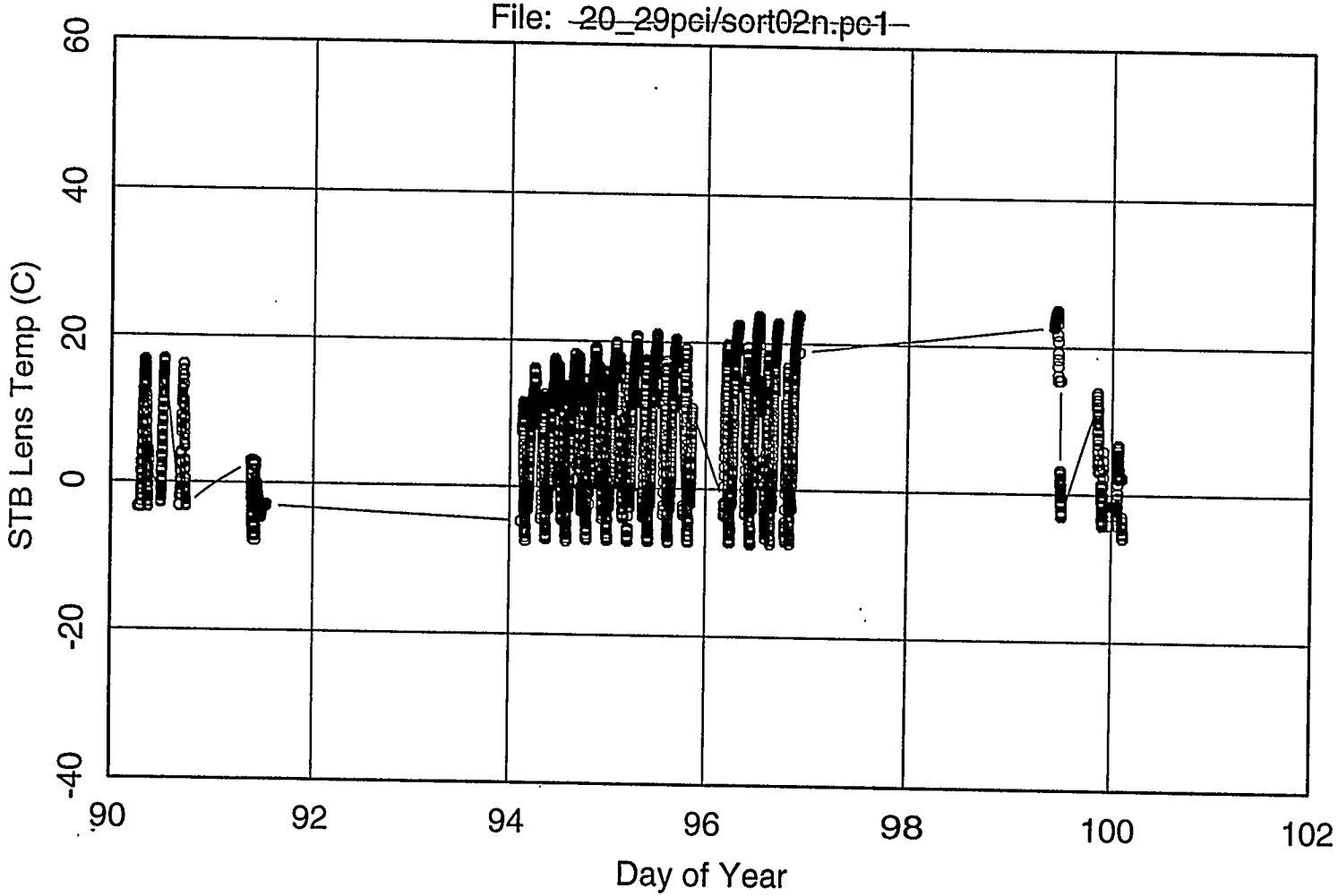

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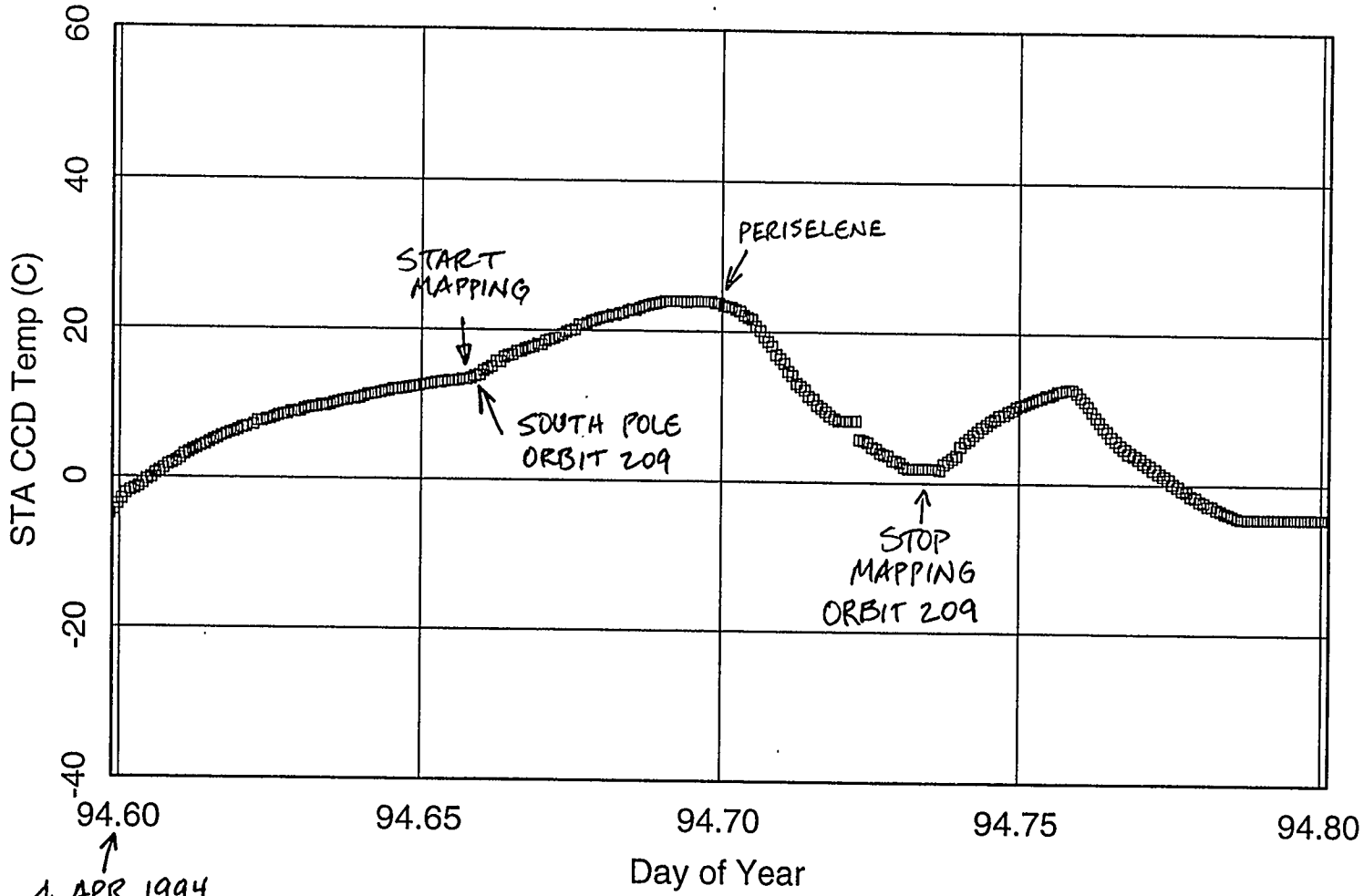
Clementine

Star Tracker A CCD Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: sort09n.PC1



4 APR 1994,
2:24 p.m. UT(Z),
ORBIT 208,
5 MINUTES BEFORE APOSELENE

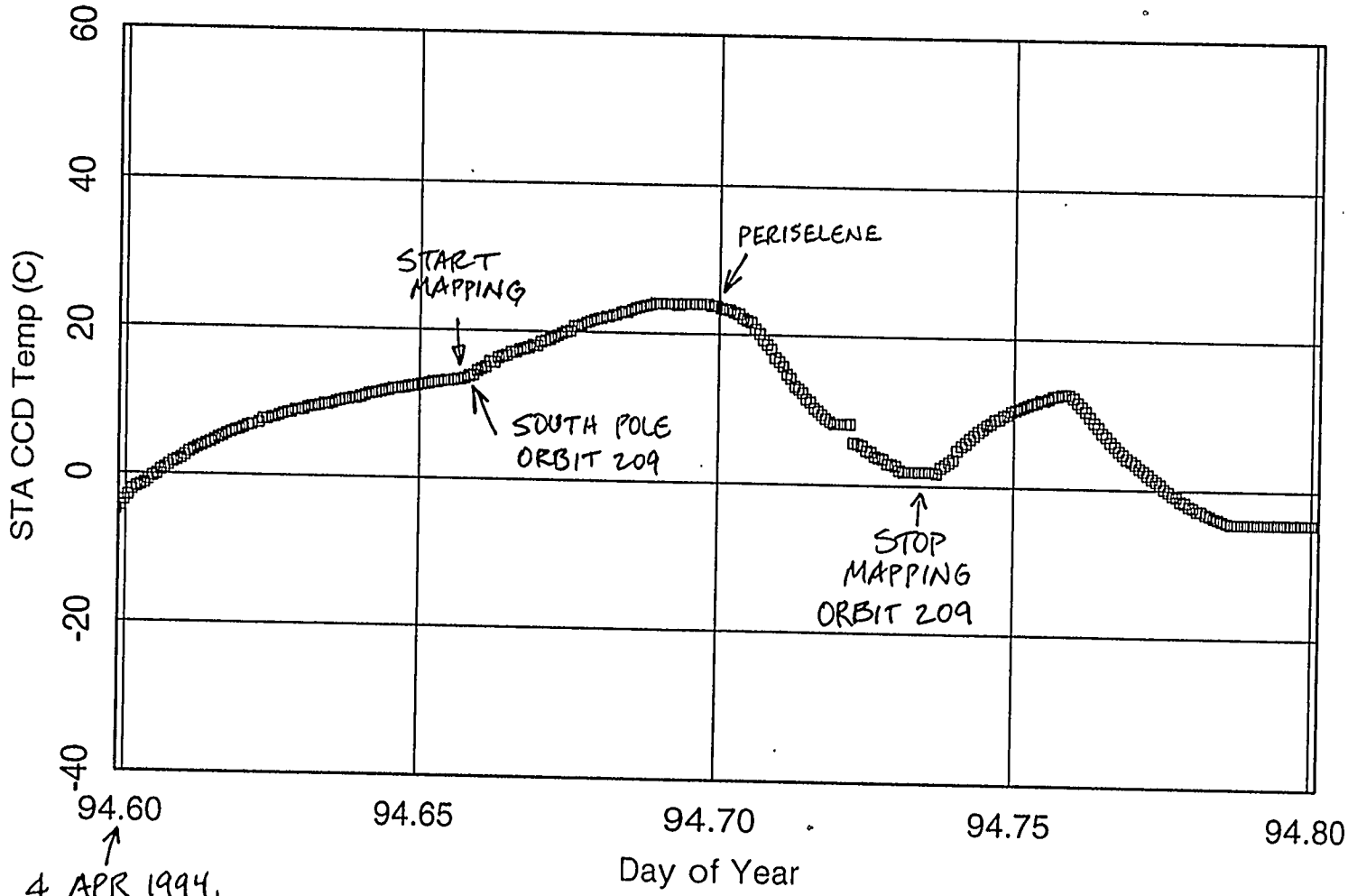
REP/LLNL created: Sat Jul 16 12:42:42 PDT 1994

Clementine

Star Tracker A CCD Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: sort09n.PC1



4 APR 1994,
2:24 pm. UT(Z),
ORBIT 208,
5 MINUTES BEFORE APOSELENE

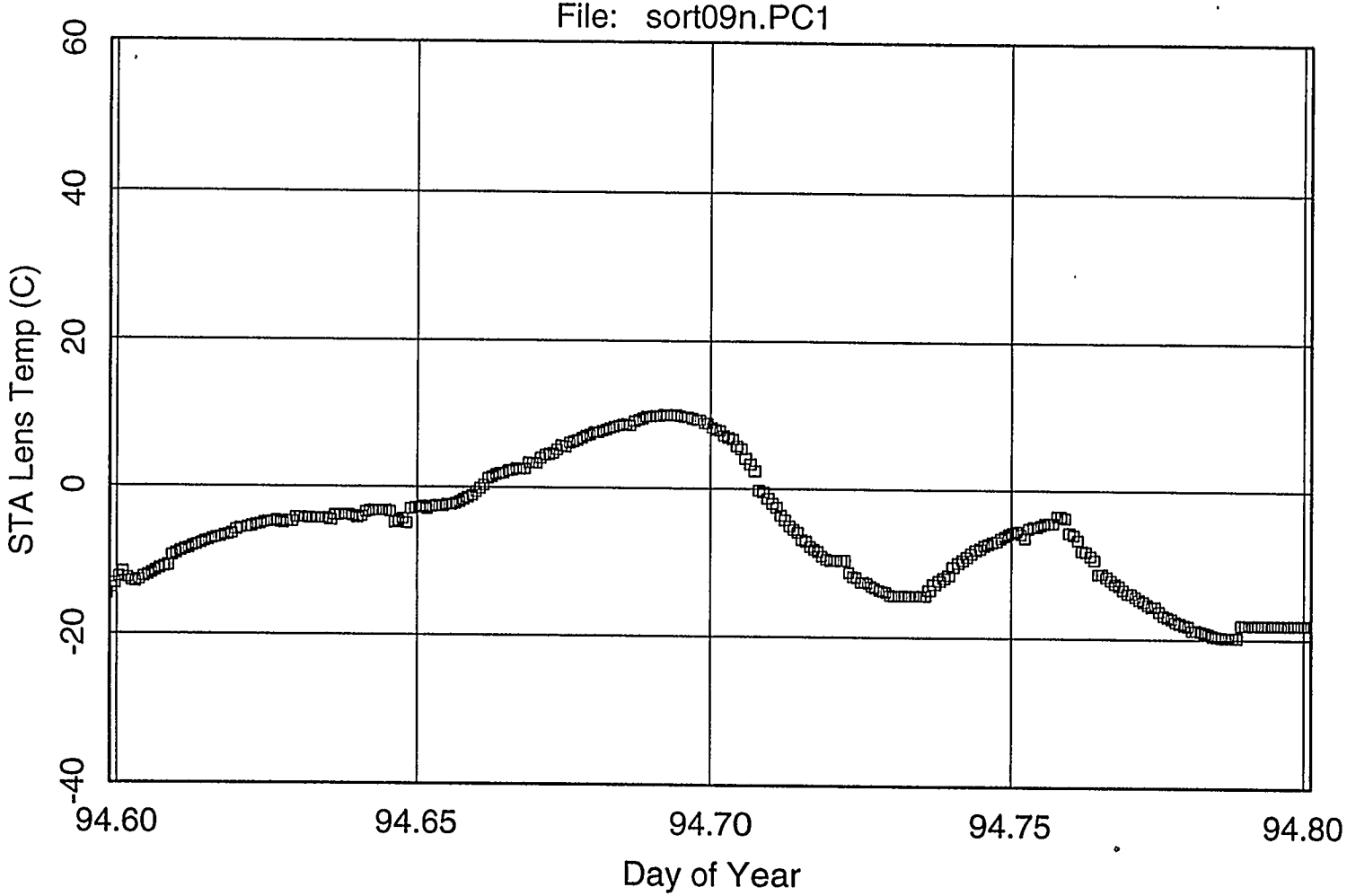
REP/LLNL created: Sat Jul 16 12:42:42 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: sort09n.PC1



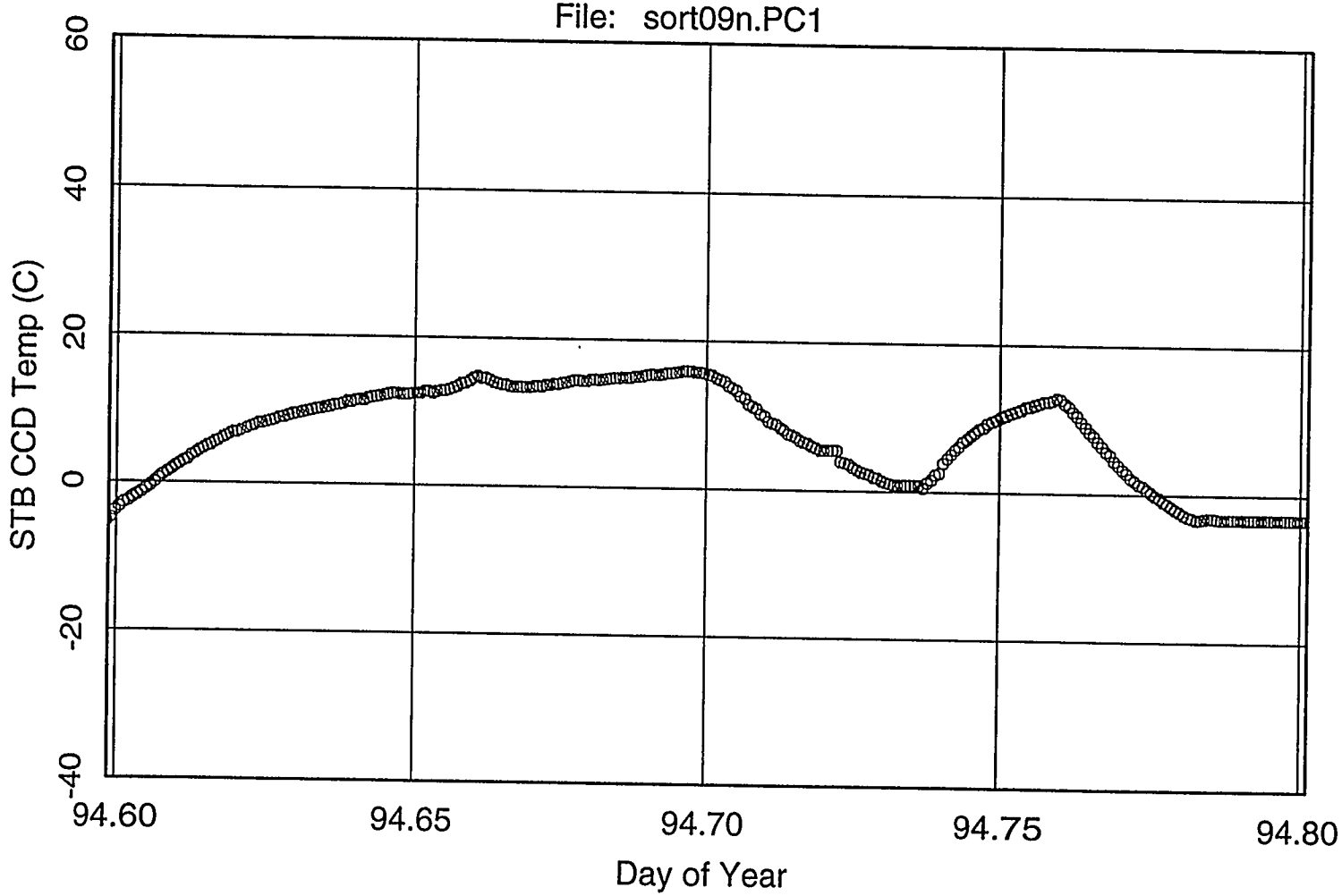
REP/LLNL created: Sat Jul 16 12:44:05 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: sort09n.PC1



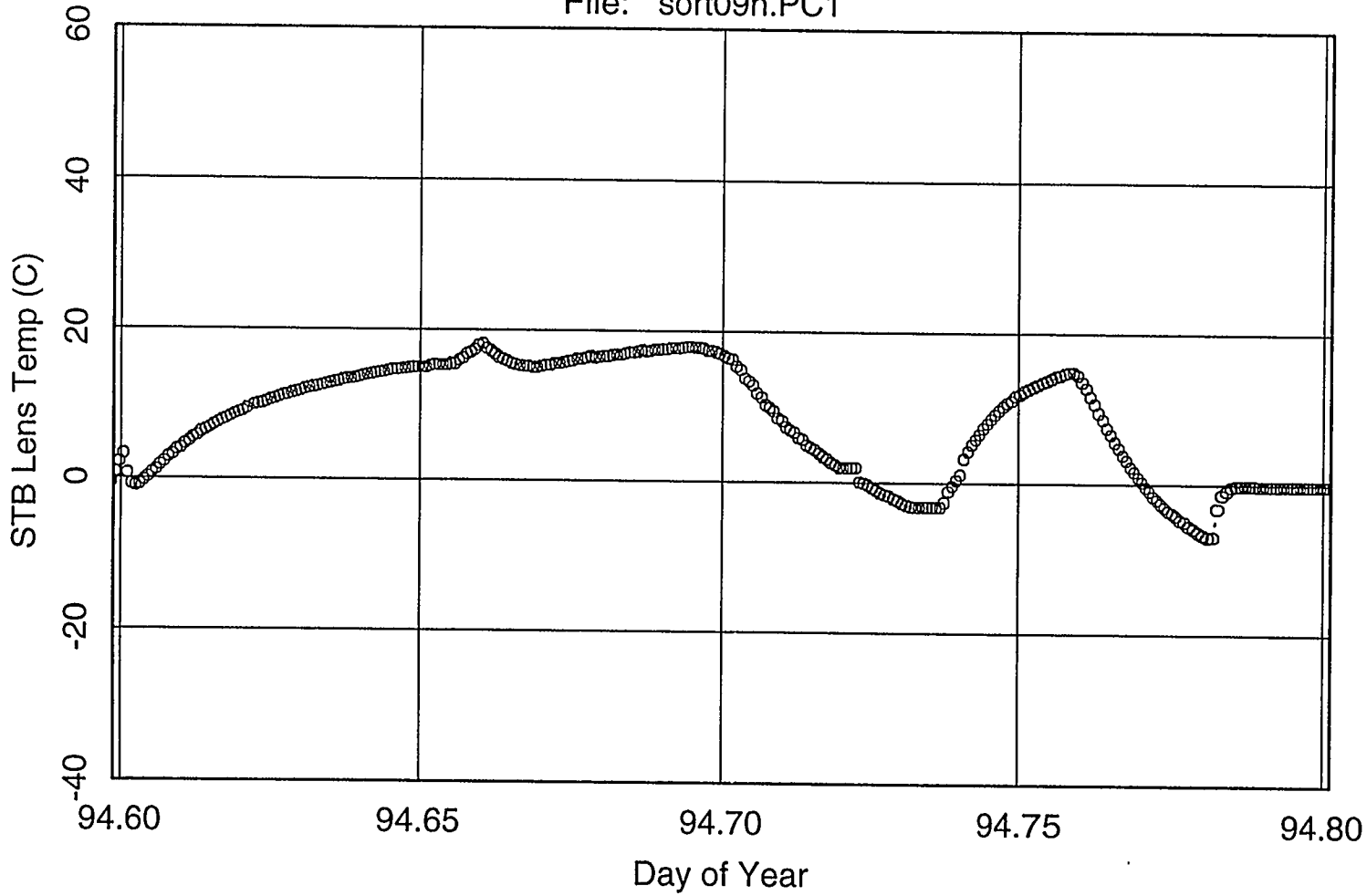
REP/LLNL created: Sat Jul 16 12:45:53 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 31-MAR-94 06:38:58.900 GMT

File: sort09n.PC1



REP/LLNL created: Sat Jul 16 12:47:34 PDT 1994

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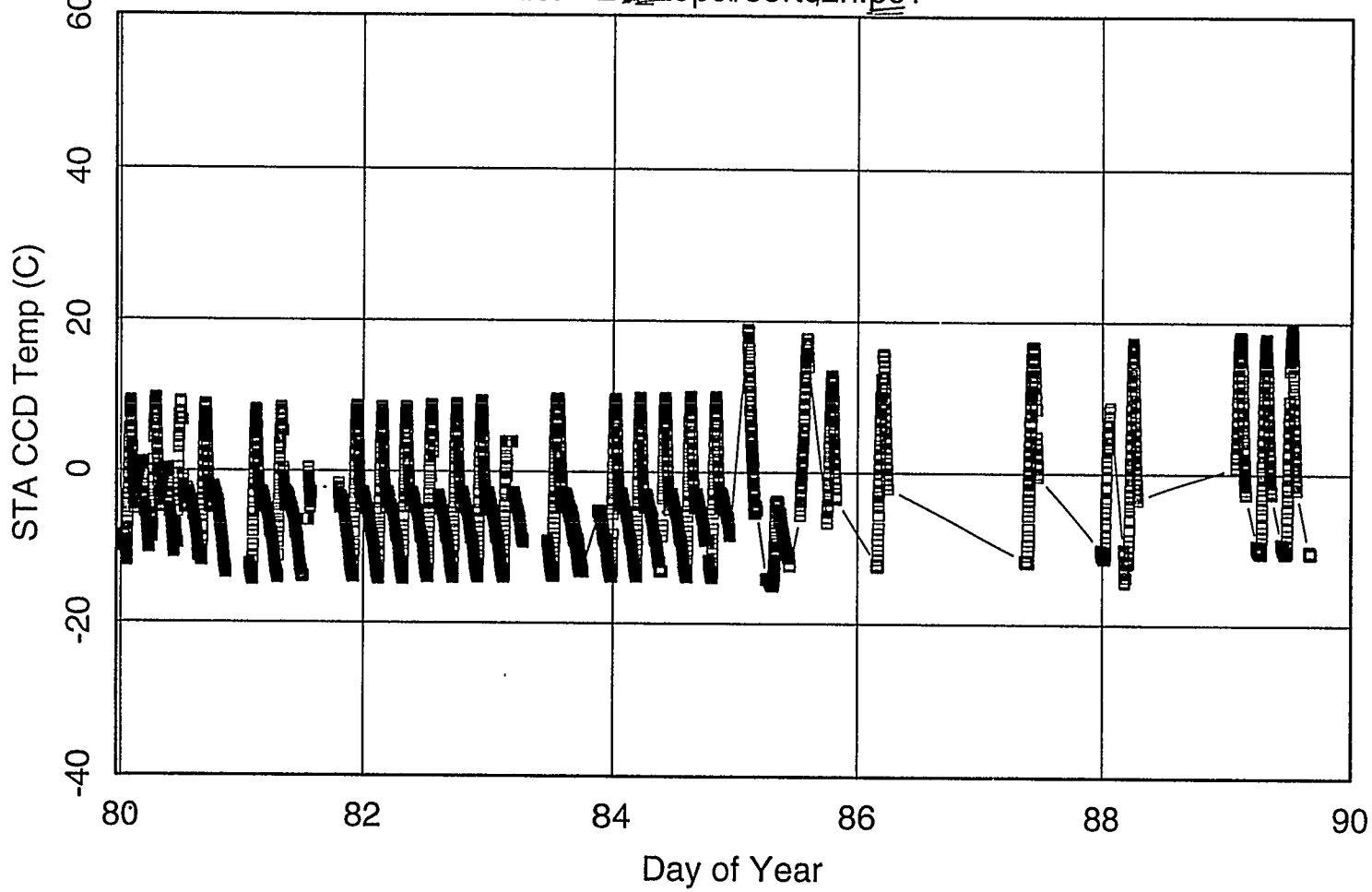
Clementine

Star Tracker A CCD Temperature

Start Time: 21-MAR-94 00:34:55.630 GMT

File: ~~20_29pci~~/sort02n.pc1



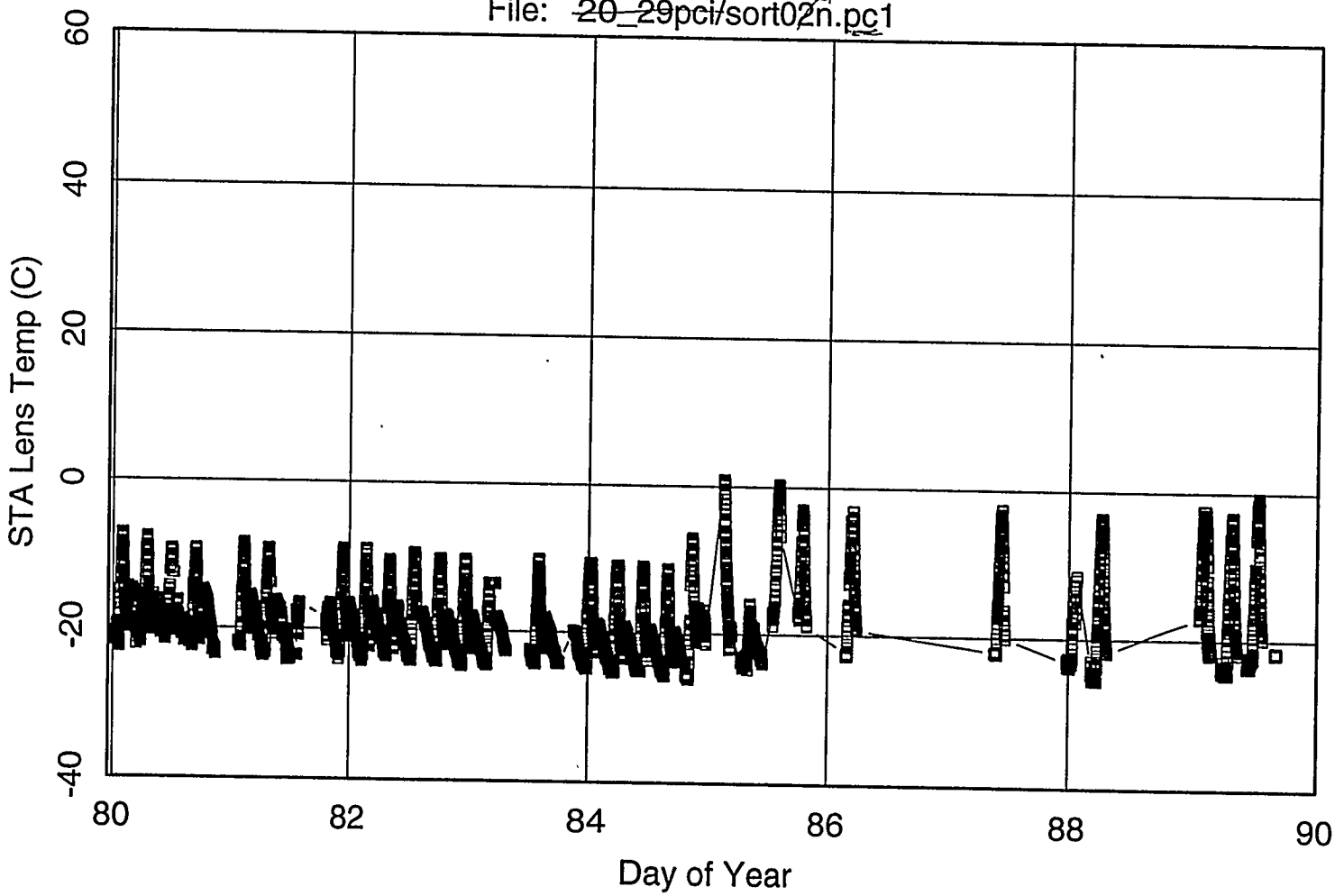
REP/LLNL created: Thu Apr 21 16:50:47 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 21-MAR-94 00:34:55.630 GMT

File: ~~20_29~~pci/sort02n.pc1



REP/LLNL created: Thu Apr 21 16:50:57 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 21-MAR-94 00:34:55.630 GMT

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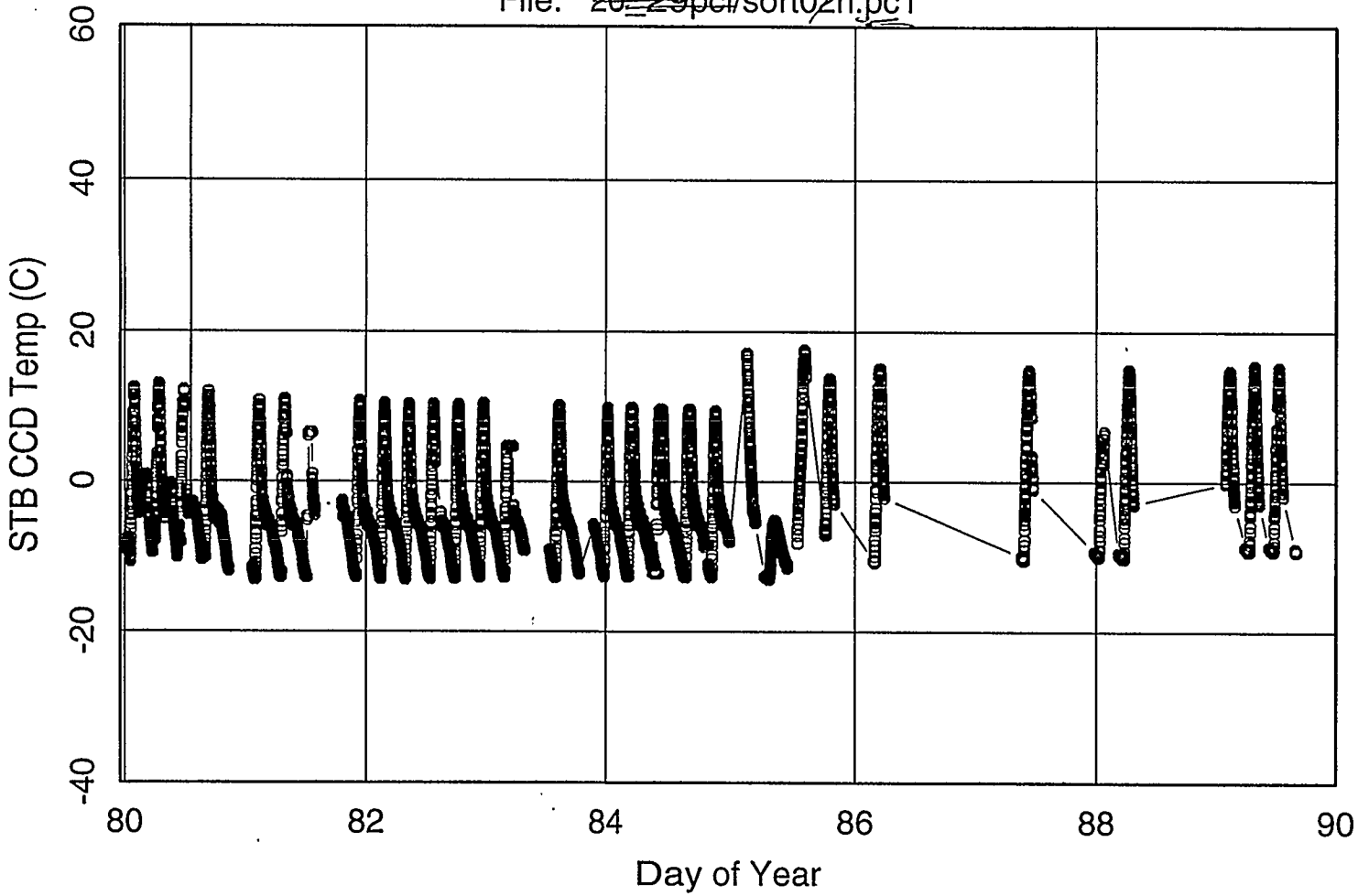


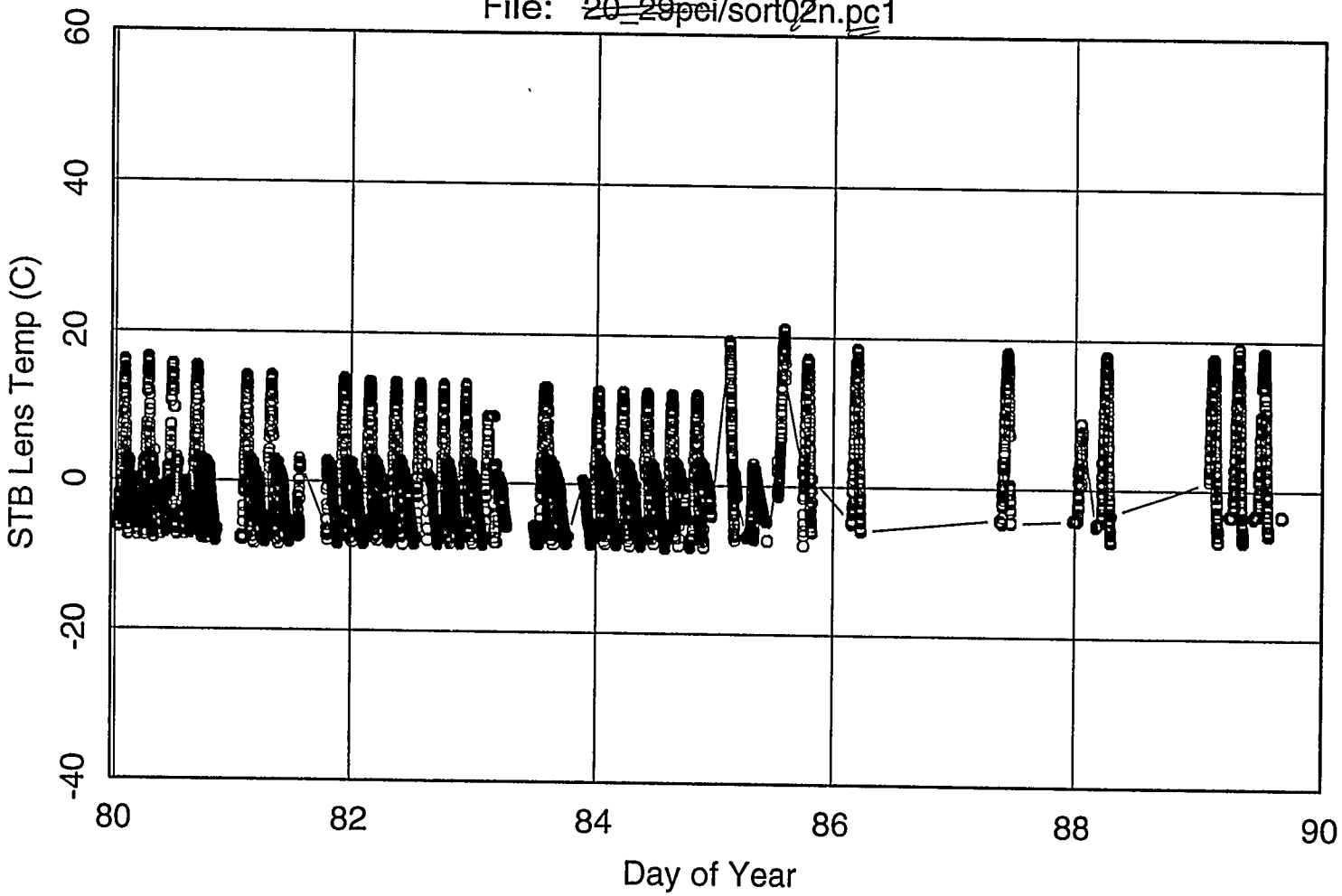
REP/LLNL created: Thu Apr 21 16:51:06 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 21-MAR-94 00:34:55.630 GMT

File: ~~20-29pci~~/sort02n.pc1



REP/LLNL created: Thu Apr 21 16:51:20 PDT 1994

Clementine

Star Tracker A CCD vs +Y VCHP Temp

Start Time: 21-MAR-94 00:34:55.630 GMT

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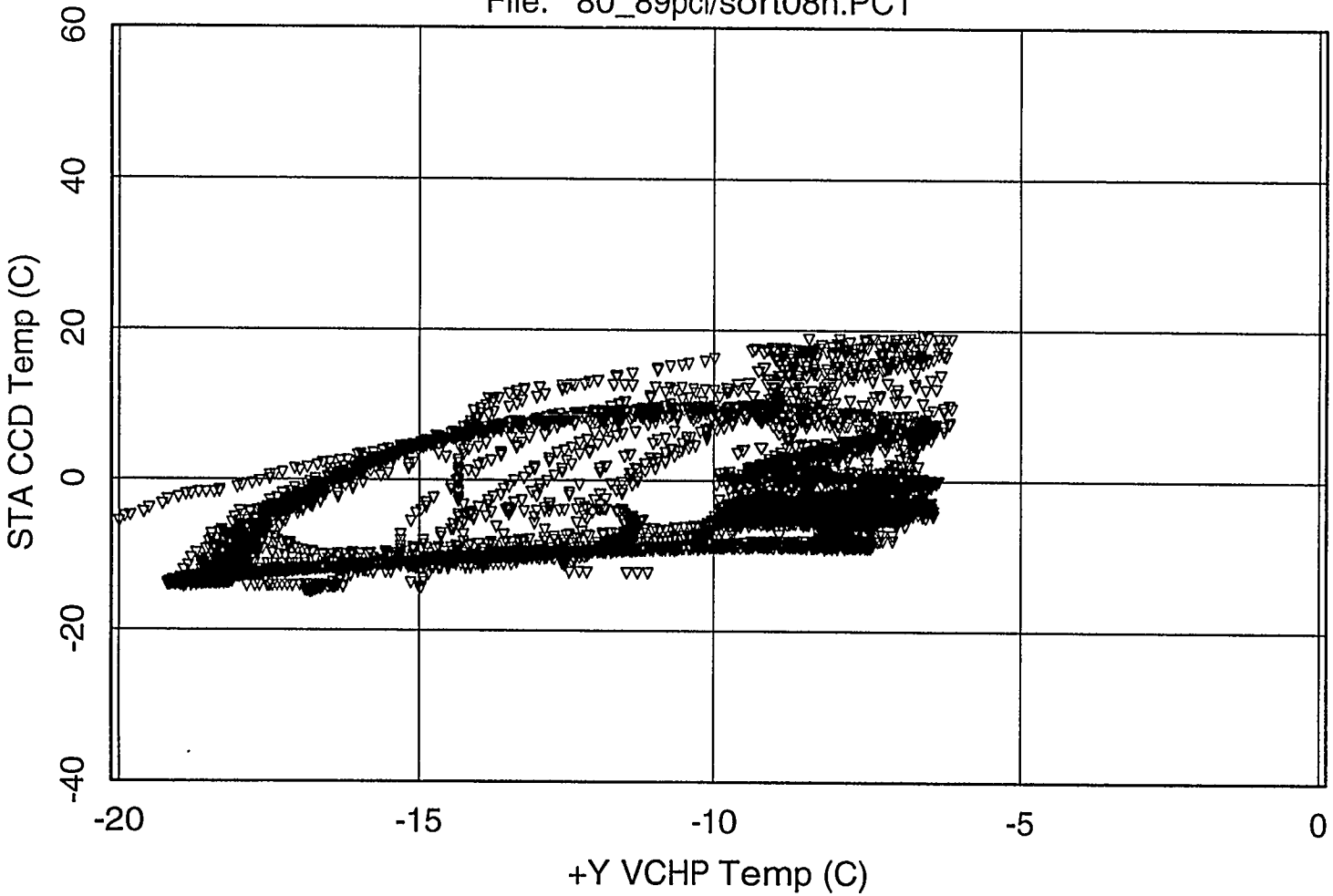


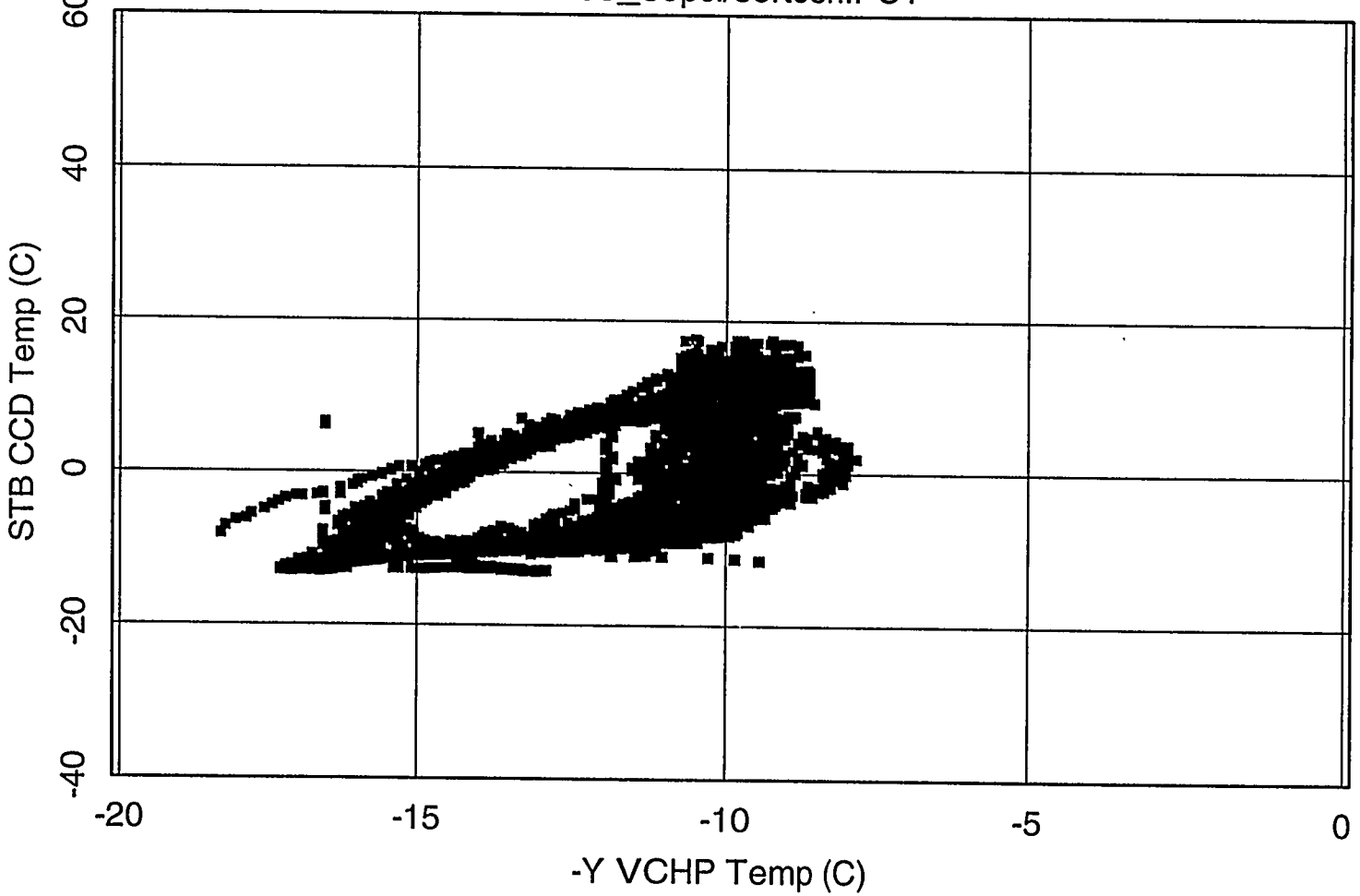
REP/LLNL created: Thu Apr 21 15:24:58 PDT 1994

Clementine

Star Tracker B CCD vs -Y VCHP Temp

Start Time: 21-MAR-94 00:34:55.630 GMT

File: 80_89pci/sort08n.PC1



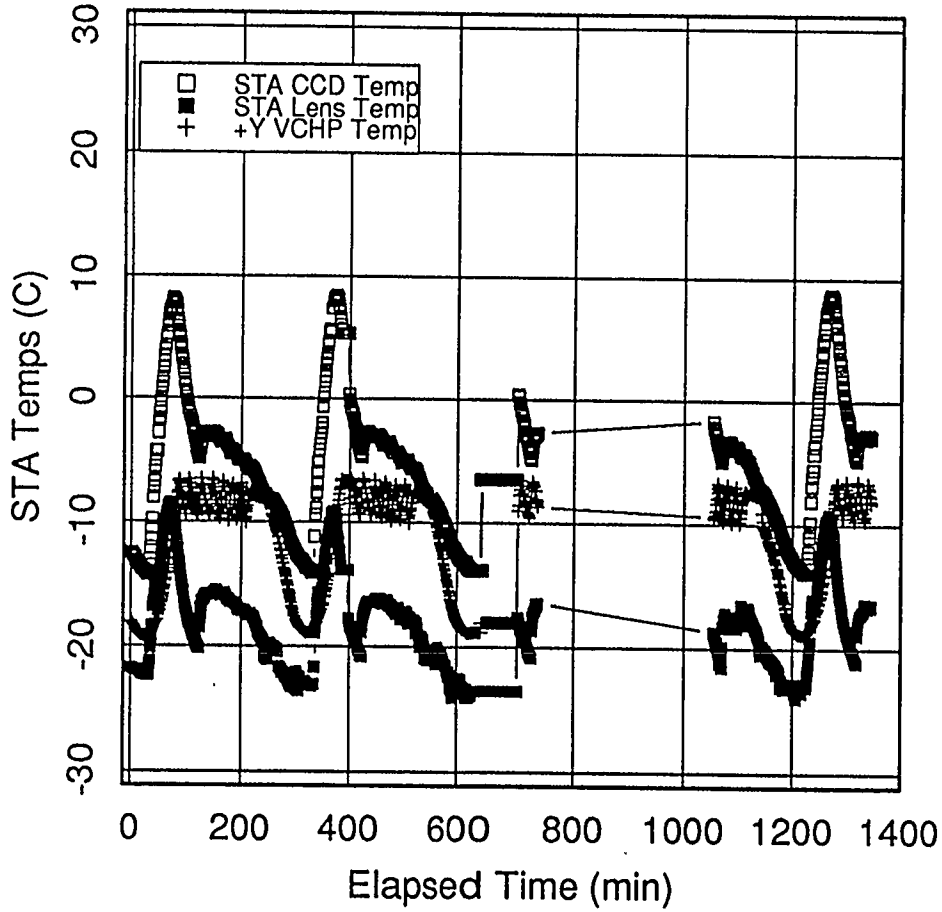
REP/LLNL created: Thu Apr 21 15:25:25 PDT 1994

Clementine

Star Tracker A - Temperatures

Start Time: 22-MAR-94 01:33:44.270 GMT

File: 081pci.PC1



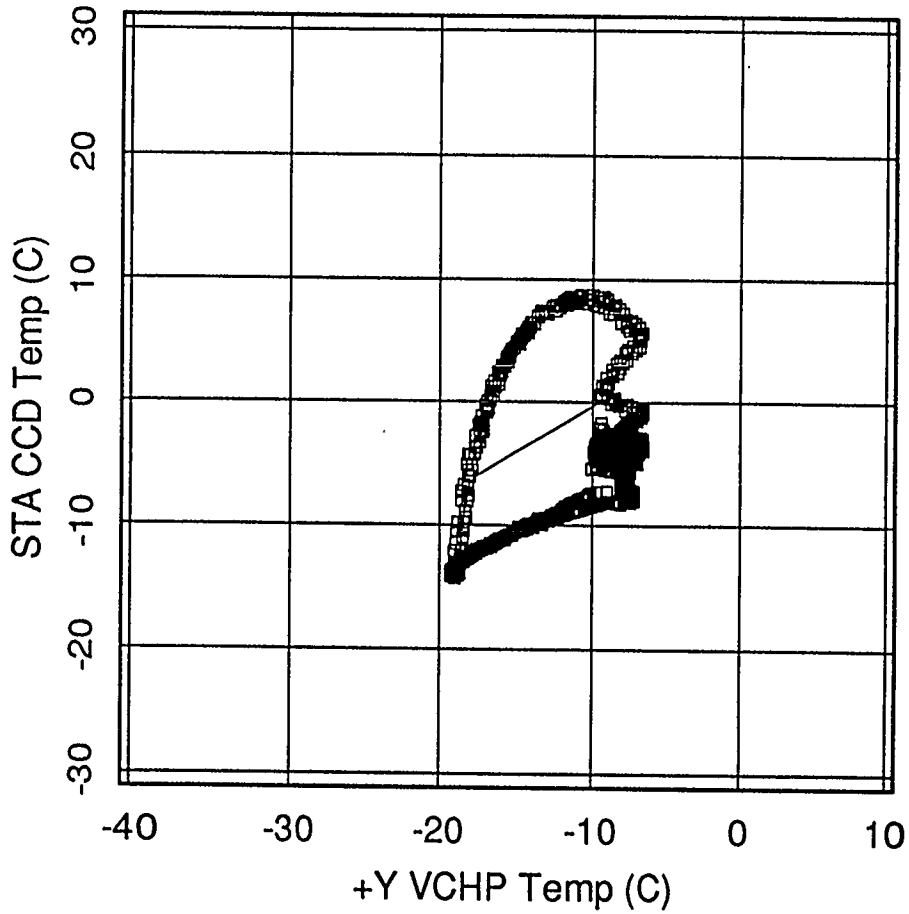


Fig 16

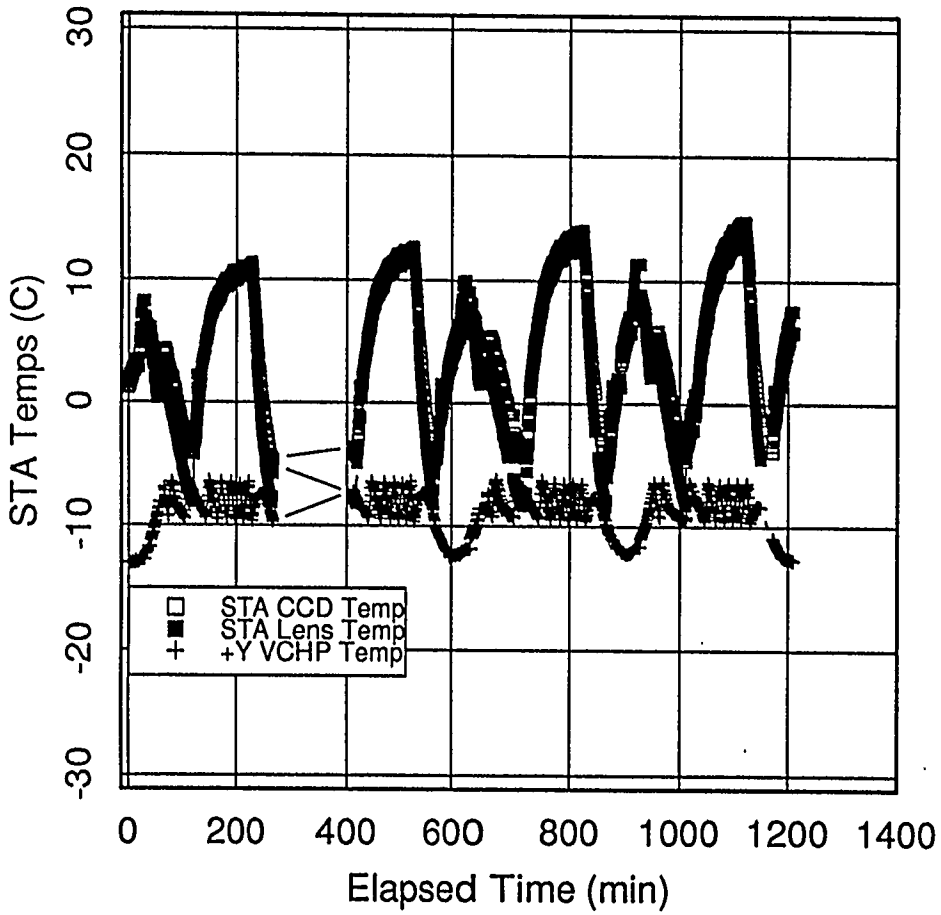
LLNL/ATP/rep report date = Thu Mar 24 08:10:22 PST 1994

Clementine

Star Tracker A - Temperatures

Start Time: 05-MAR-94 01:53:34.180 GMT

File: 064pci.pc1



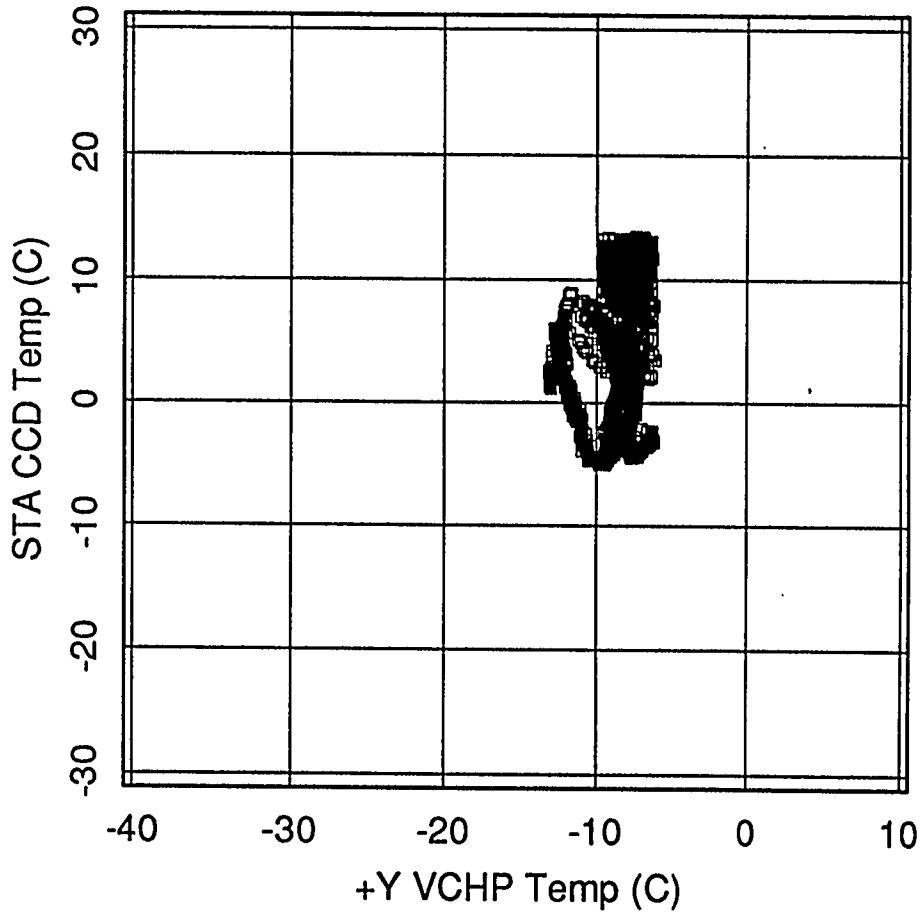


Fig 14

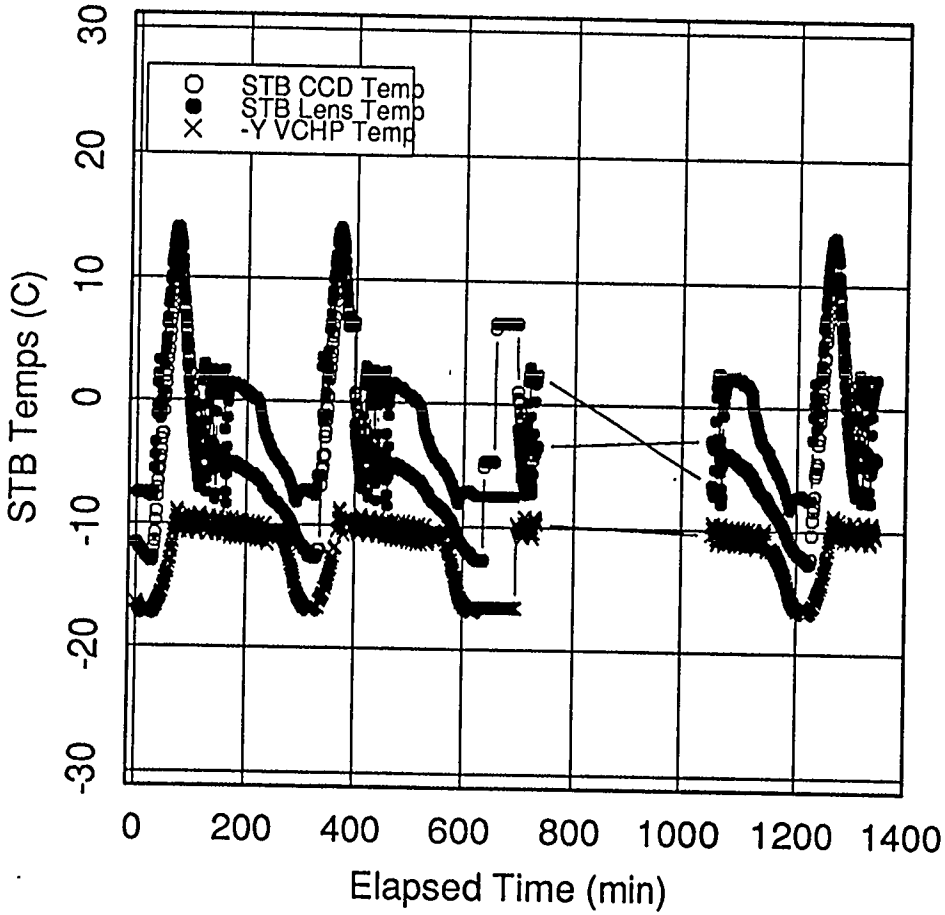
LLNL/ATP/rep report date = Thu Mar 24 06:47:05 PST 1994

Clementine

Star Tracker B - Temperatures

Start Time: 22-MAR-94 01:33:44.270 GMT

File: 081pci.PC1



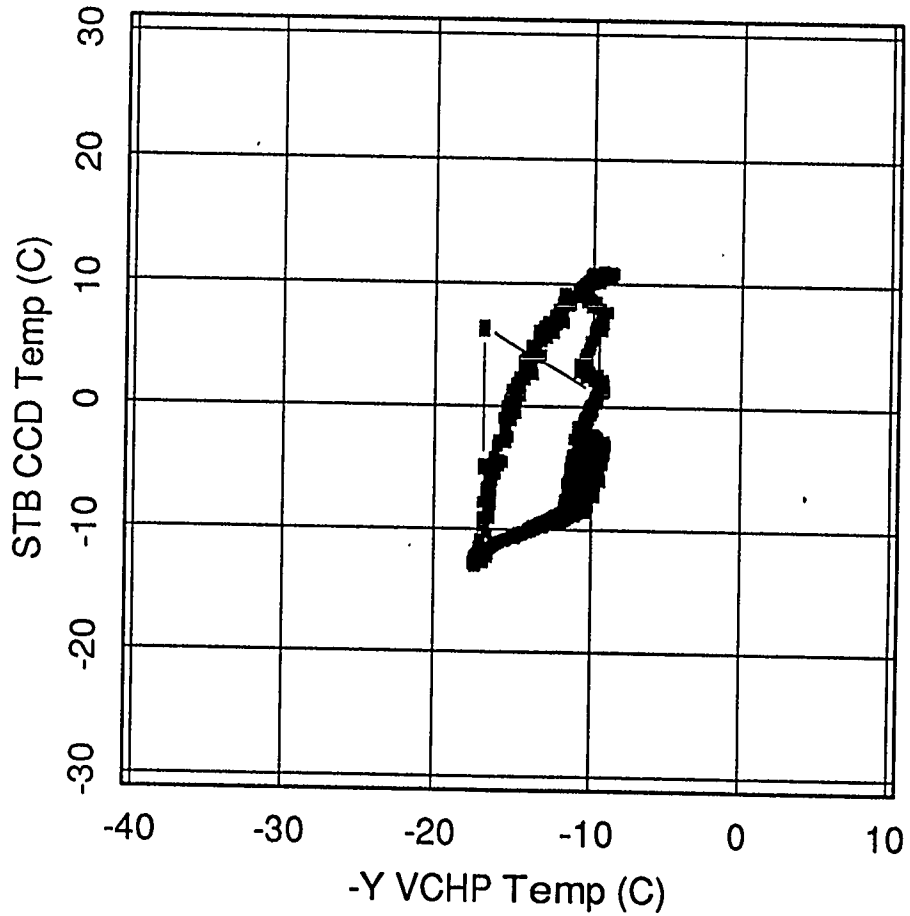


Fig 17

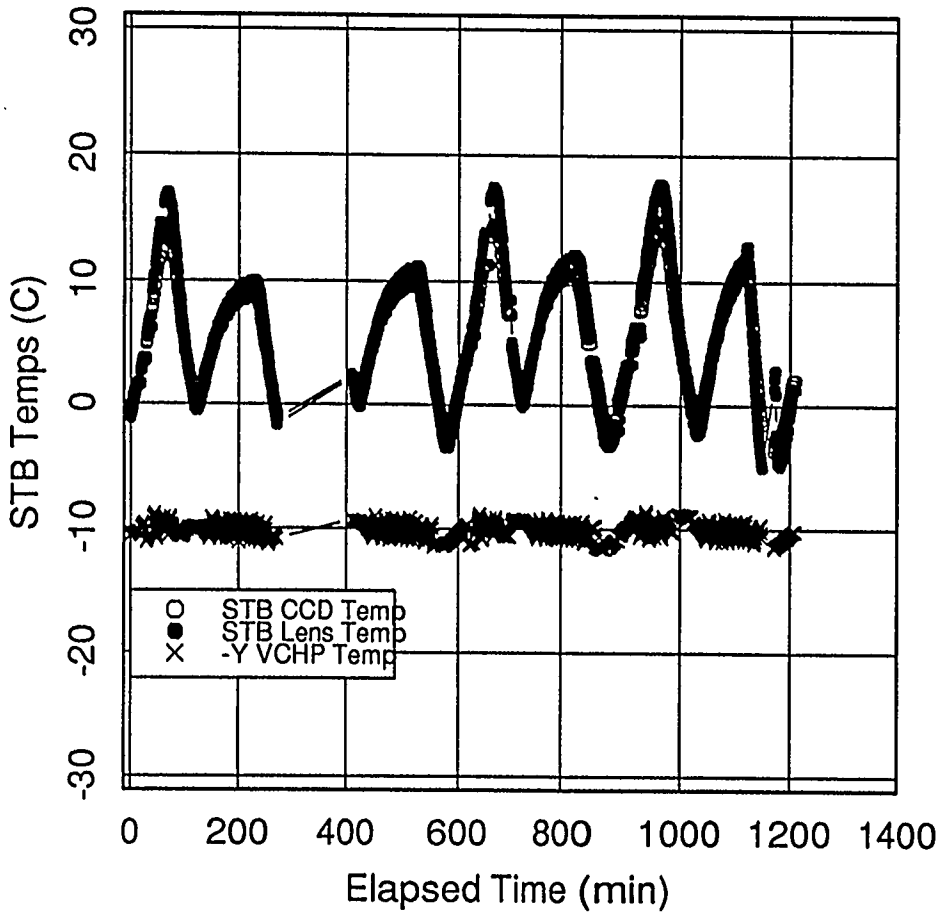
LLNL/ATP/rep report date = Thu Mar 24 08:10:40 PST 1994

Clementine

Star Tracker B - Temperatures

Start Time: 05-MAR-94 01:53:34.180 GMT

File: 064pci.pc1



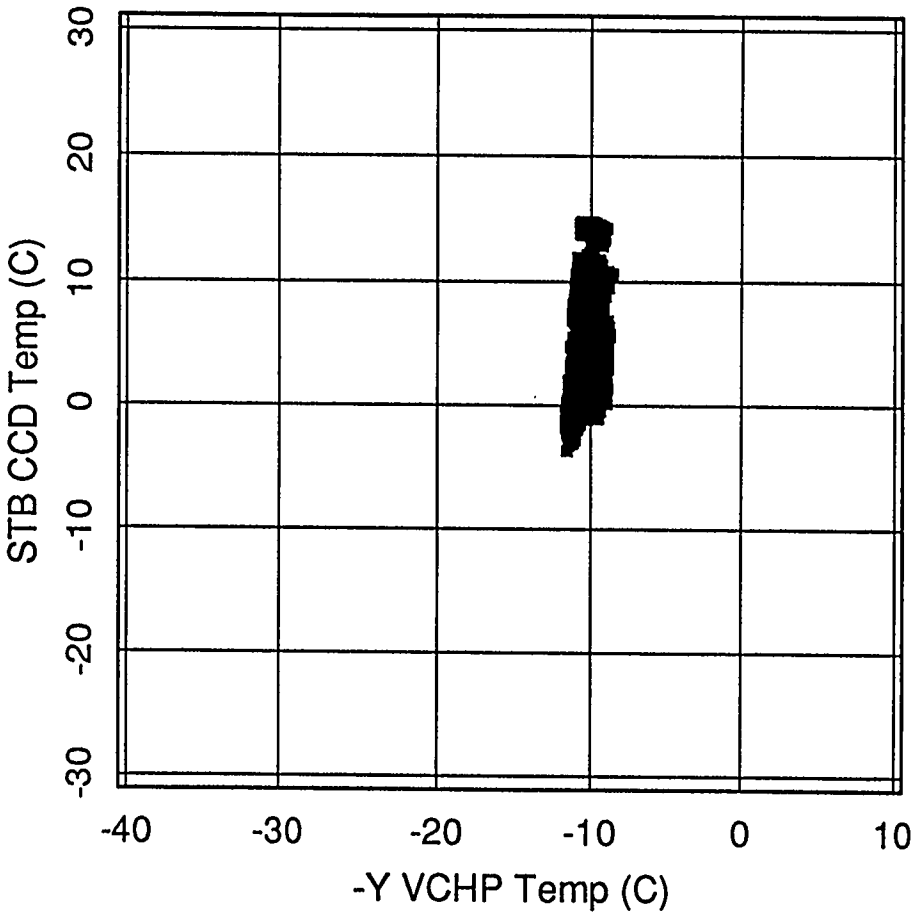


Fig 15

LLNL/ATP/rep report date = Thu Mar 24 06:53:35 PST 1994

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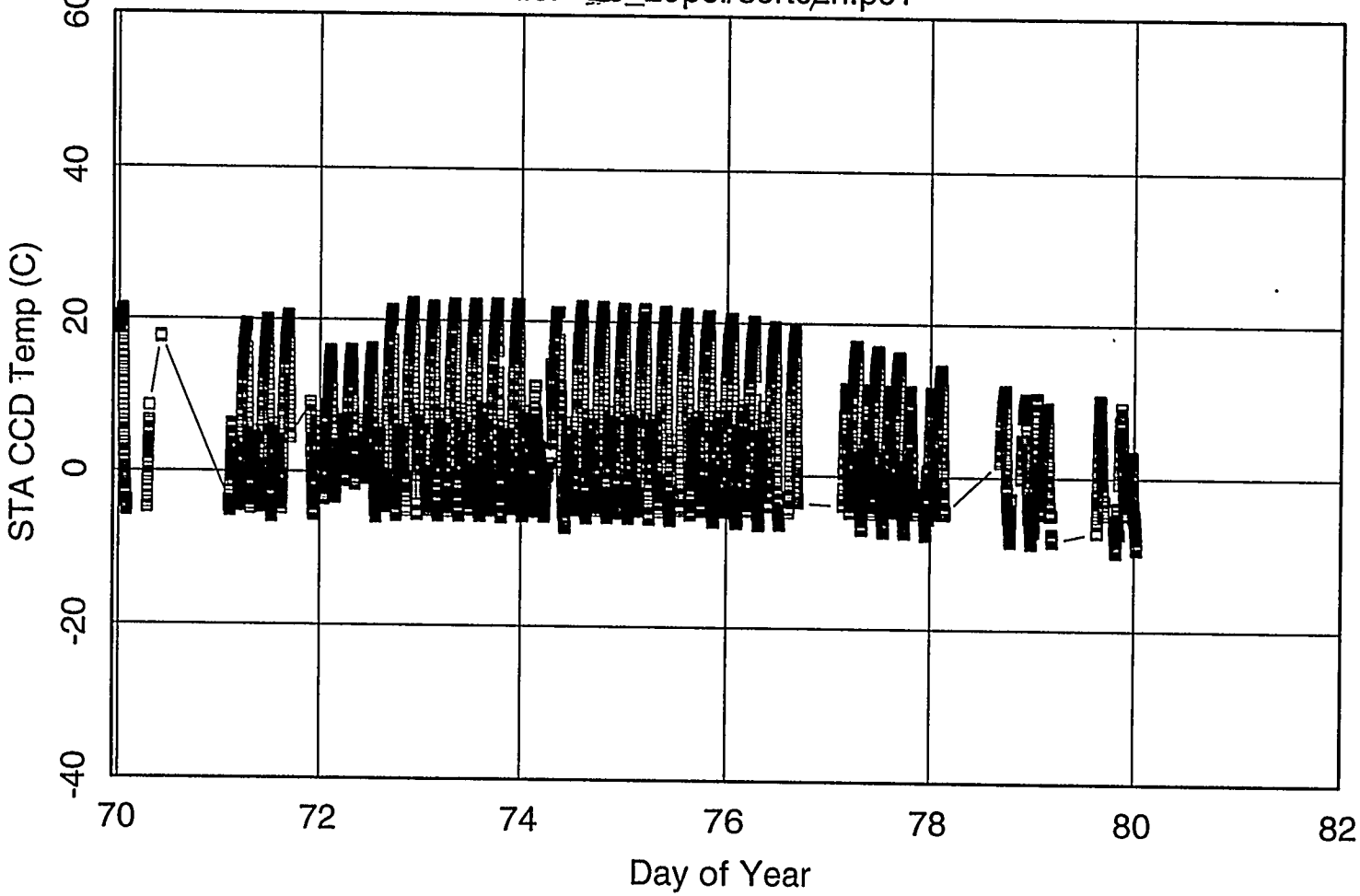
Clementine

Star Tracker A CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: ~~20_29pci~~/sort02n.pc1



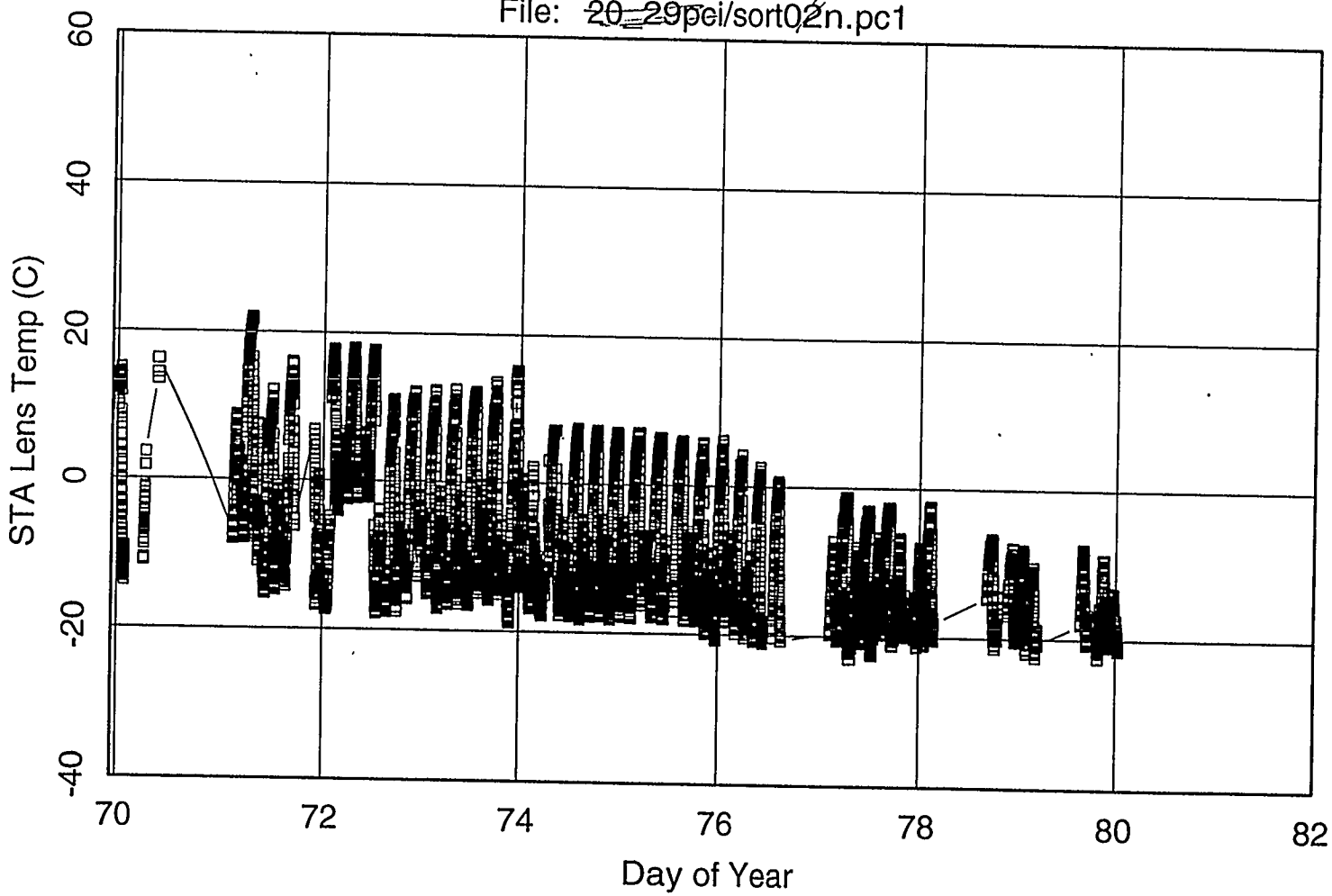
REP/LLNL created: Thu Apr 21 16:48:38 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: ~~20_29~~pci/sort02n.pc1



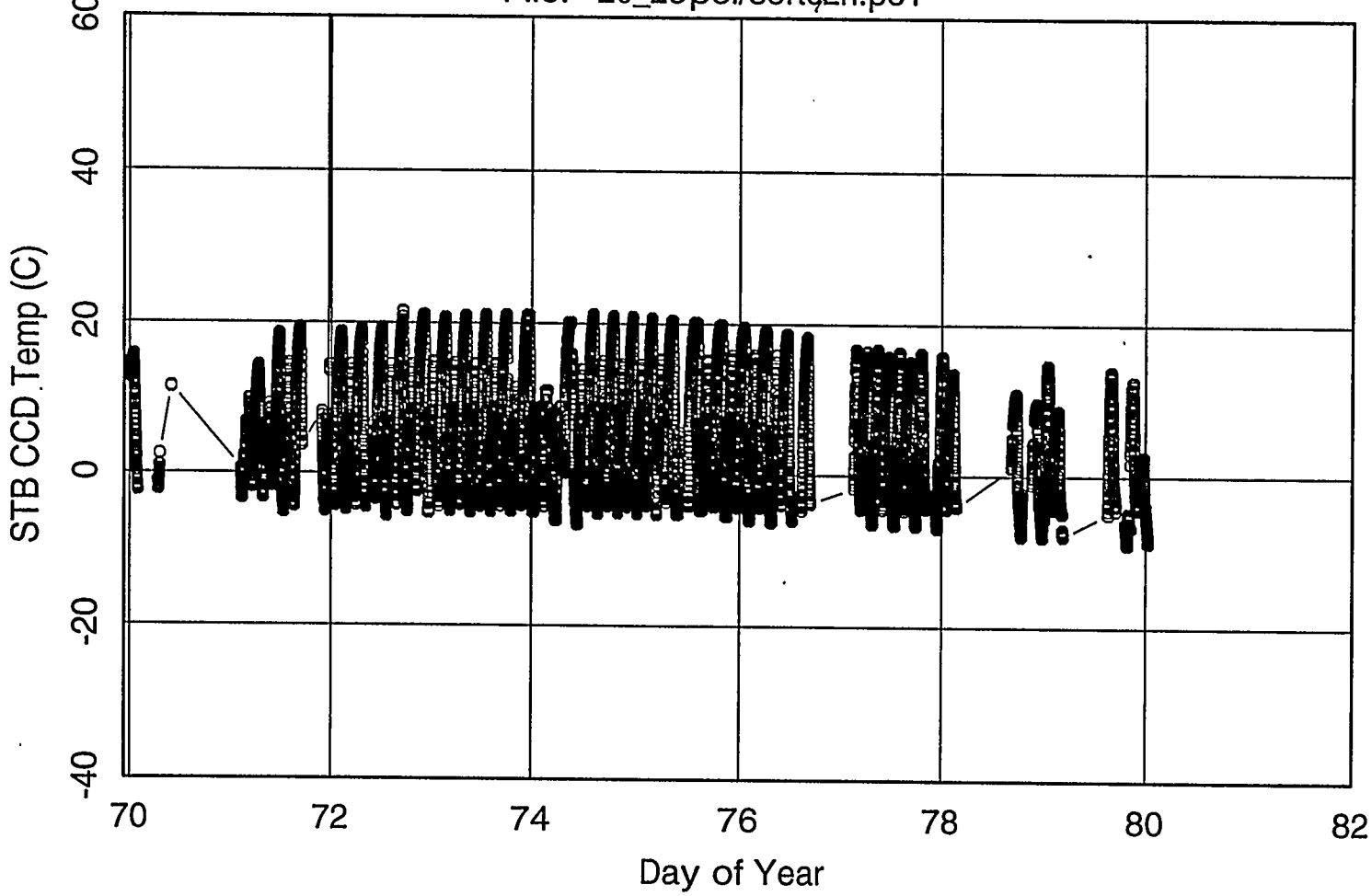
REP/LLNL created: Thu Apr 21 16:48:48 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: ~~20-29pci~~/sort02n.pc1



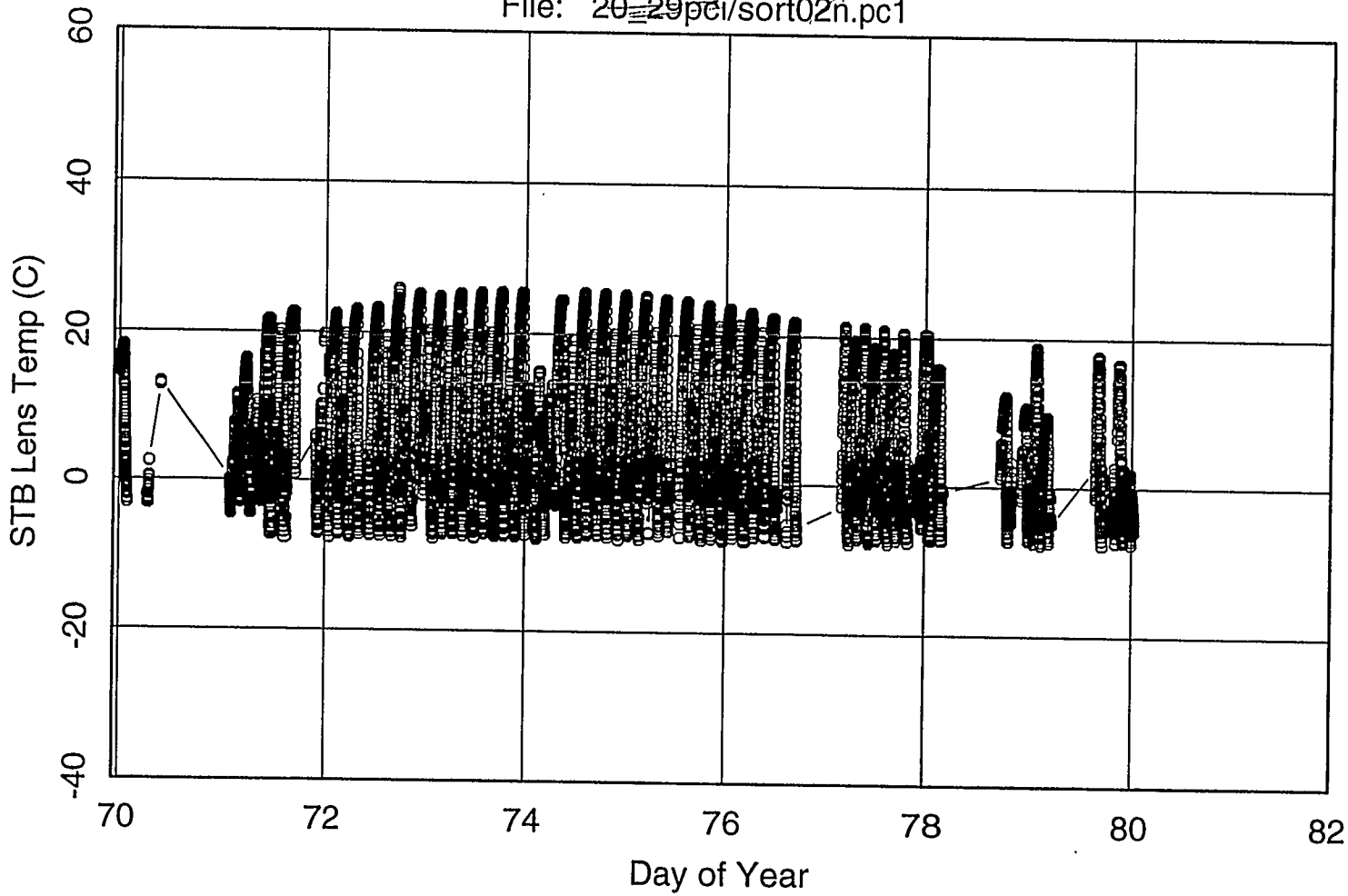
REP/LLNL created: Thu Apr 21 16:49:01 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 20_29pci/sort02n.pc1



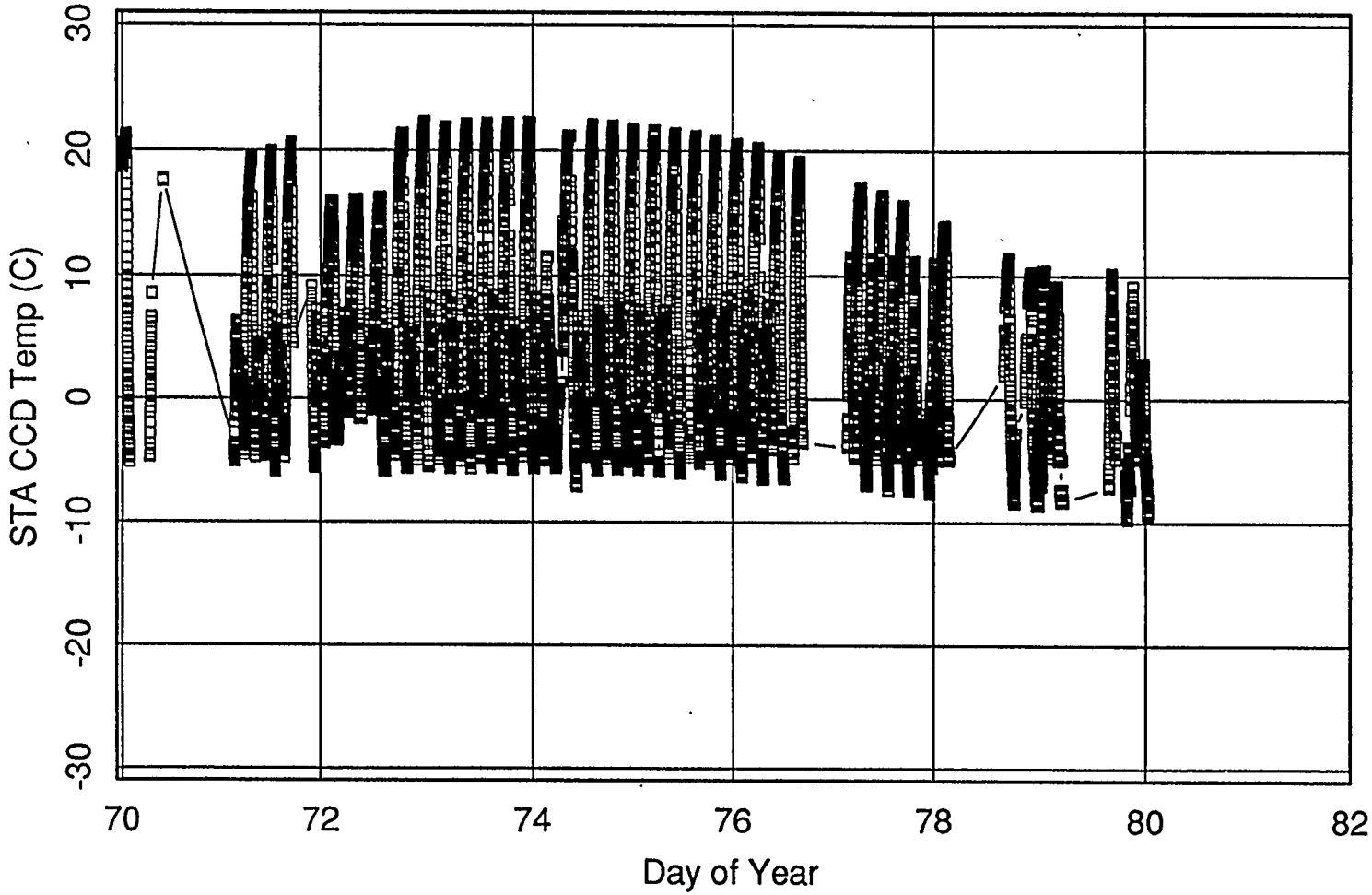
REP/LLNL created: Thu Apr 21 16:49:21 PDT 1994

Clementine

Star Tracker A CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



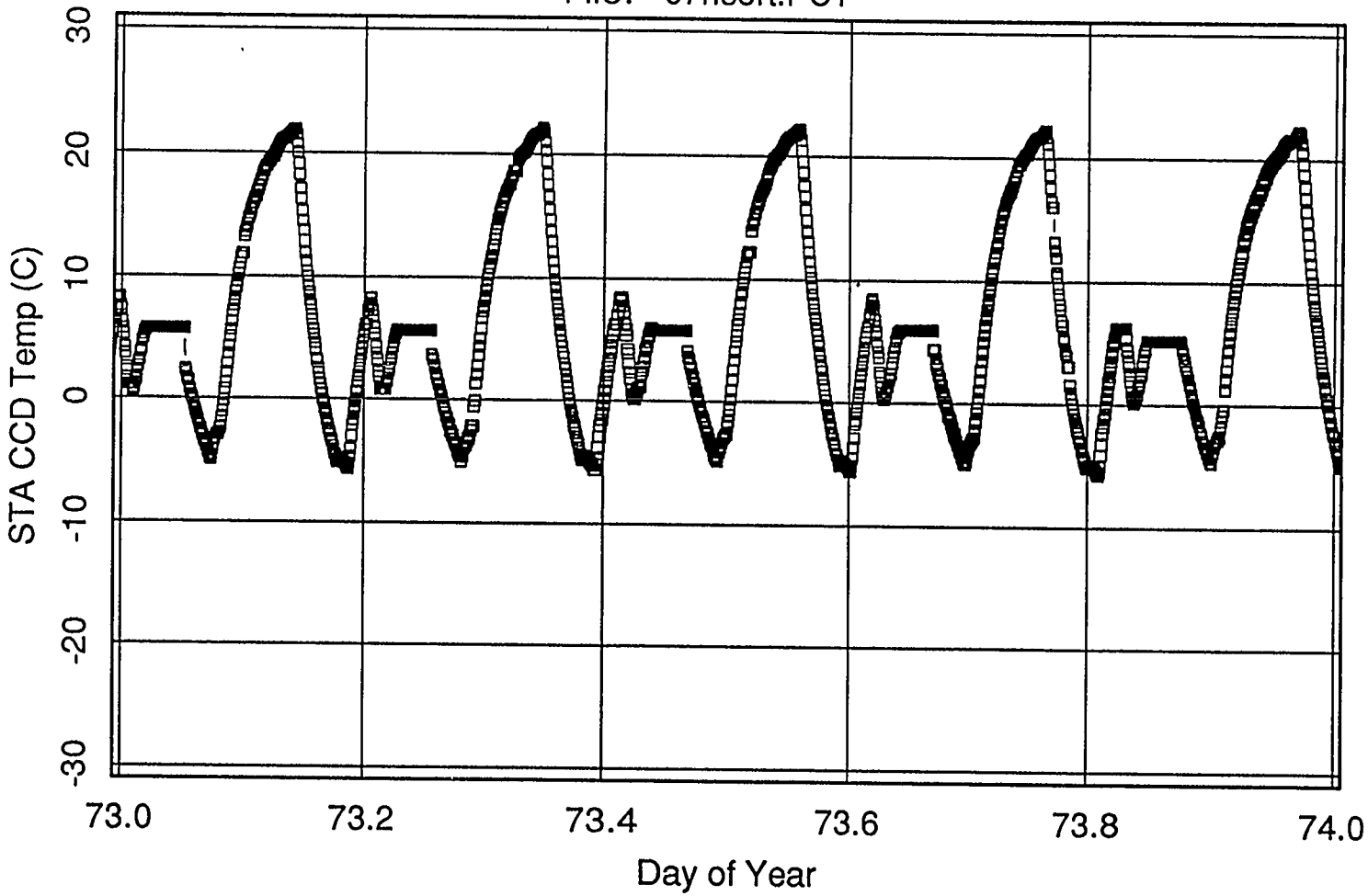
REP/LLNL created: Fri Mar 25 21:34:47 PST 1994

Clementine

Star Tracker A CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



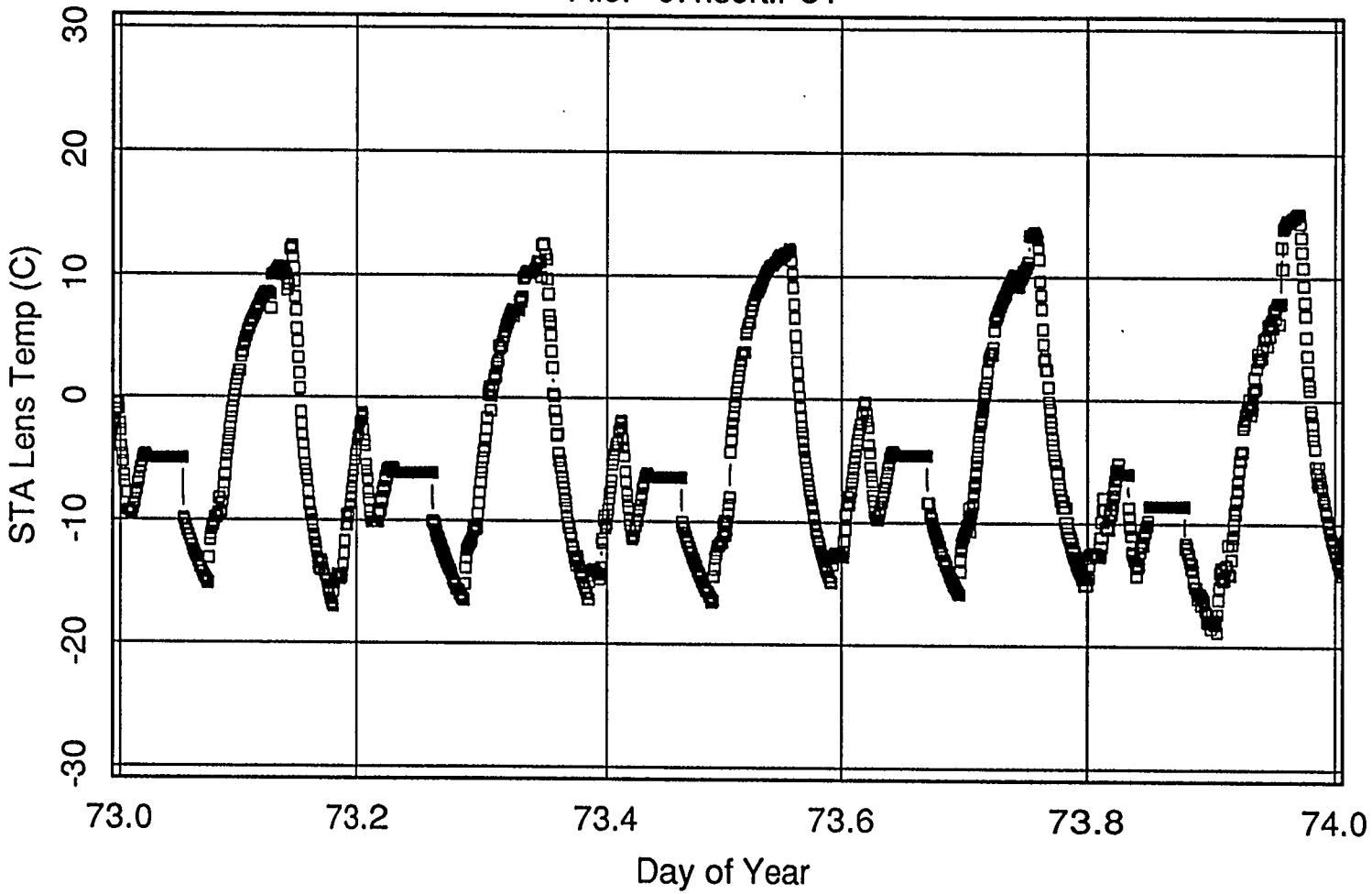
REP/LLNL created: Sat Mar 26 11:28:20 PST 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



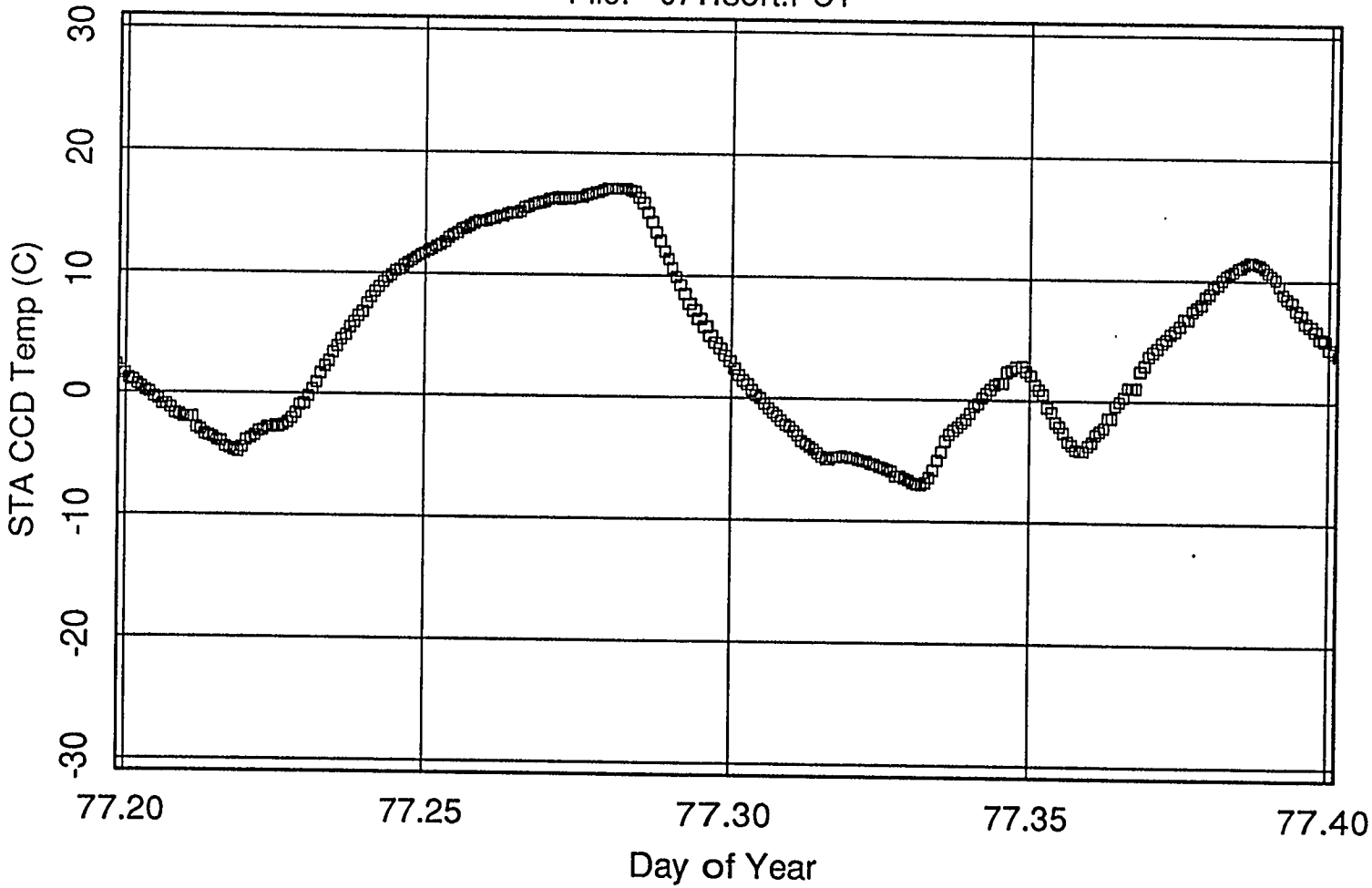
REP/LLNL created: Sat Mar 26 11:53:07 PST 1994

Clementine

Star Tracker A CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



REP/LLNL created: Sat Mar 26 11:39:23 PST 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

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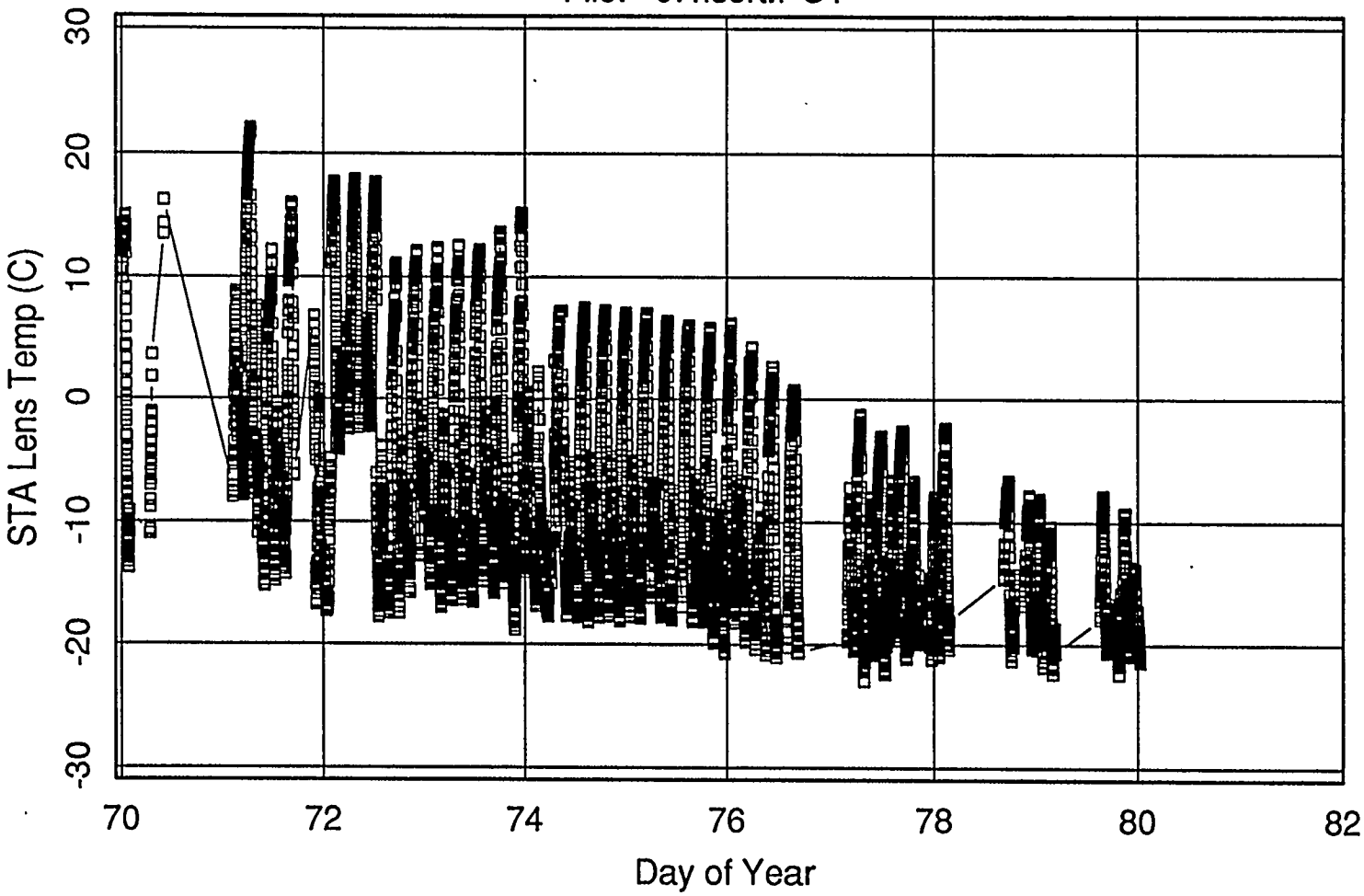


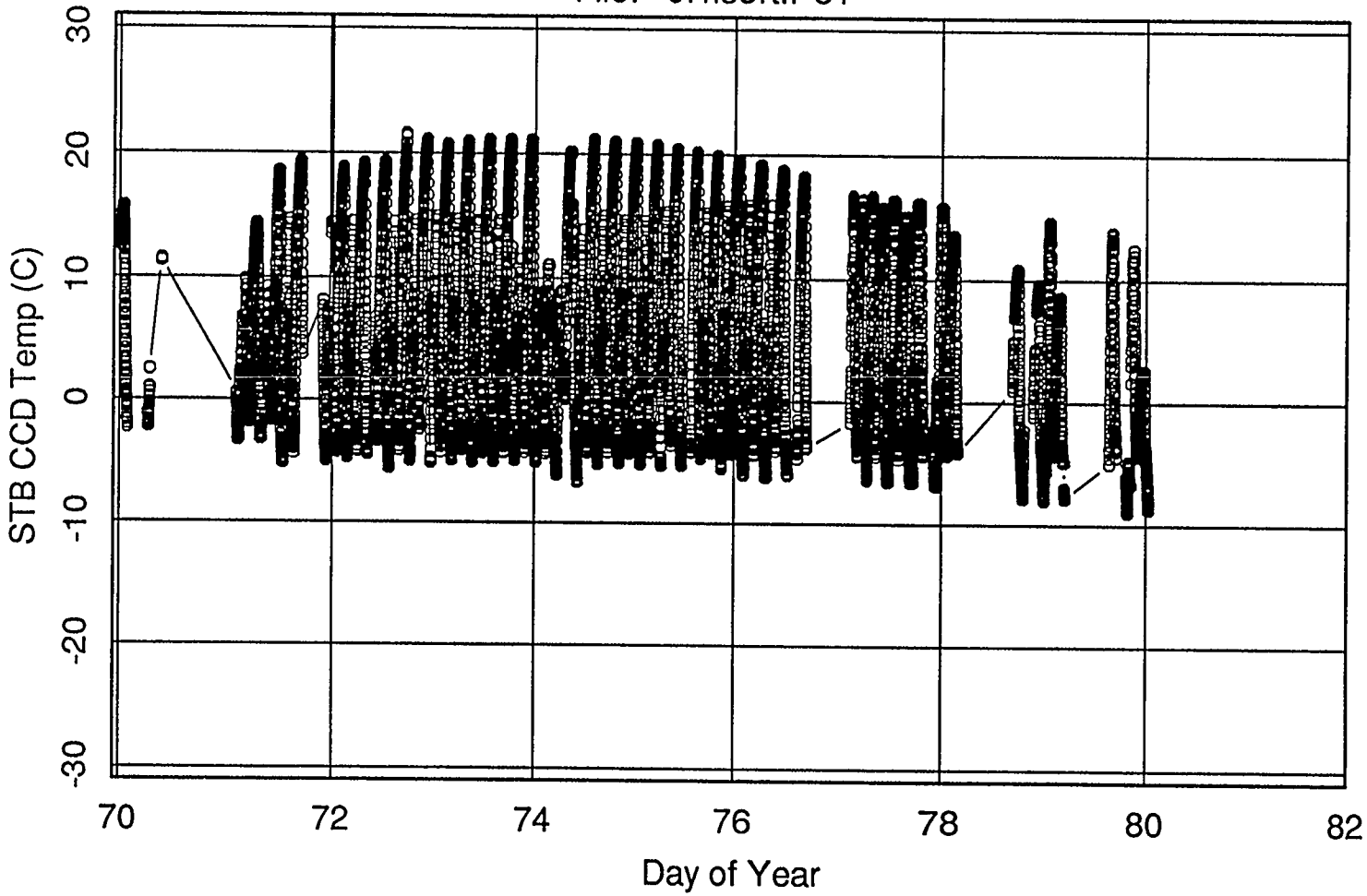
REP/LLNL created: Fri Mar 25 21:37:53 PST 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



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Clementine

Star Tracker B Lens Temperature

Start Time: 11-MAR-94 00:06:59.520 GMT

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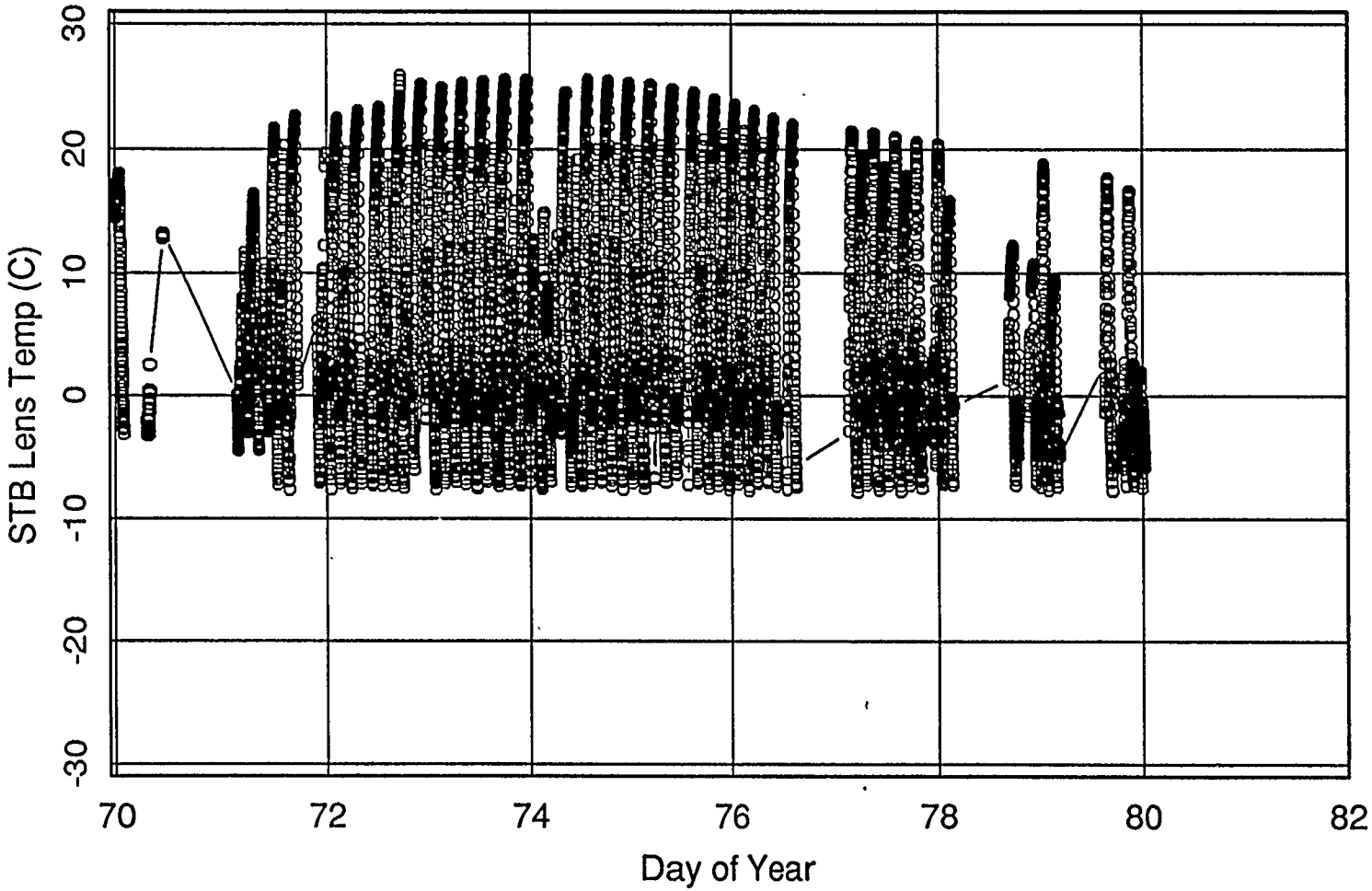


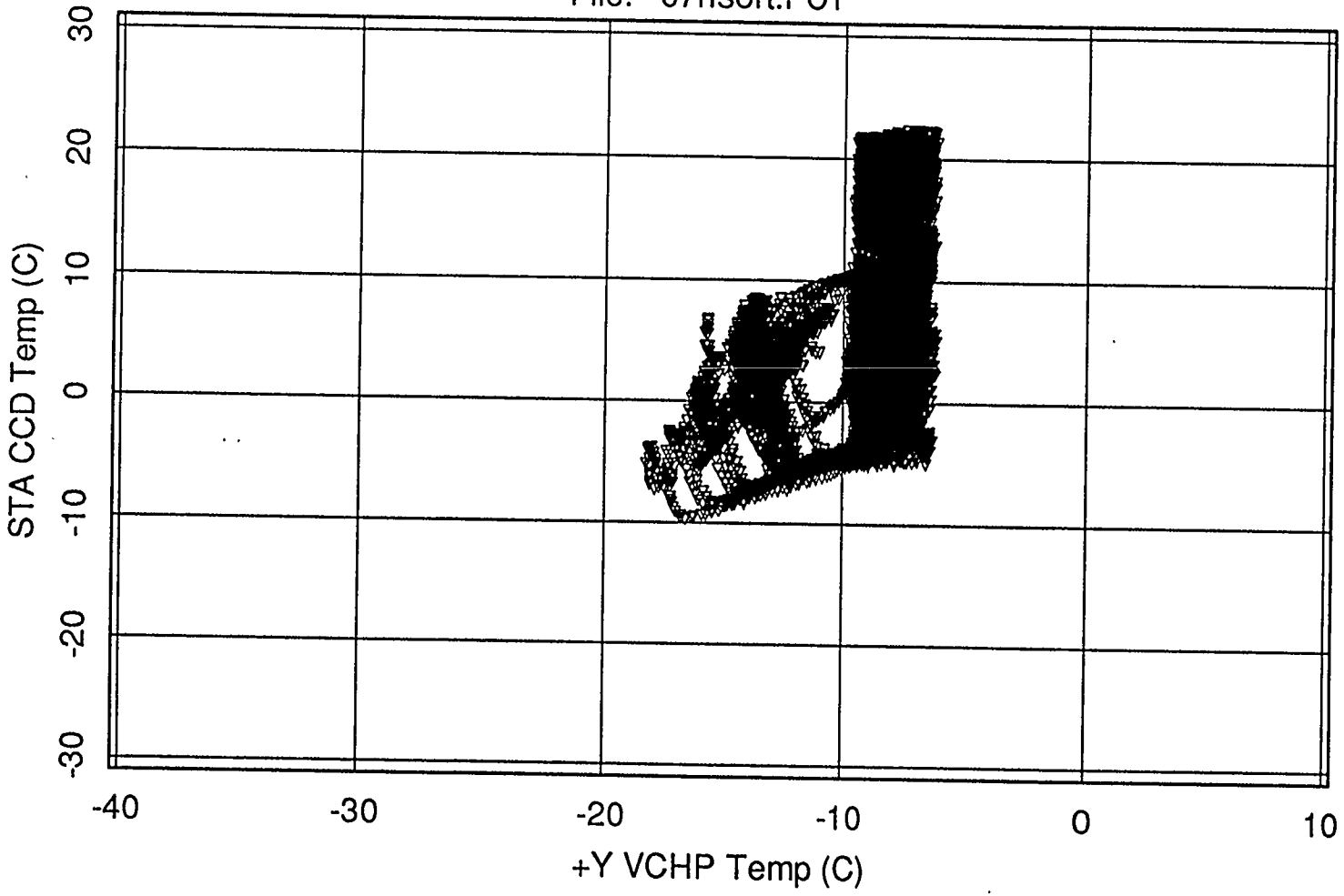
REP/LLNL created: Fri Mar 25 21:42:07 PST 1994

Clementine

Star Tracker A CCD vs +Y VCHP Temp

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



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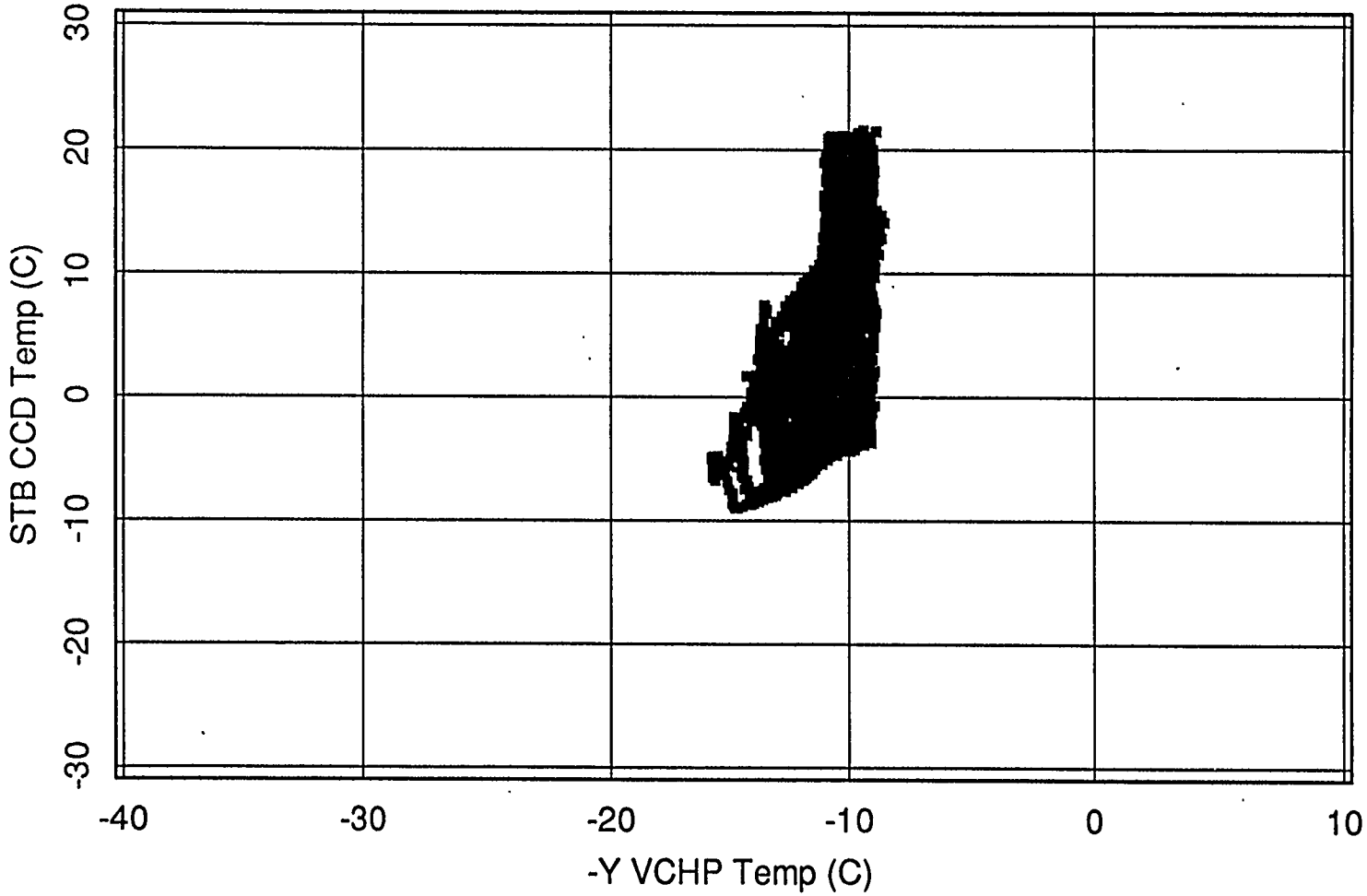
Clementine

Star Tracker B CCD vs -Y VCHP Temp

Start Time: 11-MAR-94 00:06:59.520 GMT

File: 07nsort.PC1



REP/LLNL created: Fri Mar 25 21:40:04 PST 1994

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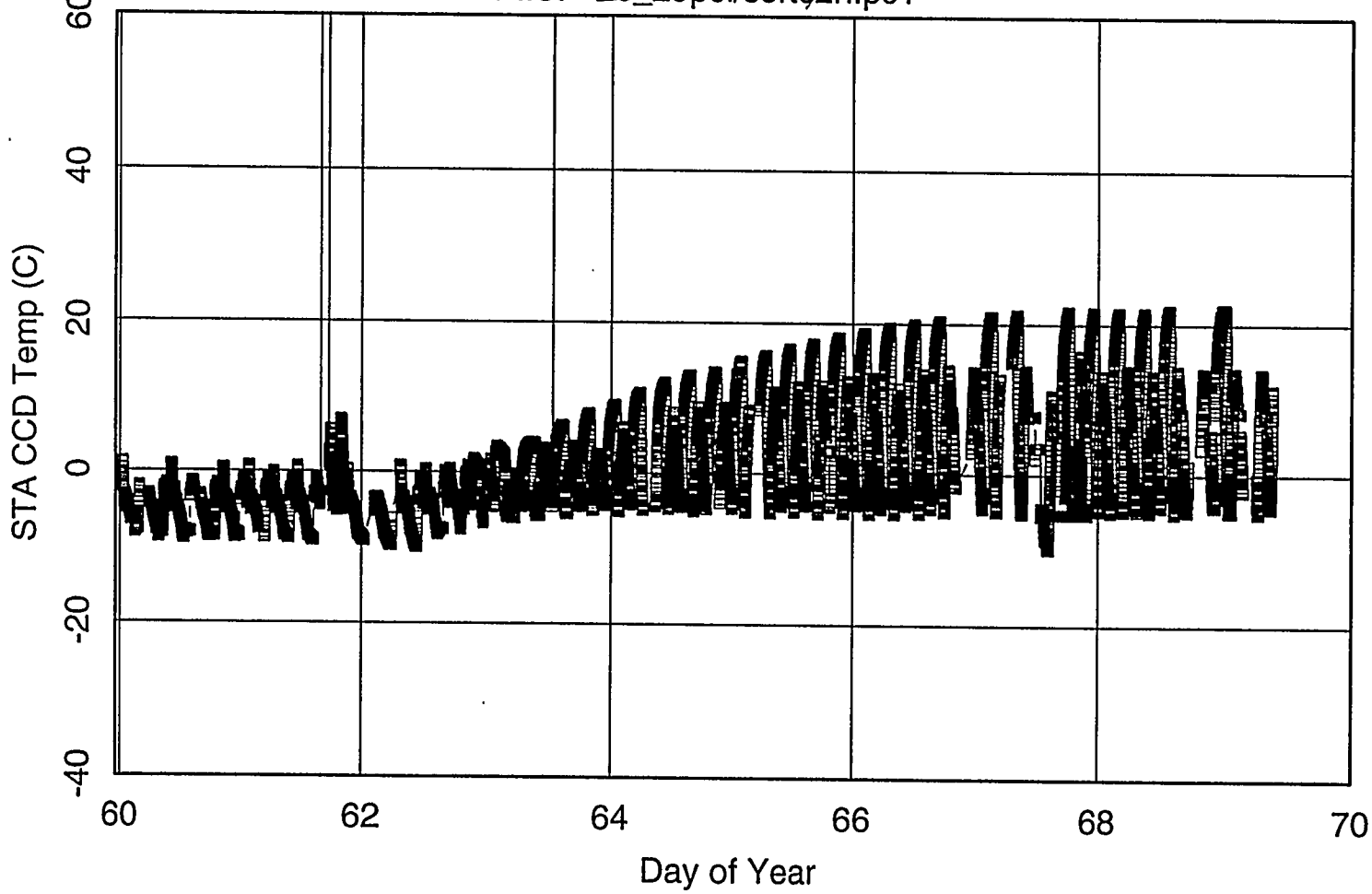
Clementine

Star Tracker A CCD Temperature

Start Time: 01-MAR-94 00:30:56.040 GMT

File: ~~20_29pcl~~/sort02n.pc1



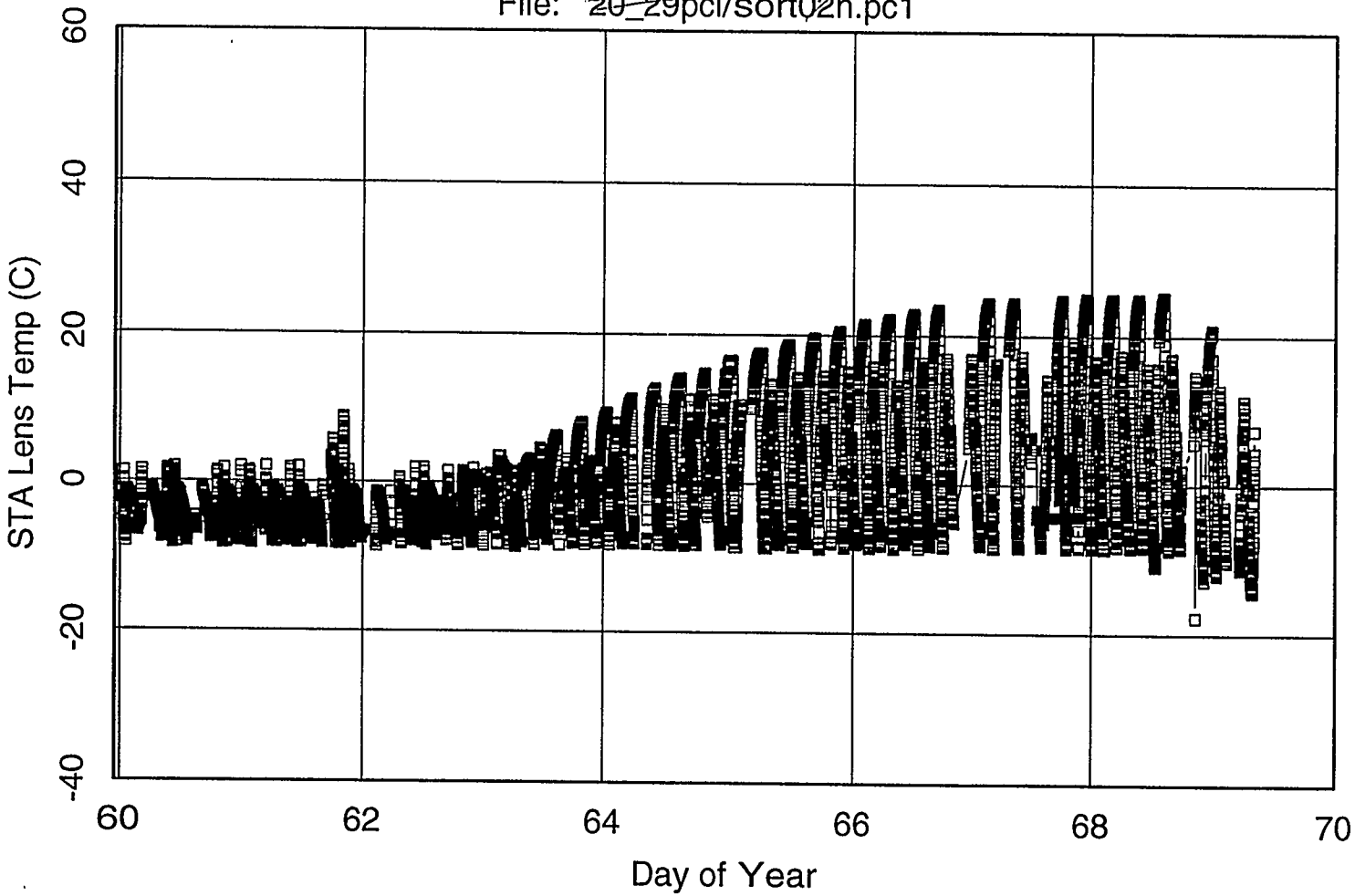
REP/LLNL created: Thu Apr 21 16:45:55 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 01-MAR-94 00:30:56.040 GMT

File: ~~20_29~~pci/sort02n.pc1



REP/LLNL created: Thu Apr 21 16:46:13 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 01-MAR-94 00:30:56.040 GMT

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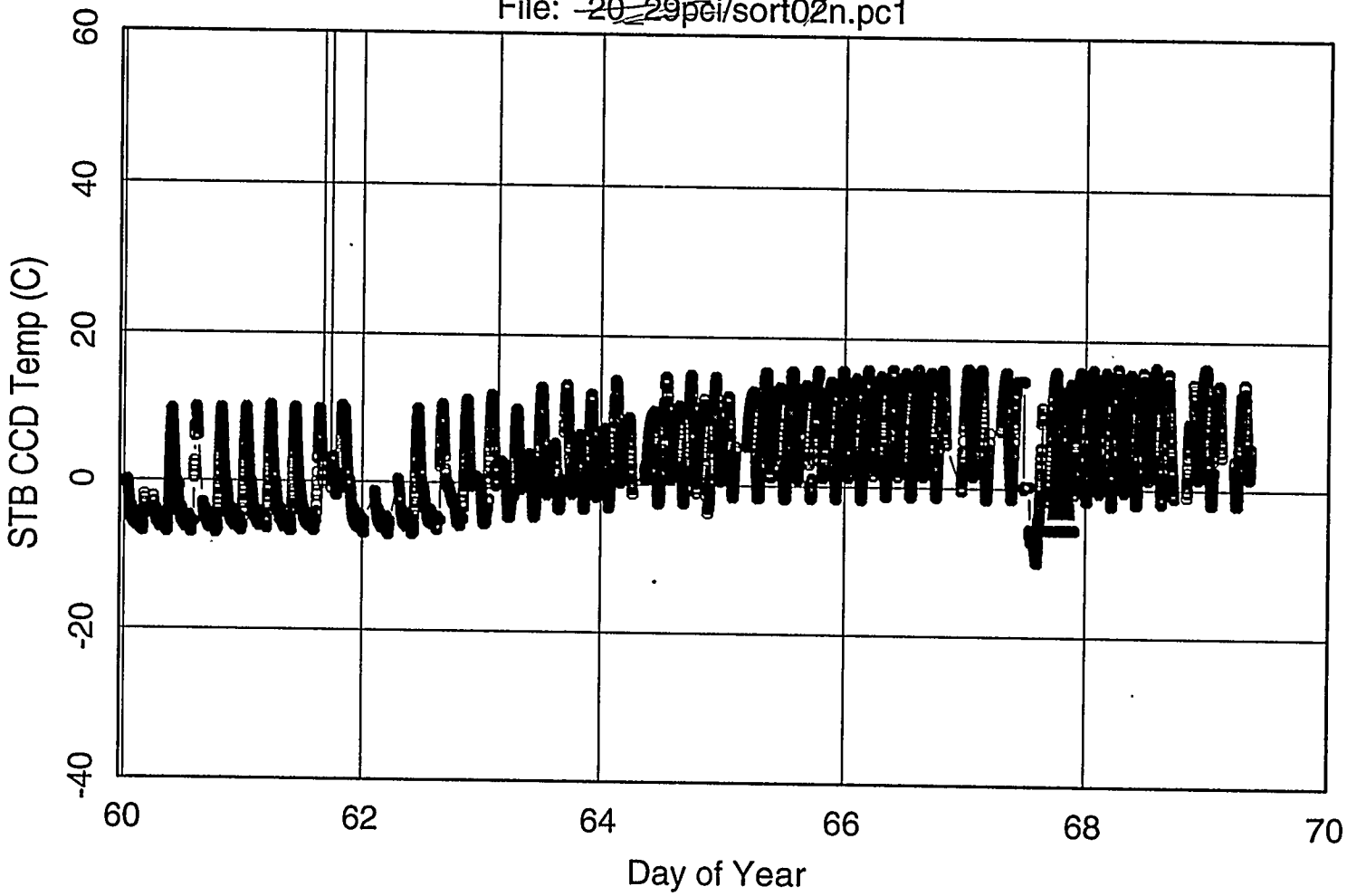


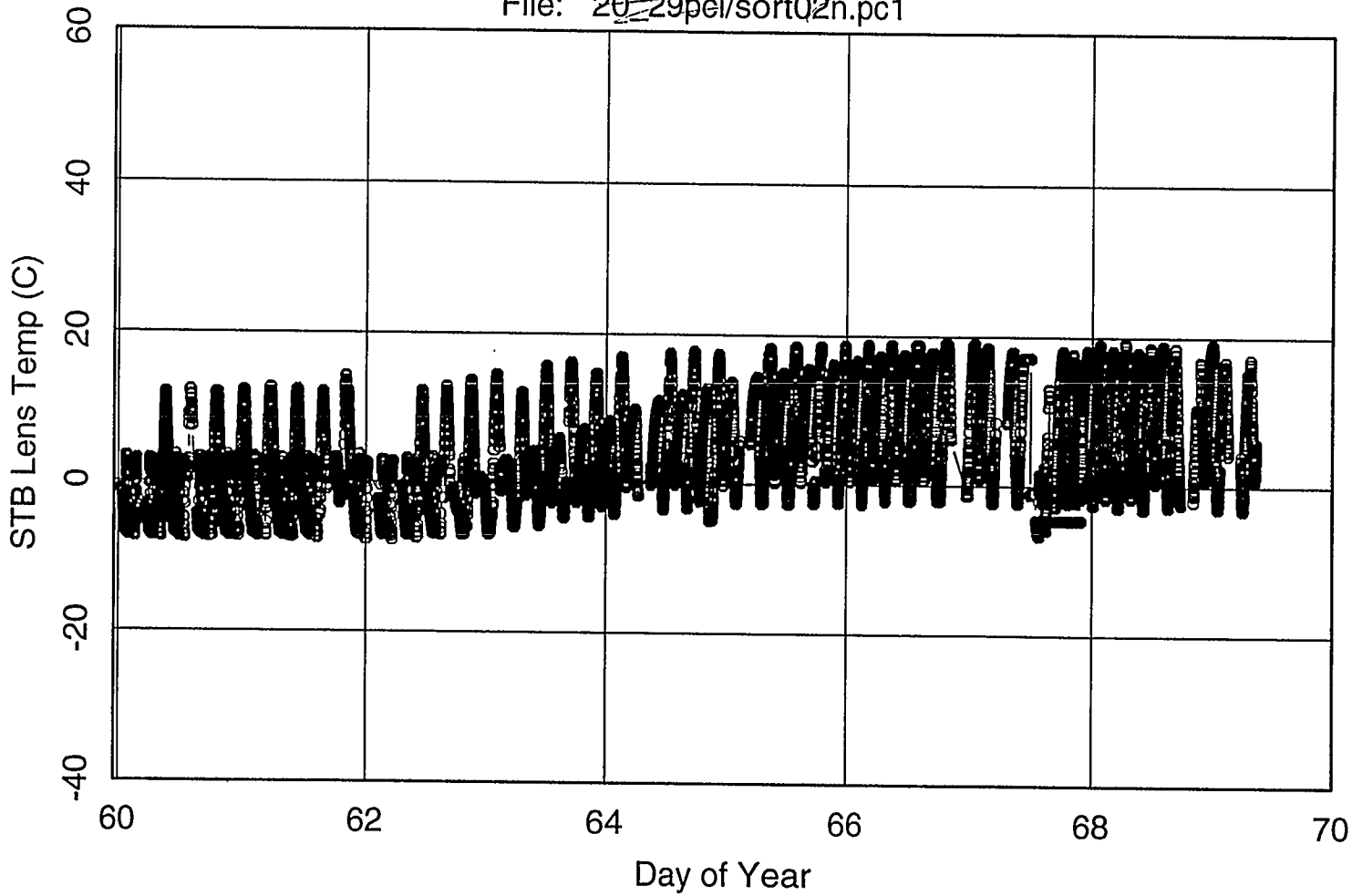
REP/LLNL created: Thu Apr 21 16:46:36 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 01-MAR-94 00:30:56.040 GMT

File: 20-29pei/sort02n.pc1



REP/LLNL created: Thu Apr 21 16:47:04 PDT 1994

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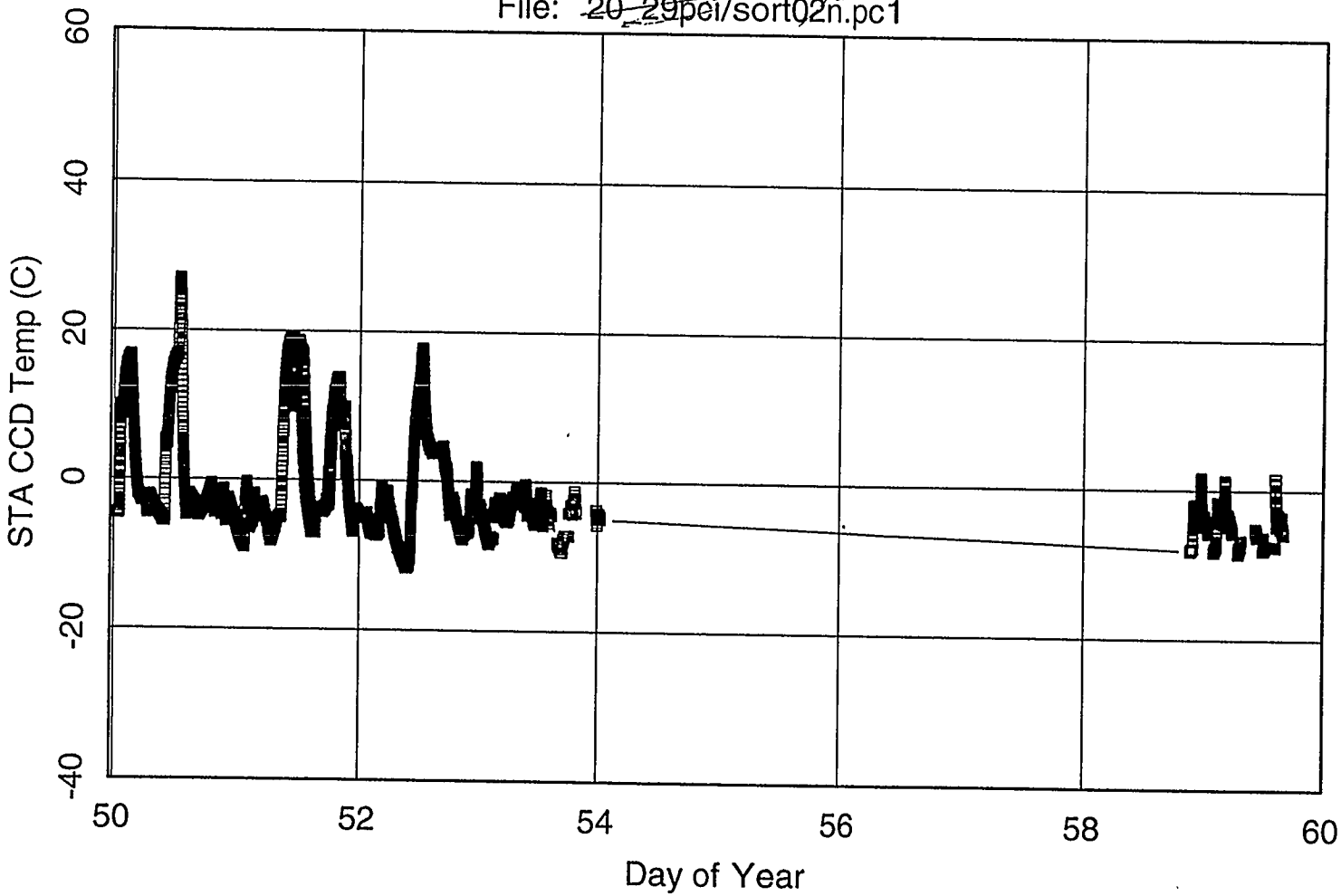
50 — 59

Clementine

Star Tracker A CCD Temperature

Start Time: 19-FEB-94 00:47:06.000 GMT

File: ~~20_29~~pei/sort02n.pc1



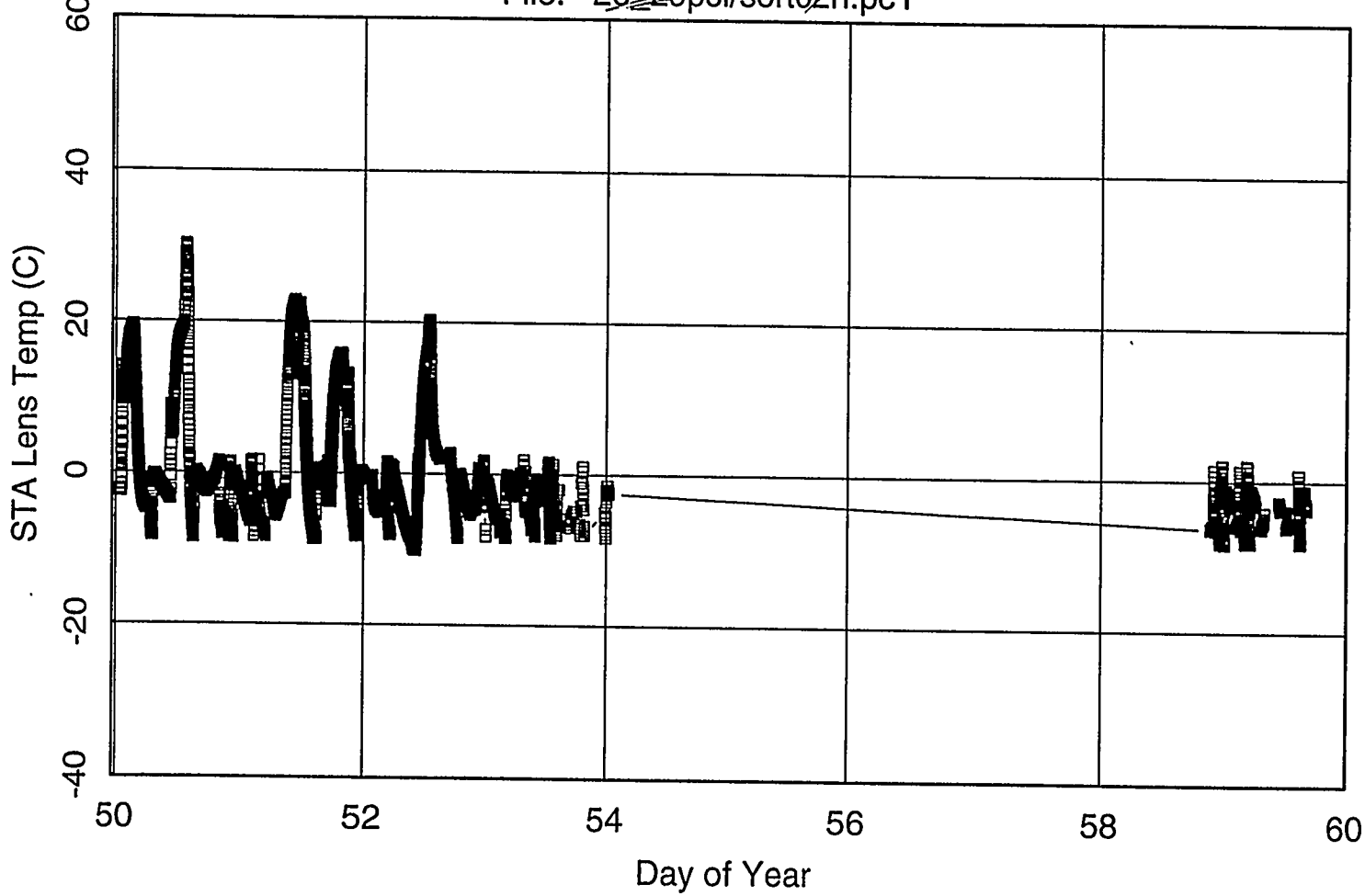
REP/LLNL created: Thu Apr 21 16:42:59 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 19-FEB-94 00:47:06.000 GMT

File: ~~20_29pci~~/sort02n.pc1



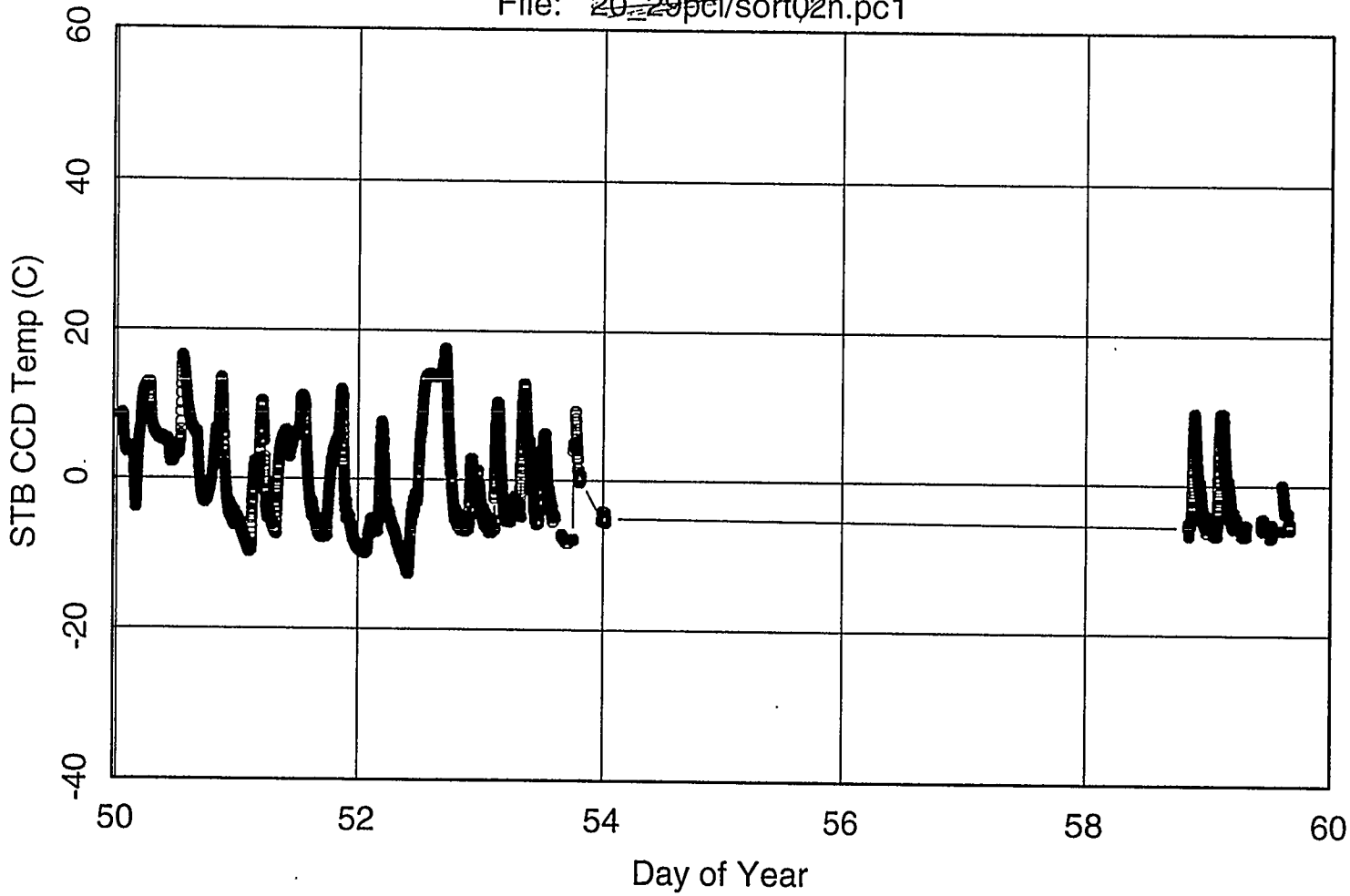
REP/LLNL created: Thu Apr 21 16:43:10 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 19-FEB-94 00:47:06.000 GMT

File: ~~20_29~~pci/sort02n.pc1



REP/LLNL created: Thu Apr 21 16:43:26 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 19-FEB-94 00:47:06.000 GMT

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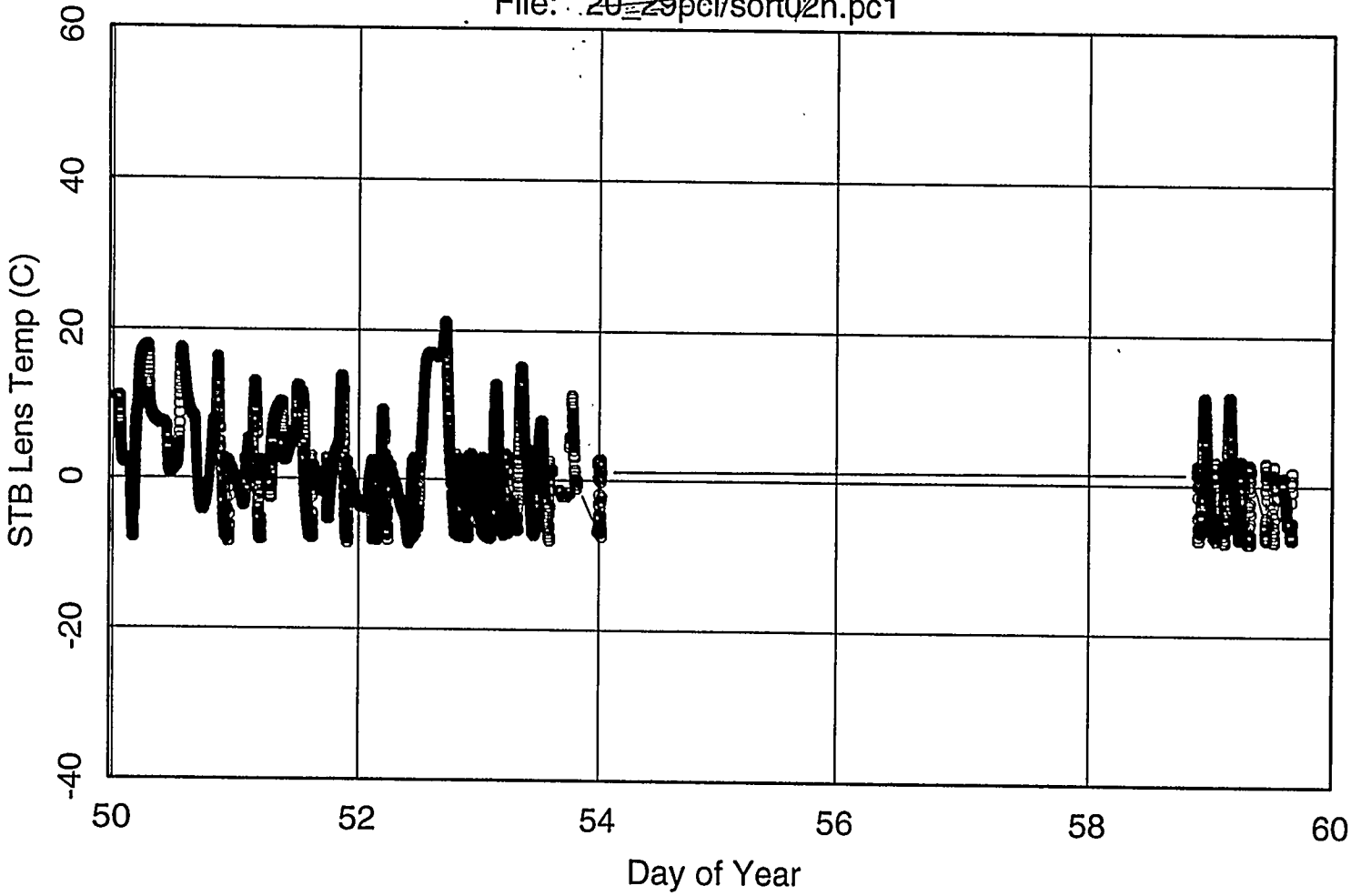


REP/LLNL created: Thu Apr 21 16:43:59 PDT 1994

S-16

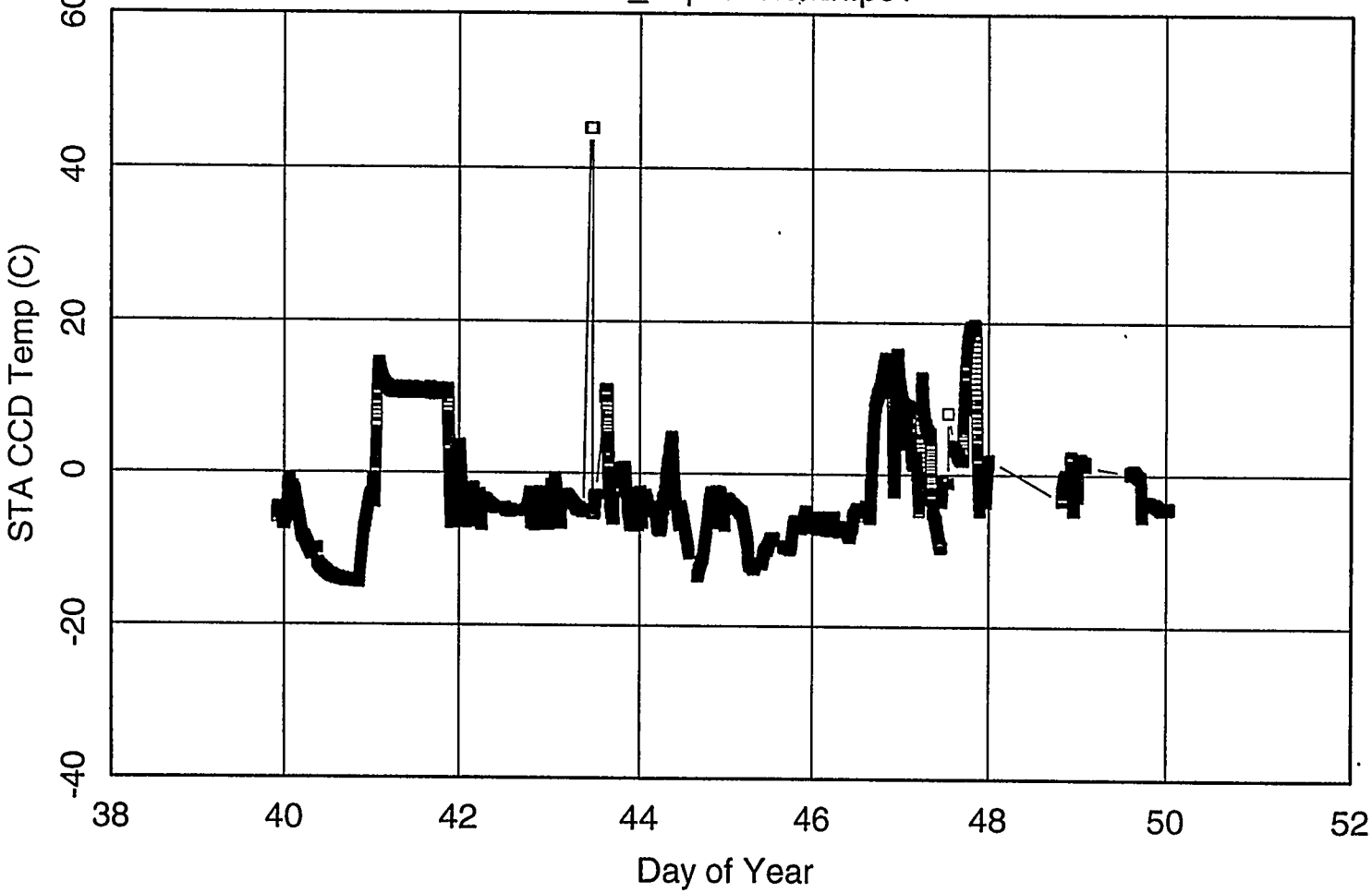
40 — 49

Clementine

Star Tracker A CCD Temperature

Start Time: 08-FEB-94 22:04:52.760 GMT

File: ~~20-29~~pci/sort02n.pc1



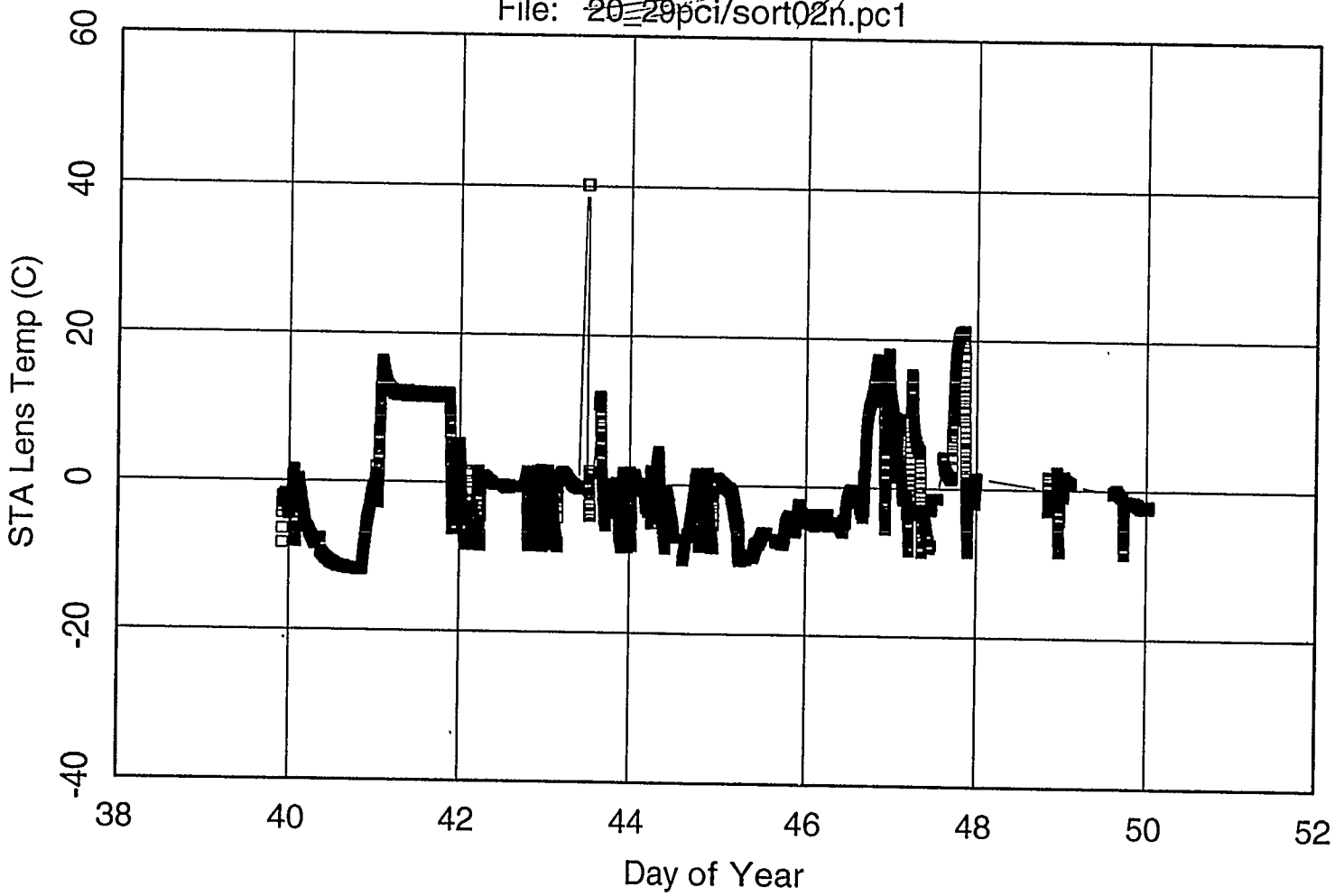
REP/LLNL created: Thu Apr 21 16:38:42 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 08-FEB-94 22:04:52.760 GMT

File: ~~20_29~~pci/sort02n.pc1



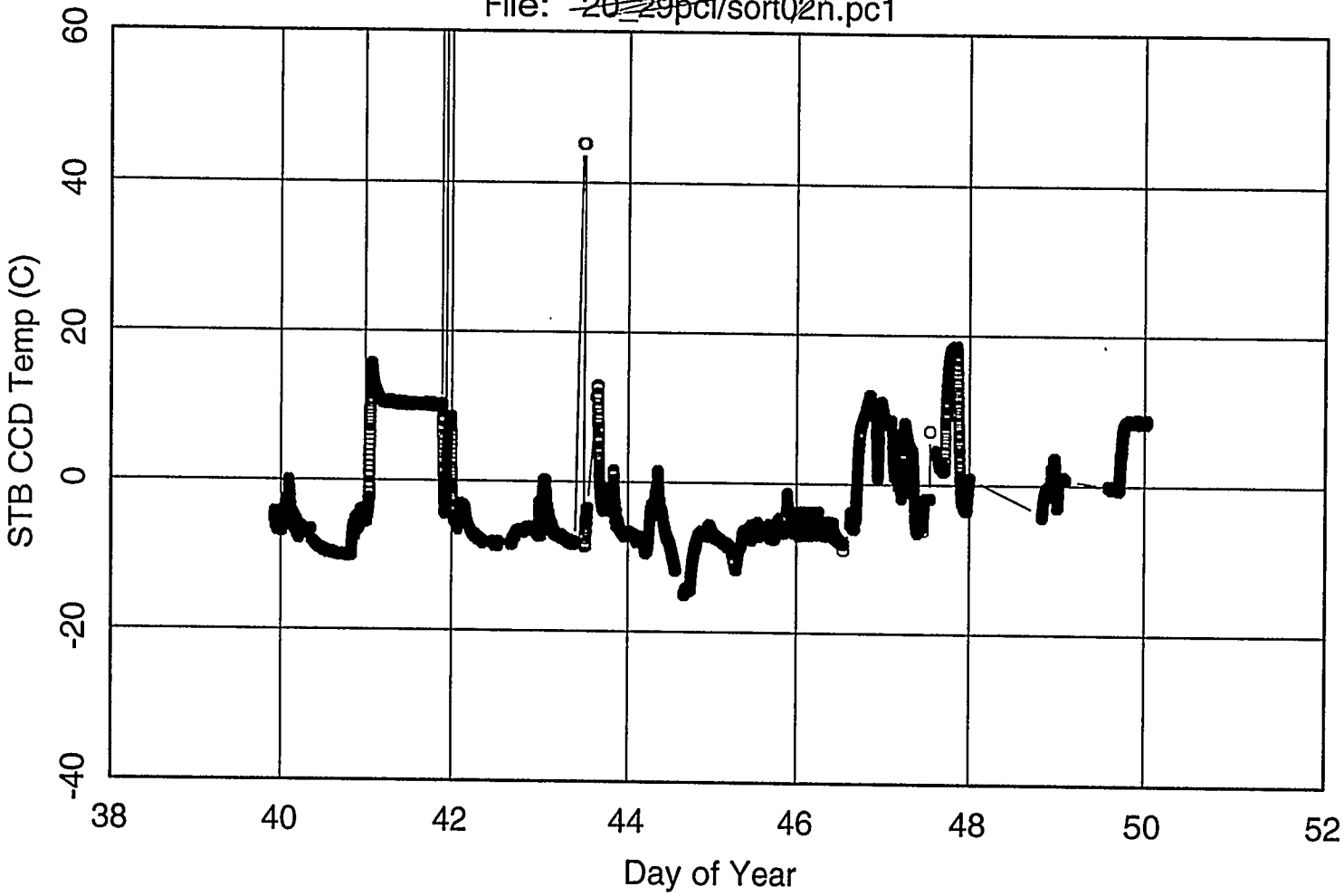
REP/LLNL created: Thu Apr 21 16:39:01 PDT 1994

Clementine

Star Tracker B CCD Temperature

Start Time: 08-FEB-94 22:04:52.760 GMT

File: ~~20_29pci~~/sort02n.pc1



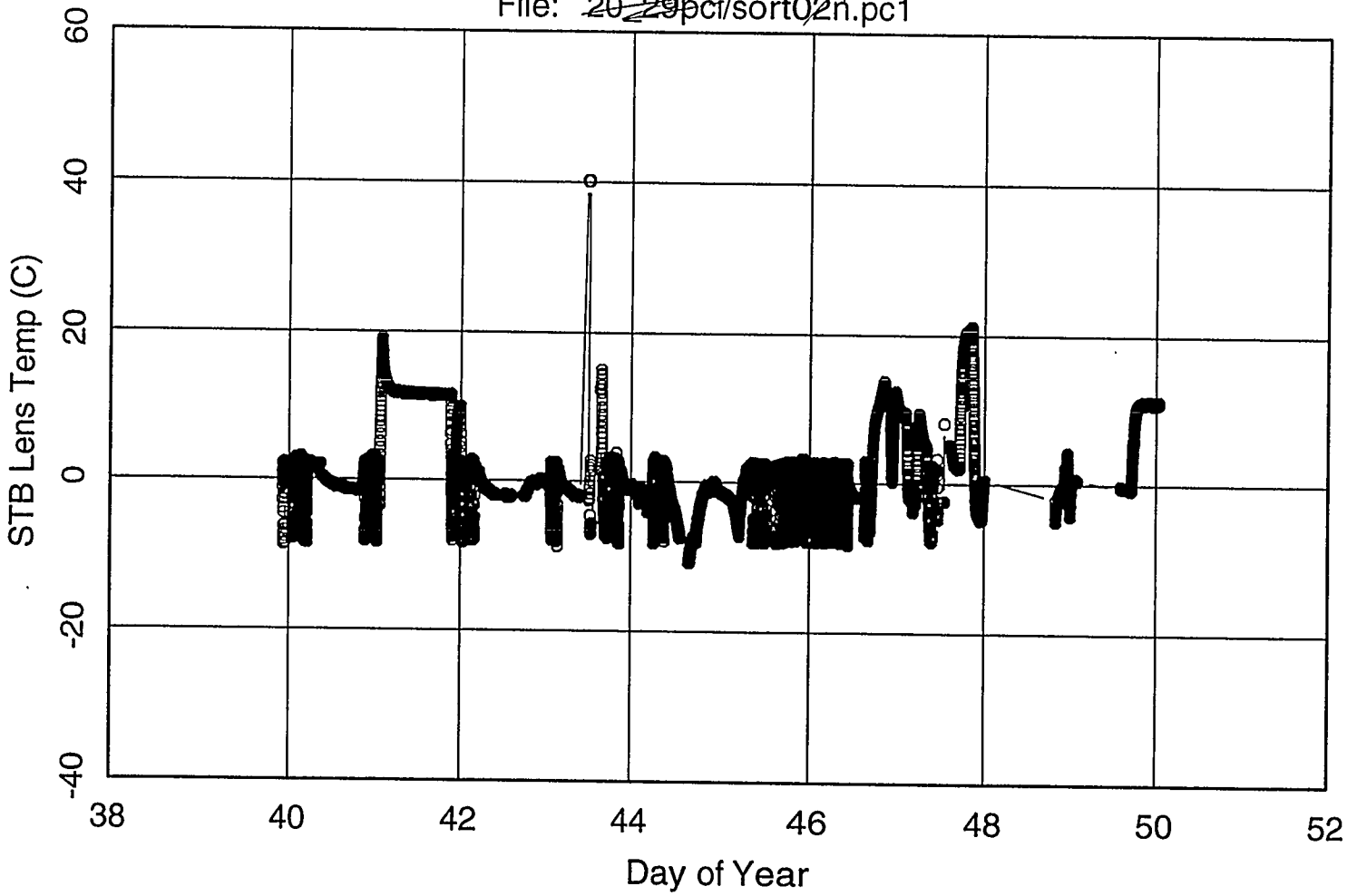
REP/LLNL created: Thu Apr 21 16:39:29 PDT 1994

Clementine

Star Tracker B Lens Temperature

Start Time: 08-FEB-94 22:04:52.760 GMT

File: ~~20_29~~pci/sort02n.pc1



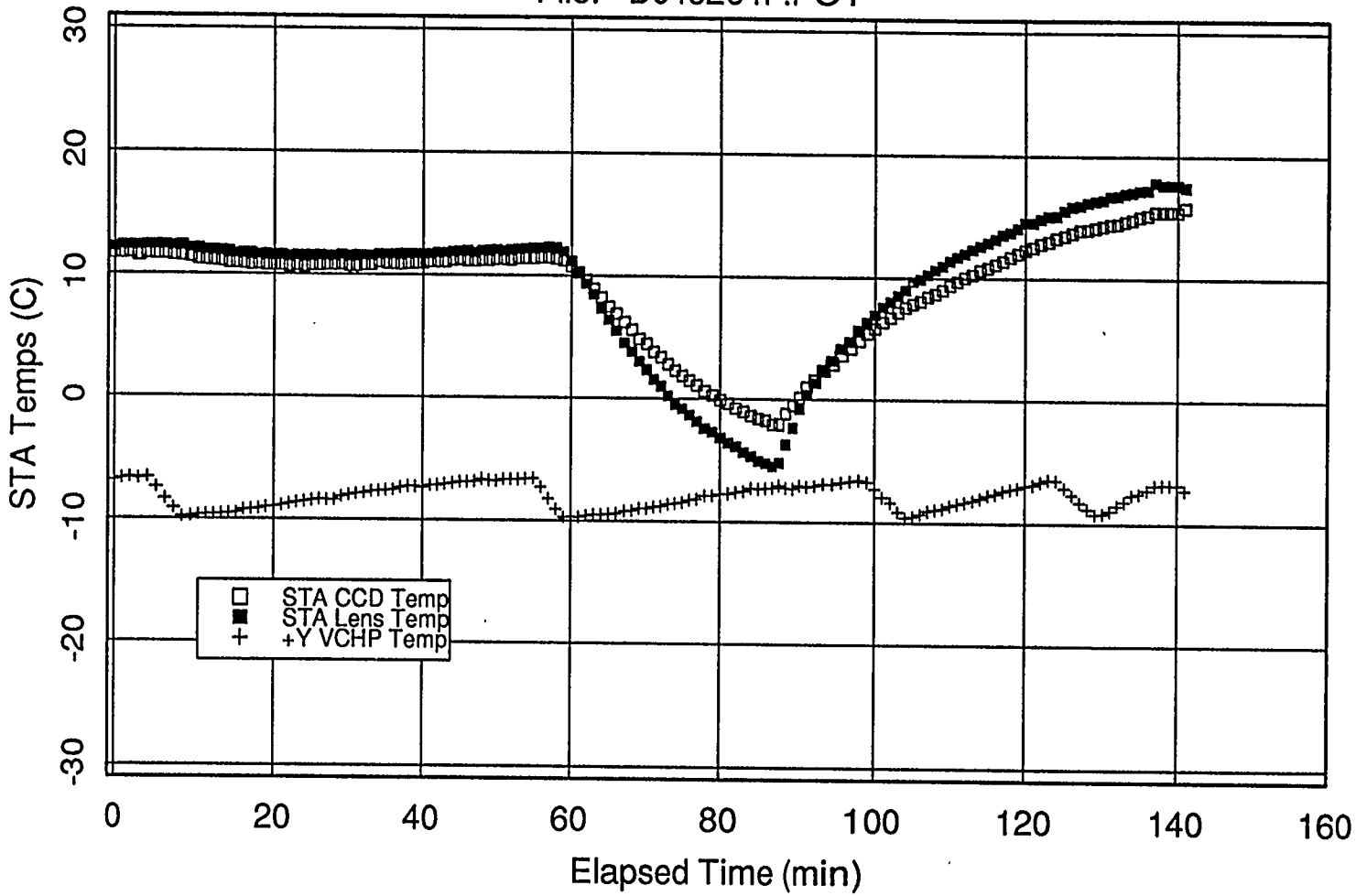
REP/LLNL created: Thu Apr 21 16:40:56 PDT 1994

Clementine

Star Tracker A - Temperatures

Start Time: 15-FEB-94 20:41:52.380 GMT

File: D046204P.PC1



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S-16

30 — 39

Clementine

Star Tracker A CCD Temperature

Start Time: 30-JAN-94 00:31:58.060 GMT

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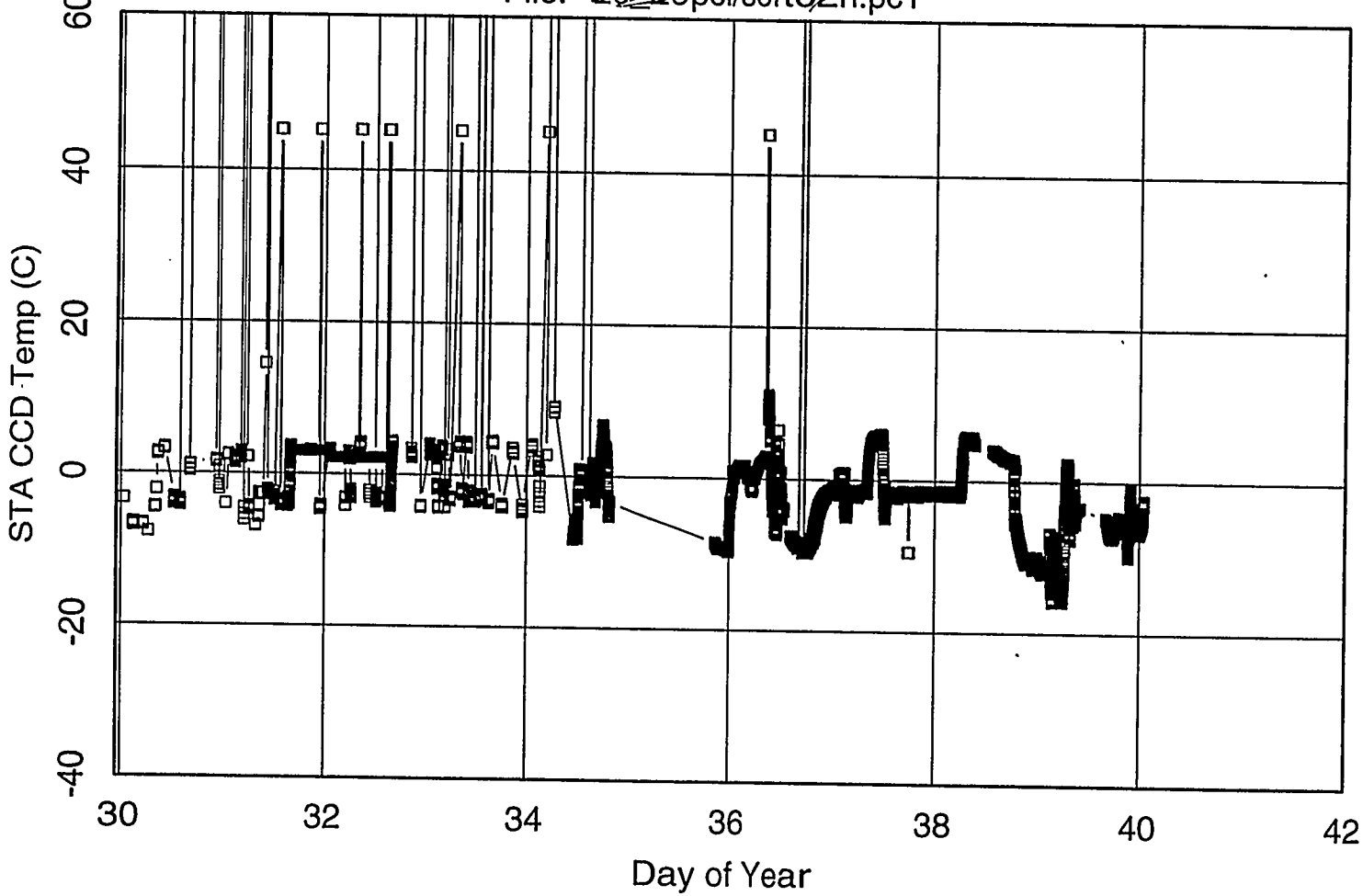


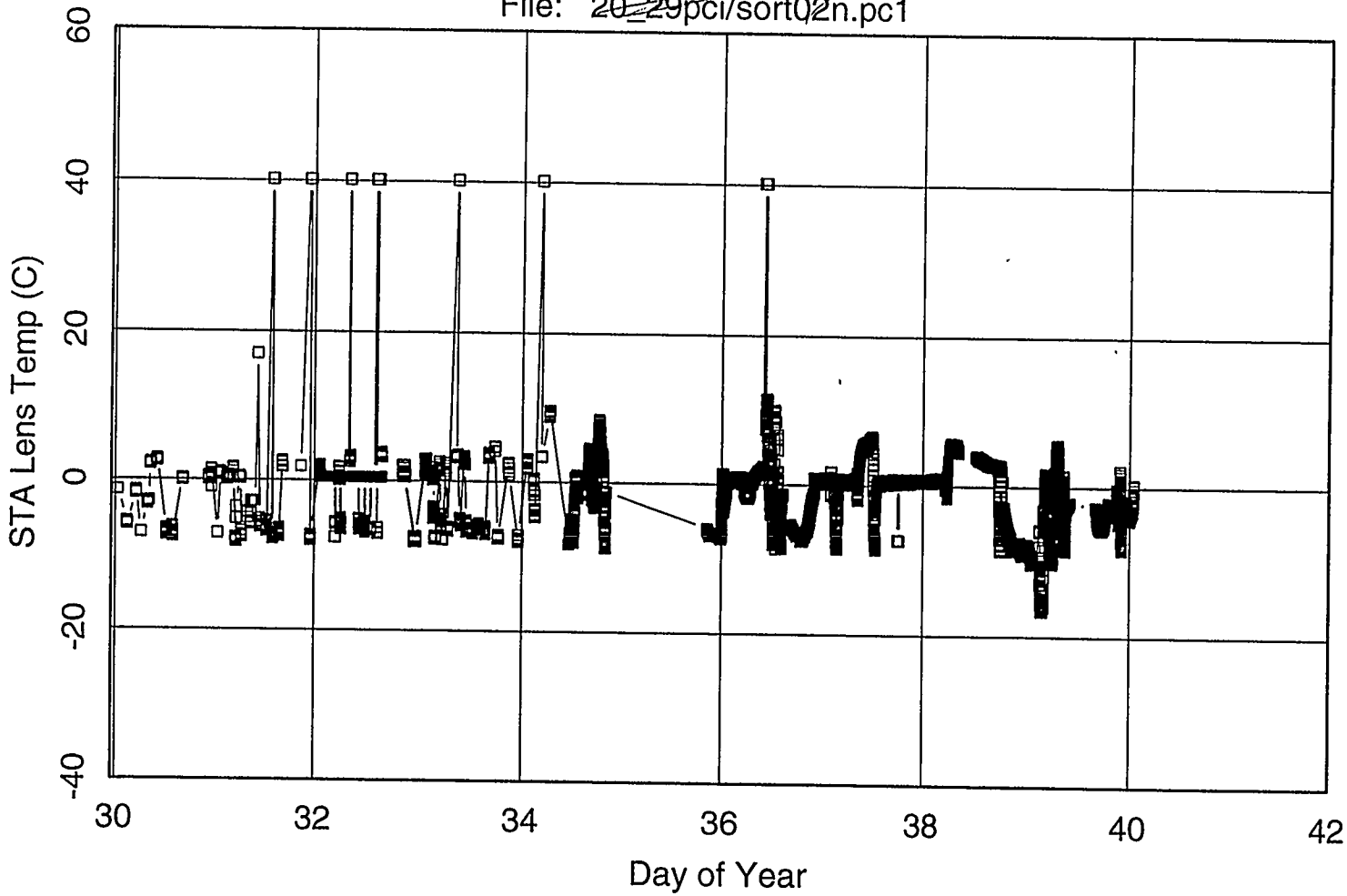
REP/LLNL created: Thu Apr 21 16:34:41 PDT 1994

Clementine

Star Tracker A Lens Temperature

Start Time: 30-JAN-94 00:31:58.060 GMT

File: ~~20-29~~pci/sort02n.pc1



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Clementine

Star Tracker B CCD Temperature

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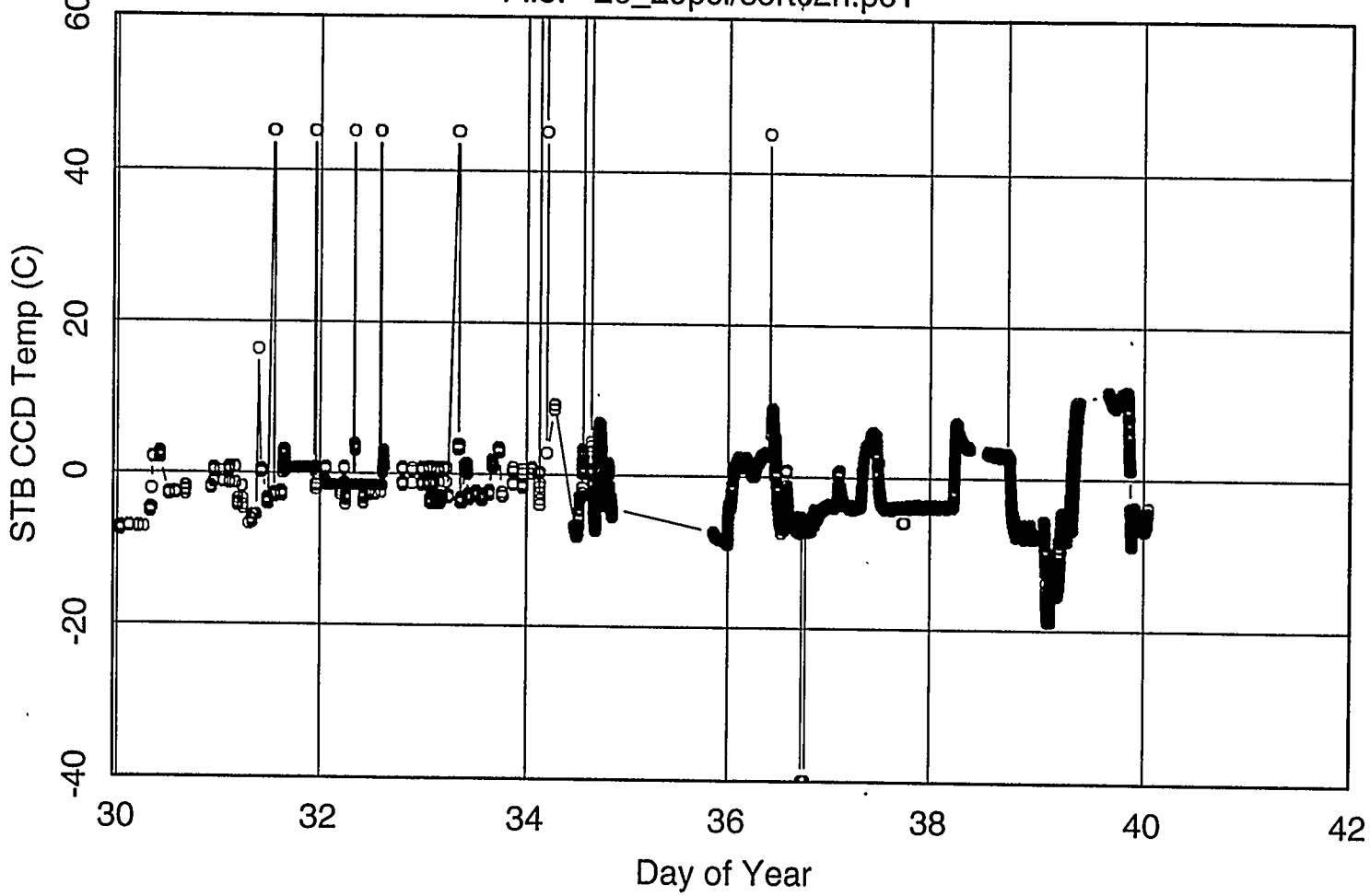

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Clementine

Star Tracker B Lens Temperature

Start Time: 30-JAN-94 00:31:58.060 GMT

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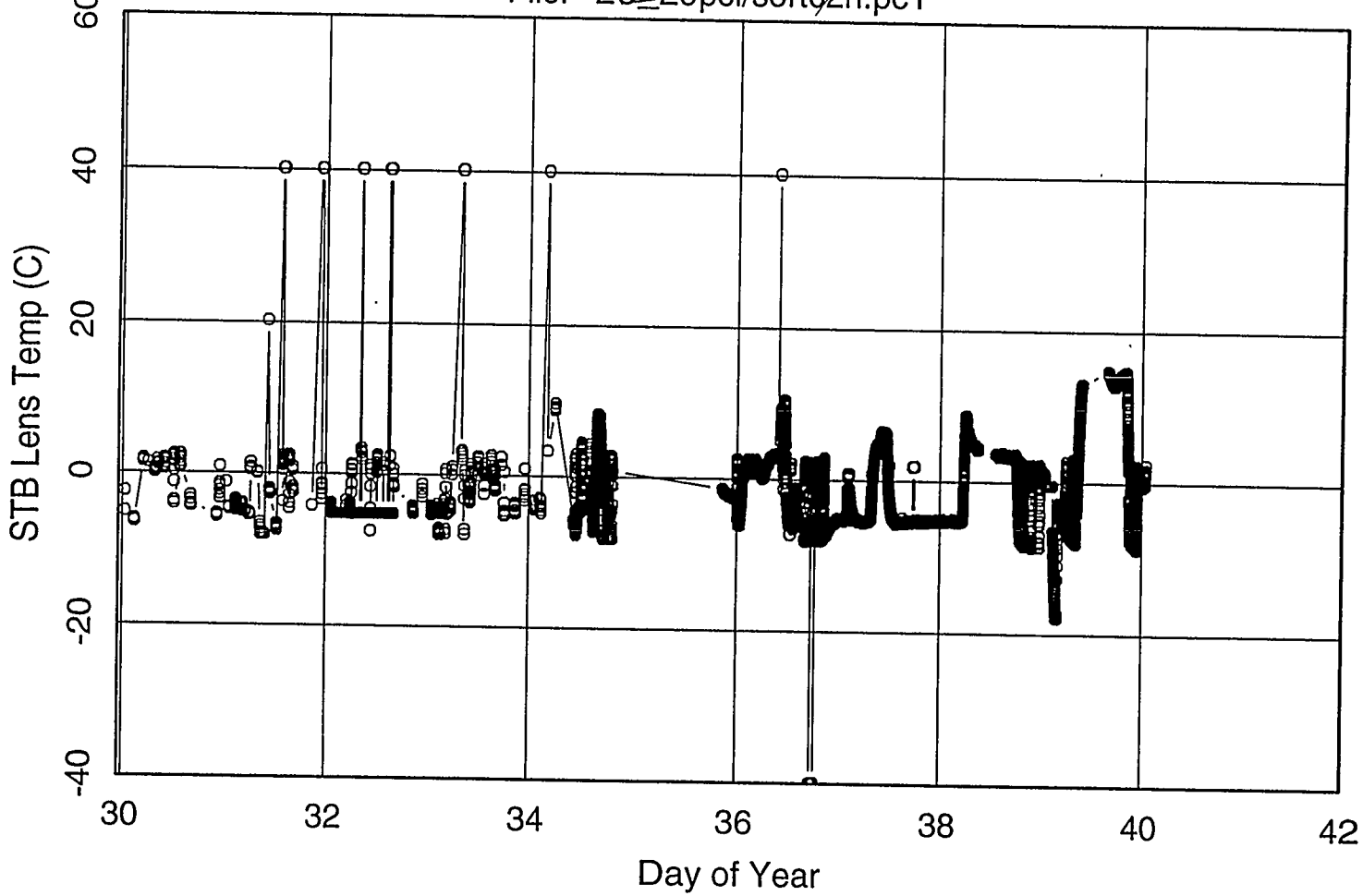

REP/LLNL created: Thu Apr 21 16:35:54 PDT 1994

S-16

20 — 29

Clementine

Star Tracker A CCD Temperature

Start Time: 24-JAN-94 06:20:47.970 GMT

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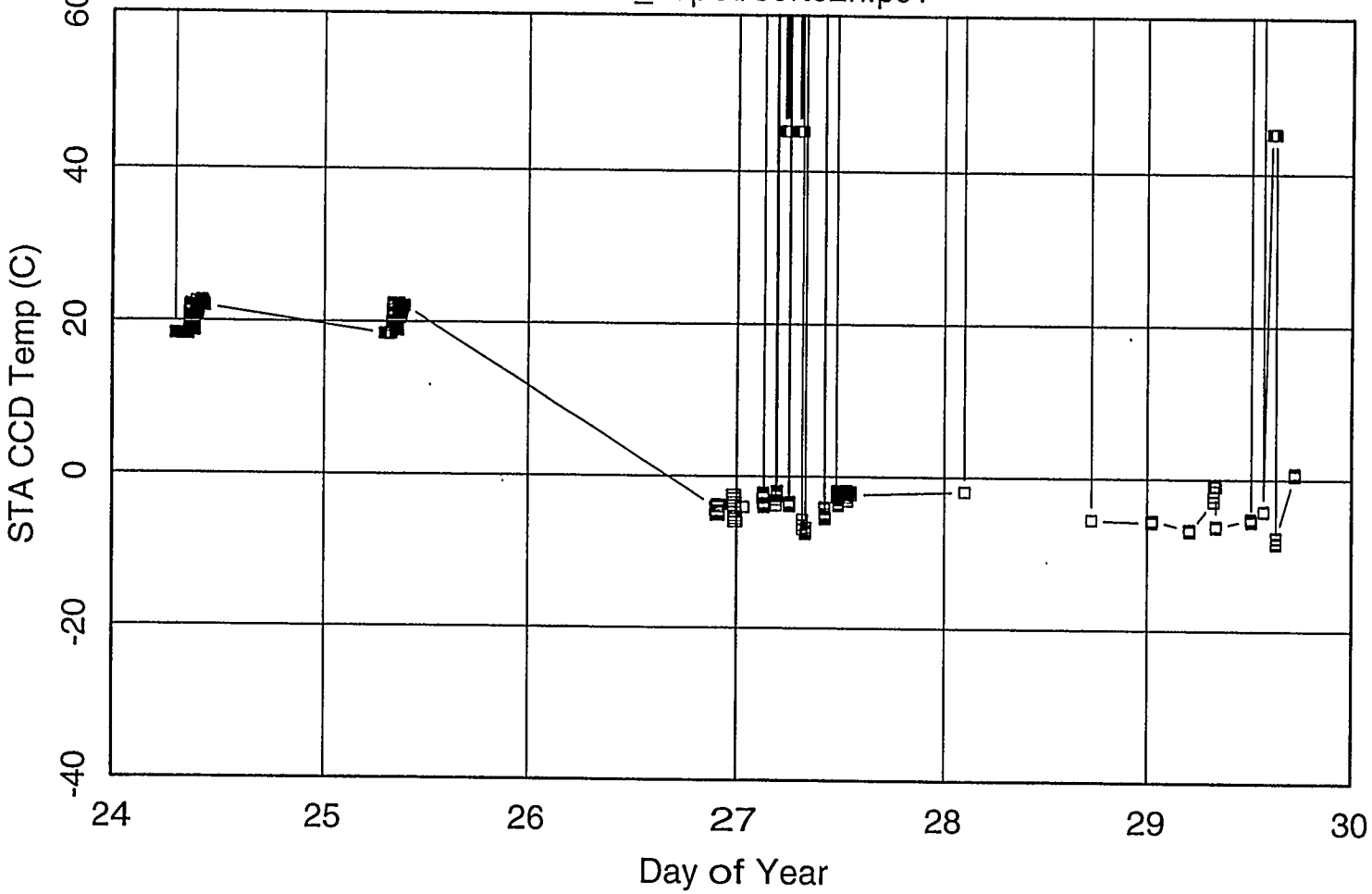

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Clementine

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Start Time: 24-JAN-94 06:20:47.970 GMT

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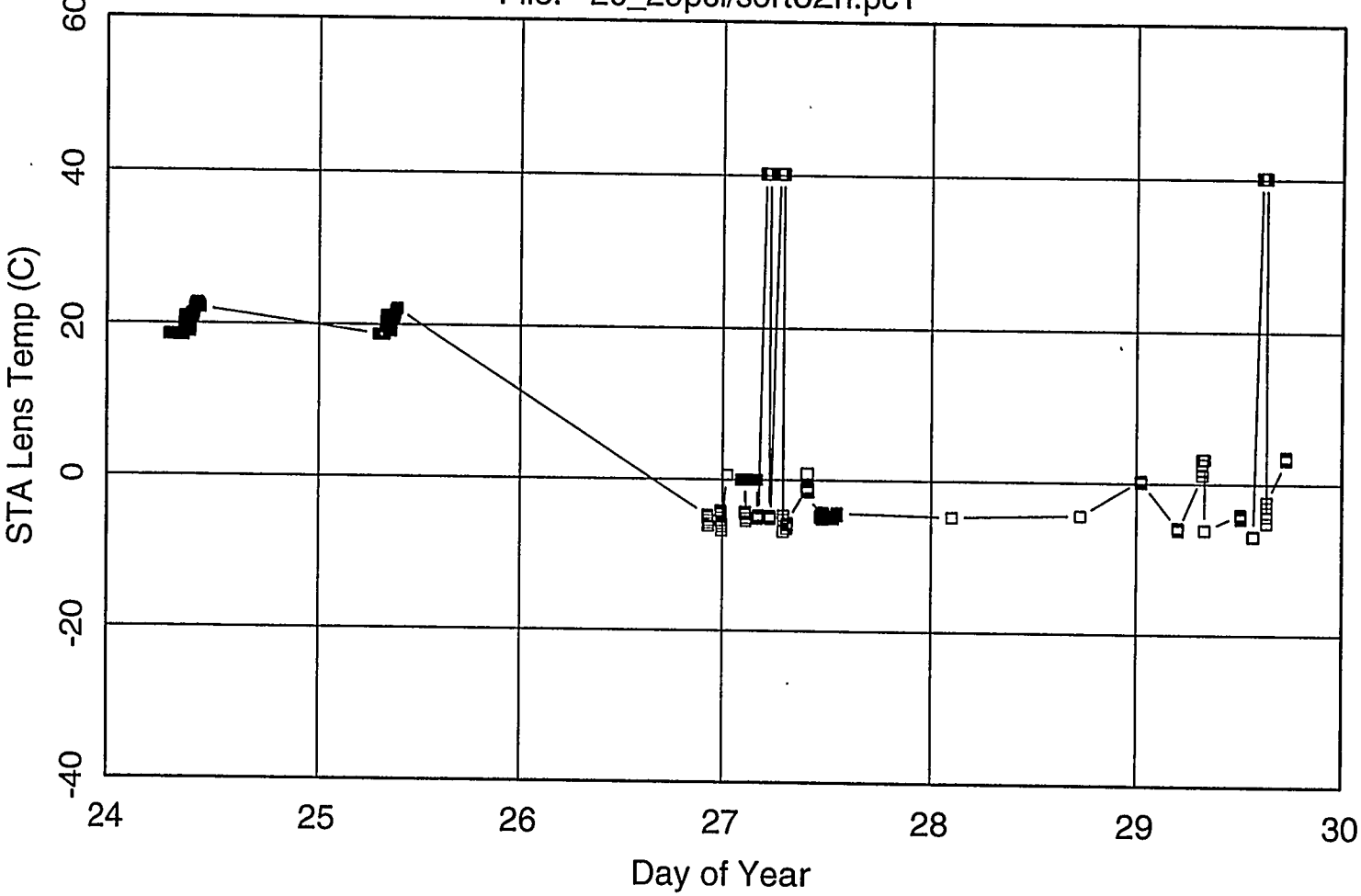

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Clementine

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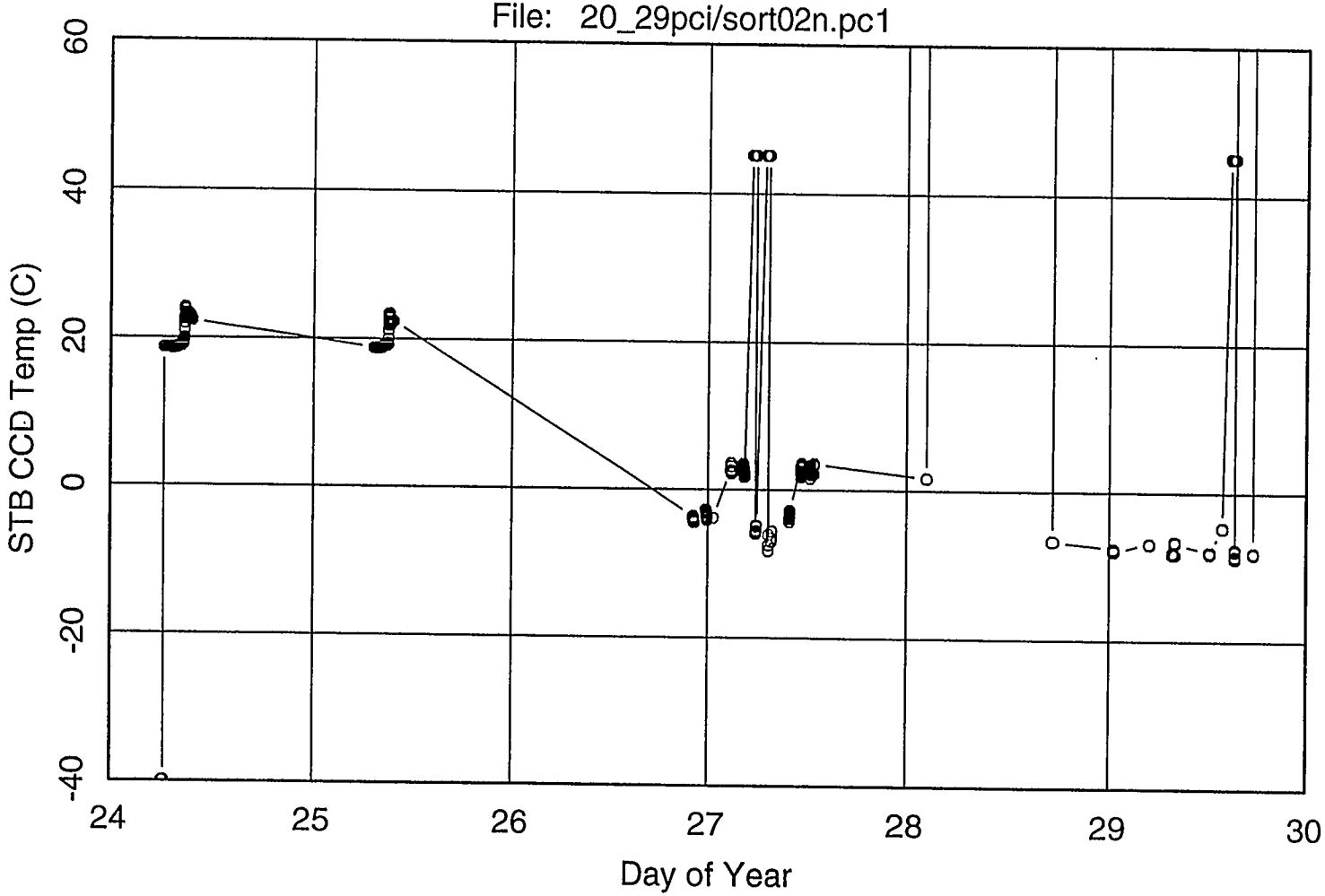

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Clementine

Star Tracker B Lens Temperature

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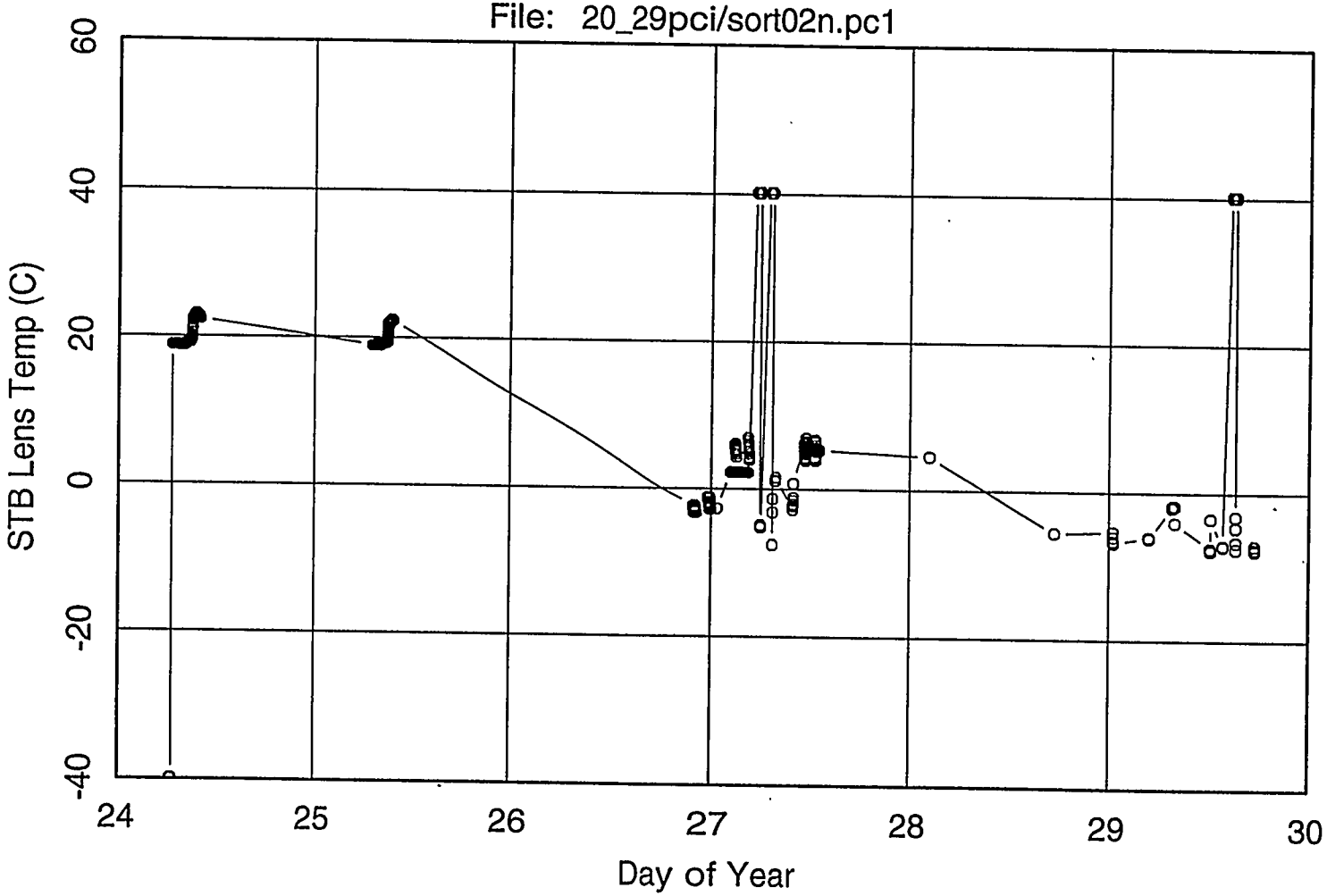


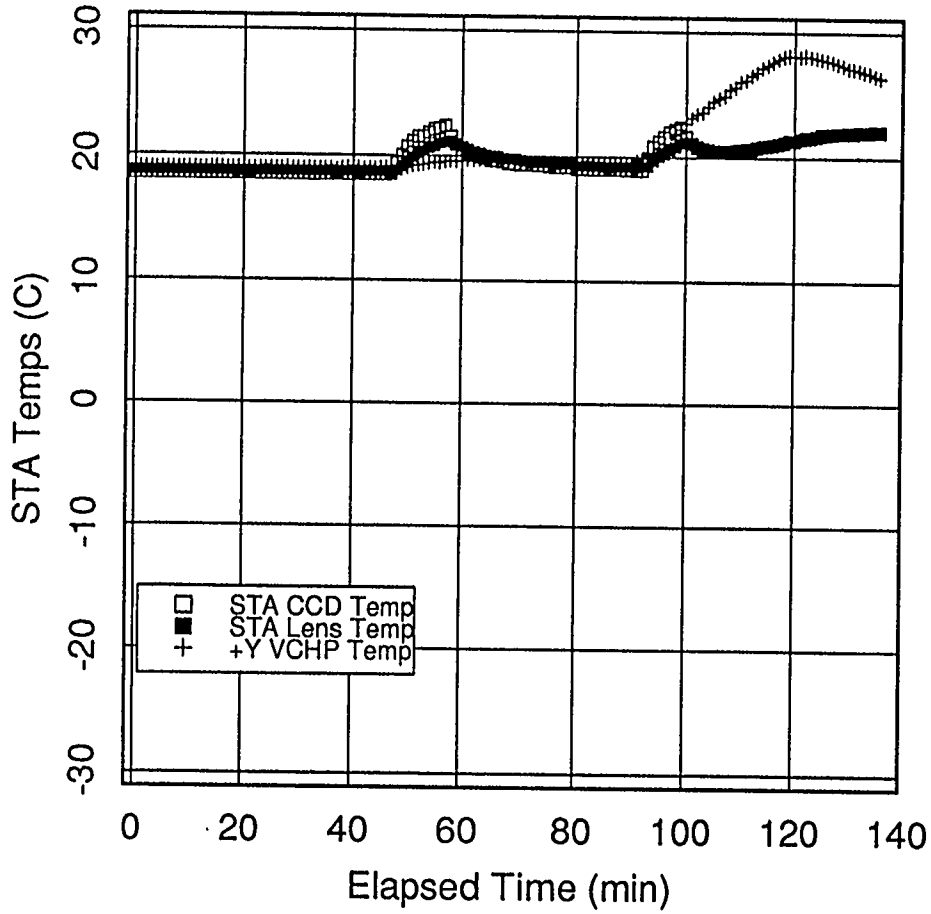
REP/LLNL created: Thu Apr 21 16:32:53 PDT 1994

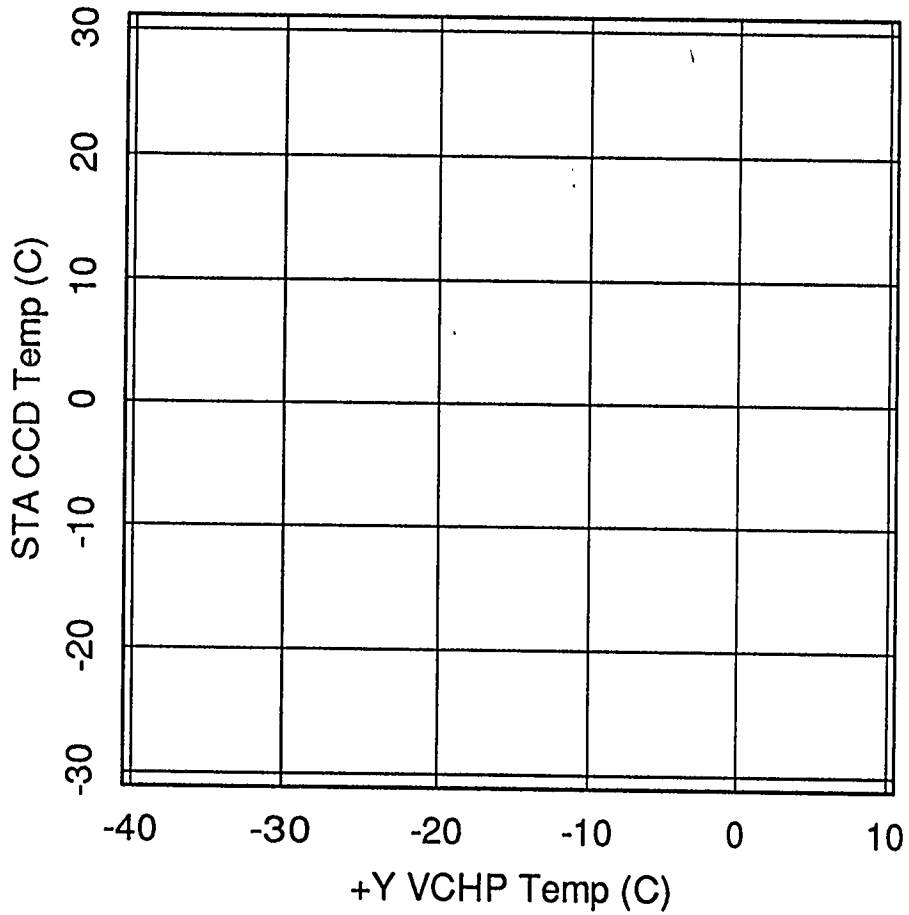
Clementine

Star Tracker A - Temperatures

Start Time: 25-JAN-94 07:07:44.950 GMT

File: a025024d.pc1





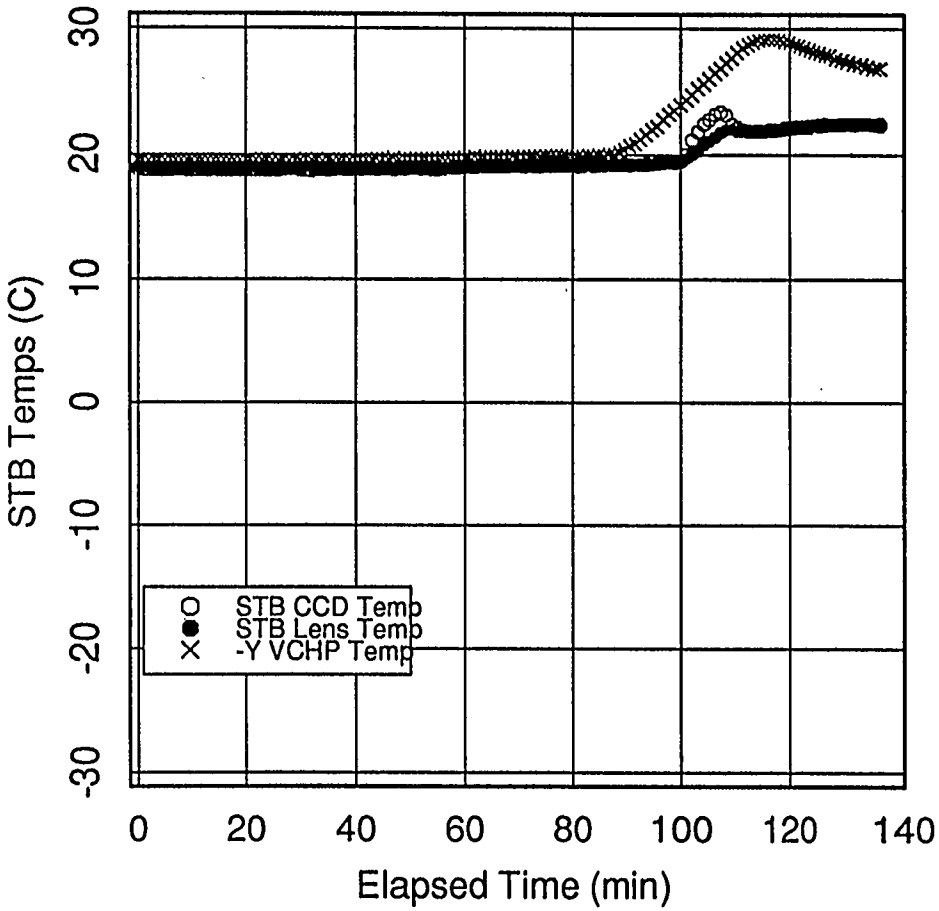
LLNL/ATP/rep report date = Tue Mar 22 10:15:41 PST 1994

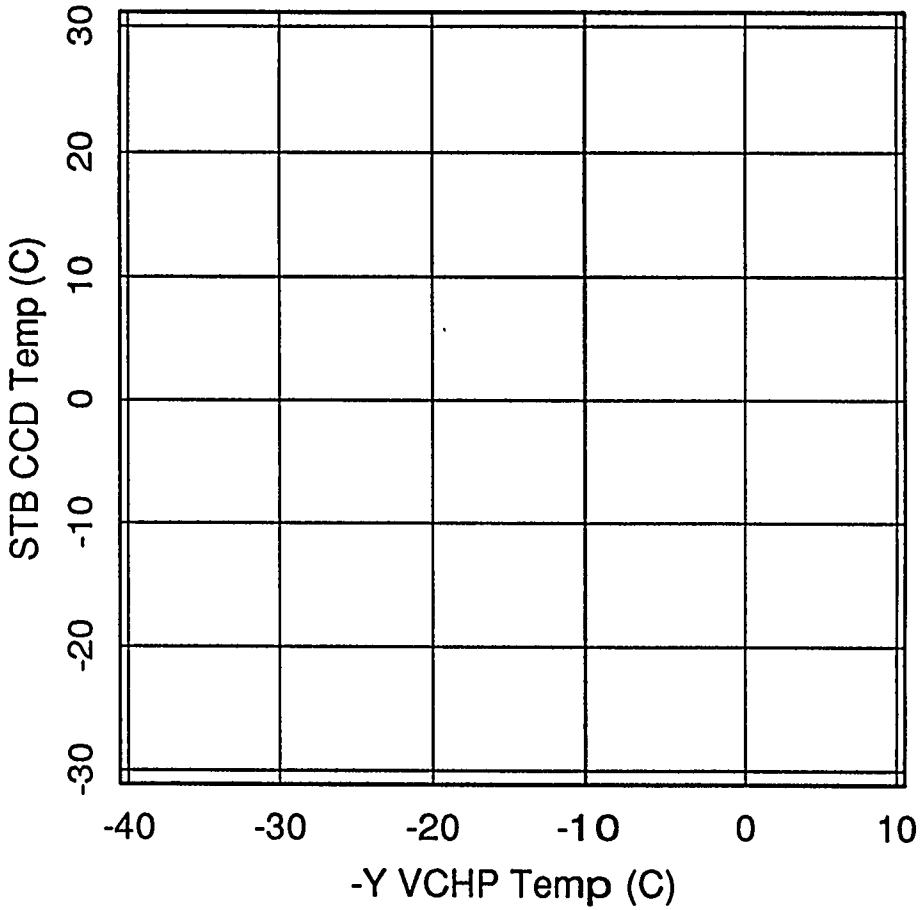
Clementine

Star Tracker ~~A~~ B - Temperatures

Start Time: 25-JAN-94 07:07:44.950 GMT

File: a025024d.pc1





LLNL/ATP/rep report date = Tue Mar 22 10:16:00 PST 1994

Appendix A
General

Appendix A.1

Clementine Sensor Suite Quality Assurance Stamp Procedure

(C1-EE-014)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-EE-014
TITLE: CLEMENTINE SENSOR SUITE Quality Assurance Stamp Procedure	ASSY: General EE ORIG: B. R. Quamme DATE: 22 DEC 1992 APPR:

Abstract:

This document presents the procedures associated with the issuance and use of Quality Assurance stamps within the Clementine Sensor Integration Project.

Lawrence Livermore National Laboratory		Total Document Pages: 3

1. Purpose

To establish a control system that will identify authorized Inspector / Operators and designated personnel.

2. Scope

This procedure applies to all personnel involved with the use of Quality Assurance (QA) Stamps.

3. Assignment of QA Stamps

3.1 QA stamps will be issued to personnel certified in the following categories per Mil-Std-2000: C-Instructor / Examiner, D-Inspector, E-Operator, H-Process Examiner and R-Restricted Operator / Inspector. In addition certain designated personnel will also be issued QA stamps.

3.1.1 QA stamps in a round configuration with blue ink will be issued to category C, D, and certain designated personnel as specified by the Quality Assurance Manager.

3.1.2 QA stamps in a triangle configuration with red ink will be issued to category C, and certain designated personnel as specified by the Quality Assurance Manager.

3.1.3 QA stamps in a round configuration with green ink will be issued to operator category E and F personnel and certain designated personnel as specified by the Quality Assurance Manager.

3.2 Upon issuance of a QA stamp the Quality Assurance Manager or their designee will fill out a stamp assignment form as shown in Appendix A. This form will be filed in the QA office. It will remain on file for a minimum of one year after the termination of the contract.

4. Maintenance of Stamp Status

4.1 Each person issued a QA stamp shall be responsible for the use and safekeeping of that stamp.

4.2 Stamps will be used only on applicable documents that require signature verification.

4.3 Revocation of stamps shall be required under the following circumstances:

a. Proficiency requirements herein are not met.
b. New techniques have been developed which require new skills.
c. Certificate holder or designated personnel changes employer or project.
d. There is a reason to question proficiency or workmanship.
e. Failure to recertify within specified time limits.

4.4 QA stamps that have been retired shall not be reissued for a period of at least 6 months.

5. Use of QA Stamps

5.1 QA stamps in a round configuration with blue ink will be used only when an inspected process, rework or assembly step is complete and or meets standards.

5.2 QA stamps in a triangle configuration with red ink will be used only when the inspected assembly or item has completed a major stage in assembly or test. These include but are not limited to the following:

a: Ready for test.
b. Ready for conformal coat.
c. Ready for mechanical assembly
d. Ready for calibration
e. Ready for environmental test
f. Ready to ship.

5.3 QA stamps in a round configuration with green ink will be used only by operators and certain designated personnel for in process steps.

APPENDIX A

STAMP ASSIGNMENT FORM
(See 3.2)

DATE ISSUED: _____/_____/_____

NAME: _____

SIGNATURE: _____

INITIAL: _____

NUMBER OF STAMP
ISSUED: _____

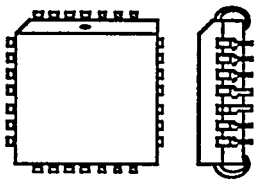
CATAGORY STATUS:
_____

PROJECT NAME: _____

DATE TERMINATED:
_____/_____/_____

Appendix A.2
Printed Wiring Board Inspection Forms
(C1-EE-020)

CLEMENTINE Sensors Integration Project	C1-EE-020 Rev 00
TITLE: CLEMENTINE SENSOR SUITE Printed Wiring Board Inspection Forms	ASSY: All ORIG: B. R. Quamme DATE: 9 Feb. 1993 APPR:



Abstract:

This document provides inspection report forms for Clementine Sensor printed wiring boards. This document includes forms for bare board visual inspection, cross sectioning reports and assembly solder inspections. Reports shall include but are not limited to the information described in this document.

Lawrence Livermore National Laboratory		Total Document Pages: 7

PWB Bare Board Visual Inspection

Requester: _____ Mil-STD-2000: _____IPC-A600D, Class 3: _____

Board Serial # _____Inspector Number or Initial _____

Date: ____/____/____ Manufacturer _____

Inspection	MIL-P-55110 Para	Acc	Rej	Inspection	MIL-P-55110 Para	Acc	Rej
Visual	4.8.1./3.5	☐	☐	Plating and Coating Thickness	3.6.9	☐	☐
Edges of PWB	3.5.1	☐	☐	Soldermask Thickness	3.6.8	☐	☐
Surface Imperfections	3.5.2	☐	☐	Plated-Thru Hole	3.6.7.2	☐	☐
Subsurface Imperfections	3.5.3	☐	☐	Annular Ring (External)	3.6.7	☐	☐
Marking	3.5.4	☐	☐	Unsupported Hole	3.6.7.1	☐	☐
Workmanship	3.5.5	☐	☐	Conductor Spacing	3.6.4	☐	☐
Solderability	3.5.6	☐	☐	Conductor Pattern	3.6.5	☐	☐
Surface	3.5.6.1	☐	☐	Layer to Layer Registration	3.6.6	☐	☐
Hole	3.5.6.2	☐	☐	Solder Mask Adhesion & Cure	3.7.1	☐	☐
Thermal Stress	3.5.7	☐	☐	Plating Adhesion	3.7.2	☐	☐
Dimensional	3.6/3.6.1/ 4.8.3	☐	☐	Conductor Edge Outgrowth	3.7.3	☐	☐
Hole Pattern	3.6.2	☐	☐	Repair	3.10.5	☐	☐
Bow & Twist	3.6.3	☐	☐				

PWB Cross Section Summary

Requester: _____ Mil-P-55110: _____ IPC-A600D, Class 3: ____

Part #: _____ Lab ID: _____ Lab Tech: _____

Date: ___/___/_____

Thermal Shock: ____ Y/N Solder Float: _____ Y/N

Board Summary (Fill in after completing page 3, if applicable)

Feature	None	Minor	Reject	Measurement if applicable	Photograph # if applicable
Epoxy Smear	☐	☐	☐		
Epoxy Etch	☐	☐	☐		
Nail Heading	☐	☐	☐		
Nodules	☐	☐	☐		
Wicking	☐	☐	☐		
Fiber Protrusion	☐	☐	☐		
Resin Recession	☐	☐	☐		
Plating Voids	☐	☐	☐		
Delamination	☐	☐	☐		
Neg. Etchback	☐	☐	☐		
Plating Folds	☐	☐	☐		
Blow Holes	☐	☐	☐		
Hole Wall Pull	☐	☐	☐		
Laminate Voids	☐	☐	☐		

Tin / Lead Thickness _____ Surface Copper Thickness _____

Minimum Hole Wall Copper Thickness _____ Maximum Mis-Registration_____

Comments:

PWB Cross Section Detail

Inspection	MIL-P-55110 Para	Acc	Rej	Inspection	MIL-P-55110 Para	Acc	Rej
Material	3.4.1.1 3.4.1.2	☐	☐	Undercutting	3.8.6	☐	☐
Traceability	3.5.4.1	☐	☐	Annular Ring (Internal)	3.8.7	☐	☐
Thermal Stress	3.5.7	☐	☐	Dielectric Layer Thickness	3.8.8	☐	☐
Conductor Spacing	3.6.4	☐	☐	Laminate Voids	3.8.9	☐	☐
Layer to Layer Registration	3.6.6	☐	☐	Resin Recession	3.8.10	☐	☐
Plating and Coating Thickness	3.6.9	☐	☐	Lifted Lands	3.8.11	☐	☐
Construction Integrity	3.8	☐	☐	Plated-Thru Holes	3.9	☐	☐
Plated Copper Thickness	3.8.2	☐	☐	Thermal Stress	3.9.1	☐	☐
Plating Voids	3.8.3	☐	☐	Electrical & Environmental Requirements	3.10 4.8.7	☐	☐
Resin Smear and Etchback	3.8.5	☐	☐	Circuitry	3.10.3 4.8.7.3	☐	☐
Hole Cleaning (Smear Removal)	3.8.5.1	☐	☐	Circuitry Continuity	3.10.3.2	☐	☐
Negative Etchback	3.8.5.2	☐	☐	Circuit Shorts	3.10.3.3	☐	☐
Etchback		☐	☐	Repair	3.10.5	☐	☐

PWB Assembly/Solder Inspection

Requester: _____ Mil-STD-2000: _____ IPC-A600D, Class 3: ____

Board Serial # _____ Inspector Number or Initial _____

Date: ___/___/___ Operator/Technician Number or Initial_____

Board Summary (Fill in after completing Visual-Inspection, if applicable)

Visual-Inspection, Mil-Std-2000 Table XI				**Visual-Inspection,** Mil-Std-2000 Table XI			
Solder Defects		**Acc**	**Rej**	**Solder Defects**		**Acc**	**Rej**
Non-soldered connections	A101	☐	☐	Bridging	A102	☐	☐
Rosin Connection	A103	☐	☐	Cold solder joint	A104	☐	☐
Fractured or disturbed	A105	☐	☐	Insufficient solder	A106	☐	☐
Excessive solder, lead not discernible	A107	☐	☐	Poor wetting	A108	☐	☐
Solder Splattering	A109	☐	☐	Pits, Pinholes, Holes, or voids	A110	☐	☐
Dewetting of solder connection areas	A112	☐	☐	Solder points, peaks, or icicles	A114	☐	☐
Flux residue, oils, greases on assembly	A115	☐	☐	Improper tinning of stranded wire	A116	☐	☐
Overheated solder	A117	☐	☐	Unfilled plated through hole,(when fill is required by drawing)	A118	☐	☐
Contaminants in solder connection	A119	☐	☐	Excess solder in bend radius	A120	☐	☐
All other solder defects except those listed as level B process indicators	A121	☐	☐				

Visual-Inspection, Mil-Std-2000 Table XI

Assembly Defects		Acc	Rej
Improper Transmission of stress of leads and wires (improper stress relief)	A130	☐	☐
Uninsulated wires or component leads routed over the circuit path where shorting is possible	A132	☐	☐
Birdcaged wire	A134	☐	☐
Leads or wires scraped, exposing metal or stretched	A136	☐	☐
Excessive lead length (electrical clearance insufficient)	A138	☐	☐
Excessive wicking	A140	☐	☐
Excessive terminal fill	A142	☐	☐
Improper lead bend clearance	A144	☐	☐
Component has improper clearance to adjacent components	A146	☐	☐
Component not sufficiently supported	A148	☐	☐
Component less than 1/16 inch (1.6 mm) to edge of PWB causing interference	A150	☐	☐
Physical damage of components	A152	☐	☐
Improper terminal swaging	A154	☐	☐
Wrong parts used	A156	☐	☐

Visual-Inspection, Mil-Std-2000 Table XI

Assembly Defects		Acc	Rej
Metal cased components mounted over circuit path (not insulated)	A131	☐	☐
Charring, burning, or damage to insulation (affecting electrical operation)	A133	☐	☐
Cut or nicked leads or wires	A135	☐	☐
Lead clinched beyond allowable limits (electrical clearance insufficient)	A137	☐	☐
Insufficient lead length	A139	☐	☐
Improper insulation clearance	A141	☐	☐
Improper lead bend radius	A143	☐	☐
Unclinched components where clinching is required	A145	☐	☐
Component has improper clearance above the PWB	A147	☐	☐
Glass-cased components not protected by buffer material when epoxy conformal coating is used	A149	☐	☐
Component obscures termination or another component (unless design dictates otherwise)	A151	☐	☐
Improper vertical mounted component clearance	A153	☐	☐
Leads cut after final soldering	A155	☐	☐
Wrong orientation of polarized components	A157	☐	☐

Visual-Inspection, Mil-Std-2000 Table XI				Visual-Inspection, Mil-Std-2000 Table XI			
Assembly Defects		**Acc**	**Rej**	**Assembly Defects**		**Acc**	**Rej**
Component improperly spaced or located	A158	☐	☐	Damage to wire or strands	A159	☐	☐
Pattern delaminated (after solder)	A180	☐	☐	Burned, scorched PWB or parts	A181	☐	☐
Excessive warp or twist (after solder)	A182	☐	☐	Delamination of base material	A184	☐	☐
Separation of conductor pattern	A185	☐	☐				

Appendix A.3

Clementine Sensor Suite Failure Reporting, Analysis and Corrective Action System

(C1-EE-021)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-EE-021
TITLE: CLEMENTINE SENSOR SUITE Failure Reporting, Analysis and Corrective Action System	ASSY: A11 ORIG: W. R. Bryson DATE: 9 February 1993 APPR:

Abstract:

This document describes the Failure Reporting, Analysis and Corrective Action System (FRACAS) that has been implemented for the Clementine Sensors Integration Project.

Lawrence Livermore National Laboratory		Total Document Pages: 10

1.0 Introduction

A closed loop system for reporting, analysis, and correction of failures will be in effect for failures occurring during the assembly and testing phase of the Clementine Sensor Integration Project. The FRACAS will determine whether failures are caused by design deficiencies, human error, defective parts, infant mortality, test equipment, environmental exposure, or software. Once the cause of the failure is determined, timely corrective action will be initiated to prevent recurrence. The corrective action will then be followed up to make certain that it is effective.

2.0 Roles and Responsibilities

Implementation, direction, and monitoring of the FRACAS is the responsibility of the LLNL Quality Assurance Group (QAG), they will review and record all discrepant material, inspection and test records, and other quality reports to ascertain the existence of quality or reliability problems. They will assure that all failures and follow-up actions occurring during the acceptance test phase are documented to enable resolution of all failures. A Test Discrepancy Report (TDR) is initiated by the cognizant test engineer immediately upon failure occurrence. The project lead engineer is responsible for the FRACA recommendations. The LLNL QAG follows up on each FRACA action to assure that adequate corrective action is implemented to correct the cause of the discrepant condition.

3.0 Procedures

The procedures described herein are based on established FRACA procedures and provide a closed loop system to report, analyze and correct failures encountered during all assembly and acceptance testing.

3.1 Discrepancy Reporting

All failures, unusual events or anomalies occurring during the assembly or acceptance test phase are reported. All TDRs will be flagged as to the level of concern (Red, Yellow or Green). The LLNL QAG will use the TDR form contained in Appendix A to record data and information. The cognizant test engineer assures that the appropriate information is included and that the TDR is complete and accurate. The project lead engineer performs a preliminary analysis of all failure reports and informs the LLNL QAG, program management, and engineering of any needed changes. Failures requiring a design change are evaluated and recommendations are made to change the baseline design.

3.2 Distribution

All TDRs are filed at LLNL and provided to SDIO in the form of a monthly report. Any Red or Yellow level event will be tracked in subsequent reports until they are closed out. The TDR report number is referenced in all "as-built" equipment logs and a master data base enables location of the TDR copy in the QA files. Distribution of the original and additional reproduced copies is as follows:

- Original TDR - The original copy remains with the failed sensor, unit, assembly, module, or part and performs the function of a shop traveler until the failure analysis is completed. Upon completion and close-out of the TDR, the original is made a part of the "as-built" documentation package.

- Backup Copy - The backup copy is provided to the LLNL QAG. This copy remains in a suspense file until the FRACA is completed. A copy of the completed and approved original copy is received by LLNL QAG for close-out of the TDR.

- Additional Copies - Reproductions of the original TDR are provided to the cognizant test engineer and are included in the monthly report to SDIO. Copies of the completed original TDR are provided to the cognizant test engineer and to LLNL QAG for formal TDR close-out.

3.3 Additional TDRs

Additional TDRs are used to document the event sequence on any hardware item that is removed from the original failed item, and the first TDR always remains with the original failed unit. Additional TDRs are minimized to maintain only those necessary to document completely the event sequence from higher-level assemblies to the failed part or component. In each case where a new TDR is initiated, the previous TDR shall be referenced to provide two-way traceability from the initial failure occurrence to the final corrective action. Appendix B provides an example that illustrates the manner in which the TDR's are prepared and copies are distributed.

4.0 Failure Analysis

A failure analysis is performed on all TDRs prepared for assembly or acceptance test failures. The failure analysis determines the cause so that necessary corrective action can be taken to maintain sensor reliability. The failure analyses and investigations are performed to the level of detail necessary to resolve the problem. Based on the following types of data, the LLNL QAG and project lead engineer mutually determine which failed parts require detailed failure analysis:

- Data provided by the FRACAS
- Narrative engineering reports
- Personal contact with engineering and test personnel
- The level of concern (Red, Yellow or Green)

Red and yellow level concerns may require convening a Material Review Board to assist in the analysis.

All failure analysis reports are to be closed out within 30 days of the failure occurrence. A written rationale is provided for any extensions beyond this period. Clementine management is automatically alerted to ineffective corrective actions. If

LLNL does not have the facilities for in-depth analysis, they will arrange for the use of an independent laboratory facility to perform such analyses.

If the cause of the problem cannot be determined within 30 days, the LLNL QAG will perform measurements and tests on assemblies and parts. When physical and chemical analyses are necessary, they will be performed by LLNL departments or competent testing laboratories. Whenever it is necessary to conduct extensive or in-depth examinations of failed components, the LLNL QAG will ask the manufacturer of the device or a qualified test laboratory to perform the analysis.

Each failed part analysis will result in one of the following decisions:

- Inherent Weakness - This decision is made if there is an inherent weakness in the part that would require redesign by the manufacturer, selection of a new vendor, or change in the part type used.

- Misapplication of Component or Part - This decision is made if the failure is caused by the misapplication of the item in the electrical, mechanical, or environmental design of the equipment, thus requiring equipment redesign.

- Random Part Failures - This decision is made only if the failure is caused by random part failures; i.e., an inherent part failure rate.

- Human Error - This decision is made if the failure is caused by human error.

Corrective action requests are forwarded to the responsible individual who will then provide a response with a description of the actions taken. These actions are monitored to assure that the corrective measures have effectively resolved the problem. Summaries of the failure reports, analyses, and corrective actions are maintained for SDIO review.

4.1 Disposition of Failed Parts and Material

The disposition of failed parts and material after the completion of the FRACA is as directed by the LLNL QAG.

4.2 Reporting

A formal failure analysis report is prepared by the laboratory or group tasked to perform the investigation. The report original is filed with the TDR original and a copy of the report is forwarded to the LLNL QAG and the TDR files.

5.0 Corrective Action

The LLNL QAG periodically reviews the status of each TDR to assess the progress of the FRACAS. Required corrective action must be implemented before the close-out of the TDR. Close-out of the TDR is initiated by the project lead engineer after corrective action is undertaken. The TDR is closed out when both the project lead

engineer and the LLNL QAG representative have signed the original TDR and have forwarded a copy to the LLNL QAG files.

6.0 TDR Completion Instructions

The original TDR serves as the master upon which all update information is entered. Figure 1 describes the TDR form in detail with instructions for each block item. The TDR is divided into four major sections.

6.1 Hardware Description and Environmental Data

The originator completes this section. It identifies the hardware levels and conditions under which the failure occurred.

6.2 Description of the Discrepancy:

The originator completes this section. It defines the nature of the report, describes the problem(s) encountered, identifies parts or modules replaced, and provides other pertinent data. A continuation sheet is used if more space is required.

6.3 Removed Hardware Results

This section records the results of investigations and analyses performed and conclusions covering the reasons for the failures or problem. Reference to failure analysis reports or other documents is made in this section. The continuation sheet is used if more space is required.

6.4 Corrective Action

This section describes the recommended corrective action. Corrective action document numbers as well as narrative indicating completion and corrective actions are included. A continuation sheet is used if more space is required. Close-out of the TDR is accomplished by authorized signatures from the project lead engineer and the LLNL QAG.

7.0 Failure Analysis Report

A formal Failure Analysis Report is completed by the cognizant test engineer responsible for the failure analysis. The format depends on the nature and severity of the failure, but in all cases the following information is included:

1. Name of the test engineer responsible for performing the analysis.
2. Name of the laboratory or subcontractor performing the detailed analysis.
3. Date the failed parts were made available to the analyst.
4. Date the analysis was completed.
5. Serial number of the TDR.

6. Classification of Failure (Modes): A statement of the primary defect or damage as determined by the analyst; e.g., Capacitor Shorted.

7. Narrative discussion of the cause of the problem. For example, the analyst shall describe the procedures used in locating and defining the defect or damage and a statement of the results obtained. Methods used by the analyst, such as electrical or mechanical measurements, X-rays, destructive physical analysis (DPA), or other user tests are included in the discussion.

8. Responsibility for Failures: A statement identifying the area or functional organization which in the analyst's opinion was principally responsible for the defects or damage is included. For example, the responsibility may be assigned to the manufacturing function, the quality organization or the test organization.

9. Recommendations: The analyst's recommendation for improving the situation is included. As applicable, recommendations may include a revision of manufacturing or handling processes, revision of a specification, revision to the design or a component, or a change to another component known to be of better quality and higher reliability.

8.0 FRACAS Definitions

During the conduct of FRACA activities, the following definitions will apply:

- Failure Analysis Laboratory - Facilities where detailed investigation(s) are performed on failed parts, components, or assemblies

- Failure Analysis - Investigations required to determine mode and causes of significant failure or malfunctions so that necessary corrective action can be taken to improve reliability

- Failure Cause - Reason (external to the device) that the condition that resulted in failure exists (e.g., improper cleaning, excessive temperature, or contaminated solder)

- Failure Mechanism - The physical or chemical condition within the device from which the failure directly resulted (e.g., cracked wire, surface contamination, or shorted internal parts)

- Failure - Any trouble in a part or assembly evidenced by one or more relevant characteristics not conforming to specified limits.

Assembly type

Date failure occurred

Serial number of failed assembly

Describe environment in which the failure occurred.

Where known, describe effect of failure or difficulty on system/subsystem performance and effect of failure to the lowest functional level possible. Include quantitative values of observed measurements.

Enter a summary of the failure analysis performed to determine the cause of the failure. Refer to any additional reports or analysis for more detailed information. Include the name, part number and serial # to the lowest level hardware where replacement was required.

Briefly describe recommended corrective action. Describe final action taken. Reference associated documents by number.

Enter date of effectivity of corrective action.

Signature of Quality Assurance representative.

Clementine Sensor Suite
Fabrication and Acceptance Test Discrepancy Report

Date:	Assembly:	Discrepancy Report Number:
Serial #:	Procedure:	Step:
Module Responsible for Failure:		
Description of discrepancy, including symptoms and test/environmental conditions:		
	Reported By:	
Corrective Action:		
	Reported By:	
Hardware or Software Change, if any:		
	Performed By:	
Approved by:	Signature:	Date:

Enter name of procedure and step number, as appropriate.

Enter part number and or assembly drawing, as applicable. Include serial number.

Signature of discrepancy originator.

Signature of corrective action originator.

Signature of individual performing analysis and date completed.

Signature of Project Engineer

Date of Signature.

Figure 1.

Appendix A

A1. See the following page for "Clementine Sensor Suite Fabrication and Acceptance Test Discrepancy Report" form.

Clementine Sensor Suite
Fabrication and Acceptance Test Discrepancy Report

Date:	Assembly:	Discrepancy Report Number:
Serial #:	Procedure:	Step:

Module Responsible for Failure:

Description of discrepancy, including symptoms and test /environmental conditions:

Reported By:

Corrective Action:

Reported By:

Hardware or Software Change, if any:

Performed By:

Approved by:	Signature:	Date:

Appendix B

TDR Example

A test failure occurs during LIDAR acceptance testing, and the fault is isolated to the Range Receiver module. The following steps are taken:

1. The top half of the TDR form is prepared for the LIDAR.

2. After the LIDAR is disassembled and the Range Receiver module is removed, the Range Receiver module identification data, including name, part number and serial number, is entered in the "Hardware or Software Change, if any:" block on the LIDAR TDR.

3. A Range Receiver module level TDR is prepared and the LIDAR TDR report number is entered in the space provided for "Description of Discrepancy, including Symptoms and Test or Environmental Conditions." In like manner, the Range Receiver module level TDR report number is referenced on the LIDAR TDR in the space provided for "Hardware or Software Change, if any:"

4. The TDRs are distributed as follows:
   - The backup copy of the LIDAR TDR and the Range Receiver module TDR is sent to the LLNL QAG.
   - The original LIDAR TDR remains with the LIDAR documentation package, and the original of the Range Receiver module TDR remains with the failed Range Receiver module to function as a shop traveler during the FRACA and Range Receiver module repair.
   - A copy of each of the LIDAR and Range Receiver module TDR original is reproduced and provided to the project lead engineer and to SDIO.

5. If further failure analysis is required on the failed parts removed from the module, a third-level TDR is prepared for the parts. The part's level TDR original will accompany the failed parts through failure analysis.

6. When the analysis is completed, the "Corrective Action" block of the parts TDR is completed, and the analysis and repair/inspection data is entered on the module TDR in the "Hardware or Software Change, if any:" and "Corrective Action" blocks.

7. The data from the Range Receiver module and part-level TDRs are summarized on the LIDAR TDR original; and the test engineer and the QAG complete the "Effectivity," "Approved" and "Date" blocks on the original.

8. The parts TDR (original) is retained by the LLNL QAG. The Range Receiver module TDR (original) is filed with the Range Receiver module "as-built" documentation package. The LIDAR TDR (original) is filed with the LIDAR "as-built" package, and two copies of the parts, Range Receiver module and LIDAR TDRs (originals) are distributed as follows:
   - Test Engineer (one copy for file)
   - LLNL QAG (one copy to close out the FRACA suspense file)
   - SDIO in the monthly report

Appendix A.4

Clementine Sensor Suite Parts Program

(C1-EE-022)

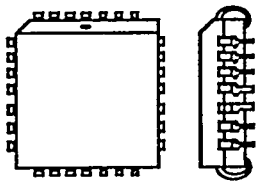
B. Quist

Clementine Sensor Suite
Parts Program

	Date	Rev.	Date	Approval
Prepared by: W. R. Bryson	3/3/93			
Reviewed by: J. F. Kordas	3/5/93			
Reviewed by: M. J. Richardson	3/4/93			
Reviewed by: T. F. Tassinary	3/8/93			
Reviewed by: M. J. Shannon	3/8/93			
Approved by: L. D. Pleasance	3/12/93			

University of California **Lawrence Livermore National Laboratory**	Clementine Sensor Suite Parts Program	C1-EE-022 Revision 00

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-EE-022
TITLE: Clementine Sensor Suite Parts Program	ASSY: General EE ORIG: W. R. Bryson DATE: 9 February 1993 APPR:



Abstract:

This document describes the parts purchase and screening program for the Clementine Sensor Suite sensors.

Lawrence Livermore National Laboratory		Total Document Pages: 19

Introduction

This document describes the requirements for the purchase and screening of EE components for the Clementine Sensor Suite. The objective is to assure that only the highest reliability parts are used in the Clementine Sensor Suite.

Parts Purchase

Active components will be purchased to the highest grade available according to the precedence shown in Table 1 below. All other parts will be purchased with the highest reliability level available within program constraints. All components will be screened per this document, as required, based on their purchased reliability level.

Precedence	Grade	Description
1	MIL-M-38510	/883B, JAN, J.
2	Extended Temp.	Ceramic Package, -55 to +125°C Operating Range Program Screening Required
3	Industrial-Ceramic	Ceramic Package, 0 to + 85°C Operating Range Program Screening Required
4	Commercial-Ceramic	Ceramic Package, 0 to + 70°C Operating Range Program Screening Required
5	Industrial-Plastic	Plastic Package, 0 to + 85°C Operating Range Program Screening Required
6	Commercial-Plastic	Plastic Package, 0 to + 70°C Operating Range Program Screening Required
7	Special	Vendor Specific Requirements Program Written Description Required Program Screening Required

Table 1. Parts Purchase Precedence

Parts Screening

Part screening is directed toward insuring that all components used in the Clementine Sensor Suite are free from incipient failures and to precipitate failure of any marginal components. The screening tests and procedures are those known to uncover potential failure mechanisms of the components.

The screening applied to a procured component after delivery will be fitted to that component in relation to the reliability level of the procured version. That is, the higher the reliability level of the procured component, the less screening required in the post procurement test program. The screening program is also varied according to component type and their respective reliability history.

Regardless of the purchased reliability level of components, all components will be subjected to supplementary screening and inspections that will result in a reliability level equivalent to parts specified in the QPL.

The program screening, test and inspection requirements, with the specific methods defined by the applicable test documents and military standards are presented in the flow diagrams given in Figures 2 thru 15. The electrical parameters that may be measured during screening are identified in Table 2. Specific parameters measured will be tailored to the exact application of that component. Full screening tests and inspections are required on industrial and commercial grade components, while supplemental screening tests will be performed on components that have been subjected to some level of reliability oriented processing and testing not considered sufficient for this application.

Part Type	Parameters to be Tested
Integrated Circuits Delay Lines (Digital, CMOS, ECL)	ICCH, ICCL, IIH, IIL, IOH, IOL, IOZH, IOZL, VIN, VIL, VIK, VOH, TPLH, TPHL, TAA, TACS, TOE, TOHZ, TCHZ, T-RISE, T-FALL, T-SKEW, Functional Performance
Integrated Circuits (Linear)	±ICC, VOS, ±IB, ±VO, CMRR, PSRR, ±CMV, IDO, IDG, ISOH, ISOHL, ISINK, VOH, VOL, GBWP, ±SLEW RATE, TPDHL, TPDLH, Functional Performance
Oscillators	Frequency, Wave form Linearity, Supply Current
Transistors (General)	h_{FE}, I_{CBO}, $V_{CE(SAT)}$, $V_{BE(SAT)}$, ICES, ICEO, I_{EBO}, VBE, BVCER, BVCES, ICEX
FET's (General)	BV_{DSS}, I_{DSS}, ID-ON, VSD, RDSON, GFS, VP, VSTH, ID-OFF, IGSS, VDS-ON, VGS-OFF
SCR's	VGT, IGT, IDRM, IRRM, VTM, IH
Diodes (Rectifiers)	VF, IR
Diodes (Zeners)	VZ, ZZ, VF
Capacitors	Capacitance, DF, IR, DCL, ESR
Resistors Resistor Networks	DC Resistance
Coils and Inductors	Inductance, Q, DC Resistance, DWV
Transformers	Inductance, Turns Ratio, DC Resistance, DWV
Connectors	DWV

Table 2. Electrical Parameter to be Tested at Final Test

Applicable Documents

The flow diagrams given in Figures 2 thru 15 refer to various military standards and test methods. A military standard will be listed in the lower left hand corner of a block in the flow diagram. The applicable test method is listed in the lower right hand corner of the block. See Figure 1 below for an example that refers to MIL-STD-883D, test method 1015.

POWER BURN-IN
(DYNAMIC)
883D TM1015

Figure 1.

Summary

Active components will be purchased according to the precedence presented in Table 1. All passive components will be purchased to the highest reliability levels consistent with project requirements. All components will be subjected to some level of screening or testing prior to use in Clementine Sensor Suite sensors.

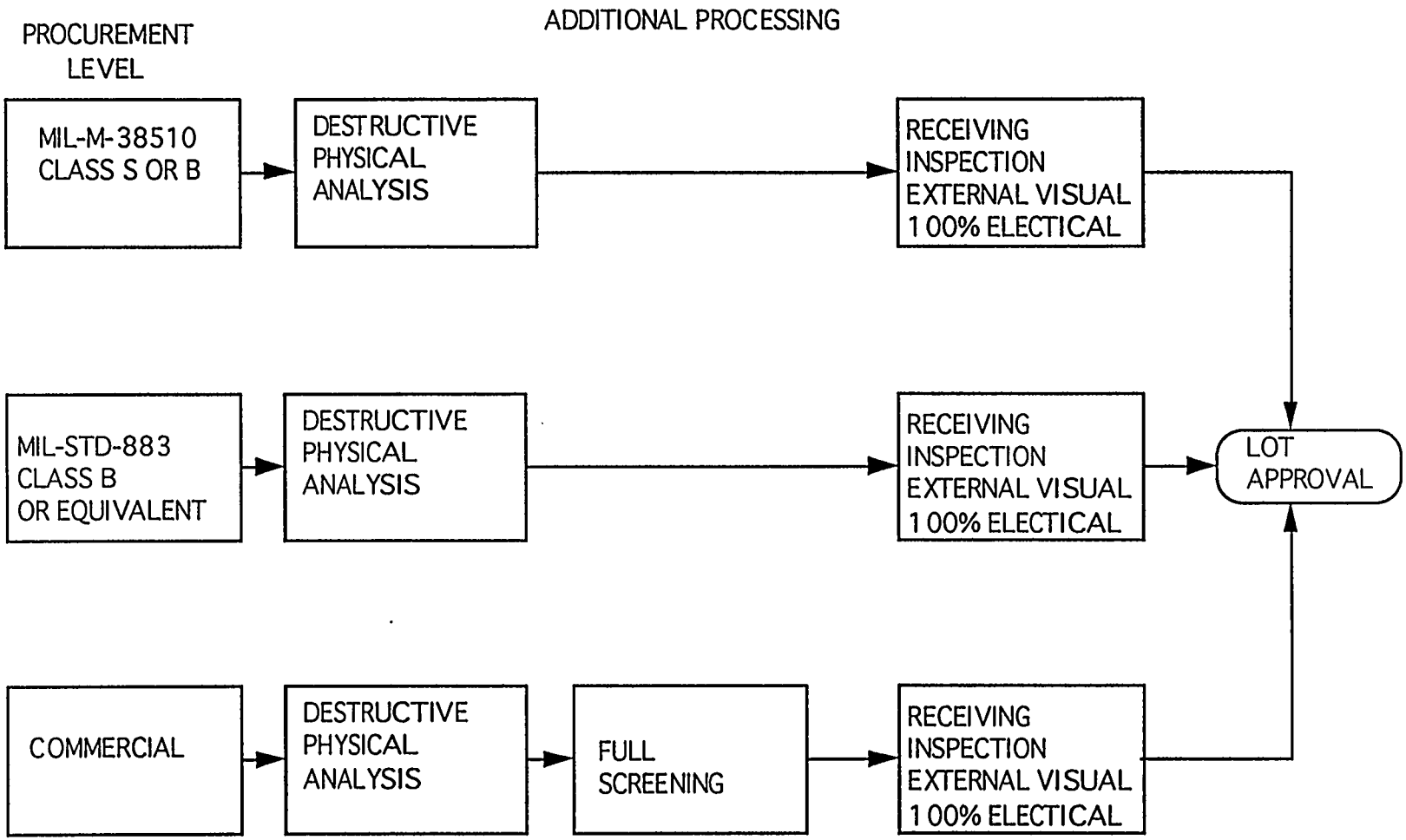


Figure 2. Overview of Integrated Circuit Screening

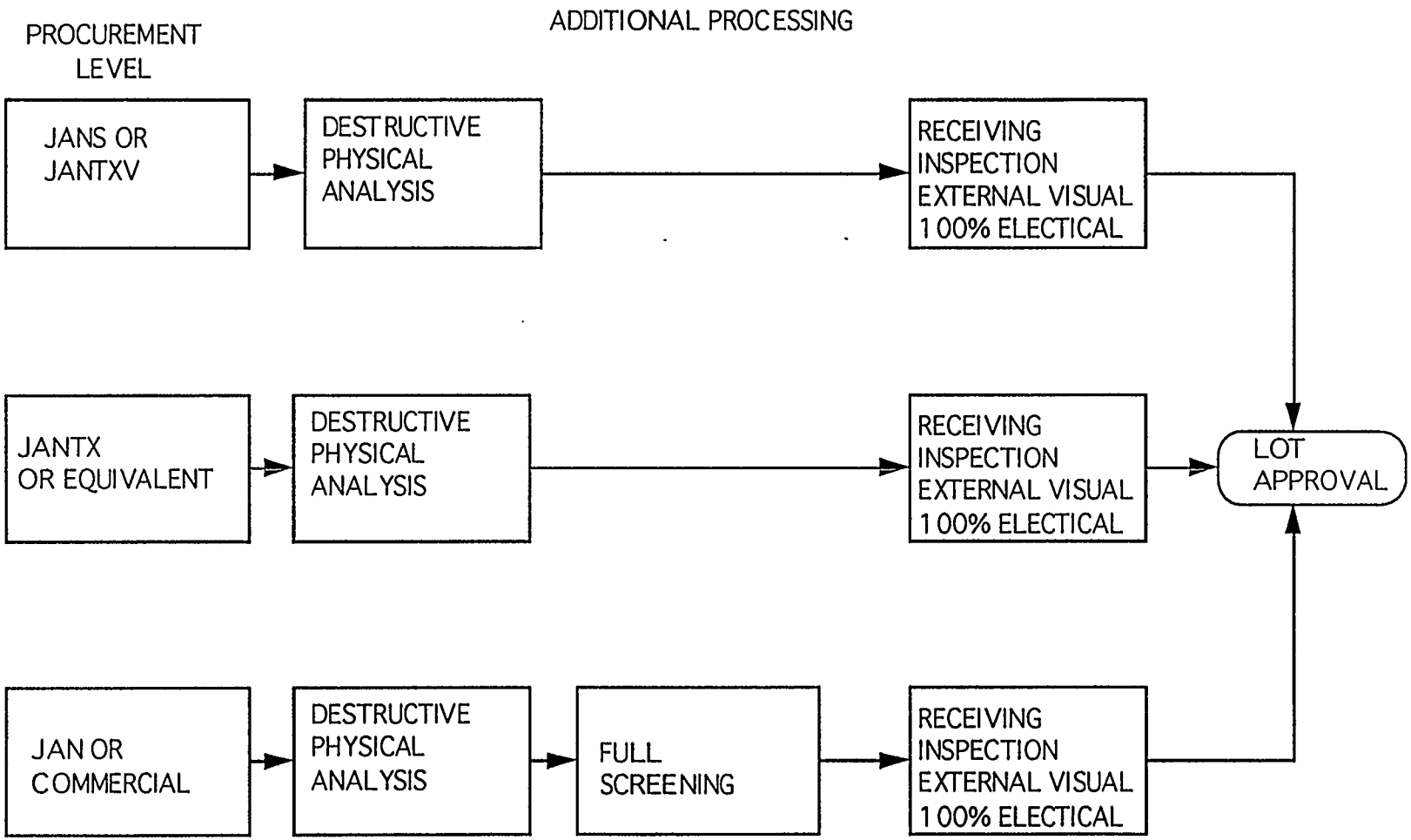
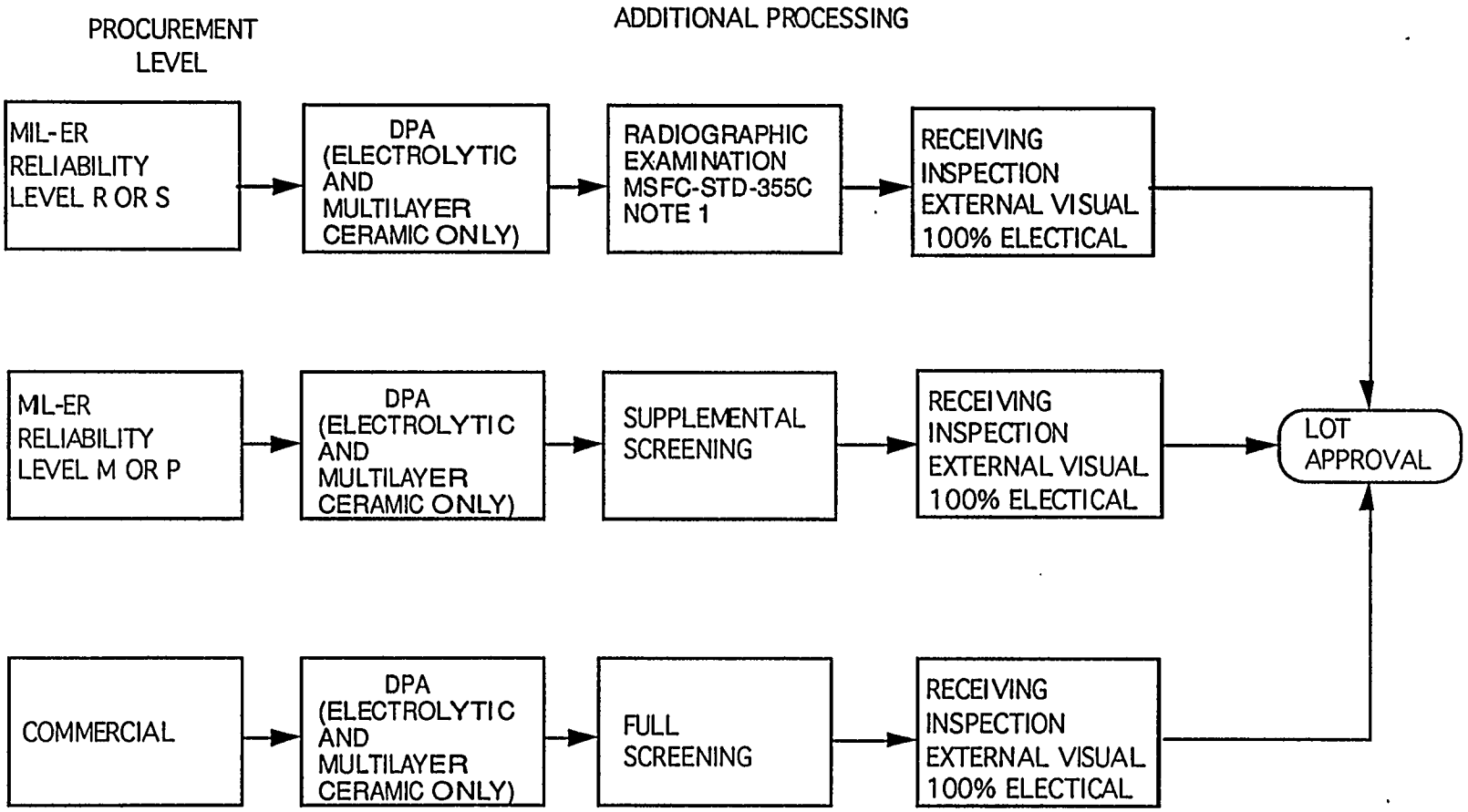
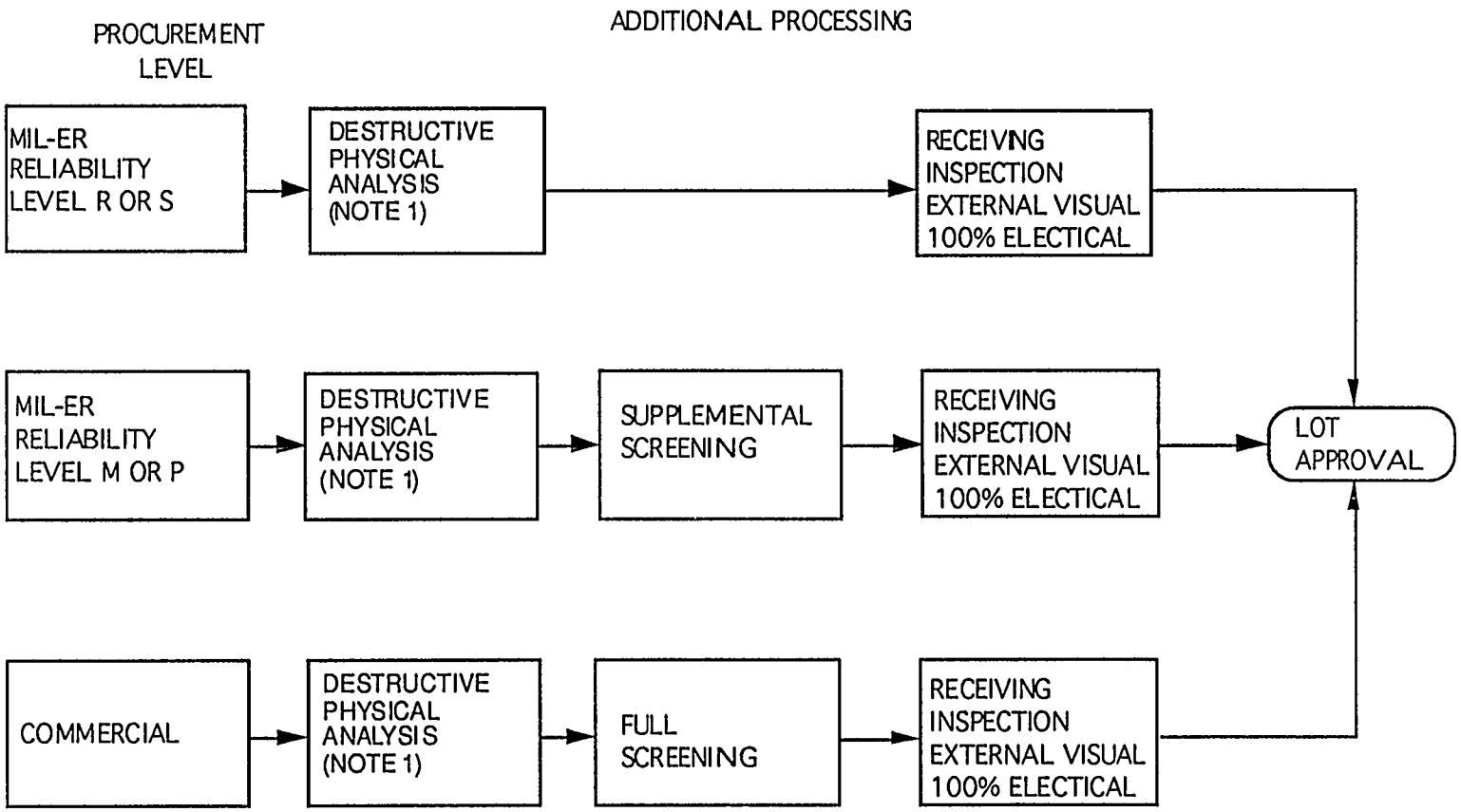


Figure 3. Overview of Discrete Semiconductor Screening



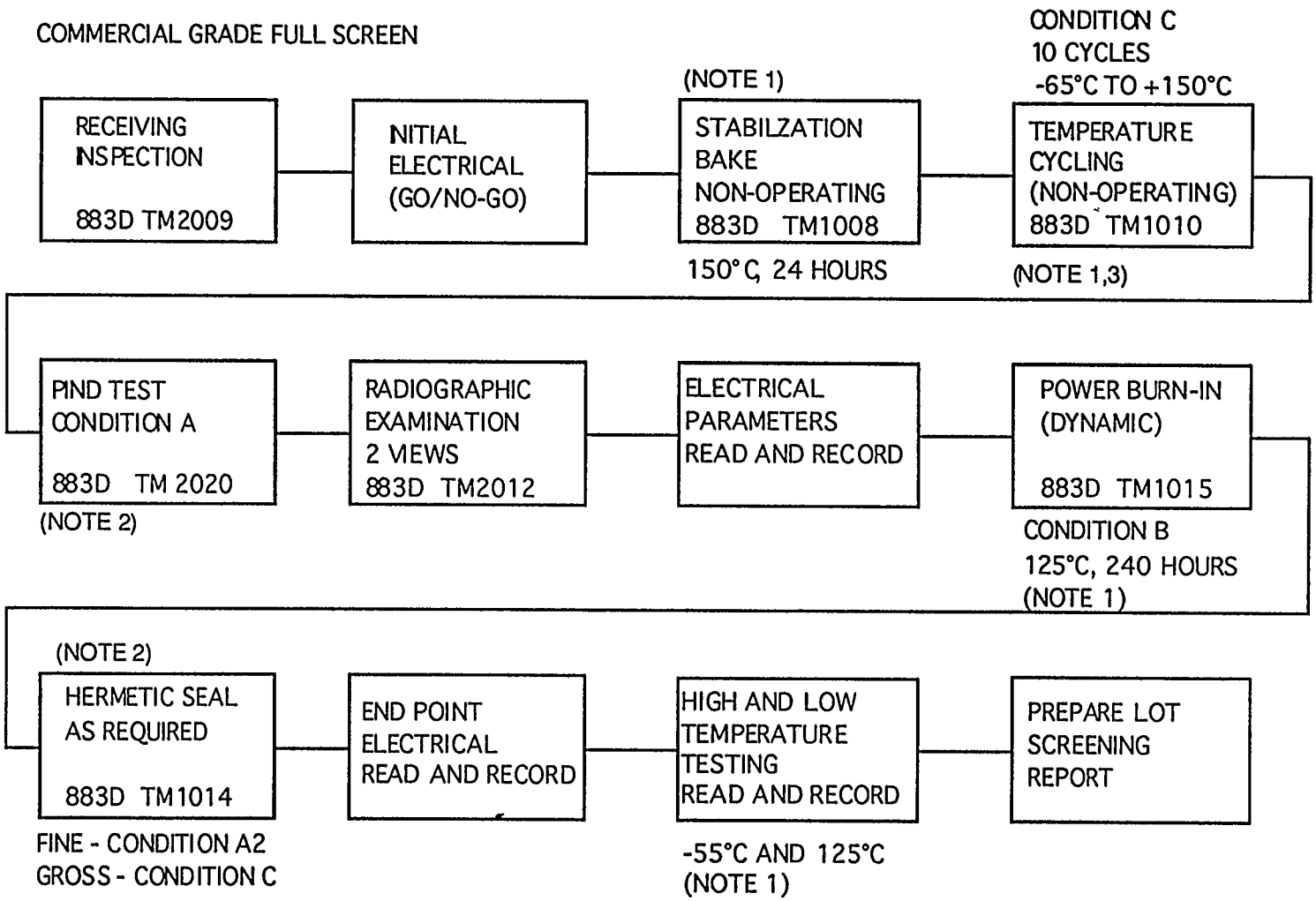
NOTE 1: APPLICABLE TO CKR11 THRU CKR14 ONLY

Figure 4. Overview of Capacitor Screening



NOTE 1: APPLICABLE TO CRYSTALS, FILTERS AND RELAYS ONLY

Figure 5. Overview of Other Passive Part Screening



NOTE 1: PARTS WITH KNOWN TEMP LIMITS ARE TESTED AT REDUCED TEMPERATURES
NOTE 2: NOT APPROPRIATE FOR PLASTIC PARTS
NOTE 3: SAMPLE OF LOT TESTED FOR PLASTIC PARTS

Figure 6. Detailed Integrated Circuit Screening

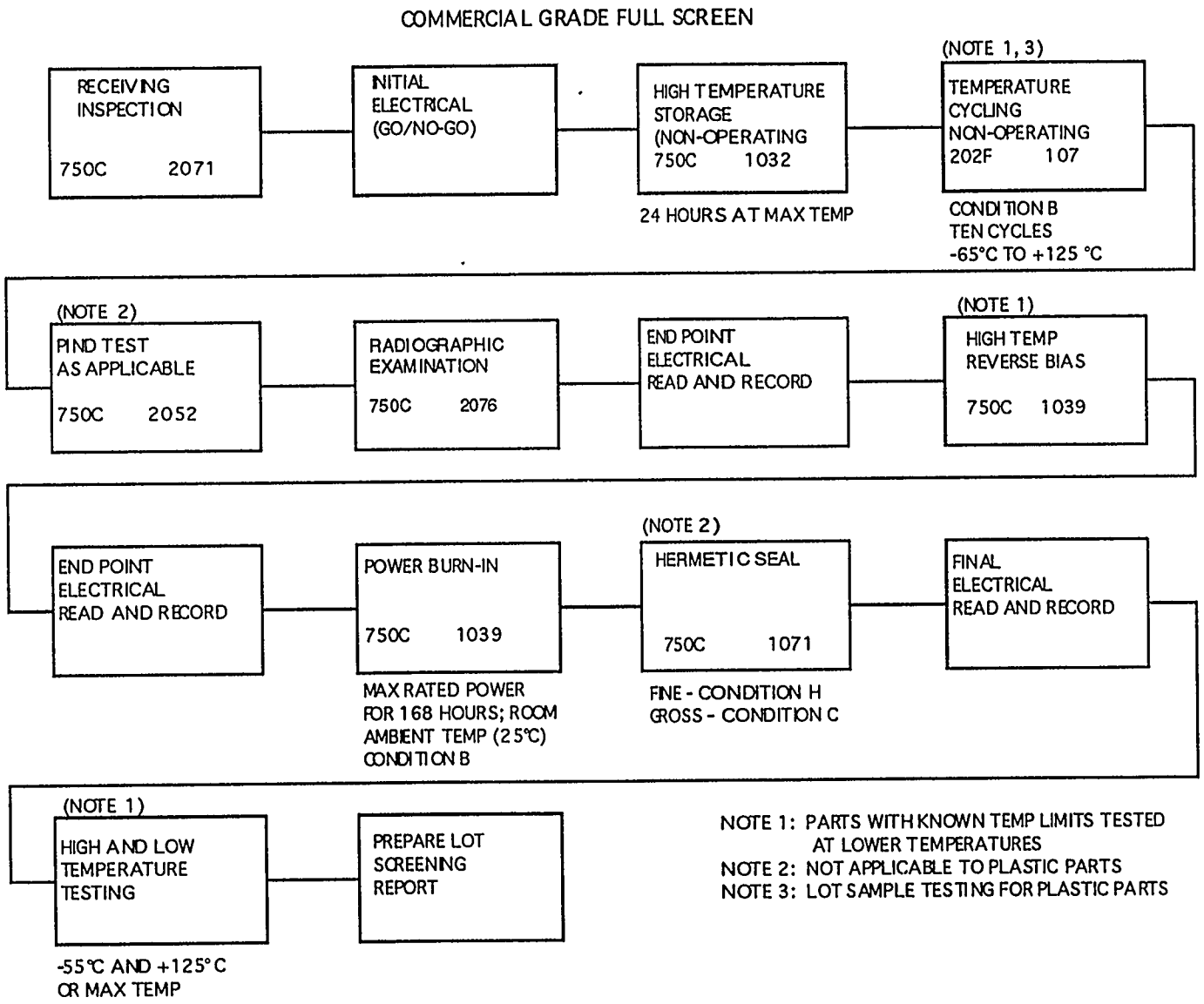


Figure 7. Detailed Transistor Screening

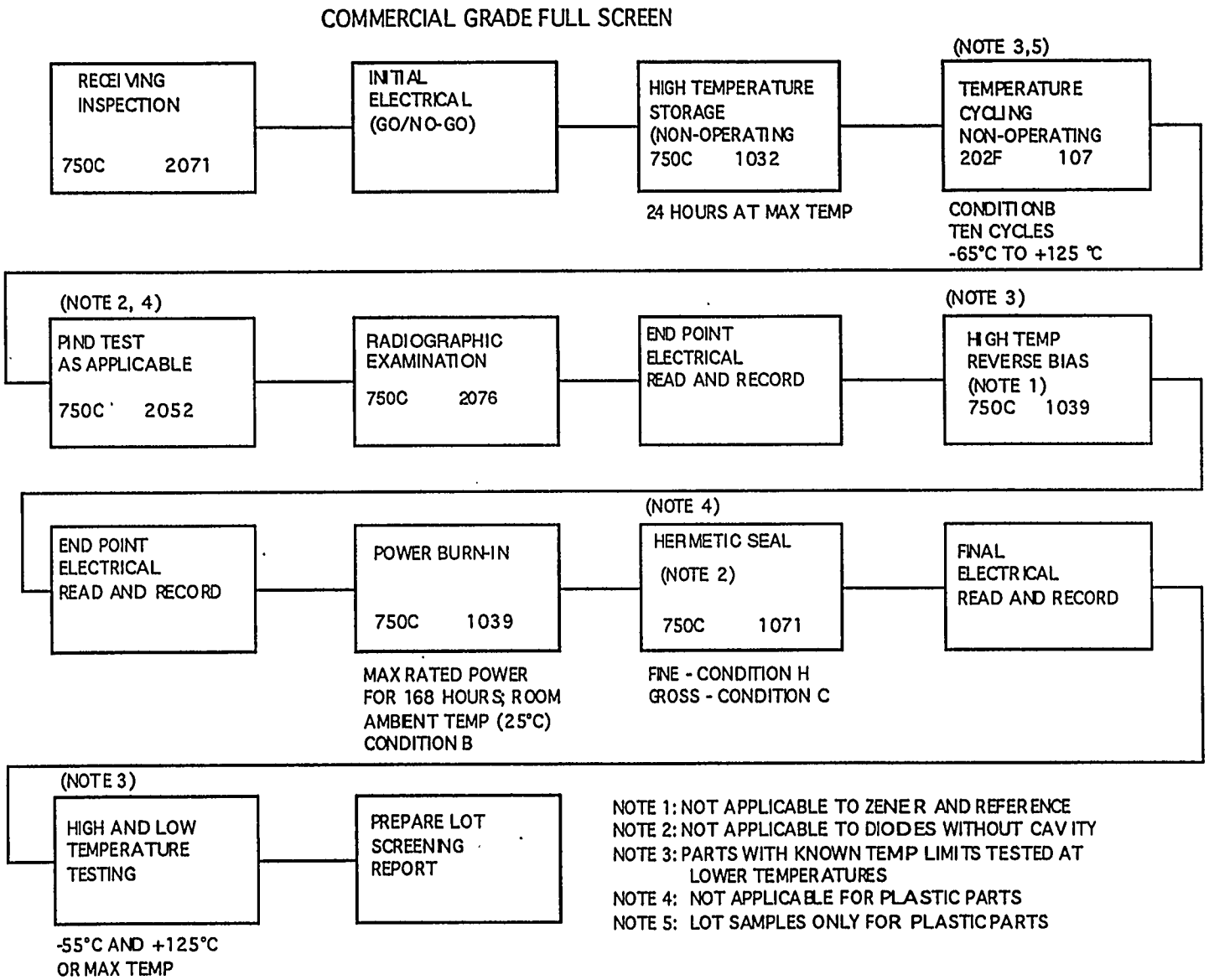
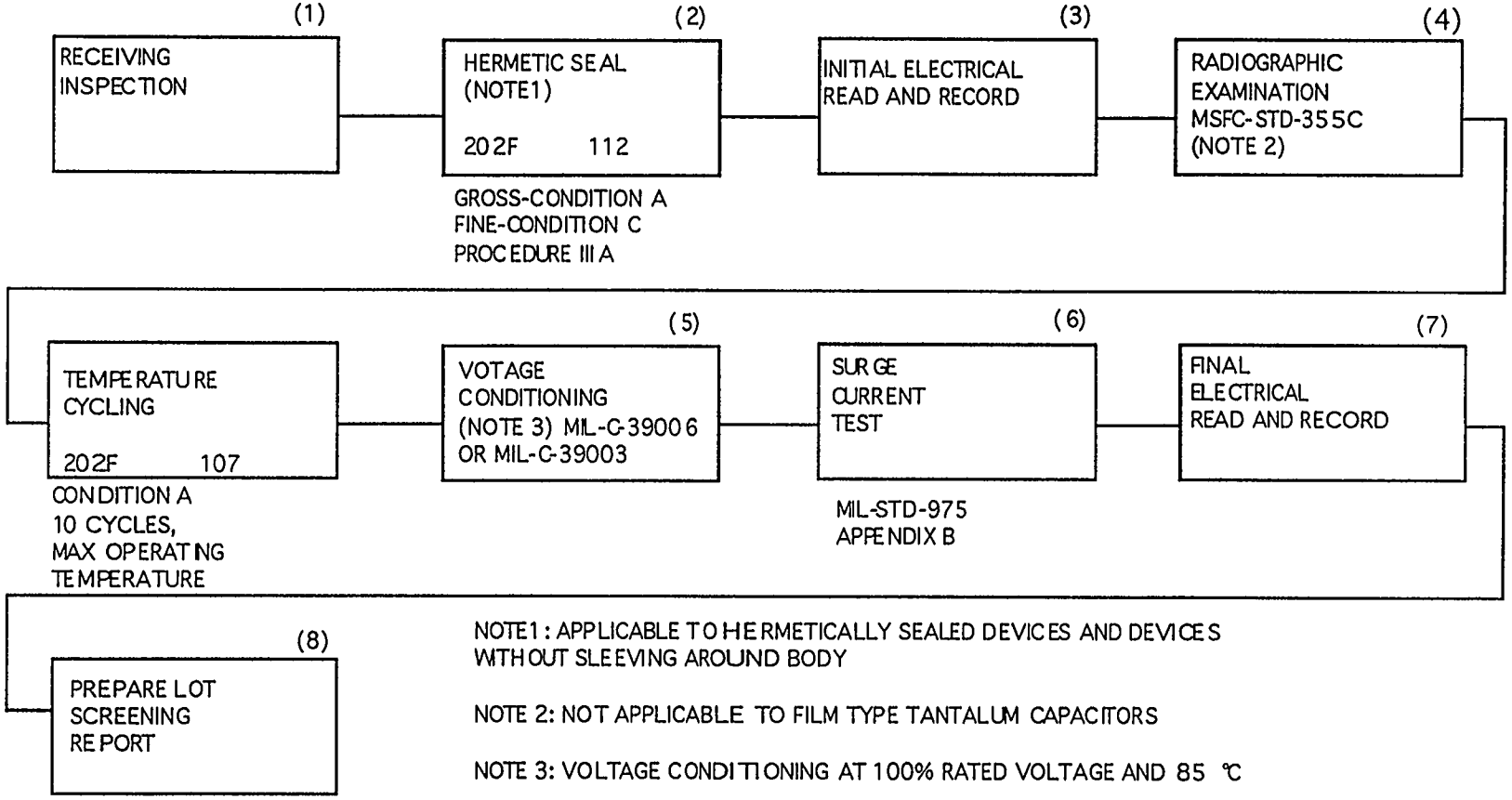


Figure 8. Detailed Diode Screening

COMMERCIAL GRADE FULL SCREEN



NOTE1: APPLICABLE TO HERMETICALLY SEALED DEVICES AND DEVICES WITHOUT SLEEVING AROUND BODY

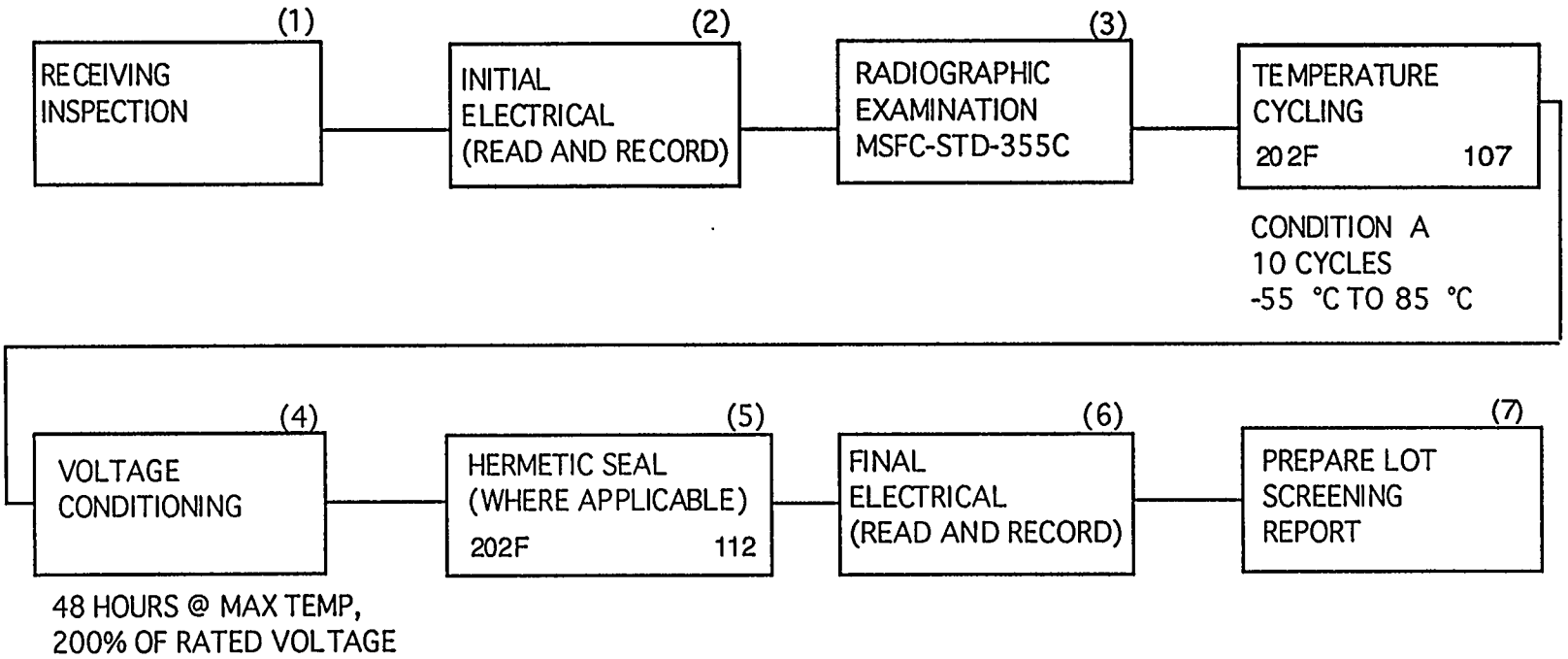
NOTE 2: NOT APPLICABLE TO FILM TYPE TANTALUM CAPACITORS

NOTE 3: VOLTAGE CONDITIONING AT 100% RATED VOLTAGE AND 85 °C

SUPPLEMENTAL SCREENING REQUIRES STEPS 1 THRU 8

Figure 9. Detailed Tantalum Capacitor Screening

COMMERCIAL GRADE FULL SCREEN



M OR P LEVEL SUPPLEMENTAL SCREEN: STEPS 1 THRU 7, EXCEPT THAT STEP 2 IS A GO / NOTO TEST AND STEP 3 IS APPLICABLE TO CKR11 THRU CKR14 ONLY

Figure 10. Detailed Ceramic Capacitor Screening

COMMERCIAL GRADE FULL SCREEN

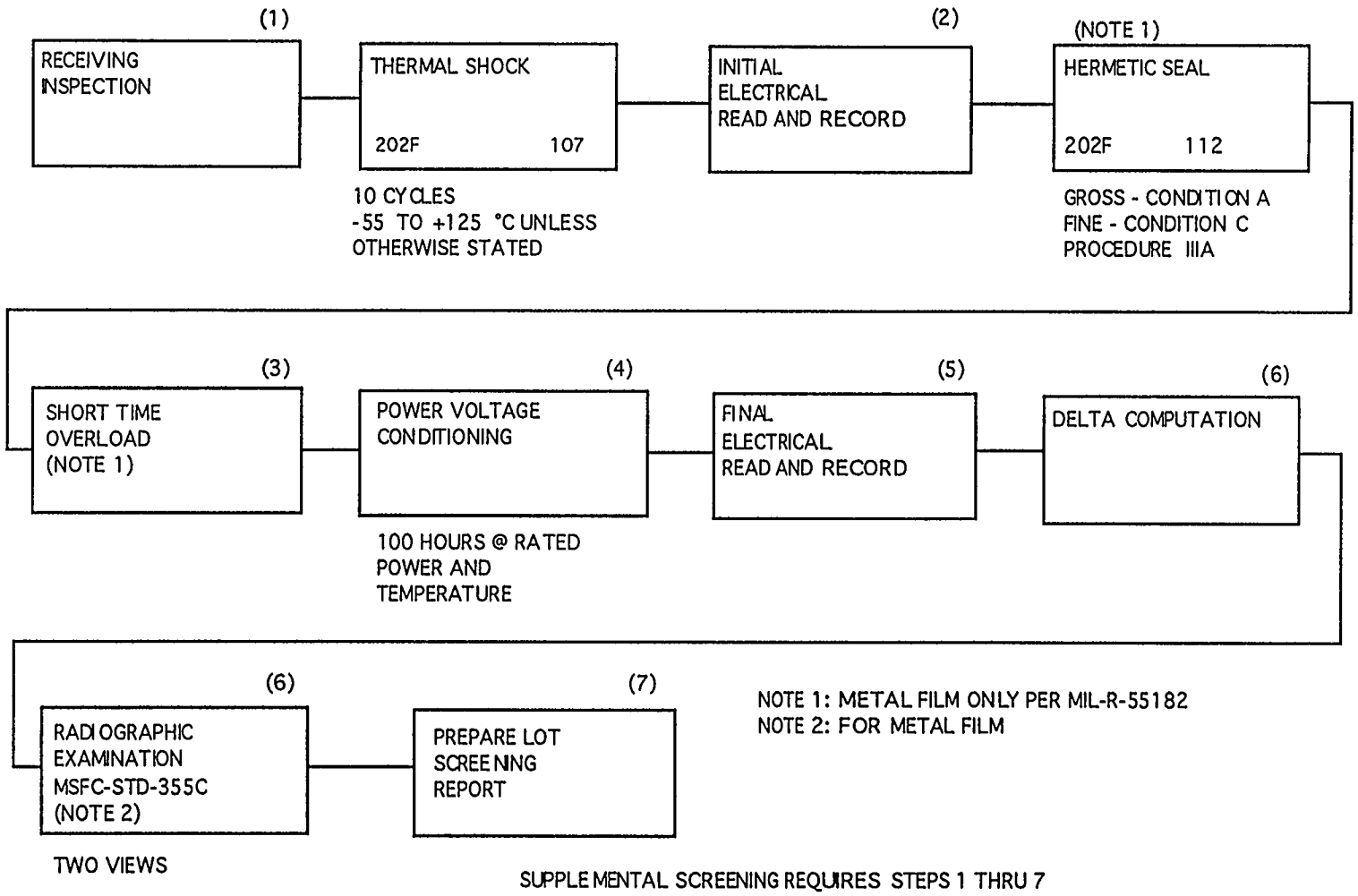
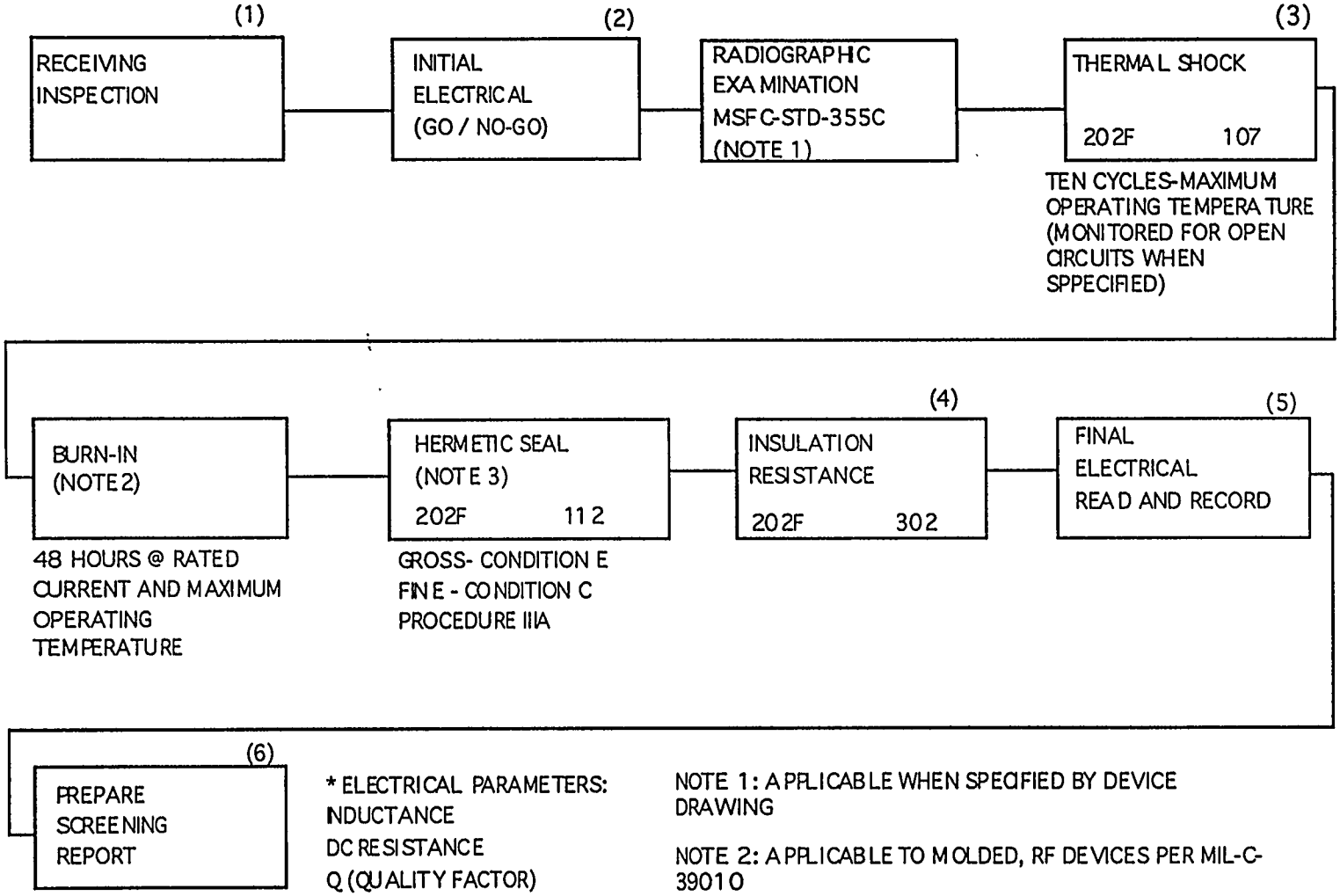


Figure 11. Detailed Resistor Screening

COMMERCIAL GRADE FULL SCREEN



* ELECTRICAL PARAMETERS:
INDUCTANCE
DC RESISTANCE
Q (QUALITY FACTOR)

NOTE 1: APPLICABLE WHEN SPECIFIED BY DEVICE DRAWING

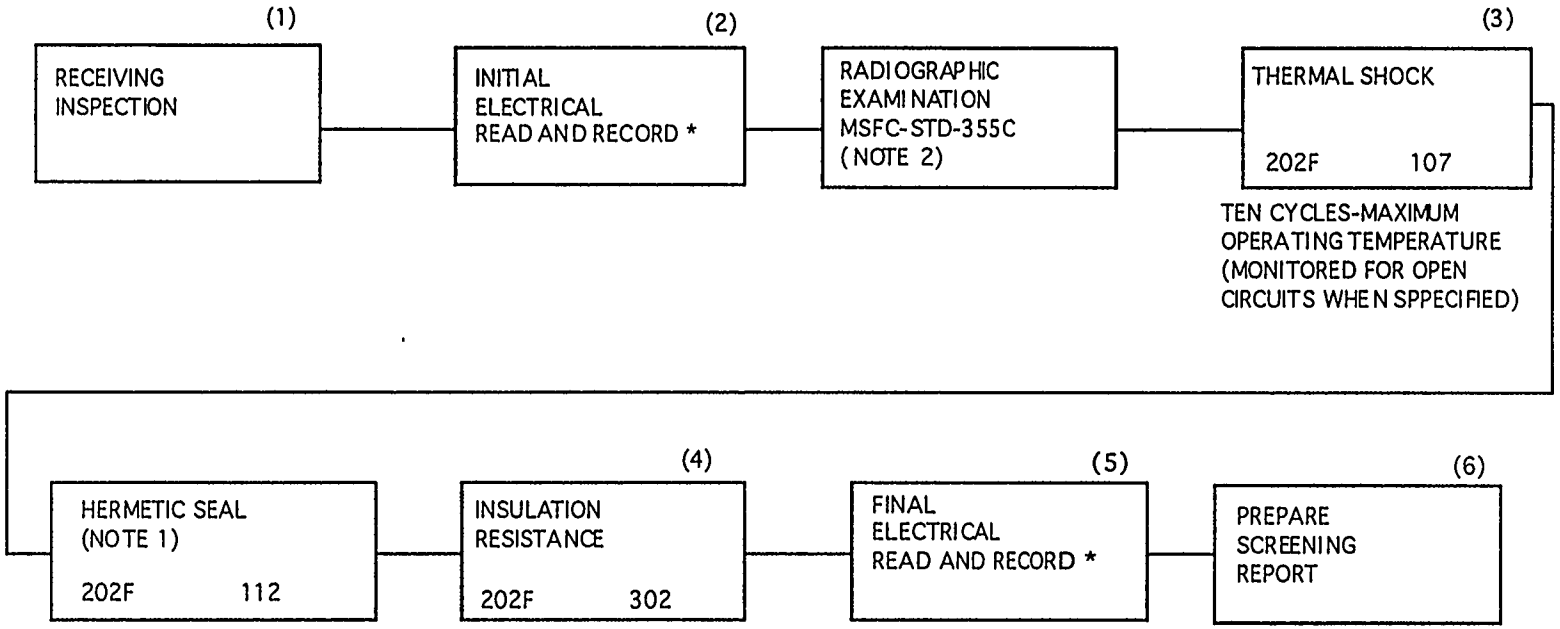
NOTE 2: APPLICABLE TO MOLDED, RF DEVICES PER MIL-C-39010

NOTE 3: APPLICABLE ONLY TO HERMETIC DEVICES

SUPPLEMENTAL SCREENING REQUIRES STEPS 1 THRU 6

Figure 12. Detailed Inductor Screening

COMMERCIAL GRADE FULL SCREEN



* ELECTRICAL PARAMETERS:
INDUCTANCE
DC RESISTANCE
Q (QUALITY FACTOR)

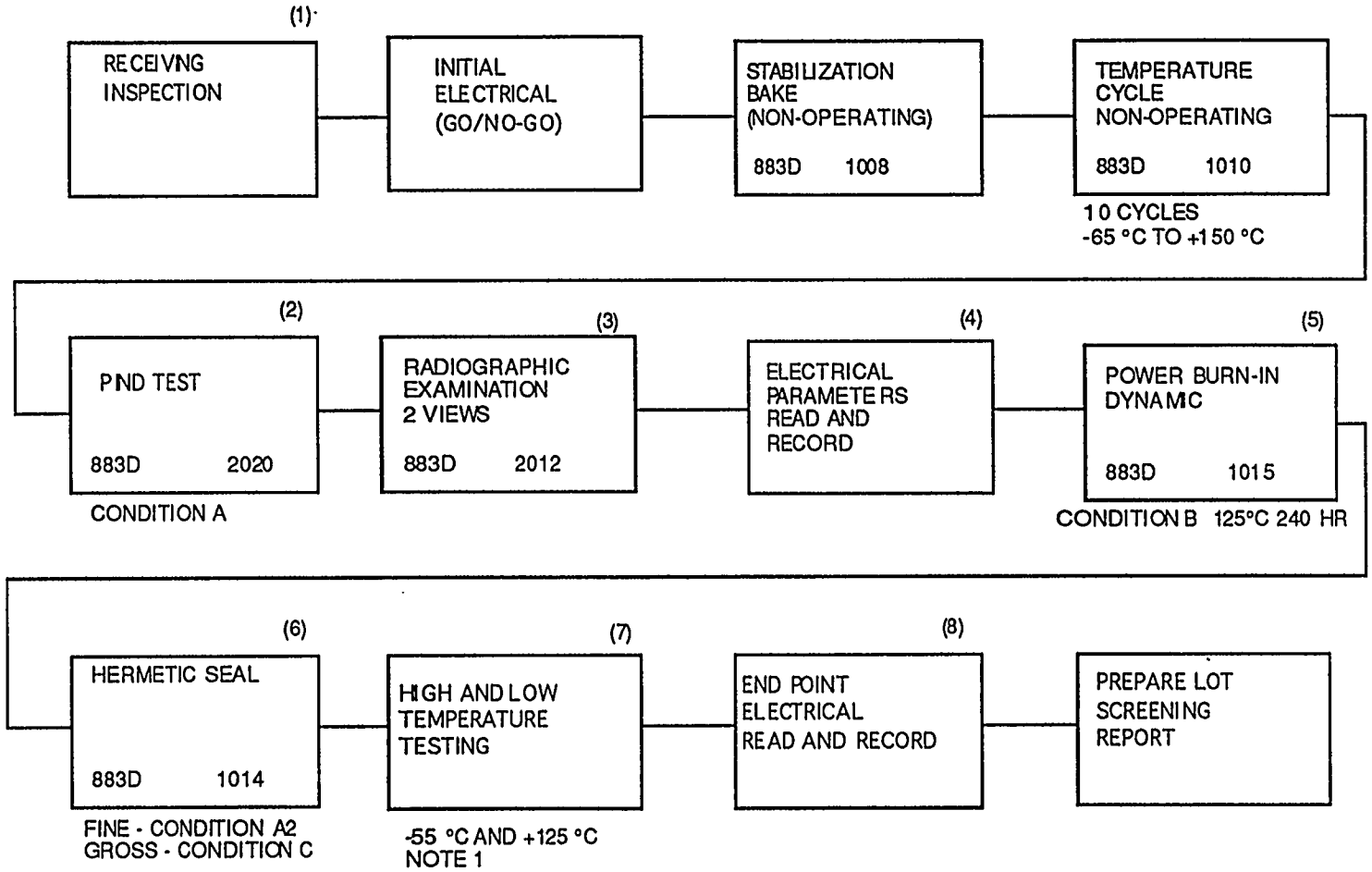
NOTE 1: APPLICABLE TO HERMETIC DEVICES

NOTE 2: APPLICABLE WHEN SPECIFIED IN DEVICE DRAWING

SUPPLEMENTAL SCREENING REQUIRES STEPS 1 THRU 6, EXCEPT THAT STEP 2 IS A GO/ NO-GO TEST.

Figure 13. Detailed Transformer Screening

COMMERCIAL GRADE FULL SCREEN

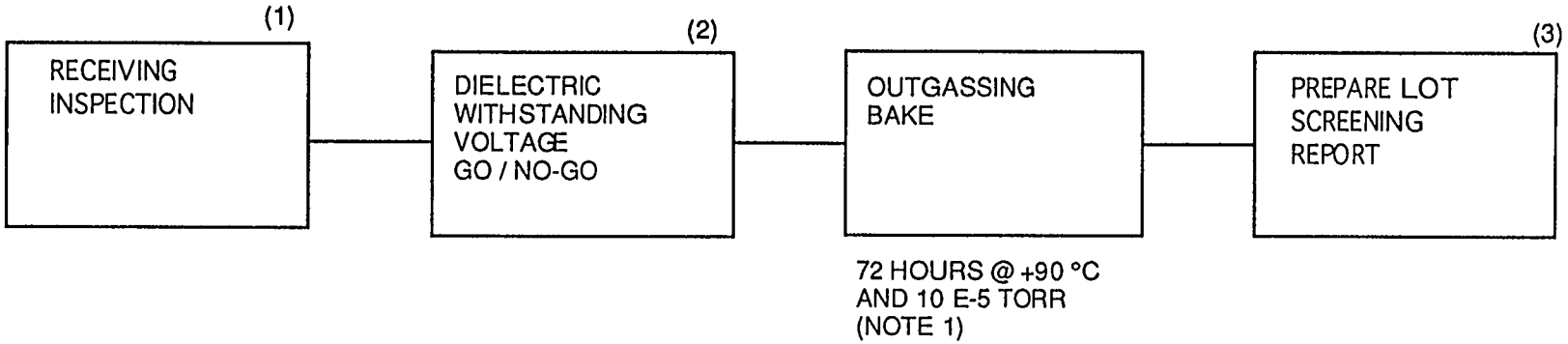


NOTE 1: PARTS WITH KNOWN TEMP LIMITS USE REDUCED TEMPERATURES

PARTIAL SCREENING REQUIRES STEPS 1 THRU 8, EXCEPT THE DURATION OF STEP 5 IS 96 HOURS

Figure 14. Detailed Crystal Oscillator Screening

COMMERCIAL GRADE FULL SCREEN



NOTE 1: PARTS WITH KNOWN TEMPERATURE LIMITS WILL HAVE REDUCED TEMPERATURES

SUPPLEMENTAL SCREEN:

STEPS 1 THROUGH 3 ONLY, ONLY IF THE OUTGASSING BAKE HAS BEEN DONE BY THE MANUFACTURER

Figure 15. Detailed Connector Screening

Appendix A.5

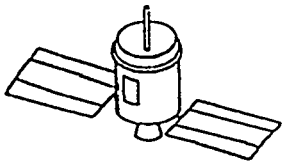
Clementine Sensor Suite Waiver Procedure

(C1-S0-006)

Clementine Sensor Suite
Waiver Procedure

	Date	Rev.	Date	Approval
Prepared by: W. R. Bryson	15 Mar 93			
Reviewed by: J. F. Kordas	18 MAR 93			
Reviewed by: E. H. Schmitt	18 Mar 93			
Reviewed by: R. E. Priest	16 Mar 93			
Reviewed by: R. F. Hills	15 MAR 93			
Reviewed by: M. J. Shannon	18 Mar 93			
Approved by: L. D. Pleasance	31 Mar 93			

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-S0-006
TITLE: Clementine Sensor Suite Waiver Procedure	ASSY: All ORIG: W. R. Bryson DATE: 15 March. 1993 APPR:



Abstract:

This document describes the conditions and methods for use of formal waivers in the Clementine Sensor Integration Project.

Lawrence Livermore National Laboratory		Total Document Pages: 3

1. Scope

This document describes the formal waiver procedure that applies to any component that fails to meet the Clementine mission requirements.

2. Purpose

In order to meet the mission reliability requirements, all components and piece parts (refered to as components from here on) are required to meet certain minimum standards. If any component does not meet these standards, then a procedure is required to determine the effects of this deficiency, explore possible alternative routes and ultimately accept the component as it is or the reject it. This procedure describes the LLNL Clementine Sensor Integration Project's Waiver Procedure.

3. Conditions Requiring Waivers

In all cases where a component fails to meet the mission radiation environment, fails to meet the required screening procedure or does not meet purchase/manufacture specifications, a formal waiver must be requested. These conditions shall include but are not limited to the following:

1) EE Parts that do not meet the 20 Krad(Si) mission requirement.
2) EE Parts that are not single event upset immune.
3) EE Parts that are not single event latchup immune.
4) EE Parts that do not meet the Clementine Sensor Integration Project Parts Program requirements, C1-EE-022.
5) Purchased or manufactured parts, components or subsystems that do not meet their specifications or standards.

4. Handling of Waiver Requests

4.1 Any purchased or manufactured part, component or subsystem (referred to as parts from here on) that requires a waiver, shall have a failure modes and analysis (on the affected system) done to determine the possible consequences to the mission.

4.2 A formal waiver request shall be prepared for the part outlining the results of 4.1 and providing alternatives to using the part. The waiver should be signed by the cognizant engineer and shall include her/his recommendation for acceptance or denial of the waiver. See Appendix A for a sample of the waiver request form.

4.3 Waivers shall be approved/disapproved by the Clementine/DSPSE waiver review committee. This committee is comprised of two representatives from LLNL, two from the NRL and one from SDIO. Waivers may be resolved formally, through meetings, or informally through telephone and FAX communications. The SDIO chairperson will determine the resolution process.

4.4 A record of waiver requests, approvals and denials shall be kept by the Clementine Quality Assurance Group.

DSPSE

Approval Need Date:

Waiver Request

DSPSE Project	Waiver Number:	Sheet 1 of

Requester:	Organization:	Phone:	Date:

System / Subsystem Effected	Related Waivers

Deliverable:

Original Requirement (List specific requirement, indicating document title, #, section and paragraph, attach additional pages as required)

Waiver Requested (Be Specific, attach additional pages as required)

Justification for Waiver: (attach additional pages as required)

Effect on Performance of Deliverable (If waiver is approved, attach additional pages as required)

APPROVAL / ROUTING
(Attach Reasons for Disapproval)

Title	Signature	Date	Yes	No
LLNL QA			☐	☐
LLNL Sys Eng			☐	☐
NRL			☐	☐
NRL			☐	☐
SDIO			☐	☐

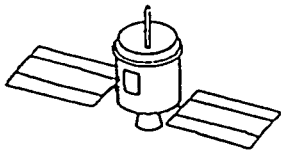
Distribution:

Appendix A.6

Parylene Conformal Coating

(C1-S0-009)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-S0-009 Rev 01
TITLE: Parylene Conformal Coating	ASSY: All ORIG: W. R. Bryson DATE: 21 Sept. 93 APPR:



Abstract:

This document describes the requirements for inspection, cleaning, masking, priming and application of Parylene conformal coatings.

Lawrence Livermore National Laboratory		Total Document Pages: 15

1 Scope

This document describes the requirements for inspection, cleaning, masking, priming and application of Parylene conformal coatings.

2 Inspection

2.1 All printed wiring assemblies shall be inspected prior to conformal coating. This inspection is to insure that the assembly has received no damage during verification and testing, that it is free of all contamination, all staking and gluing operations have been completed and all fasteners have been torqued. All rework must be completed at this point. The Assembly Log must be current and complete. The date of this final inspection and any discrepancies shall be recorded in the Assembly Log.

3 Final Cleaning

The cleaning of substrates is an extremely important step and is critical to obtaining good adhesion of Parylene. Reagent grade or equivalent solvents shall be used for all cleaning operations. Surface contamination, such as ionic and organic residues, and especially finger prints and residual solder fluxes, must be removed. These contaminants are difficult to detect but, if not removed, can cause reduction in or loss of adhesion.

Caution:

All printed wiring assemblies are to be handled with clean room gloves or finger cots from this point on.

Printed wiring assemblies are to be stored in a New anti static bag with desiccant during transportation and storage from this point on.

The shelf life of the solution prepared in 3.3 is 24 hours. Dispose of this solution after that time.

Isopropyl alcohol is poisonous.

All waste disposal must be in accordance with Federal, state and local laws and regulations in addition to LLNL and DOE rules and regulations.

3.1 All printed wiring assemblies shall be given a final cleaning in the Freon degreaser prior to conformal coating. This cleaning shall be done according to posted cleaning procedures.

3.2 Assemblies shall to be allowed to air dry for at least 30 minutes.

3.3 Prepare a Silane A174 solution using the following proportions:

1.0 ml A174
5.0 ml De-ionized Water
1000 ml reagent grade isopropyl alcohol

Allow this solution to stand overnight or stir for two hours prior to use.

3.4 Immerse the printed wiring assembly in reagent grade isopropyl alcohol for 10 minutes.

3.5 Immerse the printed wiring assembly in the Silane A174 solution prepared in 3.3 for 30 minutes.

3.6 Remove the printed wiring assembly from the Silane A174 solution and allow to air dry for 30 minutes. Suspend the assembly to insure that any solution draining off does not contact the assembly.

3.7 Rinse the printed wiring assembly in reagent grade isopropyl alcohol for 5 minutes.

3.8 Allow the printed wiring assembly to air dry for 30 minutes.

4. Bake and Vacuum Drying

Cleaned printed wiring assemblies must be baked to remove all moisture and volatiles.

4.1 Place the printed wiring assembly in a suitable temperature chamber and bake at 95 ± 5 °C for 6 hours.

4.2 Transfer the printed wiring assembly to a vacuum chamber and pump until the pressure in the vacuum chamber stabilizes at less than 10^{-6} torr.

4.3 Allow the printed wiring board to remain in the vacuum chamber for at least 6 hours.

4.4 Back fill the vacuum chamber with dry nitrogen, remove the assembly and place in a new clean antistatic bag with desiccant.

Note: Handle the assembly with new, clean room gloves or finger cots.

5. Masking Prior to Parylene Coating

5.1 Mask all areas of the assembly that are not to be Parylene coated according to the appropriate procedure using Techform TC-530. Allow the masking to cure.

6. Parylene Coating

6.1 Apply a 0.5 to 1.0 mil coating of Parylene using the methods described in appendix A of this document.

6.2 Upon completion of the coating process, remove the assembly immediately to a clean antistatic bag with desiccant. **All further operations on the assembly must be completed in a clean room environment.**

Appendix A.

Prepared by Joseph W. Burris

Section 1: Operating Procedure.

1.1 This section details the techniques required to perform Parylene deposition with the Specialty Coating Systems, Inc. Model 2010.

1.2 Cold Trap Operation

Warning: Operation of cryogenic devices poses the threat of severe injury. Refer to Section 2.4 for safety precautions required when operating the Model 2010 cold trap.

Mechanical Chiller

The Model 2010 is equipped with a mechanical chilling unit, including a cold trap thimble which inserts into the cold trap housing. For operation of this unit, follow the manufacturer's instructions.

Note: The mechanical chiller is equipped with a "T" type thermocouple which measures the temperature of the probe. This thermocouple may be used to monitor cold trap temperature during a coating cycle. If this temperature is being monitored, the vaporizer heaters should not be enabled until the cold trap probe is below -75°C. If this temperature is not being monitored, the mechanical chiller should be allowed to operate for at least 45 minutes prior to initiating the vaporizer heaters. (This is done to ensure that the cold trap is at low enough temperature to adequately capture Parylene process by-products and hence protect the vacuum pump.)

1.3 Automatic Coating Cycle

Preparation

1. Check the log book located on the front door of the PDS 2010 for the following:
   A) Not more than 9 Parylene coating runs have been made since the last vacuum pump oil change.
   B) Not more than 100 grams of Parylene dimer have been processed since the last vacuum pump oil change.

   Note 1: Vacuum pump oil changes will be noted in the log book remarks column.

Note 2: If either A or B above has been exceeded contact maintenance person listed on right side panel of PDS 2010 (proceed no further until vacuum pump oil has been changed).

2. Open the front door of the PDS 2010 and check the vacuum pump oil level located in the lower right-hand corner. The oil level should be between the "Full" arrow and the "Add" arrow. The oil should not appear cloudy, dirty, or otherwise contaminated.

Note: Any problems with oil level or clarity contact maintenance person listed on right-side panel of PDS 2010. Proceed no further until problems are corrected.

3. Weigh the Parylene dimer to be processed and enter the amount in the log book.

4. Place the Parylene dimer in the "dimer boat" and load into the vaporizer through the access port which is located in the lower front compartment.

5. Treat all surfaces of the baffle, chamber interior, and cold trap thimble with a release agent (2% soap solution). Refer to Section 3.1.1.

6. Insert the baffle in the inlet opening. Use high-temperature tape to retain the baffle securely in position.

Important: Be sure to tape the small gap which may exist at the rear side of the baffle/inlet port interface (the side closest to the center of the chamber). Failure to tape this gap results in a monomer gas path which leads directly to the substrate, without passing through the baffle. This could have a detrimental impact on coating quality.

7. Hang parts to be coated from the fixture and place the fixture on the chamber base. Allow clearance around pump outlet and avoid direct contact with the inlet baffle. Enter board size, type of board and the number of boards being processed into the log book.

Note: It is important that a glass witness plate (located next to the PDS 2010) also be hung from the fixture for each coating run. This allows coating thickness to be measured.

8. Make sure the o-rings and gaskets and their matching surfaces are very clean. Lower chamber over the base, insert cold trap thimble into the cold trap housing, close and seal the vaporizer access door.

9. Start the mechanical chiller.

Start-Up

10. Switch on Main Power. The white indicator will be illuminated, the computer will initialize, and the vacuum and temperature controllers will illuminate. Enter the "Start Time" in the log book.

11. Switch "on" the furnace/gauge, evacuate, vaporizer, and alarm rocker switches. Press cold trap thimble so that it is flat against the cold trap housing to form a vacuum seal.

Computer Control Sequence

With all control switches enabled as above, the computer will automatically control the deposition process in the following sequence:

12-1. Furnace and gauge tube heaters come on and heat up to the set point value (SU). Pump comes on and begins pumping down the system:

- Vaporizer is disabled.
- Fault alarm is disabled.

12-2. When the furnace and gauge tube heater are within the allowable deviations of their setpoint (±15°C), the pump pressure is below base pressure as indicated by the "L" light on the vacuum controller, and the protracted pump down timer has timed out:

- The vaporizer is enabled and begins to ramp up.
- The fault alarm remains disabled.

12-3. When the vaporizer exceeds 90°C, coating has begun:

- Fault alarm monitoring is enabled.
- End of run monitoring is enabled.

12-4. If the furnace or gauge tube should go out of their allowable limits, or the pump pressure exceeds 100, a fault alarm will be indicated:

- Red Fault Light comes on.
- Audio alarm is sounded (this can be silenced by turning off the alarm rocker switch).
- The 5 minute fault alarm timer is initiated. If the fault does not clear before the time elapses, then a shut down will be initiated as described in item 12-6.

12-5. When the coating run has completed:

- Vaporizer will hold at a temperature of 175°C.

- The pump pressure will go below base pressure.
- The 5 minute end of run timer begins timing out before initiating a shut down as described in item 12-6.

12-6. A controlled shutdown will occur when end-of-run or a fault condition has been indicated:

- The furnace, gauge tube, and vaporizer heaters are disabled.
- The pump remains on to secure the process by preserving the vacuum.

End of Run

13. Turn off the cold tap.

14. Place the vacuum switch in the vent position. After venting, push the vacuum switch in the center off position. The chamber is now ready to be unloaded.

In order to preclude contamination and accumulation of water vapor, evacuate the vacuum system before shutting down the equipment.

15. Unload chamber and clean unit, refer to Section 3.1.1.

1.4 Successive Runs

If a another run is desired, the following preparation must be taken:

1. Turn off the heater output control switches.

Important: DO NOT re-enable the furnace/gauge tube heaters at this time by leaving the furnace/gauge tube control switch on and pressing the computer reset button. If the furnace and gauge heaters remain at operating temperatures when the computer is reset, it will be interpreted as a brief power interruption, and the vaporizer heaters will be enabled prematurely.

2. Remove and clean the cold trap thimble. (Beware of extremely cold temperature, wear protective gloves.)

3. Hang parts on fixture (Caution: the chamber base inlet and baffle may be hot.)

4. After the vaporizer has cooled below 90°C, load a new charge of Parylene dimer. Loading the vaporizer above this temperature will cause immediate vaporization of Parylene dimer, causing pump down

problems and possibly degradation of the subsequent coating run (wear protective gloves if vaporizer has not cooled completely).

5. Reseal chamber, could trap thimble, and vaporizer door.

6. Re-start the cold trap.

7. Turn on the heater control switches and place the vacuum switch to Evacuate (observe pump down rate for possible leaks).

8. Push the computer reset button to restart the program.

9. See items 13, 14, and 15 above for "end of run" procedures.

Section 2: Machine Safety

The Model 2010 Parylene Deposition System contains potential safety hazards to operators and service personnel if appropriate precautions are not followed. These potential hazards include:

- Electric shock
- Thermal burns
- Contact freeze injury by cryogenic apparatus
- Catastrophic loss of vacuum/implosion

The following sections describe the precautions which should be reviewed and observed prior to operation of this unit. Unless service is being performed by qualified and authorized personnel, all access panels to the Model 2010 cabinet should be closed whenever the machine is powered.

2.1. Vapor and Pyrolysis Section

Under normal operating conditions, the vaporizer and pyrolysis furnace and nearby components are maintained at temperatures which can cause burns on contact, and are powered at 110 volts AC. These areas are enclosed within the 2010 cabinet and should not be touched any time the machine is powered or during cool down after a coating cycle.

2.2 Dimer Loading Door

The loading door heating element is controlled as a part of the vaporizer. A metal shield covers the heating element to protect against electric shock. However, when the vaporizer is enabled, this shield becomes hot. This part of the coating unit should not be touched during heat-up, deposition, or cool down after a coating cycle. Wear protective gloves if it becomes necessary to open the loading door when the door is hot.

2.3 Deposition Chamber Vacuum Sensor

The chamber vacuum sensor must be heated to prevent deposition of Parylene on the sensing elements. Protective gloves should be worn if it becomes necessary to handle the heating element or the sensor itself when they are hot.

2.4 Cold Trap

The Model 2010 is available with a mechanical chiller unit in lieu of the liquid nitrogen system. The surface of the thimble with this configuration can reach temperatures below negative 120 °C. Caution should be exercised to avoid direct skin contact with the thimble of a mechanical chiller cold trap when it is cold.

2.5 Inlet Baffle

Protective gloves should be worn when removing the inlet baffle from the deposition chamber after a coating run. This baffle may become heated to temperatures in excess of 200 °C via radiation from the pyrolysis furnace during deposition.

2.6 Glass Viewports

Glass viewport(s) are provided to allow viewing of the substrate and fixturing during the coating process. A viewport which is damaged or improperly installed poses a potential implosion threat while the chamber is under vacuum. Such an implosion would likely damage the substrate and/or the coating equipment, and could possible cause personal injury.

Do not operate the Model 2010 if one of the viewports is cracked or improperly installed. Avoid impacts to the viewport surfaces while the system is under vacuum.

Section 3. Maintenance Procedures

3.1 Routine Maintenance and Inspections

As with any coating process, substrate and equipment cleanliness are the keys to a high quality coating. Keeping the Model 2010 free from dust, dirt, and grime, both inside and out, will insure a clean substrate and good Parylene deposition. Conscientious observance of the following instructions can help assure smooth operation with minimal downtime.

3.1.1 Parylene Deposition Removal

The nature of the Parylene coating process necessitates the periodic removal of the Parylene that is deposited on the interior surfaces of the coating chamber and related components.

Applying Release Agent

To aid the removal of the deposited film is imperative that a release agent be applied to all surfaces that will be coated and subsequently stripped. A 2% mixture of "Micro® Laboratory Cleaning Solution" (manufactured by International Product Corp.) with de ionized water is an effective release agent. Application is most effectively performed with a spray bottle and a lint-free cloth. Components for application include:

- interior of coating chamber and base
- inlet baffle
- cold trap thimble and housing
- piping between coating chamber and cold trap
- any other items that appear in the coating chamber that will be stripped of film (reusable fixturing, witness strips, etc.)

Once Parylene has been deposited, a Micro, soap interface between the Parylene film and the coating chamber interior has been established. This Micro® soap interface will remain until the Parylene film has been removed. It is not necessary to apply the release agent to the Parylene film itself, but only to the bare, uncoated surfaces that will receive a coating during the first deposition cycle after cleaning.

NOTE: It is not necessary nor desirable to apply Micro® soap to any o-ring or gasket.

Parylene Coating Removal

The following items should be cleaned when the coating becomes excessively heavy, blisters or separates from the surface.

- Deposition Chamber
- Viewing Port
- Inlet Baffle
- Chamber Ports, Inlet and Exit

Parylene deposits thicker than .001 inch on the chamber interior walls, base and baffle should be stripped. Avoid using sharp tools for removing deposits, as they can nick the surfaces making it more difficult to remove deposits the next time.

Do not try to remove thin coatings. However, sections of coating that pull away from the surfaces can cause problems if they are not removed. The main problem which can occur is collapsing (or pulling completely away) of the coating when the system has been loaded for a run. When the system is placed under vacuum, air entrapped under the coating will migrate, possibly pulling the coating away completely. If this happens in the deposition chamber, the coating will surround the fixture, preventing the dimer from depositing properly. If this happens in the pump out port, the collapsed coating could reduce or eliminate the vacuum needed to achieve an acceptable quality coating.

Cold Trap Thimble

To insure the coldest possible cold trap thimble surfaces, deposits should be removed after each run. Also, corrosive compounds are produced (in small amounts) as a by-product of Parylene deposition and are subsequently condensed on the thimble surface. Therefore, regular cleaning is imperative to prevent corrosion and pitting of the cold trap thimble. See MACHINE SAFETY (Section 3) for precautions required when handling cryogenic apparatus.

Non-metallic Abrasive pads, such as "Scotch Brite", have been found to be useful for removing the thin layers of polymer that deposit on the lower portion of the thimble.

5.1.2 Vacuum Integrity

Vacuum leaks are usually due to contamination of sealing surfaces and o-rings. The contamination, in most cases, has been found to be small particles of trapped polymer. It is good operating practice to check the sealing surfaces of the vaporizer access door, chamber ring, and cold trap thimble flange prior to pumping the system down. For leak detection, the use of solvents is NOT recommended. Solvent flammability and noxious vapor creation could result in serious injury or equipment damage. Use of a helium leak detection system is the approved method.

5.1.3 Vacuum Pump

The oil in the vacuum pump not only provides lubrication and wear-protection for the pumps internal components, but also performs a critical role in the pump's ability to reach its ultimate pressure. For optimum performance, the pump oil should be keep free from foreign particles and excessive condensable vapors. The Model 2010 includes both a cold trap and a wire mesh inlet screen to protect the pump from most contaminants. However, as with any oil-lubricated device, the pump will require routine oil changes. (Refer to the documentation supplied by the manufacturer for a complete description of operation and service to the vacuum pump.)

Oil changes for the Model 2010 vacuum pump should be scheduled based upon the following events, whichever comes first:

- After 10 coating runs.
- After a process throughput of 120 grams of Parylene dimer.
- Anytime that the cold trap has exceeded (been higher than) -75 °C during deposition (such as when the LN_2 source has been exhausted during a run).
- Whenever the oil appears cloudy, dirty, or otherwise contaminated.
- When, after a coating cycle has been performed, the machine is scheduled to be idle for more than one (1) week. (Changing the oil before periods of non-use will prevent corrosion of pump components during storage.)

NOTE: The system base pressure should be regularly monitored. Increases not attributed to vacuum leaks or outgassing usually indicate a deterioration of the pumping system. This deterioration is usually due to the passage of process by-products that are not effectively trapped by the cold trap thimble. In some instances, lower cold trap temperatures will alleviate this condition. Normally, the lower system base pressures can be restored by cleaning the inlet screen at the pump inset and/or changing the pump oil.

5.1.4 Vacuum Pump

The vacuum gauge is heated to 140 °C to protect if from Parylene build-up. However, the small port in the chamber base to which the gauge is connected is subject to build-up. This port should be regularly inspected and stripped as polymer build-up could interfere with the vacuum readings.

5.1.5 Vaporizer

The vaporizer and access door are subject to Parylene dimer film and ash build up. These areas should be cleaned when these conditions are noted in order to prevent coating contamination.

Dimer Boat

A 2% Micro® soap solution, when used with a non-metallic abrasive pad (such as "Scotch Brite") has been found to be effective at cleaning the dark residue which accumulates in the dimer boat after a coating run. Regular removal of this residue will keep the dimer boat free from contaminants and extend its useful life. (If several runs are performed without removing this residue, it tends to harden and becomes more difficult to remove.)

Appendix A.7

Sensor Integration Project StarTracker Camera Interface Control Document

(C1-S1-010)

UNIVERSITY OF CALIFORNIA

LAWRENCE LIVERMORE NATIONAL LABORATORY

SENSOR INTEGRATION PROJECT

STAR TRACKER CAMERA

INTERFACE CONTROL DOCUMENT

5 May 1993 C1-S1-010 Rev OC

NAVAL RESEARCH LABORATORY

NAVAL CENTER FOR SPACE TECHNOLOGY

Star Tracker Camera

Interface Control Document

Approved By:

Lt. Col. P. Rustan
Program Manager
Strategic Defense Initiative Organization

Approved By:

Dr. L. D. Pleasance
Program Manager
Lawrence Livermore National Laboratory

Approved By:

P.A. Regeon
Program Manager
Naval Research Laboratory

RECORD OF CHANGES

Revision Letter	Date	Title or Brief Description	Entered by
DRAFT	12/29/92	RELEASE DRAFT FOR COMMENT	MJS
DRAFT 1	1/5/93	RELEASE REVISED DRAFT	MJS
00	1/12/93	INITIAL RELEASE	MJS
00	1/26/93	ADDED DATES FOR COMPLETION OF TBDS, CHANGED GROUNDING FIGURE. SOLAR EXPOSURE TIME CHANGED FROM 1 MINUTE TO 5 MINUTES; RELEASE FOR APPROVAL SIGNATURE	MJS
0A	2/11/93	UPDATED TABLE 1-1., OFFSET CONTROL, POWER USE REFLECTS LATEST ANALYSIS; UPDATED DOCUMENT NUMBERS SECTION 2; DELETED REFERENCE TO SOLAR HEAT LOAD SECTION 3.1.3, CHANGED SOLAR EXPOSURE DURATION TO TBD; CHANGED AND REVISED SECTIONS 3.3.2, 3.3.3, AND 3.3.4, ADDED POWER DISSIPATION, THERMAL INTERFACE DEFINITION AND RADIATION THERMAL MODEL; DELETED THERMAL ISOLATION OLD SECTION 3.3.4; ADDED CCD TEMPERATURE LIMITS NEW SECTION 3.3.5; CHANGED OPTIC HEATER SECTION TO 3.3.8 OLD 3.3.3; UPDATED FIGURE 3-5 TO REFLECT ADDED OFFSET CONTROL; ADDED OFFSET CONTROL DESCRIPTION SECTION 3.4.11.4, UPDATED TABLE 3-13 AND 3-14 TO DESCRIBE ADDED OFFSET CONTROL; REVISED FIGURE 3-10 INCORPORATED OFFSET CONTROL. CORRECTED FIGURE 3-6.	MJS
OB	4/9/93	ADDED REFERENCE TO CONTAMINATION CONTROL DOCUMENT SECTION 2.2; UPDATED TABLE 3-1; ADDED CENTER OF MASS TOLERANCE TO TABLE 3-2; UPDATED TABLE 3-4B; UPDATED FIGURE 3-1A; UPDATED FIGURE 3-1B; UPDATED BAFFLE ABSORPTIVITY AND EMISSIVITY SPECIFICATION PAGE 3-7; UPDATED THERMAL GRADIENT SPECIFICATION SECTION 3.3.6; ADDED MINIMUM LEAD LENGTH SECTION 3.3.7 AND 3.3.8; UPDATED SECTION 3.4.3	MJS
OC	4/16/93	CLARIFICATION OF ISSUES FOR OFFICIAL DOCUMENT APPROVAL	RFH

CLEMENTINE
Star Tracker Camera
Interface Control Document

	Date	Approval
Prepared by: R. E. Priest	4 May 93	
Prepared by: J.F. Kordas	6 May 93	
Reviewed by: I.T. Lewis	6 May 93	
Reviewed by: A.G. Ledebuhr	7 May 93	
Reviewed by: R. F. Hills	7 May 93	
Reviewed by: M.J. Shannon	6 May 93	
Approved by: L.D. Pleasance	6 May 93	

University of California Lawrence Livermore National Laboratory	Star Tracker Camera Interface Control Document	C1-S1-010 Revision: 0C

PLANNED UPDATES/TBDS

This document contains the best information available as the date of release. Below is a list of items which are currently TBD or are to be changed at a later date. These will be updated when new information becomes available based on ongoing analysis and or tests.

Section 1.4 Sensor General Characteristics Document "Star Tracker Camera Performance Specification, LLNL ENC1-S1-006 will be available 1 June 1993.

Section 3.3. Thermal Interfaces Thermal interfaces are by analysis only at this time. Data obtained in May 1993 from prototype testing will be used to update that information presented.

TABLE OF CONTENTS

1. SCOPE

1.1. Scope

This document is the interface control document (ICD) for the Star Tracker Camera (STC). It identifies the optical, mechanical, thermal and electrical interfaces for the wide field of view (WFOV) Star Tracker Camera (STC) to be used on the deep space program science experiment (DSPSE) spacecraft (Clementine).

1.2. Purpose

The purpose of this document is to define the optical, mechanical, thermal and electrical interfaces for the STC on DSPSE.

1.3. Revision Control

This document contains the sole and controlling definition of the interface for the STC supplied by LLNL for use on the DSPSE spacecraft under construction for the SDIO by the NRL. Revision of this document will be made only under the written authority of the LLNL Sensor Integration Project Manager. Upon acceptance by signature of the information in this document requests for revision may be initiated by either the LLNL or the NRL Program Managers for consideration by a formal, regular and timely procedure conducted under the auspices of the SDIO Program Manager. Subsequent revisions will be incorporated into all relevant documents upon the written direction from the SDIO Program Manager.

1.4. Sensor General Characteristics

As information, the general characteristics of the STC are summarized in Table 1-1. Details are contained in the Star Tracker Camera Performance Specification, LLNL document ENC1-S1-006.

LIST OF ILLUSTRATIONS

LIST OF TABLES

Table 1-1. Star Tracker Camera Characteristics

Attribute	Characteristic
Focal Plane Arrays	
Type	Thomson TH7883-F02-01-B/T Si CCD - 0.4 to 1.1 microns
Pixel Format	384 x 576
Array Size	8.83 x 13.25 mm
Pixel Size	23 x 23 microns
CCD Operating Temperature	10°C Maximum (Clementine spacecraft specific)
Optics	
Type	Concentric Refractive
Aperture	14.0 mm diameter.
Focal Length	17.5 mm
Speed	F/1.25
Imaging	
Spectral Range	0.4 to 1.1 microns
Array FOV	28.9° x 43.4°
IFOV	1.314 x 1.314 milli- radians
Point Spread	20%-40% of image blur energy in 23 μm square and >80% in 75 μm square
Noise Characteristics	< 120 electrons @ 20°C for 50 ms integration time. Dark current and non-uniformity are limiting for longer integration times.
Electronics	
A/D Resolution	8 bits
Frame Rate	<10 Hz
Readout Time	54.8 msec
Digitization	75, 150, 350 e^-/count
Readout Noise	60 e^- RMS
Integration Time	0.2-773 ms (typical ≈150 ms)
Offset Control	248 gray level offset; 5 bit control word; LSB = 8 gray levels
Average Power	
Camera	≤ 3.6 Watts (nominal)
Lens Heater	≤ 1.95 Watts (50% duty cycle @36 v)
Physical	
Envelope	11.7 cm x 11.7 cm x 13.2 cm
Mass	≤ 364g (Includes Baffle Assembly)
Thermal	
CCD Temperature	
Operating	-20 to +10 °C
Non-Operating	-40 to +85 °C
Optics Temperature	
Operating	-20 to +40 °C
Non-operating	-30 to +70 °C
Base plate Temperature	
Operating	-20 to +2 °C
Non-Operating	-30 to +70 °C

2. DOCUMENTS

2.1. Controlling Interface Drawings

Source	Drawing Number	Title
LLNL	AAA92-100839-0B	Star Tracker Camera Mechanical Interface Control

2.2. Reference Documents

Source	Drawing Number	Title
LLNL	LEA92-3128-01-0C	Schematic ACTEL Camera w/ Gain and Offset Control (Address 3)
LLNL	LEA92-3128-11-0C	Schematic ACTEL Camera w/ Gain and Offset Control (Address 6)
LLNL	C1-AAA92-106282-00	Star Tracker Camera Document Tree
LLNL	AAA92-104603-0E	Circuit Board ICD (ACTEL Camera)

Source	Documents	Title
LLNL	DN61033-30520-02	Synchronous Addressable Serial Interface (SASI)
LLNL	C1-EE-031	Actel Camera
LLNL	C1-EE-007	Actel Camera, Power Dissipation Analysis
LLNL	C1-EE-032	Actel Camera, Timing Report
LLNL	ENC1-S1-005	Star Tracker Thermal Circuit Analysis
Mil Spec	MIL-HDBK-340	Application Guidelines for MIL-STD-1540B; Test Requirements for Space Vehicles, Section 5.6.2: Rationale for Definition of Thermal Uncertainty Margin.
LLNL	ENC1-S1-006	Star Tracker Camera Performance Specification
Mil Spec	MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
LLNL	C1-EE-019	Spacecraft Shielding and Grounding
LLNL	C1-S0-008	Clementine Sensor Clean Room Exposure Time Limits

3. INTERFACE DEFINITION

The optical, mechanical, thermal and electrical interfaces are defined in this section.

3.1. Optical Interface

3.1.1. Field of View

The STC must be mounted with a 100% unobstructed field-of-view of 63 by 75 degrees defined per AAA92-100839, under all operating conditions.

3.1.2. Solar Exclusion Angle

A solar exclusion angle of 63 by 75 degrees will be maintained during camera imaging.

68x79 ?

64 x 80 ?

3.1.3. Exposure to Sun Light

The STC has been exposed to direct solar illumination for a period up to five minutes with no apparent degradation in performance. However, this represents a test of one and does not reflect the stress of cumulative effects of multiple exposures nor have these effects been adequately evaluated through analysis or additional tests to give confidence that the STC would survive if routinely operated in this mode. Other than inadvertent exposure, if a requirement exists during spacecraft operation to expose the STC to direct solar illumination, a formal waiver must be requested from SDIO.

3.1.4. Contamination Control

The STC and all surfaces within the partially sealed compartment of the contamination control cover must meet a Level 700 particulate standard per MIL-STD-1246 at the time of launch. Meeting this cleanliness requirement can be achieved by controlling the particulate level of the storage environment.

3.1.4.1 Cleanliness Level Verification

Cleanliness level will be verified by analysis of exposure conditions and verified periodically using witness samples.

3.1.4.2 Contamination Exposure Duration

Appropriate combinations of clean room levels and duration of exposure are sufficient to meet end-use cleanliness requirements. The time integrated total exposure of a clean room class will result in a level 700 particulate specification. These clean room classes are defined in Table 3-1.

Table 3-1. STC Contamination Exposure Duration

Clean Room Class	Exposure Duration
100	12 years
1000	2 years
10000	150 days
100000	20 days

3.2. Mechanical Interface

The STC consists of one component with a mechanical interface as shown in Figure 3-1 (AAA92-100839).

3.2.1. Size and Mass Properties Summary

The geometric envelope, mass, center of mass and center of mass inertial properties of the STC are shown in Table 3-2. The camera coordinate axis used in the mass properties determination is defined in Figure 3-1.

Table 3-2. Star Tracker Camera Size and Mass Property Estimate

Envelope(cm)	Mass(g)	Moment of Inertia Tensor (kg-m^2)
11.68 cm diameter x 13.00 cm long	364 (Maximum)	$\begin{bmatrix} I_{ii} & I_{ij} & I_{ik} \\ I_{ji} & I_{jj} & I_{jk} \\ I_{ki} & I_{kj} & I_{kk} \end{bmatrix} = \begin{bmatrix} 4.22 & 0.006 & -0.019 \\ 0.006 & 4.25 & 0.000 \\ -0.019 & 0.000 & 3.16 \end{bmatrix} \times 10^{-4}$
Center of Mass (±5%)		i = -0.02 cm, j = -0.01 cm, k = 3.76 cm

3.2.2. Dynamic Properties

There are no moving parts within the STC.

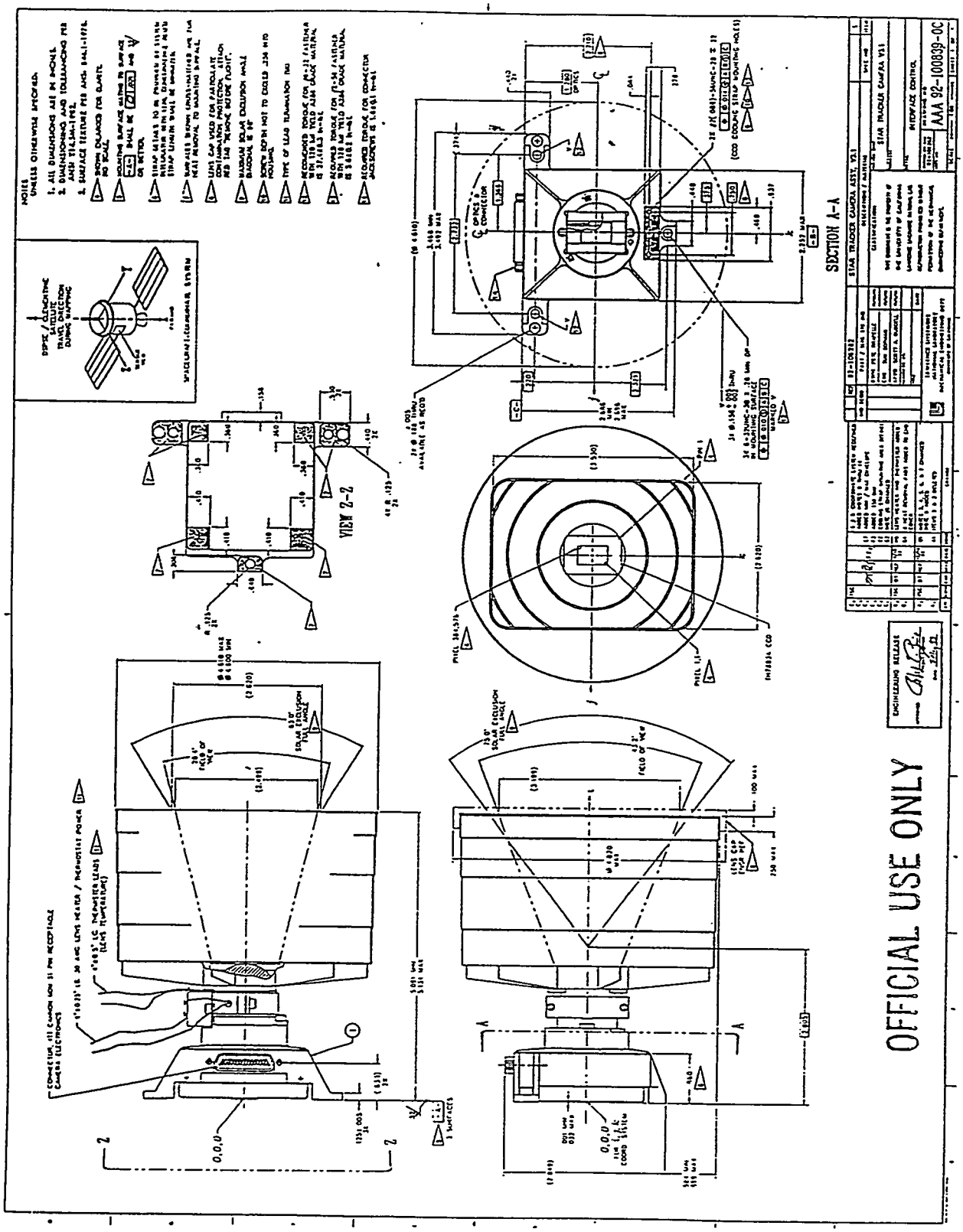


Figure 3-1. STC Interface Control Drawing

3.3. Thermal Interface

3.3.1. Temperature Limitations

Temperature limitations placed upon the STC are in terms of the Base Plate temperature, CCD temperature and the lens temperature. The base plate temperature limits are specified to protect the electronic and mechanical parts from thermal damage. The CCD temperature limits are primarily concerned with achieving required CCD performance. The lens temperature limits are concerned with the performance of the STC optics and the protecting them from thermal damage. The various temperature limits are described below:

a) Operational-In-Spec – This is the temperature range which is required in order to achieve STC performance requirements.

b) Operation-Out-Spec – This is the temperature range which is required in order to prevent damage to the STC while maintaining a functional state. Damage and/or a reduction in reliability can occur to the STC because the electronic junction temperatures are outside operating limits. This temperature limit will prevent the worst case electronic component from exceeding its maximum, derated, junction temperature. Maximum junction temperatures are derated according to thermal design and reliability requirements.

c) Non-Operating - This is the temperature range which is required in order to prevent damage to the STC when it is in an unpowered state. Damage can occur to electronic, mechanical, and optical components because storage temperatures are violated.

3.3.1.1 Base Plate Temperature Limitations

The base plate temperature is defined as the temperature at the Side Mounting Tabs and Center Mounting Tab interfaces defined in Section 3.3.3. All base plate temperature limits are summarized in Table 3-3.

3.3.1.2 CCD Temperature Limitations

The STC electro-optical performance is related to the temperature of the imaging Charge Coupled Device (CCD). The colder the CCD the lower the dark current which improves the signal-to-noise ratio.

The CCD temperature is defined by the CCD case temperature measured by the CCD temperature sensor described in Section 3.3.7. All CCD temperature limits are summarized in Table 3-3.

3.3.1.3 Ground Testing Temperature Limitations

During ground testing, at no time is the temperature of the base plate or the CCD to be low enough to allow condensation to form upon the STC. All other base plate and CCD temperature limits apply.

3.3.1.4 Lens Temperature Limitations

The lens temperature is defined by the lens temperature sensor described in Section 3.3.7. The Operational-In-Spec temperature limits are required in order to achieve STC performance requirements. The Operational-Out-Spec and Non-Operating temperature limits are required in order to prevent damage to the optical components. The lens temperature limits are summarized in Table 3-3.

Table 3-3. Thermal Interface Temperature Requirements

Temperature Limitation	Requirement
Base Plate:	
Operational-In-Spec	-20°Cto 2°C
Operational-Out-Spec	-20°C to 10°C
Non-Operating	-40°C to 70°C
CCD:	
Operational-In-Spec	-20°C to 10°C
Operational-Out-Spec	-20°C to 60°C
Non-Operating	-40°C to 85°C
Lens:	
Operational-In-Spec	-20°C to 40°C
Operational-Out-Spec	-30°C to 70°C
Non-Operating	-30°C to 70°C

3.3.2. Star Tracker Power Dissipation

The results of power dissipation analysis for the STC are presented in Table 3-4A. Shown are the nominal and maximum (+20% margin) for each of the camera operational modes. Also shown is the lens heater power dissipation.

Table 3-4A. STC Power Dissipation

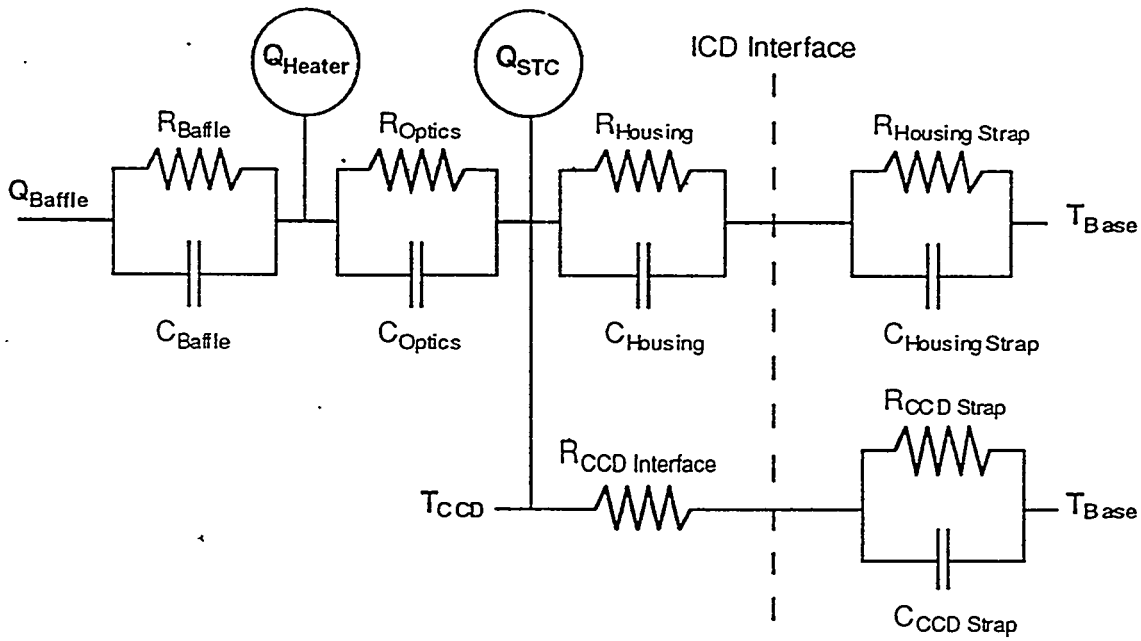
Camera Component	Power Dissipation (Watts)					
	Idle		Integrate		Readout	
	Nom.	Max.	Nom.	Max.	Nom.	Max.
Actel Camera	3.64	4.37	3.63	4.36	3.64	4.37
Lens Heater						
100% duty cycle @ 24 Vdc	0.95					
100 % duty cycle @ 36 Vdc	3.91					

STC		

3.3.3. Incident Radiation Thermal Model

External thermal loads from incident radiation upon the STC Baffle and Optics is conducted through the STC housing and into the base plate. The amount of heat transfer into the base plate from this source is a function of the flux of incident radiation, the base plate temperature, and how the sensor is thermally integrated with the spacecraft. As previously stated, the sensor housing is required to be insulated from thermal radiation emanating from other sensors and systems of the

spacecraft. The baffle and optical path are the only parts of the sensor which are exposed to thermal radiation from sources external to the spacecraft. The CCD temperature is the key requirement which must be considered when integrating the sensor with the spacecraft. The sensor model shown in Figure 3-1B. should be used to evaluate the thermal integration design.



Where:

C_{Baffle}	Lumpedthermal capacitance of the baffle - 80 W-s/°K.
$C_{CCD\ Strap}$	Lumped thermal capacitance of the CCD strap - integrator responsibility.
$C_{Housing}$	Lumped thermal capacitance of the camera housing assembly - 150 W-s/°K.
$C_{Housing\ Strap}$	Lumped thermal capacitance of the housing strap - integrator responsibility.
C_{Optics}	Lumped thermal capacitance of the optical housing assembly - 36 W-s / °K.
Q_{Baffle}	Is the heat transfer of the baffle.
Q_{Heater}	Is the heat generated by the optical housing heater.
Q_{STC}	Is the heat generated by the sensor.
R_{Baffle}	Lumped thermal capacitance of the baffle - 60 °K/W.
$R_{CCD\ Interface}$	Lumped thermal resistance between the CCD strap interface and the CCD - 6 °K/W.
$R_{CCD\ Strap}$	Lumped thermal resistance of the CCD strap - integrator responsibility.
$R_{Housing}$	Lumped thermal resistance of the camera housing assembly - 1.8 °K/W.
$R_{Housing\ CCD}$	Lumped thermal resistance of the housing strap - integrator responsibility.
R_{Optics}	Lumped thermal resistance of the optical housing assembly - 2 °K/W.
T_{Base}	Temperature of the sensor bench.
T_{CCD}	CCD temperature

Figure 3-1A. Sensor Thermal Model For Evaluating Incident Radiation Thermal Loads

It is recommended that the sensor bench include a 25% margin in heat load to insure, with a 95% certainty[1], that the bench will be able to reject the design heat load.

The following information will support the integration of the sensor into the thermal radiation environment of the spacecraft:

Baffle material: Aluminum

Hemispherical total solar absorptivity of all blackened baffle surfaces:	≥ 0.95
Hemispherical total IR emissivity of all blackened baffle surfaces:	≥ 0.95
Hemispherical total solar absorptivity of the baffle face:	≤ 0.15
Hemispherical total IR emissivity of the baffle face:	≥ 0.75
Hemispherical total solar absorptivity of the optics:	≥ 0.40
Hemispherical total IR emissivity of the optics:	≥ 0.95
Hemispherical total solar absorptivity of un-blackened external surfaces of the baffle:	≥ 0.4
Hemispherical total solar absorptivity of un-blackened external surfaces of the baffle:	≥ 0.1

LLNL recommends that the sensor be integrated into the spacecraft so that only the reflective face of the baffle and the internal paths of the baffle are exposed to thermal radiation. The entire outside of the baffle should be insulated. This will minimize the amount of heat transfer to and from the sensor and sensor base plate.

3.3.4. Thermal Interfaces

The STC is conductively cooled/heated during the mission. The STC contains eight thermal interfaces. These interfaces are depicted as part of the mechanical interface control drawing in Fig. 3-1. Fig. 3-1B. depicts the fraction of electrical power dissipated at each thermal interface for a typical application and the maximum allowable total thermal contact resistance permitted at each interface. The thermal contact resistance shall be equal to or less than the stated values. The fractional power given at each interface is for electrical power dissipation only and does not include heat dissipation due to heat load from external sources. Table 3-4B. summarizes the data presented in Figure 3-1B.

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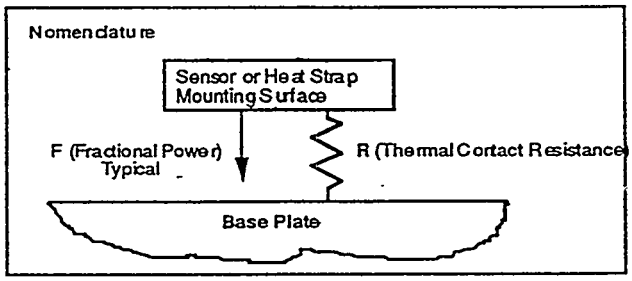
[1] MIL-HDBK-340: Application Guidelines for MIL-STD-1540B; Test Requirements for Space Vehicles, Section 5.6.2: Rationale for Definition of Thermal Uncertainty Margin, p. 21.

Table 3-4B. Thermal Interface Summary

Interface	Fractional Power	Thermal Resistance (°C/W)
Heat Strap	0.15	0.05
End Cover Corners (4)	(.21+.21+.04+.04) = 0.50	1.6 (each)
Center Mounting Tab	0.11	0.10
Side Mounting Tabs(2)	(.12+.12) = 0.24	0.06 (each)

[Note: % of Heat (Fractional Power) is independant of the operational Mode of the Sensor]



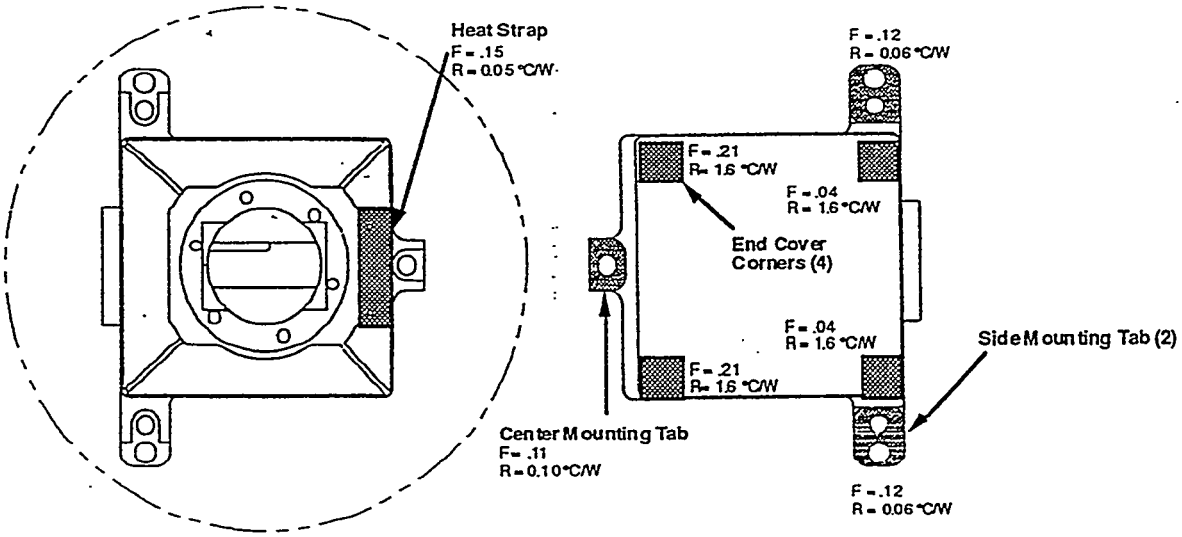


Figure 3-1B. Star Tracker Camera Thermal Interface Definition and Specification

3.3.5. Thermal Gradients

Thermal gradients on the mounting surfaces of the STC must be controlled to ≤3.3°C/cm (15 °F/in) over the area of the three mounting tabs. The STC temperature must not change at a rate greater than 2°C per minute.

3.3.6. Temperature Measurement

Two analog temperature sensors are used in the STC, one senses the CCD temperature and the other is attached to the lens. The signal from the CCD

temperature sensor is transmitted via the 51 pin connector on the STC while the lens temperature sensor uses flying leads. Lead length for the thermistor is 10.2±0.6 cm. The specifications for these sensors are given in Table 3-5.

Table 3-5. STC Analog Temperature Sensors

Item	Transducer Range		Part Operating Range		Transducer
	Min.	Max.	Min.	Max.	
CCD Temperature	-30°C	70°C	-20°C	10°C	LTN-11 thermistor, Fenwall Electronics 137-562ZXT-DOZ
Lens Temperature	-30°C	70°C	-20°C	40°C	LTN-11 thermistor, Fenwall Electronics 137-562ZXT-DOZ

3.3.7. Optics Heaters

The STC is equipped with a thermostatically controlled lens heater which will be set to turn on at -6°C[2]. The thermostat is an "open on temperature increase" type, thereby maintaining the lens temperature at or above the -6°C setting. Flying leads are used to supply power to the heater and thermostat. Lead length is 10.2±016 cm. The heater resistance is fixed at 450 ± 45Ω.

3.4. Electrical Interface

The following section defines the power requirements, the control signals to and the data signals from the STC.

3.4.1. Steady State Voltages

The STC requires an external power system that must provide on/off switching, short circuit protection, overload protection, line and load regulation. The STC nominal input voltages at the STC power connector are shown in Table 3-6. The voltages are required to meet the maximum and minimal limits shown excluding noise, ripple, and transients.

Table 3-6. Steady State Voltage Limits

Input	Minimum	Nominal	Maximum
+15 Vdc	+14.75 Vdc	+15 Vdc	+15.25 Vdc
+5 Vdc	+4.85 Vdc	+5 Vdc	+5.25 Vdc
-15 Vdc	-15.25 Vdc	-15 Vdc	-14.75 Vdc
-5 Vdc	-5.25 Vdc	-5 Vdc	-4.75 Vdc

3.4.2. Power Converter Load Transients

Single event switching transients to the STC will be limited to those shown in Table 3-7. The voltage will return to its steady state within 12 milliseconds after the single event switching has ended.

2 The lens heater temperature is set to turn on at -6° C due to the limited availability of preset thermostats.

Table 3-7. Load Transient Limits

Voltage	Minimum	Maximum
+15 Vdc	+14.2 Vdc	+15.8 Vdc
-15 Vdc	-15.8 Vdc	-14.2 Vdc
+5 Vdc	+4.75 Vdc	+5.4 Vdc
-5 Vdc	-5.4 Vdc	-4.6 Vdc

3.4.3. Power Converter Ripple

Power supply ripple limits are shown in Table 3-8.

Table 3-8 Power Supply Ripple Limits

Frequency	Limit
0 to 50 KHz	25 mV_{p-p}
50 KHz to 100 KHz	+ 12.04 dB/oct
100 KHz to 500 KHz	100 mV_{p-p}
500 KHz to 1 MHz	+ 12.04 dB/oct
1 MHz to 50 MHz	400 mV_{p-p}

3.4.4. Load Current

Power supply current values are shown in Table 3-9. The values provided for the +5 Vdc digital power are for when the data bus is disabled and enabled respectively and reflect a resistive 150 Ω termination.

Table 3-9. Current Requirements

Voltage	Current	
	Nominal	Maximum
+5 Vdc Analog	0.140 A	0.155A
+5 Vdc Digital	0.040 A/0.300A	.060A/0.330A
-5 Vdc	0.040 A	0.060 A
+15 Vdc	0.130 A	0.140 A
-15 Vdc	0.015 A	0.030 A

3.4.5. Other Considerations

STC turn-on surge current does not exceed 300% of the average current for more than 10 milliseconds. The STC does not require any sequencing of input voltages.

3.4.6. Grounding

The power supply single point grounding system is specified in Figure 3-2. No power current will flow through the chassis. Power cable shield grounding is shown in Figure 3-3. These shields are grounded only at the power source. Data cable shielding is shown in Figure 3-4. These shields are only grounded at the SIP/DHU end.

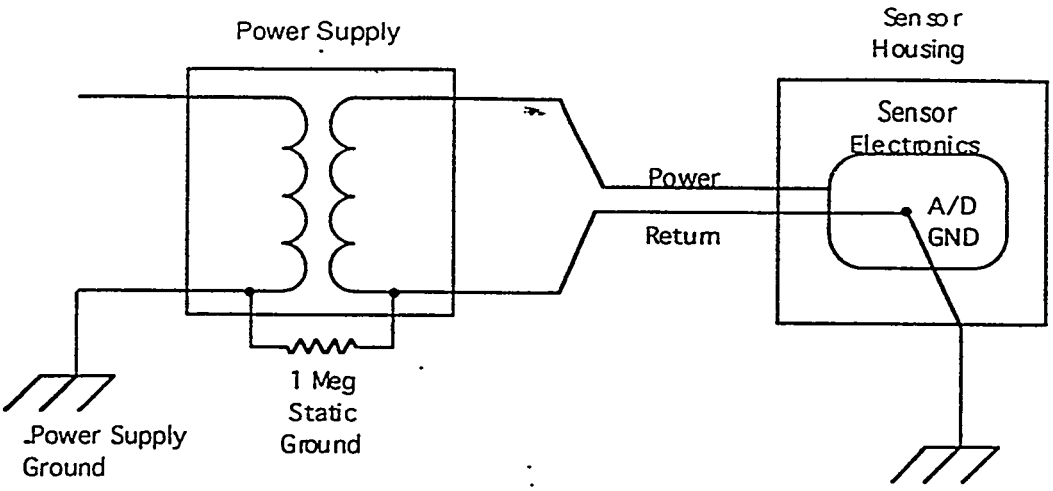


Figure 3-2. Power Supply/STC Single Point Grounding

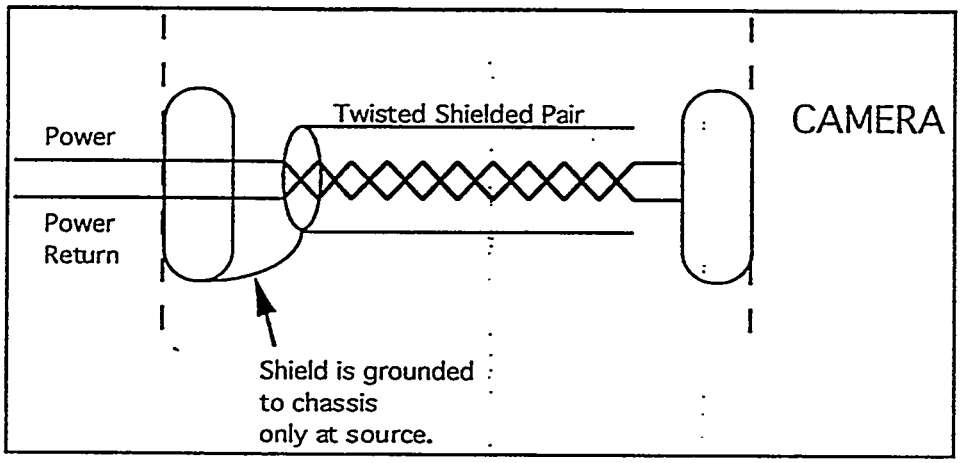


Figure 3-3. Grounding Of Power Cable Shields

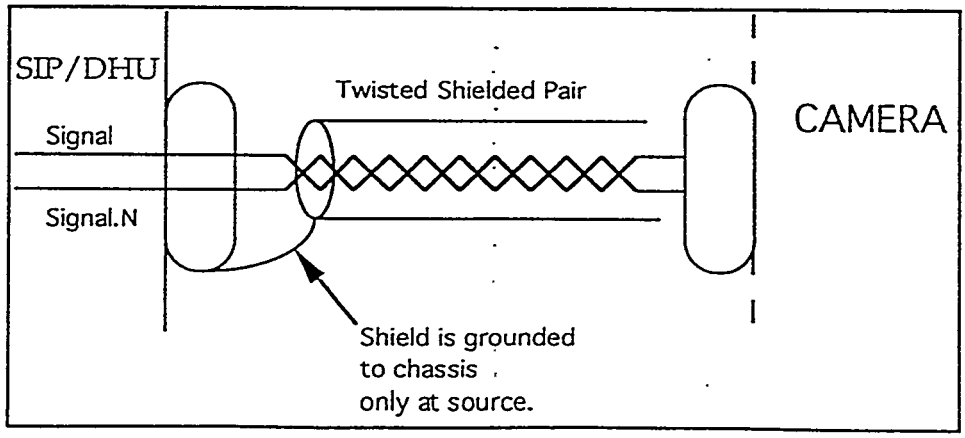


Figure 3-4. Grounding Of Command & Data Cable Shields

3.4.7. STC Electrical Interconnections

A functional block diagram of the STC is shown in Figure 3-5. The STC interfaces through a MIN-E-Con 51 socket connector. This interface contains the STC video bus data and control signals, the SASI bus command interface, analog temperature signals, shields, and power. Table 3-10 lists the symbols used to define the signals.

All digital signals are based on RS-422. CMOS tri-stated differential line drivers and receivers are used for these signals. Table 3-11 defines pin assignments and signal types. Table 3-12 describes the signals. Signal timing information is defined in paragraphs 3.4.9.1 through 3.4.9.3. When the STC is enabled these signals will drive the bus; when the STC is disabled these signals will be tri-stated and not drive the bus.

Table 3-10. Signal Symbols

Symbol	Description
Odiff	Output CMOS Differential Driver
Idiff	Input CMOS Differential Receiver
Ihc	CMOS HC Input
Ohc	CMOS HC Open Collector Output (HC05)
Iopt	Opto-Isolator Input (HCPL-6231)
DPWR	Power For Digital Circuits
DRTN	Ground Return Digital
APWR	Power For Analog Circuits
ARTN	Ground Return Analog
PWR24	Power For Filter Motor
RTN24	Ground Return For Filter Motor Power
SHLD	Shield (Tied To Chassis)
SPG	Single Point Ground

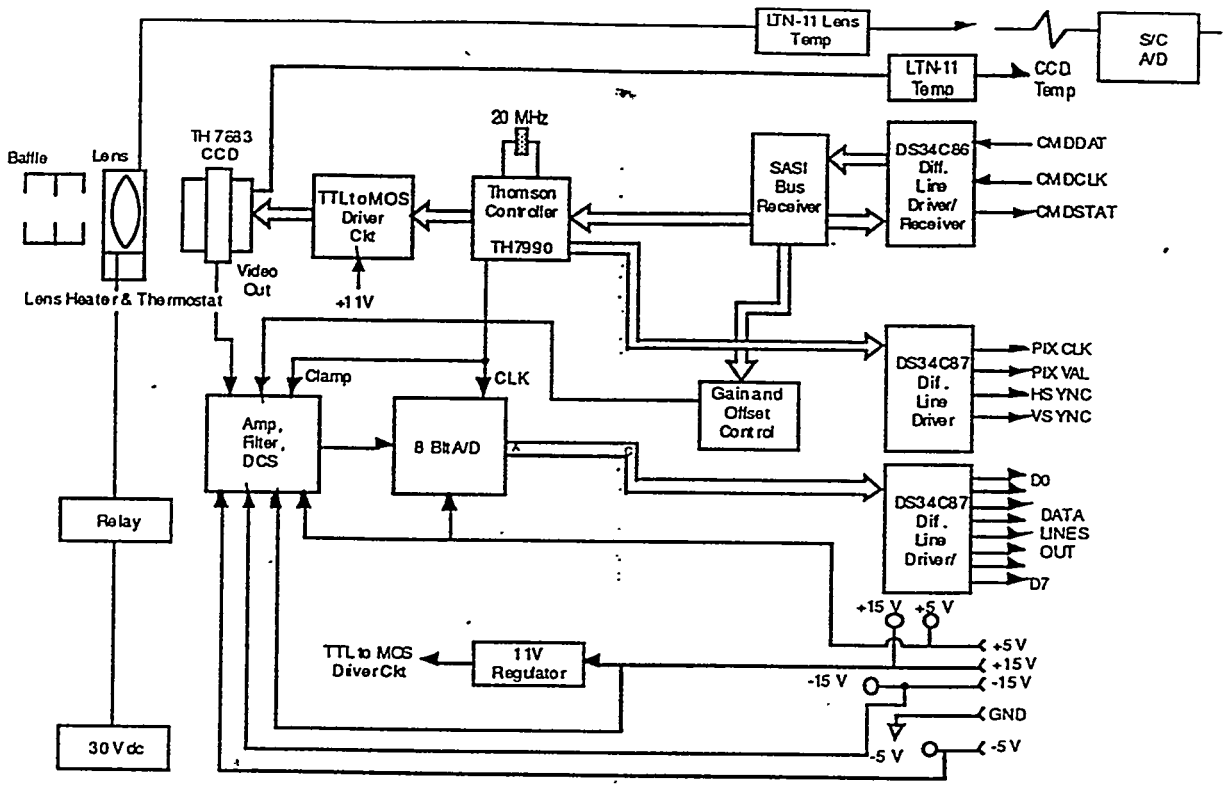


Figure 3-5. STC Functional Block Diagram

3.4.8. Video Frame Format

The video image frame format of the STC is 580 lines X 384 pixels/line. The first and last two lines are masked resulting in a total of 576 optically active lines.

Table 3-11. Connector Pin Assignments

CONNECTOR DATA:		
Manufacturer:	MIN-E-CON 51 pn Socket	
Part No.:	M83513/4-C06N	
Host Interface Connector	J1	
PIN #	SIGNAL NAME	TYPE
1	N.C.	
2	SHIELD	SHLD
3	-5VIN	APWR
4	-15 VIN	APWR
5	ARTN	ARTN
6	TEMP	Ω/°C
7	SHIELD	SHLD
8	SHIELD	SHLD
9	CMDCLK	Idiff
10	PIXVAL	Odiff
11	HSYNC.N	Odiff
12	HSYNC	Odiff
13	D6	Odiff
14	D4	Odiff
15	D2.N	Odiff
16	D2	Odiff
17	DO	Odiff
18	PIXCLK	Odiff
19	N.C.	
20	DRTN	DRTN
21	DRTN	DRTN
22	ARTN	ARTN
23	ARTN	ARTN
24	TEMPR	RTN
25	CMDSTAT N	Odiff
26	CMDCLK.N	Idiff
27	PIXVAL.N	Odiff
28	VSYNC.N	Odiff
29	D7 N	Odiff
30	D6N	Odiff
31	D4 N	Odiff
32	D3N	Odiff
33	DI N	Odiff
34	D0.N	Odiff
35	PIXCLK.N	Odiff
36	SPG	SPG
37	+5 VIN	DPWR
38	+5VIN	DPWR
39	+15 VIN	APWR
40	+5 VAIN	APWR
41	SHIELD	SHLD
42	CMDSTAT	Odiff
43	CMDDAT	Idiff
44	CMDDAT.N	Idiff
45	VSYNC	Odiff
46	D7	Odiff
47	D5.N	Odiff
48	D5	Odiff
49	D3	Odiff
50	DI	Odiff
51	SHIELD	SHLD

Table 3-12. Signal Descriptions

SIGNAL	SIGNAL NAME	DESCRIPTION
VSYNC	Vertical Sync out	VSYNC is a positive going vertical synchronization level which occurs after the photo-charge integration period and brackets the transfer of each field of digital video data. The source of this signal is the ACTEL array. It is set active (HI) at the beginning of a frame and stays HI until the frame has been completely clocked out of the A/D converter. It returns to the inactive LO state after the falling edge of the last PIXVAL signal of the frame. Data is valid when both VSYNC and PIXVAL are asserted at the same time. The frame start is controlled externally through the SASI command.
HSYNC	Horizontal Sync out	HSYNC is the horizontal synchronization pulse which precedes the transfer of each horizontal line of digital video pixel data. The HSYNC pulse will occur when PIXVAL is not true and have duration of at least one cycle of the PIXCLK. This signal goes HI prior to each horizontal line of data and then returns LO before the data is available. During HSYNC (HSYNC HI) the PIXVAL signal will be LO. The HSYNC signal must go high at least one clock cycle after the negative transition of the PIXVAL signal and go low at least 1 clock cycle prior to the assertion of PIXVAL.
PIXVAL	Pixel Valid out	PIXVAL is a signal which brackets each line of data. It must go high before the first valid pixel data appears on the D0-D7 data lines and remain high until after all valid pixel data is transferred for each line. Data transfer occurs only when PIXVAL is high. Pixel Valid goes LO at the end of each horizontal line of valid image data and then returns HI for the beginning of the next data line.
PIXCLK	Pixel Clock out	PIXCLK is the signal used to enable latching of the digital video data appearing on the D0-D7 data lines. The source of this signal is the ACTEL array. This signal clocks the output data bits from the differential line drivers into the DSPSE Spacecraft Controller interface's data latch. Data is valid on the rising edge of this signal with a setup time of at least 50 ns and stays valid until the falling edge. The clock is HI for a minimum of 60 ns.
D0 - D7	Data lines (8)	Data lines (8). These lines contain the 8 bits of data for each pixel. D7 is the most significant bit. (see Host Timing section)
CMDCLK	Command Clock in	Command Clock in. This is the command clock for the SASI bus. (see Host Interface section)
CMDDAT	Command Data in	Command Data in. This is the command data for the SASI bus. (see Host Interface section)
CMDSTAT	Command Status out	Command Status out. This is the command status data for the SASI bus. (see Host Timing Interface section)
TEMP	Camera CCD Temperature	Camera CCD Temperature. This signal and its return are connected to an LTN-11.. This device is a composite thermistor.

3.4.9. STC Timing

3.4.9.1 Interface Timing

The STC interface consists of two separate buses. One is the video bus that contains all the control signals and video image data. It is detailed in paragraph 3.4.9.2. The other is the SASI bus that handles the command and status data and is detailed in paragraph 3.4.9.3.

3.4.9.2 Video Bus Timing

The video bus consists of 4 control signals and 8 data lines. Control signals are: VSYNC, HSYNC, PIXVAL, and PIXCLK which are described in Table 3-12. The data lines are: D0 through D7. Figures 3-6 through 3-8 show the video timing.

3.4.9.3 SASI Bus Timing

The synchronous addressable serial interface (SASI) bus protocol is based on a Goddard Flight Center (GSFC) 650C custom PMOS process digital integrated circuit. For a complete description of the SASI bus refer to design note DN61033-30520-02 called out in the Applicable Documents section of this document.

The SASI bus is made up of three control signals. The control signals are CMDCLK, CMDDAT, and CMDSTAT. The SASI receiver in the STC is configured as a baseline SASI receiver. From a software perspective a command received over the SASI is made up of two bytes. One byte is the address byte and the other is the data byte as shown in Figure 3-9. The upper 3 bits of the address byte contain the subsystem identification. These 3 bits are used by the receiver hardware to determine if it has been addressed. The next 4 bits are used for sub-addressing within the subsystem to define the data parameter identification. By using 4 bits, 16 different commands may be defined. The remaining bit in the address byte is the New Data Flag (NDF) register. When a data byte is sent with NDF set to a logic HI, it is latched into the appropriate command register. The SASI receiver sends the contents of the appropriate command register to the host SASI controller as a status data byte when a command is received with the NDF bit set to a logic LOW level. This capability, as described below is used to verify camera commands. The subsystem ID's for commands to the STC are 3 and 6 (two units). It is allocated 5 parameter ID slots, 0 through 3 and 5. The STC will respond to either hex SASI addresses 60-6B or C0-CB.

3.4.10. Command Verification

The camera can return the contents of each of the five command registers. The contents of the command registers directly reflect the command sent to each command register. Refer to Table 3-13. for the camera commands and Table 3-14. for the return status data. Unused bits will be read back in an unknown state. Status values echoed back at the end of a register set operation (NDF HIGH) are the value of the register set for the previous operation.

3.4.11. Operation

3.4.11.1 Power On Initialization

After applying power, the camera must be initialized. This is done with a SASI command to the camera that asserts the initialization bit (logic LOW) followed by a command that removes the initialization bit (logic HI). Timing is not critical but the second command should immediately follow the first. The camera is initialized on the LOW to HI transition. Next, the camera gain must be set to some nominal value. This is also performed through a SASI command by setting one of the gain bits HI. At this point the camera is in stand-by mode. The video bus is tri-stated and it is continuously clearing its dark charge. Integration and readout can now be controlled through the SASI port. Schematically this is shown in Figure 3-10.

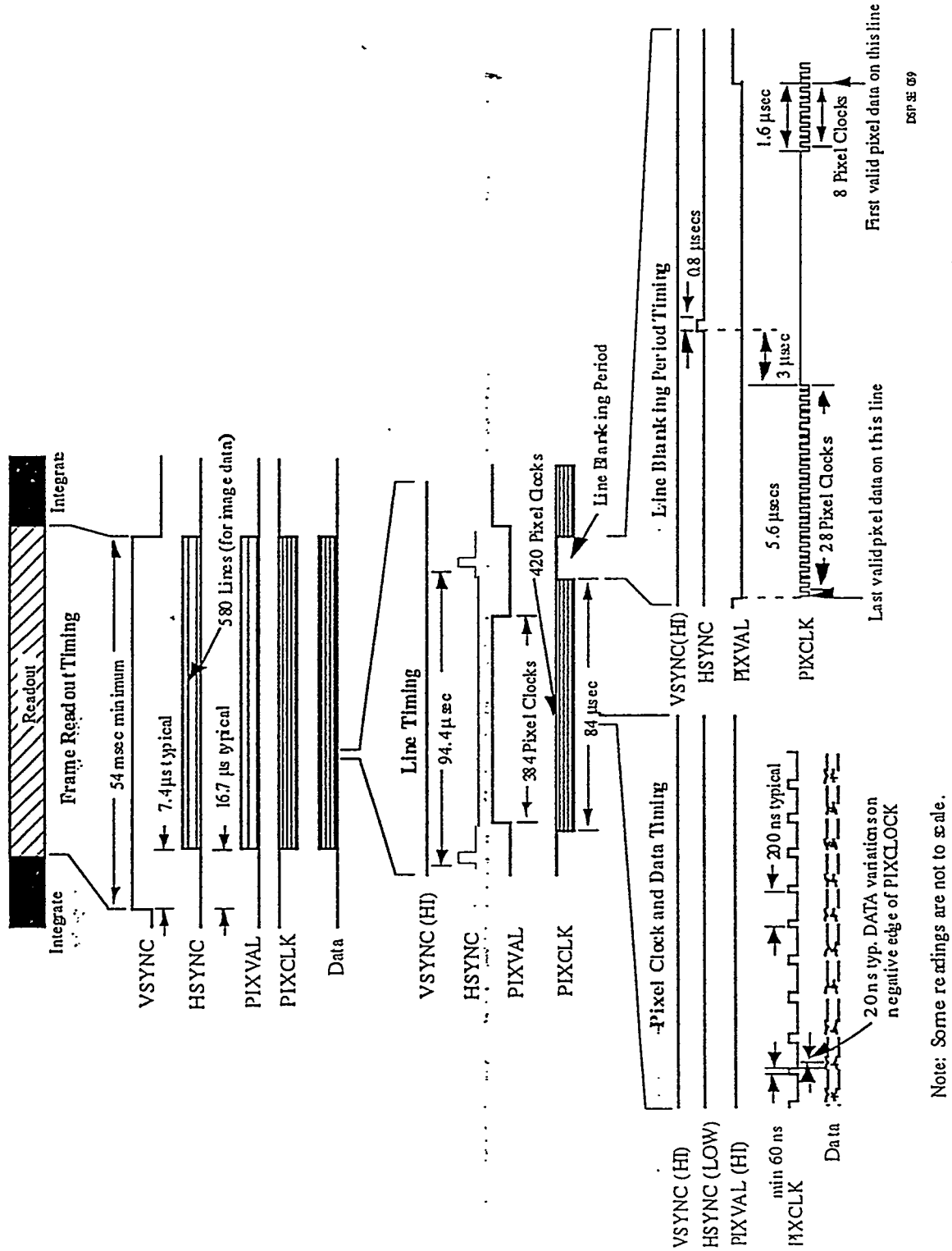


Figure 3-6. Video Timing

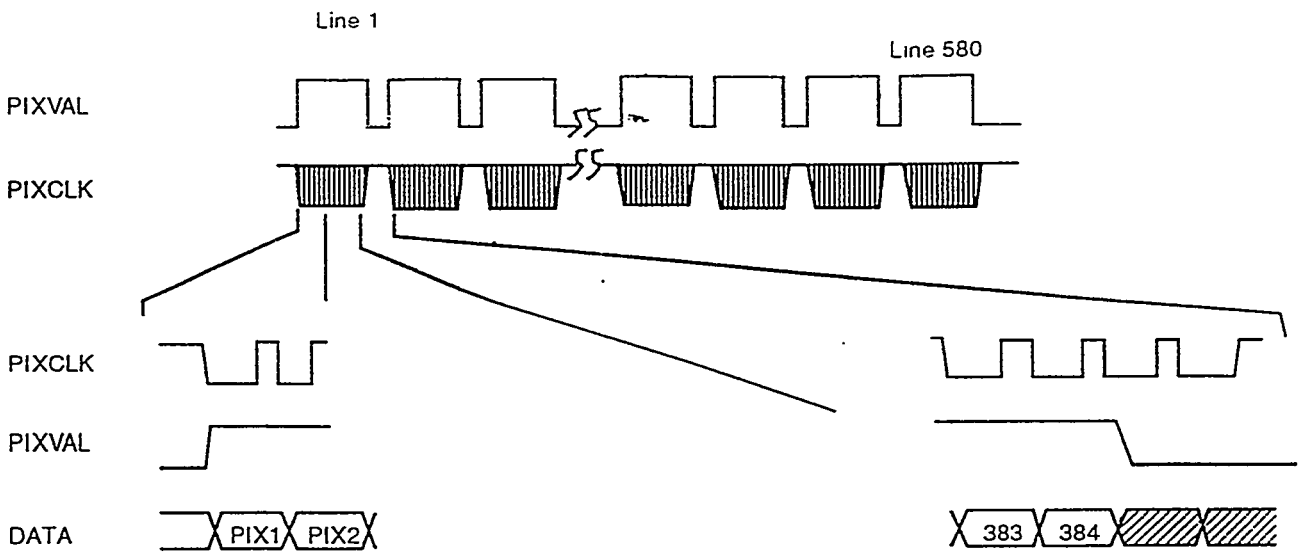
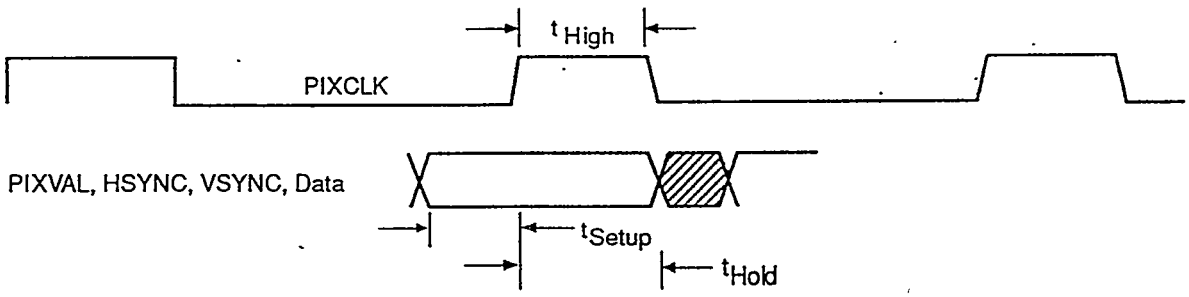


Figure 3-7. Timing Diagram



Parameter	Description	Minimum	Maximum	Units
t_{High}	PIXCLK High	60	100	ns
t_{Setup}	Rising Edge Of PIXVAL,HSYNC, VSYNC, & Data Valid To Rising Edge of PIXCLK	50	—	ns
t_{Hold}	Rising Edge Of PIXCLK To Falling Edge Of PIXVAL, VSYNC, Or Invalid Data	30		ns

Figure 3-8. Timing Diagram

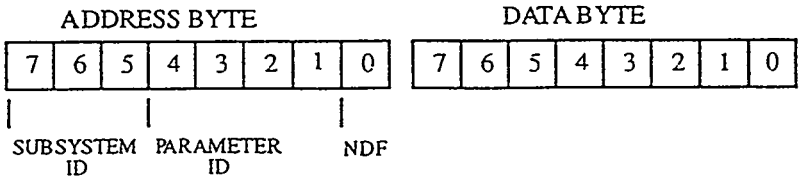


Figure 3-9 SASI Command Bytes

3.4.11.2 Integration Control

The integration control mode is selected by setting the control bit (bit 3 of parameter ID = 0) either HI for precision control or LOW for SASI control. Note that if precision integration control is selected, 13 bits of integration data must be loaded into the command data registers at parameter ID 2 and 3 with bit 4 of the command data register at ID 3 being the MSB. Integration time in this mode equals (n+1) * 94.4 µsec. The Minimum acceptable n is 1, resulting in a minimum integration time for the Star Tracker of 188.8 µsec. In the SASI control mode, integration is initiated by bringing the control bit (bit 0 of the parameter ID = 1) LOW. Readout is initiated by bringing the same bit HI. In the precision control mode, integration is initiated by a HI to LOW transition of the same control bit (bit 0 at parameter ID = 1). Readout will occur automatically after the pre-set integration time. The control bit must be returned HI before initiating the next integration cycle and left HI for at least 100 µseconds.

3.4.11.3 Gain Control

Camera gain is selected by setting one and only one of the gain control bits (bits 4-6 at parameter ID = 0) HI. See Table 3-13. for gain values which correspond to the bit selected.

3.4.11.4 Offset Control

Camera offset is selected by setting a 5 bit control word (bits 0-4 at parameter ID = 5). One LSB equals an offset of 8 gray levels. The maximum offset equals 248 gray levels.

3.4.11.5 Magnetic

The STC produces no magnetic dipoles.

3.4.11.6 High Voltages

There are no voltages greater than 36 volts in the STC.

Table 3-13. Camera Commands

Parameter ID	Data Byte	Description
0	Bit 0	Enable data bus (HI enabled, LOW tri-stated)
	Bit 1	Initialize camera (low to high transition)
	Bit 2	Reserved (set to 0)
	Bit 3	Integration mode 0 = SASI control 1 = Precision control
	Bit 4	Gain Select (HI = 350 e^-/bit)
	Bit 5	Gain Select (HI = 150 e^-/bit)
	Bit 6	Gain Select (HI = 75 e^-/bit)
	Bit 7	Reserved (Set to 0)
1	Bit 0	Image (start integration SASI control mode 0 = Integrate 1 = Readout Precision Control Mode High to Low starts integration
	Bits 1 - 7	Reserved (Set to 0)
2	8 Bits	Integration control Bit 0 is LSB (LSB = 94.4 µsec)
3	5 Bits	Integration Control Bit 4 is MSB
5	5 Bits	Offset Control, Bit 4 is MSB

Note: Parameter ID 0 Bits 4-6 (Gain Select) are mutually exclusive. Only one can be set high at a time. Having two gain bits set at the same time yields an undetermined gain state.

Table 3-14. Camera Commands That Return Status Data

Address	NDF	Data	SASI Status Return	Comments
0110000 or 1100000	0	don't care	Contents of Command Data Register at parameter ID 0	Only bits 0,1 and 3-6 are important
0110001 or 1100001	0	don't care	Contents of Command Data Register at parameter ID 1	Only bit 0 is important
0110010 or 1100010	0	don't care	Contents of Command Data Register at parameter ID 2	8 bits of integration, Bit 0 is LSB
0110011 or 1100011	0	don't care	Contents of Command Data Register at parameter ID 3	5 bits of integration Bit 4 is MSB
0110101 or 1100101	0	don't care	Contents of Command Data Register at parameter ID 5	5 bits of offset Bit 4 is MSB

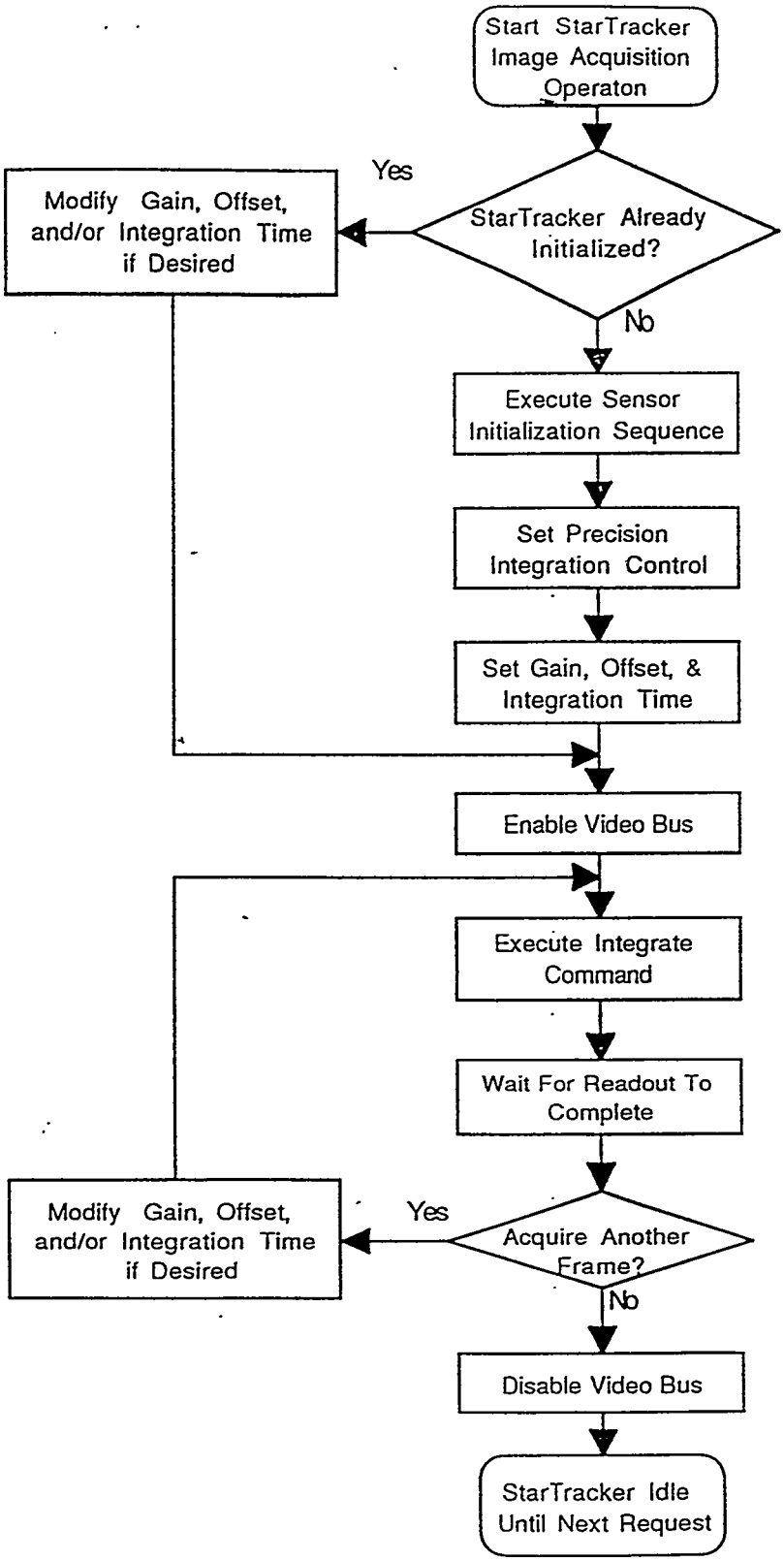


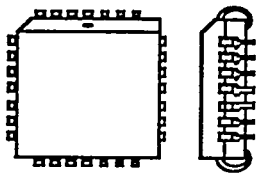
Figure 3-10. Star Tracker Operational Flow Diagram

Appendix A.8

Clementine Sensor Suite Reliability Analysis

(C1-EE-002)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1-EE-002 Rev. 01
TITLE: CLEMENTINE SENSOR SUITE RELIABILITY ESTIMATE	ASSY: General EE ORIG: W. R. Bryson DATE: 28 August 1992 APPR:



Abstract:

This document is a White Paper discussing the use of a combination of commercial and MIL-SPEC parts in the Clementine sensors. It also presents a detailed failure rate per 10^6 hours estimate and an estimate of probability of success for the sensors during a 7 month (5280 hour) mission.

Lawrence Livermore National Laboratory		Total Document Pages: 29

CLEMENTINE SENSOR SUITE RELIABILITY ESTIMATE

William R. Bryson

Mark S. Strauch

August 21, 1992

Lawrence Livermore National Laboratory

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1.0 Introduction

The purpose of this paper is to document the results of the reliability estimate done for a number of sensors developed by the Lawrence Livermore National Laboratory (LLNL) under the sponsorship of SDIO. The sensors, slated for use on Clementine, will be used in lunar orbit to obtain wide spectral band imagery of the lunar surface followed by a fly-by of a near earth asteroid for the same purpose.

1.1 Mission Objectives

Clementine is the name for a deep space exploration (DSPSE) experiment which will be launched in January 1994 with a two month mission in lunar orbit followed by a fly-by of a near earth asteroid in August 1994. The purpose of this experiment is to:

1) Demonstrate the survivability and performance of SDIO developed technologies when exposed to a deep space environment.
2) Obtain wide band spectral imagery of both the lunar surface and the surface of a near earth asteroid (Geographos).
3) Conduct other experiments during the mission relating to autonomous navigation while in lunar orbit as well as in transit to the asteroid.

The Clementine probe is slated for launch in January 1994 with lunar mapping occurring in the March / April 1994 time frame and asteroid fly by in late August 1994.

1.2 Mission Sensors

The mission sensors are two Star Trackers, used for navigation updates, one UV/Visible sensor and a Near Wave IR (NIR) sensor, used to image the surface of the moon and the asteroid, a Long Wave IR (LWIR) sensor, used for thermal measurement of the lunar terminator and a Laser Imaging Radar (LIDAR) which can be used in a high resolution imagery mode or in a ranging mode. Sensor and laser transmitter performance are summarized in Table 1.

1.3 Reliability Estimate Summary

A reliability estimate was calculated for each sensor using the methods defined by MIL-HDBK-217F[1]. The results for each sensor, treated as a system, are summarized in Table 2. Two duty cycles are assumed for the sensors, 100% and

[1]Reliability Prediction of Electronic Equipment, MIL-HDBK-217F, Department of Defense, December 2, 1991

30%. "Off time" reliability is assumed to be 1. Mission duration is assumed to be 7 months or 5280 hours. The reliability of the near infrared sensor (NIR), the long wave infrared sensor (LWIR) and the LIDAR laser transmitter has not been estimated. These are procured items and will be reported on at later date. For details on the estimate completed for the other sensors, refer to section 3, Detailed Reliability Estimate.

Sensor	FOV	IFOV	F#	Spectral Band	Comment
Star Tracker	28° x 42°	1.3 mrad	1.0	0.4 - 1.0 µm	Used for navigation - update rate sensors
UV/Visible	4.2° x 5.6°	255 µrad	2.0	0.2 - 1.1 µm	6 Selectable filters
LIDAR High Resolution Camera	0.3° x 0.4°	18x36 µrad	10	0.4 - 0.85 µm	High resolution sensor with 6 selectable filters
LIDAR Range Receiver	n/a	1.0 mrad	n/a	n/a	Avalanche photo diode+range gate; range measurement
LIDAR Laser Transmitter	n/a	n/a	n/a	1.06 µm	180 mJ; 500 µ radian beam divergence
NIR	5.6° x 5.6°	385 µrad	5	1 - 3.1 µm	6 selectable filters
LWIR	1.0° x 1.0°	143 µrad	2.3	9 - 12 µm	Thermal measurement of lunar terminator

Table 1 - Mission Sensor Performance

Sensor	λ_p failures/10^6hours	Reliability	
		100% Duty	30% Duty
Star Tracker	4.3444	0.9773	0.9931
UV/Visible	5.3986	0.9719	0.9915
LIDAR	8.7382	0.9549	0.9862
LIDAR Laser Transmitter	(TBD)	(TBD)	(TBD)
NIR	(TBD)	(TBD)	(TBD)
LWIR	(TBD)	(TBD)	(TBD)

Table 2 - System Level Reliability

2.0 Reliability Estimate Methods and Assumptions

2.1 Background

There are a number of predictive models used throughout both the national and international electronics industry for assessing the long term reliability of electronic components[2]. The methodology most familiar is that described in MIL-HDBK-217F. This is the method that has been employed by LLNL to calculate the reliability of the sensors slated for use on the Clementine spacecraft.

As a basis for comparison to the results of MIL-HDBK-217F, LLNL has employed the Bellcore reliability model[3] to determine sensor reliability estimates. Use of this approach yielded estimates for reliability comparable to those determined from MIL-HDBK-217F.

One other method which has been applied recently to the Clementine sensor electronics is the automotive electronics reliability model[4] which is based on extensive empirical data from automotive warranty claims. Application of this approach is inappropriate for space based electronics due to the substantial environmental differences. In addition using the base failure rates as derived by MIL-HDBK-217E includes a double penalty many failure rate factors. For this reason, the application of this model to calculate a reliability estimate for the Clementine sensors is not considered appropriate and its use would yield erroneous results.

2.2 Temperature Environment Assumptions

At this time a detailed thermal analysis of the sensor suite has not been completed. We have therefore made the following assumptions about the thermal environment sensor components will be exposed to. These assumptions are based on design goals. As the temperature analysis becomes complete, this reliability estimate will be updated to reflect more accurate conditions.

Optical Bench	0 ± 10 °C
Microcircuit Junction Temp	70 °C
Discrete Semiconductor Junction Temp	50 °C
Passive Component Temperature	30 °C
Connector Temperature	10 °C

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[2] A Survey of Reliability-Prediction Procedures for Microelectronic Devices, IEEE Transactions on Reliability, Vol. 41, No. 1, March 1992.

[3] Reliability Prediction Procedure for Electronic Equipment, Bell Communications Research, Technical Reference TR-NWT-0000332, Issue 3, September 1990.

[4] Automotive Electronic Reliability Prediction, SAE 870050, William K. Denson and Mary G. Priore, IIT Research Institute.

2.3 Reliability Calculation Method Based on MIL-HDBK-217F

The reliability of each of the Clementine sensors was calculated using the methods of MIL-HDBK-217F. A description of each of the models used is presented below, along with the applicable assumptions and definitions.

2.3.1 Microcircuits

For microcircuits the part failure rate is calculated using the following equation from MIL-HDBK-217F, page 5-3:

$$\lambda_P = (C_1\pi_T + C_2\pi_E)\pi_Q\pi_L$$

where:

λ_P = part failures / 10^6 hours

C_1 = complexity factor - die complexity failure rate, Section 5.1

C_2 = package factor - package failure rate, Section 5.9

π_T = temperature factor, Section 5.8

π_Q = part quality factor, Section 5.10

π_E = environment factor, Section 5.10

π_L = learning (maturity) factor, Section 5.10

The factors shown above are derived using the applicable rules of MIL-HDBK-217F. For MIL-STD-883 Class B parts, which will be used in all the sensors where appropriate, the part quality factor is 2.0. Other microelectronic circuits will be screened to the following test methods of MIL-STD-883D, TM 1015 (class S burn-in), TM 5004 (final electricals at temperature extremes), TM 2012 (radiography), and TM 2009 (external visual). Per section 5.10 of MIL-HDBK-217F, the quality factor for these parts is 3.8.

The environmental factor for space flight for all microcircuits is 0.5, again per section 5.10.

The complexity factor, package factor, temperature factor and maturity factor varies for each part and package type. These will be presented in the detailed reliability estimate for each part.

2.3.2 Discrete Semiconductors

Two types of discrete semiconductors are used in the sensor design. Each is evaluated as described below.

Diodes

Diode failure rates are calculated using the model defined in MIL-HDBK-217F, Section 6.1, page 6-2.

$$\lambda_p = \lambda_b \pi_T \pi_S \pi_C \pi_Q \pi_E$$

where:

λ_p = part failures / 10^6 hours

λ_b = base failure rate, Section 6.1

π_T = temperature factor, Section 6.1

π_S = electrical stress factor, Section 6.1

π_C = contact construction factor, Section 6.1

π_Q = quality factor, Section 6.1

π_E = environment factor, Section 6.1

The base failure rate, which is based on diode type and application , is provided in Section 6.1. With one exception, all diodes are low frequency switching diodes. The base failure rate for low frequency switching diodes is 0.001 failures/10^6 hours. The exception is a voltage reference diode that has a base failure rate of 0.002 failures/10^6 hours.

The temperature factor is based on junction temperature, which for this estimate is assumed to be 50 °C and hence a temperature factor of 2.2 is assigned to all diodes.

The electrical stress factor diodes is based on the voltage stress ratio . The voltage stress ratio is different for each diode and the electrical stress factor is shown in the detailed reliability estimate.

All diodes are metallurgical bonded and the contact construction factor is 1.0.

Except for the JANTXV parts which have a quality factor of 0.7, all others are assigned a value of 8.0.

The environment factor for space applications is 0.5.

Transistors

Three type of transistors are used in the sensor designs. These are low frequency bipolar, low frequency silicon FET and MOSFETs. The reliability models are presented below.

Low Frequency Bipolar

The failure rate for low frequency bipolar transistors is calculated from MIL-HDBK-217F, Section 6.3, pages 6-6 through 6-7.

$$\lambda_p = \lambda_B \pi_T \pi_A \pi_R \pi_S \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 6.3

π_T = temperature factor, Section 6.3

π_A = application factor, Section 6.3

π_R = power rating factor, Section 6.3

π_S = voltage stress factor, Section 6.3

π_Q = quality factor, Section 6.3

π_E = environment factor, Section 6.3

The base failure rate for low frequency bipolar transistors is 0.00074 failures/10^6 hours.

The temperature factor is 1.7 based on a junction temperature for the transistor of 50 °C.

All transistors are being used as linear amplifiers and the resulting application factor is 1.5.

The rated power is less than 0.5 watts, thus the power rating factor is 0.77.

The voltage stress factor of 0.11 based on a ratio of V_{ce} / V_{ceo} of ≤ 0.3 (applied collector to emitter voltage / maximum rated collector to emitter voltage).

All transistors are screened plastic parts but no credit is allowed for screening, therefore the quality factor is 8.0.

The environment factor for a space based application is 0.5.

Low Frequency Si FET

The failure rate model for low frequency silicon FET transistors is obtained from MIL-HDBK-217F, Section 6.4, page 6-8.

$$\lambda_p = \lambda_B \pi_T \pi_A \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 6.4

π_T = temperature factor, Section 6.4

π_A = application factor, Section 6.4

π_Q = quality factor, Section 6.4

π_E = environment factor, Section 6.4

For the JFET transistors the base failure rate is 0.0045 failures / 10^6 hours and for MOSFETs the rate is 0.012 failures/10^6 hours.

The temperature factor is 1.6 based on a junction temperature of 50 °C.

All FETs are used as linear amplifiers with a rated power of ≤ 2 watts which results in an application factor of 1.5.

As with the bipolar transistors, no credit is allowed for screening and the quality factor for screened plastic parts is 8.0.

The environment factor for space applications is 0.5.

2.3.3 Capacitors

Two types of capacitors are used in the sensor designs. These are fixed ceramic chips and solid tantalum chips.

<u>Ceramic Chip Capacitor</u>

The failure rate equation for the chip type ceramic capacitor is given in MIL-HDBK-217F, Section 10.11, page 10-20 and is reproduced below.

$$\lambda_p = \lambda_B \pi_{CV} \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 10.11

π_{CV} = capacitance factor, Section 10.11

π_Q = quality factor, Section 10.11

π_E = environment factor, Section 10.11

The base failure rate for ceramic chip capacitors is 0.0028 failures/10^6 hours which is based on a maximum temperature rating of 125 °C, an operating temperature of 30 °C and a stress factor (ratio of operating to rated voltage) of 0.3.

The capacitance factor is a function of the capacitor value, refer to the detailed reliability estimate for the actual values.

All ceramic capacitors will be procured at S reliability level resulting in a quality factor of 0.03.

The environment factor for space applications is 0.5.

Solid Tantalum Capacitors

MIL-HDBK-217F does not address solid tantalum capacitors as specified in MIL-C-55365, General Specification for Capacitor, Fixed, Electrolytic (Tantalum), Chip, Established Reliability. Therefore we are using Section 10.12 of MIL-HDBK-217F, Capacitors, Fixed, Electrolytic, Tantalum, Solid as a basis to estimate the failure rate of solid tantalum chip capacitors.

The failure rate model for solid tantalum capacitors is given in MIL HDBK-217F, Section 10.12, page 10-21.

$$\lambda_p = \lambda_B \pi_{CV} \pi_{SR} \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 10.12

π_{CV} = capacitance factor, Section 10.12

π_{SR} = series resistance factor, Section 10.12

π_Q = quality factor, Section 10.12

π_E = environment factor, Section 10.12

The base failure rate for solid tantalum capacitors is .0067 failures/10^6 hours. This is based an operating temperature of 30 °C and a stress factor (ratio of operating to rated voltage) of 0.3.

The capacitance factor is a function of the capacitor value, refer to the detailed reliability estimate for the actual values.

The series resistance factor is based on a circuit resistance (ratio of the effective resistance between the capacitor and the power supply to the voltage applied to the capacitor) of > 0.1 to 0.2 which results in a factor of 0.27.

Most parts will be procured at D reliability level and the corresponding quality factor is 0.001. Those parts procured as commercial components have a quality factor of 10.

The environment factor for space applications is 0.4 .

2.3.4 Opto-Isolators

Opto-isolators are used on several boards and the failure rate equation as defined in Section 6.11, page 6-19, of MIL-HDBK-217F and is presented below.

$$\lambda_P = \lambda_B \pi_T \pi_Q \pi_E$$

where:

λ_P = part failure rate / 10^6 hours

λ_B = base failure, Section 6.11

π_T = temperature factor, Section 6.11

π_Q = quality factor, Section 6.11

π_E = environment factor, Section 6.11

The base failure rate for an opto-isolator is 0.013 failures/10^6 hours.

Based on a junction temperature of 50 °C, the temperature factor is 2.1.

Although the parts are screened, no credit is allowed for parts screening, therefore the quality factor is 8.0.

As before, the environmental factor for space applications is 0.5.

2.3.5 Resistors

Fixed film resistors are used throughout the sensor design. Because the jumpers used in the designs are 0 Ω chip resistors, they have been included with resistors for this estimate. The failure rate equation is given in Section 9.2, page 9-3, of MIL-HDBK-217F.

$$\lambda_p = \lambda_B \pi_R \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 9.2

π_R = resistance factor, Section 9.2

π_Q = quality factor, Section 9.2

π_E = environment factor, Section 9.2

The base failure rate of 0.0013 failures/10^6 hours for fixed film resistors is based on an ambient temperature of 30 °C and a stress factor of 0.5 (ratio of operating power to rated power).

All resistors values, except one, are < .1 Meg ohms which defines the resistance factor of 1.0. The resistor with a value > 0.1 Meg ohm has a resistance factor of 1.1.

Because these are procured to an S quality level, the quality factor is 0.03.

The environment factor for space applications is 0.5.

2.3.6 Quartz Oscillators

The failure rate model for quartz oscillators is given in Section 19.1, page 19-1, of MIL-HDBK-217F.

$$\lambda_p = \lambda_B \pi_Q \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 19.1

π_Q = quality factor, Section 19.1

π_E = environment factor, Section 19.1

The base failure rate for quartz oscillators is frequency dependent, refer to the detailed reliability estimate section for numerical values.

The quality factor is 2.1 based on commercial component procurement.

The environment factor is 0.5 for space applications.

2.3.7 Inductive Devices

The reliability model for fixed inductors is defined in Section 11.2, page 11-3, of MIL-HDBK-217F and is presented below.

$$\lambda_P = \lambda_B \pi_C \pi_Q \pi_E$$

where:

λ_P = part failure rate / 10^6 hours

λ_B = base failure, Section 11.2

π_C = construction factor, Section 11.2

π_Q = quality factor, Section 11.2

π_E = environment factor, Section 11.2

The base failure rate of 0.0004 failures/10^6 hours for fixed inductors is based on a temperature of 30 °C and a maximum operating temperature of 125 °C.

All inductors are fixed (as opposed to variable), therefore the construction factor is 1.0.

The sensor designs use a mix of MIL-STD and commercial inductors. For the non MIL parts we are using the lowest quality factor listed in MIL-HDBK-217F. That is 20. For those devices that are purchased at an S level of reliability the quality factor is 0.03.

The environment factor is 0.5 for space applications.

2.3.8 Motors

The failure rate for the stepper motors is defined by Section 12.1, page 12-1 of MIL-HDBK-217F.

$$\lambda_P = \left[\frac{t^2}{\alpha_B^3} + \frac{1}{\alpha_W}\right] \times 10^6 \text{ Failures} / 10^6 \text{ hours}$$

where:

α_B = Weibull characteristic life for motor bearings

α_W = Weibull characteristic life for motor windings

The Weibull characteristics for both the bearings and windings are based on ambient temperature as well as operating time at that temperature. Two operating temperatures were selected, -10 °C and +40 °C with corresponding operating times of 50 hours and 200 hours. For non-constant temperature operation, the method defined in Section 12.1, page 12-2 was used to calculate a weighted characteristic life for both the bearings and the windings. See the section on detailed reliability estimate for numerical results.

2.3.9 Printed Circuit Board Connectors

The failure rate model, presented below, for printed circuit board connectors is given in Section 15.2, page 15-4 of MIL-HDBK-217F.

$$\lambda_p = \lambda_B \pi_K \pi_P \pi_E$$

where:

λ_p = part failure rate / 10^6 hours

λ_B = base failure, Section 15.2

π_K = mating / unmating factor, Section 15.2

π_P = active pins factor, Section 15.2

π_E = environment factor, Section 15.2

The base failure rate for printed circuit board connectors is based on the operating temperature. For a temperature of 10 °C it is .00017 failures/10^6 hours.

The mating/unmating factor is 1.0 which is based on an allowable 0 to 0.5 mating/unmating cycles/1000 hours.

The active pins factor is a function of the number of active pins in the connector. For each connector this data is provided in the detailed reliability estimate section.

The environmental factor is 0.8 based on a space environment and procurement of commercial connectors.

3.0 Detailed Reliability Estimate

3.1 Background

All of the sensors that are to be used in the Clementine sensor suite are modular in nature. The core of all sensors is the Actel Camera. Star Trackers require only an Actel Camera board. A UV /Visible camera is a combination of an Actel Camera board and a Filter Wheel board. Likewise, a LIDAR is comprised of an Actel Camera board, a Filter Wheel board, a Range Receiver board and a LIDAR System Controller board.

To avoid unnecessary duplication of data, the detailed estimate for each board will be presented in section 3.2. Sections 3.3 thru 3.5 will combine the estimates for each of the individual boards into sensors and present a sensor by sensor reliability estimate.

3.2 Board Level Detailed Reliability Estimates

The following tables represent the parts lists and all of the parameters used to derive our reliability estimates. Table 3 presents the Actel Camera board. Table 4 represents the Filter Wheel board. Table 5 represents the Range Receiver board and table 6 presents the LIDAR System Controller board.

ACTEL Camera

MICROCIRCUITS

Part No.	Description	No.	C_1	C_2	Π_T	Π_E	Π_Q	Π_L	λ_P	Comments
LM317LM/A+	REGULATOR, ADJUSTABLE	2	0.01	0.0034	2.8	0.5	3.8	1.0	0.22333	Custom screening program
DS34C86M/A+	DRIVER, LINE, QUAD, CMOS	1	0.01	0.0072	2.8	0.5	3.8	1.0	0.11889	Custom screening program
DS34C87M/A+	RECEIVER, LINE, QUAD, CMOS	4	0.01	0.0072	2.8	0.5	3.8	1.0	0.47555	Custom screening program
LF353M	AMPLIFIER, WIDE BAND, DUAL, JFET INPUT	2	0.01	0.0034	2.8	0.5	3.8	1.0	0.22333	Custom screening program
LF442CM	AMPLIFIER, DUAL, JFET INPUT	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
TSC4426COA	DRIVER, DUAL, INVERTING	5	0.01	0.0034	2.8	0.5	3.8	1.0	0.55833	Custom screening program
TSC4428COA	DRIVER, DUAL, NON INVERTING	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
CLC501AJ920	AMPLIFIER, CLAMPING	2	0.01	0.0034	2.8	0.5	3.8	1.5	0.33500	Custom screening program
54AC74/883	FLIP-FLOP, DUAL, J-K	2	0.01	0.0071	1.3	0.5	2.0	1.0	0.06570	883/B Screening
AD558TE/883	CONVERTER, DIGITAL TO ANALOG	1	0.02	0.0071	2.8	0.5	2.0	1.0	0.11786	883/B Screening
MP7684KS	CONVERTER, ANALOG TO DIGITAL	1	0.06	0.0130	2.8	0.5	3.8	1.0	0.65594	Custom screening program
LM385BZ-1.2	REFERENCE, VOLTAGE	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
REF01CS	REFERENCE, VOLTAGE	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
A1020A-1JQ44E	GATE ARRAY, FIELD PROGRAMMABLE	1	0.03	0.0167	2.8	0.5	2.0	1.0	0.20494	883/B Screening
CCD78X3	CHARGE COUPLED DEVICE	1	0.06	0.0096	2.8	0.5	2.0	1.0	0.34183	883/B Screening
TH7990	CONTROLLER, CCD	1	0.02	0.0167	0.6	0.5	3.8	1.0	0.07712	Custom screening program
AD590JH/883	SENSOR, TEMPERATURE	1	0.01	0.0006	2.8	0.5	2.0	1.0	0.05597	883/B Screening

DIODES

Part No.	Description	No.	λ_B	Π_S	Π_T	Π_E	Π_Q	Π_C	λ_P	Comments
4150-ISM	DIODE, SWITCHING, 50 VOLT, 200 MA	1	0.001	0.0054	2.2	0.5	5.5	1.0	0.00003	Hermetic commercial
BAT54S	DIODE, SCHOTTKY, 30 VOLT, 200 MA	2	0.001	0.1900	2.2	0.5	8.0	1.0	0.00339	Plastic SOT-23

TRANSISTORS

Part No.	Description	No.	λ_B	Π_A	Π_T	Π_E	Π_Q	Π_R	λ_P	Comments
MMBT3904	NPN, 40 V, 200 MA, 225 MW	3	0.00074	1.5000	1.7	0.5	8.0	.58	0.01328	Plastic SOT-23
SST215	FET, DMOS, N-CHANNEL, LATERAL	3	0.01200	1.5000	1.6	0.5	8.0	1.00	0.35612	Plastic SOT-23

Table 3a. Actel Camera Semiconductors

CHIP CAPACITORS

Part No.	Description	No.	Value(pF)	λ_B	Π_{CV}	Π_Q	Π_E		λ_P	Comments
	CAP, CHIP, CERAMIC	53	100000	0.00028	2.3488	0.03	0.5		0.000519	MIL-SPEC component
	CAP, CHIP, CERAMIC	4	220	0.00028	1.1270	0.03	0.5		0.000019	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	220000	0.00028	2.5819	0.03	0.5		0.000011	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	2200	0.00028	1.4857	0.03	0.5		0.000006	MIL-SPEC component
	CAP, CHIP, CERAMIC	2	22000	0.00028	1.9586	0.03	0.5		0.000016	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	15	0.00028	0.8166	0.03	0.5		0.000003	MIL-SPEC component
	CAP, CHIP, CERAMIC	5	3300	0.00028	1.5598	0.03	0.5		0.000033	MIL-SPEC component
	CAP, CHIP, CERAMIC	2	10000	0.00028	1.7818	0.03	0.5		0.000015	MIL-SPEC component
	CAP, CHIP, CERAMIC	3	39	0.00028	0.9158	0.03	0.5		0.000011	MIL-SPEC component
	CAP, CHIP, CERAMIC	2	270	0.00028	1.1551	0.03	0.5		0.000010	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	10	0.00028	0.7778	0.03	0.5		0.000003	MIL-SPEC component

TANTALUM CAPACITORS

Part No.	Description	No.	Value (μF)	λ_B	Π_{CV}	Π_Q	Π_E	Π_{SR}	λ_P	Comments
	CAP, CHIP, TANT	5	4.7	0.00667	1.2041	0.001	0.4	0.270	0.000004	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	1	47	0.00667	1.5873	10.000	0.4	0.270	0.011428	Commercial Part
	CAP, CHIP, TANT	9	22	0.00667	1.4491	0.001	0.4	0.270	0.000009	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	5	6.8	0.00667	1.2586	0.001	0.4	0.270	0.000005	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	4	10	0.00667	1.3183	0.001	0.4	0.270	0.000004	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	2	1.0	0.00667	1.0000	0.001	0.4	0.270	0.000001	Series R / PS Volt = ~0.15

Table 3b. Actel Camera Capacitors

RESISTORS

Part No.	Description	No.	Value(kΩ)	λ_B	Π_R	Π_Q	Π_E		λ_P	Comments
	RES, CHIP, FILM	1	1 Meg Ω	0.0013	1.1	0.03	0.2		0.000009	Stress ratio = 0.4,temp = 30 °C
	RES, CHIP, FILM	81	< .1 Meg Ω	0.0013	1.0	0.03	0.2		0.000632	Stress ratio = 0.4, temp = 30 °C

CRYSTALS

Part No.	Description	No.	MHz	λ_B	Π_Q	Π_E			λ_P	Comments
	CRYSTAL, 20 MHZ	1	20	0.0259	2.1	0.5			0.027188	Hermetic non MIL part

INDUCTORS

Part No.	Description	No.	Value	λ_B	Π_C	Π_Q	Π_E		λ_P	Comments
	INDUCTOR, 100 µH	5	100 µH	0.00037	1.0	0.03	0.5		0.000028	QPL part

CONNECTORS

Part No.	Description	No.	Pins	λ_B	Π_K	Π_Q	Π_E		λ_P	Comments
	CONNECTOR, 51 PIN, MICRO MINIATURE	1	51	0.00017	1.0	9.72	0.8		0.001323	Non mil part

Table 3c. Actel Camera Other Passive Components

Filter Wheel

MICROCIRCUITS

Part No.	Description	No.	C_1	C_2	Π_T	Π_E	Π_Q	Π_L	λ_P	Comments
DS34C86M/A+	RECEIVER, LINE, QUAD, CMOS	1	0.01	0.0072	2.8	0.5	3.8	1.0	0.11889	Custom screening program
DS34C87M/A+	DRIVER, LINE, QUAD, CMOS	1	0.01	0.0072	2.8	0.5	3.8	1.0	0.11889	Custom screening program
NE555	TIMER, PRECISION	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
A1020A-1JQ44E	GATE ARRAY, FIELD PROGRAMMABLE	1	0.03	0.0167	2.8	0.5	2.0	1.0	0.20494	883/B Screening
UGS3140HH	SWITCH, HALL EFFECT	3	0.01	0.0012	2.8	0.5	3.8	1.0	0.32246	Custom screening program

DIODES

Part No.	Description	No.	λ_B	Π_S	Π_T	Π_E	Π_Q	Π_C	λ_P	Comments
4150-ISM	DIODE, SWITCHING, 50 VOLT, 200 MA	5	0.001	0.0054	2.2	0.5	5.5	1.0	0.00017	Hermetic Part

OPTO ISOLATORS

Part No.	Description	No.	λ_B	Π_T	Π_Q	Π_E			λ_P	Comments
AQV101A	ISOLATOR, PHOTO DIODE	5	0.013	2.1	8.0	0.5			0.10733	Plastic screened part

Table 4a. Filter Wheel Semiconductors

CHIP CAPACITORS

Part No.	Description	No.	Value(pF)	λ_B	Π_{CV}	Π_Q	Π_E		λ_P	Comments
	CAP, CHIP, CERAMIC	11	10000	0.00028	1.7818	0.03	0.5		0.000082	S level reliability
	CAP, CHIP, CERAMIC	4	10	0.00082	0.7778	0.03	0.5		0.000038	S level reliability
	CAP, CHIP, CERAMIC	6	100	0.00028	1.0253	0.03	0.5		0.000026	S level reliability
	CAP, CHIP, CERAMIC	1	100000	0.00028	2.3488	0.03	0.5		0.000010	S level reliability

TANTALUM CAPACITORS

Part No.	Description	No.	Value(µF)	λ_B	Π_{CV}	Π_Q	Π_E	Π_{SR}	λ_P	Comments
	CAP, CHIP, TANT	5	1.0	0.00667	1.0000	0.001	0.4	0.27	0.000004	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	2	0.68	0.00667	0.9548	0.001	0.4	0.27	0.000001	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	4	2.2	0.00667	1.0992	0.001	0.4	0.27	0.000003	Series R / PS Volt = ~0.15
	CAP, CHIP, TANT	2	10.0	0.00667	1.3183	10.0	0.4	0.27	0.018982	Commercial Part

RESISTORS

Part No.	Description	No.	Value(kΩ)	λ_B	Π_R	Π_Q	Π_E		λ_P	Comments
	RES, CHIP, FILM	20	<.1 Meg Ω	0.0013	1.0	0.03	0.2		0.000156	MIL-SPEC Parts

INDUCTORS (FERRITE BEADS)

Part No.	Description	No.	Value	λ_B	Π_C	Π_Q	Π_E		λ_P	Comments
	BEAD, FERRITE	10	Ferrite	0.00039	1.0	20.0	0.5		0.039000	Commercial ferrites

CONNECTORS

Part No.	Description	No.	Pins	λ_B	Π_K	Π_Q	Π_E		λ_P	Comments
	CONNECTOR, 9 PIN, MICRO MINIATURE	1	9	0.00017	1.0	2.44	0.8		0.000332	Non mil part

STEPPER MOTOR

Part No.	Description	No.	Temp(C)	Time (hrs)	α	α_{WT}	α_B	α_W	λ_P	Comments
	MOTOR, STEPPER	1	-10.00	50.0	1075.3	1.4E+07	5103.1	6.2E+05	2.08E-06	
			40.00	200.0	80224.8	5.0E+05				

Table 4b. Filter Wheel Passive Components

LIDAR Range Receiver

MICROCIRCUITS

Part No.	Description	No.	C_1	C_2	Π_T	Π_E	Π_Q	Π_L	λ_P	Comments
LM307M/A+	AMPLIFIER, OPERATIONAL	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
LM317LM/A+	REGULATOR, VOLTAGE	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
LM360M	COMPARATOR, DIFF, HIGH SPEED	1	0.01	0.0034	2.8	0.5	3.8	1.0	0.11167	Custom screening program
CLC410AJE	AMPLIFIER, VIDEO, WITH DISABLE	1	0.01	0.0034	2.8	0.5	3.8	1.5	0.16750	Custom screening program
DC/DC CONV	CONVERTER, DC / DC	1	0.01	0.0016	2.8	0.5	3.8	1.5	0.16237	Mfg. custom part
CLC520AJE	AMPLIFIER, OPERATIONAL, AGC	1	0.01	0.0062	2.8	0.5	3.8	1.5	0.17548	Custom screening program
A747MW/883B	AMPLIFIER, OPERATIONAL, DUAL	1	0.01	0.0037	2.8	0.5	2.0	1.0	0.05907	883/B Screening

DIODES

Part No.	Description	No.	λ_B	Π_S	Π_T	Π_E	Π_Q	Π_C	λ_P	Comments
JANTXV1N914	DIODE, SWITCHING, 100 VOLT	1	0.001	0.1900	2.2	0.5	0.7	1.0	0.00015	QPL component
JANTXV1N823-1	REFERENCE, ZENER, TC	1	0.002	0.1900	1.6	0.5	0.7	1.0	0.00022	QPL component
HSMS-2820	DIODE, SCHOTTKY BARRIER	2	0.001	0.1900	2.2	0.5	8.0	1.0	0.00339	Plastic screened component

PHOTO DIODES

Part No.	Description	No.	λ_B	Π_T	Π_Q	Π_E			λ_P	Comments
C30954E/883B	DIODE, PHOTO AVALANCHE	1	0.004	2.1	2.4	0.50			0.009907	JAN Quality due to 883/B screen

TRANSISTORS

Part No.	Description	No.	λ_B	Π_A	Π_T	Π_E	Π_Q	Π_R	λ_P	Comments
2N7002	NPN, VHF/UHF, 15 V, 50 MA, 225 MW	4	0.00740	1.5000	1.7	0.5	8.0	.58	0.17710	Screened plastic SOT-23
SST4416	JFET, N-CHANNEL, 350 MW	1	0.00740	1.5000	1.6	0.5	8.0	0.68	0.04964	Screened plastic SOT-23
BF9965	MOSFET, DUAL, 20 VOLT, 200 MW	1	0.01200	1.5000	1.6	0.5	8.0		0.11871	Screened plastic SOT-23

Table 5a. Range Receiver Semiconductors

CHIP CAPACITORS

Part No.	Description	No.	Value(pF)	λ_B	Π_{CV}	Π_Q	Π_E		λ_P	Comments
	CAP, CHIP, CERAMIC	1	1000	0.00028	1.3516	0.03	0.5		0.000006	MIL-SPEC component
	CAP, CHIP, CERAMIC	2	1000	0.00125	1.3516	0.03	0.5		0.000051	MIL-SPEC, 1000 volt rating
	CAP, CHIP, CERAMIC	7	10000	0.00028	1.7818	0.03	0.5		0.000052	MIL-SPEC component
	CAP, CHIP, CERAMIC	2	10000	0.00125	1.7818	0.03	0.5		0.000067	MIL-SPEC, 1000 volt rating
	CAP, CHIP, CERAMIC	1	820	0.00028	1.3198	0.03	0.5		0.000006	MIL-SPEC component
	CAP, CHIP, CERAMIC	19	100000	0.00028	2.3488	0.03	0.5		0.000186	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	220	0.00028	1.1270	0.03	0.5		0.000005	MIL-SPEC component
	CAP, CHIP, CERAMIC	1	10	0.00028	0.7778	0.03	0.5		0.000003	MIL-SPEC component
	CAP, CHIP, CERAMIC	6	4700	0.00125	1.6274	0.03	0.5		0.000183	MIL-SPEC, 25 volt rating

TANTALUM CAPACITORS

Part No.	Description	No.	Value(μF)	λ_B	Π_{CV}	Π_Q	Π_E	Π_{SR}	λ_P	Comments
	CAP, CHIP, TANT	6	6.8	0.00667	1.2586	0.001	0.4	0.27	0.000005	Mil parts

RESISTORS

Part No.	Description	No.	Value(kΩ)	λ_B	Π_R	Π_Q	Π_E		λ_P	Comments
	RES, CHIP, FILM	64	<.1 Meg Ω	0.0013	1.0	0.03	0.2		0.000499	Stress ratio = 0.4,temp = 30 °C
	RES, CHIP, FILM	1	1 Meg Ω	0.0013	1.1	0.03	0.2		0.000009	Stress ratio = 0.4,temp = 30 °C

INDUCTORS

Part No.	Description	No.	Value	λ_B	Π_C	Π_Q	Π_E		λ_P	Comments
	INDUCTOR, 100 μH	4	100 μH	0.0004	1.0	0.03	0.5		0.000024	QPL part
	BEAD, FERRITE	6	Ferrite	0.00039	1.0	20.00	0.5		0.023400	Commercial ferrites

CONNECTORS

Part No.	Description	No.	Pins	λ_B	Π_K	Π_Q	Π_E		λ_P	Comments
	CONNECTOR, 15 PIN, MICRO MINIATURE	1	15	0.00017	1.0	3.28	0.5		0.000279	Commercial part

Table 5b. Range Receiver Passive Components

LIDAR System Controller

MICROCIRCUITS

Part No.	Description	No.	C_1	C_2	Π_T	Π_E	Π_Q	Π_L	λ_P	Comments
LM117HVH/883	REGULATOR, VOLTAGE	1	0.01	0.00027	2.8	0.5	2.0	1.0	0.05564	QPL part
DS34C86M/A+	DRIVER, LINE, QUAD, CMOS	1	0.01	0.0072	2.8	0.5	3.8	1.0	0.11889	Custom screening program
DS34C87M/A+	RECEIVER, LINE, QUAD, CMOS	4	0.01	0.0072	2.8	0.5	3.8	1.0	0.47555	Custom screening program
74HC05M	INVERTER, HEX, OPEN COLLECTOR	1	0.01	0.0062	1.3	0.5	3.8	1.0	0.06067	Custom screening program
54HA373LMQB	LATCH, TRANSPARENT, NON-INVERTING, OCTAL	1	0.01	0.0071	1.3	0.5	2.0	1.0	0.03285	QPL part
AD558TE/883	CONVERTER, DIGITAL TO ANALOG	2	0.02	0.0071	2.8	0.5	2.0	1.0	0.23572	QPL part
A1020-1JQ44E	GATE ARRAY, FIELD PROGRAMMABLE	2	0.034	0.0167	2.8	0.5	2.0	1.0	0.40988	883/B screened component
AS83C154	MICRO PROCESSOR, 8 BIT	1	0.14	0.0167	0.6	0.5	3.8	1.0	0.34975	Custom screening program
LMA9050	GATE ARRAY	1	0.04	0.0100	0.6	0.5	3.8	1.0	0.10988	Custom screening program
HM4-6617B-8	PROM, 2K X 16	2	0.00085	0.0118	0.6	0.5	2.0	1.0	0.02568	883/B screened component

OPTO ISOLATORS

Part No.	Description	No.	λ_B	Π_T	Π_Q	Π_E			λ_P	Comments
HCPL2631/883B	ISOLATOR, OPTICAL	1	0.013	2.1	2.4	0.5			0.03220	JAN quality factor, 883/B screen

TRANSISTORS

Part No.	Description	No.	λ_B	Π_A	Π_T	Π_E	Π_Q	Π_R	λ_P	Comments
IFR9020	FET, P-CHANNEL, REP, AVALANCHE	1	0.01200	1.5000	1.6	0.5	8.0		0.11871	

Table 6a. LIDAR System Controller Semiconductors

CHIP CAPACITORS

Part No.	Description	No.	Value(pF)	λ_B	Π_{CV}	Π_Q	Π_E		λ_P	Comments
	CAP, CHIP, CERAMIC	23	33000	0.00028	2.0562	0.03	0.5		0.000197	S reliability level
	CAP, CHIP, CERAMIC	6	10000	0.00028	1.7818	0.03	0.5		0.000045	S reliability level
	CAP, CHIP, CERAMIC	1	330	0.00028	1.1832	0.03	0.5		0.000005	S reliability level
	CAP, CHIP, CERAMIC	6	100000	0.00028	2.3488	0.03	0.5		0.000059	S reliability level

TANTALUM CAPACITORS

Part No.	Description	No.	Value(μF)	λ_B	Π_{CV}	Π_Q	Π_E	Π_{SR}	λ_P	Comments
	CAP, CHIP, TANT	5	1.0	0.00667	1.0000	0.001	0.4	0.3	0.000004	MIL-SPEC part
	CAP, CHIP, TANT	3	22.0	0.00667	1.4491	0.001	0.4	0.3	0.000004	MIL-SPEC part
	CAP, CHIP, TANT	2	15.0	0.00667	1.3840	0.001	0.4	0.3	0.000002	MIL-SPEC part
	CAP, CHIP, TANT	1	4.7	0.00667	1.2041	0.001	0.4	0.3	0.000001	MIL-SPEC part
	CAP, CHIP, TANT	2	1.0	0.00667	1.0000	0.001	0.4	0.3	0.000002	MIL-SPEC part

RESISTORS

Part No.	Description	No.	Value(kΩ)	λ_B	Π_R	Π_Q	Π_E		λ_P	Comments
	RES, CHIP, FILM	33	< .1 Meg Ω	0.0013	1.0	0.03	0.2		0.000257	Stress ratio = 0.4,temp = 30 °C

Table 6b. LIDAR System Controller Resistors and Capacitors

CRYSTALS

Part No.	Description	No.	MHz	λ_B	Π_Q	Π_E			λ_P	Comments
	CRYSTAL, 12 MHZ	1	12	0.0230	2.1	0.5			0.024174	Hermetic commercial
	CRYSTAL, 30 MHZ	1	30	0.0284	2.1	0.5			0.029845	Hermetic commercial

INDUCTORS

Part No.	Description	No.	Value	λ_B	Π_C	Π_Q	Π_E		λ_P	Comments
	BEAD, FERRITE	2	Ferrite	0.00039	1.0	20.0	0.5		0.007800	Commercial, Quality factor = 20
	TRANSFORMER, PULSE	1		0.00240	n/a	5.0	0.5		0.006000	Commercial, Quality factor = 5
	INDUCTOR	6	10, 100 μH	0.00037	1.0	0.03	0.5		0.000033	Mil part

CONNECTORS

Part No.	Description	No.	Pins	λ_B	Π_K	Π_Q	Π_E		λ_P	Comments
	CONNECTOR, 51 PIN, MICRO MINIATURE	2	51	0.00017	1.0	9.72	0.5		0.001653	Screened commercial part
	CONNECTOR, 15 PIN, MICRO MINIATURE	3	15	0.00017	1.0	3.28	0.5		0.000836	Screened commercial part
	CONNECTOR, 9 PIN, MICRO MINIATURE	1	9	0.00017	1.0	2.44	0.5		0.000207	Screened commercial part

Table 6c. LIDAR System Controller Other Passive Components

3.3 Star Tracker Reliability Estimate

When the estimated failure rates for the individual components comprising the Actel Camera board are added together the estimated failure rate per 10^6 hours is as shown in table 7 below.

Sub-System Board	Failures per 10^6 Hours
Actel Camera Board	4.34446

Table 7. Actel Camera Estimated Failures per 10^6 Hours

The equation used to convert estimated failures per 10^6 hours to an estimated probability of success is as follows:

$$\text{Estimated probability of success} = \exp(-T_m \lambda_p / 10^6)$$

Where:

T_m = Mission duration in hours

λ_p = Estimated failure rate per 10^6 hours

Using this equation the estimated probability of success for a Star Tracker for a 7 month (5280 hour) mission is as shown in table 8.

Duty Cycle	Estimated Probability of Success
100 %	0.9773
30 %	0.9931

Table 8. Actel Reliability Estimate

3.4 UV / Visible Reliability Estimate

The UV / Visible Camera is comprised of an Actel Camera board and a Filter Wheel board. When the estimated failure rates for the individual components comprising these boards are added together the estimated failure rate per 10^6 hours is as shown in table 9 below.

Sub-System Board	Failures per 10^6 Hours
Actel Camera	4.34446
Filter Wheel	1.05414
Total	5.39860

Table 9. UV/Vis Camera Estimated Failures per 10^6 Hours

Using the equation given in section 3.3 above, the estimated probability of success for a UV / Visible camera for a 7 month (5280 hour) mission is as shown in table 10.

Duty Cycle	Estimated Probability of Success
100 %	0.9719
30 %	0.9915

Table 10. UV/Vis Reliability Estimate

3.5 LIDAR Reliability Estimate

The LIDAR is comprised of an Actel Camera board and a Filter Wheel board, a Range Receiver board and a System Controller. When the estimated failure rates for the individual components comprising these boards are added together the estimated failure rate per 10^6 hours is as shown in table 11 below.

Sub-System Board	Failures per 10^6 Hours
Actel Camera	4.34446
Filter Wheel	1.05414
Range Receiver	1.27361
System Controller	2.06601
Total	8.73822

Table 11. LIDAR Estimated Failures per 10^6 Hours

Using the equation given in section 3.3 above, the estimated probability of success for the LIDAR for a 7 month (5280 hour) mission is as shown in table 12.

Duty Cycle	Estimated Probability of Success
100 %	0.9549
30 %	0.9862

Table 12. LIDAR Reliability Estimate

4.0 Summary

The Clementine Sensor Suite sensors are assembled from a mix of commercial and MIL-SPEC components. All of the components used are subjected to a screening program, either MIL-STD-883 class B or a custom program. The estimated failure rates per 10^6 hours for the Clementine Sensor Suite sensors, using MIL-HDBK-217F, has been calculated. This failure rate has been converted into a probability of success figure for each sensor. Those figures are given in table 13 below.

Sensor	Estimated Probability of Success, 100 % Duty Cycle	Estimated Probability of Success, 30 % Duty Cycle
Star Tracker	0.9773	0.9931
UV/Vis	0.9719	0.9915
LIDAR	0.9549	0.9862

Table 13. Sensor Reliability Estimates

Appendix B
Configuration

Appendix B.1

StarTracker Camera Document Tree
(C1-AAA92-106282 Tab 01)

Clementine
Configuration Management

S1
Star Tracker Camera

Document Tree #:	C1-AAA92-106282 TAB01
Title:	Star Tracker Camera Assy, V3.1
Next Higher Tree:	None

Comments:
Star Tracker Camera C1-AAA92-106282 Tab01 uses a ST1A Camera Board WITH FLIGHT CCD # TH7883F02-01B/T

Serial Number:	
File Name:	
Software/Op. System:	Excel 4.0/Macintosh

Prepared by:		Date: 3/17/93	E.E. Apvd.	Date: 4/22/93
Prod. Chk.		Date: 4/2/93	M.E. Apvd.	Date: 4/7/93
E.E. Chk.		Date: 4-15-93	Q.A. Apvd.	Date: 3 May 93
M.E. Chk.		Date: 4/2/93	Engr. Rlsd	Date: 10 May 93

REVISION HISTORY

Level	00	OA	OB								
Date	5.10.93	5.28.93	6.18.93								

LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
REF						S1	CAMERA INTERFACE CONTROL DOCUMENT		C1-S1-010	0A		
REF						S1	CAMERA ASSEMBLY PROCEDURE		C1-S1-012	0A		
REF						S1	ABBREVIATED FUNCTION TEST PROCEDURES		C1-S1-017	00		
REF						S1	ENVELOPE CONTROL		AAA92-100838	00		
REF						S1	INTERFACE CONTROL		AAA92-100839	0C		
REF						S1	OPTICAL PRESCRIPTION	OCA 17073	NONE			
REF						S1,2,4	WASHER, SMALL,#6		AAA93-103855	00	SYS.LEVEL-NOT SHOWN	
	X					S1	**STAR TRACKER CAMERA ASSY, V3.1**		AAA92-106282	00		
		X				S1	ISOLATOR SHIM		AAA93-102551	00		
		X				S1	THERMISTER, FENWALL	534-31AG04-S62	NONE			
		X				S1	CCD, THOMSON	TH7883F02-01B/T				FLIGHT
		X				S1	LENS ASSEMBLY, WFOV	880-0001-401-0C	AAA92-109469	0C		
		X				S1	FACEPLATE, FIBER OPTIC	880-1004-001-0C	AAA92-109466	0C		
		X				S1	ELEMENTS ASSEMBLED	880-0002-101-0C	AAA92-109462	0C		
		X				S1	ELEMENT NO. 1	880-1000-001-0B	AAA92-109463	0B		
		X				S1	ELEMENT NO. 2	880-1001-401-0F	AAA92-109464	0F		PURCHASED
		X				S1	ELEMENT NO. 3	880-1002-001-0B	AAA92-109465	0B		ITEM
		X				S1	FOCUS SPACER	880-1006-001-00	AAA92-109468	00		
		X				S1	HOUSING	880-1005-001-0D	AAA92-109467	0D		
		X				S1	FACEPLATE,BLANK	880-1003-001-00	NONE			
		X				S1	#2 SCREW, BAFFLE		AAA93-103859	00		
1	2	3	4	5	6							

		LEVEL					Document Title	Document Number				
1	2	3	4	5	6	Prefix		Foreign	LLNL	Rev	S/N	Status
		X				S1	HEATER,LENS, MINCO	HK17402-9311	NONE			
		X				S1	LENS STANDOFF		AAA93-102550	0A		
		X				S1	SWITCH, SUNDSTRAND	974-0014-774	NONE			
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			X			S1	COVER		AAA93-102598	00		
			X			S1	VANE, BASE		AAA93-103799	00		
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			X			S1	VANE NO. 2	880-1022-001-0A	AAA92-108746	0A		
			X			S1	VANE NO. 3	880-1023-001-0A	AAA92-108745	0A		
			X			S1	VANE NO. 4	880-1024-001-0A	AAA92-108744	0A		
		X				S1	**CAMERA ASSY**		AAA92-106277	0B		
			X			S1	CAMERA HOUSING		AAA92-106258	0C		
			X			S1	BUSHING, JACKPOST, MDM CONN.		AAA93-101167 TAB08	00		
			X			S1	CIRCUIT BOARD PAD	800-3068	AAA92-104621	00		
			X			S1	END COVER		AAA92-106249	0A		
			X			S1	SHIM, LOWER, END COVER		AAA93-102610	00		
			X			S1	SHIM, UPPER, END COVER		AAA93-102609	0A		
			X			S1	CONNECTOR BRACKET		AAA92-106257	0A		
			X			S1	PAD, CCD THERMAL		AAA93-102243	00		
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			X			S1	ICD, CAMERA		AAA92-104603	0F		
			X			S1	ST2A CAMERA ASSY, w. GAIN & OFFSET CONT.		LEA92-3128-03	0A		
			X			S1	SCHEMATIC, CAMERA, ST2A		LEA92-3128-01	0C		
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				X		S1	BILL OF MATERIALS		LEA92-3128-04	0D		
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					X	S1	MTG. HARDWARE	800-3043	AAA92-104607-TAB01	00		
					X	S1	NUT, PCB RETAINER		AAA92-109126	0A		
				X		S1	ASSEMBLY PROCEDURE		LEA92-3128-05	0B		
				X		S1	TEST PROCEDURE		LEA92-3128-06	00		
				X		S1	FAB DRAWING		LEA92-3128-07	0A		
				X		S1	CAMERA ACTEL ARRAY-U26 (ADDRESS #6)		LEA92-3128-08	00		
					X	S1	DOUBLE CORRELATED SAMPLING	(FILE: DCS_1)	LEA92-3128-48	00		
					X	S1	CAMERA INTEGRATION TIMER	(FILE: INTI3BI1)	LEA92-3128-58	00		
					X	S1	FRAME ENABLE	(FILE: FRCOUNT)	LEA92-3128-68	00		
					X	S1	SASI RECEIVER	(FILE: SASIRCVO)	LEA92-3128-78	00		
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Clementine
Configuration Management

S1
Star Tracker Camera

Document Tree #:	C1-AAA92-106282 TAB03
Title:	Star Tracker Camera Assy, V3.1
Next Higher Tree:	None

Comments:
Star Tracker Camera C1-AAA92-106282 Tab02 uses a ST2A Camera Board

Serial Number:	
File Name:	
Software/Op. System:	Excel 4.0/Macintosh

Prepared by:		Date: 3/17/93	E.E. Apvd.		Date: 4/22/93
Prod. Chk.		Date: 4/2/93	M.E. Apvd.		Date: 4/2/93
E.E. Chk.		Date: 4-15-93	Q.A. Apvd.		Date: 3-May-93
M.E. Chk.		Date: 4/2/93	Engr. Rlsd		Date: 10 May 93

REVISION HISTORY

Level	00	0A	0B								
Date	5.10.93	5.28.93	6.18.93								
	KSL	KSL	KSL								

LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
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REF						S1	CAMERA ASSEMBLY PROCEDURE		C1-S1-012	0A		
REF						S1	ABBREVIATED FUNCTION TEST PROCEDURES		C1-S1-017	00		
REF						S1	ENVELOPE CONTROL		AAA92-100838	00		
REF						S1	INTERFACE CONTROL		AAA92-100839	0C		
REF						S1	OPTICAL PRESCRIPTION	OCA 17073	NONE			
REF						S1,2,4	WASHER, SMALL,#6		AAA93-103855	00	SYS.LEVEL-NOT SHOWN	
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		X				S1	ISOLATOR SHIM		AAA93-102551	00		
		X				S1	THERMISTER, FENWALL	534-31AG04-S62	NONE			
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		X				S1	LENS ASSEMBLY, WFOV	880-0001-401-0C	AAA92-109469	0C		
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				X		S1	ELEMENT NO. 3	880-1002-001-0B	AAA92-109465	0B		ITEM
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			X			S1	HOUSING	880-1005-001-0D	AAA92-109467	0D		
			X			S1	FACEPLATE BLANK	880-1003-001-00	NONE			
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		X				S1	**BAFFLE II ASSY**		AAA93-103815	00		
			X			S1	BASE, BAFFLE II		AAA93-103798	00		
			X			S1	COVER		AAA93-102598	00		
			X			S1	VANE, BASE		AAA93-103799	00		
			X			S1	VANE NO. 1	880-1021-001-0A	AAA92-108747	0A		
			X			S1	VANE NO. 2	880-1022-001-0A	AAA92-108746	0A		
			X			S1	VANE NO. 3	880-1023-001-0A	AAA92-108745	0A		
			X			S1	VANE NO. 4	880-1024-001-0A	AAA92-108744	0A		
		X				S1	**CAMERA ASSY**		AAA92-106277	0B		
			X			S1	CAMERA HOUSING		AAA92-106258	0C		
			X			S1	BUSHING, JACKPOST, MDM CONN.		AAA93-101167 TAB08	00		
			X			S1	CIRCUIT BOARD PAD	800-3068	AAA92-104621	00		
			X			S1	END COVER		AAA92-106249	0A		
			X			S1	SHIM, LOWER, END COVER		AAA93-102610	00		
			X			S1	SHIM, UPPER, END COVER		AAA93-102609	0A		
			X			S1	CONNECTOR BRACKET		AAA92-106257	0A		
			X			S1	PAD, CCD THERMAL		AAA93-102243	00		
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LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
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			X			S1	ICD, CAMERA		AAA92-104603	0F		
			X			S1	ST2A CAMERA ASSY, w. GAIN & OFFSET CONT.		LEA92-3128-03	0A		
			X			S1	SCHEMATIC, CAMERA, ST2A		LEA92-3128-11	0C		
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					X	S1	MTG. HARDWARE	800-3043	AAA92-104607-TAB01	00		
					X	S1	NUT, PCB RETAINER		AAA92-109126	0A		
				X		S1	ASSEMBLY PROCEDURE		LEA92-3128-05	0B		
				X		S1	TEST PROCEDURE		LEA92-3128-16	00		
				X		S1	FAB DRAWING		LEA92-3128-07	0A		
				X		S1	CAMERA ACTEL ARRAY-U26 (ADDRESS #6)		LEA92-3128-18	00		
					X	S1	DOUBLE CORRELATED SAMPLING	(FILE: DCS_1)	LEA92-3128-48	00		
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					X	S1	FRAME ENABLE	(FILE: FRCOUNT)	LEA92-3128-68	00		
					X	S1	SASI RECEIVER	(FILE: SASIRCVO)	LEA92-3128-78	00		
1	2	3	4	5	6							

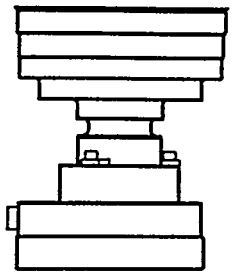
Appendix C
Optical System

Appendix C.1

Clementine WFOV StarTracker Lens Specification

(C1-S1-002)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1 - S1 - 002 Revision A
TITLE: CLEMENTINE WFOV Star Tracker Lens Specification	ASSY: Star Tracker ORIG: I. Lewis DATE: 12/10/92 APPR:



This document is the Revision 0A level of the optical lens assembly performance specification for the WFOV Star Tracker lens. Parameters specified must be met in an as-manufactured assembly and over all specified environmental conditions.

Changes from the Revision 00 specification are significant, and as such are not summarized in a change sheet.

Lawrence Livermore National Laboratory		Total Document Pages: 11 (excluding cover)

CLEMENTINE

WFOV Star Tracker

Lens Specification

	Date	Rev.	Date	Approval
Prepared by: I. T. Lewis	12/10/92	A	12/9/92	
Prepared by: R. E. Priest			12·9·92	
Reviewed by: A. G. Ledebuhr			12/11/92	
Reviewed by: M. J. Shannon			12/10/92	
Approved by: L. D. Pleasance			1/6/93	

Introduction

This document describes the optical performance parameters required for the Clementine project Star Tracker Camera lens. Parameters must be met in an as-manufactured assembly. Design and manufacturing tolerances can be budgeted as desired to achieve the required end performance. A suggested design drawing package is included in the appendix of this specification which can be manufactured to meet the requirements of this specification.

The Star Tracker lens assembly will be a 17.5 mm calibrated focal length concentric lens with a 14.0 mm entrance pupil diameter. The lens will be used to take images of stars. The images are then processed to determine the quaternoin of the star tracker and thus of the spacecraft. The camera will have a CCD focal plane and will be used to take images in the 0.4 to 1.0 μm spectral range.

The performance parameters given in this specification and their paragraph numbers are:

Parameter	Paragraph Number
Optical Parameters	
EPD	1.1
QFL	1.2
Spectral Band	1.3
Format	1.4
Image Quality	1.5
Transmission	1.6
Distortion	1.7
Physical Parameters	
Mass	2.1
Envelope	2.2
Alignment	2.3
Mechanical Interface Control	2.4

1. Optical Parameters

1.1 Entrance Pupil Diameter

The entrance pupil diameter of the lens shall be ≥ 14.0 mm.

1.2 Calibrated Focal Length

The best fit focal length parameter, f, shall be 17.5 ± 0.3 mm. Focal length (f) to be determined by curve fitting 9 points evenly spaced across the lens full diagonal to an f · sine (θ) curve.

1.3 Spectral Band

The spectral band of the lens shall be 0.4 to 1.0 μm.

1.4 Format

All optical specifications must be met over a 8.8 x 13.2 mm image format.

1.5 Image Quality

Greater than 80% of the energy imaged through the lens shall be contained within a 75 x 75 μm square centered on the image located at the rear of the fiber optic faceplate (FOFP). In this centration and location, the central 25 μm x 25 μm square shall contain between 20% and 40% of the total energy in the image. Object distance is infinity. Testing to be performed on-axis only, in air, with focus set for best performance in air.

1.6 Transmission

Transmission of the lens must be greater than the values listed at the following wavelengths:

0.4 μm: 0%; 0.5 μm: 39%; 0.6 μm: 54%; 0.8 μm: 56%; 1.0 μm: 57%

Transmission values include the concentric lens and the FOFP. Transmission requirements are on-axis only.

1.7 Distortion

The deviation from an $f \cdot \sin(\theta)$ mapping using best fit f and θ centroid pixels for the lens and FOFP shall vary by less than 20 μm *difference* between any 2 points located 0.6 mm apart at the FPA . Points shall be sampled on a 2° grid spacing through the entire focal plane. Testing will be provided by LLNL.

1.8 MTF

The MTF shall be measured as part of the acceptance test procedure on-axis only. MTF shall be measured with a point source color spectrum within 20% relative intensity of a G0 star (or a 5900 K blackbody) over the 0.4 to 1.0 μm spectral range. MTF shall be reported as a function of frequency at the single focal plane defined by the location of the fiber optic faceplate. MTF is required on-axis only.

2. Physical Parameters

2.1 Mass

The lens assembly shall mass less than 48 g.

2.2 Envelope

The lens assembly, exclusive of mounting tabs or flanges, shall fit within a 1.1 inch diameter by 1.4 inch long cylinder or equivalent volume.

2.3 Alignment

Light entering the lens perpendicular to the mounting surface plane shall be imaged within 150 μm true position of the center of the pilot diameter.

2.4 Mechanical Interface Control

Mechanical interface control shall be per AAA92-100839-00.

3. Environmental Requirements

The lens is required to perform within specifications during test and calibration on the ground, survive through environmental acceptance test procedures (ATP), through the actual launch environment, and finally for the duration of the mission. The camera is not operated during launch. No G load specifications are in force during operation.

3.1 Operating Ambient Media

The lens will be operated in air (ground testing) and in space. Testing may be performed in air, with data supplied on vacuum focal shift.

3.2 Operating Ambient Temperature

The ambient operating temperature range shall be -20°C to 40°C.

3.3 Storage Ambient Temperature

The ambient storage temperature range shall be -30°C to 70°C.

3.4 Storage Ambient Humidity

The ambient storage humidity shall be 0 to 95% relative humidity. (Noncondensing.)

3.5 Ambient Pressure Profile

The lens assembly shall not be damaged by a rapid depressurization. Maximum depressurization rate is 0.8 psi/sec. Vacuum testing levels shall be $\leq 10^{-5}$ torr to demonstrate environmental compatibility.

3.6 Outgassing

All materials used in the assembly shall exhibit less than 1% total material loss and less than 0.1% collected volatile condensible material per ASTM-E-595-77/84. Material data may be taken from NTIS N91-14437, NASA report RP 1124 Revision 2, November 1990, "Outgassing data for selecting spacecraft materials".

3.7 Quasi-Static Acceleration Loads

The unit shall be designed to survive ± 15 G loading in the three principal axes. Testing to these loads is not required.

3.8 Random Vibration

The unit shall survive 14.0 g rms random vibration per figure 2.

3.9 Shock Spectrum

The unit shall withstand a 294 g 3-σ peak-to-peak acceleration. This time series acceleration is consistent with the shock spectrum per figure 3, attenuated through at least 1 additional interface from the LLNL sensor attachment interface to the spacecraft to the lens assembly attachment point. Testing is not required for the shock spectrum compliance.

3.10 Thermal Cycles

The unit shall withstand thermal cycling from -30 °C to +70 °C at ≤ 3 °C/min over 6 cycles. Testing to begin at room temperature, drop at the specified rate to -30 °C, dwell for 2 hours, then rise to +70 °C, dwell for 2 hours, then repeat, returning to room temperature. All other test unit and flight unit tests to be performed after thermal cycling.

3.11 Radiation Requirements

The unit shall meet all performance specifications after a total dose of 20 kilorads (Si). Analysis to be provided by LLNL.

3.12 Storage Lifetime

The storage lifetime of the unit shall be 5 years.

3.13 Operating Lifetime

The operating lifetime shall be 2 years on the ground. The mission mean design life is 1 year.

3.14 Environmental Test Order

Performance testing of all optical parameters shall be at room temperature and pressure only. Optical parameters to be tested either before or after section tests. Image quality (¶ 1.5) to be tested both before and after section 3 tests. Image quality tests *after* section 3 tests will be performed by LLNL on the deliverable items for which LLNL is responsible for section 3 testing.

3.15 Cleanliness

Optical assemblies must be delivered with all internal surfaces meeting a 300 particulate standard and all internal and external surfaces meeting a Level C molecular standard per MIL-STD-1246. External surfaces shall meet a 750 particulate standard, cleanable to a 300

standard. Cleanliness verification shall be per analysis and no witness samples or inspection are required.

Figure 1 Deleted.

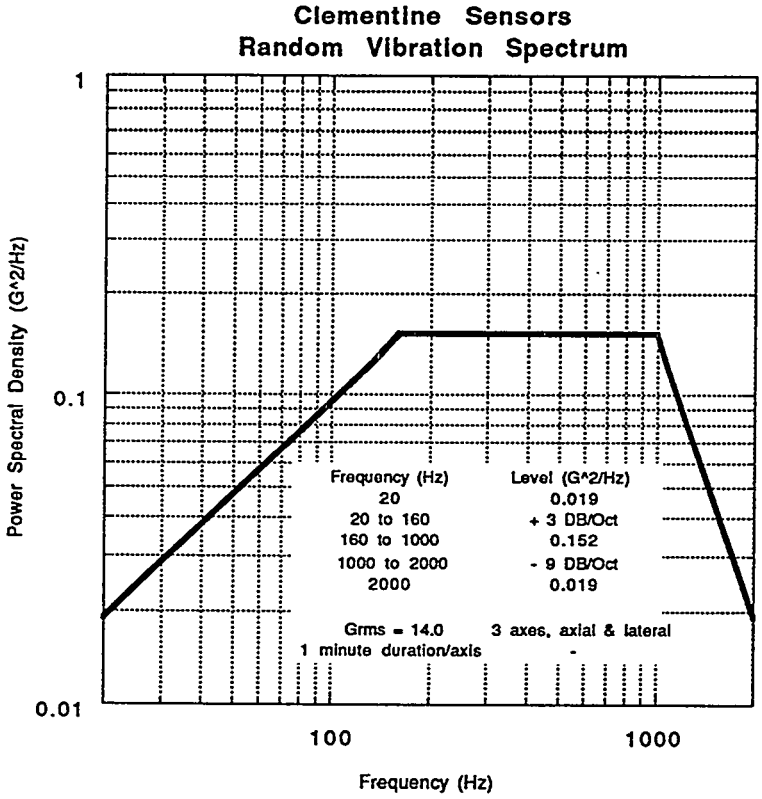


Figure 2 - CLEMENTINE Random Vibration Spectrum
Component Test Level Specification

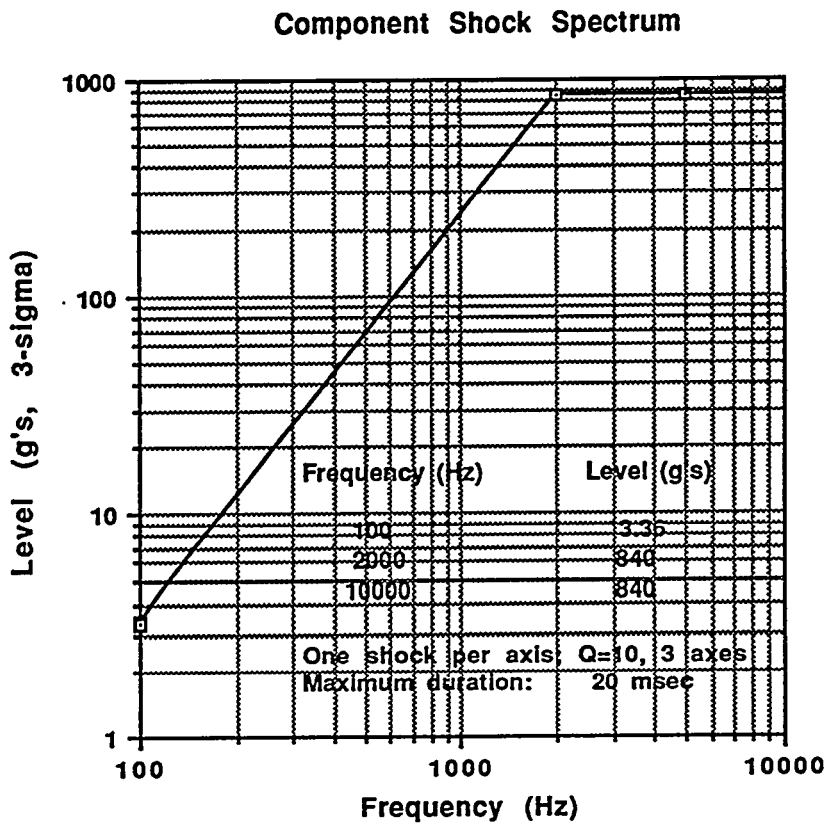


Figure 3 - CLEMENTINE Shock Spectrum
Component Test Level Specification

5.0 Verification and Test Matrix

Table 1 describes the test requirements for the specification paragraphs within this document. The verification methods to be used are: 1) test, 2) analysis, 3) inspection. When 2 boxes are checked in table 1, both methods shall be enforced. A "1" in the box indicates that the parameter must be verified for the test unit acceptance test. A "P" in the box signifies that the parameter must be verified on each prototype unit. An "F" indicates that the item must be verified (or measured) for the flight units.

Table 1 Verification Matrix

Section	Requirement	Test	Analysis	Inspection
1.1	Entrance Pupil Diameter	1, P, F		
1.2	Calibrated Focal Length	1, P, F		
1.3	Spectral Band	N/A		
1.4	Format	N/A		
1.5	Image Quality	1, P, F		
1.6	Transmission	1, P, F		
1.7	Distortion	1[1], P[1], F[1]		
1.8	MTF	1, P, F		
2.1	Mass			1, P, F
2.2	Envelope			1, P, F
2.3	Alignment	1, P, F		
2.4	Mechanical Interface Control			1, P, F
3.1	Operating Ambient Media		1	
3.2	Operating Ambient Temperature		1	
3.3	Storage Ambient Temperature[2]	*1, P[1], F[1]*		
3.4	Storage Ambient Humidity		1	
3.5	Ambient Pressure Profile	1, P[1], F[1]		
3.6	Outgassing		1	
3.7	Quasi-Static Acceleration Loads		1	
3.8	Random Vibration	1, P[1], F[1]	1	
3.9	Shock Spectrum		1	
3.10	Thermal Cycles	1, P[1], F[1]		
3.11	Radiation Requirements		1[1]	
3.12	Storage Lifetime		1	
3.13	Operating Lifetime		1	
3.14	Environmental Test Order	N/A		
3.15	Cleanliness			1, P, F

[1] Testing to be performed by LLNL.

[2] This test is encompassed by the thermal cycle testing in ¶ 3.10.

5.0 Applicable Documents

The following documents are applicable when appropriate to deliverable hardware:

MIL O 13830A	Optical components for fire control instruments; general specification governing the manufacturing, assembly, and inspection of
MIL M 13508	Mirror, front surface aluminized for optical elements
MIL F 48616	Filter (coating), Infrared interference: general specification 4
MIL C 48497	Coatings, single or multi-layer, interference: durability requirements 4
MIL C 675	Coating of glass optical elements: anti-reflection
MIL-STD-1246	Product cleanliness levels and contamination control program

Appendix D
Electronic System

Appendix D.1

Actel Camera Array Test Procedure

(C1-EE-034)

Actel Camera Array Test Procedure

C1-EE-034

	Date	Rev.	Date	Approval
Prepared by: Darron Nielsen	5/3/93			
Reviewed by: J.F. Kordas	5/3/93			
Reviewed by: W.R. Bryson	5/3/93			
Reviewed by: E.H. Schmitt	3-May-93			
Approved by: M.J. Shannon	5/3/93			

TABLE OF CONTENTS

1. Purpose

1.1 This document is the chip level test procedure for the Actel Camera Arrays. You will need to know how the Actel Camera Array test board and software work.

2. Scope.

- This document describes equipment and procedures required to verify the electrical performance of Actel Camera Arrays
- All tests in this procedure are to be performed before Testing any arrays in the Actel Camera Array test board.

3. Required Documents and Test Equipment.

3.1 Required Documents

- Actel Camera Array Test Board Certification C1-EE-033
- Schematic of Camera [Actel] tester

3.2 Required Test Equipment

- Macintosh with LabView and NB-DIO-32F, GPIB, NB-MIO-16
- Tektronix 540, Digital Oscilloscope, HP plotter
- HP8116A pulse/function Generator
- Fluke 77 or 87 Multimeter
- Lambda Dual Regulated power supply

3.3 Conditions and Requirements

3.3.1 Precautions

(1) Responsibility for Safety. All personnel are responsible for maintaining a safe work environment. The Test Conductor or cognizant operator shall assure that appropriate safe practices are implemented during these operations, and that operations are performed in a proper order.

(2) ESDS Equipment. The test specimen contains electrostatic-sensitive devices which are exposed at the electrical interfaces. Therefore, it shall be handled per MIL-STD-1686 Class 1. The test specimen, the test operator (using wrist straps), and related electrical test equipment shall be connected to a common ground before any electrical mating or de-mating operations, and during the use of any electrical test equipment probes. There shall be no "hot-plugging" of the test specimen with any test equipment.

(3) Examine socket For Bad pins and Debris. Before installing any flight Actel arrays.

3.4 Cleanliness and Environment

(1) Standard laboratory conditions of atmospheric temperature, pressure, and humidity are acceptable for the testing defined herein.

(2) Normal housekeeping standards will be required. If appropriate, the unit may be cleaned prior to installation into the next assembly, or prior to return to storage.

3.5 Quality Assurance (QA) Provisions

QA provisions operative during activities defined in this procedure shall be as specified in the project's QA Plan. This section identifies the interfaces between QA and test personnel. QA and test personnel are jointly responsible for the effectiveness of these interfaces in implementing the QA provisions.

(1) QA shall be notified, in advance, of performance of any activities described in this procedure. A QA Inspector may monitor those activities as is deemed necessary or appropriate, in accordance with the project QA Plan. The inspector shall verify that the proper revision of this procedure is used, and that the required Certification Log is in proper order. QA will then give the "OK to Test" prior to the start of test activities.

(2) The QA Inspector shall verify: that calibration is current for all measuring equipment used in these operations, and will not expire prior to completion of these operations; that applicable project-specific electrical support test equipment (STE) has been properly certified and tagged; and that applicable lifting and handling STE has been properly proof tested and tagged.

(3) The QA Inspector may assist in assuring that the precautionary and environmental requirements stated in 3.1 and 3.2 are met. He shall also, at his discretion, assist in the inspection of test setups prior to application of power to a test specimen, and prior to any mechanism-assisted lifts or moves.

(4) Upon the occurrence of a test anomaly (any event that deviates from the planned procedures, exceeds normal variations, or generates unexpected data), operation of the test article shall be stopped immediately. All other test conditions and parameters shall be maintained (except as those conditions may pose an immediate hazard). The QA Inspector shall be notified that a test anomaly has occurred.

(5) The QA Inspector or Test Conductor (with QA concurrence) shall note each test anomaly on the Failure Reporting And Corrective Action System (FRACAS). The Inspector and the Test Conductor shall review the anomaly. Minor troubleshooting may be done to determine the cause of the anomaly; however, no disassembly or other actions that present a risk to the test article shall be allowed. If the anomaly is found to result from human error or test equipment problems that have not affected the test article, corrective action shall be taken and testing may continue. All troubleshooting steps and results shall be recorded on the FRACAS. The Test Conductor shall supervise any troubleshooting or retesting required in resolving test anomalies.

Quality Assurance (QA) Provisions (continuation)

(6) If a test anomaly cannot be resolved as described above, the Project Engineer shall be notified. If the action indicates that a rework or repair may be required, the anomaly and troubleshooting results shall be noted in the Action Item List (AIL) portion of the Certification Log, Fracus report and a Material Discrepancy Report (MDR) shall be initiated (if required) and processed as prescribed in the QA Plan.

(7) The QA Inspector shall stamp log entries as appropriate, attesting to the proper completion of these operations as previously approved in this procedure document.

3.6 Pre-Test Operations

CAUTION
ESD SENSITIVE HARDWARE. HANDLE PER MIL-STD-1686 Class 1

____(1) Assure readiness to test, including the following items:

(a) Visual examination of the test item and its interfaces, including any special test instrumentation .

(b) Calibration is current for measuring instruments

(c) Proper edition of the procedure, and QA approval of any unincorporated redlines.

(d) Notification of QA of the time that testing will begin.

____(2) Record the "Occasion for Test" on all Data Sheets.

____(3) On the applicable data sheets, record the required information for measuring equipment to be used in the test. Verify that all such equipment bears current calibration stickers, and that calibration will not expire prior to the end of the test.

____(4) Have completed Actel Camera Array Test Board Certification C1-EE-033.

____(5) Solicit and obtain the QA Inspector's "OK to Continue."

Test Conductor _____ Date _____

3.7 TEST

Test Start Date: _____ Test Completion Date: _____

Equipment Used	S/N	Calibration In-date

Enter Name of LabView programs to Use

Name	Date Created	Date Modified

NOTES:

_____

_____

_____

_____

_____

Test Conductors:

Name: _____ Initials: _____ Date _____

Name: _____ Initials: _____ Date _____

Functions to Be tested

1. Sasi Functions

Check bits can be set and cleared and read back.

Name: _____ Initials: _____Date _____

2. Double Correlated Sampling

TP14 is OL2
TP15 is ORfet
TP16 is OR

Name: _____ Initials: _____Date _____

3. Precision Integration mode Check and Frame Enable
{frame xfer of UV-vis arrays}

TP9 SM1
TP10 SM0
TP11 EOL
TP3 VSync {frame enable}
TP13 VTC

Name: _____ Initials: _____Date _____

4. Test Initialization

TP8 T2
TP7 Init

Name: _____ Initials: _____Date _____

DATA is to go in certification log of camera that array is going into.

Appendix D.2
Schematics

NOTES, UNLESS OTHERWISE SPECIFIED

1. C15, C17, AND C47 SHOULD BE PLACED AS CLOSE AS POSSIBLE TO RESPECTIVE VDD PINS
2. PLACE GUARD STRUCTURE AROUND TRACE FROM U19 PIN 16 TO BASE AND EMITTER OF Q2 NO CLOCKING SIGNALS SHOULD BE PLACED UNDERNEATH THIS TRACE
3. SEE CONFIGURATION TABLE, BILL OF MATERIALS, AND ASSEMBLY PROCEDURES FOR APPROPRIATE COMPONENT VALUE
4. ANALOG RETURN & DIGITAL RETURN SHALL ONLY BE TIED TOGETHER BY JUMPER JP13, WHICH SHALL BE AS CLOSE AS POSSIBLE TO U8
5. RESISTOR VALUES IN OHMS, 1/4W +/-1%, METAL FILM
6. CAPACITOR VALUES ARE IN MICROFARADS, 100V, +/-10%, CERAMIC
7. TEMPERATURE SENSOR T1 BONDED TO HEAT SINK OF U19
8. ELECTROLYTIC CAPACITOR VALUES IN UF, +/ 10%, VOLTAGE AS SPECIFIED TANTALUM

KEEP AWAY FROM SWITCHING SIGNAL LINES

CRITICAL VIDEO LINES DO NOT RUN NEAR POWER OR SWITCHING LINES

TRACES TO BE AS SHORT AS POSSIBLE

12 01 04, 010 011 USE CALMOS ONLY
02 03 08 012 013, 014 USE MOTOROLA ONLY
SEE CONFIGURATION TABLE

POWER AND GROUND TABLE		
REF DES	+5V	GND
U2, U6, U7, U12, U25	16	8
U26	3, 14, 25, 35	10, 21, 32, 43
U8, U31	16	8

CAMERA (ACTEL) CONFIGURATION TABLE					
COMPONENT DESIGNATION	ZONE	FIGURE 2 ACTEL 30K74 STD	FIGURE 2 ACTEL 30K74 LOW	UV/VIS STD	UV/VIS LOW
R6	D8				
R7	F8				
R24	F4	1.62K	1.62K	3.01K	3.01K
R28	C6	0 Ω	0 Ω	3.01K	3.01K
JP2 1-2	F6			X	X
JP3	F6				
JP4	F6	X	X	X	X
JP5	E6				
JP6	F5	X	X		
JP7	G6	X	X	X	X
JP8	G6				
JP9	D6	X	X		
JP10	C6			X	X
JP11	B5	X	X		
JP12	B5			X	X
JP13	A3	X	X	X	X
JP14	F1	X	X	X	
JP15	F1	X	X	X	
JP16	F1	X	X	X	
R131		931 Ω	931 Ω	2.74K	2.74K
R134		383 Ω	383 Ω	931 Ω	931 Ω
R137		178 Ω	178 Ω	383 Ω	383 Ω
U26	G7	LEA92-312808	LEA92-312818	LEA92-312828	LEA92-312838

X = INSTALLED

LEA92 3128-01-DC

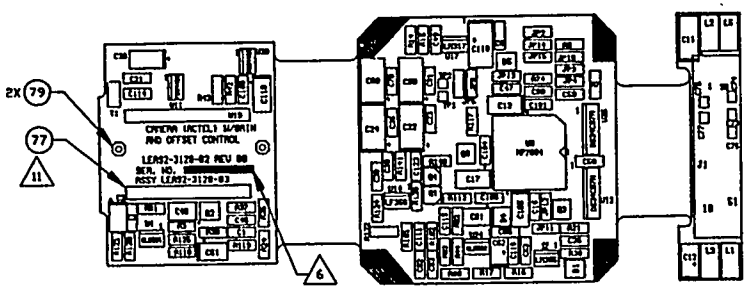
SHEET 1 OF 1

DWG NO.	SHEET	REV
LEA92-3128-03	1	0A

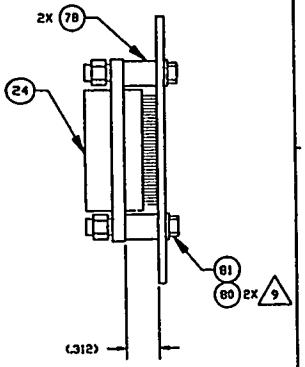
REV	DESCRIPTION	DATE	APPROVED
0A	Revised	4/9/02	

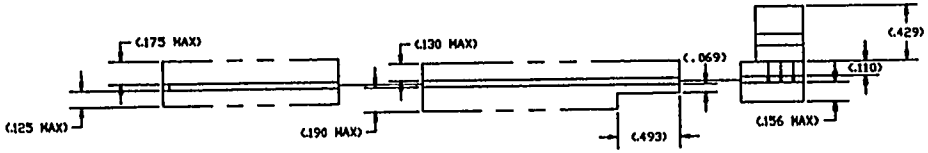
NOTES: UNLESS OTHERWISE SPECIFIED

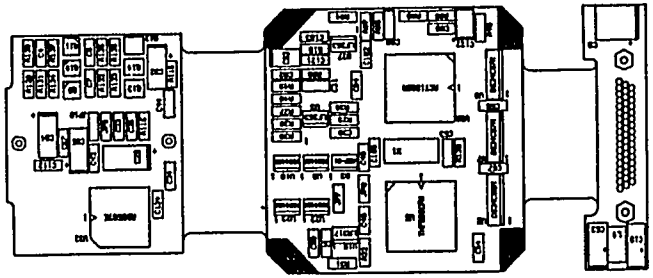
1. INTERPRET DRAWING PER DOD-STD-100 WITH DIMENSIONS AND TOLERANCES PER ANSI Y14.5M-1982.
2. FOR SCHEMATIC DIAGRAM SEE LEA92-3128-01.
3. FOR PRINTED WIRING LAYOUT SEE LEA92-3128-02.
4. WORKMANSHIP PER MIL-STD-454, REQ.9.
5. SOLDER PER MIL-STD-2000.
6. MARK SERIAL NUMBER APPROX. WHERE SHOWN BAG & TAG WITH PART NO. LEA92-3128-03.
7. BOARD IS PROVIDED IN A FRAME. DO NOT REMOVE FORM FRAME UNTIL COMPLETION OF ALL ELECTRICAL TESTS AND CONFORMAL COATING.
8. COMPONENTS ARE ELECTROSTATIC SENSITIVE, USE ELECTRO STATIC DISCHARGE HANDLING PRECAUTIONS .
9. TORQUE TO 2.2 ±.4 IN-LBS.
10. SEE INDIVIDUAL BILL OF MATERIALS (LEA92-3128-04) AND ASSEMBLY PROCEDURES (LEA92-3128-05) FOR SPECIFIC ASSEMBLY.
11. TRIM PIN 16 ON CCD SOCKET TO SURFACE PAD ON PRIMARY SIDE. SEE DETAIL A. THE OTHER 19 PINS ARE THROUGH HOLES.
12. DO NOT INSTALL T1 TEMP. SENSOR AT INITIAL ASSEMBLY.
13. ICD DRAWING NO. AAA92-104603.



(PRIMARY SIDE)







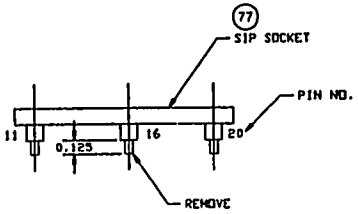
(SECONDARY SIDE)

STAR TRACKER LEA 92-3128-04 | W/VIS SENSOR NO. 2 LEA 92-3128-14 | LIDAR LEA 92-3128-14

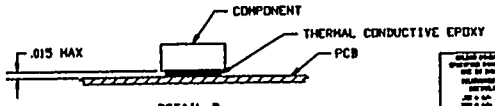
CONFIGURATION TABLE 10

REF DES	-01	-02	-04
R6	150Ω		
R7	150Ω		
R24	1.62K	3.01K	3.01K
R28	0 Ω	3.01K	3.01K
JP2 1-2			X
JP2 2-3			
JP3			X
JP4	X	X	
JP5		X	X
JP6	X		
JP7	X	X	X
JP8			
JP9	X		
JP10		X	X
JP11	X		
JP12		X	X
JP13			
JP14	X	X	
JP15	X	X	
JP16	X	X	
R131	931	2.74K	2.74K
R134	383	931	931
R137	178	383	383

X = INSTALLED



DETAIL A
SCALE: NONE
CCD SIP SOCKET
MODIFICATION PIN NO. 16, SEE NOTE 11



DETAIL B
SCALE: NONE
TYPICAL OF
U8, U9, U11, U17
U2, U1, U24, U25

6/10/93

P.C. DESIGN BY JARDOM ENTERPRISES

LAWRENCE LIVERMORE NATIONAL LABORATORY

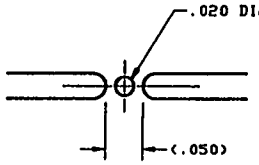
PCB ASSEMBLY-
CAMERA (ACTEL) W/GAIN AND OFFSET CONTROL

LEA92-3128-03 | 0A

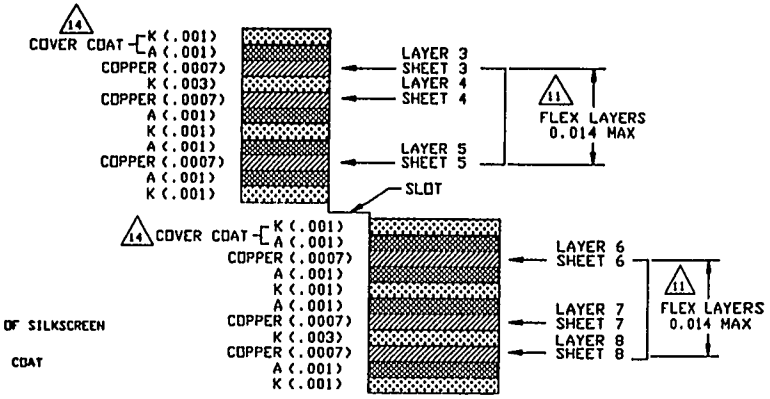
CAD SYS: ACAD | FILE:

DWG NO	SHEET	REV
LEA92-3128-07	1	0A

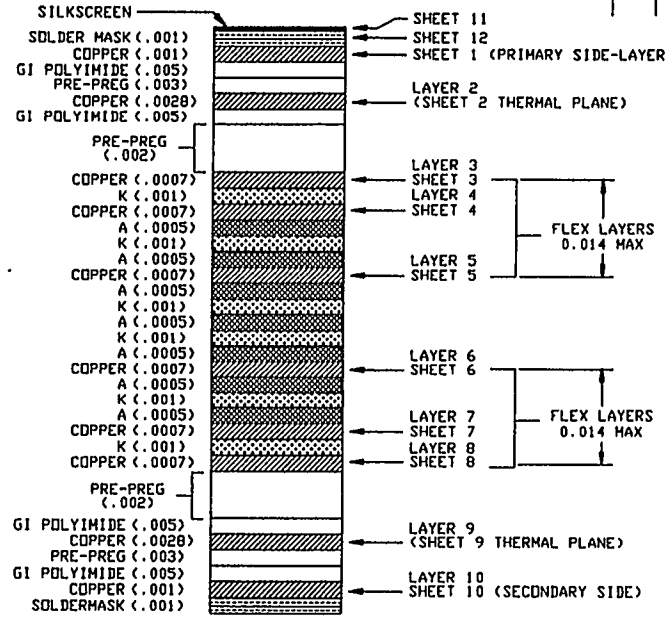
REV	DESCRIPTION	DATE	APPROVED
0A	Revised	4/93	G.Z.



DETAIL A
SCALE: NONE



SECTION B-B D-D
SCALE: NONE
FLEX ONLY



SECTION A-A, C-C, E-E
SCALE: NONE
A = ADHESIVE
K = KAPTON

16 0,0 ORGIN ON GERBER FILES.

15. FOOT PRINTS OF COMPONENTS TO BE FREE OF SILKSCREEN EPOXY PAINT.

14 .050 TYPICAL OVER LAP OF OUTER COVER COAT OF FLEX LAYERS.

13. ICD DRAWING NO. AAA92-104603

12 RIGID MIDDLE SECTION MODIFICATION FOR PRIMARY & SECONDARY SIDE SEE DETAIL G.

11 SEE INDIVIDUAL ARTWORK LAYER.

10. ACCEPTABILITY OF PRINTED BOARDS PER ANSI/IPC-A-600D, CLASS III. (HI-REL)

9. USE ARTWORK NO. LEA92-3128-02:

SHEET 1 FOR PRIMARY SIDE
SHEET 2 FOR CHASSIC GROUND - THERMAL PLANE
SHEET 3 FOR ANALOG POWER
SHEET 4 FOR ANALOG TRACES
SHEET 5 FOR ANALOG GROUND
SHEET 6 FOR DIGITAL GROUND
SHEET 7 FOR DIGITAL TRACES
SHEET 8 FOR DIGITAL POWER
SHEET 9 FOR CHASSIC GROUND - THERMAL PLANE
SHEET 10 FOR SECONDARY SIDE
SHEET 11 FOR SILKSCREEN ON PRIMARY SIDE (WHITE)
SHEET 12 FOR PRIMARY SIDE SOLDERMASK
SHEET 13 FOR SECONDARY SIDE SOLDERMASK
SHEET 14 FOR PADMASTER
— ARTWORK

8. IDENTIFY PART PER MIL-STD-130, BAG AND TAG WITH SERIAL NUMBER.

7. MATERIAL:

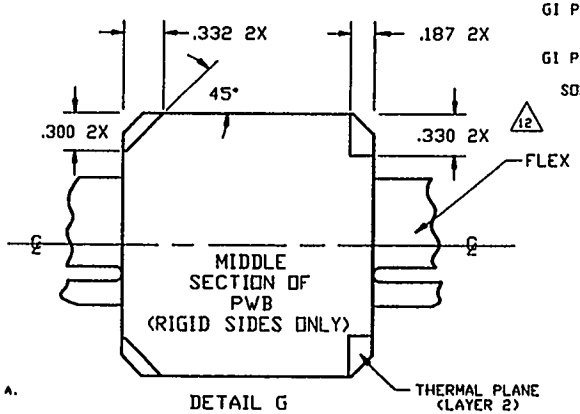
A. 1 OZ., .005 THICK, GI POLYIMIDE MIL-P-13949 (PRIMARY & SECONDARY SIDES).

B. 1/2 OZ. COPPER/FT2, .001 THICK, GI POLYIMIDE PER IPC-FC-241 (FLEX LAYERS).

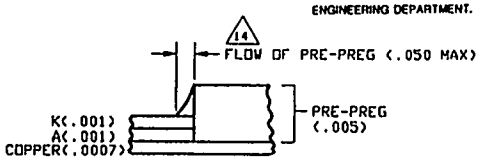
C. 2 OZ. COPPER, COPPERFOIL PER IPC-MF-150 THERMAL PLANE, LAYER NO. 2 & 9.

D. ADHESIVE PER IPC-FC-233 0.0005.

E. SOLDER MASK .001 THICK MAX. PER IPC-SM-840, COLOR-GREEN, OVER BARE COPPER. (SMOBC)



DETAIL G
SCALE: NONE
SEE SHEET NO. 1 AND NO. 10 OF ARTWORK MASTER



SECTION F-F

THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE LABORATORY REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE ELECTRONICS ENGINEERING DEPARTMENT.

6 WIDTH OF CONNECTING AREAS (RIBS) ON BOARD CARRIER IN SHEET 2 IS .050" MIN. SEE DETAIL A. LOCATION IS NOT CRITICAL AND SHOULD BE APPROX. WHERE SHOWN.

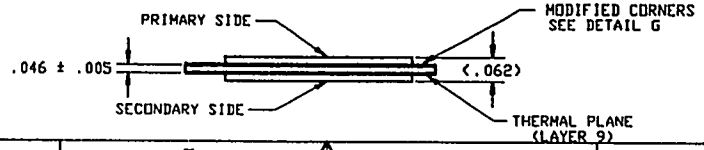
5. INDICATED DIMENSIONS APPLY PRIOR TO REMOVAL FROM RIGID PANEL. DO NOT REMOVE BOARD FROM HANDLING FRAME.

4. AFTER APPLICATION OF SOLDER MASK, ALL EXPOSED COPPER SURFACES SHALL BE SOLDER COATED OR TIN-LEAD PLATED FOLLOWED BY FUSING AND SHALL BE .0003 MINIMUM THICKNESS. SOLDERABILITY TO BE PER MIL-STD-2000.

3. FINISHED ITEM SHALL MEET THE REQUIREMENT OF MIL-P-50884, TYPE 4, CLASS A, AND IPC-D-275 USING MASTER PATTERN LEA92-3128-02.

2. DIMENSIONS APPLY TO PART AFTER PLATING.

1. INTERPRET DRAWING PER DOD-STD-100 WITH DIMENSIONS AND TOLERANCES PER ANSI Y14.5M-1982.



NOTES: UNLESS OTHERWISE SPECIFIED

CAD SYS: ACAD | FILE:

LAWRENCE LIVERMORE NATIONAL LABORATORY

P.C.B

CAMERA (ACTEL) W/AGAIN AND OFFSET CONTROL

JARDON ENGINEERING

LEA92-3128-07 | 0A

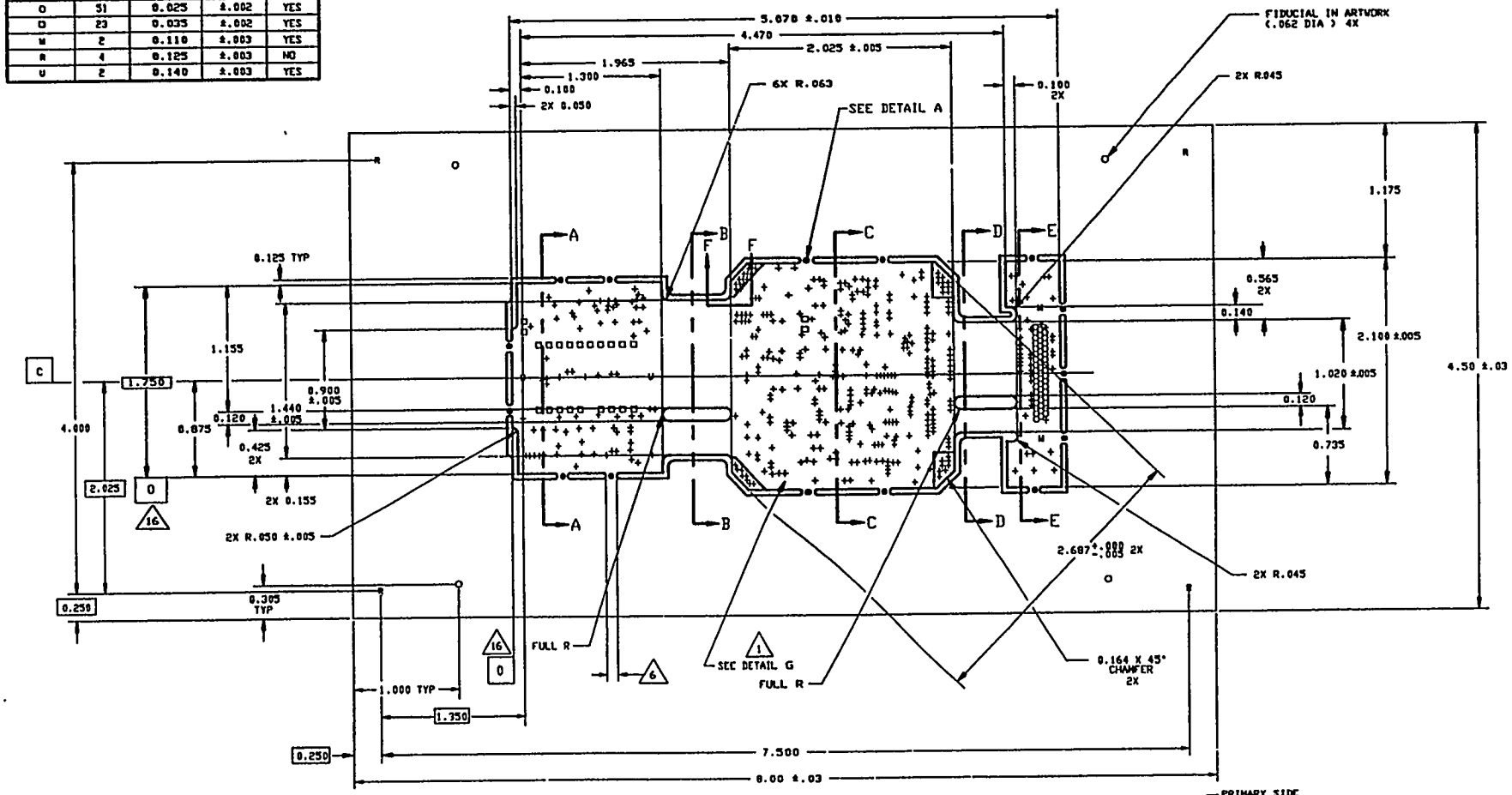
DWG NO.	SHEET	REV
LEA92-3128-07	2	0A

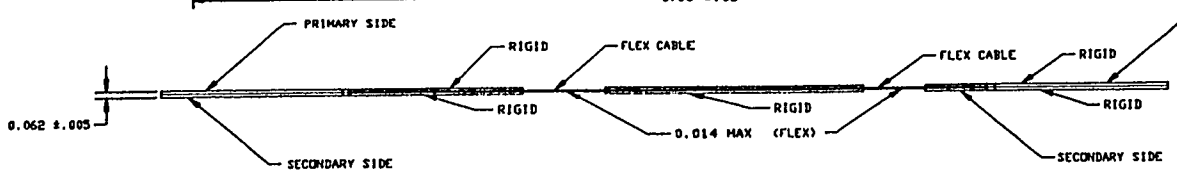
REVISIONS

REV	DESCRIPTION	DATE	APPROVED
	SEE SHEET 1		

HOLE SCHEDULE

HOLE SYM	QTY	SIZE	TOL	PLATED
+	449	0.017	±.002	YES
O	51	0.025	±.002	YES
D	23	0.035	±.002	YES
M	2	0.110	±.003	YES
R	4	0.125	±.003	NO
U	2	0.140	±.003	YES





10/6/93

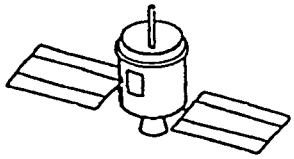
LEA92-3128-07 0A

CAD SYS: ACAD FILE:

Appendix D.3

Electromagnetic Compatibility Tests (C1-EE-030)

CLEMENTINE Sensors Integration Project	ENGINEERING NOTE C1 - EE- 030
TITLE: Electromagnetic Compatibility Tests	ASSY: Sensors ORIG: T. F. Tassinari DATE: 4-8-93 APPR:



Abstract: This document outlines electromagnetic test requirements for LLNL Sensors. This shall include compatibility testing as well as performance measurements.

1. SCOPE

This document outlines the electromagnetic test requirements for LLNL sensors.

2. REQUIREMENTS

2.1 Reference Documents and Drawings

a MIL-STD-1686A, Handling ESD Sensitive Equipment.

b. MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.

c. MIL-STD-462, Electromagnetic Interference Characteristics, Measurement of.

2.2 Electrostatic Discharge (ESD) Control Requirements

The sensor assembly is susceptible to ESD damage and shall be treated as a Class 1 sensitivity device per MIL-STD-1686A.

3. Sensor Electromagnetic Compatibility

These tests are intended to be be conducted and evaluated at the input to the Sensor Power Supply (SPS). The purpose is to determine the Electromagnetic compatibility of the SPS and the sensor as a system.

The sensor, when connected to the SPS, shall not be susceptible to, nor shall it radiate emission levels greater than those specified in MIL-STD-461, *Electromagnetic Interference Characteristics, Requirements for Equipment*, herein after referred to as "MIL-STD-461" as delineated in this subsection. Levels greater than those specified shall be identified to LLNL. The sensor has been designed to operate without malfunction, undesirable response, or deviation from specified performance tolerances when subjected to these electromagnetic environments. Compliance shall be proven

using the procedures of MIL-STD-462, *Electromagnetic Interference Characteristics, Measure of*, and an approved EMI test plan.

The following requirements are based on MIL-STD-461 and MIL-STD-462 and have been modified for the DSPSE program. The tests shall be run as a system.

3.1.1 Conducted Emission

The sensor shall meet the conducted emissions levels defined below:

a. CE01 - As specified in MIL-STD-461C.
b. CE03 - Narrowband only as specified in MIL-STD-461C.
c. CE07 - As specified in MIL-STD-461C with the following exception: paragraph 5.2 b) shall be modified to read: "DC leads: +50 percent, -50 percent of nominal line voltage."

3.1.2 Conducted Susceptibility

The sensor shall not exhibit malfunctions, degradation of performance, or deviation from specifications when subjected to the levels defined below:

a. CS01 - As specified in MIL-STD-461C tailored by Figure 1-1
b. CS02 - As specified in MIL-STD-461C with the following exception: paragraph 7.2 shall be modified to read: "...when subjected to 0.5 volt from a 50-ohm source."
c. CS06 - Section 11.2 a. only and as modified to read: "E1 = ± 30 Volts peak".

3.1.3 Radiated Emissions

The sensor shall be not radiate emissions in excess of the levels defined below:

a. RE02 - Broadband as specified in MIL-STD-461C. Narrowband as tailored by Figure 1-2.

3.1.4 Radiated Susceptibility

The sensor shall not exhibit malfunctions, degradation of performance, or deviation from specifications when subjected to the levels defined below:

a. RS03 - As specified in MIL-STD-461C with a 50% duty cycle,

1KHz square wave modulation, and the following modifications:

Frequency Range	E-Field (Volts/meter).
14 KHz to 30 MHz	1
30 MHz to 10 GHz	5
Above 10 GHz	N/A

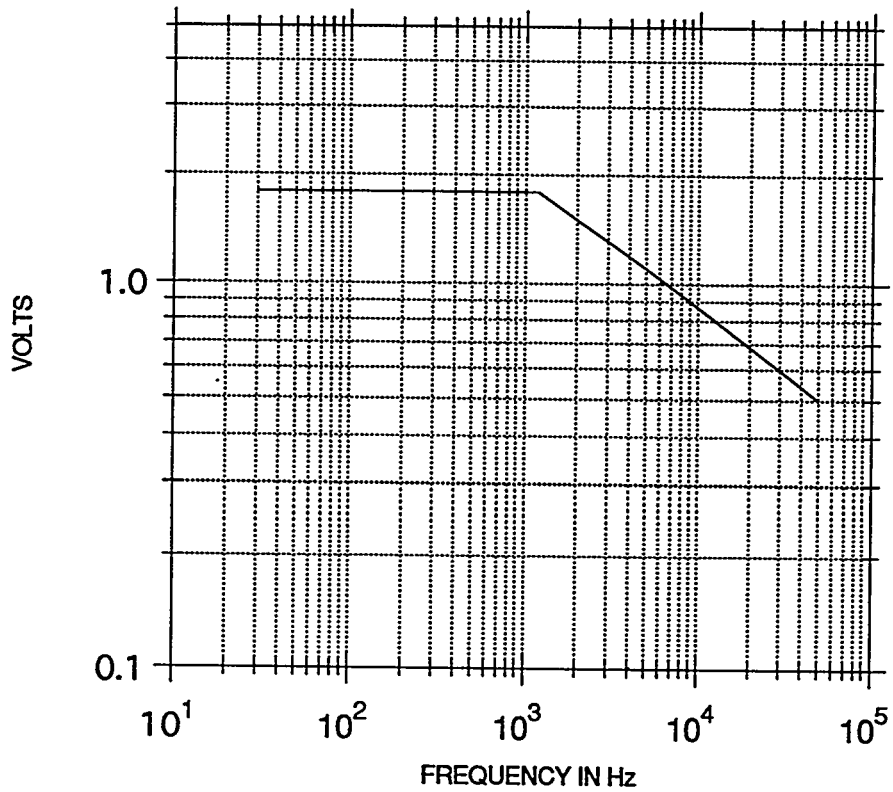


Figure 1-1. Limit For CS01 Susceptibility

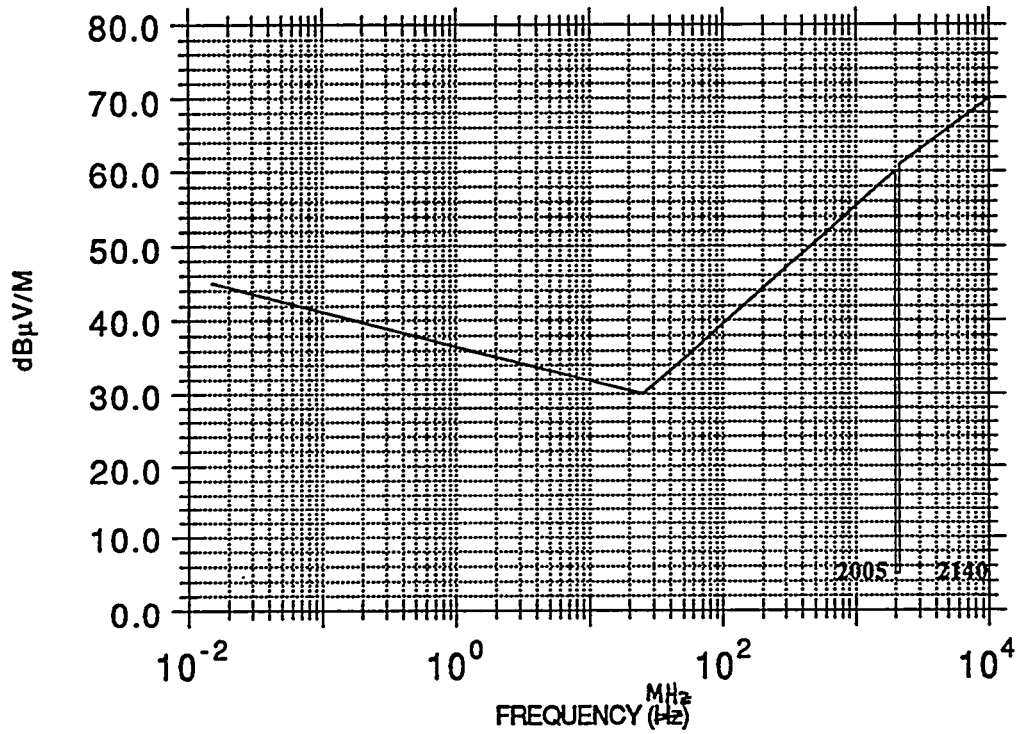


Figure 1-2. Limit For RE02 Narrowband Emissions

3.2 Susceptibility Criteria

The Sensor susceptibility shall be broken into two sections, the imager susceptibility (for all sensors) and the ranger susceptibility (for Hires Lidar only). These criteria shall serve to deem a sensor susceptible when subjected to specified RS03, CS01, CS02 and CS06 test levels.

3.2.1 Image Susceptibility Criteria

When subjected to RS03, CS01, CS02 and CS06, data frames are acquired and analyzed. The noise floor histogram shall be examined and shall not exceed the levels indicated in table 1.

Test	Gain	Max Level
RS03	150 e'/bit	Ambient +0.5*(one grey level)
CS01	150 e'/bit	Ambient +0.5*(one grey level)
CS02	150 e'/bit	Ambient +0.5*(one grey level)
CS06	150 e'/bit	Ambient +0.5*(one grey level)

Table 1

3.2.2 Ranger Susceptibility Criteria

When subjected to RS03, CS01, CS02 and CS06, the range data are monitored at a given discriminator threshold. The false alarm rate (F.A.R.) shall be determined for each test and shall not exceed the levels indicated in table 2. The rate is simply the ratio of false targets per 100 shots. *This criteria is only applicable to the HiRes Lidar Sensor.*

Test	Threshold (mV)	Ambient F.A.R.	Max F.A.R
RS03	10	0	1
CS01	10	0	1
CS02	10	0	1
CS06	10	0	1

Table 2

4. Sensor Electromagnetic Performance

These tests are intended to be be conducted and evaluated at the input to the sensor. The purpose is to determine the Electromagnetic performance of the sensor by itself.

The following tests and requirements are based on MIL-STD-461 and MIL-STD-462.

4.1 Conducted Emission

The conducted emission levels of the sensor by itself shall be evaluated as defined below:

a. CE01 - As specified in MIL-STD-461C.
b. CE03 - Narrowband only as specified in MIL-STD-461C.
c. CE07 - As specified in MIL-STD-461C with the following exception: paragraph 5.2 b) shall be modified to read: "DC leads: +50 percent, -50 percent of nominal line voltage."

4.2 Conducted Susceptibility

The conducted susceptibility levels of the sensor by itself shall be evaluated as defined below:

a. CS01 - As specified in MIL-STD-461C tailored by Figure 1-1.(ratioed to 10% of specific line voltage so as to not damage sensor)
b. CS02 - As specified in MIL-STD-461C with the following exception: paragraph 7.2 shall be modified to read: "...when subjected to 0.5 volt from a 50-ohm source."(ratioed to 10% of specific line voltage so as to not damage sensor)

4.3 Radiated Emissions

4.3.1 Sensor

The sensor radiated emission levels, not including cables, shall be evaluated as defined below:

RE02 - Broadband as specified in MIL-STD-461C. Narrowband as tailored by Figure 1-2.

4.3.2 Components

The radiated emission levels from the cryo cooler and stepper motor shall be evaluated as defined below:

RE01 - Magnetic field direction and intensity from DC to 1 KHz.

Optional- add 1KHz to 50KHz

4.4 Radiated Susceptibility

The sensor radiated susceptibility levels of the sensor by itself shall be evaluated at the levels defined below:

a. RS03 - As specified in MIL-STD-461C with a 50% duty cycle, 1KHz square wave modulation, and the following modifications:

Frequency Range	E-Field (Volts/meter).
14 KHz to 30 MHz	2
30 MHz to 10 GHz	10
Above 10 GHz	N/A

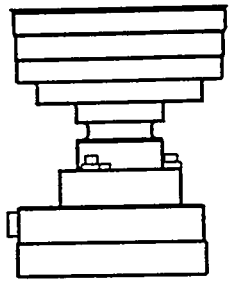
Appendix E
Mechanical System

Appendix E.1

StarTracker Camera Structural Analysis

(C1-S1-008)

CLEMENTINE Sensor Integration Project	ENGINEERING NOTE C1-S1-008
TITLE: Star Tracker Camera Structural Analysis	ASSY: Star Tracker Cam ORIG: D. J. Pines A. Harral DATE: 11 January-93 APPR:



Abstract:

This engineering note discusses structural analysis of the Star Tracker Camera under various Clementine loading environments. Results indicate that the Star Tracker Camera is qualified by analysis to survive all mission loading conditions.

Copies: Ken Leach (Engineering Note Master File), L-287
Emma Harris (Clementine Project File), L-285
Bob Priest, L-285
Scott Ruddell, L-287
Lyn Pleasance, L-285
Mike Shannon, L-285
Arno Ledebuhr, L-287
Preston Carter, L-285
Alfred Harral, P.O. Box 175 Bethel Island, CA. 94511
Dave Trummer, L-194
Dr. Mowan Aswani, M4/920 P.O. Box 92957, Los Angeles, CA. 90009

1.0 Scope

The scope of this Engineering Note is to demonstrate that the Star Tracker Camera is qualified by analysis to meet all loading requirements seen by the Deep Space Program Science Experiment-DSPSE spacecraft.

2.0 Requirements

The requirements for qualification of payload components are detailed in the Engineering and Test Specficification Plan document dated September 1992 and are summarized here for completeness:

2.1 Camera Mission Survivability

Table 1.0: Derived Requirements for Qualification

Loading Condition	Requirements
Steady-State	100 g's loading in each axis (applied separately)
Random Vibration	14 g' rms loading with frequency content from 20 to 2000 Hz (Loading applied simultaneously in all three axis)
Pyro-shock-(for 20 msec)	Peak acceleration = 501 g's with frequency content from 100 to 10000 Hz and attenuated through 5 interfaces with a transmissibilty of 0.168.(Loading applied simultaneously in all three axis)

2.2 Frequency Content

The Engineering and Test Specification Plan did not explicitly establish a frequency content requirement for Star Tracker Camera components. LLNL chooses to adopt a requirement which states that all structural modes must have frequency content > 50 Hz.

2.3 Camera Design Factors of Safety

Table 2.0: DSPSE Design Factors of Safety

Mechanical Property	Factor of Safety
Yield	1.10
Ultimate	1.25
Local Buckling	1.10
General Instability	1.25
Fitting Factor	1.15
Static Test	1.05

2.4 Deflection

The Engineering and Test Specification Plan did not explicitly establish a deflection requirement for internal and external components of the Star Tracker. LLNL chooses to adopt a requirement which states that the clearance between internal components be maintained at all times.

3.0 Star Tracker Camera Structural Model

To meet the above derived requirements for flight qualification a three-dimensional Star Tracker finite element model-FEM, with 342 solid and 800 shell elements, was developed from the most recent camera design drawings dated November 18, 1992. From these drawings six components of the camera were modelled. They included the Baffle Assembly, Lens Assembly, Camera Housing, Mounting Brackets and the two Actel Circuit Boards connected by a flexible hinge. This model was used for determining the mode shapes and natural frequencies of the Star Tracker. In addition, this model was also used to determine the survivability of the camera under various loading environments which include transportation, launch and mission maneuvers. Figures 1-3 show the unloaded model, an exploded view of the internal parts which make up the camera and an illustration of the boundary nodes used to simulate how the camera mounts to the sensor platform. The actual mounting brackets were analyzed individually in separate FEM's. All external loading conditions were applied in **camera body-fixed-(x,y,z)** frame for one particular Star Tracker Camera. To transform to **spacecraft body fixed coordinates-(X,Y,Z)**, the following direction cosine matrices must be applied:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_1 = \begin{bmatrix} -\cos(21) & \sin(48.5)\sin(21) & -\cos(48.5)\sin(21) \\ 0 & \cos(48.5) & \sin(48.5) \\ \sin(21) & \sin(48.5)\cos(21) & -\cos(48.5)\cos(21) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix};$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_2 = \begin{bmatrix} -\cos(21) & -\sin(40.5)\sin(21) & -\cos(40.5)\sin(21) \\ 0 & \cos(40.5) & -\sin(40.5) \\ \sin(21) & \sin(40.5)\cos(21) & \cos(40.5)\cos(21) \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

3.1 Mass Budget of Modelled Components

The mass budget for the modelled Star Tracker components is given in Table 3.0. Using these mass properties and the geometry of the camera the moments of inertia and center of mass of the Star Tracker's FEM were computed and are summarized in Table 4.0.

Table 3.0: Mass Budget of Star Tracker

Component	Mass-(grams)
Camera Housing (Top Cover, End Cover, Four Gussets, Four Corner Posts, Remaining Walls, CCD, Connector, Actel Circuit Boards and Misc.)	135
Lens Assembly Elements w/ cellsHousingMisc	34
Focus Spacer (Thermal Management, Lens Heater & Thermostat)	41
Baffle Assembly (Vanes, Housing, Six Gussets)	60
Mounting Brackets	12
Total Mass Budget	**282**

Table 4.0: Inertia and Center of Mass Properties of Star Tracker

Inertia Matrix of Camera	
$\begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix} = \begin{bmatrix} 3.88 & 0.0059 & -.019 \\ 0.0059 & 3.90 & 0.00012 \\ -.019 & 0.00012 & 2.90 \end{bmatrix} x10^{-4} \quad kg-m^2$	
Center of Mass-(inches)	
X	-0.008
Y	-0.004
Z	1.482

3.2 Material Properties of Components

The camera is made of Aluminum 6061-T651 and is structurally adequate even though this Aluminum alloy was selected primarily for its high thermal conductivity rather than for its strength. The mechanical material properties of Aluminum 6061-T651 are listed in Table 5.0.

Table 5.0: Mechanical Properties of Aluminum 6061-T651

Property	Value
Density	0.09 lb/in^3
Young's Modulus	1x10^7 psi
Shear Modulus	3.76 x10^6 psi
Bulk Modulus	9.804x10^6 psi
Poisson's Ratio	0.33
Yield Strength	39 ksi
Ultimate Strength	42 ksi

The refractive elements in the Lens Assembly are made from an optical glass derivative which has a density of 2.2 kg/m^3. Each element is bonded to its cell using Dow Corning 93-500 optical couplant. Reflective elements are nickel-plated aluminum for the primary and aluminum flashed on fused silica for the secondary.

4.0 Modal Analysis

The first five mode shapes and natural frequencies of the Star Tracker camera were calculated using LLNL NIKE3D finite element code. Table 6.0 summarizes the eigenanalysis performed by this software tool. Figures 4-8 illustrate the corresponding mode shapes. Notice that the first two modes are cantilever bending where the housing top cover and the baffle base deform allowing the baffle to swing from side to side. There is slightly more stiffness in the Y-Y direction due to the narrower geometry of the top cover of the housing in the Y-direction.

The 40 mil thick top cover of the housing and the four 45 mil thick stiffening gussets control the frequency content of modes 1 and 2. Increasing the thickness of these parts raises the frequencies of modes 1 and 2. But this is not necessary since the 50 Hz lower limit is well exceeded by the present configuration. Higher modes occur in the baffle vanes corresponding to radial extension and tranverse vibration.

Table 6.0: Modal Analysis Summary

Mode Number	Natural Frequency-Hz	Mode Shape
1	213	Cantilever Bending (x-x)
2	219	Cantilever Bending (y-y)
3	286	Vane #4 Radial Ext.
4	353	Vane #4 Transverse
5	422	Vane #3 Radial Ext.

5.0 Stress Analysis

Although most of the Clementine mission loading conditions are benign, there are instances, when the entire spacecraft including the payload are subjected to severe loading conditions. This occurs during first, second and third stage separation of the Titan IIG and during the TLI transfer burn. This section discusses the state of stress in each of the components under steady-state, random vibration and pyro-shock loading environments. The Actel circuit boards are treated separately since they are not directly in the load bearing path of the inputs.

5.1 Steady-State

For spacecraft sensor qualification, the Engineering and Test Specification Plan recommends that the sensor be subjected to a steady-state load according to its weight-(See Figure 9.0). Thus, the applied g-loading is found by extracting the value of the ordinate which corresponds to the sensor weight and multiplying this value by 2. Following this procedure, a steady-state loading of 100 g's was applied separately in each of the principal orthogonal axis of the Star Tracker. The state of stress was calculated using the NIKE3D finite element code. Table 7.0 gives the maximum effective stress occurring in each of the camera components for each of the principal orthogonal axis. The safety factors are given in the right column of Table 7.0 against the Yield Strength of Aluminum 6061-T651. Figures 10-19 show the finite element mesh with fringes of effective stress and the deflections amplified by a factor of 20 for each steady-state loading condition. Figures 20-22 show the state of stress in the mounting brackets and the deformation for the 100 g steady-state Z acceleration.

Table 7.0: Steady-State Peak Effective Stresses-(ksi)

Camera Component	x	y	z	Qualification Exceeded By
Camera Housing (Sides)	9.88	9.2	8.42	3.9
Camera Housing (Top Cover)	12.6	16.6	10.5	2.3
Camera Housing (Top Cover Gussets)	14.4	15.1	10.1	2.6
Focus Spacer	2.7	2.9	1.97	13
Lens Housing	0.49	0.56	0.21	70
Baffle Base Ring	1.4	1.5	0.40	26
Baffle Gussets	2.3	2.1	2.0	17
Baffle Back Disk	0.93	0.86	0.60	42
Baffle Outer Cylinder	0.43	0.38	0.56	70
Baffle Vanes	0.05	0.05	1.64	4.3
Mounting Bracket	2.22	2.32	3.77	10

The deflections for the steady-state loading condition were calculated and the maximum deflections are located at the end of the baffle. These deflections are summarized in Table 8.0 for each axis.

Table 8.0: Maximum Deflections at end of Baffle

Direction	Deflection-(inches)
X	0.029
Y	0.028
Z	0.010

5.2 Random Vibration

Random vibration qualification of the star tracker is based on the camera being able to surve the structural acoustic environment of the Titan IIG during first, second and third stage ignitions. The response spectrum for this loading is shown in Figure 23 which is equivalent to 14 g's rms loading from 20 to 2000 Hz. The lack of phase information is this figure implies that there are an infinite number of time domain curves which when transformed yields the same frequency domain spectrum. Three such acceleration versus time curves , used as input to LLNL DYNA3D finite element code, in the X, Y and Z directions were generated to simulate the environment of the Titan IIG PSD response. These curves are shown in Figures 24-26. Since the runtime was prohibitive on a 486/33 MHz computer, Dave Trummer of LLNL ran the random vibration dynamic analysis, with this input, on the YMP Cray using the DYNA3D code. The results are shown in Figures 27-31. The maximum stress of 5.0 ksi occurs at 0.0058 seconds in element #219 corresponding to the top cover of the camera housing. The summary of maximum stresses and deflections are give in Table 9.

The duration of 70 milli-seconds was chosen to limit the computation time of each run. This arbitrary truncation of the time series is not expected to affect the simulated value of the peak effective stress in each component. This is because the 70 ms time series contains approximately 10 cycles of mode 1. Therefore, during this time period all transients are expected to have died out, leaving only steady-state random behaviour associated with the spectrum.

5.2.1 Damping and Exponential Decay

The viscous damping factor for solid aluminum is between 1-5% of critical due to internal friction. The coulomb damping for a structure with tightly bolted joints is between 5-10% of critical due to resistance to slippage at the joints. Using the cantilever bending natural frequency and estimating the damping to be 5% of critical, the time and number of cycles to damp out a step load has been calculated. For an initial deflection of 30 mils, the baffle will decay by 95% after approximately 10 cycles to a deflection of 1.5 mils. Figure 32 shows the baffle ring

down for a damping factor of 5% of critical and also plots the decay times to reach 95% of steady-state value for damping factors from 1-10% of critical.

5.3 Pyro-shock

Similar to qualification under the random vibration specification, pyro-shock qualification of the star tracker requires surviving short duration loads imparted by the Titan IIG during final stage separation. The Engineering and Test Specification Plan document gives a representative shock response spectrum for sensor qualification under loads occurring at the launch vehicle/spacecraft adapter interface-(See Figure 33). The frequency content of the response spectrum extends from 100 to 10,000 Hz. However, below 1,000 Hz there is very little energy content in the shock. The Star Tracker Camera is located 5 interfaces removed from the shock source and an attenuation factor of 0.7 is used for the transmission loss at each interface. The total attenuation for the shock is therefore 0.7^5, or an overall factor of 0.168. Jim Houghton at NRL has simulated the pyro-shock pulse at its source on a shaker and measured the acceleration vs time history. This acceleration vs time shock pulse has a duration of approximately 20 ms. It is shown, attenuated by a factor of 0.168, in Figures 34-35 and was used as input for the dynamic analysis with the DYNA3D code.

Dave Trummer of LLNL also ran the pyro-shock analysis on the YMP Cray. The results are shown in Figures 36-40 and Table 9. Here the resulting stress values are corrected for the square root of 3 overload. Notice that the maximum stress is only 3.79 ksi even though the peak accelerations are over 220 G's. The reason that this stress level is not higher, is that the high accelerations of pyro-shock pulse occur at a much higher frequency than the natural frequency of the Star Tracker Camera. The transmissibility is low at this level of frequency mismatch.

Table: 9.0: Stresses under Steady-State, PSD and Pyro-shock Loadings

Loading direction	Time of maximum stress (sec)	Maximum effective stress (ksi)	Maximum deflection (in.) at end of Baffle
X 100 G's	steady state	12.6	0.029
Y 100 G's	steady state	16.6	0.028
Z 100 G's	steady state	10.5	0.010
X Pyro-shock	0.0162	2.19	0.003
Y Pyro-shock	0.0071	1.62	0.004
Z Pyro-shock	0.0069	1.62	0.004
X 14 Grms random	0.0185	2.2	0.011
Y 14 Grms random	0.0058	5.0	0.013
Z 14 Grms random	0.0059	5.0	0.009

5.4 Fatigue During Life Testing

Figures 41 and 42 are a Constant-Life Diagram for the fatigue behavior of 6061-T6 aluminum alloy. The maximum stress calculated in the Star Tracker Camera is 16.6 ksi and the fatigue life for an alternating stress (+ and -) of this level, taken from the diagram, is approximately 2.8E+06 cycles. The mode 1 cantilever bending natural frequency of the camera is 219 Hz in the Y-Y direction and the random vibration testing lasts 60 seconds in each axis, and there would be 13,140 cycles in each test. If the camera were to undergo a full stress reversal of 16.6 ksi for each and every cycle, then it could survive 213 minutes of testing before fatigue would be a problem.

5.5 Bolt Loads and Safety Factors

The yield safety factors for the various bolted joints of the camera have been calculated for the steady-state 100 g load in the direction that causes the maximum bolt load. The INGRID mesh generation code was used to calculate the part masses and CG locations. The bolts are high strength cap screws with a yield stress of 150-155 ksi and an ultimate stress of 170 ksi. Table 10 lists the maximum load and yield safety factor for each bolted joint.

Table 10: Bolted joint yield safety factors

Bolted joint	Cap screw number and size	Maximum bolt load (lb)	Cap screw yield force (lb)	Cap screw yield safety factor
Lens housing to baffle	3 ea. 2-56	49 lb from 100 G's Y acceleration	566	12
Camera housing to lens housing	3 ea. 2-56	16 lb from 100 G's Y acceleration	566	35
Camera mounting brackets	3 ea. 6-32	35 lb from 100 G's Y acceleration	1377	39
Camera housing bottom cover	4 ea. 2-56	0.5 lb from 100 G's Z acceleration	566	110

5.6 Circuit Board Stress Analysis

A 3D finite element model of the 2X2 in. square ACTEL circuit board was generated. The model simulates the board thickness of 58.5 mils and 28 layers with 196 shell elements with average material properties. The mode shapes and natural frequencies plus the response to steady-state acceleration loading was analyzed using the NIKE3D code. The equivalent Young's modulus for the 28 layer stack up of the circuit board is 2.58E+06 psi. The 30 gram mass of the board was uniformly distributed over the entire board and the four corners were clamped as shown in Figure 42. Table 11 and Figures 43-47 show the first four mode shapes and natural frequencies of the board. Figure 48 shows the circuit board under a steady-state 100 G's of acceleration normal to the board (Z direction). The maximum stress is 1.6 ksi and is located in the board corners and

the center deflection is 2.7 mils. The radius of curvature can be used in estimating the loading on the mounted components. The board has a width of approximately two inches and a center deflection of 2.7 mils results in a radius of curvature of 185 in.

Table 11: ACTEL circuit board mode shapes and natural frequencies

Mode number	Natural frequency (Hz)	Mode shape
1	740	Panel breathing Z-Z
2	1405	Center twisting
3	1680	Edges deflecting
4	2340	Complex breathing Z-Z

A separate 2D finite element plane strain model was used with the NIKE2D code to calculate the stress developed in the circuit board during assembly when the four cap screws are torqued to 6.3 in.-lb. Each of the 28 layers with its material property listed in Table 12 was included in the model. The steady-state 100 G's acceleration load produces much less stress than when the board is clamped in place during assembly. Figures 49-54 show a section of one corner of the board clamped with a bolt load of 254 lb at the corner (left edge in the Figure). After the bolt load is applied, the center of the board is then forced to a deflection of 10 mils (four times the deflection produced at 100 G's). Table 13 lists the maximum effective stress in each layer. The lowest ultimate safety factor is 1.2, however, the effective stresses are composed of primarily compressive components.

Analysis of component stresses in soldered joints will be covered in a separate engineering note.

Table 12: Material Properties

Material	Density- (lb/in3)	Elastic Modulus Mpsi	Poisson's Ratio	Yield Strength (ksi)	Ultimate Strength (ksi)
Solder Mask 60Sn-40Pb	0.308	4.35	0.42	5.0	≈7.6
Copper Clad & Copper Foil	0.321	17.0	0.33	10.0	32.0
Glass/Capton	0.009	2.5	0.4	-	35.0
Pyralux Adhesive	0.0397	0.22	0.45	-	3.5
Kapton	0.35	0.33	0.35	-	20.0

Table 13: Steady-State Peak Effective Stresses in Actel 2x2 Circuit Board using 2-56 cap screws torqued to 6.3 lb-in.

Circuit board material	Maximum effective stress at 0.36 mil of compression and a 254 lb load (ksi)	Maximum effective stress at 0.36 mil of compression plus 10 mils of deflection (ksi)	Ultimate safety factor at 0.36 mil of compression plus 10 mils of center deflection
Solder mask 60Sn-40Pb	5.48	5.13	1.5
Copper clad & Copper foil	10.48	10.38	3.1
Glass/Kapton (FR-4)	9.30	9.48	6.3
Pyralux adhesive	2.93	3.01	1.2
Kapton	5.44	5.22	3.8

Dynamic analysis was performed on an earlier version of the 2x2 circuit board. Results from that study indicated that the board had a peak stress of 0.4 ksi corresponding to a maximum deflection of 0.0048 inches at the center.

5.5 Stress Analysis Summary

Table 14 summarizes the highest stress seen in each component under all three loading conditions. Notice that the highest stress is seen under steady-state loading in the top cover of the camera housing. The stress is 16.6 ksi and is well below the Yield Strength-(39 ksi) of 6061-T651 Aluminum. Thus, the minimum factor of safety is 2.3 which is well above the design factor of safety-(1.10) given in the Engineering and Test Specification document.

Table 14: Star Tracker Camera Yield Safety Factors for Different Environments

	Highest Stress in the component-ksi			Yield Safety Factor against qualification Loads			Yield Safety Factor
Star Tracker	S-S 100'g	PSD 14 g's rms	PYRO*	S-S 100'g	PSD 14 g's rms	PYRO	S-S Design 14'gs
Camera Housing	16.6	3.79		2.3	10.3		16.4
Housing Gussets	15.1	2.7		2.6	14.4		18.6
Baffle Gussets	2.3	1.0		17	39		121
Vane #1	9.05	<0.1		4.3	>39		30.7
Mounting Brackets	3.77	<0.5		10.3	>39		73.5

*Not computed for individual parts

6.0 Star Tracker Structural Analysis Summary

Camera meets all mission requirements and is qualified by analysis.

7.0 References

J. Houghton, "Engineering Specification and Test Plan", NRL Document, September, 1992.

8.0 Appendix

8.1 Qualification of Camera using Static Analysis

A separate analysis was done to verify that a static analysis at a steady-state 100 G's in each of the three orthogonal axes qualifies a Star Tracker Camera sized payload to survive the dynamic Titan IIG testing and launch environments. A mock payload was generated with similar mass properties and mode frequencies to the Star Tracker Camera. The finite element model of this mock payload had a much smaller number of elements than the complete Star Tracker Camera finite element model. Because of its reduced size, both the steady-state and dynamic analysis could be performed on this model within a reasonable amount of computer run time. Figures 55-57 and Table 15 show the first four mode shapes and natural frequencies of the mock payload. The first two modes are cantilever bending modes similar to those of the Star Tracker Camera.

Table 15: Mock payload mode shapes and natural frequencies

Mode number	Natural frequency (Hz)	Mode shape
1	265	Cantilever bending X-X
2	265	Cantilever bending Y-Y
3	675	Mock baffle panel breathing
4	840	Mock baffle panel bending

Figures 58-61 show the steady-state stresses and deflections of the mock payload calculated for the 100 g X, Y, and Z acceleration conditions applied separately. Figures 62-68 show the dynamic stresses and deflections calculated for the **20 ms** pyro-shock loading five interfaces removed from the source. Three unique pryo-shock loading conditions were applied simultaneously in the three orthogonal directions. This loads the model in all three directions as a vector sum and is also an over load by a factor of the square root of 3 because of the vector sum. Finally Figures 69-75 show the dynamic stresses and deflections calculated for the mock payload being exposed to 60 ms of acceleration vs time random vibration from three 14 Grms PSD curves applied simultaneously in the three orthogonal

directions. Here there is also an overload by a factor of the square root of 3 because of the vector sum. The analysis is linear elastic and the dynamic values in Table 16 have been divided by 1.732 to correct for the square root of 3 overload.

In all cases in Table 16, the stress and deflection calculated for the steady-state loading is larger than that for the dynamic loading. If the steady-state calculations show large safety factors, then the steady-state analysis is sufficient and the dynamic analysis is not necessary. However, if the safety factors are near 1.0 then the dynamic analysis is necessary and may uncover some structural weaknesses.

Table 16: Summary of the mock payload steady state and dynamic comparison

Loading direction	Time of maximum stress (sec)	Maximum effective stress (ksi)	Maximum deflection at end of Baffle (in.)
X 100 G's	steady state	3.38	0.016
Y 100 G's	steady state	3.38	0.016
Z 100 G's	steady state	0.84	0.002
X Pyro-shock	0.01425	1.26	0.0021
Y Pyro-shock	0.01609	2.35	0.0046
Z Pyro-shock	0.00761	0.95	0.0014
X 14 Grms random	0.0488	2.09	0.0072
Y 14 Grms random	0.0321	3.16	0.0125
Z 14 Grms random	0.0012	0.40	0.0091

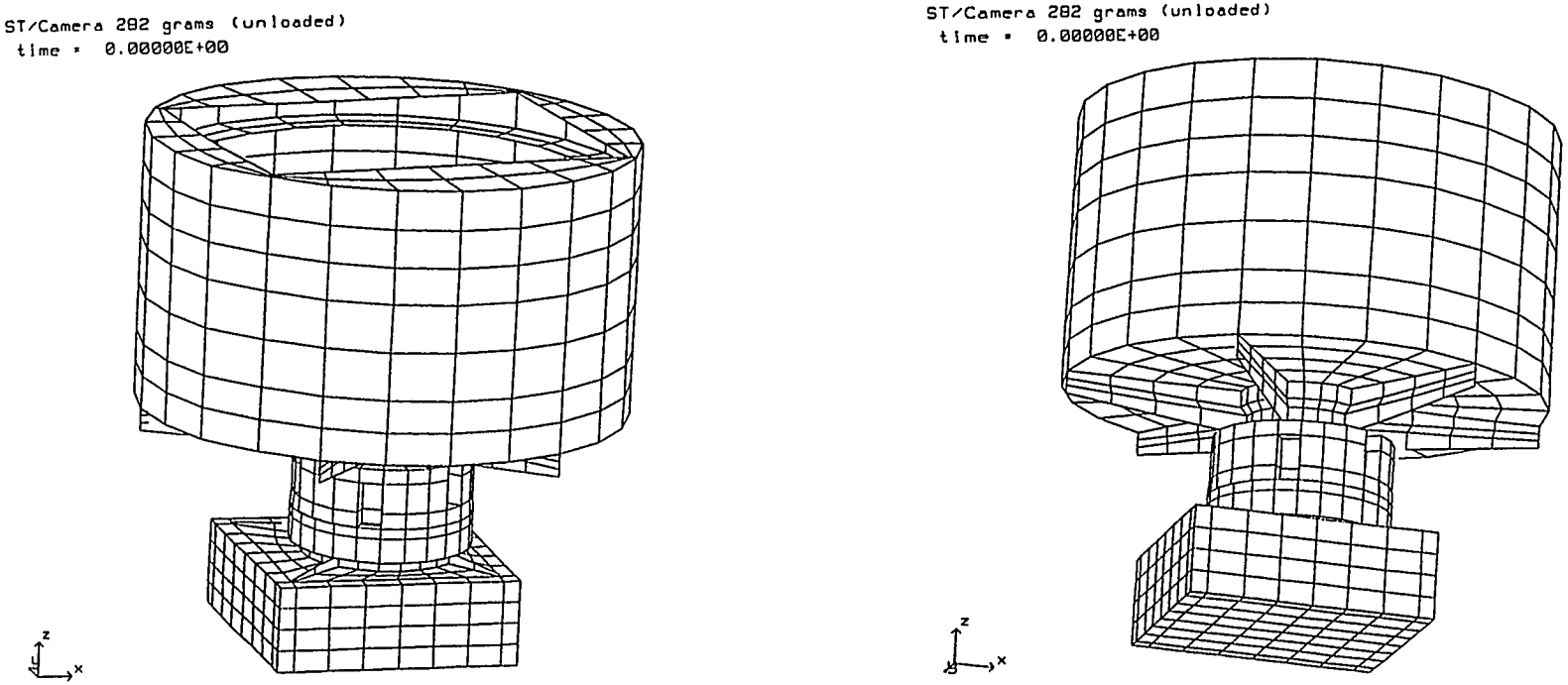


Figure 1: Unloaded View of Star Tracker Camera.

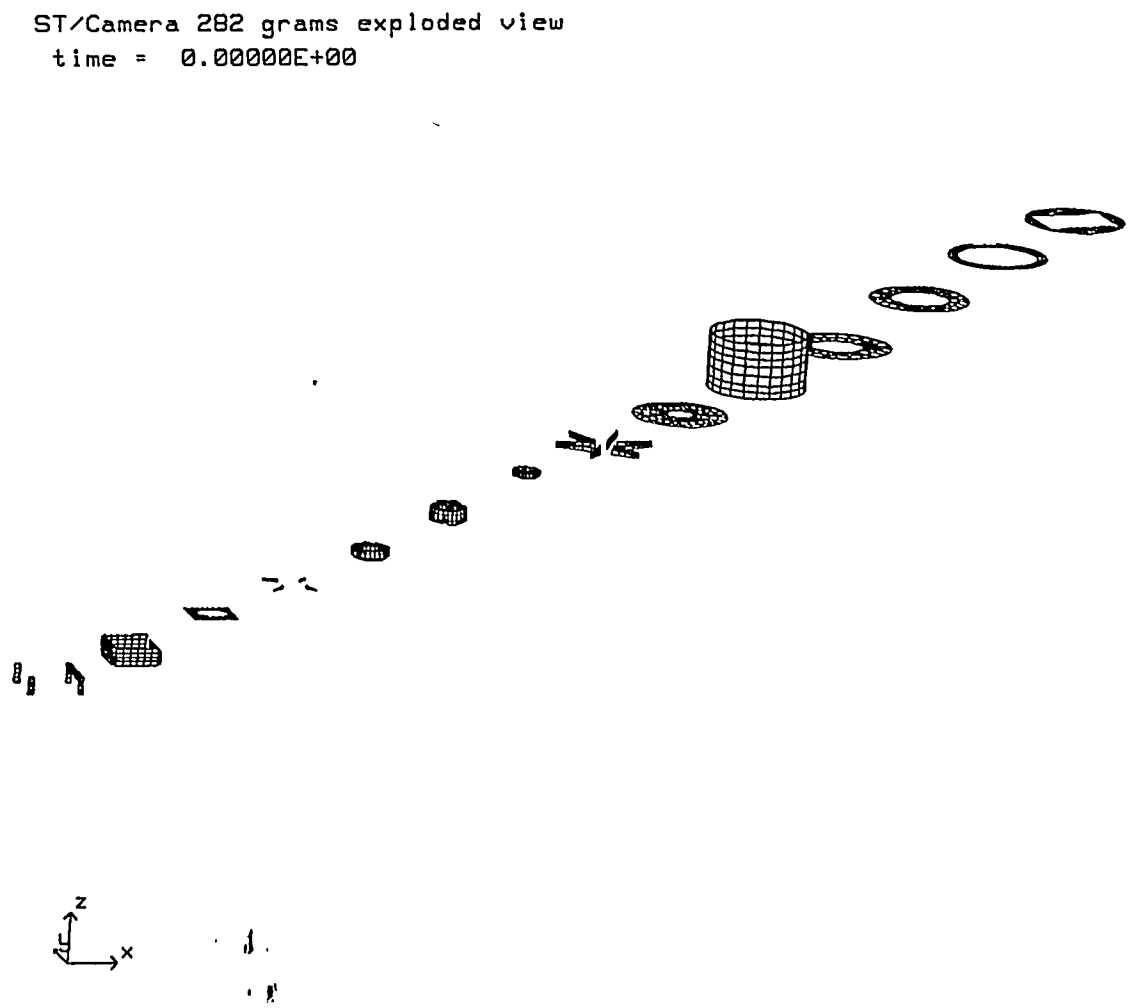


Figure 2: Exploded View of Star Tracker Camera Components.

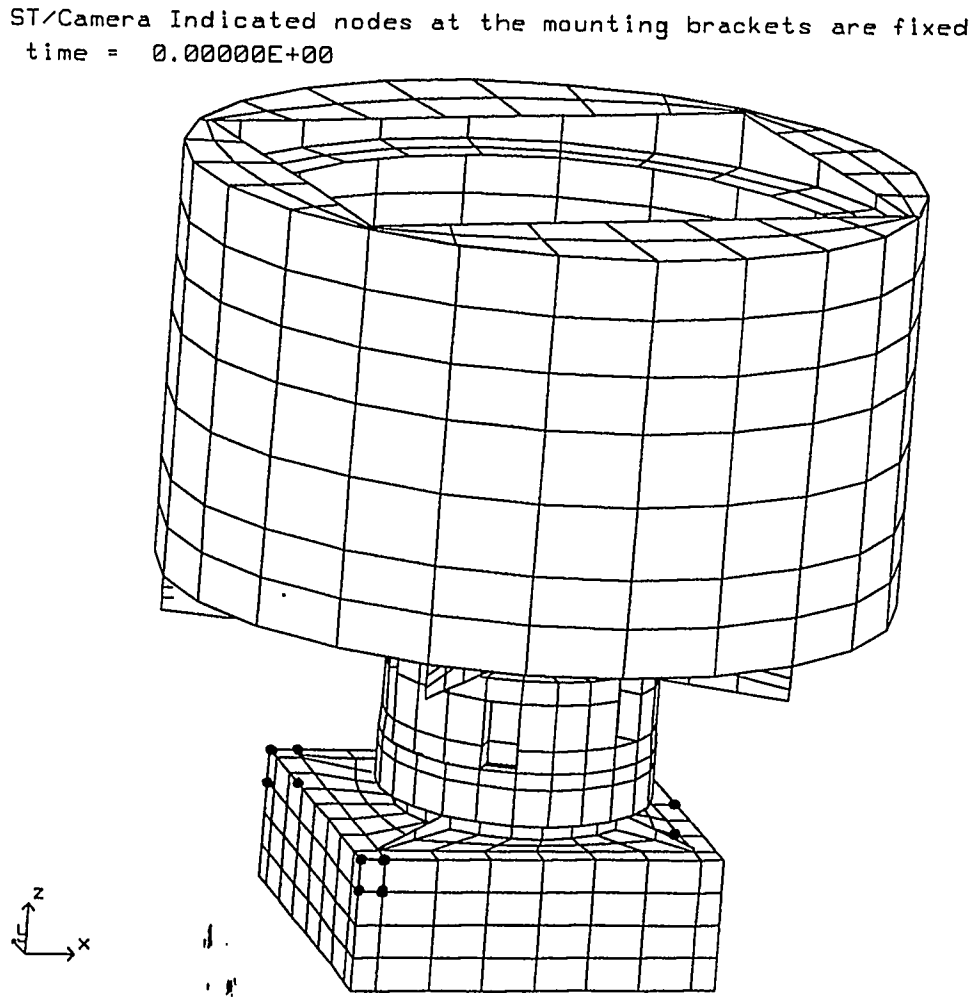


Figure 3: Indicated Nodes at the Mounting Brackets are fixed.

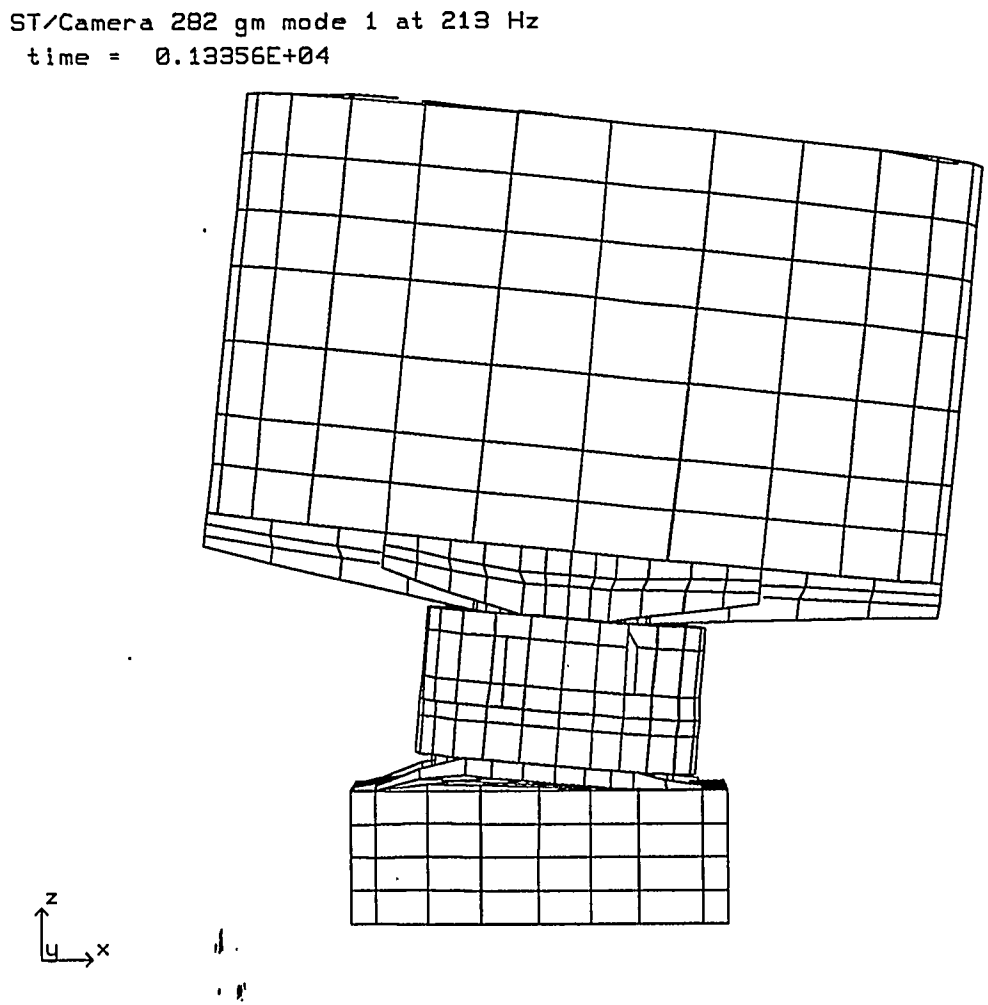


Figure 4: Mode 1 at 213 Hz.

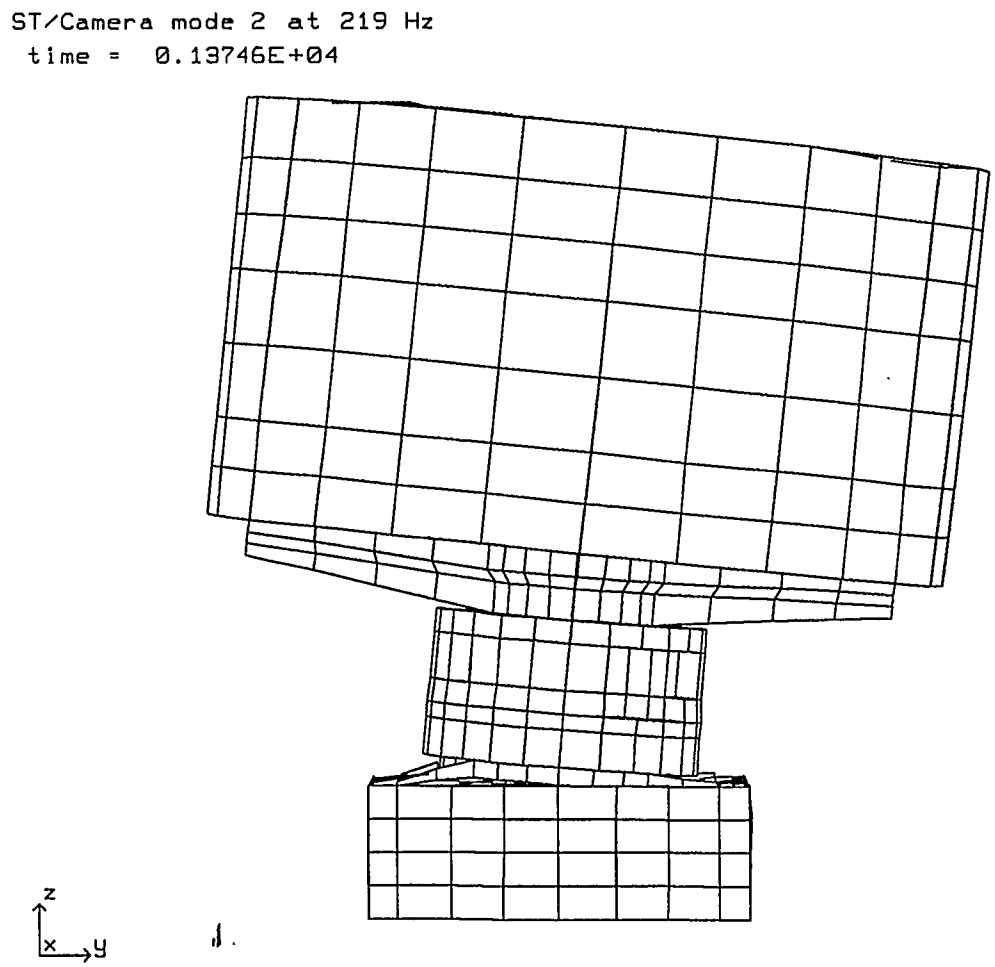


Figure 5: Mode 2 at 219 Hz.

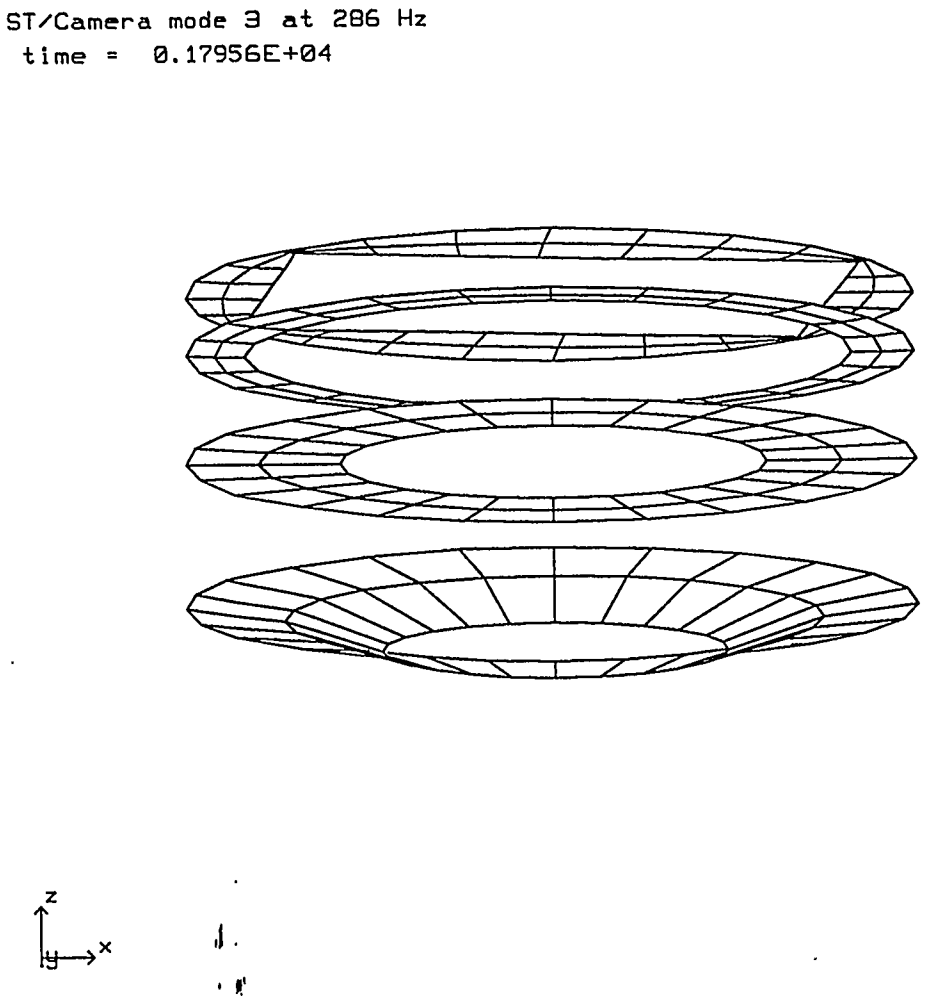


Figure 6: Mode 3 at 286 Hz.

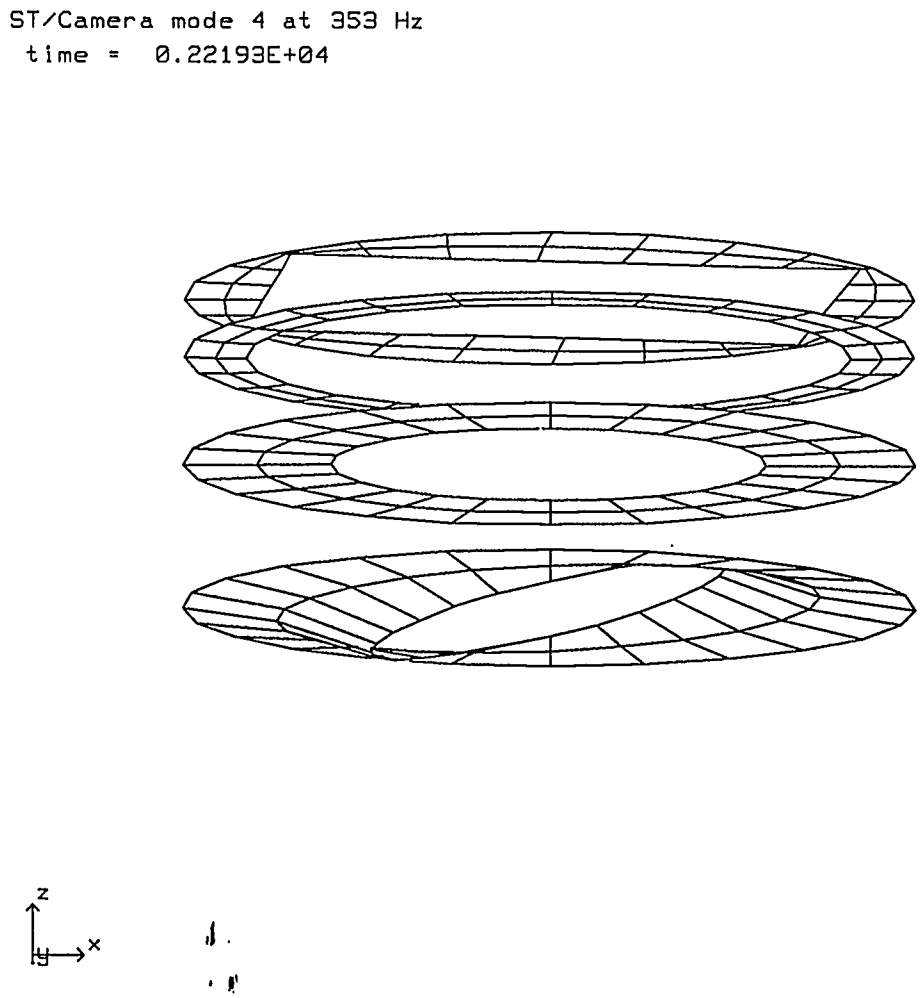


Figure 7: Mode 4 at 353 Hz.

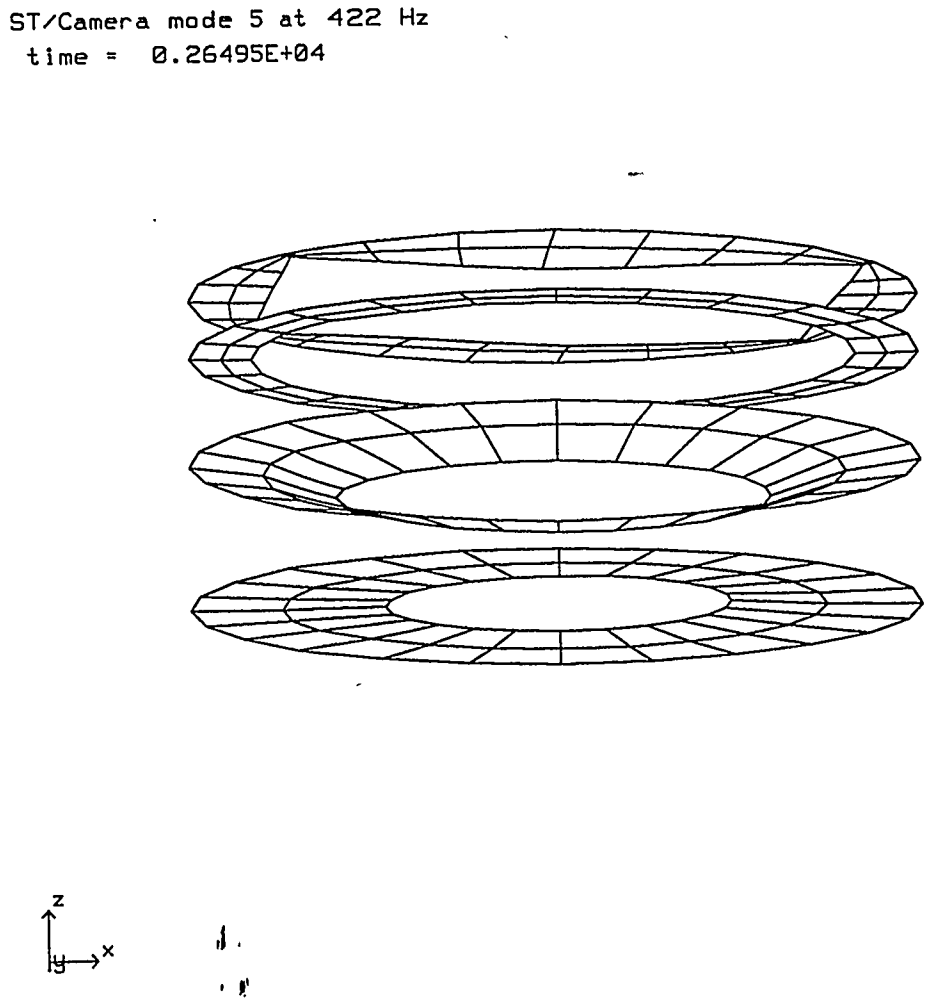


Figure 8: Mode 5 at 422 Hz.

5.1.3 General Component Steady State Accelerations

The component(s) shall be shown by analysis or test to be capable of withstanding a steady state inertial acceleration load in each of its 3 principal orthogonal axis. If a test is used to fulfill this requirement, the applicable loads are taken directly from Figure 3.1.2-1 of the DSPSE Structural Analysis Plan. If the components are qualified by analysis, use loads that are equal to the test loads multiplied by a factor of 2.

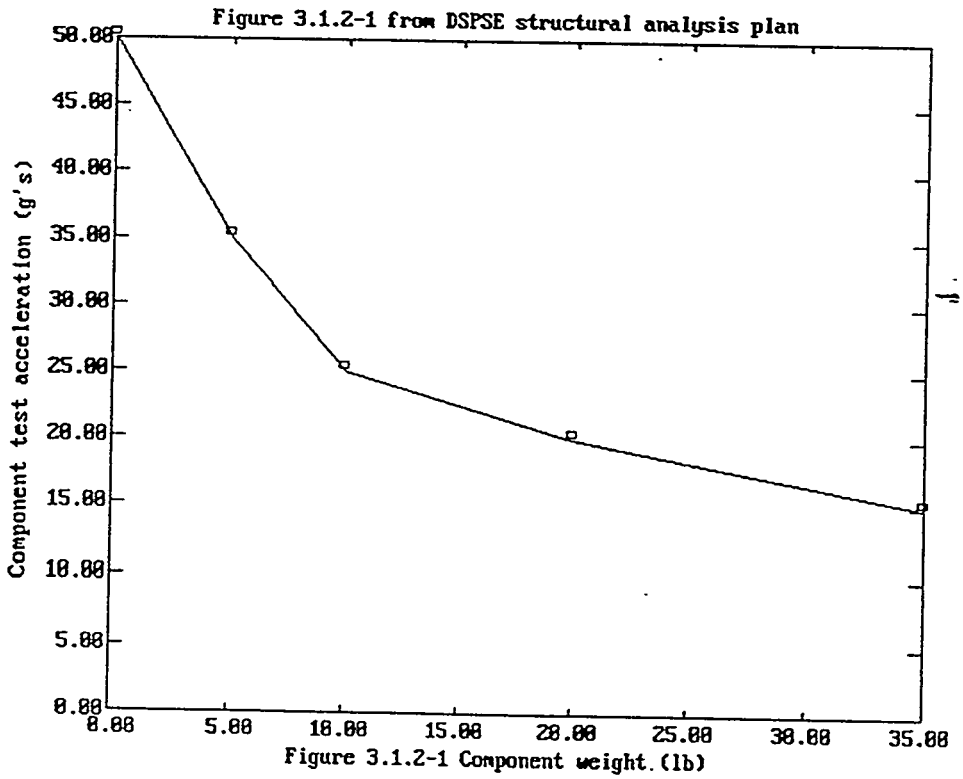


Figure 9: Qualification load for Steady-State Analysis.

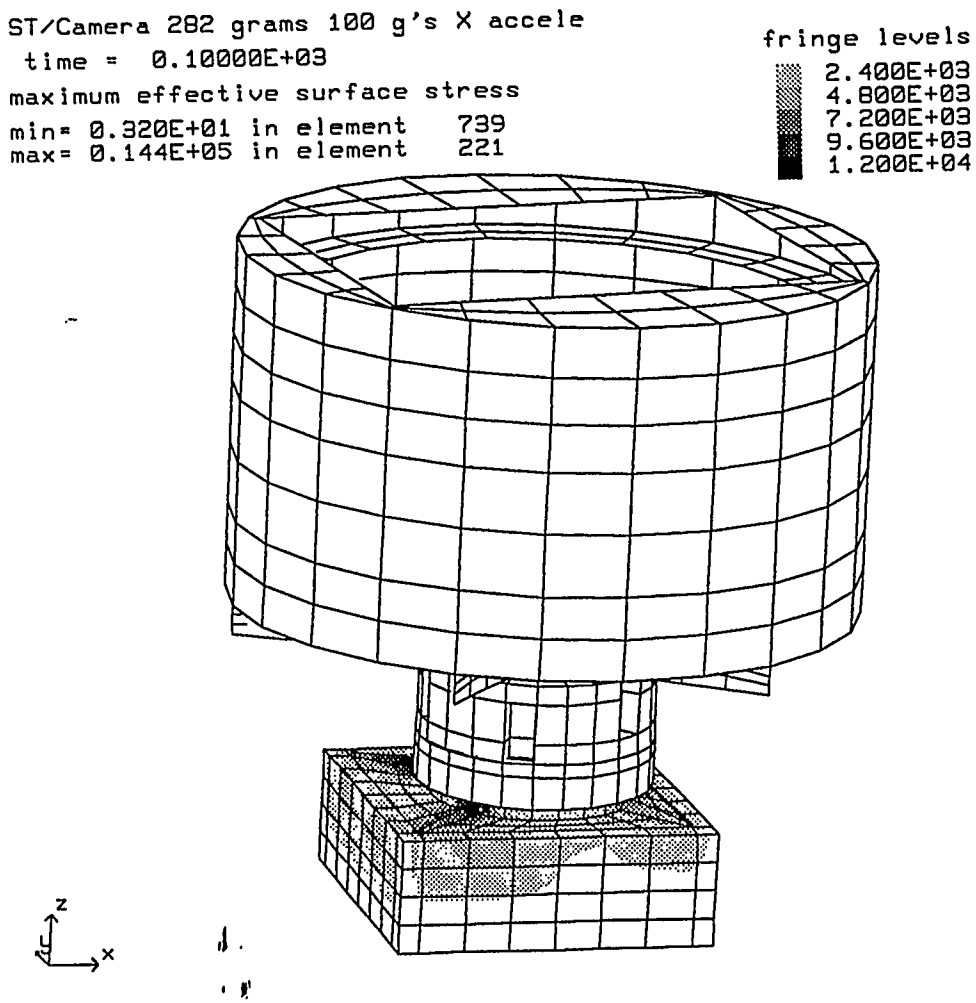


Figure 10: Star Tracker Camera Steady-State Stress Fringes under x-direction loading.

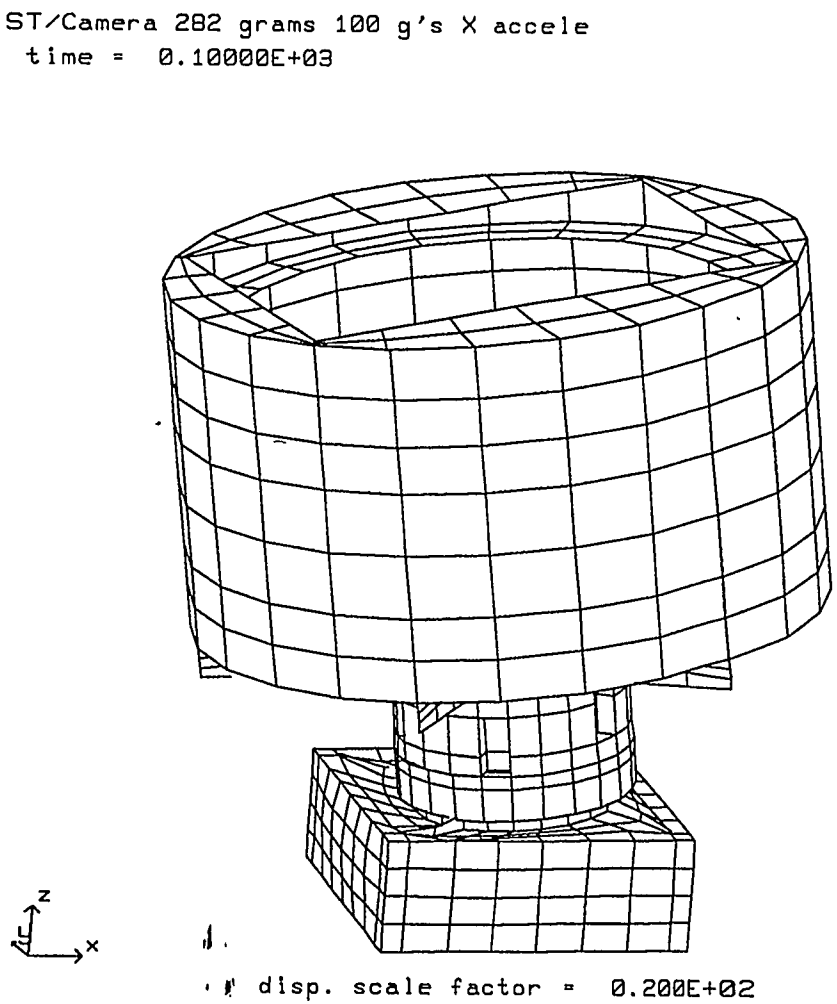


Figure 11: Star Tracker Camera Deflection under x-direction loading.

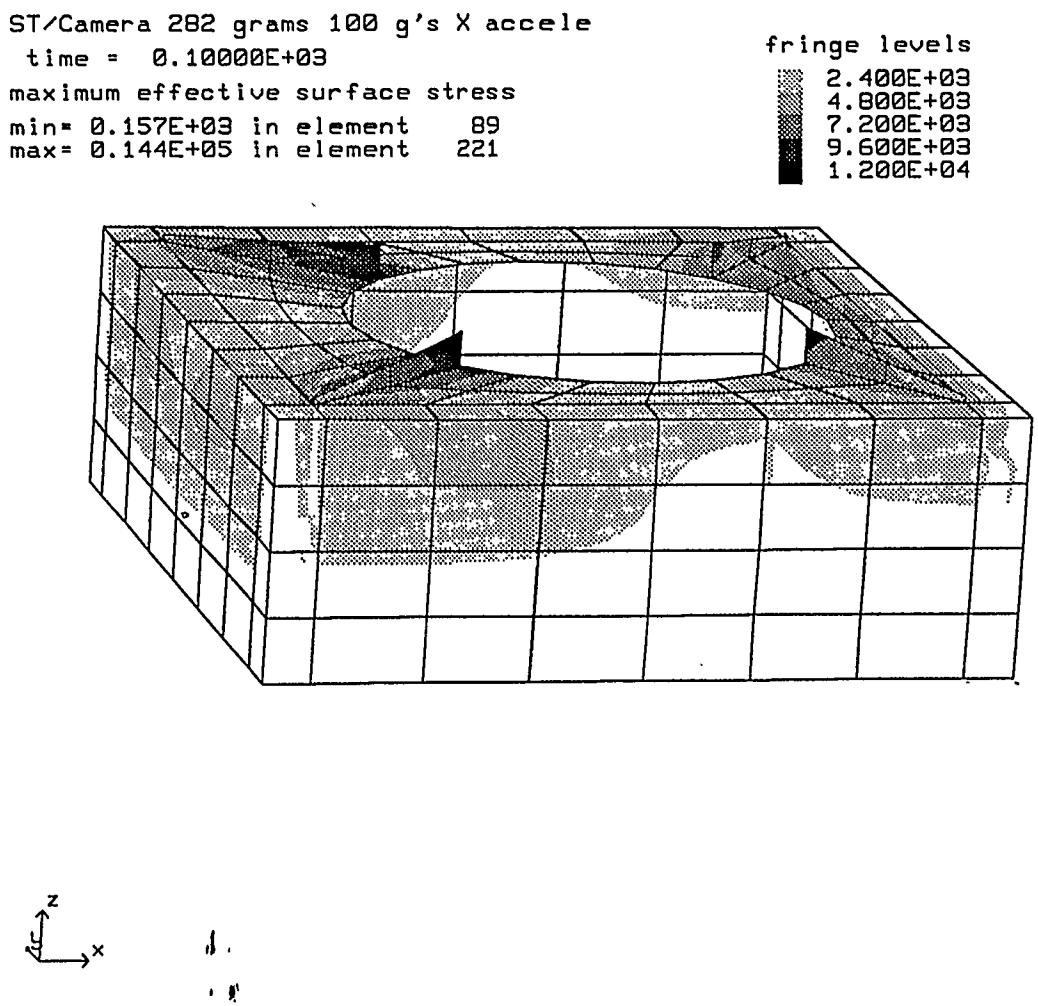


Figure 12: Enlarged View of Stress Fringes on Top Cover of Camera Housing under x-direction loading.

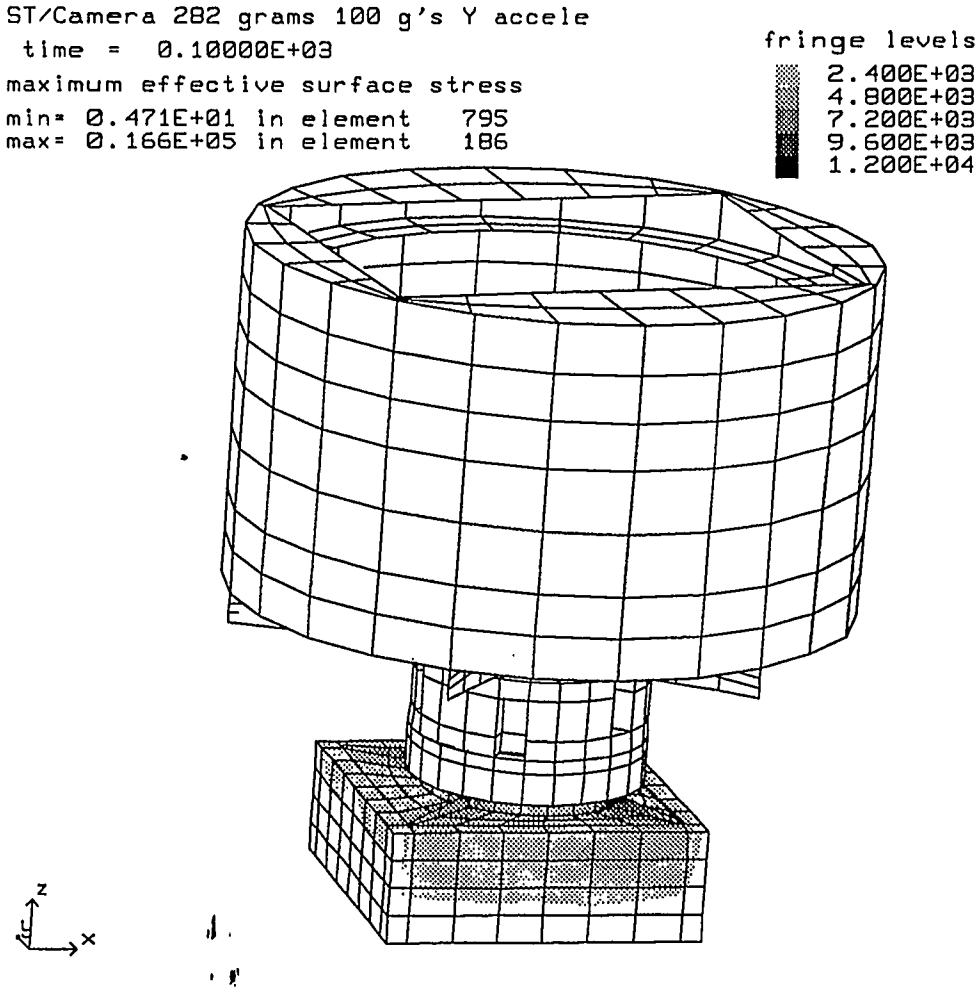


Figure 13: Star Tracker Camera Steady-State Stress Fringes under y-direction loading.

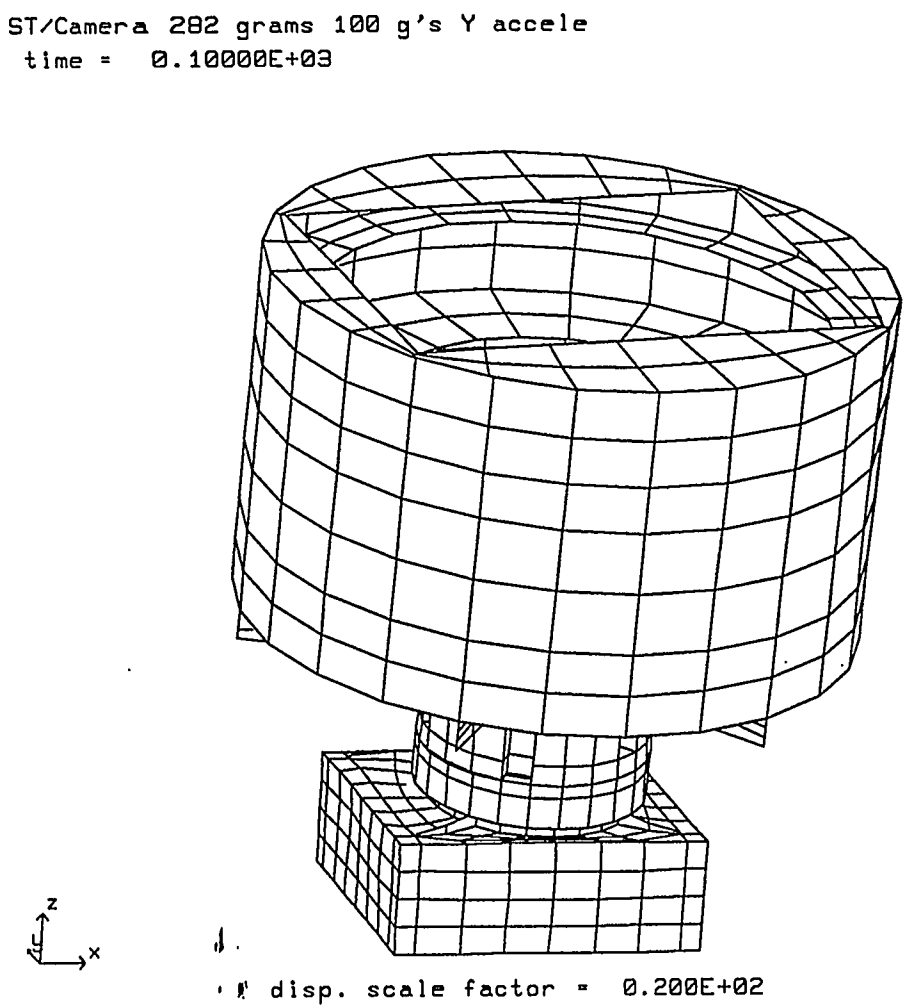


Figure 14: Star Tracker Camera Deflection under y-direction loading.

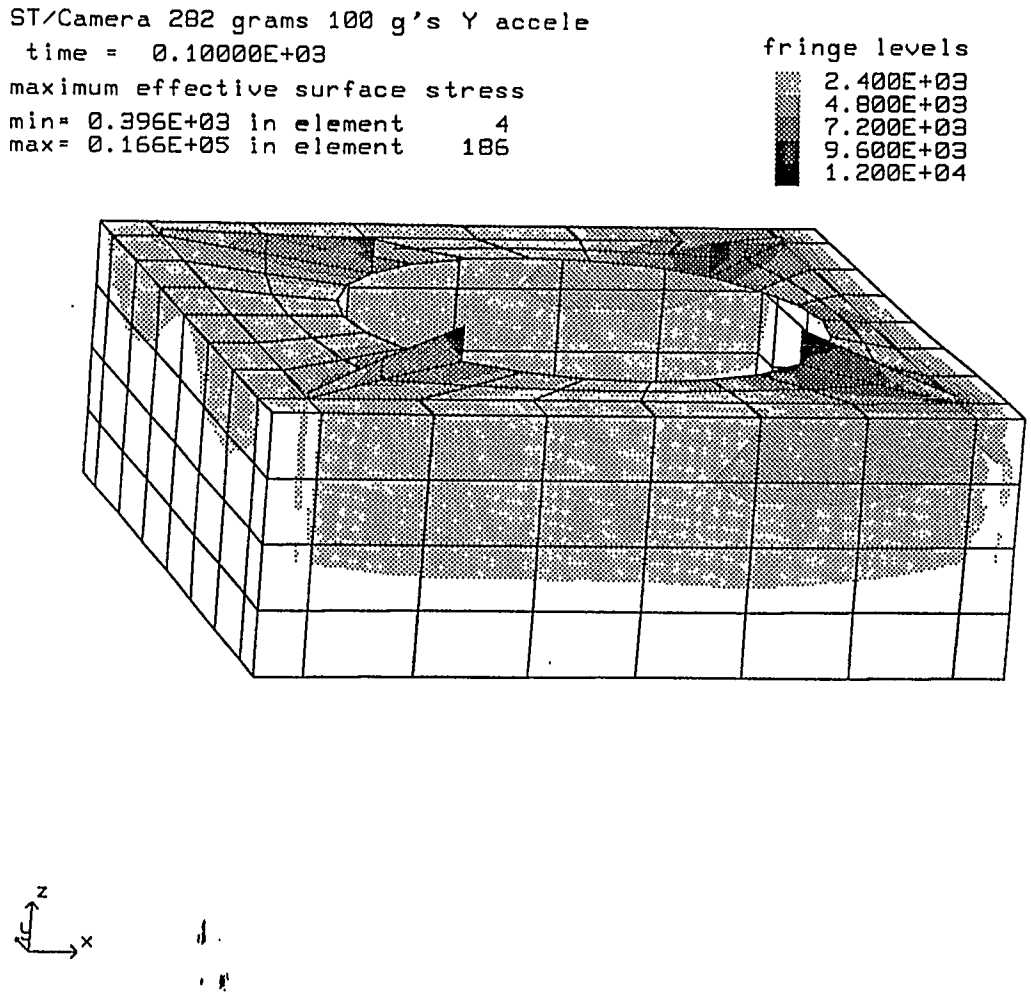


Figure 15: Enlarged View of Stress Fringes on Top Cover of Camera Housing under y-direction loading.

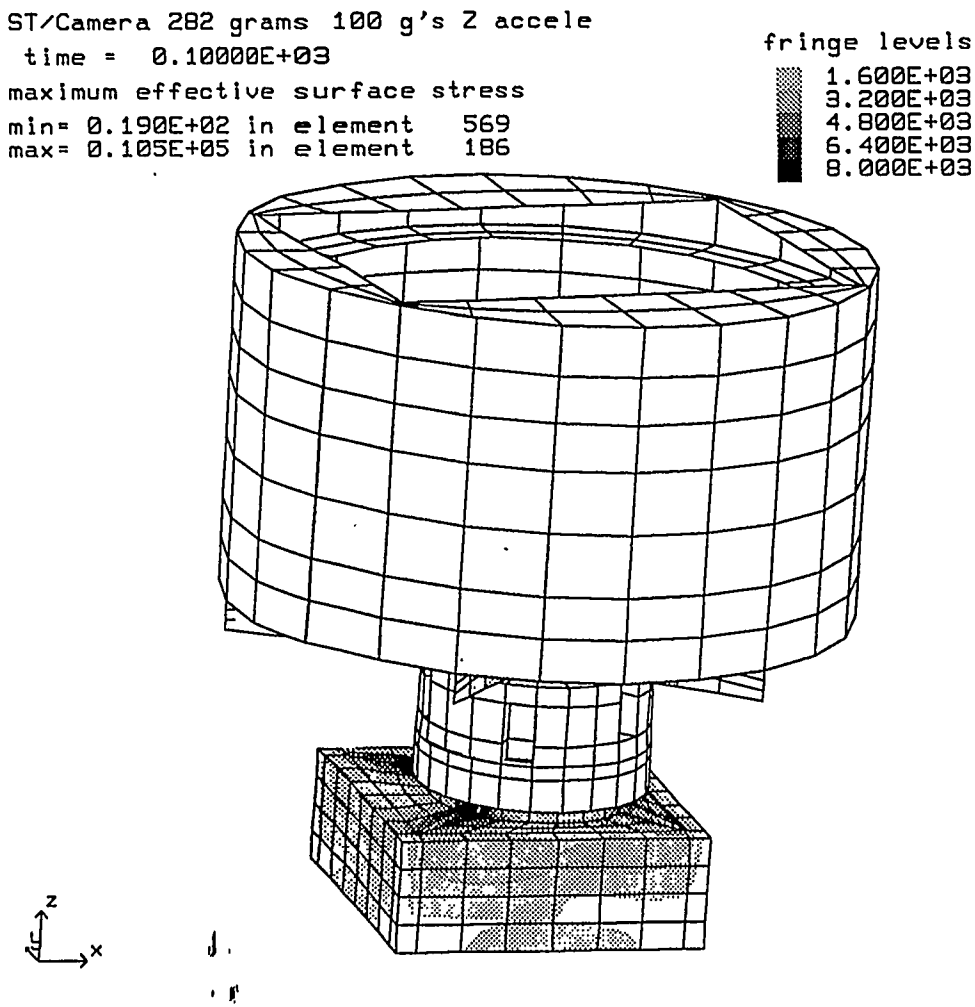


Figure 16: Star Tracker Camera Steady-State Stress Fringes under z-direction loading.

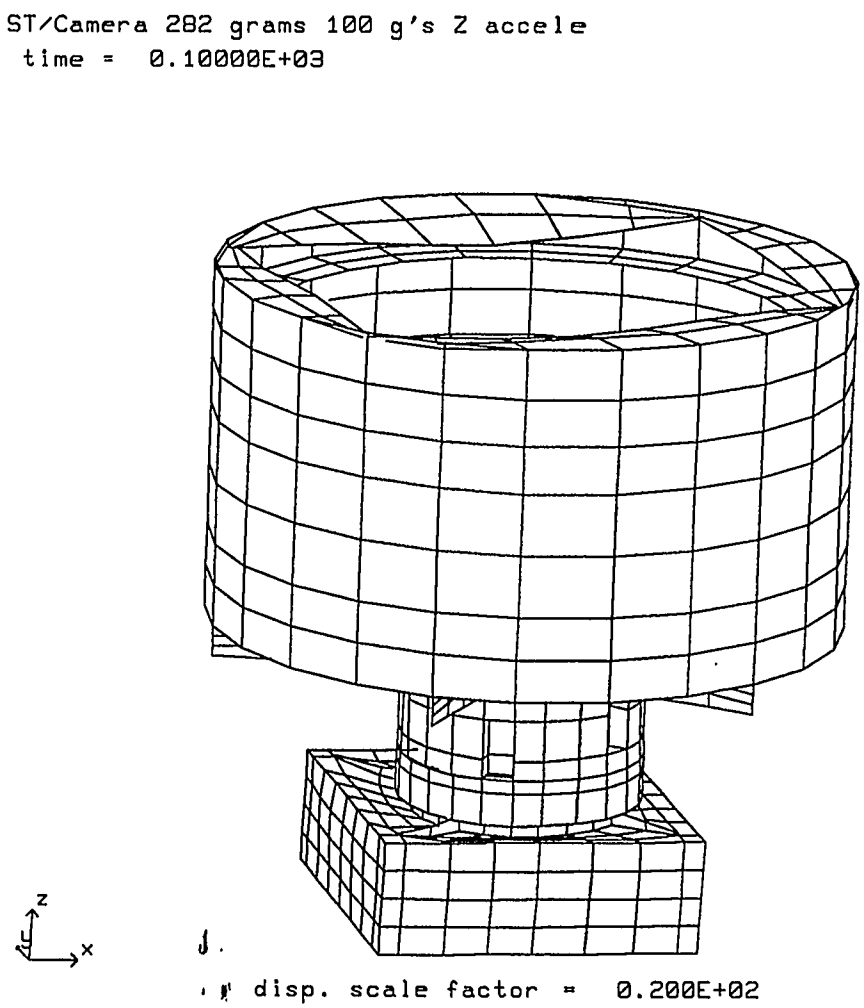


Figure 17: Star Tracker Camera Deflection under z-direction loading.

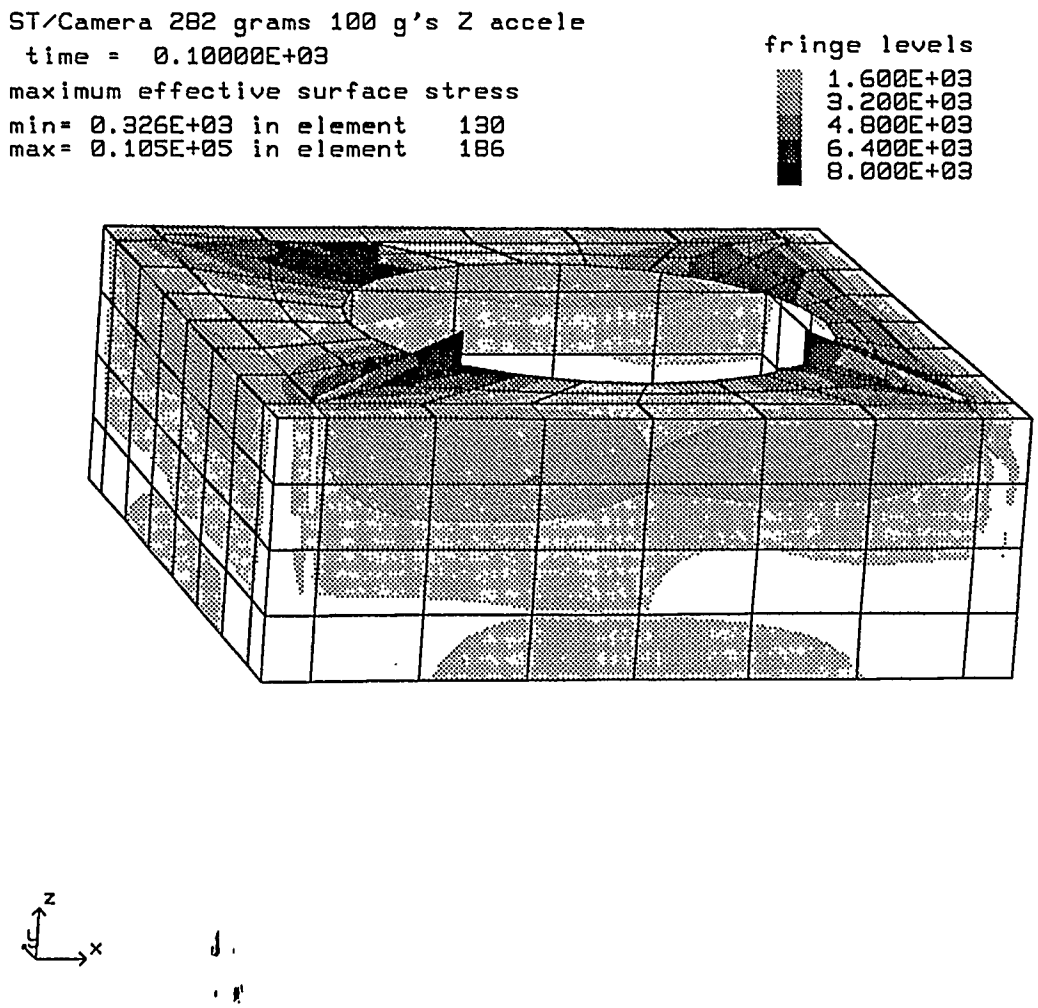


Figure 18: Enlarged View of Stress Fringes on Top Cover of Camera Housing under z-direction loading.

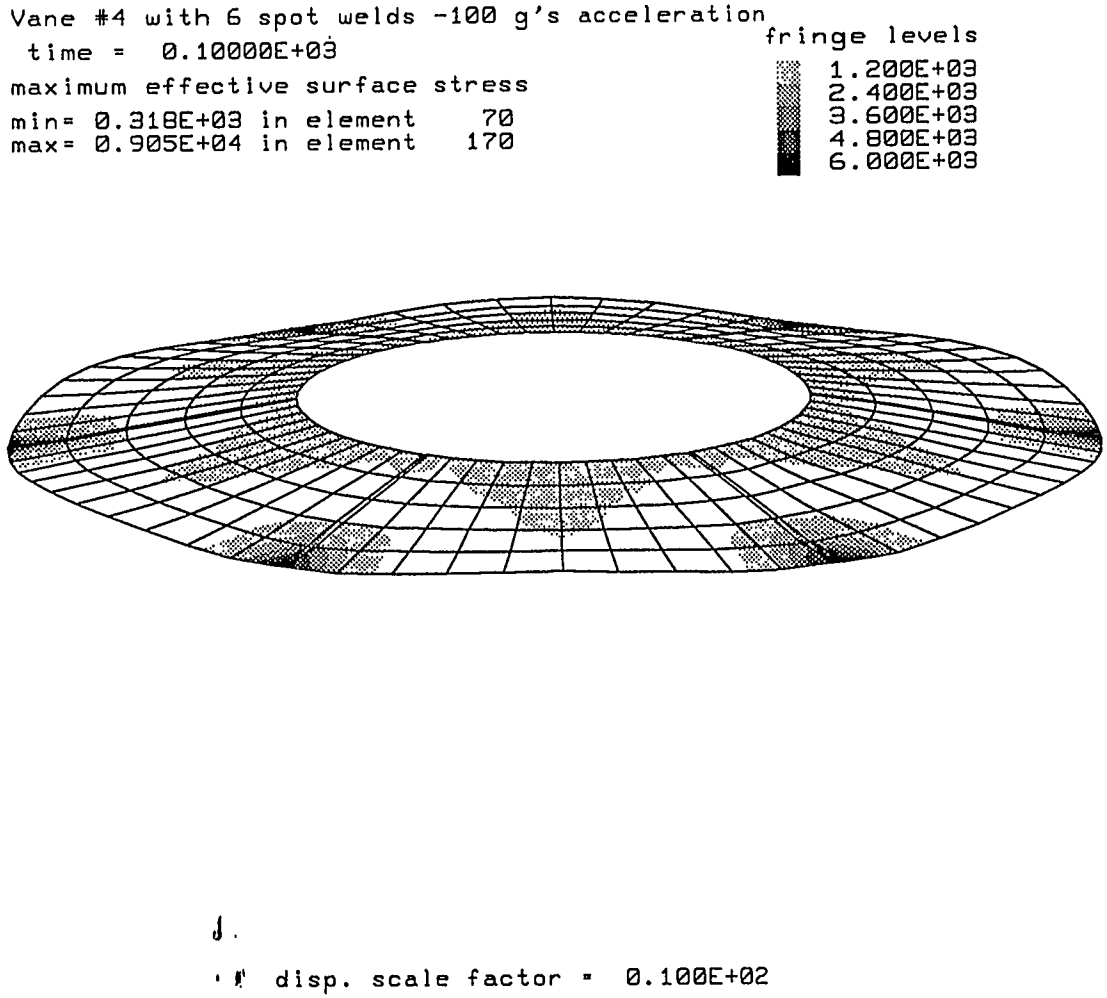


Figure 19: Steady-State Stress Fringes in Vane #4 under z-direction loading.

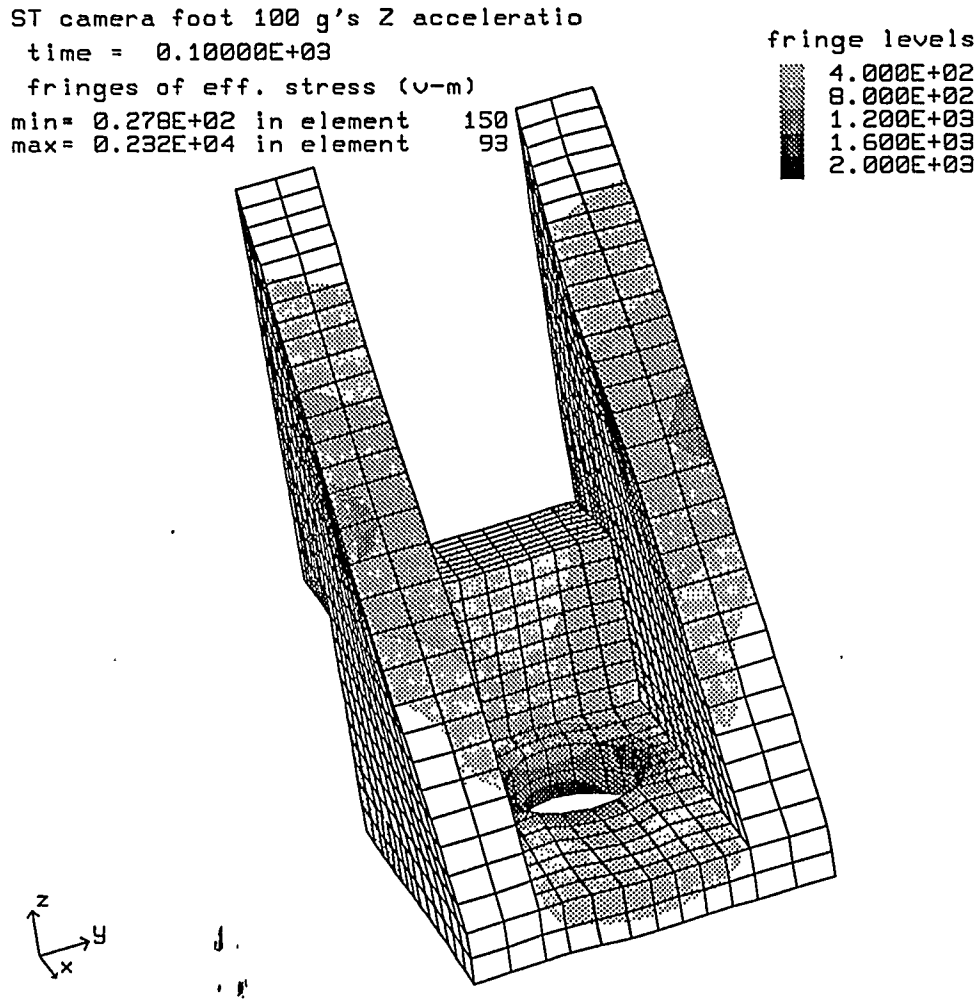

ST camera foot 100 g's Z acceleratio
time = 0.10000E+03
fringes of eff. stress (v-m)
min= 0.278E+02 in element 150
max= 0.232E+04 in element 93
fringe levels
4.000E+02
8.000E+02
1.200E+03
1.600E+03
2.000E+03
z
y
x

Figure 20:

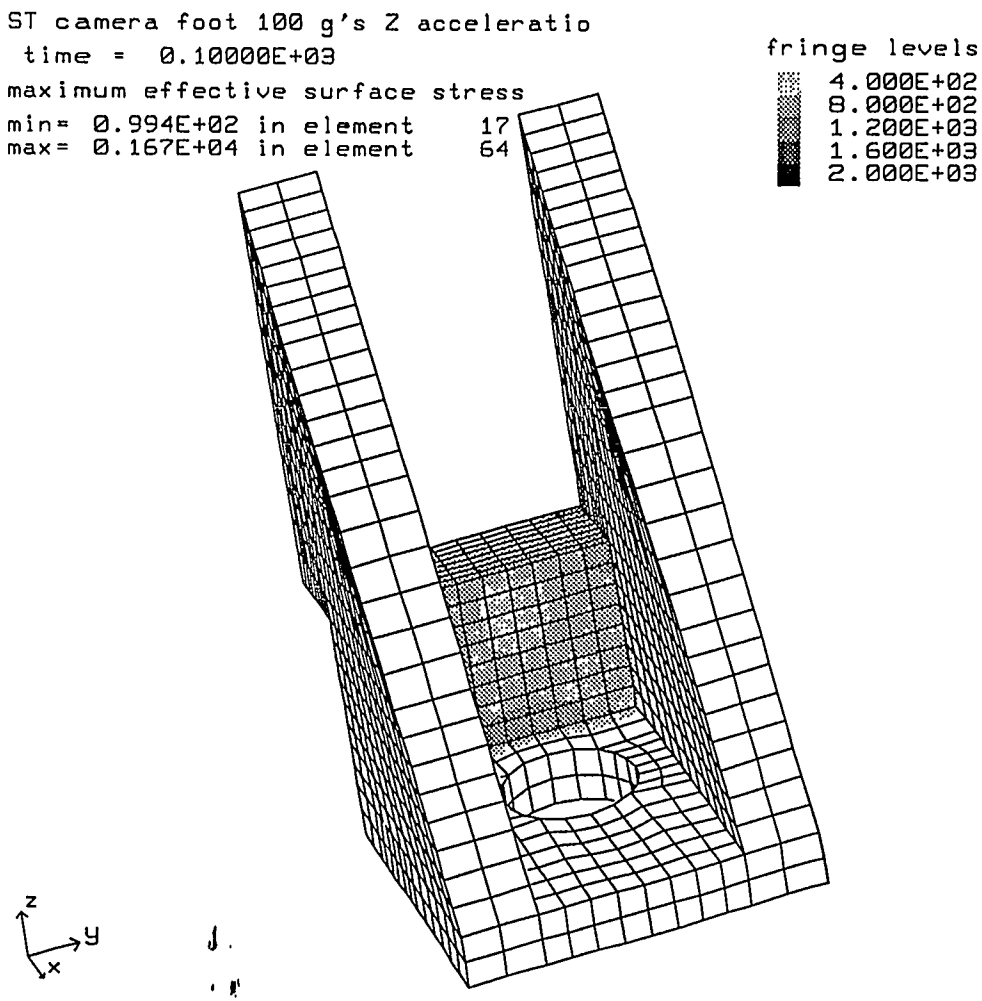

ST camera foot 100 g's Z acceleratio
time = 0.10000E+03
maximum effective surface stress
min= 0.994E+02 in element 17
max= 0.167E+04 in element 64
fringe levels
4.000E+02
8.000E+02
1.200E+03
1.600E+03
2.000E+03
z
y
x

Figure 21:

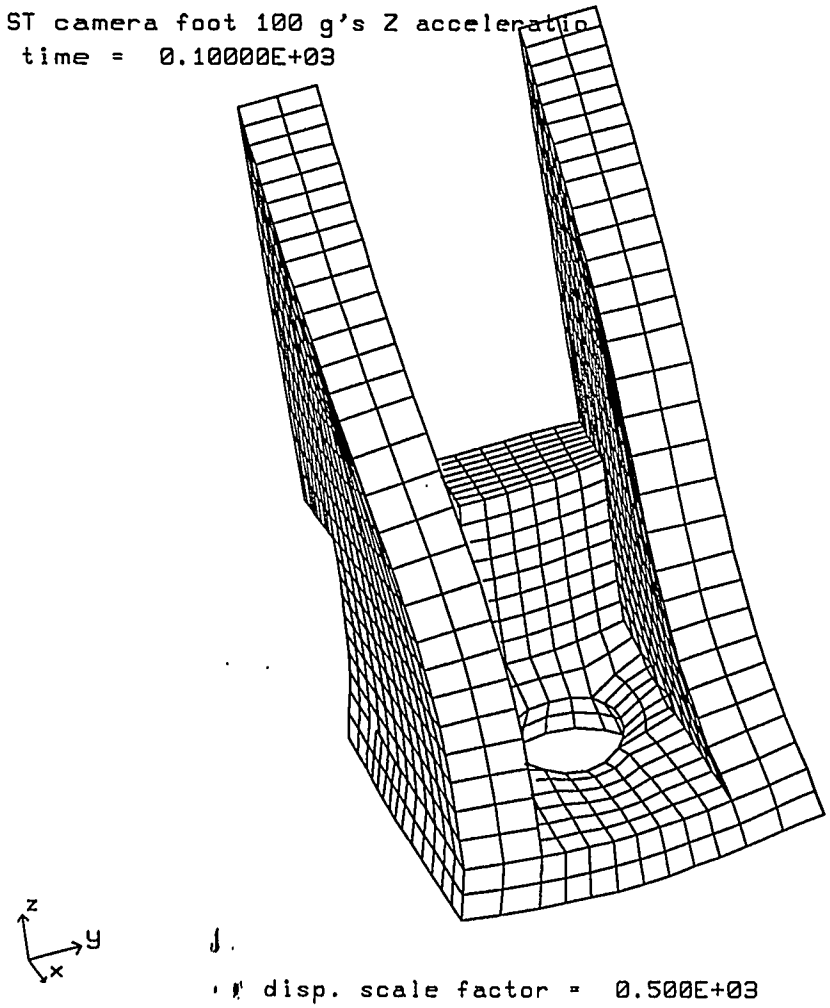

ST camera foot 100 g's Z acceleratio
time = 0.10000E+03
z
y
x
disp. scale factor = 0.500E+03

Figure 22:

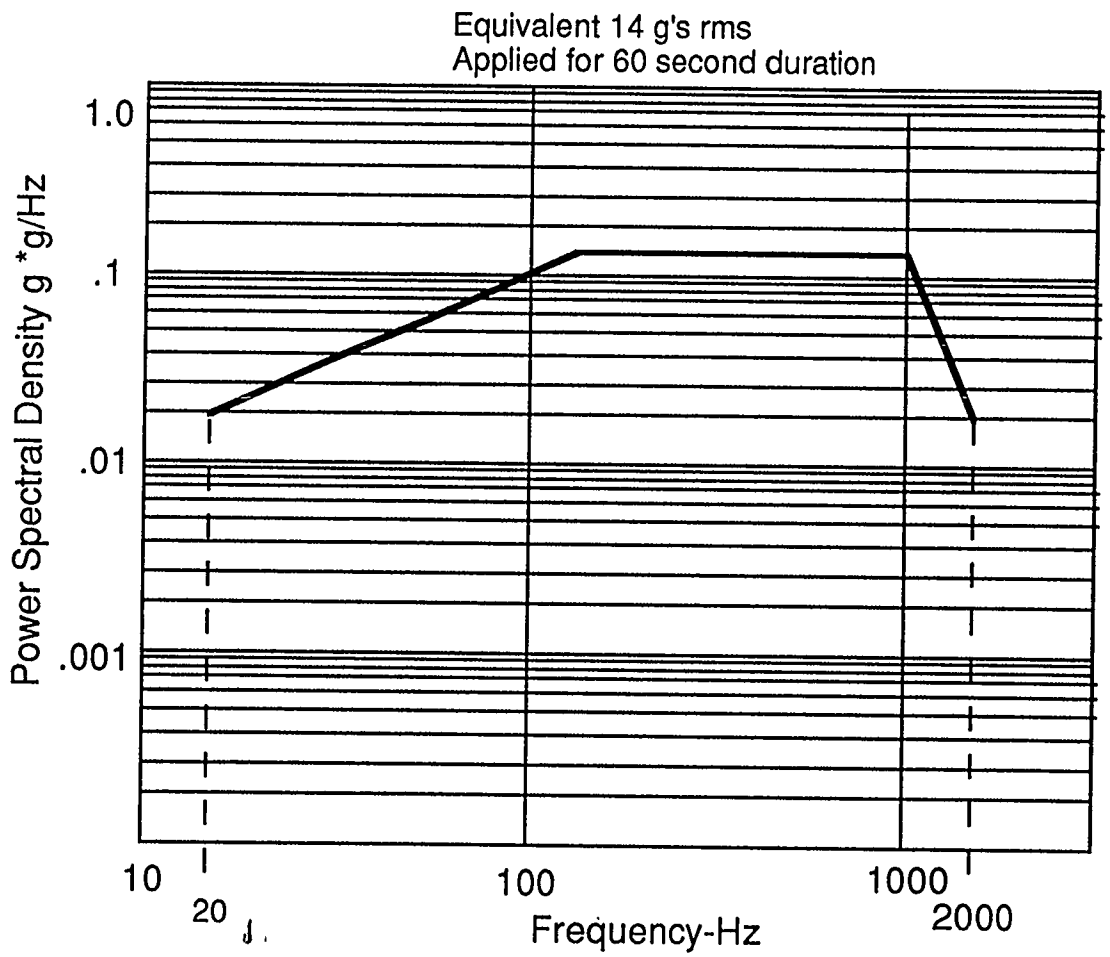


Figure 23: DSPSE Protoflight Random Vibration Spectrum Test Level

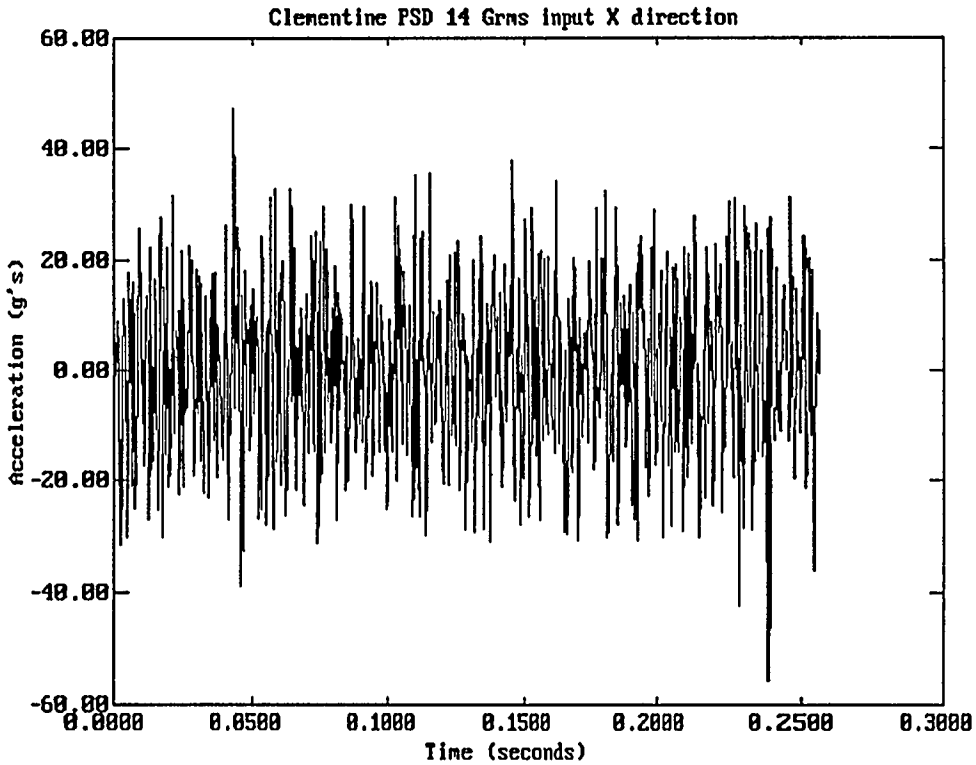


Figure 24: X-direction time series for PSD spectrum

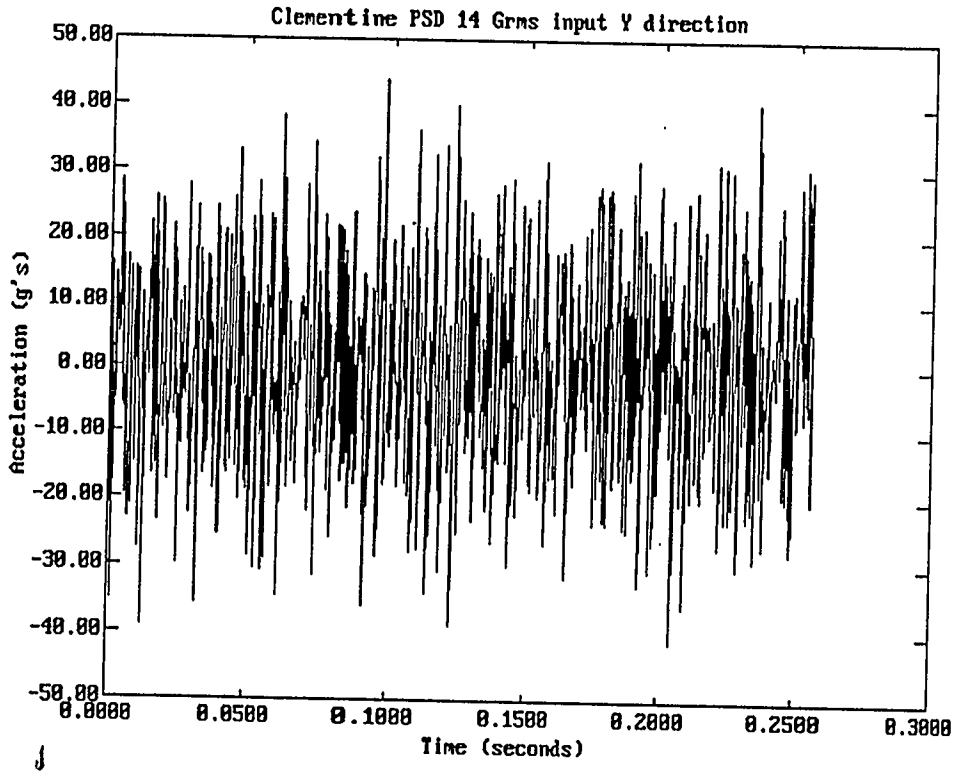


Figure 25: Y-direction time series for PSD spectrum

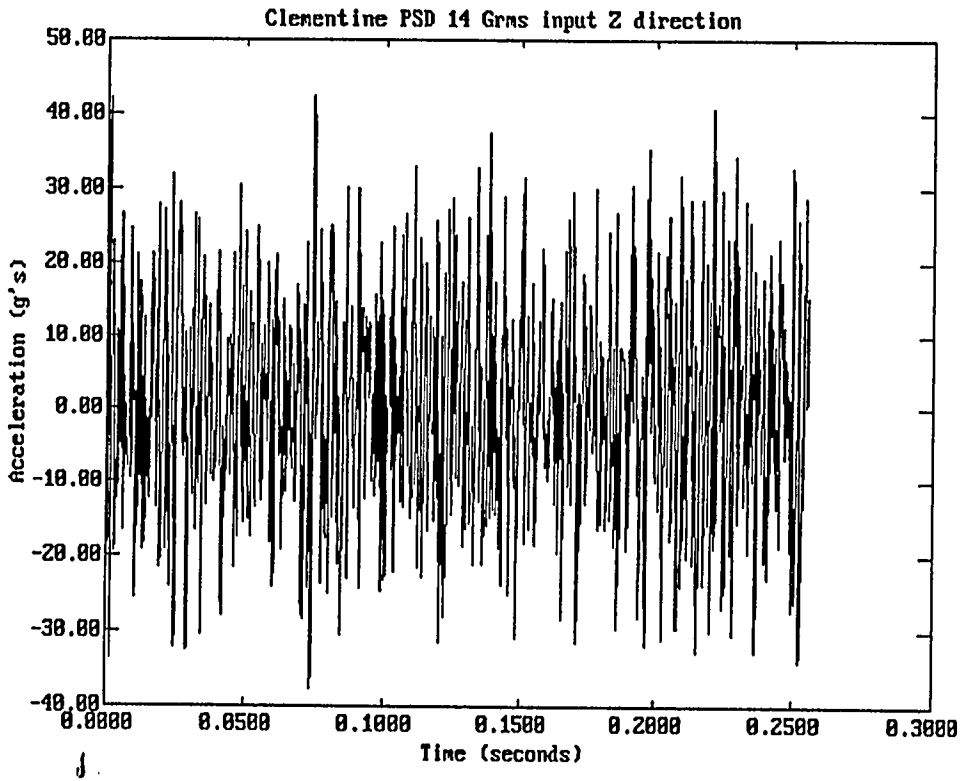


Figure 26. Z-direction time series for PSD spectrum

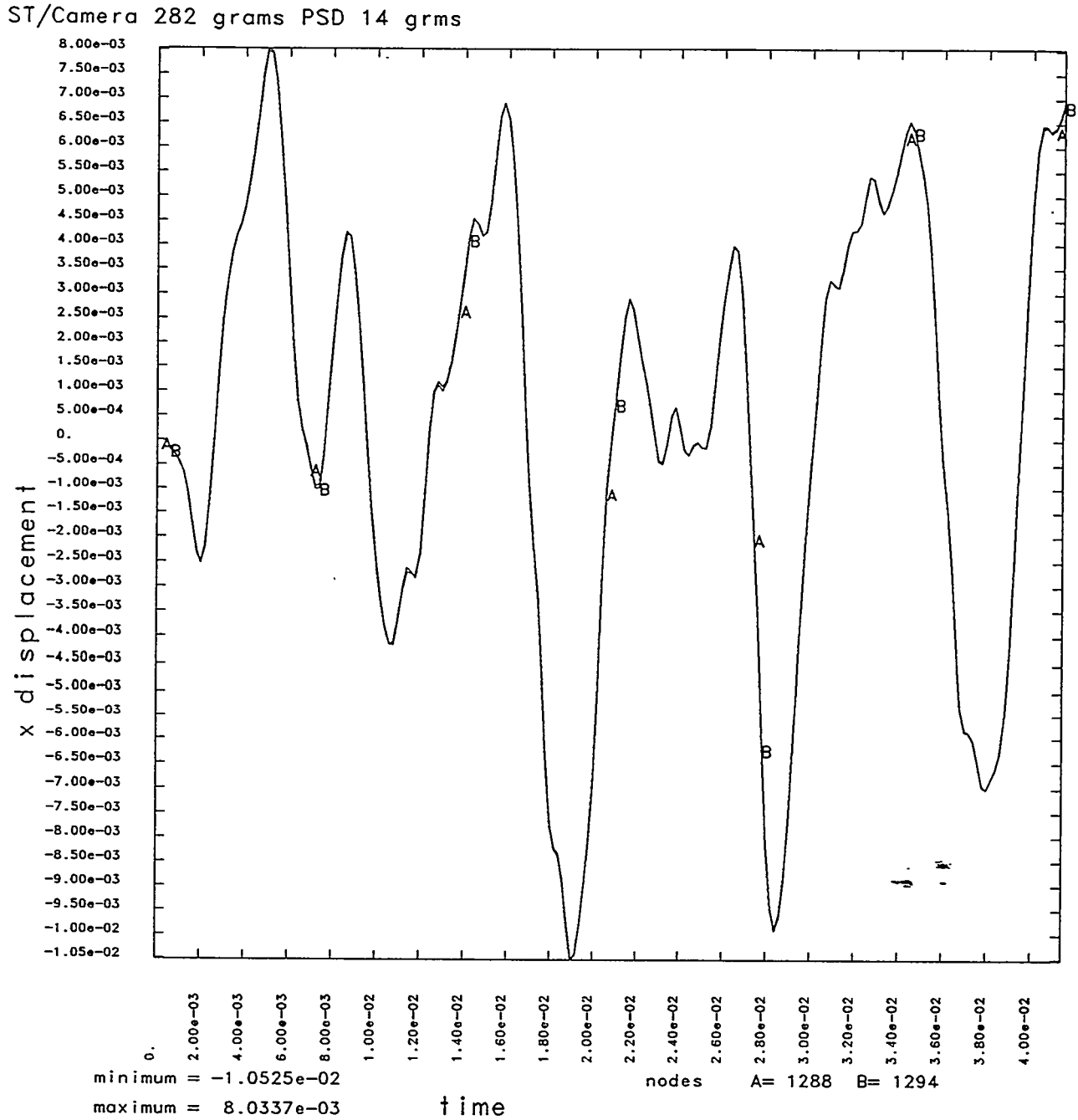


Figure 27: Dynamic displacement at end of baffle in x-direction

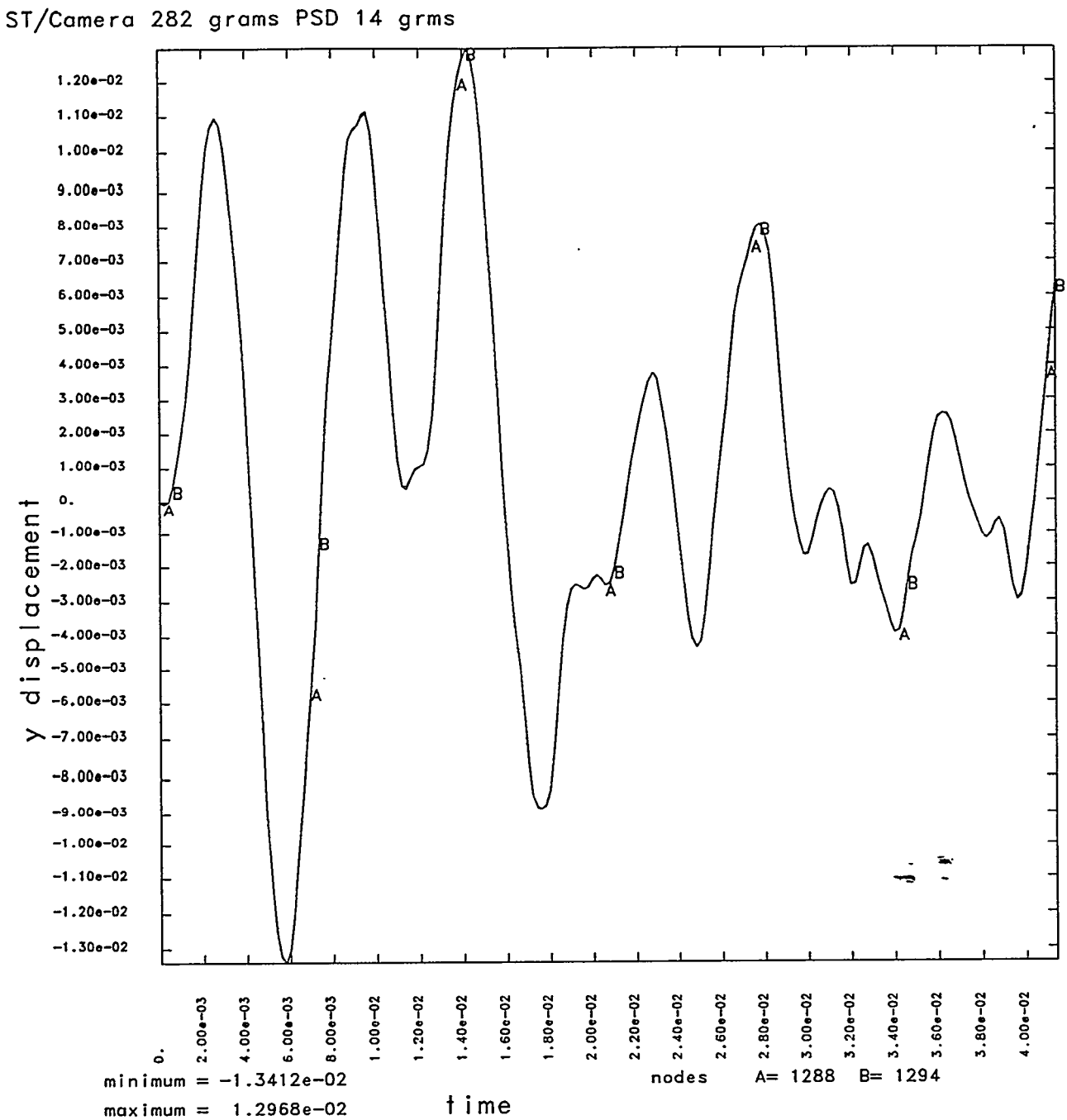


Figure 28: Dynamic displacement at end of baffle in y-direction

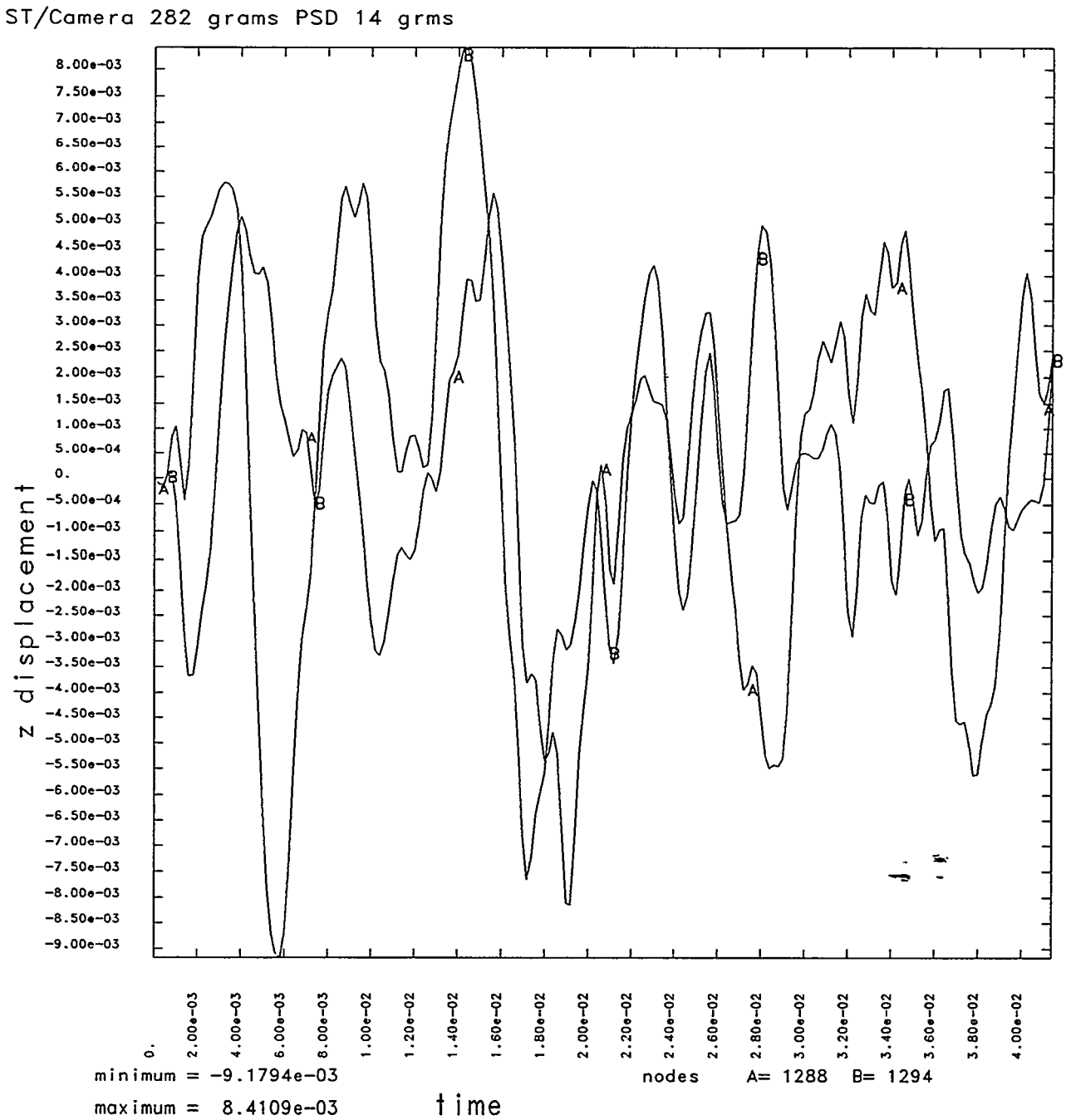


Figure 29: Dynamic displacement at end of baffle in z-direction

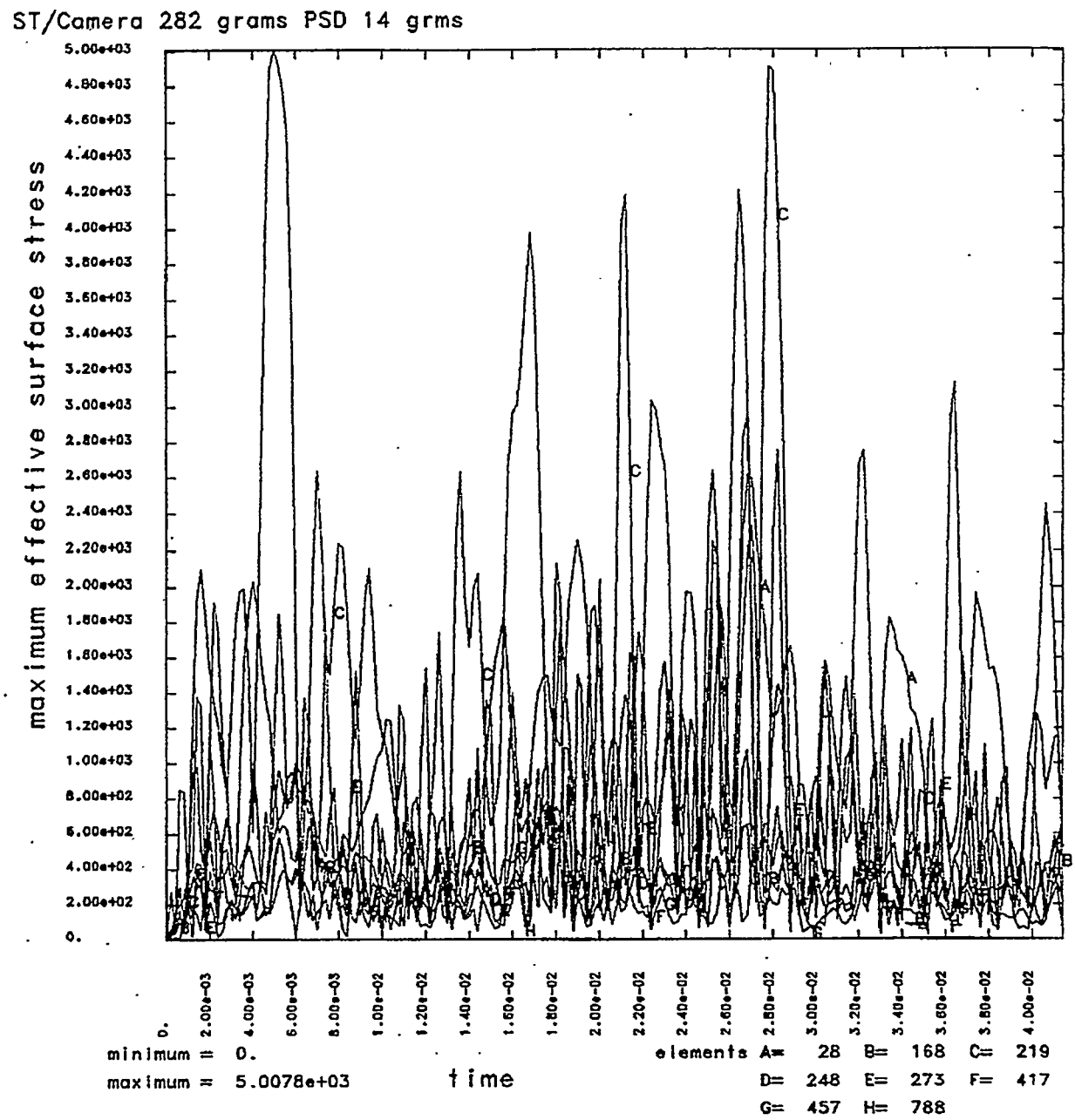


Figure 30: Dynamic stress for various elements

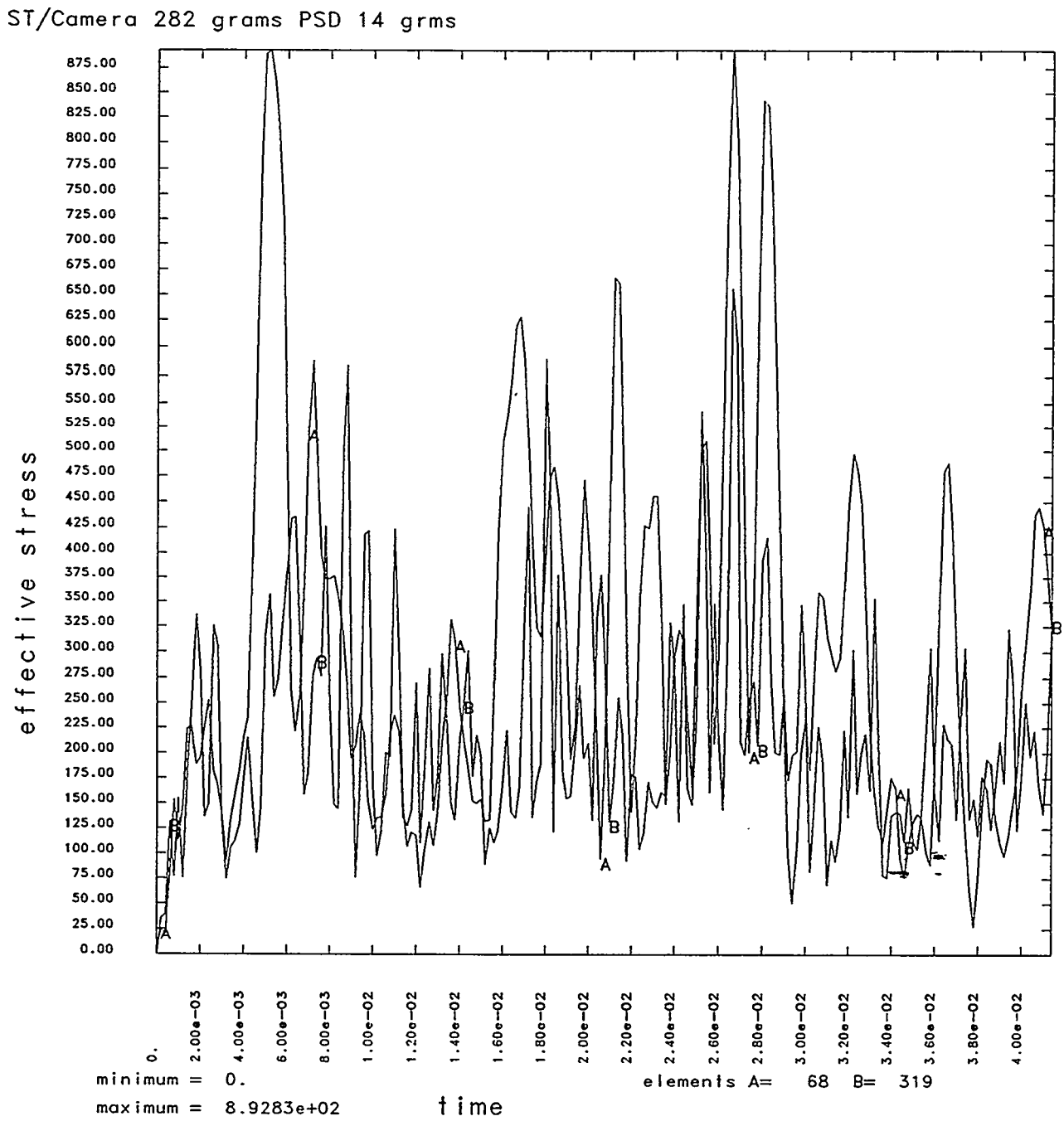
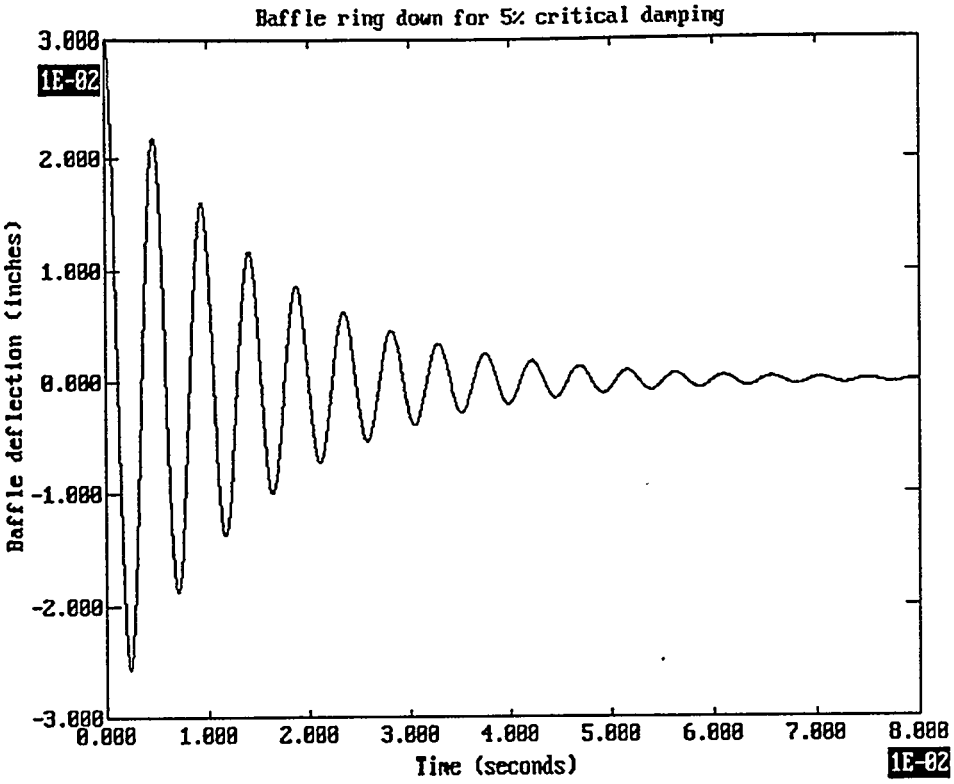


Figure 31: Dynamic stress for various elements



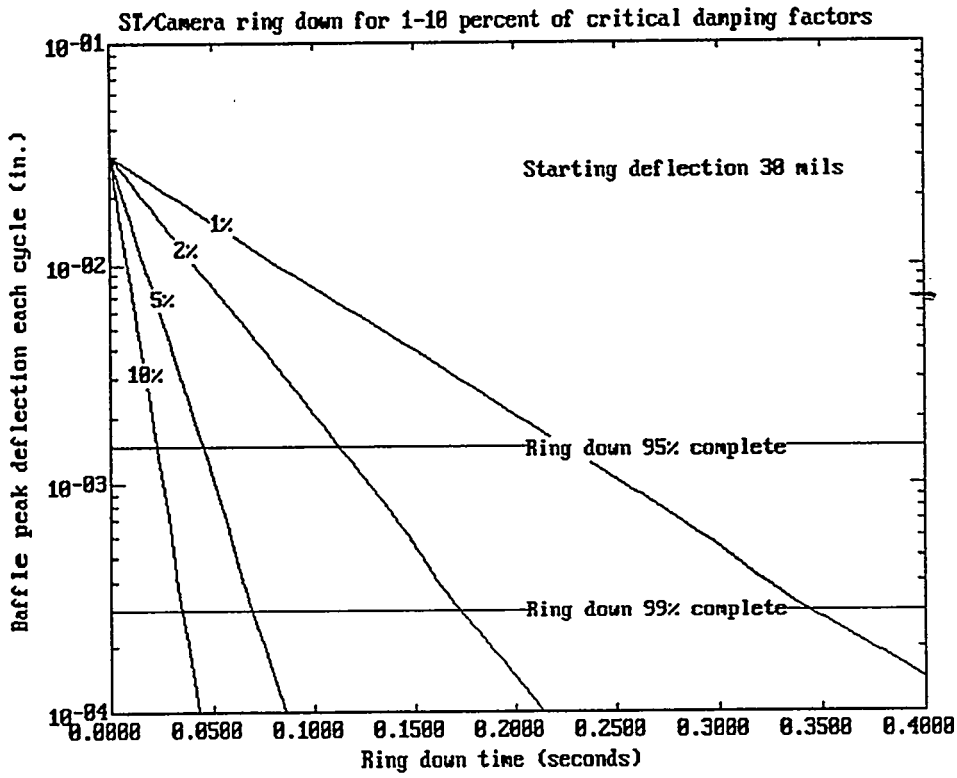
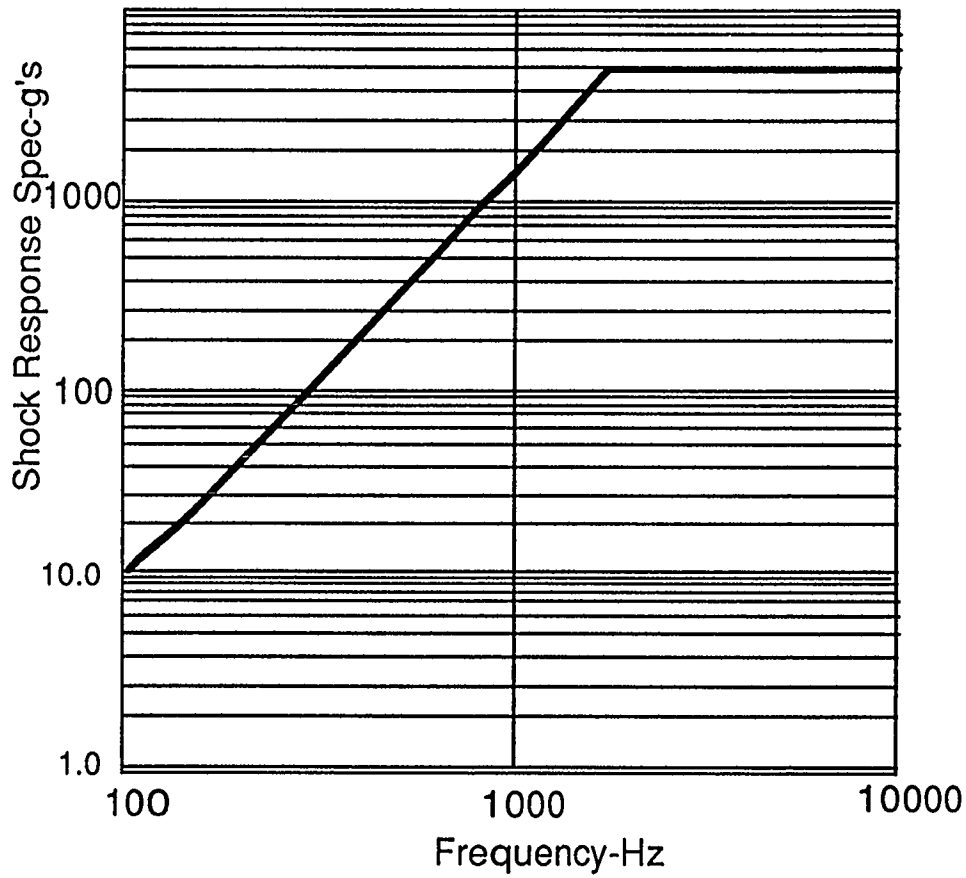


Figure 32: Ring-down response



Five Interfaces between the pyroshock and Sensor Bench

Attentuation Factor $=0.7^5$

Figure 33: Pyro-shock Response Spectrum

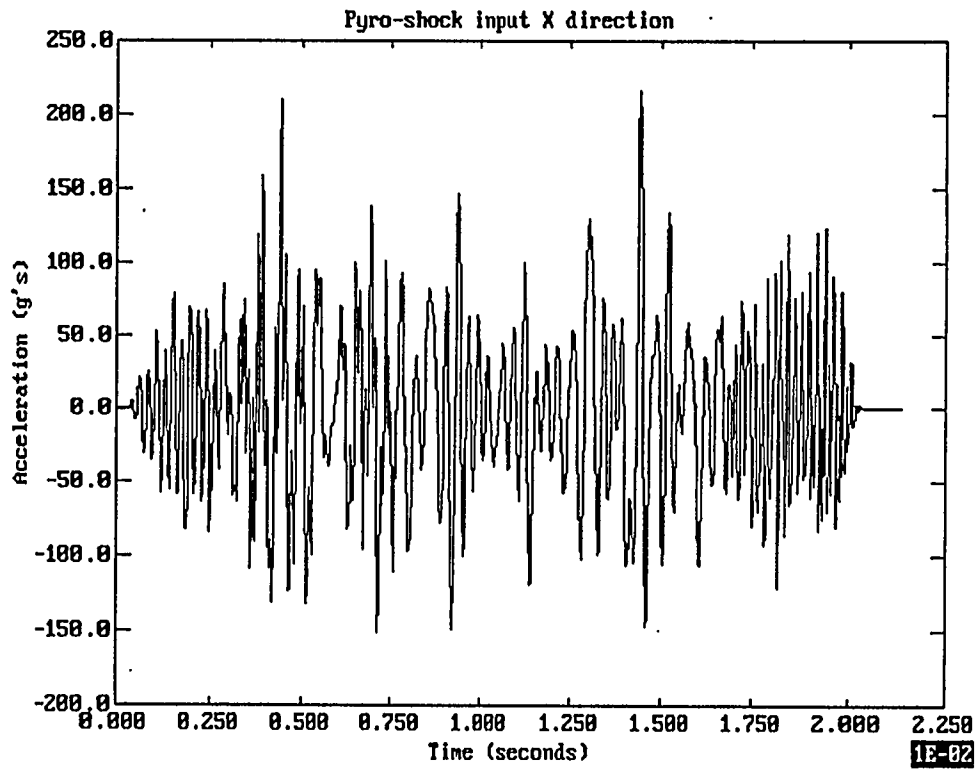


Figure 34: X-direction time series for Pyro-shock spectrum

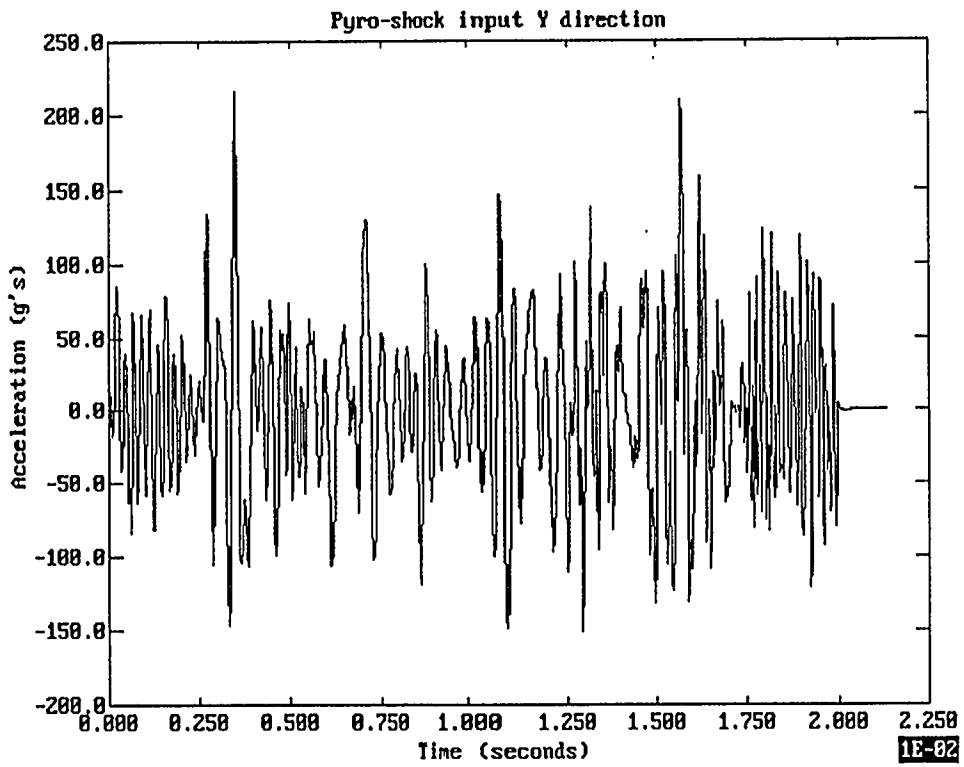


Figure 35: Y-direction time series for Pyro-shock spectrum

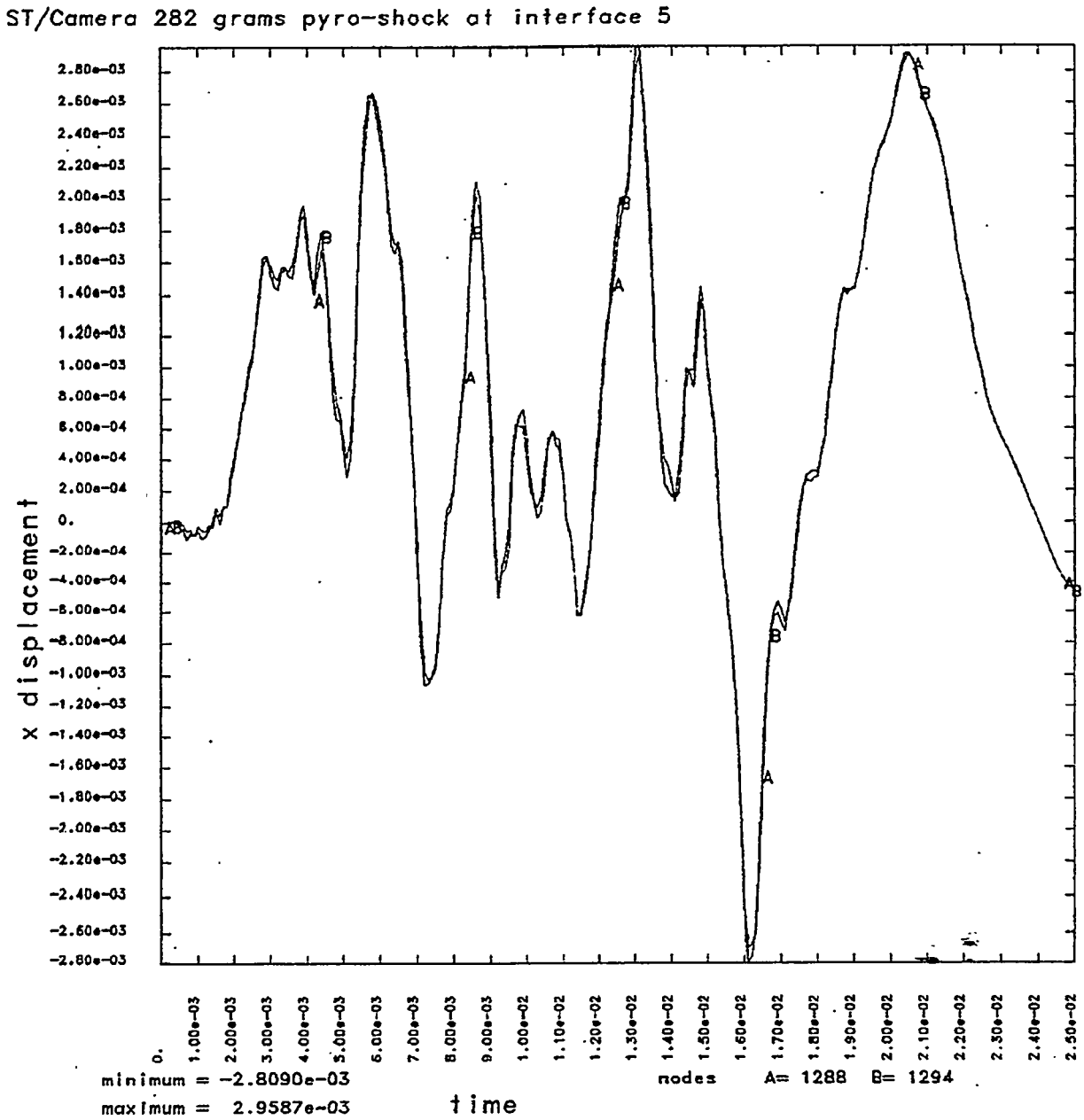


Figure 36: Dynamic displacement at end of baffle in x-direction

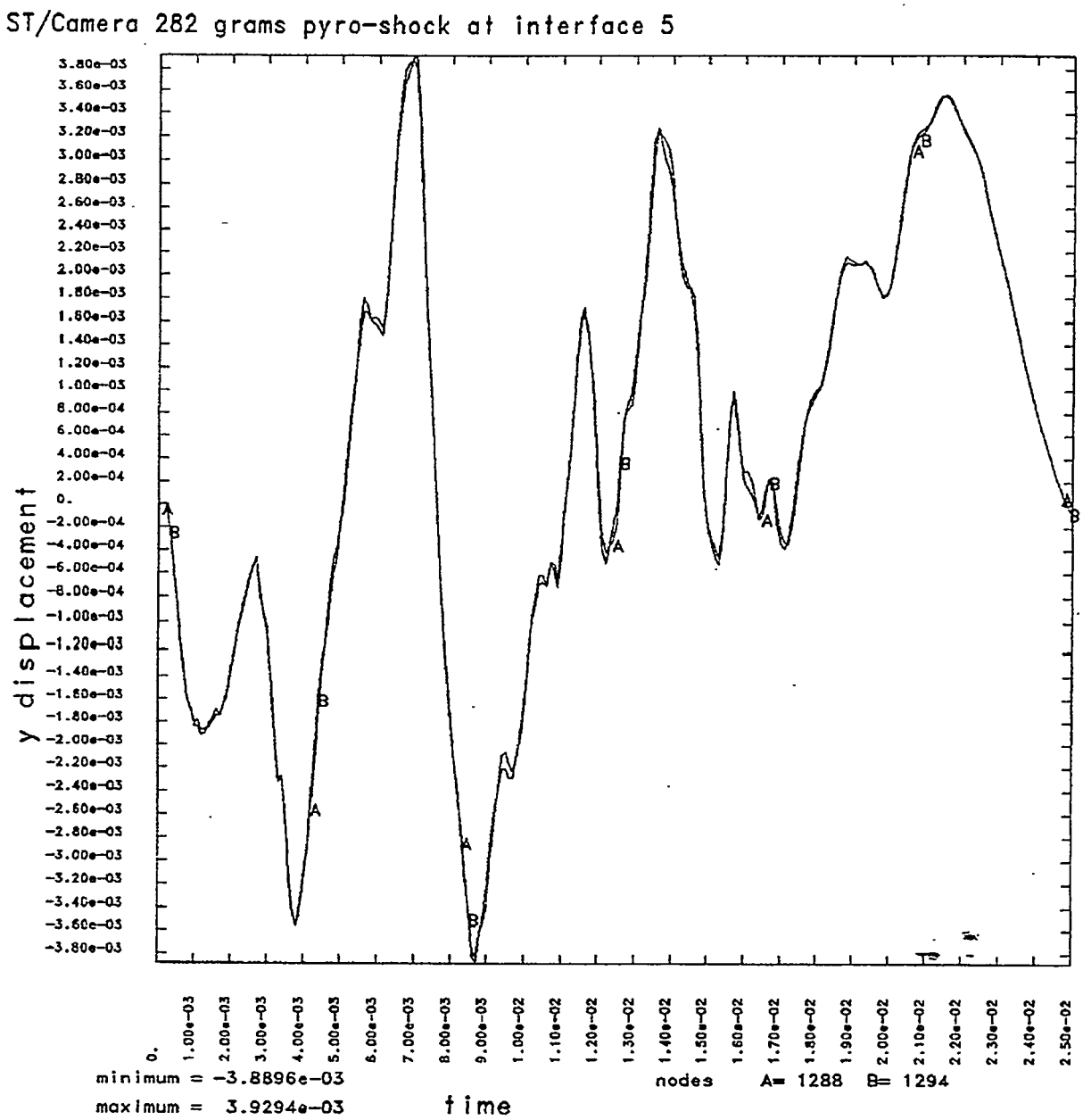


Figure 37: Dynamic displacement at end of baffle in y-direction

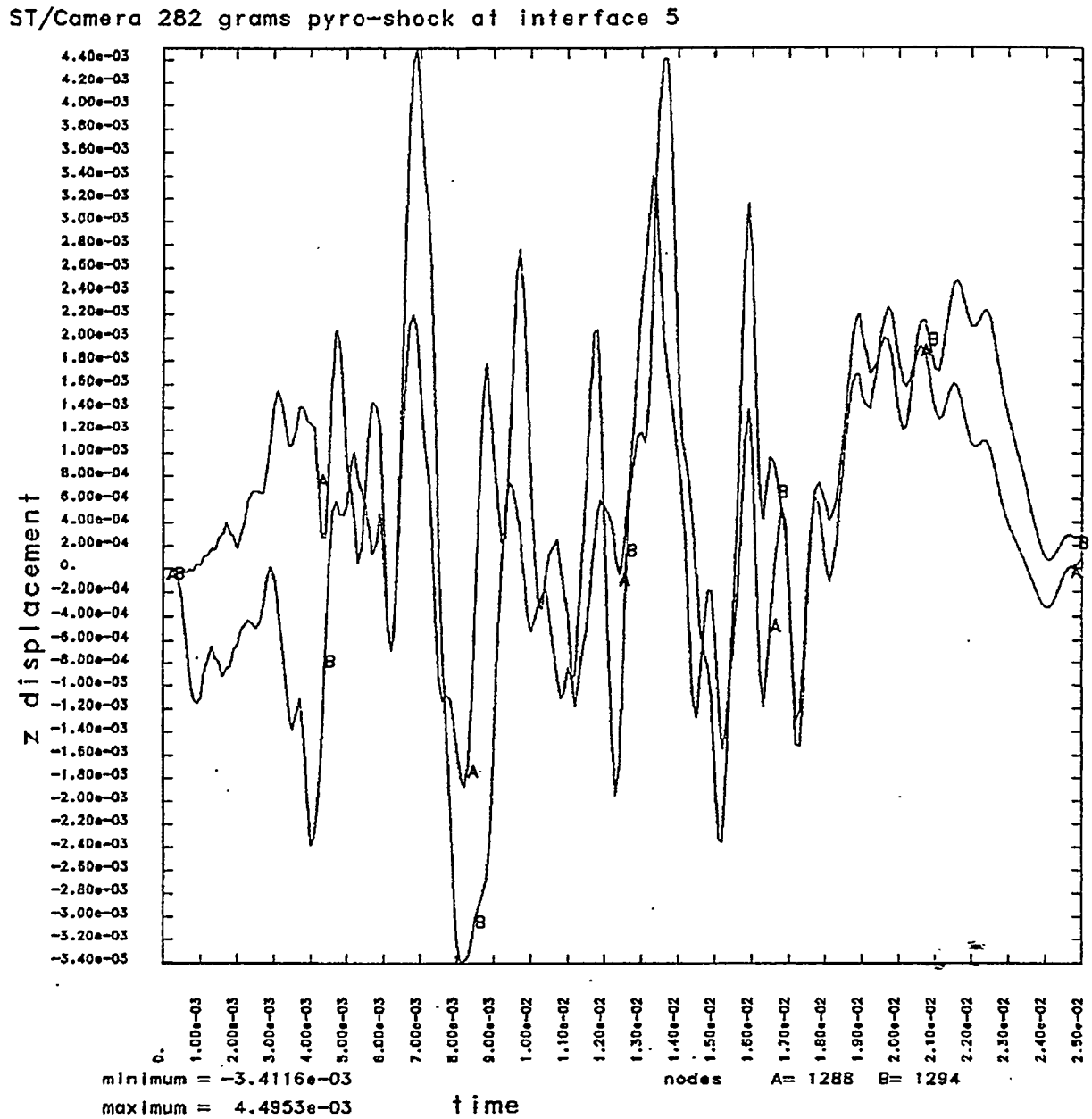


Figure 38: Dynamic displacement at end of baffle in z-direction

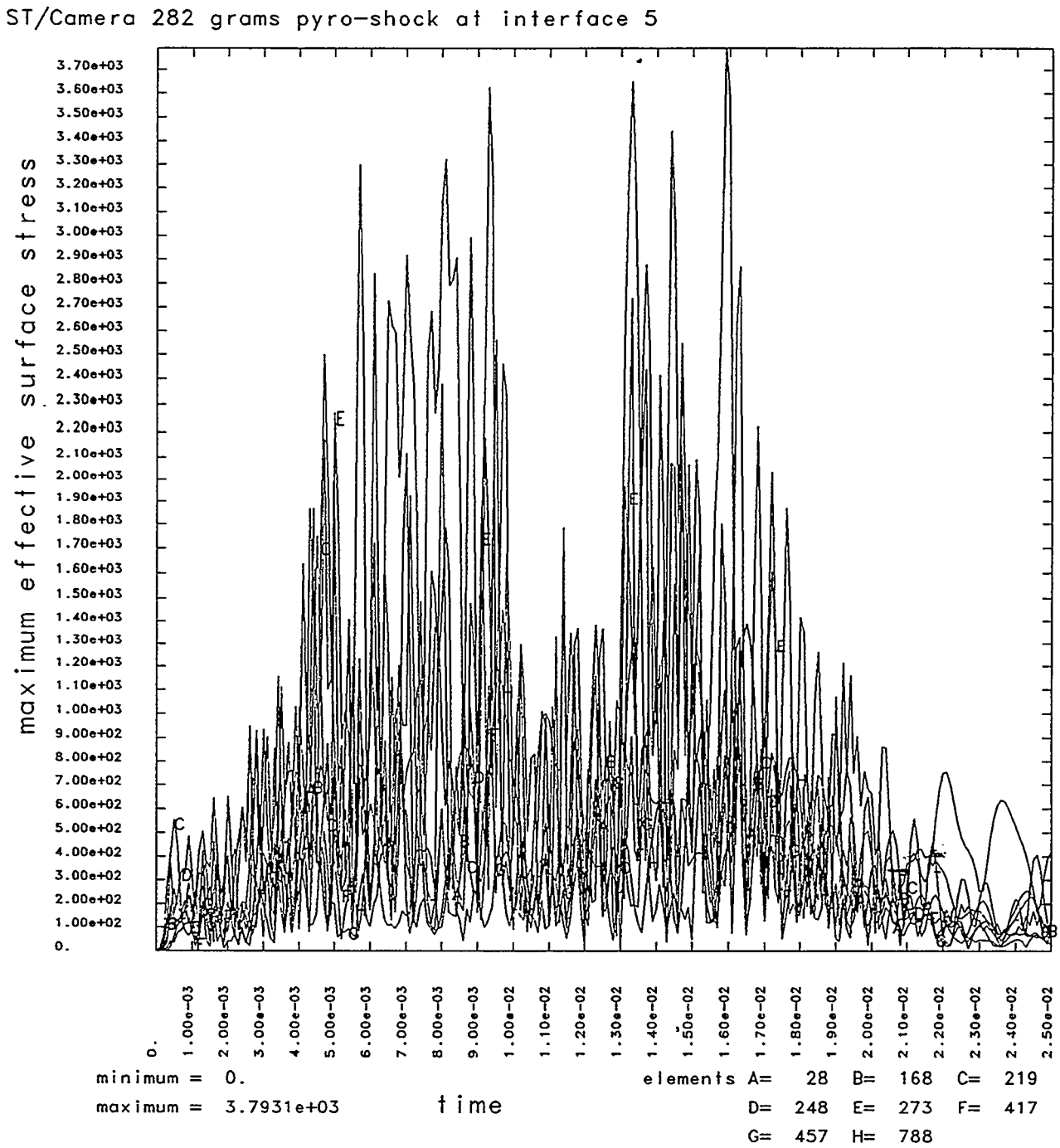


Figure 39: Dynamic stress for various elements

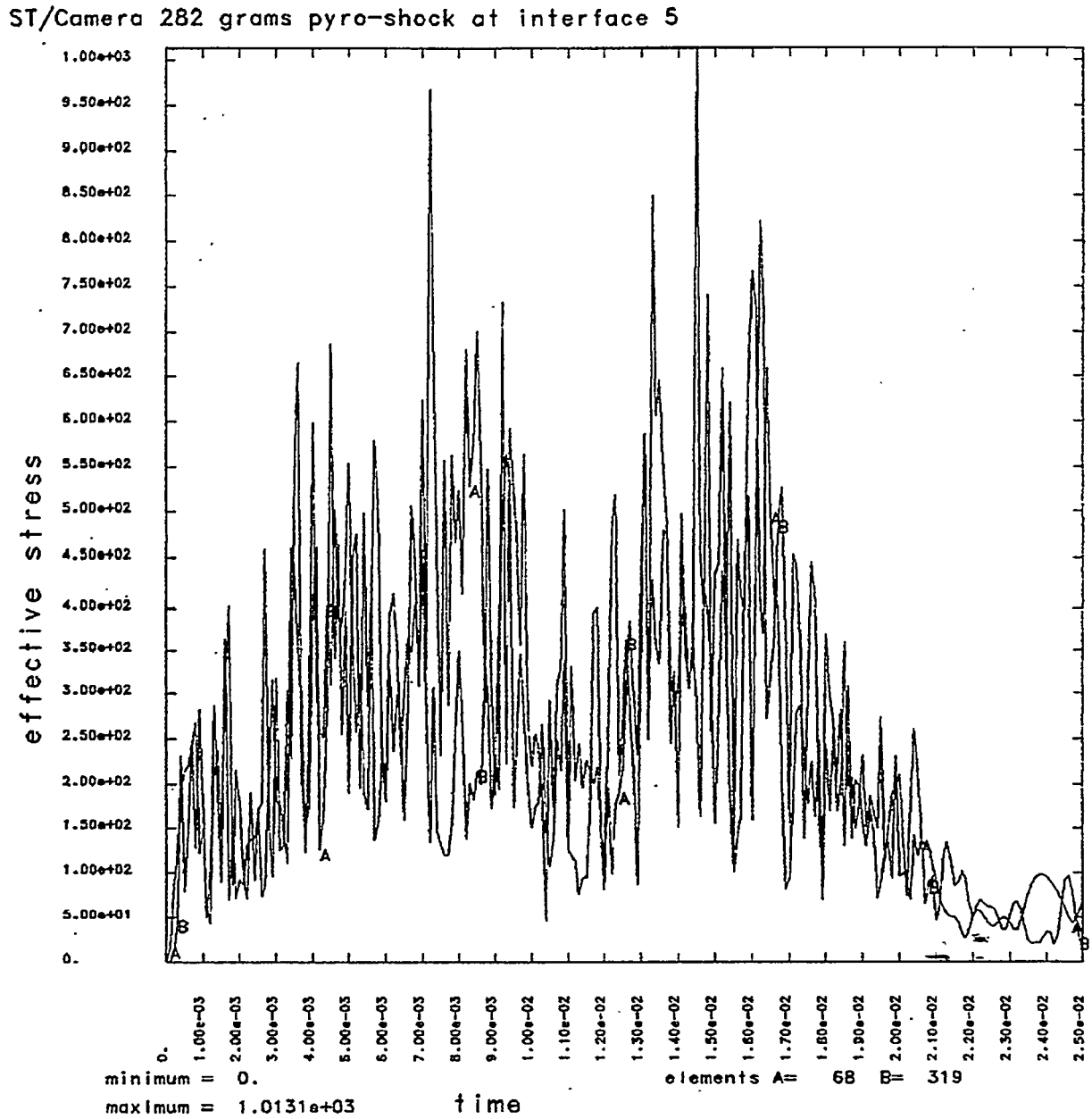


Figure 40: Dynamic stress for various elements

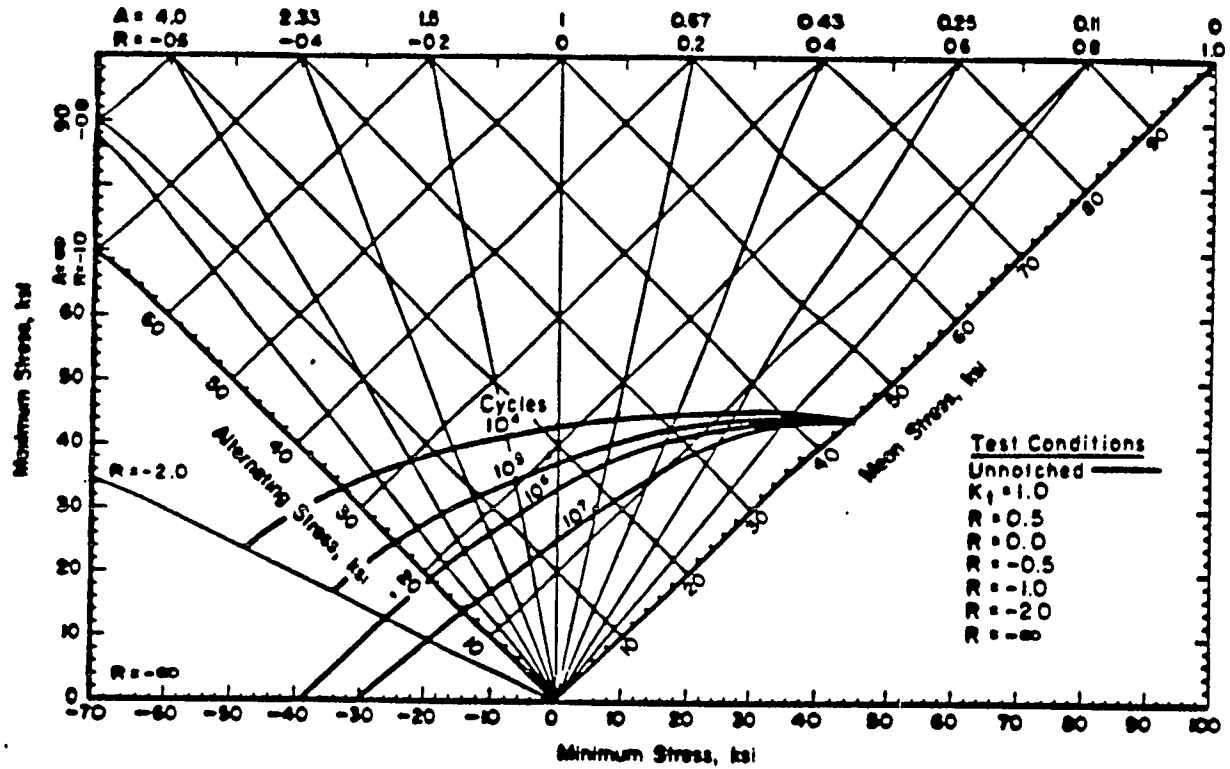


FIGURE 3.6.1.2.8. *Typical constant-life diagram for fatigue behavior of various wrought products of 6061-T6 aluminum alloy.*

Correlative Information for Figure 3.6.1.2.8

Product Form: Drawn Rod, 3/4-inch diameter
Rolled bar, 1 x 7-½ inches

Properties:

TUS, ksi	TYS, ksi	Temp, F
44.3	39.5	RT

Specimen Details: Unnotched: 0.200-inch diameter

Surface Condition: Unnotched: not known

Test Parameters:

Loading - Axial
Frequency - 2000 cpm
Temperature - RT
Atmosphere - Air

Figure 41: Constant life diagram for fatigue behavior of 6061-T6 Aluminum alloy.

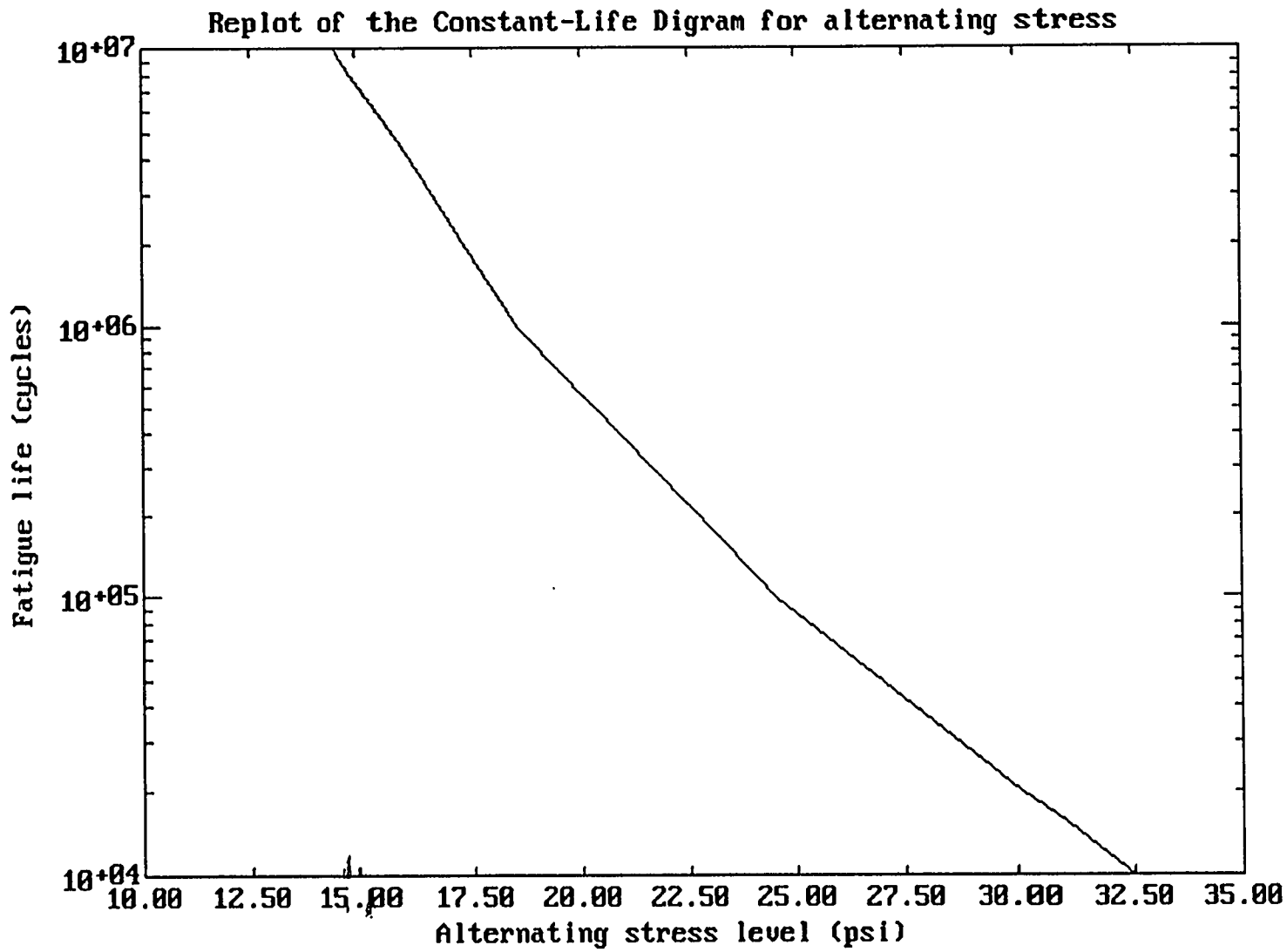


Figure 42: Fatigue life.

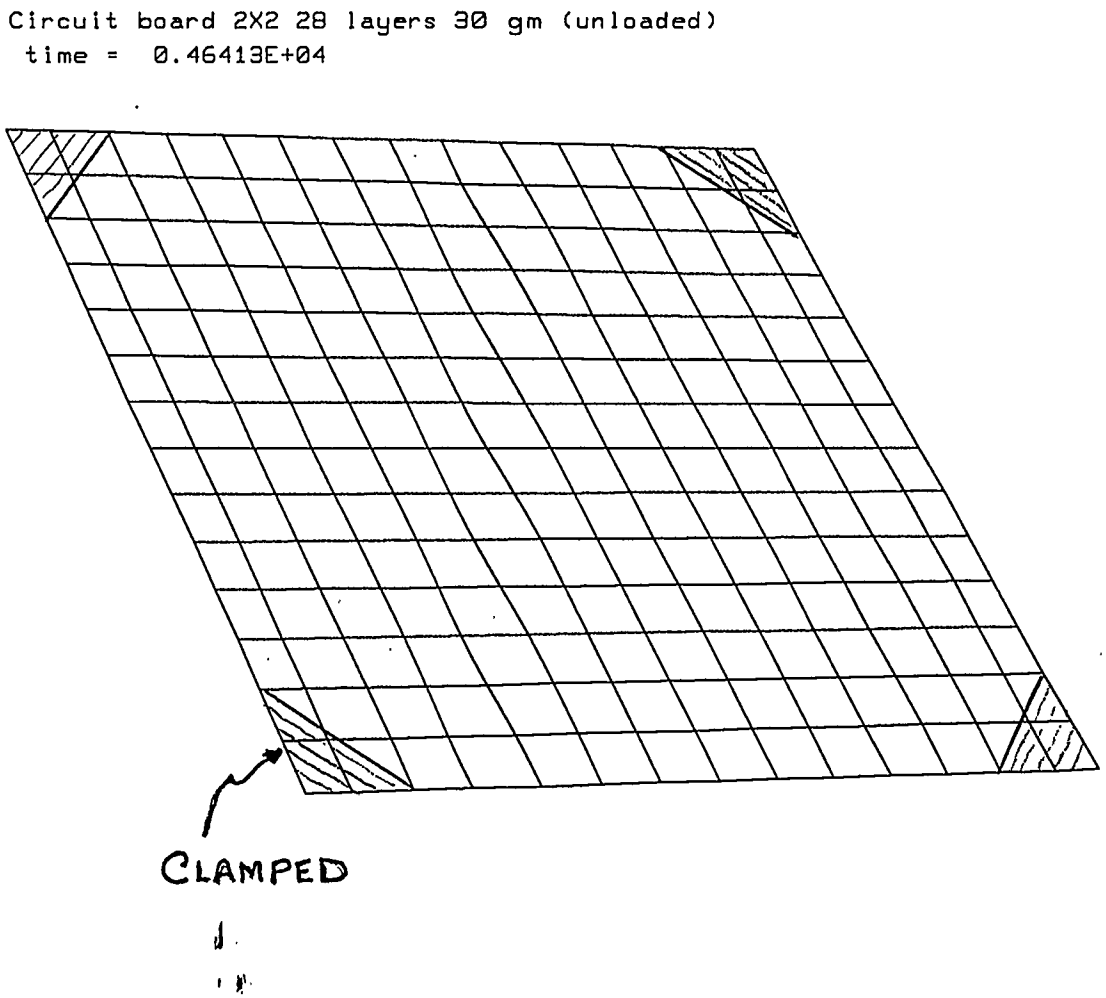


Figure 43: Unloaded circuit board showing clamped locations

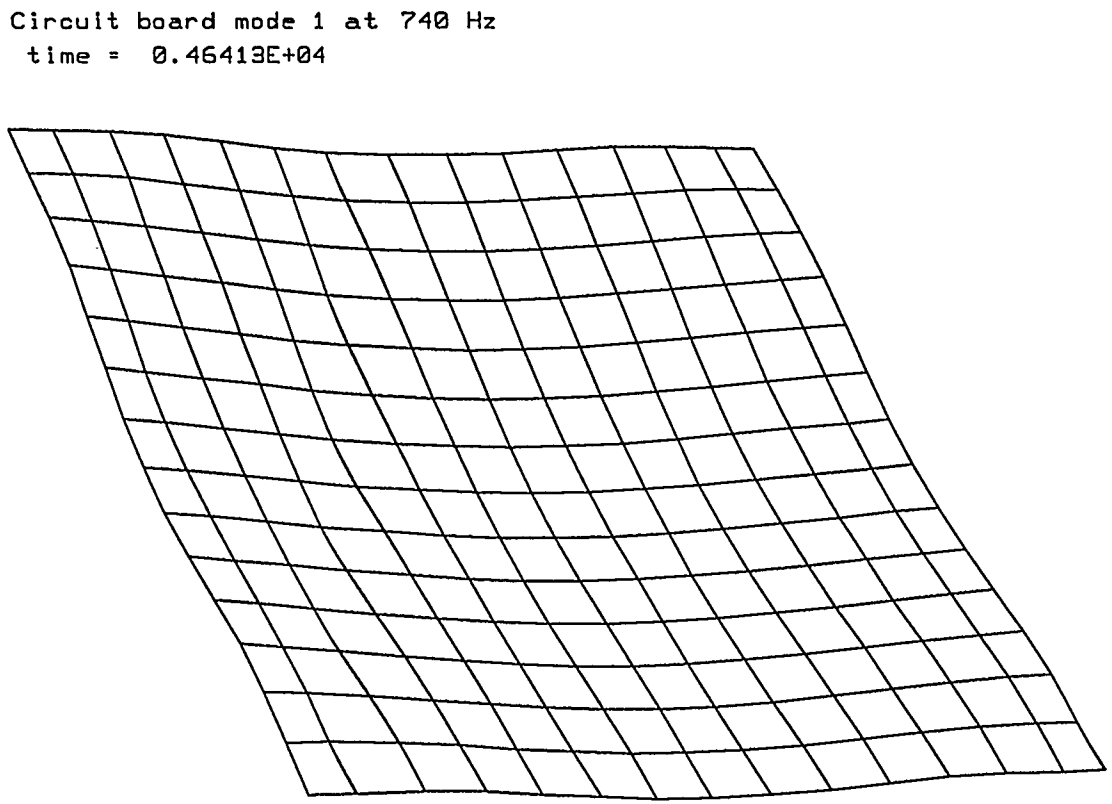


Figure 44: Mode 1 at 740 Hz.

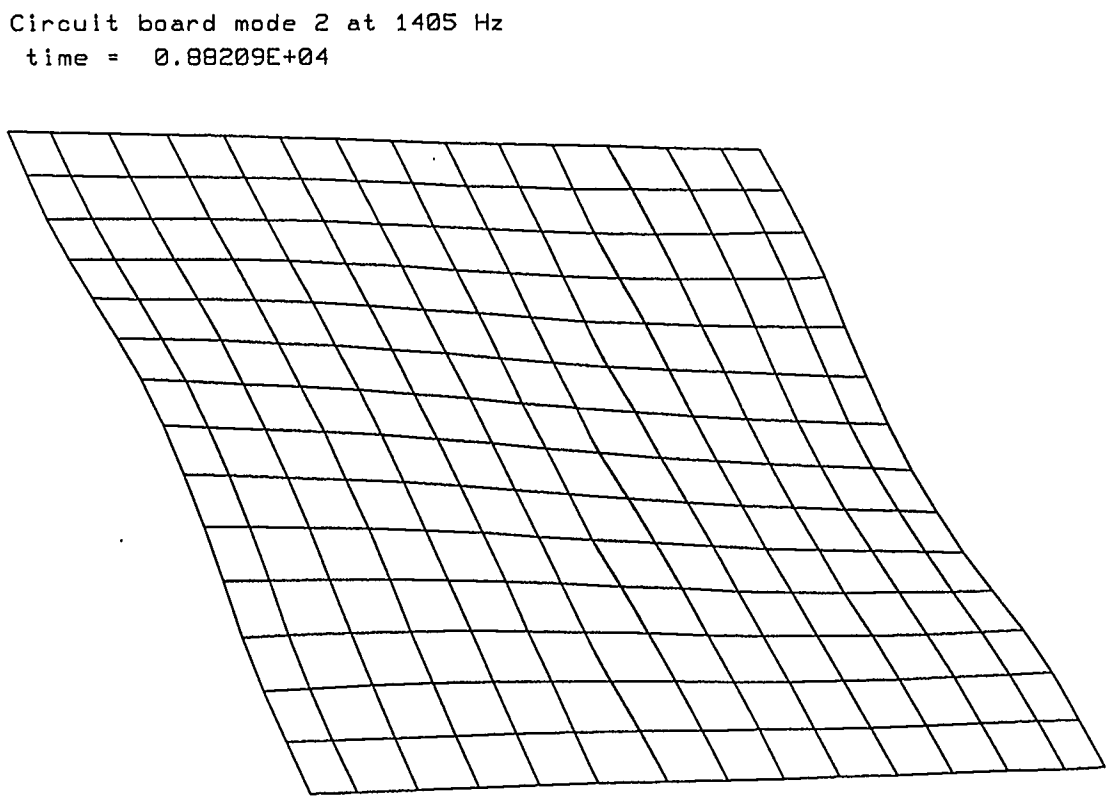


Figure 45: Mode 2 at 1405 Hz.

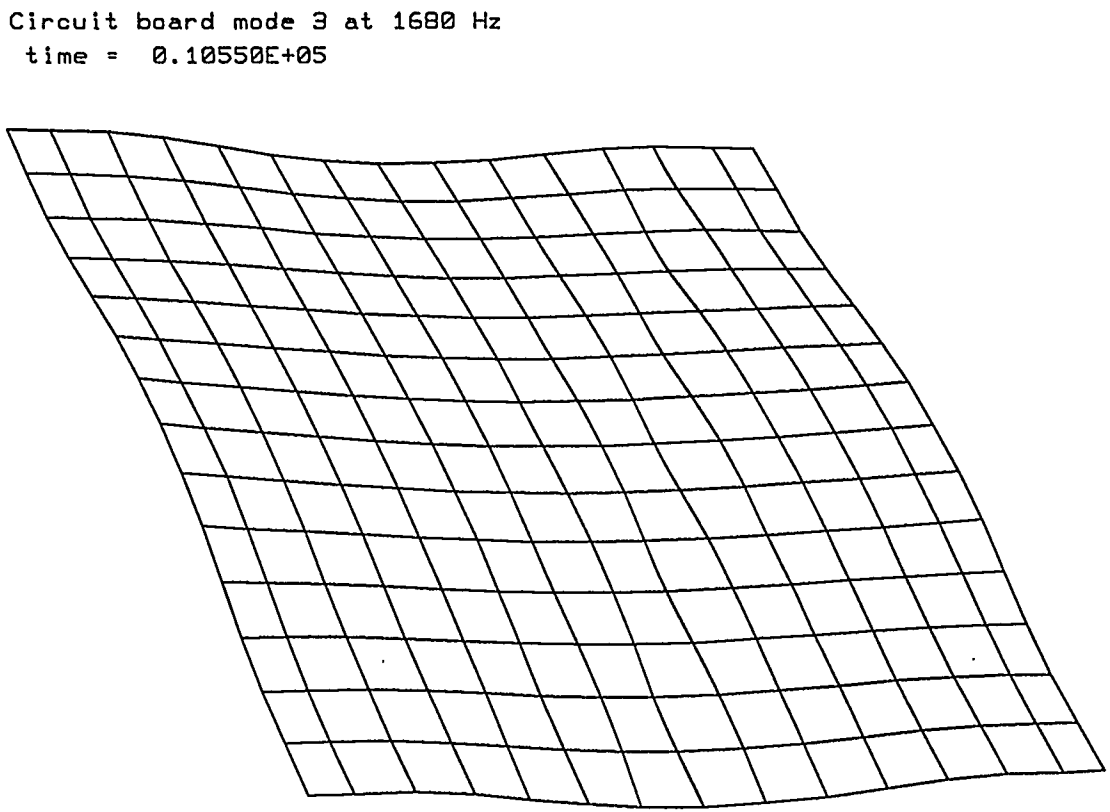


Figure 46: Mode 3 at 1680 Hz.

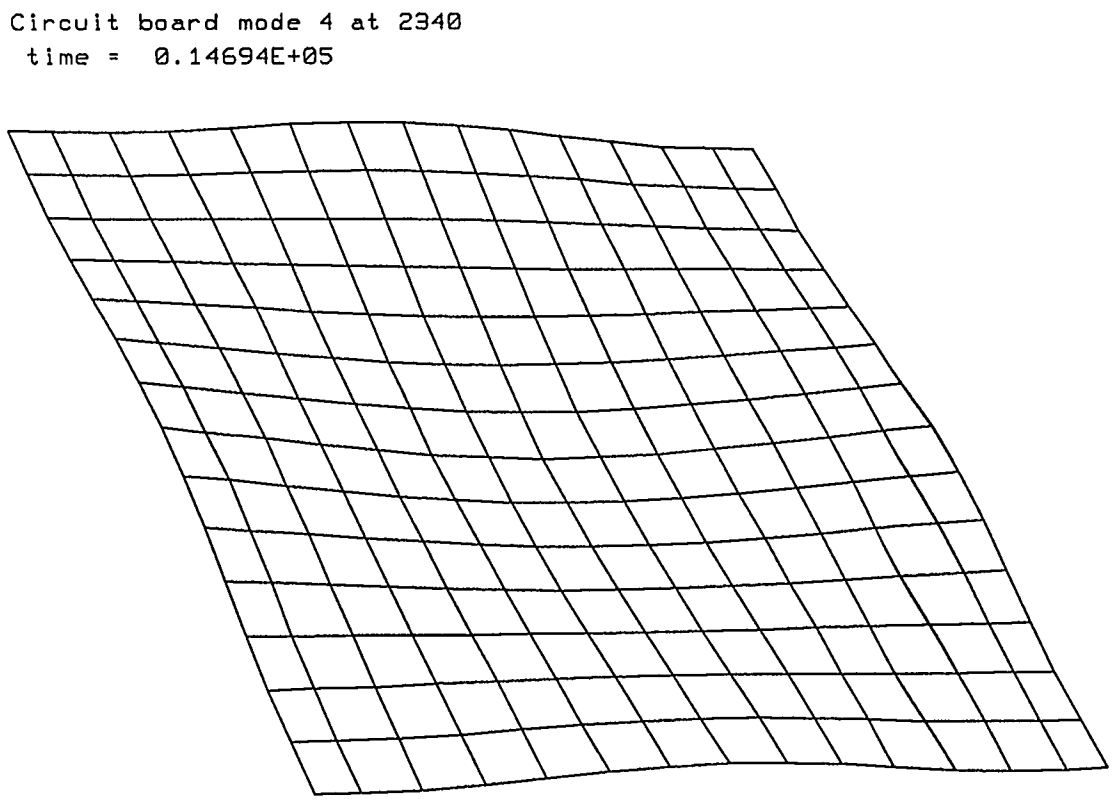


Figure 47: Mode 4 at 2340 Hz.

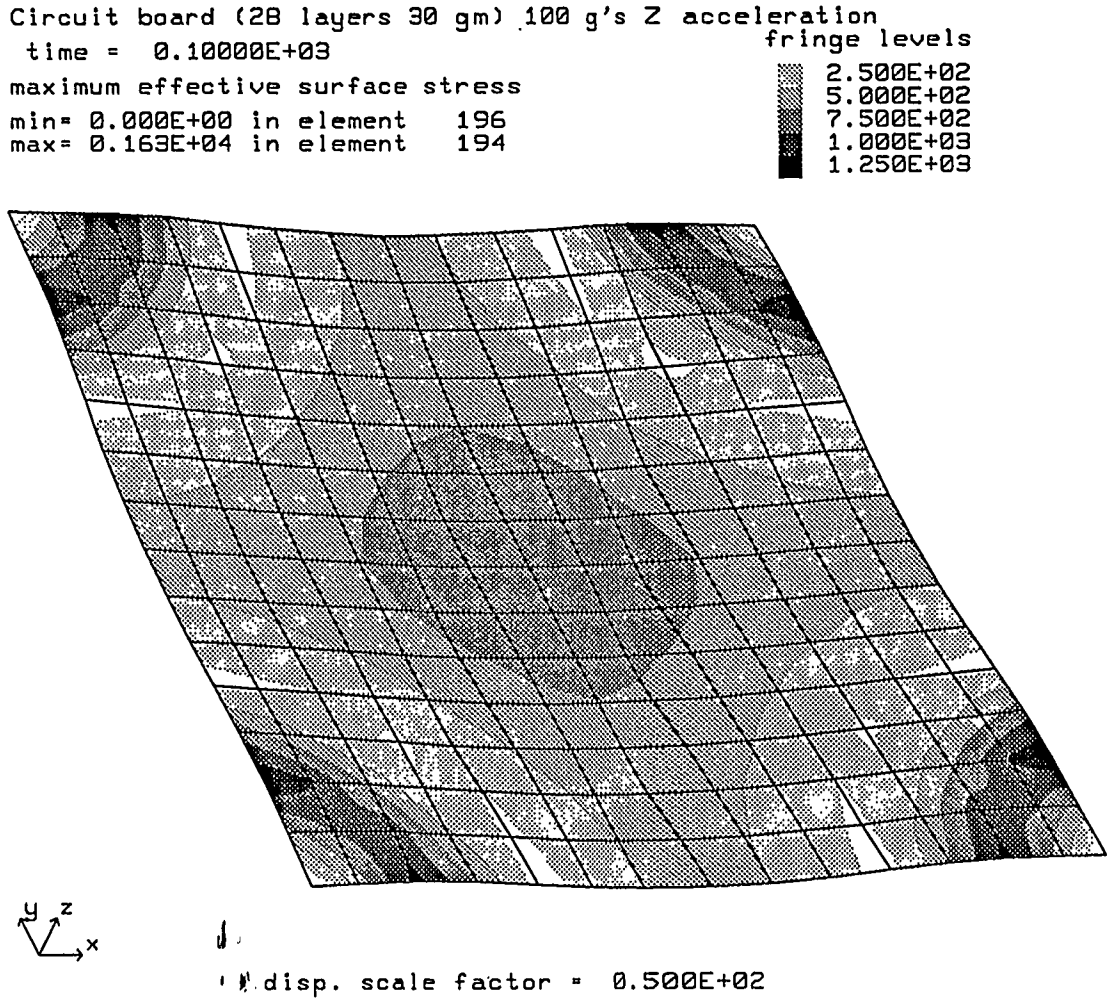


Figure 48: Stress fringes in circuit board induced by z-direction loading

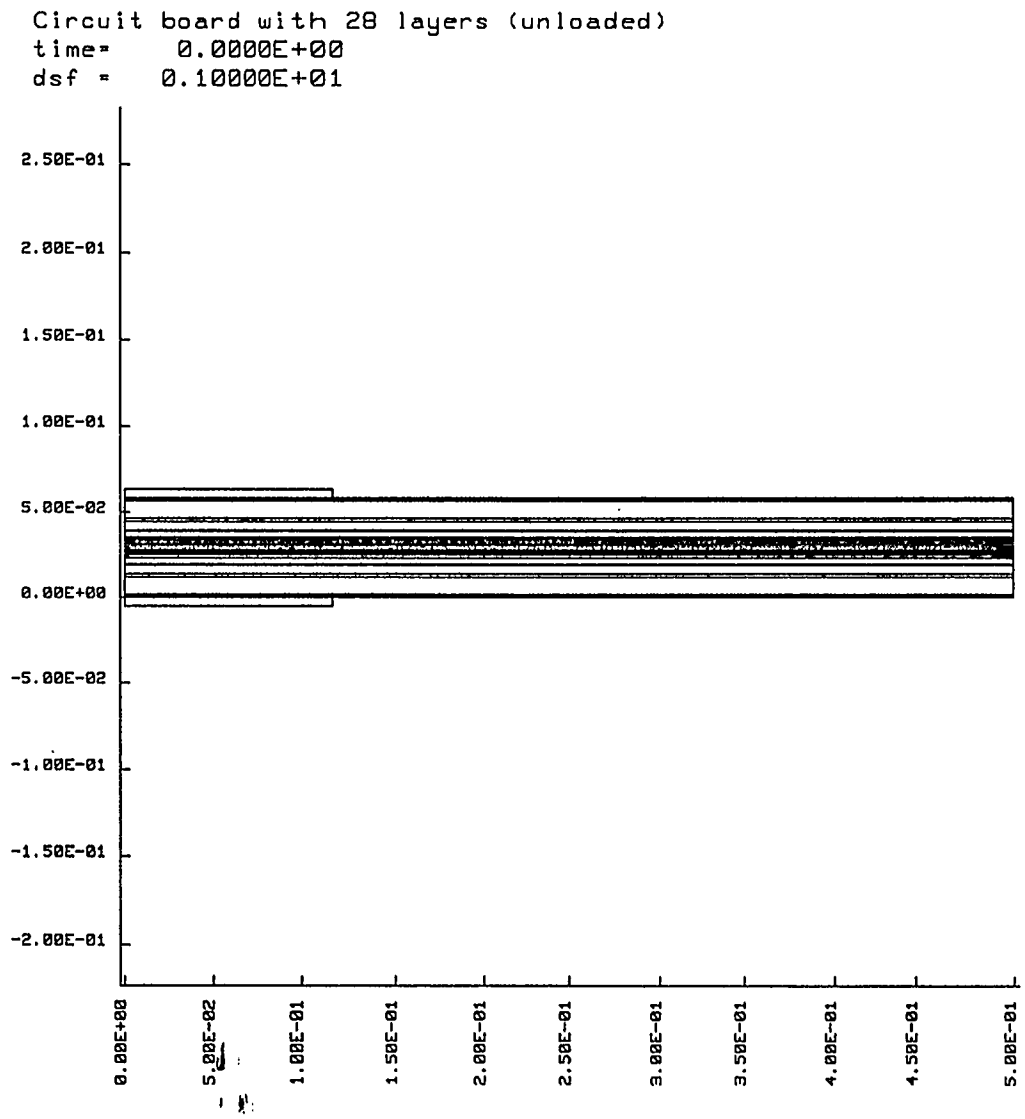

Circuit board with 28 layers (unloaded)
time= 0.0000E+00
dsf = 0.10000E+01
2.50E-01
2.00E-01
1.50E-01
1.00E-01
5.00E-02
0.00E+00
-5.00E-02
-1.00E-01
-1.50E-01
-2.00E-01
0.00E+00
5.00E-02
1.00E-01
1.50E-01
2.00E-01
2.50E-01
3.00E-01
3.50E-01
4.00E-01
4.50E-01
5.00E-01

Figure 49:

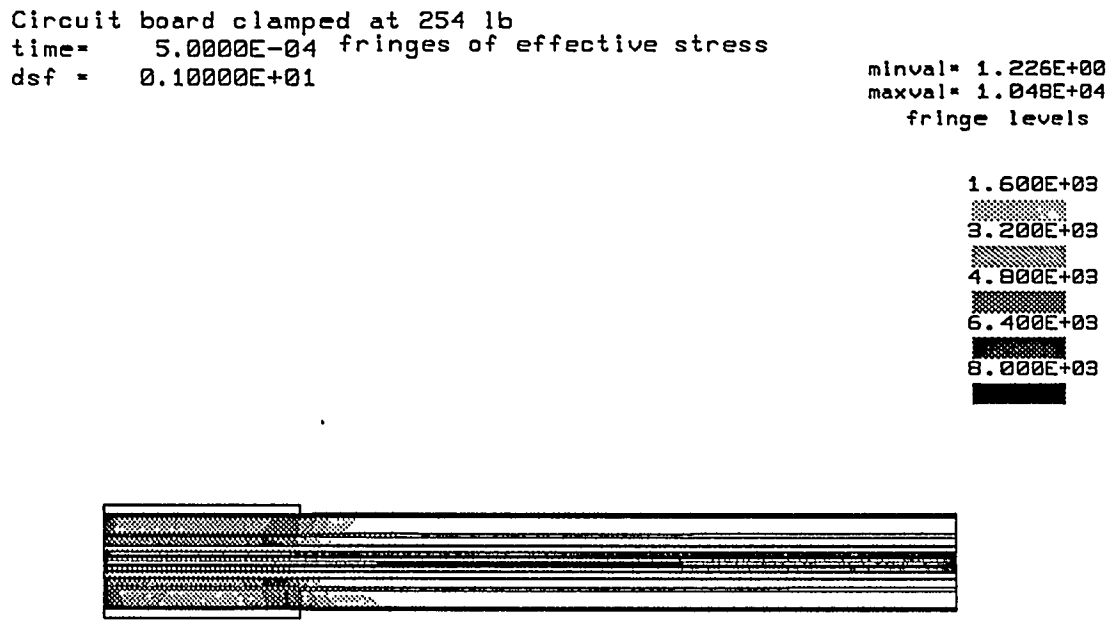

Circuit board clamped at 254 lb
time= 5.0000E-04 fringes of effective stress
dsf = 0.10000E+01
minval= 1.226E+00
maxval= 1.048E+04
fringe levels
1.600E+03
3.200E+03
4.800E+03
6.400E+03
8.000E+03

Figure 50:

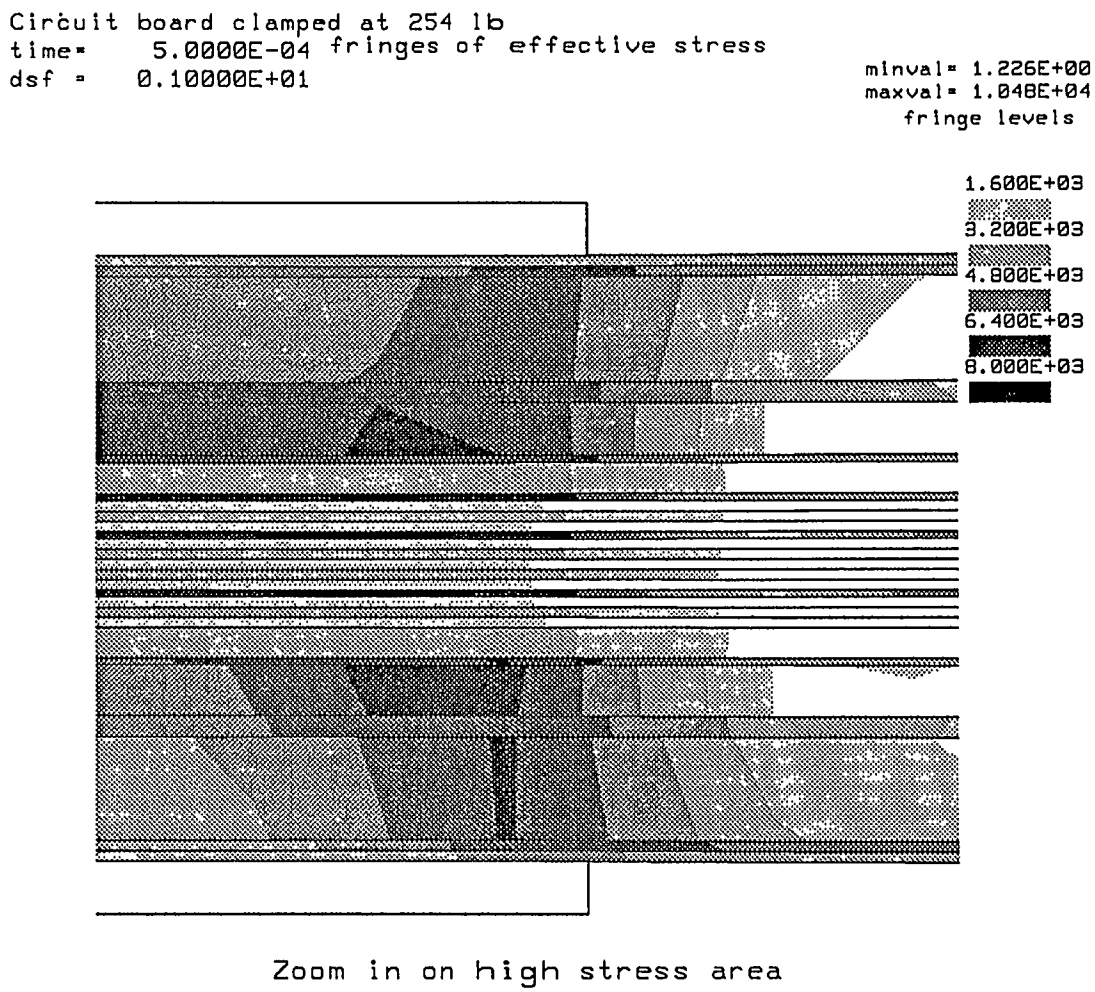

Circuit board clamped at 254 lb
time= 5.0000E-04 fringes of effective stress
dsf = 0.10000E+01
minval= 1.226E+00
maxval= 1.048E+04
fringe levels
1.600E+03
3.200E+03
4.800E+03
6.400E+03
8.000E+03
Zoom in on high stress area

Figure 51:

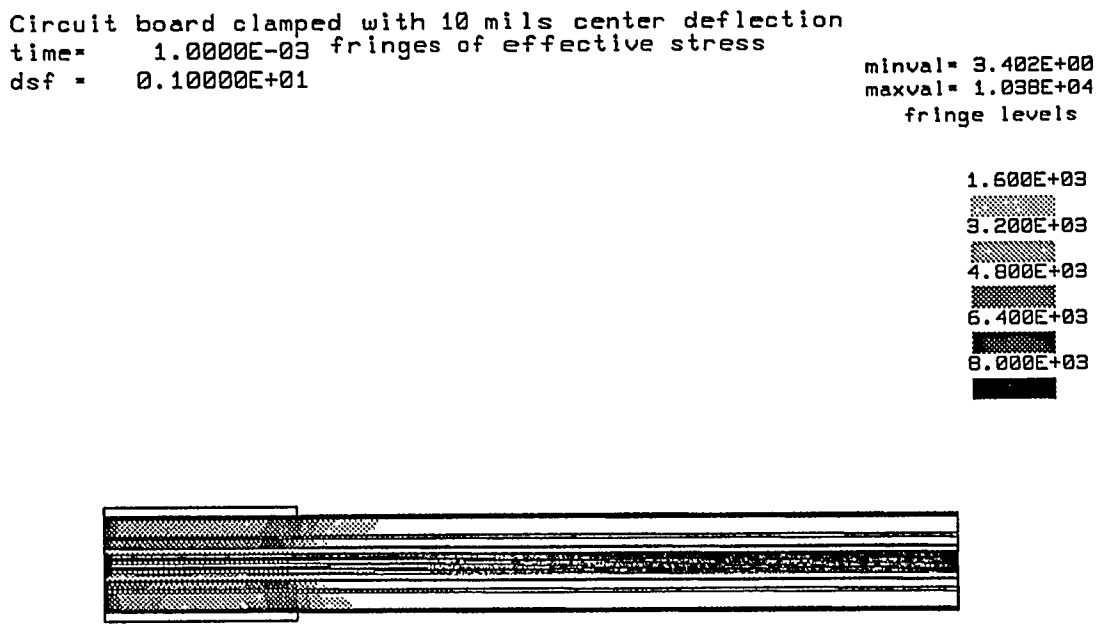

Circuit board clamped with 10 mils center deflection
time= 1.0000E-03 fringes of effective stress
dsf = 0.10000E+01
minval= 3.402E+00
maxval= 1.038E+04
fringe levels
1.600E+03
3.200E+03
4.800E+03
6.400E+03
8.000E+03

Figure 52:

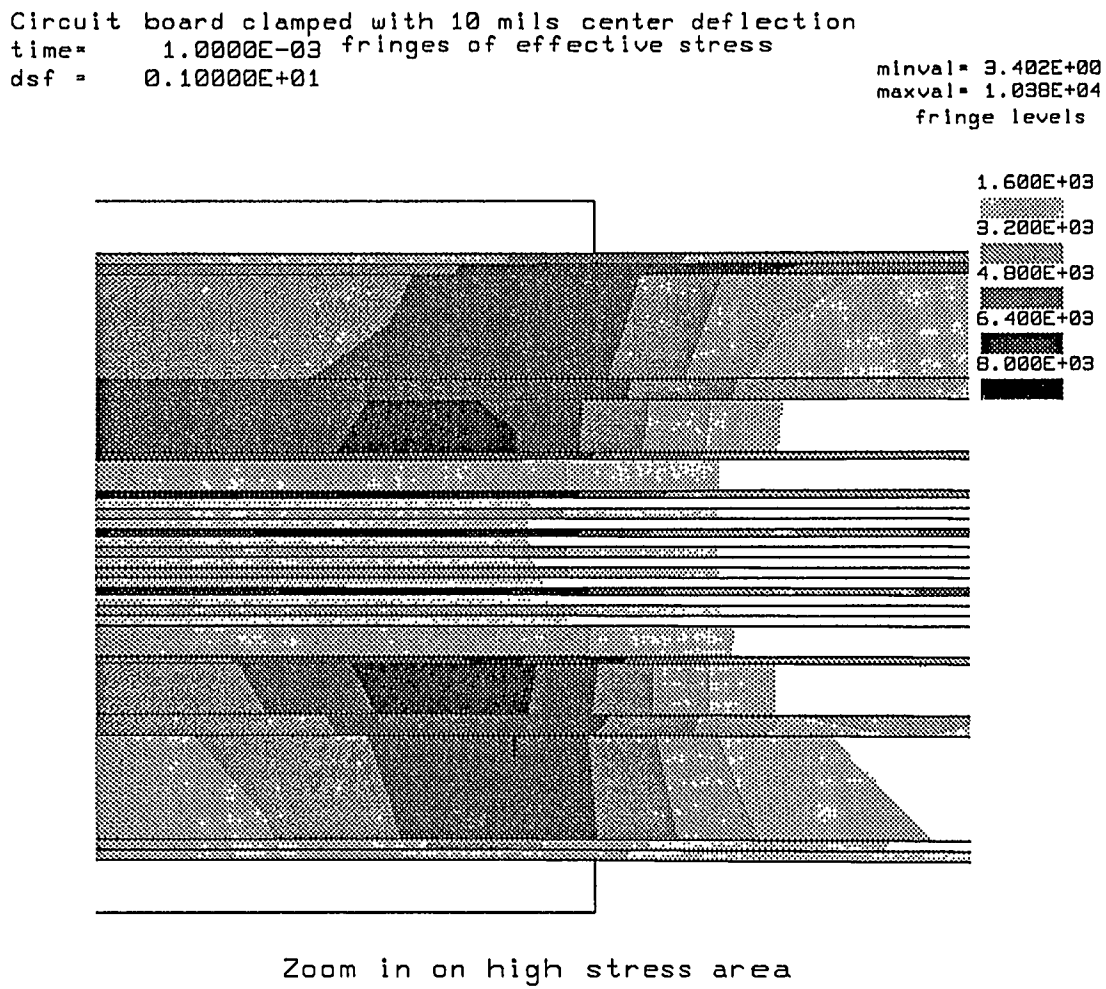
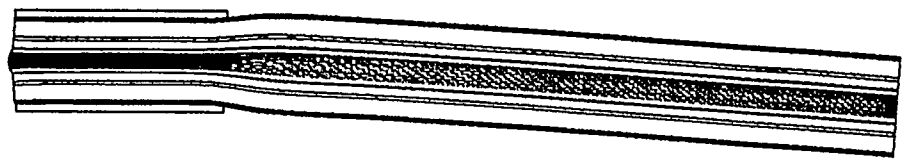

Circuit board clamped with 10 mils center deflection
time= 1.0000E-03 fringes of effective stress
dsf = 0.10000E+01
minval= 3.402E+00
maxval= 1.038E+04
fringe levels
1.600E+03
3.200E+03
4.800E+03
6.400E+03
8.000E+03
Zoom in on high stress area

Figure 53:

Circuit board clamped with 10 mils center deflection
time= 1.0000E-03
dsf = 0.25000E+02



Deflections amplified by 25X

Figure 54:

Appendix Figures

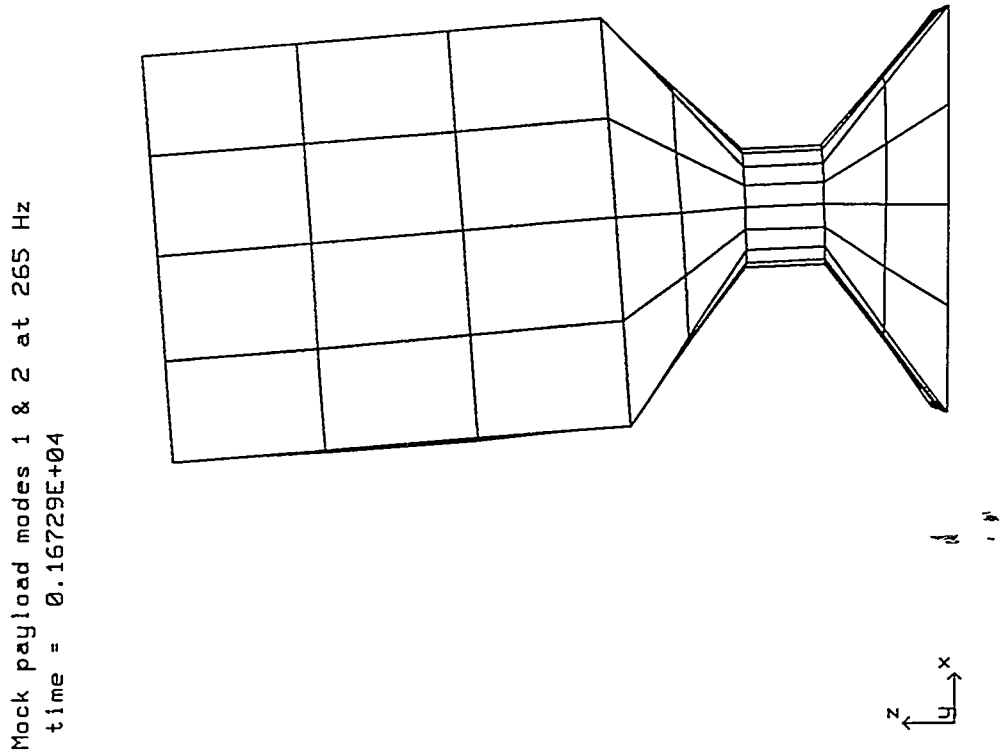


Figure 55

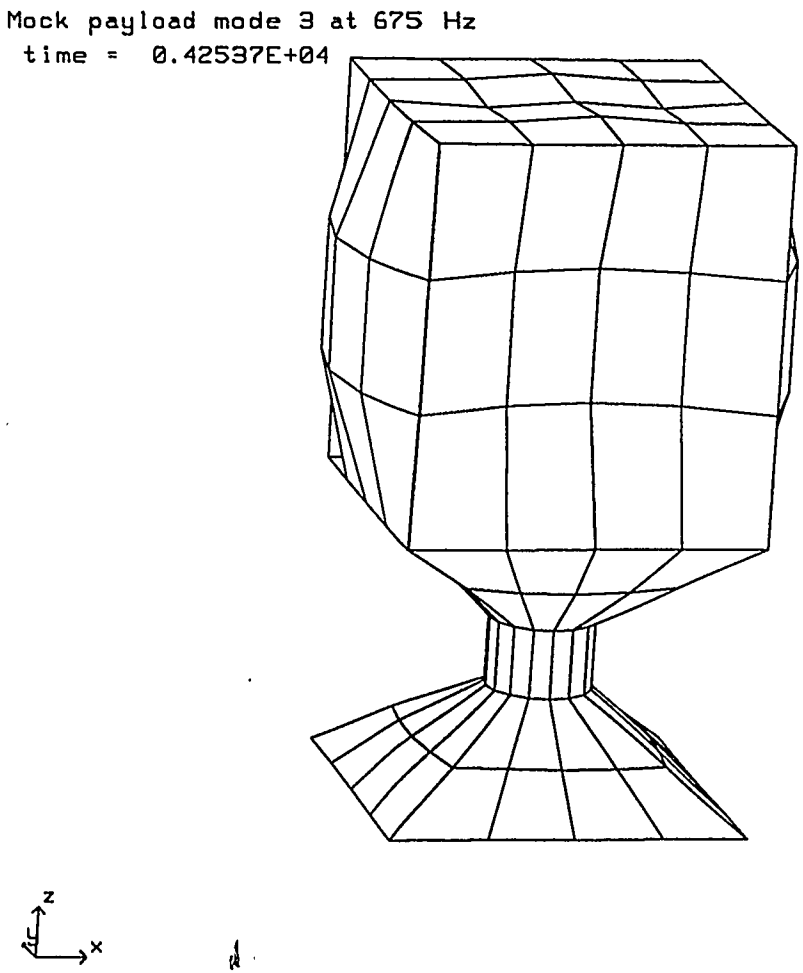


Figure 56

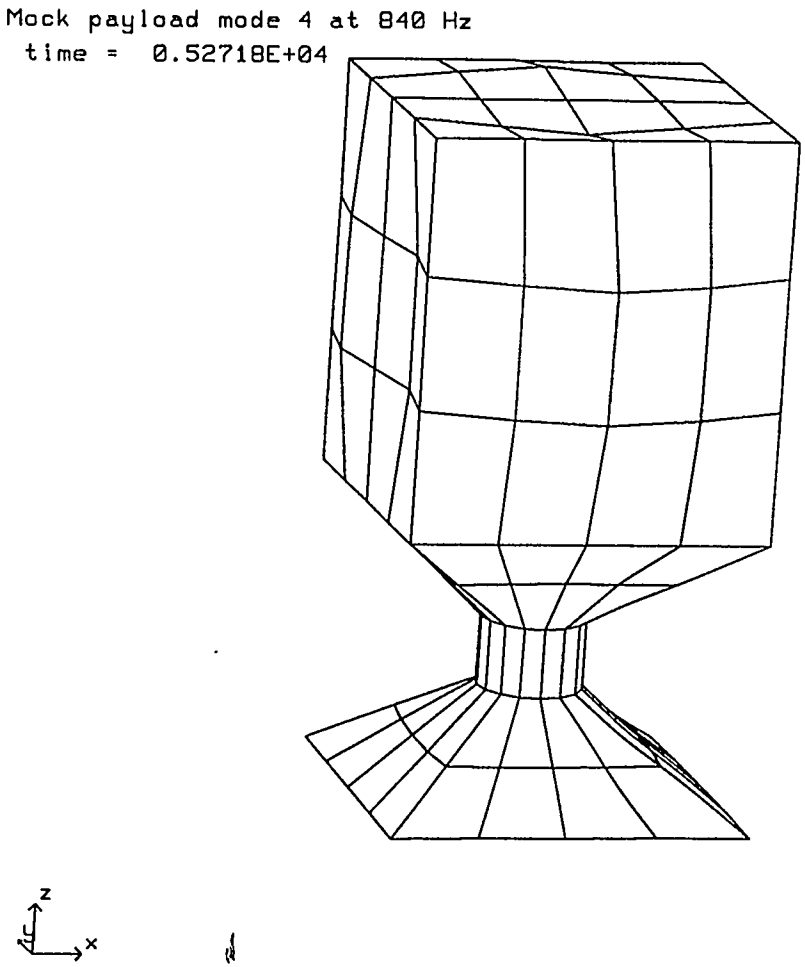


Figure 57

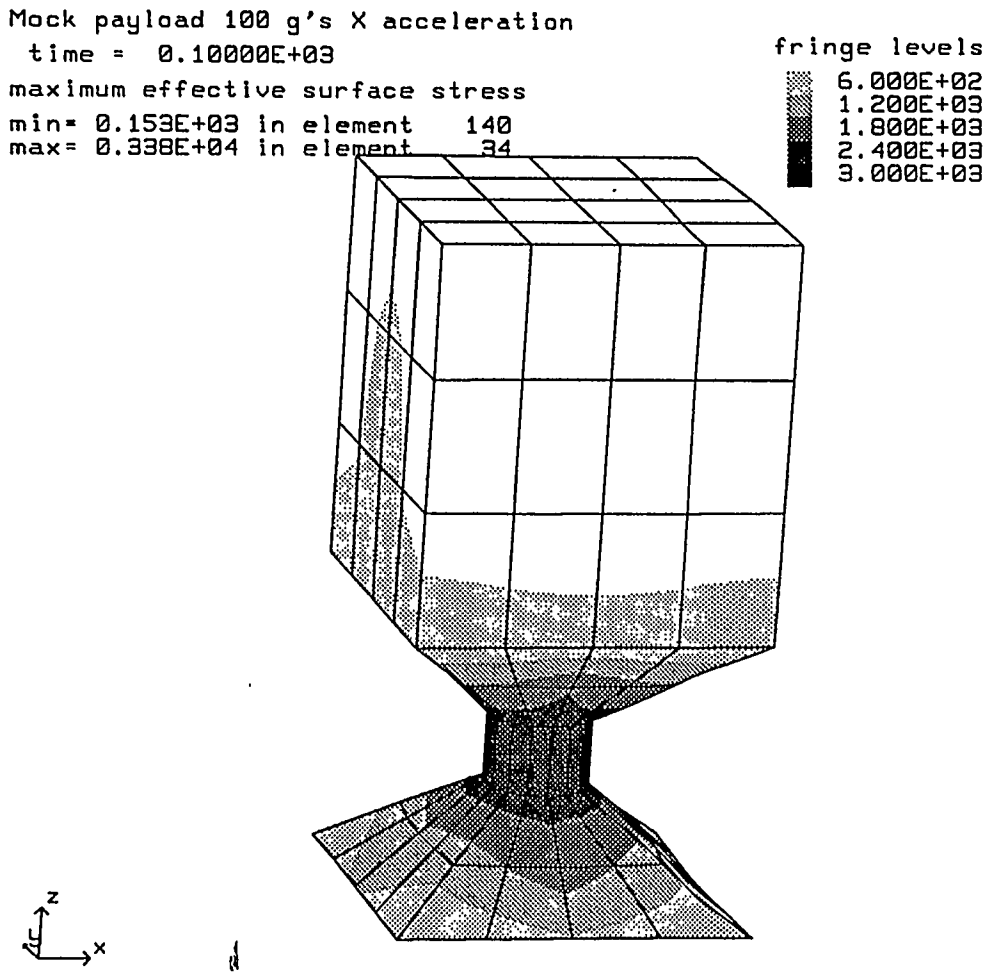
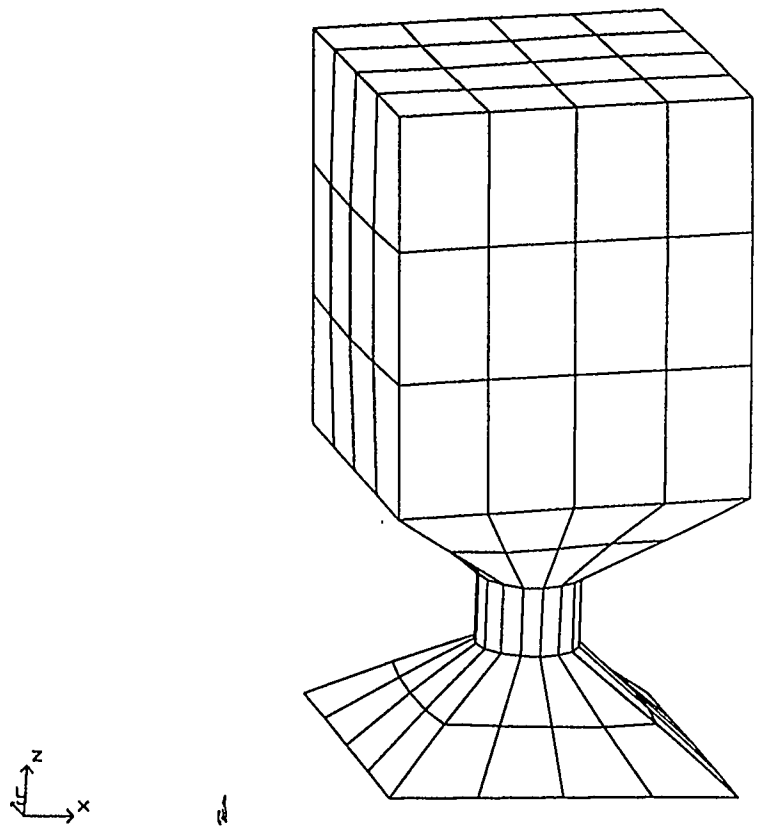

Mock payload 100 g's X acceleration
time = 0.10000E+03
maximum effective surface stress
min= 0.153E+03 in element 140
max= 0.338E+04 in element 34
fringe levels
6.000E+02
1.200E+03
1.800E+03
2.400E+03
3.000E+03
Z
X

Figure 58

Mock payload 100 g's X acceleration
time = 0.10000E+03



disp. scale factor = 0.200E+02

Figure 59

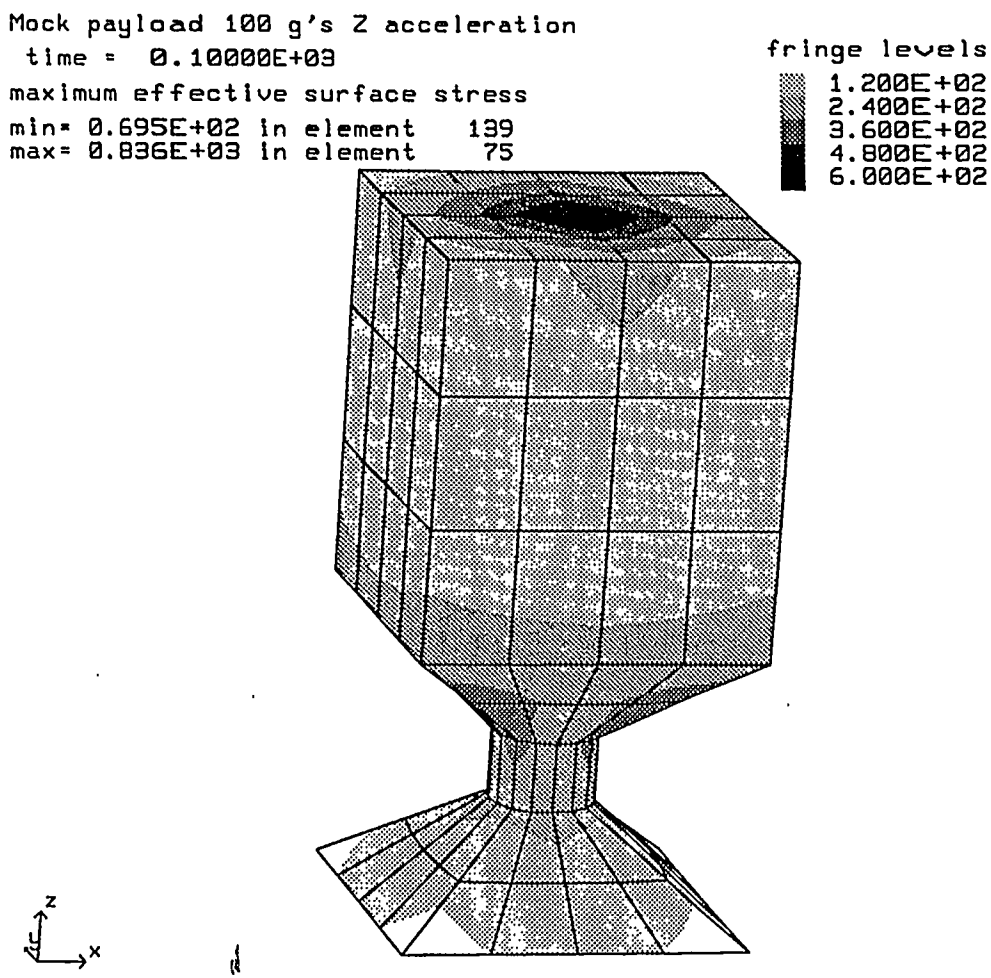

Mock payload 100 g's Z acceleration
time = 0.10000E+03
maximum effective surface stress
min= 0.695E+02 in element 139
max= 0.836E+03 in element 75
fringe levels
1.200E+02
2.400E+02
3.600E+02
4.800E+02
6.000E+02
Z
X

Figure 60

Mock payload 100 g's Z acceleration
time = 0.10000E+03

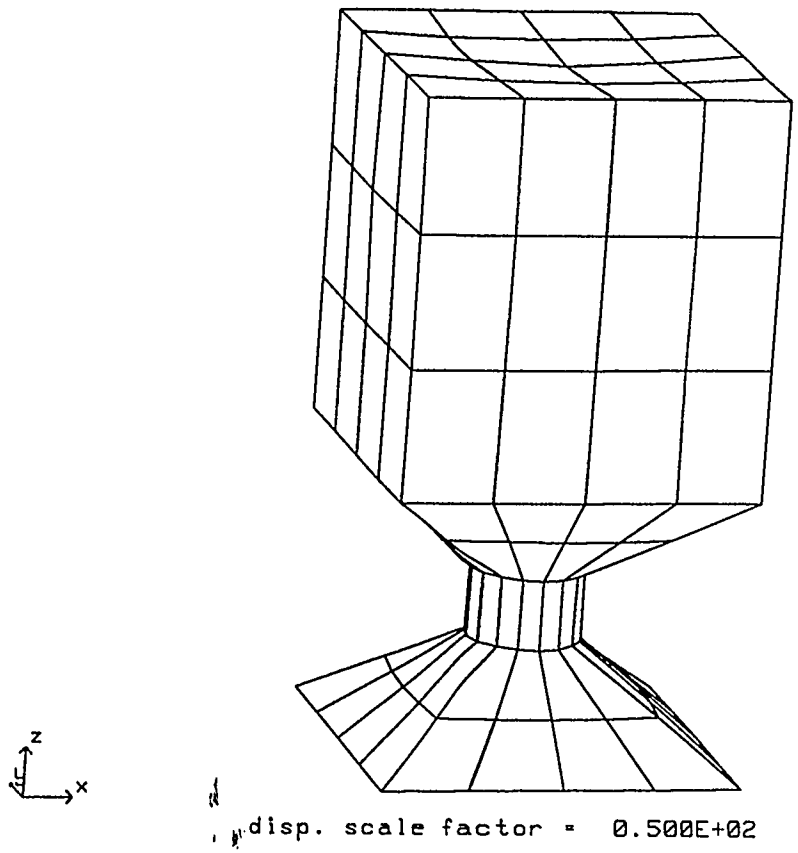


Figure 61

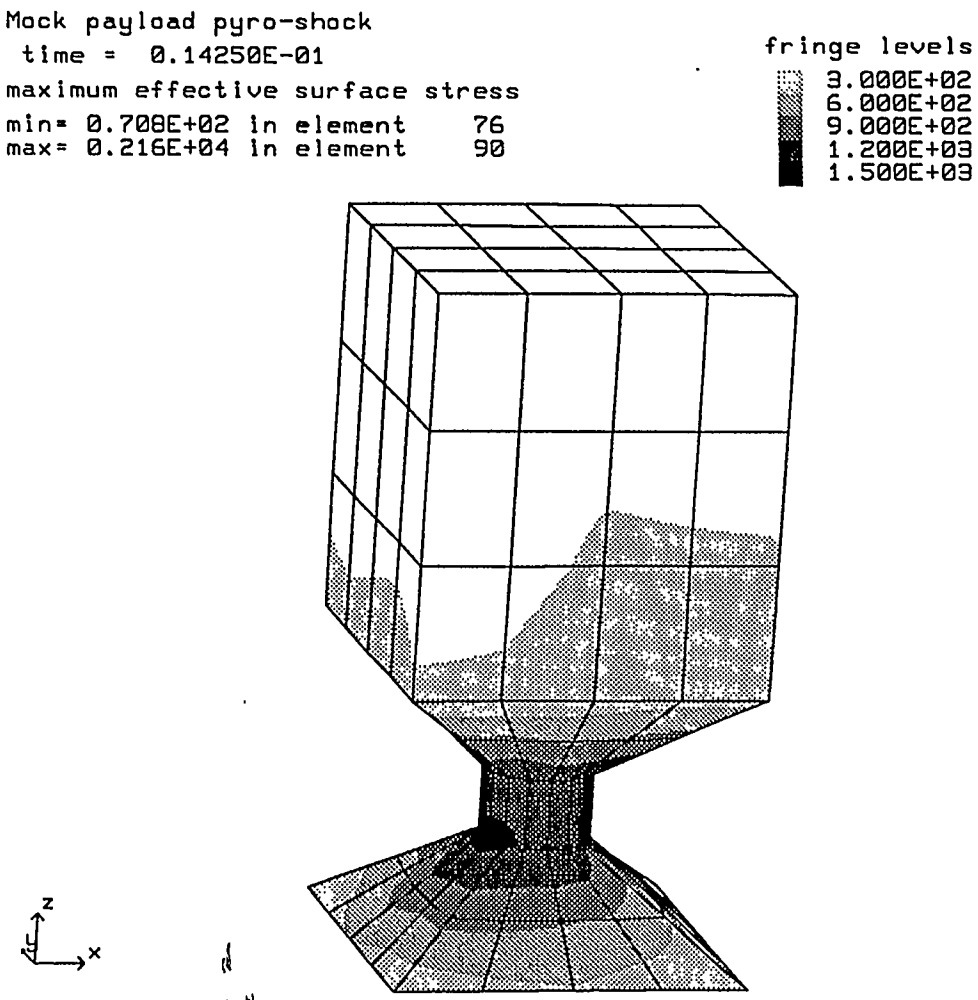

Mock payload pyro-shock
time = 0.14250E-01
maximum effective surface stress
min= 0.708E+02 in element 76
max= 0.216E+04 in element 90
fringe levels
3.000E+02
6.000E+02
9.000E+02
1.200E+03
1.500E+03
z
x

Figure 62

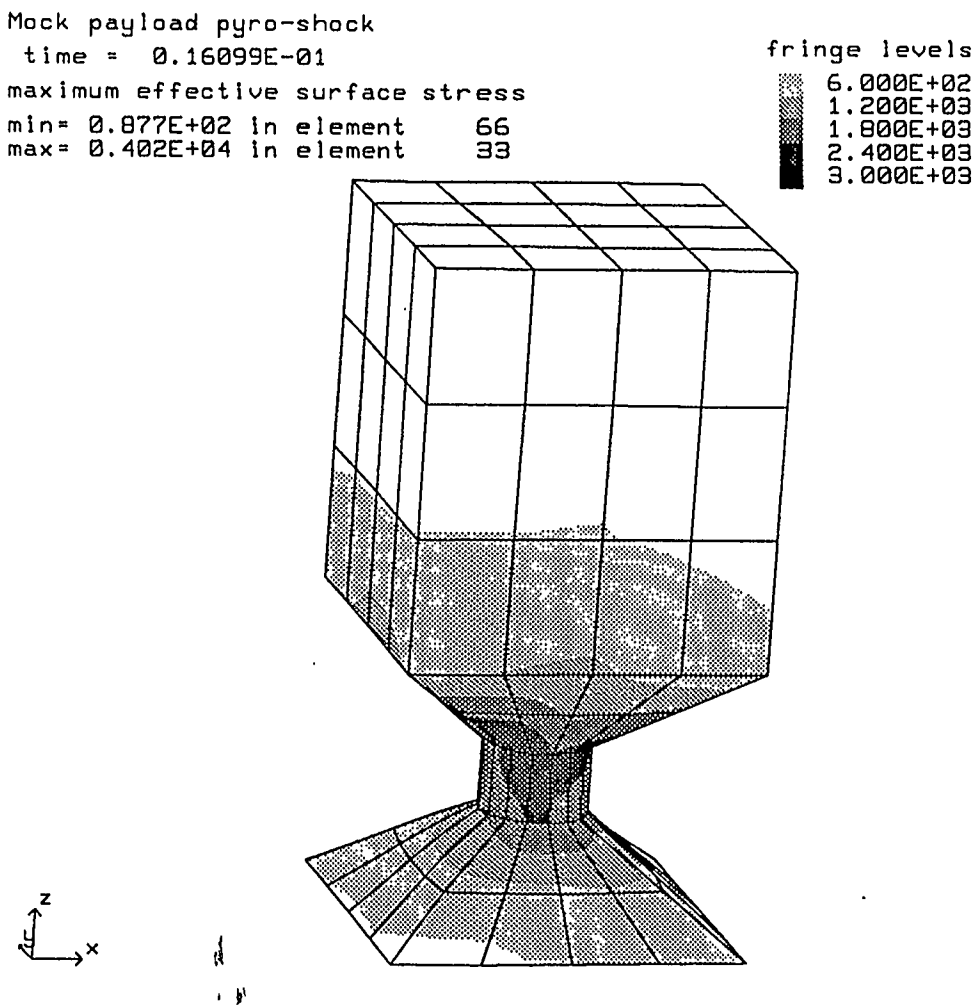

Mock payload pyro-shock
time = 0.16099E-01
maximum effective surface stress
min= 0.877E+02 in element 66
max= 0.402E+04 in element 33
fringe levels
6.000E+02
1.200E+03
1.800E+03
2.400E+03
3.000E+03
z
x

Figure 63

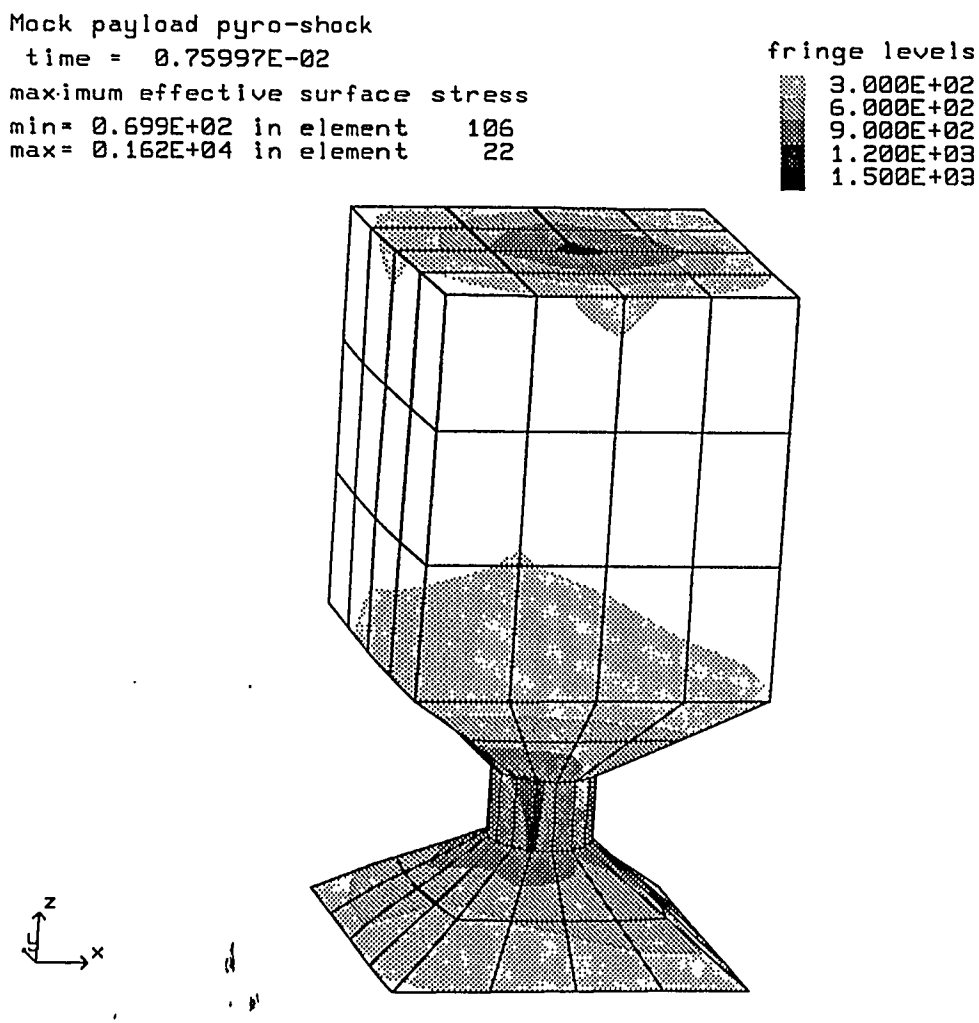

Mock payload pyro-shock
time = 0.75997E-02
maximum effective surface stress
min= 0.699E+02 in element 106
max= 0.162E+04 in element 22
fringe levels
3.000E+02
6.000E+02
9.000E+02
1.200E+03
1.500E+03
Z
X

Figure 64

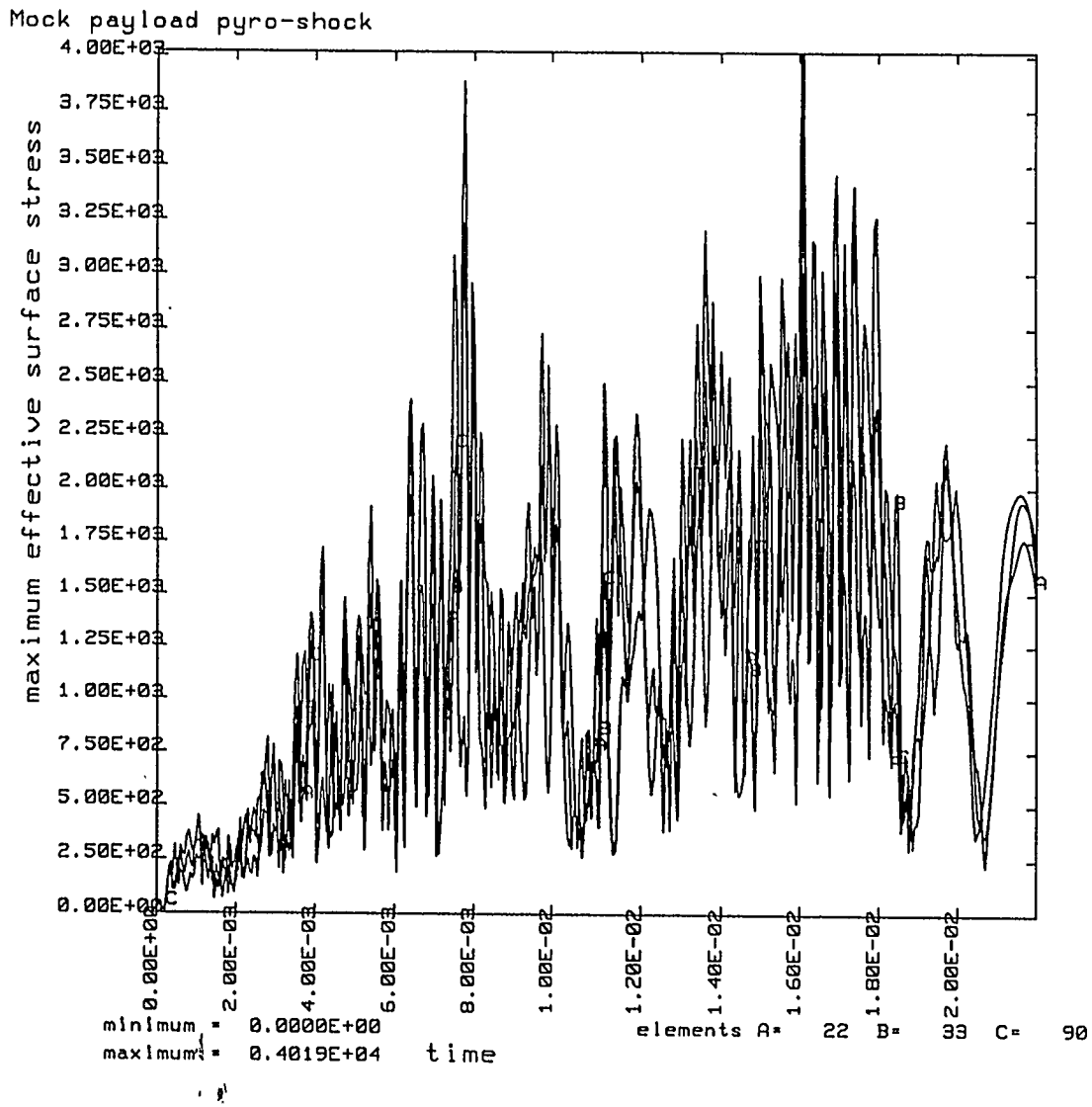

Mock payload pyro-shock
maximum effective surface stress
4.00E+03
3.75E+03
3.50E+03
3.25E+03
3.00E+03
2.75E+03
2.50E+03
2.25E+03
2.00E+03
1.75E+03
1.50E+03
1.25E+03
1.00E+03
7.50E+02
5.00E+02
2.50E+02
0.00E+00
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
1.40E-02
1.60E-02
1.80E-02
2.00E-02
minimum = 0.0000E+00
maximum = 0.4019E+04
time
elements A= 22 B= 33 C= 90

Figure 65

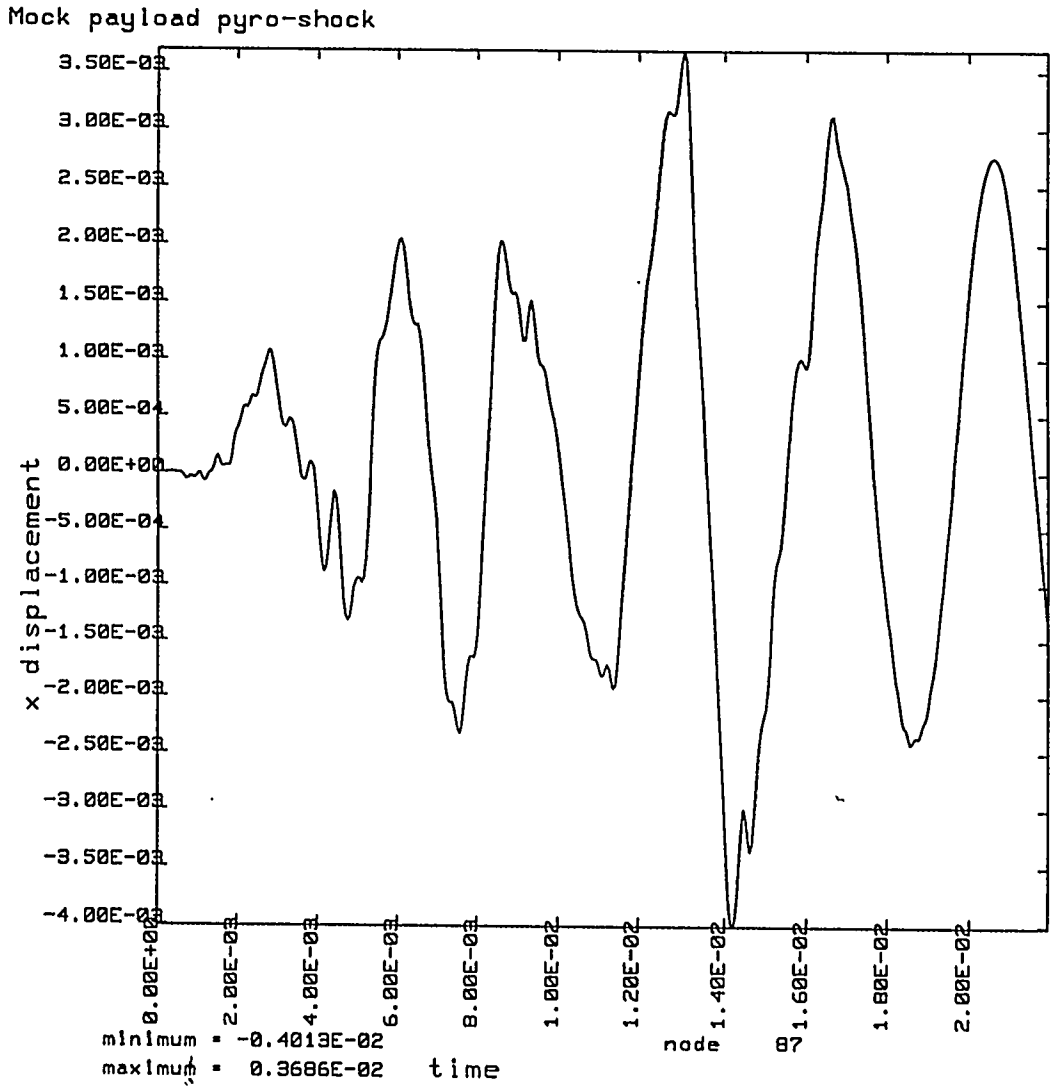

Mock payload pyro-shock
3.50E-03
3.00E-03
2.50E-03
2.00E-03
1.50E-03
1.00E-03
5.00E-04
0.00E+00
-5.00E-04
-1.00E-03
-1.50E-03
-2.00E-03
-2.50E-03
-3.00E-03
-3.50E-03
-4.00E-03
x displacement
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
1.40E-02
1.60E-02
1.80E-02
2.00E-02
minimum = -0.4013E-02
maximum = 0.3686E-02
time
node 87

Figure 66

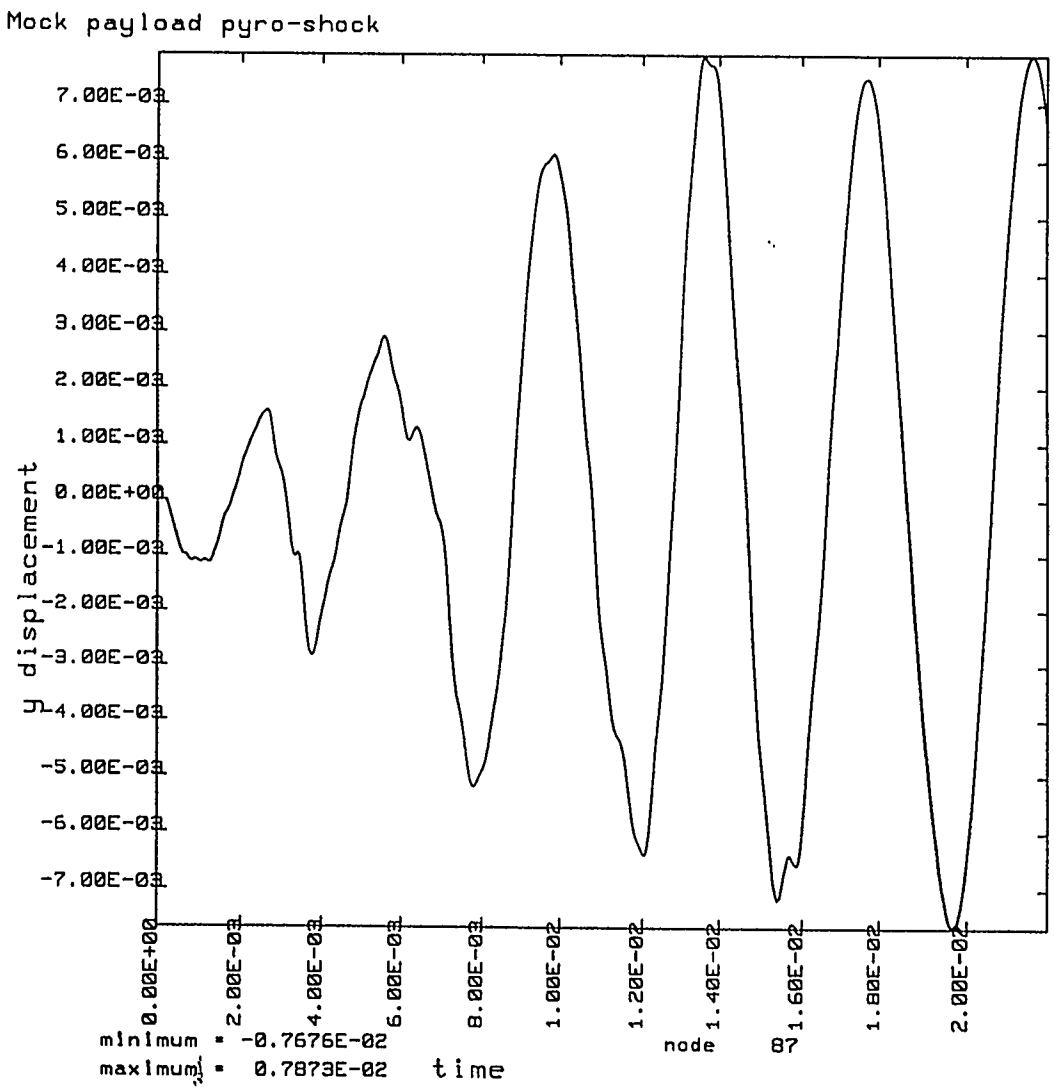

Mock payload pyro-shock
7.00E-03
6.00E-03
5.00E-03
4.00E-03
3.00E-03
2.00E-03
1.00E-03
0.00E+00
-1.00E-03
-2.00E-03
-3.00E-03
-4.00E-03
-5.00E-03
-6.00E-03
-7.00E-03
y displacement
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
1.40E-02
1.60E-02
1.80E-02
2.00E-02
minimum = -0.7676E-02
maximum = 0.7873E-02
time
node 87

Figure 67

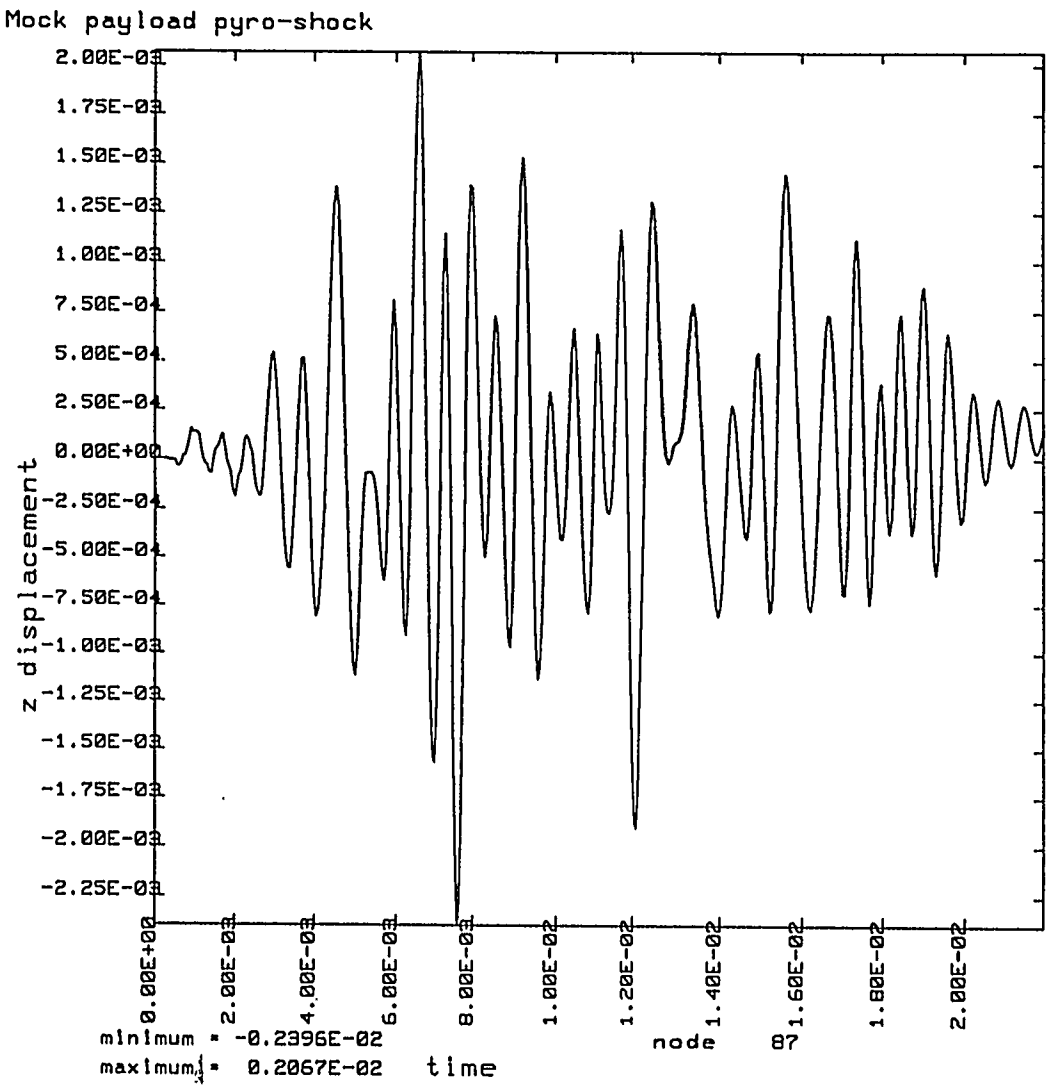

Mock payload pyro-shock
2.00E-03
1.75E-03
1.50E-03
1.25E-03
1.00E-03
7.50E-04
5.00E-04
2.50E-04
0.00E+00
-2.50E-04
-5.00E-04
-7.50E-04
-1.00E-03
-1.25E-03
-1.50E-03
-1.75E-03
-2.00E-03
-2.25E-03
z displacement
0.00E+00
2.00E-03
4.00E-03
6.00E-03
8.00E-03
1.00E-02
1.20E-02
1.40E-02
1.60E-02
1.80E-02
2.00E-02
minimum = -0.2396E-02
maximum = 0.2067E-02
time
node 87

Figure 68

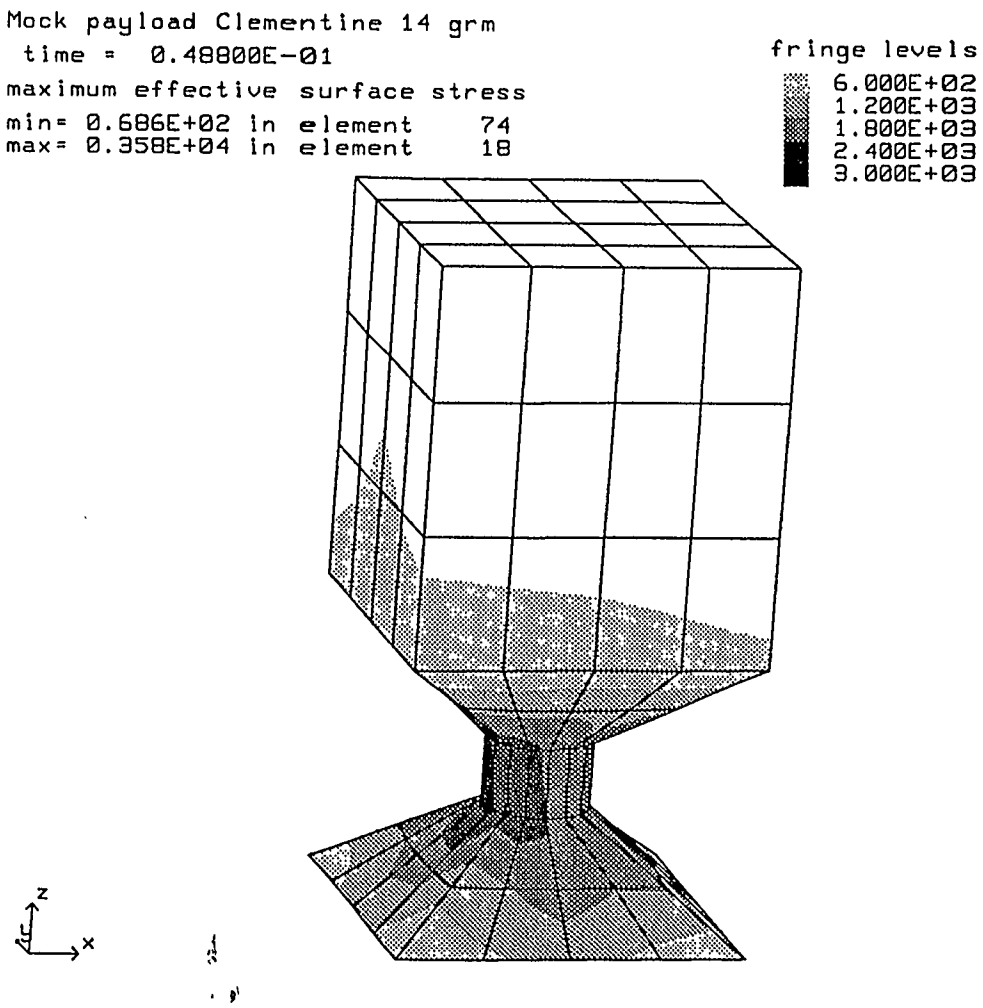

Mock payload Clementine 14 grm
time = 0.48800E-01
maximum effective surface stress
min= 0.686E+02 in element 74
max= 0.358E+04 in element 18
fringe levels
6.000E+02
1.200E+03
1.800E+03
2.400E+03
3.000E+03
Z
X

Figure 69

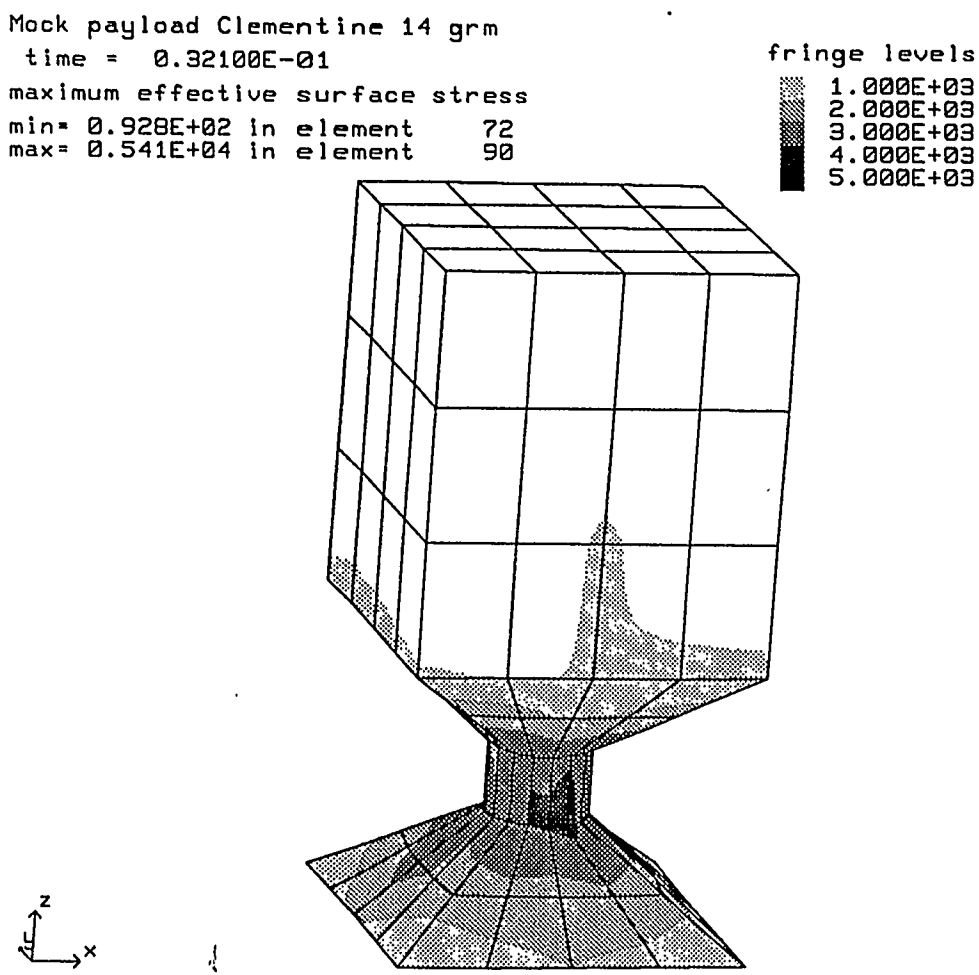

Mock payload Clementine 14 grm
time = 0.32100E-01
maximum effective surface stress
min= 0.928E+02 in element 72
max= 0.541E+04 in element 90
fringe levels
1.000E+03
2.000E+03
3.000E+03
4.000E+03
5.000E+03
Z
X

Figure 70

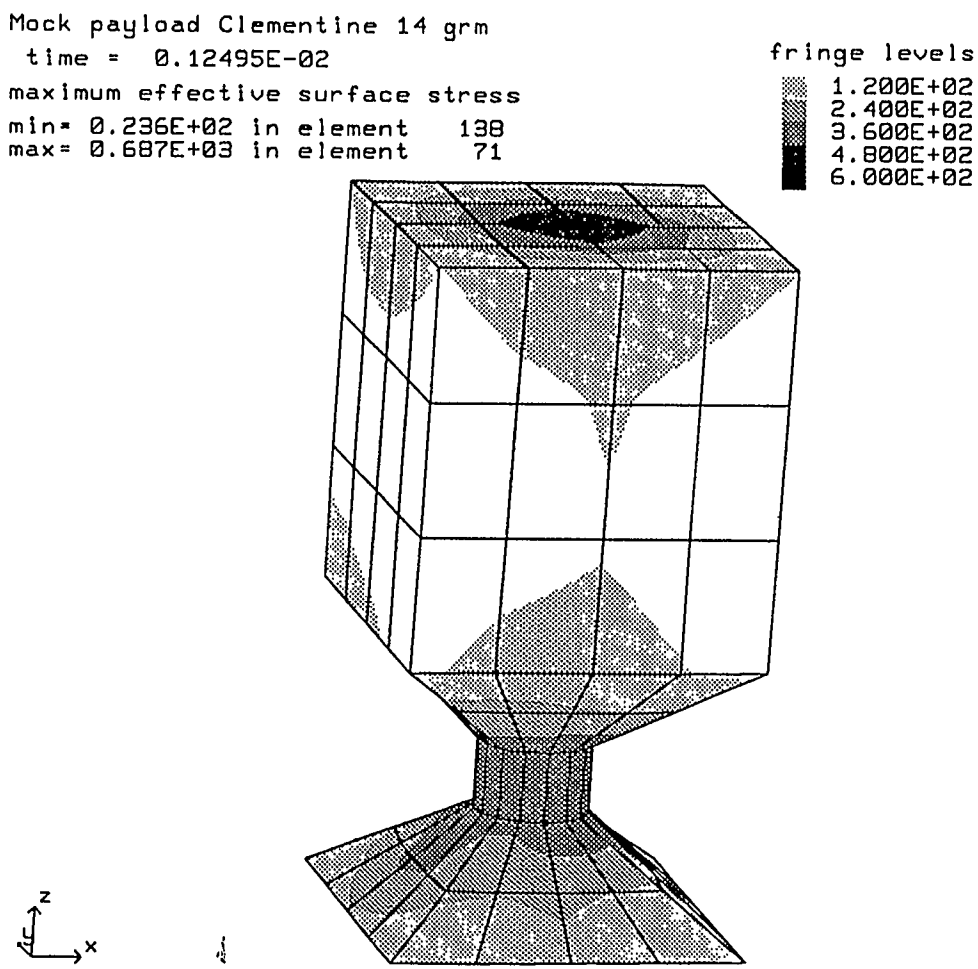

Mock payload Clementine 14 grm
time = 0.12495E-02
maximum effective surface stress
min= 0.236E+02 in element 138
max= 0.687E+03 in element 71
fringe levels
1.200E+02
2.400E+02
3.600E+02
4.800E+02
6.000E+02
z
x

Figure 71

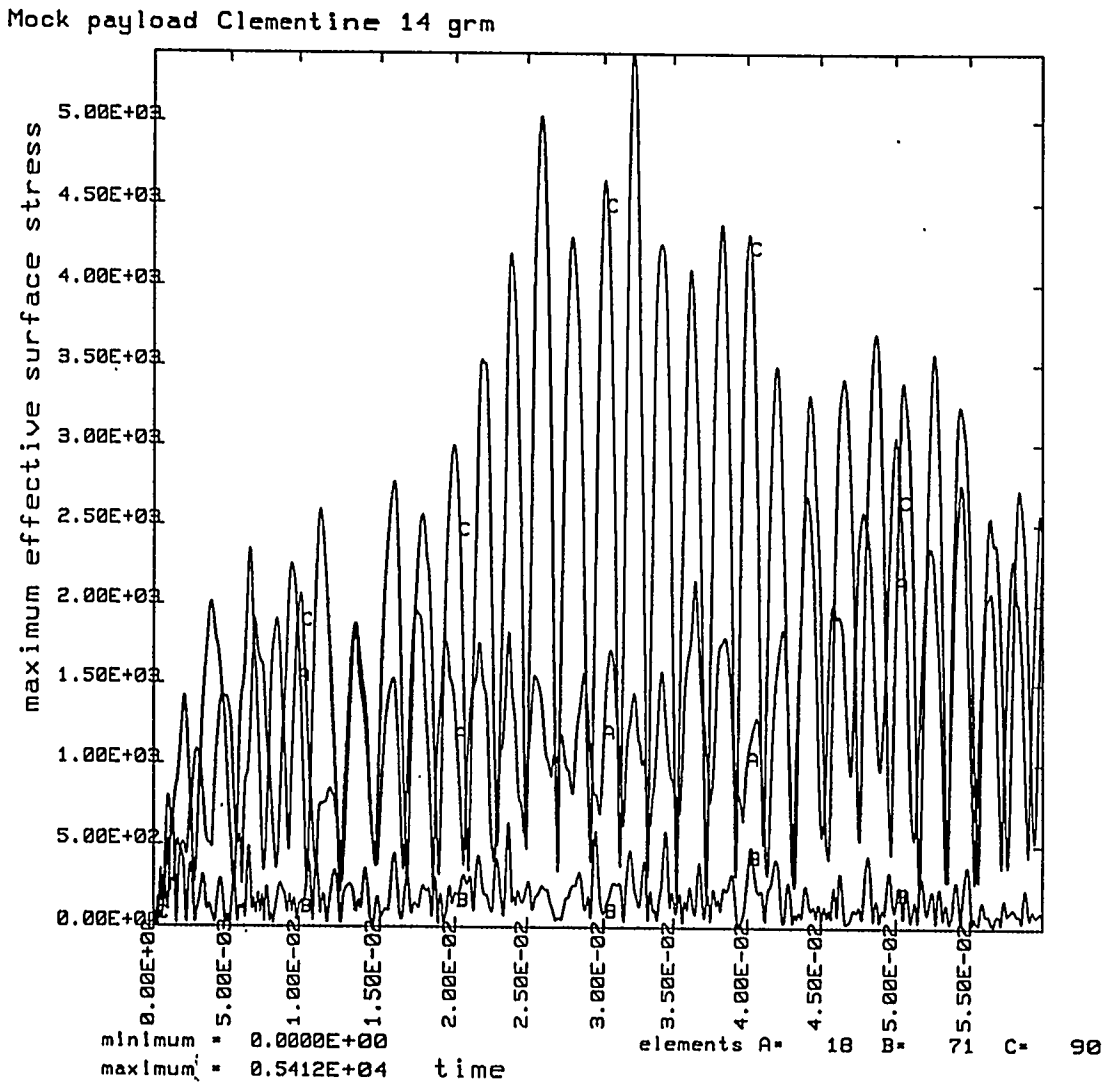

Mock payload Clementine 14 grm
maximum effective surface stress
5.00E+03
4.50E+03
4.00E+03
3.50E+03
3.00E+03
2.50E+03
2.00E+03
1.50E+03
1.00E+03
5.00E+02
0.00E+00
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
3.00E-02
3.50E-02
4.00E-02
4.50E-02
5.00E-02
5.50E-02
minimum = 0.0000E+00
maximum = 0.5412E+04
time
elements A= 18 B= 71 C= 90

Figure 72

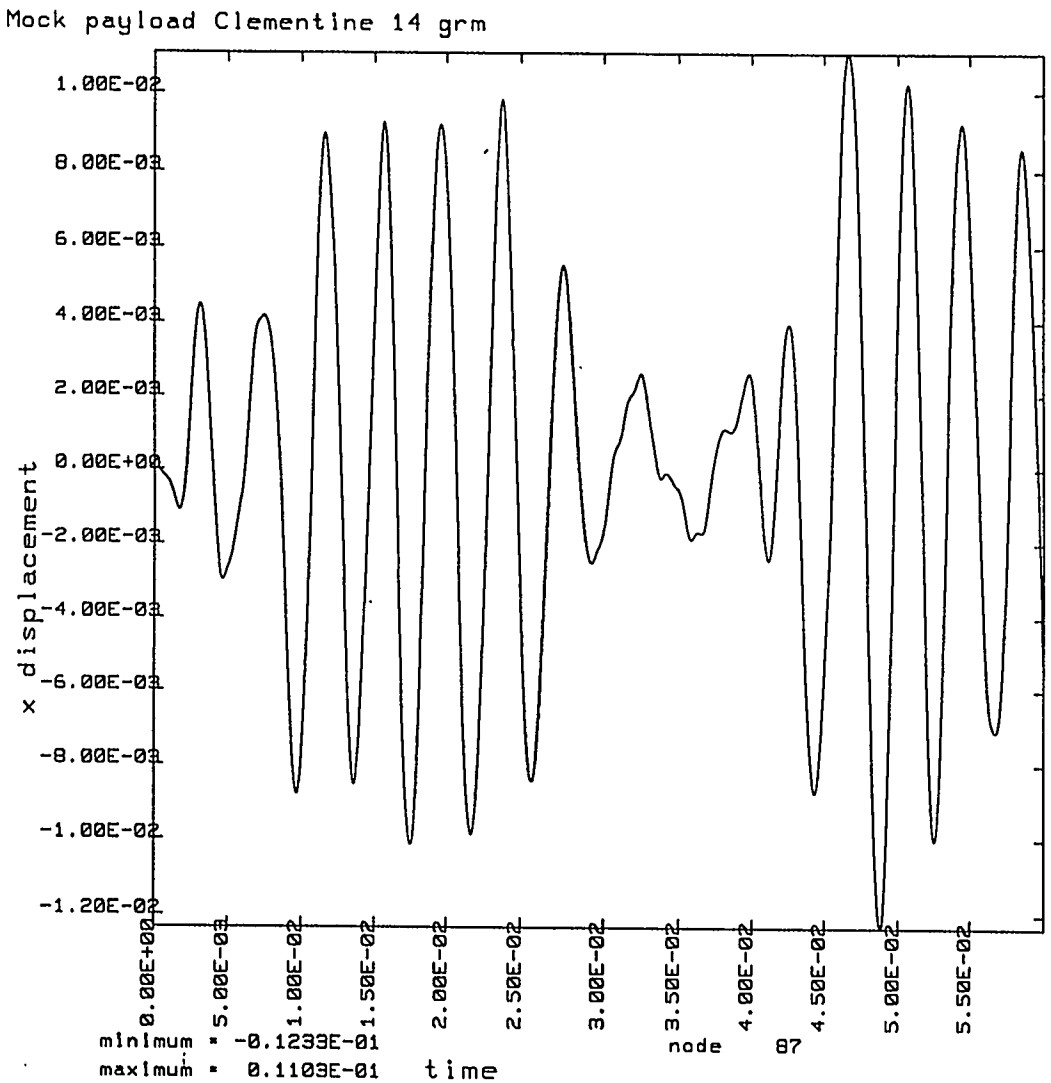

Mock payload Clementine 14 grm
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
-2.00E-03
-4.00E-03
-6.00E-03
-8.00E-03
-1.00E-02
-1.20E-02
x displacement
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
3.00E-02
3.50E-02
4.00E-02
4.50E-02
5.00E-02
5.50E-02
minimum = -0.1233E-01
maximum = 0.1103E-01
time
node 87

Figure 73

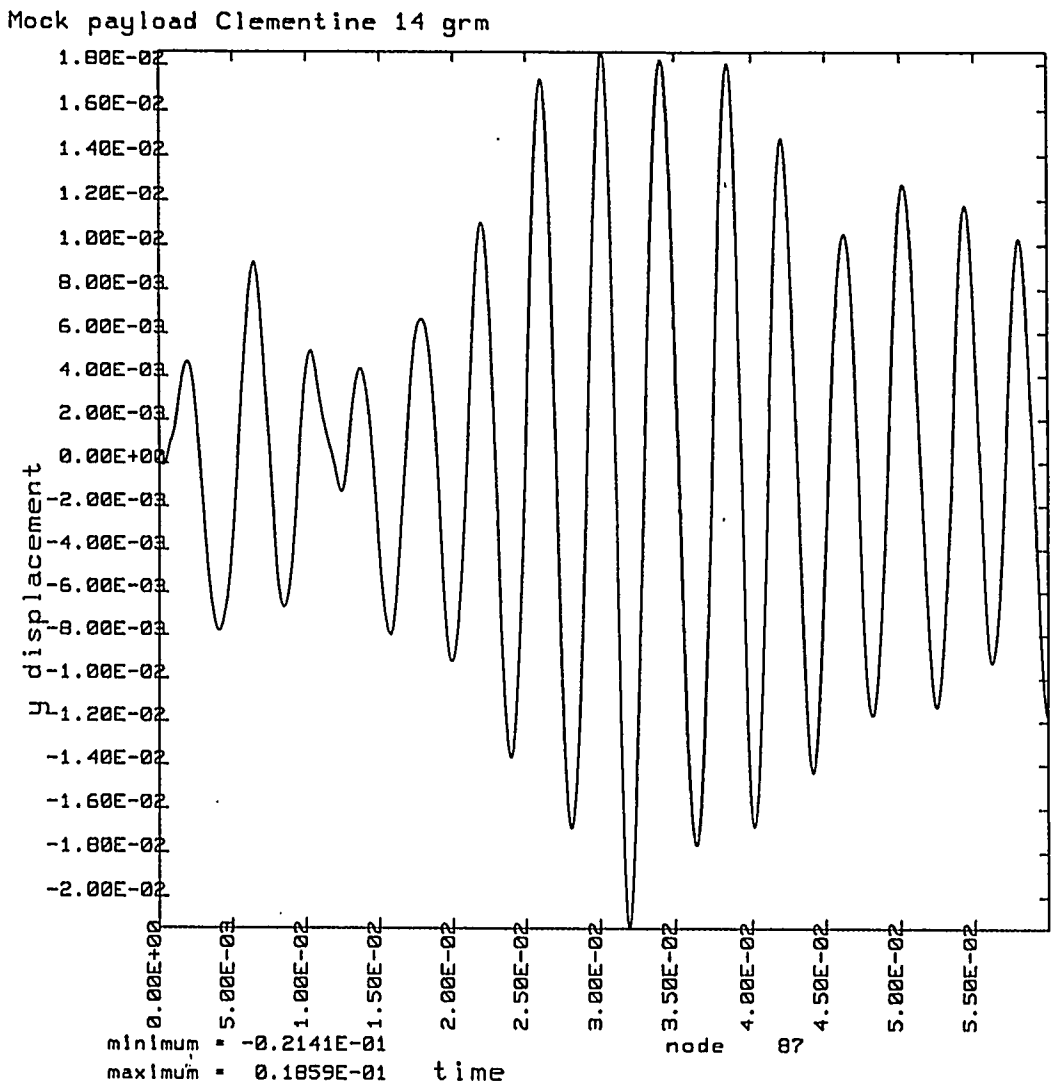

Mock payload Clementine 14 grm
1.80E-02
1.60E-02
1.40E-02
1.20E-02
1.00E-02
8.00E-03
6.00E-03
4.00E-03
2.00E-03
0.00E+00
-2.00E-03
-4.00E-03
-6.00E-03
-8.00E-03
-1.00E-02
-1.20E-02
-1.40E-02
-1.60E-02
-1.80E-02
-2.00E-02
y displacement
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
3.00E-02
3.50E-02
4.00E-02
4.50E-02
5.00E-02
5.50E-02
minimum = -0.2141E-01
maximum = 0.1859E-01
time
node 87

Figure 74

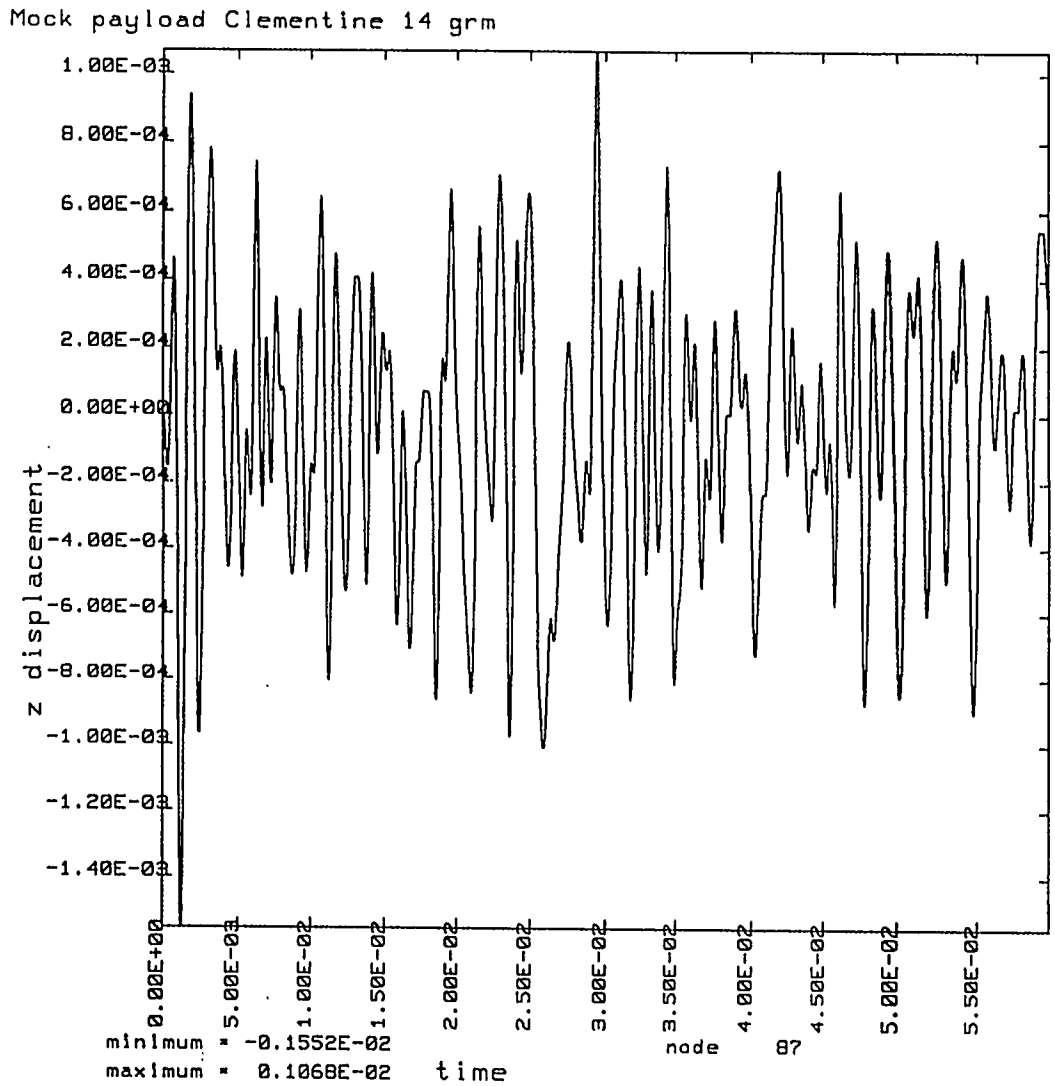

Mock payload Clementine 14 grm
1.00E-03
8.00E-04
6.00E-04
4.00E-04
2.00E-04
0.00E+00
-2.00E-04
-4.00E-04
-6.00E-04
-8.00E-04
-1.00E-03
-1.20E-03
-1.40E-03
z displacement
0.00E+00
5.00E-03
1.00E-02
1.50E-02
2.00E-02
2.50E-02
3.00E-02
3.50E-02
4.00E-02
4.50E-02
5.00E-02
5.50E-02
minimum = -0.1552E-02
maximum = 0.1068E-02
time
node 87

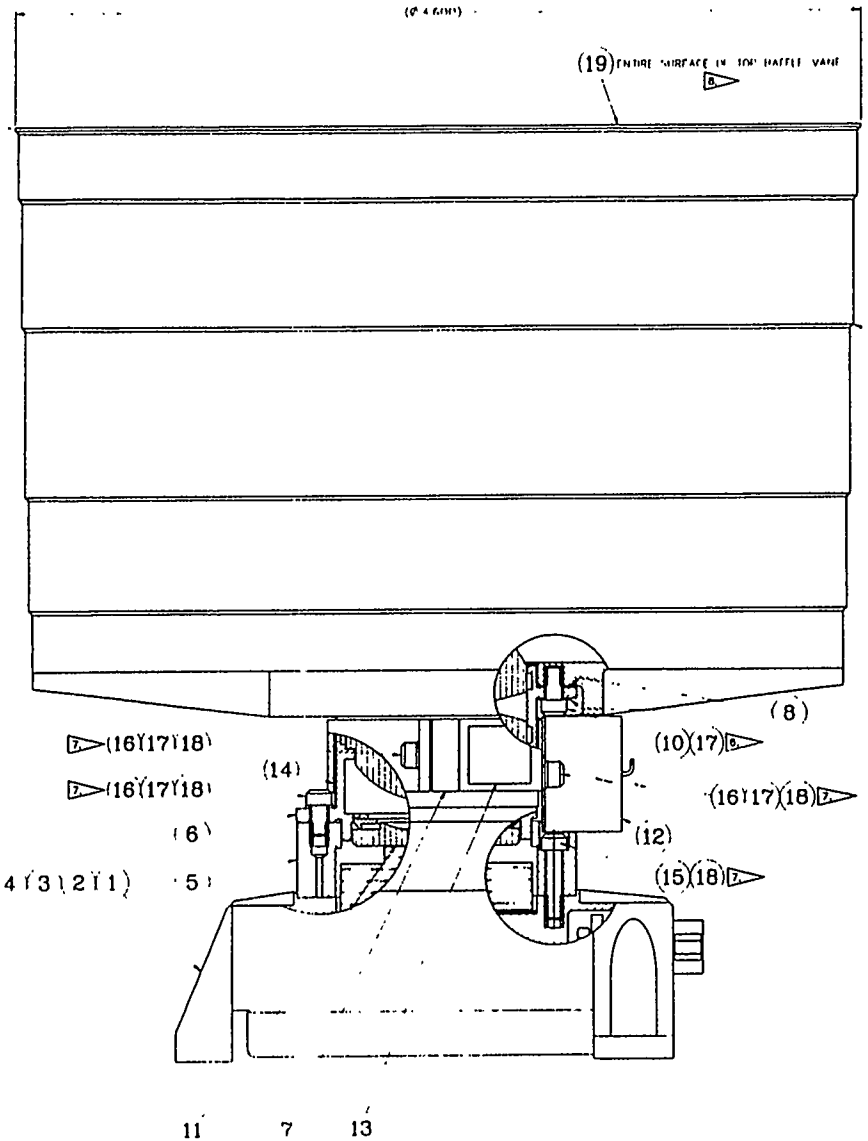
Figure 75

Appendix E.2

Mechanical Drawing Package

NOTES
UNLESS OTHERWIS[illegible]IED:

1. ALL DIMENSIO[illegible] N INCHES
2. DIMENSIONING [illegible] TOLERANCING PER ANSI Y14.5M-1[illegible].
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. ALL COMPONENTS ARE ELECTROSTATIC SENSITIVE. USE HANDLING PRECAUTIONS PER DOD-STD-1686 CLASS 1.
5. ASSEMBLE PER STAR TRACKER CAMERA ASSEMBLY PROCEDURE C1-S1-012.
6. REQUIRED TORQUE FOR #2-56 FASTENER WITH 120 ksi YIELD A-286 GRADE MATERIAL IS 2.0±0.1 in-lbf.
7. REQUIRED TORQUE FOR #2-56 FASTENER WITH 120 ksi YIELD A-286 GRADE MATERIAL IS 3.5±0.1 in-lbf
8. DO NOT APPLY TAPE WITHIN .06± .01 OF VANE KNIFE EDGE
9. WRAP IN CLEAN, LINT-FREE MATERIAL, BAG & TAG WITH PART NO. & REV. LETTER DO NOT MARK ON PART.



AR	AR	AR	AR	SHELDAHL #G401900	5.0 MIL TYPE A TEFLON X VACUUM DEPOSITED SILVER X VACUUM DEPOSITED INCONEL X 966 ACRYLIC PRESSURE SENSITIVE ADHESIVE TAPE	19
AR	AR	AR	AR		STAKING COMPOUND, HYSOL EA934NA	18
7	7	7	7		WASHER, #2 SCREW SIZE, .149 O.D. X .016 THK. SST	17
7	7	7	7		SCREW, HEX SOC HD., NO.2-56 UNC X .19L, A286	16
3	3	3	3		SCREW, HEX SOC HD., NO.2-56 UNC X .38L, A286	15
1	1	1	1		HEATER, MINCO #HK17402-9311	14
1	1	1	1		FENWAL THERMISTOR, P/N 534-31AC04-582	13
1	1	1	1		THERMAL SWITCH, SUNDSTRAND #974-0014-774	12
AR	AR	AR	AR		OPTICAL COUPLANT, DOW CORNING #DC93-500	11
3	3	3	3	93-103859	BAFFLE SCREW, #2 SIZE	10
1	1	1	1	93-103815	BAFFLE II ASSY	9
6	6	6	6	93-102551	ISOLATOR SHIM	8
1	1	1	1	93-102221	CLAMP, LENS HEATER	7
1	1	1	1	92-109469	LENS ASSEMBLY (OCA 880-0001-401-0C)	6
1	1	1	1	93-102550	LENS STANDOFF	5
1	-	-	-	92-106277 TAB-04	CAMERA ASSY (ST2A BOARD W/ TH7883F0P393 PROTO CCD)	4
-	1	-	-	92-106277 TAB-03	CAMERA ASSY (ST2A BOARD W/ TH7883F02-01 FLIGHT CCD)	3
-	-	1	-	92-106277 TAB-02	CAMERA ASSY (ST1A BOARD W/ TH7883F0P393 PROTO CCD)	2
-	-	-	1	92-106277 TAB-01	CAMERA ASSY (ST1A BOARD W/ TH7883F02-01 FLIGHT CCD)	1
	NO REQD			PART / LENS STE NO	DESCRIPTION / MATERIAL	SPEC NO / ITEM

TAB-04 TAB-03 TAB-02 TAB-01

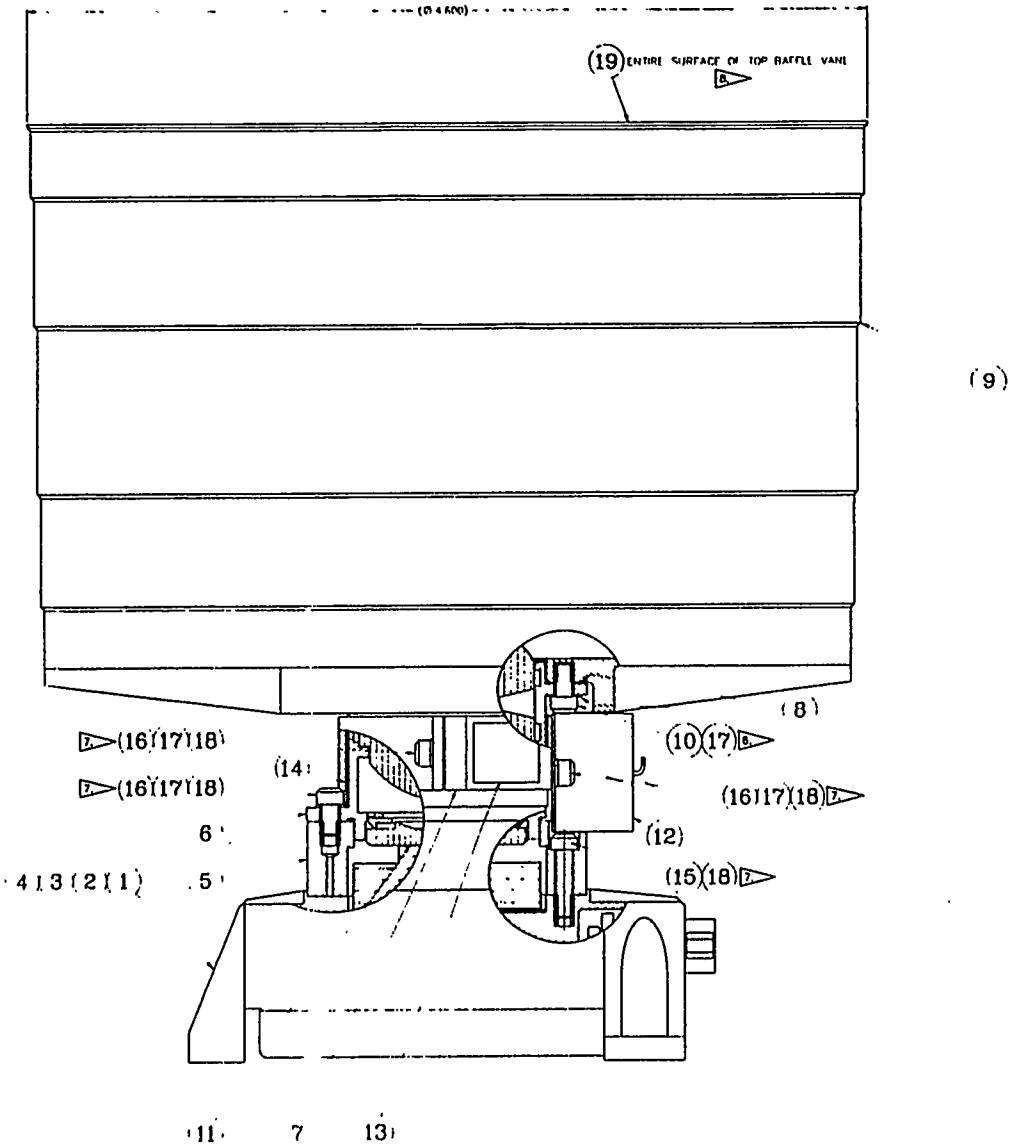
DWN [illegible] DATE
CHK [illegible] DATE
APVD [illegible] DATE
RESTRICTED BY
DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

MAJOR UNIT: STAR TRACKER CAMERA, V3.1
SUBASSY
DETAIL
DRAWING NO: AAA92-106282-00
SCALE SHEET 1 OF 1

ENGINEERING RELEASE
APPROVAL
Date



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. ALL COMPONENTS ARE ELECTROSTATIC SENSITIVE. USE HANDLING PRECAUTIONS PER DOD-STD-1686 CLASS 1.
5. ASSEMBLE PER STAR TRACKER CAMERA ASSEMBLY PROCEDURE C1-S1-012.
6. REQUIRED TORQUE FOR #2-56 FASTENER WITH 120 ksi YIELD A-286 GRADE MATERIAL IS 2.0±0.1 in-lbf.
7. REQUIRED TORQUE FOR #2-56 FASTENER WITH 120 ksi YIELD A-286 GRADE MATERIAL IS 3.5±0.1 in-lbf.
8. DO NOT APPLY TAPE WITHIN .06±.01 OF VANE KNIFE EDGE.
9. WRAP IN CLEAN, LINT-FREE MATERIAL. BAG & TAG WITH PART NO. & REV. LETTER. DO NOT MARK ON PART.

TAB-04	TAB-03	TAB-02	TAB-01	PART / LSME STD NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
AR	AR	AR	AR	SHELDAHL #G401900	5.0 MIL TYPE A TEFLON X VACUUM DEPOSITED SILVER X VACUUM DEPOSITED INCONEL X 966 ACRYLIC PRESSURE SENSITIVE ADHESIVE TAPE		19
AR	AR	AR	AR		STAKING COMPOUND, HYSOL EA934NA		18
7	7	7	7		WASHER, #2 SCREW SIZE, .149 O.D. X .016 THK. SST		17
7	7	7	7		SCREW, HEX SOC HD., NO.2-56 UNC X .19L, A286		16
3	3	3	3		SCREW, HEX SOC HD., NO.2-56 UNC X .38L, A286		15
1	1	1	1		HEATER, MINCO #HK17402-9311		14
1	1	1	1		FENWAL THERMISTOR, P/N 534-31A004-562		13
1	1	1	1		THERMAL SWITCH, SUNDSTRAND #974-0014-774		12
AR	AR	AR	AR		OPTICAL COUPLANT, DOW CORNING #DC93-500		11
3	3	3	3	93-103859	BAFFLE SCREW, #2 SIZE		10
1	1	1	1	93-103815	BAFFLE N ASSY		9
6	6	6	6	93-102551	ISOLATOR SHIM		8
1	1	1	1	93-102221	CLAMP, LENS HEATER		7
1	1	1	1	92-109469	LENS ASSEMBLY (OCA 880-0001-401-0C)		6
1	1	1	1	93-102550	LENS STANDOFF		5
1	-	-	-	92-106277 TAB-04	CAMERA ASSY (ST2A BOARD W/ TH7883F0P393 PROTO. CCD)		4
-	1	-	-	92-106277 TAB-03	CAMERA ASSY (ST2A BOARD W/ TH7883F02-01 FLIGHT CCD)		3
-	-	1	-	92-106277 TAB-02	CAMERA ASSY (ST1A BOARD W/ TH7883F0P393 PROTO CCD)		2
-	-	-	1	92-106277 TAB-01	CAMERA ASSY (ST1A BOARD W/ TH7883F02-01 FLIGHT CCD)		1

NO REQD

DWN
CHK
APVD
MFG
QA

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MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

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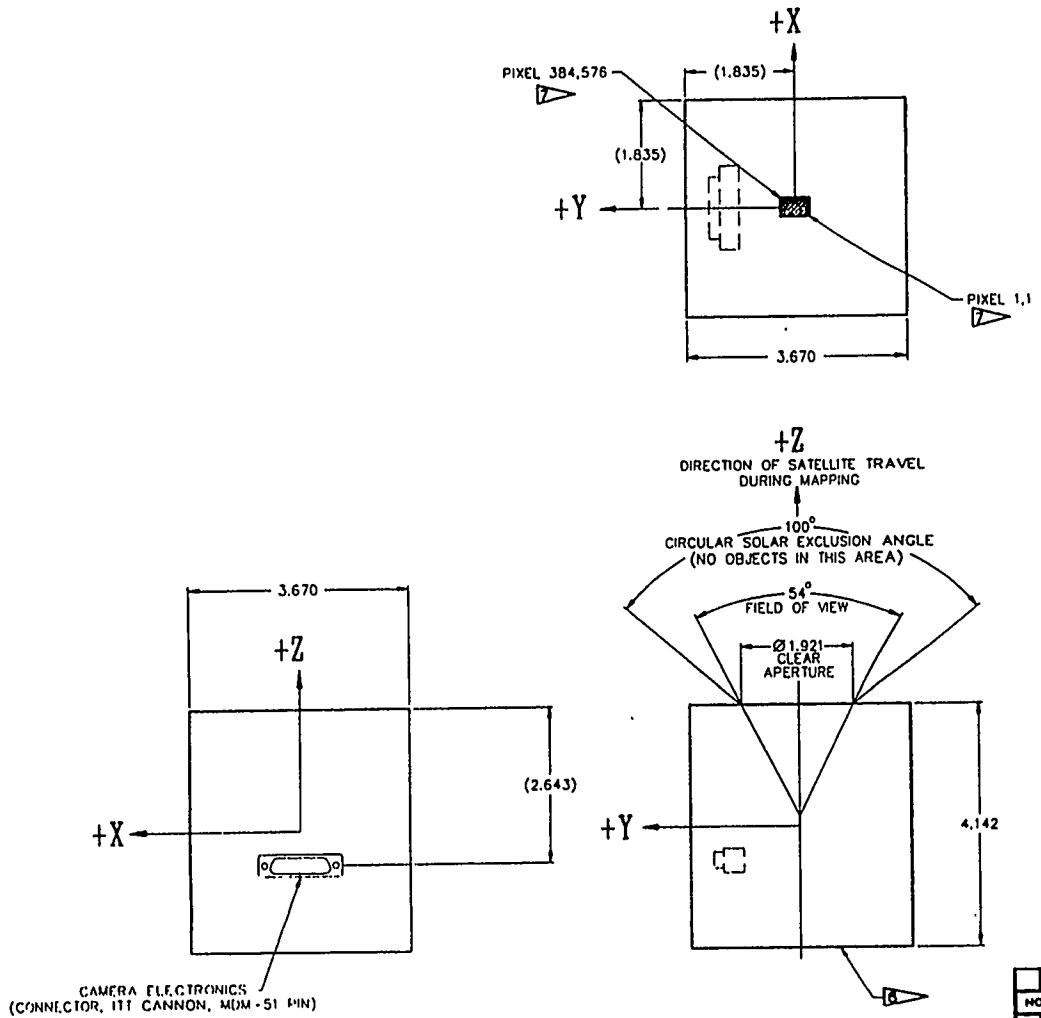
STAR TRACKER CAMERA, V3.1

DRAWING NO
AAA92-106282-00

SCALE
SHEET 1 OF



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.

[redacted]

4. PROVISION FOR A REMOVABLE DEBRIS COVER IS TBD AND MAY AFFECT REQUIRED ENVELOPE SPECIFIED HEREIN.
5. PROVISION FOR SENSOR THERMAL CONTROL IS TBD AND MAY AFFECT REQUIRED ENVELOPE SPECIFIED HEREIN.

6 MOUNTING SURFACE.

7 SHOWN ENLARGED FOR CLARITY. (NO SCALE)

8. COORDINATE SYSTEM DEPICTS STAR TRACKER OPTICAL AXIS (+Z) AS BEING ORIENTED 90° FROM OPTICAL AXIS OF IMAGING SENSORS (+X).
9. ORIENTATION OF CCD MAY BE ROTATED 90° IN X-Y PLANE IF REQUIRED. RELATIONSHIP BETWEEN CONNECTOR AND CCD IS FIXED.

NO REQD	PART / LLNL STR NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM

DWN Tom Gorman 4/23/92
CHK R.P. Wesley 5/1/92
APVD [illegible] 5/4/92
CLASSIFIED BY
TITLE DATE

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MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

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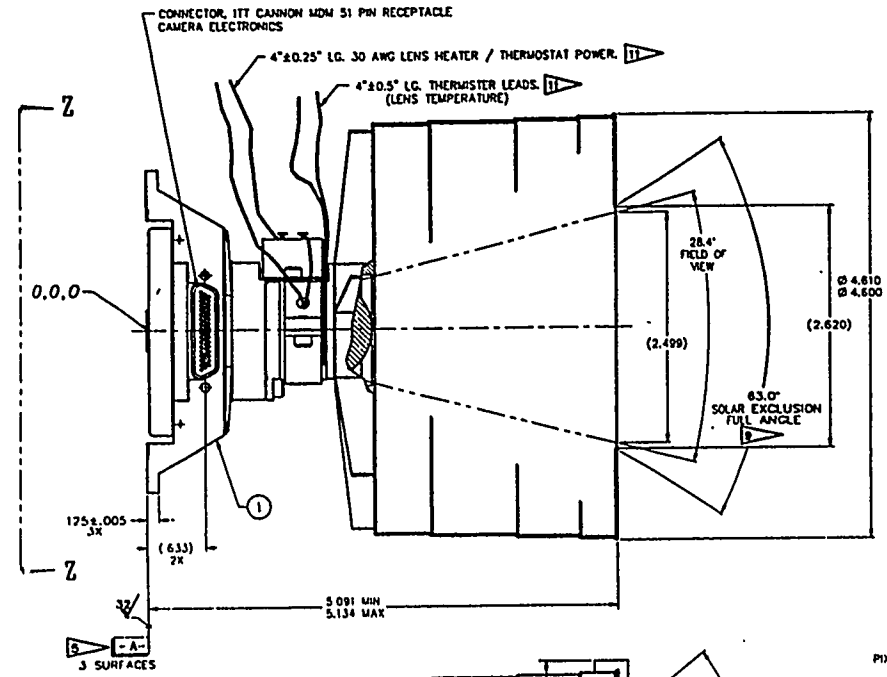
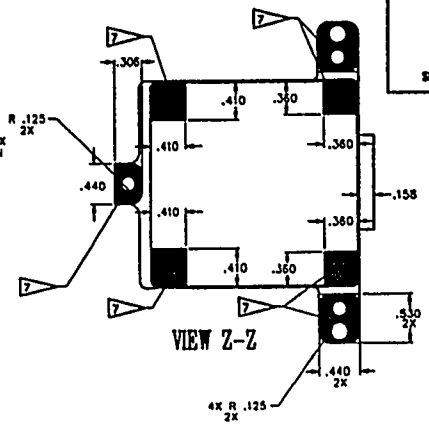
MAJOR UNIT: STAR TRACKER V3.1
SUBASSY
OBTAN: ENVELOPE CONTROL DRAWING
SHOWN ON AAA
NCET NO
DRAWING NO: AAA 92-100838-00
SCALE 2.00
SHEET 1 OF 1

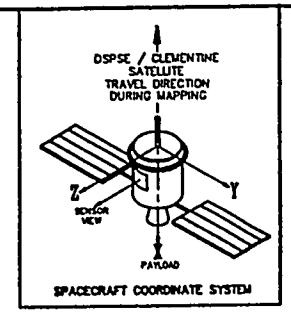
ENGINEERING RELEASE
APPROVED Project Engineer
Date

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE

OFFICIAL USE

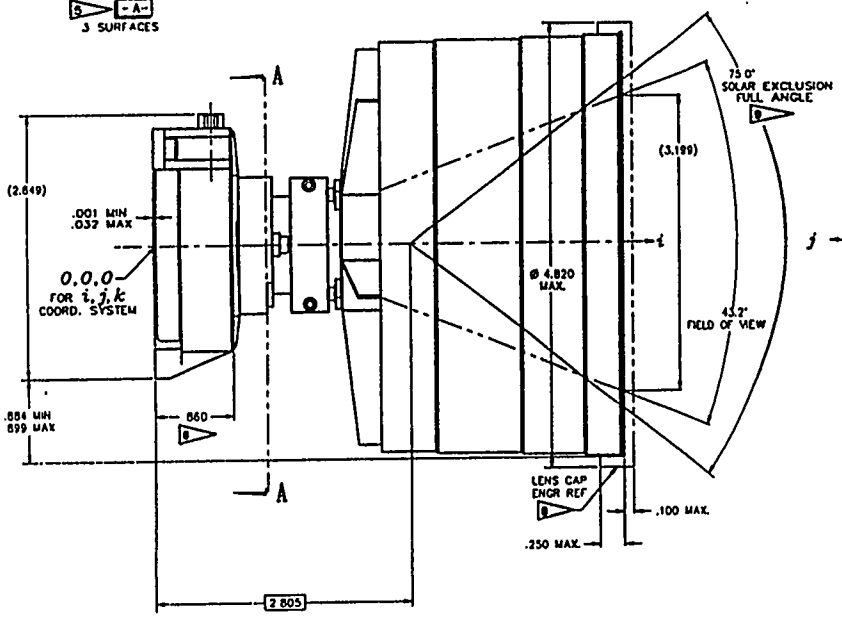


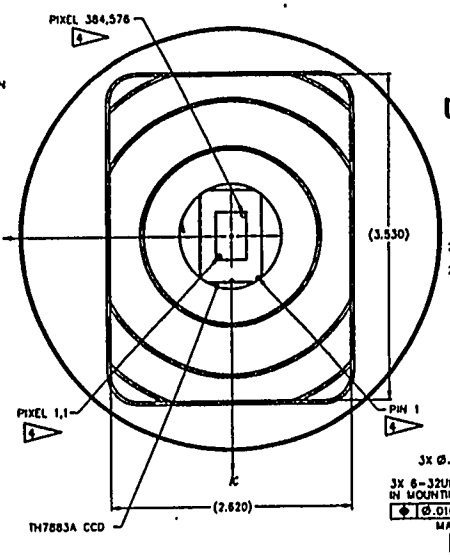


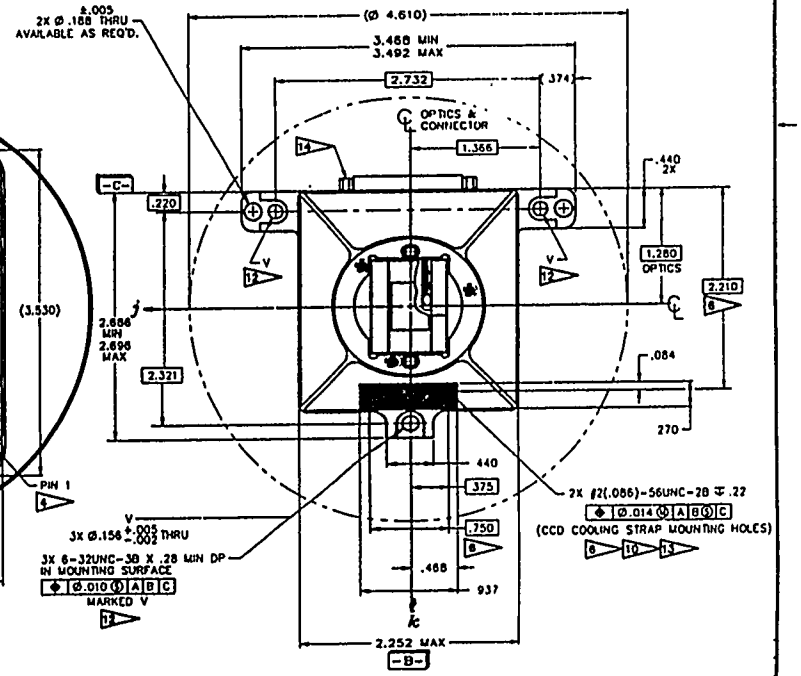


NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. SHOWN ENLARGED FOR CLARITY. NO SCALE.
5. MOUNTING SURFACE MATING TO SURFACE -A- SHALL BE ▱ .001 AND 32 OR BETTER.
6. STRAP DETAILS TO BE PROVIDED BY SYSTEM INTEGRATOR WITH LLNL CONCURRENCE REQ'D. STRAP LENGTH SHALL BE MINIMIZED.
7. SURFACES SHOWN CROSS-HATCHED ARE FOR HEAT REMOVAL TO MOUNTING SURFACE.
8. LENS CAP USED FOR PARTICULATE CONTAMINATION PROTECTION. ATTACH RED TAG "REMOVE BEFORE FLIGHT".
9. MAXIMUM SOLAR EXCLUSION ANGLE DIAGONAL IS 98°
10. SCREW DEPTH NOT TO EXCEED .250 INTO HOUSING.
11. TYPE OF LEAD TERMINATION TBD.
12. RECOMENDED TORQUE FOR #6-32 FASTENER WITH 120 ksi YIELD A286 GRADE MATERIAL IS 27.4±0.3 in-lbf.
13. REQUIRED TORQUE FOR #2-56 FASTENER WITH 120 ksi YIELD A286 GRADE MATERIAL IS 5.6±0.2 in-lbf.
14. REQUIRED TORQUE FOR CONNECTOR JACKSCREWS IS 1.6±0.1 in-lbf.







SECTION A-A

C₇	TSC					E7	i, j & k COORDINATE SYSTEM REDEFINED
C₆						F3	ADDED NOTES 9 THRU 14
C₅						C2	ADDED MIN / MAX ENVELOPE
C₄						G2	ADDED .150 DIM
C₃							COOLING STRAP MOUNTING AREA DEFINED
C₂							NOTE #8 CHANGED
B₂	TSC	BT	MCP	11/15/92		H8	LENS HEATER AND THERMISTER ADDED
B₁						G4	4 HEAT REMOVAL PADS ADDED TO END COVER
A₂	TSC	BT	MCP	11/14/92		G1	NOTES 3, 4, 5, 6, & 7 CHANGED
A₁						A1	NOTE 9 ADDED
							ITEMS 2 & 3 DELETED
ECO	DRWN	CHK	APVD	DATE	DRWN		CHANGE

ENGINEERING RELEASE
APPROVED
Date

OFFICIAL USE

REV	92-100282	STAR TRACKER CAMERA ASSY, V3.1	1
NO REQD	PART / LINE SYS NO	DESCRIPTION / MATERIAL	SPEC NO / ITEM
	DWN PETE TRAPELLE		
	CHK TOM CORMAN		
	APVD SCOTT A. RUDDELL		

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

TITLE: STAR TRACKER CAMERA V3.1

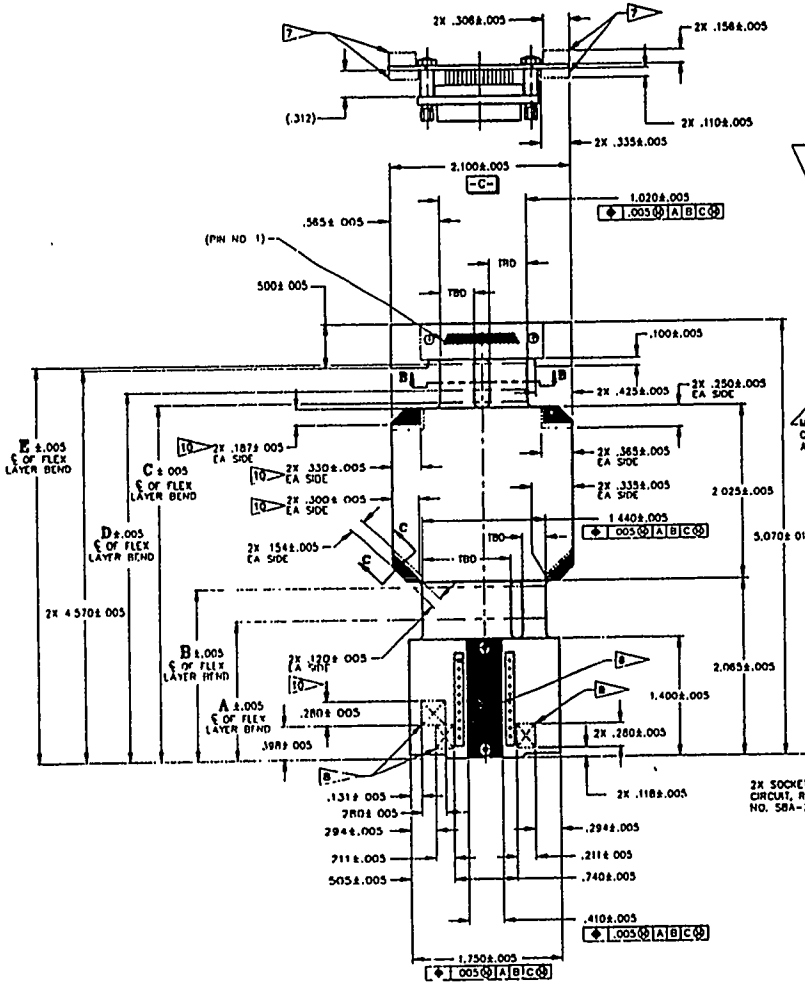
TITLE: INTERFACE CONTROL

DRAWING NO: AAA 92-100839-0C

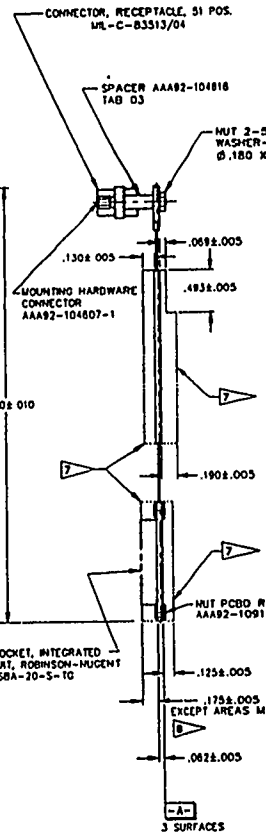
SCALE 1.00 SHEET 1 OF 1

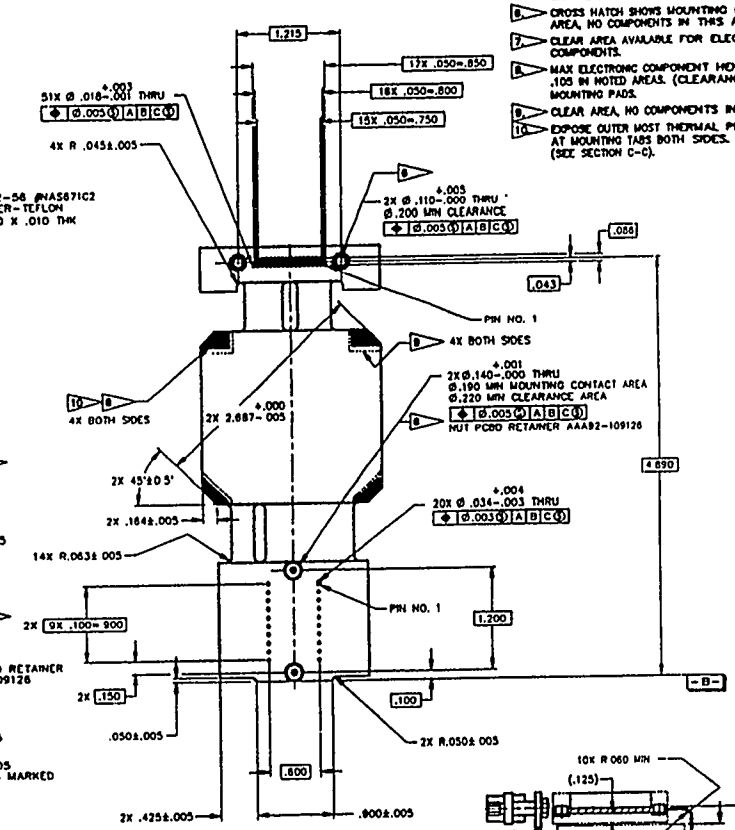
NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. ∛ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. CROSS HATCH SHOWS MOUNTING CONTACT AREA, NO COMPONENTS IN THIS AREA.
7. CLEAR AREA AVAILABLE FOR ELECTRONIC COMPONENTS.
8. MAX ELECTRONIC COMPONENT HEIGHT= .105 IN NOTED AREAS. (CLEARANCE FOR MOUNTING PADS.
9. CLEAR AREA, NO COMPONENTS INSIDE.
10. EXPOSE OUTER MOST THERMAL PLANE AT MOUNTING TABS BOTH SIDES. (SEE SECTION C-C).

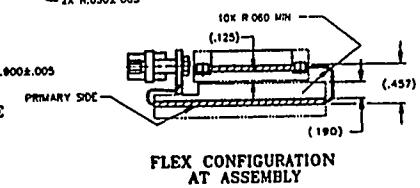


PRIMARY SIDE

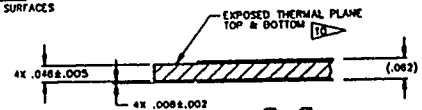




SECONDARY SIDE

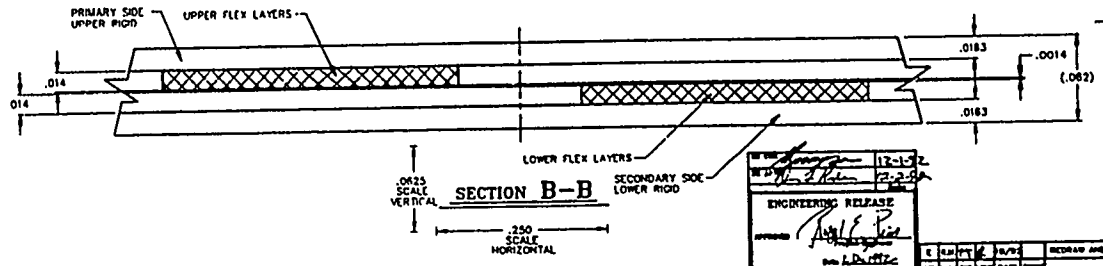


FLEX CONFIGURATION AT ASSEMBLY



SECTION C-C
NOT TO SCALE

	A	B	C	D	E
FLEX LAYERS UPPER	1.632	2.003	4.150	4.299	4.617
FLEX LAYERS LOWER	1.644	2.003	4.150	4.287	4.617



SECTION B-B

ENGINEERING RELEASE

NO REQD	PART / SUBL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM

CLASSIFICATION

THIS DRAWING IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LAB & REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL DRAWING DEPARTMENT.

LAWRENCE LIVERMORE NATIONAL LABORATORY MECHANICAL ENGINEERING DEPT UNIVERSITY OF CALIFORNIA

TITLE: STAR TRACKER CAMERA ASSY, V3.1

SUBTITLE: CAMERA ASSY

SUBTITLE: CIRCUIT BOARD KCD (ACTEL CAMERA).

DRAWING NO: AAA92-104603-0E

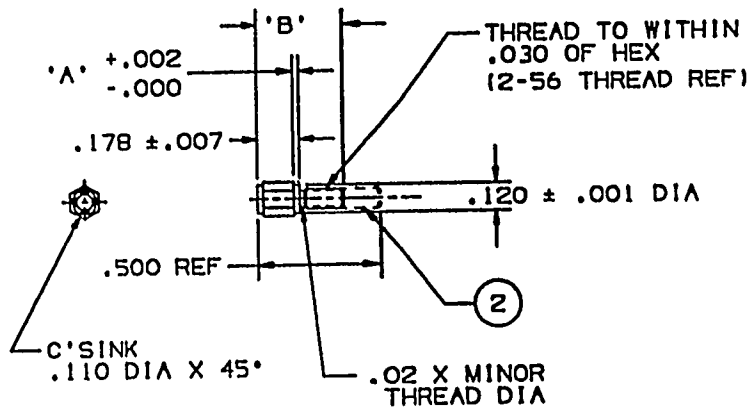
SCALE: 1.00 SHEET 1 OF 1

OFFICIAL USE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. SURFACE FINISH TO BE 63

DASH NO.	DIM-A	DIM-B
-1	.025	.390
-2	.015	.370



ALTERED ITEM

AAA92-104607-00

QTY REQD	CAGE NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO.
1		003448	JACKPOST (SET OF 2)	ULTI MATE	2
REF	16735	860-3043-001	MOUNTING HARDWARE, CONNECTOR		1

PARTS LIST

PART DASH NO.	QTY REQD PER ASSY	NEXT APPLICATION	NEXT ASSY	USED ON
-2	1 SET	800-1148		
-1	2 SETS	800-1147		
-1	1 SET	800-0525		
-1	1 SET	800-1140		
-1	1 SET	800-1149		

WEIGHTS		
STRESS		
MATERIALS & PROCESSES		
MANUFACTURING ENGR	M. Ling	3/23/92
QUALITY ASSURANCE	S. Lunn	3/23/92
ADDITIONAL APPROVALS		DATE

LAYERS: 1
RETRIEVE: 800-3043
CAD SYS: OCA FILE:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE: FRACTIONS ±1/32 DECIMALS .XX=±.01 .XXX=±.005 ANGLES ±1/2°
DO NOT SCALE DRAWING

TREATMENT NOTED
FINISH NOTED
SIMILAR TO | ACT BY | CALC BY

CONTRACT NO.

APPROVALS	DATE
DRAWN S. J. PATTI	91-05-22
CHECKED R. L. MINNIX	92-02-17
P.E. L. SCHOU	7-17-92
PM J. Parnell	92-3-11

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

MOUNTING HARDWARE
CONNECTOR

SIZE	CAGE NO.	DWG NO.	REV.
B	16735	800-3043	

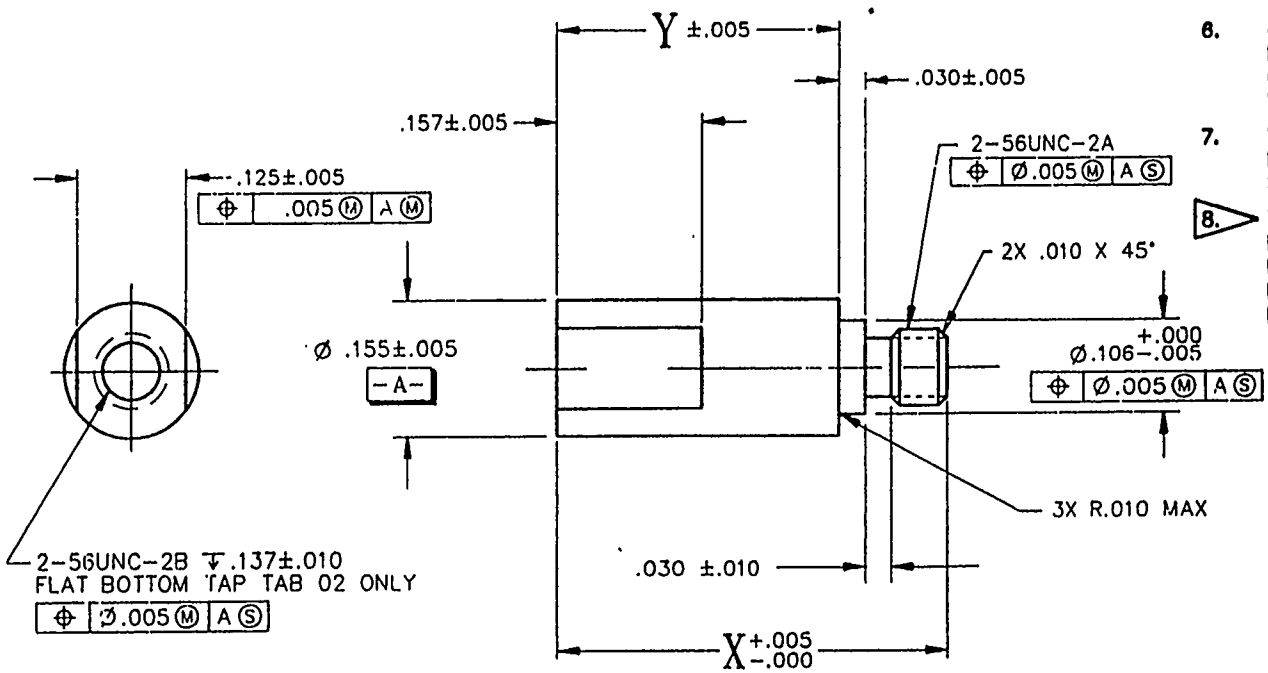
SCALE 2:1 | RELEASE DATE 91- | SHEET 1 OF 1

AAA92-104607-00

OFFICIAL USE

NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ✓ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. CLEAN FINISHED PART PER LLNL SPEC. MFIN-UHV-003, OR EQUIVALENT AS AGREED UPON WITH LLNL.
7. WRAP IN CLEAN LINT-FREE MATERIAL BAG AND TAG WITH PART NO. AND SERIAL NO. DO NOT MARK ON PART.
8. THIS PART USED ON PWA PART NO.:
   LEA92-3013-03 PWA CONTROLLER INTERFACE.
   LEA92-3021-03 PWA RANGE RECEIVER.
   LEA92-3022-03 PWA FILTER WHEEL.
   LEA92-3067-03 PWA BETA CAMERA W/GAIN CONTROL.



TAB	X	Y
01	.385	.257
02	.279	.157
03	.437	.312
04	.342	.217

ENGINEERING RELEASE
APPROVED Robert E. Price Project Engineer
Date 2 Dec 1992

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		303 CRES		

DWN	Riley Marlin	10/9/92
CHK	BILL TAYLOR	10/22
APVD	SCOTT A. RUDDELL	10/22
CLASSIFIED BY:		
TITLE		DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

MAJOR UNIT: UV/ VISIBLE CAMERA ASSY. V3.1
SUBASSY: PWA FILTER WHEEL
DETAIL: SPACER
SHOWN ON AAA: 8.
ACCT NO
DRAWING NO: AAA 92-104616-0B (B)
SCALE .200 — SHEET 1 OF 1

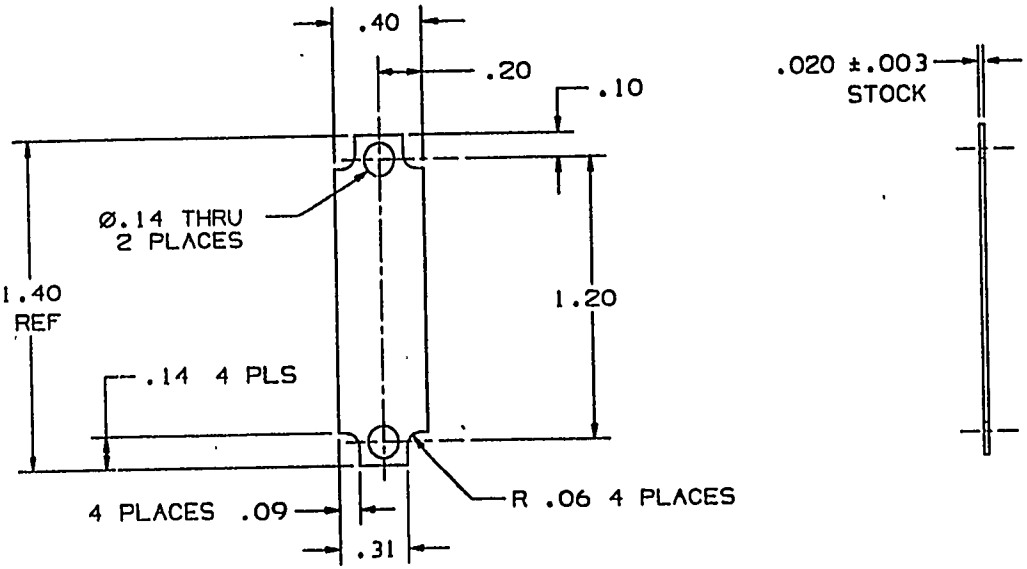
LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE
B	LC	RW	R	12/4/92	C4	ADDED FEATURE CONTROL TO .125 DIM
					B1	ADDED TAB 04
A	R.M.	B.T.	S.R.	11/92		ADDED ENG RELEASE BOX & NOTE 8.
					B1	ADDED TAB 03

8.AAA92-104616-0B#

OFFICIAL USE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. MATERIAL: #61-20-0808-6161, CHOMERICS INC



AAA92-104621-00

WEIGHTS						
STRESS						
MATERIALS & PROCESSES						
MANUFACTURING ENGRG M. IRIB	3/2/92	1		800-0526		
QUALITY ASSURANCE S. Young	3/4/92	PART DASH NO.	NEXT QTY REQD PER ASSY	FINAL	NEXT ASSY	USED ON
ADDITIONAL APPROVALS	DATE				APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ±1/32 DECIMALS .XX±.01 .XXX±.005 ANGLES ±1/2°
DO NOT SCALE DRAWING

TREATMENT

FINISH

SIMILAR TO | ACT WT | CALC WT

CONTRACT NO.

APPROVALS	DATE
DRAWN Edgar Espino	91-10-29
CHECKED H. TORGERSEN	91-10-29
P.E. USCHA	92-3-12
P.M. D. J. Provence	92-03-11

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

CIRCUIT BOARD PAD

SIZE	CAGE NO.	DWG NO.	REV.
B	16735	800-3068	

SCALE 2:1 | RELEASE DATE 91- | SHEET 1 OF 1

LAYERS: 1,10
RETRIEVE: 800-3068
CAD SYS: OCA | FILE:

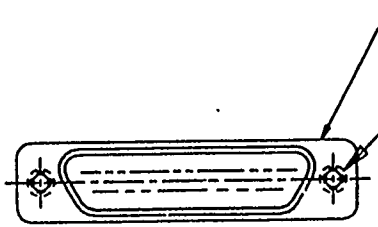
6 Feb 92

OFFICIAL USE

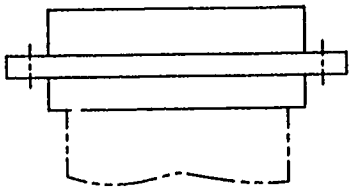
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. SURFACE FINISH TO BE 63
5. FINISH: CHEMICAL CONVERSION COATING PER MIL-C-5541, CLASS 1A
6. THE TWO JACKPOST'S THAT COME WITH THE CONNECTOR KIT ARE TO BE ALTERED AS PER DWG. 800-3043



5 THREAD THRU FOR .086-56UNC-2B HELICAL INSERT PER MS33537 2 PLACES



ALTERED ITEM

AAA92-104976-00

QTY REQD	CAGE NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO.
2	16735	MS122095	INSERT, HELICAL COIL	2-56 X 1 DIA	3
1	16735	003334-51	CONNECTOR, 51 PIN WITH JACKPOST'S	ULTI MATE INC. MRS1-3503-28C3-1.00502	2
REF	16735	800-3042	CONNECTOR, 51 PIN MODIFIED		1

6

PARTS LIST

WEIGHTS						
STRESS						
MATERIALS & PROCESSES						
MANUFACTURING DWG		1			800-0205	
QUALITY ASSURANCE		PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON
ADDITIONAL APPROVALS	DATE		QTY REQD PER ASSY		APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/32 DECIMALS .XX=±.01 .XXX=±.005 ANGLES ±1/2° DO NOT SCALE DRAWING

TREATMENT NOTED

FINISH NOTED

SIMILAR TO | ACT WT | CALC WT

CONTRACT NO.

APPROVALS	DATE
DRAWN S.J.PATTI	91-07-23
CHECKED RJ TORGERSEN	91-07-23
P.E.	
P.M.	

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

CONNECTOR
51 PIN MODIFIED

SIZE B | CAGE NO. 16735 | DWG NO. 800-3042 | REV.

SCALE 2:1 | RELEASE DATE 91- | SHEET 1 OF 1

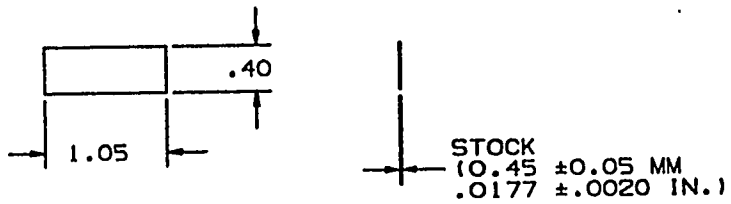
LAYERS: 1
RETRIEVE: 800-3042
CAD SYS: OCA | FILE:

AAA92-104976-00

OFFICIAL USE

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. MATERIAL: SARCONHR 45H, FUJIPOLY INC.

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



AAA92-104977-00

LAYERS: 1	
RETRIEVE:800-3045	
CAD SYS: OCA	FILE:

WEIGHTS	
STRESS	
MATERIALS & PROCESSES	
MANUFACTURING ENGRG	91/6/6
QUALITY ASSURANCE	91/6/10
ADDITIONAL APPROVALS	DATE

PART DASH NO.	QTY REQD PER ASSY NEXT	QTY REQD PER ASSY FINAL	NEXT ASSY	USED ON
	&		[redacted]	
	1		800-0220	
	1		800-0330	
			APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS ±1/32 DECIMALS .XX=±.01 .XXX=±.005 ANGLES ±1/2°
DO NOT SCALE DRAWING

TREATMENT	NOTED
FINISH	NOTED
SIMILAR TO	ACT WT / CALC WT

CONTRACT NO.

APPROVALS	DATE
DRAWN R NICHOLSON	91-04-25
CHECKED	91-05-12
	91-06-05
P.M. D.	91-06-05

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE., GARDEN GROVE, CA 92641

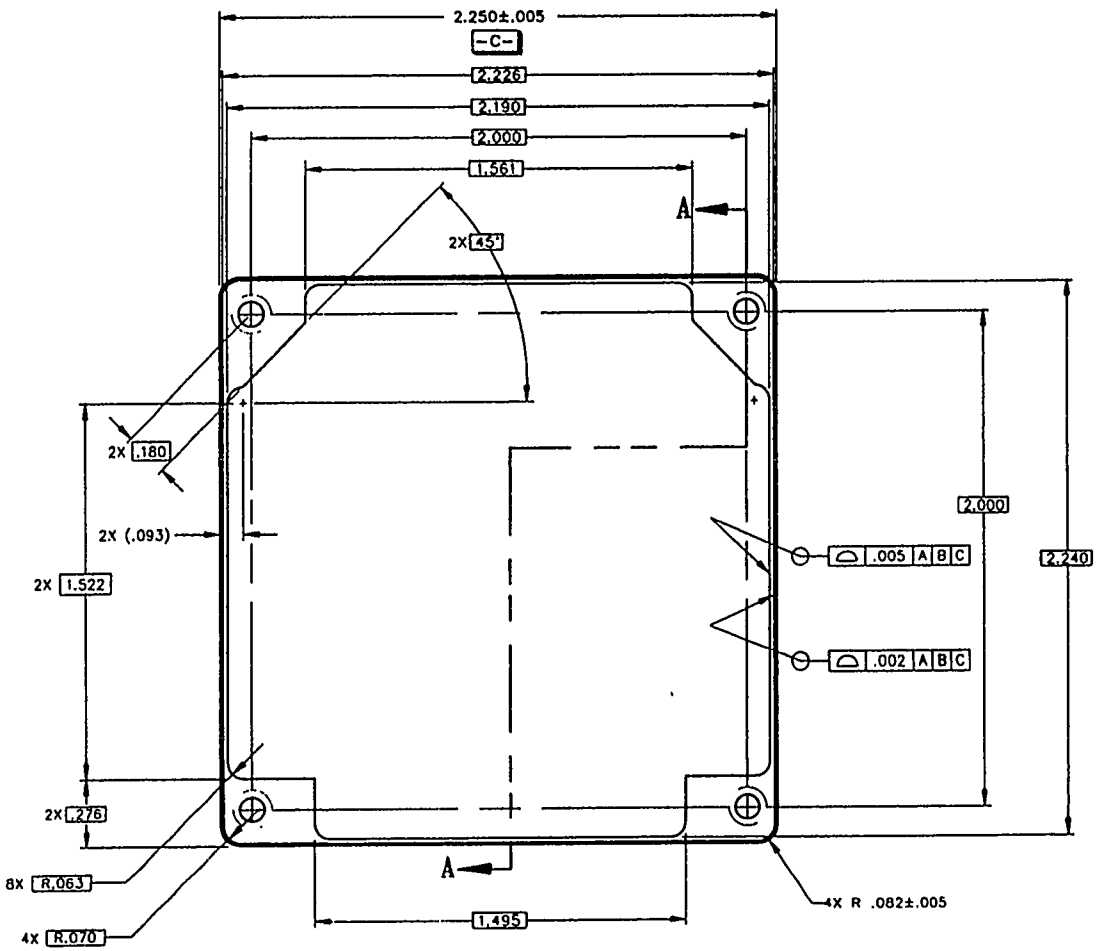
HEATSINK PAD

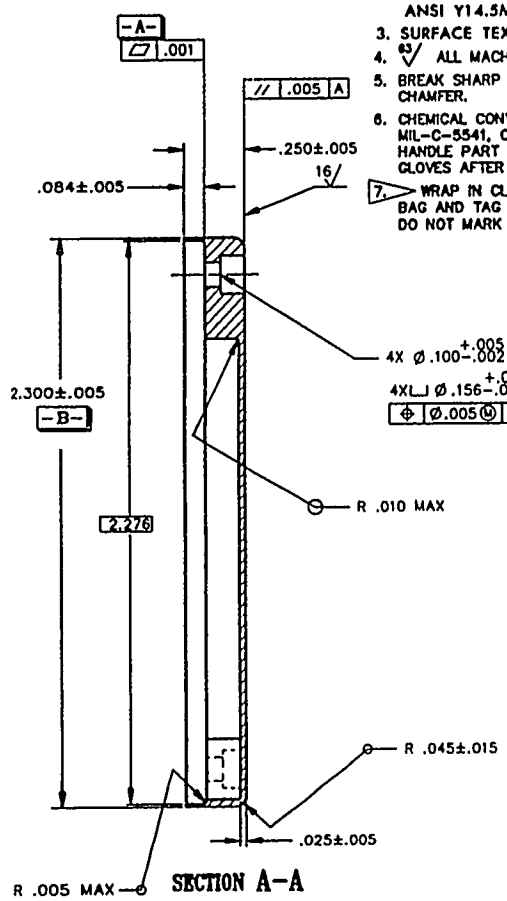
SIZE	CAGE NO.	DWG NO.	REV.
B	16735	800-3045	

SCALE	RELEASE DATE	SHEET
1:1	91-	1 OF 1

.AAA92-104977-00

OFFICIAL USE





NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. CHEMICAL CONVERSION COAT PER MIL-C-5541, CLASS 3, GOLD. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER COATING.
7. WRAP IN CLEAN LINT-FREE MATERIAL. BAG AND TAG WITH PART NO. & REV. LETTER. DO NOT MARK ON PART.

NO REQD	PART / ELEM STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		AL ALY TYPE 6061-T651	QQ-A-250/11	

DWN Riley Martin 8/31/92
CHK BILL TAYLOR 10/31/92
APVD SCOTT A. RUDDELL 10/31/92
CLASSIFIED BY
THIS DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

MAJOR UNIT: STARTRACKER CAMERA ASSY V3.1
SUBASSY: CAMERA ASSY
DETAIL: END COVER
DRAWING NO: AAA 92-106249-0A
SCALE .500
SHEET 1 OF 1

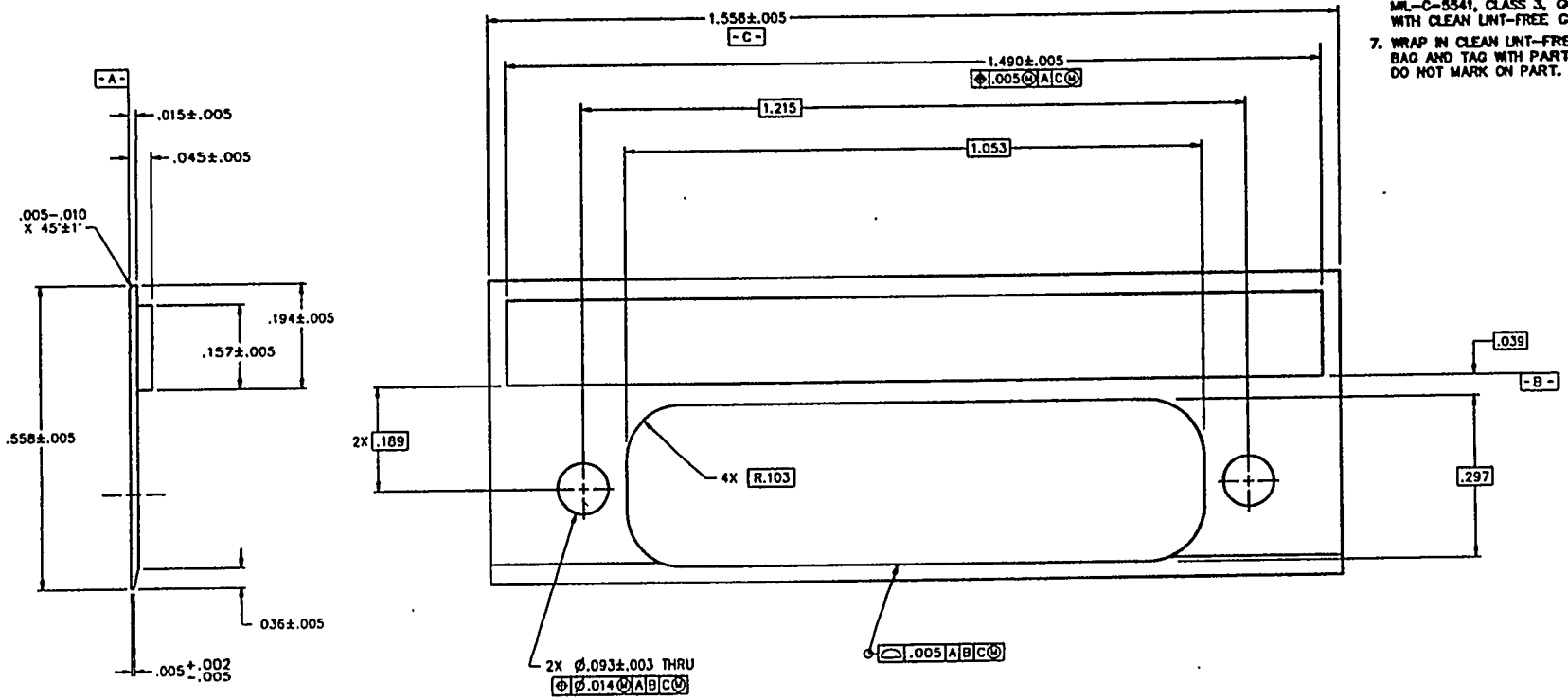
ENGINEERING RELEASE
APPROVED Project Engineer
Date 1 Feb 1993

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE
A	T.G.				C7	ADDED 2X .180

OFFICIAL USE

NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. CHEMICAL CONVERSION COAT PER MIL-C-5541, CLASS 3, GOLD. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER COATING.
7. WRAP IN CLEAN LINT-FREE MATERIAL. BAG AND TAG WITH PART NO. AND REV LETTER. DO NOT MARK ON PART.



ENGINEERING RELEASE
APPROVED Project Engineer
Date 13 Jan 1992

A	LC	PPT			CB	ADDED .005-.010 X 45°±1°
LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE

NO REQD	PART / ELM. STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		AL ALY TYPE 6061-T651		

DWN JAMES O. TRAVIS
CHK BILL TAYLOR
APVD SCOTT A. RUDDELL
CLASSIFIED BY
TITLE
DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

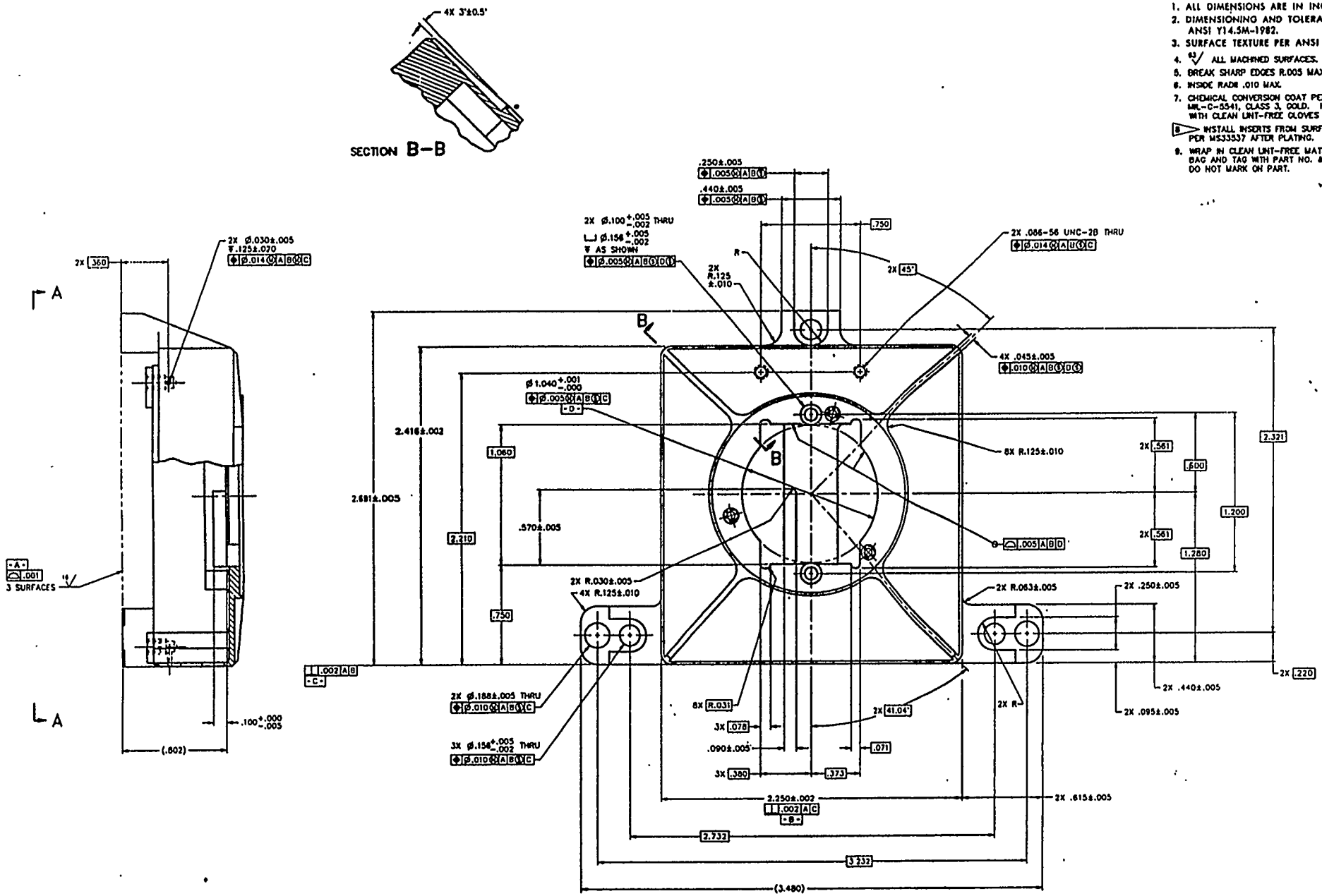
CLASSIFICATION

MAJOR UNIT: STAR TRACKER CAMERA ASSY V3.1
SUBUNIT: CAMERA ASSY
TITLE: CONNECTOR BRACKET
DRAWING NO: AAA 92-106257-0A
92-106277
SCALE .2
SHEET 1 OF 1

OFFICIAL USE

NOTES
UNLESS OTHERW .CIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ✓ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. INSIDE RADII .010 MAX.
7. CHEMICAL CONVERSION COAT PER MIL-C-5541, CLASS 3, GOLD. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER COATING.
8. INSTALL INSERTS FROM SURFACE INDICATED PER MS33537 AFTER PLATING.
9. WRAP IN CLEAN LINT-FREE MATERIAL. BAG AND TAG WITH PART NO. & REV. LETTER. DO NOT MARK ON PART.



7		INSERT, SCREW LOCKING, CRES, 2-56 X .128 L	MS21209-C0215	2
1		AL ALY TYPE 6061-T651	00-A-250/11	1
NO REQD	PART / LINE STE NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM

DWN JAMES D. TRAVIS	M/M/YY	CLASSIFICATION
CHK BILL TAYLOR	M/M/YY	THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LAB. REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT
APVD SCOTT A. RUDDELL	M/M/YY	
CLOSURE BY		
TITLE		

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT

C	T.G.					ADDED 2X .252
B						.384 WAS .334
A	T.G.					ADDED 2X .112

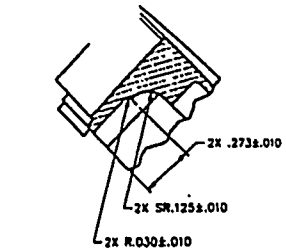
ENGINEERING RELEASE

STAR TRACKER CAMERA ASSY, V3.1

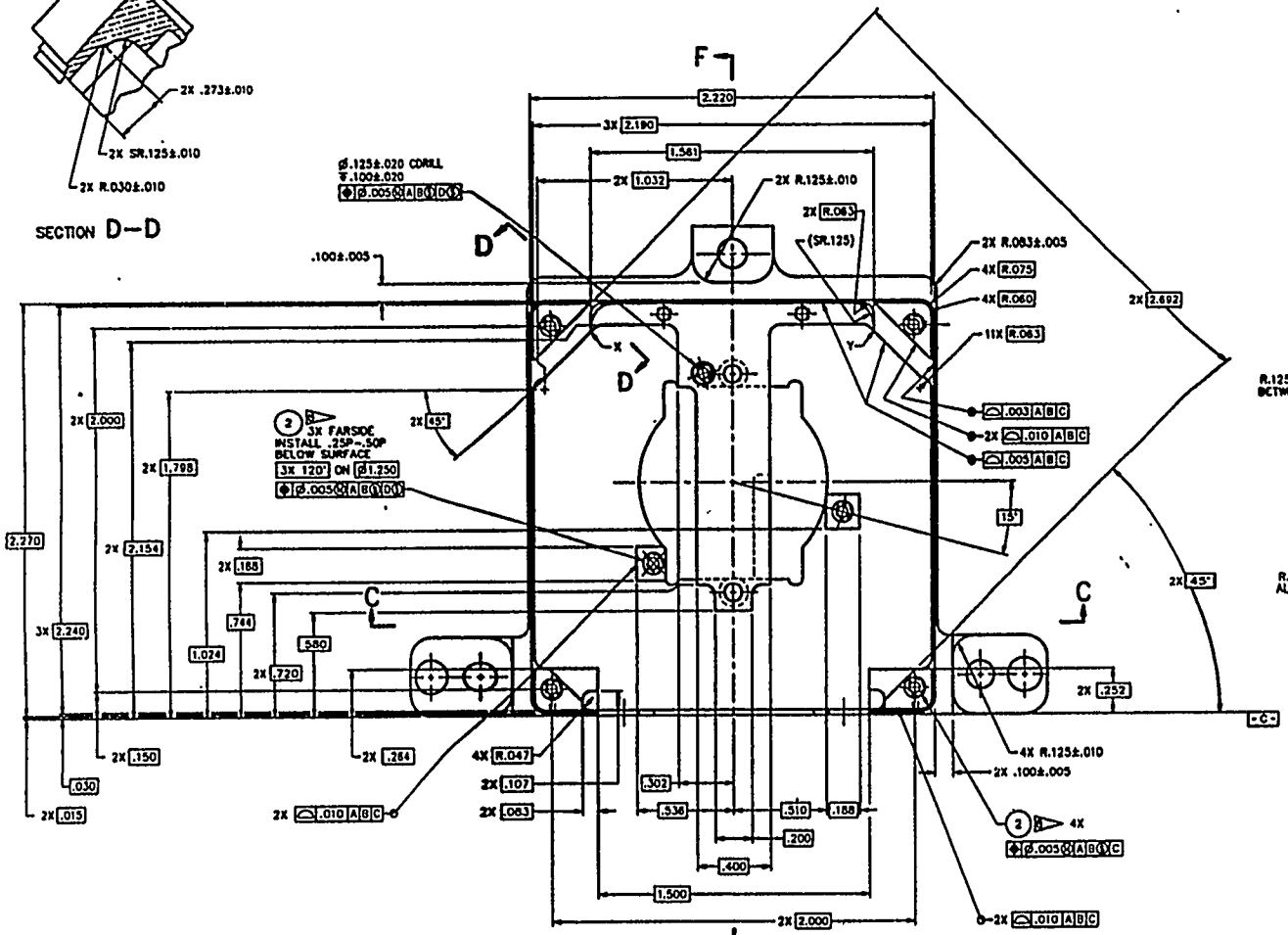
SUBASSY: CAMERA ASSY

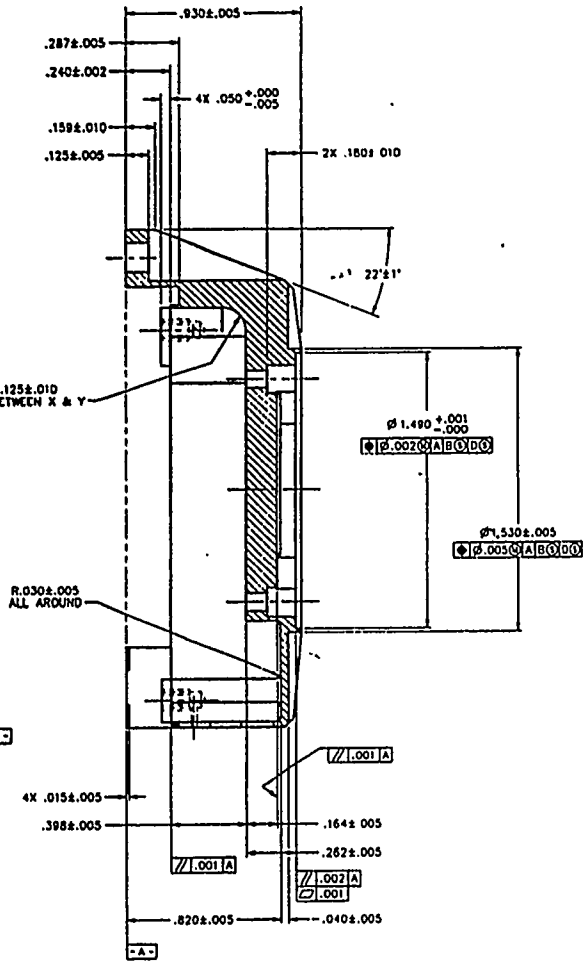
TITLE: CAMERA HOUSING

DRAWING NO: AAA 92-106258-0C ©

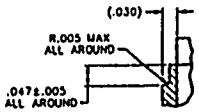


SECTION D–D



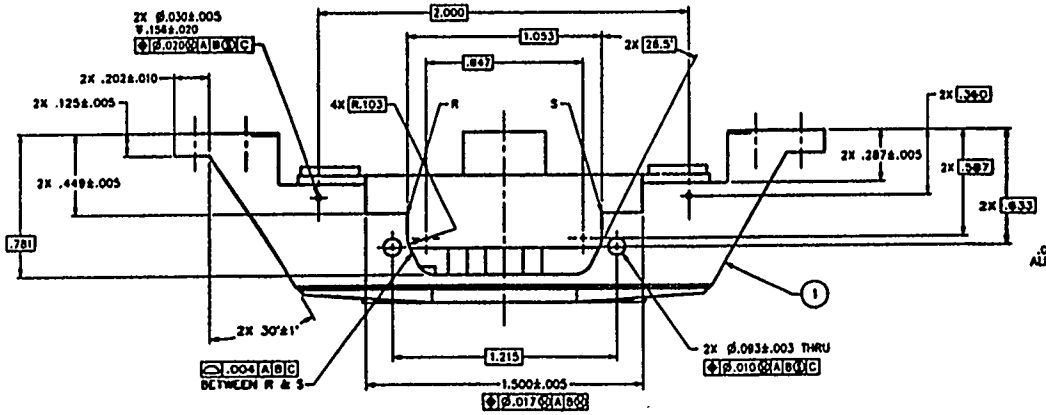


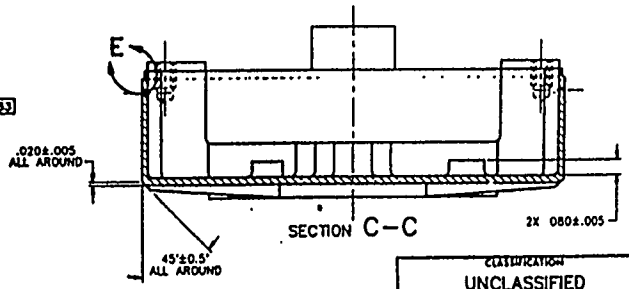
SECTION F–F



VIEW E

SCALE 2

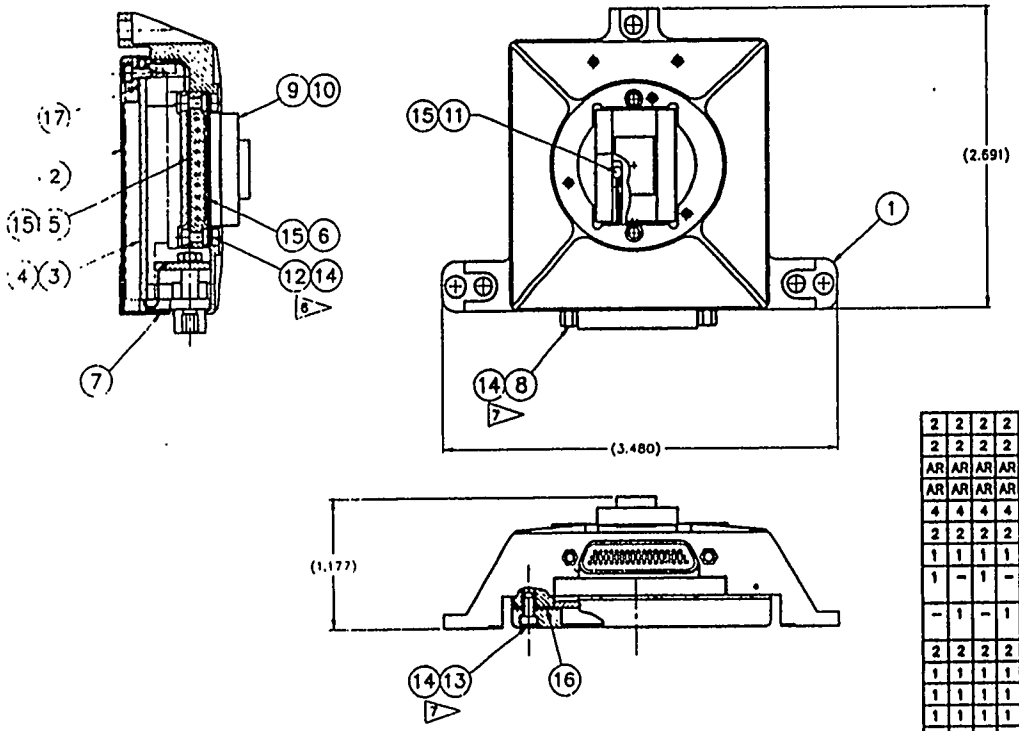




SECTION C–C

OFFICIAL USE

CLASSIFICATION	UNCLASSIFIED
DRAWING NO	AAA 92-106258-0C
SCALE	SHEET 1 OF 3



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. ALL COMPONENTS ARE ELECTROSTATIC SENSITIVE. USE HANDLING PRECAUTIONS PER DOD-STD-1686 CLASS 1.
5. ASSEMBLE PER STAR TRACKER CAMERA ASSEMBLY PROCEDURE C1-S1-012.
6. 3.0±0.2 in-lb. TORQUE.
7. 2.9±0.1 in-lb. TORQUE.

TAB-04	TAB-03	TAB-02	TAB-01	PART / LIML STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
2	2	2	2	93-102609	END COVER SHIM, UPPER		17
2	2	2	2	93-102610	END COVER SHIM, LOWER		16
AR	AR	AR	AR		THERMALLY CONDUCTIVE RTV, NuSil CV-2946		15
AR	AR	AR	AR		STAKING COMPOUND, HYSOL EA934NA		14
4	4	4	4		SCREW, HEX SOC HD., NO.2-56 UNC X .19L, A286		13
2	2	2	2		SCREW, HEX SOC HD., NO.2-56 UNC X .25L, A286		12
1	1	1	1		FENWALL THERMISTER, P/N 137-562-ZXT-002		11
1	–	1	–		IMAGE SENSOR CCD, TH 7883A W/ FIBER OPTIC WINDOW, THOMSON COMPOSANTS MILITAIRES ET SPATIAUX (COMMERCIAL)		10
–	1	–	1		IMAGE SENSOR CCD, TH 7883A W/ FIBER OPTIC WINDOW, THOMSON COMPOSANTS MILITAIRES ET SPATIAUX (B/T)		9
2	2	2	2	92-104607 TAB-01	MOUNTING HARDWARE, CONNECTOR JACKPOST		8
1	1	1	1	92-106257	CONNECTOR BRACKET		7
1	1	1	1	92-104609	HEATSINK PAD		6
1	1	1	1	92-104621	CIRCUIT BOARD PAD		5
1	1	–	–	92-104603	CIRCUIT BOARD ICD (ACTEL CAMERA) ST2A BOARD		4
–	–	1	1	92-104603	CIRCUIT BOARD ICD (ACTEL CAMERA) ST1A BOARD		3
1	1	1	1	92-106249	END COVER		2
1	1	1	1	92-106258	CAMERA HOUSING		1

DWN Tom Ozamoto 6/8/93
CHK BILL TAYLOR 6/11/93
APVD JIM W. DICKEY 6/15/93
CLASSIFICATION
TITLE DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

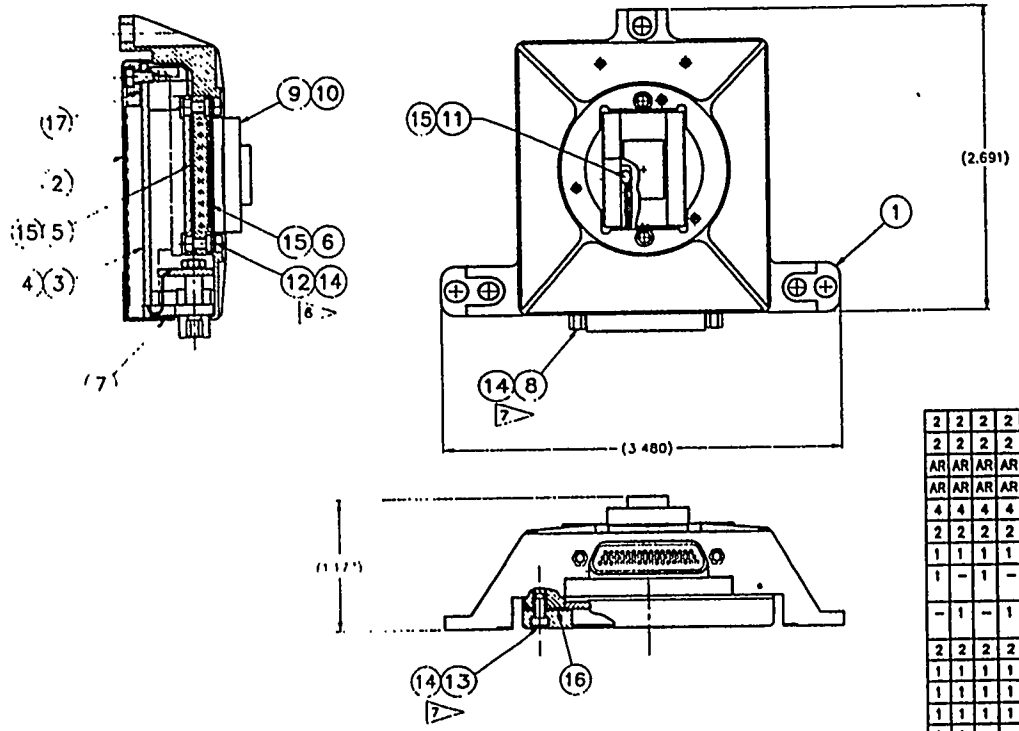
CLASSIFICATION
THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LAB REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT

MAJOR UNIT: STAR TRACKER CAMERA ASSY, V3.1
SUBASSY
DETAIL: CAMERA ASSY
DRAWING NO: AAA 92-106277-0A
SCALE 1.00 SHEET 1 OF 1

ENGINEERING RELEASE
APPROVED Project Engineer
Date 22 May 1993

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE
A	TSG					ADDED ITEMS 16 & 17

OFFICIAL USE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. ALL COMPONENTS ARE ELECTROSTATIC SENSITIVE. USE HANDLING PRECAUTIONS PER DOD-STD-1686 CLASS 1.
5. ASSEMBLE PER STAR TRACKER CAMERA ASSEMBLY PROCEDURE C1-S1-012.

6 3.0±0.2 in-lb. TORQUE.

7 2.9±0.1 in-lb. TORQUE.

TAB-04	TAB-03	TAB-02	TAB-01	PART / ELMS STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
2	2	2	2	93-102609	END COVER SHIM, UPPER		17
2	2	2	2	93-102610	END COVER SHIM, LOWER		16
AR	AR	AR	AR		THERMALLY CONDUCTIVE RTV, NuSil CV-2946		15
AR	AR	AR	AR		STAKING COMPOUND, HYSOL EA934NA		14
4	4	4	4		SCREW, HEX SOC HD., NO.2-56 UNC X .19L, A286		13
2	2	2	2		SCREW, HEX SOC HD., NO.2-56 UNC X .25L, A286		12
1	1	1	1		FENWALL THERMISTER, P/N 137-562-ZXT-D02		11
1	–	1	–		IMAGE SENSOR CCD, TH 7883A W/ FIBER OPTIC WINDOW, THOMSON COMPOSANTS MILITAIRES ET SPATIAUX (COMMERCIAL)		10
–	1	–	1		IMAGE SENSOR CCD, TH 7883A W/ FIBER OPTIC WINDOW, THOMSON COMPOSANTS MILITAIRES ET SPATIAUX (B/T)		9
2	2	2	2	92-104607 TAB-01	MOUNTING HARDWARE, CONNECTOR JACKPOST		8
1	1	1	1	92-106257	CONNECTOR BRACKET		7
1	1	1	1	92-104609	HEATSINK PAD		6
1	1	1	1	92-104621	CIRCUIT BOARD PAD		5
1	1	–	–	92-104603	CIRCUIT BOARD ICD (ACTEL CAMERA) ST2A BOARD		4
–	–	1	1	92-104603	CIRCUIT BOARD ICD (ACTEL CAMERA) ST1A BOARD		3
1	1	1	1	92-106249	END COVER		2
1	1	1	1	92-106258	CAMERA HOUSING		1

NO REQD

DWN Tom Gamson 4/9/93
CHK BILL TAYLOR 4/11/93
APVD JM W DICKEY 4/13/93
CLASSIFIED BY
TITLE DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

MAJOR UNIT
STAR TRACKER CAMERA ASSY, V3.1
SUBASSY
DETAIL
CAMERA ASSY
SHOWN ON AAA 92-106262
NEXT HIGH
DRAWING NO
AAA 92-106277-0A
SCALE 1.00 SHEET 1 OF

ENGINEERING RELEASE
APPROVED
Date 21 Apr 1993

A	TSC					ADDED ITEMS 16 & 17
LTR	DWN	CHK	APVD	DATE	PCN	CHANGE

OFFICIAL USE

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

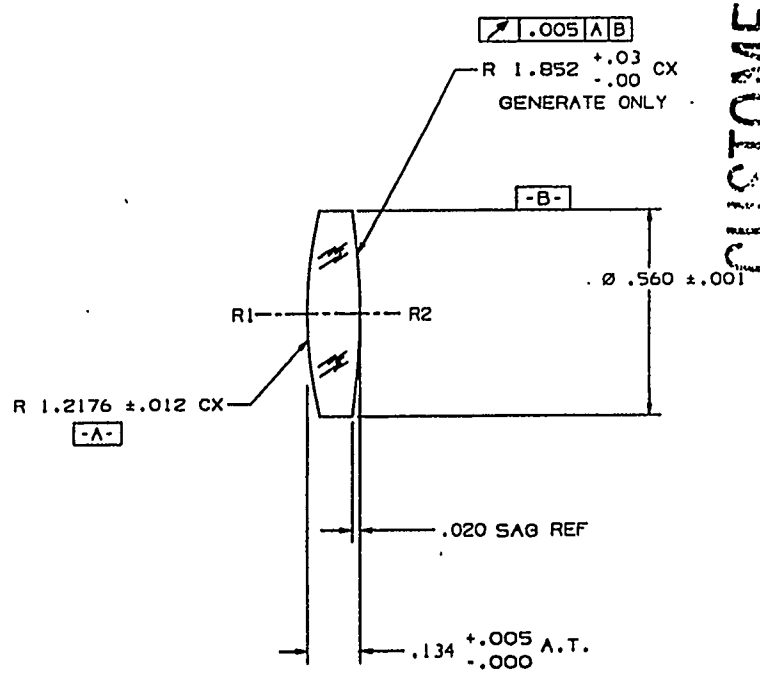
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN 92106 3 NOV 92 09:01:46
3. MATERIAL: ZINC SELENIDE
4. MELT VARIATIONS DO NOT REQUIRE RECOMPUTATION.
5. SURFACE R1 IS POLISHED AND ALL OTHERS TO BE FINE GROUND WITH 220 GRIT SIZE OR EQUIV.
6.

SURFACE	R1
POWER (WAVES)	N/A
IRREGULARITY (WAVES)	1
SCRATCH-DIG	E-E
MINIMUM CLEAR APERTURE	0.460 IN.
COATING	SEE NOTE8
CEMENT	---

POWER AND IRREGULARITY ARE SPECIFIED AT 633nm
SCRATCH AND DIG IN ACCORDANCE WITH MIL-F-48616

7. PROTECTIVE BEVEL ON ALL EDGES PER AOD 14188 EXCEPT AS NOTED
8. COATING: SEE SHEET 1

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



CUSTOMER COPY

MAY 3 1993

AAA92-109643-0A

THIS SHEET IS
FOR PRE-DIAMOND TURNED ELEMENT

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

ELEMENT NO. 7

SIZE	CAGE NO.	DWG NO.	REV.
C	16735	806-5058-001	A

SCALE 4:1 | DATE 92- | SHEET 2 OF 2

806-5058-001 REV. A

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 806-5058-001SH2 | LAYERS: 1

OFFICIAL USE

1 NEW TOLERANCE BLOCK

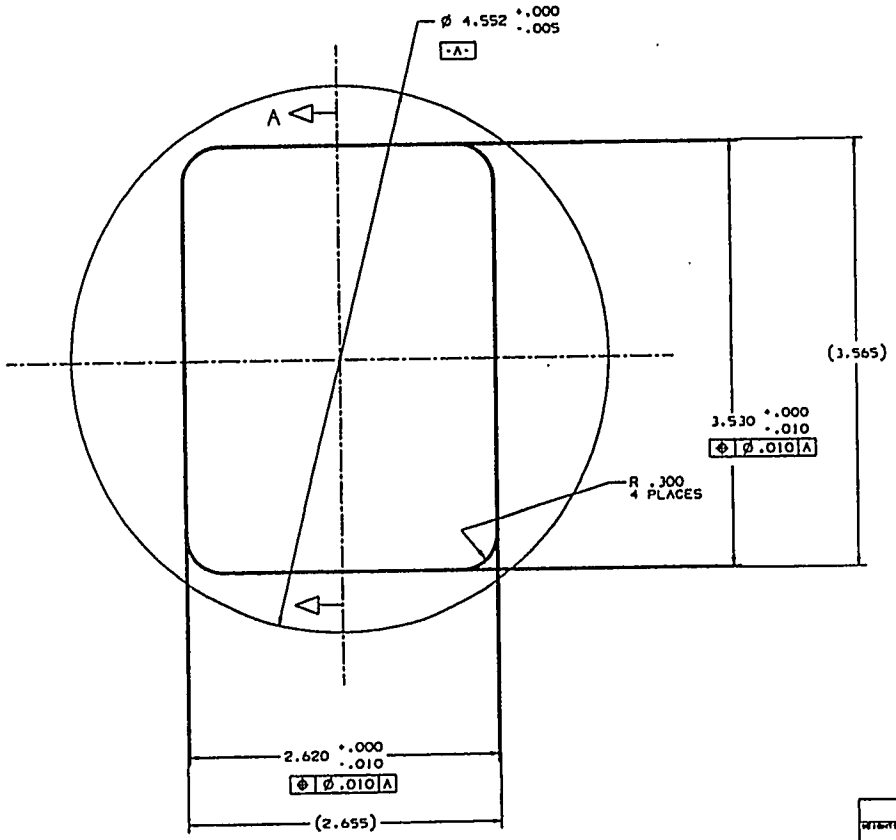
DWG NO.	REV.
880-1024-001	A

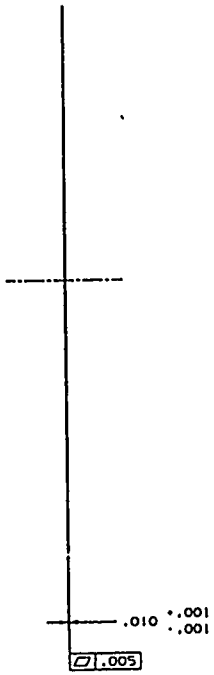
REVISIONS

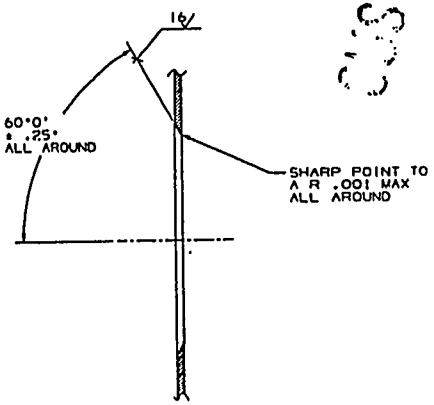
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	PER ECN 14723	93/04/27	

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-651 ALUM-ALLOY PER QQ-A-250/11.
7. FINISH: SPIRE ION BEAM TEXTURING TANTULUM SEEDED ARGON SPUTTERING BLACKENING PROCESS IS TO BE USED. CAUTION: HANDLING PRECAUTIONS MUST BE TAKEN TO AVOID ABRASION ON ANY INTERIOR SURFACE, ESPECIALLY ON THE VANE INNER EDGES.







SECTION A
NOT TO SCALE

CUSTOMER COPY

AAA92-108744-0A

WEIGHTS			
STRESS			
MATERIALS & PROCESSES			
MANUFACTURING ENGR D SMALL	92/11/17	000	
QUALITY ASSURANCE J DELISO	92/11/17		
ADDITIONAL APPROVALS	DATE	PART DASH NO.	QTY REQD PER ASSY

NEXT / FINAL	USED ON
880-0004-001 NEXT ASSY	
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES ± ±XX±.03 ±1/2° ±XXX±.010 DO NOT SCALE DRAWING

TREATMENT SEE NOTES

FINISH SEE NOTES

DISTRIBUTION | ACT. DT | CALC DT

CONTRACT NO.

APPROVALS	DATE
DRAWN K PARK	92-10-13
CHECKED RHN	92/11/11
ENG RVONHANDROF	92/11/11
PROJ M SEILONEN	92/11/17

O C A APPLIED OPTICS
7051 GRANDWOOD AVE., GARDEN GROVE, CA 92641

BAFFLE VANE #4
STAR TRACKER

SIZE	CAGE NO.	DWG NO.	REV.
D	16735	880-1024-001	A

SCALE 2/1 | SHEET 1 OF 1

NEW TOLERANCE

CAD SYSTEM: OCA | FILE: CLEM | RETRIEVE: 880-1024-001 | LAYER(S): 1

AAA92-108744-0A

OFFICIAL USE

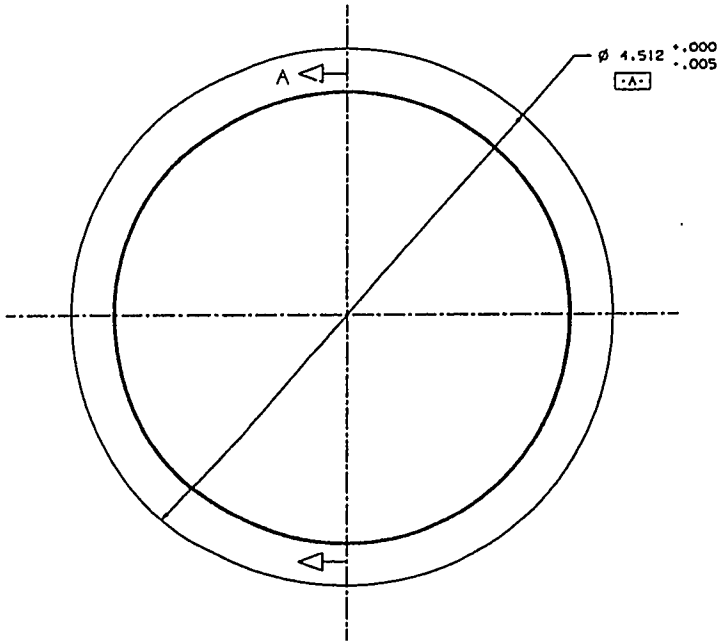
DWG NO. 880-1023-001 SH 1 REV A

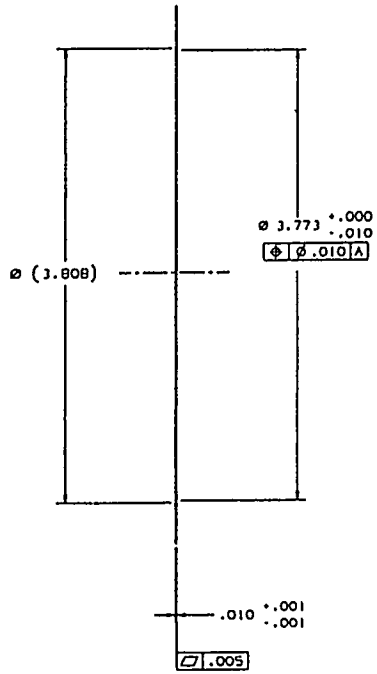
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	PER ECN 14723	93/04/22	

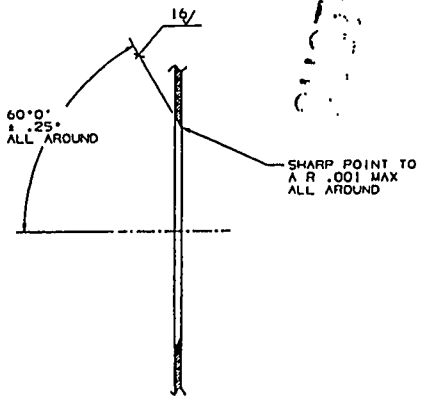
NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-651 ALUM-ALLOY PER QQ-A-250/11.
7. FINISH: SPIRE ION BEAM TEXTURING TANTULUM SEEDED ARGON SPUTTERING BLACKENING PROCESS IS TO BE USED. CAUTION: HANDLING PRECAUTIONS MUST BE TAKEN TO AVOID ABRASION ON ANY INTERIOR SURFACE, ESPECIALLY ON THE VANE INNER EDGES.







SECTION A
NOT TO SCALE

AAA92-108745-0A

A)

WEIGHTS			
STRESS			
MATERIALS & PROCESSES			
MANUFACTURING DATA D SMALL	92/11/12	-000	
QUALITY ASSURANCE J DELISO	92/11/11	PART DASH NO.	NEXT ASSY 880-0004-001
ADDITIONAL APPROVALS	DATE	QTY REQD PER ASSY	APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/2° ANGLES ± .XX± .03 ±1/2° .XXX± .010 DO NOT SCALE DRAWING

TREATMENT SEE NOTES

FINISH SEE NOTES

SIMILAR TO | ACT. QT | CALC QT

USED ON

CONTRACT NO.

APPROVALS	DATE
DRAWN K PARK	92-10-13
CHECKED RWN	92/11/11
ENG R VONHANDORF	92/11/11
PM M SEILONEN	92/11/17

O C A APPLIED OPTICS
7451 BRANDEWOOD AVE, GARDEN GROVE, CA 92641

BAFFLE VANE #3
STAR TRACKER

SIZE D | CAGE NO. 16735 | DWG NO. 880-1023-001 | REV A

SCALE 2/1 | WEIGHT SHEET 1 OF 1

NEW TOLERANCE

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 880-1023-001 | LAYER(S): 1

AAA92-108745-0A

OFFICIAL USE

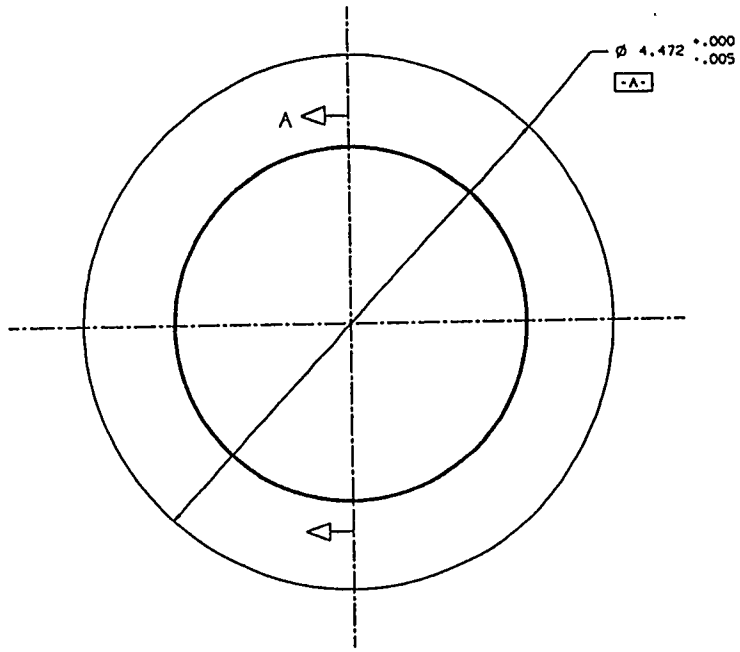
DWG NO. 880-1022-001 REV. A

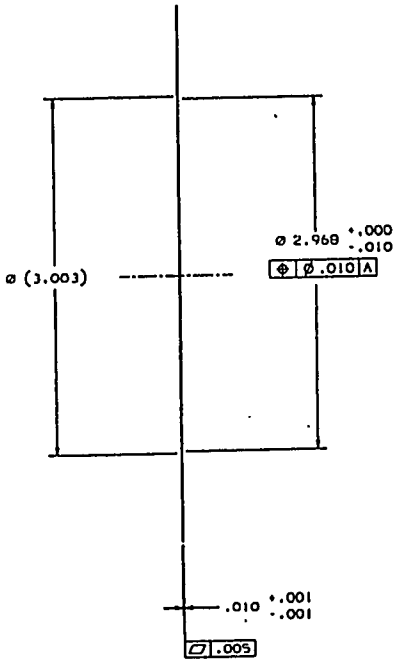
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	PER ECN 14723	93/01/22	

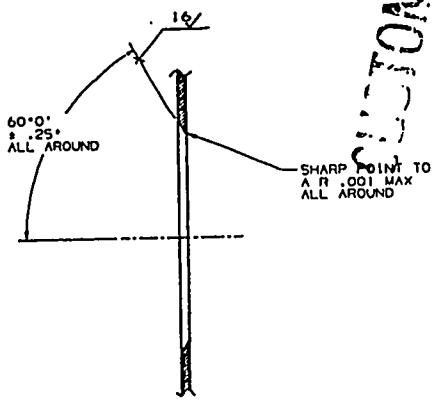
NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-651 ALUM-ALLOY PER QQ-A-250/11.
7. FINISH: SPIRE ION BEAM TEXTURING TANTULUM SEEDED ARGON SPUTTERING BLACKENING PROCESS IS TO BE USED. CAUTION: HANDLING PRECAUTIONS MUST BE TAKEN TO AVOID ABRASION ON ANY INTERIOR SURFACE, ESPECIALLY ON THE VANE INNER EDGES.







SECTION A
NOT TO SCALE

CUSTOMER COPY

AAA92-108746-0A

MATERIALS					
STRESS					
MATERIALS & PROCESSES					
MANUFACTURING ENGR D SMALL	92/11/17	-000		880-0004-001	
QUALITY ASSURANCE J DELISO	92/11/17	PART DASH NO.	NEXT / FINAL	NEXT ASSY	USED ON
ADDITIONAL APPROVALS	DATE		QTY REQD PER ASSY	APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONAL DECIMALS ANGLES ± .XX ± .03 ± 1/2° ± .XXX ± .010 DO NOT SCALE DRAWING

MATERIAL: SEE NOTES

FINISH: SEE NOTES

SIGNOUT TO | ACT. QT | CALC QT

CONTRACT NO.

APPROVALS	DATE
DRAWN K PARK	92-10-13
CHECKED RHN	92/11/11
ENGR RVONHANDROF	92/11/11
PM M SEILONEN	92/11/17

O C A APPLIED OPTICS
7421 GRANDWOOD AVE., RANCHO CRONE, CA 91701

BAFFLE VANE #2
STAR TRACKER

SIZE D | CAGE NO. 16735 | DWG NO. 880-1022-001 | REV. A

SCALE 2/1 | WEIGHT LBS 52. | SHEET 1 OF 1

NEW TOLERANCE

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 880-1022-001 | LAYERS: 1

OFFICIAL USE

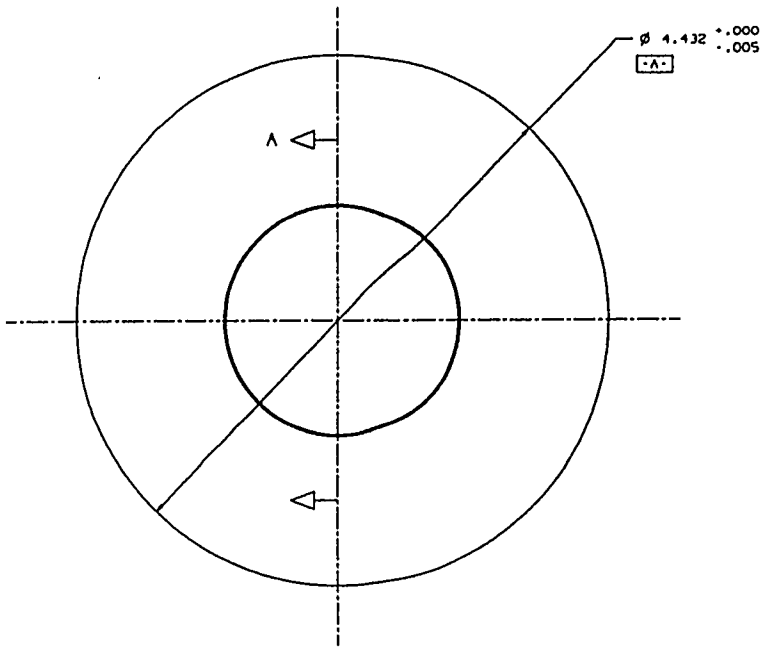
AAA92-108746-0A

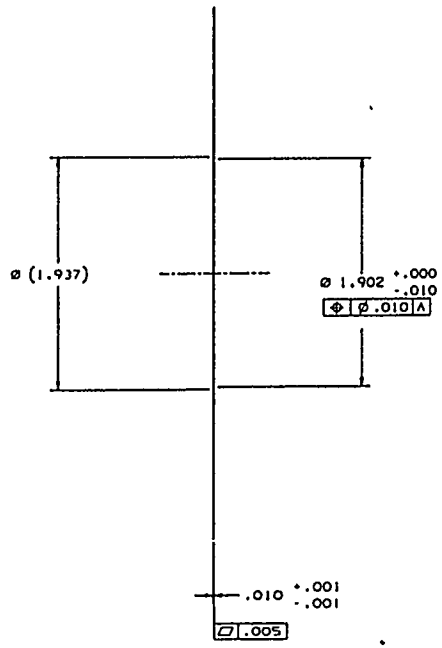
DWG NO. 880-1021-001 REV. A

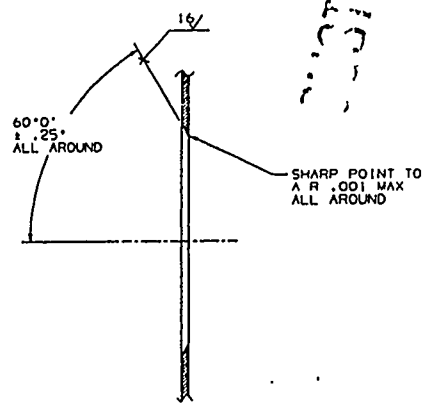
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	PER ECN 14723	93/01/22	

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-651 ALUM-ALLOY PER QQ-A-250/11.
7. FINISH: SPIRE ION BEAM TEXTURING TANTULUM SEEDED ARGON SPUTTERING BLACKENING PROCESS IS TO BE USED. CAUTION: HANDLING PRECAUTIONS MUST BE TAKEN TO AVOID ABRASION ON ANY INTERIOR SURFACE, ESPECIALLY ON THE VANE INNER EDGES.







SECTION A
NOT TO SCALE

CUSTOMER COPY

AAA92-108747-0A

WEIGHTS			
STRESS			
MATERIALS & PROCESSES			
MANUFACTURING DWG D SMALL	92/11/11	-000	
QUALITY ASSURANCE J DELISO	92/11/11	PART DASH NO.	NEXT / FINAL
ADDITIONAL APPROVALS	DATE		QTY REQD PER ASSY

880-0004-001 NEXT ASSY | USED ON | APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±1/2° ± .XXX±.010 DO NOT SCALE DRAWING

TREATMENT SEE NOTES
FINISH SEE NOTES
SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO.

APPROVALS	DATE
DRAWN K PARK	92-10-13
CHECKED RHN	92/11/11
PE RVONHANDORF	92/11/11
PM M SEILONEN	92/11/17

O C A APPLIED OPTICS
7421 GRANDWOOD AVE., BARDOW BROWE, CA 92641

BAFFLE VANE #1
STAR TRACKER

SIZE D | CAGE NO. 16735 | DWG NO. 880-1021-001 | REV. A
SCALE 2/1 | RELEASE DATE 92- | SHEET 1 OF 1

NEW TOLERANCE

CAD SYS:OCA | FILE: CLEM | RETRIEVE: 880-1021-001 | LAYER(S): 1

AAA92-108747-0A

OFFICIAL USE

DWG NO. 880-0004-001 SH REV C

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14469	92-11-23	
	B	SEE ECN 14654	93-01-18	
	C	SEE ECN 14722	93-04-22	

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982. WELDING PER AWS A2.4-79.

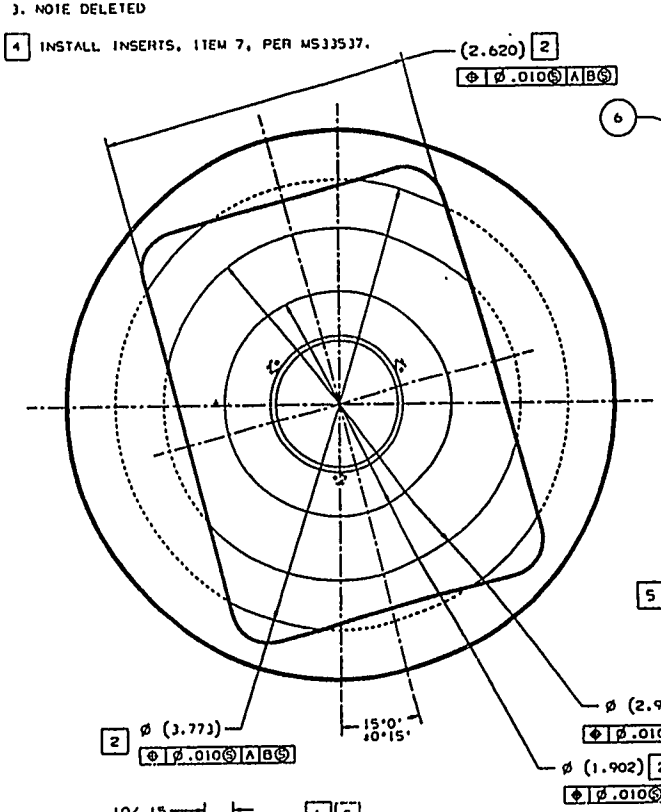
[2] ANY FIXTURE REQUIRED TO OBTAIN BAFFLE ALIGNMENT MUST NOT MAR OR DEFORM INSIDE EDGE OF BAFFLES OR ANY INTERNAL SURFACE.

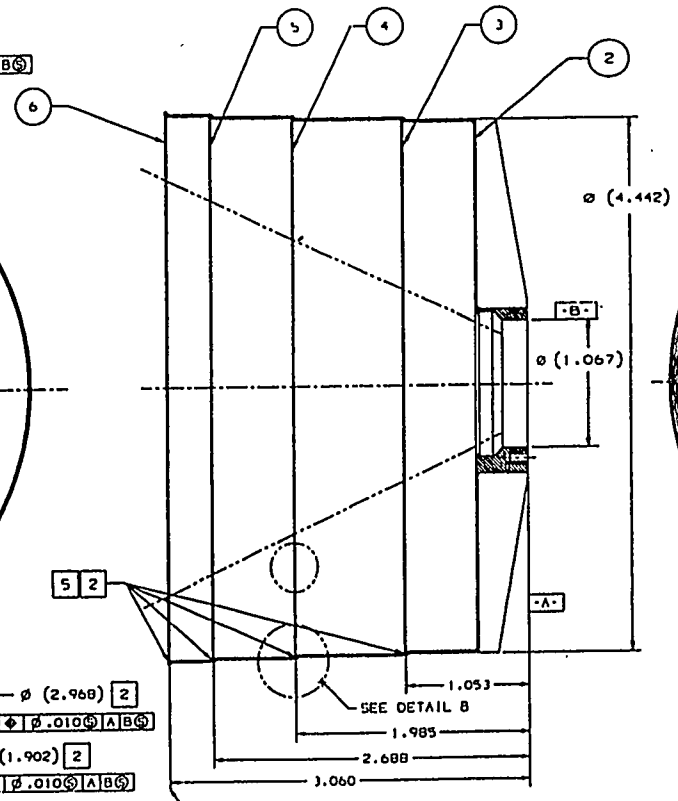
3. NOTE DELETED

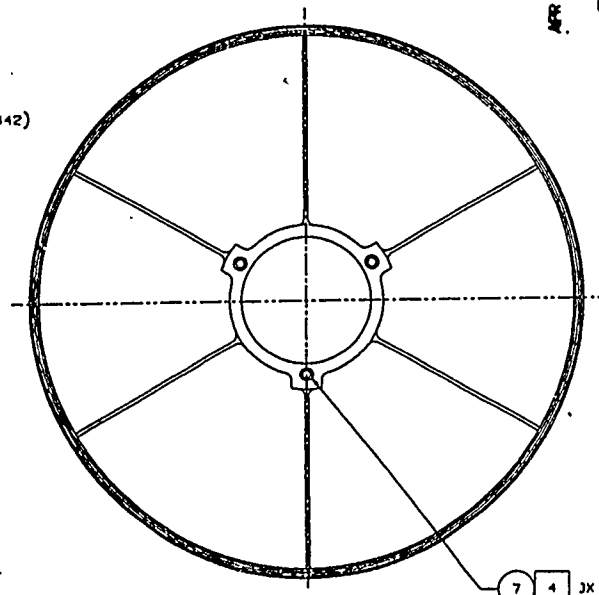
[4] INSTALL INSERTS, ITEM 7, PER MS33537.

[5] PREPARE SURFACES NOTED FOR BONDING (WITH ITEMS 8 AND 9) BY CLEANING WITH A GENTLE WASH, WITH A SQUEEZE BOTTLE OF ACETONE

[6] APPLICATION IS MADE IN 8 SPOTS AROUND THE PERIPHERY OF THE VANES, EACH APPROX. 1/8 IN LENGTH, IN A FILLET, AS SHOWN APPLIED TO THE "TOP" SURFACE OF EACH VANE.
i.e. THE VANES ARE LOCATED AGAINST THE SEAT FIRST, THEN THE ADHESIVE IS APPLIED FROM THE "LIGHT ENTERING" BAFFLE END).

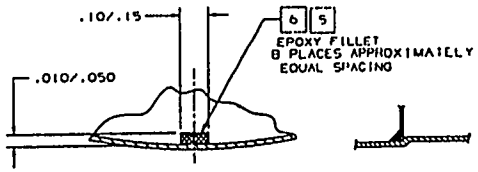




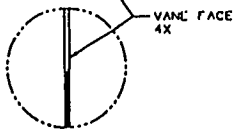


CUSTOMER COPY

AAA92-108748-OC



DETAIL B
SCALE 4X
TYPICAL 4 VANES AS SHOWN [6]



ORIENTATION OF VANES
4 PLACES
NOT TO SCALE

QTY REQD	CAGE NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO.
A/R		003555-140	CATALYST	VERSAMID 140	10
A/R		003549-820	ADHESIVE	EPON 828	9
3		MS122035	INSERT, CRES HELICAL COIL	2-56 X 1 Ø LG	8
1		880-1024-001	BAFFLE VANE #4		7
1		880-1023-001	BAFFLE VANE #3		6
1		880-1022-001	BAFFLE VANE #2		5
1		880-1021-001	BAFFLE VANE #1		4
1		880-1000-001	BAFFLE BASE		3
1		880-0004-001	BAFFLE ASSEMBLY		2
					1

PARTS LIST

WEIGHTS					
STRESS					
MATERIALS & PROCESSES					
MANUFACTURING DESIGN	D SMALL	92-11-17			
QUALITY ASSURANCE	J DELISO	92-11-17			
ADDITIONAL APPROVALS		DATE	PART DASH NO.	QTY REQD PER ASSY	880-0001-DASH NEXT ASSY / USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS DECIMALS ANGLES
± .XX±.03 1/2°
±.XXX±.010
DO NOT SCALE DRAWING
TREATMENT SEE NOTES
FINISH SEE NOTES
SIMILAR TO | NEXT ASSY | CALC QT

CONTRACT NO.

APPROVALS	DATE
DRAWN K PARK	92-10-13
CHECKED R NICHOLSON	92-11-12
ENG R VONHANDORF	92-11-17
PM M SEILONEN	92-11-17

O C A APPLIED OPTICS
7481 GRANDWOOD AVE., GARDEN GROVE, CA 92641

BAFFLE ASSEMBLY, STAR TRACKER

SIZE D CAGE NO. 16735 DWG NO. 880-0004-001 REV. C
SCALE 2/1 SHEET 1 OF 1

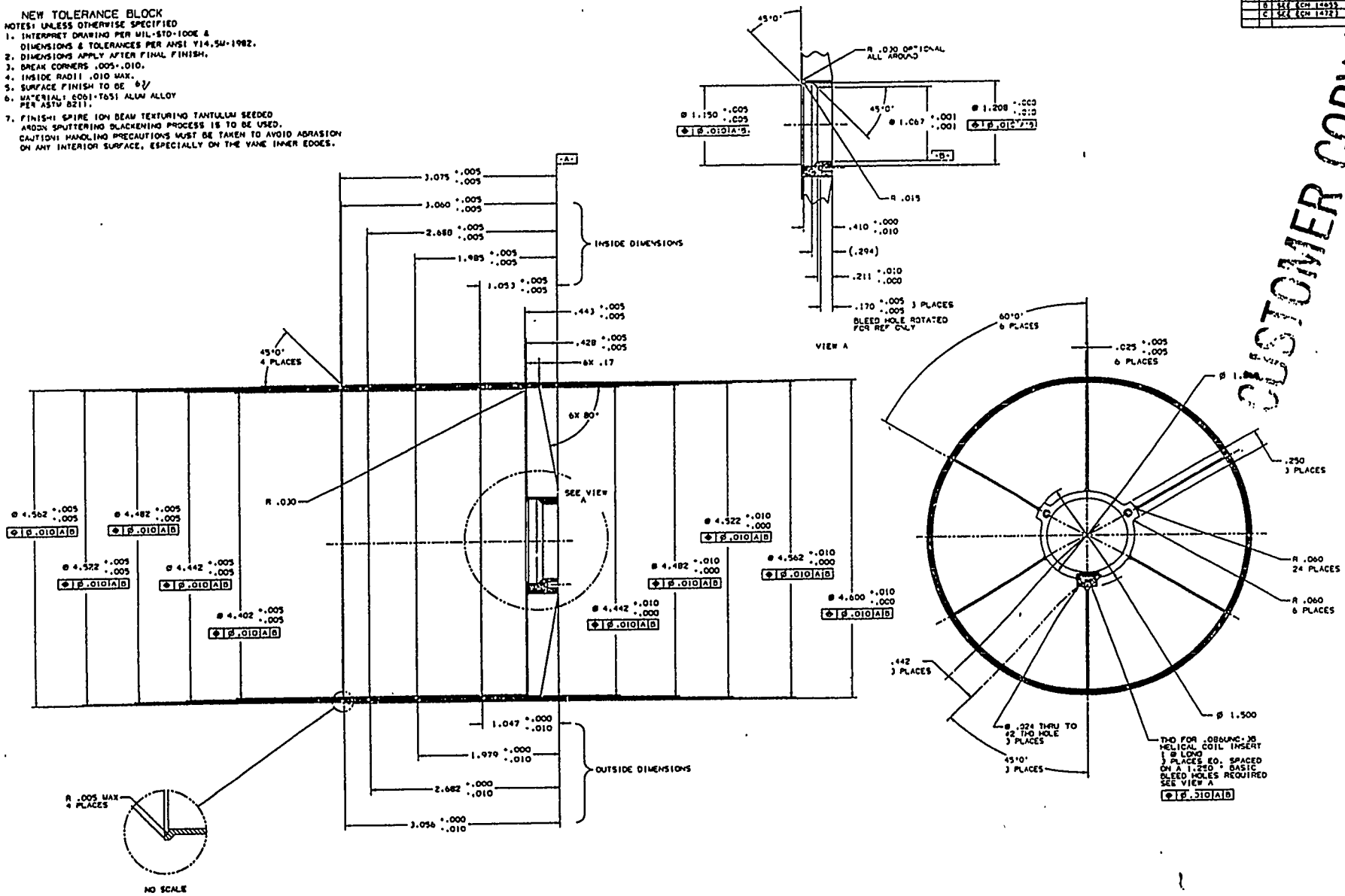
CAD SYSTEM FILE FILE1CLFM RETRIEVE: 880-0004-001 LAYER(S): 1

NEW TOLERANCE

OFFICIAL USE

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5M-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005+.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 64
6. MATERIAL: 6061-T651 ALUM ALLOY PER ASTM B211.
7. FINISH: SPIRE ION BEAM TEXTURING TANTULUM SEEDED ARGON SPUTTERING BLACKENING PROCESS IS TO BE USED. CAUTION: HANDLING PRECAUTIONS MUST BE TAKEN TO AVOID ABRASION ON ANY INTERIOR SURFACE, ESPECIALLY ON THE VANE INNER EDGES.



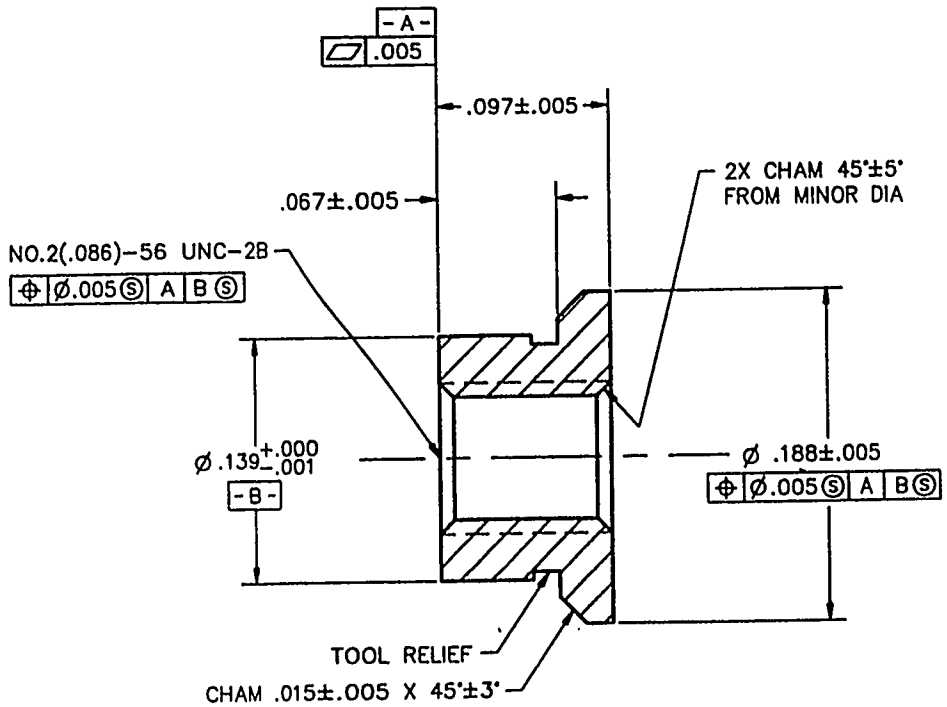
CUSTOMER COPY

AA492-108749-0C

OFFICIAL USE

	O C A APPLIED OPTICS
	BAFFLE BASE, STAR TRACKER
	E 16735 880-1080-001 C

NEW TOLERANCE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. ELECTROLESS NICKEL PER MIL-C-26074 CLASS 1 .0001 TO .00015 THICK.
7. WRAP IN CLEAN LINT-FREE MATERIAL. BAG AND TAG WITH PART NO. AND REV LETTER. DO NOT MARK ON PART.

ENGINEERING RELEASE
APPROVED Project Engineer
Date 13 Jan 1993

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		BRASS, CDA 360 1/2 HARD	QQ-B-626	

DWN JAMES O. TRAVIS	11/92	
CHK Bill Taylor	1/93	
APVD	1/93	
CLASSIFIED BY:		
TITLE	DATE	

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

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OFFICIAL USE

MAJOR UNIT: CAMERA ASSY
SUBASSY: PWA, BETA CAMERA W/GAIN CONTROL
DETAIL: NUT, PCBD RETAINER
SHOWN ON AAA: LEA92-3067-03
ACCT NO
DRAWING NO: AAA92-109126-00 (0
SCALE .10 SHEET 1 OF 1

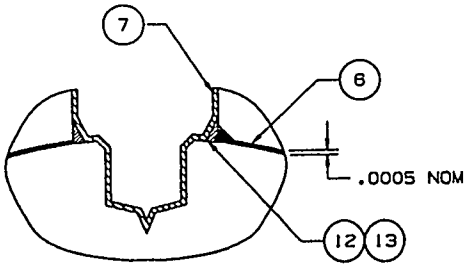
LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14430		
	B	SEE ECN 14445	92-10-12	MAS
	C	SEE ECN 14653	93-1-17	

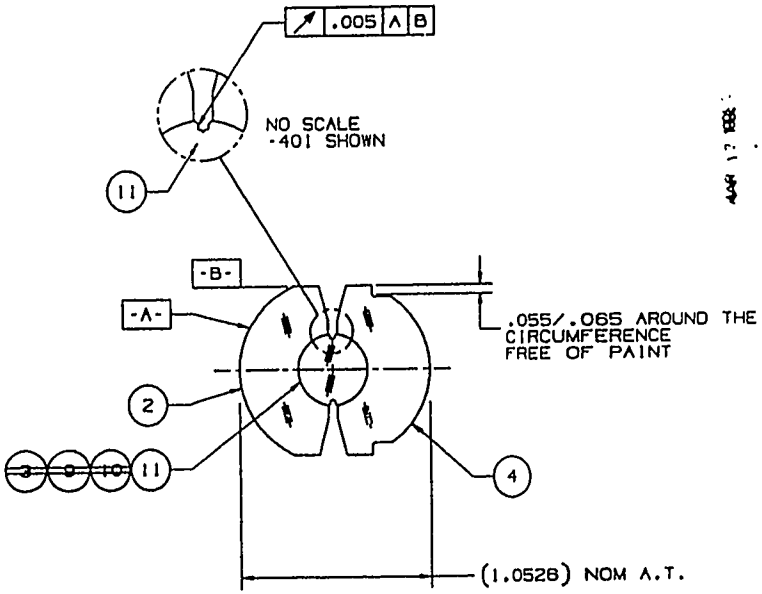
NEW TOLERANCE BLOCK

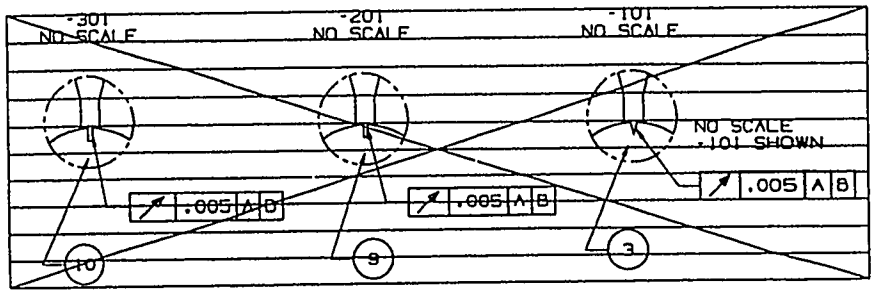
NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN OCA 17073, 15 DEC 92, 8:12:59
3. CEMENT ELEMENTS TOGETHER USING ITEM 6 IN ACCORDANCE OCA 14384, CLASS I REF., NOMINAL THICKNESS BETWEEN ELEMENTS TO BE .0005.
4. DELETED
5. SEAL ITEM 6 (CEMENT) USING ITEMS 12 AND 13 PER OCA 14385.
6. BLACKEN ALL GROUND SURFACES USING ITEM 7 PER AOD 14023 AFTER SEALING CEMENT PER NOTE 5. VACUUM BAKE AT 70°C FOR 8 HOURS.



NO SCALE





AAA92-109462-0C

QTY REQD -401	-301	-201	-101	CODE NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	ITEM NO.
AR					003484-2	SILICONE PRIMER	NUSIL CF2-135	13
AR					003158-CF5	FLUOROSILICONE ELASTOMER	NUSIL CF5-3521-2	12
1					880-1001-401	ELEMENT NO. 2		11
	1				~~880-1001-301~~	~~ELEMENT NO. 2~~		~~10~~
		1			~~880-1001-201~~	~~ELEMENT NO. 2~~		~~9~~
								8
AR	AR	AR	AR		003322	COATING, OPTICAL BLACK	FLOQUIL	7
AR	AR	AR	AR		002349	CEMENT, DC93-500	DOW CORNING	6
								5
1	1	1	1		880-1002-001	ELEMENT NO. 3		4
			1		~~880-1001-101~~	~~ELEMENT NO. 2~~		~~3~~
1	1	1	1		880-1000-001	ELEMENT NO. 1		2
REF	REF	REF	REF		880-0002-DASH	ELEMENTS ASSEMBLED		1

PARTS LIST

-401	1				880-0001-401		
-301	1				880-0001-301		
-201	1				880-0001-201		
-101	1				880-0001-101		
PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON			
	QTY REQD FOR ASSY		APPLICATION				

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/16 DECIMALS .XX±.03 .XXX±.010 ANGLES ±1/2° DO NOT SCALE DRAWING

TREATMENT NOTED

FINISH NOTED

CONTRACT NO.

APPROVALS	DATE
DRAWN R. NICHOLSON	92-09-01
CHECKED E. ARRIOLA	92-09-10
P.E. H. VON HANDORF	92-09-10
F.M. M. SEILONEN	92-09-11

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE., GARDEN GROVE, CA 92641

ELEMENTS ASSEMBLED
STAR-TRACKER OPTICS

SIZE	CODE NO.	DWG NO.	REV.
C	16735	880-0002-DASH	C

SCALE 2:1 | NO. RELEASE DATE 92- | SHEET OF

CAD SYS: OCA	FILE: CLEM	RETRIEVE: 880-0002DASH	LAYERS: 1

D. SMALL 92-09-10
J. DELISO 92-09-10
ADDITIONAL APPROVALS DATE

OFFICIAL USE

NEW TOLERANCE BLOCK

880-0002-DASH

SHEET C

OFFICIAL COPY

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14427		
	B	SEE ECN 14573	93-2-11	

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

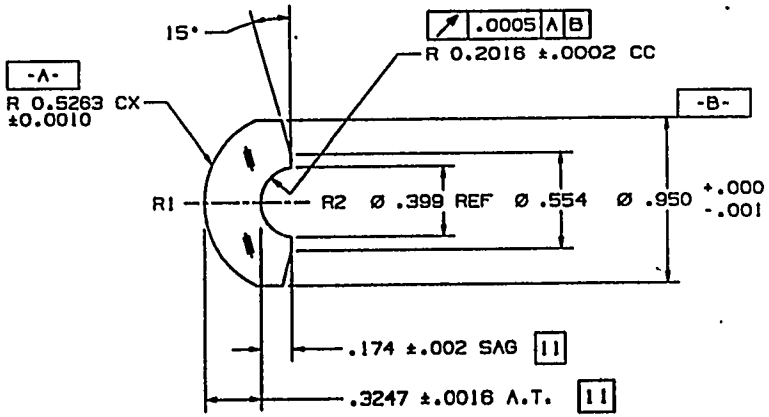
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN OCA 17073, 15 DEC 92, 8:12:59
3. MATERIAL: OPTICAL GLASS, TYPE SF6G05, 809-253, GRADE A PER MIL-G-174, FINE ANNEAL
4. MELT VARIATIONS DO NOT REQUIRE RECOMPUTATION
5. SURFACES R1 AND R2 TO BE POLISHED AND ALL OTHERS TO BE FINE GROUND WITH 220 GRIT SIZE OR EQUIV.
6.

SURFACE	R1	R2
POWER (WAVES)	NOTED	NOTED
IRREGULARITY (WAVES) P-V	SEE NOTE 9	SEE NOTE 10
SCRATCH - DIG	40-20	60-40
MINIMUM CLEAR APERTURE Ø	0.838 IN.	0.394 IN.
COATING	SEE NOTE 8	---
CEMENT	---	R1, 880-1001

POWER AND IRREGULARITY ARE SPECIFIED AT 633nm.

7. PROTECTIVE BEVEL ON EDGE PER AOD 14188
8. COATING: A/R COAT USING MgF2 TO REDUCE REFLECTANCE IN THE SPECTRAL RANGE 450-1000NM. COATING TO MEET THE DURABILTY, ADHESION AND SEVERE ABRASION REQUIREMENTS OF MIL-C-48497A
9. LESS THAN 1 FRINGE IRREGULARITY OVER ANY DIAMETER GREATER THAN 0.55 IN.
10. LESS THAN 1 FRINGE IRREGULALRITY OVER ANY DIAMETER GREATER THAN 0.260 IN.

[11] DIMENSIONS TO BE MEASURED AND RECORDED TO NEAREST, 4-PLACE DECIMAL FOR CEMENTING PURPOSES AT NEXT ASSY



AAA92-109463-0B

CAD SYS: OCA	FILE: CLEM	RETRIEVE: 880-1000-001	LAYERS: 1

ARTISTS						
DRAWN						
CALCULATIONS & PROGRAMS						
MANUFACTURING ENGRG D. SMALL	92-09-10	-001	1			
QUALITY ASSURANCE J. DELISO	92-09-10	PART DASH NO.	NEXT	FINAL STY REQD FOR ASSY	NEXT ASSY	USED ON
ADDITIONAL APPROVALS	DATE				APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/16 DECIMALS .XX±0.03 .XXX±0.010 ANGLES ±1/2° DO NOT SCALE DRAWING

TREATMENT NOTED

FINISH NOTED

SIMILAR TO | REV BY | CALC BY

CONTRACT NO.

APPROVALS	DATE
DRAWN R. NICHOLSON	92-09-08
CHECKED E. ARRIOLA	92-09-10
P.E. A. VON HANDORF	92-09-10
P.M. G. SEILONEN	92-09-11

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE., GARDEN GROVE, CA 92641

ELEMENT NO. 1
STAR TRACKER OPTICS

SIZE	CAGE NO.	DWG NO.	REV.
C	16735	880-1000-001	B

SCALE 2:1 | RELEASE DATE 92- | SHEET OF

1 NEW TOLERANCE BLOCK.

OFFICIAL USE

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN OCA 17073, 15 DEC 92, 8:12:59
3. MATERIAL: OPTICAL GLASS, TYPE LAK9G15, 691-547, GRADE A PER MIL-G-174, FINE ANNEAL
4. MELT VARIATIONS DO NOT REQUIRE RECOMPUTATION
5. SURFACES R1 AND R2 TO BE POLISHED AND ALL OTHERS TO BE FINE GROUND WITH 220 GRIT SIZE OR EQUIV.
6.

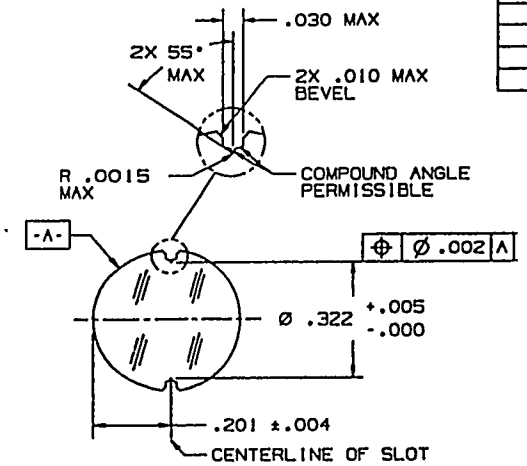
SURFACE	R1	R2
POWER (WAVES)	NOTED	NOTED
IRREGULARITY (WAVES) P-V	SEE NOTE 8	SEE NOTE 8
SCRATCH - DIG	60-40	60-40
MINIMUM CLEAR APERTURE Ø	0.394 IN.	0.376 IN.
COATING	---	---
CEMENT	R2, 880-1000	R1, 880-1002

POWER AND IRREGULARITY ARE SPECIFIED AT 633nm.

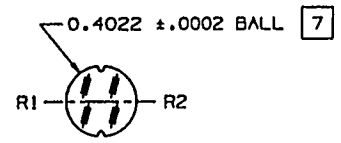
7. DIMENSION TO BE MEASURED AND RECORDED TO NEAREST 4-PLACE DECIMAL FOR CEMENTING PURPOSES AT NEXT ASSY.
8. LESS THAN 1 FRINGE IRREGULALRITY OVER ANY DIAMETER GREATER THAN 0.260 IN.
9. MANUFACTURE GROOVE IN ACCORDANCE WITH OCA 14382.

REVISIONS

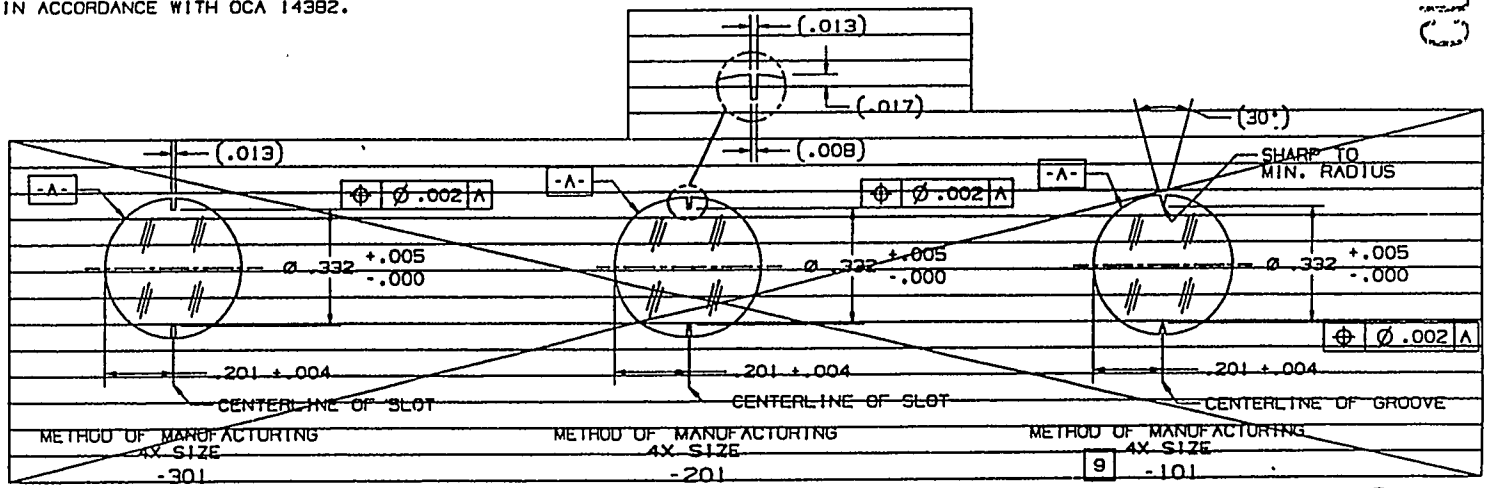
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14434		
	B	SEE ECN 14444	92-10-12	
	C	SEE ECN 14472	92-11-23	m.m.
	D	SEE ECN 14507	92-12-15	
	E	SEE ECN 14530	93-01-13	RVH
	F	SEE ECN 14574	93-03-15	



METHOD OF MANUFACTURING
4X SIZE
-401



FINISHED ELEMENT
-401 SHOWN



METHOD OF MANUFACTURING 4X SIZE -301

METHOD OF MANUFACTURING 4X SIZE -201

METHOD OF MANUFACTURING 4X SIZE -101

AAA92-109464-0F (F)

-401	1	880-0002-401			
-301	1	880-0002-301			
-201	1	880-0002-201			
-101	1	880-0002-101			
PART DASH NO.	NEXT ASSY	FINAL	NEXT ASSY	USED ON	
	QTY REQD FOR ASSY		APPLICATION		

RELEASE		
STRESS		
MATERIALS & PROCESSES		
MANUFACTURING BASIS D. SMALL	92-09-10	
QUALITY ASSURANCE J. DELISO	92-09-11	
ADDITIONAL APPROVALS	DATE	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/16 DECIMALS .XX±.03 .XXX±.010 ANGLES ±1/2° DO NOT SCALE DRAWING

TREATMENT NOTED

FINISH NOTED

SIMILAR TO | ACT BY | DATE BY

CONTRACT NO.

APPROVALS	DATE
DRAWN R NICHOLSON	92-09-08
CHECKED E. ARRIOLA	92-09-10
P.E. A VON HANDORF	92-09-10
P.M. U. SEILONEN	92-09-11

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

ELEMENT NO. 2
STAR TRACKER OPTICS

SIZE	CAGE NO.	DWG NO.	REV.
C	16735	880-1001-DASH	F

SCALE 2:1 | RELEASE DATE 92- | SHEET OF

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 880-1001DASH | LAYERS: 1

1 NEW TOLERANCE BLOCK

880-1001-DASH F

OFFICIAL USE

OFFICIAL COPY

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 1447[illegible]		
	B	SEE ECN 1457[illegible]	93-02-15	[illegible]

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

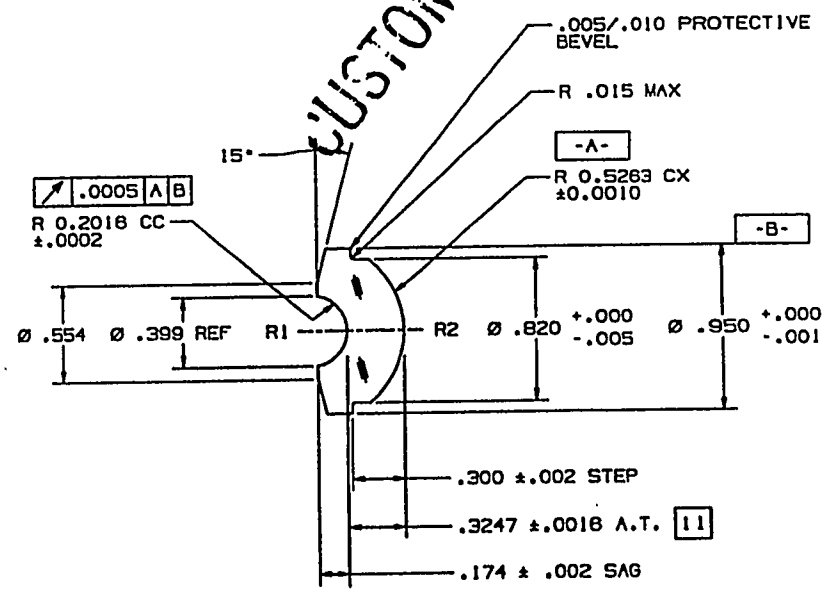
1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN OCA 17073, 15 DEC 92, 8:12:59
3. MATERIAL: OPTICAL GLASS, TYPE LAK9G15, 691-547, GRADE A PER MIL-G-174, FINE ANNEAL
4. MELT VARIATIONS DO NOT REQUIRE RECOMPUTATION
5. SURFACES R1 AND R2 TO BE POLISHED AND ALL OTHERS TO BE FINE GROUND WITH 220 GRIT SIZE OR EQUIV.
6.

SURFACE	R1	R2
POWER (WAVES)	NOTED	NOTED
IRREGULARITY (WAVES) P-V	SEE NOTE 9	SEE NOTE 10
SCRATCH - DIG	60-40	40-20
MINIMUM CLEAR APERTURE Ø	0.376 IN.	0.598 IN.
COATING	---	SEE NOTE 8
CEMENT	R2, 880-1001	---

POWER AND IRREGULARITY ARE SPECIFIED AT 633nm.

7. PROTECTIVE BEVEL ON EDGE PER AOD 14188
8. COATING: A/R COAT USING MgF2 TO REDUCE REFLECTANCE IN THE SPECTRAL RANGE 450-1000NM. COATING TO MEET THE DURABILTY, ADHESION AND SEVERE ABRASION REQUIREMENTS OF MIL-C-48497A
9. LESS THAN 1 FRINGE IRREGULARITY OVER ANY DIAMETER GREATER THAN 0.260 IN.
10. LESS THAN 1 FRINGE IRREGULALRITY OVER ANY DIAMETER GREATER THAN 0.550 IN.

[11] DIMENSIONS TO BE MEASURED AND RECORDED TO NEAREST 4-PLACE DECIMAL FOR CEMENTING PURPOSES AT NEXT ASSY



AAA92-109465-0B (B)

DRAWN	R NICHOLSON	92-09-08	
DESIGNED	E. ARRIOLA	92-09-10	
M.E.	R VON HANDORF	92-09-10	
Q.A.	W. SEILONEN	92-09-11	

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE. GARDEN GROVE, CA 92641

ELEMENT NO. 3
STAR TRACKER OPTICS

SIZE C | CODE NO. 16735 | DWG NO. 880-1002-001 | REV. B
SCALE 2:1 | RELEASE DATE 92- | SHEET OF

D. SMALL	92-09-11	-001	1
J. DELISO	92-09-11	PART DASH NO.	NEXT ASSY
ADDITIONAL APPROVALS	DATE		APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/16 ANGLES ±1/2° .XX±.03 .XXX±.010 DO NOT SCALE DRAWING
TREATMENT NOTED
FINISH NOTED
CONTRACT NO.

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 880-1002-001 | LAYERS: 1

1 NEW TOLERANCE BLOCK

OFFICIAL USE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14523	92-1-7	RVH
	B	SEE ECN 14576	93-2-11	[illegible]

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.

2. REF. OPTICAL DESIGN OCA 17073, 15 DEC 92, 8:12:59

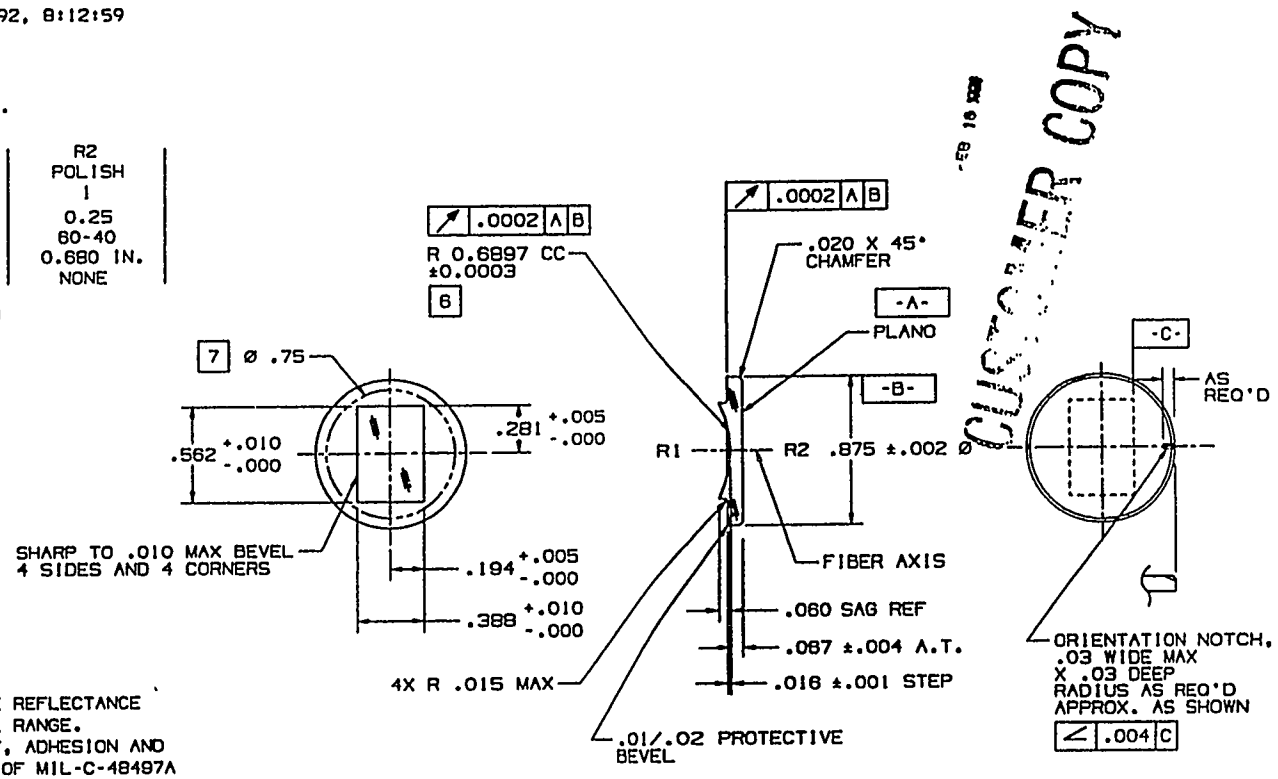
1. MATERIAL: MAKE FROM P/N 880-1003.

2. FINE GRIND WITH 220 GRIT SIZE OR EQUIV.

3. SURFACE

	R1	R2
FINISH	POLISH	POLISH
POWER (WAVES)	2	1
IRREGULARITY (WAVES)	1	0.25
SCRATCH - DIG	60-40	60-40
MINIMUM CLEAR APERTURE Ø	.542 X .368	0.680 IN.
COATING	SEE NOTE 5	NONE

4. PROTECTIVE BEVEL ON EDGE PER AOD 14188



5. COATING: A/R COAT USING MgF2 TO REDUCE REFLECTANCE IN THE 450 TO 1000 nm SPECTAL RANGE. COATING TO MEET THE DURABILTY, ADHESION AND SEVERE ABRASION REQUIREMENTS OF MIL-C-48497A

6 MEASURE AND RECORD RADIUS OF CURVATURE OF R1 TO .0001 INCH.

7 ALL GROUND SURFACES WITHIN DIAMETER NOTED TO BE BLACKENED PER AOD 14023. (INCLUDING SIDES OF RECTANGLE)

CUSTOMER COPY

AAA92-109466-0B (B)

DRAWN	R NICHOLSON	92-09-17	O C A APPLIED OPTICS	
DESIGN	R CHAVEZ	92-10-02	7421 ORANGEWOOD AVE., GARDEN GROVE, CA 92641	
P.E.	A VON HANDORF	92-10-02	FACEPLATE, FIBER OPTICS STAR TRACKER OPTICS	
Q.A.	M. SEILONEN	92-10-05	SIZE C / CODE ID. 16735 / DWG NO. 880-1004-001 / REV. B	
			SCALE 2:1 / RELEASE DATE 92- / SHEET OF	

TREATMENT: NOTED
FINISH: NOTED
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS ±1/16, DECIMALS .XX ±.03, .XXX ±.010, ANGLES ±1/2°. DO NOT SCALE DRAWING

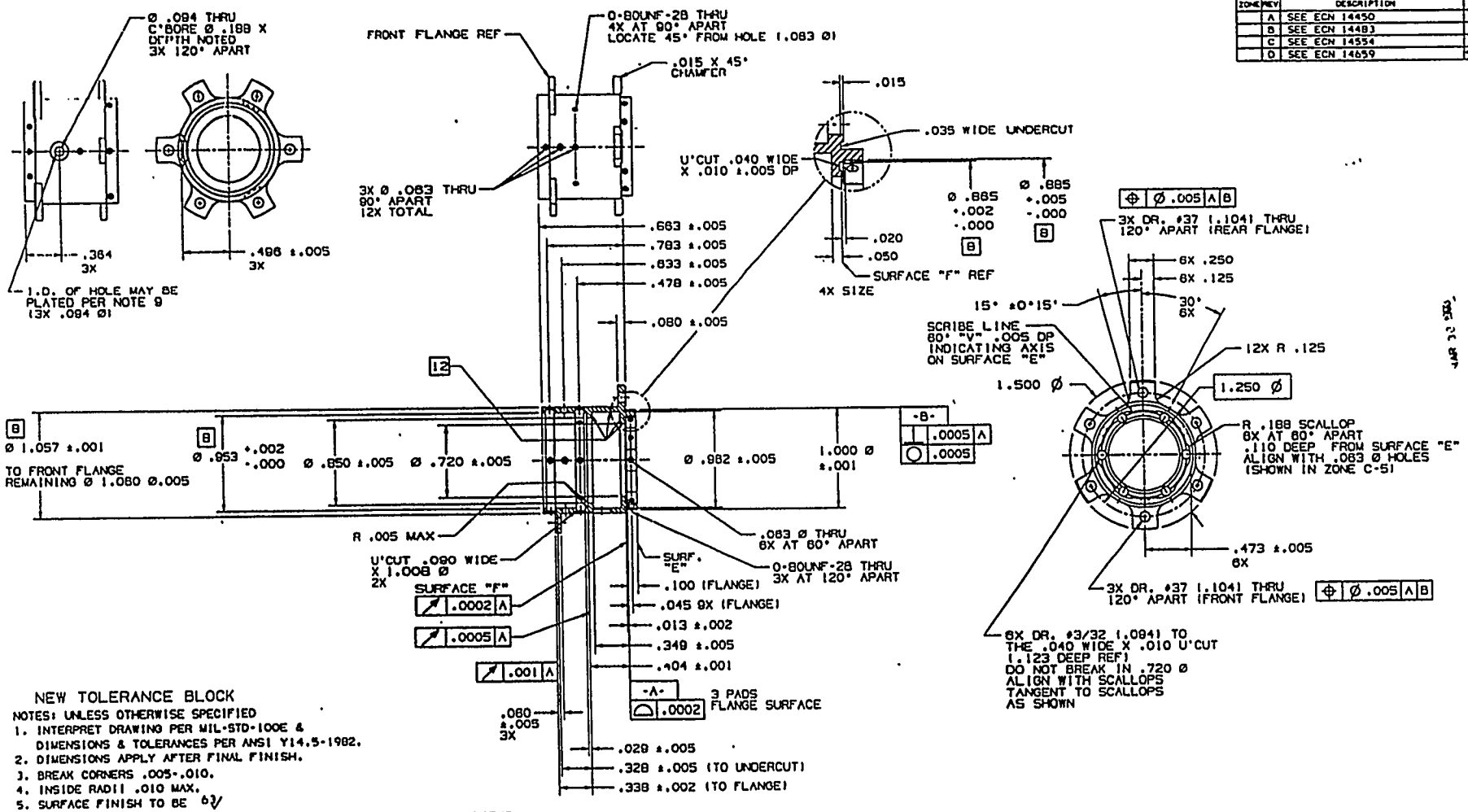
CAD SYS: OCA | FILE: CLEM | RETRIEVE: 880-1004-001 | LAYERS: 1

1 NEW TOLERANCE BLOCK

OFFICIAL USE

880-1005-001 REV. D

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14450	92-10-20	[illegible]
	B	SEE ECN 14483	92-12-3	[illegible]
	C	SEE ECN 14554	93-06-17	[illegible]
	D	SEE ECN 14659	[illegible]	[illegible]



NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-T651 ALUM ALLOY PER QQ-A-200/8 OR QQ-A-225/8.
7. STRESS RELIEVE PER AOD 15023 BEFORE FINAL MACHINING

[8] RUNOUT OF SURFACES NOTED TO BE WITHIN .001 OF DATUM -B-

[9] DELETED

[10] DELETED

11. DELETED
12. FINISH: PLATE ENTIRE PART WITH 0.0001 TO 0.00015 INCH THICK NICKEL PER MIL-C-26074, CLASS 1, THEN PLATE ENTIRE PART WITH 0.00025 TO 0.00035 INCH THICK COPPER PER MIL-C-14550, THEN BLACKEN PER MIL-F-495. DO NOT HANDLE SURFACES NOTED AFTER BLACKENING.
13. PART TO BE BAGGED AND TAGGED IN A MANNER TO PROTECT IT FROM DEBRIS.

CAD SYSTICA | FILE:CLEM | RETRIEVE: 880-1005-001 | LAYER(S): 1

AAA92-109467-0D (D)

WEIGHTS			
STRESS			
MATERIALS & PROCESSES			
MANUFACTURING BASIS	D SMALL	92-10-15	-001
QUALITY ASSURANCE	J DELISO	92-10-14	PART DASH NO.
ADDITIONAL APPROVALS		DATE	QTY REQD PER ASSY

NEXT | FINAL | 880-0001DASH- | NEXT ASSY | USED ON | APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES .XX±.03 ±1/2° .XXX±.010 DO NOT SCALE DRAWING

TREATMENT: SEE NOTES
FINISH: SEE NOTES
SIMILAR TO | ACT. WT | CALC WT

CONTRACT NO.

APPROVALS	DATE
DESIGN R NICHOLSON	92-10-07
DRAFTER R CHAVEZ	92-10-14
MFG R VONHANDORF	92-10-15
QA M SEILONEN	92-10-15

O C A APPLIED OPTICS
[illegible]

HOUSING
STAR TRACKER OPTICS

SIZE D | CAGE NO. 16735 | DWG NO. 880-1005-001 | REV. D
SCALE 2/1 | PLANE ZONE 52- | SHEET 1 OF 1

NEW TO FRANCE

CUSTOMER COPY

OFFICIAL USE

NEW TOLERANCE BLOCK

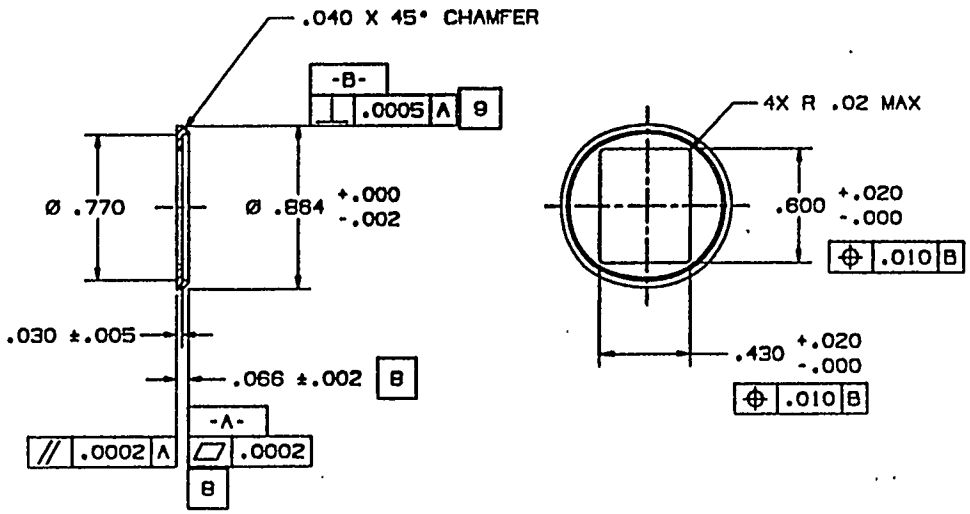
NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. DIMENSIONS APPLY AFTER FINAL FINISH.
3. BREAK CORNERS .005-.010.
4. INSIDE RADII .010 MAX.
5. SURFACE FINISH TO BE 63
6. MATERIAL: 6061-T651 ALUM ALLOY PER QQ-A-200/8.
7. STRESS RELIEVE PER AOD 15023 BEFORE FINAL MACHINING.

[8] ADDITIONAL MACHINING WILL BE REQUIRED AT NEXT ASSY TO MEET OPTICAL REQUIREMENTS FROM SURFACE NOTED. .015 EXCESS MATERIAL HAS BEEN ADDED TO DIMENSION SHOWN.
ALODINE "1201" PER MIL-C-5541, CL. 1A TO ALL EXPOSED SURFACES.

[9] PART TO BE RACKED ON SURFACE NOTED FOR ANODIZING.

10. FINISH: FLAT BLACK ANODIZE PER AOD 15012.



CUSTOMER COPY

AAA92-109468-00

OFFICIAL USE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

CAD SYS: OCA	FILE: CLEM	RETRIEVE: 880-1006-001	LAYERS: 1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ARE: FRACTIONS ±1/16 DECIMALS .XX±.03 .XXX±.010 ANGLES ±1/2° DO NOT SCALE DRAWING

TREATMENT: NOTED

FINISH: NOTED

APPROVALS: R NICHOLSON

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE., GARDEN GROVE, CA 92641

SPACER, FOCUS
STAR TRACKER OPTICS

SIZE C | CAGE NO. 16735 | DWG NO. 880-1006-001 | REV. 0

SCALE 2:1 | SHEET OF

1 NEW TOLER

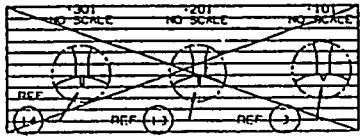
880-0001-DASH | C

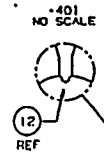
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14449	92-10-20	[illegible]
	B	SEE ECN 14533	92-01-18	[illegible]
	C	SEE ECN 14539	93-04-27	[illegible]

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN OCA 17073 15 DEC 92 8:12:59
3. ADDITIONAL MACHINING FROM FOCUS SPACER IS REQUIRED TO MEET OPTICAL REQUIREMENTS. ALODINE "1201" PER MIL-C-5541, CL. 1A TO ALL EXPOSED SURFACES.





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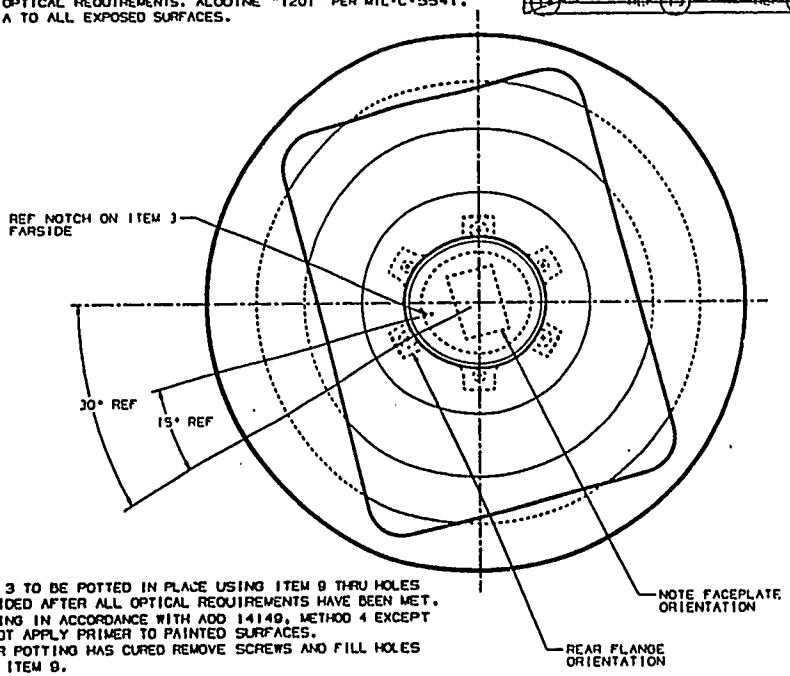
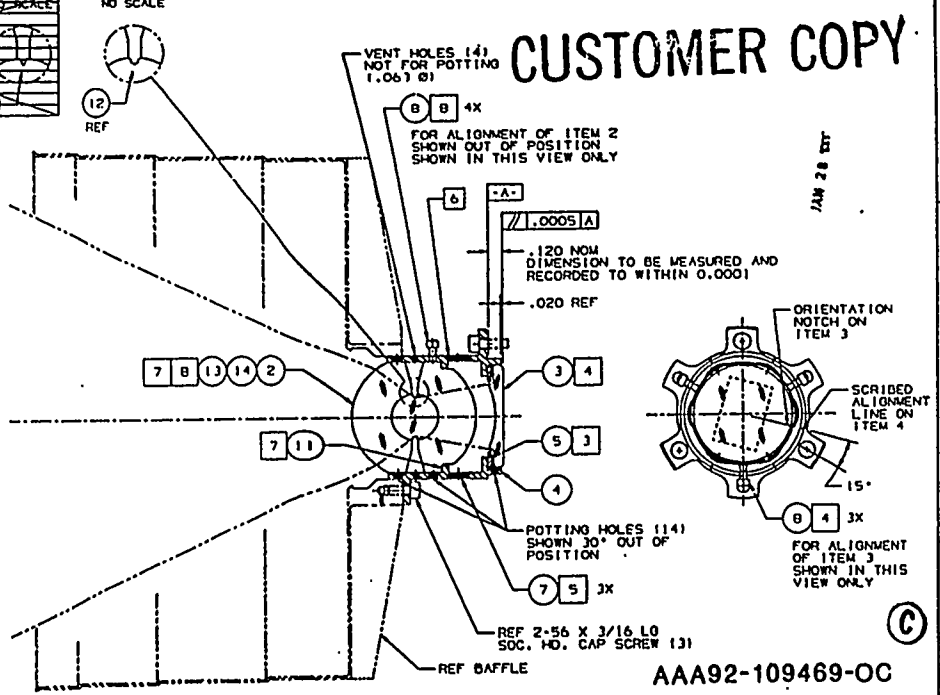




AAA92-109469-OC

4. ITEM 3 TO BE POTTED IN PLACE USING ITEM 9 THRU HOLES PROVIDED AFTER ALL OPTICAL REQUIREMENTS HAVE BEEN MET. POTTING IN ACCORDANCE WITH ADD 14149, METHOD 4 EXCEPT DO NOT APPLY PRIMER TO PAINTED SURFACES. AFTER POTTING HAS CURED REMOVE SCREWS AND FILL HOLES WITH ITEM 9.
5. ITEM 7 TO BE BONDED IN PLACE USING ITEM 8 IN ACCORDANCE WITH ADD 14149, METHOD 1 OR 2 AS APPLICABLE.
6. MARK EACH LENS WITH ITS PART NUMBER AND A SERIAL NUMBER IN THE FASHION: "S/N _". BEGIN WITH S/N 1 AND NUMBER SEQUENTIALLY WITHOUT SKIPPING USING ITEM 10.
7. INITIAL BONDING OF ITEMS 2, 13 AND 14 INTO ITEM 4 USING A MIXTURE OF ITEM 9 AND 11. MIX BY VOLUME APPROX 5% OF ITEM 11 INTO ITEM 9. APPLY TO THE MATING SURFACES BETWEEN THE ELEMENT SEAT AND HOUSING ONLY. APPROX. THICKNESS OF CEMENT IS .0055. APPLY PER MANUFACTURERS RECOMMENDATIONS. DO NOT APPLY PRIMER TO PAINTED SURFACES. ALIGN ITEM 2 TO ACCURACY REQUIRED WITHIN 30 MINUTES OF APPLYING BONDING MATERIAL.
8. ITEMS 2, 12, 13 AND 14 TO BE POTTED IN PLACE USING ITEM 9 AND 17 PER ADD 14149, METHOD 4 EXCEPT DO NOT APPLY PRIMER TO PAINTED SURFACES. POTTING HOLES ARE PROVIDED. AFTER POTTING HAS CURED REMOVE SCREWS AND FILL HOLES WITH ITEM 9.
9. TRACEABILITY IN ACCORDANCE WITH ADD 13033.

AR						002824-4155	PRIMER, SILICONE RUBBER	G.E. SS-4155	17
	3	3	3	3		MS16995-1	SCREW, SOC HD, CAP	2-56 X 3/16	16
	REF	REF	REF	REF		000-0004-001	BAFFLE (CUST SUPPLIED)		15
	1					000-0003-001	ELEMENTS ASSEMBLED		14
						000-0002-001	ELEMENTS ASSEMBLED		13
1						000-0002-401	ELEMENTS ASSEMBLED		12
7	AR	AR	AR	AR		003418-373	UNIFORM GLASS SPHERES (140um (.0055) #373 OR 3738)	DUKE SCIENTIFIC CORP	11
	AR	AR	AR	AR		001054	INK, WHT/CAT, #9	WORNOW 50-100	10
	AR	AR	AR	AR		000364	ADHESIVE	G.E. RTV566A/B	9
	7	7	7	7		MS16361C-00-2	SCREW, SOC HD, CAP	0-00 X 1/8 LO	8
	3	3	3	3		002473	POROUS FILTER, S-1630	SINTERED SPECIALTIES	7
									6
	1	1	1	1		880-1006-001	SPACER, FOCUS		5
	1	1	1	1		880-1005-001	HOUSING		4
	1	1	1	1		000-1004-001	FACEPLATE, FIBER OPTICS		3
						000-0002-101	ELEMENTS ASSEMBLED		2
	REF	REF	REF	REF		000-0001-DASH	STAR TRACKER OPTICS		1
	REF NO.	REF NO.	REF NO.	REF NO.	ZONE NO.	PART OR IDENTIFYING NO.	DESCRIPTION OR NOMENCLATURE	REFERENCE DESIGNATION	ITEM NO.

PARTS LIST

WEIGHTS			
STATUS			
MATERIALS & PROCESSES			
MANUFACTURING ENGR D SMALL	92-10-15		
QUALITY ASSURANCE J DELISO	92-10-15		
ADDITIONAL APPROVALS	DATE		

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES ± .XX±.03 ±1/2° .XXX±.010 DO NOT SCALE DRAWING

TREATMENT SEE NOTES

FINISH SEE NOTES

SIMILAR TO | ACT. QT | CALC QT

CONTRACT NO.

APPROVALS	DATE
DRAWN R NICHOLSON	92-09-29
CHECKED R CHAVEZ	92-10-14
ENG R VONHANDORF	92-10-15
PROJ M SEILONEN	92-10-15

O C A APPLIED OPTICS

[illegible] GROVEWOOD AVE., GARDEN GROVE, CA 92641

STAR TRACKER OPTICS (CLEMENTINE)

SIZE D | CAGE NO. 16735 | DWG NO. 880-0001-DASH | REV. C

SCALE 2/1 | SHEET 1 OF 1

NEXT ASSY | USED ON | APPLICATION

CAD SYS: OCA | FILE: ICLEM | RETRIEVE: 880-0001DASH | LAYER: STI: 1

NEW TOLERANCE

OFFICIAL USE

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED
	A	SEE ECN 14727	93-04-29	

NEW TOLERANCE BLOCK

NOTES: UNLESS OTHERWISE SPECIFIED

1. INTERPRET DRAWING PER MIL-STD-100E & DIMENSIONS & TOLERANCES PER ANSI Y14.5-1982.
2. REF. OPTICAL DESIGN 921026 3 NOV 92 09:01:46
3. MATERIAL: ZINC SELENIDE
4. MELT VARIATIONS DO NOT REQUIRE RECOMPUTATION.
5. SURFACE R2 AND SURFACES NOTED TO BE DIAMOND TURNED. R1 WAS POLISHED ON SHEET 2, ALL OTHERS ARE FINE GROUND
6.

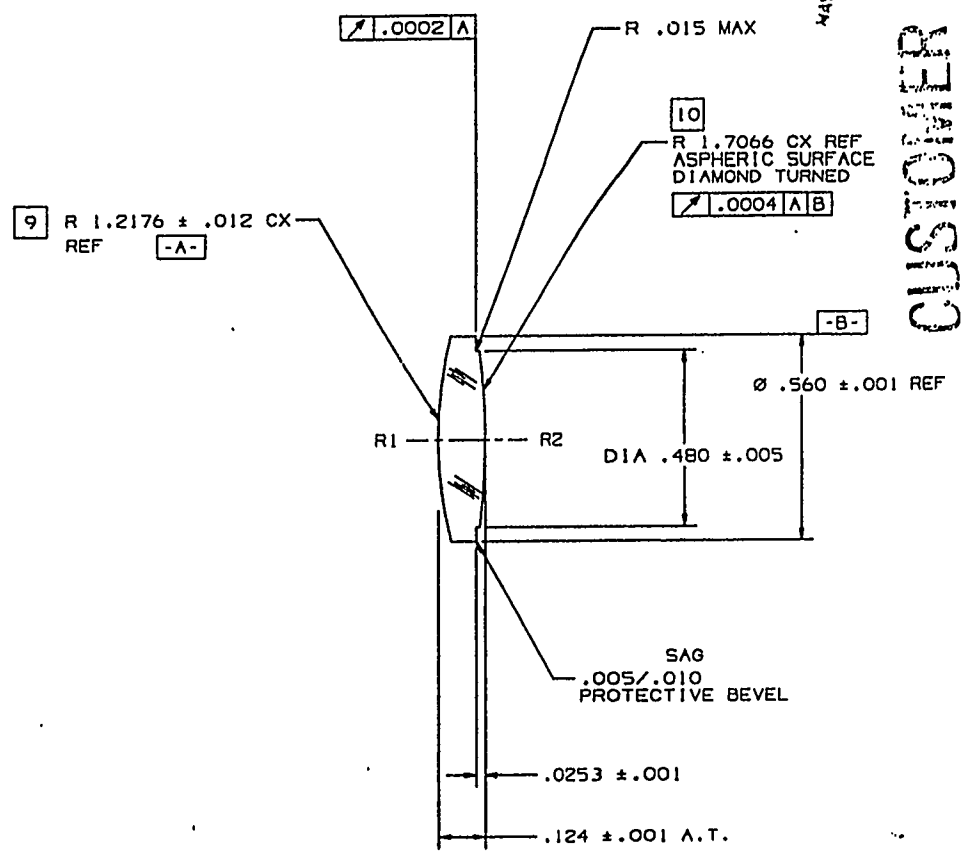
SURFACE	R1	R2
POWER (WAVES)	SEE SHEET 2	N/A
IRREGULARITY (WAVES)	SEE SHEET 2	.5
SCRATCH-DIG	SEE SHEET 2	E-E
MINIMUM CLEAR APERTURE	SEE SHEET 2	0.442 IN.
COATING	SEE NOTE 8	SEE NOTE 8
CEMENT	---	---

POWER AND IRREGULARITY ARE SPECIFIED AT 633nm
SCRATCH AND DIG IN ACCORDANCE WITH MIL-F-48616

7. PROTECTIVE BEVEL ON ALL EDGES PER AOD 14188 EXCEPT AS NOTED
8. AR COATING FROM 8.0 TO 9.5um WITH ANGLES OF INCIDENCE FROM 0° TO 25°. THE COATING SHALL HAVE LESS THAN 0.5 AVERAGE REFLECTIVITY OVER THE SPECIFIED BAND AND ANGLES OF INCIDENCE. COATING SHALL MEET THE DURABILITY, ADHESION AND MODERATE ABRASION REQUIREMENTS OF MIL-C-48497A.

[9] EXISTING RADIUS GENERATED PER SHEET 2.

[10] DIAMOND TURNED ASPHERIC SURFACE
ASPHERIC CONSTANTS:
VERTEX RADIUS =-1.7066
A2 = 0.000000E+00
A4 = 5.953731E-01
A6 =-1.789388E+00
A8 =-1.382198E+01



THIS SHEET IS
FINAL FABRICATED PART
AAA92-109643-0A

CISCO CORP COPY

806-5058

-000	1		806-5058-001				
PART DASH NO.	NEXT	FINAL	NEXT ASSY	USED ON			
	QTY REQD PER ASSY		APPLICATION				

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ±1/16 DECIMALS .XX±±.03 .XXX±±.010 ANGLES ±1/2° DO NOT SCALE DRAWING
TREATMENT NOTED
FINISH NOTED

CONTRACT NO.

APPROVALS	DATE
DRAWN MIES	92-11-11
CHECKED R.TORGERSEN	92-11-30
P.E. R.VONHANDORF	92-11-01
P.M. M.SEILONEN	92-12-01

M.PATE 92-12-01
J.DELISO 92-12-01
ADDITIONAL APPROVALS DATE

O C A APPLIED OPTICS
7421 ORANGEWOOD AVE, GARDEN GROVE, CA 92641

ELEMENT NO. 7

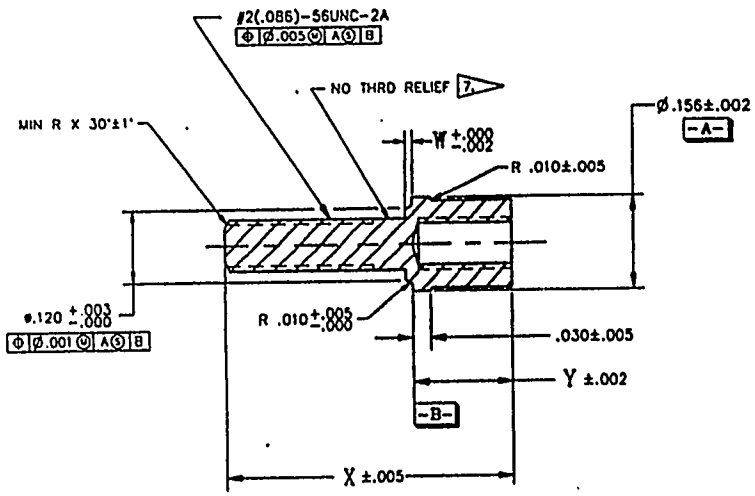
SIZE	CAGE NO.	DWG NO.	REV.
C	16735	806-5058-001	A

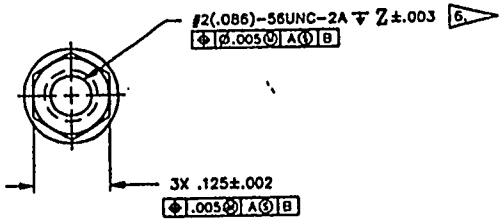
SCALE 4:1 RELEASE DATE 92- SHEET 1 OF 2

CAD SYS: OCA | FILE: CLEM | RETRIEVE: 806-5058.00ASHI | LAYERS: 1

OFFICIAL USE

1 NEW TOLERANCE BLOCK





NOTES

UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ✓ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES .005 ±.005 R OR CHAMFER.
6. DO NOT DRILL TAP DRILL BEYOND SPECIFIED THREAD DEPTH. USE BOTTOMING TAP ONLY TO ACHIEVE THREAD.
7. DO NOT MACHINE THREAD RELIEF. USE OF THREADING DIE TO ACHIEVE THREAD IS RECOMMENDED.
8. CLEAN FINISHED PART PER LLLNL SPEC. MFIN-UHV-003, OR EQUIVALENT AS AGREED UPON WITH LLLNL.
9. WRAP IN CLEAN LINT-FREE MATERIAL. BAG AND TAG WITH DWG NO., REV LTR, AND TAB NO. DO NOT MARK ON PART.

TAB NO	—W—	—X—	—Y—	—Z—	DESCRIPTION	USED ON
08	.040	.392	.142	.142	FOR .045 PANELS	CAMERA HOUSING
07	.038	.395	.145	.142	FOR .040 PANELS	
06	.026	.470	.155	.145	FOR .030 PANELS	FILTER HOUSING
05	.020	.417	.160	.150	FOR .025 PANELS	NIR FILTER WHEEL MODULE
04	.014	.385	.165	.155	FOR .020 PANELS	RANGE RECEIVER HOUSING
03	.012	.390	.170	.160	FOR .015 PANELS	CONTROLLER HOUSING
02	.012	.417	.170	.160	FOR .015 PANELS	
01	.012	.485	.170	.160	FOR .015 PANELS	

ENGINEERING RELEASE

APPROVED [signature] PROJECT ENGINEER

DATE 22 April 1993

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		SST 316		

DWN CK. WONG 2/93
CHK [signature] 4/93
APVD [signature] 4/93
CLASSIFIED BY
TITLE DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

SUBUNIT

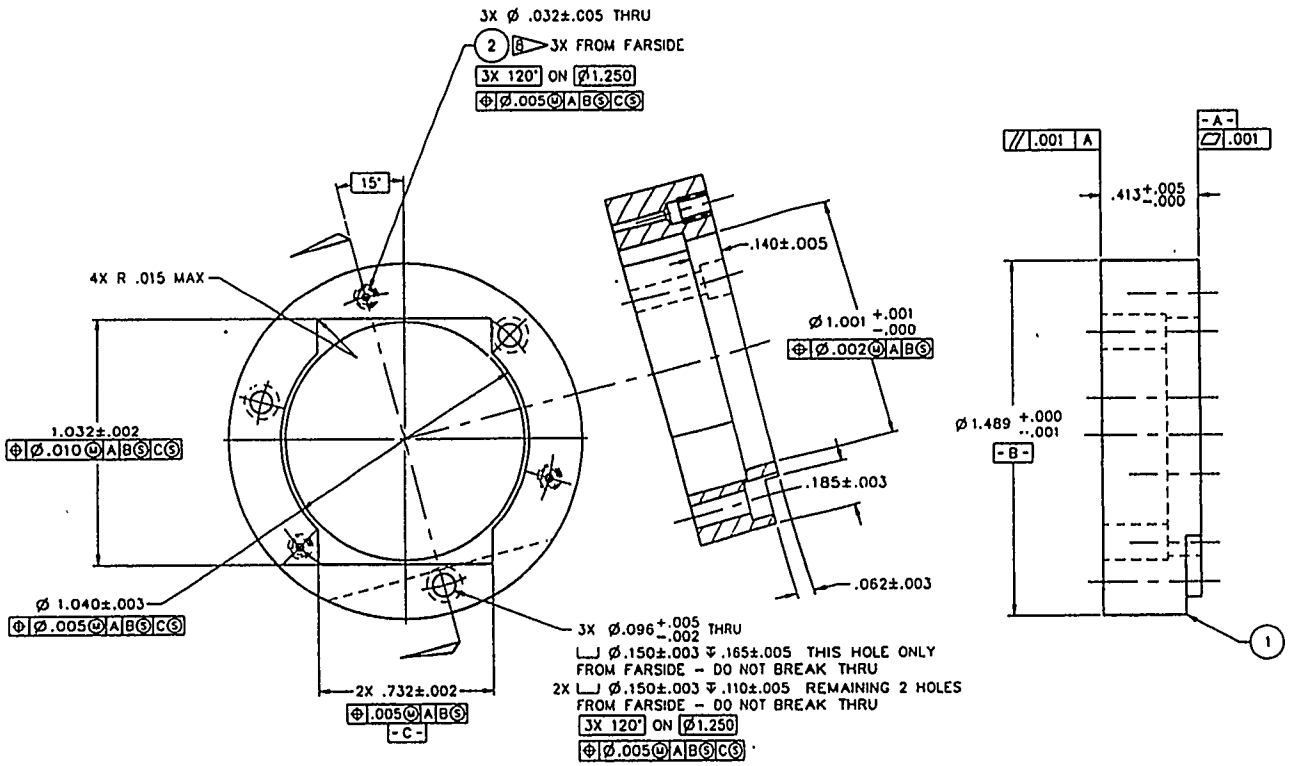
SUBASSY

TITLE MDM CONNECTOR JACKPOST BUSHING

DRAWING NO AAA 93-101167-00

SCALE .200 SHEET 1 OF 1

LTR DWN CHK APVD DATE ZONE CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 ✓ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R.005 MAX OR CHAMFER.
6. INSIDE RADII .010 MAX.
7. CHEMICAL CONVERSION COAT PER MIL-C-5541, CLASS 3, GOLD. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER COATING.
8. INSTALL INSERTS FROM SURFACE INDICATED PER MS33537 AFTER COATING.
9. WRAP IN CLEAN LINT-FREE MATERIAL. BAG & TAG WITH PART NO. & REV. LETTER. DO NOT MARK ON PART.

NO REQD	PART / LINE STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
3		INSERT, SCREW LOCKING, CRES, 2-56 X .129 L	MS21209-C0215	2
1		AL ALY TYPE 6061-T651	QQ-A-250/11	1

DWN Tom Yamam 3/2/93
CHK U TAYLOR 3/93
APVD H. L. PRIEST 3/93
CLASSIFIED BY
TITLE DATE

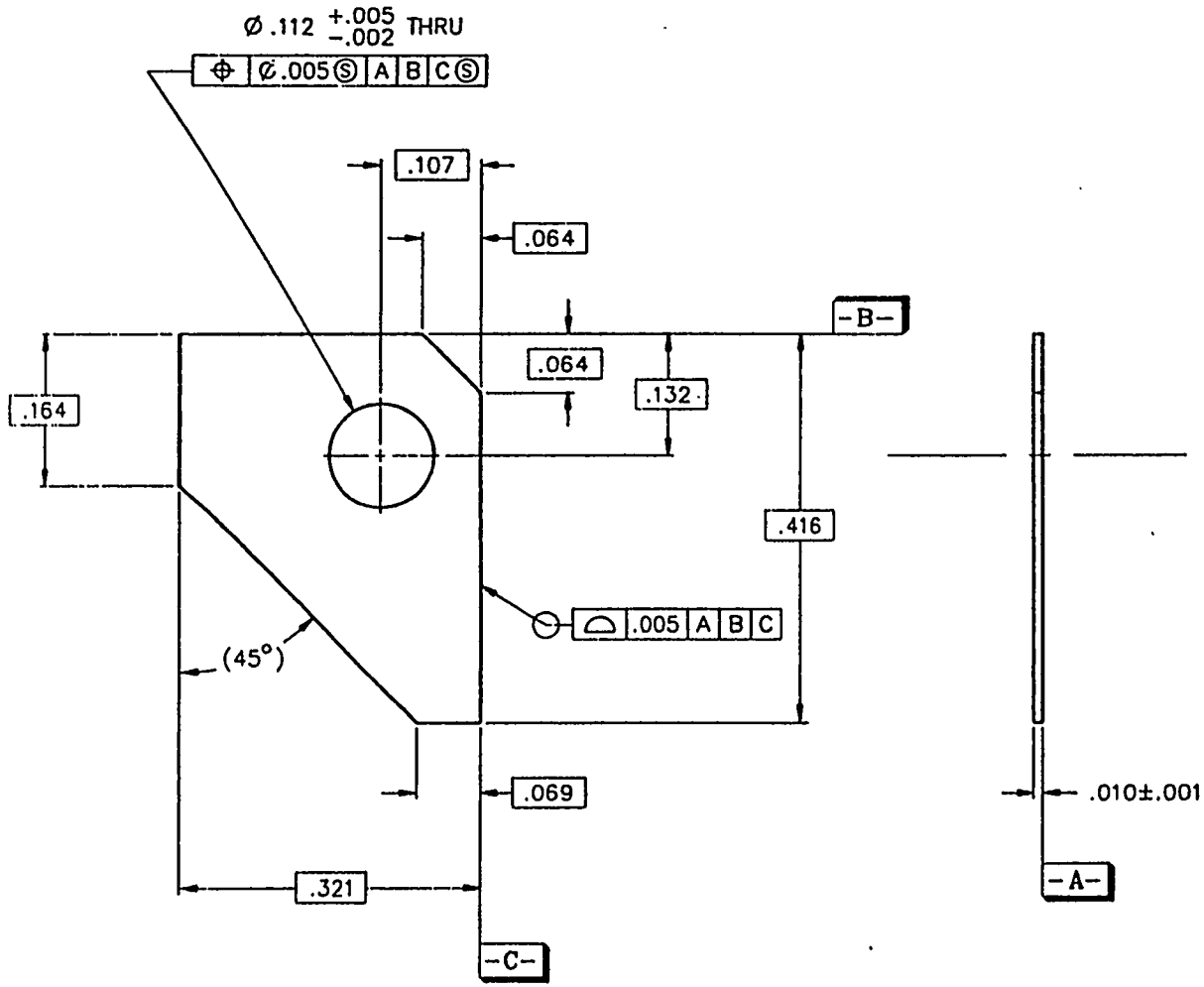
CLASSIFICATION
THIS DOCUMENT IS THE PROPERTY OF THE UNIVERSITY OF CALIFORNIA LAWRENCE LIVERMORE NATIONAL LAB REPRODUCTION PROHIBITED WITHOUT PERMISSION OF THE MECHANICAL ENGINEERING DEPARTMENT

MAJOR UNIT: STAR TRACKER CAMERA ASSY, V3.1
SUBASSY
SYSTEM: LENS STANDOFF
SHOWN ON AAA 92-106282
ACCT NO
DRAWING NO: AAA 93-102550-0A
SCALE 50 SHEET 1 OF 1

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

ENGINEERING RELEASE
APPROVED Project Engineer
Date 8 Apr 1993

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE
A	TSG	[illegible]	[illegible]	4-93	B5	2X C'BORE ADDED



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63√ ALL MACHINED SURFACES
5. BREAK SHARP EDGES R .005 MAX OR CHAMFER
6. CHEMICAL CLEAN PART PER MEL84-001723-00. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER CLEANING.
7. WRAP IN CLEAN LINT-FREE MATERIAL. BAG & TAG WITH PART NO. & REV LETTER. DO NOT MARK ON PART.

ENGINEERING RELEASE
APPROVED Robert E. Priest
Project Engineer
Date 29 Apr 93

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		HALF HARD COPPER (UNS-C11000)	QQ-C-576	

DWN Tom Gorman	4/21/93
CHK J. ROBINSON	4/22/93
APVD R. E. PRIEST	4/23/93
CLASSIFIED BY:	
TITLE	DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

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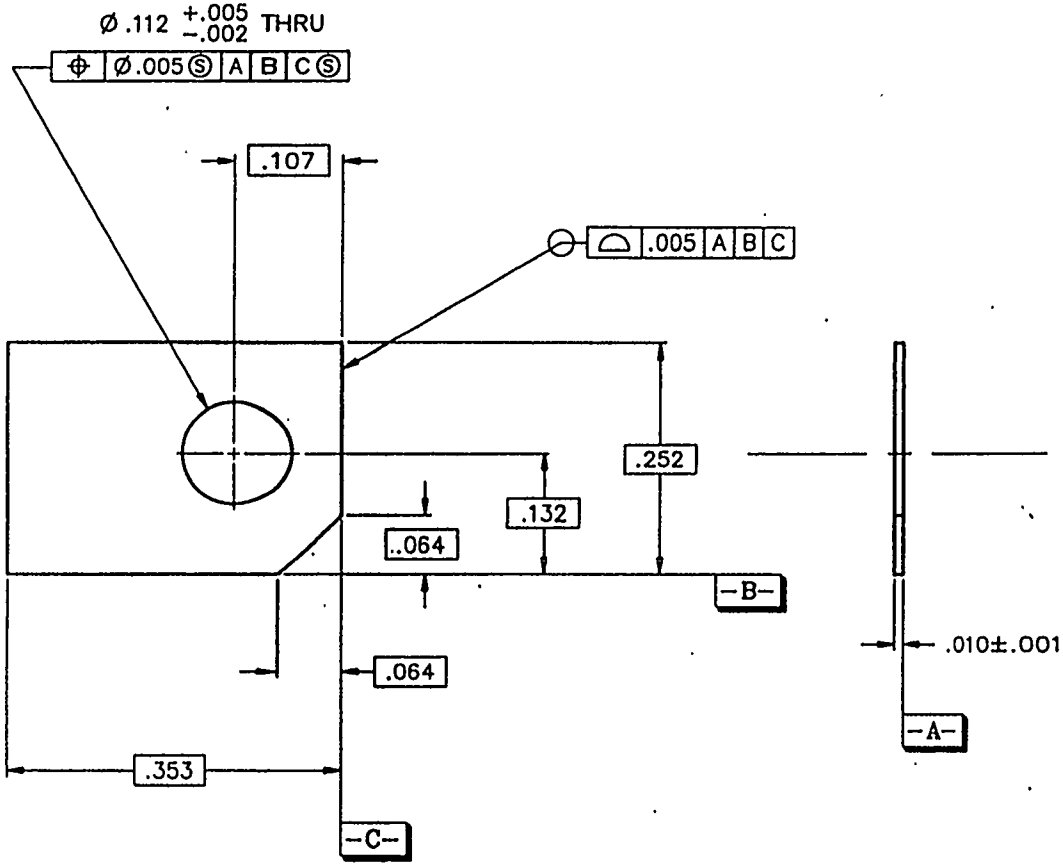
OFFICIAL USE

MAJOR UNIT: STAR TRACKER CAMERA, V3.1
SUBASSY: CAMERA ASSY
DETAIL: END COVER SHIM, UPPER
SHOWN ON AAA: 92-106277
ACCT NO:
DRAWING NO: AAA93-102609-0A
SCALE: .200
SHEET 1 OF 1

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE
A	TSG	JR	RJ	4/93	C4	ADDED .164 DIM



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63 √ ALL MACHINED SURFACES
5. BREAK SHARP EDGES R .005 MAX OR CHAMFER
6. CHEMICAL CLEAN PART PER MEL84-001723-00. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER CLEANING.
7. WRAP IN CLEAN LINT-FREE MATERIAL. BAG & TAG WITH PART NO. & REV LETTER. DO NOT MARK ON PART.

ENGINEERING RELEASE
APPROVED Robert C. Pruit Project Engineer
Date 22 Apr 93

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
		HALF HARD COPPER (UNS-C11000)	QQ-C-576	

DWN Tom Gorman 4/21/93
CHK JAR 4/21
APVD Bob Pruit 4-22-93
CLASSIFIED BY
TITLE DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION
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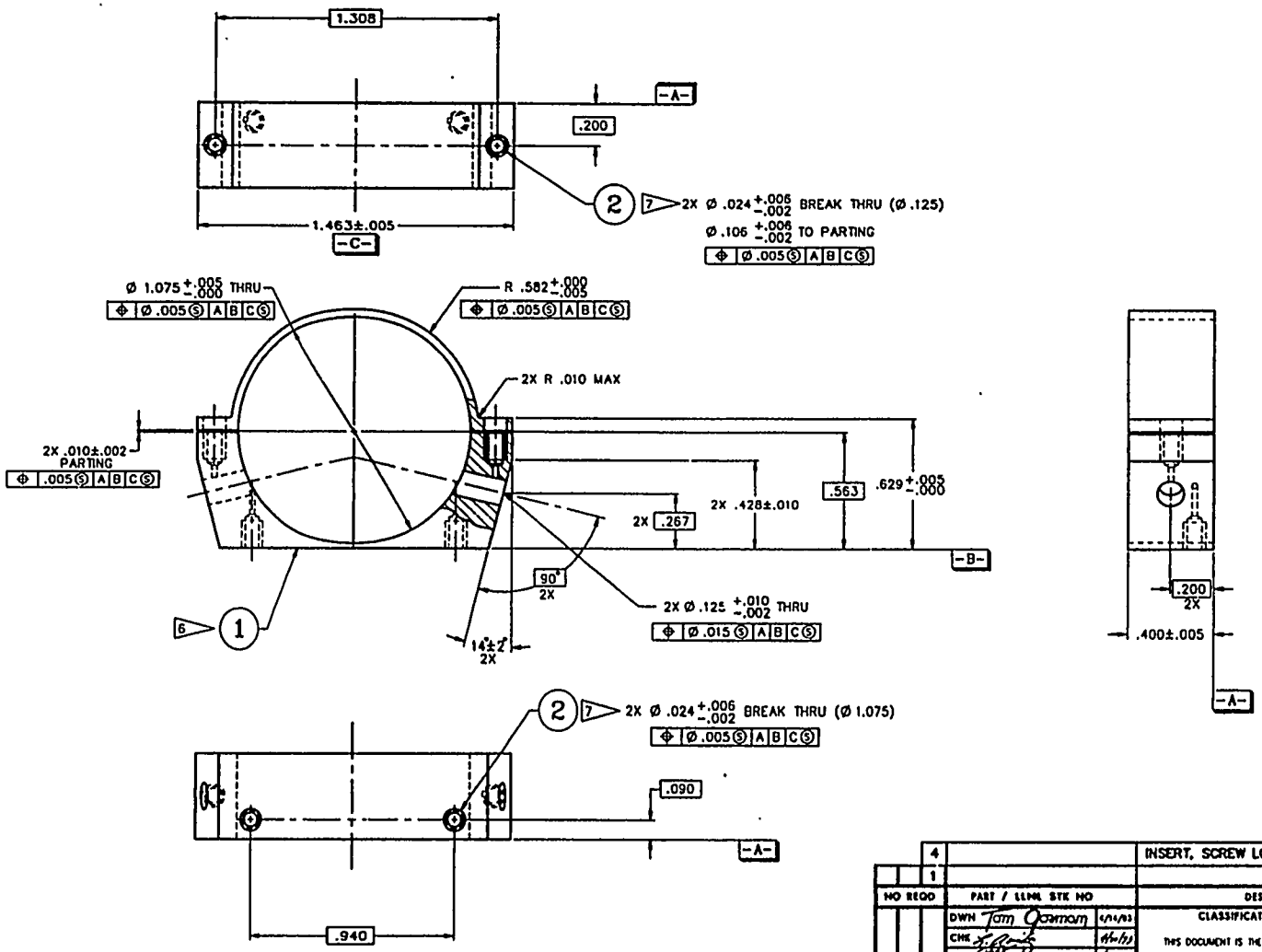
MAJOR UNIT: STAR TRACKER CAMERA, V3.1
SUBASSY: CAMERA ASSY
DETAIL: END COVER SHIM, LOWER
SHOWN ON AAA 92-106277
ACCT NO
DRAWING NO: AAA 93-102610-00
SCALE .200 SHEET 1 OF 1

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE



NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN INCHES.
2. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M-1982.
3. SURFACE TEXTURE PER ANSI B46.1-1978.
4. 63√ ALL MACHINED SURFACES.
5. BREAK SHARP EDGES R .010 MAX OR CHAMFER.
6. CHEMICAL CONVERSION COAT PER MIL-C-5541, CLASS 3, GOLD. HANDLE PART WITH CLEAN LINT-FREE GLOVES AFTER COATING.
7. INSTALL PER MS-33537 AFTER COATING.
8. WRAP IN CLEAN LINT-FREE MATERIAL. BAG & TAG WITH PART NO. & REV. LETTER. DO NOT MARK ON PART.

NO REQD	PART / LLNL STK NO	DESCRIPTION / MATERIAL	SPEC NO	ITEM
4		INSERT, SCREW LOCKING, CRES, 2-56UNC X .129L, MS21209-C0215		2
1		AL ALY TYPE 6061-T651	QQ-A-250/11	1

ENGINEERING RELEASE
APPROVED Project Engineer
Date 20 Apr 93

LTR	DWN	CHK	APVD	DATE	ZONE	CHANGE

DWN Tom Oamon 4/14/93
CHK 4/14/93
APVD 4-20-93
DATE

LAWRENCE LIVERMORE NATIONAL LABORATORY
MECHANICAL ENGINEERING DEPT
UNIVERSITY OF CALIFORNIA

CLASSIFICATION

MAJOR UNIT: STAR TRACKER CAMERA ASSY, V3.1
SUBUNIT
UNIT: CLAMP, LENS HEATER
DRAWING NO: AAA 93-102221-00
SCALE .500
SHEET 1 OF 1

OFFICIAL USE

Appendix F
Calibration

Appendix F.1

ST 313 Calibration Summary

Star Tracker (313, 314)

- Radiometric Calibration at 600 and 700 nm
- Optical Distortion Map

  Residual is ~0.2 pixel (260 μrad) average
- Star Matching Results : Overnight runs in controlled environment

  Repeatability < 60 μrad (1σ)

  Absolute Pointing Accuracy

  | Star Matched Dec. - LLNL Dec. | > 350 μrad (0.02°)
  (RA Residual from WWV Time) Maximum 550 μrad (0.03°)

  Study under way

Star Tracker (313, 314)

- Radiometric Calibration at 600 and 700 nm
- Optical Distortion Map

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  Repeatability < 60 μrad (1σ)

  Absolute Pointing Accuracy

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  (RA Residual from WWV Time) Maximum 550 μrad (0.03°)

  Study under way

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- Optical Distortion Map

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  Absolute Pointing Accuracy

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  Study under way

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  Study under way

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- Optical Distortion Map

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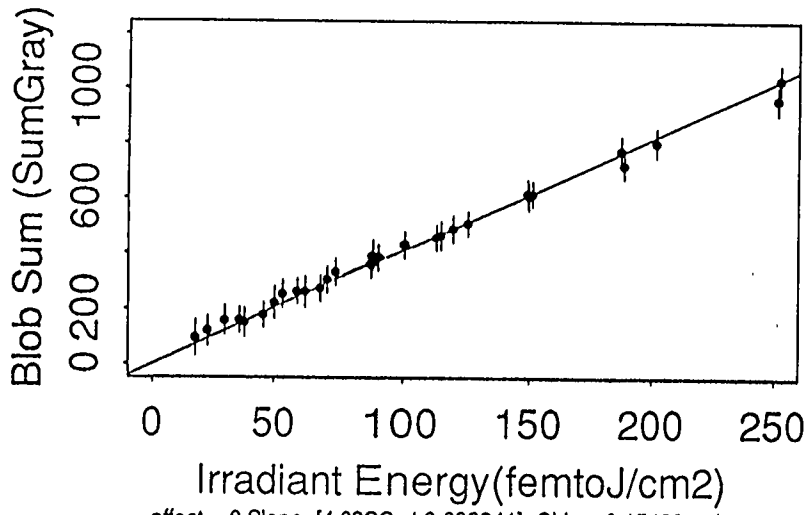
  Absolute Pointing Accuracy

  | Star Matched Dec. - LLNL Dec. | > 350 μrad (0.02°)
  (RA Residual from WWV Time) Maximum 550 μrad (0.03°)

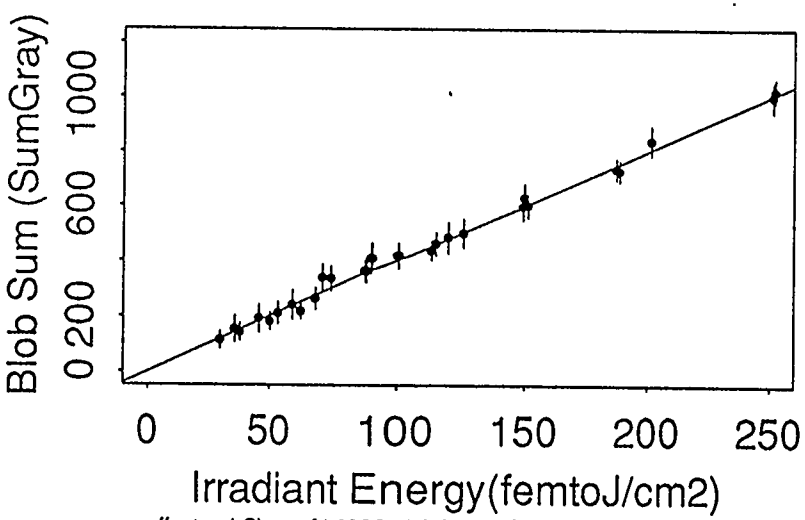
  Study under way



offset = 0 Slope=[4.0892+/-0.033241]; Chisq=0.15402; ndata=26

Clementine Star Tracker Camera

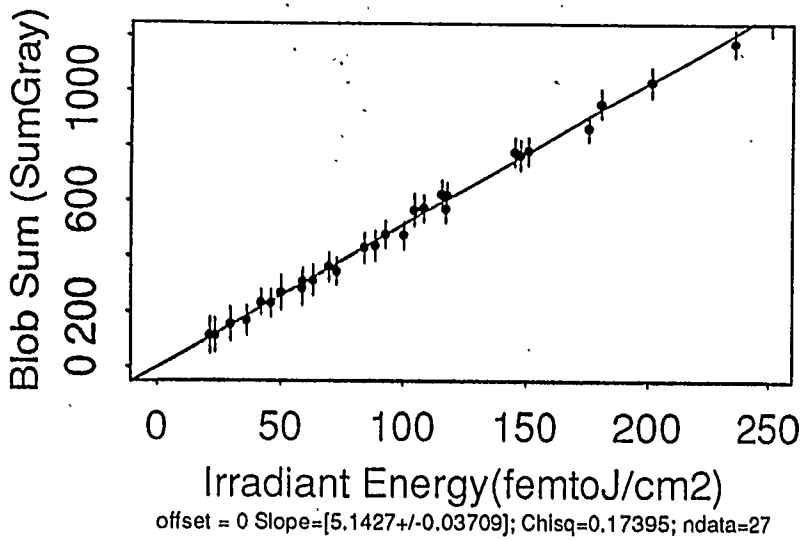
Serial Number : SN313
Wavelength(nm): 600 nm
Voltage Setting : Nominal_postvib
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 0



offset = 4 Slope=[4.0033+/-0.033605]; Chisq=0.25703; ndata=27

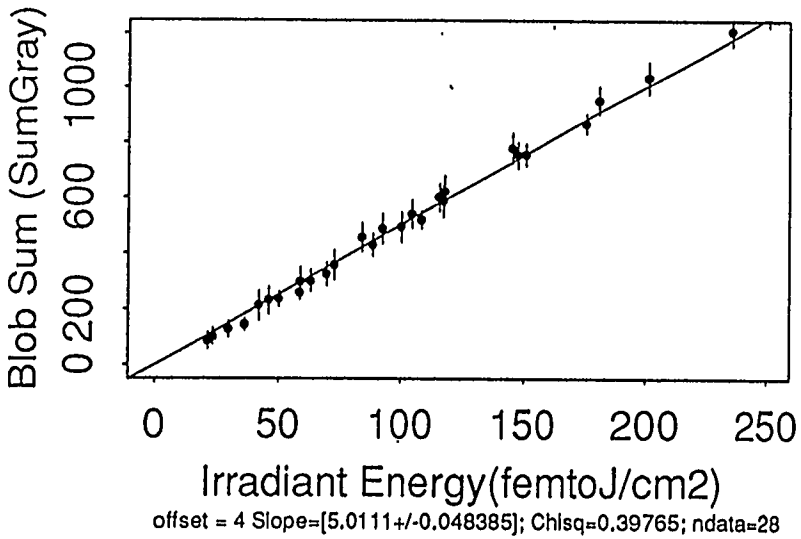
Clementine Star Tracker Camera

Serial Number : SN313
Wavelength(nm): 600 nm
Voltage Setting : Nominal_postvib
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 4



Clementine Star Tracker Camera

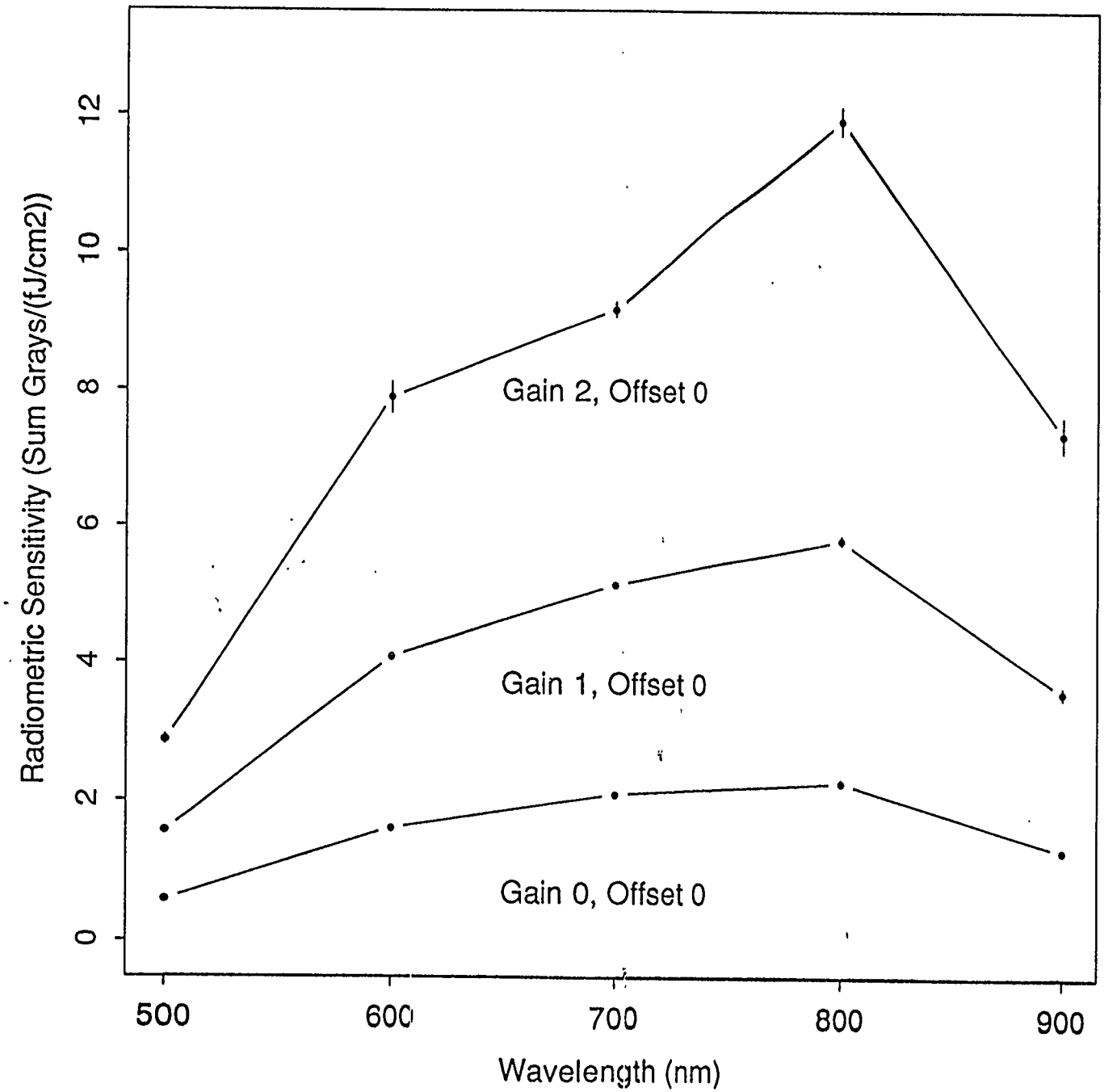
Serial Number : SN313
Wavelength(nm): 700 nm
Voltage Setting : Nominal_postvib
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 0



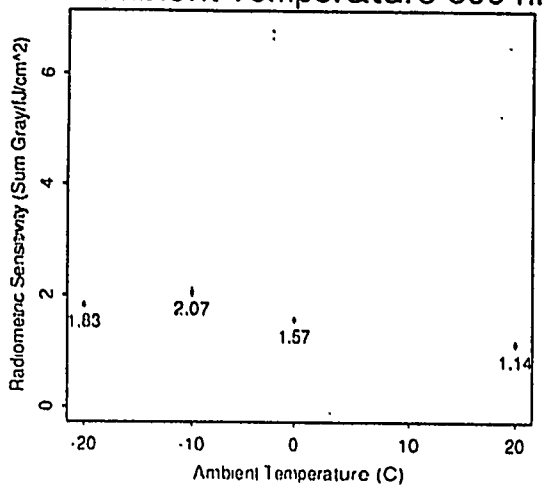
Clementine Star Tracker Camera

Serial Number : SN313
Wavelength(nm): 700 nm
Voltage Setting : Nominal_postvib
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 4

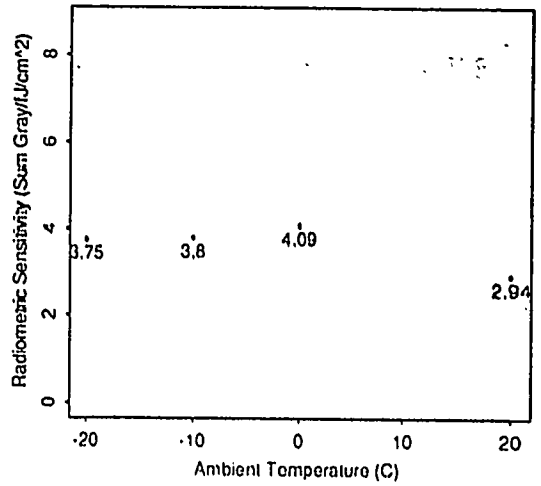
ST313 Radiometric Sensitivity (Amb T=0C)



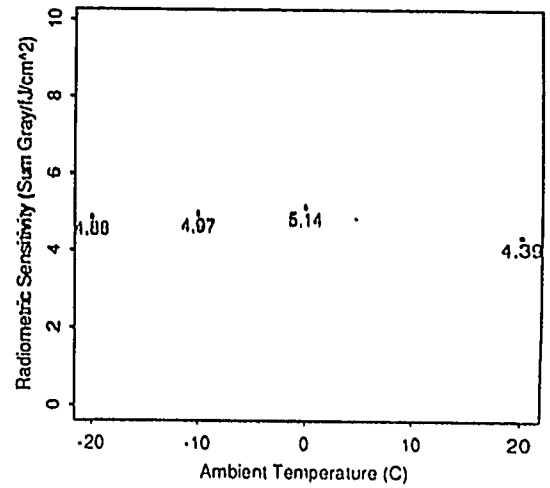
ST313 Radiometric Sensitivity vs Ambient Temperature 500 nm



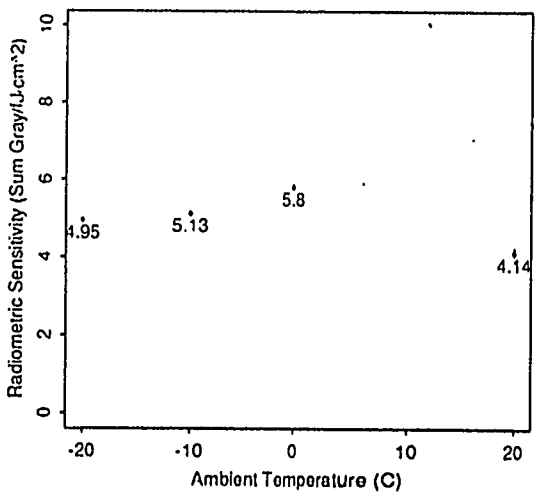
600 nm; Offset 0 Data



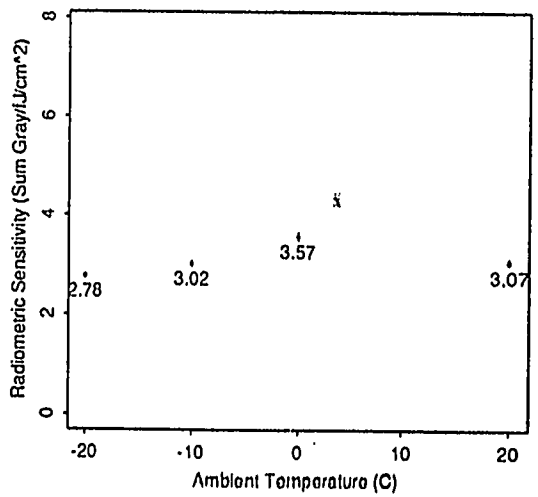
700 nm; Offset 0 Data



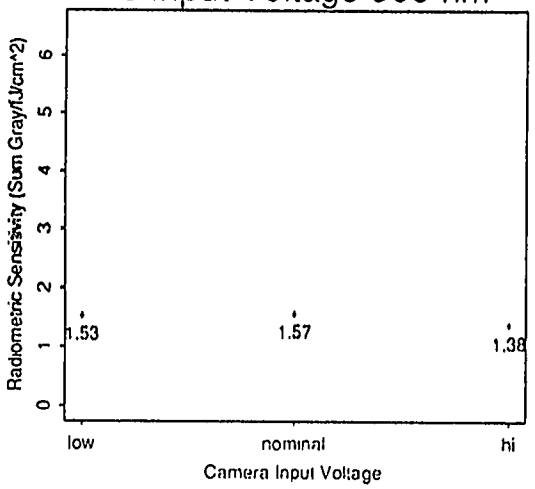
800 nm; Offset 0 Data



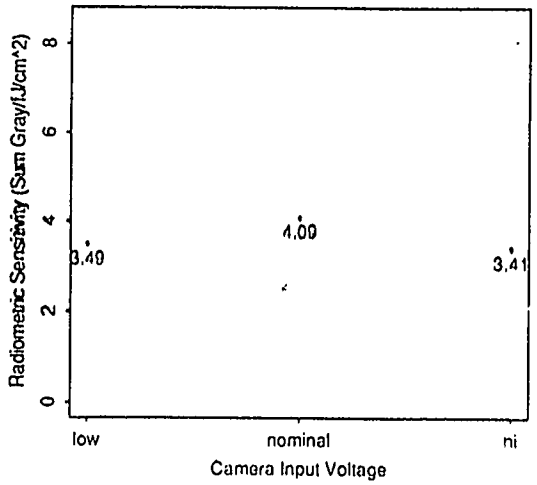
900 nm; Offset 0 Data



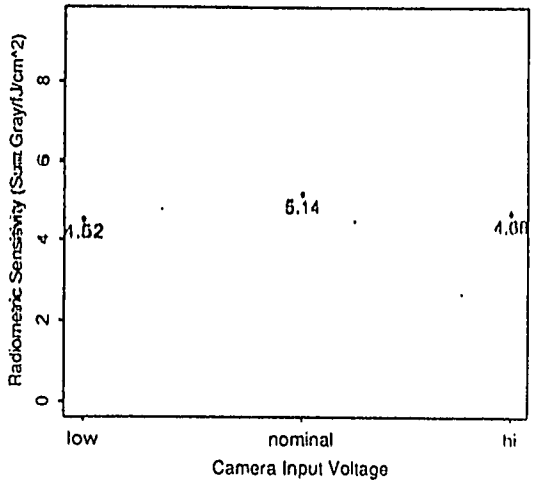
ST313 Radiometric Sensitivity vs Input Voltage 500 nm



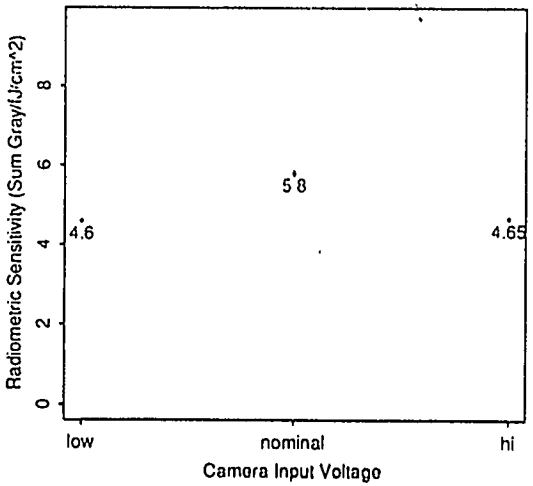
600 nm; Offset 0 Data



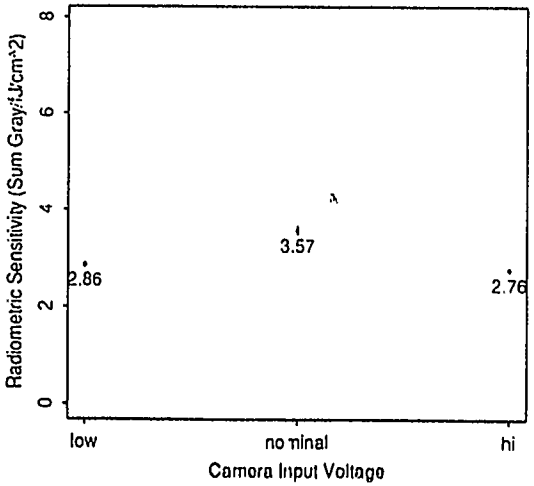
700 nm; Offset 0 Data

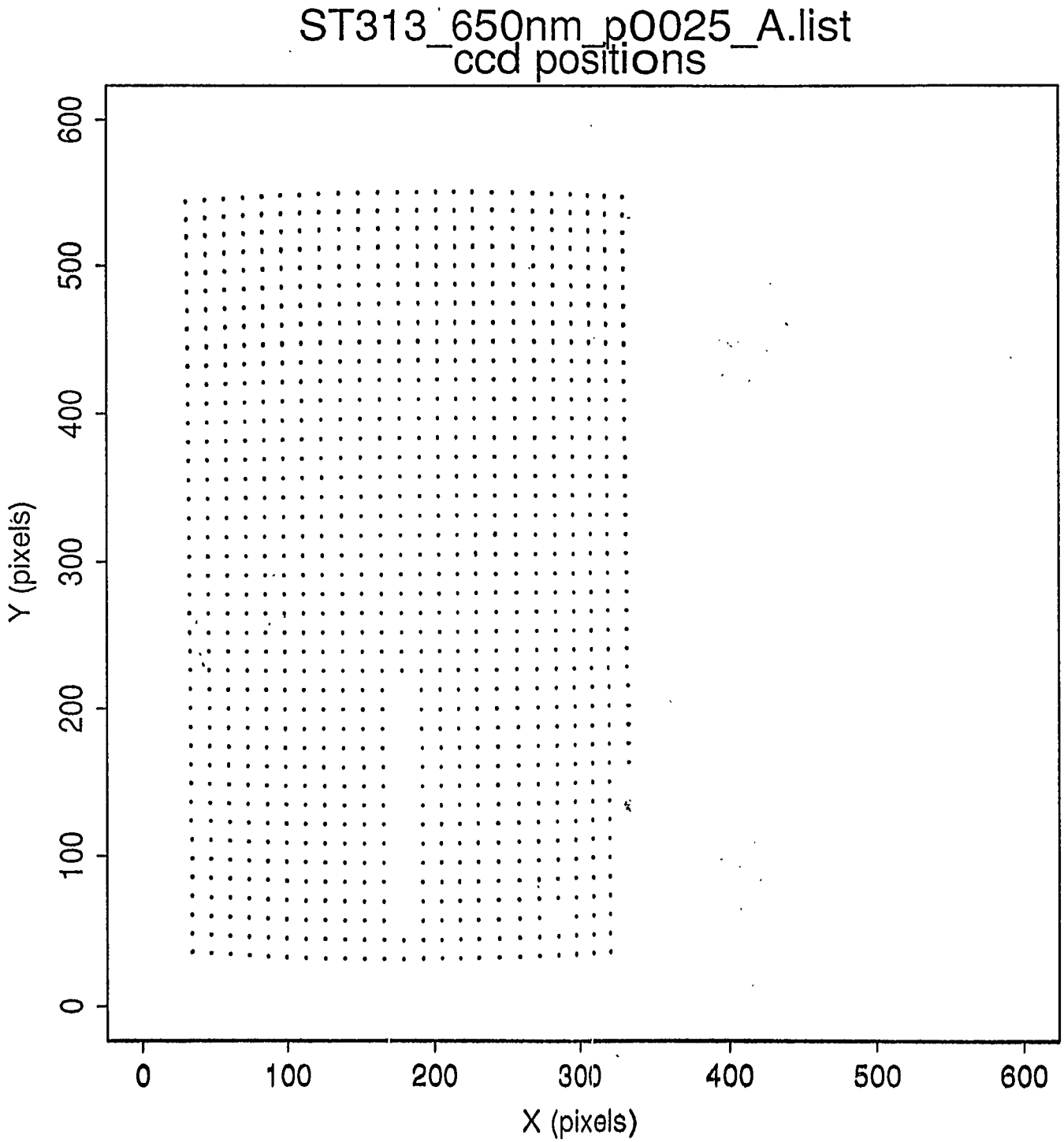


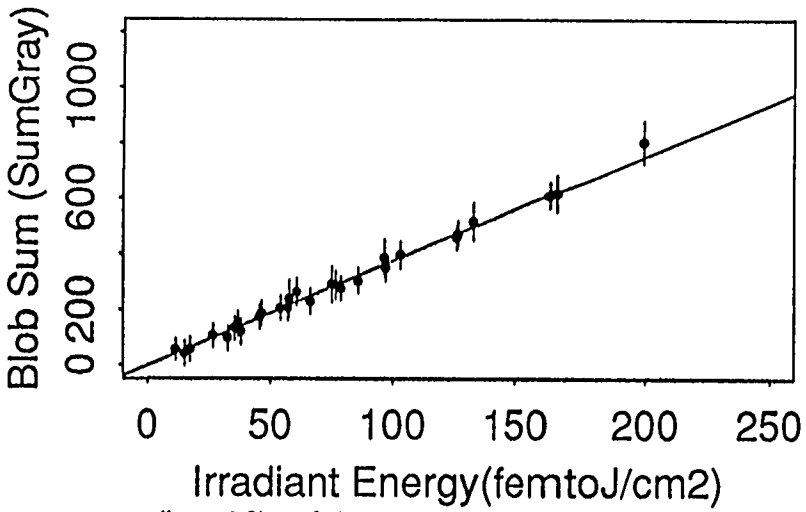
800 nm; Offset 0 Data



900 nm; Offset 0 Data



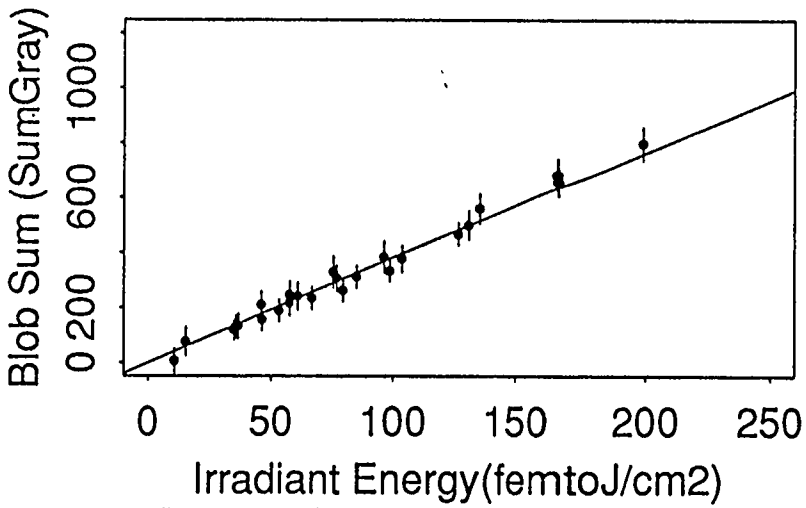

ST313_650nm_p0025_A.list
ccd positions
Y (pixels)
X (pixels)
0
100
200
300
400
500
600



offset = 0 Slope=[3.7603+/-0.037997]; Chisq=0.12847; ndata=27

Clementine Star Tracker Camera

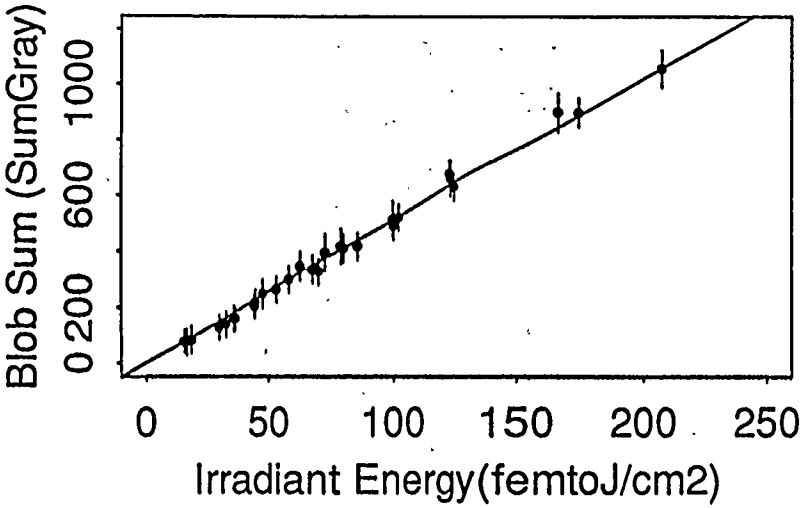
Serial Number : ST314
Wavelength(nm): 600 nm
Voltage Setting : nominal
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 0



offset = 4 Slope=[3.8107+/-0.057779]; Chisq=0.34019; ndata=24

Clementine Star Tracker Camera

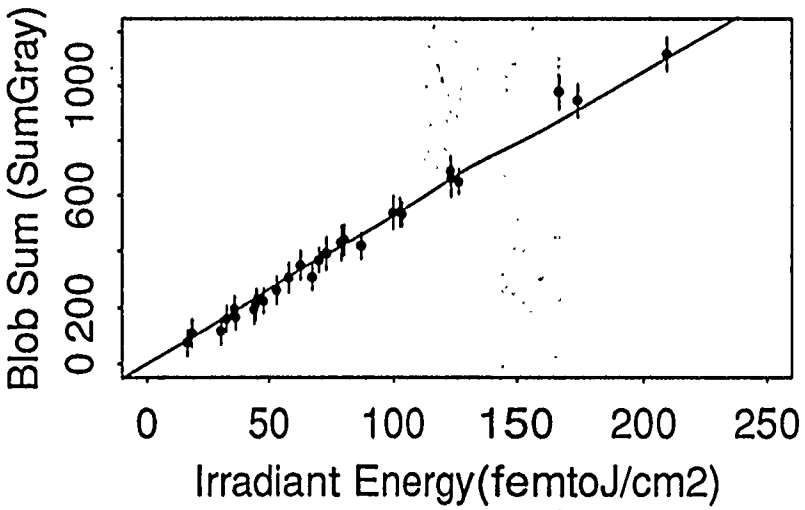
Serial Number : ST314
Wavelength(nm): 600 nm
Voltage Setting : nominal
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 4



offset = 0 Slope=[5.1043+/-0.045125]; Chisq=0.17655; ndata=29

Clementine Star Tracker Camera

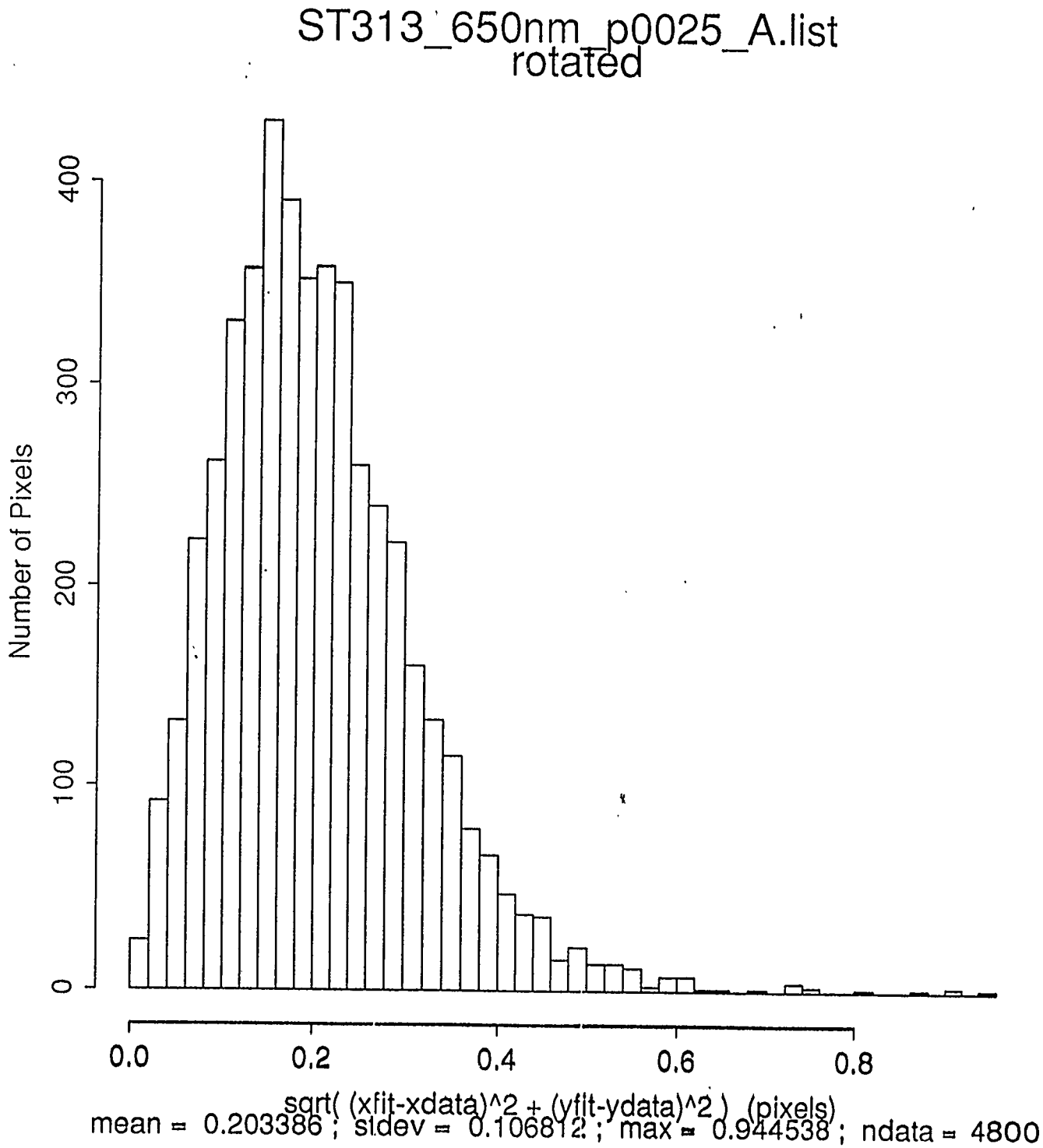
Serial Number : ST314
Wavelength(nm): 700 nm
Voltage Setting : nominal
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 0

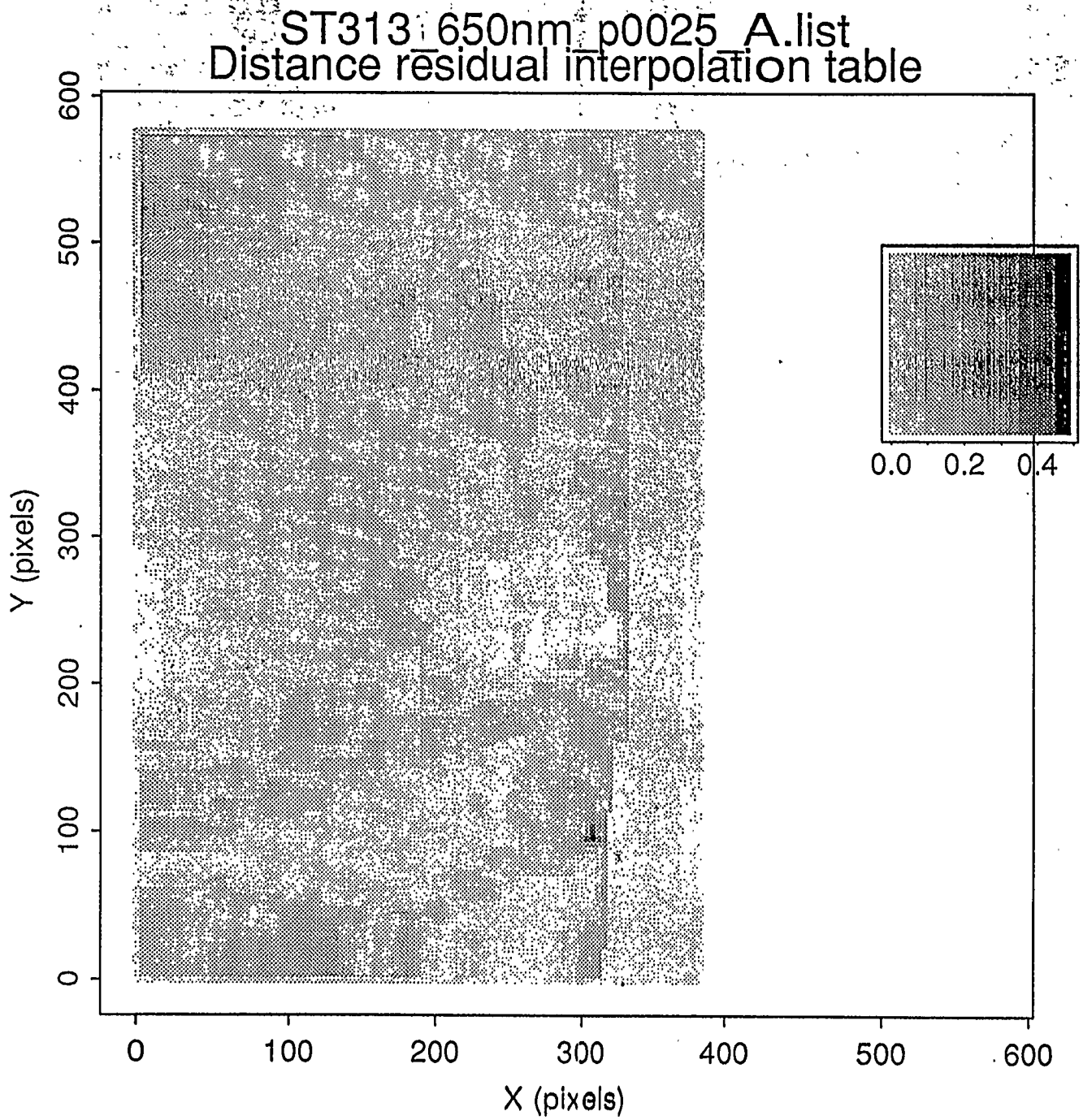


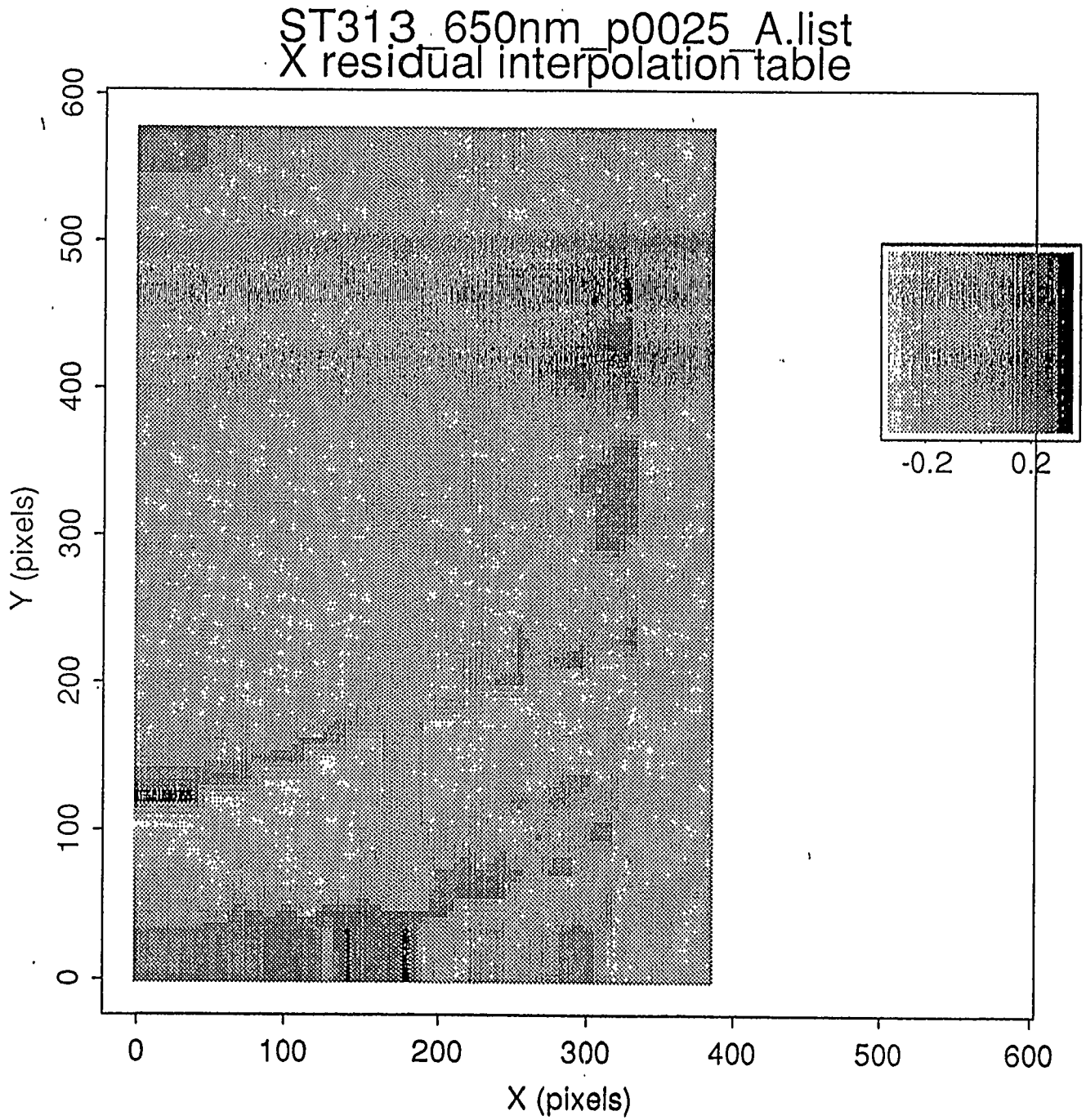
offset = 4 Slope=[5.2636+/-0.064514]; Chisq=0.37216; ndata=28

Clementine Star Tracker Camera

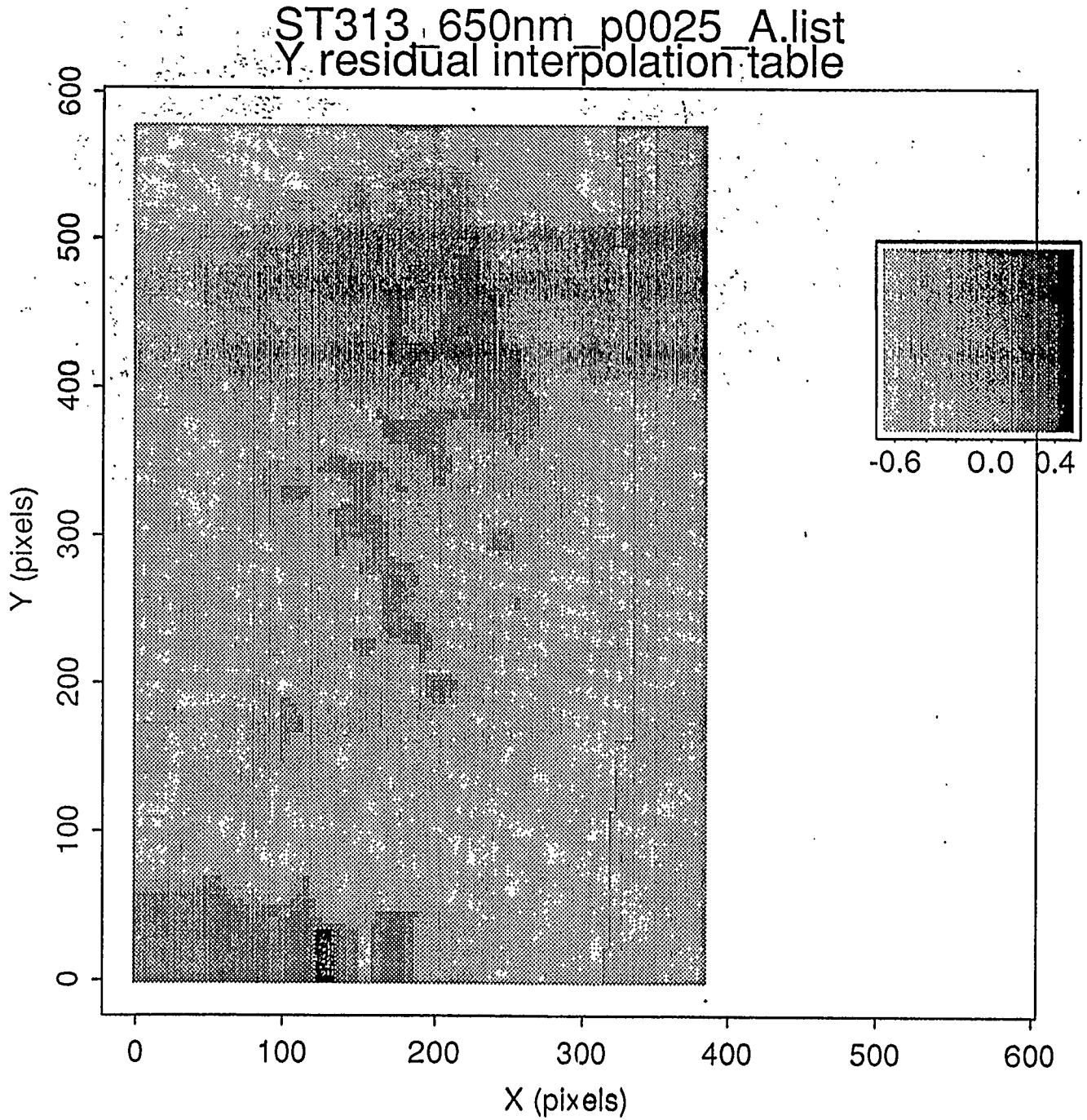
Serial Number : ST314
Wavelength(nm): 700 nm
Voltage Setting : nominal
Pinhole : 0.043in
Ambient T : 0C
Gain : 1
Offset: 4

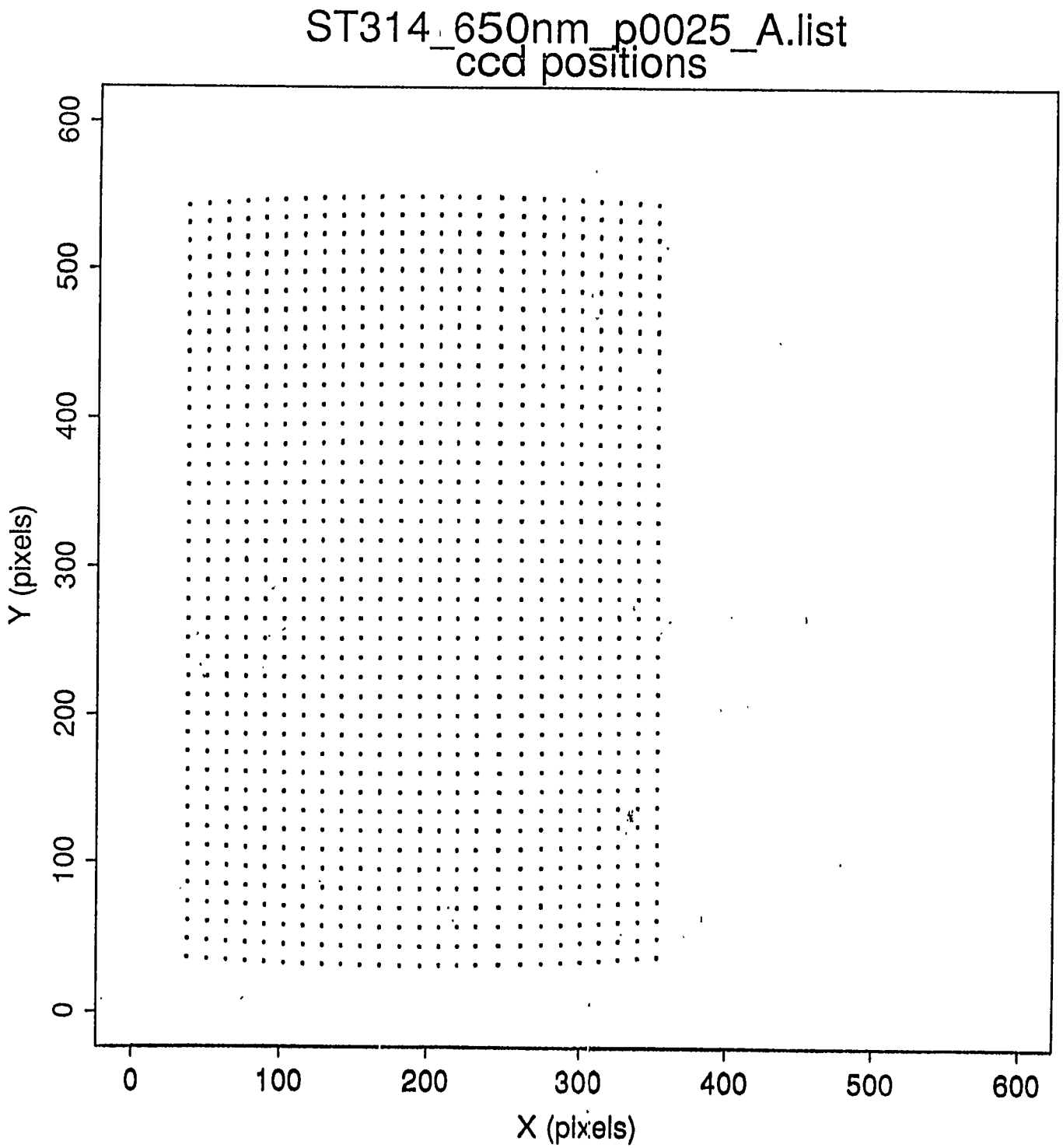

ST313_650nm_p0025_A.list
rotated
Number of Pixels
0
100
200
300
400
0.0
0.2
0.4
0.6
0.8
sqrt((xfit-xdata)^2 + (yfit-ydata)^2) (pixels)
mean = 0.203386 ; sldev = 0.106812 ; max = 0.944538 ; ndata = 4800

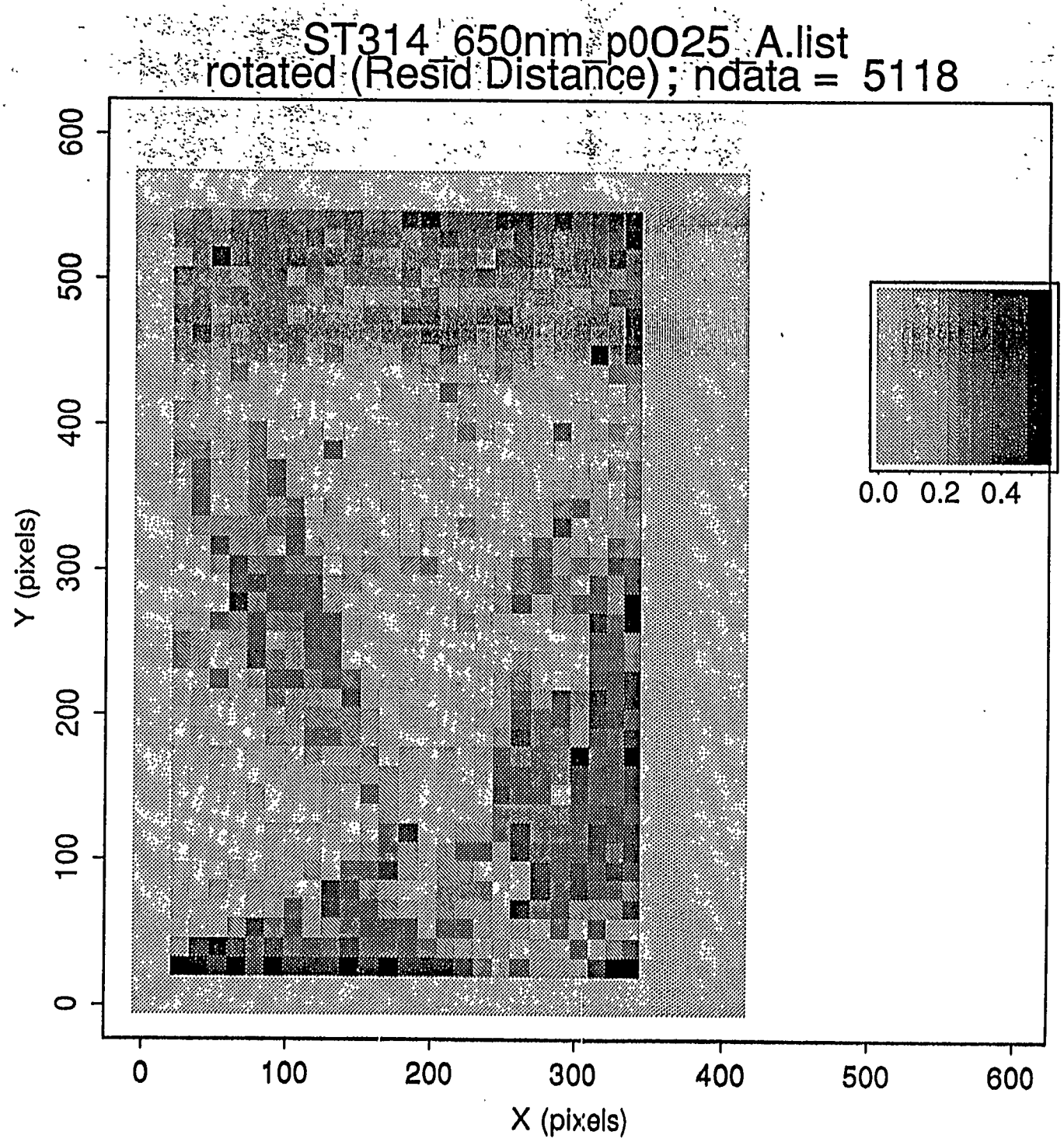

ST313 650nm p0025_A.list
Distance residual interpolation table
Y (pixels)
X (pixels)
0
100
200
300
400
500
600
0.0
0.2
0.4

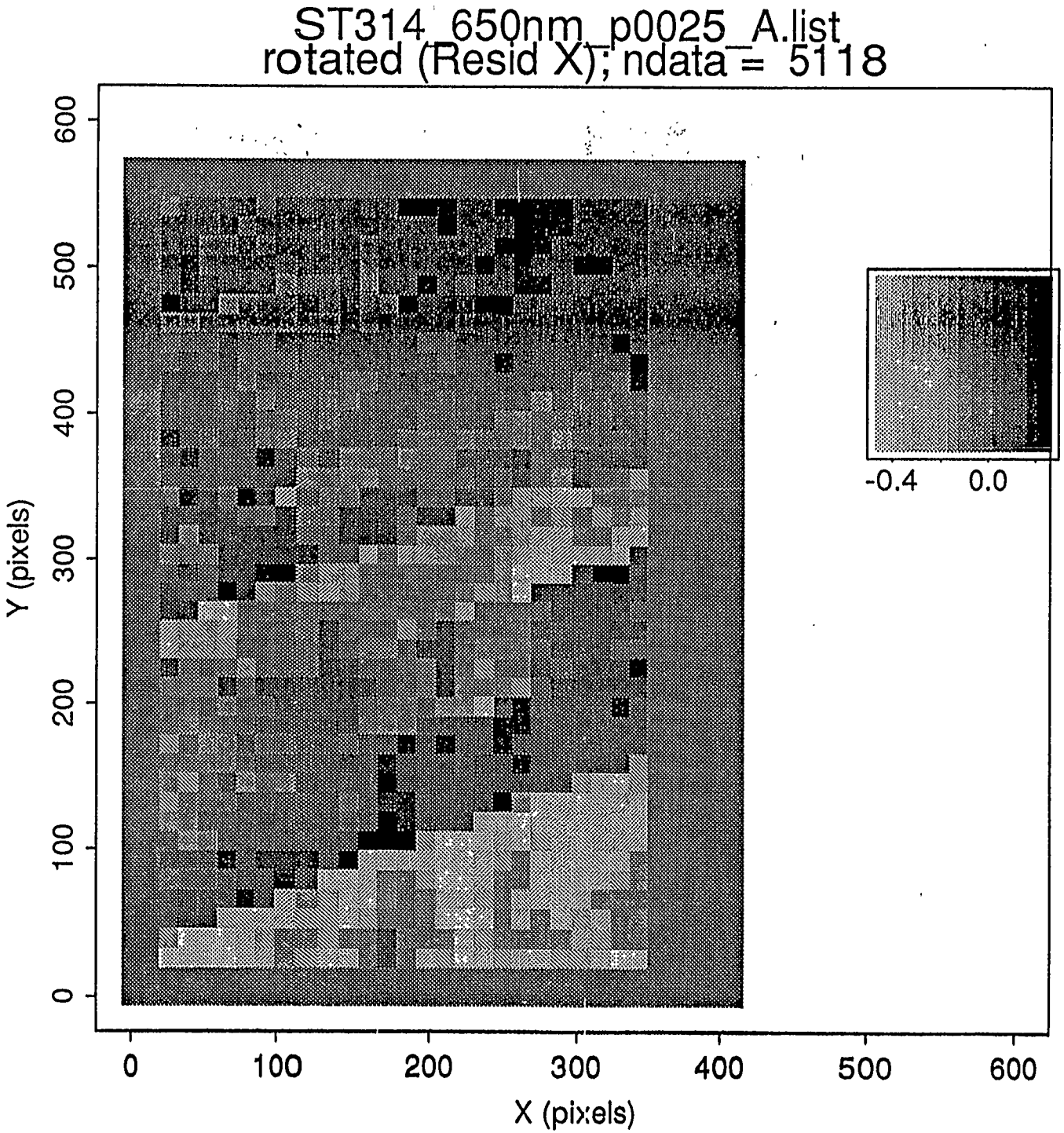


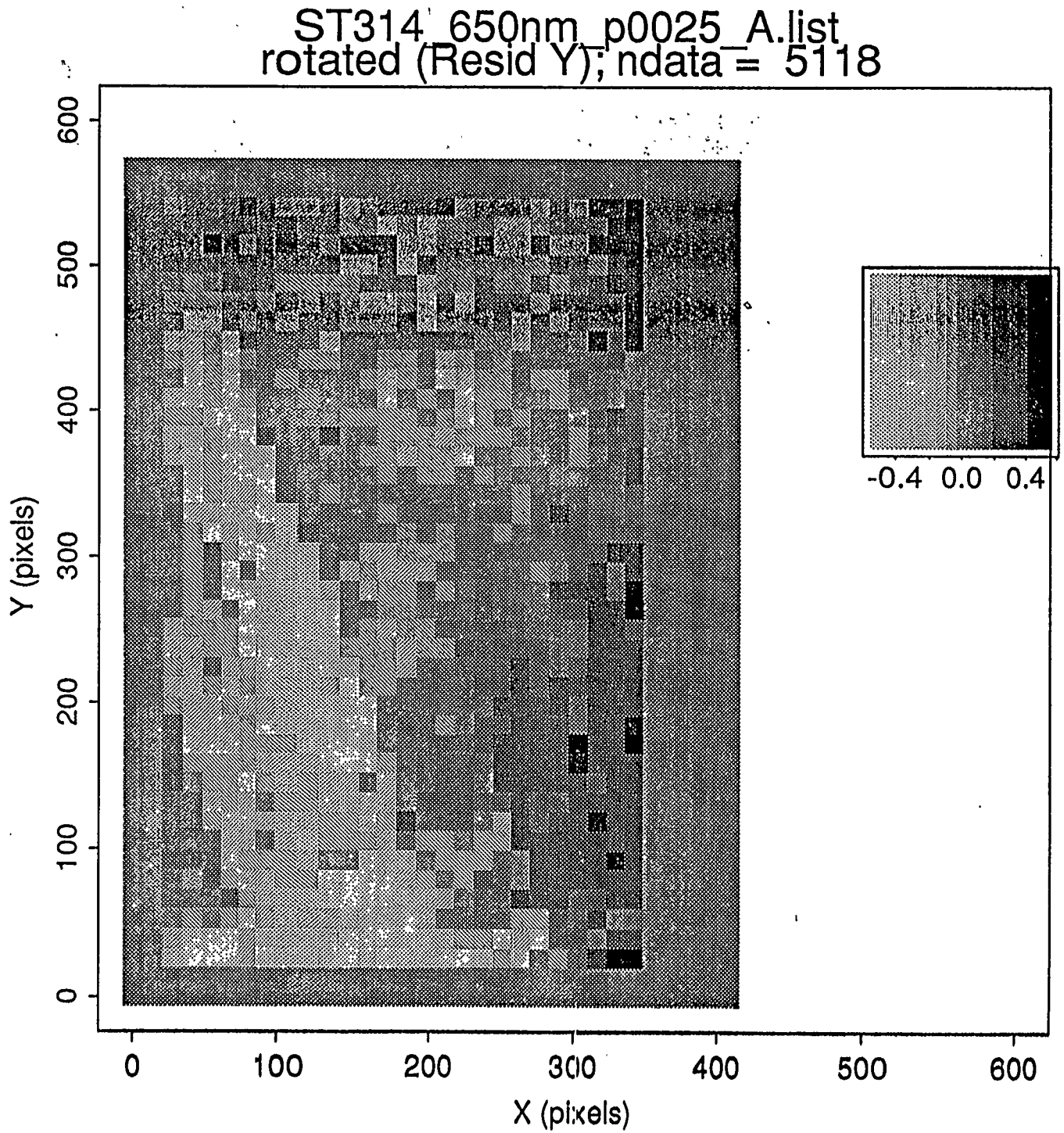
LLNL - ATP Camera Calibration Laboratory Mon Jun 28 12:29:05 PDT 1993 /tmp_mnt/auto/qo/ST313_clem/Optical_Distortion


ST313_650nm_p0025_A.list
Y residual interpolation table
Y (pixels)
X (pixels)
0
100
200
300
400
500
600
-0.6
0.0
0.4


ST314_650nm_p0025_A.list
ccd positions
Y (pixels)
X (pixels)
0
100
200
300
400
500
600


ST314_650nm_p0O25_A.list
rotated (Resid Distance); ndata = 5118
Y (pixels)
X (pixels)
0
100
200
300
400
500
600
0.0
0.2
0.4

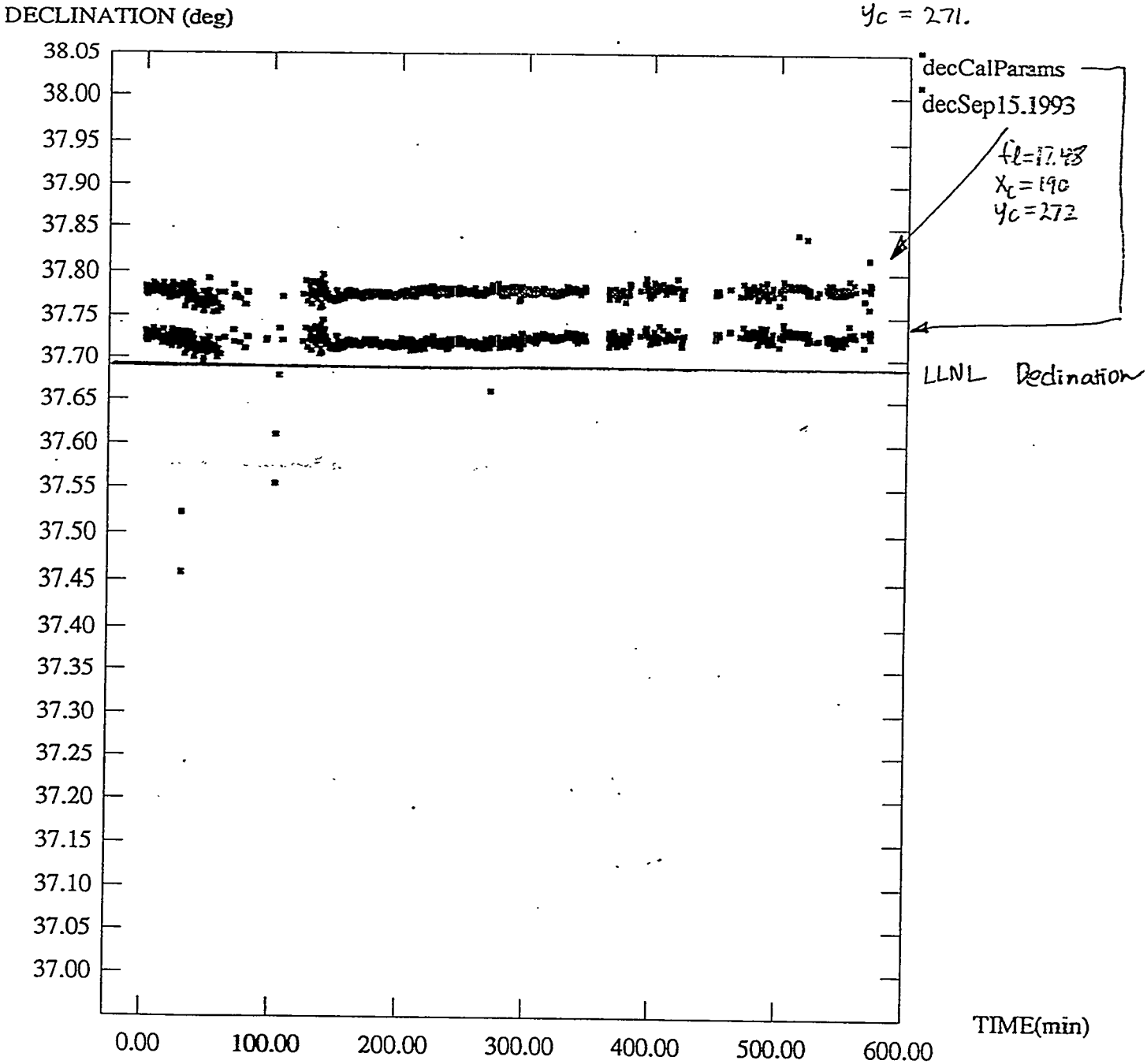

ST314_650nm_p0025_A.list
rotated (Resid X); ndata = 5118
Y (pixels)
X (pixels)
0
100
200
300
400
500
600
-0.4
0.0


ST314_650nm_p0025_A.list
rotated (Resid Y); ndata = 5118
Y (pixels)
X (pixels)
0
100
200
300
400
500
600
-0.4
0.0
0.4

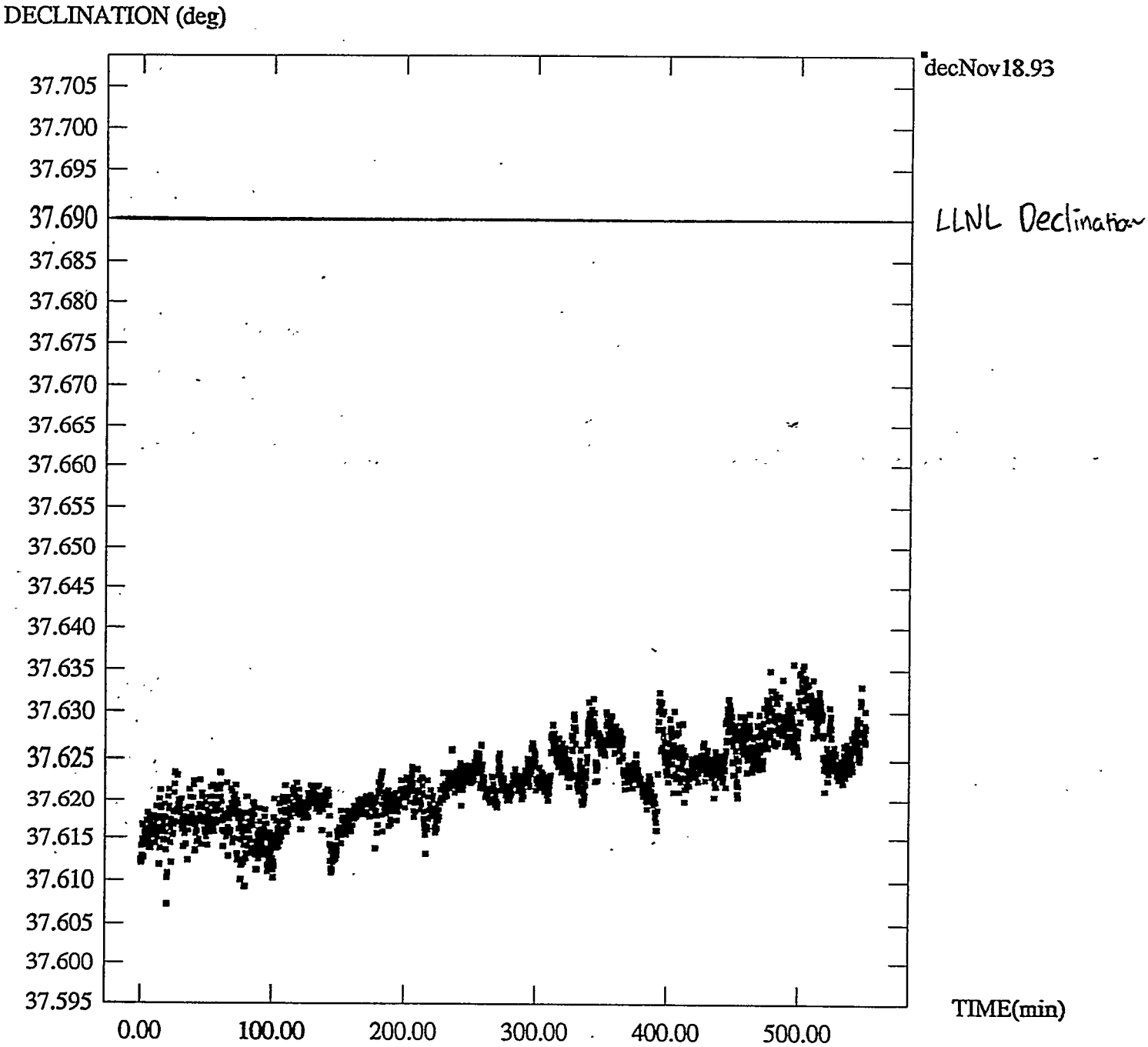
LLNL Dec = 37.6909°

CALIB_LAB:
fl = 17.495 mm
X_c = 190.
y_c = 271.

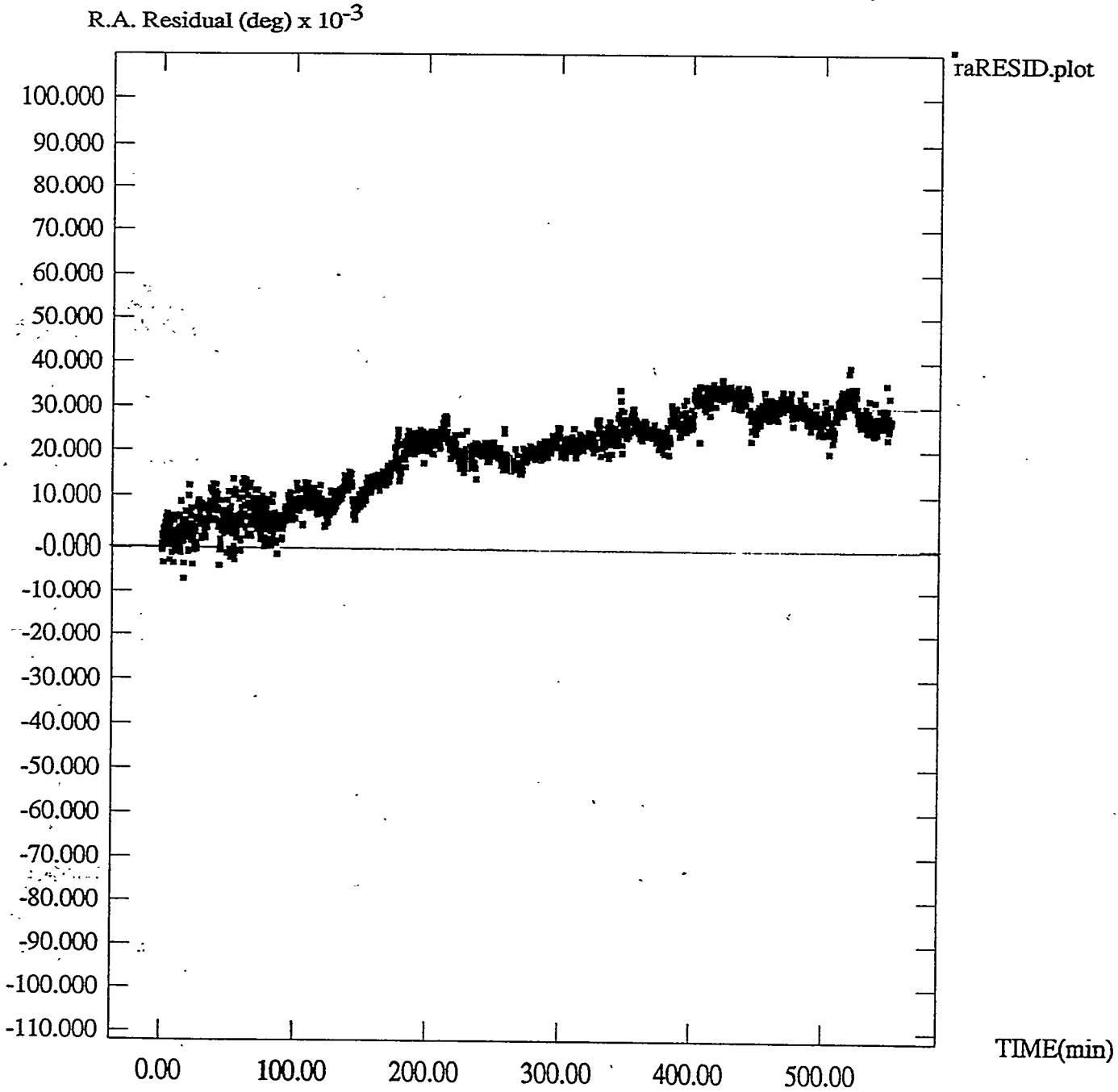
ST315_09/15/93 DATACUBE



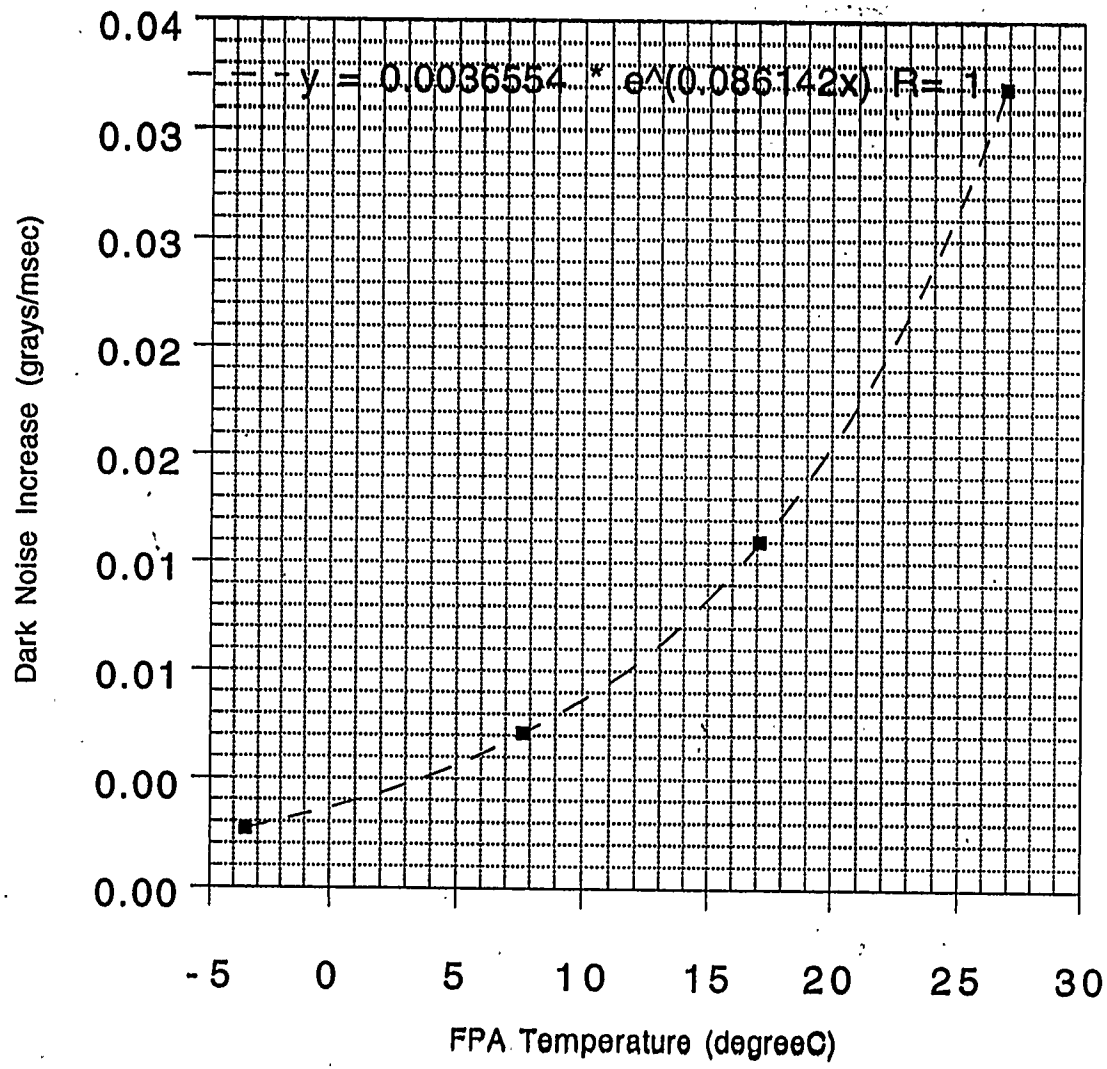
ST316_350ms_g1_o6 11/18/93 (star16c)

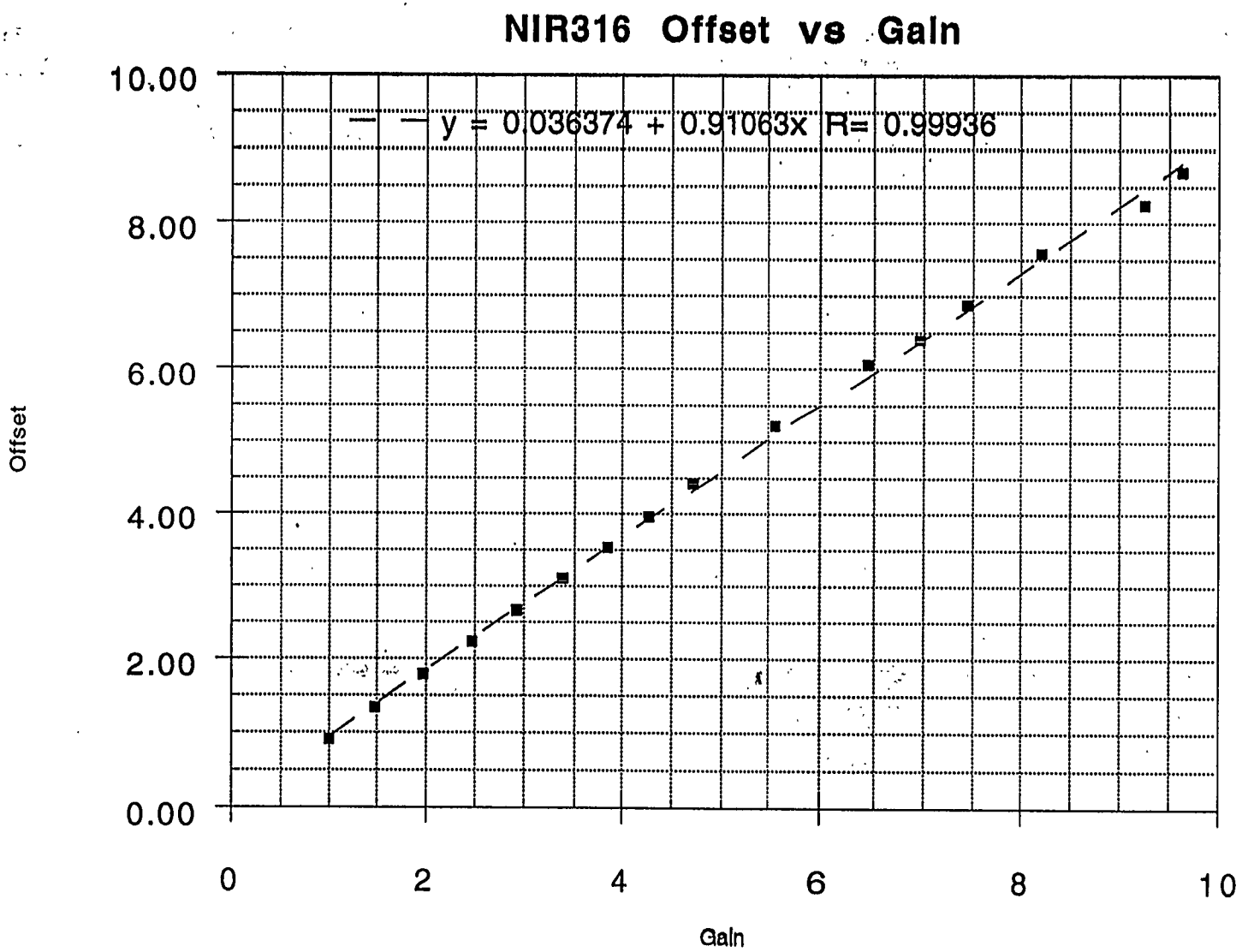


ST316_350ms_g1_o6 11/18/93 (star16c)



UV314 Dark Noise
Temperature Dependence




NIR316 Offset vs Gain
y = 0.036374 + 0.91063x R= 0.99936
10.00
8.00
6.00
4.00
2.00
0.00
Offset
0
2
4
6
8
10
Gain

Appendix G

Certification Log for StarTracker B (ST 313)

StarTracker Camera

Document No. C1-AAA92-106282, Tab 01

Flight No. 1

Serial No. ST-313

May 3, 1993

Appendix G.1
Summary Technical Data

Summary Technical Data

ST 313

Parameter	Specification	Measured Value
Mass	< 483 g	280 g
Current at 22°C +5 Vdc analog +5 Vdc digital[1] -5 Vdc +15 Vdc -15 Vdc	 < 155 mA < 140 mA / < 410 mA < 60 mA < 140 mA < 30 mA	 109.2mA / 109.2mA 51.8mA /300 mA 39.6mA /39.6 mA 111mA /111mA 14 mA /13.96mA
Lens Heater Resistance at 22° C (ST ONLY)	450 ± 45 Ω	455 Ω

[1] These values are with data bus disabled / data bus enabled with150 ohm termination.

Appendix G.2
Board Assembly Log

Appendix G.2.1
Operations Sheet

Clementine Operations Sheet, Assembly

Part Number LEA92-3128	**Serial No.** Pioneer 04-06	**Description** Actel Startracker #2 w/Gain and Offset Control	**Assembly Log #** AL023
			End Use Flight
Next Assembly / Deliver To: Star Tracker Camera Sensor		**Account Number:** 7069-26 / **Release To (Shop):** 1883	**Production: Date:**
Prepared By: K.F. Coatney	**Date:** 15 April 93	**QA:** W.R.Bryson **Date:**	**Approved By: Date**

Associated Documentation:	**Notes:**
Schematic, LEA92-3128-11 Rev 0B	
Bill of Material, LEA92-3128-04 Rev 0B	
Assembly Procedure, LEA92-3128-05	
Assembly Drawing, LEA92-3128-05 Rev 0A	
Fabrication Drawing, LEA92-3128-07 Rev 0A	

Change Verification Record or Engineering Change Notice Record

Parts List or Dwg Number	Dwg Chg Letter	Eco Number	Description or Remarks	Opr	QA

Appendix G.2.2

Work Sheets

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	1

#	Operation	Date:	Oper.	Insp.
1	Visual Inspection preformed - Lot# 6862	3/29/93		QA #2
2.	Board baked at 95 c for 6 hrs in Oven			
	S/N # 12664-1 7:00 p.m - to 1:00 A.M.	4/15/93		QA #2
3	Turned Over to Laura Aranda for Assy/Solder	4/16/93		QA #2
7.	received kit assigned to Helen Reisdorff for assembly	4-16-93	Oper #2	
8.	Verified Kit. MEASURED ALL Resistors and Capacitors	4-16-93	HR	
	FLUKE - 3/19/93 - 3/19/95			
	DYNASCAN - 9/3/92 - 9/3/93			
9.	Resistance measurements made To J1	4.16.93	Oper #9	
10.	Assy 7.1 - 7.2 ITEM 83	4.16.93	HR	
11	CLEANED BOARD SENT TO QA	4.16.93	Oper #9	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	2

#	Operation	Date:	Oper.	Insp.
13	Inspected Assy/Solder Oper's 7-11-OK	4/18/93		QA #2
14	Baked Board at 95 c for 6hrs in			
15	Oven S/N # 12664-1 - 5:00 p.m 11:00 p.m	4/18/93		QA #2
16	Assy 7.2 - Item 28 - 7.5 Item 40	4.21.93	H.B. Oper #9	
17	Cleaned Board - Sent To QA	4.21.93		
18	Baked Board at 95C for 6 hrs in Oven	4.21.93	H.B.	
	S/N# 12664-1 - 8:00 P.M - 1:00 A.M.		Oper #9	
19	Assy 7.5 - Item 41 - 7.12 Item 18	4.22.93	H.B.	
20	Cleaned Board Sent To QA	4.22.93	H.B. Oper #9	
22	Inspected Assy/Solder Oper's 7.2 - 7.12	4/22/93		QA #2
23	C24 - + side A119 - Contaminates ?/Damaged?			
24	C122 - A119 Contaminates			
25	Q 12, 13 & 14 - Residue ON Component	4/22/93		QA #2

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	3

#	Operation	Date:	Oper.	Insp.
26	D3 - Nonsoldered	4/22/93		QA #2
27	Baked Board at 95c for 6 hrs in			
	S/N # 12664-1 Oven 7:30p.m to 1:30A.m	4/22/93		QA #2
28	Rework C24-A119 - Removed cap - Replaced with new one	4/23/93	Oper H.#8	
29	Rework C122-A119 - Resoldered	4/23/93		
30	Rework Q12,13,4 - Cleaned	4/23/93	H.R.	
31	Soldered D3	4/23/93	Oper H.#8	
32	Assy 7.12 Item 19 - 7.13	4/23/93	H.R.	
33	Unable to install U26 - programmed chip - Do not have	4/23/93	H.R. Oper #8	
34.	Assy 7.15 - 7.20	4/23/93	H.R.	
35.	Measured spacers Item 78 - .387 - .388	4/23/93	H.R. Oper #8	
36	51 distance from PWB - .261 - .261	4/23/93	H.R.	
37.	Assy 7.20 - 7.26	4/23/93	H.R.	
38.	Cleaned Board - Sent to QA	4/23/93	Oper H.#8	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	4

#	Operation	Date:	Oper.	Insp.
39	Inspected Rework Oper.'s # 28-31 - OK	4/23/93		QA #2
40	Inspected Assy/solder Oper's 32-38 - OK			
41	Baked Board at 95 c for 16hrs in			
42	S/W # 126164-1 Oven - 7:00 P.M 1:00 A.M.	4/23/93		QA #2
43	Waiting for U26 - Gate Array			
44	Ready to Record J1 Reading 7:30	4/23/93		QA #2
45	Remove C4, C7 and C8 and replace with	4/29/93	gtK	
	0.1 mfd, 50 Volt. Remove R119 and replace			
	with 6.19K 1%. Please measure and record before			
	installation. Remove R49 ~~and replace with 100Ω 1%~~ JK see 36			
	Remove R6 and R7.			
			Oper #4	
51	Removed C4, C7 + C8, Removed R119, R49, R6 + R7	5-4-93	D.J.	
52	Inspected Rework Oper. #51 - OK	5/4/.		QA #2

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	5

#	Operation	Date:	Oper.	Insp.
53	Installed U 26 ST2D 4/22/93 DPN	5-4-93	Ld.	Oper #4
53a	Log co-plete cd consistant to this point. Resume @ 7.31 ~~7.29~~			QA #1
54	R137 need to be replaced, stripped. ~~Ed~~)			
55	Remove R128. Temporarily tack a wire between R128 and	5/5/93	Kathy	
	C123 per Assy. Procedure 7.19. Complete item 45. Temporarily	5/5/93	Courtney	QA #1
	tack a 1K 1% resistor in R49 as per Assy. Procedure 7.5.1	5/5/93		
59	Installed C4 .121 measured C7 .110 C8 .113	5-5-93		
60	Installed R119 measured 6.19 kΩ.			Oper #3
61	Tack in R49 measured 1003Ω.			
62	Removed R128 → R128+C123			Oper #3
63	Installed jumper wire between R128	5-5-93		
	and C123			

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	6

#	Operation	Date:	Oper.	Insp.
65.	replaced R137 (178-2) (rework item 54)	5-5-93	Oper #2	
66.	cleaned board in freon tank, sent to QA	5-5-93	Oper #2	
68	Inspected Rework Oper's 59-63 + 65 - OK	5/5/93		QA #2
69	Baked Board at 95 c for 16 hrs.			
	S/N # 12664-1 7:30 pm to 1:30 A.M	5/5/93		QA #2
72	made resistance readings per 7.32, recorded results			
	on table 8	5-6-93	Oper #2	
75	Inspected Assy/Oper. #72 - OK	5/6/93		QA #2
76	Ready to turn over to Test (Don Antelman)	5/6/93		
77	Inspect or evaluate accidental power disconnect during test, Prior to ~~[illegible]~~ gain selection varification par 5.9	•		

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	7

#	Operation	Date:	Oper.	Insp.
	Remove R49 and			
78	Install R49 100Ω 1%. Remove jumper between			
	pad of R128 and C123. Install R128			
	100Ω 1%.			
81	Removed Jumper R128 - C123	5-7-93	Oper #3	
	Installed R128 measured 100.5Ω			
	Removed R49 measured 100.3Ω →		Oper #3	
	Installed R49 measured 100.4Ω	5-7-93		
86	Inspected Rework Oper.'s 81 - OK	5/7/93		QA #2
87	Ready to Return to Test After			
88	QA. Manager Bill Bryson Inspects.	5/7/93		QA #2
89	Board is consistent up to this point	5/7/93		QA #2

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	8

#	Operation	Date:	Oper.	Insp.
90	Electronics Testing is complete. RE: Passed! MD	5/12/93	MD	
91	Board delivered to QA for preconformal coat assurance	5/12/93	MD	
93	Inspected Board throughly for probe	5/13/93		QA #2
	mark defects and prior to Assy. for Conformal	5/13/93		
	Coating. — OK	5/13/93		QA #2
97	Ready for Bryson to Inspect	5/13/93		QA #2
100	Log Complete and Consistant to ~~7.3T~~ QA #1 8.5			
	~~Sent to Engineering for Evaluation~~ WB	14 May 93		QA #1

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	9

#	Operation	Date:	Oper.	Insp.
105	Ready to proceed @ 8.6 Board Bake out.	14May93		VQ
107	BAKed Board at 95 c for 6 Hr's in S/N	5/17/93		QA #2
	#12664-1 over 8:30 A.M - 2:30 P.M	5/17/93		QA #2
110	Did Oper * items 8.7, 8.8, 8.9, 8.10, 8.11, 8.12, 8.13.			
	8.14, 8.15, 8.16, 8.17, 8.18, 8.19, +			
	Sent to QA	5/17/93	Oper #4	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	10

#	Operation	Date:	Oper.	Insp.
115	Inspected Assy/Solder Oper's - OK	5/18/93		QA #2
116	Ready for Clean and Bake and	5/18/93		QA #2
	Next process 8.20 ON	5/18/93		QA #2
117	Did Oper # item 8.20, 8.21 then baked at 60°c			
	for 30 min	5-18-93	Oper #4	
120	Inspected Staking operations	18 May 93		QA #1
121	Put in oven for 30 min cure @ 60°c	18 May 93		I.P.

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	11

#	Operation	Date:	Oper.	Insp.
125.	Next step, Freon Cleaning prior to Conformal coat.	18 May 93	QA #1	
126	Did Oper #125 Cleaned in Freon	5-18-93	Oper #4	
128	Reinspected for Cleanliness prior to	5/18/93		QA #2
	Masking and Conformal Coating procedure.			QA #2
	OK - Turn Over to Joe Burris for			QA #2
	Conformal Priming procedure.	5/18/93		QA #2
				QA #2
133	Cleaned and Immersed in Silane	5/18/93	JMB	
	A174 solution	5/18/93	JMB	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	12

#	Operation	Date:	Oper.	Insp.
137	Baked Board at 95 C for 6 hrs in	5/18/93		BD
	S/N # 12664-1 Oven 7:30 - 1:30			
140	Removed Board From oven	5/19/93	JAB	
142	Placed Board vacuum chamber at 0705	5/19/93	JAB	
144	Removed From vacuum chamber 1110	5/19/93	JAB	
146	Placed Board in Hi-Vac chamber 1130	5/19/93	JAB	
148	Removed From Hi-Vac chamber 1145 2×10^{-5}	5/19/93	JAB	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	13

#	Operation	Date:	Oper.	Insp.
151	Masked connector, 4 corners around edges, both	5-19-93	Oper #2	
152	sides, installed screws in CCD, then masked			
153	both sides. Covered CCD connector with			
154	ESD Tape then masked. Masked surface under			
155	CCD			
156	Sent To QA for Inspection and coating	5-19-93	Oper #2	
157				
158	Inspected Masking prior to curing	5/19/93		QA #2
159	in Oven for 4 hrs.			QA #2
160	Baked in Oven for 4 hrs at 60°C.	5/19/93		QA #2
161	Cut Board from holder prior to Conformal Coating	5/19/93	Oper #20	QA #2
162	Inspected Masking prior to Conformal coating	5/19/93		QA #2
163				
164				

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	14

#	Operation	Date:	Oper.	Insp.
165	Placed Board in parylene deposition	5/19/93	JWB	
	unit and started conformal coating	5/19/93	JWB	
	process at 2045	5/19/93	JWB	
169	Removed from parylene deposition	5/19/93	JWB	
	unit after conformal coating 0645	5/19/93	JWB	
170	Moved to 182-B for Inspection and removal			
	of Masking material	20 May 93		
171	Removed MASKING Material	5/20/93	B	B
172	Functionality Verified (partially housed)	5/24/93	MA	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	15

#	Operation	Date:	Oper.	Insp.
175	Verify Thermistor operation (Dean Hadley)			
	next step final functional Test.	20 May 93	[illegible]	
176	Verified Thermistor operation. Meter Read	20 May	DRH	
	5740 Ω = ≈ 22.5°C used Fluke 77 @			
	cert # E 000706			
177	Functionality Verified. DATA IN T. PROCED. SECTION	25/MAY/93	MD	
188	Pre-VIB RADIOMETRIC TEST (OC NOMINAL)	6/19/93	[illegible]	
189	Post VIB RADIOMETRIC TEST (OC NOMINAL)	6/21/93	[illegible]	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
LEA92-3128	P04-06	Pioneer Fabricated Actel Startracker Board	16

#	Operation	Date:	Oper.	Insp.
190	20C Nominal post vib	6/19/93	DWD	
191	70C Nominal	6/21/93	DWD	
192	-20C Nominal	6/22/93	DWD	

Appendix G.2.3
Bill of Materials

Actel Camera with Gain and Offset Control
Startracker Configuration
Rev. 00 Printed Wiring Board
Bill of Materials, Rev. 00
LEA92-3128-04

	Date	Rev.	Date	Approval
Prepared by: K. F. Coathey	30 Mar 93	OA	13Apr.1/93	
Reviewed by: W. R. Bryson	30 Mar 93	OB	16Apr.1/93	
Reviewed by: J. F. Kordas	30-MAR-93	OC	22Apr 93	
Reviewed by: M.L. Dickerson	3/31/93	OD	5 May 93	
Reviewed by: E.H. Schmitt	4/2/93			
Reviewed by: M. J. Shannon	4/2/93			

University of California Lawrence Livermore National Laboratory	22 March 1993 Actel Startracker Bill of Materials	LEA92-3128-04 Revision 00

Actel Camera with Gain and Offset Control
Startracker Configuration
Rev. 00 Printed Wiring Board
Bill of Materials, Rev. 00
LEA92-3128-04

	Date	Rev.	Date	Approval
Prepared by: K. F. Coathey	30 Mar 93	CA	13 Apr 1993	
Reviewed by: W. R. Bryson	30 Mar 93	OB	16 Apr 1993	
Reviewed by: J. F. Kordas	30-MAR-93	OC	22 Apr 93	
Reviewed by: M.L. Dickerson	3/31/93			
Reviewed by: E.H. Schmitt	4/2/93			
Reviewed by: M. J. Shannon	4/2/93			

University of California Lawrence Livermore National Laboratory	22 March 1993 Actel Startracker Bill of Materials	LEA92-3128-04 Revision 00

1.0 Scope

This document is the bill of materials for the Actel Camera with Gain and Offset Control for use in the Startracker, Rev 00 Printed Wiring Board, LEA92-3128-04, Rev 00.

2.0 Parts

Where a dual part number listing exists, the first number listed is a commercial part suitable for prototype work only. If the MIL-SPEC part is not available at the time flight boards are assembled, Quality assurance must OK the use of the commercial part on a part by part basis in writing.

Parts may not be substituted without the written permission of the Quality Assurance Group.

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
1	44	C1,C3,C5,C6, C15,C21, C23,C25,C26, C30,C31,C33, C34,C38,C39, C40,C42,C44, C45,C47,C48, C54,C56,C57, C58,C59,C60, C63,C64,C66, C67,C70,C91, C92,C98,C102, C103,C104,C106, C109,C112,C114, C121,C124	0.039 µF, 50V, 10%, FR=0.01%/ 1000 hr	RM1206	CDR32BX393AKUR
2	5	C2,C51,C61,C62, C122	4.7 µfd, Tant, 10V, 10%, WFR=0.01%/ 1000hr	H-CASE	CWR06FH475KC
3	1	C9	47 µfd, Tant, 20V, 10%	R-CASE	Sprague / 195D476X9020R2T

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
4	2	C10,C11	22 µfd, Tant, 15V, 10%, WFR=0.01%/ 1000hr	G-CASE	CWR06HH226KC
5	4	C12,C13,C17, C105	6.8 µfd, Tant, 10V, 10%, WFR=0.1%/ 1000hr	E-CASE	CWR06FH685KB
6	2	C20,C110	6.8 µfd, Tant, 20V, 10%, WFR=0.01%/ 1000hr	F-CASE	CWR06JH685KC
7	6	C22,C24,C29, C69,C90,C118	22 µfd, Tant, 20V, 10%, WFR=0.01%/ 1000hr	H-Case	CWR06JH226KC
8	4	C32,C52,C94, C95	10 µfd, Tant, 25V,10%, WFR=0.01%/ 1000hr	G-CASE	CWR06KH106KC
9	1	C35	0.22 µfd, 50V, 10%	RC1206	Garrett / 1206Z224M500N
10	2	C46,C93	1.0 µfd, Tant 35V, 10%, WFR=0,01%/ 1000hr	D-CASE	CWR06MH105KC
11	2	C49,C50	0.022 µfd, 100V, 10%, FR=0.01%/ 1000hr	RM1206	Garrett / CE223K3NR
12	1	C53	15 pf, 100V, 5%, FR=0.01%/ 1000hr	RM1206	CDR32BP150BJUR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
13	5	C73,C74,C75, C76,C77	3300 pf, 50V, 10%, FR=0.001%/ 1000hr	RC0402 RC0505	Novacap / 0402B332K500N CDR11BP332AKUS
14	1	C83	0.01 µfd, 100V, 10%, FR=0.01%/ 1000hr	RM1206	CDR32BX103BKUR
15	1	C111	47 pf, 100V, 5%, FR=0.01%/ 1000 hr	RM1206	CDR32PB470BJUR
16	2	C115,C116	270 pf, 100V, 10%, FR=0.01%/ 1000hr	RM1206	CDR32BP271BKUR
17	1	D1	Diode, Switching, 50V, 200 mA MBAV74	SOT-23	Motorola / MBAV74L SN 00201
18	1	D2	Diode, Voltage Reference LM285-1.2	SOIC-8	Linear / LM285MX-1.2 SN 01501
19	1	D3	Reference, Voltage, Precision, 10V, REF-01	SOIC-8	PMI / REF01CS SN 01420
20	2	D4,D5	Diode, Schottky, 30V BAT54S	SOT-23	Phillips / BAT54S SN's 03519 03518
21	9	JP4,JP6,JP7,JP9, JP11,JP13,JP14, JP15,JP16	Jumper, 0 Ω, 1%, 1/4 Watt	RM1206	D55342K07B00DOS
22	3	L1,L3,L4	Inductor, 100 µH	LQH4	MuRata Erie / LQH4N101K-TA

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
23	1	L5	Inductor, 10 µH	LQH4	MuRata Erie / LQH4N100K-TA
24	1	J1	Connector, 51 Contact, Socket	MDM51	M83513/04-G06N
25	5	Q1,Q4,Q9, Q10,Q11 SN's 04701, 04702, 04703	Transistor, FET, SST215 04704, 04705	SOT-143	Calogic / **No Substitute** Calogic No. SST215E
26	3	Q2,Q3,Q8 SN's 00020, 00019, 00018	Transistor, 2N3904	SOT-23	Motorola / MMBT3904 **No Substitute**
27	3	Q12,Q13,Q14 SN's 00920, 00918, 00919	Transistor, 2N7002	SOT-23	Motorola / 2N7002 **No Substitute**
28	2	R3,R66	7.5 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B7E50R
29		This space left intentionally blank			
30	2	R14,R31	243 Ω, 1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B243DR
31	2	R15,R32	1.82 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E82R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
32	5	R16,R116,R130 R133,R136	49.9 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B49D9R
33	5	R17,R21,R49, R74,R94,R95 **TEMPORARILY LOAD R49**	1.0 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E00R
34	1	R18	2.49 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E49R
35	1	R20	2.7 KΩ, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2H70R
36	1	R24	1.62 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E62R
37	1	R25	9.09 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B9E09R
38	1	R26	24.3 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B24E3R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
32	5	R16,R116,R130 R133,R136	49.9 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B49D9R
33	5	R17,R21, R74,R94,R95	1.0 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E00R
34	1	R18	2.49 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E49R
35	1	R20	2.7 KΩ, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2H70R
36	1	R24	1.62 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E62R
37	1	R25	9.09 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B9E09R
38	1	R26	24.3 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B24E3R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
39	1	R27	7.68 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B7E68R
40	2	R28,R91	0 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B00D0R
41	9	R29,R48,R101, R102,R129,R132, R135,R140,R141	10 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B10E0R
42	1	R30	2.15 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E15R
43	4	R37,R115, R49,R122,R128 **DO NOT LOAD R49 OR R128**	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B100DR
44	1	R38	3.01 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B3E01R
45	2	R42,R43	30 Ω, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B30G0R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
39	1	R27	7.68 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B7E68R
40	2	R28,R91	0 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B00D0R
41	9	R29,R48,R101, R102,R129,R132, R135,R140,R141	10 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B10E0R
42	1	R30	2.15 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E15R
43	4	R37,R115, R122,R128	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B100DR
44	1	R38	3.01 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B3E01R
45	2	R42,R43	30 Ω, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B30G0R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
46	2	R44,R93	1.96 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E96R
47	1	R46	100 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B100ER
48	1	R92	20 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B20E0R
49	4	R96,R98,R118, R120	2.61KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E61R
50	1	R97	301 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B301DR
51	2	R99,R119	6.19 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B6E19R
52	1	R112	511 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B511DR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
53	1	R117	40.2 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B40D2R
54	1	R121	649 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B649DR
55	1	R124	5.1 Ω 1%, 1/8 Watt	RC1206	KOA / RM73B2B5R1JT
56	1	R125	499 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B499DR
57	1	R131	931 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	Dale / CRCW12069310FT
58	1	R134	383 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	Rohm / MCR12064420FT
59	2	R137,R49	178 Ω, 1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B178DR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
60	1	R139	20.0 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B20D0R
61	1	T1	Sensor, Temperature 534-31AG04-562	TO-52/3	Fenwell / LTN11 Type 534-31AG04-562
62	1	U1	Amplifier,. Operational, Clamping CLC501AJE	SOIC-8	Comlinear / CLC501AJE SN 02870
63	1	U2	Receiver, Line Quad DS34C86	SOIC-16	National / DS34C86M SN 05320
64	2	U3,U27	Amplifier, Dual, Wide Band LF353	SOIC-8	National / LF353M SN 01320, 01319
65	1	U5	Controller, CCD TH7990	JLCC-44	Thomson-CSF / TH7990C SN 13
66	4	U6,U7, U12,U25	Driver, Line, Quad DS34C87	SOIC-16	National / DS34C87M SN 04920 04919 04918 04917
67	1	U8	Converter, Analog to Digital 8 bit MP7684	LCC-28	Micropower / MP7684ATL/883
68	4	U9,U10,U22 U23	Driver, Dual Inverting TSC4426	SOIC-8	Teledyne / TSC4426EOA SN's 05520 05519 05518 05517

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
69	2	U11,U30	Driver, Differential, Dual TSC4428	SOIC-8	Teledyne / TSC4428EOA SN's 01820, 01819
70	1	U14	Amplifier, Operational, LF356	SOIC-8	National / LF356M SN's 01720
71	2	U17,U18	Regulator, Voltage, Adjustable LM317	SOIC-8	National / LM317LM SN's 05701 05703
72	1	U19 **DO NOT KIT**	Charged Coupled Device CCD 7860 or7863	DIP-20	Type Chosen on Camera Selection
73	1	U24	Amplifier, Operational, Clamping CLC502	SOIC-8	Comlinear, CLC502AJE SN 02951
74	1	U26 **DO NOT KIT**	Gate Array, Field Program, ACT1020A	JLCC-44	Actel / ACT1020A-1JQ44B
75	1	U32	Converter, Digital to Analog AD558TE/883	LCC20	Analog Devices / AD558TE/883
76	1	X1	Crystal, 20 MHz ±50ppm	CXAT	MicroCrystal / 20.000 MHz CXAT-T2
77	2	U19 Socket	Socket Strip 10 pin	SIP-10	LLNL / 5975-64700

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
78	2	N/A	Spacer	N/A	AAA92-104616-OB Tab-01
79	2	N/A	Brass CCD Mounting Nuts	N/A	AAA92-109126 REV 00
80	2	N/A	#2-56 Stainless Steel Nut	N/A	NAS671C2
81	2	N/A	Washer, Stainless Steel, #2	N/A	NAS620C-2
82	2	TP1,TP2	Test Points	N/A	LLNL / 5975-66833
83	8	C4,C7,C8,C82, C99,C100, C101,C123	0.1 µfd, 50 Volt, 10%	RC1206	Rohm / CE104K3NR-T2
84	1	L2	Inductor, 47 µH	LQH4	MuRata Erie / LQH4N470K-TA

old Rev

Actel Camera with Gain and Offset Control
Startracker Configuration
Rev. 00 Printed Wiring Board
Bill of Materials, Rev. 00
LEA92-3128-04

	Date	Rev.	Date	Approval
Prepared by: K. F. Coathey	30 Mar 93	0A	13 Apr. 93	
Reviewed by: W. R. Bryson	30 Mar 93	0B	16 Apr. 93	
Reviewed by: G. F. Kordas	30-MAR-93			
Reviewed by: M.L. Dickerson	3/31/93			
Reviewed by: E.H. Schmitt	4/2/93			
Reviewed by: M. J. Shannon	4/2/93			

University of California Lawrence Livermore National Laboratory	22 March 1993 Actel Startracker Bill of Materials	LEA92-3128-04 Revision 00

1.0 Scope

This document is the bill of materials for the Actel Camera with Gain and Offset Control for use in the Startracker, Rev 00 Printed Wiring Board, LEA92-3128-04, Rev 00.

2.0 Parts

Where a dual part number listing exists, the first number listed is a commercial part suitable for prototype work only. If the MIL-SPEC part is not available at the time flight boards are assembled, Quality assurance must OK the use of the commercial part on a part by part basis in writing.

Parts may not be substituted without the written permission of the Quality Assurance Group.

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
1	47	C1,C3,C4,C5,C6, C7,C8,C15,C21, C23,C25,C26, C30,C31,C33, C34,C38,C39, C40,C42,C44, C45,C47,C48, C54,C56,C57, C58,C59,C60, C63,C64,C66, C67,C70,C91, C92,C98,C102, C103,C104,C106, C109,C112,C114, C121,C124	0.039 µF, 50V, 10%, FR=0.01%/ 1000 hr	RM1206	CDR32BX393AKUR
2	5	C2,C51,C61,C62, C122	4.7 µfd, Tant, 10V, 10%, WFR=0.01%/ 1000hr	H-CASE	CWR06FH475KC
3	1	C9	47 µfd, Tant, 20V, 10%	R-CASE	Sprague / 195D476X9020R2T

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
4	2	C10,C11	22 µfd, Tant, 15V, 10%, WFR=0.01%/ 1000hr	G-CASE	CWR06HH226KC
5	4	C12,C13,C17, C105	6.8 µfd, Tant, 10V, 10%, WFR=0.1%/ 1000hr	E-CASE	CWR06FH685KB
6	2	C20,C110	6.8 µfd, Tant, 20V, 10%, WFR=0.01%/ 1000hr	F-CASE	CWR06JH685KC
7	6	C22,C24,C29, C69,C90,C118	22 µfd, Tant, 20V, 10%, WFR=0.01%/ 1000hr	H-Case	CWR06JH226KC
8	4	C32,C52,C94, C95	10 µfd, Tant, 25V,10%, WFR=0.01%/ 1000hr	G-CASE	CWR06KH106KC
9	1	C35	0.22 µfd, 50V, 10%	RC1206	Garrett / 1206Z224M500N
10	2	C46,C93	1.0 µfd, Tant 35V, 10%, WFR=0,01%/ 1000hr	D-CASE	CWR06MH105KC
11	2	C49,C50	0.022 µfd, 100V, 10%, FR=0.01%/ 1000hr	RM1206	Garrett / CE223K3NR
12	1	C53	15 pf, 100V, 5%, FR=0.01%/ 1000hr	RM1206	CDR32BP150BJUR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
13	5	C73,C74,C75, C76,C77	3300 pf, 50V, 10%, FR=0.001%/ 1000hr	RC0402 RC0505	Novacap / 0402B332K500N CDR11BP332AKUS
14	1	C83	0.01 µfd, 100V, 10%, FR=0.01%/ 1000hr	RM1206	CDR32BX103BKUR
15	1	C111	47 pf, 100V, 5%, FR=0.01%/ 1000 hr	RM1206	CDR32PB470BJUR
16	2	C115,C116	270 pf, 100V, 10%, FR=0.01%/ 1000hr	RM1206	CDR32BP271BKUR
17	1	D1	Diode, Switching, 50V, 200 mA MBAV74	SOT-23	Motorola / MBAV74L
18	1	D2	Diode, Voltage Reference LM285-1.2	SOIC-8	Linear / LM285MX-1.2
19	1	D3	Reference, Voltage, Precision, 10V, REF-01	SOIC-8	PMI / REF01CS
20	2	D4,D5	Diode, Schottky, 30V BAT54S	SOT-23	Phillips / BAT54S
21	9	JP4,JP6,JP7,JP9, JP11,JP13,JP14, JP15,JP16	Jumper, 0 Ω, 1%, 1/4 Watt	RM1206	D55342K07B00DOS
22	3	L1,L3,L4	Inductor, 100 µH	LQH4	MuRata Erie / LQH4N101K-TA

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
23	1	L5	Inductor, 10 µH	LQH4	MuRata Erie / LQH4N100K-TA
24	1	J1	Connector, 51 Contact, Socket	MDM51	M83513/04-G06N
25	5	Q1,Q4,Q9, Q10,Q11 SN's 04701,04702,04703,	Transistor, FET, SST215 04704, 04705	SOT-143	Calogic / **No Substitute** Calogic No. SST215E
26	3	Q2,Q3,Q8 SN's 00020,00019,00018	Transistor, 2N3904	SOT-23	Motorola / MMBT3904 **No Substitute**
27	3	Q12,Q13,Q14 SN's 00920,00918 00919	Transistor, 2N7002	SOT-23	Motorola / 2N7002 **No Substitute**
28	2	R3,R66	7.5 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B7E50R
29	2	R6,R7	150 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B150DR
30	2	R14,R31	243 Ω, 1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B243DR
31	2	R15,R32	1.82 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E82R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
32	5	R16,R116,R130 R133,R136	49.9 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B49D9R
33	5	R17,R21, R74,R94,R95	1.0 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E00R
34	1	R18	2.49 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E49R
35	1	R20	2.7 KΩ, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2H70R
36	1	R24	1.62 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E62R
37	1	R25	9.09 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B9E09R
38	1	R26	24.3 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B24E3R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
39	1	R27	7.68 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B7E68R
40	2	R28,R91	0 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B00D0R
41	9	R29,R48,R101, R102,R129,R132, R135,R140,R141	10 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B10E0R
42	1	R30	2.15 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E15R
43	4	R37,R115, R122,R128	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B100DR
44	1	R38	3.01 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B3E01R
45	2	R42,R43	30 Ω, 2%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B30G0R

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
46	3	R44,R93,R119	1.96 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B1E96R
47	1	R46	100 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B100ER
48	1	R92	20 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B20E0R
49	4	R96,R98,R118, R120	2.61KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B2E61R
50	1	R97	301 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B301DR
51	1	R99	6.19 KΩ, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B6E19R
52	1	R112	511 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B511DR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
53	1	R117	40.2 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B40D2R
54	1	R121	649 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B649DR
55	1	R124	5.1 Ω 1%, 1/8 Watt	RC1206	KOA / RM73B2B5R1JT
56	1	R125	499 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B499DR
57	1	R131	931 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	Dale / CRCW12069310FT
58	1	R134	383 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	Rohm / MCR12064420FT
59	1	R137	178 Ω, 1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B178DR

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
60	1	R139	20.0 Ω,1%, 1/4 Watt, 100ppm, FR=0.01%/ 1000hr	RM1206	D55342K07B20D0R
61	1	T1	Sensor, Temperature 534-31AG04-562	TO-52/3	Fenwell / LTN11 Type 534-31AG04-562
62	1	U1	Amplifier,. Operational, Clamping CLC501AJE	SOIC-8	Comlinear / CLC501AJE
63	1	U2	Receiver, Line Quad DS34C86	SOIC-16	National / DS34C86M
64	2	U3,U27	Amplifier, Dual, Wide Band LF353	SOIC-8	National / LF353M
65	1	U5	Controller, CCD TH7990	JLCC-44	Thomson-CSF / TH7990C
66	4	U6,U7, U12,U25	Driver, Line, Quad DS34C87	SOIC-16	National / DS34C87M
67	1	U8	Converter, Analog to Digital 8 bit MP7684	LCC-28	Micropower / MP7684ATL/883
68	4	U9,U10,U22 U23	Driver, Dual Inverting TSC4426	SOIC-8	Teledyne / TSC4426EOA

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
69	2	U11,U30	Driver, Differential, Dual TSC4428	SOIC-8	Teledyne / TSC4428EOA
70	1	U14	Amplifier, Operational, LF356	SOIC-8	National / LF356M
71	2	U17,U18	Regulator, Voltage, Adjustable LM317	SOIC-8	National / LM317LM
72	1	U19 **DO NOT KIT**	Charged Coupled Device CCD 7860 or7863	DIP-20	Type Chosen on Camera Selection
73	1	U24	Amplifier, Operational, Clamping CLC502	SOIC-8	Comlinear, CLC502AJE
74	1	U26 **DO NOT KIT**	Gate Array, Field Program, ACT1020A	JLCC-44	Actel / ACT1020A-1JQ44B
75	1	U32	Converter, Digital to Analog AD558TE/883	LCC20	Analog Devices / AD558TE/883
76	1	X1	Crystal, 20 MHz ±50ppm	CXAT	MicroCrystal / 20.000 MHz CXAT-T2
77	2	U19 Socket	Socket Strip 10 pin	SIP-10	LLNL / 5975-64700

Item	Qty.	Designator	Description	Case	Mfg. / Part Number
78	2	N/A	Spacer	N/A	AAA92-104616-OB Tab-01
79	2	N/A	Brass CCD Mounting Nuts	N/A	AAA92-109126 REV 00
80	2	N/A	#2-56 Stainless Steel Nut	N/A	NAS671C2
81	2	N/A	Washer, Stainless Steel, #2	N/A	NAS620C-2
82	2	TP1,TP2	Test Points	N/A	LLNL / 5975-66833
83	5	C82,C99,C100, C101,C123	0.1 µfd, 50 Volt, 10%	RC1206	Rohm / CE104K3NR-T2
84	1	R49	200 Ω, 5%, 1/4 Watt, 100 ppm, FR=0,01%/ 1000hr	RM1206	D55342K07B200JR
85	1	L2	Inductor, 47 µH	LQH4	MuRata Erie / LQH4N470K-TA

Appendix G.2.4
Assembly Procedures

Assembly Procedure
for
ACTEL Camera with Gain and Offset Control, StarTracker Configuration

Address: 2

	Date:	Rev.:	Date:	Approval:
Prepared by: W. R. Bryson				
Reviewed by: M. L. Dickerson				
Reviewed by: J.F. Kordas				
Reviewed by: R. E. Priest				
Reviewed by: E.H. Schmitt				
Approved by: M.J. Shannon				

1.0 Scope

This document describes the assembly procedure for the Actel Camera with Gain and Offset Control, StarTracker Configuration, Rev 00 printed wiring board. This procedure has been written for hand assembly, workmanship standards shall be MIL-STD-2000.

2.0 Required and Related Documents and General Notes

2.1 Required documents:

Bill of Materials, LEA92-3128-04 Actel Camera with Gain and Offset Control, StarTracker Configuration, Rev 00 Printed Wiring Board

Assembly Drawing, LEA92-3128-03 Actel Camera with Gain and Offset Control, StarTracker Configuration, Rev 00 Printed Wiring Assembly

Adhesive Compounds and Optical Couplets, C1-S0-005

Preparation of Gold Plated Leads, C1-EE-023

Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029

2.2 Related documents:

MIL-STD-1686A

Clementine Quality Assurance Program Plan, C1-S0-007

Clementine Sensor Suite Waiver Procedure, C1-S0-006

Clementine Failure Reporting, Analysis and Corrective Action System, C1-EE-0021

2.3 General Notes

1) All measuring devices used during the assembly of the Actel Camera board with Gain and Offset Control must be in current calibration. The calibration expiration date must be far enough in the future to allow completion of this assembly.

2) Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected or baked.

3) Clean and inspect, followed by printed wiring board bake are inserted at recommended locations. More or less components may be installed between clean and inspect points at the discretion of the QAG. It is mandatory that the printed wiring board is baked after solvent cleaning operations prior to continued solder assembly.

3.0 Visual Inspection

3.1 The printed wiring board shall have been inspected by the Quality Assurance Group (QAG) prior to loading. Record inspectors name both below and in the certification log work sheets by paragraph number.

Date: 3/29/93 (Inspection Date) QA: QA #2 (QA Stamp)

3.2 Record the manufacturer, serial number and manufactures lot code of the printed wiring board to be used in this assembly. Record both below and in the certification log work sheets by paragraph number.

Manufacturer Pioneer Circuits

Serial #: 0406 Lot Code: 6862

3.3 Mount the printed wiring board in an Actel Camera printed wiring board carrier.

4.0 Printed Wiring Board Bake Out

4.1 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Oven Calibration and Certification Current: QA #2 (Operator or QA Stamp)

Start Time: 7:00 p.m. End Time: 1:00 A.M.

Start Temp: 95 °C End Temp: 95 °C

Oven Make: Versa Temp II Oven Model: THJR

Oven Serial #: 12664-1

Date: 4/15/93 (Date Recorded) Operator: QA #2 (Operator or QA Stamp)

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

5.0 Parts Verification

5.1 Verify that all measuring devices to be used in 5.2 are in current calibration. Record both here and in the Assembly Log work sheets.

Equipment is in current calibration. Operator: H.R. Oper #9
Operator or QA Stamp

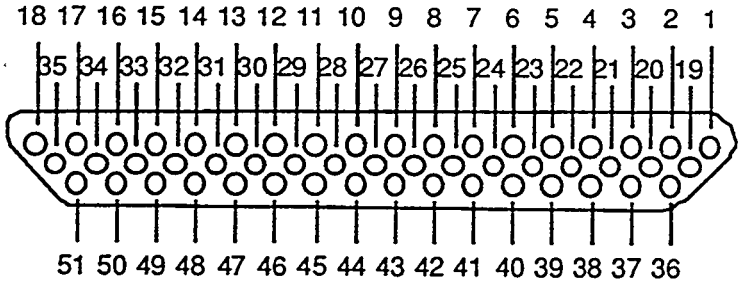
FLUKE - 3/19/93 - 3/19/95
DYNASCAN - 9/3/92 - 9/3/93

5.2 Verify that parts have been kitted per the bill of materials, LEA92-3128-04. This includes verification that all resistors and capacitors are within proper tolerance as specified in the bill of materials. Record both below and in the certification log work sheets by paragraph number.

Date: April 16, 1993 Operator: H.R. Oper #9
Date Verified Operator or QA Stamp

6.0 Resistance Measurements

6.1 Resistance measurements are to be made at J1 prior to assembly. Make and record the measurements as indicated in table 1. **All readings must be greater than 10 Meg ohms, except where noted.** See figure 1 below for the location of pins in J1.



MDM 51 Contact Connector.
Face View of Socket Insert.

Figure 1.

Meter Common	Signal	Meter Signal	Signal	Actual
J1-5	AGND	J1-39	+15VDC	O.L
J1-5	AGND	J1-4	-15VDC	O.L
J1-5	AGND	J1-37	+5VDC	O.L
J1-5	AGND	J1-3	-5VDC	O.L
J1-5	AGND	J1-40	+5VIN	O.L
J1-5	AGND	J1-20	DGND	O.L
J1-20	DGND	J1-39	+15VDC	O.L
J1-20	DGND	J1-4	-15VDC	O.L
J1-20	DGND	J1-37	+5VDC	O.L
J1-20	DGND	J1-3	-5VDC	O.L
J1-20	DGND	J1-40	+5VIN	O.L
J1-39	+15VDC	J1-4	-15VDC	O.L
J1-39	+15VDC	J1-37	+5VDC	O.L
J1-39	+15VDC	J1-3	-5VDC	O.L
J1-39	+15VDC	J1-40	+5VIN	O.L
J1-4	-15VDC	J1-37	+5VDC	O.L
J1-4	-15VDC	J1-3	-5VDC	O.L
J1-4	-15VDC	J1-40	+5VIN	O.L
J1-37	+5VDC	J1-3	-5VDC	O.L
J1-37	+5VDC	J1-40	+5VIN	O.L
J1-3	-5VDC	J1-40	+5VIN	O.L

Table 1.

7.0 Detailed assembly

7.1 Installation of item 79, brass CCD mounting nuts, AAA92-109126-00.

7.1.1 Insert item 79 from the secondary side of the printed wiring board as shown in figure 2 below.

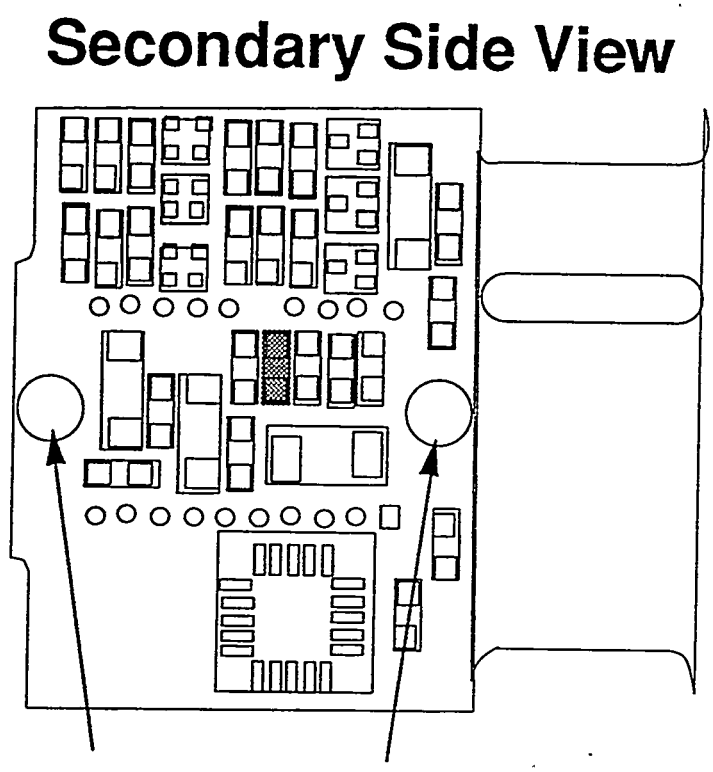


Figure 2.

7.1.2 Verify that the flange on the CCD nut is flush with the surface of the printed wiring board.

7.1.3 Solder the CCD mounting nuts in place.

Note: Use caution to prevent solder from entering the threaded area of the CCD nut.

7.2 Install the items listed in the table 2 below:

Item	Qty	Designator	Description	Case
1	44	C1,C3,C5,C6,C15,C21, C23,C25,C26, C30,C31,C33,C34,C38, C39,C40,C42,C44,C45, C47,C48,C54,C56,C57, C58,C59,C60,C63,C64, C66,C67,C70,C91,C92, C98,C102,C103,C104, C106,C109,C112,C114, C121,C124	0.039 µF, 100V, 10%	RM1206
9	1	C35	0.22 µfd, 50V, 10%	RM1206
11	2	C49,C50	0.022 µfd, 100V, 10%	RM1206
12	1	C53	15 pf, 100V, 5%	RM1206
13	5	C73,C74,C75,C76,C77	3300 pf, 50V, 10%	RC0402 RC0505
14	1	C83	0.01 µfd, 100V, 10%	RM1206
15	1	C111	47 pf, 100V, 5%	RM1206
16	2	C115,C116	270 pf, 100V, 10%	RM1206
83	8	C4,C7,C8,C82,C99, C100, C101,C123	0.1 µfd, 50 Volt, 10%	RC1206
28	2	R3,R66	7.5 KΩ, 1%	RM1206
30	2	R14,R31	243 Ω, 1%	RM1206
31	2	R15,R32	1.82 KΩ, 1%	RM1206

Table 2.

Item	Qty	Designator	Description	Case
1	47	C1,C3,C4,C5,C6,C7,C8, C15,C21,C23,C25,C26, C30,C31,C33,C34,C38, C39,C40,C42,C44,C45, C47,C48,C54,C56,C57, C58,C59,C60,C63,C64, C66,C67,C70,C91,C92, C98,C102,C103,C104, C106,C109,C112,C114, C121,C124	0.039 µF, 100V, 10%	RM1206
9	1	C35	0.22 µfd, 50V, 10%	RM1206
11	2	C49,C50	0.022 µfd, 100V, 10%	RM1206
12	1	C53	15 pf, 100V, 5%	RM1206
13	5	C73,C74,C75,C76,C77	3300 pf, 50V, 10%	RC0402 RC0505
14	1	C83	0.01 µfd, 100V, 10%	RM1206
15	1	C111	47 pf, 100V, 5%	RM1206
16	2	C115,C116	270 pf, 100V, 10%	RM1206
83	5	C82,C99,C100, C101,C123	0.1 µfd, 50 Volt, 10%	RC1206
28	2	R3,R66	7.5 KΩ, 1%	RM1206
29	2	R6,R7	150 Ω, 1%	RM1206
30	2	R14,R31	243 Ω, 1%	RM1206
31	2	R15,R32	1.82 KΩ, 1%	RM1206

Table 2.

7.3 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

Date: 4 / 18 / 93 (Date Inspected) QA: QA #2 (QA Stamp)

7.4 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Calibration and Certification Current, Initial: QA #2 (Operator or QA Stamp)

Start Time: 5:00 p.m End Time: 11:00 p.m

Start Temp: 95 °C End Temp: 95 °C

Oven Make: Versa Temp II Oven Model: THJR

Oven Serial #: 12664-1

Date: 4 / 18 / 93 (Date Completed) Operator: QA #2 (Operator or QA Stamp)

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.5 Install the items listed in tables 3a and 3b below.

Item	Qty	Designator	Description	Case
32	5	R16,R116,R130, R133,R136	49.9 Ω, 1%	RM1206
33	5	R17,R21,R74,R94,R95	1.0 KΩ, 1%	RM1206
34	1	R18	2.49 KΩ, 1%	RM1206
35	1	R20	2.7 KΩ, 5%	RM1206
36	1	R24	1.62 KΩ, 1%	RM1206
37	1	R25	9.09 KΩ, 1%	RM1206
38	1	R26	24.3 KΩ, 1%	RM1206
39	1	R27	7.68 KΩ, 1%	RM1206
40	2	R28,R91	0 Ω, 1%	RM1206
41	9	R29,R48,R101,R102,R129, R132,R135,R140,R141	10 KΩ, 1%	RM1206
42	1	R30	2.15 KΩ, 1%	RM1206
43	3	R37,R115, R122	100 Ω, 1%	RM1206
44	1	R38	3.01 KΩ, 1%	RM1206
45	2	R42,R43	30 Ω, 2%	RM1206
46	2	R44,R93	1.96 KΩ, 1%	RM1206
47	1	R46	100 KΩ, 1%	RM1206
48	1	R92	20 KΩ, 1%	RM1206
49	4	R96,R98,R118,R120	2.61KΩ, 1%	RM1206
50	1	R97	301 Ω, 1%	RM1206

Table 3a.

7.5 Install the items listed in tables 3a and 3b below.

Item	Qty	Designator	Description	Case
32	5	R16,R116,R130, R133,R136	49.9 Ω, 1%	RM1206
33	5	R17,R21,R74,R94,R95	1.0 KΩ, 1%	RM1206
34	1	R18	2.49 KΩ, 1%	RM1206
35	1	R20	2.7 KΩ, 5%	RM1206
36	1	R24	1.62 KΩ, 1%	RM1206
37	1	R25	9.09 KΩ, 1%	RM1206
38	1	R26	24.3 KΩ, 1%	RM1206
39	1	R27	7.68 KΩ, 1%	RM1206
40	2	R28,R91	0 Ω, 1%	RM1206
41	9	R29,R48,R101,R102,R129, R132,R135,R140,R141	10 KΩ, 1%	RM1206
42	1	R30	2.15 KΩ, 1%	RM1206
43	4	R37,R115, R122,R128	100 Ω, 1%	RM1206
44	1	R38	3.01 KΩ, 1%	RM1206
45	2	R42,R43	30 Ω, 2%	RM1206
46	3	R44,R93,R119	1.96 KΩ, 1%	RM1206
47	1	R46	100 KΩ, 1%	RM1206
48	1	R92	20 KΩ, 1%	RM1206
49	4	R96,R98,R118,R120	2.61KΩ, 1%	RM1206
50	1	R97	301 Ω, 1%	RM1206

Table 3a.

Item	Qty	Designator	Description	Case
51	2	R99,R119	6.19 KΩ, 1%	RM1206
52	1	R112	511 Ω, 1%	RM1206
53	1	R117	40.2 Ω, 1%	RM1206
54	1	R121	649 Ω, 1%	RM1206
55	1	R124	5.1 Ω 1%	RM1206
56	1	R125	499 Ω, 1%	RM1206
57	1	R131	931 Ω, 1%	RM1206
58	1	R134	383 Ω,1%	RM1206
59	1	R137	178 Ω, 1%	RM1206
60	1	R139	20.0 Ω,1%	RM1206

Table 3b.

7.5.1 Temporarily install a 1K 1% RM1206 resistor for R49. Tack this part only do not fully solder.

7.6 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

See old page 10

Date: 4/22/93 QA: [illegible]

Date Inspected QA Stamp

7.7 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Item	Qty	Designator	Description	Case
51	1	R99	6.19 KΩ, 1%	RM1206
52	1	R112	511 Ω, 1%	RM1206
53	1	R117	40.2 Ω, 1%	RM1206
54	1	R121	649 Ω, 1%	RM1206
55	1	R124	5.1 Ω 1%	RM1206
56	1	R125	499 Ω, 1%	RM1206
57	1	R131	931 Ω, 1%	RM1206
58	1	R134	383 Ω,1%	RM1206
59	1	R137	178 Ω, 1%	RM1206
60	1	R139	20.0 Ω,1%	RM1206
84	1	R49	200 Ω, 5%	RM1206

Table 3b.

7.6 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

Date: 4/22/93 (Date Inspected) QA: QA #2 (QA Stamp)

7.7 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Calibration and Certification Current, Initial: QA #2 (Operator or QA Stamp)

Start Time: 7:00p.m End Time: 1:00 p.m

Start Temp: 95 °C End Temp: 95 °C

Oven Make: VersaGen II Oven Model: THJR

Oven Serial #: 12664-1

Date: 4/21/93 (Date Completed) Operator: QA #2 (Operator or QA Stamp)

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.8 Install the items listed in tables 4a and 4b below.

Item	Qty	Designator	Description	Case
2	5	C2,C51,C61,C62,C122	4.7 µfd, Tant, 10V, 10%	D-CASE
3	1	C9	47 µfd, Tant, 20V, 10%	R-CASE
4	2	C10,C11	22 µfd, Tant, 15V, 10%	G-CASE
5	4	C12,C13,C17,C105	6.8 µfd, Tant, 10V, 10%	E-CASE
7	6	C22,C24,C29,C69,C90, C118	22 µfd, Tant, 20V, 10%	H-CASE
8	4	C32,C52,C94, C95	10 µfd, Tant, 25V,10%	G-CASE
10	2	C46,C93	1.0 µfd, Tant 35V, 10%	D-CASE

Table 4a.

Item	Qty	Designator	Description	Case
17	1	D1	Diode, Switching, MBAV74	SOT-23
20	2	D4,D5	Diode, Schottky, 30V BAT54S	SOT-23
26	3	Q2,Q3,Q8	Transistor, 2N3904	SOT-23
27	3	Q12,Q13,Q14	Transistor, 2N7002	SOT-23
22	3	L1,L3,L4	Inductor, 100 µH	LQH4
23	1	L5	Inductor, 10 µH	LQH4
84	1	L2	Inductor, 47 µH or 39 µH	LQH4
25	5	Q1,Q4,Q9, Q10,Q11	Transistor, FET, SST215	SOT-143
76	1	X1	Crystal, 20MHZ	CXAT

Table 4b.

7.8.1 The landing pattern for item 6 was incorrectly designed on some boards. If so, item 6 must be installed on its side. Install item 6 as listed in table 5 below.

Item	Qty	Designator	Description	Case
6	2	C20,C110	6.8 µfd, Tant, 20V, 10%	F-CASE

Table 5.

7.9 Install the jumpers indicated in table 6 below. These parts are located as shown in Figure 3 on the primary side of the printed wiring board and in Figure 4 on the secondary side of the printed wiring board.

Item	Qty	Designator	Description	Case
21	9	JP4,JP6,JP7,JP9,JP11, JP13,JP14,JP15,JP16	Jumper, 0 Ω, 1%	RM1206

Table 6.

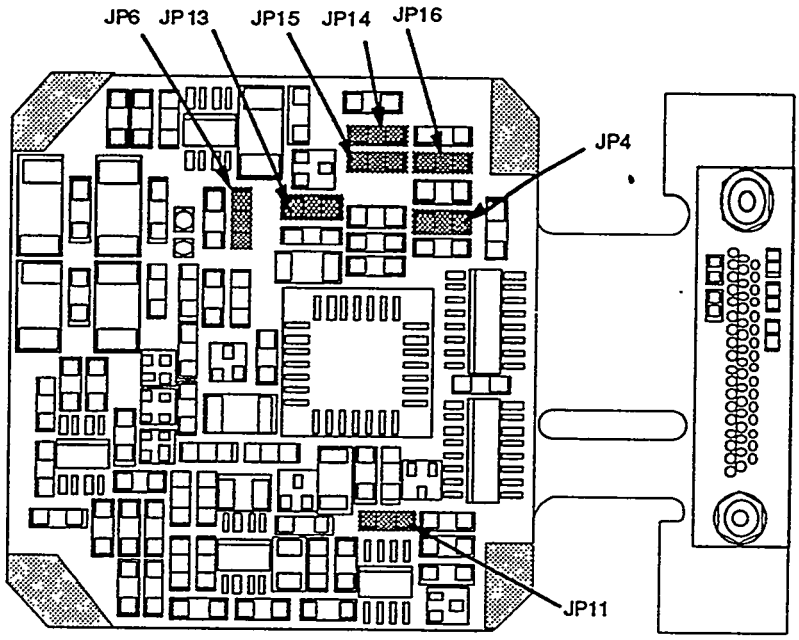


Figure 3, Primary Side View.

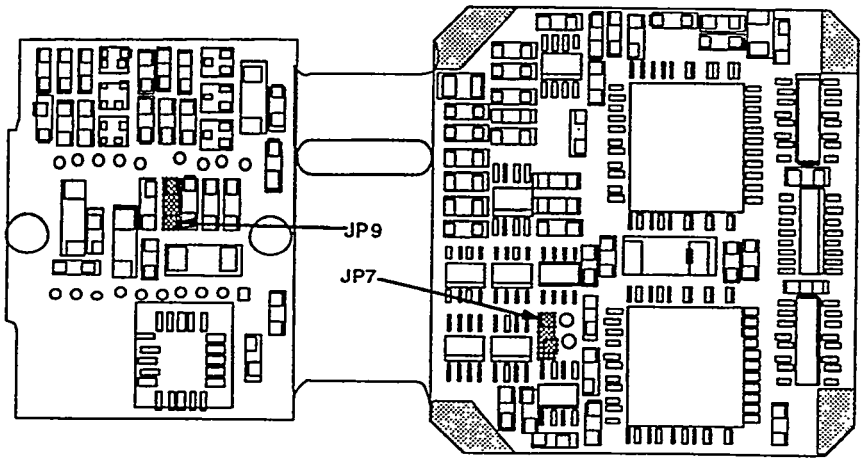


Figure 4, Secondary Side View.

7.10 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

Date: 4/22/93 (Date Inspected) QA: QA #2 (QA Stamp)

7.11 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Calibration and Certification Current, Initial: QA #2 (Operator or QA Stamp)

Start Time: 7:30 p.m. End Time: 1:30 A.M

Start Temp: 95 °C End Temp: 95 °C

Oven Make: Versa Tem II Oven Model: THJR

Oven Serial #: 121664-1

Date: 4/22/93 (Date Completed) Operator: QA #2 (Operator or QA Stamp)

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.12 Install the items listed in tables 7a and 7b below.

Item	Qty	Designator	Description	Case
18	1	D2	Diode, Voltage Reference LM285-1.2	SOIC-8
19	1	D3	Reference, Voltage, Precision, 10V, REF-01	SOIC-8
62	1	U1	Amplifier,. Operational, Clamping CLC501AJE	SOIC-8
64	2	U3,U27	Amplifier, Dual, Wide Band LF353	SOIC-8
68	4	U9,U10,U22 U23	Driver, Dual Inverting TSC4426	SOIC-8
69	2	U11,U30	Driver, Differential, Dual TSC4428	SOIC-8
70	1	U14	Amplifier, Operational, LF356	SOIC-8
71	2	U17,U18	Regulator, Voltage, Adjustable LM317	SOIC-8

Table 7a.

Item	Qty	Designator	Description	Case
73	1	U24	Amplifier, Operational, CLC502	SOIC-8
63	1	U2	Receiver, Line, Quad DS34C86	SOIC-16
66	4	U6,U7, U12,U25	Driver, Line, Quad DS34C87	SOIC-16
67	1	U8	Converter, Analog to Digital 8 bit MP7684	LCC-28
75	1	U32	Converter, Digital to Analog AD558TE/883	LCC20
65	1	U5	Controller, CCD TH7990	JLCC-44

Table 7b.

7.13 Item 74, U26, an Actel ACT1020A is a programmed device. Due to its critical function in the operation of the Actel Camera it is not provided until requested. **QA verification of the Actel array is required.** Record below and in the Assembly Log work sheets the identifying information for the Actel gate array. Record the address on the front page of this document.

File Name: ST2D Link File Date 4/22/93 Check Sum: N/A

Programming Date: 4-May 93 StarTracker Address 2
#1 or #2

Device Supplied By: DPN
Name of Engineer or Technologist

QA: QA #1
QA Stamp

7.14 Install item 74, U26, ACTEL ACT1020A.

7.15 Cut pin number 16 of Item 77, socket strip for U19. **Important!** The cut must be flush with the base of the taper. See figure 5 below.

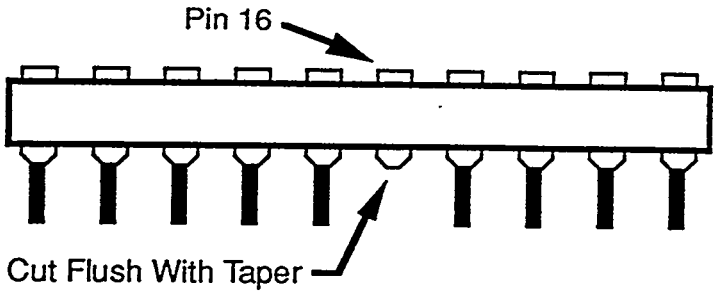


Figure 5.

7.16 Insert both strips of item 77,U19 socket, through the printed wiring board. Insert a dummy 20 pin DIP into the socket strips. Verify that the dummy DIP is completely seated in the socket strips and that the strips sit square and flat to the printed wiring board. Solder the socket strips to the printed wiring board. Remove the dummy DIP from the socket strips.

7.17 Pretin the leads of item 82 TP1 and TP2, two pin terminal strips per C1-EE-023, Preparation of Gold Plated Leads.

7.18 Install Item 82, two pin terminal strips

7.19 Temporarily tack a wire between the outermost pads of R128 and C123. See figure 6 below.

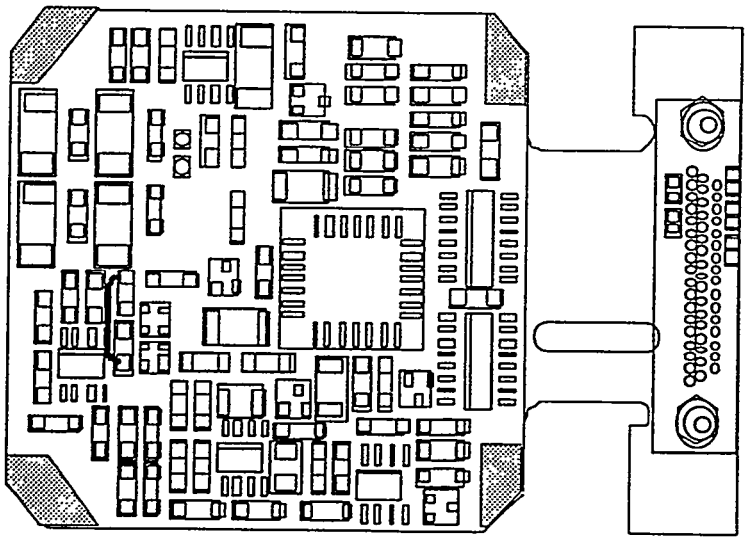


Figure 6.

7.14 Install item 74, U26, ACTEL ACT1020A.

7.15 Cut pin number 16 of Item 77, socket strip for U19. **Important!** The cut must be flush with the base of the taper. See figure 5 below.

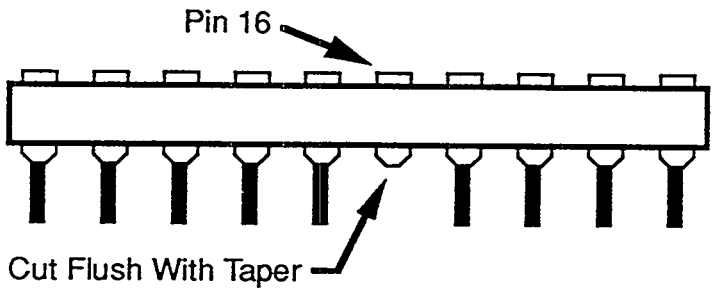


Figure 5.

7.16 Insert both strips of item 77,U19 socket, through the printed wiring board. Insert a dummy 20 pin DIP into the socket strips. Verify that the dummy DIP is completely seated in the socket strips and that the strips sit square and flat to the printed wiring board. Solder the socket strips to the printed wiring board. Remove the dummy DIP from the socket strips.

7.17 Pretin the leads of item 82 TP1 and TP2, two pin terminal strips per C1-EE-023, Preparation of Gold Plated Leads.

7.18 Install Item 82, two pin terminal strips

7.19 Pretin the leads of item 24, J1 per C1-EE-023, Preparation of Gold Plated Leads.

7.20 Measure the longest dimension of item 78, spacers, AAA92-104616-0B TAB 01. They should be 0.385 + 0.005, - 0.000 inch long. Record the measurement both here and in the assembly log work sheets.

Length of Spacers .387 .388

7.21 Assemble 2 each spacers, 2 each #2 stainless steel washers, item 81, and 2 each #2-56 stainless steel nuts, item 80, through the printed wiring board as shown in figure 6. Spacers are mounted from the primary side with nuts and washers on the secondary side. Using a calibrated tool, torque nuts to 40.0 ± 2 oz-in.

Torqued nuts to 40.0 oz. in. - Used an uncalibrated tool

NK

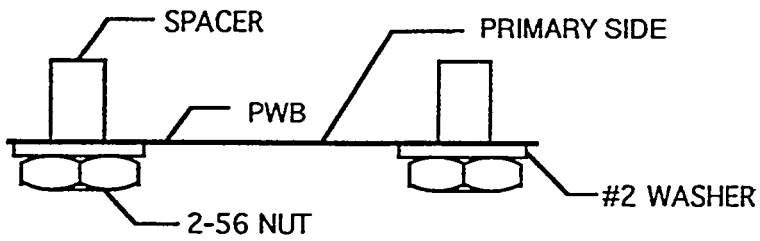


Figure 6.

7.22 Insert the leads of J1 through the printed wiring board. The connector J1 sits on top of the standoffs.

7.23 Assemble J1 to the spacers using 2 each #2-56 x .25 long. screws as shown in figure 7. Finger tighten only, do not torque.

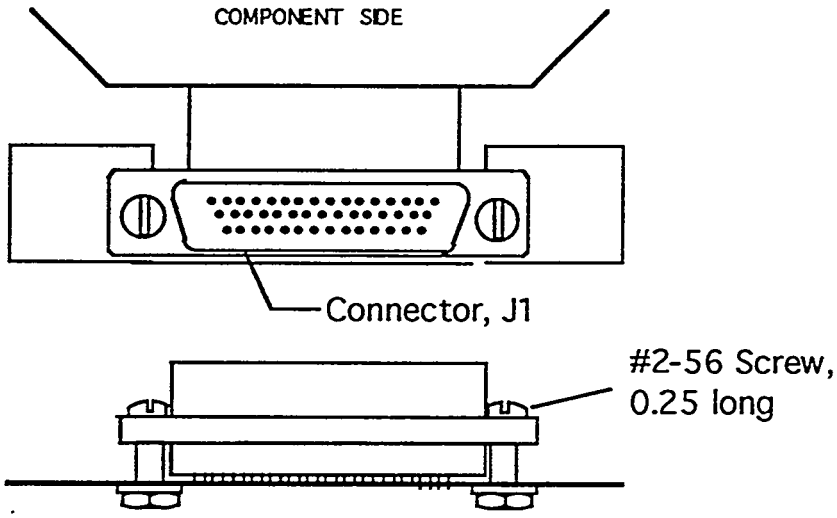


Figure 7.

7.24 Trim the leads of J1 such that they extend thru the printed wiring board by 0.020 to 0.040 inch.

7.25 Verify that the bottom surface of the flange of J1 is 0.257 ± .005 inch from the surface of the printed wiring board at both ends of the connector. Record the spacing both here and in the work sheet section of the assembly log.

J1 Bottom Surface distance from PWB: .261

J1 Bottom Surface distance from PWB: .261

Operator: N.A. Oper #9
Operator or QA Stamp

7.19 Temporarily tack a wire between the outermost pads of R128 and C123. See figure 6 below.

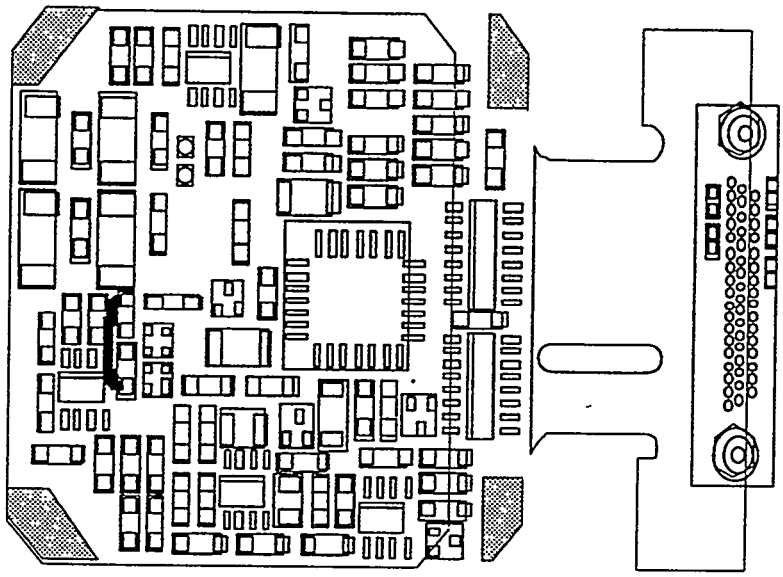


Table 6.

7.20 Pretin the leads of item 24, J1 per C1-EE-023, Preparation of Gold Plated Leads.

7.21 Measure the longest dimension of item 78, spacers, AAA92-104616-0B TAB 01. They should be 0.385 + 0.005, - 0.000 inch long. Record the measurement both here and in the assembly log work sheets.

Length of Spacers _____ _____

7.22 Assemble 2 each spacers, 2 each #2 stainless steel washers, item 81, and 2 each #2-56 stainless steel nuts, item 80, through the printed wiring board as shown in figure 7. Spacers are mounted from the primary side with nuts and washers on the secondary side. Using a calibrated tool, torque nuts to 40.0 ± 2 oz-in.

7.26 Solder the leads of J1 to the printed wiring board.

7.27 Installation of item 61, T1, thermistor will be done after completion of engineering evaluation.

7.28 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

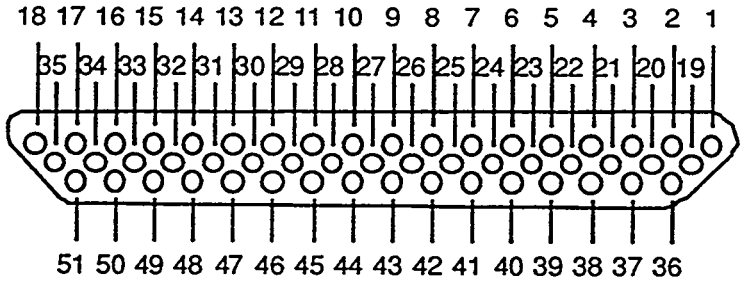
Date: 4/23/93 (Date Inspected) QA: QA #2 (QA Stamp)

Baked Bd. at 95 c for 6 hrs in Oven S/N # 12664-1

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.29 Install a connector saver on J1.

7.30 Resistance measurements are to be made at J1 at this time. Make and record the measurements as indicated in table 8. **All readings must be greater than 1 KΩ, except where noted.** See figure 8 below for the location of pins in J1.



MDM 51 Contact Connector.
Face View of Socket Insert.

Figure 8.

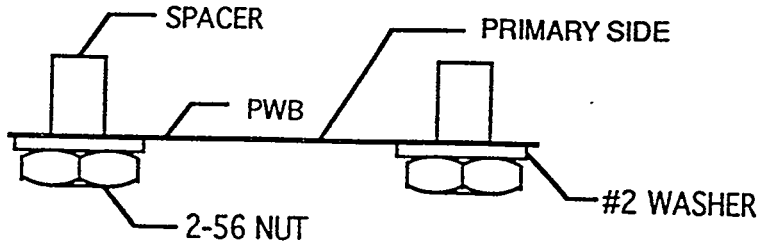


Figure 7.

7.23 Insert the leads of J1 through the printed wiring board. The connector J1 sits on top of the standoffs.

7.24 Assemble J1 to the spacers using 2 each #2-56 x .25 long. screws as shown in figure 8. Finger tighten only, do not torque.

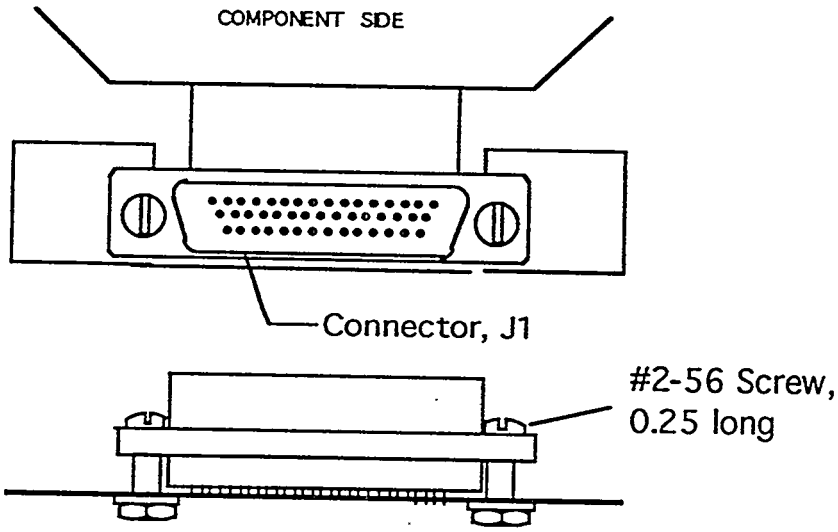


Figure 8.

7.25 Trim the leads of J1 such that they extend thru the printed wiring board by 0.020 to 0.040 inch.

7.26 Verify that the bottom surface of the flange of J1 is 0.257 ± .005 inch from the surface of the printed wiring board at both ends of the connector. Record the spacing both here and in the work sheet section of the assembly log.

J1 Bottom Surface distance from PWB: _____

J1 Bottom Surface distance from PWB: _____

Operator: _____
Operator or QA Stamp

7.27 Solder the leads of J1 to the printed wiring board.

7.28 Installation of item 61, T1, thermistor will be done after completion of engineering evaluation.

7.29 Installation of items listed in table 8 below will be done after test.

Item	Qty	Designator	Description	Case
43	2	R49,R128	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206

Table 8.

7.30 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

Date: 5/5/93
Date Inspected

QA: QA #2
QA Stamp

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.31 Install a connector saver on J1.

7.20 Pretin the leads of item 24, J1 per C1-EE-023, Preparation of Gold Plated Leads.

7.21 Measure the longest dimension of item 78, spacers, AAA92-104616-0B TAB 01. They should be 0.385 + 0.005, - 0.000 inch long. Record the measurement both here and in the assembly log work sheets.

See old page 17

Length of Spacers .387 .387

7.22 Assemble 2 each spacers, 2 each #2 stainless steel washers, item 81, and 2 each #2-56 stainless steel nuts, item 80, through the printed wiring board as shown in figure 7. Spacers are mounted from the primary side with nuts and washers on the secondary side. Using a calibrated tool, torque nuts to 40.0 ± 2 oz-in.

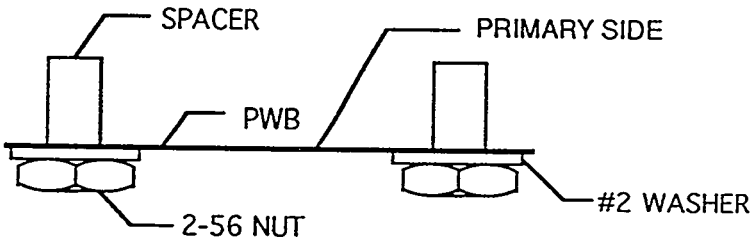


Figure 7.

7.23 Insert the leads of J1 through the printed wiring board. The connector J1 sits on top of the standoffs.

7.24 Assemble J1 to the spacers using 2 each #2-56 x .25 long. screws as shown in figure 8. Finger tighten only, do not torque.

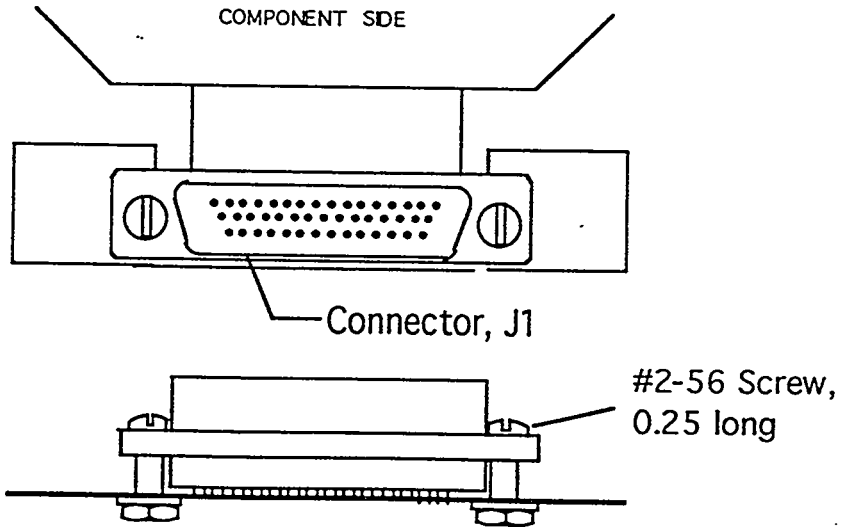


Figure 8.

7.25 Trim the leads of J1 such that they extend thru the printed wiring board by 0.020 to 0.040 inch.

7.26 Verify that the bottom surface of the flange of J1 is 0.257 ± .005 inch from the surface of the printed wiring board at both ends of the connector. Record the spacing both here and in the work sheet section of the assembly log.

J1 Bottom Surface distance from PWB: .261

J1 Bottom Surface distance from PWB: .261

Operator: QA #7 See old page 18

Operator or QA Stamp

7.27 Solder the leads of J1 to the printed wiring board.

7.28 Installation of item 61, T1, thermistor will be done after completion of engineering evaluation.

7.29 Installation of items listed in table 8 below will be done after engineering evaluation.

Item	Qty	Designator	Description	Case
43	2	R49,R128	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206

Table 8.

7.30 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets. See old page 19

Date: 4/23/93 QA: [illegible]

Date Inspected QA Stamp

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

7.31 Install a connector saver on J1.

7.32 The printed wiring assembly now goes to engineering for evaluation.

8. Post Evaluation Assembly

8.1 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

This bake out step was skipped

Calibration and Certification Current, Initial: _____
Operator or QA Stamp

Start Time: _____ End Time: _____

Start Temp: _____ °C End Temp: _____ °C

Oven Make: _____ Oven Model: _____

Oven Serial #: _____

Date: _____ Operator: _____
Date Completed Operator or QA Stamp

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

8.2 Remove the jumper from outermost pads of R128 and C123 that was installed at step 7.19

8.3 Install the items listed in table 9 below.

Item	Qty	Designator	Description	Case
43	2	R49,R128	100 Ω, 1%, 1/4 Watt, 100 ppm, FR=0.01%/ 1000hr	RM1206

Table 9.

8.4 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

See work sheet #68

Date: 5/5/93 QA: 1# VO

Date Inspected QA Stamp

8.5 The printed wiring assembly now goes to engineering for additional evaluation.

8.6 The printed wiring board shall be baked at 130 ± 5 °C for a minimum of 6 hours prior to loading, per Polyimide Based Printed Wiring Board Conditioning Methods, C1-EE-029. Prior to baking the printed wiring board, verify that the oven to be used is in current calibration and has been verified by the QAG. The start and end times along with the start and end temperatures shall be recorded. The oven temperature profile shall be recorded, using a strip chart recorder, for the duration of the bake out. Record the date, assembly, serial number, assembly step and operator on the chart and insert in the certification section of the assembly log. The make, model and serial number of the oven used for bake out shall be recorded. Record both below and in the certification log work sheets by paragraph number.

Calibration and Certification Current, Initial: QA #2
Operator or QA Stamp

Start Time: 8:30 A.M End Time: 2:30 P.M

Start Temp: 95 °C End Temp: 95 °C

Oven Make: Versa Temp II Oven Model: THJR

Oven Serial #: 12664-1

Date: 5/17/93 (Date Completed) Operator: QA #2
Operator or QA Stamp

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

8.7 Trim and form the leads of TR1 and TR2 as shown in figure 10 below.

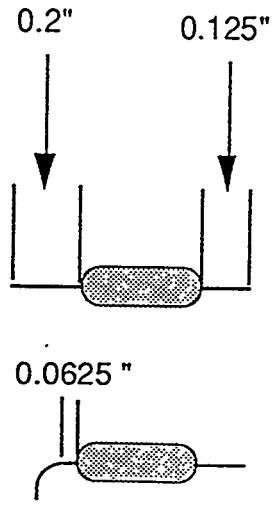


Figure 10.

8.8 Place, **do not solder at this point,** TR1 and TR2 on the secondary side of the board as shown in figure 11 below.

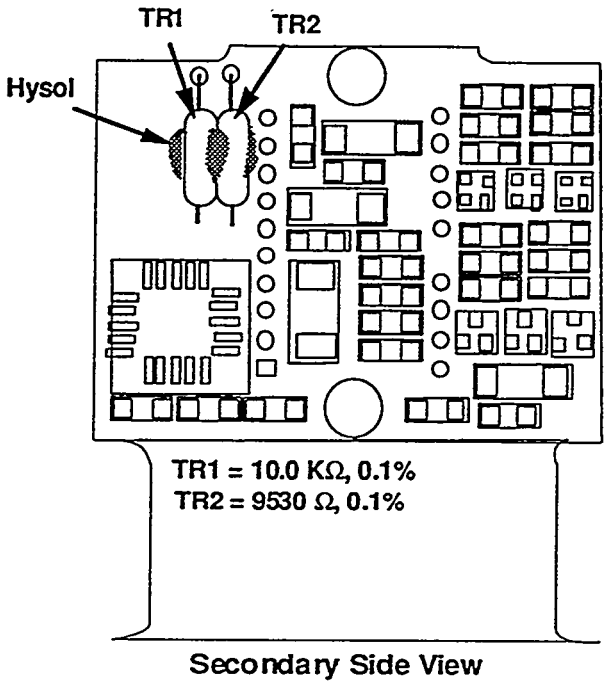


Figure 11.

8.9 Bond TR1 and TR2 to the printed wiring board as shown in figure 11 using EA 934 (reference, Eng. Note C1-S0-005). Bake for 30 minutes at 60 °C.

8.10 Identify the leads of item 61, T1, thermistor. Lead L1 is the longest lead, L4 is the shortest and L2/L3 is in between. Verify the lead identity by making resistance measurements as shown in figure 12.

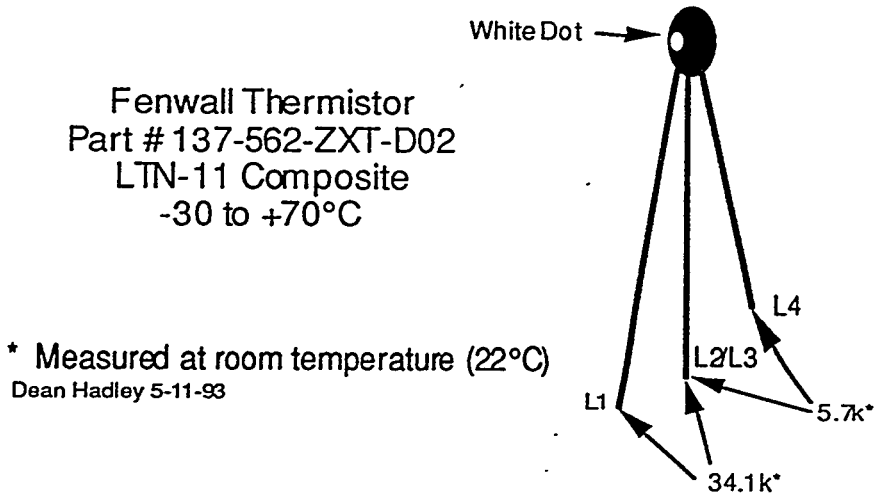


Figure 12.

8.11 Using #28 wire wrap wire insulation, insulate lead L4 and L1 to a length of 0.75 inch. Insulate leads L2/L3 to a length of 1.5 inch. Use a different color insulation for each lead.

8.12 Insert the lead for L4, from the primary side, through the hole indicated in figure 13. The lead from TR2 is also in this hole. Allow 0.75 inch of lead length between the printed wiring board and the body of the thermistor. See figure 14 for detail.

8.13 Insert the lead for L1, from the primary side, through the hole indicated in figure 13. The lead from TR1 is also in this hole. Allow 0.75 inch of lead length between the printed wiring board and the body of the thermistor. See figure 14 for detail.

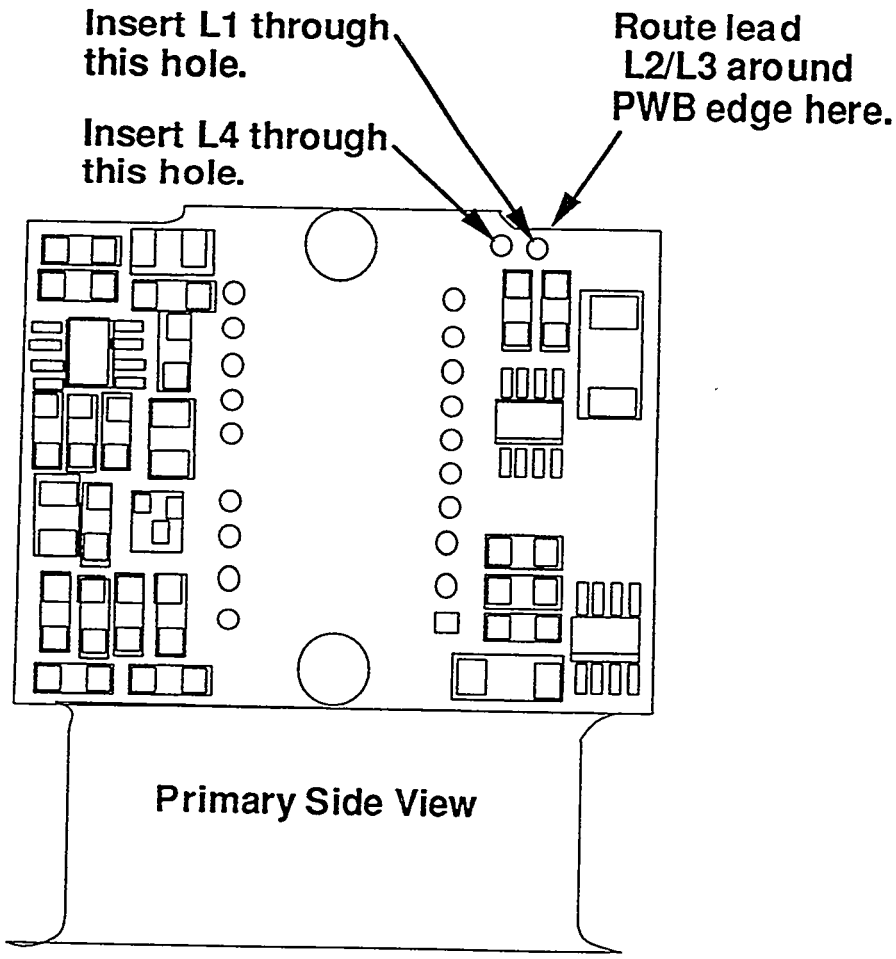


Figure 13.

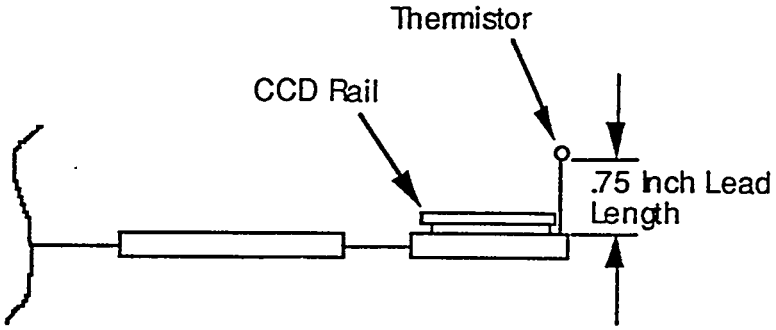


Figure 14.

8.14 Trim L4 to the correct length and solder it along with TR2. **Do not trim the lead L1.**

8.15 **Without trimming the lead,** solder L1 and TR1.

8.16 Route lead L2/L3 of T1 around the edge of the printed wiring board and to TR1 as shown in figures 13 and 15. Route lead L1 to TR2 as shown in figure 15.

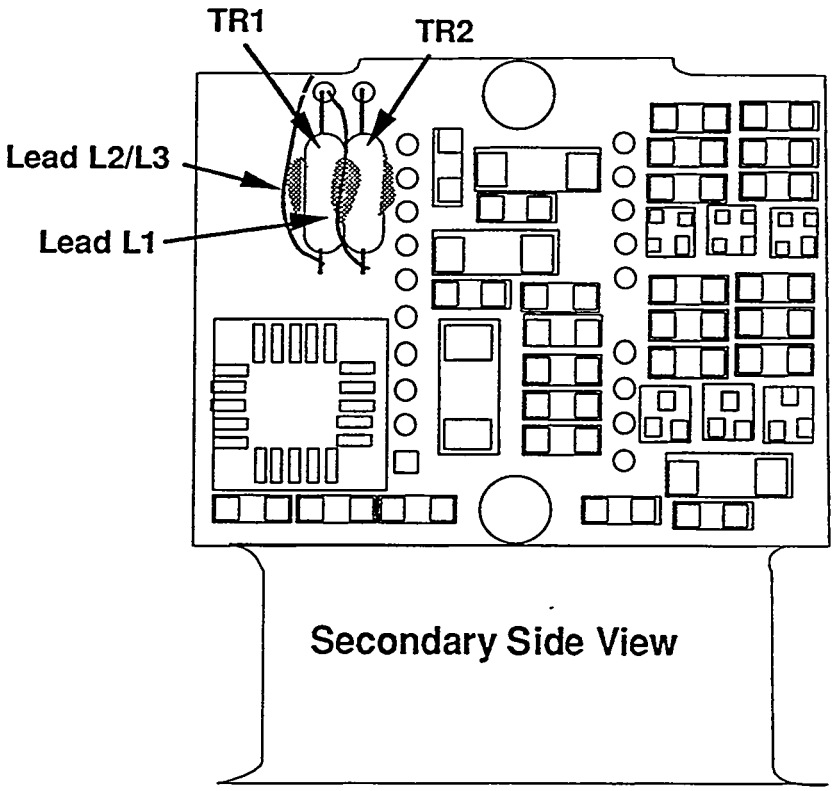


Figure 15.

8.17 Dress the thermistor wires around the end of the CCD rail as shown in figure 16 below.

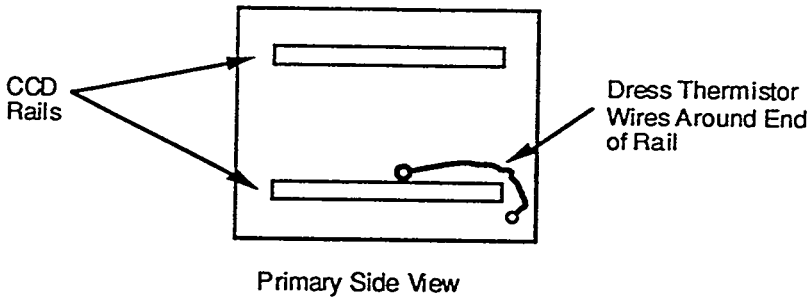


Figure 16.

8.18 Solder the leads of the thermistor to the leads of TR1 and TR2 as shown in figure 15. The leads of T1 must be wrapped at least 3 times around the lead of TR1 or TR2. Wrap the leads in the middle of the resistor lead.

8.19 Clean and inspect all solder joints per MIL-STD-2000. Rework any substandard solder joints. Record inspection both here and in the certification log worksheets.

Date: 5/18/93 QA: QA #2

Date Inspected QA Stamp

8.20 Stake the thermistor wires, using EA 934 (reference, Eng. Note C1-S0-005), on the secondary side of the printed wiring board as shown in figure 17. Keep the staking on the edge of the printed wiring board as thin a practical.

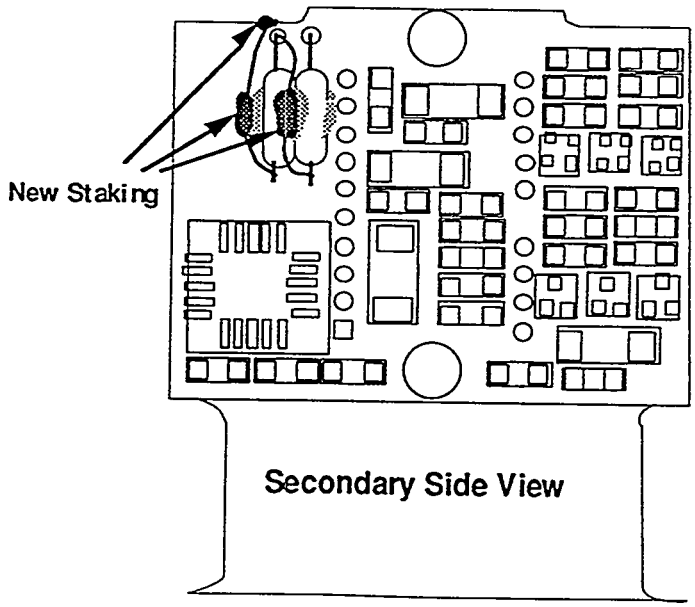


Figure 17.

Retorque and

HARDWARE to Board

8.21 Stake the connector standoff ~~nuts~~ and any other items indicated by Quality Assurance. Bake for 30 minutes @ 60 °C.

8.22 Inspect all staking operations. Record inspection both here and in the certification log worksheets.

Date: 5/18/93 _____ QA: _____

Date Inspected QA Stamp

Note: Printed wiring boards are to be stored in an airtight, antistatic bag with a desiccant at all times the board is not being loaded, cleaned, inspected, tested or baked.

Appendix G.2.5
Certificates of Conformance

3.6 Pre-Test Operations

CAUTION
ESD SENSITIVE HARDWARE. HANDLE PER MIL-STD-1686 Class 1

_X_(1) Assure readiness to test, including the following items:

(a) Visual examination of the test item and its interfaces, including any special test instrumentation .

(b) Calibration is current for measuring instruments

(c) Proper edition of the procedure, and QA approval of any unincorporated redlines.

(d) Notification of QA of the time that testing will begin.

_X_(2) Record the "Occasion for Test" on all Data Sheets.

_X_(3) On the applicable data sheets, record the required information for measuring equipment to be used in the test. Verify that all such equipment bears current calibration stickers, and that calibration will not expire prior to the end of the test.

_X_(4) Have completed Actel Camera Array Test Board Certification C1-EE-033.

_X_(5) Solicit and obtain the QA Inspector's "OK to Continue."

ST2D
4/22/93

DPN
Startracker #2 array
AL023 Bd # 04-06

Test Conductor [signature] Date 5/4/93

3.7 TEST

Test Start Date: 5/4/93 Test Completion Date: 5/4/93

Equipment Used	S/N	Calibration In-date
TDS540	B023760	01/Oct/93
Mac 2x		

Enter Name of LabView programs to Use

Name	Date Created	Date Modified
Actel Test Program.1	4/29/93	5/3/93

NOTES:

Test Conductors:

Name: Dinesh Nutan Initials: DPN Date 5/4/93

Name: _____ Initials: ____ Date _____

Functions to Be tested

1. Sasi Functions

Check bits can be set and cleared and read back.

Name: _____ Initials: DPN Date 5/4/93

2. Double Correlated Sampling

TP14 is OL2
TP15 is ORfet
TP16 is OR

Name: _____ Initials: DPN Date 5/4/93

3. Precision Integration mode Check and Frame Enable
{frame xfer of UV-vis arrays}

TP9 SM1
TP10 SM0
TP11 EOL
TP3 VSync {frame enable}
TP13 VTC

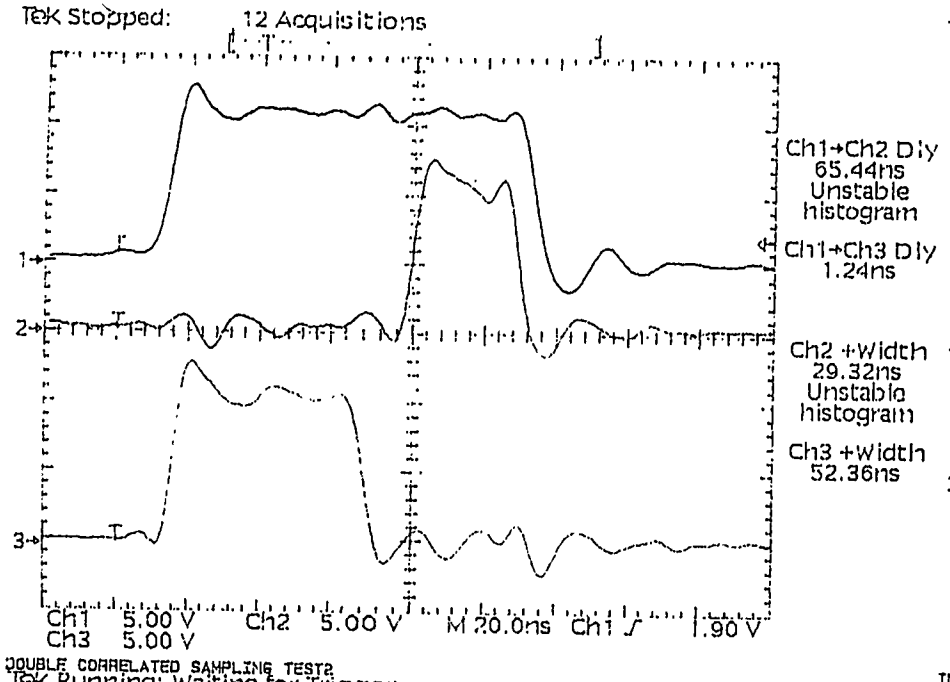
Name: _____ Initials: DPN Date 5/4/93

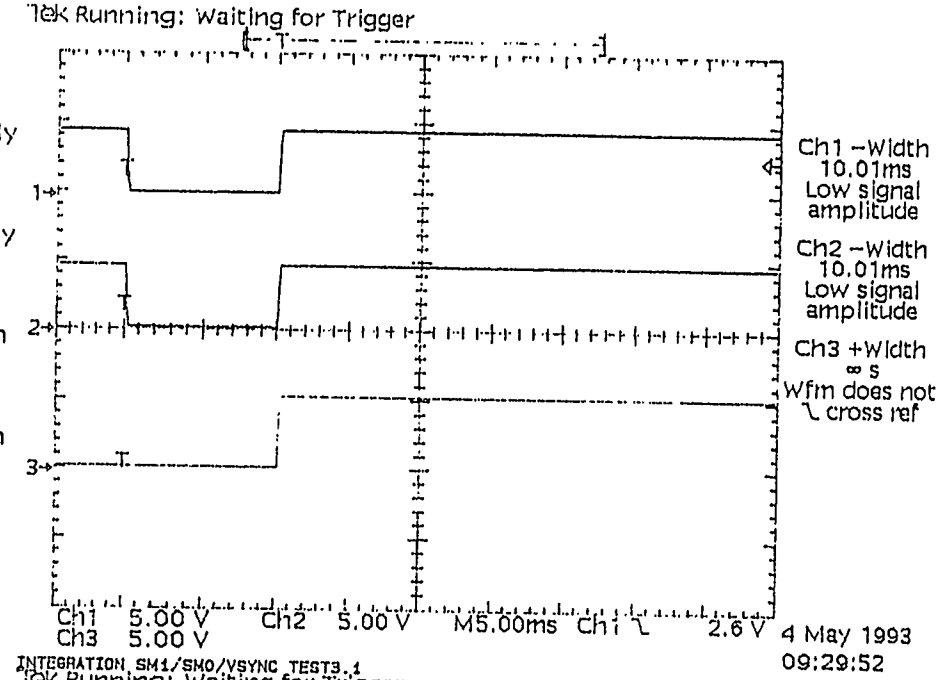
4. Test Initialization

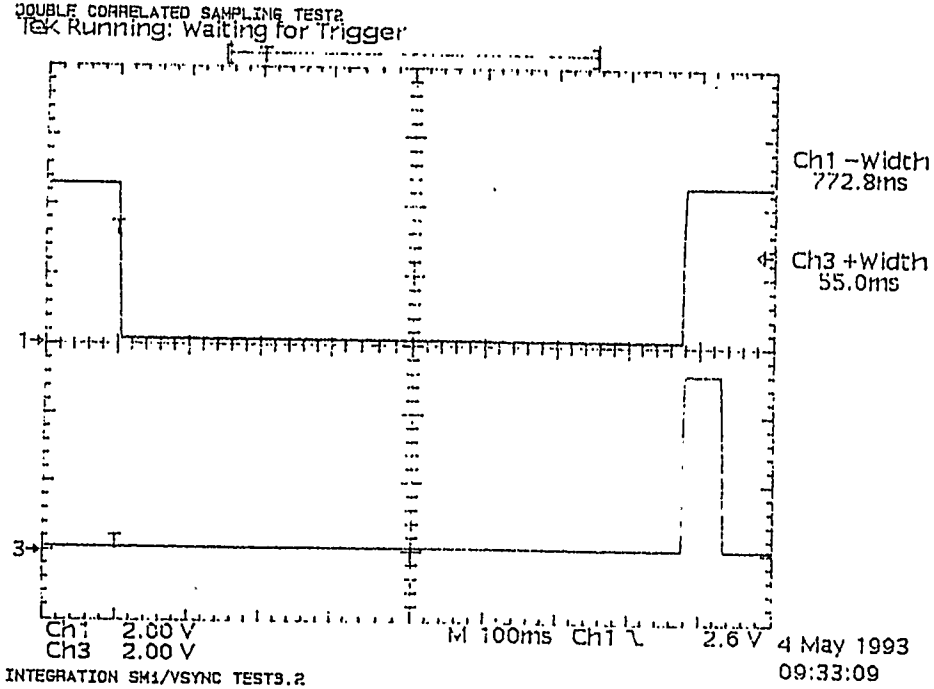
TP8 T2
TP7 Init 214.6ns - Width

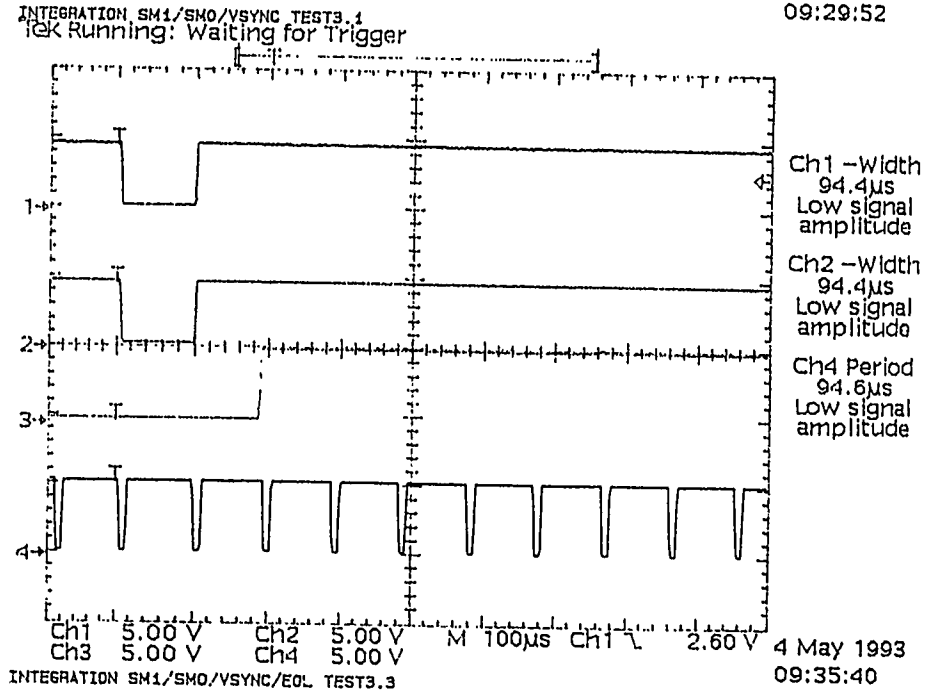
Name: _____ Initials: DPN Date 5/4/93

DATA is to go in certification log of camera that array is going into.

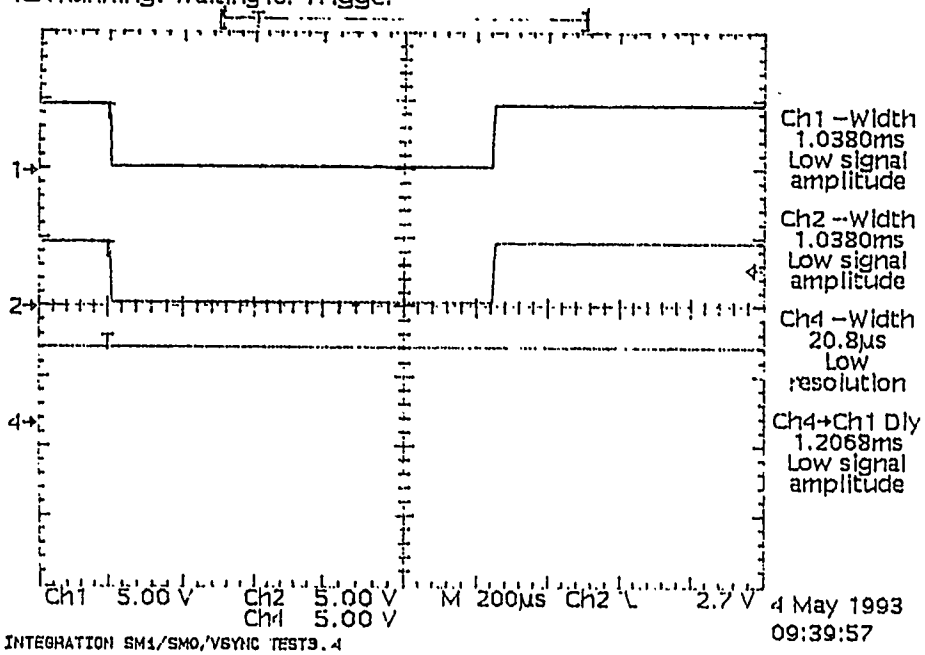

Tek Stopped: 12 Acquisitions
Ch1→Ch2 Dly
65.44ns
Unstable
histogram
Ch1→Ch3 Dly
1.24ns
Ch2 +Width
29.32ns
Unstable
histogram
Ch3 +Width
52.36ns
Ch1 5.00 V Ch2 5.00 V M 20.0ns Ch1 ∕ 1.90 V
Ch3 5.00 V
DOUBLE CORRELATED SAMPLING TEST2


Tek Running: Waiting for Trigger
Ch1 −Width
10.01ms
Low signal
amplitude
Ch2 −Width
10.01ms
Low signal
amplitude
Ch3 +Width
∞ s
Wfm does not
cross ref
Ch1 5.00 V Ch2 5.00 V M5.00ms Ch1 ∖ 2.6 V
Ch3 5.00 V
INTEGRATION SM1/SMO/VSYNC TEST3.1
4 May 1993
09:29:52


Tek Running: Waiting for Trigger
Ch1 −Width
772.8ms
Ch3 +Width
55.0ms
Ch1 2.00 V M 100ms Ch1 ∖ 2.6 V
Ch3 2.00 V
INTEGRATION SM1/VSYNC TEST3.2
4 May 1993
09:33:09

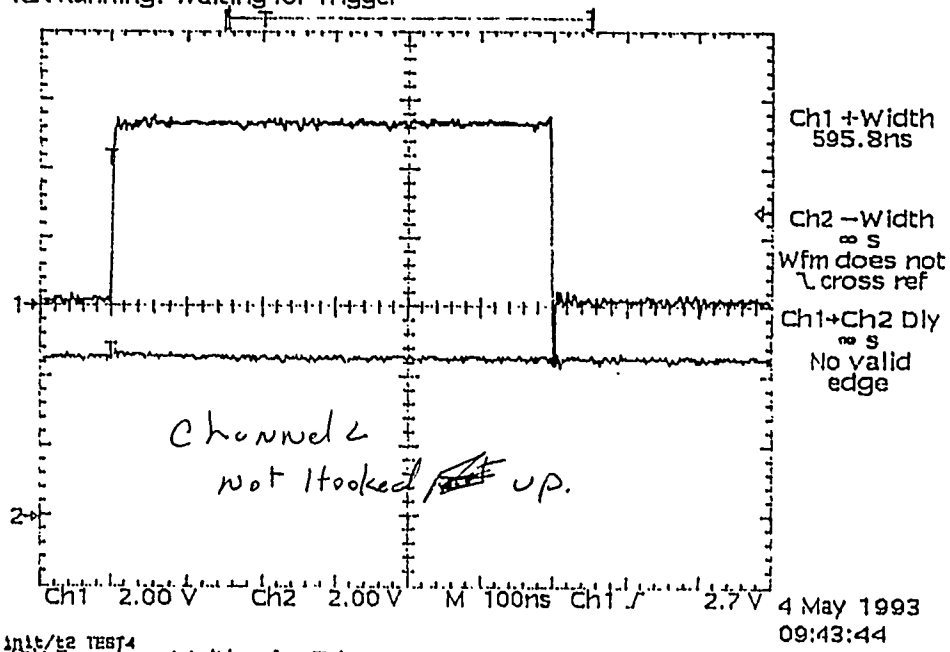

Tek Running: Waiting for Trigger
Ch1 −Width
94.4µs
Low signal
amplitude
Ch2 −Width
94.4µs
Low signal
amplitude
Ch4 Period
94.6µs
Low signal
amplitude
Ch1 5.00 V Ch2 5.00 V M 100µs Ch1 ∖ 2.60 V
Ch3 5.00 V Ch4 5.00 V
INTEGRATION SM1/SMO/VSYNC/EOL TEST3.3
4 May 1993
09:35:40

Tek Running: Waiting for Trigger



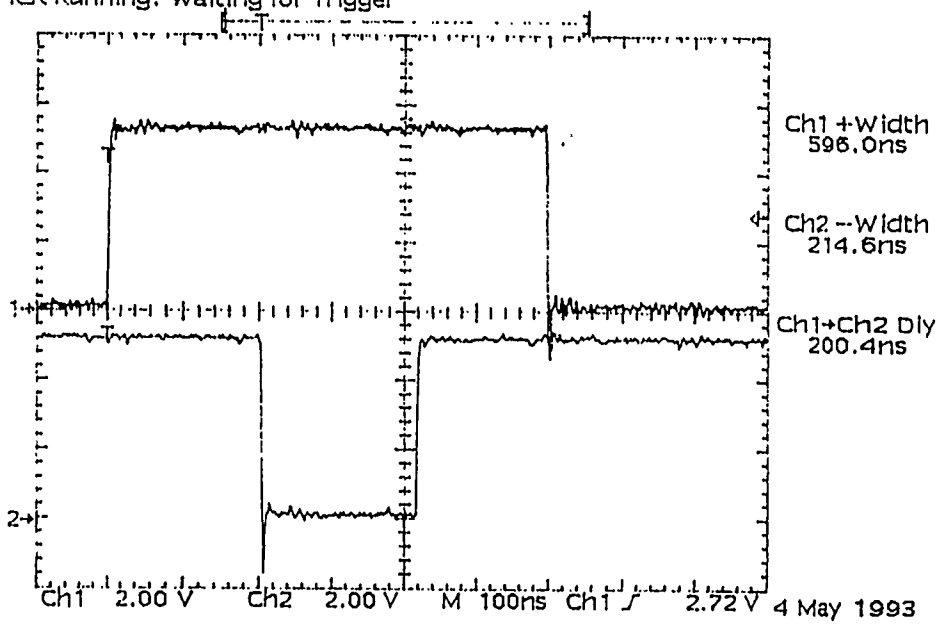
INTEGRATION SM1/SM0/VSYNC TEST3.4

Tek Running: Waiting for Trigger



init/t2 TEST4

Tek Running: Waiting for Trigger



init/t2 TEST4

ACTEL CAMERA ARRAY TEST

PROGRAM OF ARRAY AND DATE CODE
:2d
4-22-93

TESTER NAME DARRON NIELSEN

5/4/93
9:23
SASI BIT TEST 1
SASI BIT TEST 1 PASSED

5/4/93
9:24

DOUBLE CORRELATED SAMPLING TEST2
DOUBLE CORRELATED SAMPLING TEST 2 PASSED
CH1 -> CH2 DELAY
6.54E-8s
CH1 -> CH3 DELAY
1.24E-9s
CH2 +WIDTH
2.93E-8s
CH3 +WIDTH
5.24E-8s
CH1 +WIDTH
9.90E-8s

5/4/93
9:28

INTEGRATION SM1/SM0/VSYNC TEST3.1
PASSED
PARM ID 0 9
PARM ID 1 1
PARM ID 2 6A
PARM ID 3 0
PARM ID 5 1F
CH1 -WIDTH
1.00E-2s
CH2 -WIDTH

1.00E-2s
CH3 +WIDTH
9.90E37s

5/4/93
9:32

INTEGRATION SM1/VSYNC TEST3.2
PASSED
PARM ID 0 9
PARM ID 1 1
PARM ID 2 FF
PARM ID 3 1F
PARM ID 5 1F
CH1 -WIDTH
7.73E-1s
CH3 +WIDTH
5.50E-2s

5/4/93
9:35

INTEGRATION SM1/SMO/VSYNC/EOL TEST3.3
PASSED
PARM ID 0 9
PARM ID 1 1
PARM ID 2 1
PARM ID 3 0
PARM ID 5 1F
CH1 -WIDTH
9.44E-5s
CH2 +WIDTH
9.44E-5s
CH4 PERIOD
9.46E-5s

5/4/93
9:38

INTEGRATION SM1/SM0/VSYNC TEST3.4
PASSED
PARM ID 0 9
PARM ID 1 1

PARM ID 2 B
PARM ID 3 0
PARM ID 5 1F
.H1 -WIDTH
1.04E-3s
CH2 -WIDTH
1.04E-3s
CH4 -WIDTH
2.08E-5s
/CH4 -> /CH1 delay
1.21E-3s

5/4/93
9:42

init/t2 TEST4
PASSED
CH1 -WIDTH
5.96E-7s
CH2 -WIDTH
~~9.90E37s~~ 2 14.6NS

)

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 1-8-93

CUSTOMER ORDER # 6X12344000 LOT#/DATE CODE A3607-1 / 9302T

CUSTOMER PART # CWR06FH475KC SPRAGUE M.O. A5397401

AMOUNT SHIPPED 275

SUMMARY OF TEST DATA
MIL-C-55365C
GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .005	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jane Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

Linda
9

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics Corp DATE 12/31/92

CUSTOMER ORDER # 6X12344000 LOT#/DATE CODE A3628-1 / 9301T

CUSTOMER PART # CWR06HH226KC SPRAGUE M.O. A53974-03

AMOUNT SHIPPED 125

SUMMARY OF TEST DATA
MIL-C-55365C

GROUP A INSPECTION DATA (Weibull)

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .0001	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 3/4/93

CUSTOMER ORDER # 6X12344000 LOT#/DATE CODE K5873-1 / 9309T

CUSTOMER PART # CWR06FH685KC SPRAGUE M.O. A5397402

AMOUNT SHIPPED 175

SUMMARY OF TEST DATA
MIL-C-55365C

GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .0004	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jesse Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE 70 Pembroke Rd. Concord, NH 03301

70 Pembroke Rd. Concord, NH 03301

SHIP DATE 03/04/93

CUSTOMER PO #

SALES ORDER #

CAPSTONE ELECTRONICS CORP

25 HUB DRIVE

MELVILLE, NY 11747

SHIP TO

[illegible]

[illegible] FRASER STREET

[illegible], CO 80011

CARTONS	WEIGHT	CHARGES	CUSTOMER PART

SHIP VIA		TRACKER NO.	SPRAGUE PART
1	1		CUR06FH685KC MIL

QTY. ORDERED	CEL SERVICE	QTY. SHIPPED	QTY. BACK ORDER	01DE8
175		175		

REF: QUOTE #48177

[illegible] C CERTS REQUIRED

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 3/4/93

CUSTOMER ORDER # 6X12344000 LOT#/DATE CODE K5873-1 / 9309T

CUSTOMER PART # CWR06FH685KC SPRAGUE M.O. A5397402

AMOUNT SHIPPED 175

SUMMARY OF TEST DATA
MIL-C-55365C

GROUP A INSPECTION DATA (Weibull) C

	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
SUBGROUP I (100%)				
Weibull Life	4.7.17	100%	F/R= .0004	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jesse Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 1-22-93

CUSTOMER ORDER # 6X1234400I LOT#/DATE CODE K3161-1 / 9304T

CUSTOMER PART # CWR06JH685KC SPRAGUE M.O. A5397702

AMOUNT SHIPPED 200

SUMMARY OF TEST DATA
MIL-C-55365C

GROUP A INSPECTION DATA (Weibull)

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .005	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 1-21-93

CUSTOMER ORDER # 6X12344001 LOT#/DATE CODE A3598-1 / 9302T

CUSTOMER PART # CWR06JH226KC SPRAGUE M.O. A5397701

AMOUNT SHIPPED 400

SUMMARY OF TEST DATA
MIL-C-55365C
GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R- .0005	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE® 70 Pembroke Rd. Concord, NH 03301

Sprague Electric Co.
70 Pembroke Rd.
Concord, NH 03301

Pack Slip # 0089086

CUSTOMER PO #	SALES ORDER #
6X12344001	053977 02 01

SHIP DATE 01/22/93

SOLD TO
CAPSTONE ELECTRONICS CORP
25 HUB DRIVE
MELVILLE, NY 11747

SHIP TO
CAPSTONE ELECTRONICS CORP
DISTRIBUTION WAREHOUSE
DOCK 2
3254 FRASER STREET
AURORA, CO 80011

CARTONS	WEIGHT	CHARGES	CUSTOMER PART

SHIP VIA	TRACKER NO.	SPRAGUE PART
1 1		CWR06JH685KC MIL

QTY. ORDERED	QTY. SHIPPED	QTY. BACK ORD.
200	200	

UNITED PARCEL SERVICE

194D685X9020F8

REF: QUOTE #48177
C OF C CERTS REQUIRED

CERTIFICATE OF COMPLIANCE

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 1-21-93

CUSTOMER ORDER # 6X12344001 LOT#/DATE CODE A1075-1/9301T

CUSTOMER PART # CWR06JH226KC SPRAGUE M.O. A539 7701

AMOUNT SHIPPED 12

SUMMARY OF TEST DATA
MIL-C-55365C
GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100% F/R=	.0004	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

SPRAGUE

... Pembroke Rd.
Concord, NH 03301

Sprague Electric Co.
70 Pembroke Rd.
Concord, NH 03301

Pack Slip #
0088997

SHIP DATE 01/21/93

SOLD TO

CAPSTONE ELECTRONICS CORP

25 HUB DRIVE

MELVILLE, NY 11747

CUSTOMER PO #	SALES ORDER #
4Y1234 5031	053077 01 01

SHIP TO

CAPSTONE ELECTRONICS CORP

DISTRIBUTION WAREHOUSE

DOCK 2

3254 FRASER STREET
AURORA, CO 80011

CARTONS	WEIGHT	CHARGES	CUSTOMER PART

SHIP VIA		TRACKER NO.	SPRAGUE PART
1	1		CWR06JH226KC MIL

QTY. ORDERED	QTY. SHIPPED	QTY. BACK ORD.
412	412	

UNITED PARCEL SERVICE

194D226X9020H8

9302

REF: QUOTE #48177
C OF C CERTS REQUIRED

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/15/92

CUSTOMER NAME Capstone Electronics DATE 1-29-93

CUSTOMER ORDER # 6X12344001 LOT#/DATE CODE K3571-1 / 9305 V

CUSTOMER PART # CWR06KH106KC SPRAGUE M.O. A5397703

AMOUNT SHIPPED 225

SUMMARY OF TEST DATA
MIL-C-55365C

GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .0017	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.15	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

CERTIFICATE OF COMPLIANCE

SPRAGUE ELECTRIC COMPANY
Solid Tantalum Capacitor Operations
Concord, N.H.

WE CERTIFY THAT THIS MATERIAL HAS BEEN MANUFACTURED AND TESTED TO CONFORM TO THE APPLICABLE SPECIFICATIONS AND/OR DRAWING. TEST REPORTS AND/OR TEST SUMMARY SHOWING CONFORMANCE ARE ON FILE FOR EXAMINATION IF REQUIRED

SINCERELY YOURS,

WITNESSES:

SPRAGUE ELECTRIC COMPANY
CAR MANAGER

SPRAGUE
CONCORD, NEW HAMPSHIRE

PQP# 37
7/16/92

CUSTOMER NAME Capstone Elect.
DATE 2/18/93
CUSTOMER ORDER # 6X12344002
LOT#/DATE CODE K5077-1 / 9305V
CUSTOMER PART # CWR06MH105KC
SPRAGUE M.O. A5397802
AMOUNT SHIPPED 270

SUMMARY OF TEST DATA
MIL-C-55365C
GROUP A INSPECTION DATA (Weibull) C

SUBGROUP I (100%)	REF. PARA.	AMOUNT TESTED	AMOUNT FAILED	ALLOWED FAILURES
Weibull Life	4.7.17	100%	F/R= .0017	N/A
SUBGROUP II				
DC Leakage	4.7.4	PPM	0	0
Capacitance	4.7.5	Sampling	0	0
Dissipation Factor	4.7.6		0	0
ESR (when applicable)	4.7.10		0	0
Mechanical Exam	4.7.2		0	0
SUBGROUP III				
Visual Exam	4.7.2	13	0	0
SUBGROUP IV				
Stability at Low & High Temperature	4.7.12	13	0	0
SUBGROUP V				
Solderability **	4.7.16	13	0	0

GROUP C INSPECTION DATA

SUBGROUP I				
Vibration, High Frequency	4.7.7	12		
Thermal Shock	4.7.8			
SUBGROUP II				1
Resistance To Solder Heat	4.7.9	18		
Moisture Resistance	4.7.11			
SUBGROUP III				
Life (2000 hrs. @+125oC)	4.7.14	24		
SUBGROUP V				
Resistance to Solvents (when applicable)	4.7.16	N/A		0

NOTE: Capacitors furnished against the applicable specification and as represented by this test data meet all requirements.

Certified by: Jeanne Williams
SPRAGUE
QAR FOREMAN

** N/A to gold plated termination finishes.

CALIFORNIA CAPACITOR, INC.

CERTIFICATE OF COMPLIANCE

DATE: 1/25/93

PURCHASER: LAWRENCE LIVERMORE LABS

ORDER #: B231974

ITEM: #2 500pcs. CDR32BX333AKUS

#4 500PCS. CDR32BX103BKUS

THIS IS TO CERTIFY THAT THE MATERIALS, PROCESSES AND FINISHED PARTS USED IN THE MANUFACTURE OF THESE ITEMS WERE CONTROLLED AND TESTED IN ACCORDANCE WITH THE APPLICABLE SPECIFICATIONS.

OBJECTIVE QUALITY EVIDENCE AND SUBSTANTIATIVE TEST DATA IS ON FILE FOR EXAMINATION UPON REQUEST.

TIMOTHY D. BILYK

T. D. Bilyk

Post-it™ brand fax transmittal memo 7671	# of pages ▸ 1
To KATHY	From TIM
Co. LLL	Co. CAL-CAP
Dept. 2-NCS.	Phone # (408) 262-6000
Fax # (510) 423-4986	Fax # (408) 262-0272

1579 Centre Pointe Drive • Milpitas, CA 95035-6834 • (408) 262-6000

CAL CAP
CALIFORNIA CAPACITOR, INC.
1579 Centre Pointe Drive • Milpitas, CA 95035-6834
(408) 262-6000

CUSTOMER P/O NUMBER	INVOICE NUMBER
9231974	100400-01

BILL TO

LAWRENCE LIVERMORE LABS
PO BOX 5001/ACCT. DEPT.
LIVERMORE, CA.
94550

SHIP TO

LAWRENCE LIVERMORE LABS
7000 EAST AVE/RECV DEPT
LIVERMORE, CA. 94550

COMPLETE	PARTIAL	PHONE:	EXT.:	BUYER:
	X	5104221100		KAY MINKLER

AREA	CUSTOMER CODE	SALESMAN	INVOICE DATE	F.O.B.	SHIPPED VIA
A13	A23999	ATB	01/13/93	SHIP	~~FED EX PRIORITY 1~~ UPS

LINE	FACT.	PART NUMBER/DESCRIPTION	QTY BACK ORDER	QTY SHIPPED
4	AVJ	CDR32BX103BKUS .01UF 100V DXA2 PRIORITY RATING CONTRACT#W-7405-ENG-48	6	500
		SPECIFICATION INFORMATION: *PKG.MUST NOT BE OPENED BY LLNL REC. CONTENTS WILL		
		TOTAL UNITS SHIPPED:		500

B231974-01
1/14/93

PACKING SLIP

ALL CLAIMS MUST BE MADE IN WRITING WITHIN FIVE DAYS AFTER RECEIPT OF GOODS
RETURN NO GOODS WITHOUT OUR PREVIOUS WRITTEN AUTHORIZATION

GREEN - SHP/RCRD, YELLOW - PACKING SLIP, WHITE - SALES

REC'D.

ZEUS COMPONENTS, Inc.

100 MIDLAND AVE. • PORTCHESTER, NY 10573
PH: (914) 937-7400

military distribution specialists

Certificate of Conformance
and Procurement Traceability

ATTENTION: QUALITY ASSURANCE DEPARTMENT

DATE

CUSTOMER NAME AND ADDRESS	MANUFACTURER	ASSEMBLY CODE
LAWRENCE LIVERMORE LAB ACCTG DEPT PO BOX 5001 LIVERMORE CA 94550	KEMET	

PART NUMBER	MIL SPEC	U M	QUANTITY	MIL-S-19500
CDF32BP470BJUR		EA	100	

CUSTOMER PURCHASE ORDER #	CERTIFICATION TYPE:
623847[illegible]	☐ PER MIL-S-19500 ☐ MILR ☐ COMMERCIAL ☐ PER MIL-M-38510 ☐ PER MIL STD 883 ☐ MILC

DATE CODE Q1 [illegible]
9237 [illegible]
[illegible] 047 [illegible] 051

RETEST

[illegible]

EXPIRATION

The undersigned certifies that all articles included in each shipment under the above purchase order are in accordance with said purchase order and with all requirements, specifications and drawings referenced therein; and that records of inspection and test providing objective evidence of the foregoing are on file at this facility, or at the manufacturer's plant, and are available upon request. Certification that this shipment is a part of the shipment covered by the manufacturer's documentation.

[illegible] PART NO CDM [illegible] HOUR [illegible]
[illegible] IN [illegible] WE [illegible] ARE [illegible]
[illegible] ING DATA NOT [illegible] IS [illegible] TO [illegible]

AUTHORIZED QUALITY ASSURANCE INSPECTOR

☐ WHEN CHECKED MANUFACTURER'S CERTIFICATE ATTACHED

NOTICE REGARDING RETURN ACCEPTANCE OF MATERIAL.

ZEUS cannot accept the return of this lot or any part of this lot which does not include the original or copies of this and other documents supplied with this shipment.

KEMET ELECTRONICS CORPORATION
HIGHWAY 385 S. E.
GREENVILLE, SOUTH CAROLINA 29606
803/963-6300 - FAX: 803/963-6322 - TELEX: 570496 - TWX: 810/287-2536

33529677A

ADDRESS REPLY TO:
P. O. BOX 5928
GREENVILLE, S. C. 29606

CERTIFICATE OF COMPLIANCE

TO : ZEUS SEMICAP, INC.

REF: PURCHASE ORDER NUMBER: 749137

WE HEREBY CERTIFY THAT THE CAPACITORS SUPPLIED TO THE ABOVE NAMED COMPANY AGAINST THE REFERENCED PURCHASE ORDER WERE MANUFACTURED IN ACCORDANCE WITH THAT PURCHASE ORDER AND ALL APPLICABLE DOCUMENTS.

KEMET PART NUMBER: C1206N470J1GRH7506

CUSTOMER PART NUMBER (IF APPLICABLE): C1206N470J1GRH7506

DATE/LOT CODE(S):

MILITARY PART NUMBER (IF APPLICABLE): CDR32BP470BJUR

MILITARY INSPECTION LOT NUMBER(S) (IF APPLICABLE): 9237LH

TOTAL QUANTITY SHIPPED: 150

INVOICE NUMBER: S3U0665 LINE: 104A

DEVIATION(S)/WAIVER(S) (IF APPLICABLE): _____

CERTIFIED BY: Mary Hay 1-13-93
KEMET QUALITY CONTROL/DATE

7506B (10/16/91)

Certificate of Compliance

To: University of California

Lawrence Livermore Lab

7000 East Ave.

Livermore, CA 94550

Date 10-9-92

It is hereby certified that the products (Model numbers listed below) supplied to Lawrence Livermore Lab on Purchase Order No. B227575, are in conformance with all your purchase order requirements, including applicable government, your or other specifications and drawings, to the extent specified.

The required test and/or inspection reports resulting from compliance with applicable purchase order requirements are on file and available for review by your representative or government inspectors at any reasonable time.

ANALOG DEVICES, INC.

(97 pc) Refolcs

Authorized Signature

Andrew Spisak/ Office Manager

ANALOG DEVICES, INC.
ROUTE 1 INDUSTRIAL PARK • NORWOOD, MASSACHUSETTS 02062 • TEL: 617/329-4700

21693

Certificate of Compliance

To: University of California

Lawrence Livermore Lab

7000 East Ave.

Livermore, CA 94550

Date 10-9-92

It is hereby certified that the products (Model numbers listed below) supplied to Lawrence Livermore Lab on Purchase Order No. B227575, are in conformance with all your purchase order requirements, including applicable government, your or other specifications and drawings, to the extent specified.

The required test and/or inspection reports resulting from compliance with applicable purchase order requirements are on file and available for review by your representative or government inspectors at any reasonable time.

ANALOG DEVICES, INC.

(97 pc) Refclcs

Authorized Signature

Andrew Spisak/ Office Manager

ANALOG DEVICES, INC.
ROUTE 1 INDUSTRIAL PARK • NORWOOD, MASSACHUSETTS 02062 • TEL: 617/329-4700

883

Certificate of Compliance

To: University of California

Lawrence Livermore Lab

7000 East Ave.

Livermore, CA 94550

Date 10-9-92

It is hereby certified that the products (Model numbers listed below) supplied to Lawrence Livermore Lab on Purchase Order No. B227575, are in conformance with all your purchase order requirements, including applicable government, your or other specifications and drawings, to the extent specified.

The required test and/or inspection reports resulting from compliance with applicable purchase order requirements are on file and available for review by your representative or government inspectors at any reasonable time.

ANALOG DEVICES, INC.

(97 pc) Refclcs

Authorized Signature

Andrew Spisak/ Office Manager

ANALOG DEVICES, INC.
ROUTE 1 INDUSTRIAL PARK • NORWOOD, MASSACHUSETTS 02062 • TEL: 617/329-4700

MIN-E-CON

Q 0011

ACCEPTANCE DATA

CUSTOMER P.O.# B243053 M.E.C. JOB# 301093

CUSTOMER PART # _____ M.E.C. PART # M83513/04-G06N

LOT SIZE 32 pcs DATE CODE OR LOT # 9308

CHARACTERISTIC	SAMPLE SIZE	PASS	FAIL	INSP. BY	NOTES
VISUAL	AQL 1.0	13	0	M/6	
DIMENSIONAL	AQL 1.0	13	0	M/6	
INSULATION RES.	AQL 1.0	13	0	M TEST 2	100 V. D. C. 5000 MEG
D.W.V.	AQL 1.0	13	0	M TEST 2	600/900 VRMS
CONTACT RESISTANCE	1.0 S-4	13	0	M TEST 2	
MATING/UNMATING FORCES	1.0 S-4	13	0	M TEST 2	31 LBS. 14 OZS MAX.

DATE. 2-25-93

MIN-E-CON

Q 0011

ACCEPTANCE DATA

CUSTOMER P.O.# B 231921 M.E.C. JOB# 210070

CUSTOMER PART # — M.E.C. PART # M83513/04-G06N

LOT SIZE 30 pcs DATE CODE OR LOT # 9245

CHARACTERISTIC	SAMPLE SIZE	PASS	FAIL	INSP. BY	NOTES
VISUAL	AQL 1.0	13	0	M/6	
DIMENSIONAL	AQL 1.0	13	0	M/6	
INSULATION RES.	AQL 1.0	13	0		100 V. D. C. 5000 MEG
D.W.V.	AQL 1.0	13	0		600/900 VRMS
CONTACT RESISTANCE	1.0 S-4	13	0		
MATING/UNMATING FORCES	1.0 S-4	13	0		31 LBS. 14 OZS MAX.

DATE. 11-16-99

Certificate Of Compliance

It is hereby certified that the parts furnished on this Certificate Of Compliance have been manufactured in conformance with the requirements of all applicable drawings and specifications as defined by the purchase order.

Customer Part Number _____

Calogic Part Number SST 215

Purchase Order Number B238535

Lot # 90-0384

Quantity 150

Wafers(s) # _____

calogic
CORPORATION

Quality Assurance

January 21, 1993
Date

FUTURE ELECTRONICS CORP.
41 MAIN STREET E
BOLTON, MASS. 01740
TEL. (508) 779-3000

SHIP TO
LAWRENCE LIVERMORE LABS

7000 EAST AVENUE
LIVERMORE, CA
94550 (415) 422-1363

****
* UPS SHIPPER NO *
* MA 376-9X6 *
* PKG ID# 815977 *
****

93/01/12 12:40:02:69 4

CUSTOMER ORDER NUMBER					
B238487	FEDX P1	1X10N30	1	01-12-93	815977

300	C05046 T20040 S54040	1	02	MOR	FREIGHT CHARGE 2N7002TR;2N7002LT1;	9242 IT 2419703

PACKING SLIP SHOULD READ
GOVERNMENT OVERNIGHT
FEDX ACCT#-0941-0200-7
BOX #1

PACKING SLIP COMPLETE

B238487-01
Jim Casey
1-13-93

I 815977	L2900001	B238487	FUTURE ELECTRONICS CORP. 41 MAIN STREET BOLTON, MA 01740	PULLED BY S-01/11/93	CHECKED BY

IMPORTANT

ITEMS ON BACK ORDER ARE TEMPORARILY OUT OF STOCK. THEY WILL BE SHIPPED UPON RECEIPT. NO CLAIMS WILL BE ACCEPTED UNLESS MADE WITHIN 30 DAYS OF RECEIPT OF GOODS. 2% INTEREST PER MONTH ON PAST DUE ACCOUNTS.

PACKING SLIP - CUSTOMER COPY

PENSTOCK, INC.
520 MERCURY DRIVE
SUNNYVALE, CA 94086-4018
PH:408 730-0300 FAX:408 [illegible]

UPS SHIPPER # CA 9-65-148

SHIP VIA: UPS

KSLIP	PACK DATE	CUSTOMER PO#
24901	09-18-92	8229231 See comments below.

order referenced below has been manufactured, tested, and/or inspected in accordance with the requirements of the applicable specifications.

No metallic mercury compounds are used in the process or in the parts furnished herein. Inspections and/or tests have been performed as applicable, on both a variable and GO-NO-GO basis, utilizing equipment in accordance with the requirements of MI-STD-45662.

Documentary evidence in the form of test and/or inspection reports are on file and are available upon request.

Quality Representative

IP TO: UCLLNL
7000 EAST AVENUE
LIVERMORE CA 94550

BILL TO: UNIV. CAL. LAWRENCE NAT.
P. O. BOX 5001
LIVERMORE CA 94550

DATE: 09-18-92 ID: UCLLN-2 INSIDE: NC6 OUTSIDE: NC2 WEIGHT: 39.36 Page 1 of 1

IE	BIN	PART NUMBER	APN	U/M	QTY SHIPPED
		CLC5?0AJE COM	154796	EA	22
		CLC410AJE COM	154899	EA	22
	R0903	CLC501AJE COM	154673	EA	60

ackage must not be opened by ULNNL
Receiving
Static Sensative Products Enclosed

DISCREPANCIES MUST BE REPORTED WITHIN 5 DAYS.

Requester will verify all contents

2/3

THOMSON COMPONENTS AND TUBES CORPORATION
THOMSON MILITARY AND SPACE COMPONENTS DIVISION

40G Commerce Way
Post Office Box 540
Totowa, New Jersey 07511
Telephone 201 812-9000
FAX 201-812-9050

CERTIFICATE OF CONFORMANCE
-QSC2-

TO: LLNL DATE: 10-13-92

7000 EAST AVE, LIVERMORE, CA 94550

(CUSTOMER'S NAME AND ADDRESS)

CUSTOMER P/O: B228341

TETD ORDER CONFIRMATION: CCD1038
SHIPPING DOCUMENT: 2L0102247

DEVICE TYPE: TH7990C
LOT SIZE: SHIPPED QUANTITY: 20
LOT NUMBER:
DATE CODE: REINSPECTION DATE:
GENERIC SPECIFICATION: 1988 CCD DATABOOK REV:
DETAIL SPECIFICATION: REV:
SCREENING CLASS:

REMARKS:
OLD PART NUMBER : THX33501

THE UNDERSIGNED CERTIFY THAT THE PARTS LISTED UNDER YOUR PURCHASE ORDER SHOWN ABOVE ARE PART OF THE SHIPMENT COVERED BY THE MANUFACTURER'S CERTIFICATION ATTACHED, THAT ALL PRODUCTS ARE AS DESCRIBED ON THE CERTIFICATE, AND THAT PRODUCTS HAVE BEEN HANDLED IN ACCORDANCE WITH JEDEC PUBLICATION 108 & 109 WHEN IN POSSESSION OF ABOVE VENDOR.

DATE	ESD INSPECTOR	MILITARY APPROVAL (WHEN REQUESTED)
10-14-92	INSP. #3	

NOTE: WHEN REFERRING TO THESE PARTICULAR DEVICES, PLEASE MENTION THE FOLLOWING INSPECTION NUMBER:
2D10034/2L102247.

2/3

THOMSON COMPONENTS AND TUBES CORPORATION

THOMSON MILITARY AND SPACE COMPONENTS DIVISION

40G Commerce Way
Post Office Box 540
Totowa, New Jersey 07511
Telephone 201 812-9000
FAX 201-812-9050

CERTIFICATE OF CONFORMANCE
-QSC2-

TO: LLNL

DATE: 10-13-92

7000 EAST AVE, LIVERMORE, CA 94550

(CUSTOMER'S NAME AND ADDRESS)

CUSTOMER P/O: B228341

TETD ORDER CONFIRMATION: CCD1038
SHIPPING DOCUMENT: 2L0102247

DEVICE TYPE: TH7990C
LOT SIZE: _____ SHIPPED QUANTITY: 20
LOT NUMBER: _____
DATE CODE: _____ REINSPECTION DATE: _____
GENERIC SPECIFICATION: 1988 CCD DATABOOK REV: _____
DETAIL SPECIFICATION: _____ REV: _____
SCREENING CLASS: _____

REMARKS:
OLD PART NUMBER : THX33501

THE UNDERSIGNED CERTIFY THAT THE PARTS LISTED UNDER YOUR PURCHASE ORDER SHOWN ABOVE ARE PART OF THE SHIPMENT COVERED BY THE MANUFACTURER'S CERTIFICATION ATTACHED, THAT ALL PRODUCTS ARE AS DESCRIBED ON THE CERTIFICATE, AND THAT PRODUCTS HAVE BEEN HANDLED IN ACCORDANCE WITH JEDEC PUBLICATION 108 & 109 WHEN IN POSSESSION OF ABOVE VENDOR.

DATE	ESD INSPECTOR	MILITARY APPROVAL (WHEN REQUESTED)
10-14-92	INSP. #3	

NOTE: WHEN REFERRING TO THESE PARTICULAR DEVICES, PLEASE MENTION THE FOLLOWING INSPECTION NUMBER:
2D10034/2L102247

Micro Power Systems

CERTIFICATE OF CONFORMANCE

TO: UC Lawrence Livermore Labs
7000 East Avenue
Livermore CA. 94550

DATE: Oct. 15, 1992
SALES ORDER NO: 38676
PURCHASE ORDER NO: D3390689
CUSTOMER PART NO: MP 7684 ATL/883
CUSTOMER DWG NO:
LOT NO: 7688084A1-4-1
MPS PART NO: 7684A-TL--883
QUANTITY: 10
COUNTRY OF ORIGIN: U.S.A
DATE CODE: 2B 9226
LAST ELECTRICAL TEST DATE: 10/9/92

SELLER CERTIFIES THAT:

1. The parts furnished against this purchase order were produced in conformance with all contractually applicable specifications.

2. Data taken to characterize the final product under the above purchase order is available for examination by duly authorized personnel.

SELLER: MICRO POWER SYSTEMS, INC.

QUALITY REPRESENTATIVE: M. Harden

TITLE: QA Specialist

P.O. Box 54965, 3100 Alfred Street, Santa Clara 95094-0965
Telephone: (408) 727-5350 Fax: (408) 562-3605

D224400

Micro Power Systems

CERTIFICATE OF CONFORMANCE

TO: UC Lawrence Livermore labs.
7000 EAST AVE.
Livermore CA. 94550

DATE: Sept. 30, 1992

SALES ORDER NO: 38676

PURCHASE ORDER NO: D3390689

CUSTOMER PART NO: MP7684 ATL/883

CUSTOMER DWG NO:

LOT NO: 7688084A1-3

MPS PART NO: 7684 A-TL--883

QUANTITY: 50

COUNTRY OF ORIGIN: USA

DATE CODE: 2B 9226

LAST ELECTRICAL TEST DATE: 7/28/92

SELLER CERTIFIES THAT:

1. The parts furnished against this purchase order were produced in conformance with all contractually applicable specifications.

2. Data taken to characterize the final product under the above purchase order is available for examination by duly authorized personnel.

SELLER: MICRO POWER SYSTEMS, INC.

QUALITY REPRESENTATIVE: M. Harlan

TITLE: QA Specialist

P.O. Box 54965, 3100 Alfred Street, Santa Clara 95094-0965
Telephone: (408) 727-5350 Fax: (408) 562-3605

DOCUMENT NUMBER: RA-304	QUALIFICATION TEST DATA FLOW TRAVELER	7684A-TL--883 MANUFACTURING PRODUCT CODE
REV: Ø, ECN #: 0585, Originator: ÷, Date: 5/26/92	Micro Power Systems	QA REPORT #:
		DATE:
		LOT #: 7688084A-3
TEST PER 883 CLASS B M5005	PAGE 1 OF 1	DATE CODE: 2B9226

FLASH CONVERTERS GROUP A TEST DATA

CUSTOMER		P.O. NUMBER	
CUST P/N		SALES ORDER	
DRAWING #			

TESTS	LTPD	DEVICES SAMPLED	ACC#	IN	OUT	REJ #	PROC
SUBGROUP 1, +25°C STATIC TESTS	2	100		100	100	Ø	TO-032
SUBGROUP 2, +125°C STATIC TESTS	2	100		100	100	Ø	TO-032
SUBGROUP 3, -55°C STATIC TESTS	2	100		100	100	Ø	TO-032
SUBGROUP 7, +25°C FUNCTIONAL TESTS	2	100		100	100	Ø	TO-032

TESTING COMPLETED AND APPROVED

MPS ACCEPT 79

Quality Assurance — Date: 7-28-92

STATIC SENSITIVE PRODUCT - OBSERVE PROCESS 6P-006 AT ALL TIMES

Micro Power Systems

CERTIFICATE OF CONFORMANCE

TO: UC Lawrence Livermore Labs
7000 East Avenue
Livermore CA. 94550

DATE: Oct. 15, 1992
SALES ORDER NO: 38676
PURCHASE ORDER NO: D3390689
CUSTOMER PART NO: MP 7684 ATL/883
CUSTOMER DWG NO:
LOT NO: 7688084A1-4-1
MPS PART NO: 7684A-TL--883
QUANTITY: 10
COUNTRY OF ORIGIN: USA
DATE CODE: 2B 9226
LAST ELECTRICAL TEST DATE: 10/9/92

SELLER CERTIFIES THAT:

1. The parts furnished against this purchase order were produced in conformance with all contractually applicable specifications.

2. Data taken to characterize the final product under the above purchase order is available for examination by duly authorized personnel.

SELLER: MICRO POWER SYSTEMS, INC.

QUALITY REPRESENTATIVE: M. Harden

TITLE: QA Specialist

P.O. Box 54965, 3100 Alfred Street, Santa Clara 95094-0965
Telephone: (408) 727-5350 Fax: (408) 562-3605

B229988

Micro Power Systems

CERTIFICATE OF CONFORMANCE

TO: UC Lawrence Livermore Labs.
7000 EAST AVE.
Livermore CA. 94550

DATE: Sept. 30, 1992
SALES ORDER NO: 38676
PURCHASE ORDER NO: D3390689
CUSTOMER PART NO: MP7684 ATL/883
CUSTOMER DWG NO:
LOT NO: 7688084A1-3
MPS PART NO: 7684 A-TL--883
QUANTITY: 50
COUNTRY OF ORIGIN: USA
DATE CODE: 2B 9226
LAST ELECTRICAL TEST DATE: 7/28/92

SELLER CERTIFIES THAT:

uced in conformance

Collette
Screening tes

/e purchase order is

P.O. Box 54965, 3100 Alfred Street, Santa Clara 95094-0965
Telephone: (408) 727-5350 Fax: (408) 562-3605

Exhibit II

ALL AMERICAN®

a quality electronics distributor
16085 N.W. 52ND AVENUE, MIAMI, FLORIDA 33014-9317

CERTIFICATE OF CONFORMANCE

CUSTOMER NAME UNIV. CALIF LIVERMORE
AND ADDRESS LIVERMORE NAT'L LABS
7000 EAST AVENUE, RECEIVING
LIVERMORE, CA 94550

ALL AMERICAN CERTIFIES THAT THE MATERIAL SUPPLIED ON YOUR PURCHASE ORDER 68227573 IS DESIGNED TO MEET SPECIFICATIONS PER:

1) ☐ MIL-S-19500/____ 2) ☐ MIL-M-38510 3) ☐ MIL-STD-883

4) ☐ DESC DRAWING NO.____ 5) ☑ COMMERCIAL

QUANTITY 250

PART NUMBER TC4428 EOA

MANUFACTURER TEL

DATE CODE

DATE SHIPPED 10-6-92

INSPECTION DATE

ALL AMERICAN SEMICONDUCTOR CERTIFIES THAT ALL ARTICLES INCLUDED IN EACH SHIPMENT UNDER THE ABOVE PURCHASE ORDER(S) ARE MANUFACTURED IN ACCORDANCE WITH ALL MANUFACTURER'S AND/OR APPLICABLE MILITARY SPECIFICATIONS SO DESIGNATED ON SUBJECT PURCHASE ORDER, AND FURTHER CERTIFIES THAT THIS SHIPMENT IS A PART OF THE SHIPMENT COVERED BY THE MANUFACTURER'S DOCUMENTATION. TEST REPORTS FOR MATERIAL SUPPLIED ARE ON FILE, AND ARE AVAILABLE FOR EXAMINATION AT THE POINT OF MANUFACTURE.

QUALITY CONTROL DESIGNEE

MANUFACTURER'S CERTIFICATE ENCLOSED ☐

ALL AMERICAN®

a quality electronics distributor
16085 N.W. 52ND AVENUE, MIAMI, FLORIDA 33014-9317

CERTIFICATE OF CONFORMANCE

CUSTOMER NAME UNIV. CALIF LIVERMORE
AND ADDRESS LIVERMORE NAT'L LABS
7000 EAST AVENUE, RECEIVING
LIVERMORE, CA 94550

ALL AMERICAN CERTIFIES THAT THE MATERIAL SUPPLIED ON YOUR PURCHASE ORDER BB227573 IS DESIGNED TO MEET SPECIFICATIONS PER:

1) ☐ MIL-S-19500/____ 2) ☐ MIL-M-38510 3) ☐ MIL-STD-883

4) ☐ DESC DRAWING NO____ 5) ☒ COMMERCIAL

QUANTITY 250

PART NUMBER TC4426EOA

MANUFACTURER TEL

DATE CODE

DATE SHIPPED 10-6-92

INSPECTION DATE

ALL AMERICAN SEMICONDUCTOR CERTIFIES THAT ALL ARTICLES INCLUDED IN EACH SHIPMENT UNDER THE ABOVE PURCHASE ORDER(S) ARE MANUFACTURED IN ACCORDANCE WITH ALL MANUFACTURER'S AND/OR APPLICABLE MILITARY SPECIFICATIONS SO DESIGNATED ON SUBJECT PURCHASE ORDER, AND FURTHER CERTIFIES THAT THIS SHIPMENT IS A PART OF THE SHIPMENT COVERED BY THE MANUFACTURER'S DOCUMENTATION. TEST REPORTS FOR MATERIAL SUPPLIED ARE ON FILE, AND ARE AVAILABLE FOR EXAMINATION AT THE POINT OF MANUFACTURE.

H. Whyte
QUALITY CONTROL DESIGNEE

MANUFACTURER'S CERTIFICATE ENCLOSED ☐

PENSTOCK, INC.
520 MERCURY DRIVE
SUNNYVALE, CA 94086-4018
PH:408-730-0300 FAX:408-730-4782

UPS SHIPPER # CA 9-65-148

SHIP VIA: UPS

PACKSLIP	PACK DATE	CUSTOMER PO#
P9324903	10-06-92	B229281

This is to certify that the material furnished pursuant to the purchase order referenced below has been manufactured, tested, and/or inspected in accordance with the requirements of the applicable specifications.

No metallic mercury compounds are used in the process or in the parts furnished herein. Inspections and/or tests have been performed as applicable, on both a variable and GO-NO-GO basis, utilizing equipment in accordance with the requirements of MI-STD-45662.

Documentary evidence in the form of test and/or inspection reports are on file and are available upon request.

10/6/92

Quality Representative

SHIP TO: UCLLNL
7000 EAST AVENUE
LIVERMORE CA 94550

BILL TO: UNIV. CAL. LAWRENCE NAT.
P. O. BOX 5001
LIVERMORE CA 94550

DER DATE: 09-18-92 ID: UCLLN-2 INSIDE: NCG OUTSIDE: NC2 WEIGHT: 4.76 Page 1 of 1

LINE	BIN	PART NUMBER	APN	U/M	QTY SHIPPED
003		CLC502AJE COM	154710	EA	4

B229281-03

10/7/92

DISCREPANCIES MUST BE REPORTED WITHIN 5 DAYS.

520 MERCURY DRIVE
SUNNYVALE, CA 94086-4018
PH:408-730-0300 FAX:408-730-4782

UPS SHIPPER # CA 9-65-148

SHIP VIA: UPS

PACKSLIP	PACK DATE	CUSTOMER PO#
P9324902	10-01-92	B229281

This is to certify that the material furnished pursuant to the purchase order referenced b[illegible] has been manufactured, tested, and/or inspected in accordance with the requirements of the applicable specifications.

No metallic mercury compounds are used in the process or in the parts furnished herein. Inspections and/or tests have been performed as applicable, on both a variable and GO-NO-GO basis, utilizing equipment in accordance with the requirements of MI-STD-45662.

Documentary evidence in the form of test and/or inspection reports are on file and are available upon request.

10/1/92

Quality Representative

SHIP TO: UCLLNL
7000 EAST AVENUE
LIVERMORE CA 94550

BILL TO: UNIV. CAL. LAWRENCE NAT.
P. O. BOX 5001
LIVERMORE CA 94550

ORDER DATE: 09-18-92 ID: UCLLN-2 INSIDE: NCG OUTSIDE: NC2 WEIGHT: 21.06 Page 1 of 1

LINE	BIN	PART NUMBER	APN	U/M	QTY SHIPPED
003		CLC502AJE COM	154710 B/O=4	EA	56

B229281.02
10/5/92

Certificate of Compliance

ANALOG DEVICES, INC.
3 TECHNOLOGY WAY • NORWOOD, MASSACHUSETTS 02062 • TEL: 617/329-4700

SOLD TO
UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
ACCOUNTING OFFICE
P O BOX 5001

LIVERMORE
CA 94551 1015 YS

UNIV OF CALIFORNIA
LAWRENCE LIVERMORE LAB
7000 EAST AVE

LIVERMORE
CA 94550 1015 YS

B243191

*REPRI

CUSTOMER PURCHASE ORDER NO.
B243191

DATE OF ORDER
02/17/93

PRINT DATE
02/19/93

DATE CODES AS REQUIRED	SALES CATALOG NUMBER	DESCRIPTION	QTY SHIP
COMPLIANT TO PAR 1.2.1 OF MIL-STD-883 QTY 40 9135A 883	AD558TE/883B	IC, MONO 8-BIT D/A CONVER	40

It is hereby certified that the products (Model numbers listed above) supplied on the above referenced purchase order, are in conformance with all purchase order requirements, including applicable government, or other specifications and drawings, to the extent specified. All 883 product is compliant to paragraph 1.2.1 of MIL- STD-883.
The required test and traceability documentation resulting from compliance with applicable requirements are on file and available for review by your representative or government inspectors at any reasonable time.

THORIZED ANALOG DEVICES QUALITY CONTROL REPRESENTATIVE

Certificate of Compliance

SOLD TO
UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
ACCOUNTING OFFICE
P O BOX 5001

LIVERMORE
CA 94551 1015 YS

ANALOG DEVICES, INC.
3 TECHNOLOGY WAY • NORWOOD, MASSACHUSETTS 02062 • TEL: 617/329-4700

CUSTOMER PURCHASE ORDER NO. B22754

DATE OF ORDER 09/18/92

PRINT DATE 09/21/92

DATE CODES AS REQUIRED			SALES CATALOG NUMBER	DESCRIPTION	QTY. SHIP
COMPLIANT TO PAR.1.2.1. OF MIL-STD-883	QTY	CODE			
883	45	9040 13	AD558TE/883B	IC, MONO 8-BIT D/A CONVER	45
PIE					

It is hereby certified that the products (Model numbers listed above) supplied on the above referenced purchase order, are in conformance with all purchase order requirements, including applicable government, or other specifications and drawings, to the extent specified. All 883 product is compliant to paragraph 1.2.1 of MIL- STD-883.
The required test and traceability documentation resulting from compliance with applicable requirements are on file and available for review by your representative or government inspectors at any reasonable time.

THORIZED ANALOG DEVICES QUALITY CONTROL REPRESENTATIVE

ANALOG DEVICES

MIL-STD 883 ATTRIBUTES TEST DATA

Customer		Special/Generic	QC Lot #
		AD558TE/883B	F141072/01
Date Code 9040A	Prepared By E. Johnston	QC Lot Size 81 pcs.	Ship Qty.

VISUAL/MECHANICAL/ELECTRICAL SCREENING

Method	Screen Mil-Std 883; Method 5004	Cond.	Gross	Net	Rej/Other	Date	Comments
2010	INTERNAL VISUAL	B	476	476	0	10/6/90	
1008	STABILIZATION BAKE	C	476	476	—	10/8/90	
1010	TEMPERATURE CYCLE	C	476	476	—	10/8/90	
2001	CONSTANT ACCELERATION	E	476	476	—	10/9/90	Y_1 axis
1014	HERMETICITY FINE LEAK	A	476	472	4	10/9/90	
1014	HERMETICITY GROSS LEAK	C	472	472	0	10/9/90	
	PRE BURN-IN ELECTRICAL		459	447	12	10/22/90	
1015	BURN IN		447	447	—	10/22/90 10/29/90	160 hours, +125°C
	POST BURN-IN ELECTRICAL	25°C	447	445	2	10/29/90	PDA = 5%; PD = 1.459/10
		25°C	445	369	76	11/6/90	Per ADS Data Sheet
		T_{MIN}-T_{MAX}	369	358	11	11/6/90	
2009	EXTERNAL VISUAL		100	81	19	11/21/90	
5005	GROUP A INSPECTION	LTPD 2	116	116	0	11/6/90	Per ADS Data Sheet
5005	GROUP B INSPECTION						
2016	Subgroup 1 N/A	S.S. = 2	–	–	–	–	
2015	Subgroup 2	S.S. = 4	4	4	0	11/26/90	
2003	Subgroup 3	LTPD 10	3	3	0	11/21/90	22 leads
2014	Subgroup 4 N/A	S.S. = 1	–	–	–	–	
2011	Subgroup 5	LTPD 15	4	4	0	11/26/90	15 wires
1018	Subgroup 6 N/A	—	—	—	—	—	
1014	Subgroup 7 N/A	LTPD 5	–	–	–	–	
3015	Subgroup 8 N/A	—	—	—	—	—	

QUALITY CONFORMANCE INSPECTION

Approved By Edward W Carson Date 12/1/90

ADS 198 Rev. C

ANALOG DEVICES

MIL-STD 883 ATTRIBUTES TEST DATA

Customer

Date Code	Prepared By	Special/Generic	QC Lot #
9135A	S. Kattamuri	7055TE/883B	F200108-01
		QC Lot Size	Ship Qty.
		213 pcs	

VISUAL/MECHANICAL/ELECTRICAL SCREENING

Method	Screen Mil-Std 883; Method 5004	Cond.	Gross	Net	Rej/Other	Date	Comments
2010	INTERNAL VISUAL	B	487	487	—	8/27/91	
1008	STABILIZATION BAKE	C	487	487	—	8/31/91	
1010	TEMPERATURE CYCLE	C	487	487	—	9/01/91	
2001	CONSTANT ACCELERATION	E	487	487	—	9/01/91	Y_1 axis
1014	HERMETICITY FINE LEAK	A	487	484	3	9/07/91	
1014	HERMETICITY GROSS LEAK	C	484	484	—	9/07/91	
	PRE BURN-IN ELECTRICAL		476	475	1	10/31/91	
1015	BURN IN		475	475	—	11-01-91 / 11-08-91	160 hours, +125°C
	POST BURN-IN ELECTRICAL	25°C	475	475	—	11-8-91	PDA = 5%; PD = 0%
		25°C	464	433	31	11-18-91	
		T_{MIN} T_{MAX}	433	353	50	11-18-91	Per ADS Data Sheet
2009	EXTERNAL VISUAL		218	217	1	8/26/92	

QUALITY CONFORMANCE INSPECTION

5005	GROUP A INSPECTION	LTPD 2	116	116	—	11-18-91	Per ADS Data Sheet
			116	116	—	11-18-91	
			116	116	—	11-19-91	
5005	GROUP B INSPECTION						
2016	Subgroup 1 N/A	S.S. = 2	—	—	—	—	
2015	Subgroup 2	S.S. = 4	4	4	—	8/26/92	
2003	Subgroup 3	LTPD 10	3	3	—	11/26/91	22 Leads
2014	Subgroup 4 N/A	S.S. = 2	—	—	—	—	
2011	Subgroup 5	LTPD 15	4	4	—	11/26/91	15 WIRES
1018	Subgroup 6 N/A	—	—	—	—	—	
1014	Subgroup 7 N/A	LTPD 5	—	—	—	—	
3015	Subgroup 8 N/A	—	—	—	—	—	

Approved By: Ron Ratcliffe

Date: 9/1/92

ADS 156 Rev C

Micro Crystal
Div. of ETA
2540 Grenchen
Switzerland

MC Quality Level
1

QUALITY CONFORMANCE INSPECTION MIL-C-3098 G

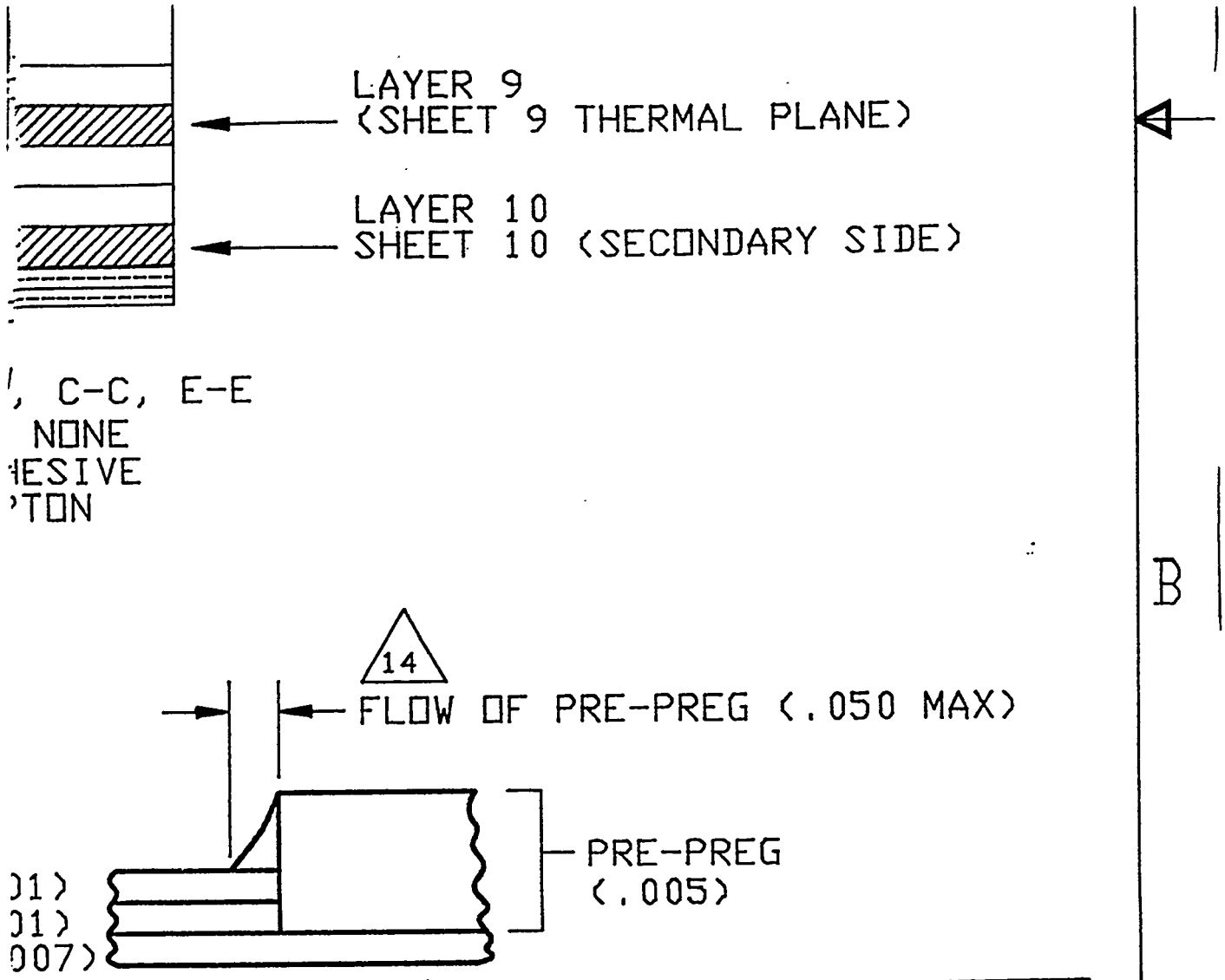
CUSTOMER Uni of California	PO.No. B243124
TYPE CXAT-T2	PCS 25
LOT No.: CQ001176	
FREQUENCY 20.0 MHz [kHz]	FREQ.TOLERANCE ± 50 [ppm]
LOAD CAPACITANCE CL 20 [pF]	SHUNT CAPACITANCE Co 3.20 [pF]
SERIES RESISTANCE R 1 0.050 [kΩ]	OPERAT.TEMP.RANGE -55° ÷ +125°C
DRIVE LEVEL MAX [μ W]	MARKING MC 20.000 MT
MEASURING EQUIPMENT No. QC-Tester II	OSCILLATOR No. 999

	Insp.Level / AQL	n – c MIL STD 105D	n – c eff EFFECTIVE	$\bar{X}$ ARITHM. MEAN	S STAND. DEV.
SERIES RESISTANCE R 1 [kΩ]	2 / 0.65	100%	25-0	0.015	0.004
SERIES CAPACITANCE C 1 [fF]	2 / 0.65	100%	25-0	9.84	0.24
FREQUENCY DEVIAT. Δ f/f[ppm]	2 / 0.65	100%	25-0	8.4	7.3
VISUAL	2 / 1.0	100%	25-0		
TURNOVER POINT [°C]	S4 / 0.65	100%	25-0	48.01	7.82
TEMP.COEFFICIENT α [°C $^{-1}$]	S4 / 0.65	100%	25-0	$-.162\ 10^{-6}$	$.109\ 10^{-6}$
TEMP.COEFFICIENT β [°C $^{-2}$]	S4 / 0.65				
OPERATING TEMP.RANGE	S4 / 0.65	100%	25-0		

QUALITY FACTOR 57704	AGING [7 / 85°C] Δ f/f [ppm]
DATE : 18. Februar 93 QC:	QA:

Appendix G.2.6

Artwork



ENGINEERING RELEASE

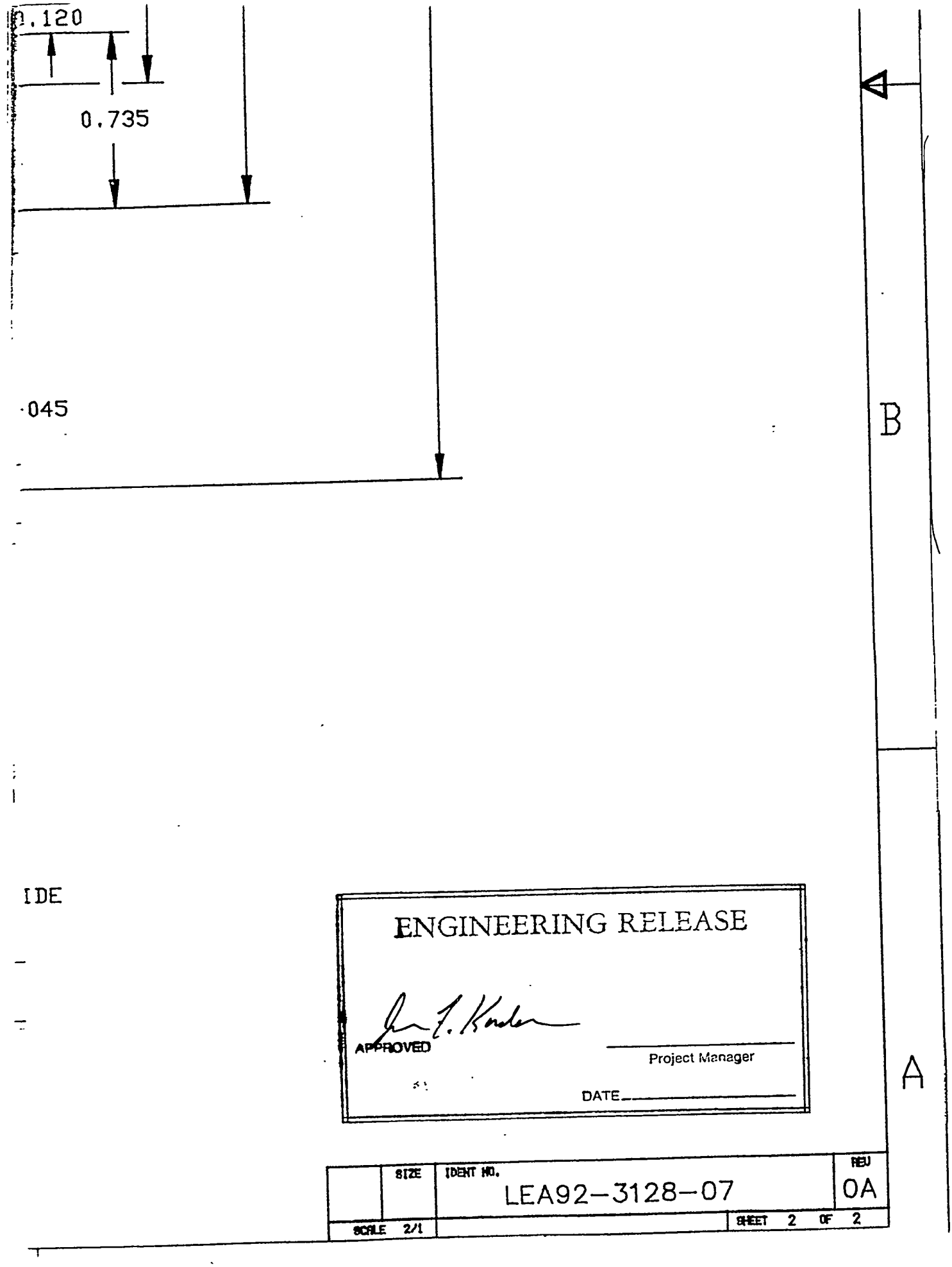
APPROVED

Project Manager

DATE

OTHERWISE DIMENSIONS IN INCHES ANCES ON CIMALS +/- .03 +/- .010 ABLES +/- 30	DRAWN BY	JARDON ENG.	4/07/93	LAWRENCE LIVERMORE NATIONAL LABORATORY
	CHECKED BY			
	MFG. ENG.	S. ZAMMOZA	4/07/93	P.C.B
	APPROVED BY			CAMERA (ACTEL) W/AGAIN AND OFFSET CONTROL
ESIGN BY JARDON NEERING CALIF 92698	ENG.	J. KORDAS	4/07/93	
	ENG.	D. NIELSEN	4/07/93	SIZE / IDENT NO. LEA92-3128-07 / REV 0A
	NEXT USING DRAWING			SCALE / SHEET 1 OF 2

A



ENGINEERING RELEASE

APPROVED

Project Manager

DATE

SIZE	IDENT NO.	REV
	LEA92-3128-07	0A
SCALE 2/1	SHEET 2 OF 2	

Appendix G.2.7

Electronic Test Data

Appendix G.2.7.1

Electronic Test Procedure:
Actel Camera, PWA with Gain and Offset Control

Electronic Test Procedure

Actel Camera, PWA
with Gain and Offset Control

SN# 04-06
(ST2 configured)

	Date	Rev.	Date	Approval
PREPARED BY: MERCEDES L. DICKERSON	5/6/93			
REVIEWED BY: DARRON P. NIELSEN	5/6/93			
REVIEWED BY: WILLIAM R. BRYSON				
REVIEWED BY: JOSEPH F. KORDAS	5-6-93			
REVIEWED BY: MICHAEL J. SHANNON				

University of California Lawrence Livermore National Laboratory	Actel Camera, PWA with Gain and Offset Control Electronic Test Procedure	LEA92-3128-16 Revision 00

Table of Contents

Table of Contents cont.

1. Scope.

This document specifies equipment and procedures required to verify the electrical performance of the ACTEL Camera Printed Wiring Assembly (LEA92-3128-02) in the startracker configuration.

Oscilloscope camera photos and graphs should be attached to the test procedure. Other printer data should be placed in a document protector and inserted in this certification log.

Section 16 describes those tests that are required after conformal coating.

2. Required Documents and Test Equipment.

2.1 Required Documents:

Actel Camera PWB Schematic, LEA92-3128-01-0C OR LEA92-3128-11-0C
Actel Camera PWB Assembly Drawing, LEA92-3128-03
SUN DatacubeTest Station
A Short Guide to Running hspcube , C1-S1-002

2.2 Required Test Equipment:

SUN DatacubeTest Station
includes: Protomax Interface
S1/S2 Data Interface Power Supply, AIT EE-0090-10
Engineering TH7883 CCD for test purposes
Digital voltmeter such as Fluke model 77
AM 503 Current Probe (2ea) powered by a TM502A Power Supply
Tektronix 2465B Analog Oscilloscope with P6106A probes (4ea)
Oscilloscope recording camera
Tektronix TDS540 Digital Oscilloscope
Hewlett Packard Desk Jet 500 Printer
HP 4194 Impedance Gain-Phase Analyzer, with probe and RG 58 cabling
Tektronix HC100 color plotter
Philips PM 3585, 200 MHz Logic Analyzer
TV Optoliner Model K-4000 (with neutral density (ND) filters) and Lamphead
HeNe Laser, 1mW at 632.8nm (with ND filters)
Surface mount testing probes,
Tektronix 20-pin and 44-pin SMQK1 PLCC
Actel Camera board carrier mount, to prevent carrier/pc card flexing
PC board holder/clamp
Video Copier Processor Tektronix Model HC02
Environmental chamber
Timer
Black cloth or an opaque cover for the CCD
Packing Foam
Breakout Connector, 51 contact miniD

The above listed test equipment MUST have calibration dates within one year of test integration. Calibration records should also be available for inspection.

Any fabricated testing hardware, such as the 51-pin breakout connector,MUST have quality assurance tagging and records stating such.

3. Conditions and Requirements

3.1 Precautions

(1) Responsibility for Safety. All personnel are responsible for maintaining a safe work environment. The Test Conductor or cognizant operator shall assure that appropriate safe practices are implemented during these operations, and that operations are performed in a proper order.

(2) ESDS Equipment. The test specimen contains electrostatic- sensitive devices which are exposed at the electrical interfaces. Therefore, it shall be handled per MIL-STD-1686 Class 1. The test specimen, the test operator (using wrist straps), and related electrical test equipment shall be connected to a common ground before any electrical mating or de-mating operations, and during the use of any electrical test equipment probes. There shall be no "hot-plugging" of the test specimen with any test equipment.

(3)Examine Connectors. Before mating any flight connector, examine the connector and the connector with which it is to be mated, to assure that there are no interferences at the pin interface. **Connector savers will be used at all times.**

3.4 Cleanliness and Environment

(1) Standard laboratory conditions of atmospheric temperature, pressure, and humidity are acceptable for the testing defined herein.

(2) Normal housekeeping standards will be required. If appropriate, the unit may be cleaned prior to installation into the next assembly, or prior to return to storage.

3.5 Quality Assurance (QA) Provisions

QA provisions operative during activities defined in this procedure shall be as specified in the project's QA Plan. This section identifies the interfaces between QA and test personnel. QA and test personnel are jointly responsible for the effectiveness of these interfaces in implementing the QA provisions.

(1) QA shall be notified, in advance, of performance of any activities described in this procedure. A QA Inspector may monitor those activities as is deemed necessary or appropriate, in accordance with the project QA Plan. The inspector shall verify that the proper revision of this procedure is used, and that the required Certification Log is in proper order. QA will then give the "OK to Test" prior to the start of test activities.

(2) The QA Inspector shall verify: that calibration is current for all measuring equipment used in these operations, and will not expire prior to completion of these operations; that applicable project-specific electrical support test equipment (STE) has been properly certified and tagged; and that applicable lifting and handling STE has been properly proof tested and tagged.

Quality Assurance (QA) Provisions (continuation)

(3) The QA Inspector may assist in assuring that the precautionary and environmental requirements stated in 3.1 and 3.2 are met. He shall also, at his discretion, assist in the inspection of test setups prior to application of power to a test specimen, and prior to any mechanism-assisted lifts or moves.

(4) Upon the occurrence of a test anomaly (any event that deviates from the planned procedures, exceeds normal variations, or generates unexpected data), operation of the test article shall be stopped immediately. All other test conditions and parameters shall be maintained (except as those conditions may pose an immediate hazard). The QA Inspector shall be notified that a test anomaly has occurred.

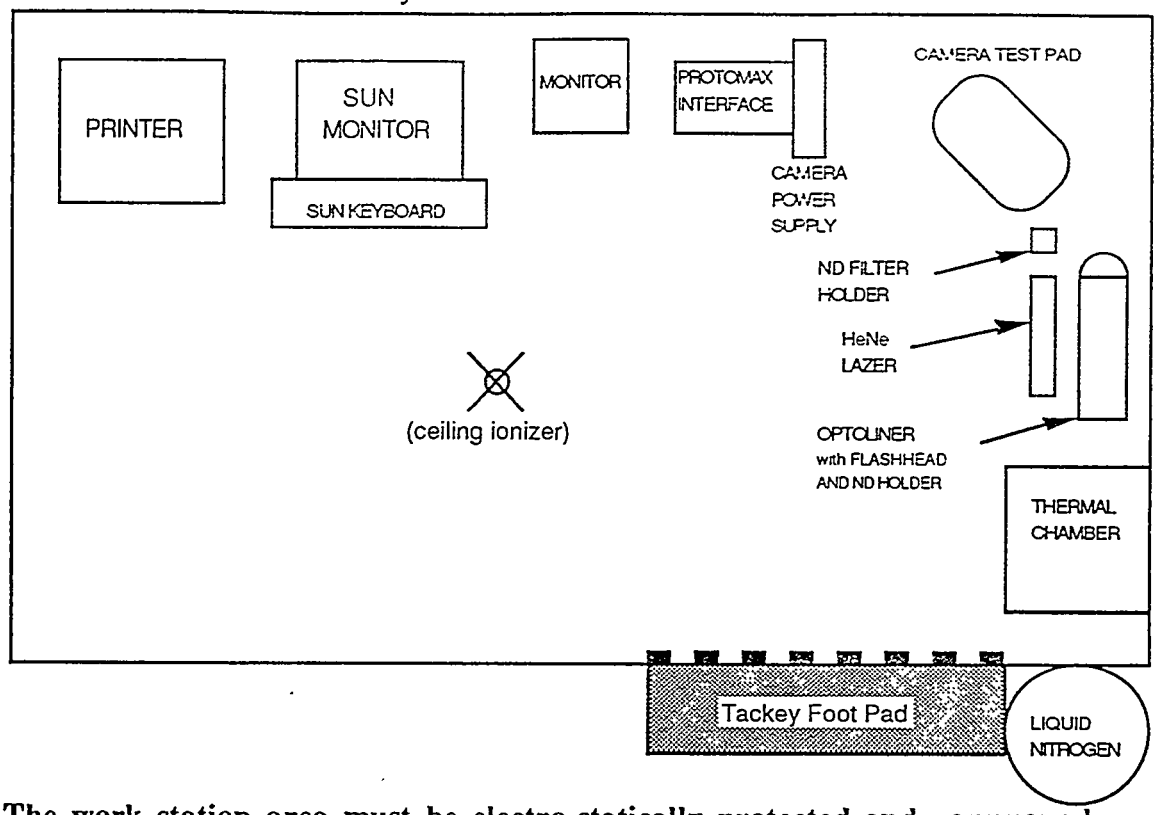
(5) The QA Inspector or Test Conductor (with QA concurrence) shall note each test anomaly on the Failure Reporting And Corrective Action System (FRACAS). The Inspector and the Test Conductor shall review the anomaly. Minor troubleshooting may be done to determine the cause of the anomaly; however, no disassembly or other actions that present a risk to the test article shall be allowed. If the anomaly is found to result from human error or test equipment problems that have not affected the test article, corrective action shall be taken and testing may continue. All troubleshooting steps and results shall be recorded on the FRACAS. The Test Conductor shall supervise any troubleshooting or retesting required in resolving test anomalies.

(6) If a test anomaly cannot be resolved as described above, the Project Engineer shall be notified. If the action indicates that a rework or repair may be required, the anomaly and troubleshooting results shall be noted in the Action Item List (AIL) portion of the Certification Log, Fracus report and a Material Discrepancy Report (MDR) shall be initiated (if required) and processed as prescribed in the QA Plan.

(7) The QA Inspector shall stamp log entries as appropriate, attesting to the proper completion of these operations as previously approved in this procedure document.

3. SUN DatacubeTest Station

The LLNL SUN Test Station layout looks like this:



The work station area must be electro-statically protected and approved.

A Short Guide to Running hspcube , C1-S1-002, by Ray Aley, Hye-Sook Park, and Eric Parker explains the Sun3 Computer-Datacube workstation and the software imaging options for the Startracker (S1), UV-Visible (S2), and Lidar (S4) modes.

5. Printed Wiring Assembly Specificity

5.1 Inspection

Inspect the carrier mounted Actel board for any conflict with the configuration table, assembly drawing or obvious fabrication flaws. Inspect the action item list of the certification log for any anomalies. **NOTE!! The camera board should remain attached to the carrier mount until ultimately bent and housed.!!**

SN# 04-06 Inspection completed By DRa (initials) Date 5/6/93

5.2 Power Plane Resistance Measurements

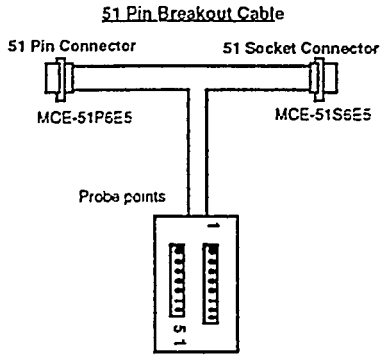
Measure power plane resistances at J1. NOTE: N0 cable attached!

pin# DVM(common)	vs	pin# DVM(signal)	expected Ω	measured Ω
5 (AGND)	-	39 (+15VDC)	≥2MΩ	3 M Ω
	-	4 (-15VDC)	≥2MΩ	2.8M Ω
	-	37 (+5VDC)	≈479Ω	476 Ω
	-	38 (+5VDC)	≈479Ω	476 Ω
	-	3 (-5VDC)	≈1.54kΩ	1542 Ω
	-	40 (+5VIN)	≈2.9kΩ	4.35K Ω
20 (DGND)	-	5	≈.2Ω	0.4 Ω
	-	39	>2MΩ	2.4 M Ω
	-	37	≈468Ω	475 Ω
	-	38	≈468Ω	476 Ω
	-	3	≈1.5kΩ	1541 Ω
	-	40	≈3KΩ	4.35K Ω
39 (+15VDC)	-	4	≥11KΩ	11.5K Ω
	-	37	≥2MΩ	3M Ω
	-	38	≥2MΩ	2.9M Ω
	-	3	≥2MΩ	2.8M Ω
	-	40	≥2MΩ	2.7M Ω
4 (-15VDC)	-	37	>2MΩ	2.7 M Ω
	-	38	>2MΩ	2.7M Ω
	-	3	>2MΩ	2.6M Ω
	-	40	>2MΩ	2.6M Ω
37 (+5VDC)	-	38	≈.3Ω	0.4 Ω
		3	≈2kΩ	2K Ω
	-	40	>3KΩ	4.83K Ω
3 (-5VDC)	-	40	≈4.5kΩ	5.89K Ω

5.3 Power Plane Voltage Measurements

Using a flight certified breakout connector, verify power voltages at camera connector before attaching it to the camera board. Complete the table below, then turn off the power. Use J1-pin 20 for DVM ground.

Using P.S. S/N 1



J1 pin #	Expected V	Measured V
39	+15V	+15.18
4	-15V	-15.18
37,38	+5VDC	+5.15
3	-5V	-5.30
40	+5VAIN	+5.15

Cable voltages satisfied, now measure the power plane voltages. Connect camera side of the breakout connector to the camera board. Once the breakout is attached to the camera board, leave it in place throughout the testing procedure to save the board's connector.

Power up the camera board and record the voltages between single point ground (SPG) or TP1 and indicated voltage points:

used [illegible] supply for test. [illegible]

PRIMARY SIDE

+5.0V

U12-pin 16	+5.06 v
U25-pin 16	+5.06 v

+5.0VA

+C11	+4.94 v
U8-pins 7,15, 18,21,23, 26	+4.92 v
U1-pin 7	+4.92 v
U24-pin 7	+4.92 v
D4-pin 2	+4.92 v

SECONDARY SIDE

+C10	+5.06 v
U2-pins 4, 9, 15,16	+5.06 v
U26-pins 3, 14, 16, 25, 35	+5.06 v
U5-pin 22	+5.06 v
U6-pin 16	+5.06 v
U7-pin 16	+5.06 v
U32-pin14	+4.92 v

PRIMARY SIDE		SECONDARY SIDE	
-5.0VA			
-C12	-5.21 v	Q9-pin 4	-5.21 v
U1-pin 4	-5.21 v	Q10-pin 4	-5.21 v
U24-pin 4	-5.21 v	Q11-pin 4	-5.21 v
Q1-pin 4	-5.21 v		
Q4-pins 4	-5.21 v		
+15.0V			
Q2-pin 3	+15.02 v	+C9	+15.01 v
U17-pin 1	+15.08 v	U18-pin 1	+15.07 v
U14-pin 7	+15.02 v	U27-pin 8	+15.02 v
		U3-pin 8	+15.03 v
		D3-pin 2	+15.02 v
-15.0V			
U14-pin 4	-15.17 v	-C52	-15.17 v
		U3-pin 4	-15.17 v
		U27-pin 4	-15.17 v

5.4 CCD Bias Voltage Measurements

S1—	≈0v Vss		
S2 & S4—	≈-3.0v Vss		
U19-pins 1, 10 and 17	0.0 v	U3-pin 1	0.0 v
S1—	≈1.5v Vgs		
S2 &S4—	≈2.5v Vgs		
U19-pin 20	~~1.516~~ v 1.516 DXRA		
≈13.0v Vdr			
U19-pin 18	+13.16 v	U3-pin 7	+13.16 v
≈15.0v Vdd			
U19-pins 5, and15	+15.02 v		

PRIMARY SIDE SECONDARY SIDE

5.5 Reference Voltage Measurements

10.0V ref D3-pin 6 +10.00 v

0.1V DARK REF +C93 +0.099 v Check after R128 installed SRA 5/7/93

U27-pin 3 +0.099 v " " " " SRA 5/7/93

10.7VA clocking ref (ØL1, ØR, ØRFET)

U17-pin 3 +10.78 v

U11- pin 6 +10.78 v

U30-pin 6 +10.78 v

10.7VB clocking ref (P, ØP)

U18-pin 3 +10.63 v

U9-pin 6 +10.63 v

U10-pin 6 +10.63 v

U22-pin 6 +10.63 v

U23-pin 6 +10.63 v

Analog to digital (A/D) converter reference voltages:
≈2.5V A/D ref

U27-pin 5 +2.496 v

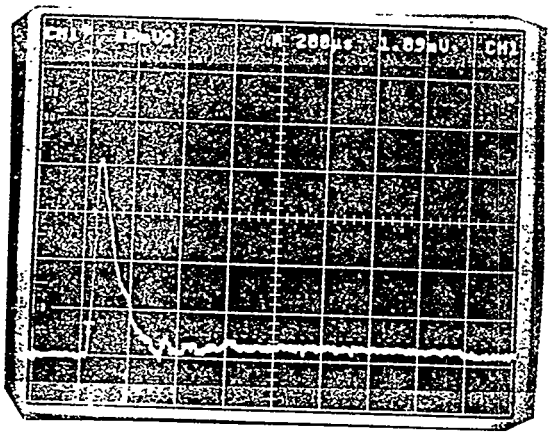
	expected volts	measured volts
U8-pin 6	≈0.620v	+0.618 v
U8-pin 22	≈1.245v	+1.246 v
U8-pin 9	≈1.875v	+1.876 v
U8-pin 17	≈2.500v	+2.498 v

5.6 Video Clamping Voltage Measurements

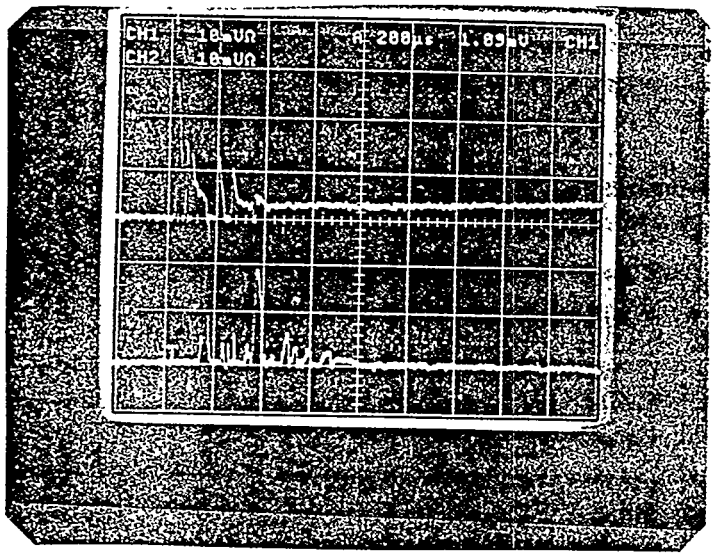
	expected volts	measured volts
U1-pin 8	≈~~2.0v~~ 3.5 or SRA	+3.45 v
U24-pin 8	≈3.5v	+3.45 v
U1-pin 5	≈-1.0v	-1.031 v
U24-pin 5	≈-0.5v	-0.535 v

Turn off the test fixture.

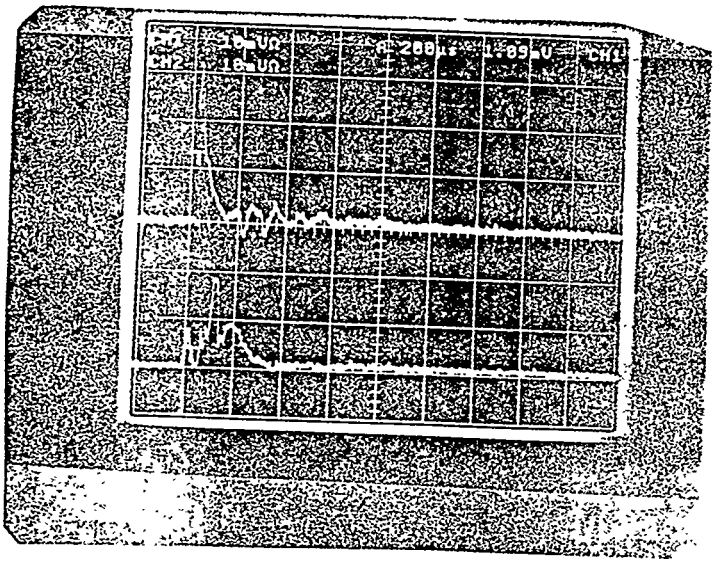
5/10/93 CURRENT MEASUREMENTS ST2 #04 06



5 Amp



±15



±5

5.7 DC Steady State Current Measurements:

These measurements require an oscilloscope and the AM503 Current Probe powered by a TM502A.

Operation of the AM 503 requires that the **oscilloscope be set at 10mV/div** and that the **probe be in the locked position.**

Isolate and label the camera wiring harness with respect to the individual power voltages. **Note!!** There are two +5VDC wires#37&38 so isolate these wires together.

Power up the camera board. Using the appropriate menu based on the camera board's configuration (Startracker) **disable** the Video bus. Consult *A Short Guide to Running hspcube*, C1-S1-002 for the necessary SASI or SUN keyboard commands.

With the Probe and Oscilloscope functional, attach the current probe around each input voltage wire and in the case of the +5VDC the wire pair, each time acquiring and recording the oscilloscope display. Note the units/div used at the AM503 so that the current can be calculated.

Consult *A Short Guide to Running hspcube*, C1-S1-002 for the necessary SASI command to **enable** the Video bus. Repeat the current measurements. Each time acquiring and recording the oscilloscope display and recording the units/div used at the AM503 so that the current can be calculated.

Calculate the currents under each Video bus state and complete the table below.

Voltages	AM503 units/div	Calculated Current Video Bus Disabled	Calculated Current Video Bus Enabled	ICD Max Waive	PASS/NO PASS
+15V	50mA	111 mA	111 mA	140	PASS
-15V	2mA	14 mA	13.96mA	30	PASS
+5VDC	10mA/50mA	51.8mA	300mA	60/330	PASS
-5V	10mA	39.6mA	39.6mA	60	PASS
+5VAIN	20mA	109.2mA	109.2mA	155	PASS

SN# 04-06 By DRQ (initials) Date 5/10/93 (passed)

REMEMBER to attach your recorded documentation to this test procedure!
(A document protector is advised)

5.8 Offset Digital-to-Analog (D/A) Verification

To verify data transfer and D/A output voltage, a Fluke 77 or voltmeter is needed.

Within the appropriate menu select and send the indicated offset data via the SASI . Measure the output voltage of U32, AD558TE pins 19, 20. Record the results in the table below.

IMPORTANT: All readings must meet indicated tolerances!

Decimal Data Input	Expected Voltage	Measured Voltage Out	
00	0.0V±10mV	.002	✓
01	80mV±10mV	.082	✓
02	160mV±10mV	.162	✓
04	320mV±10mV	.321	✓
08	640mV±10mV	.641	✓
16	1.28V±10mV	1.281	✓
20	1.61V±10mV	1.600	✓
26	2.09V±10mV	2.079	out of Tol by 1mV
31	2.49V±10mV	2.477	out of Tol by 3mV

SN# 04-06 By MD/DA (initials) Date 4-7-93 (passed)

Any significance?
BP no
JK

5.9 Gain Selection Verification

To verify proper data transfer of gain setting, use a Fluke 77 voltmeter.

Within the appropriate menu select and send the indicated gain data via the SASI. Measure the voltage at Q11,Q10 and Q9 gates. Record the results in the table below.

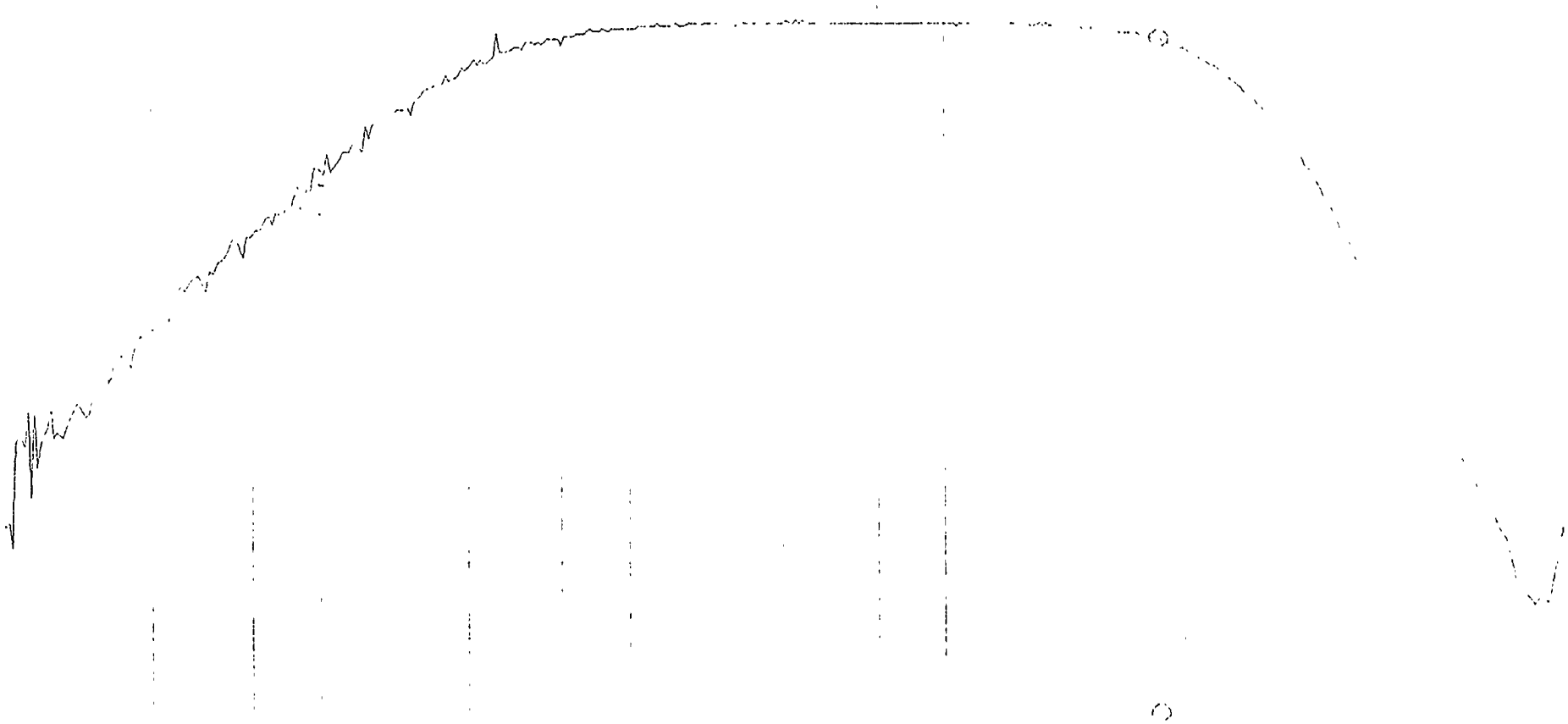
	msb		lsb
S1 INPUT 0	75e/bit Q11 .08	150e/bit Q10 .08	350e/bit Q9 .08
1	.08	.08	15.17
2	.08	15.17	.08
3	.08	15.17	15.17
4	15.17	.08	.08
5	15.17	.08	15.17
6	15.17	15.17	.08
7	15.17	15.17	15.17
8			

SN# 04-06 By MD/DA (initials) Date 5/7/96 (passed)

A: Γ/R (dB) B: 0 MKR

A MAX 35.00 dB GAIN

B MAX 180.0 deg PHASE



A/DIV 5.000 dB

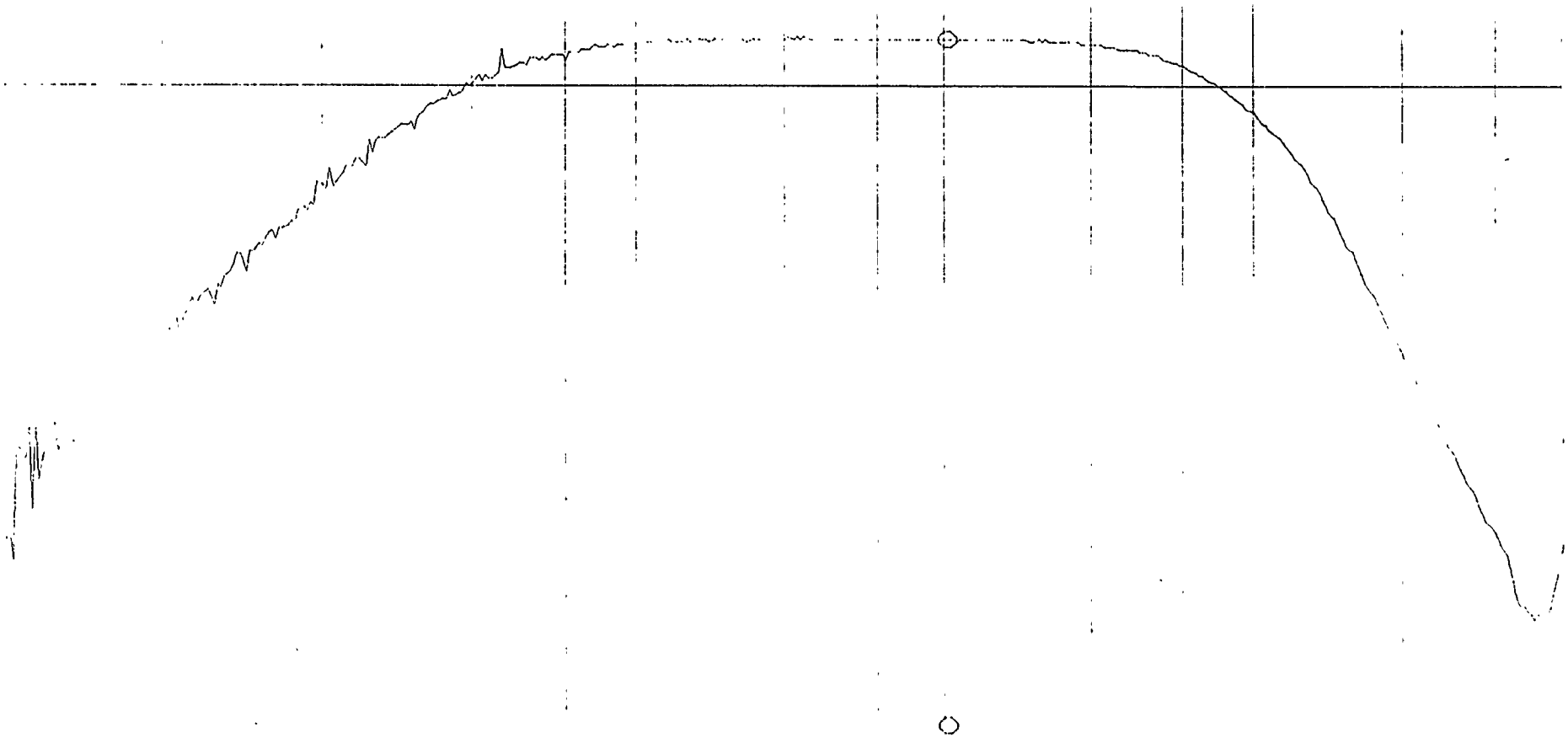
B/DIV 180.0 deg

ST2 #04-06

150e/bit

5/7/93

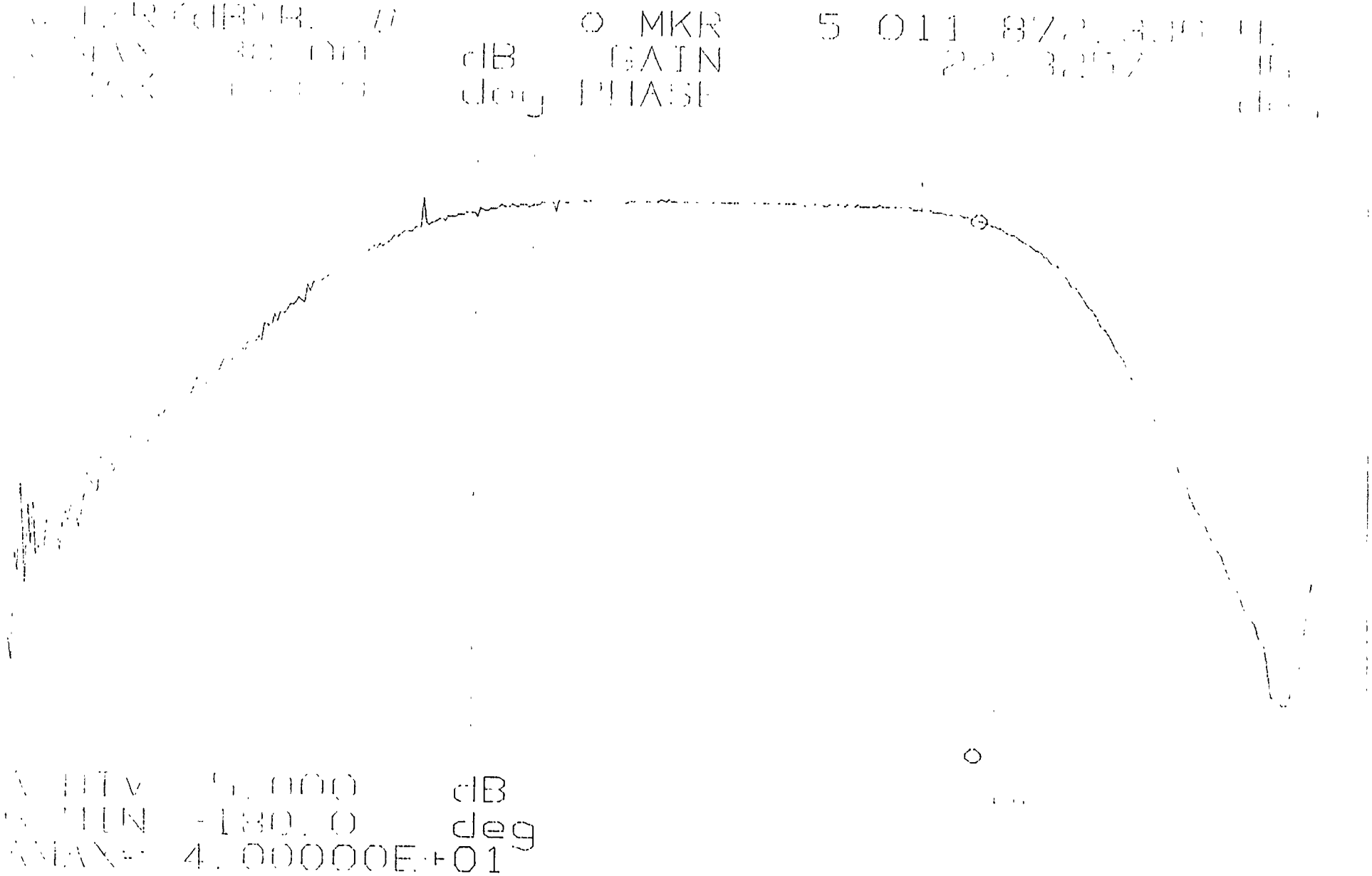
A 1/DIV dB B. 0 ΔCRS_A -3.09033 dB
1X 10.00 dB LEFT 28 761.320 Hz
1A 1.00 deg RIGHT / 947 651.062 Hz



A/DIV 5.000 dB
1X MIN -180.0 deg

ST2 #04-06
150 e/bit

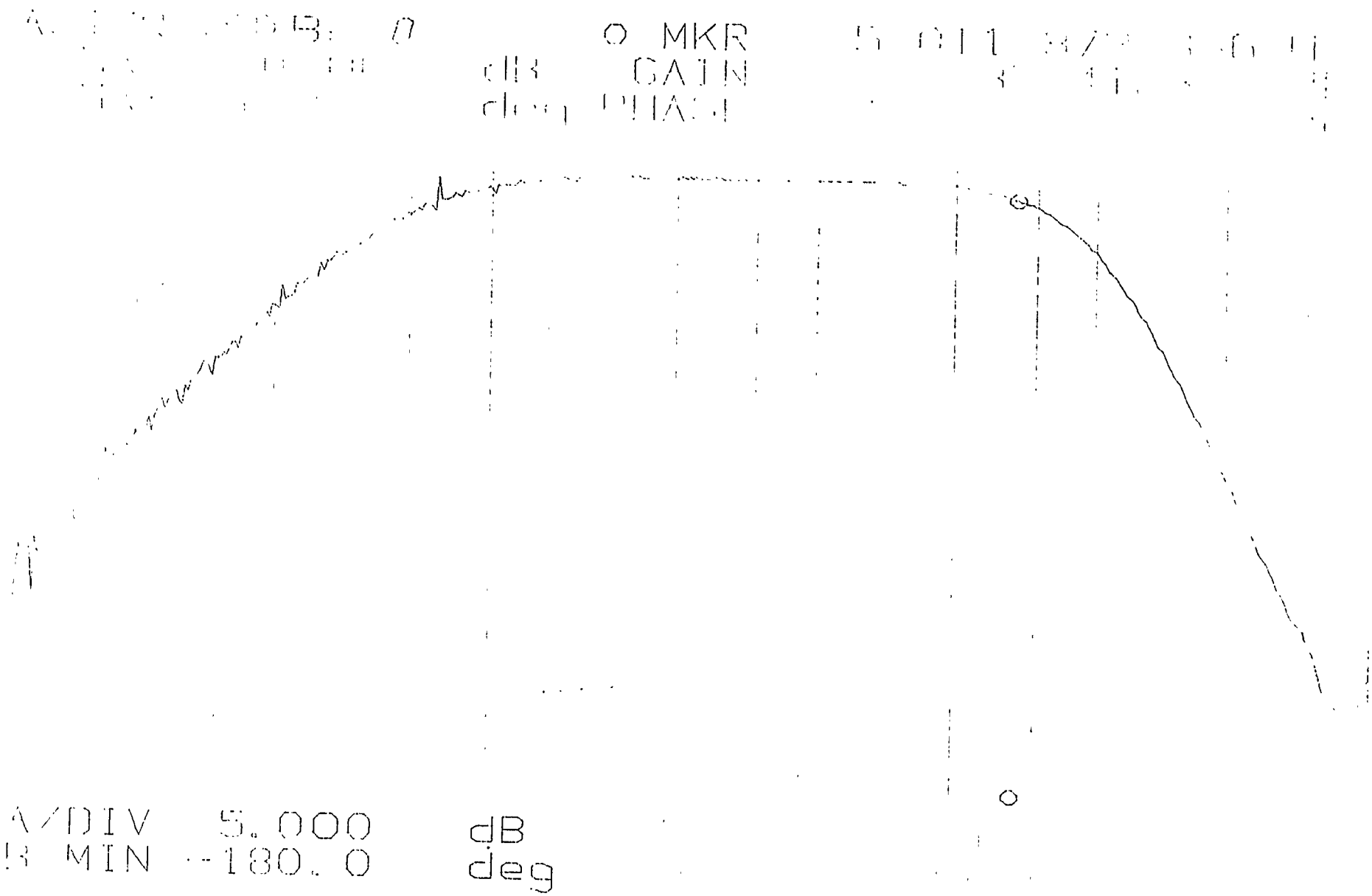
5/7/93



S12 SN# 04-06 (2ND CONFIGURATION)

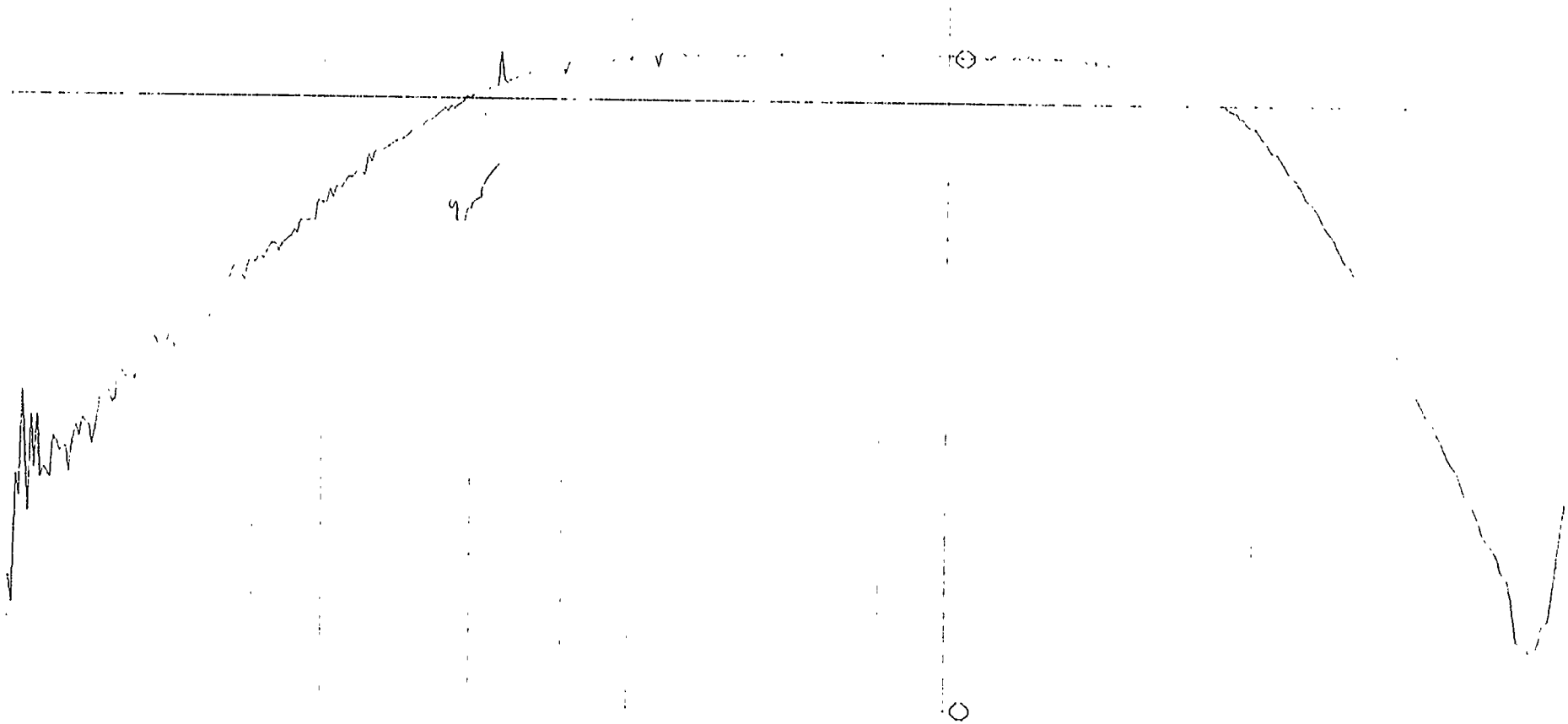
350 e/bit

5/7/93



STZ #04-06
75 elbit 5/7/93

A: T/R (dB) B: θ ΔCRS_A -3.03467 dB
A MAX 30.00 dB LEFT 28 575.142 Hz
B MAX 180.0 deg RIGHT 8 081 097.930 Hz



A DIV 5.000 dB
B MIN -180.0 deg
AMAX: 4.00000E+01

ST2 SN # 04-06 (2ND CONFIGURATION) 5/7/93
350 e/bit

6.0 Video Amplifier Gain Verifications.

The video gain measurements require use of the HP4194 Impedance Gain/Phase Analyzer.

6.1 Test Board Configuration

Configure the board under test as follows:

Replace R49 with a 1.0 Kohm 1% resistor.

Remove R128 and connect R128's outermost pad with C123's outermost pad. This grounds Q1 and Q4 gates.

Disable the 20MHz oscillator by connecting U5 pins 5 and 23 together.

6.2 HP4194 Analyzer Configuration and Connection.

Configure the HP4194 Analyzer as follows:

Gain/Phase measurement,
A Scale linear and AutoScale,
Log Sweep, 1 KHz to 100 MHz,
Oscillator Level equal to -45 dBm.

Insert a 1 Kohm resistor from U19 pin 18 to U19 pin 16. Attach the HP4194 oscillator output to U19 pin 16 and its ground to the ground test point.

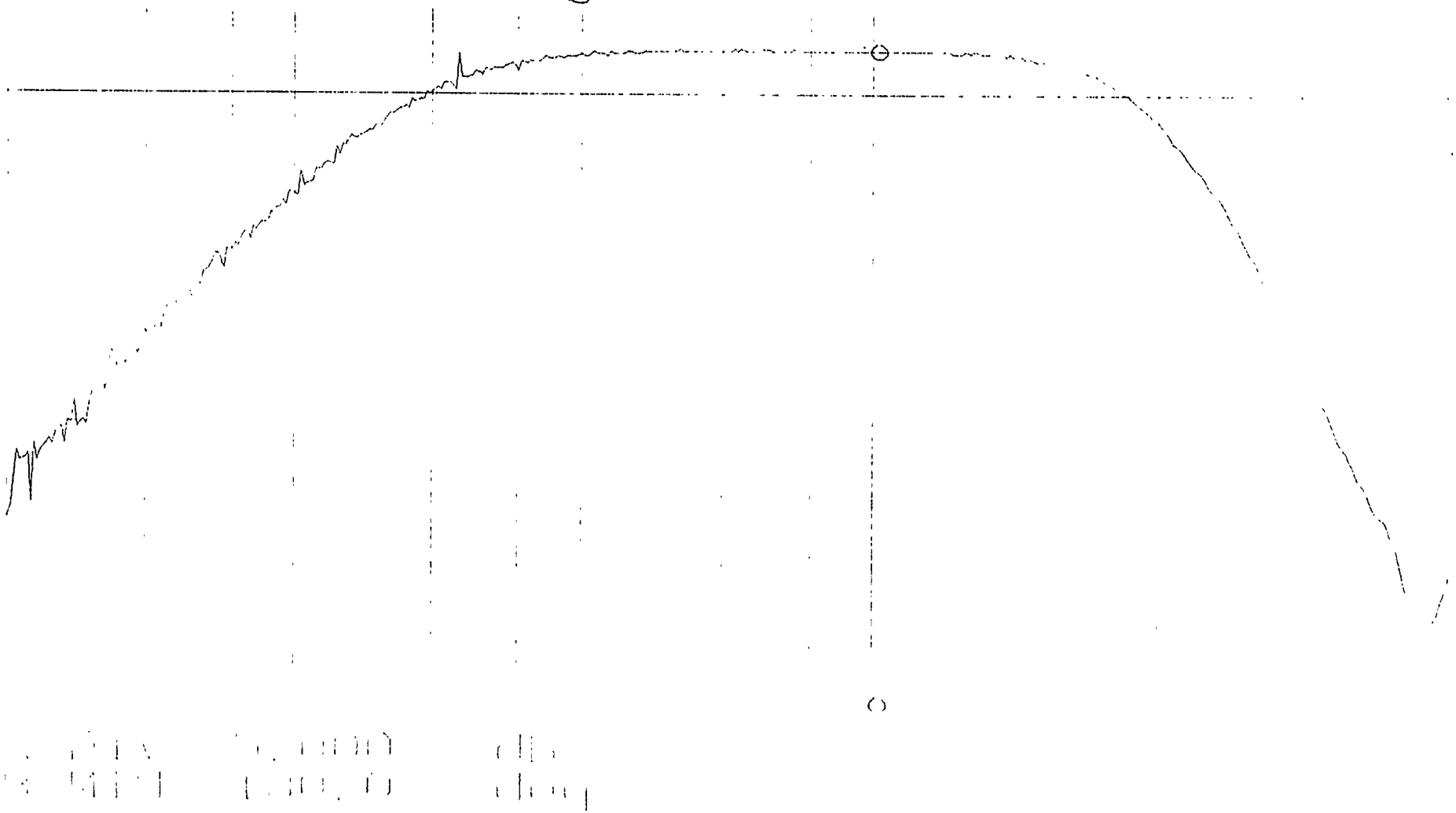
6.3 Gain and 3dB Bandwith Acquisition.

Measure and store the reference level. Then measure the gain at 5MHz and 3dB frequency at U8 pin 28 for all three gain settings. Record the measured values in the following table and attach the data plots in a document protector.

Gain Setting	Expected Gain dB	Measured Gain dB	Expected 3dB bandwidth(MHz)	Measured 3dB bandwidth(MHz)
4	35.5±0.5	35.41	7.5±0.5	7.7
2	29.5± 0.5	29.57	7.5±0.5	7.9
1	22.2±0.5	22.33	7.5±0.5	8.1 ✓ OK

SN# 04-06 By DRa (initials) Date 5/10/93 (passed)

A: T/R (dB) B: θ ΔCRS_A -3.08126 dB
A MAX 40.00 dB LEFT 28 728.244 Hz
B MAX 180.0 deg RIGHT 7 707 825.220 Hz



STZ #04-06 5/7/93
75 e/bit

7. Clocking Measurements with CCD installed

Verify that U19 pin 16 is not shorted to ground.
Measured 4.5 M Ω (>1MΩ)

Insert the appropriate prototype TH7883 CCD into location U19.

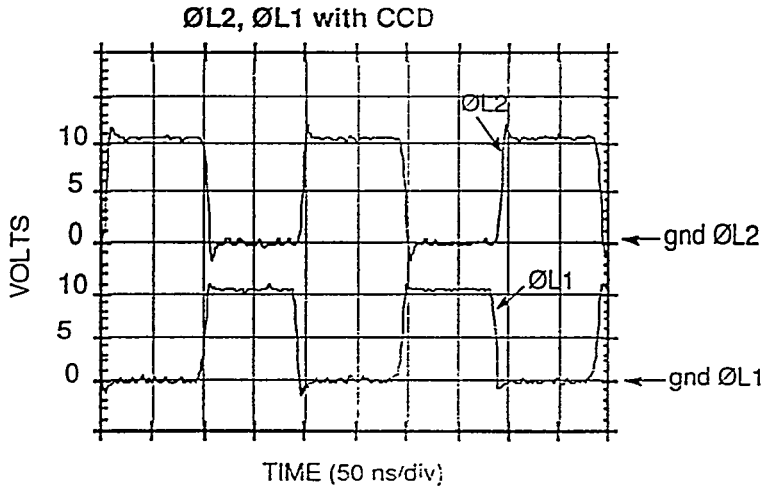
Carefully Check CCD Orientation!!

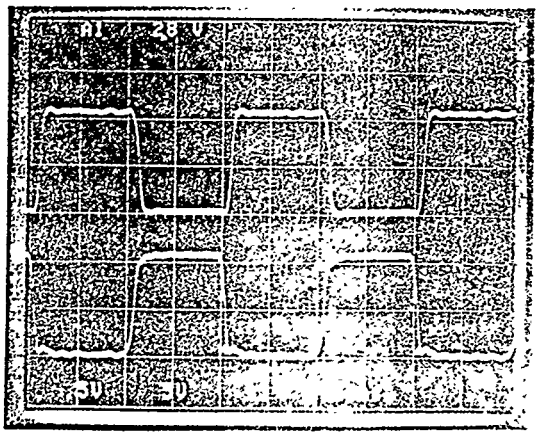
7.1 Acquire and record the ØL2 and ØL1 clocks:

Make these scope probe connection:

Probe	Location
Channel 1	U19 pin 2
Channel 2	U19 pin 3

Change the scope horizontal sweep frequency to 50ns per division.



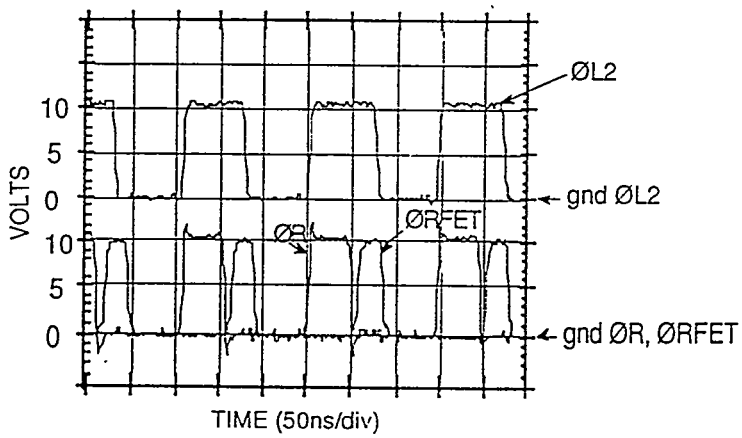


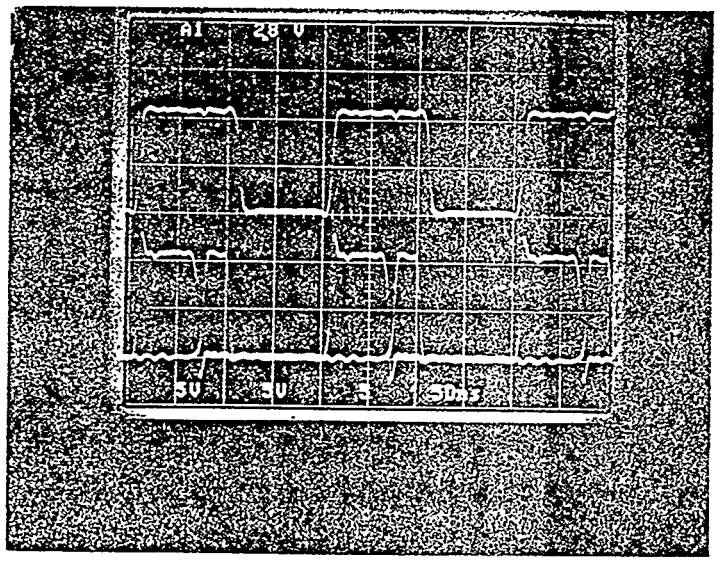
7.2. Acquire and record the ØL2, ØR, and ØRFET clocks:

Move the scope ØR, and ØRFET probe to these locations:

Probe	Location
Channel 2	U19 pin 19
Channel 3	R128 Q1 gate side

ØL2, ØR, AND ØRFET



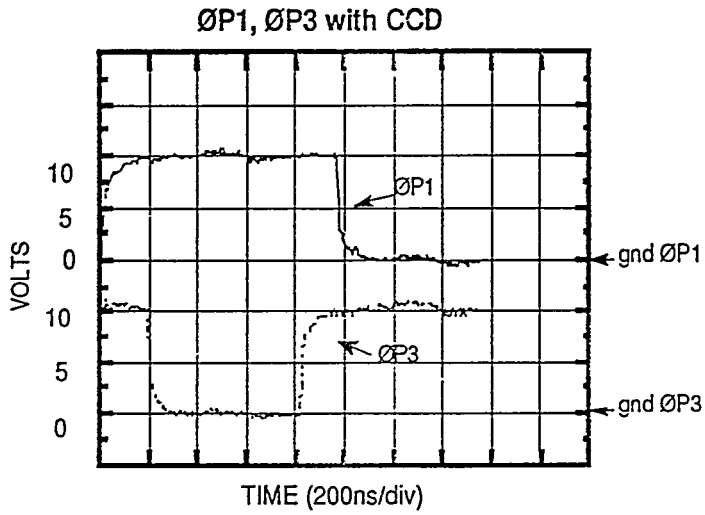


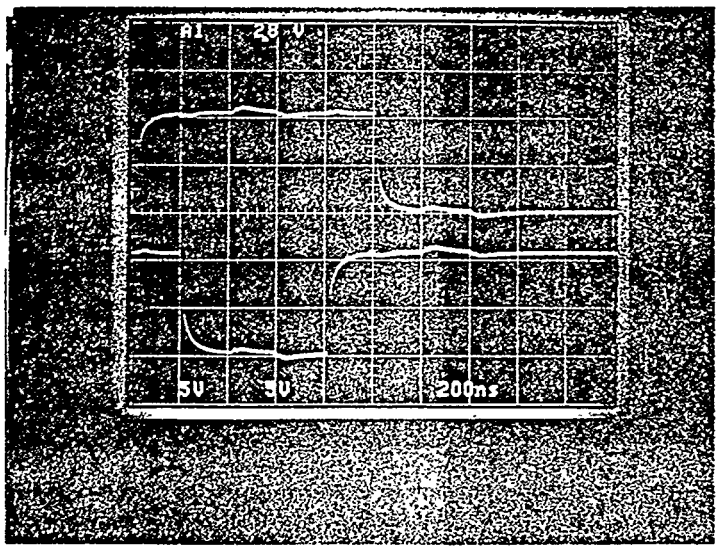
7.3 Acquire and record the ØP1, and ØP3 clocks:

Move the scope probes to these locations:

Probe	Location
Channel 1	U19 pin 14
Channel 2	U19 pin 13

Shift the horizontal sweep frequency to 200ns per division.

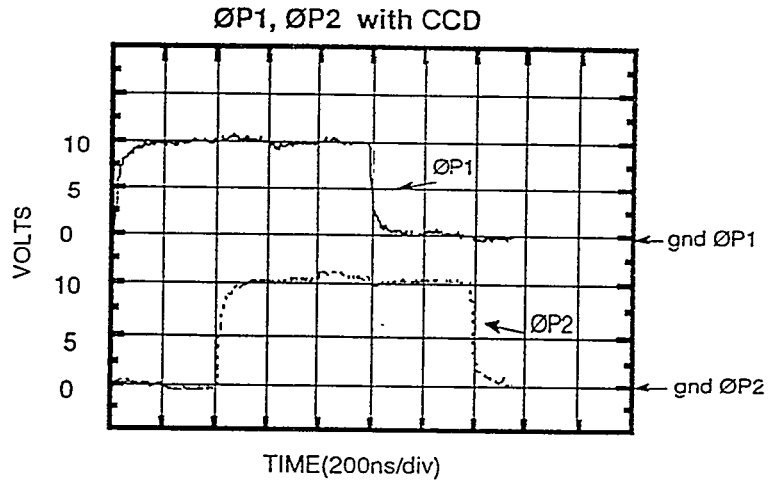


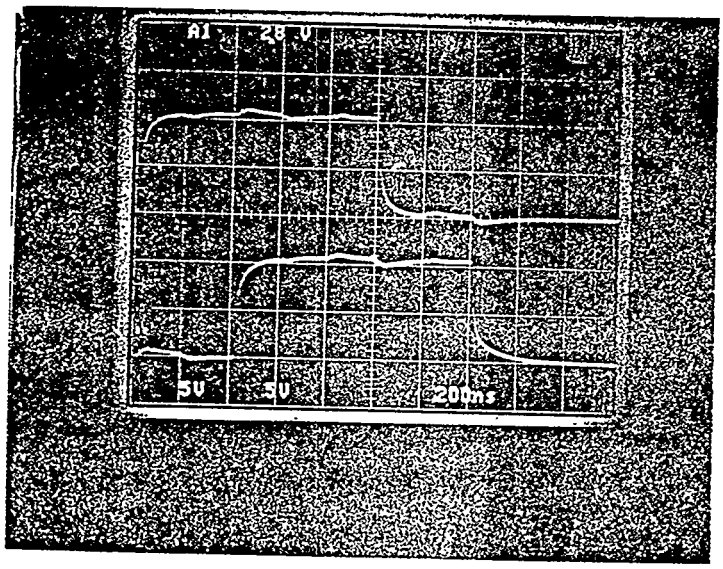


7.4 **Acquire and record the ØP1, and ØP2 clocks:**

Move the scope probe to this location:

Probe	Location
Channel 2	U19 pin 12

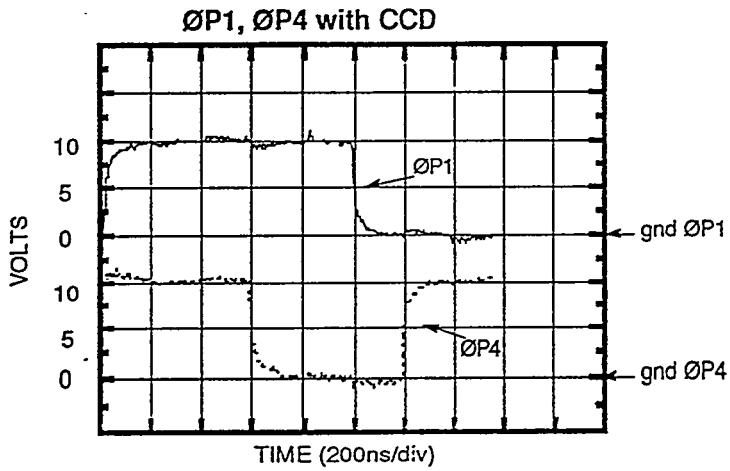


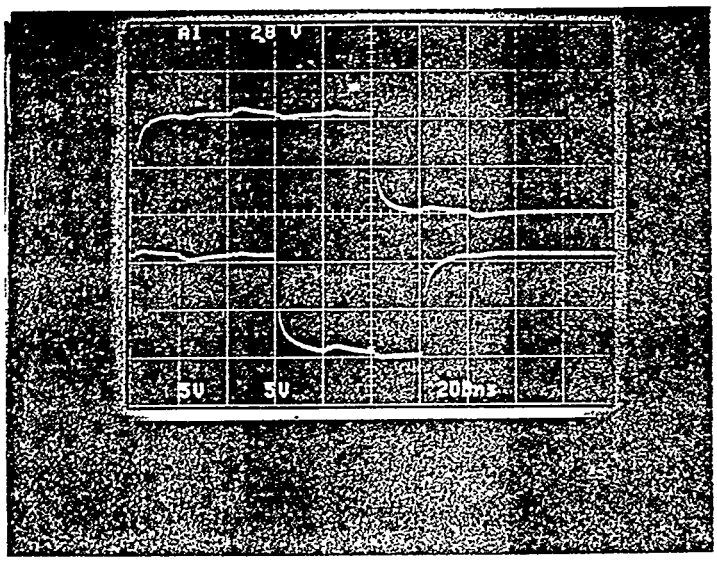


7.5 Acquire and record the ØP1, and ØP4 clocks:

Move the scope probe to the location indicated:

Probe	Location
Channel 2	U19 pin 11

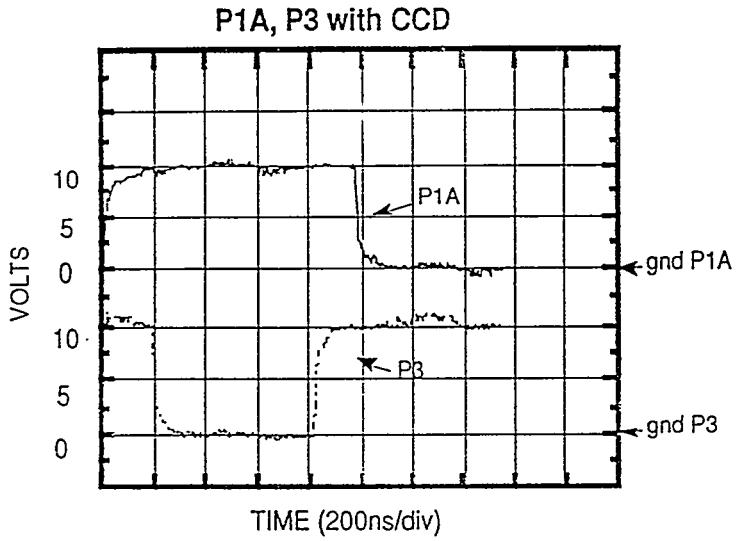


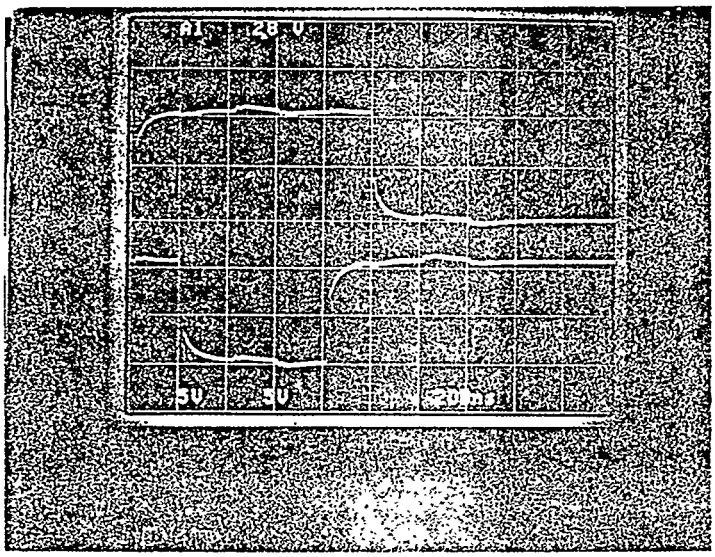


7.6 Acquire and record the P1A, and P3 clocks:

Move the scope probes to these locations:

Probe	Location
Channel 1	U19 pin 9
Channel 1	U19 pin 8

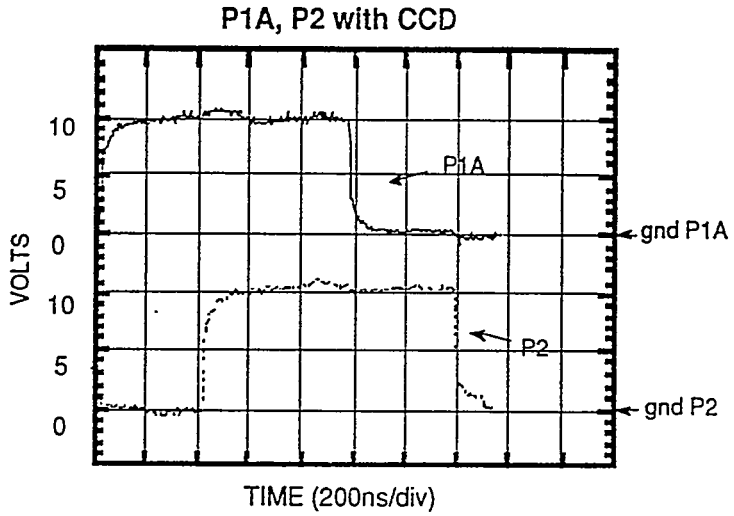


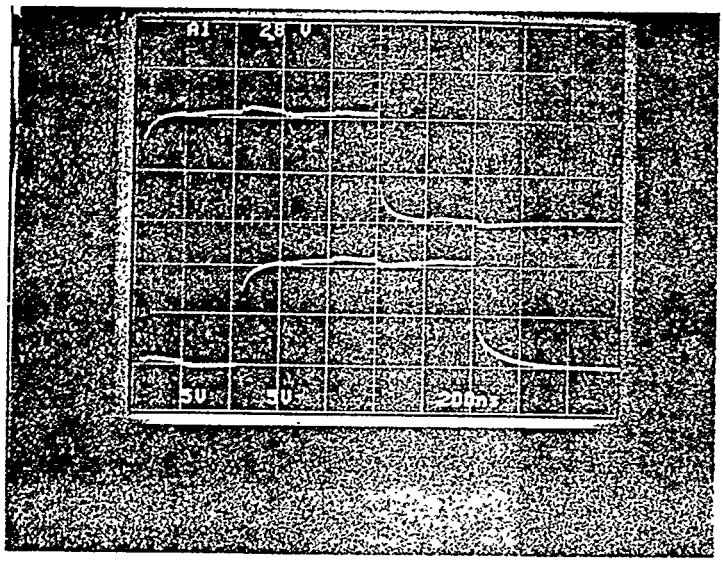


7.7 Acquire and record the P1A, and P2 clocks:

Move the scope probe to this location:

Probe	Location
Channel 2	U19 pin 7

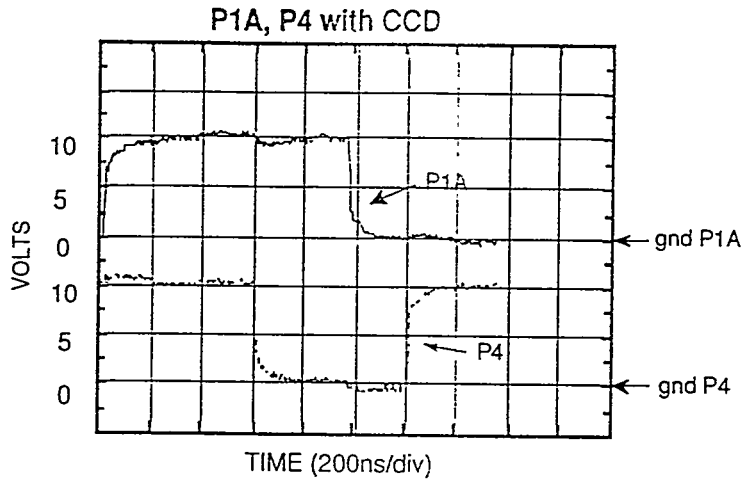


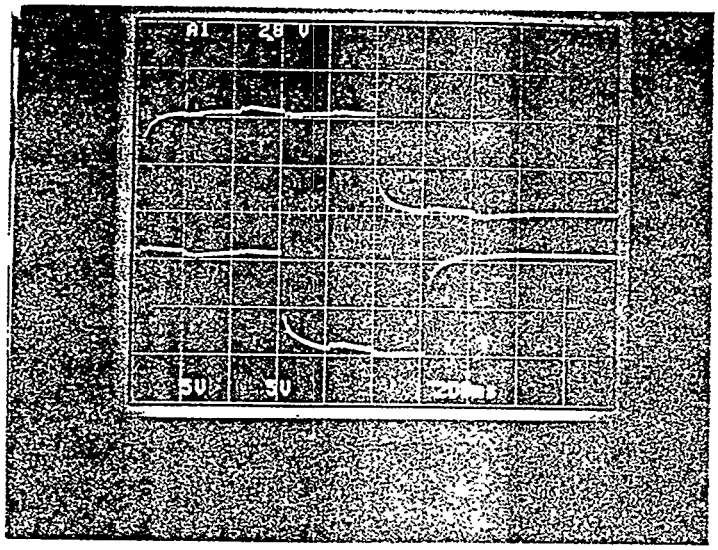


7.8 Acquire and record the P1A, and P4 clocks:

Move the scope probe to this location:.

Probe	Location
Channel 2	U19 pin 6

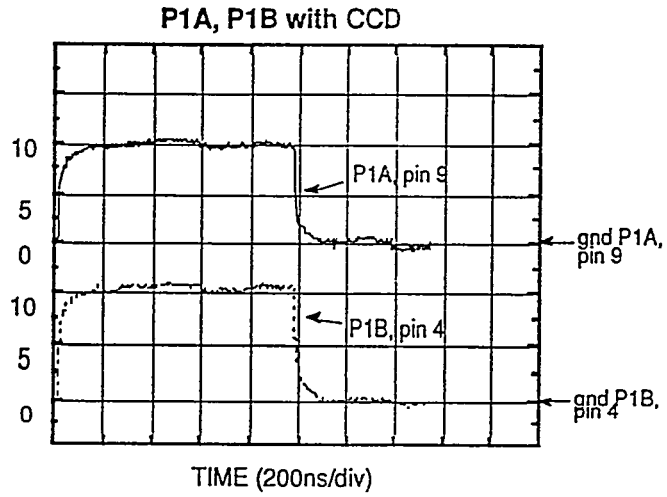


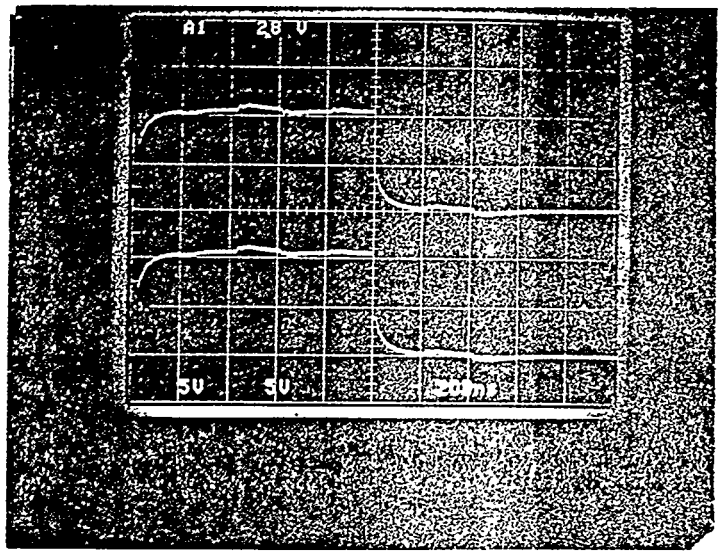


7.9 Acquire and record the P1A, and P1B clocks:

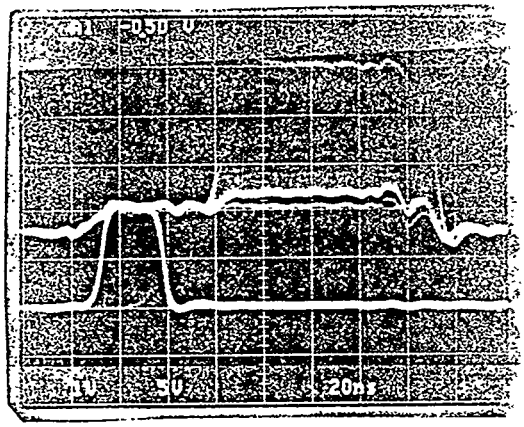
Move the scope probe to this location:

Probe	Location
Channel 2	U19 pin 4

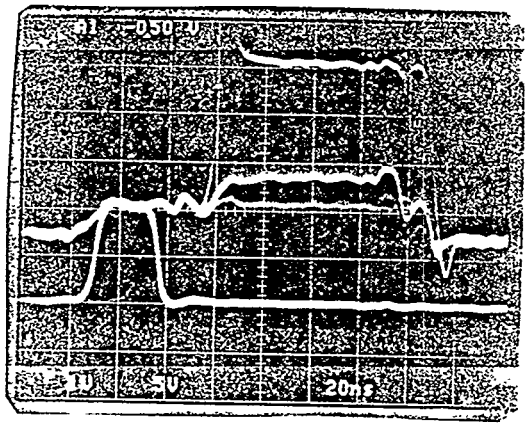




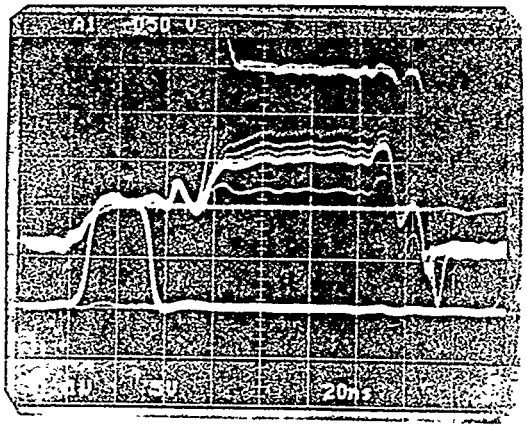
5/10/93



350e/bit



150e/bit



75e/bit

8. Double Correlated Sampling Functionality Verification

This measurement requires the use of a Tektronix 2465B—or like—oscilloscope.

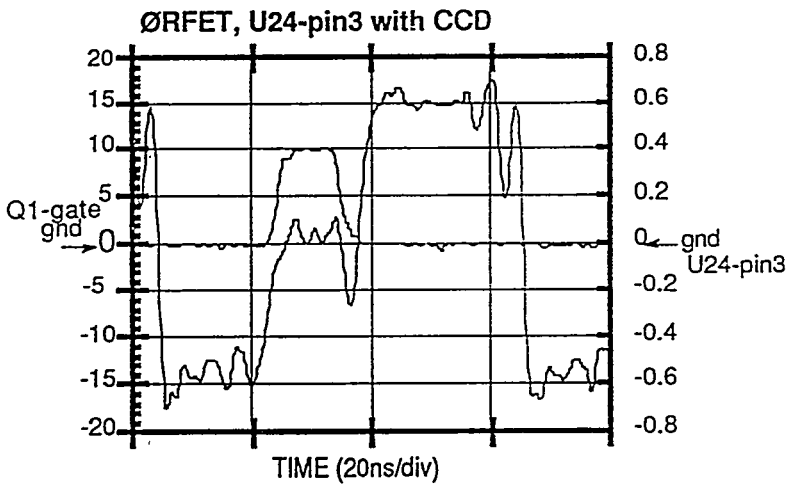
Verify the gain of the camera is 150e/bit via the SASI.

Make these scope probe connection:

Probe	Location
Channel 2	U24 pin 3
Channel 3	R128 Q1 gate side

Adjust the time base to **20ns** per division.

Acquire and record the Q1 or ØRFET vs Video signals:



Make the same measurement at 350e/bit and 1000e/bit.

Note: During the Q1 or ØRFET pulse, the video signal should be ≈0v or ground. At high gains, the sensor may require cool down by non-operation and/or an opaque covering to acquire this measurement.

9. Analog to Digital (A/D) Converter Clock vs U24-pin 6 & U8-pin 28

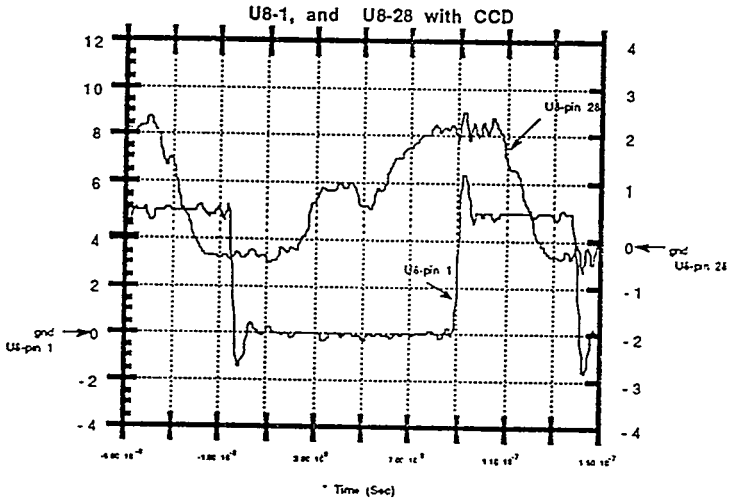
This measurement requires the Tektronix 2465B analog—or like—oscilloscope.

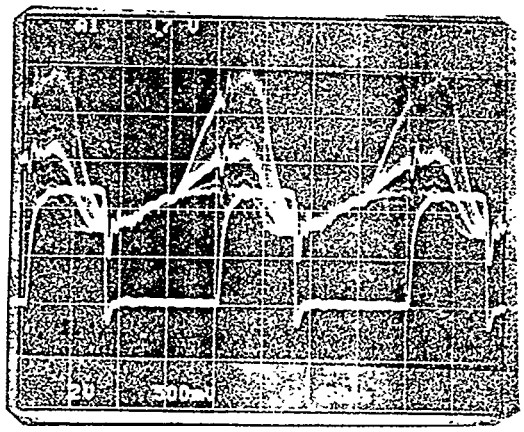
Set the scope to trigger on channel 1.

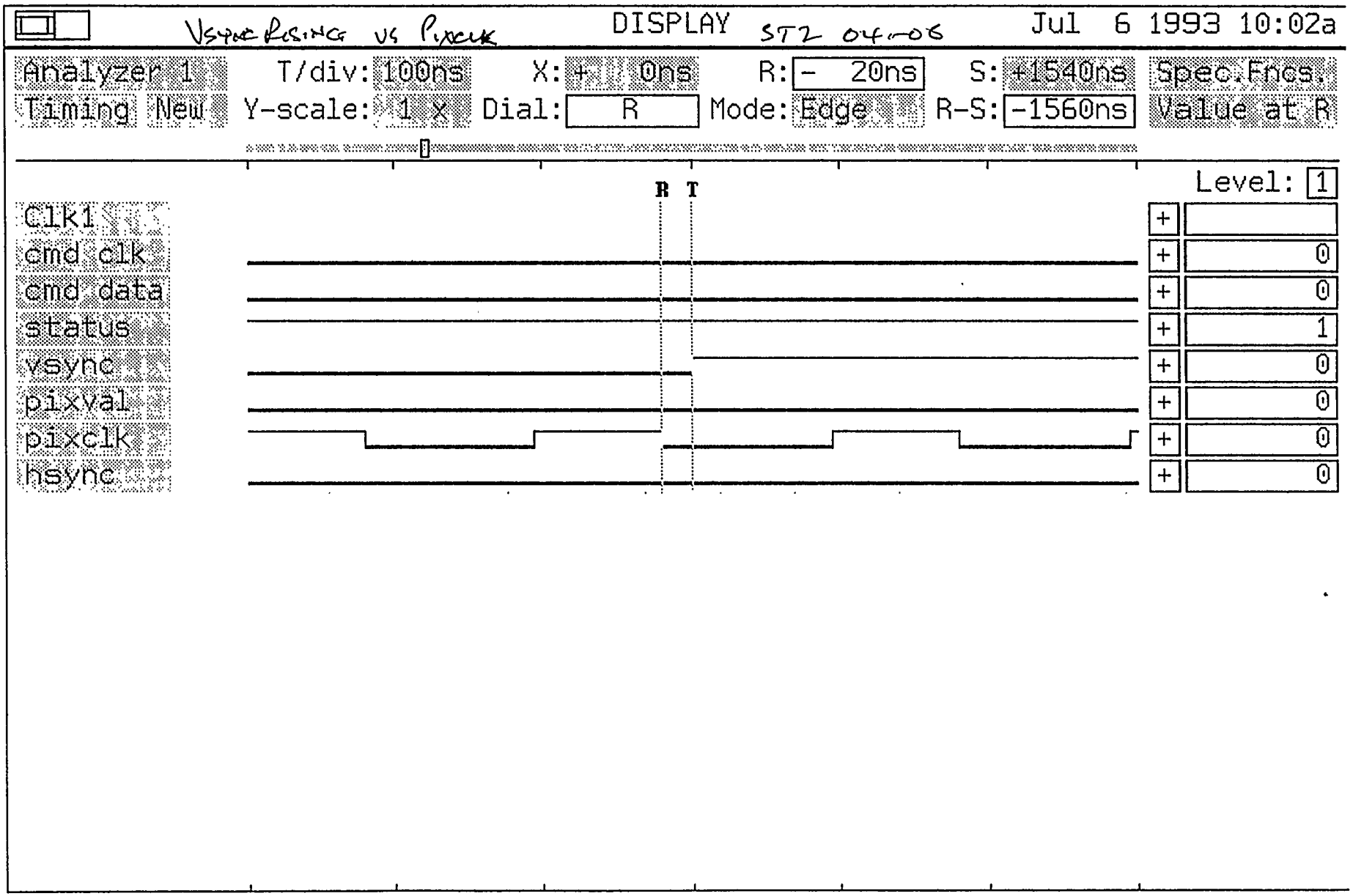
Set the horizontal sweep to **50ns**/division.

Move the scope probes to these locations:

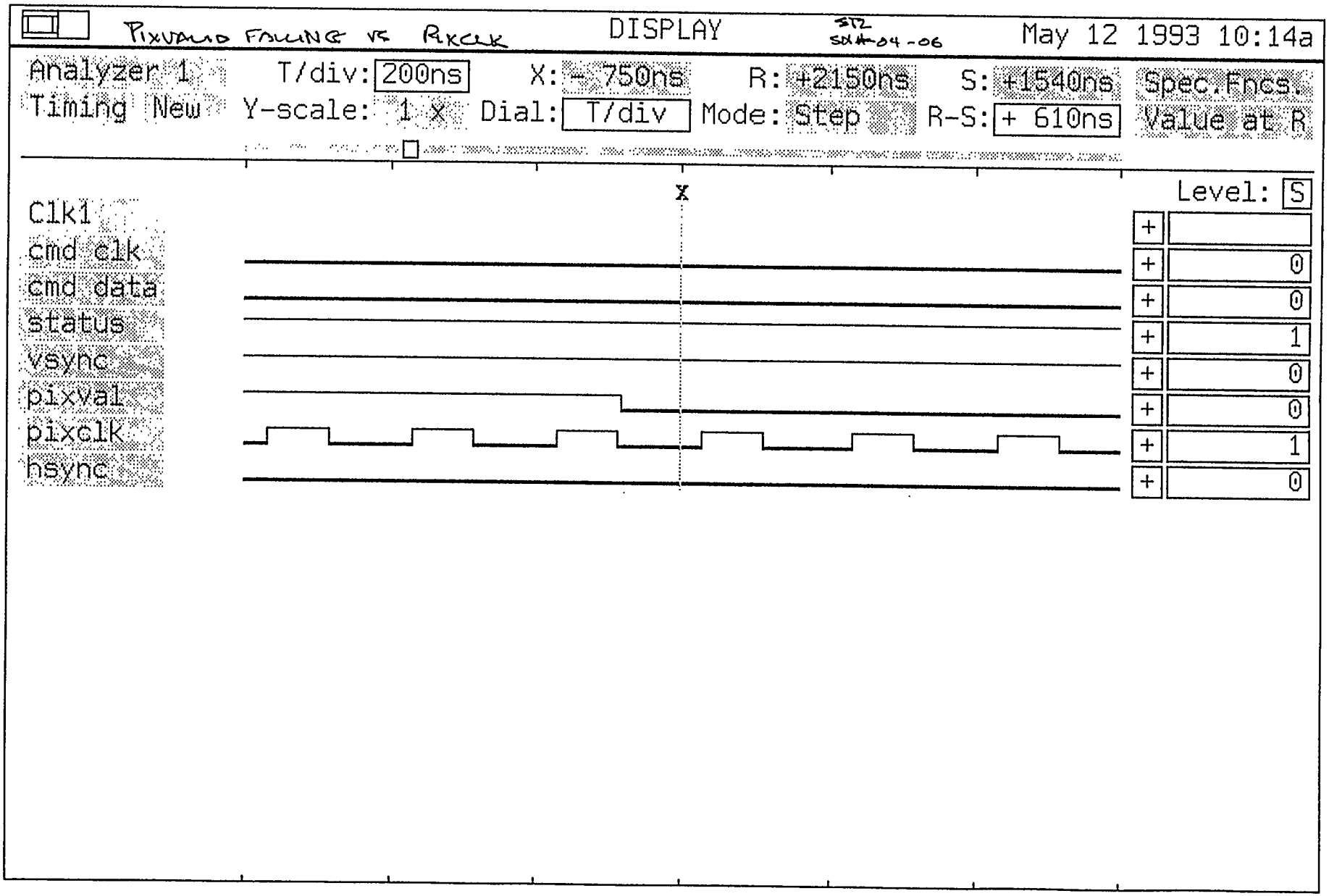
Probe	Location	Vertical Gain
Channel 1	U8 pin 1	2 V/division
Channel 2	U8 pin 28	500 mV/division

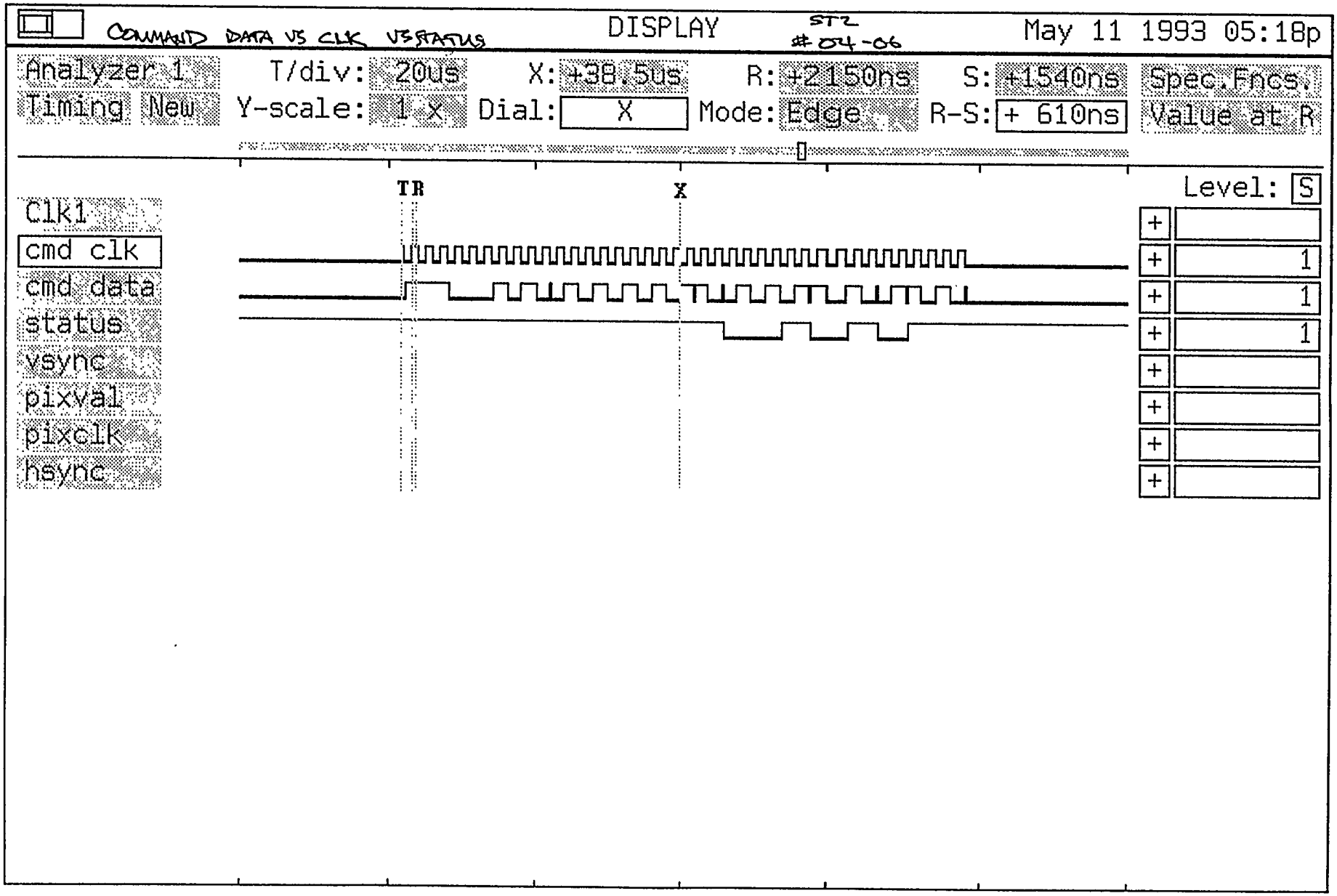






Philips PM3580/PM3585


PIXVALID FALLING VS PIXCLK
DISPLAY
May 12 1993 10:14a
Analyzer 1
Timing New
T/div: 200ns
Y-scale: 1 x
X: -750ns
Dial: T/div
R: +2150ns
Mode: Step
S: +1540ns
R-S: + 610ns
Spec.Fncs.
Value at R
Level: S
Clk1
cmd clk
cmd data
status
vsync
pixval
pixclk
hsync
0
0
1
0
0
1
0



Philips PM3580/PM3585

Philips PM3580/PM3585

Data Bus vs Pixclk

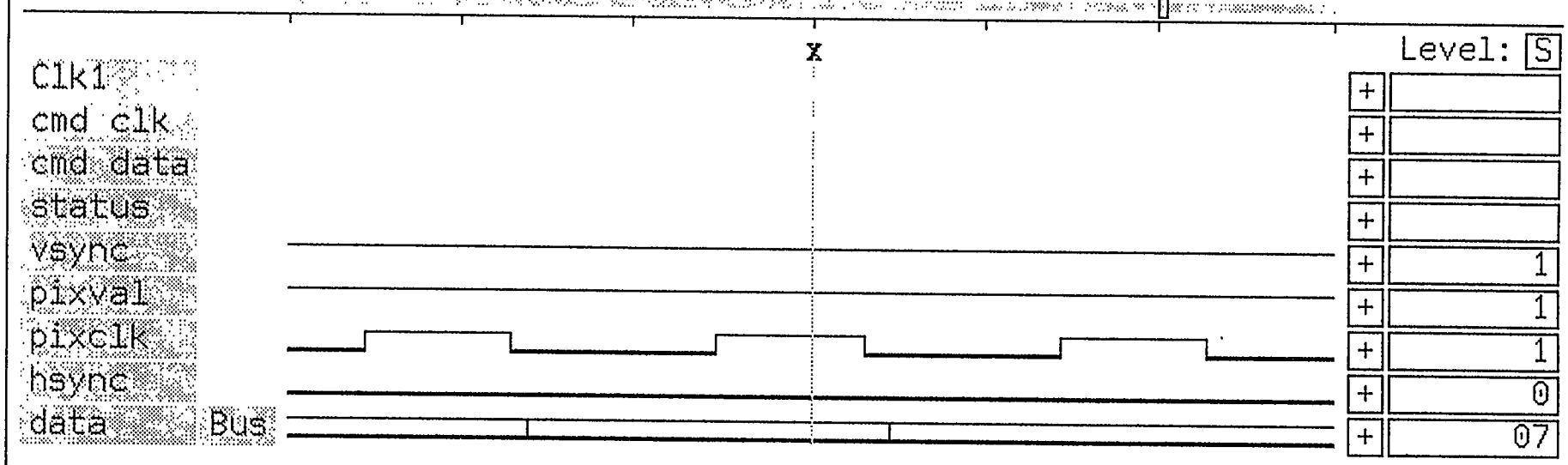
DISPLAY

STZ SN# 04-06

May 11 1993 05:50p

Analyzer 1 | T/div: 100ns | X: +28.4us | R: + 0ns | S: + 0ns | Spec.Fncs.

Timing New | Y-scale: 1 x | Dial: X | Mode: Scroll | R-S: + 0ns | Value at X



PIXVALID RISING VS PIXCLK

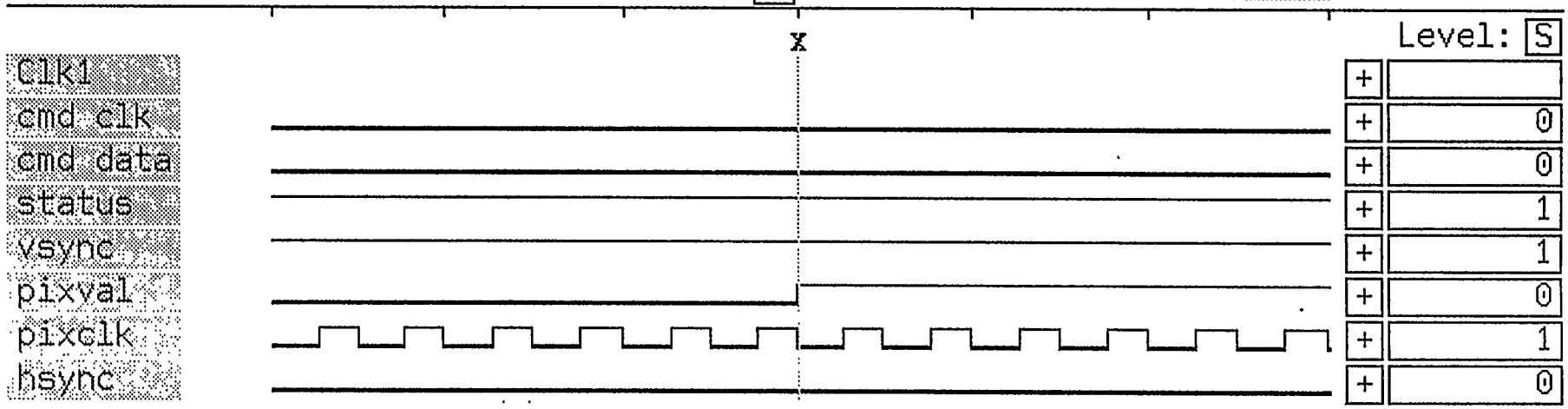
DISPLAY

ST2 SN#04-06

May 11 1993 05:29p

Analyzer 1 | T/div: 400ns | X: +16.8us | R: +2150ns | S: +1540ns | Spec.Fncs.

Timing | New | Y-scale: 1 x | Dial: T/div | Mode: Step | R-S: + 610ns | Value at R

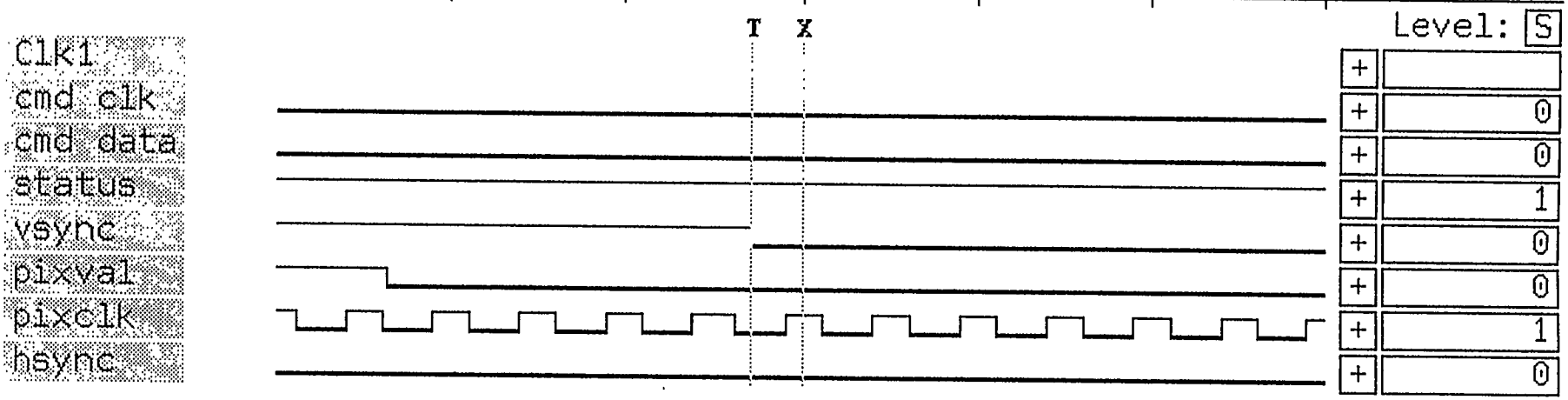


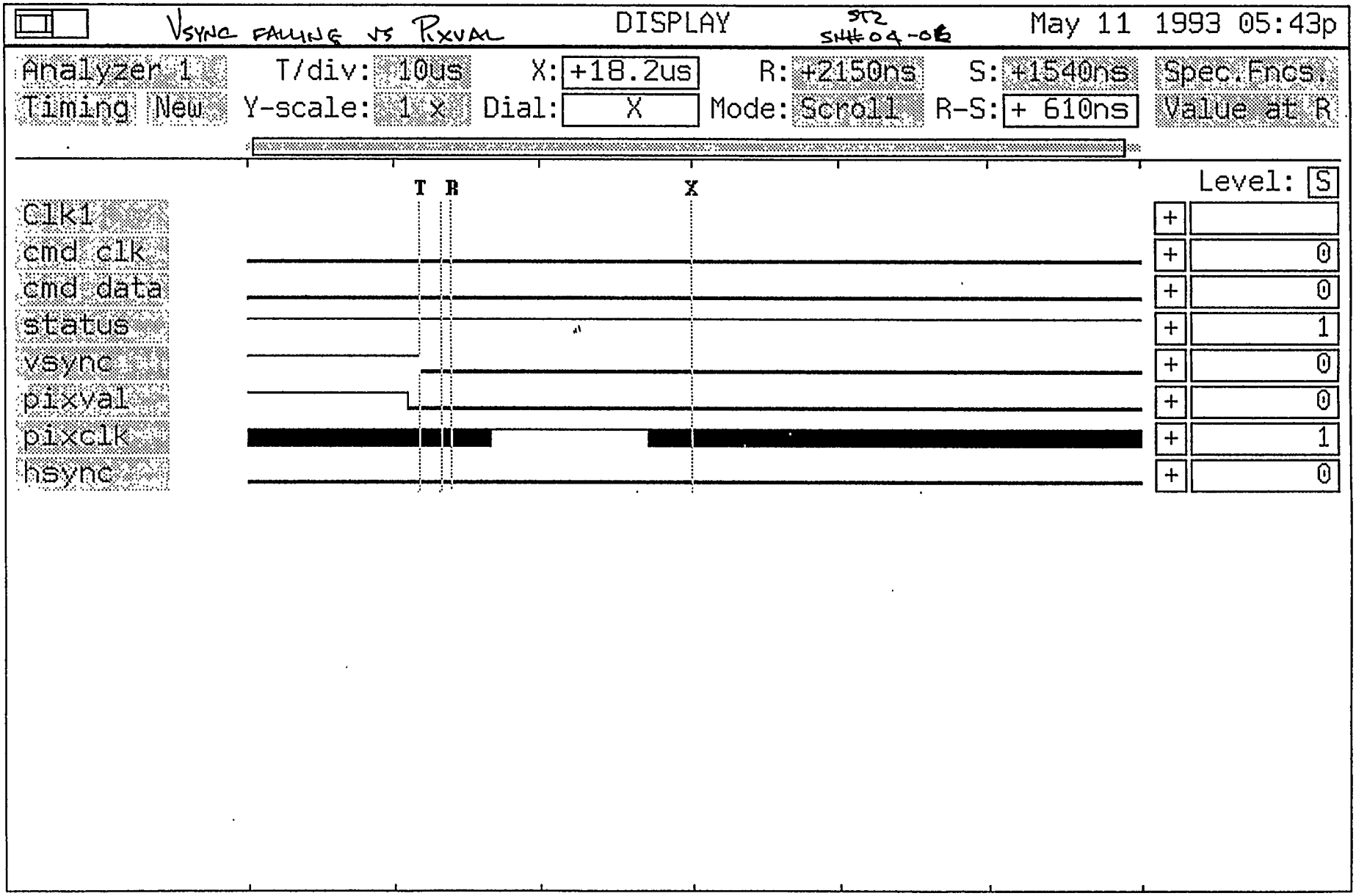
Philips PM3580/PM3585

VSYNC FALLING VS PIXCLK VS PIXVALID DISPLAY STZ SN#04-06 May 12 1993 09:31a

Analyzer 1 T/div: 400ns X: + 120ns R: +2150ns S: +1540ns Spec.Fncs.

Timing New Y-scale: 1 x Dial: X Mode: Scroll R-S: + 610ns Value at R





Philips PM3580/PM3585

Pixval

~~Vsync~~ Rising vs Pixclk

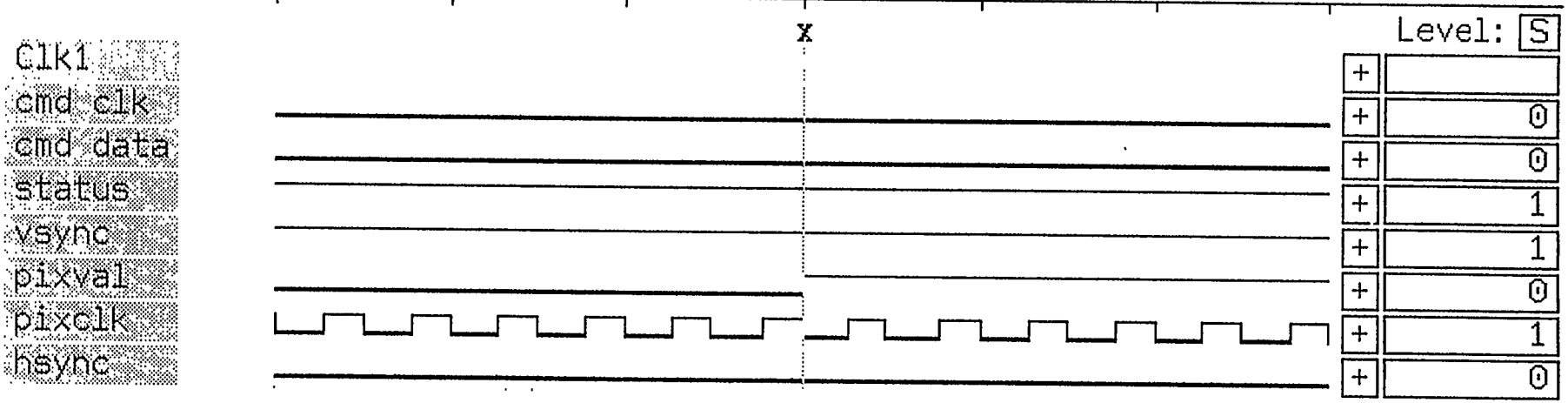
DISPLAY

STZ SN#04-06

May 11 1993 05:37p

Analyzer 1 | T/div: 400ns | X: +16.8us | R: + 85ns | S: +16.8us | Spec.Fncs.

Timing New | Y-scale: 1 X | Dial: X | Mode: Edge | R-S: -16.7us | Value at R



Philips PM3580/PM3585

VSYNC RISING VS PIXVALID

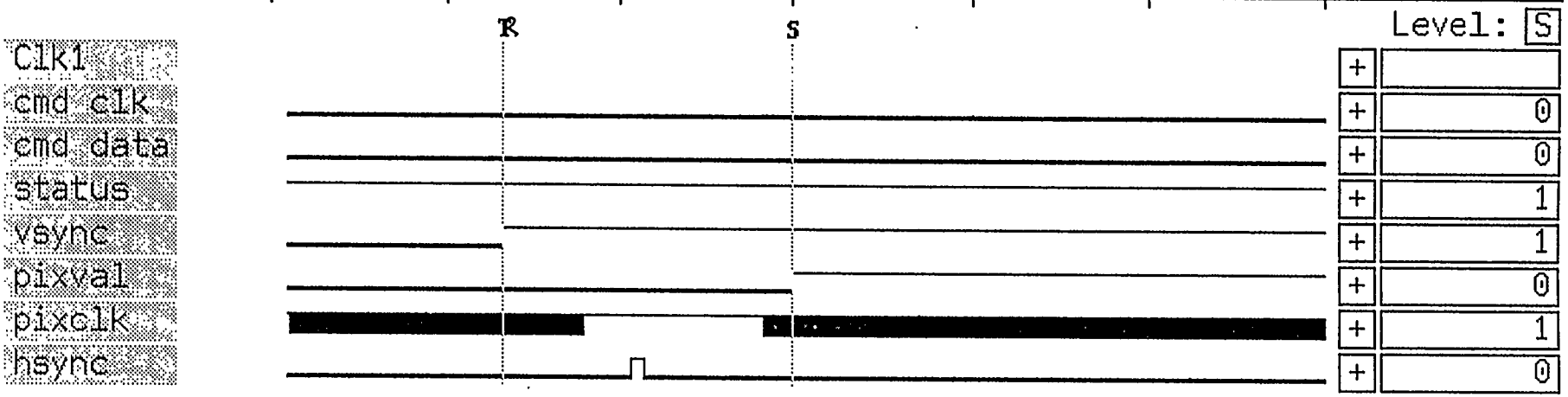
DISPLAY

SAZ SN# 04-06

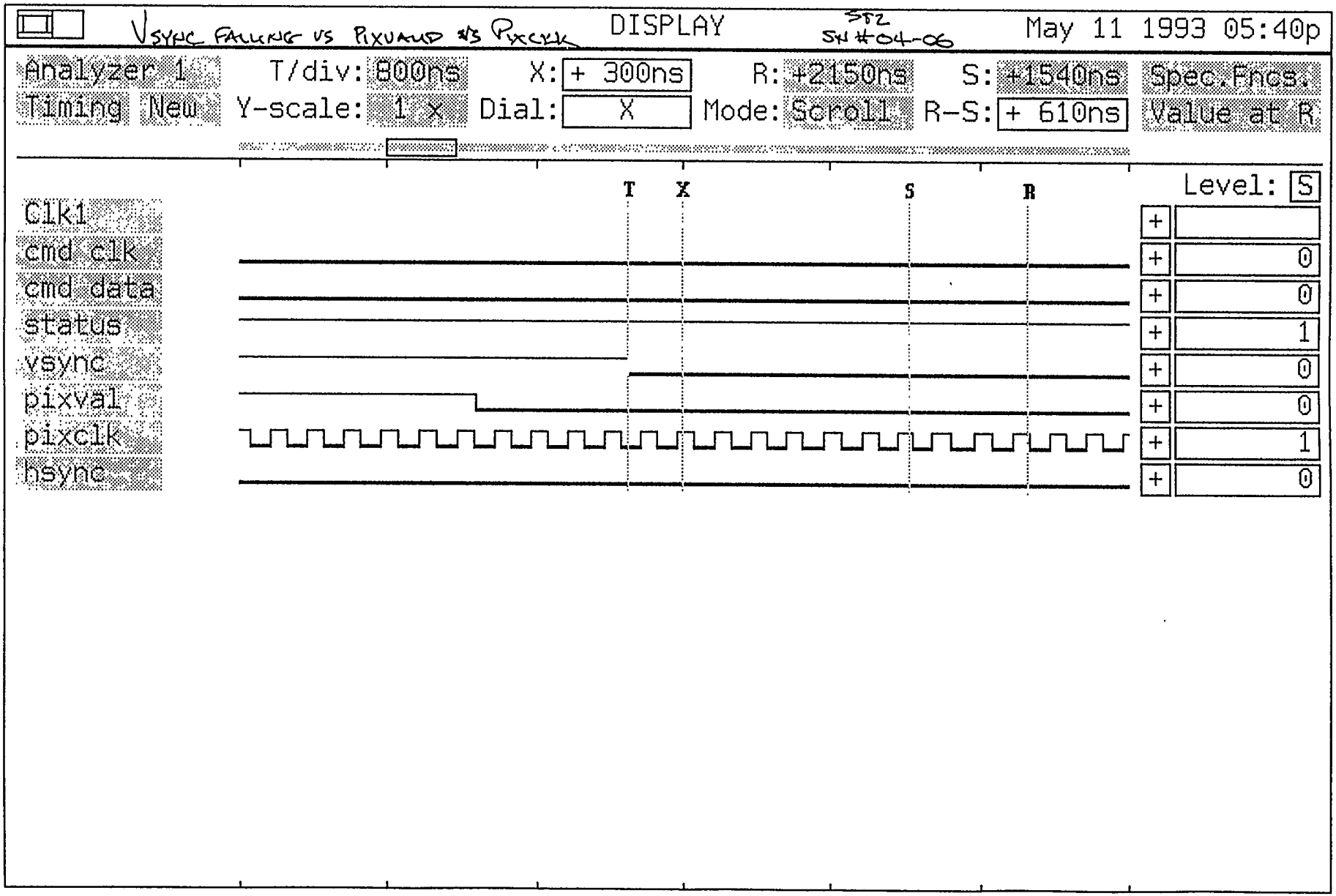
May 11 1993 05:33p

Analyzer 1 | T/div: 10us | X: +16.8us | R: + 85ns | S: +16.8us | Spec.Fncs.

Timing New | Y-scale: 1 x | Dial: S | Mode: Edge | R-S: -16.7us | Value at R



Philips PM3580/PM3585



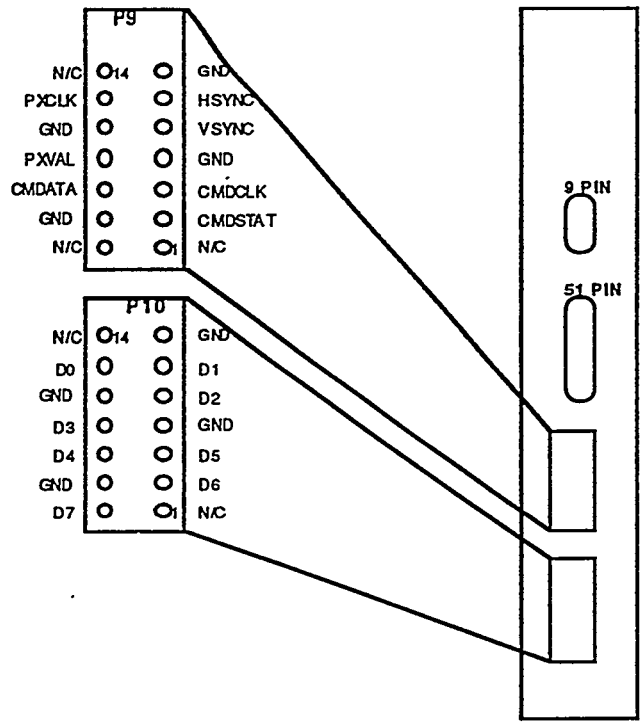
Philips PM3580/PM3585

10. Video Interface Timing Confirmation

This test requires the use of the Phillips PM 3585 Logic Analyzer.

10.1 Logic Analyzer Setup

Move the analyzer pod probes to the following locations at the Datacube interface card connectors designated as P9 and P10:



channel 1-CMDCLK
channel 2-CMDDATA
channel 3-CMDSTAT
channel 4-VSYNC
channel 5- PIXVAL
channel 6-PIXCLK
channel 7-HSYNC
channel 9-16-DATA BUS

Attach the pod ground to any of the GND pins indicated.

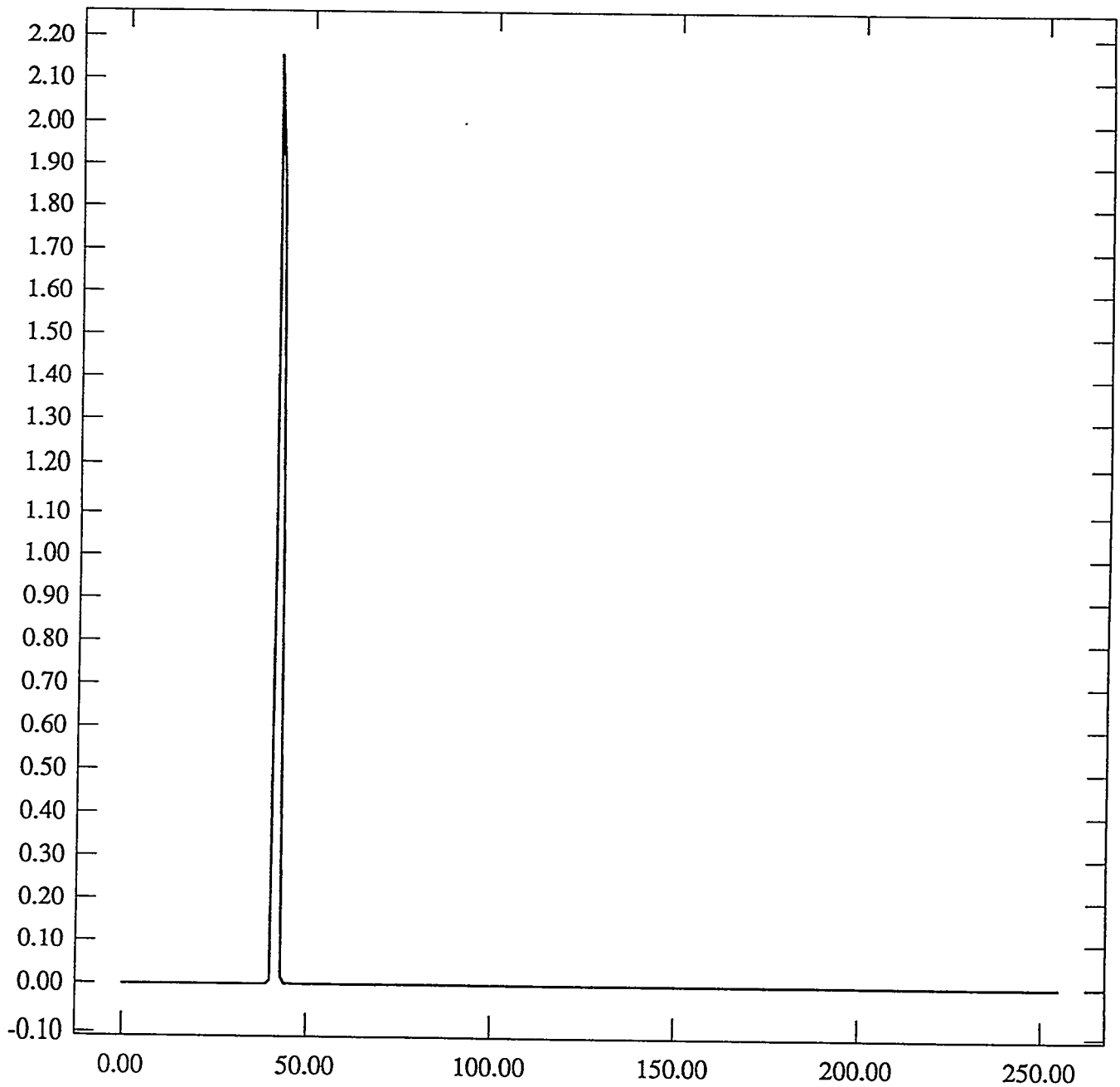
10.2 Timing acquisitions:

Pixclk vs Data
Vsync vs Pixvalid (condensed and expanded at the beginning of line & frame)
(condensed and expanded at the end of line & frame)
SASI Command (this is CMDDATA while a SASI is sent from the SUN keyboard)
Rising and falling edges at Vsync vs Pixclk
Rising and falling edges at Pixval vs Pixclk

REMEMBER to attach your recorded documentation to this test procedure!
(A document protector is advised)

ST Camera: ST2 04-06 PreC: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:05:45 1993

Pixel Values Min 40 Max 45 Mean 41.5 Sigma 0.51 x 10^3



11. Dark Noise Measurements.

This measurement requires only the SUN Datacube Test Station and its image processing capabilities and an opaque covering.

Remove all test probes and place an opaque cover over the test CCD. turn the camera on and collect the dark frames as quickly as possible and record histograms.

Verify the gain of the camera is 4(75e/bit) and the integration time is 50msec and offset is 0 via the SASI.
Make the same measurement at gain level 2(150e/bit) and 1(350e/bit).

Fill in the Mu/Sigma values in the table below:

Gain (e/Bit)	Expected Average Black Level	Measured Average Black Level	Expected Histogram Sigma	Measured Histogram Sigma
4(75e/bit)	160		1.2	
2(150e/bit)	750		0.7	
1(350e/bit)	32	41.5	0.5	.51

SN# 04-06 By hwd (initials) Date 5/11/93 (passed)

Turn off the test fixture.

REMEMBER to attach your recorded documentation to this test procedure!
(A document protector is advised)

12. Thermal Test

This test requires the SUN Datacube and its image processing capabilities, an environmental chamber with limit, rate controls, and a timer.

Carefully Insert The Flight CCD
Into The Test Board.
Check Its Orientation

12.1. Thermal Test Setup

Secure the carrier mounted Actel board in a PC board holder and place the holder in the environmental chamber. Care should be taken so that the board does not short to chamber walls.

Attach the camera cable harness to the Actel board via a feed-through hole. Wrap a piece of foam around the cable harness. Squeeze the wrapped harness into the feed-through so that the hole is sealed and there is no strain on the inside/outside cabling.

Place an opaque cover over the CCD.

Power-up and confirm a functioning camera/acquisition system by capturing a frame. At room temperature this should resemble the dark measurement histogram acquired in SECTION 11.

Turn-off the camera board under test

Seal the environmental chamber.

Set chamber temperature ramp rate at 2° C/min.

Set chamber temperature deviation limit to 2° C.

Set chamber soak time to 20 minutes.

Start the thermal sequence at -20°C or at a °C determined by your requester.

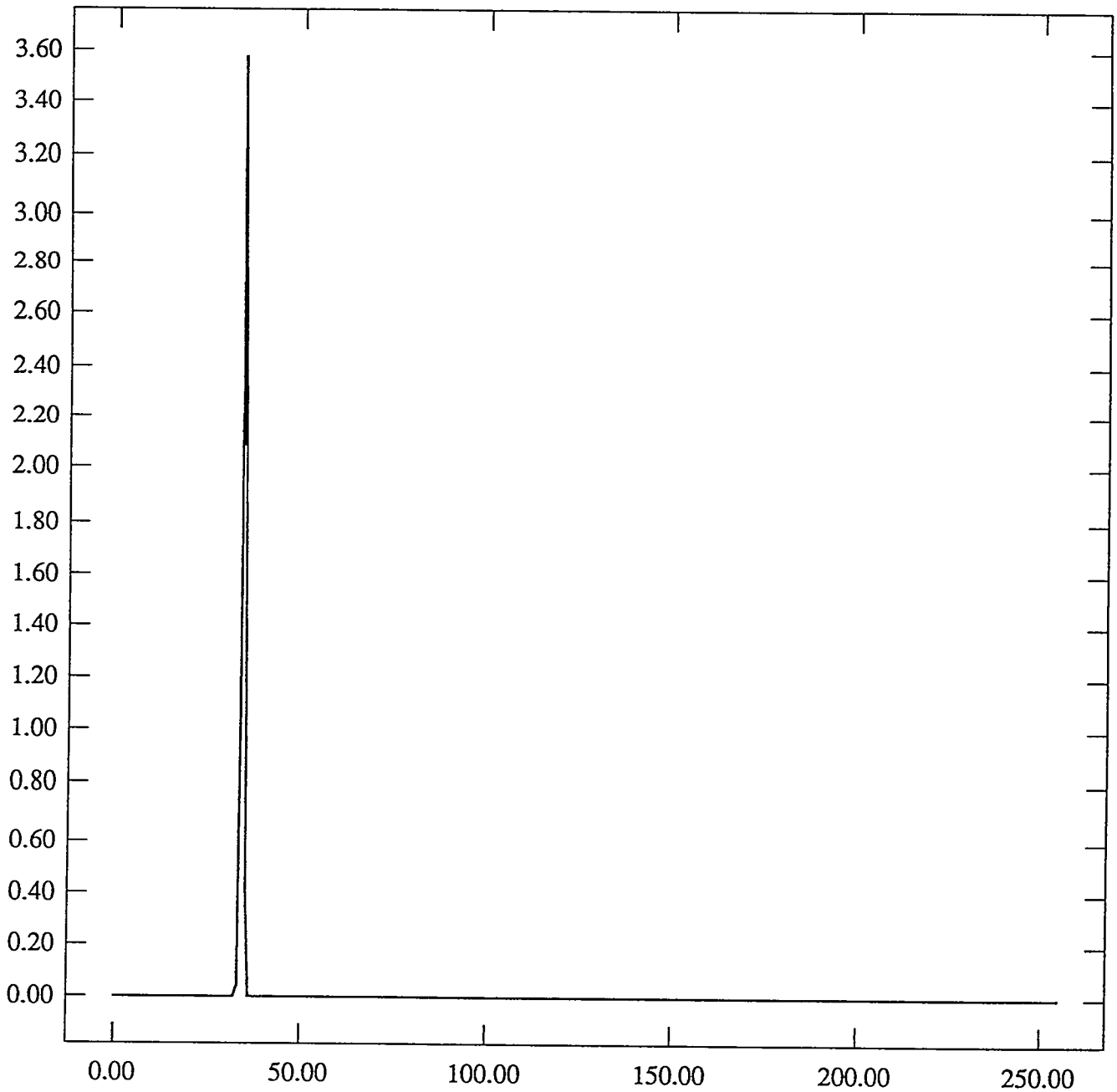
ST2#04-06\CDT\350e

Thu, May 13, 1993 10:56 AM

	TEMP (degrees C)	50ms/mu	50ms/sigma	100ms/mu	100ms/sigma	200ms/mu	200ms/sigma	NOTES:
1								
2	-20	34.10	0.33	34.20	0.39	34.30	0.46	5/11/93
3	-10	35.30	0.71	35.50	0.74	35.70	0.48	Flight F.0. CCD#2
4	0	36.20	0.45	36.70	0.44	37.50	0.51	
5	10	38.10	0.34	39.00	0.26	40.80	0.43	350e/bit
6	20	41.30	0.46	43.50	0.53	48.00	0.68	R49=100Ω
7	30	47.10	0.59	52.00	0.72	61.80	0.89	

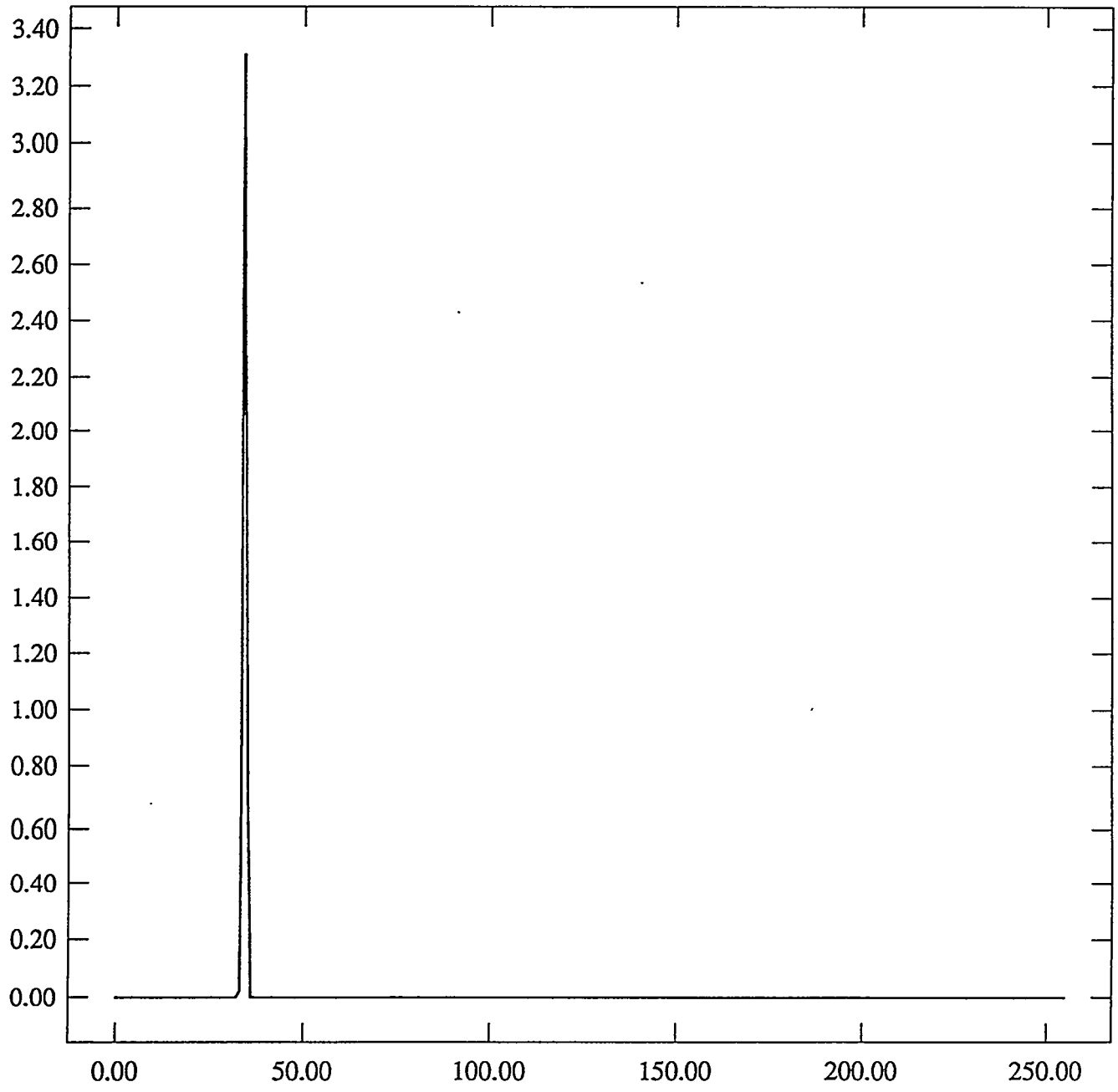
ST Camera: ST2 04-06 -20C: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:33:24 1993

Pixel Values Min 33 Max 35 Mean 34.1 Sigma 0.33 x 10^3



ST Camera: ST2 04-06 -20C: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:34:47 1993

Pixel Values Min 33 Max 36 Mean 34.2 Sigma 0.39 x 10^3



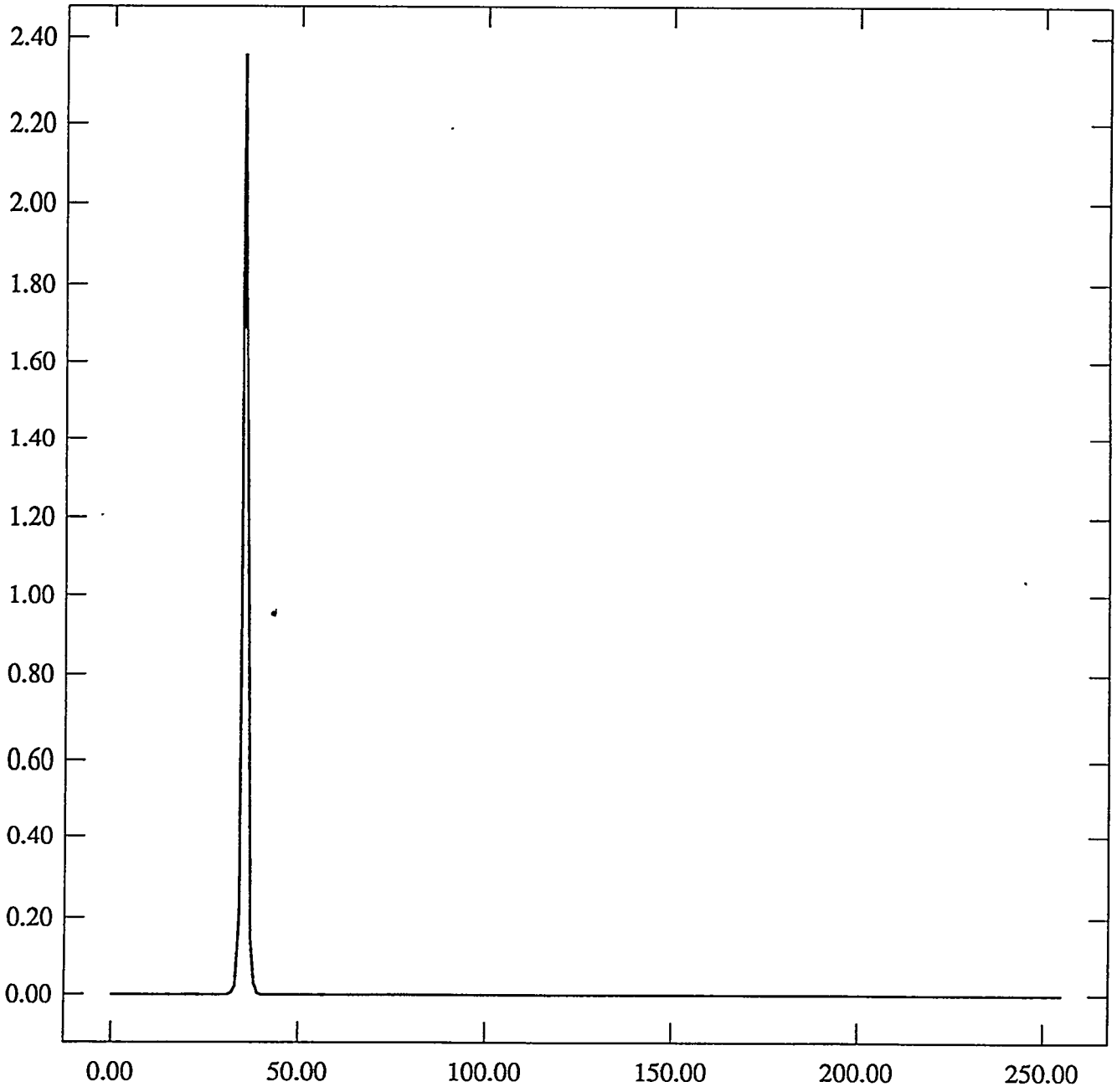
-20 #0406 ST2

20/ms Min = 33 Max = 35 Mean 34.296535

Sigma = 0.462653

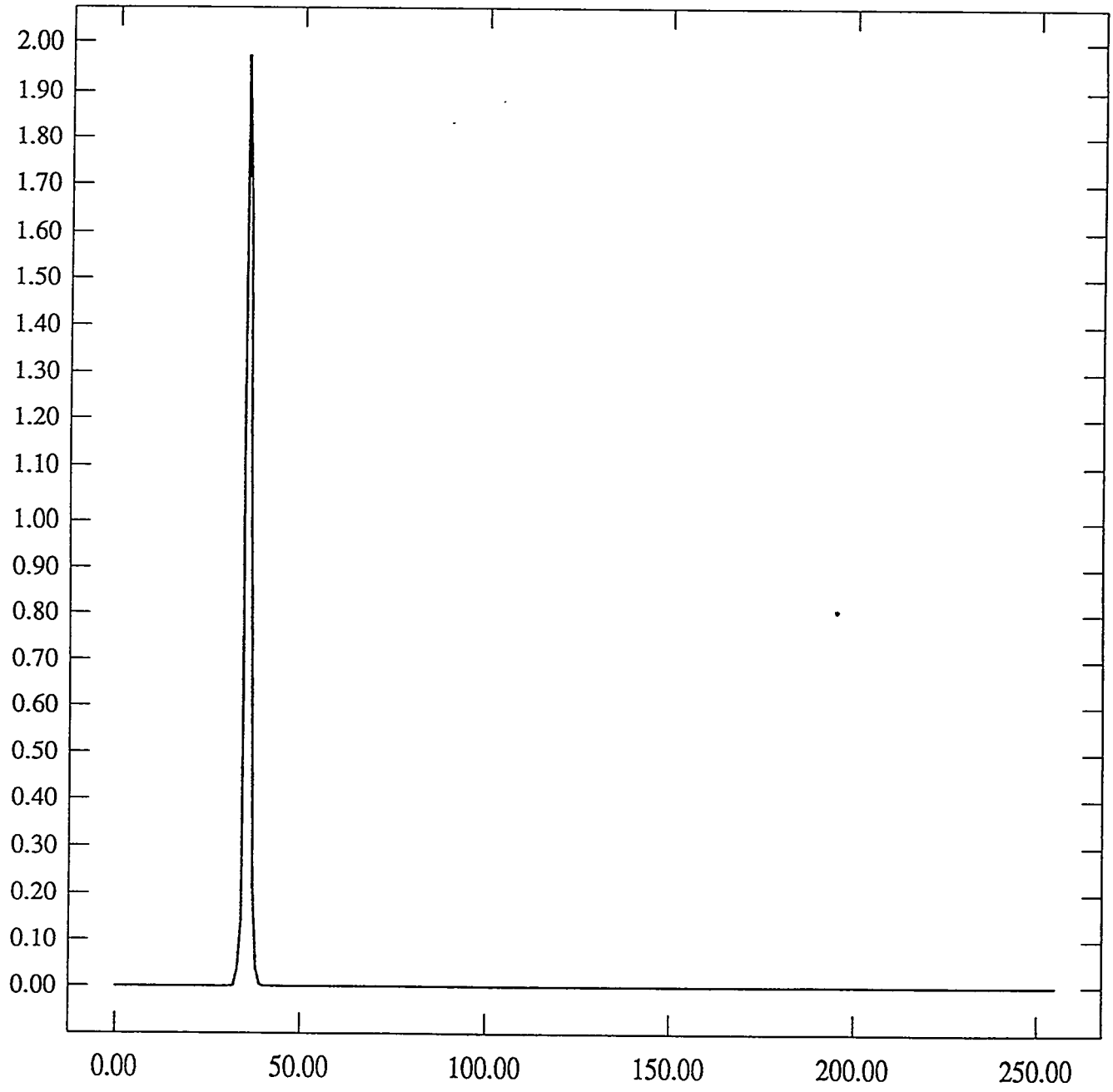
ST Camera: ST2 04-06 -10C: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:50:25 1993

Pixel Values Min 32 Max 39 Mean 35.3 Sigma 0.71 x 10^3



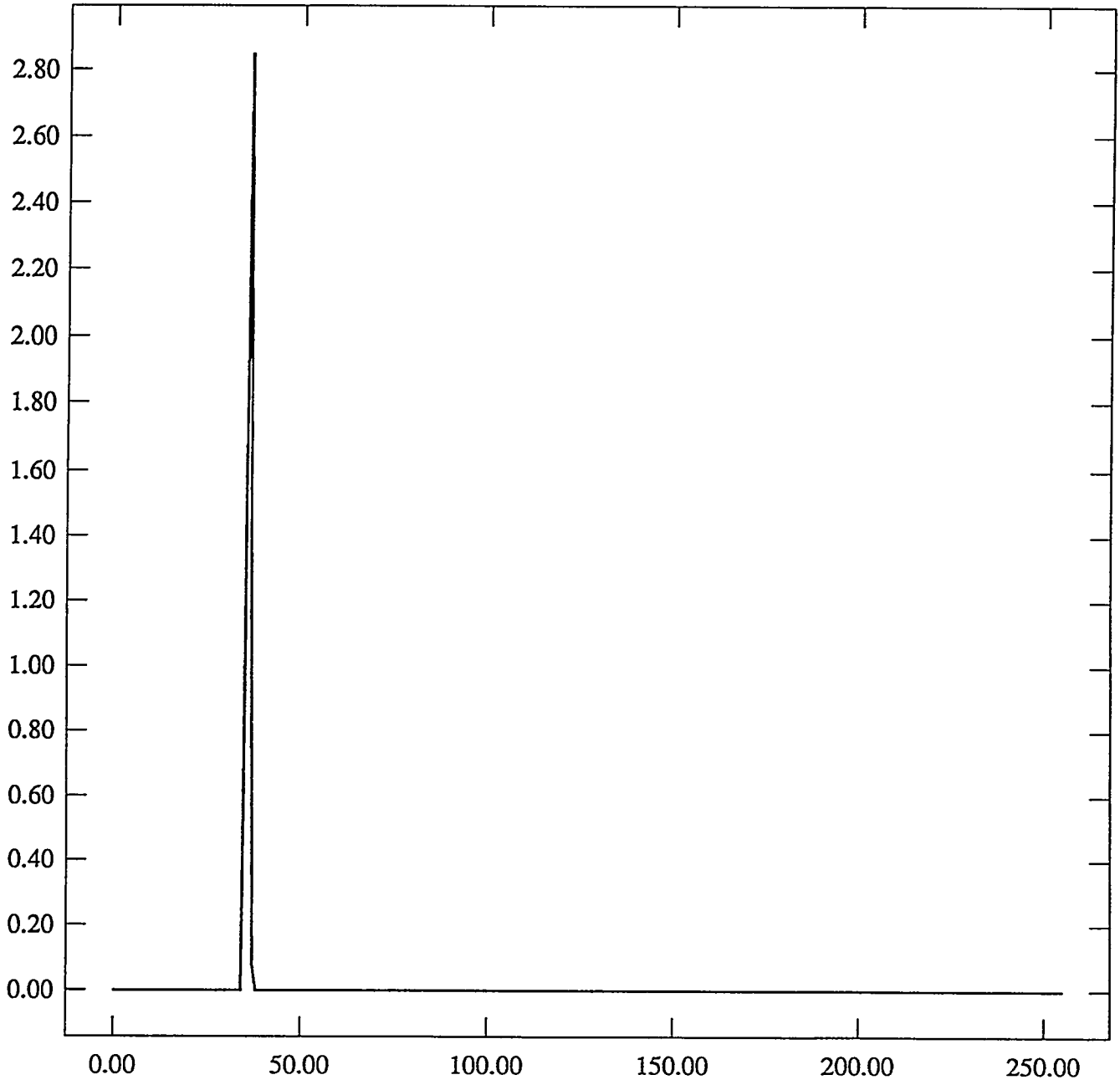
ST Camera: ST2 04-06 -10C: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:51:15 1993

Pixel Values Min 32 Max 39 Mean 35.5 Sigma 0.74 x 10^3



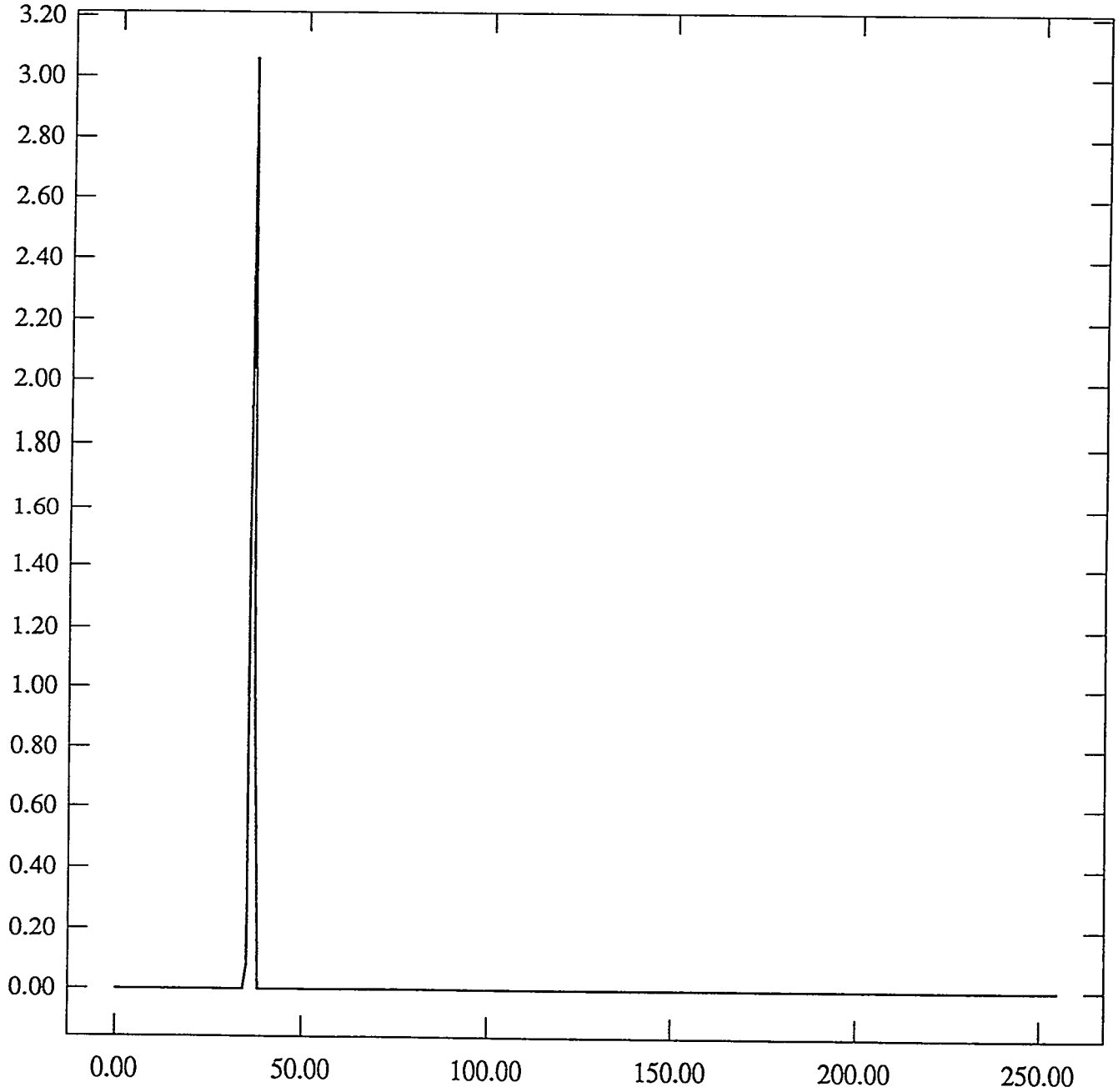
ST Camera: ST2 04-06 -10C: int_time=200ms, offset= 0, gain=1 (350 e/bit) Tue May 11 15:51:52 1993

Pixel Values Min 35 Max 37 Mean 35.7 Sigma 0.48 x 10^3



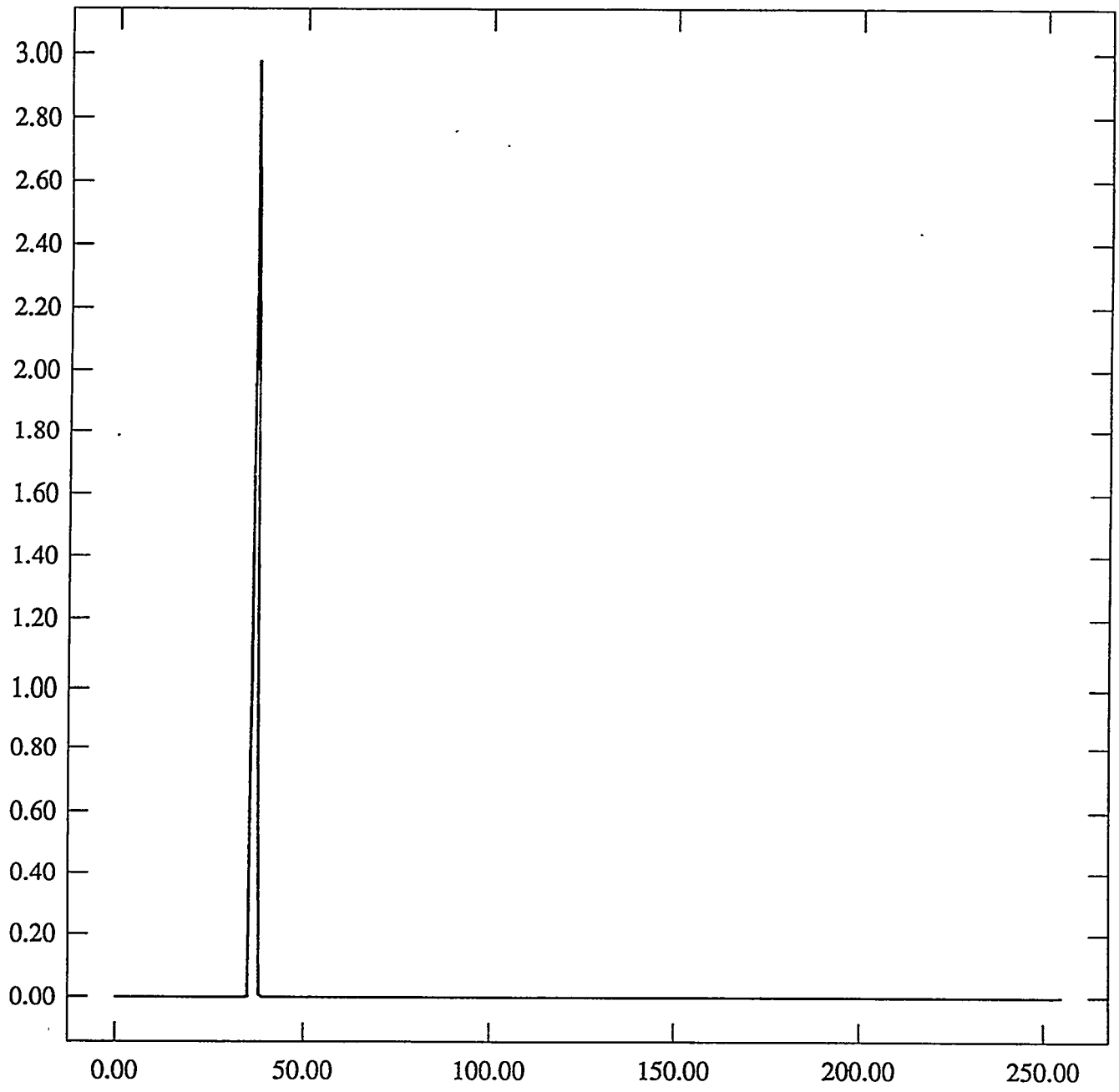
ST Camera: ST2 04-06 0C: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:06:56 1993

Pixel Values Min 35 Max 37 Mean 36.2 Sigma 0.45 x 10^3



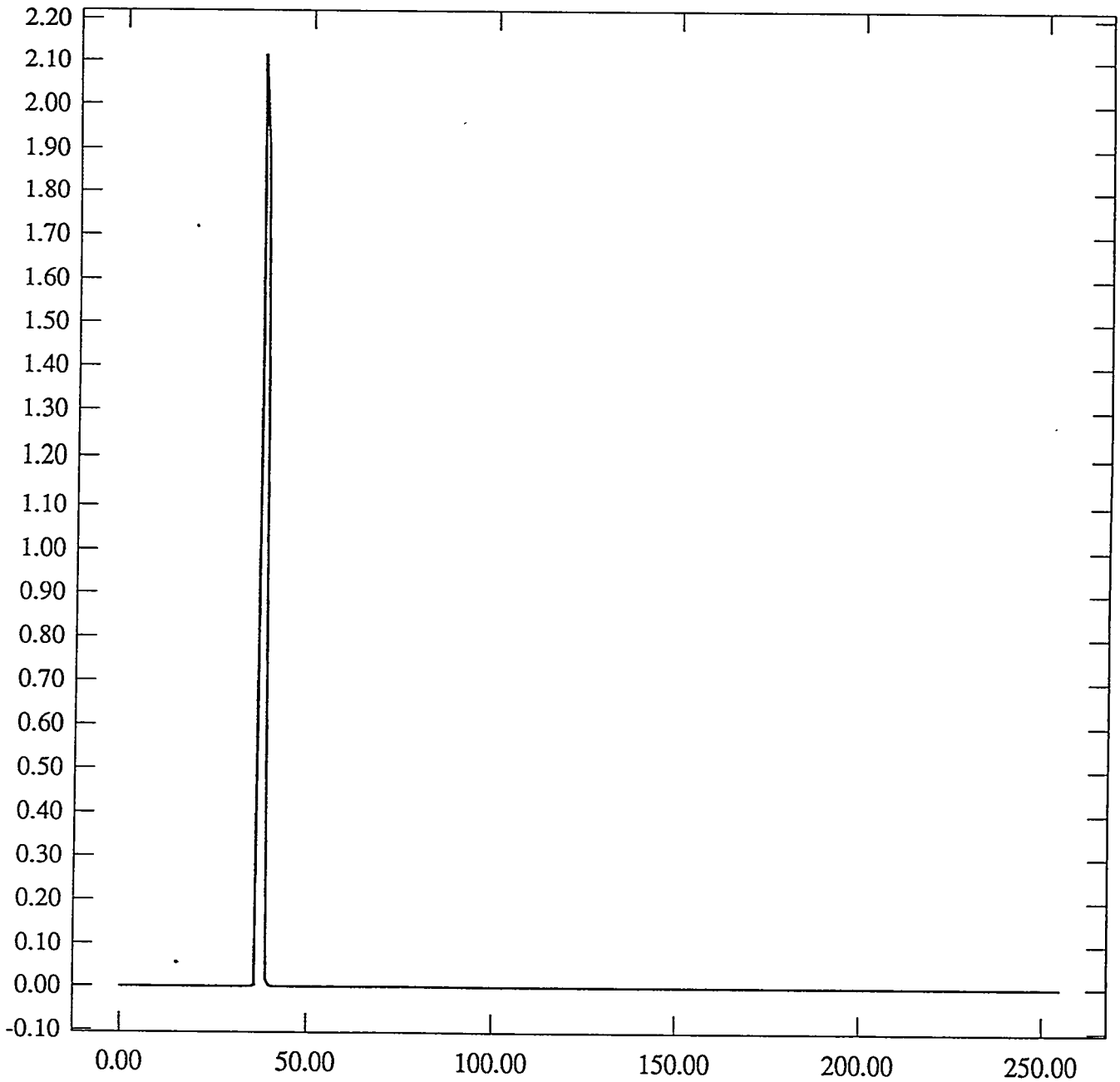
ST Camera: ST2 04-06 0C: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:07:59 1993

Pixel Values Min 35 Max 38 Mean 36.7 Sigma 0.44 x 10^3



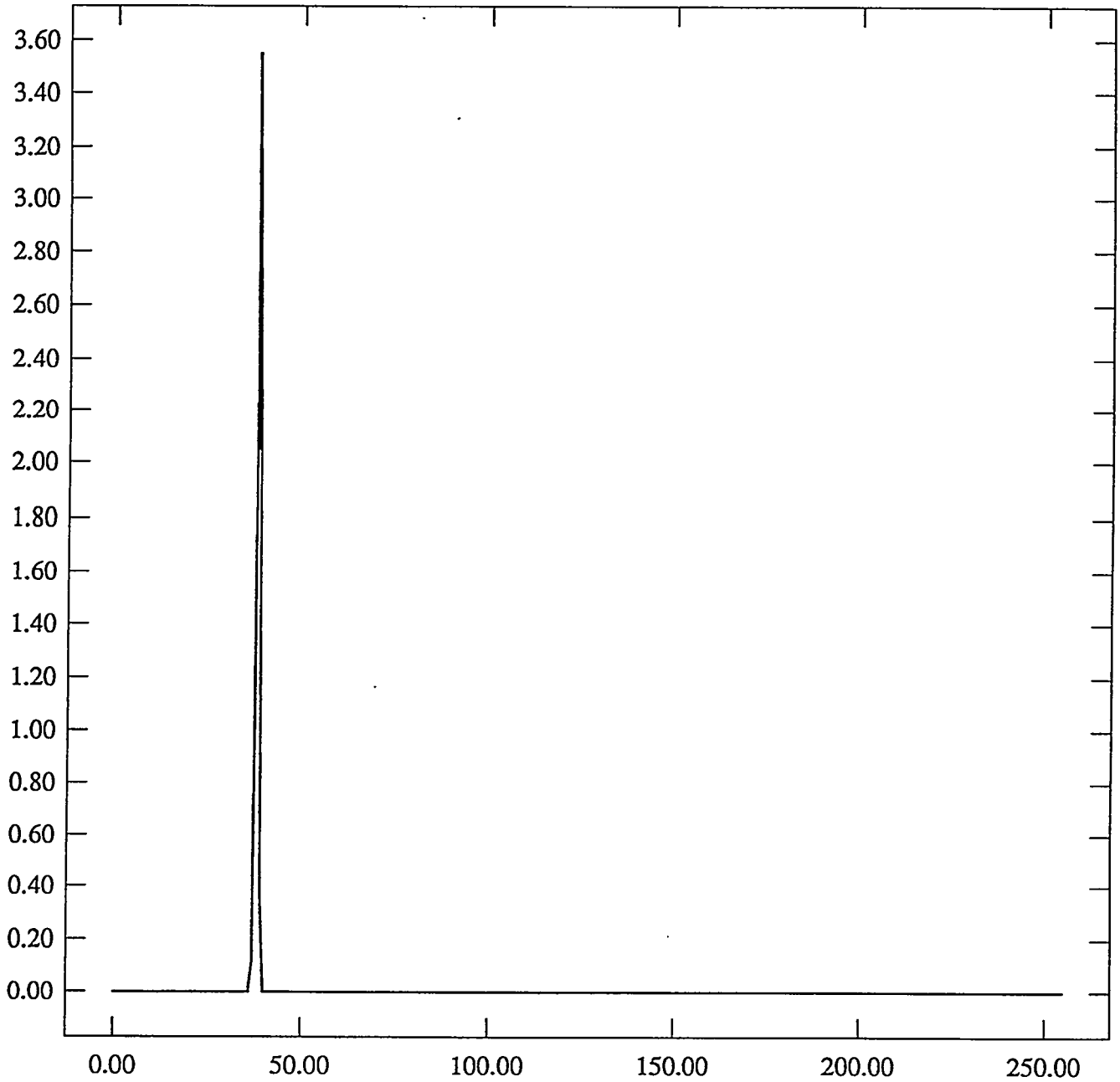
ST Camera: ST2 04-06 0C: int_time=200ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:08:37 1993

Pixel Values Min 36 Max 40 Mean 37.5 Sigma 0.51 x 10^3



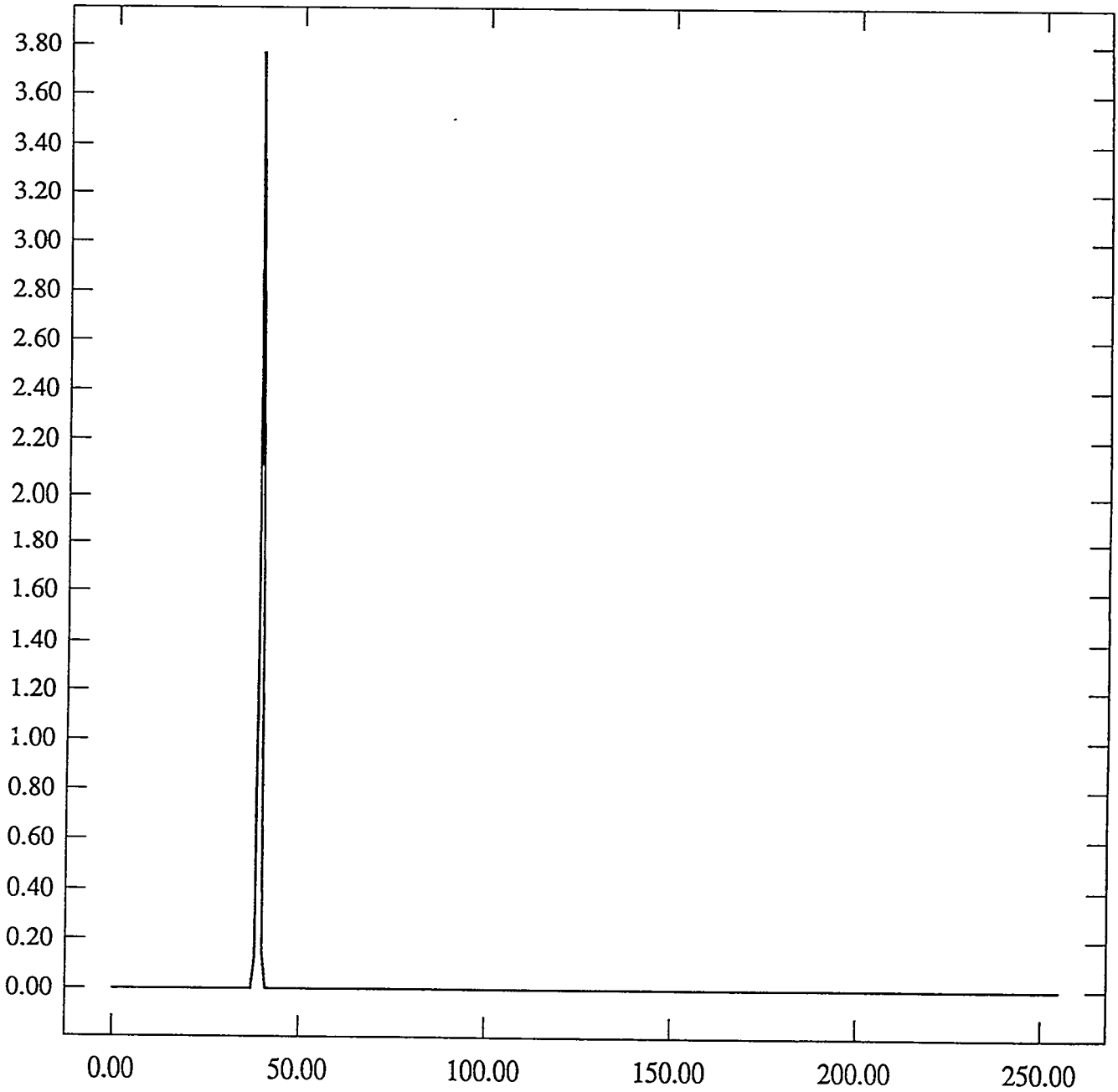
ST Camera: ST2 04-06 +10: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:24:02 1993

Pixel Values Min 37 Max 39 Mean 38.1 Sigma 0.34 x 10^3



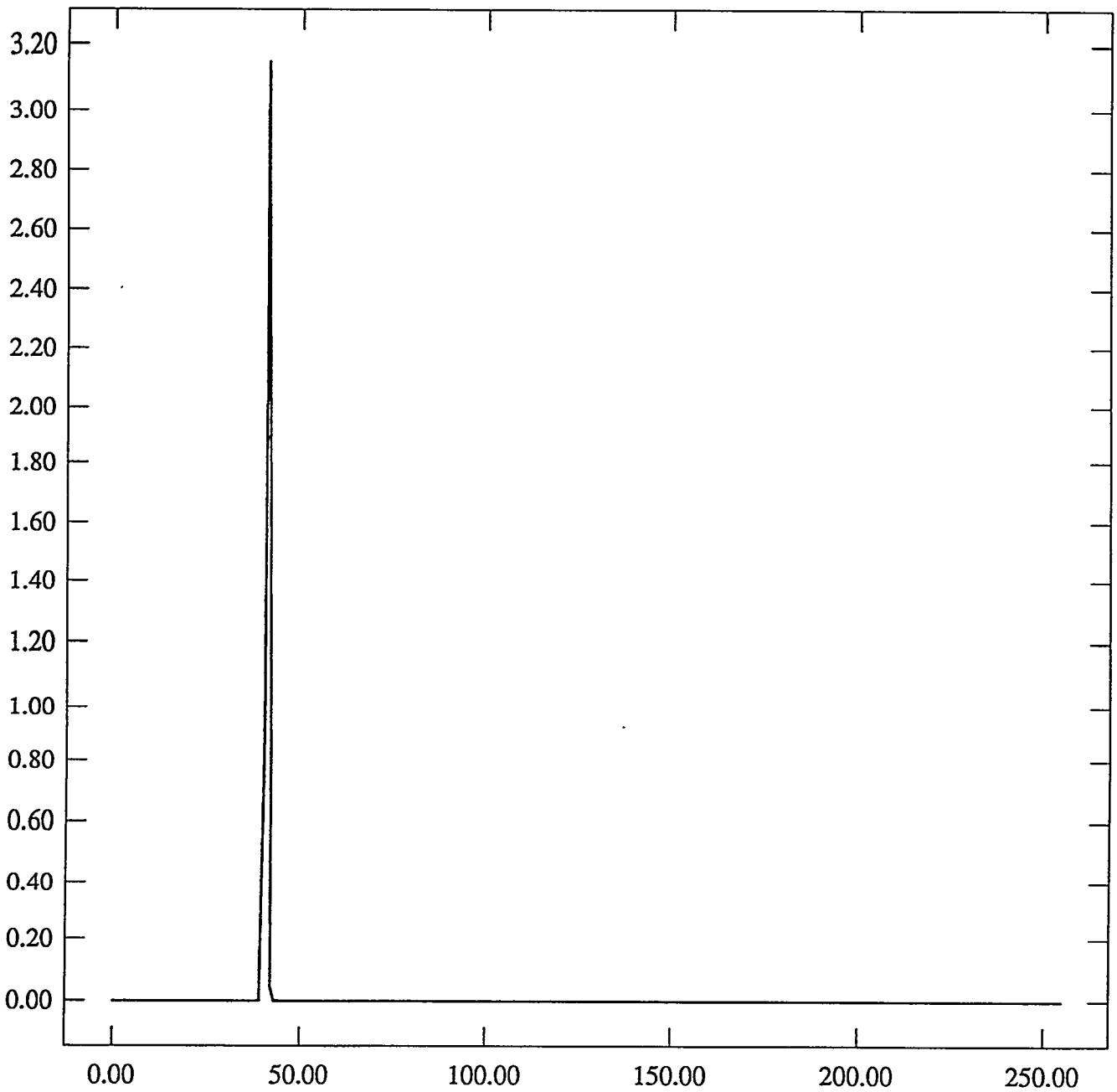
ST Camera: ST2 04-06 +10: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:24:40 1993

Pixel Values Min 38 Max 41 Mean 39.0 Sigma 0.26 x 10^3



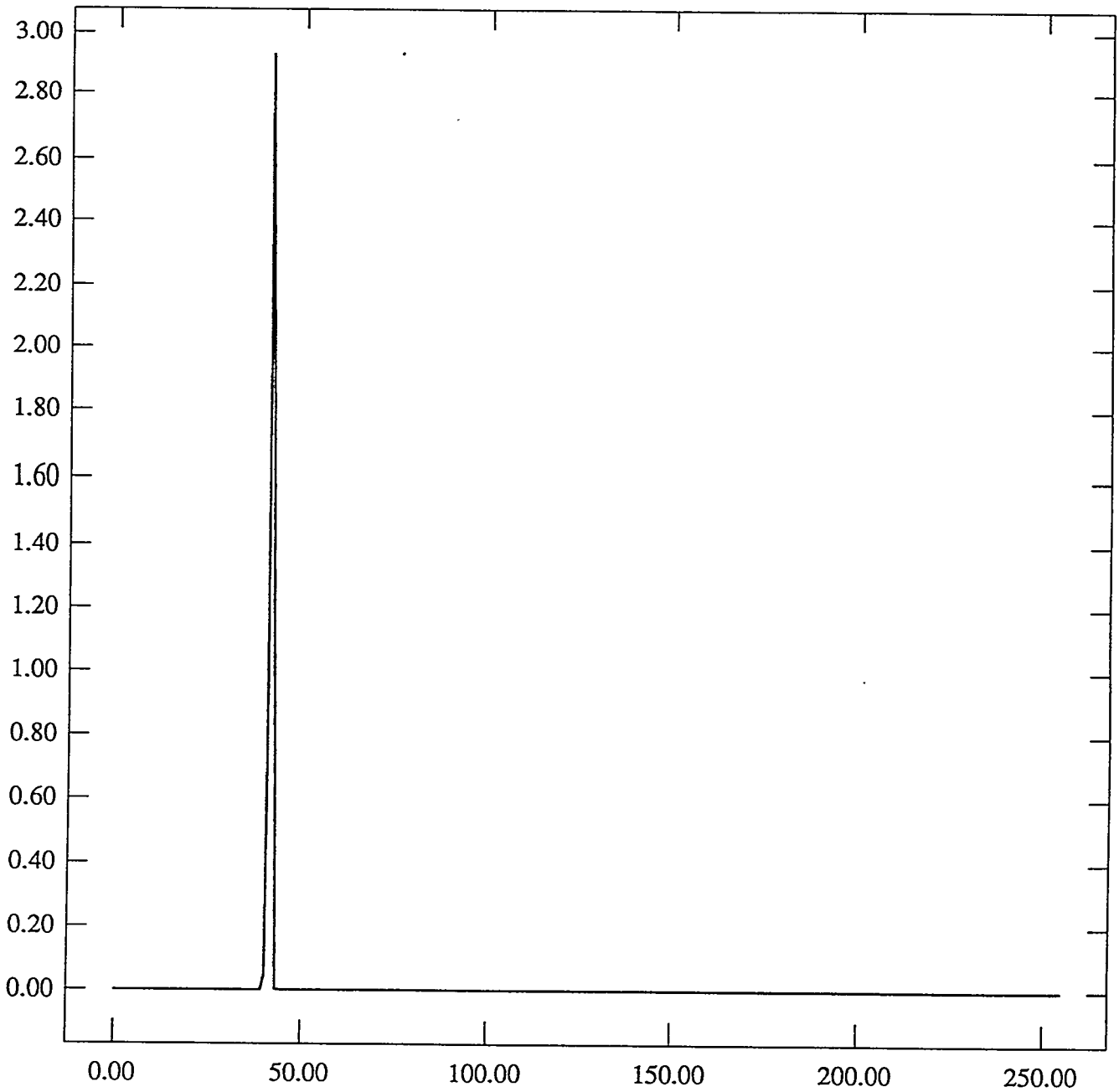
ST Camera: ST2 04-06 +10: int_time=200ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:25:37 1993

Pixel Values Min 39 Max 44 Mean 40.8 Sigma 0.43 x 10^3



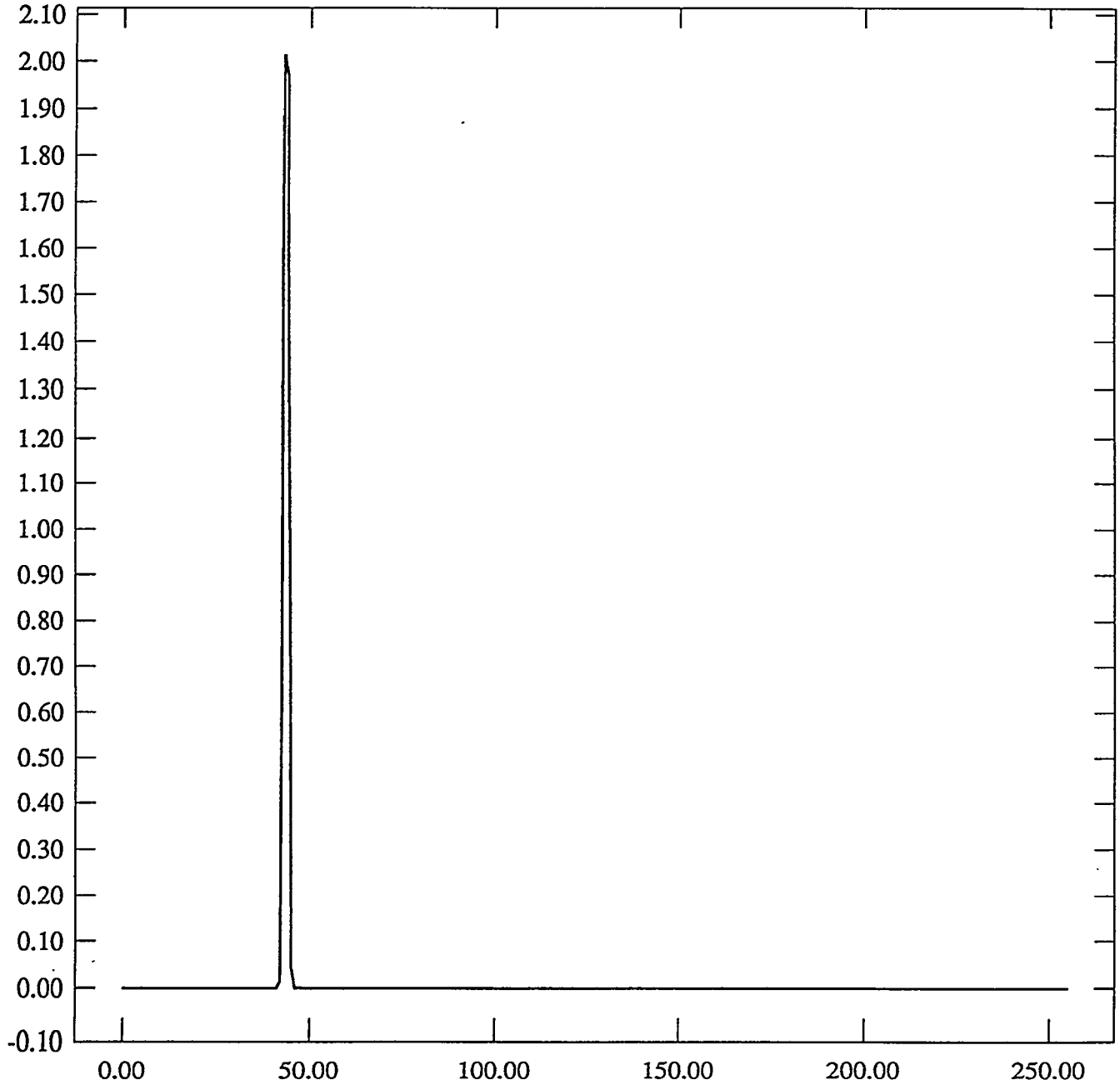
ST Camera: ST2 04-06 +20: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:41:22 1993

Pixel Values Min 40 Max 43 Mean 41.3 Sigma 0.46 x 10^3



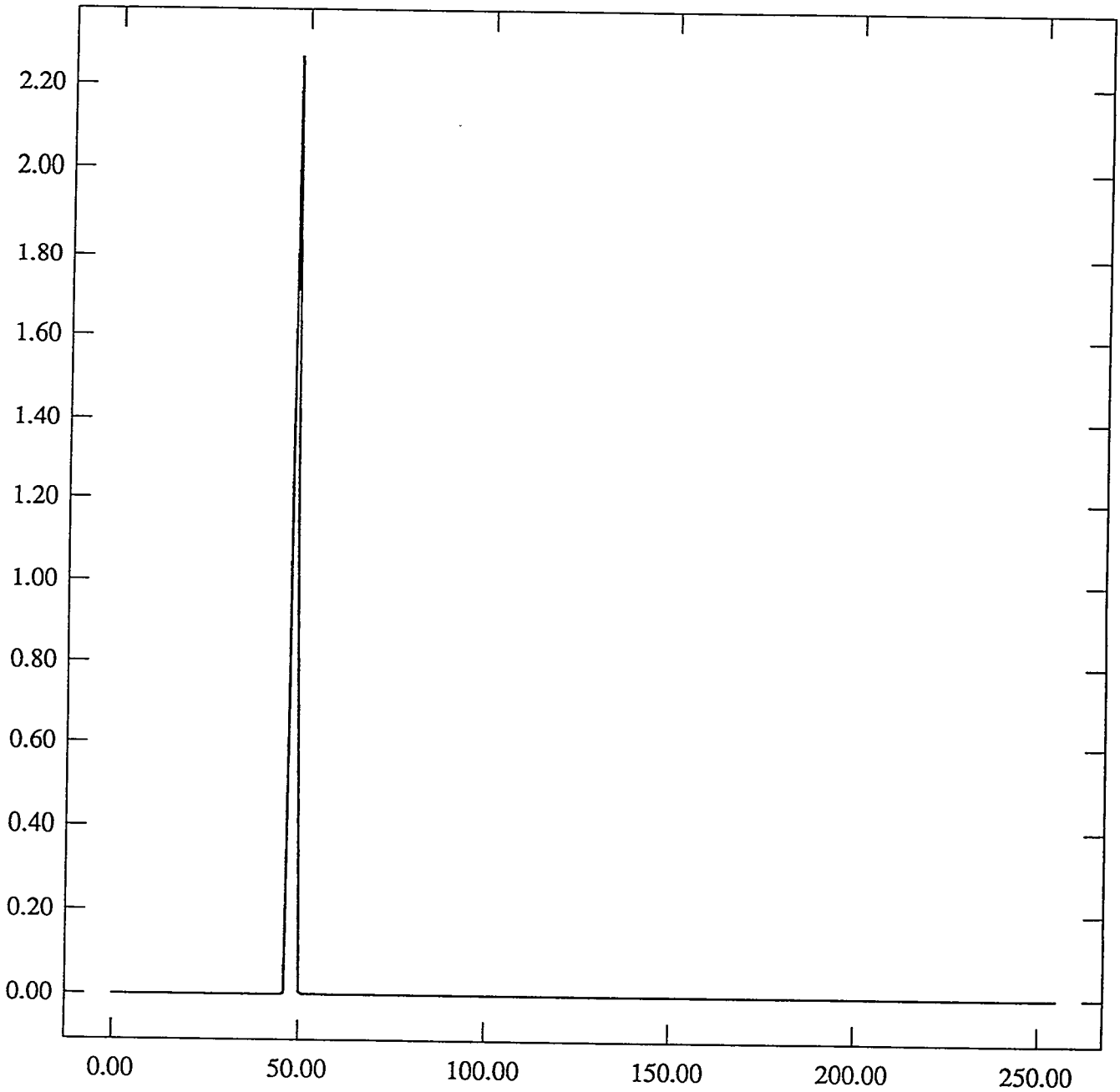
ST Camera: ST2 04-06 +20: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:42:03 1993

Pixel Values Min 42 Max 47 Mean 43.5 Sigma 0.53 x 10^3



ST Camera: ST2 04-06 +20: int_time=200ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:42:42 1993

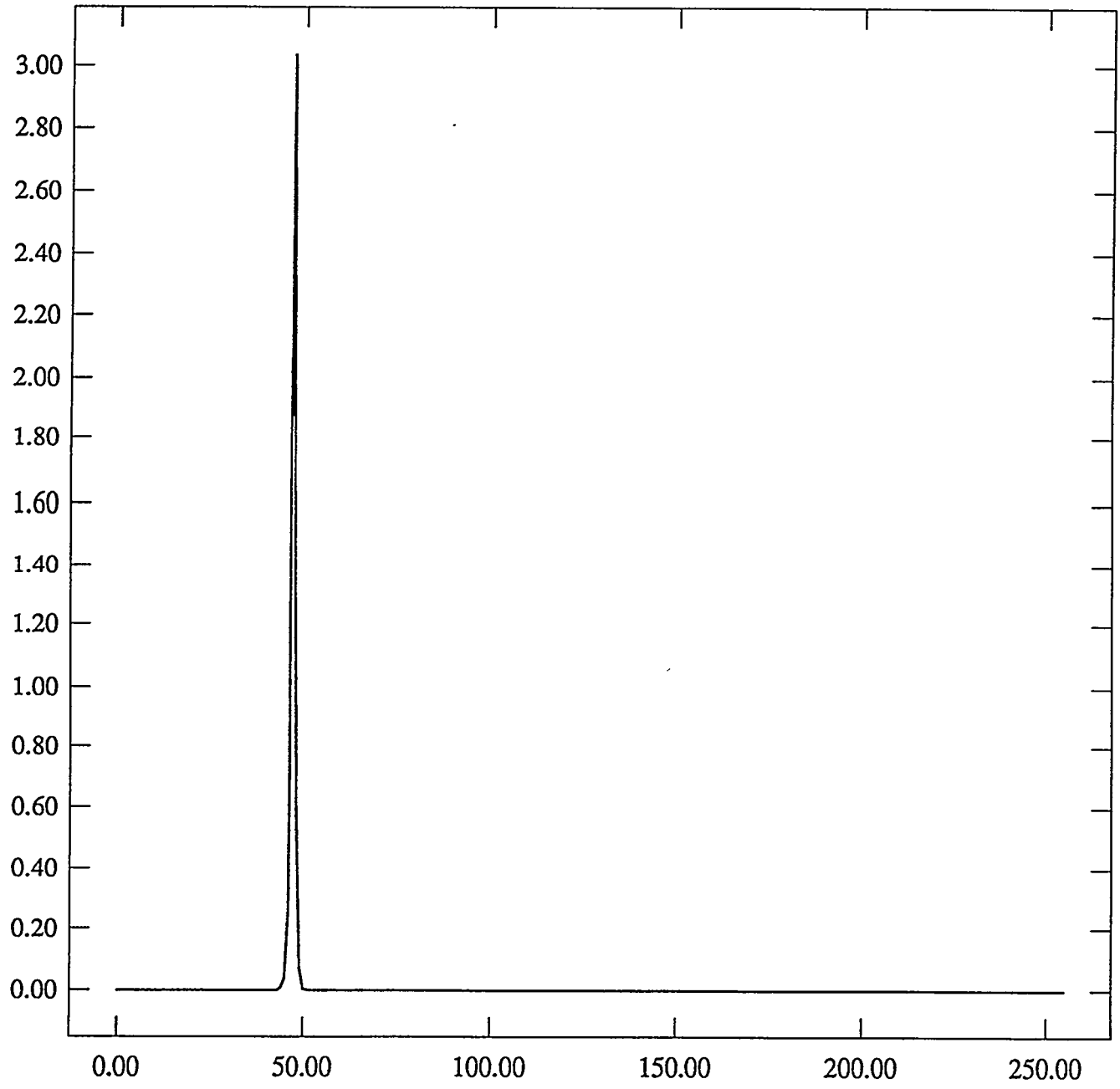
Pixel Values Min 46 Max 54 Mean 48.0 Sigma 0.68 x 10^3



DRA

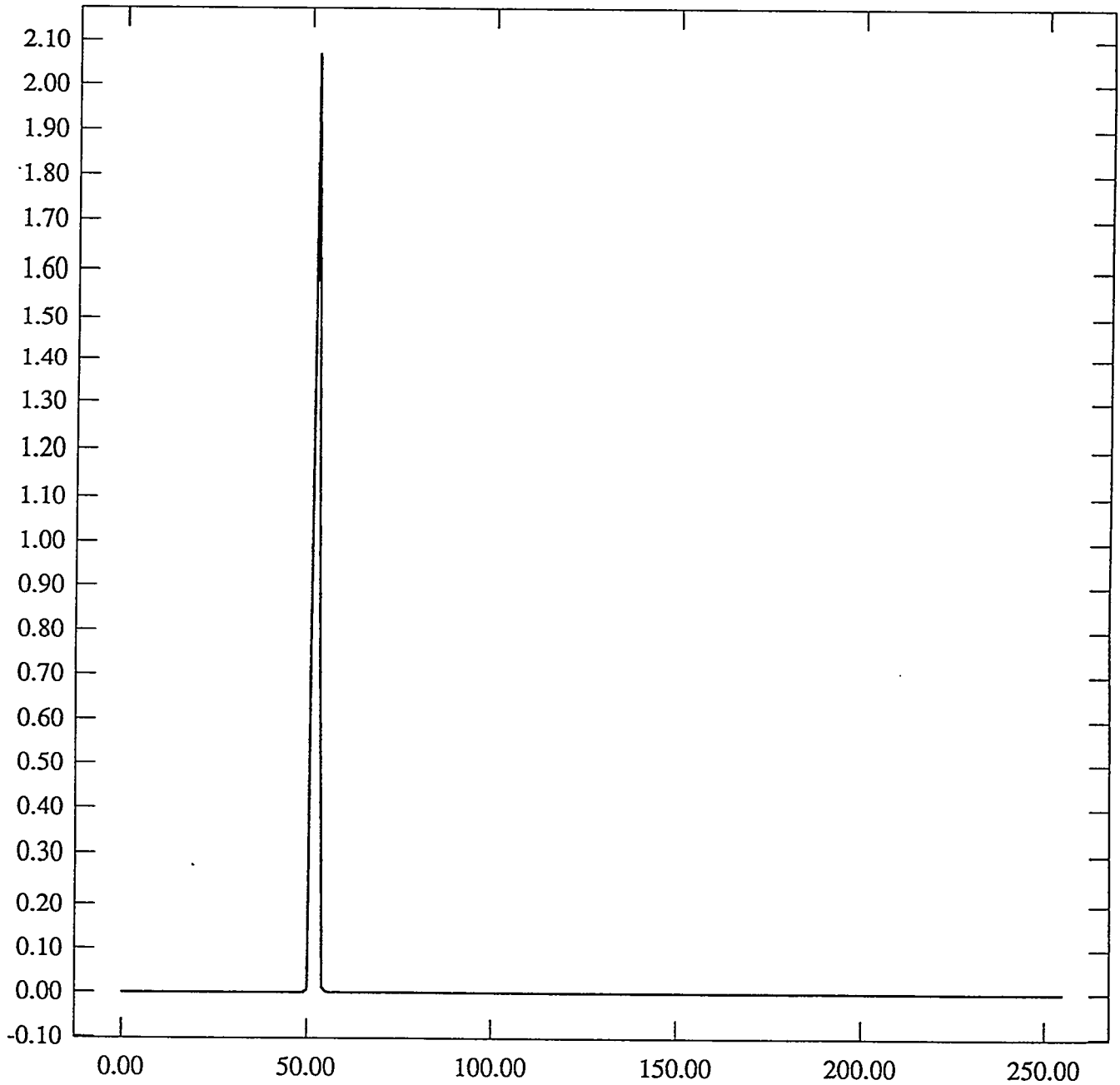
ST Camera: ST2 04-06 +30: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue May 11 16:59:10 1993

Pixel Values Min 44 Max 51 Mean 47.1 Sigma 0.59 x 10^3



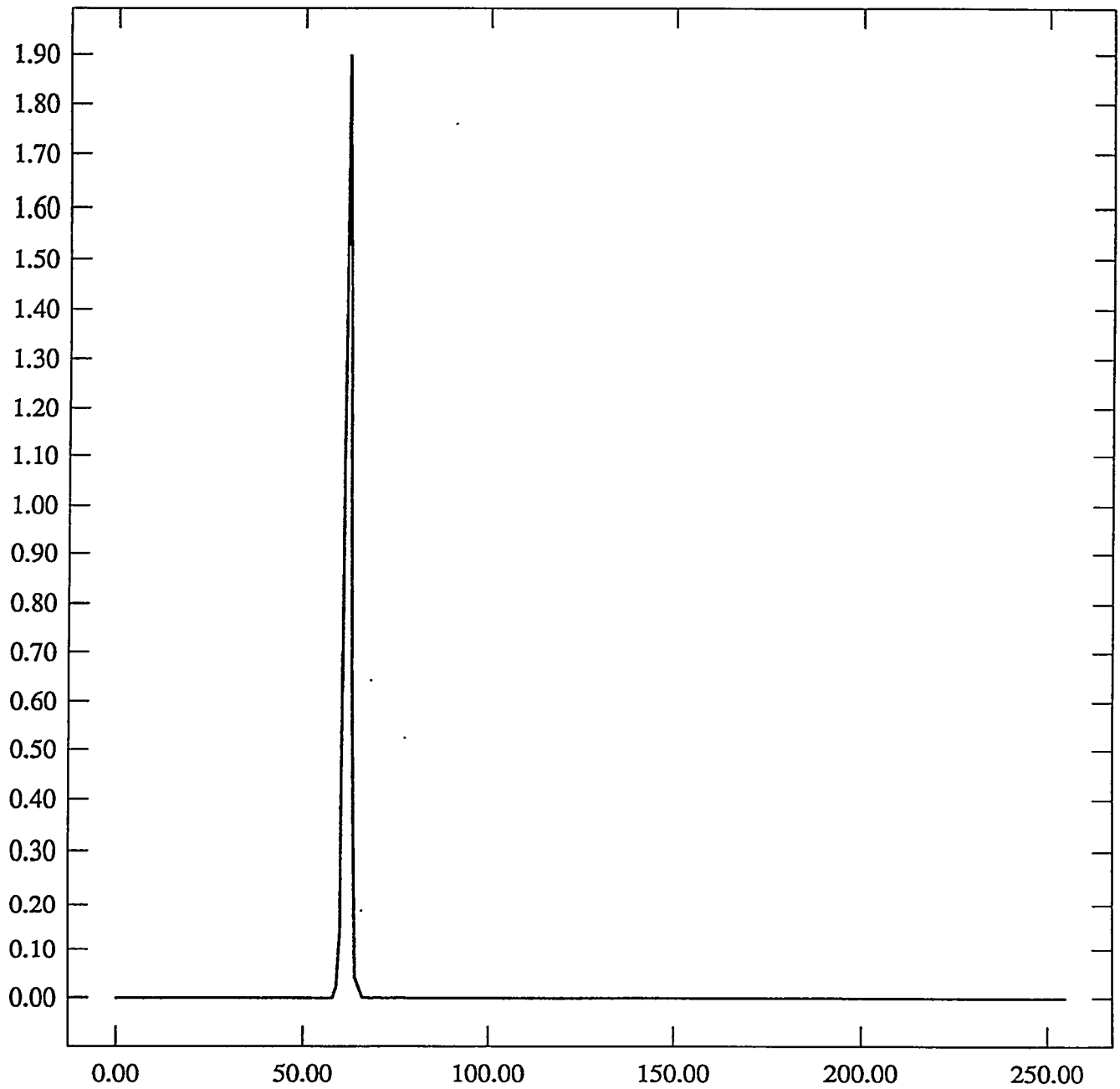
ST Camera: ST2 04-06 +30: int_time=100ms, offset= 0, gain=1 (350 e/bit) Tue May 11 17:01:09 1993

Pixel Values Min 50 Max 58 Mean 52.0 Sigma 0.72 x 10^3

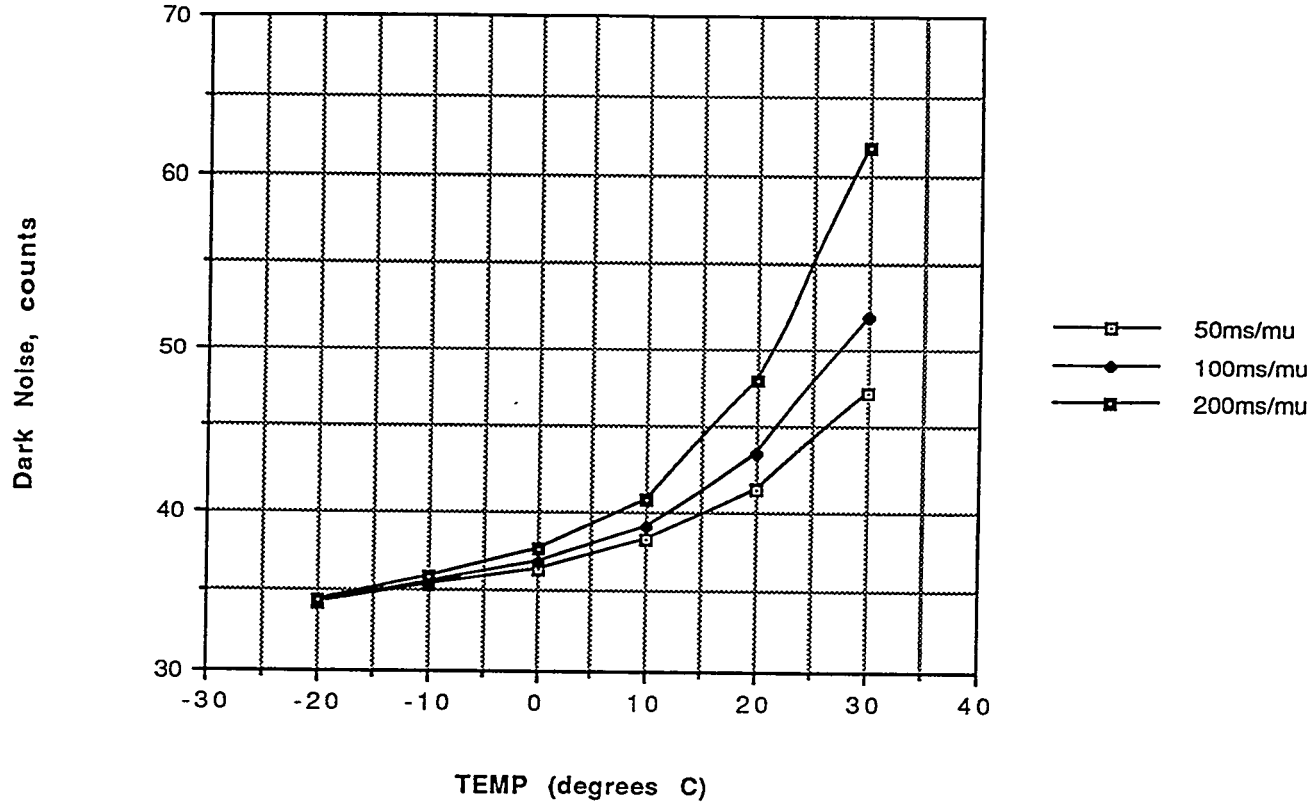


ST Camera: ST2 04-06 +30: int_time=200ms, offset= 0, gain=1 (350 e/bit) Tue May 11 17:01:49 1993

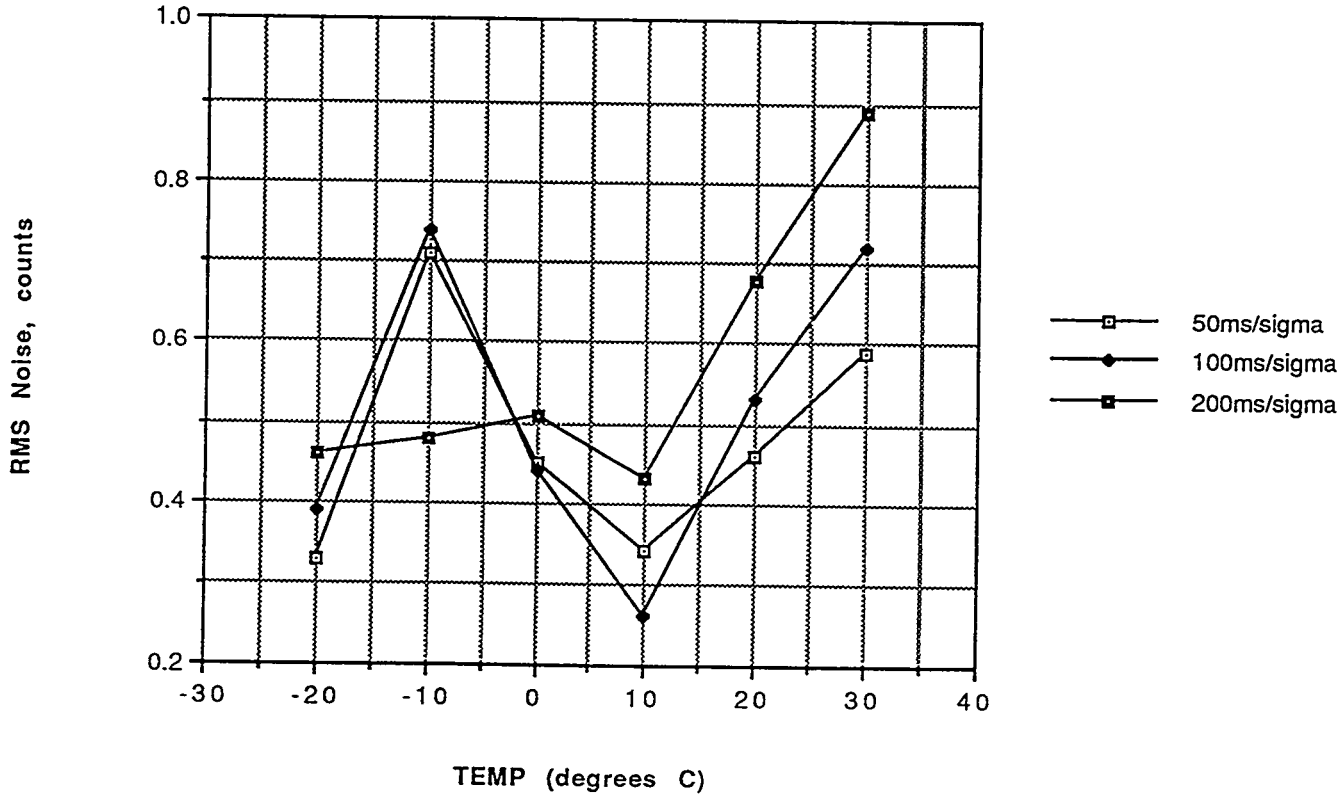
Pixel Values Min 59 Max 76 Mean 61.8 Sigma 0.89 x 10^3



ST2#04-06 350e/bit Mu °C Graph



ST2#04-06 350e/bit Sigma °C Graph



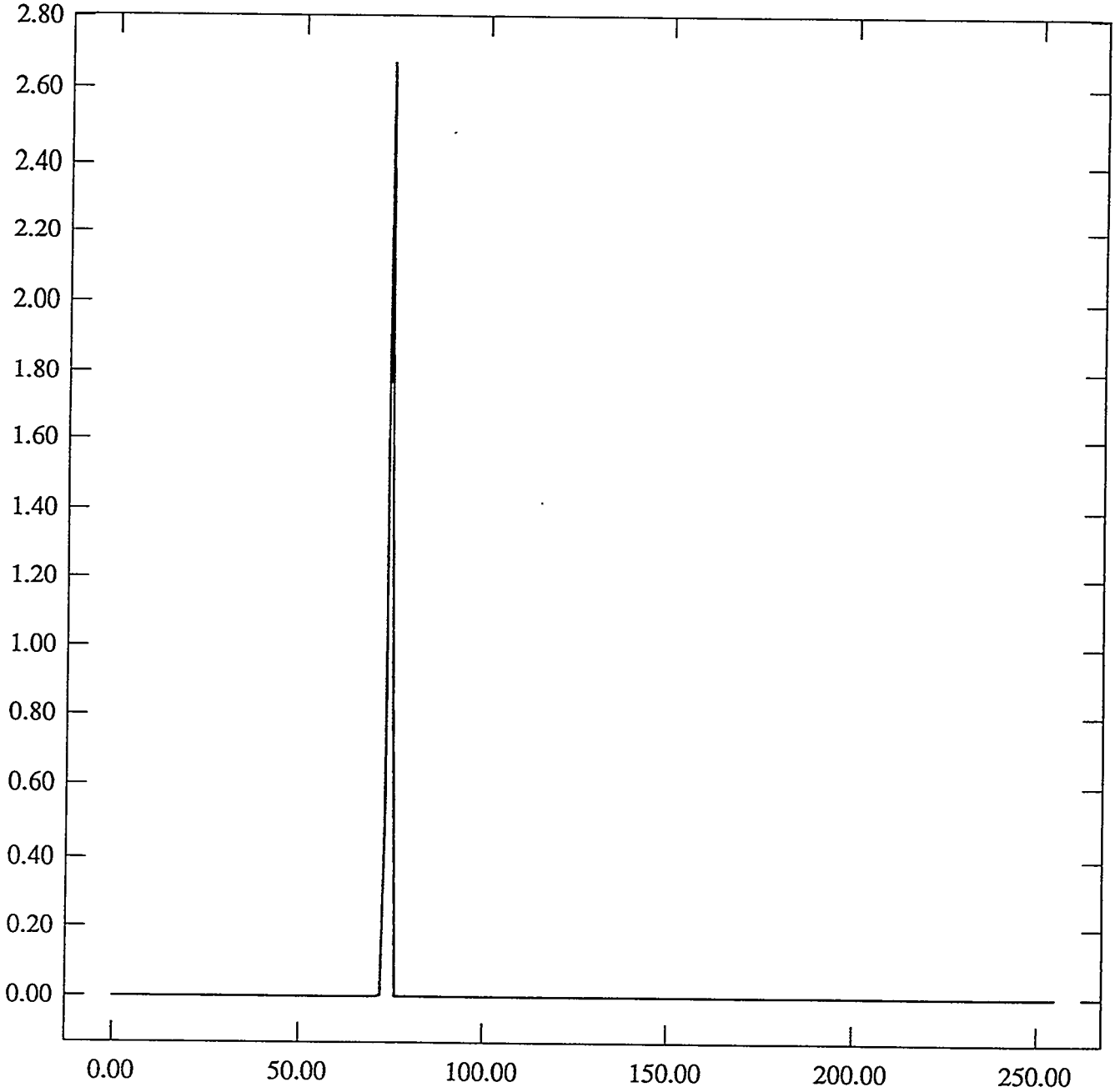
ST2#04-06\CDT\150e

Thu, May 13, 1993 11:05 AM

	TEMP (degrees C)	50ms/mu	50ms/sigma	100ms/mu	100ms/sigma	200ms/mu	200ms/sigma	NOTES:
1								
2	-20	74.10	0.58	74.30	0.59	74.50	0.57	5/11/93
3	-10	76.50	0.81	76.80	0.64	77.30	0.51	Flight F.0. CCD#2
4	0	79.20	0.74	80.10	0.66	81.70	0.58	
5	10	83.40	0.62	85.60	0.63	89.50	0.70	150e/bit
6	20	90.90	0.81	96.30	0.76	106.80	1.11	R49=100Ω
7	30	104.00	0.91	115.60	1.10	139.30	2.33	

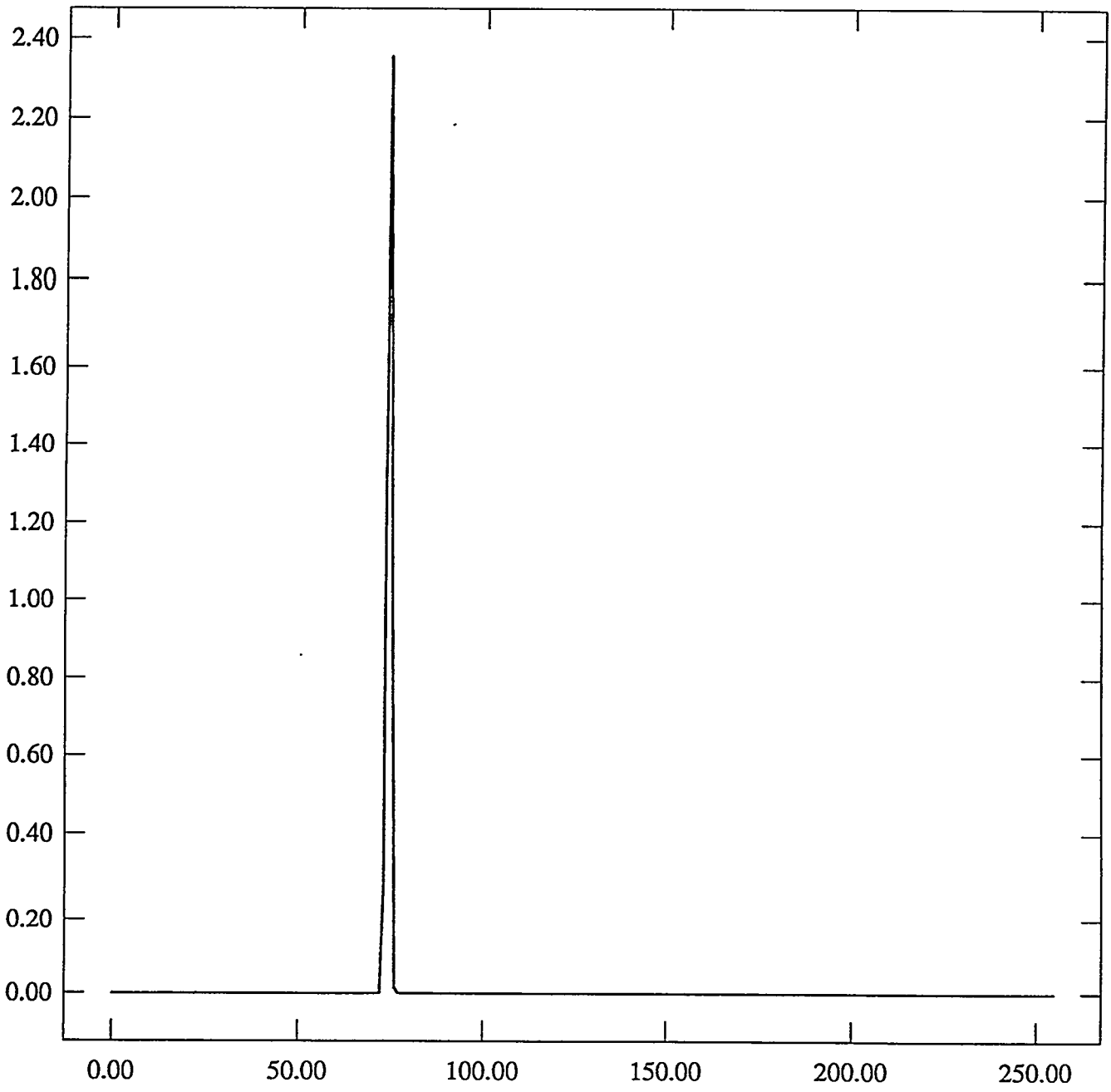
ST Camera: ST2 04-06 -20C: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:36:48 1993

Pixel Values Min 72 Max 75 Mean 74.1 Sigma 0.58 x 10^3



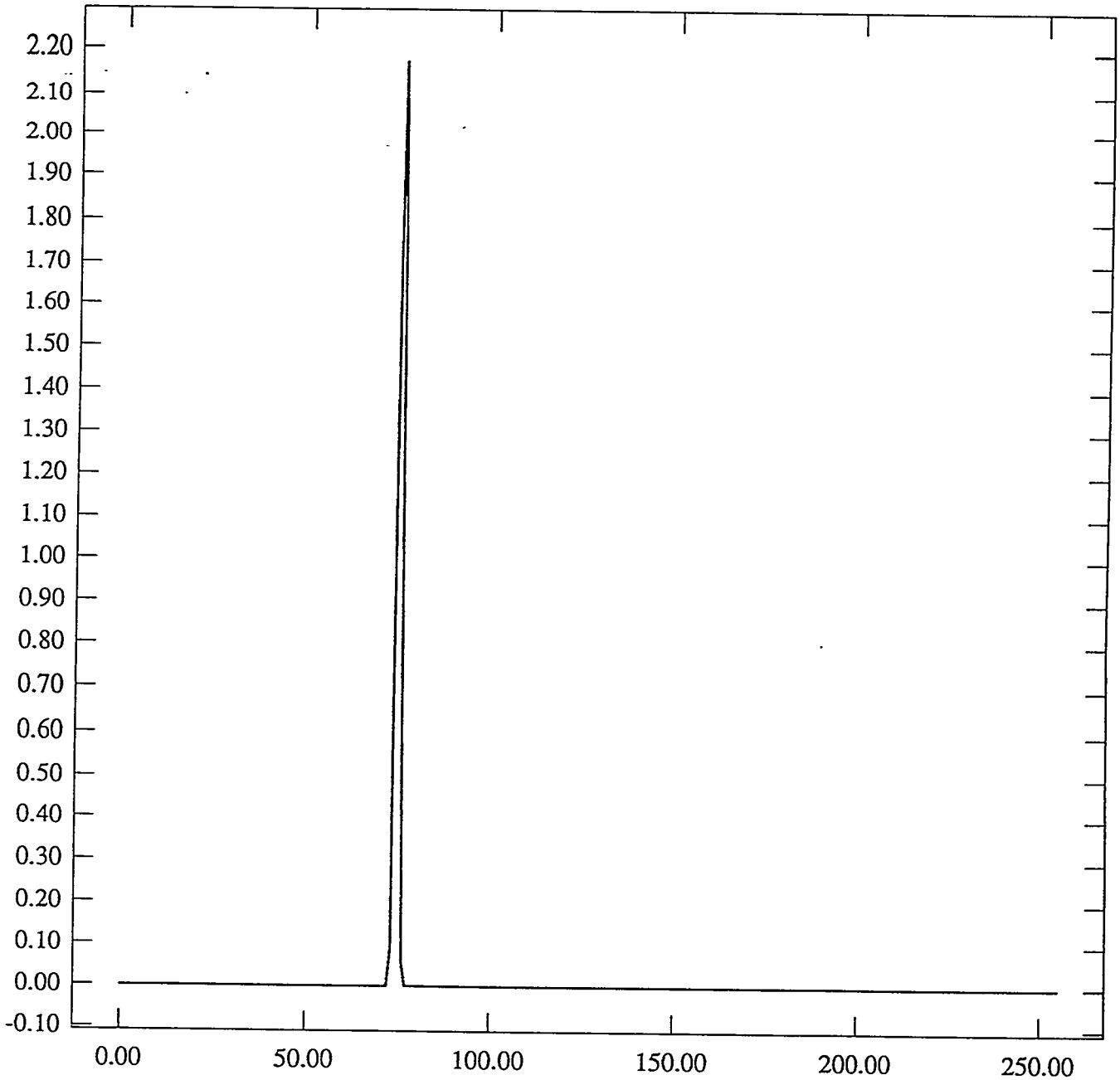
ST Camera: ST2 04-06 -20C: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:38:25 1993

Pixel Values Min 73 Max 76 Mean 74.3 Sigma 0.59 x 10^3



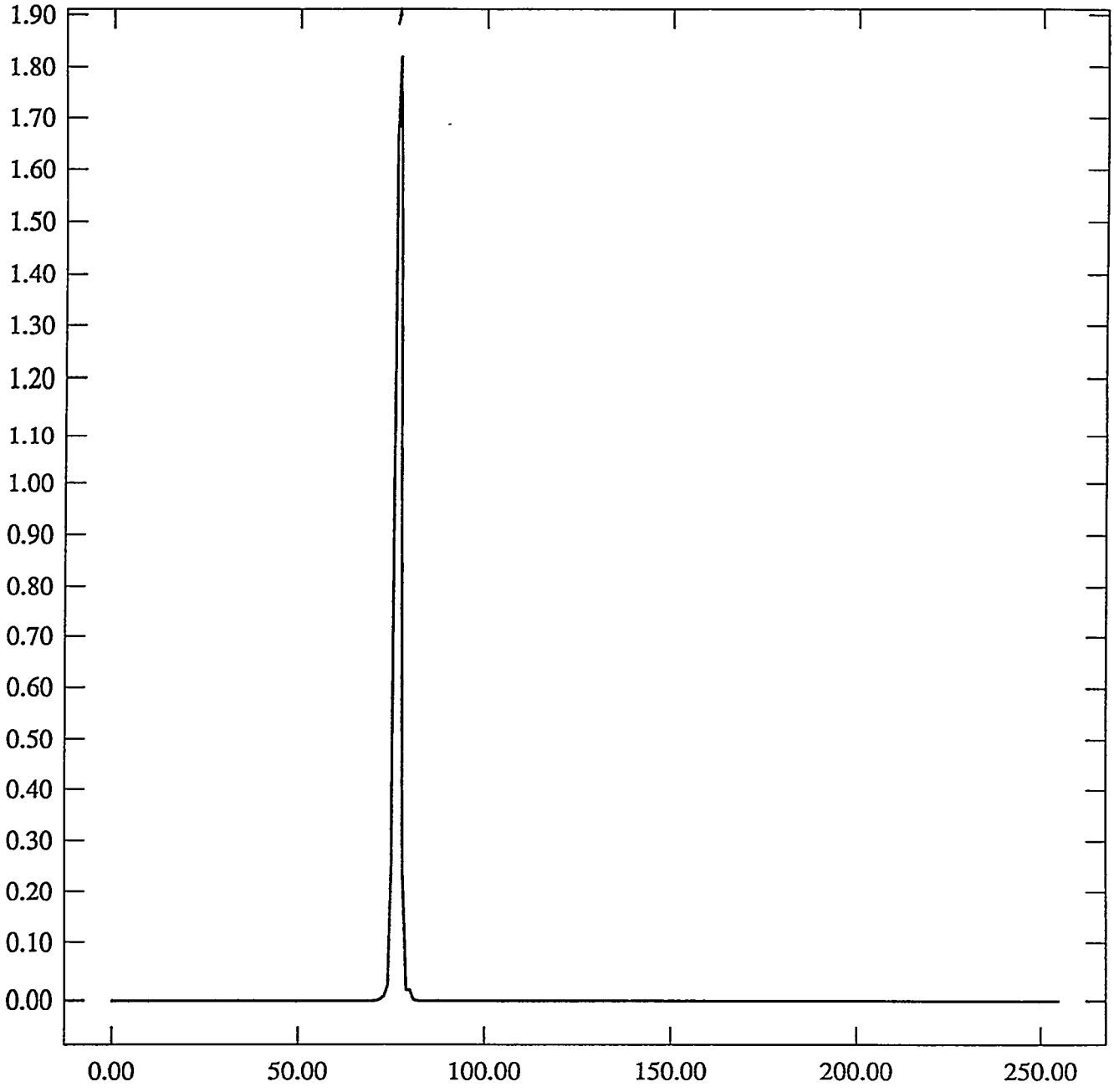
ST Camera: ST2 04-06 -20C: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:39:05 1993

Pixel Values Min 73 Max 76 Mean 74.5 Sigma 0.57 x 10^3



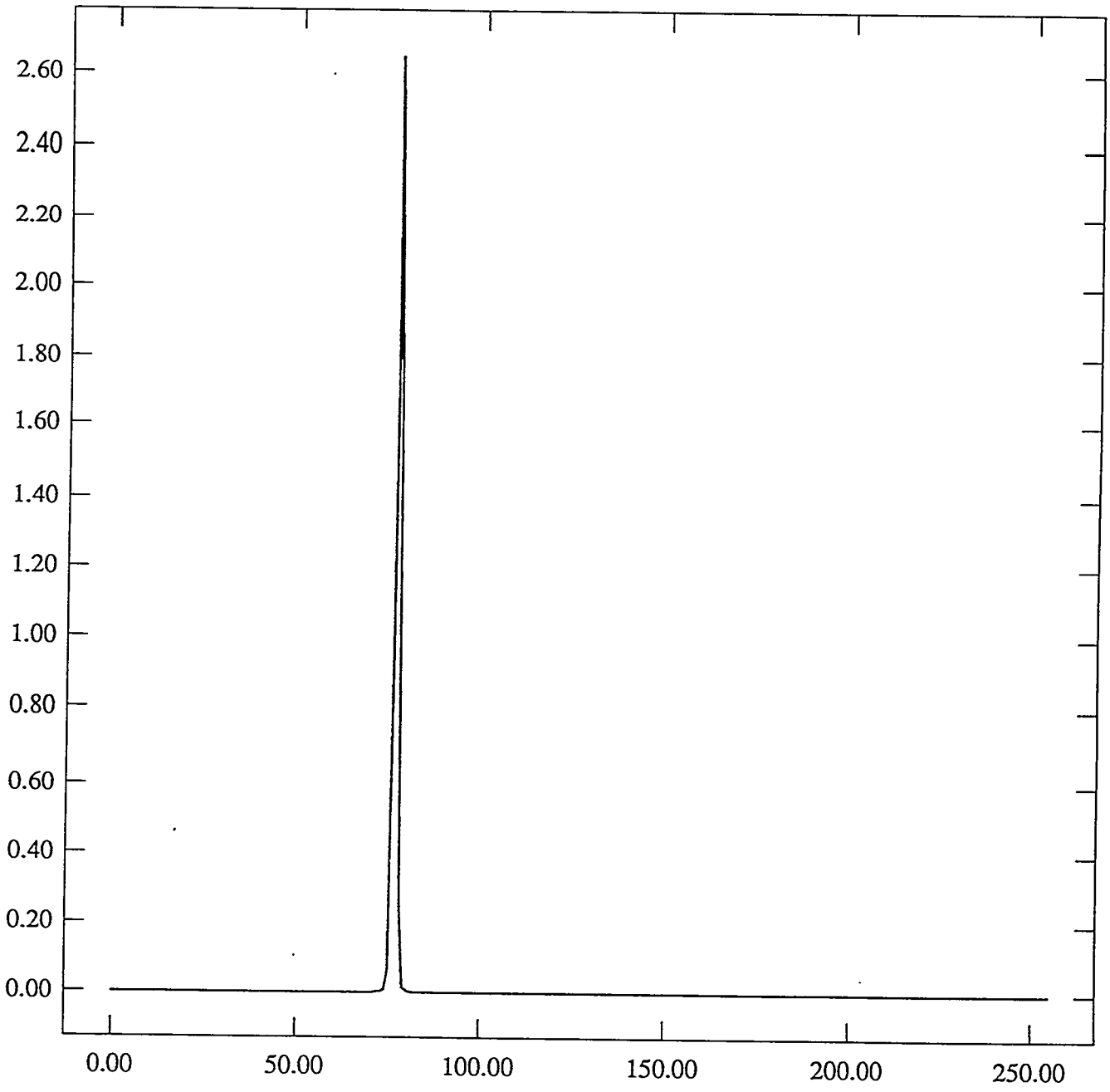
ST Camera: ST2 04-06 -10C: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:52:24 1993

Pixel Values Min 72 Max 81 Mean 76.5 Sigma 0.81 x 10^3



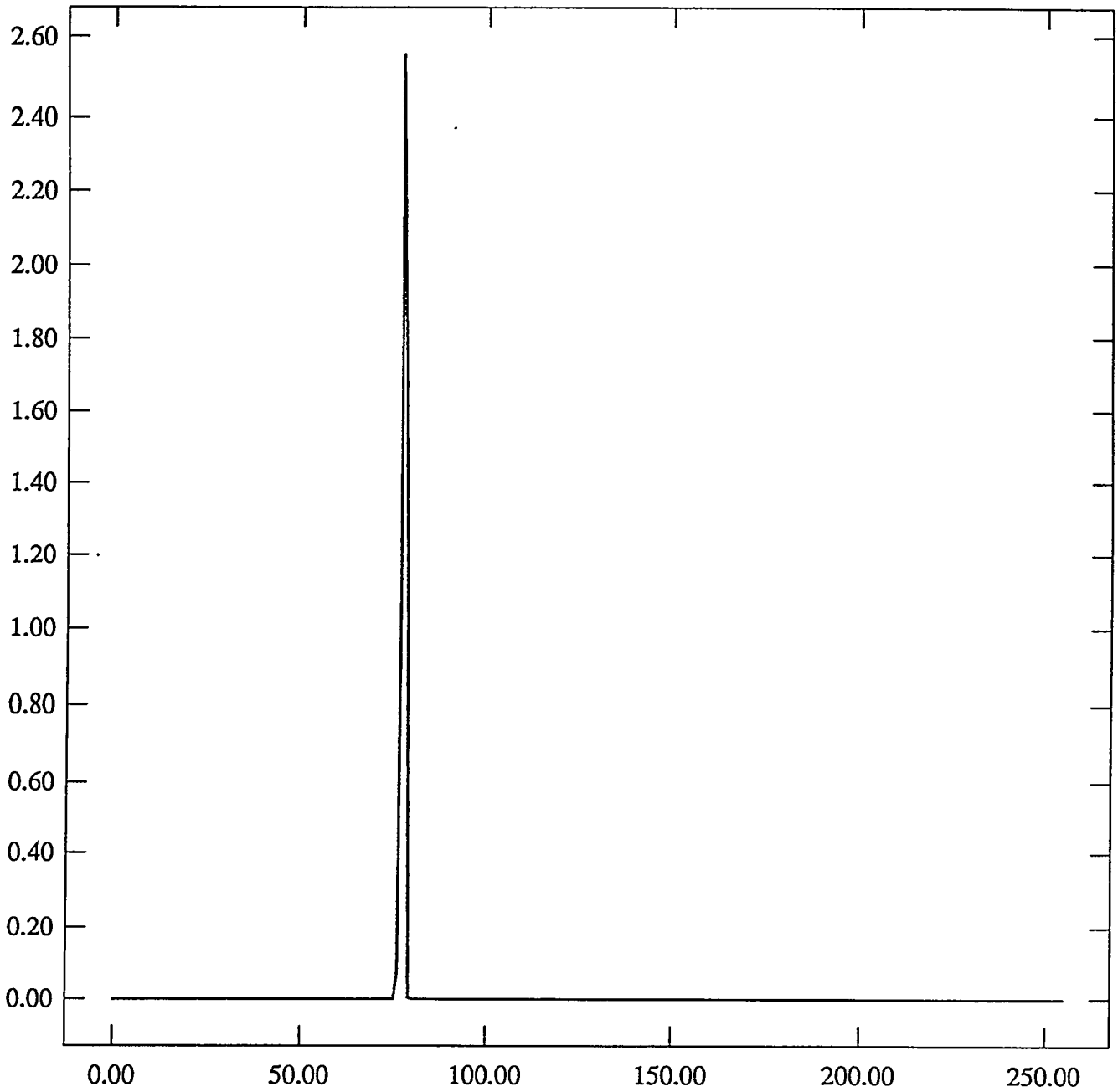
ST Camera: ST2 04-06 -10C: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:52:57 1993

Pixel Values Min 72 Max 81 Mean 76.8 Sigma 0.64 x 10^3



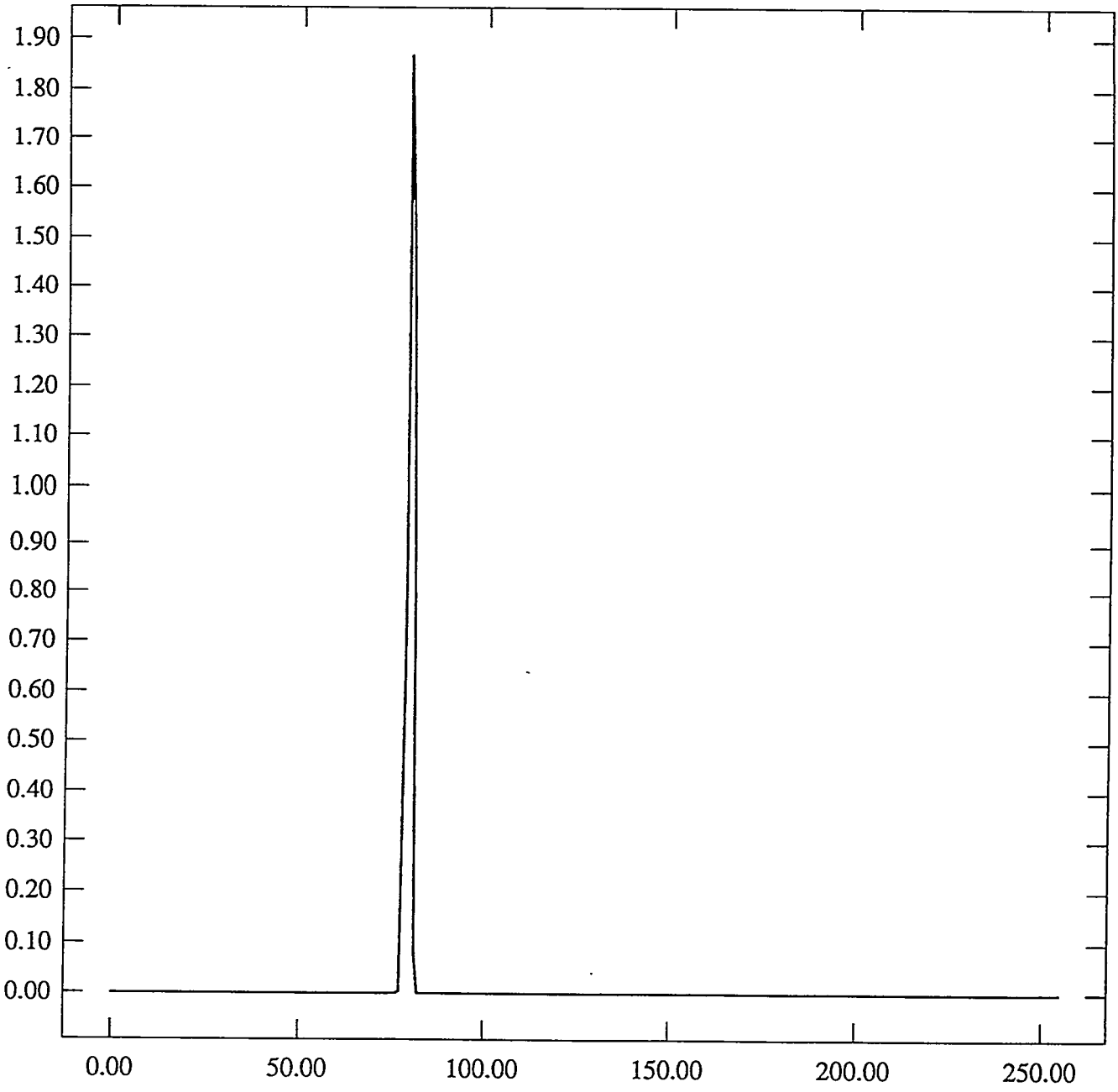
ST Camera: ST2 04-06 -10C: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 15:53:29 1993

Pixel Values Min 76 Max 79 Mean 77.3 Sigma 0.51 x 10^3



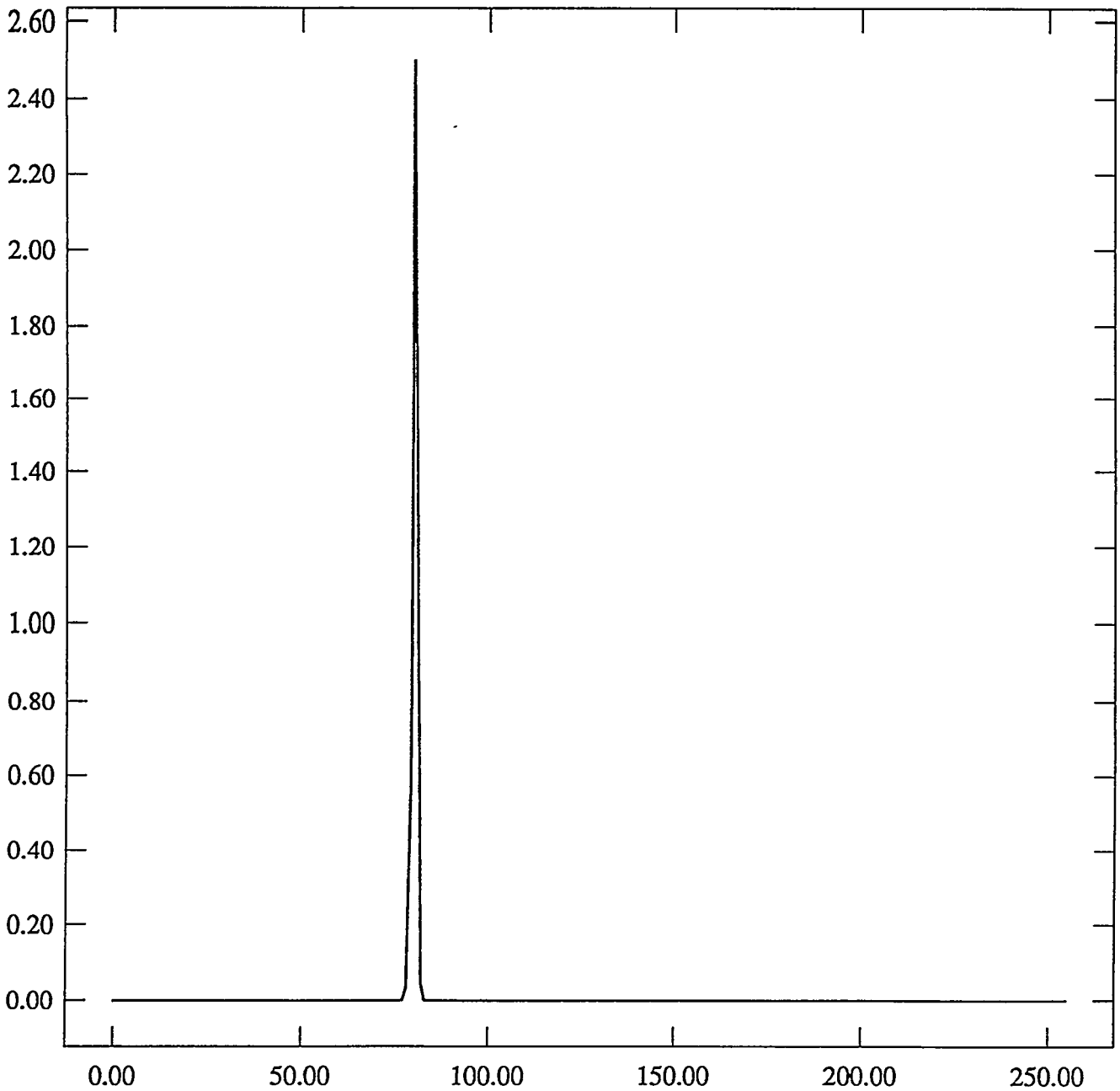
ST Camera: ST2 04-06 0C: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:09:12 1993

Pixel Values Min 77 Max 81 Mean 79.2 Sigma 0.74 x 10^3



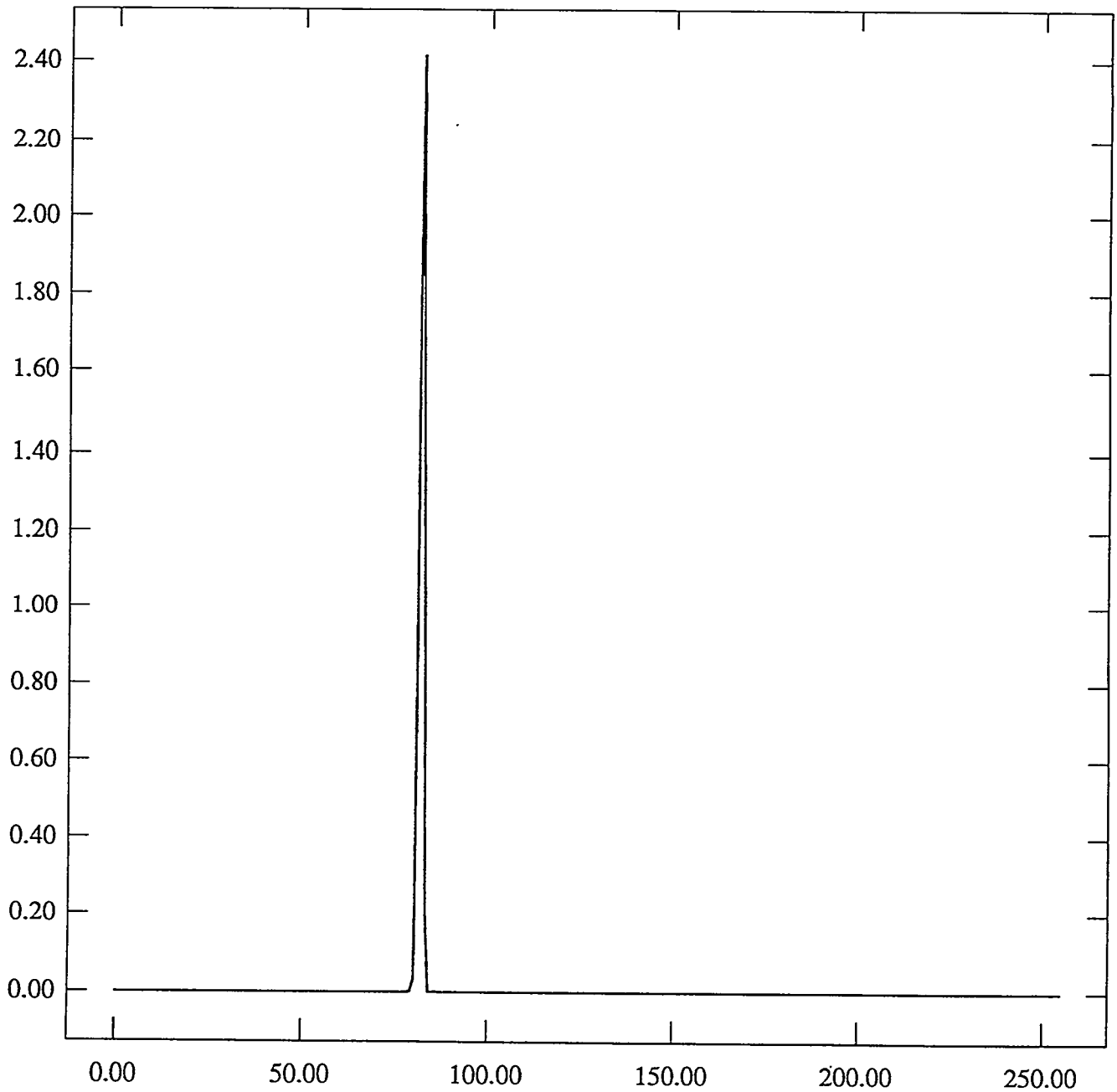
ST Camera: ST2 04-06 0C: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:09:55 1993

Pixel Values Min 78 Max 82 Mean 80.1 Sigma 0.66 x 10^3



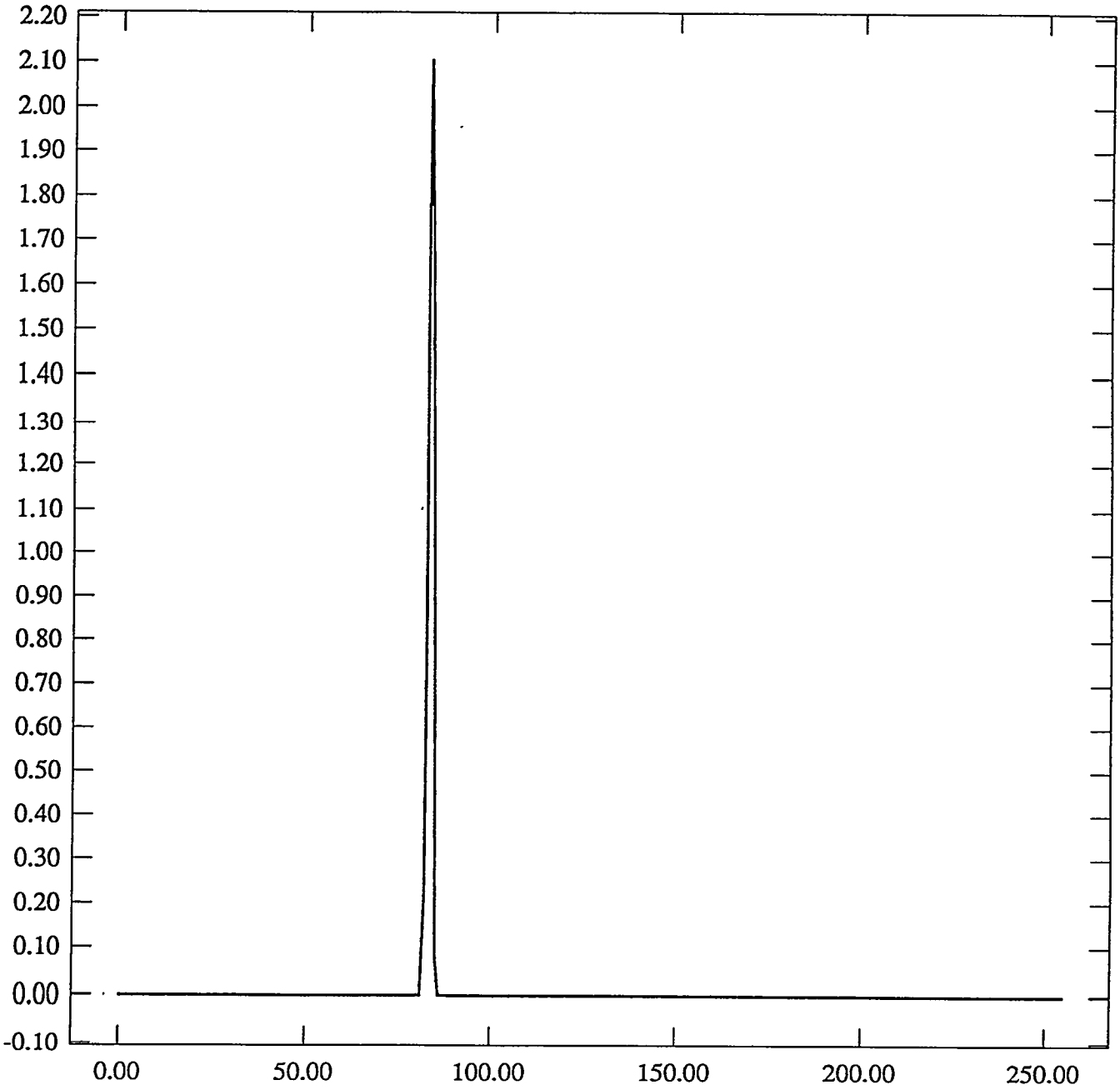
ST Camera: ST2 04-06 0C: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:10:26 1993

Pixel Values Min 79 Max 86 Mean 81.7 Sigma 0.58 x 10^3



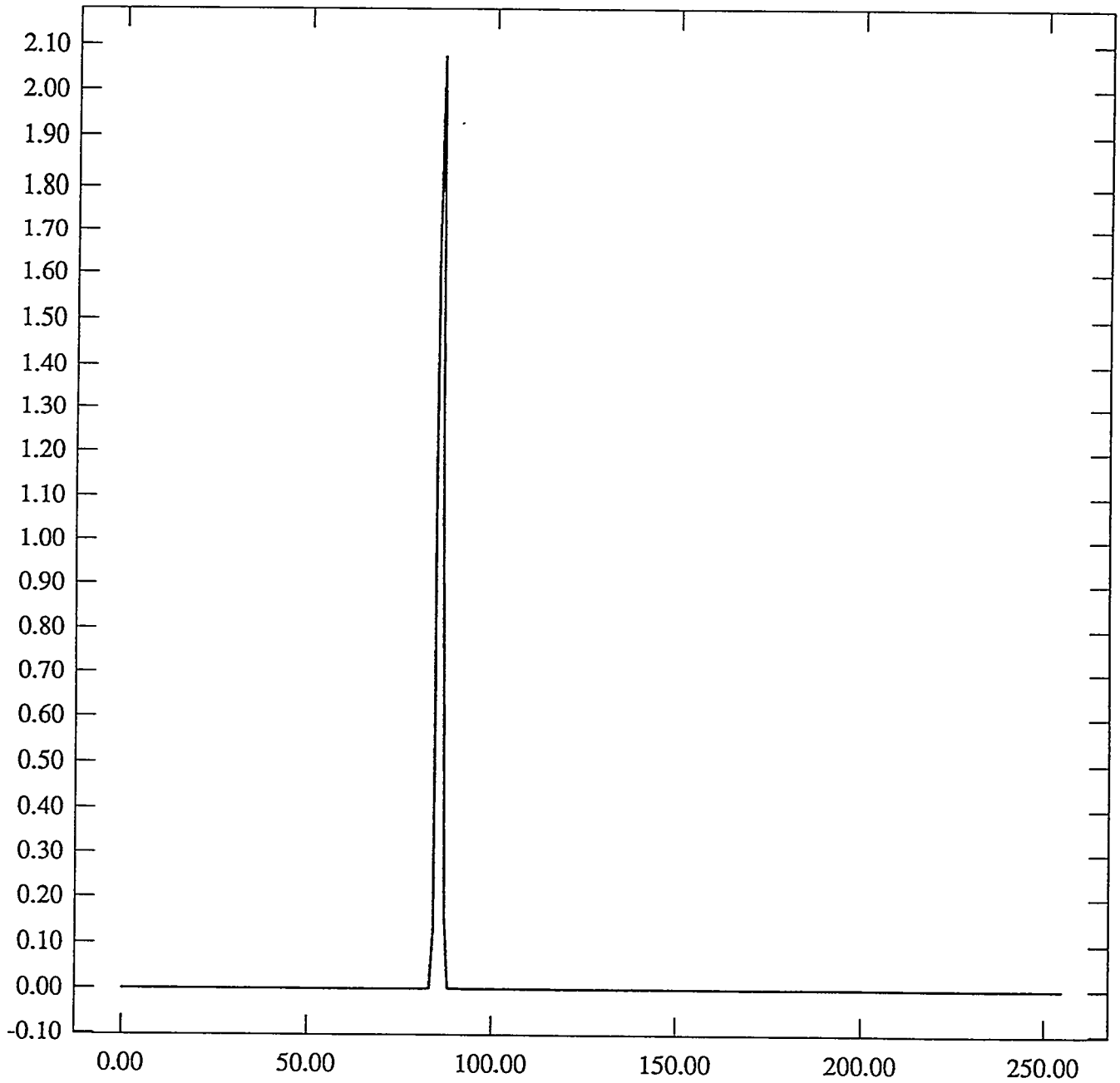
ST Camera: ST2 04-06 +10: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:26:24 1993

Pixel Values Min 82 Max 85 Mean 83.4 Sigma 0.62 x 10^3



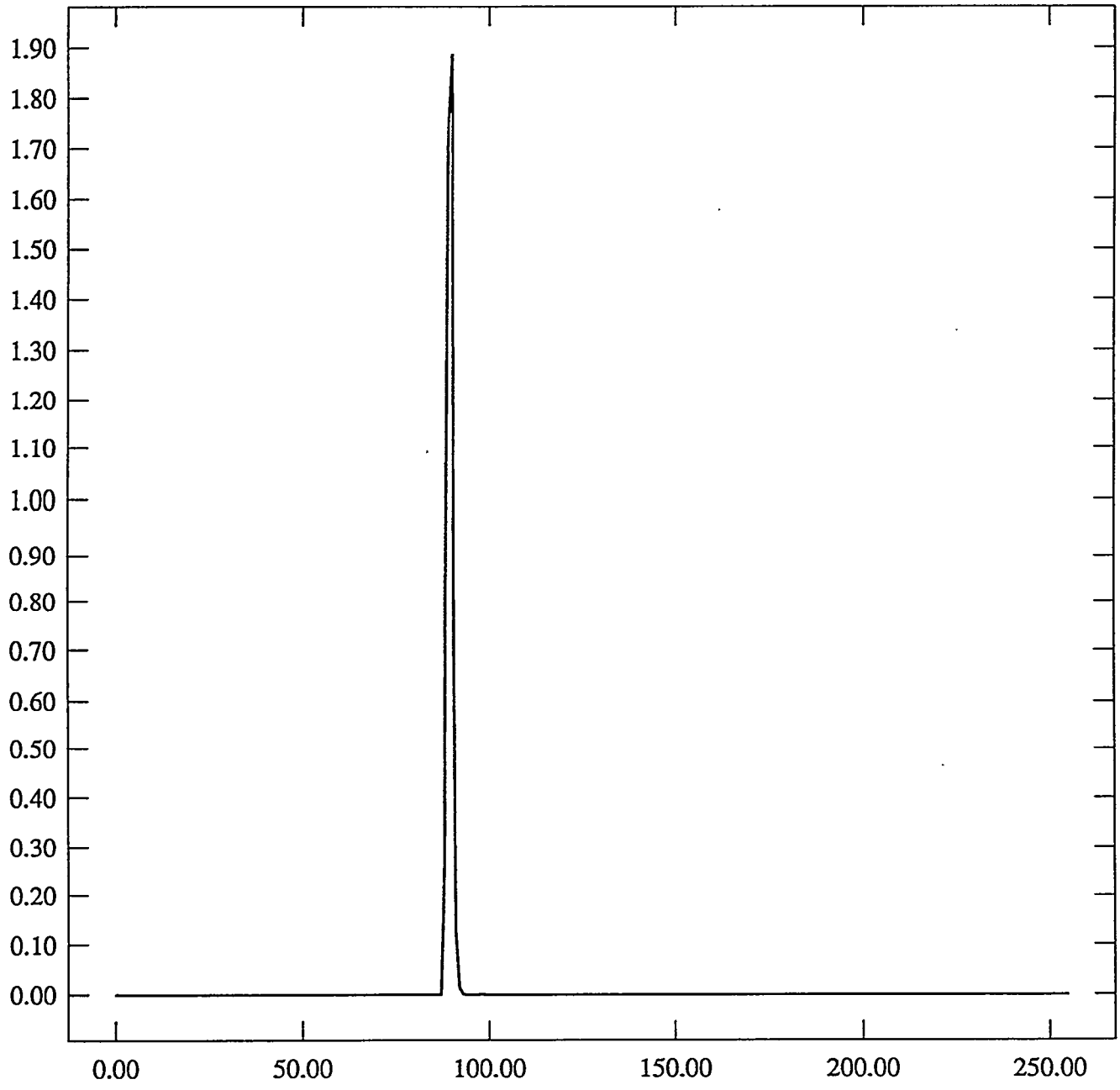
ST Camera: ST2 04-06 +10: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:27:54 1993

Pixel Values Min 83 Max 90 Mean 85.6 Sigma 0.63 x 10^3



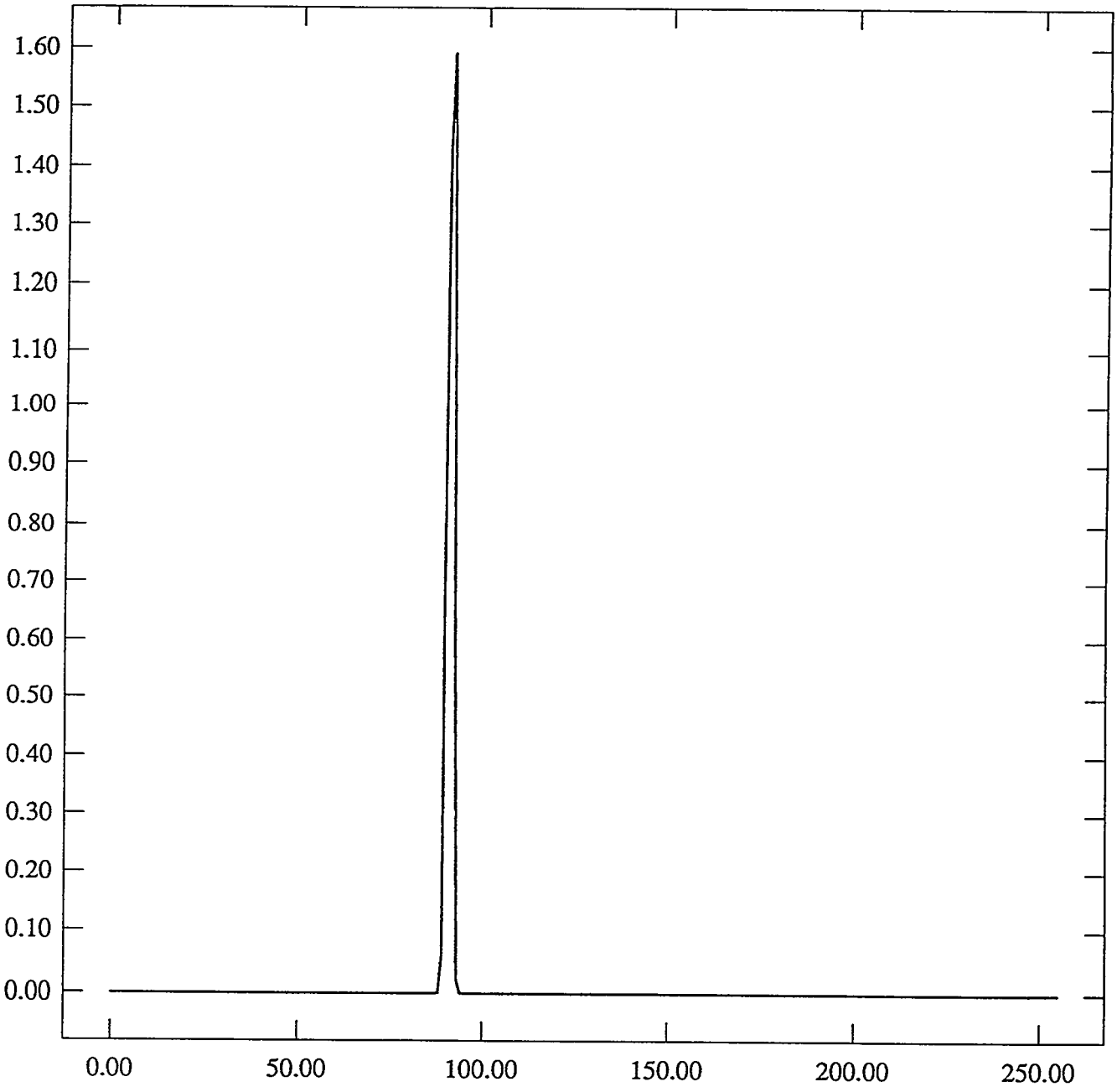
ST Camera: ST2 04-06 +10: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:28:59 1993

Pixel Values Min 88 Max 98 Mean 89.5 Sigma 0.70 x 10^3



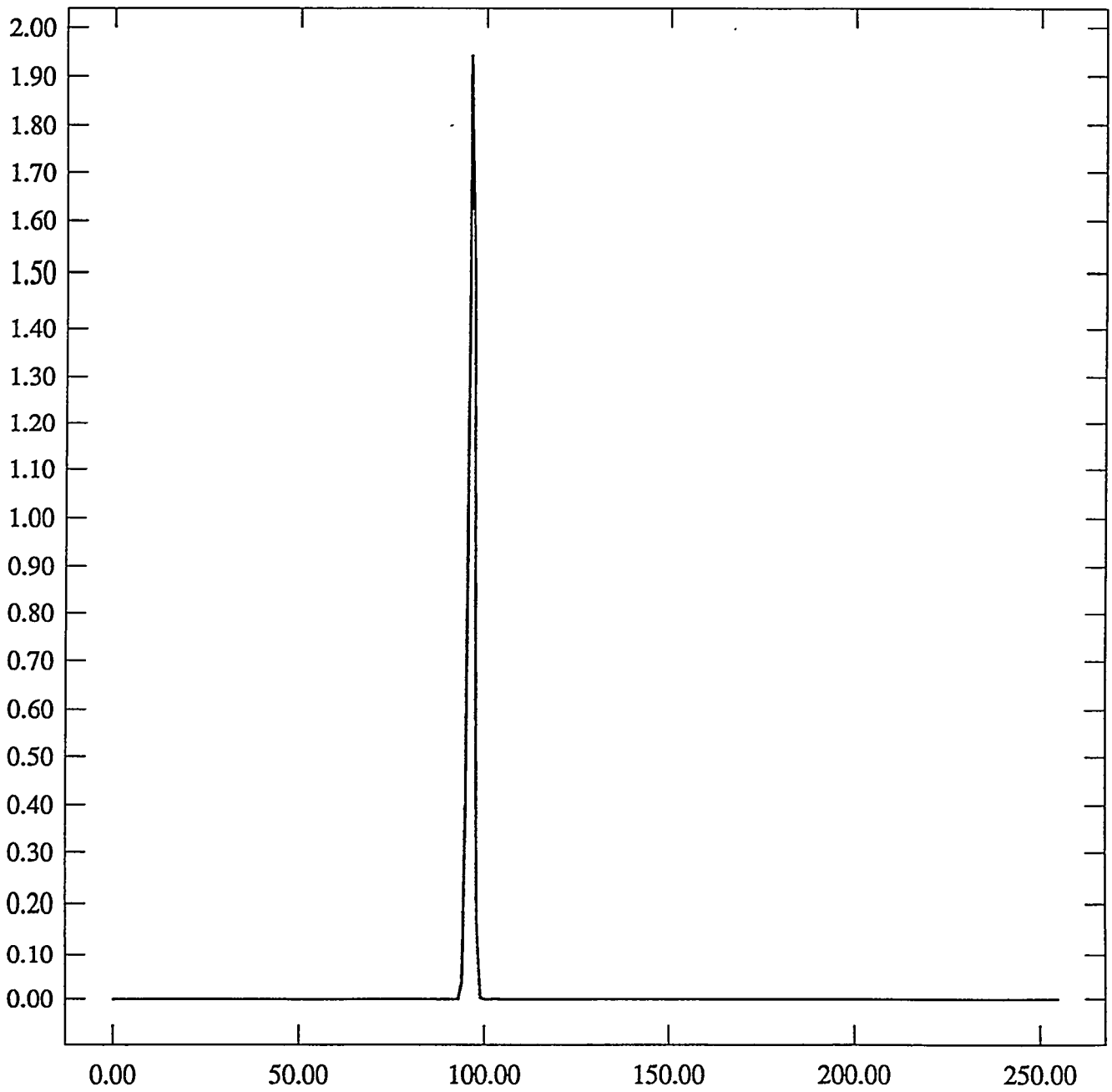
ST Camera: ST2 04-06 +20: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:43:16 1993

Pixel Values Min 88 Max 93 Mean 90.9 Sigma 0.81 x 10^3



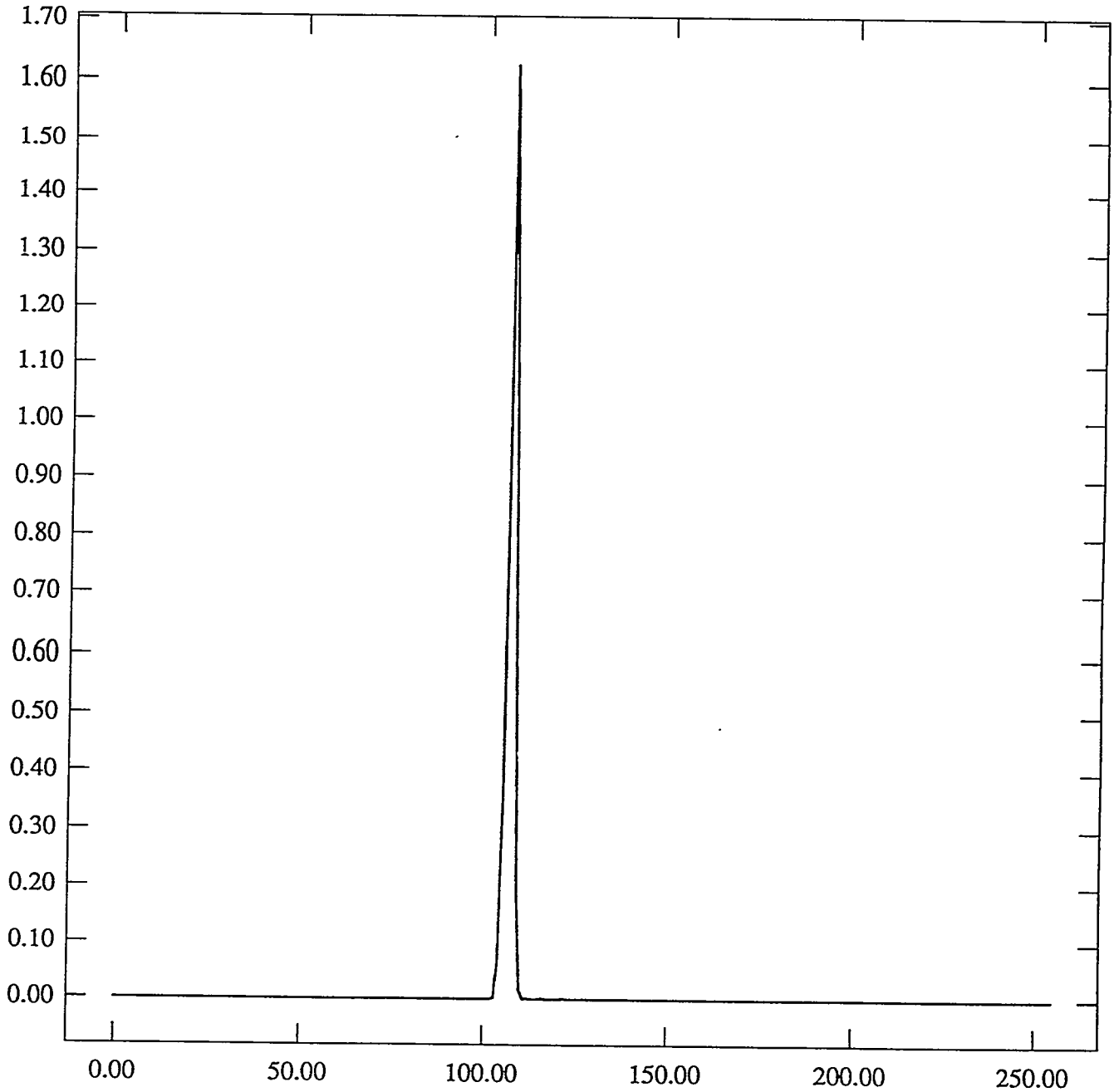
ST Camera: ST2 04-06 +20: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:43:50 1993

Pixel Values Min 94 Max 103 Mean 96.3 Sigma 0.76 x 10^3



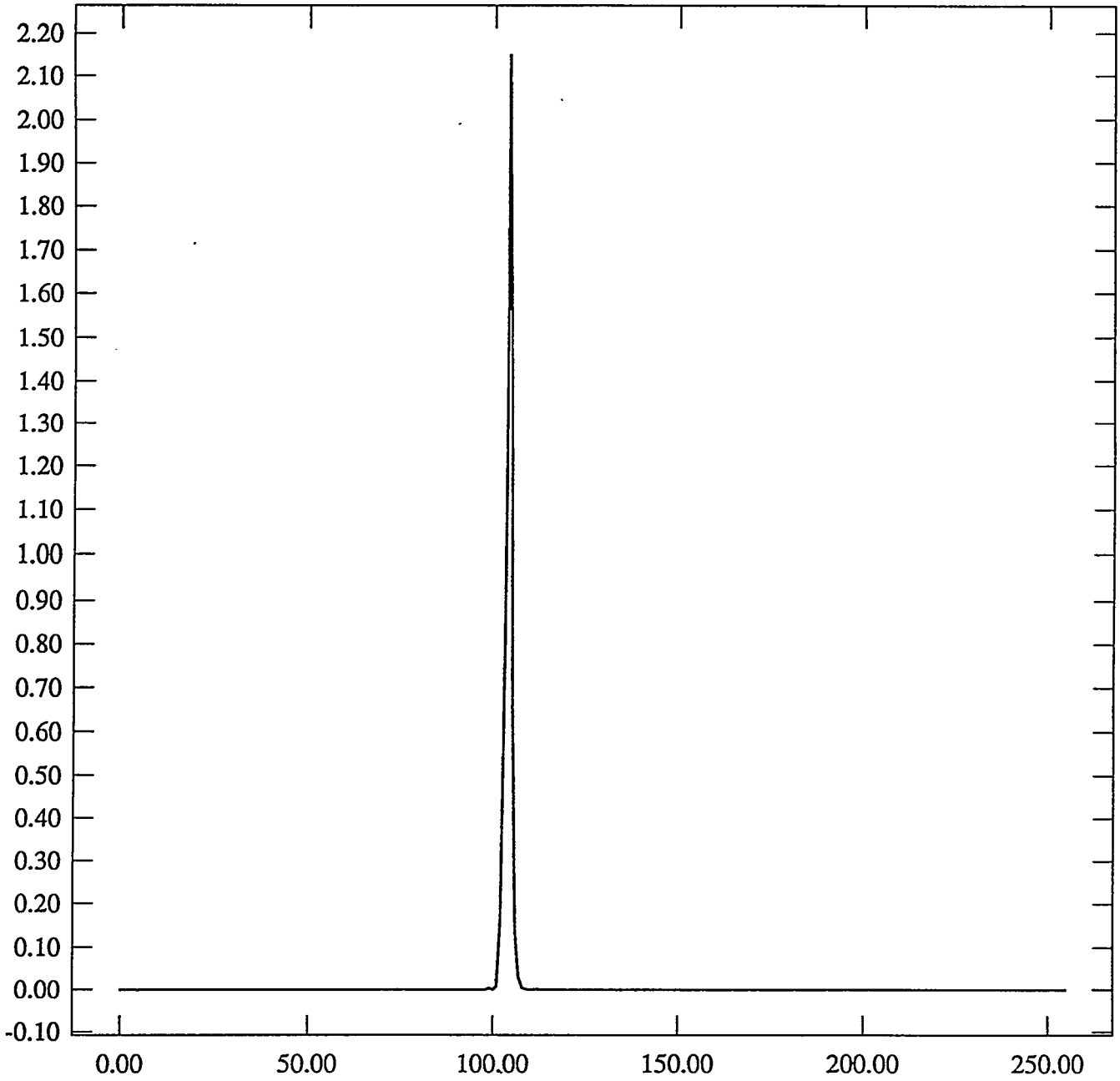
ST Camera: ST2 04-06 +20: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 16:44:24 1993

Pixel Values Min 103 Max 122 Mean 106.8 Sigma 1.11 x 10^3



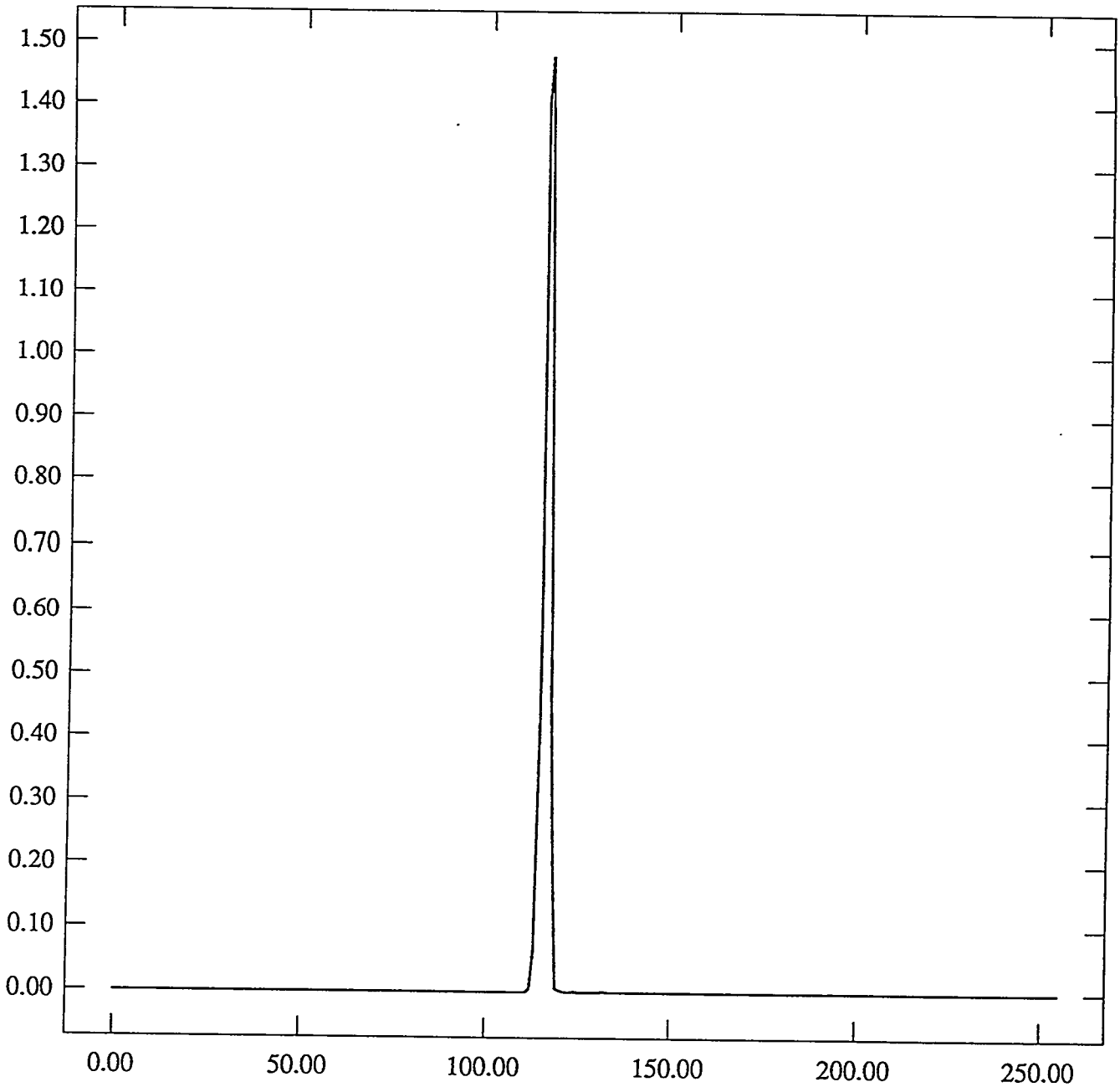
ST Camera: ST2 04-06 +30: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue May 11 17:02:41 1993

Pixel Values Min 99 Max 112 Mean 104.0 Sigma 0.91 x 10^3



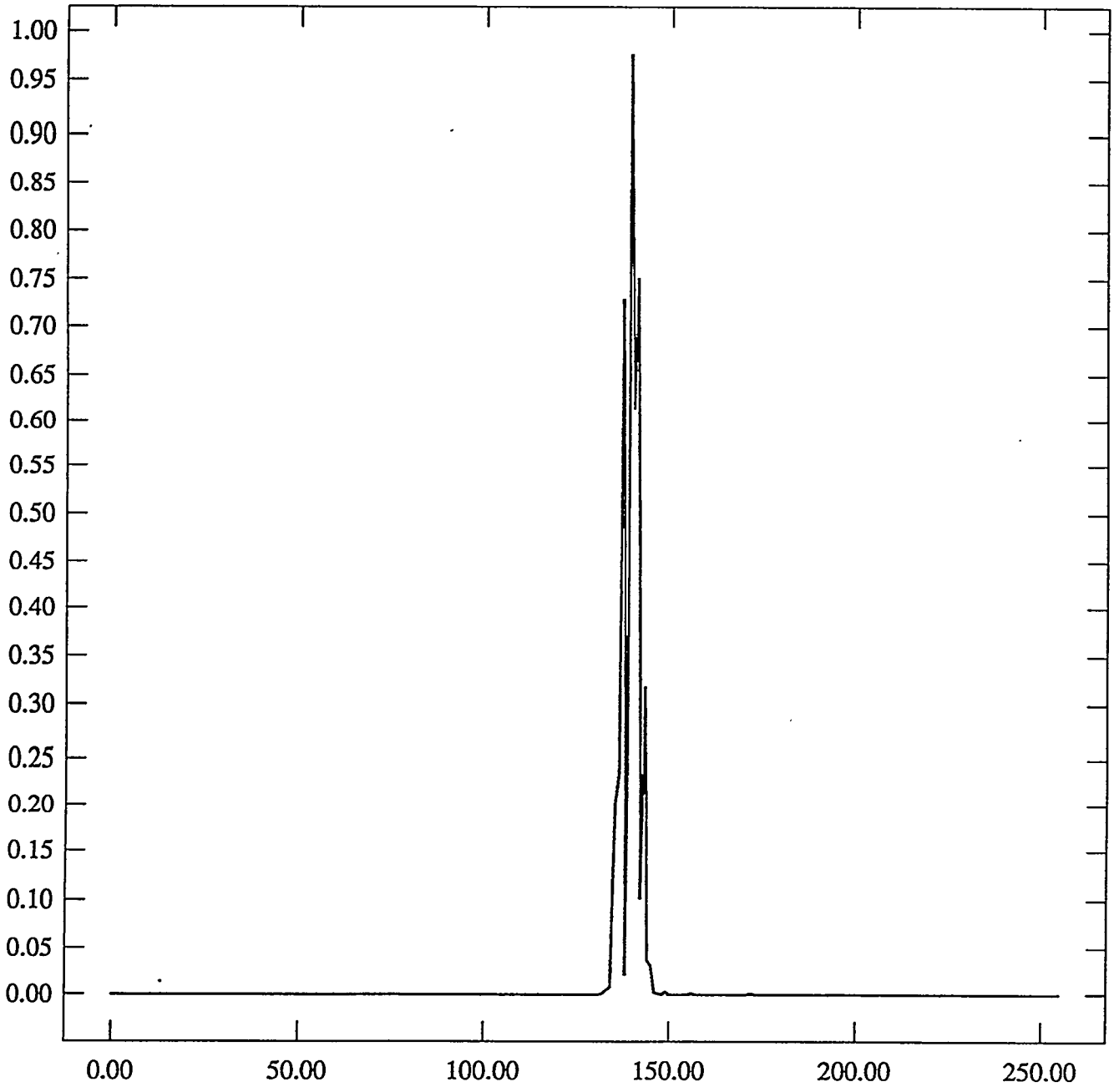
ST Camera: ST2 04-06 +30: int_time=100ms, offset= 0, gain=2 (150 e/bit) Tue May 11 17:03:23 1993

Pixel Values Min 112 Max 132 Mean 115.6 Sigma 1.10×10^3

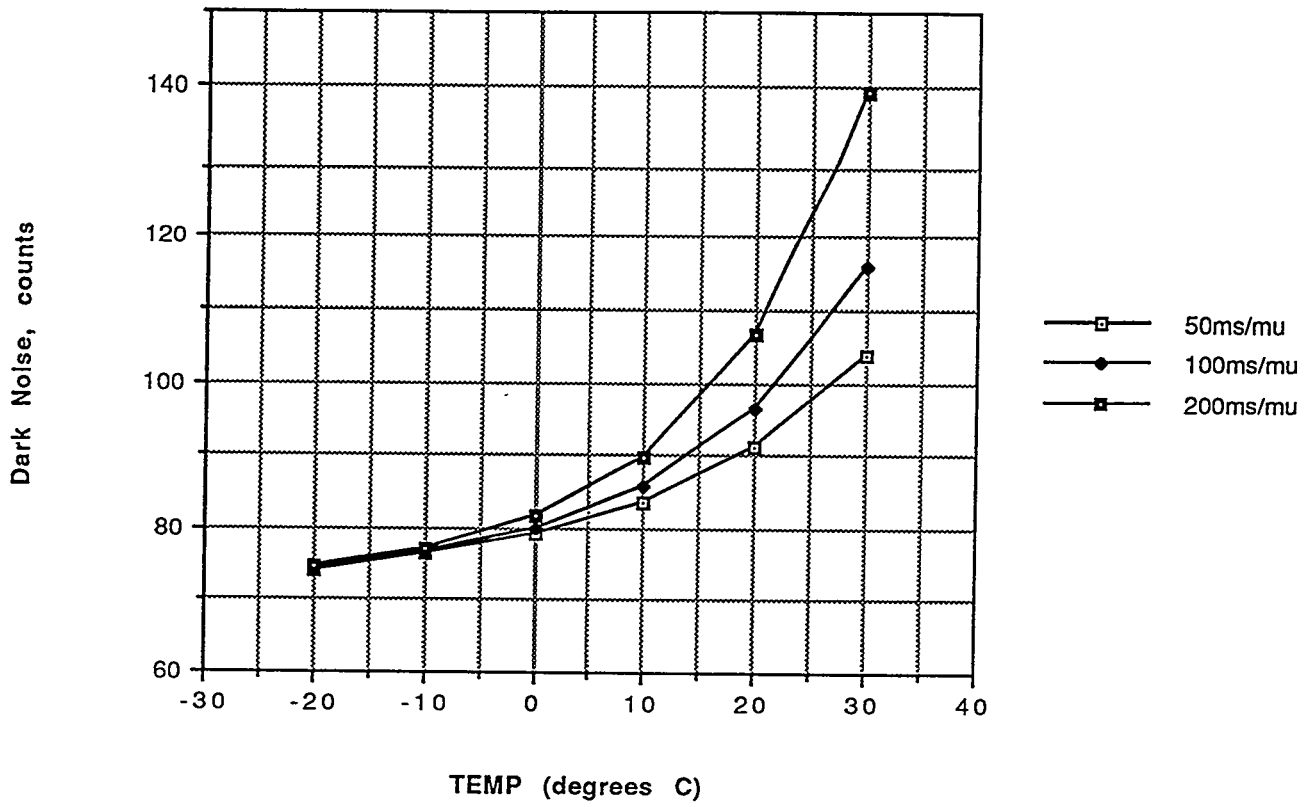


ST Camera: ST2 04-06 +30: int_time=200ms, offset= 0, gain=2 (150 e/bit) Tue May 11 17:04:31 1993

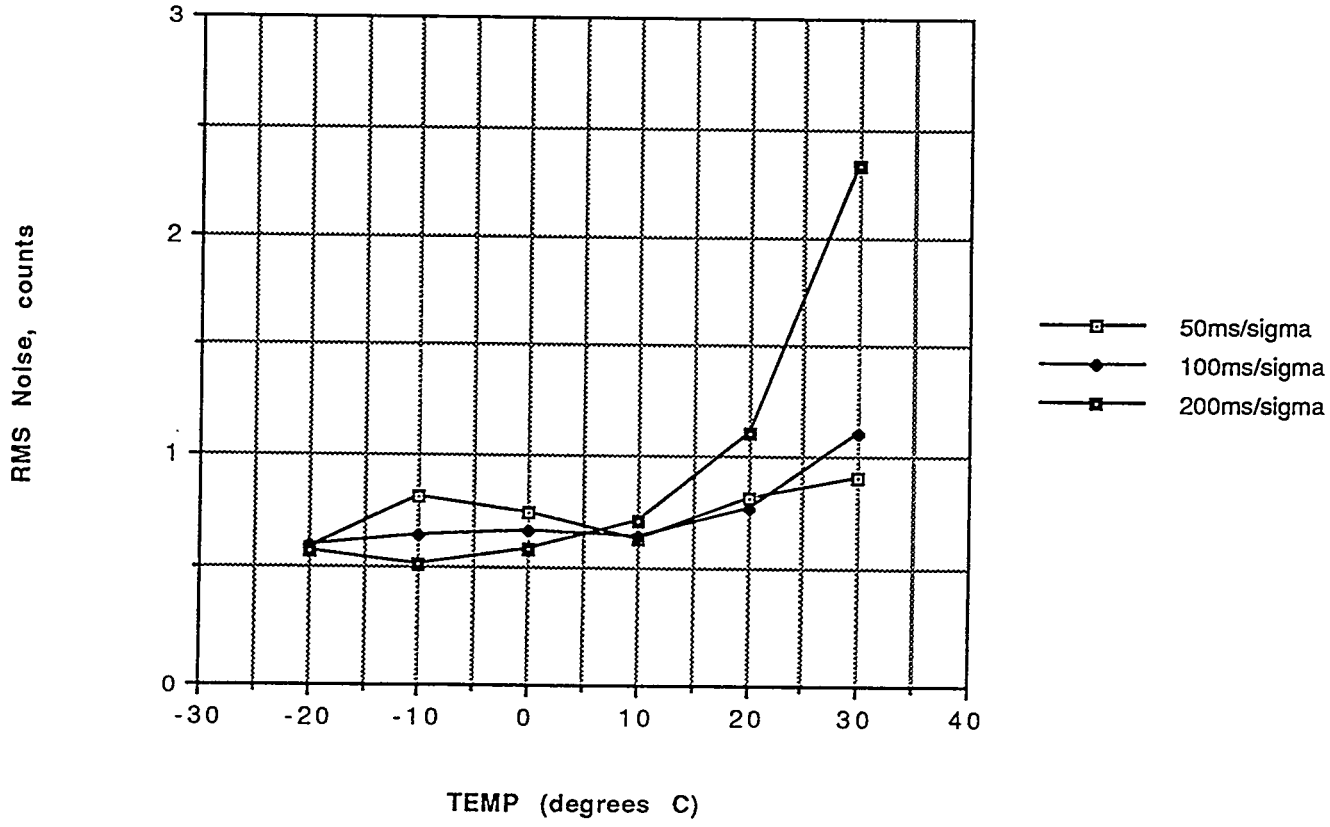
Pixel Values Min 132 Max 172 Mean 139.3 Sigma 2.33 x 10^3



ST2#04-06 150e/bit Mu °C Graph



ST2#04-06 150e/bit Sigma °C Graph



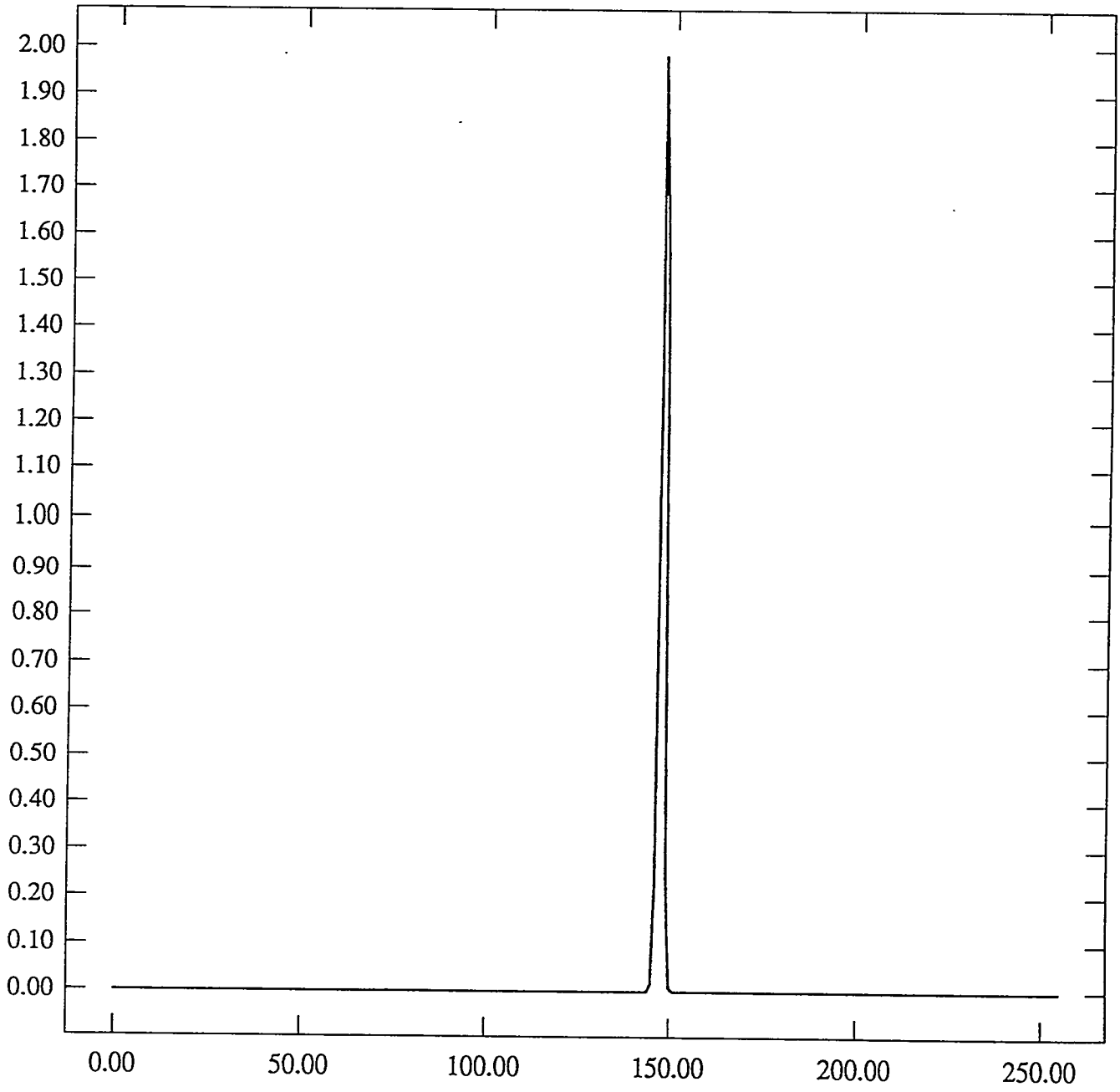
ST2#04-06\CDT\75e

Thu, May 13, 1993 11:05 AM

	TEMP (degrees C)	50ms/mu	50ms/sigma	100ms/mu	100ms/sigma	200ms/mu	200ms/sigma	NOTES:
1								
2	-20	147.40	0.72	147.70	0.76	148.10	0.81	5/11/93
3	-10	151.70	0.85	152.20	0.86	153.30	0.75	Flight F.0. CCD#2
4	0	156.70	0.78	158.30	0.93	161.30	0.85	
5	10	164.80	1.17	168.50	1.06	176.60	1.57	75e/bit
6	20	179.30	0.90	188.70	1.33	209.40	2.04	R49=100Ω
7	30	203.10	1.49	226.10	2.14			

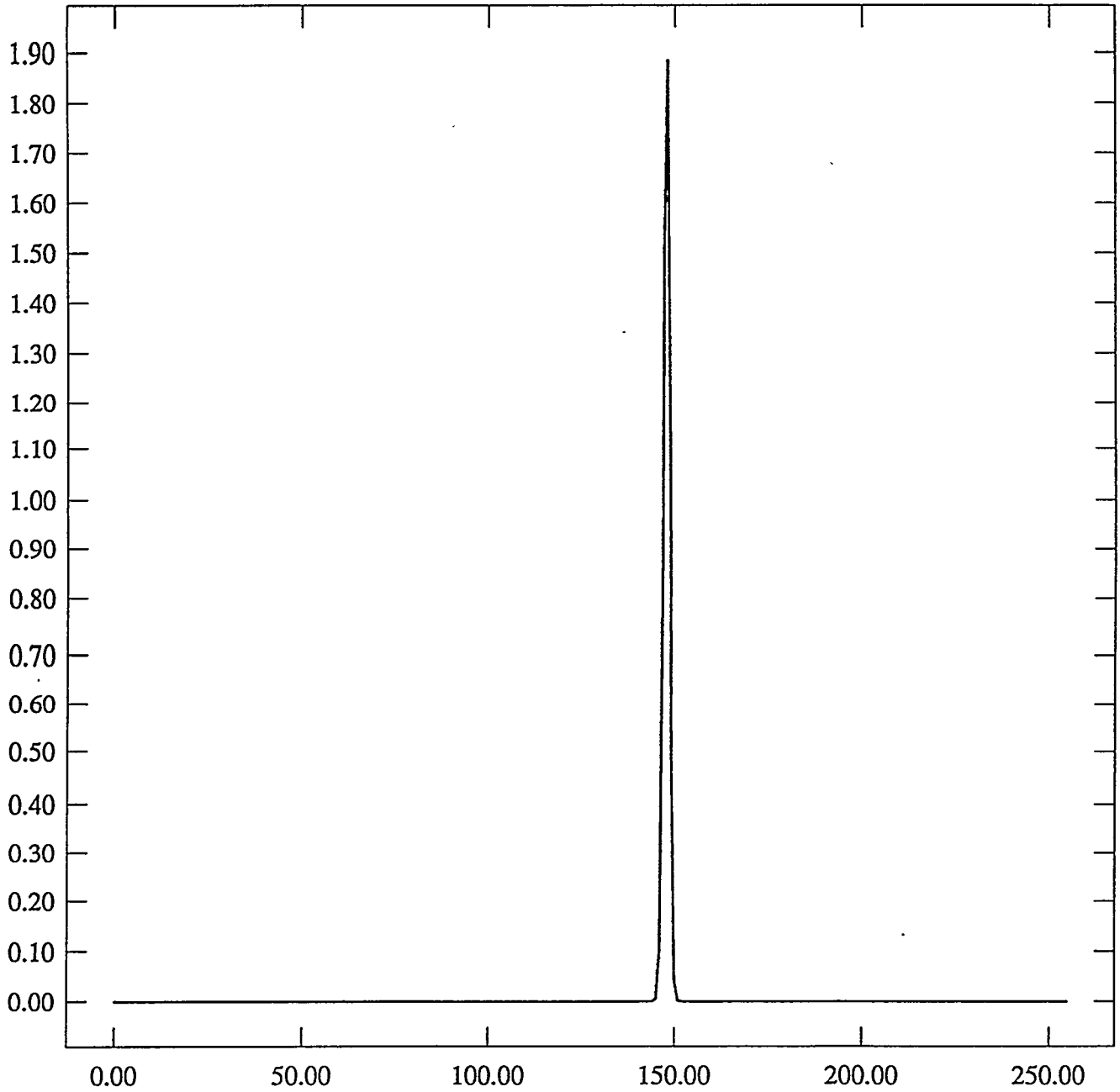
ST Camera: ST2 04-06 -20C: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:39:41 1993

Pixel Values Min 145 Max 150 Mean 147.4 Sigma 0.72 x 10^3



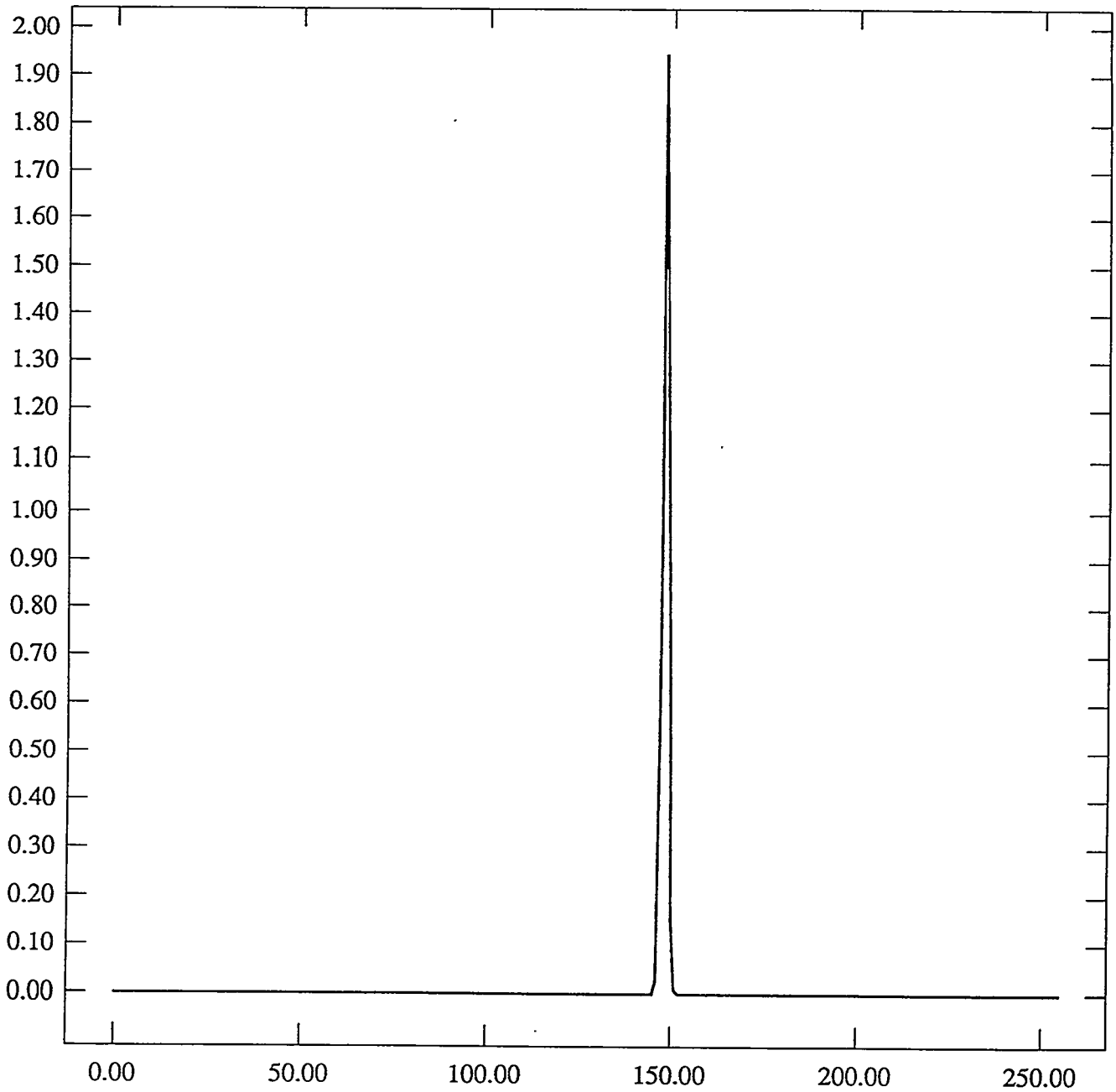
ST Camera: ST2 04-06 -20C: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:40:19 1993

Pixel Values Min 145 Max 151 Mean 147.7 Sigma 0.76 x 10^3



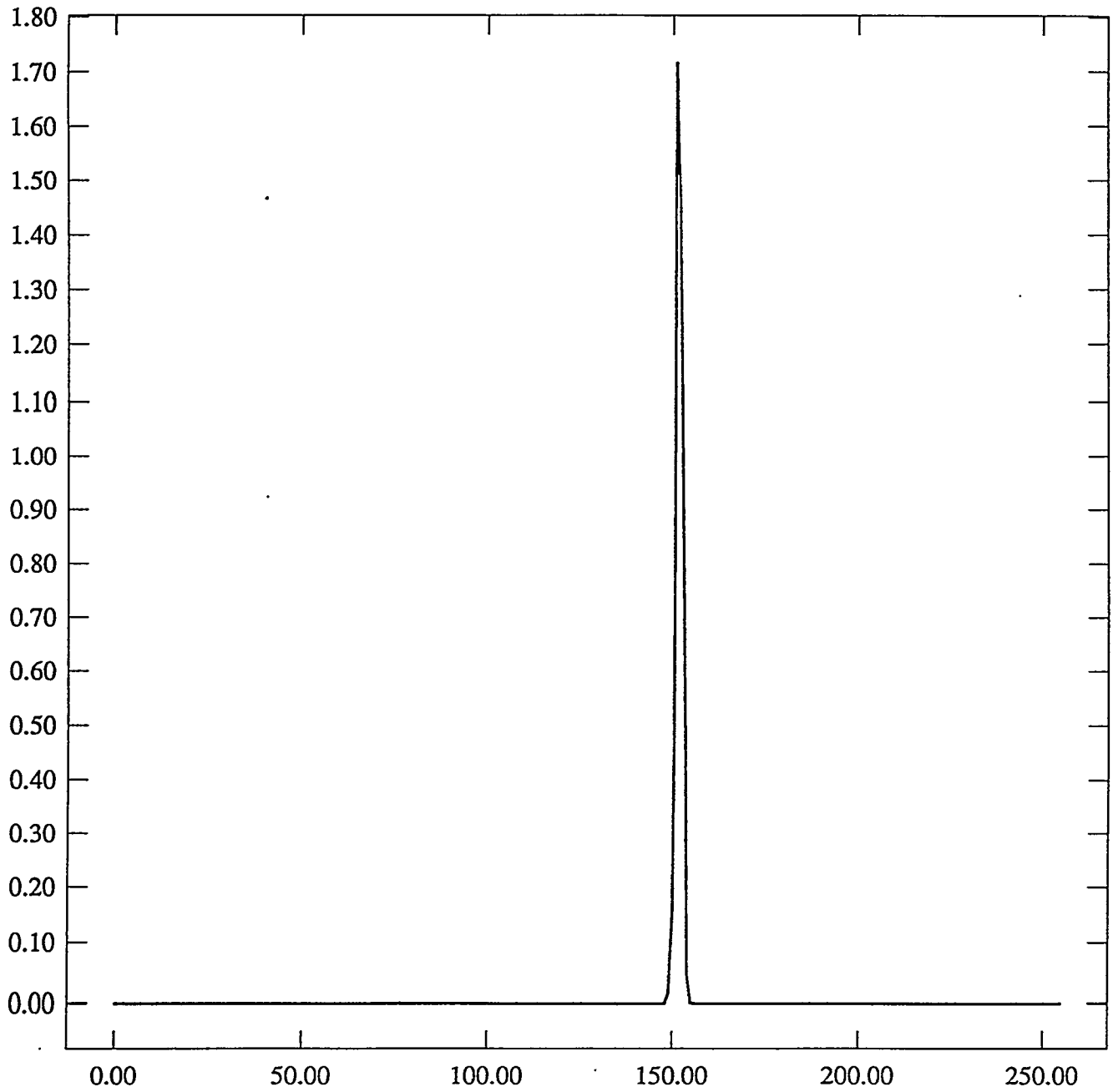
ST Camera: ST2 04-06 -20C: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:40:55 1993

Pixel Values Min 146 Max 151 Mean 148.1 Sigma 0.81 x 10^3



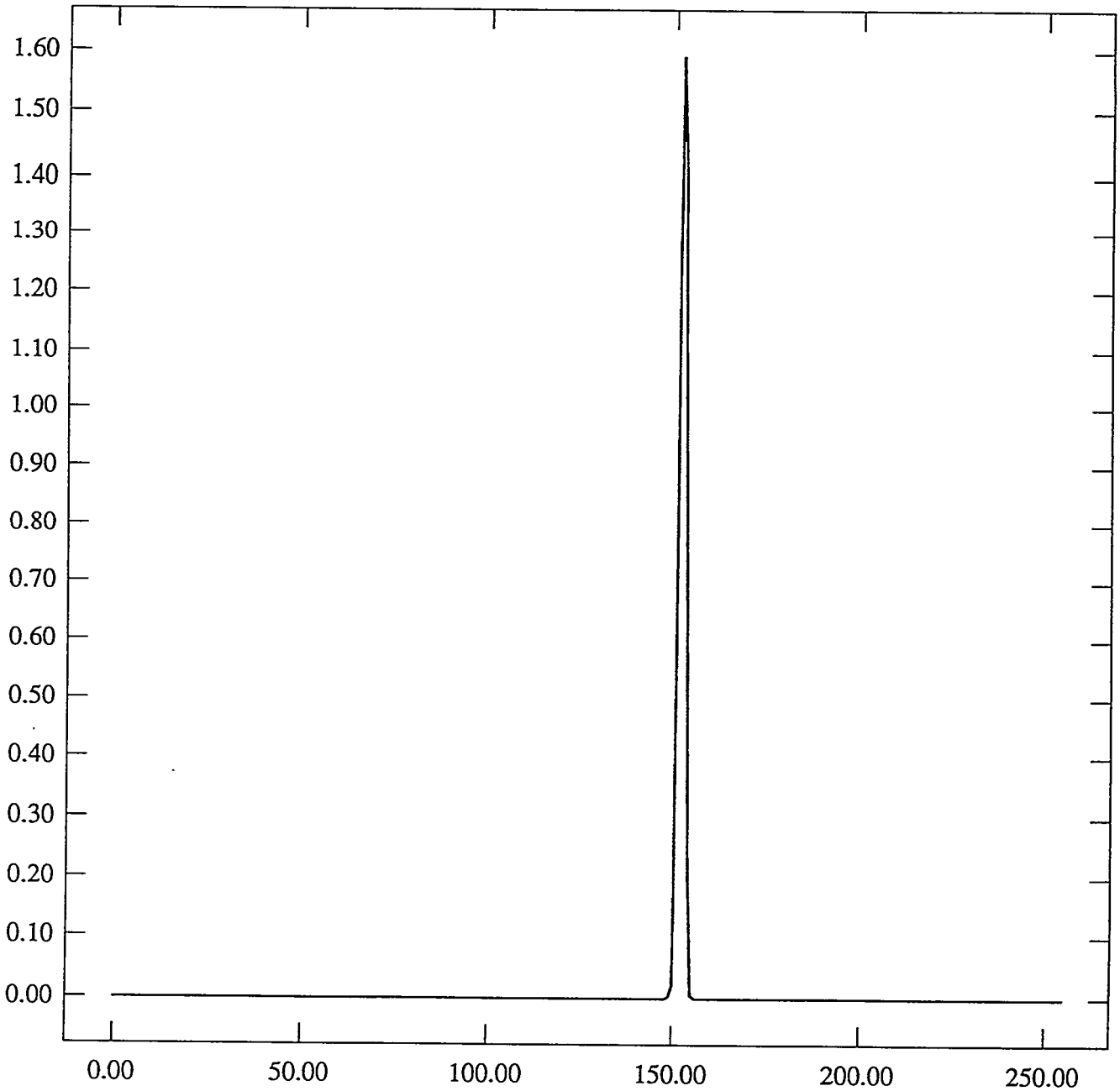
ST Camera: ST2 04-06 -10C: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:54:04 1993

Pixel Values Min 149 Max 155 Mean 151.7 Sigma 0.85 x 10^3



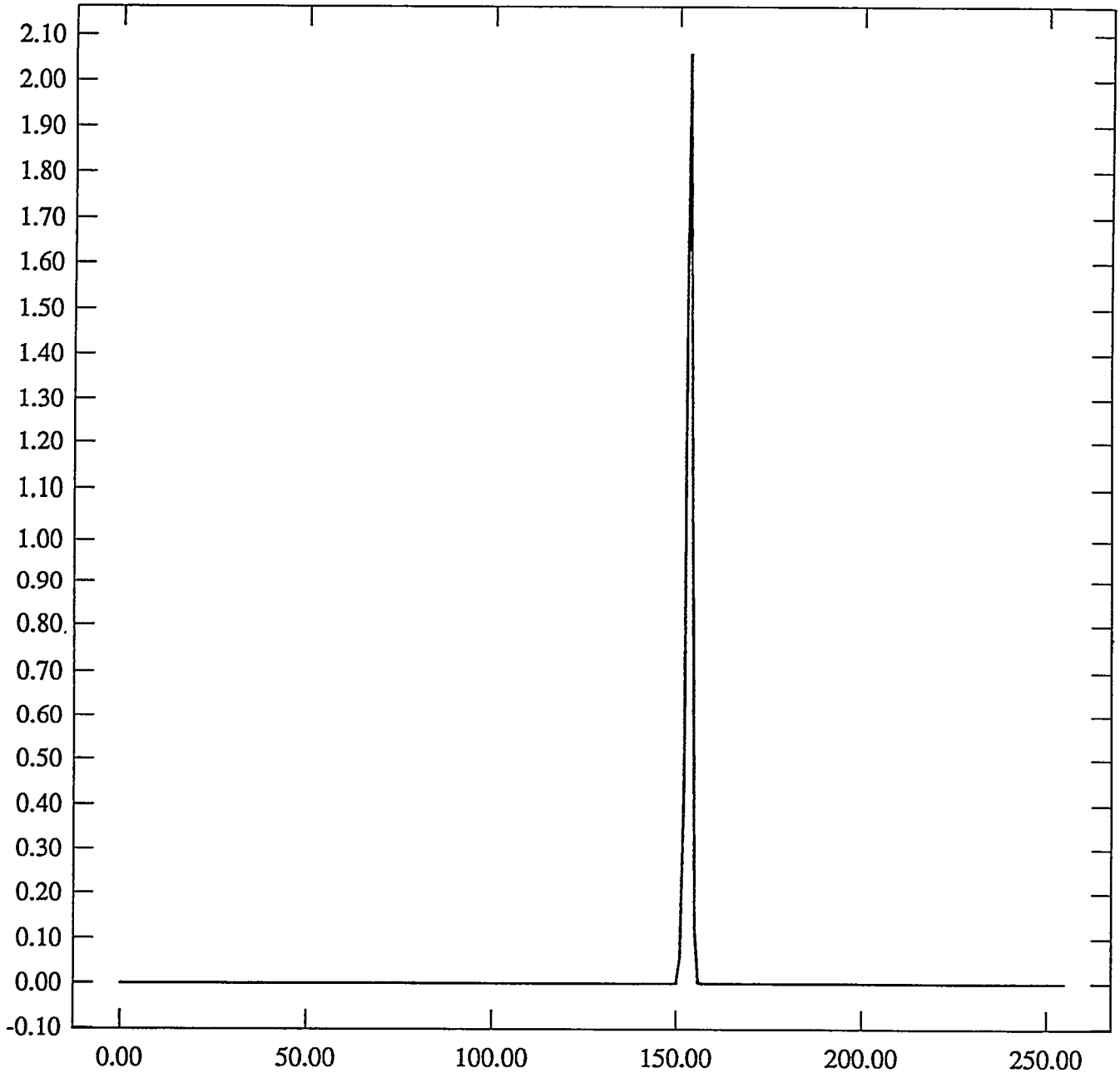
ST Camera: ST2 04-06 -10C: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:54:39 1993

Pixel Values Min 149 Max 155 Mean 152.2 Sigma 0.86 x 10^3



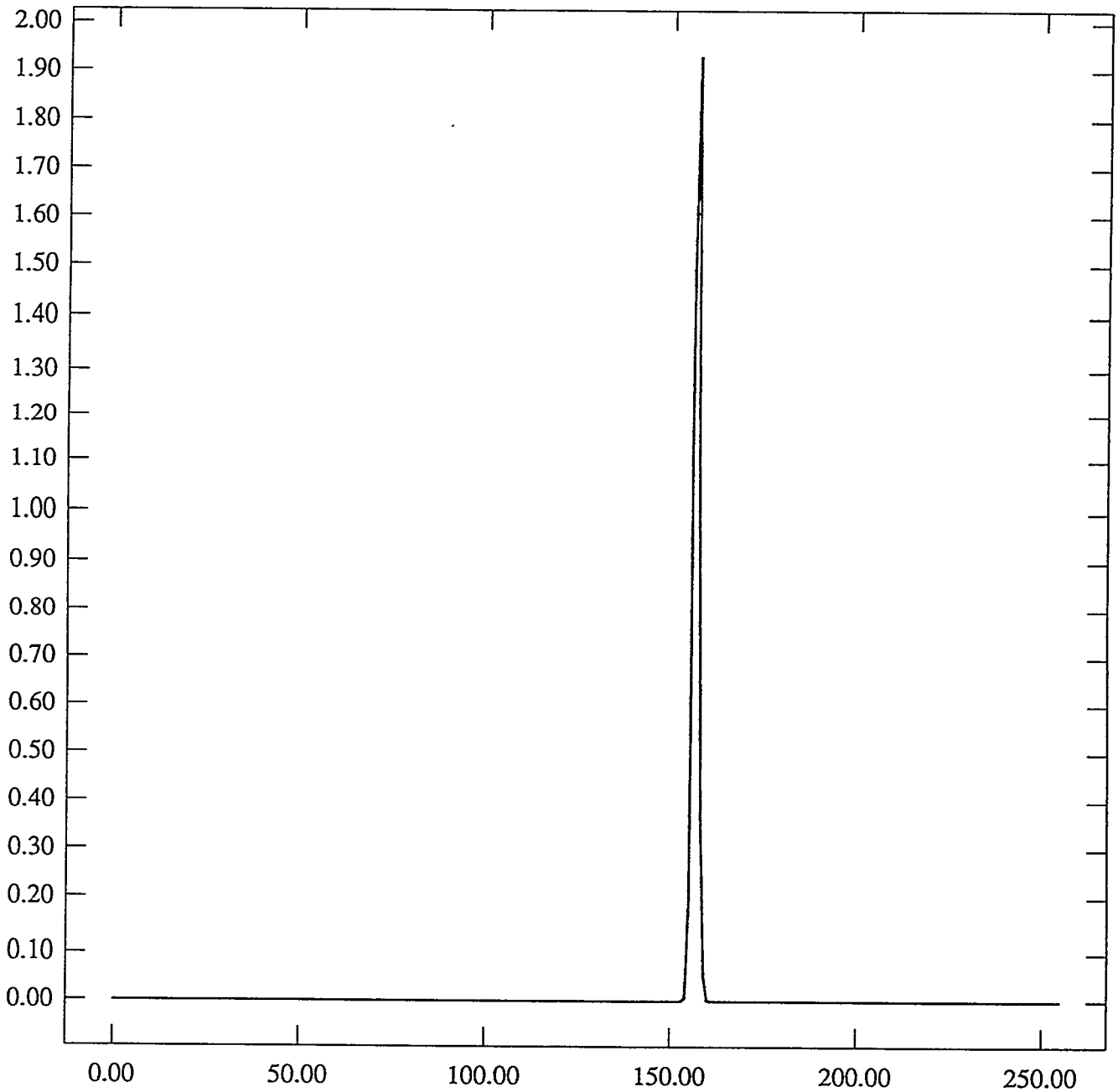
ST Camera: ST2 04-06 -10C: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 15:55:28 1993

Pixel Values Min 151 Max 156 Mean 153.3 Sigma 0.75 x 10^3



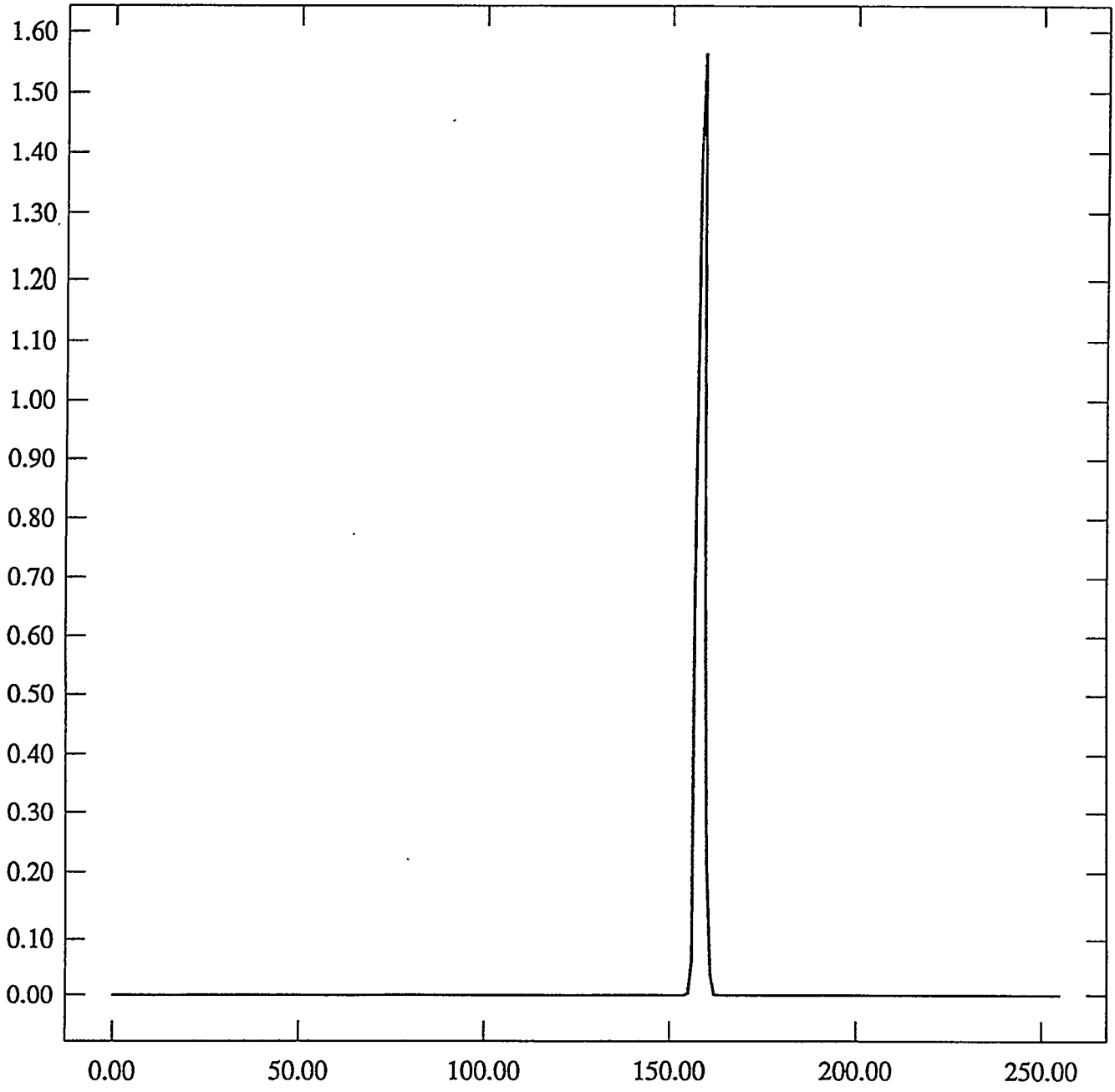
ST Camera: ST2 04-06 0C: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:10:59 1993

Pixel Values Min 154 Max 160 Mean 156.7 Sigma 0.78 x 10^3



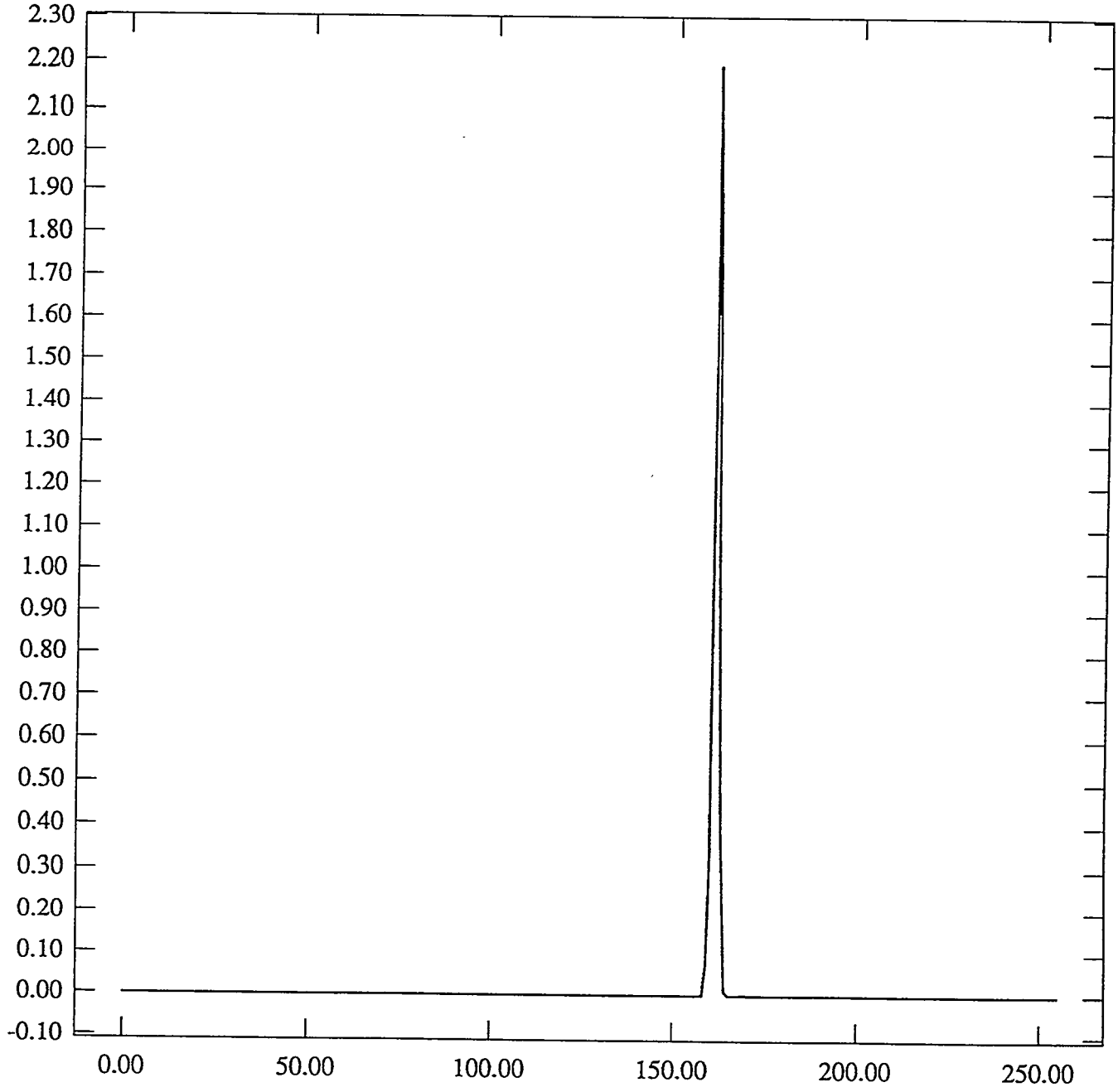
ST Camera: ST2 04-06 0C: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:11:36 1993

Pixel Values Min 155 Max 162 Mean 158.3 Sigma 0.93 x 10^3



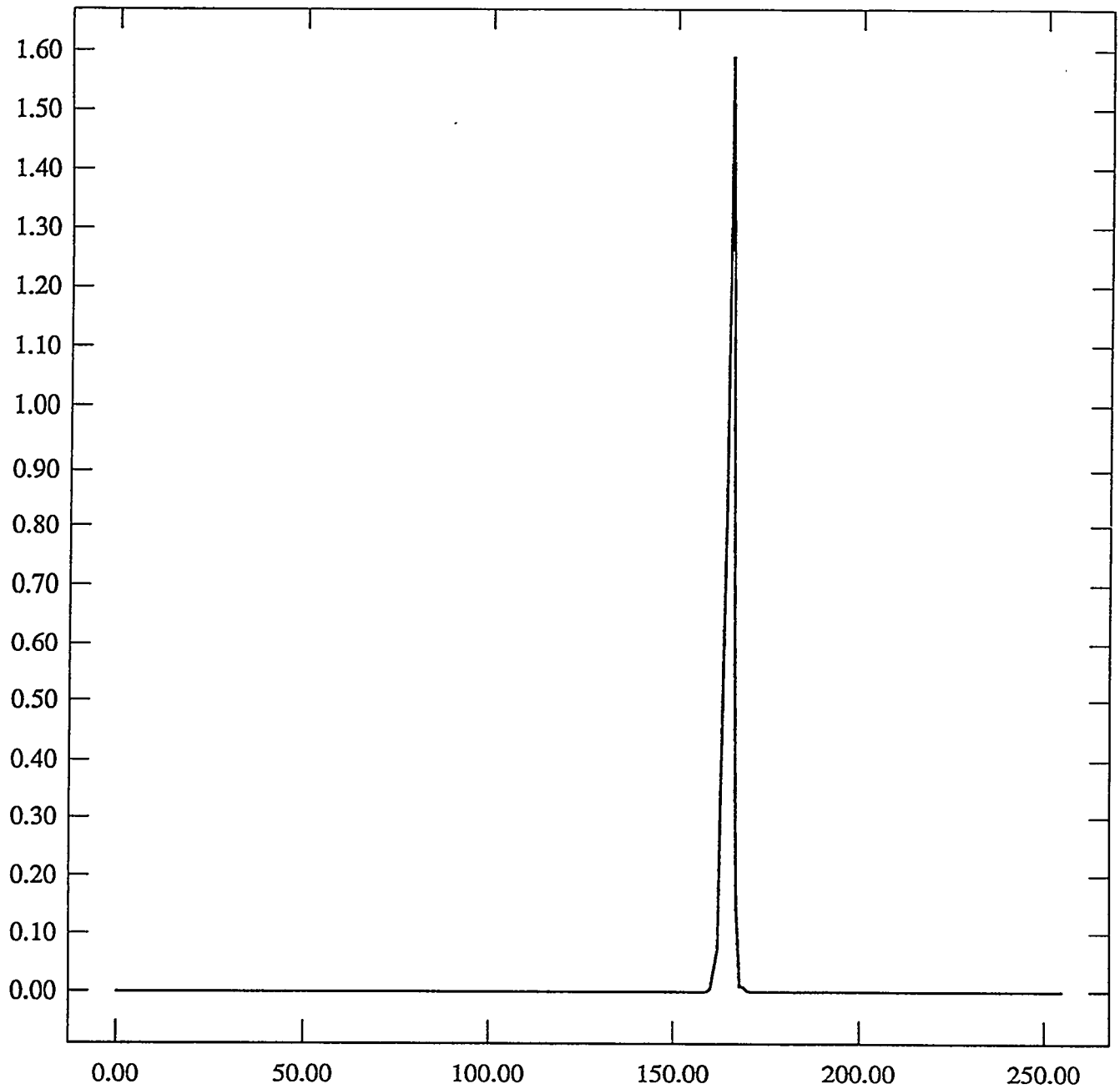
ST Camera: ST2 04-06 0C: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:12:13 1993

Pixel Values Min 159 Max 169 Mean 161.3 Sigma 0.85 x 10^3



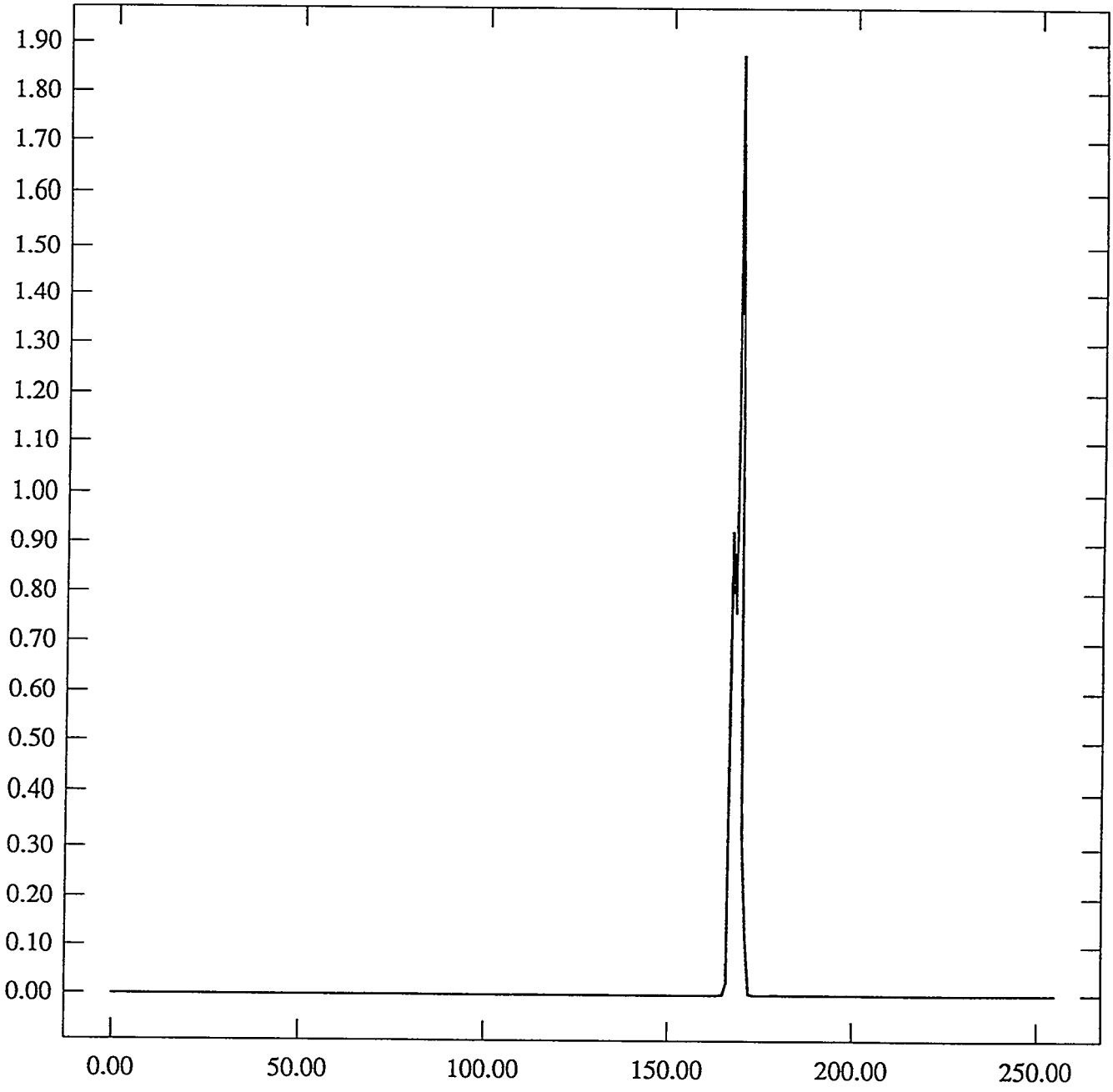
ST Camera: ST2 04-06 +10: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:29:36 1993

Pixel Values Min 160 Max 170 Mean 164.8 Sigma 1.17 x 10^3



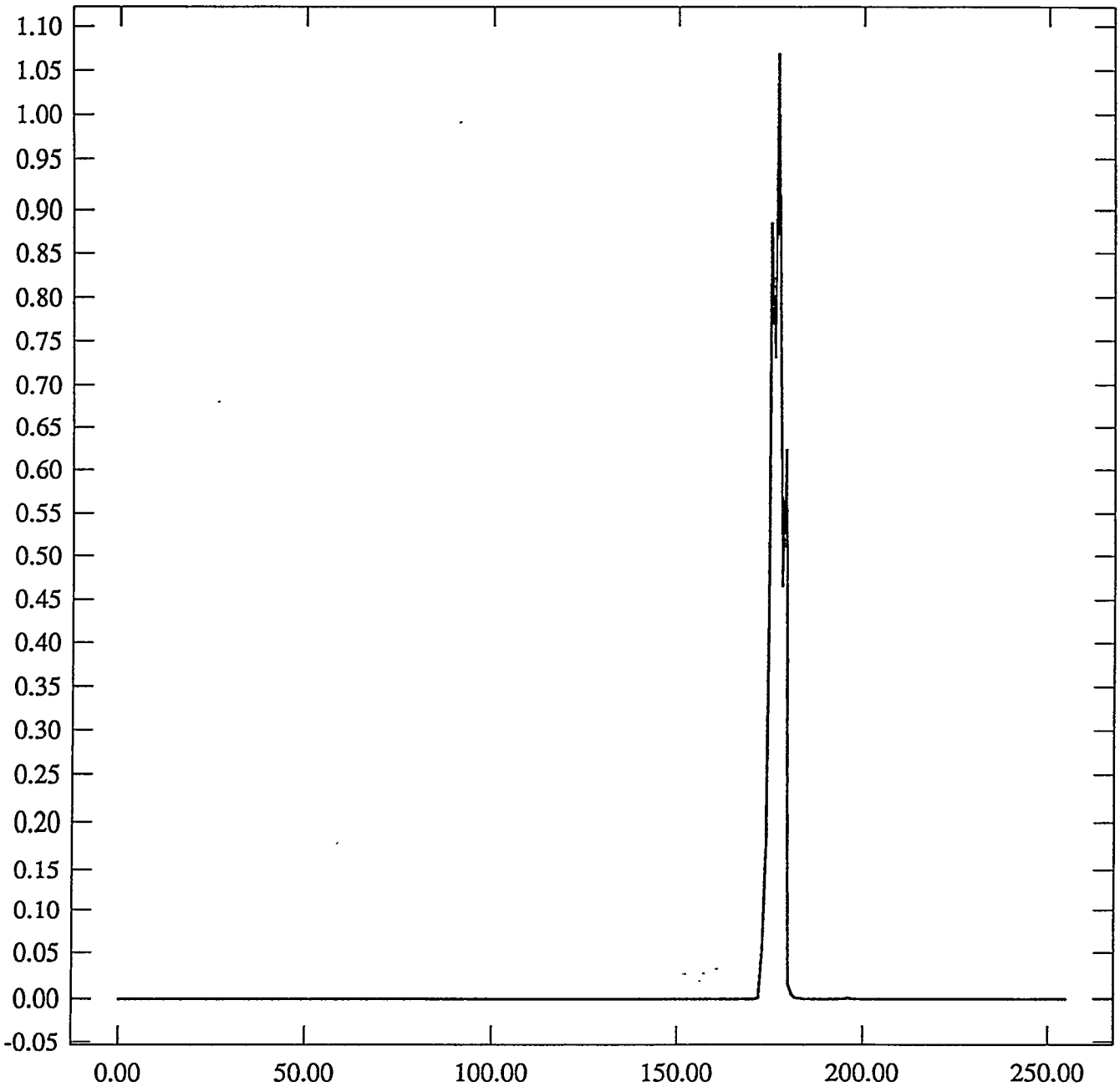
ST Camera: ST2 04-06 +10: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:30:11 1993

Pixel Values Min 165 Max 179 Mean 168.5 Sigma 1.06 x 10^3



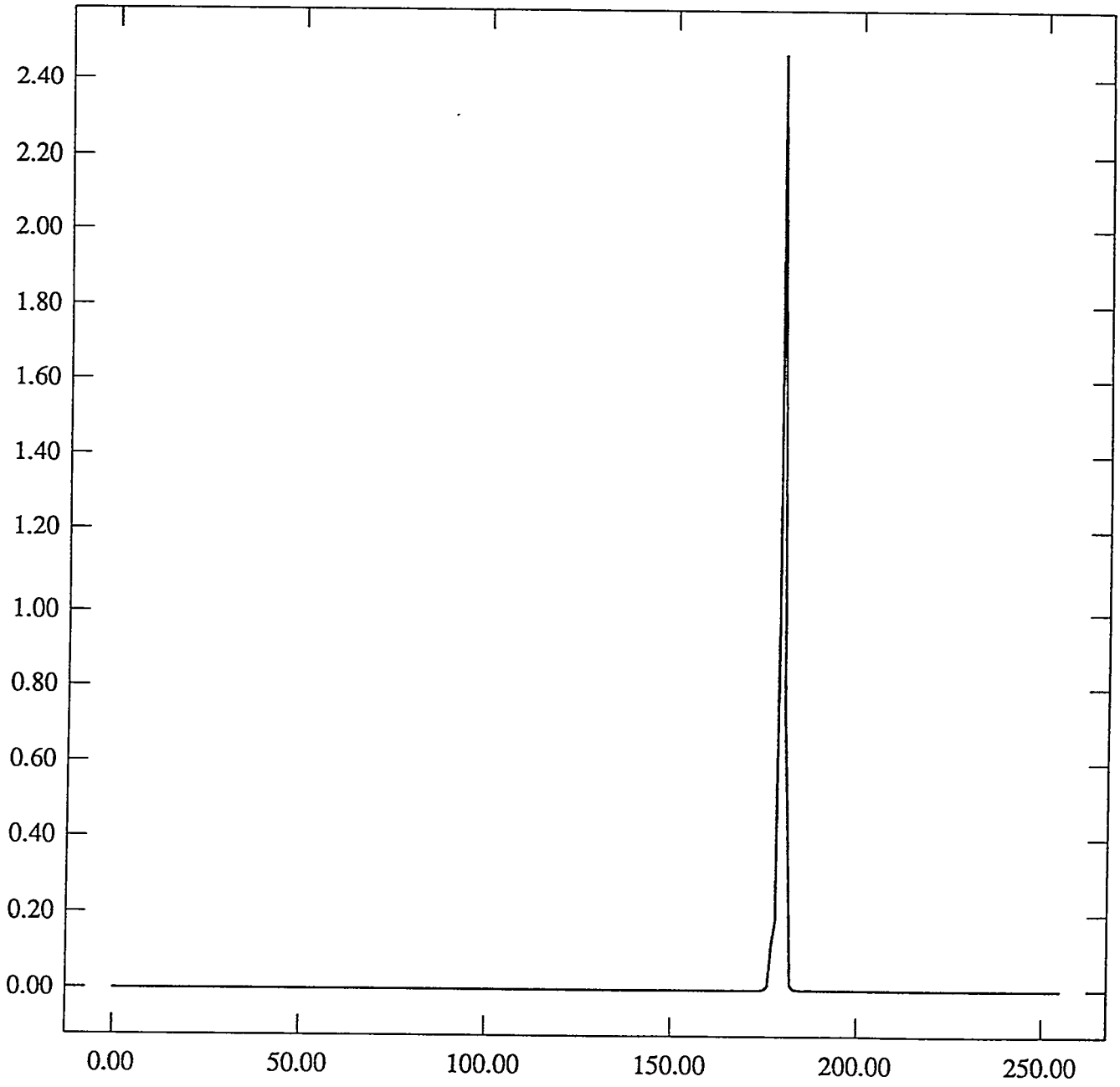
ST Camera: ST2 04-06 +10: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:30:46 1993

Pixel Values Min 172 Max 196 Mean 176.6 Sigma 1.57 x 10^3



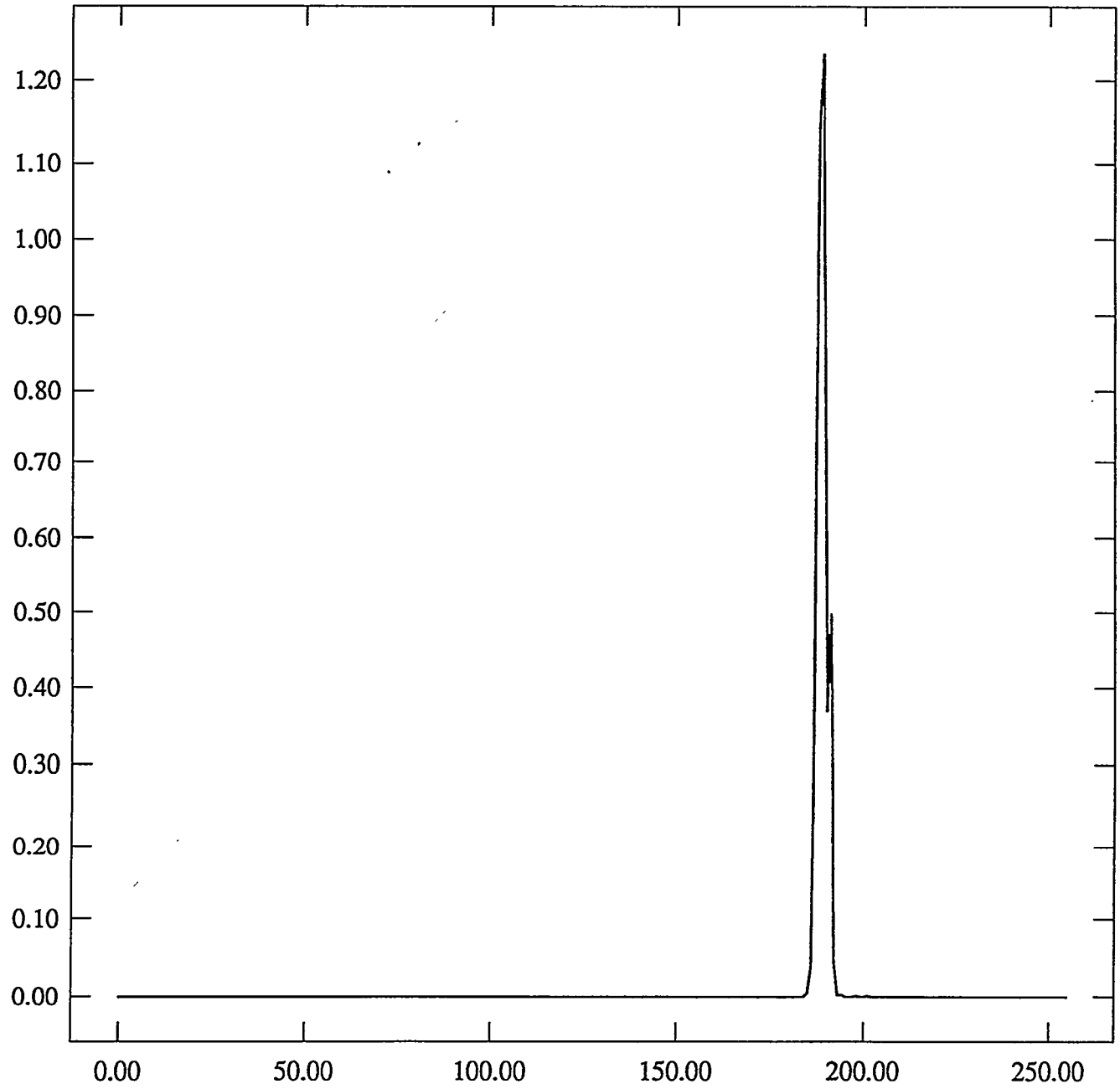
ST Camera: ST2 04-06 +20: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:44:58 1993

Pixel Values Min 175 Max 187 Mean 179.3 Sigma 0.90 x 10^3



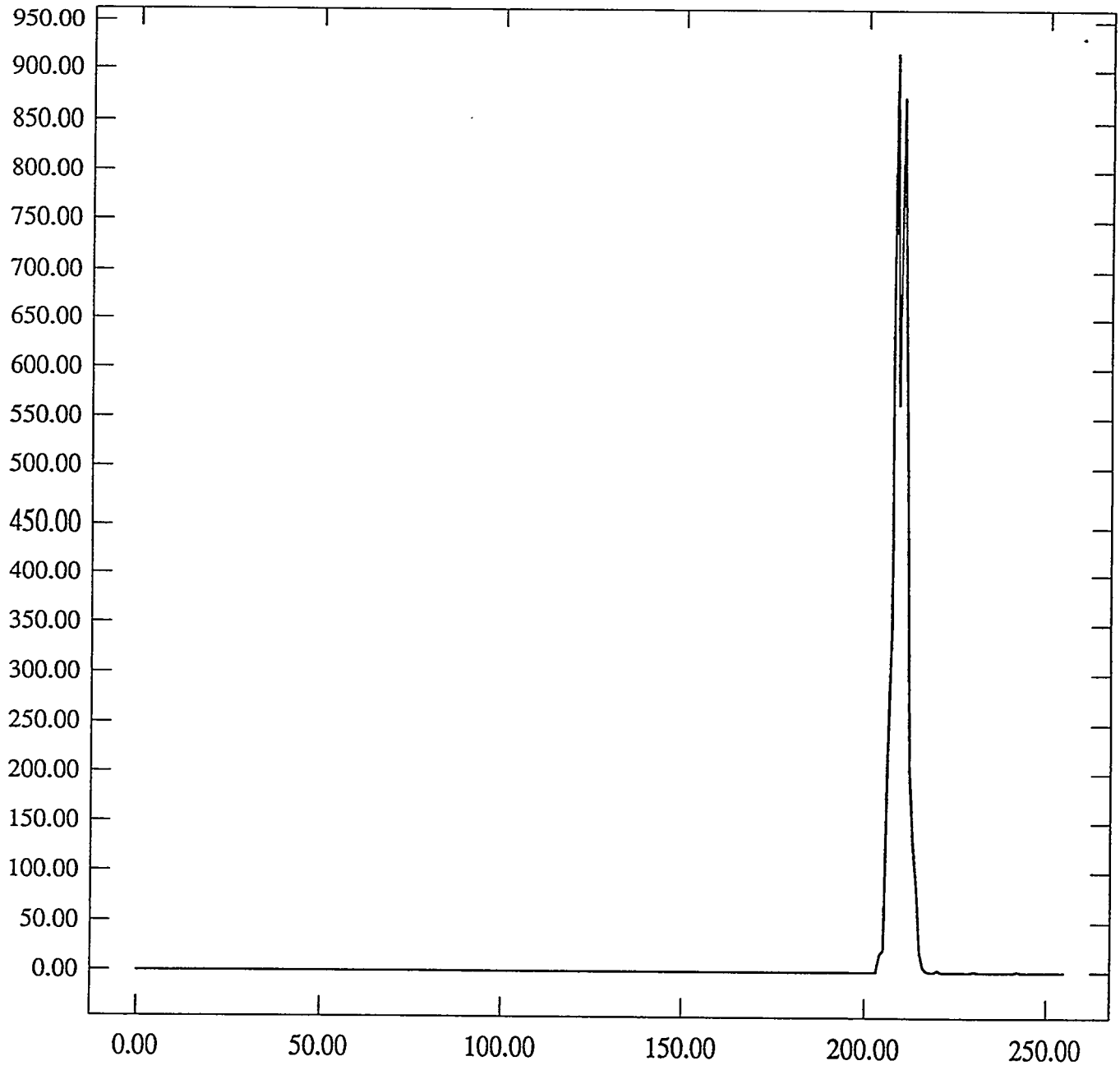
ST Camera: ST2 04-06 +20: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:45:31 1993

Pixel Values Min 185 Max 201 Mean 188.7 Sigma 1.33 x 10^3



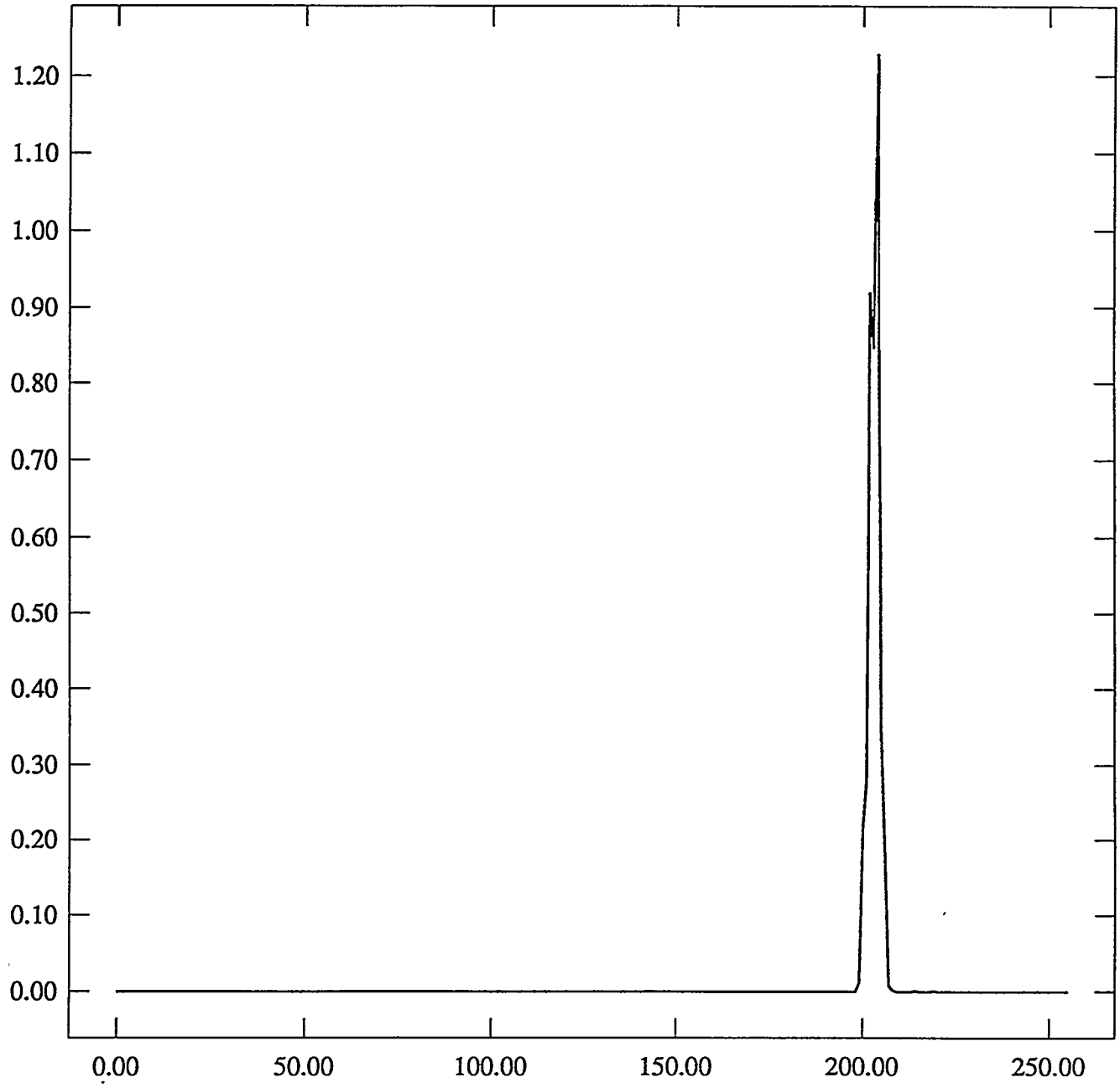
ST Camera: ST2 04-06 +20: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 16:46:03 1993

Pixel Values Min 204 Max 242 Mean 209.4 Sigma 2.04



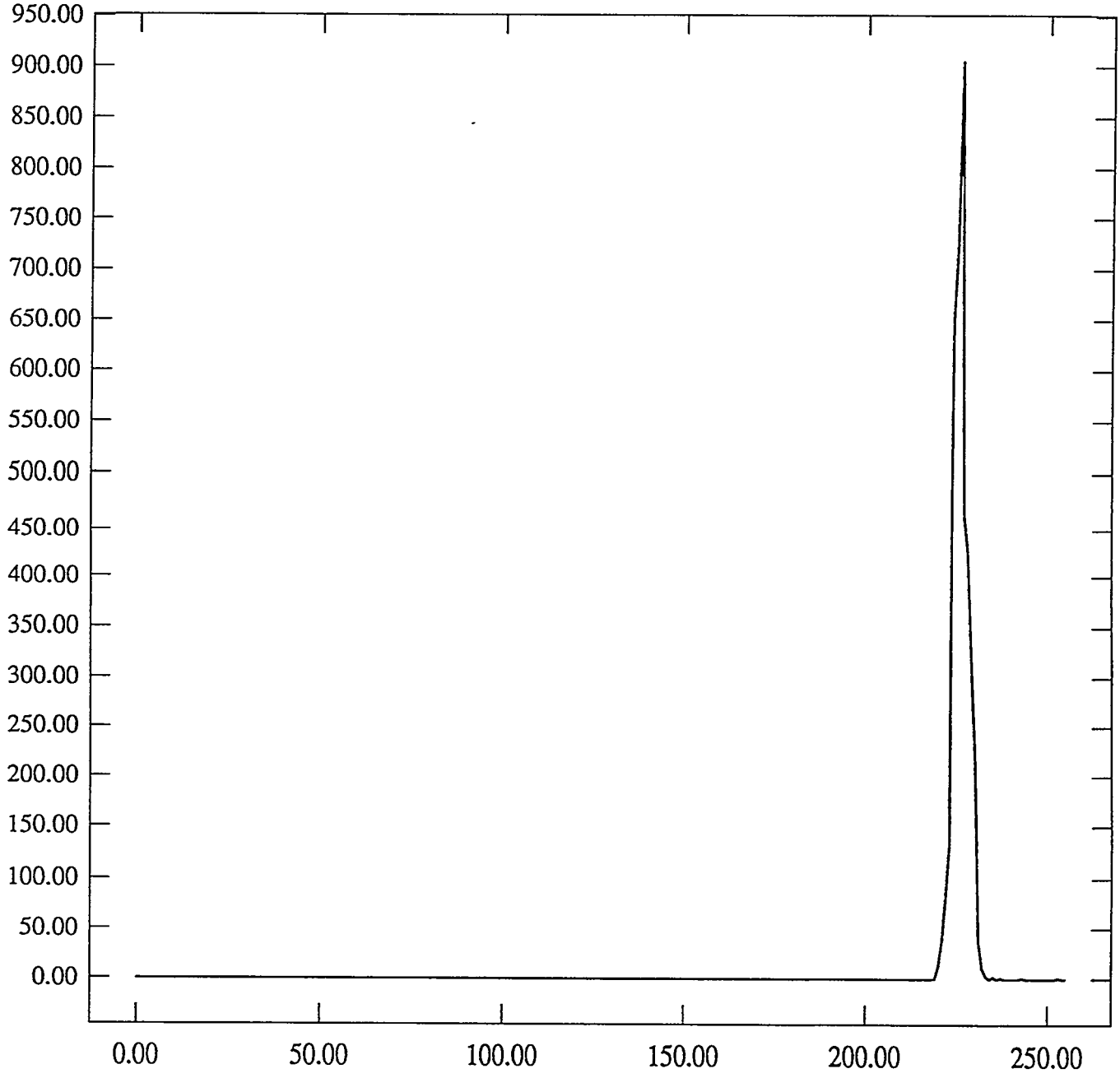
ST Camera: ST2 04-06 +30: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue May 11 17:05:07 1993

Pixel Values Min 199 Max 219 Mean 203.1 Sigma 1.49×10^3



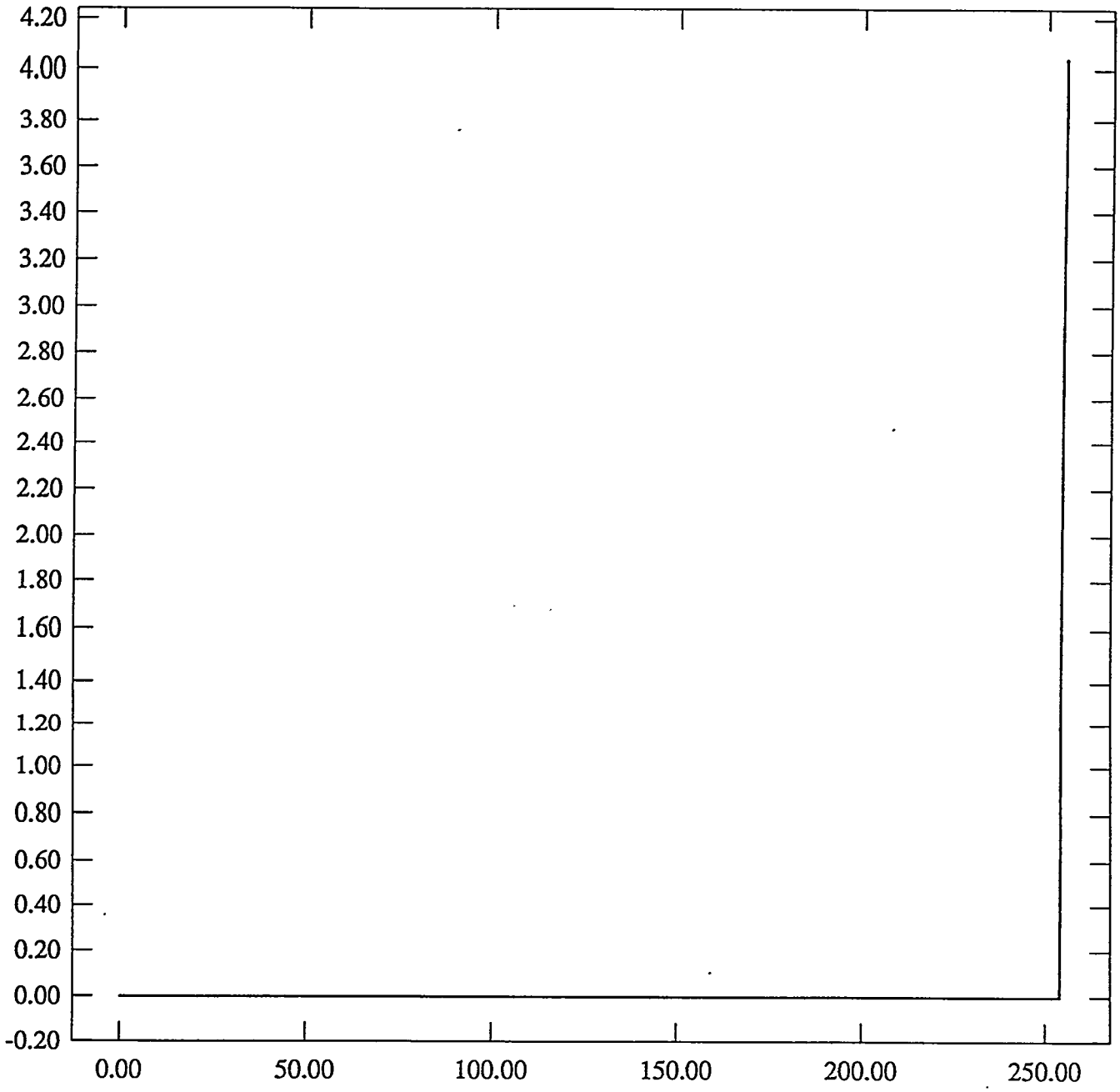
ST Camera: ST2 04-06 +30: int_time=100ms, offset= 0, gain=4 (75 e/bit) Tue May 11 17:06:07 1993

Pixel Values Min 220 Max 253 Mean 226.1 Sigma 2.14

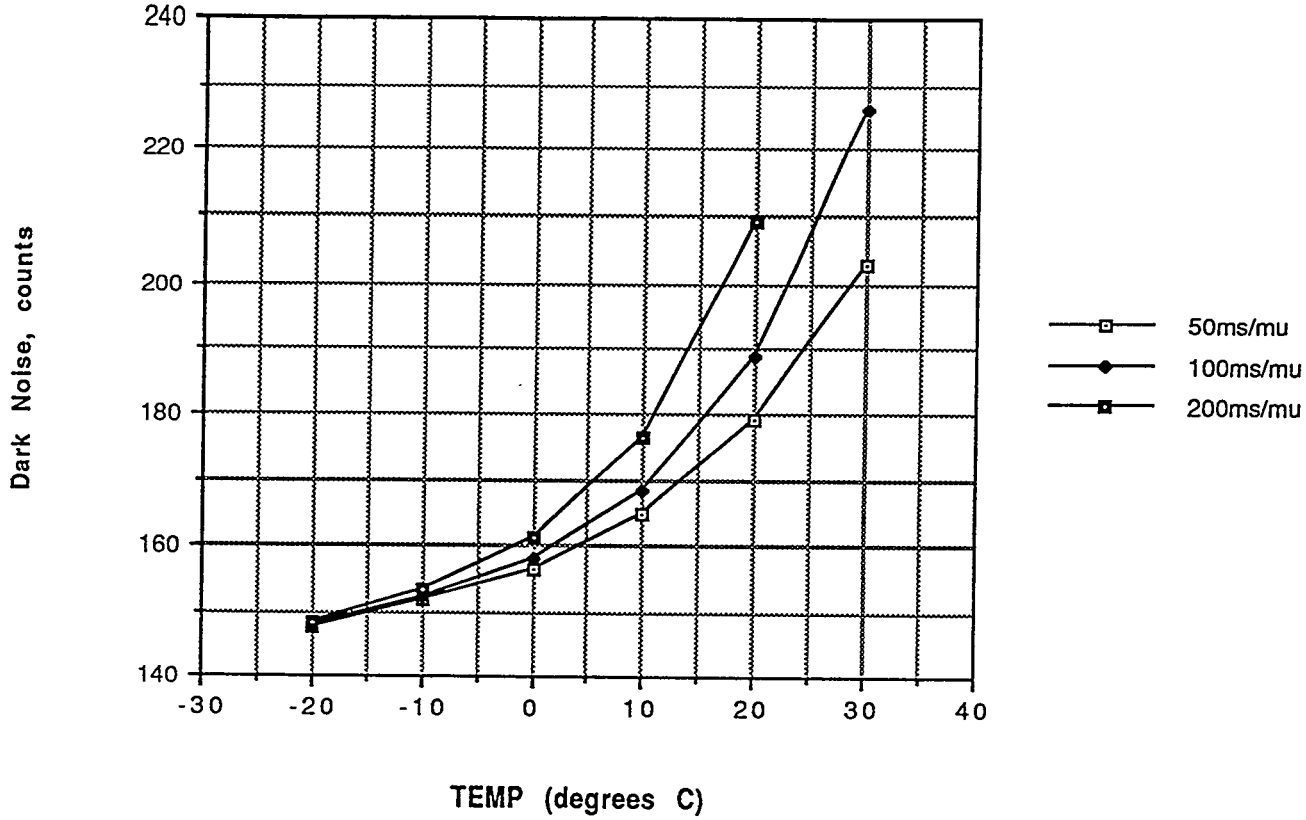


ST Camera: ST2 04-06 +30: int_time=200ms, offset= 0, gain=4 (75 e/bit) Tue May 11 17:07:04 1993

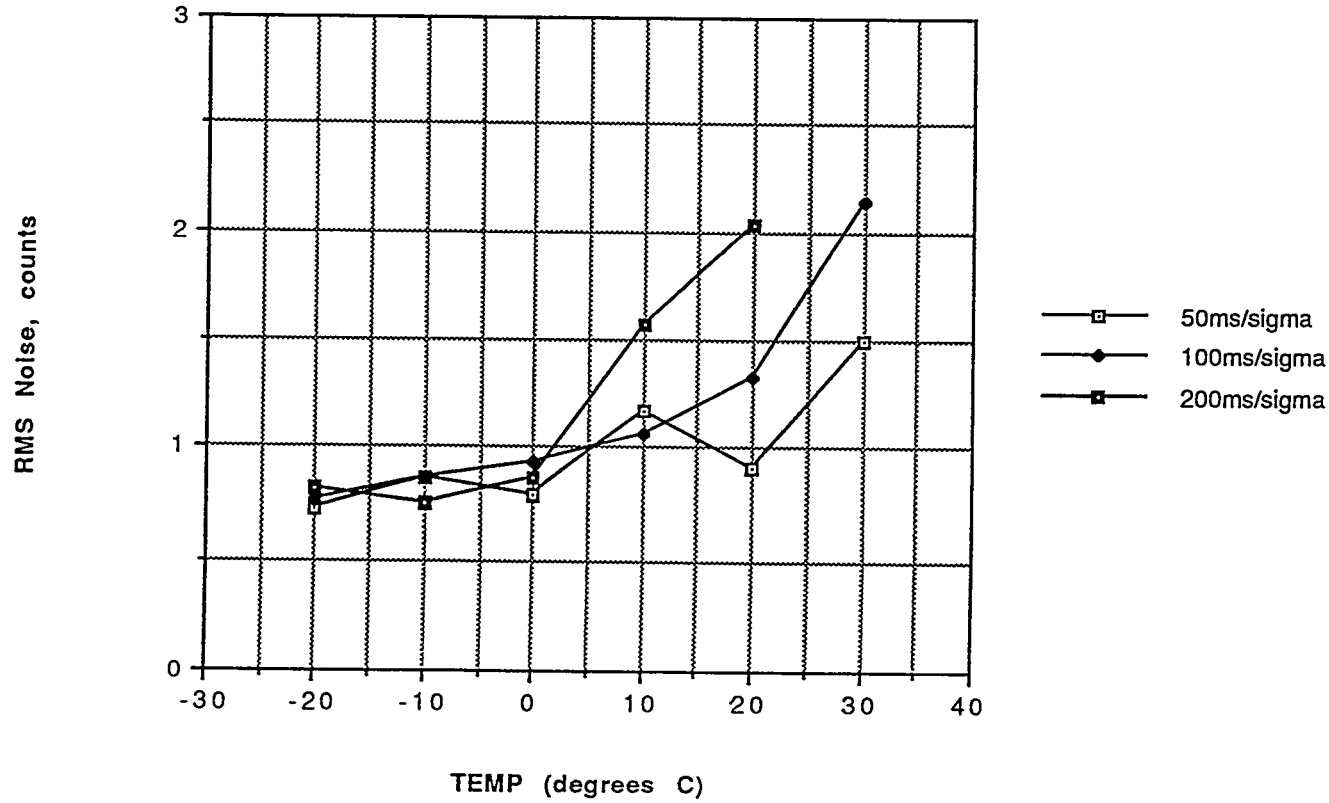
Pixel Values Min 255 Max 255 Mean 255.0 Sigma 0.00 x 10^3



ST2#04-06 75e/bit Mu °C Graph



ST2#04-06 75e/bit Sigma °C Graph



12.2 Thermal Measurement Acquisition

The Guide to running hspcube, C1-S1-002 explains a Fast 9 image capture. This program module automatically grabs a 50ms, 100ms and 200ms integration time images at all three gains. It then does a histogram of those images using a region of interest specified by the user.

Repeat Fast 9 completing your needed temperature range.

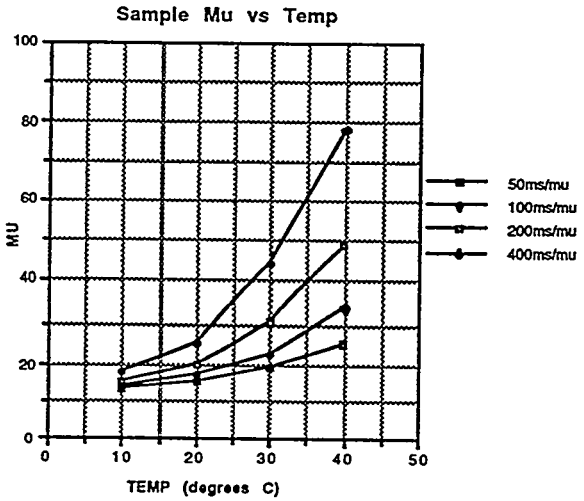
Fill in the Table below.

	50ms	50ms	100ms	100ms	200ms	200ms
Temp	Mu	Sigma	Mu	Sigma	Mu	Sigma
-20° C						
-10° C						
0° C						
10° C						
20° C						
30° C						

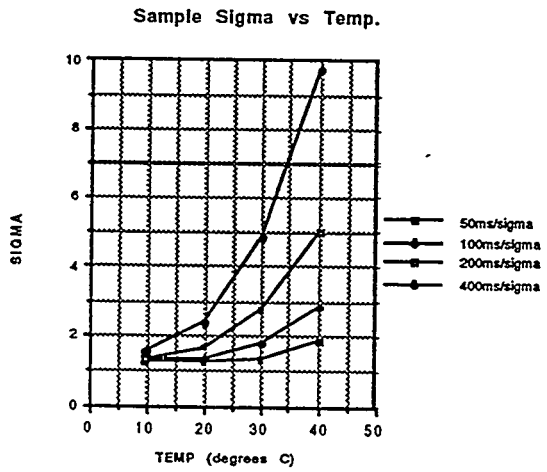
12.3 Thermal Data and Graphs

Graphing techniques will vary with software. However, if you use Cricketgraph, use the "line" graph format.

Plot Mu vs Temperature as below:



Plot Sigma vs Temperature like this:



SN# 04-06 By MO Date 5/18/93

initials passed

Remember to attach graphs and associated data to test procedure!
(a document protector is advised)

13. Flat Field Linearity Test

This test requires the use of the SUN Datacube and its image processing capabilities, a TV Optoliner Model K-4000 with neutral density(ND) filters ranging from 0.8 to 2.8, and a resolution chart for focusing.

13.1. Linearity Test Setup

Using alcohol and Q-tips clean the installed CCD.

Verify a properly connected camera acquisition system by acquiring an image. Always use a connector saver.

Turn on the test fixture.

Put the SUN Datacube in the Acquire mode, see *Guide to Running hspcube*—C1-S1-002.

Install a total 0.8ND filter and test pattern in the T.V. Optoliner.

Adjust the camera board so that the test pattern image is centered and focused on the CCD.

NOTE: Once focused, neither the camera nor the optoliner can be moved. Allow the T.V. Optoliner and camera to warm up under continuous operation for ≈1 hour before proceeding. Keeping the camera's environmental temperature constant and allowing a long warm up requires only one background histogram for linearity computation.

Remove the test pattern and replace with a flat field image.

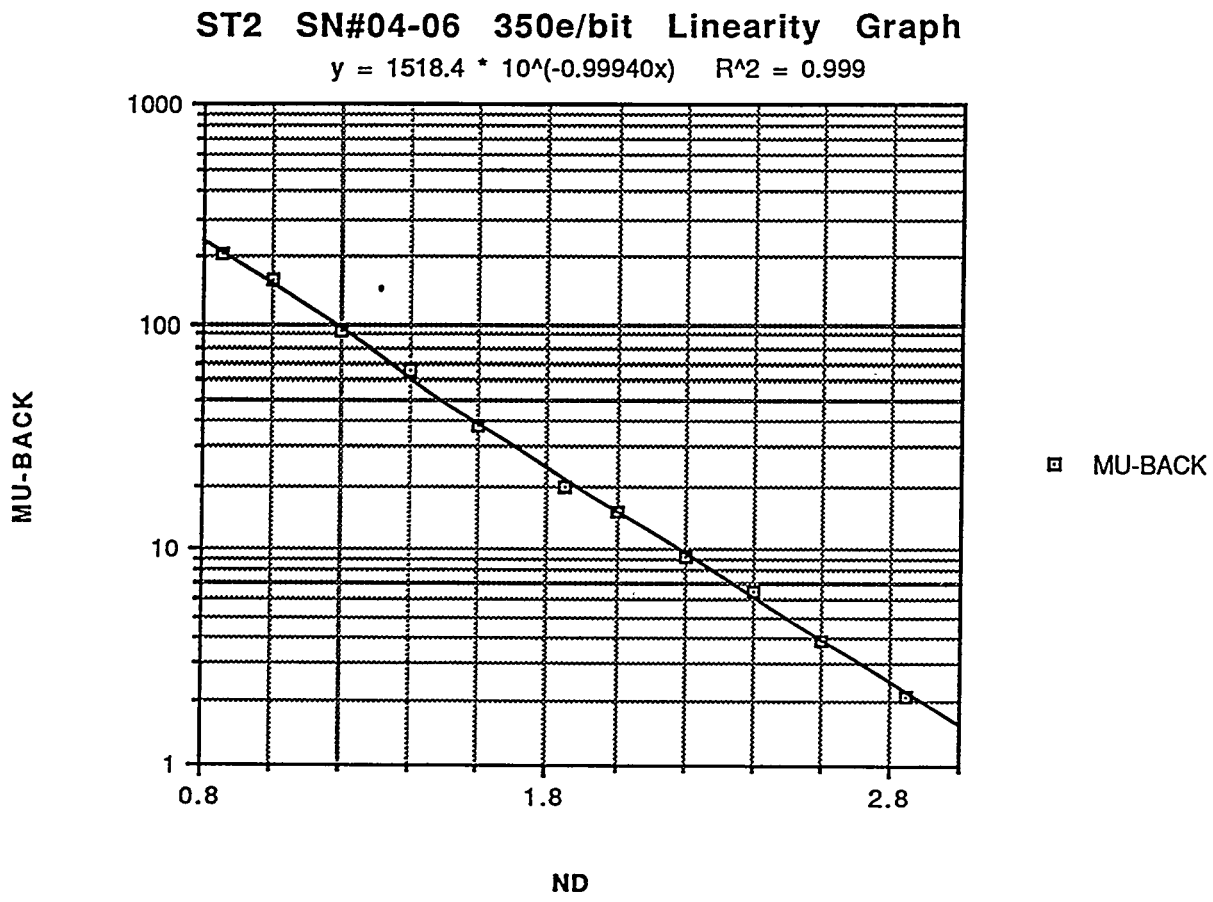
With 0.8 ND filtering installed in the optoliner, adjust the T.V. Optoliner lamp voltage so that you get a Mu count between 235 and 250.

13.2 Linearity Measurement Acquisition

Use the SUN Datacube "Acquire and build histogram Sequence " to capture a frame and process a defined region of interest. Then obtain its histogram.

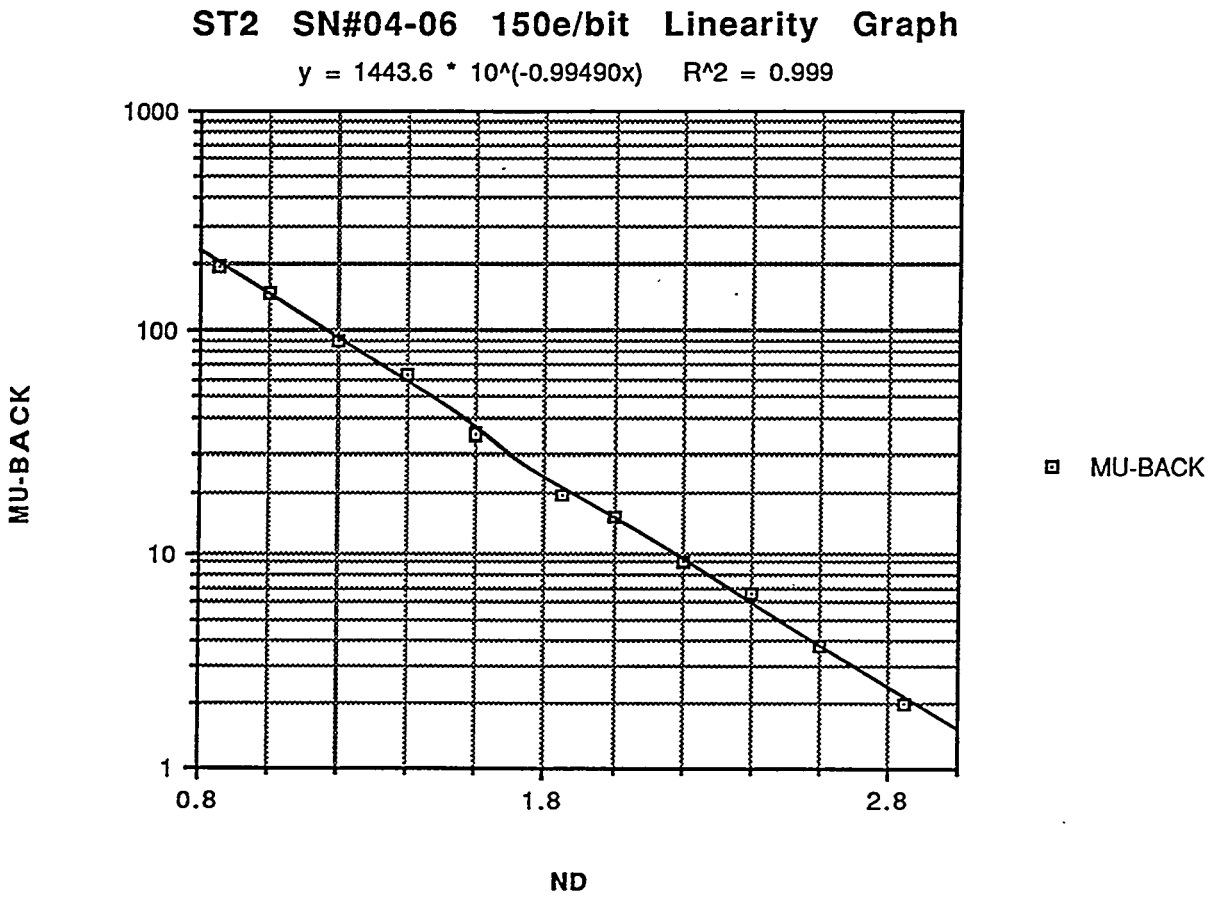
Pre-Linearity Focus
S/N # 04-06
5-11-93

200


ST2 SN#04-06 350e/bit Linearity Graph
y = 1518.4 * 10^(-0.99940x) R^2 = 0.999
1000
100
10
1
MU-BACK
0.8
1.8
2.8
ND
MU-BACK

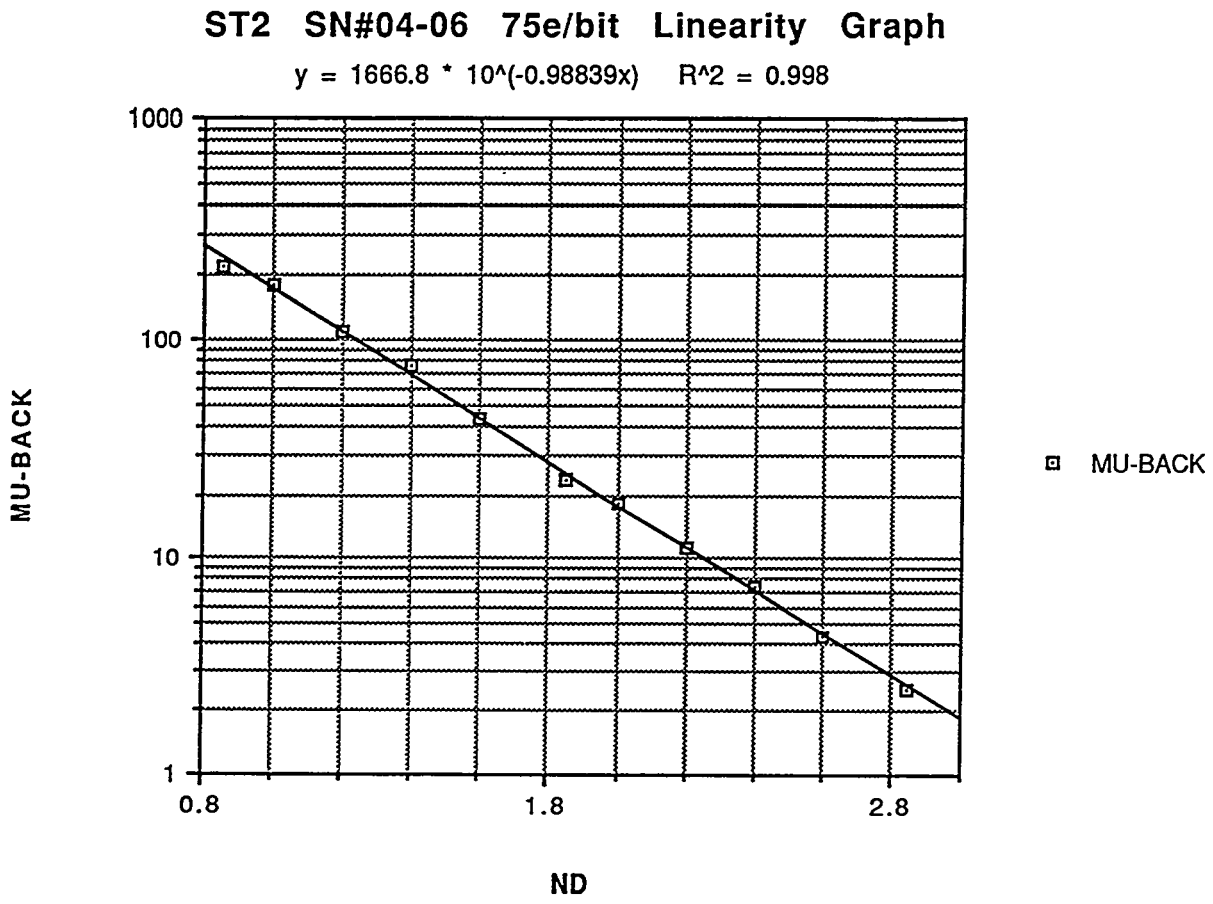
ST2/SN#04-06/350e/LNDT Thu, May 13, 1993 1:56 PM

	ND	MU	BACK	MU-BACK	Colu	NOTES:
1						
2	0.85	224.40	18.43	205.97		5/11/93
3	1.00	175.34	18.43	156.91		ST2 SN#04-06
4	1.20	113.20	18.43	94.77		14.0v
5	1.40	83.92	18.43	65.49		
6	1.60	55.98	18.57	37.41		SUNDATACUBE
7	1.85	38.68	18.57	20.11		offset=3
8	2.00	33.91	18.57	15.34		350e/bit
9	2.20	27.93	18.57	9.36		P.S.#5008
10	2.40	25.20	18.64	6.56		HEAD#4163
11	2.60	22.50	18.64	3.86		
12	2.85	20.72	18.64	2.08		


ST2 SN#04-06 150e/bit Linearity Graph
y = 1443.6 * 10^(-0.99490x) R^2 = 0.999
1000
100
10
1
0.8
1.8
2.8
MU-BACK
ND
MU-BACK

ST2/SN#04-06/150e/LNDT Thu, May 13, 1993 11:40 AM

	ND	MU	BACK	MU-BACK	Colu	NOTES:
1						
2	0.85	219.05	22.35	196.70		5/11/93
3	1.00	172.99	22.35	150.64		ST2 SN#04-06
4	1.20	113.87	22.35	91.52		12.0v
5	1.40	85.77	22.35	63.42		
6	1.60	58.26	22.46	35.80		SUNDATACUBE
7	1.85	41.86	22.46	19.40		offset=9
8	2.00	37.52	22.46	15.06		150e/bit
9	2.20	31.55	22.46	9.09		P.S.#5008
10	2.40	29.05	22.52	6.53		HEAD#4163
11	2.60	26.25	22.52	3.73		
12	2.85	24.54	22.52	2.02		


ST2 SN#04-06 75e/bit Linearity Graph
y = 1666.8 * 10^(-0.98839x) R^2 = 0.998
1000
100
10
1
MU-BACK
0.8
1.8
2.8
ND
MU-BACK

ST2/SN#04-06/75e/LNDT Thu, May 13, 1993 11:34 AM

	ND	MU	BACK	MU-BACK	Colu	NOTES:
1						
2	0.85	241.40	26.93	214.47		5/11/93
3	1.00	207.14	26.93	180.21		ST2 SN#04-06
4	1.20	135.97	26.93	109.04		11.3v
5	1.40	103.32	26.93	76.39		
6	1.60	70.91	27.53	43.38		SUNDATACUBE
7	1.85	50.68	27.53	23.15		offset=20
8	2.00	45.94	27.53	18.41		75e/bit
9	2.20	38.69	27.53	11.16		P.S.#5008
10	2.40	35.44	27.99	7.45		HEAD#4163
11	2.60	32.36	27.99	4.37		
12	2.85	30.43	27.99	2.44		

13.3 Linearity Data Collection.

Select the first gain setting.

Begin by taking a background level. Use an ND of 8.0 for background. Adjust the Offset so that the black level is equal to 20 counts and readjust the lamp voltage so that the average is equal to 240 - 250 counts with an ND of 0.85.

Starting with 0.8 ND, increment the ND filter value with 0.2 steps until MU almost equals the background. Acquire, build histogram, and record mu/sigma information for each ND value. Repeat this sequence for all 3 Gain settings.

Turn off power.

Sample data table:

ND	Mu	Backgnd	Mu-Back
0.85	249	82	167
1.0	211	82	129
1.2	159	82	77
1.4	136	82	54
1.6	113	82	31
1.85	99	82	17
2.0	95	82	13
2.2	90	82	8
2.4	87	82	5
2.6	85	82	3
2.85	84	82	2

Actual data table for gain of 4 = 75e/bit

SN# 04-06 Date 5/11/93
Offset 20 ..P.S.Volt 11.3 v

ND	Mu	Backgnd	Mu-Back
0.85	~~240.40~~	26.93	
1.0	207.14		
1.2	135.97		
1.4	103.32		
1.6	79.91	27.53	
1.85	50.68		
2.0	45.94		
2.2	38.69		
2.4	35.44	27.99	
2.6	32.36		
2.85	30.43		

Actual data table for gain of 2 150e/bit

SN# 04 - 06 Date 5/11/93
Offset 9 ..P.S.Volt 12v

ND	Mu	Backgnd	Mu-Back
0.85	219.05	22.35	
1.0	172.99		
1.2	113.87		
1.4	85.77		
1.6	58.26	22.46	
1.85	41.86		
2.0	37.52		
2.2	31.55		
2.4	29.05	22.52	
2.6	26.25		
2.85	24.54		

Actual data table for gain of 1 350e/bit

SN# 04 - 06 Date 5/11/93
Offset 3 ..P.S.Volt 14.0v

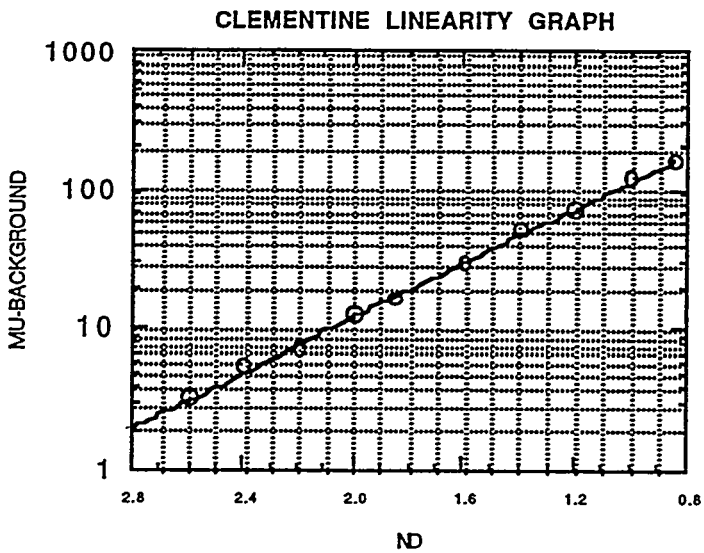
ND	Mu	Backgnd	Mu-Back
0.85	224.40	18.43	
1.0	175.34		
1.2	113.20		
1.4	83.92		
1.6	55.98	18.57	
1.85	38.68		
2.0	33.91		
2.2	27.93		
2.4	25.20	18.64	
2.6	22.50		
2.85	20.72		

13.4 Linearity Data Processing

Graphing techniques will vary with software. If you use Cricketgraph, select the "scatter" graph format. Note: Y axis = Mu-Back; X axis = ND.

Choose a logarithmic Y axis and an exponential curve fit.

Here is a flat field linearity graph using Cricketgraph:



Confirm your linear results:

SN# 04-06 By MD Date 5/11/93

initials passed

REMEMBER to include your recorded documentation in the test procedure!
(a document protector is advised)

14. Offset Linearity Test

This test requires the use of the SUN Datacube and its image processing capabilities, a TV Optoliner Model K-4000 with neutral density(ND) filters ranging up to 1.8, and a resolution chart for focusing.

14.1. Offset Linearity Test Setup

Using alcohol and Q-tips, clean the installed CCD.

Verify a properly connected camera acquisition system.

Power up the test fixture.

Put the frame grabber in the grab mode.

Install a total 0.8 Neutral Density (ND) filter and test pattern in the T.V. Optoliner.

Adjust the camera board so that the test pattern image is focused on the CCD.

NOTE: With the focal plane now established, neither the camera nor the optoliner can be moved.

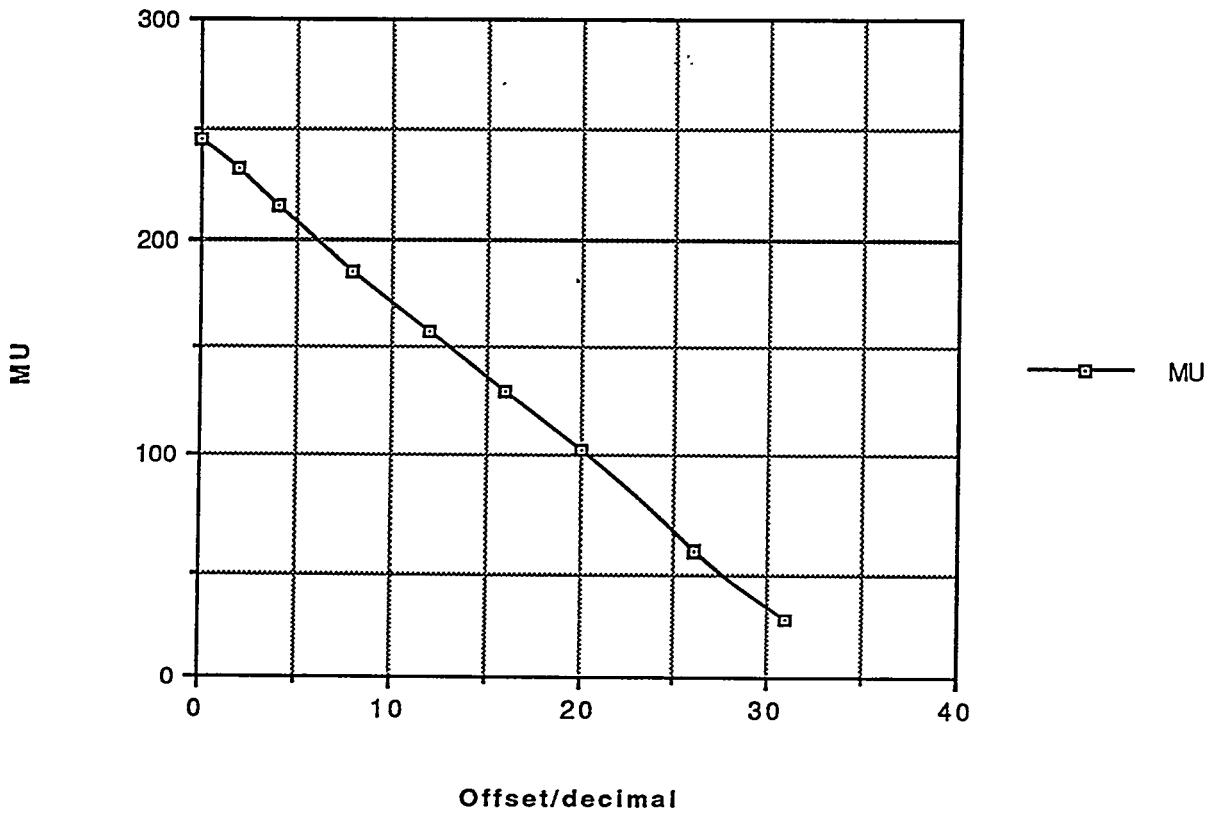
Remove test pattern for a flat field image.Set the board gain to gain setting of 2.

Remove all ND (ND = 0.0) and input a HEX offset of 00.

Adjust the T.V. Optoliner lamp voltage so that you get a *MU* of ≈250 counts.

Allow the T.V. Optoliner and camera to warm up under continuous operation for ≈1 hour before proceeding. Keeping the camera's environmental temperature constant and allowing a long warm up requires only one background histogram for linearity computation.

ST2 SN#04-10 Offset Linearity Graph



ST2/SN#04-06/OffLNDT Thu, May 13, 1993 2:22 PM

	Offset/decimal	MU	Colum	Column 4
1				
2	0	244.71		5/10/93
3	2	231.80		ST2 SN#04-06
4	4	215.30		P. S. = 14.0v
5	8	185.76		CCD#8846
6	12	157.43		SUNDATACUBE
7	16	129.87		
8	20	102.70		350e/bit
9	26	60.23		P.S.#5008
10	31	28.37		HEAD#4163

14.2 Offset Linearity Measurement Acquisition

Use the SUN Datacube " Acquire and build histogram Sequence " to capture a frame and process a defined region of interest and to analyze for mu/sigma histograms.

14.3 Offset Linearity Data and Graph

Begin by taking a background level. Use an ND of 8.0 for background.

Input the offset values listed in the table below recording a histogram of the defined region of interest each time.

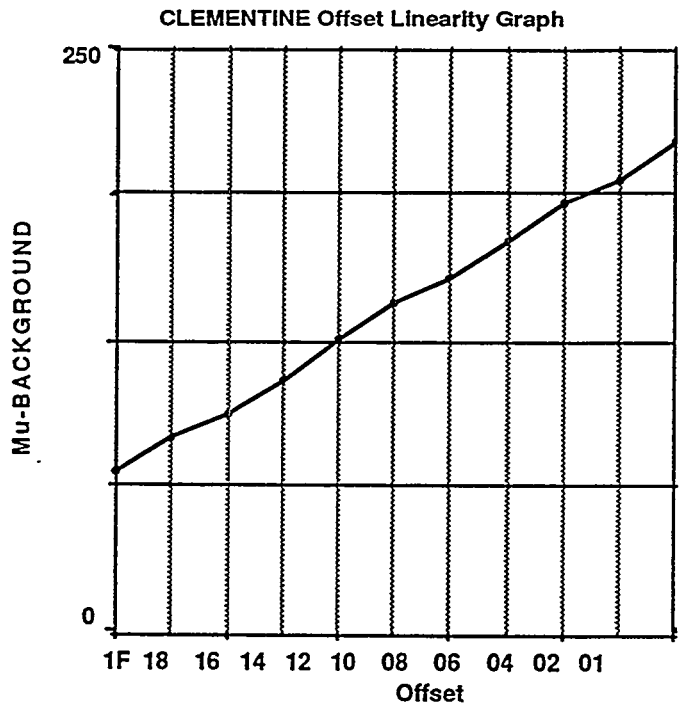
Power down the test fixture.

Offset	Mu	Backgnd	Mu-Back
00	244.71		
02	231.80		
04	215.30		
08	185.76		
12	157.43		
16	129.87		
20	102.70		
26	60.23		
31	28 37		

Graphing techniques will vary with software. If you use Cricketgraph, select the "scatter" graph format. Plot MU-BACKGROUND vs OFFSET

Choose a linear Y axis and linear curve fit.

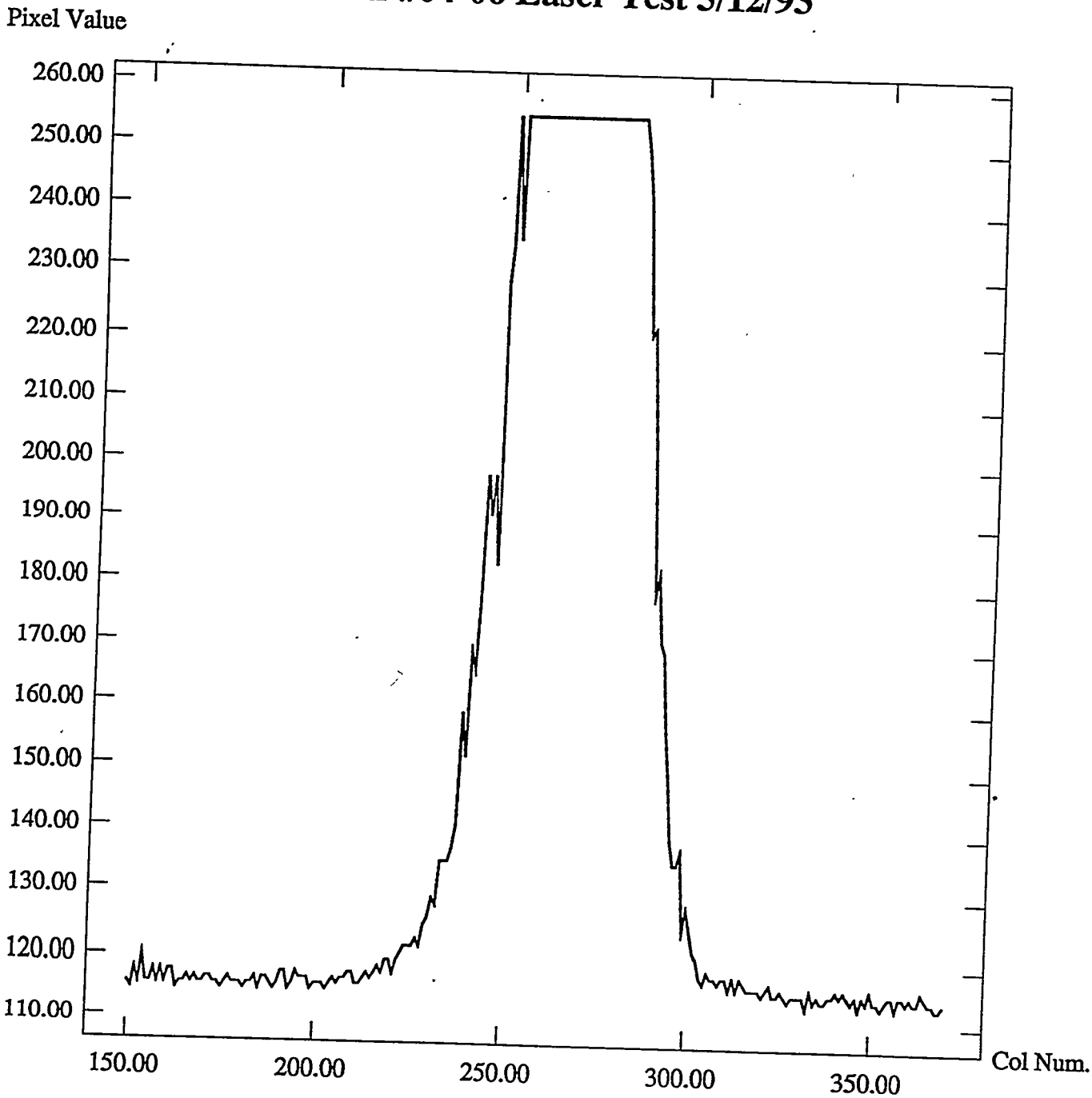
Here is an offset linearity graph using Cricketgraph:



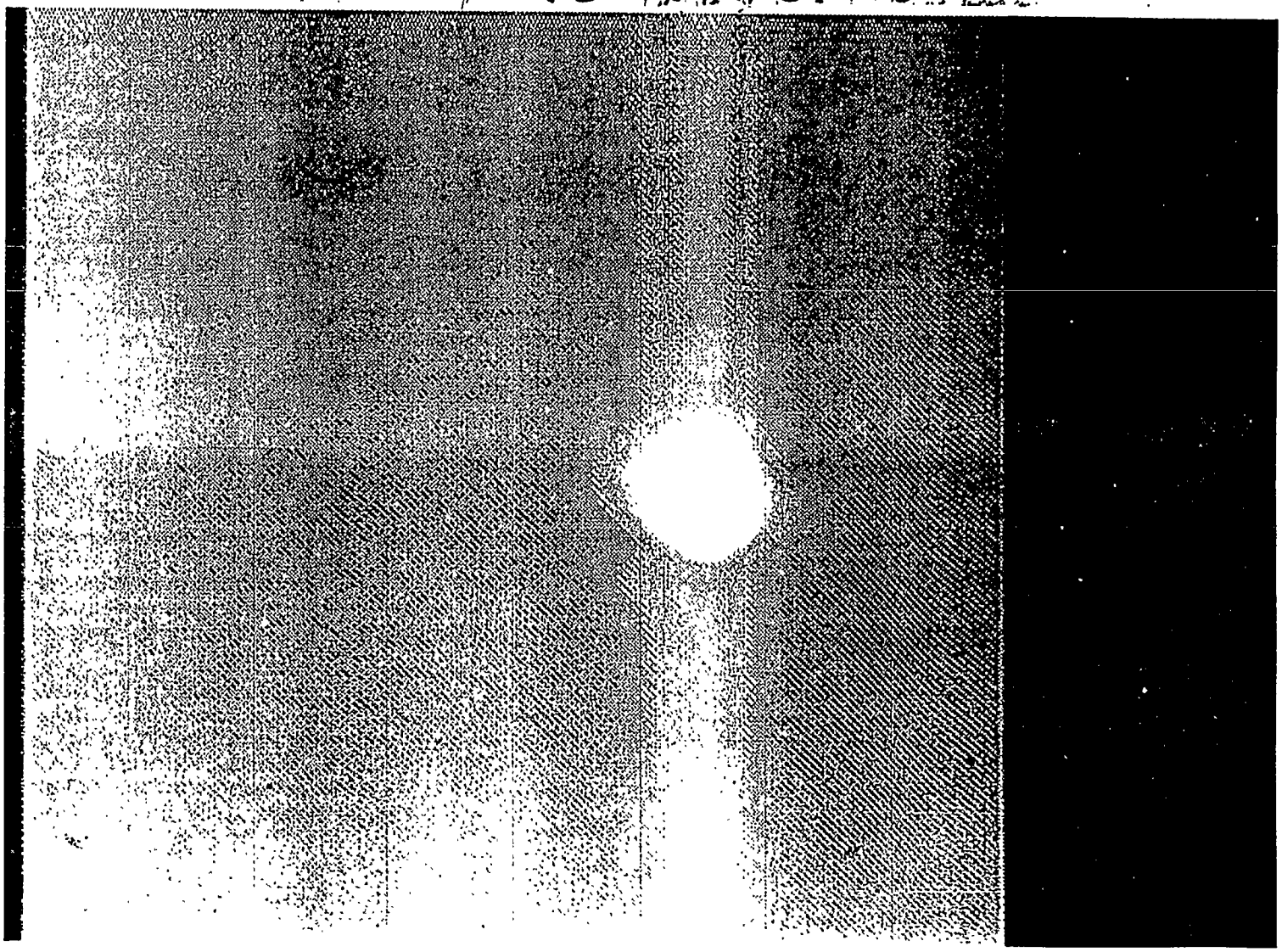
SN# 04-06 By MT (initials) Date 5/10/96 (passed)

REMEMBER to include your recorded documentation in the test procedure!
(a document protector is advised)

ST2 #04-06 Laser Test 5/12/93



Laser Test: 5/12-93 S/N: # 04-06



15. Laser Test

This test requires the use of the SUN Datacube and its image processing capabilities, a HeNe Laser, 1mW at 632.8nm appropriate ND filters ranging from 2.0 to 6.0 or combinations equaling such.

Verify a working camera system.

Turn off camera power.

Position a HeNe Laser on the approximate center of the CCD.

Place an optical ND filter holder in the path of the laser beam.

Power the camera.

Place the SUN Datacube in the Acquire mode.

Do a Print Pixel—see *Guide to Running hspcube, C1*-S1-002—to check pixel values of illuminated area.

Install sufficient optical ND to reduce the intensity of the laser light to the saturation level of the CCD or 255 counts.

Do a Get Row Lineout plot—see *Guide to Running hspcube*,C1-S1-002—through the illuminate area.

Note: There should be no oscillations or tailing around the saturated spot.

Use the video copier to record the non-oscillating saturated laser spot image.

SN# 04-06 By MD (initials) Date 5/12/93 (passed)

REMEMBER to include your recorded documentation in the test procedure!
(a document protector is advised)

16. Tests Required after Conformal Coating

Archive/record a post conformal coat:

1) Dark Noise Measurement (Section 11).

2) A focused test pattern image using the TV Optoliner.

SN#_____ By_____ Date_____
initials passed

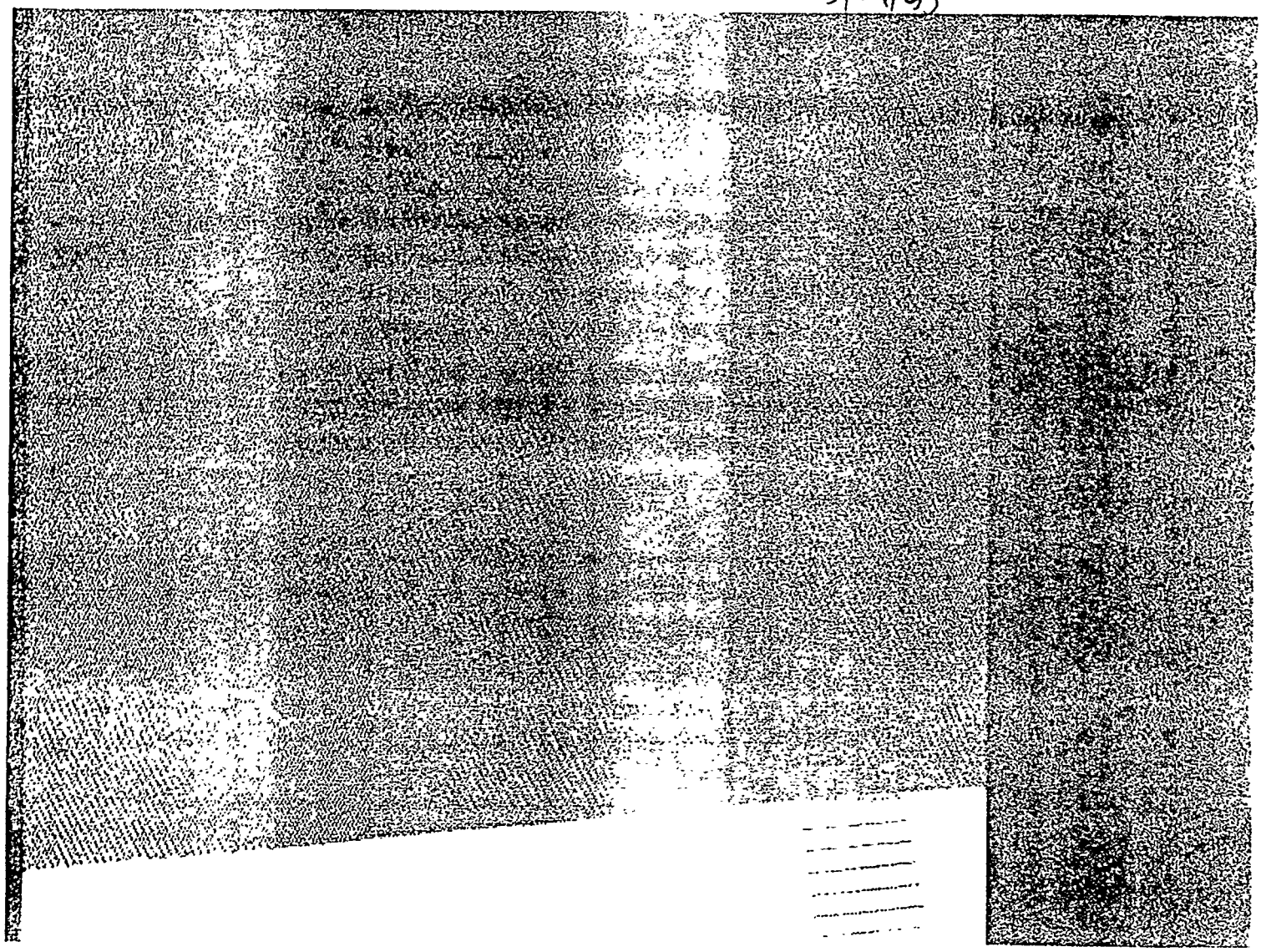
REMEMBER to include your recorded documentation in the test procedure!
(a document protector is advised)

Was this satisfactorily completed?

BP

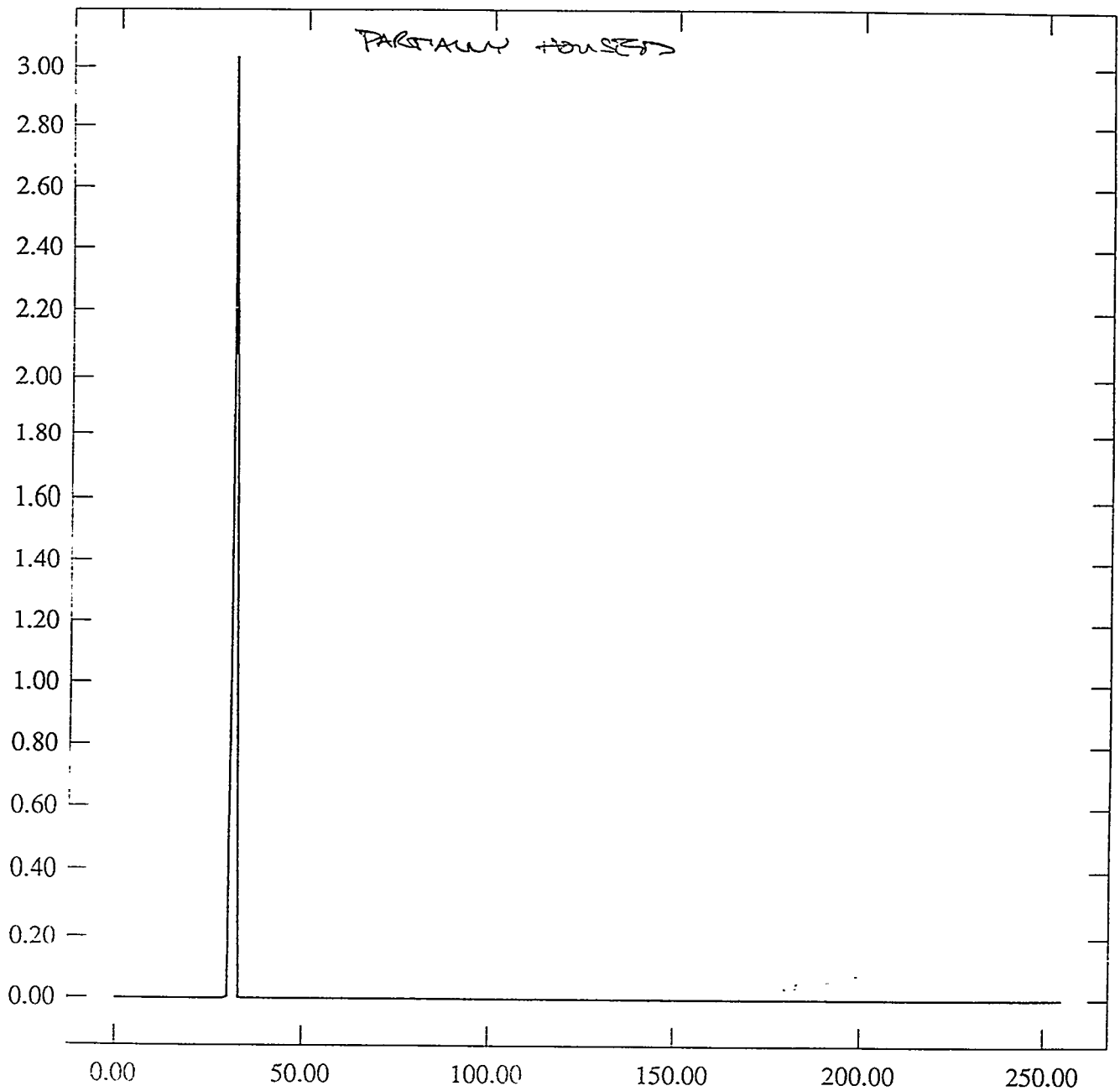
Is the test a moot point? If so, strike it & initial

5/24/93



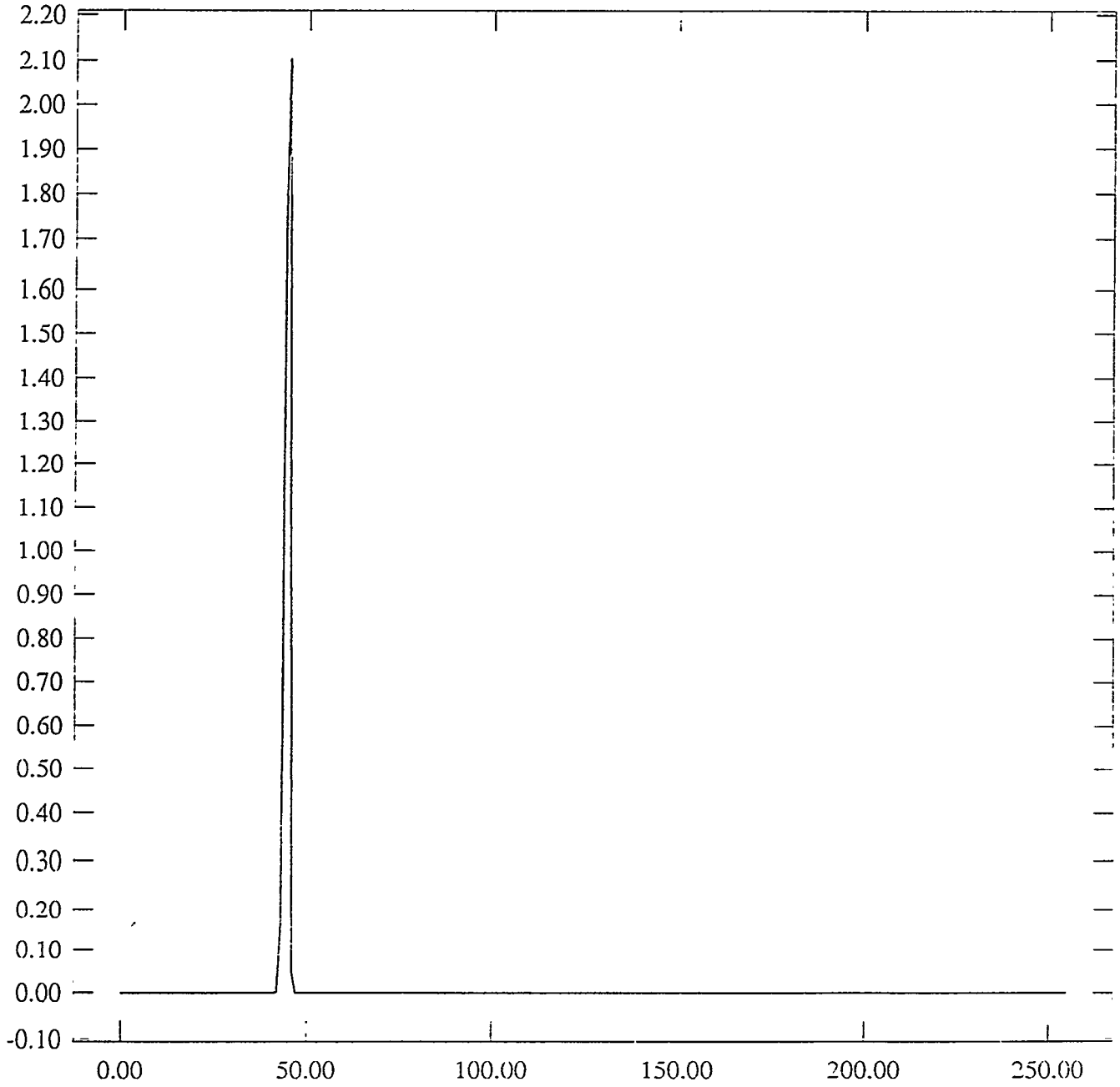
ST Camera: sn#04-06: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Mon May 24 09:52:09 1993

Pixel Values Min 30 Max 33 Mean 31.2 Sigma 0.43 x 10^3



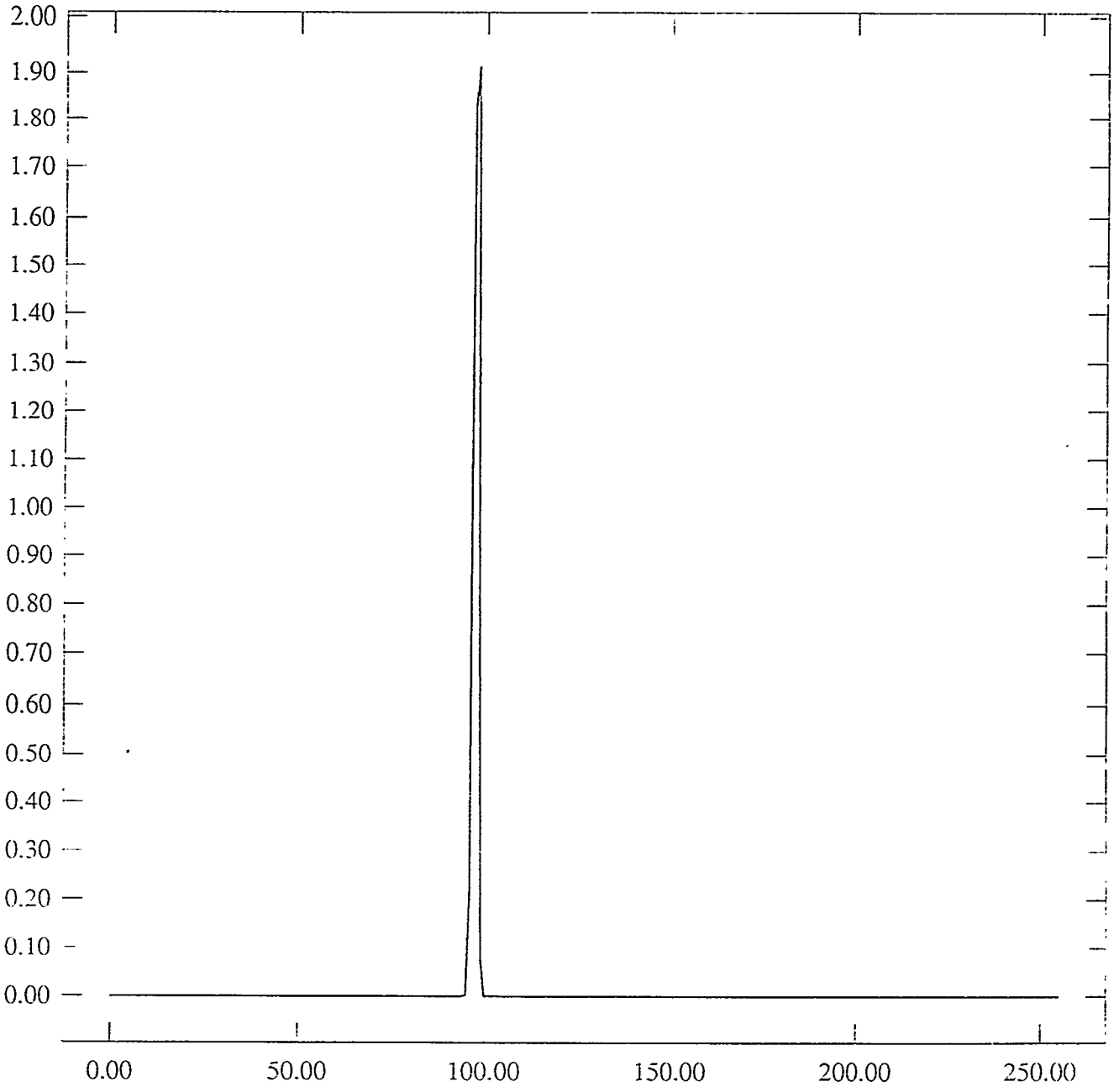
ST Camera: SN#04-06hsdFO#1: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Mon May 24 23:09:27 1993

Pixel Values Min 42 Max 46 Mean 44.5 Sigma 0.60 x 10^3



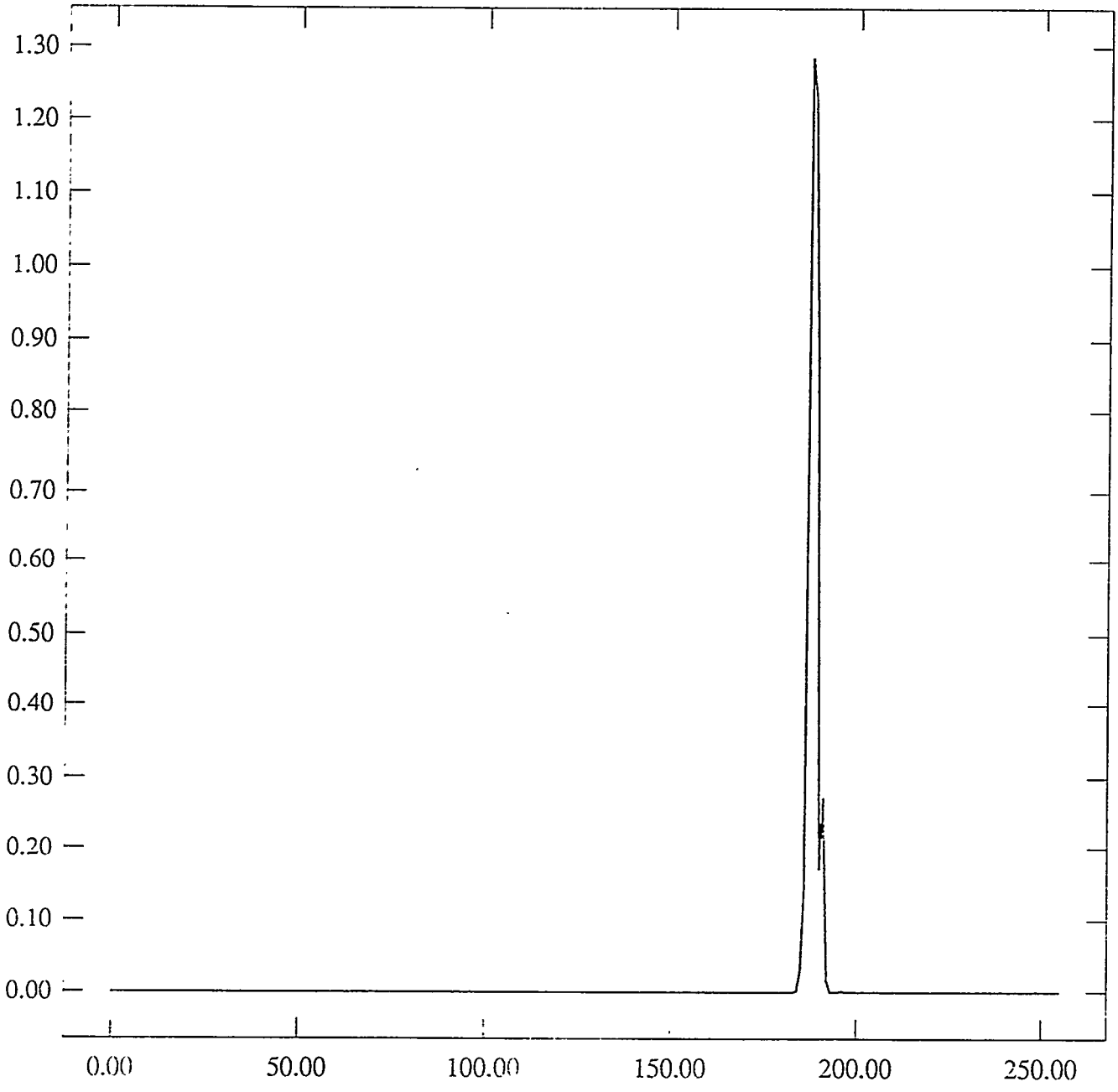
ST Camera: SN#04-06hsdFO#1: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Mon May 24 23:10:51 1993

Pixel Values Min 95 Max 103 Mean 97.5 Sigma 0.64 x 10^3



ST Camera: SN#04-06hsdFO#1: int_time= 50ms. offset= 0. gain=4 (75 e/bit) Mon May 24 23:12:29 1993

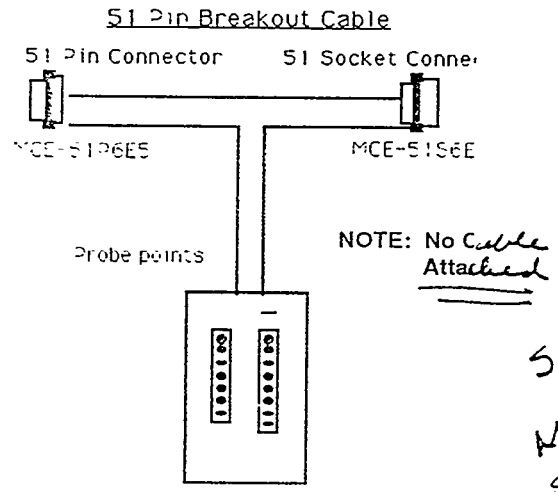
Pixel Values Min 184 Max 196 Mean 188.1 Sigma 1.27 x 10^3



1. Sub and Final Assembly Resistance and Voltage Specificity prior to Power-up

Inspect the camera for connector saver and shorting plug. If one or both of these are not present obtain them. A 51-contact breakout should be attached to the connector saver to perform this test. The 51-contact shorting plug should be attached to the connector saver for transport or storage once this test is complete.
Using a flight certified breakout connector—

ST 313



ST 313 Matches previous ST with CCD installed

—Verify these resistances:

pin# DVM(common)	vs	pin# DVM(signal)	expected	measured Ω
5 (AGND)	-	39 (+15VDC)	>400Ω	487 Ω
	-	4 (-15VDC)	>12KΩ	12KΩ
	-	37 (+5VDC)	>400Ω	429 Ω
	-	38 (+5VDC)	>400Ω	429 Ω
	-	3 (-5VDC)	>1kΩ	1.5KΩ
	-	40 (+5VIN)	>4kΩ	4 KΩ ?
20 (DGND)	-	5	≤1Ω	.3 Ω
	-	39	>400Ω	481 Ω
	-	37	>400Ω	429 Ω
	-	38	>400Ω	429 Ω
	-	3	>1kΩ	1.53KΩ
	-	40	>4KΩ	4.31KΩ ?
39 (+15VDC)	-	4	>11KΩ	11.7KΩ
	-	37	>10KΩ	958 Ω ? ? 958
	-	38	>10KΩ	958 Ω ? ? 958.
	-	3	>10KΩ	2 KΩ ? ? 2KΩ
	-	40	>15KΩ	4.8KΩ ? ? 4.8K

4 (-15VDC)	-	37	>12KΩ	13KΩ
	-	38	>12KΩ	13KΩ
	-	3	>13KΩ	14KΩ
	-	40	>13KΩ	13KΩ
37 (+5VDC)	-	38	≤1Ω	0KΩ ?
	-	3	>2kΩ	1.9KΩ
	-	40	>4KΩ	4.8KΩ ?
3 (-5VDC)	-	40	>5kΩ	5.9KΩ ?
2 (CGND)	-	51	≤1Ω	<1Ω ~~0KΩ~~ Ω
	-	36	∞	open ~~0KΩ~~ Ω
	-	5	∞	open ~~0KΩ~~ Ω

Using a flight certified breakout connector, verify power voltages at cable connector—camera end—**before** attaching it to the camera board. Use J1-pin 20 for multimeter ground and complete the following table.

J1 pin #	Expected V	Measured V	chassis gnd
39	+15V	_____	open
4	-15V	_____	open
37,38	+5VDC	_____	open, open
3	-5V	_____	open
40	+5VAIN	_____	open

Turn off the power. Specificity verified, the camera and cabling are ready for power-up.

SN# ST313 By_____ (initials) Date 6/15/93 (passed)

2. Room Temperature Dark Measurement Data

Connect a quality assured data acquisition system and cabling with the resistance verified camera to be tested.

Acquire images at all three gain values—1.2. and 4—using a 50ms integration time and 0 offset.

Turn off power.

Using the same region of interest for each acquired image, process a histogram resulting in MU and SIGMA values. These values should correspond to those taken at ≈20°C during the Thermal Test. Therefore. review the 50ms data for all three gains at 20°C. NOTE: This assumes the thermal test was performed with the same CCD now housed.

SN# ST 313 By_____ (initials) Date 6/15/93 (passed)

3. Imaging Verification

With adequate lensing, capture an image with the Startracker or UV-Vis camera and verify that it does image.

Place an image-on-clear or text-on-clear transparency against the Lidar intensifier and gate the intensifier appropriately to capture a Lidar image.

SN# ST313 By_____ (initials) Date 6/15/93 (passed)

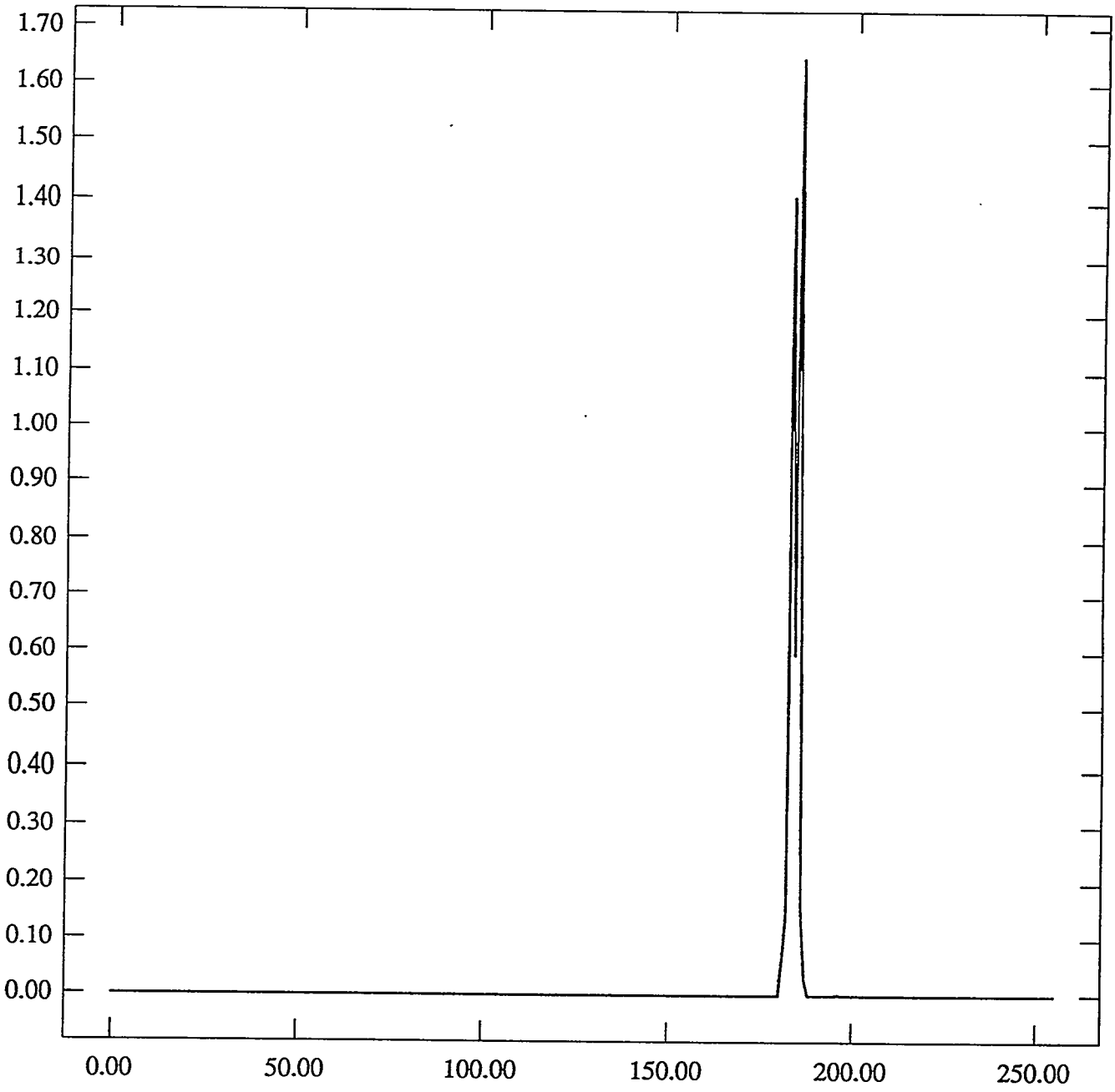
REMEMBER to attach your recorded documentation to this test procedure!
(A document protector is advised)

Imaging Verified 4.15.93

Particles . = Hot Camera

ST Camera: SN#04-06 HSD: int_time= 50ms, offset= 0, gain=4 (75 e/bit) Tue Jun 15 12:39:11 1993

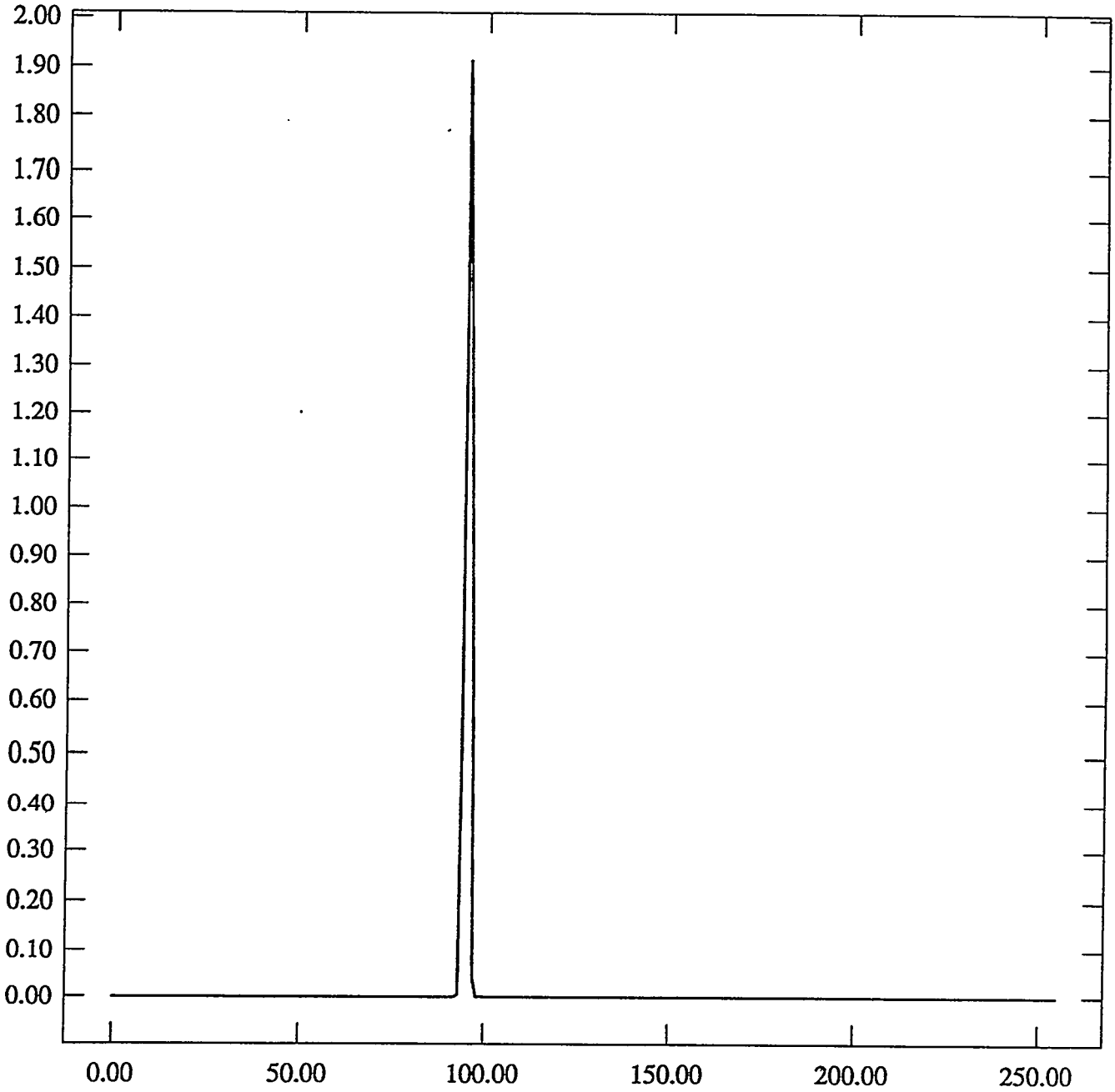
Pixel Values Min 181 Max 196 Mean 184.0 Sigma 1.13 x 10^3



Dark Areas. HOT Camera

ST Camera: SN#04-06 HSD: int_time= 50ms, offset= 0, gain=2 (150 e/bit) Tue Jun 15 12:38:11 1993

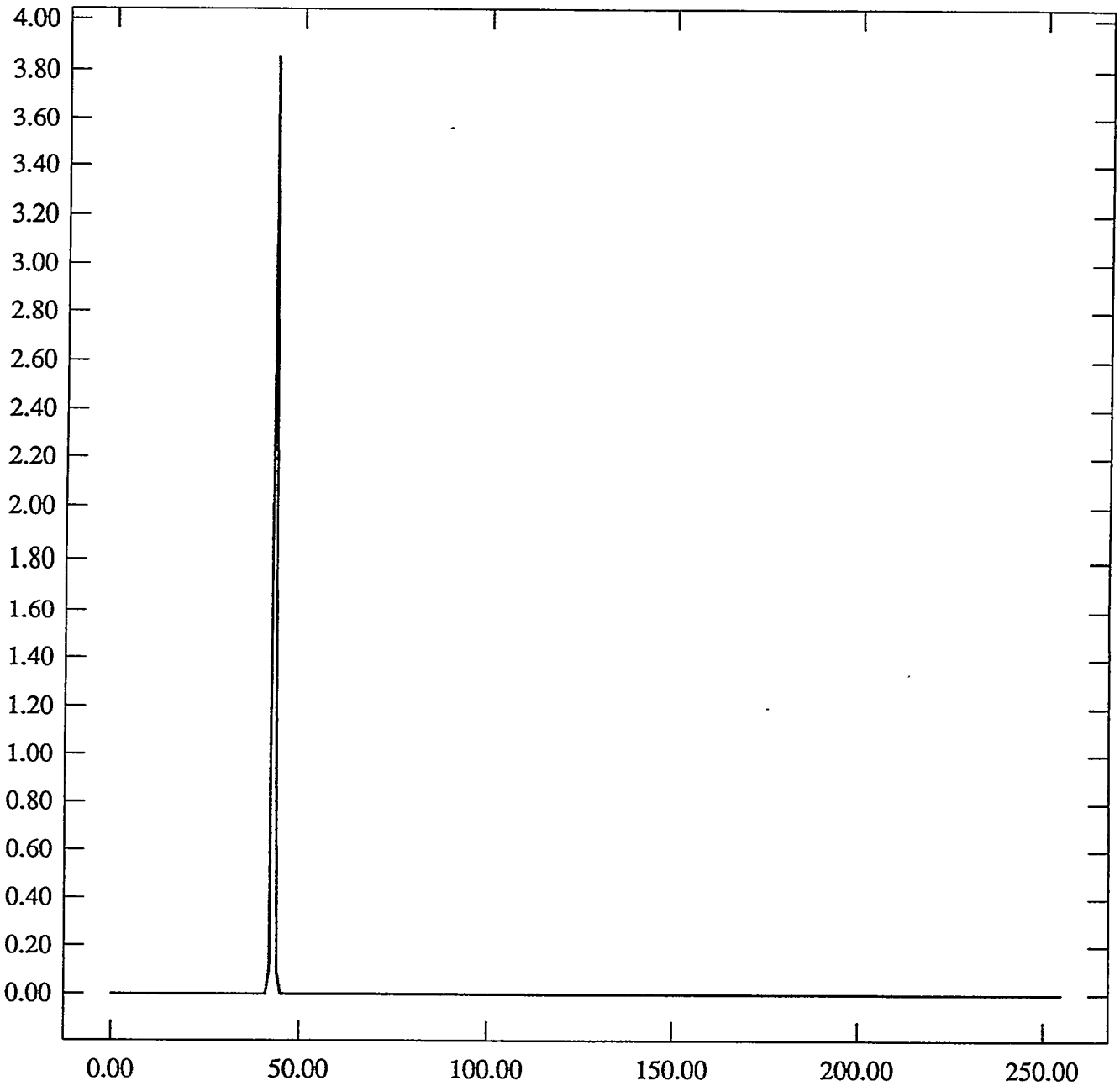
Pixel Values Min 93 Max 99 Mean 95.0 Sigma 0.75 x 10^3



Dark Frame = Hot camera

ST Camera: SN#04-06 HSD: int_time= 50ms, offset= 0, gain=1 (350 e/bit) Tue Jun 15 12:37:04 1993

Pixel Values Min 42 Max 45 Mean 43.0 Sigma 0.22 x 10^3



Appendix G.3

Mechanical Assembly Log

Appendix G.3.1

Operations Sheet

8-4-93

Clementine Operations Sheet, Certification

Part Number C1-AAA92-106282 TAB~~01~~ 02	**Serial No.** ST313	**Description** Star Tracker Camera, V3.1	**Certification Log #** CL007
Next Assembly / Deliver To: None		**Account Number:** 7069-20 / **Release To (Shop):** Jim Dickie 1882B	**End Use** Flight
Prepared By: Kathy Coatney	**Date:** 3 May 93	**QA:** W.R. Bryson	**Production Date:** 3-24-93
			Approved By: / **Date**

Associated Documentation:	**Notes:**
Assembly Log,	
Document Tree, C1-AAA92-106282 Tab 01-00	
Assembly Procedure, C1-S1-012	
Assembly Drawing, AAA92-106277-00	
Test Procedure,	

Change Verification Record or Engineering Change Notice Record

Parts List or Dwg Number	Dwg Chg Letter	Eco Number	Description or Remarks	Opr	QA

Appendix G.3.2

Work Sheets

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
C1-AAA92-106282 Tab 01	ST313	Star Tracker Camera, V3.1	01

#	Operation	Date:	Oper.	Insp.
1	Bonded 4 Corner (.010 Cu) Shims into Rear	5/22/93	JWD	
	Cover - Used Tra-Con 2902 - Cured 2 Hrs @ 60°C			
2	Bonded 2 2-56 (.015 THK) Washers To PWA Tab	5/22/93	JWD	
	w/ Tra-Con 2902 - Cured 2 Hrs @ 60°C			
3	Assembled PWA 04-06 into Housing			
	Bonded Thermistor w/ Tra-Con 2151			
	Staked internal fasteners - Paralene Coated	5/22/93	JWD	
	PWA is Tight!! fit.			
4	Functional Chk O.K.	5/24/93	JWD	
5	Installed Kapton Tape inside rear cover.	5/24/93	JWD	
6	Installed CCD Shim + B/F CCD - Verified parallel O.K.	5/24	JWD	
7	Installed Lens standoff + checked Parallelism OK.	5/25	JWD	
8	Bonded Lens To CCD with DC-93-500 Silicone	6/4	JWD	
9	In oven @ 40°C for 24 Hrs Starting 10:00A	6/7	JWD	

Work Sheet

Part Number:	Serial # :	Title:	Sheet:
C1-AAA92-106282 Tab 01	ST313	Star Tracker Camera, V3.1	03

#	Operation	Date:	Oper.	Insp.
25	RANDOM VIBRATION X, Y, Z 19.8 GRMS	6/15		
	REMOVE FROM CONTAINER / ANTI STATIC BAG - 10:10			
	Return to container / anti static bag - 10:57			
	TESTED @ B131-HB DYNAMICS LAB		JWD	
26	VERIFIED OPERATION W/ M. DICKENSON - ALL O.K.	6/15		
	DONE IN T-1879 'BLACK' RM. - OUT of bag @ 45 MIN.		JWD	
27	THERMAL CYCLE TESTED +20°C TO -30°C W/ 1 HR			
	SOAK - 6 cycles ALL O.K.	6/16-6/17	JWD	
29	Out of Bag 9:30A	7/6/93	MD	
30	Thermal Test of Lens Heater Re: OK!	7/6/93	MD	
31	In BAG 12:15p	7/6/93	MD	
32	Camera Assembly HTR = 150 ohms	[illegible]	[illegible]	
33	LENS HEATER RESISTANCE = 415 ohms	[illegible]	[illegible]	

Appendix G.3.3
Bill of Materials

Clementine
Configuration Management

S1
Star Tracker Camera

Document Tree #:	C1-AAA92-106282 TAB01-00
Title:	Star Tracker Camera Assy, V3.1
Next Higher Tree:	None

Comments:
Star Tracker Camera C1-AAA92-106282 Tab01
uses a ST1A Camera Board

Serial Number:	
File Name:	
Software/Op. System:	Excel 4.0/Macintosh

Prepared by:		Date: 3/17/93	E.E. Apvd.	Date: 4/22/93
Prod. Chk.		Date: 4/2/93	M.E. Apvd.	Date: 4/7/93
E.E. Chk.		Date: 4-15-93	Q.A. Apvd.	Date: 3 May 93
M.E. Chk.		Date: 4/2/93	Engr. Rlsd	Date:

REVISION HISTORY

Level	00										
Date											

LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
	X					S1	**STAR TRACKER CAMERA ASSY, V3.1**		AAA92-106282	00		
	X					S1	CAMERA ASSEMBLY PROCEDURE		C1-S1-012	00		
		X				S1	ISOLATOR SHIM		AAA93-102551	00		
		X				S1	THERMAL SHIM		AAA93-102241	00		
	X					S1	INTERFACE CONTROL		AAA92-100839	0B		
		X				S1	CCD, THOMSON	TH7883F02-01B/T				FLIGHT
		X				S1	CCD, THOMSON	TH7883F02-01	7883FOP393			PROTO
	X					S1	ENVELOPE CONTROL		AAA92-100838	00		
	X					S1	OPTICAL PRESCRIPTION	OCA 17073	NONE			
		X				S1	LENS ASSEMBLY	880-0001-401-0C	AAA92-109469	0C		PURCHASED ITEM
			X			S1	FACEPLATE, FIBER OPTIC	880-1004-001-0B	AAA92-109466	0B		
			X			S1	ELEMENTS ASSEMBLED	880-0002-101-0C	AAA92-109462	0C		
				X		S1	ELEMENT NO. 1	880-1000-001-0B	AAA92-109463	0B		
				X		S1	ELEMENT NO. 2	880-1001-401-0F	AAA92-109464	0F		
				X		S1	ELEMENT NO. 3	880-1002-001-0B	AAA92-109465	0B		
			X			S1	FOCUS SPACER	880-1006-001-00	AAA92-109468	00		
			X			S1	HOUSING	880-1005-001-0D	AAA92-109467	0D		
			X			S1	CLAMP, LENS HEATER		AAA93-102221	00		
		X				S1	**BAFFLE ASSY**	880-0004-001-0B	AAA92-108748	0B		
			X			S1	BASE, BAFFLE	880-1080-001-0B	AAA92-108749	0B		
1	2	3	4	5	6							

DOCUMENT TREE NUMBER: C1-AAA92-106282 TAB01

LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
			X			S1	COVER		AAA93-102598	00		
			X			S1	VANE NO. 1	880-1021-001	AAA92-108747	00		
			X			S1	VANE NO. 2	880-1022-001	AAA92-108746	00		
			X			S1	VANE NO. 3	880-1023-001	AAA92-108745	00		
			X			S1	VANE NO. 4	880-1024-001	AAA92-108744	00		
		X				S1	**CAMERA ASSY**		AAA92-106277	00		
			X			S1	CAMERA HOUSING		AAA92-106258	0C		
			X			S1	BUSHING, JACKPOST, MDM CONN.		AAA93-101167 TAB08	00		
			X			S1	CIRCUIT BOARD PAD	800-3068	AAA92-104621	00		
			X			S1	END COVER		AAA92-106249	0A		
			X			S1	SHIM, LOWER, END COVER		AAA93-102610	00		
			X			S1	SHIM, UPPER, END COVER		AAA93-102609	0A		
			X			S1	CONNECTOR BRACKET		AAA92-106257	0A		
			X			S1	PAD, CCD THERMAL		AAA93-102243	00		
			X			S1	ICD, CAMERA		AAA92-104603	0E		
			X			S1	ST1A CAMERA ASSY, w.GAIN & OFFSET CONT.		LEA92-3128-03	0A		IN FILE
			X			S1	SCHEMATIC, CAMERA		LEA92-3128-01	0B		IN FILE
				X		S1	ARTWORK		LEA92-3128-02	00		IN FILE
				X		S1	BILL OF MATERIALS		LEA92-3128-04	0C		IN FILE
1	2	3	4	5	6							

DOCUMENT TREE NUMBER: C1-AAA92-106282 TAB01

LEVEL 1	2	3	4	5	6	Prefix	Document Title	Document Number Foreign	LLNL	Rev	S/N	Status
					X	S1	SPACER (CONN. STANDOFF)		AAA92-104616-TAB01	0C		
					X	S1	NUT, PCB RETAINER		AAA92-109126	0A		
					X	S1	MTG. HARDWARE	800-3043	AAA92-104607-TAB01	00		
				X		S1	ASSEMBLY PROCEDURE		LEA92-3128-05	0B		IN FILE
				X		S1	TEST.PROCEDURE		LEA92-3128-06	00		N/A
				X		S1	FAB DRAWING		LEA92-3128-07	0A		IN FILE
				X		S1	ARRAY DOCUMENTATION-U26		LEA92-3128-08	00		NOT SIGNED
			X			S1	THERMISTER, FENWALL	137-562-ZXT-D02				
			X			S1	LENS STANDOFF		AAA93-102550	0A		
1	2	3	4	5	6							

DOCUMENT TREE NUMBER: C1-AAA92-106282 TAB01