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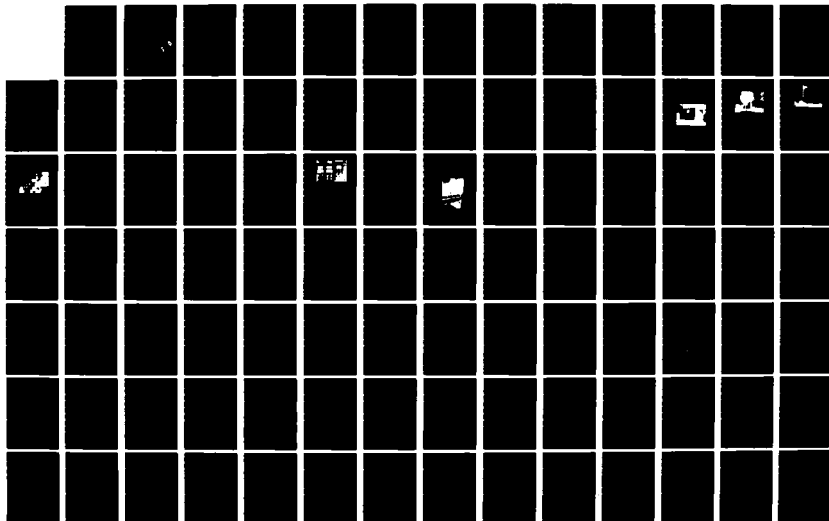
STUDY OF CCD EYEPIECE ON T-4 THEODOLITE(U) MARYLAND
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STUDY OF CCD EYEPiece ON T-4 THEODOLITE

Douglas G. Currie

University of Maryland
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College Park, MD 20742

Final Report
July 1977 - November 1982

November 1982

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This document describes the effort at the University of Maryland to develop a Charge Coupled Device (CCD) Camera System, with the necessary support hardware and analysis software, to act as an impersonal electronic eyepiece on the T-4 Theodolite for astronomical longitude and latitude determinations. This report will describe the concept, the implementation, and the current status of this project. Analysis of the field test data shows that the developed system has a		

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performance level significantly higher than the original design goals, as well as being far above the best human skill level. The system is now being operated by personnel of the Geodetic Survey Squadron. The results of the overall operation will be addressed with respect to the current performance and future potential of this system.

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I. OVERALL REVIEW OF OBJECTIVES

The overall objectives in this program have been directed toward providing a significantly improved capability in the determination of field astroposition. These investigations address several of the fundamental errors in field astrometry, particularly, the effects of anomalous atmospheric refraction and personal error. As we shall discuss later, these will indirectly influence the questions of star catalogs.

The initial efforts under this contract were addressed toward Two-Color Refractometry. This is a technique for the determination of the total refraction suffered by the light of a star prior to entry into the instrument. This may be separated into conventional refraction, which is normally corrected in the procedures and analysis of field astroposition, and anomalous refraction, which is not normally corrected. The Two-Color Refractometer is an instrument to measure this and provide data to correct for this difficulty. This initial effort was then shifted to exclusively develop the Charge Coupled Device as an array eyepiece for the Two-Color Refractometer.

The Array Eyepiece for the Two-Color Refractometer permits automated data recording to provide processing of the astroposition observations. Thus, one does not need an optical observer to record the star position with respect to the wires of the T-4 Theodolite. This device has been designed, fabricated, tested and evaluated in the field. The results of these evaluations at the U.S. Naval Observatory indicate a highly consistent performance, apparently limited by other errors in the astroposition procedure.

Future efforts on other projects will consist of the return to the Two-Color Refractometry to provide a parallel correction for the mean

anomalous refraction, and later, a device incorporating aspects of an astrolabe and the Two-Color Refractometer operating through the same aperture which will permit instantaneous corrections for the refraction and for the use of an Array Eyepiece.

The latter joint instrument, which was the long-term objective of the overall program, should provide a quantum leap in the accuracy of astroposition measurements.

II. REVIEW OF TWO-COLOR REFRACTOMETRY OBJECTIVES

The original objectives of the program in Two-Color Refractometry were to fabricate and demonstrate an instrument which had initially been invented and proposed by the University of Maryland. This instrument was to operate as an adjunct to a field determination of astroposition using a conventional (or automated) T-4 Theodolite.

In addition to the fabrication and demonstration of such a piece of equipment, we planned to perform detailed measurements of the variation in refraction in the sky in order to establish both the temporal and the angular stability and reproduceability of measurements of the anomalous refraction. These measurements are especially important in the definition of a final field instrument, as this addresses the question of the star magnitude required for observation. If it is necessary to observe stars simultaneously, an FK4 star being observed by the T-4 Theodolite dictates that the Two-Color Refractometer must operate to sixth magnitude and over a variety of spectral types. This would require that the instrument have a large aperture. On the other hand, if there is the expected stability in time and in angle to permit the anomalous refraction to be determined in a general region near zenith, then we may use these as corrections to the T-4 Theodolite measurements on the FK4 stars. The latter measurement technique will require a much smaller aperture and therefore a much less complex system.

For this reason, we had expected to operate with a variety of aperture sizes and to provide a survey of the variations. This survey would be done in an automated fashion.

However, the latter portions of this effort were not completed due to the shift in emphasis to the Charge Coupled Device Array Eyepiece for the T-4 Theodolite.

III. ACHIEVEMENTS IN TWO-COLOR REFRACTOMETRY DURING THIS CONTRACT

The instrument was fabricated and tested initially in the laboratory. It was also interfaced to the Goddard telescope. A considerable amount of time was spent in working with this telescope and on its pointing system. This interaction was due to short-comings of the telescope system. In the end, this system work plus certain optical problems (which occurred after the end of the support) resulted in the shifting of emphasis to the CCD.

A. Design of the Two-Color Refractometer

A detailed design of the Two-Color Refractometer was approached and completed. This transformed the initial concept, which specified only nominal components and nominal specifications, into a series of designs that could be shop fabricated, both in the electrical and mechanical areas, as well as items that could be purchased. This design was then reviewed to assure that the null aspects were addressed that would be expected in a design of this type.

IV. ACHIEVEMENTS DURING REPORT PERIOD

A. Field Site Constuction

The TCR was installed on the 48-inch telescope at its Coude port.

(See Figure 1.)

1. Selection

The selection of a telescope for the initial observations with the TCR had several technical requirements. Predominant among these were the need for:

- a. Reflecting telescope
- b. Ability to make many observations
- c. Frequent access

This requires that the telescope be in the Washington area during equipment development.

The reason for computer control is the desire, at a later stage in the program, to determine the temporal and angular stability of the correction. This has a large impact on the aperture to be used in the system. For this reason, we would like a computer controlled drive.

The above criteria led to the selection of the 48-inch telescope at the Goddard Space Flight Center. Due to their interest in the results of this program, this use of the telescope at that time was contributed without cost.

The major disadvantage of this telescope consisted of prototype nature of the programs. A very considerable effort has been required to bring their programs up to the level required. UM personnel have had a very close involvement in this procedure.

2. Telescope Configuration

The 48-inch telescope is an azimuth/elevation drive. The beam is brought to a reflecting mirror and then directed to 6 different ports. One of these ports was made available for the work with Two-Color Refractometry. Thus, the TCR was mounted at this point.

3. Interface and Programming

With the aid of Goddard personnel, the Two-Color Refractometer interfacing had been completed earlier. This was an interface between the TCR and the telescope drive system. The physical interface was made at the University of Maryland shop.

However, the software interfacing proved more difficult. Various types of instabilities and difficulty with telescope encoders were encountered and, by joint work with University of Maryland personnel and Goddard personnel, corrected. This provided a stationary place where it could be repeatedly accessed. However, it was found that this required interaction with Goddard personnel with respect to developing their on-going improvement program.

B. Electronics Fabrication

The electronics consist of two major domains. The first is the control of the system, and the rest is the computer system and interfacing.

1. Specialized Electronics System

This is the Display and Control Console (DCC). This was designed and fabricated to provide the proper control of the

various experimental functions and to provide the interfacing required between the data outputs and the computer to do the final control and the data processing.

The individual components of this consist of:

a. Wedge Drivers

The mounts, which hold the wedges, were purchased through Klinger Scientific Company. The wedges consist of two elements of glass, UBBK7 and fused silica. These were chosen in order to provide dispersion but no deviation. They are mounted in a drive which provides rotary motion. There is also a 16 bit encoder and initializing track. The encoder is read by the DCC and the voltage to drive the wedges is derived from the DCC.

b. Image Stabilizers

These are small mirrors mounted on galvanometer drive motors. Motors are from General Scanning Corporation. The drive for these motors is contained in the DCC. They are in a closed servo loop to maintain the image in a stabilized position.

c. Color Wheel

This serves the function of rapidly changing red and blue filters. It consists of intermittent RG610 glass and UG11 glass in a wheel. The rotational speed is 60 rps. This results in 4800 filter changes per second. The shroud provides both safety and reduction of required motor power due to control of turbulence and inertial interaction with the air. The position of the wheel is

determined by a light emitting diode observing changes in the reflectivity of the wheel.

d. Reflective Reimager

The focal length of the 48-inch telescope is much too long to be suitable for this experiment. For this reason, we have to re-image or change the focal ratio. This reflective recollimator is a small inverted Cassegrain telescope which is frequently used for microscope lens systems. This changes the f ratio. It is a commercially available device. However, it appears to have significant vignetting problems in actual operation and has proved very difficult to align.

e. Photomultiplier

The photomultipliers are fabricated by Electronic Vision Company and are quadrant devices. These were difficult to obtain, but we had a sufficient supply to operate the program, although at much lower quantum efficiency than desired.

f. Preamplifier System

C. Software Development

The software development for the Two-Color Refractometer has fallen into two major areas. These consist of:

1. Operational Software

a. Wedge Drive Computation

The drive for the wedges is a significantly complicated algebraic expression with decision points required. Thus, this must be run in the NOVA minicomputer

in real time. For different telescopes, the break points must be defined differently in order to get stable operation.

b. Data Handling

This consists of interrogating different sites at which data is generated, combining these into proper records, and writing to magnetic tape.

c. Real Time Processing

This consists of providing display outputs that permit one to determine if the instrument is operating in a basically proper manner.

D. Operating Procedures

These procedures were required for acquisition, alignment, and tests.

E. Observation Series

A number of observation series were taken.

F. Results

Dispersion was determined. A significant bias was observed. The reason for this bias is unclear, although it is believed to be the now alignment due to shadowing of the secondaries. This occurs differently for the two different colors which remains somewhat of a mystery.

G. Recommendations

At this point, more precise alignment is needed. Masks have been used to some advantage. However, testing had not been feasible by the end of this program.

VI. REVIEW OF OBJECTIVES

The work described in this section of the report is part of a program conducted at the University of Maryland to develop an impersonal electronic eyepiece system for the T-4 Theodolite. The critical element of this impersonal eyepiece is an electronic camera head which operates the Charge Coupled Device and the associated electronics. This is designed to replace the conventional visual eyepiece on the T-4 Theodolite. The overall system thus includes the Charge Coupled Device, the electronics required for camera control and data acquisition, the software to operate the system in the field, and the algorithms and software developed to analyze the data which is produced by the Array Eyepiece System.

The basic principle involved in the application of a specially designed CCD camera for use in astroposition observations with a T-4 Theodolite consists of the use of the intrinsic structure of the CCD to encode a series of timing signals as a star image moves across the CCD. The structure of the signals is similar to those timing signals provided by the motion of the drum which occur when a visual observer is tracking the star with the conventional eyepiece. The actual epoch of these timing signals is derived from a computer analysis of each of several thousand images for each exposure which are recorded on magnetic tape. This is recorded in conjunction with a reading of a precision clock.

The CCD camera that is currently in use is the "Mark V" CCD Camera Head which has been developed at the University of Maryland. In addition to the electronics used to operate the CCD itself, the Camera Head contains a remotely controlled and powered thermoelectric cooler to

stabilize the CCD temperature, an isolated, buffered video amplifier, an analog-to-digital converter, and a subtraction system that permits the removal of leakage pattern, or the "fixed pattern noise" from the CCD output. (This is accomplished by the subtraction of the stored "dark" image from the video output in real time. The "dark" image is that pattern obtained in the absence of any light input).

The ultimate objective of this program is to deliver a complete, self-contained T-4 observing system (with related analysis software) to the Air Force Geophysics Laboratory/Defense Mapping Agency, and to train observers to use this system in the field.

VII. ACHIEVEMENTS AND OBJECTIVES

In this section, we shall address the primary objectives and achievements within the program. These will be addressed from the point of view of the subtasks which require different approaches. The details of these different approaches will be considered in a later section.

A. Summary of Objectives

The principal objectives during the current report period will be briefly summarized in this section, then elaborated in later sections.

They consist of:

1. Observing Field Site

An observing site was developed at the Goddard Optical Research Facility (GORF). This observing site (previously on the roof at the University of Maryland) provided a site from which to make regular measurements in a reasonably dark environment. It also provided security and power. The initial operation was conducted using a trailer which had been involved in the Amplitude Interferometry Program (AIP). The later observations were conducted with a mobile van supplied by the Geodetic Survey Squadron. The equipment was installed in this van by the University of Maryland.

2. Electronic Opto/Mechanical Fabrication and Evaluation

This task consists of the fabrication and evaluation of various electronic subsystems and opto/mechanical components for the Array Eyepiece System as used on the T-4 Wilde Theodolite. The major items addressed consist of the integration of the computer into the overall system as well as various tasks concerning the opto/mechanical positioning of the

Array Eyepiece System.

3. Astronomical Position Observation Series

This task consists of conducting a series of observations at the AIP Site at GORF. The purpose of these observations is to evaluate the current implementation of the University of Maryland Array Eyepiece System for operation on the T-4 Theodolite.

4. Array Eyepiece System Data Reduction

This task consists of the reduction of the CCD data that is obtained from the astroposition observations conducted at the AIP Site at GORF. The purpose of this task is to evaluate the current status of the hardware and "analysis software", which has been developed for the analysis of the CCD data. This software is used to determine the time of meridian passage for the determination of the longitude.

5. Software Development

This task consists of the development and evaluation of the computer programs and software required to analyze the output of the CCD and to derive from this data the time of meridian passage for the star. This task thus consists of the definition and the implementation of various computer programs and procedures to overcome difficulties in the electronic hardware, the atmospheric conditions, and the observing procedures, in order to obtain more precise results.

6. Production Data Reduction

This task consists of the continuation of the support of the Geodetic Survey Squadron. Their task consists of the

operation of the University of Maryland computer programs for the analysis of the CCD data from the Array Eyepiece System. These programs are expected to operate on the Data General VAX Computer located at Cheyenne, Wyoming.

VIII. AREAS OF EFFORT

We now address each of these areas in more detail.

A. Field Site Construction

We consider here the three independent field test sites.

1. University of Maryland Campus

This consisted of the roof of the Physics building on campus. This had the high convenience of permitting a rapid cycling of equipment for electronic repair. It also permitted access to auxiliary equipment during the initial break-in phase. Finally, it provided the convenience of not moving the computer from its daytime configuration. This was especially important, since, at this time, the computer was on loan from another program.

2. Goddard Optical Research Facility/AIP Trailer

The remaining tests were conducted at the AIP site. The primary facility used at the Goddard Optical Research Facility (GORF) consists of an observing site which had previously been developed within our group for Very long Baseline Amplitude Interferometry. This had resulted in the availability of a trailer with heat and suitably situated for observations. A telephone was also available at the site as well as sufficient power. Security was available via the Goddard Space Flight Center security.

This site had been investigated with respect to geographic and geologic stability. The results of these investigations implied that this particular site is relatively stable. This has been discussed in some detail in the Goddard report titled,

"On the Geodetic Stability of the Goddard Optical Research Facility."

Surrounding the concrete pier, a wooden floor was fabricated. This floor permitted observer and equipment to be used near the pier without placing varying forces on the pier itself or on the ground immediately surrounding the pier. Beyond this, a conventional T-4 observing tent, supplied as government furnished equipment by the Defense Mapping Agency and the Geodetic Survey Squadron, was erected. This was done, with the aid of Mr. Rudolf Salvermoser of the Defense Mapping Agency, to provide a shelter which would be useful for the test of the Array Eyepiece System as well as to follow the conventional rules for observation using a T-4 Theodolite.

This system remained in operation for over a year. During this time there were some modifications. In addition to the observing tent, a trailer which was originally intended for use within a separate program at the University of Maryland was provided for use in the AFGL/DMA/GSS program. This trailer provided shelter for the special University of Maryland electronics, the NOVA minicomputer, and its required peripheral equipment. It also provided shelter for the Data Metrics clock, which was supplied as government furnished equipment by the Defense Mapping Agency and the Geodetic Survey Squadron, and for the terminals and monitors required by an observer in the operation of the Array Eyepiece System. The trailer also provided a working area for the evaluation, repair and testing of the electronic and computer systems. It also provided

shelter for the observer, recorder and computer operator during the observing sessions. Various additions were made to the trailer shelter during the period of observation. This included improved WWV reception, heating for winter operations, air conditioning to maintain the equipment during the summer. A work area for the recorder was also provided.

3. GSS Van

In order to provide a field portable system which could easily be carried to different sites, a van capable of being towed in a reasonable manner on the highway was supplied by the Geodetic Survey Squadron (GSS) as government furnished equipment. This van was converted from previous applications by personnel at GSS in Cheyenne, Wyoming. The van was then supplied to the University of Maryland. Racks were purchased by the University of Maryland and installed. Heating and air conditioning were provided by GSS. The equipment was transferred from the University of Maryland trailer to the GSS van. This included the full set of equipment, plus temporary equipment for time checks. Special feed throughs were provided in order to permit cables to be passed from within the van to the T-4. Connectors were provided to disconnect these cables and a shelter box for the storage of these cables without disconnecting was also provided.

This van was operated first at the Goddard Optical Research Facility and then at the U.S. Naval Observatory. A photograph of this van, or enclosure, is shown in Figure 1. In the installation at USNO, the T-4 Theodolite with the Array

Eyeiece System was operated in the USNO Astrolabe building. The T-4 was mounted on a special pier modification which attached to the astrolabe pier. In the following photograph, we indicate the Array Eyeiece System enclosure and the astrolabe building. Note the power generator on the back of the Array Eyeiece System enclosure.



Figure 1

Array Eyeiece enclosure in operational configuration as used at USNO.



Figure 2

Array Eyepiece System enclosure operating at
USNO adjacent to astrolabe building.

The transfer of cables through the wall is indicated in Figure 3. This provides minimal wear on the fiber optic coolers and minimal wear on the connectors for disconnecting. It provides shelter for these during non-observing periods in the box.



Figure 3

Trailer with wire cable connected.

B. Electronics Fabrication

In this section, we shall address the overall configuration and the individual components of the electronic/computer system used to operate the Array Eyepiece System on the T-4 Theodolite. The overall layout of the electronic system evolved, in terms of individual components, from the early tests on the campus site to the final delivered form.

In this document, we shall address one or more typical configurations. These configurations frequently used a variety of different equipment, in particular, equipment being fabricated and tested for final delivery, inserted and tested in a matrix of equipment provided on loan from the Electronics Shop and on loan from an independent program in interferometry of the Office of Naval Research.

1. Overall Configuration

We now consider the overall configuration at one particular era. This is indicated in Figure 4.

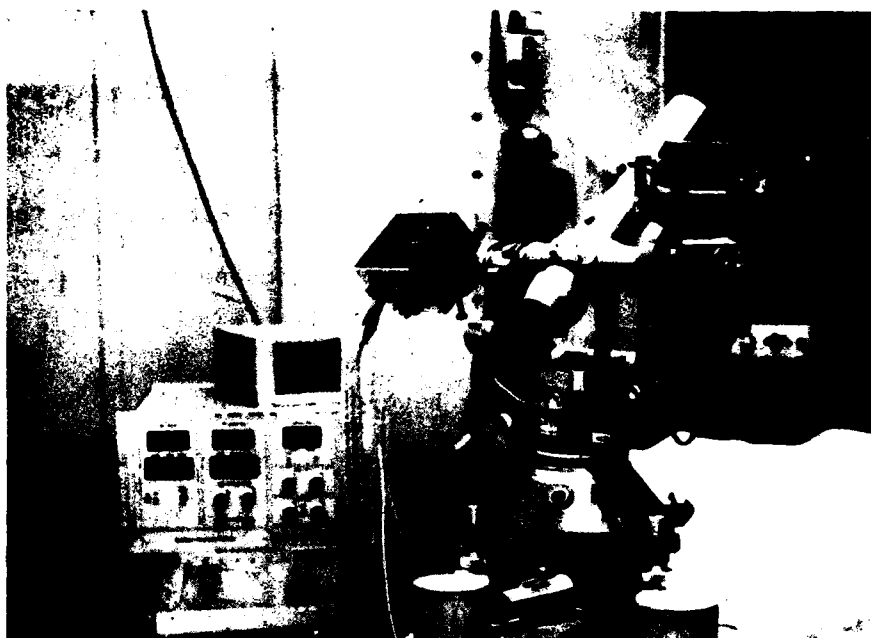


Figure 4

9 June 1982 configuration for the
Array Eyepiece System for the T-4 Theodolite.

This illustrates the details of the system as it was to be tested on 9 June. We now consider several evolutionary steps in the system which are expected in the near future. We expect certain components which have been tested, but not required, to be installed by GSS.

This configuration was to be completed by the end of June. It included the installation of the Circulating Semiconductor Memory (CSM) and the Fiber Optic Camera. However, these tests were delayed, at the request of the

Geodetic Survey Squadron until the system, without subtraction, had been tested at the observing station in Cheyenne, Wyoming. Thus, the system as used for the final series of tests did not include the subtraction.

This reflects the frequent situation of requested modifications that propagated throughout the entire system which required minor but significant modifications at a variety of points in order to maintain the full accuracy of the system.

We now describe individual components.

2. Mark V CCD Camera Head

The Mark V Camera Head consists of the black box which is 6 3/16" by 4" by 5" in dimension. This has a weight of 3.4 pounds. A second configuration for the Mark V Camera Head has been developed and tested. This second configuration consists of an interface to a fiber optic data transmission system. This system converts the digital electronic data into digital optical data. A similar receiving unit is required at the Remote Control Unit. When combined with the basic Mark V Camera Head, this combined configuration has a dimension of 6 3/16" by 5 by 7 inches. For this combined system, the weight is 6.7 pounds, including the fiber optic interface. The overall function of this unit consists of the receipt of light from the outside and the conversion of this into digital signals for further processing.

a. CCD Driver Card

This card, which is an element of the Mark V camera head, contains the Charge Coupled Device which senses the

light. This CCD is mounted on the card in a dual in-line socket. Also contained on this card are "clock driver" integrated circuits which convert the various voltage pulse trains to high current pulse trains. The latter are required to drive the Charge Coupled Device.

b. Thermoelectric Cooler Card

This card contains the thermoelectric cooler which is used to maintain the Charge Coupled Device at a predetermined temperature. This temperature is typically a few degrees below the ambient temperature. This card also has special brackets which permit the rapid conduction of the heat extracted from the CCD and the heat therein generated by the thermoelectric cooler to be conducted to the body of the camera head.

c. A-to-D Converter Card

This removeable card contains the circuitry for conversion of the analog signals received from the Charge Coupled Device into digital signals. This must be done with high precision over a large range to fully accomodate the operating range of the CCD and the expected range of the signals. The advantage of the use of digital signals consists in the immunity to external radiation and ground loop difficulties.

d. Video Card

This removeable integrated circuit card performs the signal amplification of the CCD signal, permits zero restoration of the offset of the signal which is obtained

from the CCD, performs a "correlated double sampling" which permits the use of an internal CCD reference to provide the signal from which the optical signal is computed as a differential. This printed circuit card also buffers the analog signal to reduce vulnerability to external signals.

e. D-to-A Card

This printed circuit card has a digital-to-analog conversion circuitry. This unit receives a digital signal from a memory located in the NOVA minicomputer. It then converts this signal into a digital signal. This digital signal is buffered and adjusted with respect to gain. This will provide a signal which will subtract the variation in leakage current which may be found in the CCD. The purpose of this circuit is to permit the operator to utilize the highest gain possible on the monitor which views the output of the Charge Coupled Device. This is necessary to permit rapid identification of the fainter stars in the FK4 catalog.

3. Remote Control Unit (RCU) on Camera Control Unit

The Remote Control Unit is an electronic subsystem which is mounted separately in a conventional 19-inch rack. This unit provides a variety of independent functions. In particular, it provides the drive or clock voltages required by the Charge Coupled Device and organizes the routing of various signals and controls between the computer and the CCD Camera on the T-4 Theodolite.

One section of the RCU consists of a read-only memory and microprocessor which creates the appropriate pulse trains. By the use of this microprocessor, the RCU generates the clock voltage trains for scanning the CCD. This set of commands for the structure of the clock voltages may be changed by the creation and installation of a new Programmable Read-Only Memory (PROM).

Another section of this system selects the clock voltages which are used to control the charge transistor on the CCD. A set of front panel controls permits the choice of a variety of different tables of clock voltages. This permits the control of the temperature of the CCD. This may be set at any point by a control on the front panel. It also provides the temperature regulation for the CCD. It acts as a transmission point for the data from the CCD to the minicomputer. In the present configuration, this is located near the pier to permit these adjustments to be made in the vicinity of the CCD Camera system. It also provides the connection point for converting from the fiber optic information to the copper transmission to the computer.

A photograph of the front panel of the Remote Control Unit appears in Figure 5. This indicates some of the functions of the RCU, or the CCD camera control unit. (RCU is a designation of a similar unit in an earlier configuration which was also used in the earlier test of the Array Eyepiece System on loan from the Office of Naval Research.)



Figure 5

Front panel of the Remote Control Unit

The Remote Control Unit is in an enclosure for handling in setting it up at the pier. The current version of this unit is a plastic box with two handles. This is designated as the "RCU Enclosure."

4. Minicomputer

The following discusses the commercially purchased equipment which has been supplied by the University of Maryland in the van. In general, these items are under warranty (if it has not expired). The warranty procedures and information are contained in the van.

a. NOVA 4 Minicomputer

The NOVA 4 Minicomputer (Model 4c) operates the overall system. This is responsible for both the control

of the experiment and the processing and routing of the output data. This NOVA 4 Minicomputer is basically a commercial device. However, it has been specially adapted in order to provide a more rugged and more operational unit for use in the field. This has primarily resulted in changing the physical I/O structure of the NOVA 4 Minicomputer in order to permit connector based interconnections with external devices.

b. Digidata Tape Deck

The Digidata Tape Deck (Model 1640) and Controller (Model NCI) are used in the system in order to record the output data. This is recorded in real time and permits processing off-site by a large computer. These units are mounted in the rack in the van.

c. Floppy Dual Disk System

The programs for equipment control and data handling and routing are resident on a floppy disk system. Intermediary real time data storage is also performed by the floppy disk system. This unit consists of a dual floppy system by Data General (Model 6030). This is a portion of the system purchased by the University of Maryland. It was provided on loan to AFGL/GSS/DMA during the time required to adapt the FORTH to a full Winchester disk based system which is capable of preliminary field reduction.

Thus, the unit in the van is one on loan from the University of Maryland and the alternate one to be interfaced with the new FORTH is at the University of

Maryland.

A figure showing the recording peripherals for this system appears in Figure 6. In this photograph we see the magnetic tape unit, on which the data for offline analysis is recorded, and the floppy disk system, on which the program for operating the system is recorded.



Figure 6

Recording Peripherals for System

5. Special Printed Circuit Cards for the NOVA Minicomputer

These are special large printed circuit boards which are installed in the NOVA Minicomputer. They provide specialized hardware/software interfaces between the NOVA Minicomputer and other equipment.

a. Patch Generator Card

This printed circuit card, designed and fabricated at the University of Maryland, accepts the digital data from the Mark V Camera Head and the Remote Control Unit and preprocesses this data to convert it into a form which is acceptable for the NOVA Minicomputer. There is a hardware selection, by a software provided word, of a patch of this data. Thus, the data is preselected by the hardware resident on the patch generator card. Thus, the NOVA Minicomputer does not require the use of CPU time in order to perform this selection procedure. Just prior to the second series at U.S. Naval Observatory this was modified to provide FIFO (First In, First Out) buffering on the card. This modification corrected the previously observed problem which caused a considerable delay. In particular, the patch generator card was found not to operate on different models of the NOVA Minicomputer. This was contrary to the advertised claim that these units were identical. The engineering staff of Data General also felt that they were identical and that there should be no such difficulty. However, with the new modification, we are able to operate this on the different NOVA models.

The patch generator card is placed in the computer. This is in Slot 5 (from the bottom, starting at 1).

b. Event Timer Printed Circuit Card

The "event timer card" is a large printed circuit card designed and fabricated at the University of Maryland. The primary purpose of this interface card is to provide timing references for the photogate pulses, and the ticks from the reference DMA clock. The photogates define the time of exposure of the CCD and thus provide the fundamental reference, equivalent to the ticks in the manual eyepiece. The ticks from the Data Metrics DMA clock provide the reference to WWV time as determined within the Data Metrics clock. Thus, the "event timer card" is a card mounted in the NOVA minicomputer. This is mounted in Slot 7 and has eight connectors bringing information to this.

6. Circulating Semiconductor Memory

The Circulating Semiconductor Memory (CSM) is a printed circuit card which has been developed at the University of Maryland. This printed circuit card has 128k of RAM memory. This permits the storage of a complete array, with 16 bit precision. This array is stored in order to permit the subtraction of this array from the real time data of the Charge Coupled Device. Various timing circuits permit this data to be synchronized with the scanning of the Charge Coupled Device. Special software in the NOVA Minicomputer permits the recording and processing of data from the Charge Coupled Device when a

light blocker is placed over the lens of the T-4 Theodolite. Thus, one gathers the background leakage current and stores this in the Circulating Semiconductor Memory, properly processed in order to permit the correct value and timing to be subtracted from the real time data from the Charge Coupled Device. The Circulating Semiconductor Memory is a double height card which is located in slot 10 in the NOVA minicomputer.

7. Image Display

The image display system consists of a device for the conversion of the computer signals to X and Y drives and proper Z modulation for the display devices and monitors. In addition to the image display, we also have a video terminal which permits the operator to control the computer system, data recording and the Charge Coupled Device. This control is actuated by FORTH operating systems which are discussed separately. The operation of these programs is discussed in Appendix I.

8. WWV Receiver

The WWV receiver consists of a Zenith radio. This item is government furnished equipment to the University of Maryland. This requires an outside antenna and connection to the Data Metrics box.

9. Temporary Equipment in Van

This consists of equipment which will not be in the final van, but is currently used for diagnostic material during the operations at the Goddard Optical Research Center.

- a. Four trace oscilloscope
- b. WWV receiver

C. Mechanical Mounting

The CCD camera must now be mounted to the T-4 Theodolite. This is done with an interface unit which provides adjustment and some focussing. The result of this combination is the completed system ready for the T-4 observation.

D. Observing Sequences

We may divide this into three observing sequences.

The first of these consists of various configurations. Thus, for the first observing sequence, we have Configuration 101 at GORF, Configuration 102 at USNO, Configuration 103 at USNO.

We may treat the data from each of these configurations separately. There is both an improvement in the data handling, observing procedures, equipment uniformity.

LED flasher tests were performed which enabled direct measurement of timing instabilities in data recording. These results suggested further investigations on the event timer and CCD patch generator circuit boards. As a result we have made several minor circuit modification to both of these boards. Preliminary tests have indicated that electrical glitches, which may have been responsible for random timing jumps, have been eliminated.

The CCD 211 photo array sensor circuit board, which had been modified due to changes in electrical specification from the manufacturer, has been completed. Preliminary tests on the board (not employing the sensor array chip) have been done.

The new X/Y/Z display driver for viewing the T-4 camera image inside the van has been completed. Tests have been performed at the shop. It appears to provide a much improved resolution of the camera

image.

The entire FORTH software package for the system has been updated into a more efficient package. The result is a more modular configuration, which will permit easier implementation of both electronics modular changes and software updates. This software package has been successfully installed and checked out at the optical site.

E. Observing Series

Observations have been conducted in various configurations. Some of these configurations have been used in order to provide information on the performance of the system at a time prior to the availability of the AFGL/DMA/GSS equipment. Thus, in the initial configurations (and in the final delivered configuration) conventional copper ribbon cables were used between the Mark V CCD Camera Head and the Remote Control Unit. The initial configuration with the Remote Control Unit used the electronic system which had been developed for the Office of Naval Research for use in the Multi-Aperture Amplitude Interferometer. This initial test configuration also used the NOVA 3 minicomputer system (including the NOVA 3 central processing unit, the magnetic tape drive, and the floppy disk drive) on loan from the Electronics Group of the University of Maryland. This series of tests has been conducted using an electronics system which was not designed for precision timing of data from CCDs, but was designed and fabricated for the Amplitude Interferometry measurements, which involves the use of the system for photon counting with an intensified CCD.

The later observing sequences consisted of tests of the AFGL/DMA/GSS equipment replacing individual elements in this configuration. A portion of these tests consisted of the use of the

fiber optic camera. However, requested upgrades in the camera system were not also implemented on the fiber optic camera. In addition, the fiber optic transmitters/receivers appears to have a problem in the form of a finite lifetime. That is, their output has been gradually decreasing as a function of time.

The delivered system consisted of the equipment described in a separate section.

F. Results of Data Reduction

In this section, we address the results of the data reduction.

1. Determination of Epoch

The first portion of the procedure to determine the epoch of a given star is to evaluate the internal precision one may expect from repeated measurements. This will involve two types of error, or uncertainty, in the epoch. The first contribution is due to the random noise generated in the preamplifier. Smaller similar contributions to the overall noise are due the random noise caused by the Poisson variations in the leakage current and the Poisson noise in the light which comes from the background brightness of the sky. However, the latter two effects are seldom important.

As discussed in the proposal, we derive a quasi-theoretical relation between precision and stellar magnitude in the following form:

TABLE 1. Relation Between Precision and Stellar Magnitudes

		Relative Readout Noise	Number of "Wires"	Desired Accuracy	
				0.03"	0.1"
CCD	202	300	99	4.3	6.0
CCD	211	50	189	6.6	8.3
CCD	221	50	379	7.3	9.0
ICCD	202	1	99	8.9	11.5
ICCD	211	1	189	9.3	11.8

The actual internal agreement which we have found may be illustrated by the following table on the latest observation.

In the discussion of the actual data, we must now distinguish between the performance of the CCD camera, image motion, and a group of other errors which we shall combine (Trunion axis, catalog, spirit levels, etc.). This division is somewhat arbitrary but will help to illustrate the procedure. Table 1 refers to theoretical calculations of the internal error, based upon measured parameters for the CCD 202 and projected parameters for other devices. On the other hand, if we consider field astroposition observations of stars, we may have internal errors of the order of one milliarcsecond, or somewhat larger, as the average star error during the night. This is addressed in Table 2. The numbers in the theoretical table were rather conservative, compared to actual operational equipment, in two respects. First, we are using the 202, but its noise is running on the order of 50 or 60 electrons. In addition, we are using the full spectral range rather than just

the visual variance. These improvements permit agreement with the high internal precision found in this data.

However, a phenomena such as image motion will, over the time period involved, provide a random component of the order of 0.1 arcseconds. Thus, the Table was realistic as well as properly defined (it addressed only the array) in the reproduceability from one determination to the next.

TABLE 2. Summary of Geodetic Data

DATE (GCD)	R	SD*	D	SD*
12/01/81	0.9508	0.0014	0.572	0.066
12/10/81	0.9521	0.0016	0.525	0.025
12/17/81	0.9512	0.0009	0.476	0.027

* : Standard Deviation (Unit)

R : Equatorial Width of One Pixel

D : Equatorial Width of Photosensitive Part of Pixel

LONG: Observed Difference in Longitude to be Applied to
-05^H 07^M 18^S.9

The above discussion is a criteria for evaluation but not the actual internal agreement of stars through the night. In order to determine the latter, we may look at the internal agreement of a single star. This is a number not dissimilar from the standard deviation of the width of a cell, but it cannot be cross-checked. If we cross-check from one star to another, we find the larger number of 0.03 seconds of time, or 0.5 arcseconds. A portion of this uncertainty, and probably the major constituent, is due to the image motion caused by the turbulence and fluctuations in the earth's atmosphere. These would be predicted to have a fluctuation in this time of this

magnitude. However, analysis has not been carried out to date as to the separation of the atmospheric phenomena and various effects which might be attributed to the structure of the T-4 Theodolite. Note that within this variation, or uncertainty, all of the short term motions of the trunion axis, the azimuth axis, and other mechanical parts, such as the interface between the camera and the telescope, are included.

2. Evaluation of the Geodetic Determinations of Longitude

In this section, we wish to consider both the precision and the accuracy for the determination of astronomical longitude using the Array Eyepiece System on the T-4 Theodolite.

In order to permit an internal comparison in which we include the capabilities and skill of a standard observing crew, we shall address in this section data which has been collected by personnel of the Geodetic Survey Squadron and analyzed by Mr. Rudolf Slavermoser and the personnel of the Geodetic Survey Squadron in Cheyenne, Wyoming. In particular, we consider the data for the interval from 29 April 1982 to 11 May 1982 which was recorded at the U. S. Naval Observatory in Washington. This was performed with one set of equipment. This equipment was then replaced almost entirely with the equipment to be delivered to the Geodetic Survey Squadron.

The second interval from 13 May 1982 to 8 June 1982 was recorded by personnel of the Geodetic Survey Squadron and represents the equipment that was transferred to them.

TABLE 3. CCD Mark V Project, "Old System Night Results

1982 Local Date	Astronomic Longitude for Night Sec.	Residual from Standard Sec.	Standard Error of Mean Sec.	Number of Sets	No. of Stars Obs. Acc.		
29 April	58.04	- 0.19	+ 0.219	2	14	12	F
03 May	58.12	- 0.11	+ 0.102	4	33	32	F
04 May	58.42	+ 0.19	+ 0.091	4	33	32	F
05 May	58.09	- 0.13	+ 0.093	5	36	35	P
06 May	58.21	- 0.02	+ 0.097	5	36	32	P
10 May	58.32	+ 0.09	+ 0.102	4	28	25	P
11 May	58.01	- 0.22	+ 0.087	3	22	20	P
TOTALS				27	202	188	
Weighted Mean:		58.19	- 0.04				
Standard Error of the Mean:				+ 0.056			
Standard Error of a Single Night:				+ 0.147			

NOTES: Standard Longitude: $77^{\circ}03' 58.23'' \text{ W} + 0.0086'' \text{ SE}$

Based on Danjon Astrolabe Results from 1969-1978 observations.

Results include final UT1 time and CIO pole corrections.

Weights for each night are the number of acceptable stars.

Observer: Bernard Instrument: Wild T4-120741
Chronometer: Datametrics 231

Table 4. CCD Mark V Project, "New" System Night Results

1982 Local Date	Astronomic Longitude for Night Seconds	Residual from Standard Seconds	Standard Error of Mean Seconds	Number of Sets	No. of Stars	
					Obs.	Acc.
13 May	58.39	+ 0.16	+ 0.098	2	17	16
25 May	58.25	+ 0.02	+ 0.061	4	26	26
26 May	58.25	+ 0.02	+ 0.070	5	33	32
01 June	58.12	- 0.11	+ 0.068	5	27	27
02 June	58.13	- 0.10	+ 0.085	3	29	26
07 June	57.98	- 0.25	+ 0.104	3	21	21
08 June	58.15	- 0.08	+ 0.130	2	11	11
TOTALS				24	164	159
Weighted Mean: 58.18		- 0.05				
Standard Error of the Mean:			+ 0.046			
Standard Error of a Single Night:			+ 0.121			

NOTES: Standard Longitude: 77 03 58.23 W + 0.0086 SE

Based on Danjon Astrolabe Results from 1969-1978 observations.

Results include preliminary UT1 time and CIO pole corrections.

Weights for each night are the number of acceptable stars.

Observer: Courbis
Chronometer: Datametrics 231

Instrument: Wild T4-120741

In order to make a cross-comparison, we now form a table to describe this data.

TABLE 5. Summary of the Results of Longitude Determination at USNO

	April - May	May - June	Difference of Two Runs
Equipment	UM/ONR		
Weighted Mean of Longitude	77°03'58".190	77°03'58".180	0".010
Standard Error of the Mean for the Weighted Mean	0".056	0".046	0".072
Standard Error of a Single Night	0".147	0".121	-----

Thus, we find the internal agreement of these two measures to be $.01 \pm .08$ and the accuracy to be $-.04 \pm .08$. For comparison, a standard determination is approximately 0.28 arcseconds.

Further data was taken after the completion of this contract at the U.S. Naval Observatory which will be addressed in more detail in a separate paper.

G. Overall Conclusions

The overall conclusion which one may derive from both this data and data performed after the termination of this contract consists in the statement that the equipment is performing significantly better than may be performed by a manual observer. In particular, this is in reference to the results obtained with the GSS study for the internal agreement of several different observers. The results at the U.S. Naval Observatory

also indicated performance that was better than any single observer (single observers in the GSS study were internally more consistent than combining all observers). There initially appeared to be offsets in the data when the equipment was changed (at the U.S. Naval Observatory site) from the equipment of the U.S. Office of Naval Research to the AFGL/DMA/GSS equipment. However, re-analysis in terms of proper use of the earth rotation data indicated that this offset was less than significant.

It is believed that with suitable flasher calibration conducted by the operating crew, such a recalibration would not have been necessary. However, this has not been verified.

IX. SOFTWARE

In this section, we consider in more detail the software which has been developed within this program to both operate the CCD Array Eyepiece System and to analyze the data which has been obtained from the CCD Array Eyepiece System.

This software which has been developed for use with the University of Maryland Array Eyepiece System operated on the T-4 Theodolite addresses two areas in particular. These consist of the operational software and the data analysis software. The operational software is used at the same time during which observations are taken. It provides the operational commands and procedures for the operation of various elements of the equipment and provides for the reception, re-formatting, and recording on magnetic media of the data output of the observation. The analysis software is used after the completion of the observations in an off-line manner. This software, which was developed at the University of Maryland, is typically used on either the Eclipse system at the University of Maryland or the Data General VAX at the Geodetic Survey Squadron in Cheyenne, Wyoming. This overall program structure has been successfully transferred to the VAX computer at Cheyenne. Most of the discussions of the details of these programs and their procedures will be addressed in various appendices and in separate documents. In this section, we shall primarily review their relationship.

A. Operational Software

The operational software is defined as that software which is required to support the field operation of the system. This software may be logically divided into two parts. The major portion is the software which is required for the operation of the NOVA minicomputer

and for the operation of the special purpose printed circuit cards developed by the University of Maryland. The second portion of this software consists of the one part which is resident in the CCD Camera Control Unit. This consists of the program which operated the microprocessor in the CCD Control system.

1. NOVA Operational Software

- a. Objectives

The objectives of the NOVA operational software consist of the following:

- (1) Control of Hardware data compaction

The data is compacted in a specially built University of Maryland card. The parameters to properly operate this card in a dynamic fashion, related to the motion and position of the star, is controlled within the NOVA operational software.

- (2) Data Formatting

The data is reformatted into records which have the appropriate data for analysis at a later time. These are collected and then written to magnetic tape.

- (3) Display

To provide the operator with a display of the system status and operation.

- (4) Circulating Memory Structure

This receives data from the CCD Camera Eyepiece, restructures it and loads this into the Circulating Memory. It then controls the transmission of this data to the Camera Head for real time background

subtraction.

(5) Timing Information

This consists of reading and operating the printed circuit card developed at the University of Maryland to provide timing for the operation of the CCD and, separately, for the reference clock in the Data Metrics. Auxiliary ports are provided for other comparative information as so desired.

b. Description

A description of the functions of the NOVA software is attached as Appendix V from a previous document. This has some modification to bring it up to date but basically is as was described in that document.

The code for this appears as Appendix VI.

2. CCD Control Unit Software

a. Objectives

The objectives of the software contained in the CCD Control Unit consist of the following:

(1) Creation of CCD Scan Pattern

This creates a scan pattern with the appropriate rows, columns, and overlays.

(2) Clock Voltage Trains

These are the clock voltage trains required to operate the CCD and transfer the charge in a proper manner to the preamplifier and operate the preamplifier.

(3) Clock Voltage Selection

These are responsible for the selection of the proper set of clock voltages for the appropriate temperature. These are contained in a ROM burned table and the software permits the direct operator change of these in order to fine tune operation.

b. Description

More detailed description of the functions has been briefly in other documents.

c. Availability

The details of this software, as it is written in machine code, is attached in an appendix.

B. Analysis Software

1. Objective

The objectives of the analysis software consists of transforming the field data which appears on digital magnetic tape into information which may be used as an input to the Geodetic Survey Squadron programs.

Thus, we wish to convert the intensities recorded during an observation (which consist of 200,000 16-bit numbers) into a single timing numbers with attendant parameters on internal accuracy and structural integrity.

2. Description

The analysis software has undergone considerable evolution. There have been two major versions. These have been the so-called Generation I (or GEN I) and Generation III (GEN III) Programs. The GEN I program performed the analysis

in the manner which was more tolerant of hardware and hardware/software variations. This summed the intensity in a vertical set of 10 rows. The increase in this data provided the signal which one analyzed. This has the advantage that it is less affected by analysis of the two independent fields. In addition, it is tolerant of irregularities in the motion of the defining patch. The required computer time is considerably lower.

The GEN II Program was developed, but not put into actual production run.

The GEN III Program analyzes the intensity of each pixel independently and optimizes the results. This technique is less sensitive to background and produces a significantly higher accuracy. On the other hand, it requires considerably more computer time. For this reason, a decision should be made concerning when one wishes to get reasonable results on faint stars, and when one wishes to save computer time.

A more complete discussion of this distinction and the various approaches was presented in the Quarterly Reports.

3. Documentation

The Generation I program is described in Appendix II.

The Generation III program is briefly described in Appendix VII. A fuller documentation of this will be provided at a later time.

The code of Generation III is provided in Appendix VIII.

X. OPERATING MANUAL

The "Operating Manual" has been created to summarize the entire CCD Array Eyepiece System from an operational point of view. This includes the equipment required, operating procedures, data handling, and data processing. This is an evolving document and, at present, is an intermediary draft. However, it has the following interesting items.

A. Required Equipment

The required equipment describes the equipment which was supplied with the operating van.

B. Observing Procedure

The operating procedure consists of the steps and procedures required in order to set up the equipment, take data, and record the data.

C. Data Handling Procedures

The data handling procedures consists of a description of the procedures conducted at the University of Maryland and a rough description of the procedures conducted by Rudi Salvermoser and by the Geodetic Survey Squadron. The latter two serve as comparative descriptions, not necessarily the requirements for the operation of the experiment.

XI. RESULTS

The overall results obtained by using the CCD eyepiece with the T-4 Theodolite show excellent agreement and an improved precision with respect to the conventional observations with the T-4. The initial proposal stated that the CCD eyepiece should be expected to do as well as the T-4 with no assurance of improvement. There are three major sources of error: the effects of anomalous refraction in the atmosphere, the personal equation of the operator, and the wobble of the trunion axis. We may only expect to reduce the impact of the personal equation problem with the use of the CCD eyepiece. Since we do not know the balance of these various effects, we cannot determine the improvements, but only demonstrate that the data may be obtained in an impersonal manner without a trained optical observer. However, the results quoted earlier indicate that we have in fact reduced the standard deviation of a night, or the night error, from the value for a typical observer (0.28 arcsecond) down to a night error of 0.13 arcsecond. One might hope that this goes further and that we continue to try to separate out various error sources in order to more correctly evaluate the performance of the instrument. However, its performance at this time is at the level beyond that originally discussed in the proposal.

Limiting magnitude (or faintest star which may be observed) depends upon the spectral type, or color of the star. This lies between 4.5 and 6.0 for the visual magnitude.

The procedure for the acquisition of the stars seems to be reasonable in terms of difficulty. However, we are supplying a Circulating Semiconductor Memory (CSM), which is to be installed shortly.

The software is operational and additional improvements are being supplied.

XII. PERSONNEL

The personnel who have been involved in this consist of:

LAWRENCE R. BLEAU, Data Processing Computer Operator

Mr. Bleau has developed a number of the programs for reading the data from the field tape and for preparing it for analysis. He has also been responsible for the maintenance of the ECLIPSE computer, which was used for the analysis systems and programs at the University of Maryland.

DOUGLAS G. CURRIE, Professor of Physics and Astronomy

Dr. Currie is the Principal Investigator for this project. He developed the original concept for the use of a CCD to perform high accuracy astroposition measurements and has guided this project at the University of Maryland to implement this concept.

ANDREW DANTZLER

Mr. Dantzler has aided in the observations, in the site development, and in various aspects of the laboratory support of this program.

JOHN J. GIGANTI, Design Engineer

Mr. Giganti, who is also Director of the Electronics Development Group, has been and is responsible for guiding the design of most of the electronic subsystems required in the CCD Array Eyepiece. He is also responsible for the fabrication and development of this equipment.

JOHN L. HERSHEY, Visiting Associate Professor

Dr. Hershey developed an initial set of programs to process data from the Mark IV Camera Head. He has developed and run the programs to determine the timing of meridian passage with the use of the CCD as it is used in the astroposition application. He aids in the conduct of the field observations and provides an evaluation of the quality of the data. He is involved with the development of further programs which will minimize the influence of various electronic, environmental, and astronomical sources of errors.

JOSEPH G. MATHEWS, Data Processing System Analyst

Mr. Mathews is responsible for the design of a significant number of the component subsystems.

FAUST MERALDI, Instrument Maker

Mr. Meraldi has designed and fabricated the interface between the T-4 Theodolite and the Mark II Camera Head, as well as the Mark V Camera Head. Several versions have been fabricated and tested. He has also aided in the definition of the modifications required for the T-4 Theodolite in order to permit the T-4 observations.

RUDOLF SALVERMOSER

Mr. Salvermoser is an employee of the Geodetic Survey Squadron of the Defense Mapping Agency. Mr. Salvermoser has been working closely with the University of Maryland in order to provide an evaluation of the Array Eyepiece System for the T-4 Theodolite. Mr. Salvermoser has performed all of the T-4 observations, operating the T-4 Theodolite. He

has also performed the data reduction to convert the meridian passage time, which is produced by the analysis programs, and form a nominal determination of longitude.

FREDERICK C. WIRE, Research Programmer

Mr. Wire has been responsible for the development of the NOVA software required for the operation of the system. He has also been responsible for a large portion of the debugging of the major subsystems. Mr. Wire has also aided in the observations conducted at the AIP Site at GORF.

DAVID M. ZIPOY, Professor of Astronomy

Professor Zipoy has been responsible for the programming of the microprocessor used to control the scanning and data sampling of the CCD. This is located in the Remote Control Unit. He has thus defined the procedures required in order to operate the various scanning and interrogation modes which may be used for the Mark V Camera Head. These modes are required both for normal operation, for system development and for system evaluation.

APPENDIX I

Terminologies

Within the University of Maryland program for the development of a new system for astropositioning, and particularly in the area of data analysis, various local terminologies have developed to describe the system and its behavior. In the interest of retaining communications among the various groups who are interested in the details of such a system, this section describes these terminologies in a more generally recognized language and should permit the interpretation of these terms.

COLUMN RECORD OR PROFILE

The column record, or profile, is a brightness as a function of time in a single column. Ideally, this has a form



Figure 7

where the dashed curve indicates an ideal form or very good seeing and the solid curve indicates a more typical curve for our current configurations.

GHOST

This is a phenomenon which occurs in the Fairchild Charge Coupled Device. This is typically related to the use of non-optimal clock voltages at the operating temperature. These may also be an absolute temperature effect. This phenomenon appears as a second peak, as illustrated below in Figure 8.

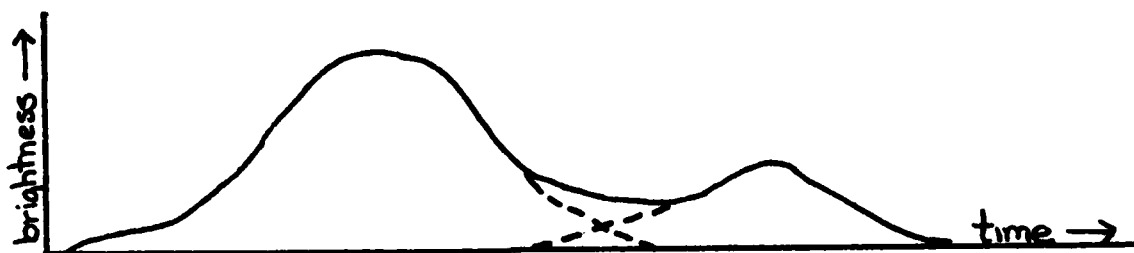


Figure 8

This illustrates the magnitude of the signal (in A to D units) summed over eight rows in one column. This is as a function of time, or for successive frames.

The ghost is separated from the main peak by approximately $1/\cos(\text{declination})$ seconds of time. Its magnitude may range between zero and 0.4 of the strength of the primary peak. This depends on the equipment and temperature. Depending upon the optical configuration, the ghost may either lead the main peak in time or lag the "true" pulse. The figure illustrates the latter case.

PRECURSORS, OR ASYMMETRIES

In the April 15 data only, a low amplitude, broad (in time) augmentation of the primary signal has been seen either before or after the primary pulse. These have attributed to a variety of effects.

However, this generally refers to something of the form



FIGURE 9

GEN I PROGRAM

This is a family of computer programs which analyze the data in order to determine the time at which the star crossed the meridian. It performs calculations upon data which is obtained from the total signal, or column record, obtained by summing the signals in the individual pixels in one column and in several rows. It is most frequently used when the star is crossing the array computer in an approximately horizontal (i.e., parallel to a row) manner.

GEN III PROGRAM

Also known as Diagonal Program, TWOD, and Array Program. The program can model the passage of a star across the array at any angle. An approximate ephemeris for the motion is adopted and differentially corrected until it can generate the amount of light detected by each pixel in the neighborhood of the star for each of several thousand frames ("exposures").

APPENDIX II

COMPUTER ANALYSIS OF LONGITUDE DATA
FROM THE UNIVERSITY OF MARYLAND ARRAY EYEPIECE
(COLUMN-CROSSING ANALYSIS)

by
John Hershey
and
Larry Bleau

ABSTRACT

This document describes one level of analysis of data from the University of Maryland Array Eyepiece System (UMAES) as used on a T-4 Wild Theodolite. The Array Eyepiece electronic system is described in The Array Eyepiece System for the Wilde T-4 Theodolite.

There are two major programs which make up the column crossing, or "Generation I" process. The first, CCTAPE, reads the original data tape and performs a relatively simple sorting process on the data, producing as its output disk files organized as input for the second program. CCDRED needs to be run only once for each data tape, and produces as output a separate disk file for each passage of a star across the array.

The second program, CCDRED, examines the light intensity over a particular column of the CCD array as a function of time, searching for the profile of a star. For each column, the characteristics of the star's profile, if present, are determined. This process is repeated with each column of the CCD array for which data was recorded. After all columns have been processed, a linear least squares fit to the times of column crossing is made. The residuals from the fit are used to eliminate any defective values from the time of meridian determination.

The time of instrument meridian is determined by means of column crossing times before and after instrument reversal.

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I. INTRODUCTION

A. Brief Description of the Analysis

This document describes the computer analysis of data taken from a T-4 Theodolite equipped with a diode array (CCD) in an observation mode for longitude determination. The longitude is found from the information recorded from the crossing of a star image over columns of pixels on the CCD array. This type of analysis is called the "Generation I" mode.

There are two major program units in the Gen I system. The first, CCDTAPE, reads the original data tape and performs a relatively simple preprocessing of the data, producing as its output disk files organized by diode array column number for the second program.

The second program, CCDRED, examines the time variation of light intensity over each column of the CCD array as a function of time, searching for the profile of a star. If a profile is found, its characteristics are determined and saved.

The time of meridian is determined by taking means of column crossing pairs which result from reversing the T-4 Theodolite as the star crosses the meridian. The crossing of the array columns is analogous to wire crossing or contact times in visual operation of the Theodolite.

B. Outline of the "Generation I" or Column Crossing Analysis for Time of Meridian Determination

1. Tape generated by UMAES at the T-4 Theodolite containing timing information and pixel light energies from the small patch area of the diode array.
2. Tape read, and energies of pixels sorted by diode array column number. Program CCDTAPE. Disk file created with array pairs of time

and energy for each column. One file created for each star passage across the array.

3. Disk file read, column by column. Program CCDRED. Each Energy-time array pair contains an energy profile as a function of time, representing the passage of the star across the diode column, if a star was present. Qualitatively this is a bell-shaped profile, where the peak represents the star centered on the column. The profile is fitted mathematically and a time of centering, or two half-power points are extracted. The timings for each column are stored. After all column times are determined a linear fit to column crossing times is made and stored. The residuals from the fit are used to eliminate defective crossing times. For a longitude observation, the above is carried out twice, once for before ("IN") and once after ("OUT") telescope reversal across the meridian.
4. Column crossing times read. The crossing times of "IN" and "OUT" are checked for matching column pairs, and are printed out if both are present. The means of pairs and their error, along with many other parameters of interest, are printed out. The mean of all column pairs is computed, printed out, and written to a "night file" as the time of instrument meridian passage.

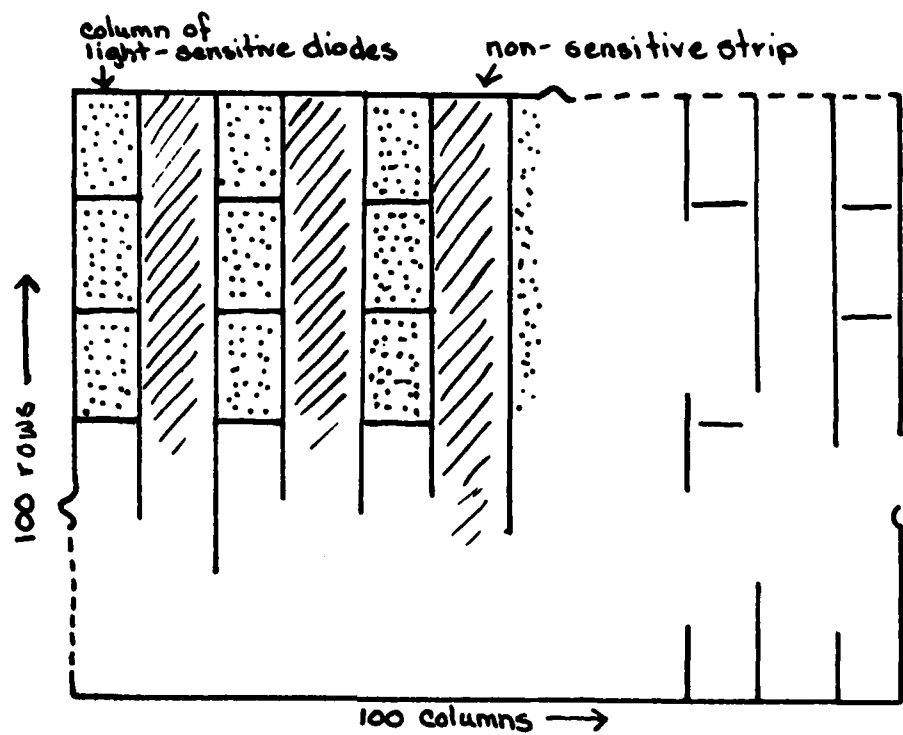


FIGURE 1

Geometry of the CCD Array

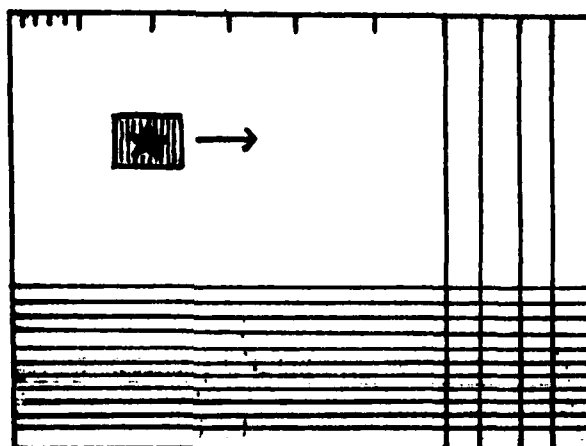


FIGURE 2

The moving patch which defines the part of the diode array to be recorded

II. DATA PREPROCESSING (From Tape to Disk) (CCDTAPE)

The purpose of CCDTAPE is to transform the recorded T-4 data from magnetic tape to disk in a form more usable to the Generation I program CCDRED (known as EPOCH on the Eclipse system). Since CCDRED requires a series of star profiles over time for each column of the CCD array, the primary task of CCDTAPE is to reduce the two dimensional data contained in a frame, usually 10 by 8 pixels in size, or less, to one dimensional data, with one point per frame associated with each column. This is done by averaging the pixels in each column in the frame and associating the mean with that column number and the frame's time, making a triple (e, t, C). Here "e" (energy) is the adjusted mean of pixels in column "C" at frame time "t". The star's profile, as seen by CCDRED, is a series of energy-time pairs (e, t) for each column that was recorded.

The operations of CCDTAPE can be broken down into four phases: initialization, reading physical tape records, processing frames, and constructing the proper triples (e,t,C). All phases are performed repeatedly except the initialization phase, which is executed once at the start of a CCDTAPE run. CCDTAPE is usually run in a mode that allows it to process an entire physical reel of tape with one execution. In the following descriptions, the terms "tape file" and "run" are synonymous.

The initialization phase fetches the value of three parameters: where to begin processing on tape, how many tape files to process, and the filename skeleton to be used. In generating output filenames, the skeleton, which is limited to seven characters, is used as a prefix to the current tape file number. For example, PLEIADS08, PLEIADS09, and PLEIADS10 are legitimate disk file names. To produce this result, the user could have directed CCDTAPE to start processing at tape file 8, process three tape files, and specify a skeleton of "PLEIADS".

The next phase handles not only the physical reading of tape records, but also any end of run or error handling required. Since a record may contain several frames of data, a subroutine which processes a frame is called repeatedly, and it examines a different portion of the tape record each time it is called. When the data in that record is exhausted, another physical tape record is read and the process continues through the end of the run, which is detected by an end of file on tape. At the end of a run, all the needed triples (e,t,C) have been generated; they exist as pairs (e,t) for each column and reside in several distinct files that are referenced by C; e.g., "COL25", "COL26". All of these files are now concatenated to form a single entity with which CCDRED can deal, and all the scratch files are deleted.

Timing information is also handled by CCDTAPE. There are currently three distinct clocks, each with a specific purpose. Here, the word "clock" is used in a software sense. That is, "clock X" represents the time, usually in microseconds, of the occurrence of event X. The Datametrics clock is used as the time standard and generates two external signals, one at 1Hz for counting seconds and one at 1MHz for driving the Event Timer board.

The software clock (SC) is in units of seconds and is incremented once each second by the 1Hz signal. It is initialized at the start of a run to the local time, so SC always represents the number of seconds since midnight.

The one second tick clock (OST) is in microseconds. It represents the time at which SC was incremented. In this manner it provides a link between Universal Time and the times used on the Event Timer board.

The photo-gate tick clock (PGT) is also in microseconds. It represents the time of the photo-gate pulse. This pulse is sent whenever a new field is read from the CCD. Since there are two fields which are read out at different times, only one of the PGT times is written on tape and it is adopted as the

"frame time".

Each of these clocks is recorded as a 32 bit entity. Also, since OST and PGT derive their values from the Event Timer board, which has only a 28 bit counter, the counter (and thus the time) reset to zero approximately every 4 minutes. To provide steadily increasing time, CCDTAPE adds $2^{**}28$ to the clock value whenever it decreases (rolls over) with respect to its previous value.

The first step in processing a frame of data is to interleave the frame. When the data was recorded, it was read out of the CCD and written on tape as two separate arrays, called fields, one of which represents all the even numbered rows and the other the odd numbered rows. These two fields are merged so that the row numbering and orientation are the same in the working array as they appear on the monitor at the observing site. The frame is also checked that it is self-consistent; i.e., correct number of words and patch corners within limits of screen.

The pixels in the frame are now summed by column, producing a single number associated with each column (C) for this particular frame time t. The sums are adjusted to take into account the vertical movement of the patch onto or off of a "bright spot", then an adjusted mean (e) is computed by dividing the adjusted sum by the number of rows. A bright spot is a CCD element which is defective and always reads out as the highest possible value. Without this adjustment, vertical motion of the patch onto a bright spot would have the effect of greatly increasing the energy in that column and distorting the star's profile.

The adjusted means can now be written as pairs (e,C) for frame time t. The values of "e" and "t" are written to a scratch file which is uniquely determined by "C". This has the effect of generating the (e,t,C) triples, which were originally sorted by "t", to triples sorted by "C".

III. ANALYSIS OF STELLAR COLUMN CROSSING PROFILES

This section gives a more detailed description of the program CCDRED, introduced in section I.B.3. above.

A. Input Parameters

A variety of input parameters and options are available. A few must be set specifically for each star. Some will normally be used at their default value, and several are inactive or useful only for special diagnostic or test purposes. The options are listed and explained below, in roughly in the order given above.

1. Options to be set on each run

a. Discriminator (D)

The discriminator value is used to test for the presence of a profile. The background is removed approximately and the data is searched for any point exceeding the value of D. D should be set to about one-half the average profile height expected. If it is set too low for faint stars, the program can mistake background variations for profiles. In the present instrumental configuration, the following guide can be used:

CCD Magnitude:	<2	2.5	3	3.5	4	4.5	5
D:	50	30	20	15	12	8	6

CCD Magnitude can be estimated from the following corrections as a function of spectral type: B: +3/4mag; A: +1/2mag; F: +1/4mag; G: 0; K: -1/4mag; M: -1/2mag.

Both of these tables may need refinement in the future, or

significant change if major instrumental changes are made.

Although the discriminator setting could in principle be automated by surveying the data on a file before detailed analysis, it is more practical to give this parameter in advance. On the VAX, an iterative loop resets D, if needed, to a value consistent with the profile heights found and repeats the profile search. The star number is recorded on tape at the observation site. With computer access to a star catalog, D can be set by the computer.

b. Width of profile (W)

The approximate width of a star profile rise time or fall time in terms of number of frames is needed. This value, used in the profile search algorithm, varies greatly because the drift rate of a star is proportional to secant declination. The rise time is about 10 frames at the equator. The desired value of W is $10 \sec \delta$.

Although the drift rate and thus declination could be determined by a preliminary reading of the entire file, practicality favors giving this parameter in advance. With access to a star catalog keyed by star number, the value of W can be set by the computer.

c. Reverse (R)

Because of the presence of "ghosts" in the profiles, the direction of search for the presence of a profile and its approximate location, must be done from the "ghost free" side of the profile. The "ghost" is described later in Section III. The ghost appears to lead in time or follow in time depending on the

orientation of the diode array. In the present observing practice, the ghost leads on the "IN" half of the longitude pair and trails on the "OUT". Thus, the R option is used on the "IN" passage, causing the profile search and location to be done in the reverse direction of time.

2. Little used or diagnostic options

Many options are included in the program which need not be used for production runs. Most options were added in order to do diagnostics or corrections for various instrumental problems which appeared throughout the long development of the electronic observing equipment.

a. Glitch height (H)

This option calls an algorithm which searches for wild points, or "glitches", in the data. Default is to skip the glitch search. Earlier on in the development of the equipment, wild points appeared both in and out of the profile, which confused the profile search and fitting process. The glitch algorithm searches for points which disagree with their neighbors by more than "H" energy units. Obviously, "H" should be set to a value greater than the noise of the data. A message is printed when a glitch is found. Too many messages may mean H has been set too small.

b. Smoothing window (S)

A default value is used which is appropriate to the present properties of the data. A strongly smoothed copy of the profile in a column is formed in array "B" for searching for a profile and locating its center and edges approximately for fitting

ranges. Another smoothing parameter can smooth the raw data for reducing noise in the profile before least squares fitting of a polynomial to the data. The number given for S is the number of frames in the window to be convolved.

c. Diagnostics (DIAG)

The presence of this option causes a variety of intermediate results to be printed out, with labels for locating sources of trouble.

d. First column to process (F)

This causes the program to skip the first F columns.

e. Number of columns to process (N)

Combined with F, a predetermined group can be selected.

f. Minimum points (M)

Causes program to ignore columns with less than M points.

g. Inversion (I)

This option is a remnant of a period when the energies from the diode array were recorded in the sense of increasing number for decreasing energy. The option subtracts the recorded numbers from a constant, thus changing their directional sense as a function of brightness.

B. Data Reading

The reading process is divided into calls on a reading module which brings the data for one column into computer memory. The data has been prepared in this form by the sorting process described in Section II. The reading subroutine is called REEDR. The subroutine fills and passes out the following via a parameter list:

1. The array column number - JCOL

2. The number of time-energy point pairs - NP
3. The time of the opening of the column in seconds from midnight - BASE1
4. The one-dimensional array "T" carrying the time of each point in seconds counted from the BASE1 as the zeropoint.
5. The one-dimensional array "A" carrying the total energy integrated by the column of pixels at the time indicated by the corresponding array element in the array "T".

The arrays A and T typically carry several hundred point pairs of information on the star passage. Various errors in reading are tested in the subroutine. Appropriate warning messages are printed when errors occur.

C. Preliminary Processing of the Column Data

In the "main line" program, called EPOCH, various preliminary operations can be done in the column processing loop. These operations, under option controls, are mentioned in discussion of input options. Before fitting the profile, the subroutine INVERT can be called for reversing the order of the data in time and/or inverting the sense of the energies. The subroutine GLITCH can be called for removing wild points. The smoothing operation can be called with a narrow window for reducing the noise in the array A to improve fitting. The smoothing operation is called with a broad window to fill an auxiliary array B containing the same number of elements as A but with strongly smoothed data for use by the profile search and locating algorithm.

D. The Profile Search and Locating Algorithm

After a column of data has been prepared as described in C., a call is made in the mainline on a module called STRSR (star search) which attempts to determine whether a star profile is present and to find its approximate

location in the array. This subroutine developed gradually with much experience with faulty data, and has accumulated many minor features, but the overall operation is as follows:

The strongly smoothed array, B, of column energies is passed in for profile detection. The noise is greatly reduced by the smoothing so as not to confuse the search for the profile or the location of fractional power points on the profile. The value of the discriminator in the input option is used to test for energy or "height" in the array, starting from the low numbered element of the array. Since the array is smoothed, the first several points provide an initial estimate of the background. The array is assumed to be reversed if necessary so that the ghost, if any, is trailing with regard to increasing array element number. When the first point is reached such that its value minus the background exceeds the discriminator, the subroutine assumes a profile is present and attempts to locate it.

The value of "width" passed in, is the number of array elements expected on the side of the profile. Since the discriminator represents an appreciable fraction of the expected profile height, the peak should certainly occur within two widths of the point where the discriminator is exceeded. The subroutine searches for a maximum point within this range. The maximum point is assumed to be near the center of the profile. The subroutine then "backs up" and searches for the 15 percent and 85 percent points on the leading side of the profile. From the top of the profile the 85 percent point on the trailing side is located. The height of a point one width from the 85 percent point is found. From the 85 percent point, a range of three widths is set for searching for a minimum. If a normal ghost is present, the bottom of the valley between the profile and ghost is located. If the star is very bright the valley may be filled in and the end of the range is likely the minimum

point. Initial profile ranges are then set. The left end is the 15 percent point minus 1.6x width.

All points outside of the total profile range including the ghost are then used to compute a background value. This value is subtracted from all points in the array. The profile search process is repeated, and the background computed a second time. The total background found is subtracted from array A which contains the data which will be used for fitting the profile. The outputs of the profile search algorithm are the array elements which determine the fitting range on the profile. In Figure 3, the range for fitting the rise of the profile will be from points lying between a and f.

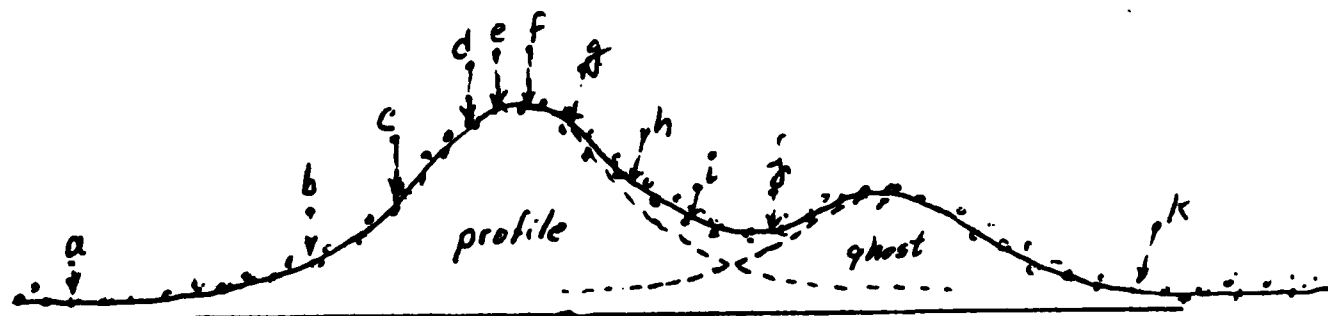


FIGURE 3

Features of the Column-Crossing Profile

The falling side will be fit from points lying between e and j. For an equatorial star, about 10 points lie between b and d, and more if the star has higher declination, increasing in number as secant δ .

Array ISYMT (1-6) passes out the element number of a, c, f, e, h, and j, in that order.

E. Profile Fitting

1. Polynomial Fit

The two profile sides are fit separately by two calls on the

same subroutine called FITAM. The left point, mid-height point, and right point of the fitting range are passed into the subroutine. The subroutine fits this range of the profile with a function of time. The times for each point in the profile are passed in as a one dimensional array T with a one-to-one correspondence to the elements of array A which carries the energies, or star profile.

For the least squares fit to the half profile, a zero point in time is removed. The time corresponding to point c in Fig. 3 is subtracted so that the least squares solution is more nearly balanced in time. A least squares solution then gives the energies of the profile as $E(t) = \sum a_i t^{e_i}$, a polynomial representation where the a_i are constants found by a least squares solution and the e_i are fractional exponents. The left side of a profile shown in Fig. 4, illustrates many features of the fitting process.

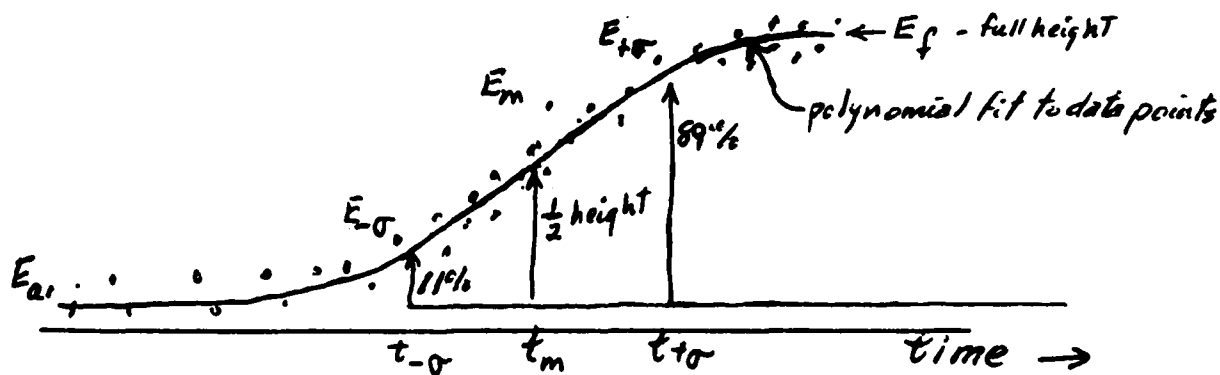


FIGURE 4

Detail of Fit to One Side of a Profile

The function E is evaluated at points a and f. The difference of $E_f - E_a$ is the height of the profile as estimated by the polynomial

fit. The desired time is the half power height of the profile. This would be the point where $1/2$ the star image is on the pixel column if the star diameter is less than the pixel width. A good initial estimate of this is point c which was passed into the fit routine. A subroutine, XOFY, which inverts a function by Newton's method, is called to take $E_m = (E_f - E_a)/2$ and find the value of t_m in the polynomial to yield $E(t_m) = E_m$. Similarly, the values of t are found for $E = 0.11$ of full height and $E = 0.89$ of full height. These values of $t_{\pm\sigma}$ would correspond to points at $\pm 1\sigma$ from the center of the star image if the star image were Gaussian in its brightness distribution. The difference of these two are a good measure of star diameter in time.

The polynomial for fitting the profile curve works best if it is zeroed near the half height of the profile. As an additional precaution, the zero point in time is taken as t_m found above which should be better and could be significantly different from the t_c originally used.

The above process is used again to fit $E(t)$ and find E_f , E_a , t_m , $t_{+\sigma}$ and $t_{-\sigma}$.

The right side of the profile is treated by the same subroutine with a different fitting range passed in.

Output from the subroutine is the time at half height, the time $t_{\sigma-}$ before half height and the time $t_{\sigma+}$ after half height. The height of the profile as determined by $E(t_{\text{right end}}) - E(t_{\text{left end}})$ is passed out. This changes sign from positive on the left side to negative on the right, which is a useful diagnostic in the printout.

The polynomial used to fit the half profiles was developed by

experimentation. Assuming the star point spread functions are Gaussian and smaller than a pixel, the profile sides are the integral of

$$\exp \left(\frac{-t^2}{2\sigma^2} \right)$$

Tabulated values of this integral were fit with various terms including trigonometric functions. The most successful function was $E(t) = a_1 + a_2t + a_3t^{0.8} + a_4t^{0.5} + a_5t^{0.3}$, with $t = 0$ at the half height and where the sign of t^e is applied after the fractional exponent is evaluated for t positive. The zero point of t should be near the half height of the profile for the best fit.

The least squares routine is designed for a minimum of code in the routine which makes the call for a least squares solution. An array called EQ is loaded with the individual equations of observation. For the equation above, they are

EQ (n,	1	2	3	4	5	6)
	1	t_1	$t_1^{.8}$	$t_1^{.5}$	$t_1^{.3}$	E_1
	1	t_2	$t_2^{.8}$	$t_2^{.5}$	$t_2^{.3}$	E_2
	:	:	:	:	:	:
	:	:	:	:	:	:
	1	t_n	$t_n^{.8}$	$t_n^{.5}$	$t_n^{.3}$	E_n

The call must give the number of equations and the number of unknowns: DALSQ (n,5).

The values of the a_i in the polynomial are returned in an array called CN.

Other very different and better methods of extracting the timing information from the profiles are treated in Section V. The

treatment of the two sides of the profile corresponds to the manual operation of the T-4 with contact closing and contact opening times.

F. Array Storage of the Column Data

When the time of immersion and emersion and other parameters of each column profile are determined, they are stored in scratch files (or arrays in VAX) in the main line of the program.

The identifiers are as follows:

SEQCOL - sequential count of acceptable columns.

INPCOL - the column number on the array.

CLOCK - the value of the count of seconds since midnight for the opening of the column (Basetime).

ISYMT - six frame numbers corresponding to points a, c, f, e, h, and i, in Fig. 3. (These values are not being used later and this storage could be eliminated.)

SIGMA - four values of the time differences of b and d from c of Fig. 3, and the similar pair on the right side of the profile.

ENR - the two values of profile height, from the left and right side of the profile.

TIM - the two values of time of immersion and emersion as defined in III. E. These times are times in seconds elapsed beyond the value of CLOCK and thus have a value of a few seconds.

G. Testing, Diagnostic Printout and File Storage of Column Crossing Times

The final module in the processing of a single set of column crossings is a subroutine called TIMFN, which reads back the data stored in III. F., performs an analysis, prints out some results and writes a storage file. The storage file name is the name of the input data file with an .SM (summary)

extension.

First the profile time widths (SIGMA of III. F.) are read into an array. The mean and r.m.s. of these four sets of values are computed by a call on RMS and printed out. The values are written out to the summary file. The values of profile heights are handled similarly.

The values of array column number INPCOL are read into the array COLMN and written to the summary file.

The values of CLOCK are read in, subtracted from the value of CLOCK for the first column, added to the times of immersion and emersion and stored in the two dimensional array TIM. These times are thus in units of seconds from the integer second of opening of the first column. They are written to the summary file.

A subroutine called TIMFT is called to perform a linear least squares fit on the column crossing times. A column number near the middle of the column range is subtracted before the fit is made and this "zero point column" number is printed out. The equation fitted is $T = a + bx(\text{col.}\# - \text{mid-col.}\#)$. The constant a is then the time at the zero point column number and b is the rate in seconds per column at which the star moves.

Throughout the development of the T-4 recording system a great variety of problems have appeared which caused some profiles to be defective. In order to avoid destroying the quality of an array transit due to only a few bad profiles, an iterative feature has been included in the fitting procedure. After a fit to the crossing times has been made and the standard error of a column has been determined, the residual of each column is compared to two (CUTOFF) standard errors. For any column exceeding this limit, a zero is entered into an array WEIGHT. A new solution is made eliminating the bad columns and residuals are again tested. If fewer than 10% of the columns

exceed the limit, the loop is exited. Residuals of bad columns are also computed from the current fit. Revision of the value of "CUTOFF" may be advisable in the future after study of the behavior of the residuals. The values of a, b (CN(1), CN(2)) errors of a, b (SE(1), SE(2)), standard error of a column (SE1), and the weight array of 0's and 1's are passed out of subroutine TIMFT and written to the storage file. The fit routine is called separately for the times of immersion and the times of emersion. All residuals of both immersion and emersion times and their weights are printed out for examination of the quality of the data.

The storage file carries various parameters in record 0. The first nine elements are presently unused. The remaining elements are as follows:

ELEMENT #	PARAMETER
10	Thousands of seconds of first column basetime
11	Remainder of first column basetime
12	Number of columns
13	Zero point column
14	a
15	b
16	Error of a
17	Error of b
18	Standard error of a column

Elements 13 - 18 are for immersion. Elements 19 - 24 repeat the same parameters for the emersion. Records 1 - 11 carry information for each column in their elements. The identifiers shown below are those used in III. F.

Records 1 - 4 four values of SIGMA, the time widths of profiles
 5 - 6 two values of ENR, the heights

7 - 8 two values of time $T(1, n)$ $T(2, n)$

9 Diode Array column numbers COLUMN

10 - 11 the 1's and 0's for good or bad column

On the VAX version, this file information is kept in arrays and the program described in IV is part of one large program.

IV. TIME OF MERIDIAN DETERMINATION

The observational technique being used for time of meridian determination with the T-4 and diode array is to reverse the entire T-4 instrument by 180° in azimuth near meridian passage. With appropriate level corrections, the time of a star crossing of a given column before and after reversal is equally spaced in time from star transit of the instrument meridian as indicated in Fig. 5.

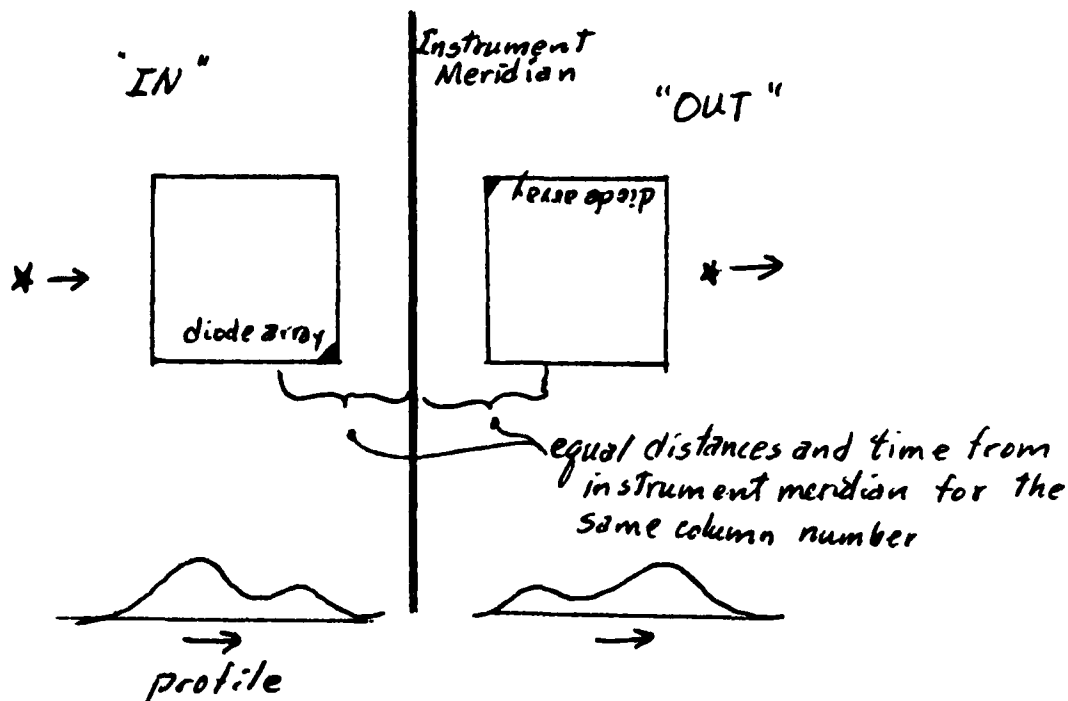


FIGURE 5

Geometry of Diode Array Reversals about the Meridian

The mean of the two crossing times of a column on IN and OUT thus gives a time of instrument meridian transit. Means of all columns with both an IN time and OUT time recorded give many values for the time of meridian which together form a more accurate mean time of instrument meridian passage. The star is not recorded for all columns because it must be visually located and

covered with the cursor field before data can be recorded.

A time of meridian passage could be calculated from the constants of the linear fits to crossing time by extrapolating the linear fit to a fictitious column number at the meridian where both IN and OUT functions yield the same crossing time. However, the means of the same column on IN and OUT give more insight into the behavior of the columns and avoid the weakness in extrapolation.

The program which takes the means of the column pairs is called SMREVP. This program reads the pair of .SM files which carry the timing information on the IN and OUT passages. A subroutine has been written which can compute the time of meridian by the extrapolation method described above. The major part of the program is concerned with forming various combinations of pairs and printing them out.

In practice, the "times of column crossing" involve both immersion and emersion and the symmetry of these in reversal must be considered. As shown in Fig. 6 the emersion side of the column on the IN passage is equidistant from the meridian with immersion on the OUT passage. Similarly, IN-immersion pairs with Out-emersion.

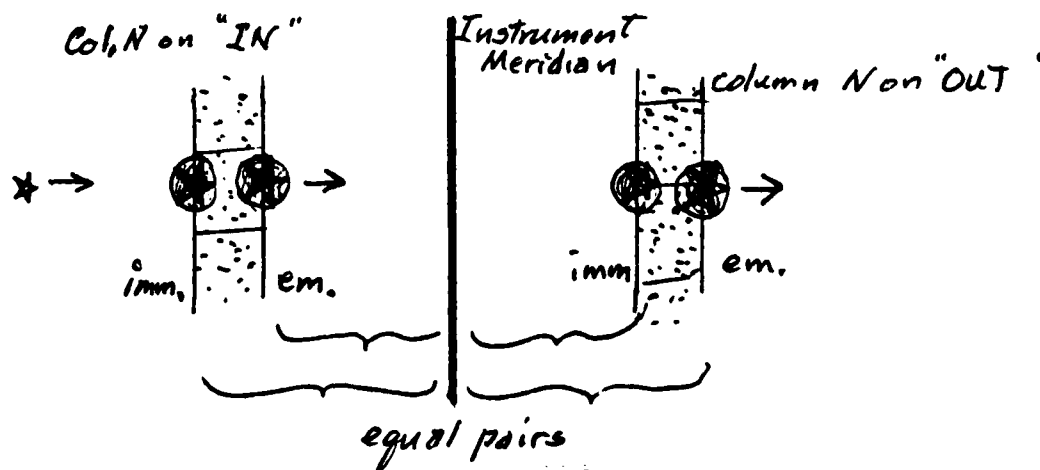


FIGURE 6

Geometry of Equal Pairs of "Immersion" and "Emersion" in Reversal

If the orientation of the ghost profile is considered, one of the above combinations has the "ghost-free" profile edges. The orientation used thus far is shown in Fig. 6, and thus the IN-emersion, OUT-immersion is the preferred combination, although experience has shown that the ghost-side can also yield the same precision if there is a minimum in the profile between ghost and main profile. (A centering method which finds one value for the center of the profile only, such as the double Gaussian fit described in V. does not, of course, have the problem of pairing immersions and emersions.)

Other combinations of immersion and emersion would seem possible with a strip width correction. However, it has been found that in the present instrumental arrangement, the effective star diameter is comparable to the diode column width and thus the difference of immersion and emersion times is not constant, but a function of focal adjustment and other variables.

The program which determines the time of meridian forms a two-dimensional array P (100, 11) for printing a table of timing combinations of IN, OUT, immersion, emersion for each good column pair. The array IP carries the 0's and 1's indicating which are the good and bad columns. A mean of all pair combinations is computed and one or more combinations can be taken as the time of instrument meridian passage. The standard error of a pair is computed and the error of the mean of all pairs is computed and printed out for each pair combination. If the error of ghost-side mean is low, it can be averaged with the ghost-free value. An example of the results appears in VI. Formal internal errors of the transit time often are as low as a few milliseconds.

V. ALTERNATE FITTING METHODS

A. Double Gaussian Fit

The major alternative to the separate profile side fitting described in III is a fitting algorithm which fits the entire profile and ghost in one operation with a single function. The profiles are not necessarily Gaussian in shape, but due to the star image diameter being comparable to the diode column width, the profiles do not have a flat top, but have qualitatively the same properties of a Gaussian or bell-shaped curve. The instrumental effects which cause the ghost are expected to generate the same shape as the main profile but smaller in vertical scale.

A subroutine has been developed to model the profile as the sum of two Gaussian functions and a zero-point constant, as shown in Fig. 7.

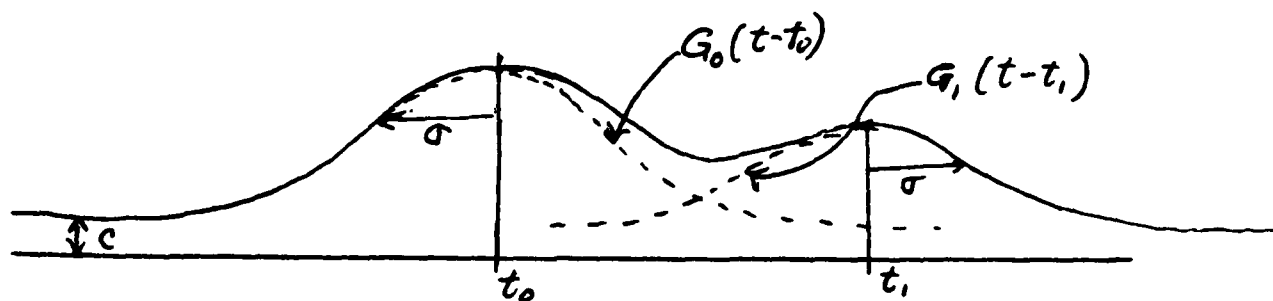


FIGURE 7

Gaussian Representation of the Profile

In mathematical terms, the profile height is

$$H(t) = C + A \exp \left(-\frac{(t - t_0)^2}{2\sigma^2} \right) + f A \exp \left(-\frac{(t - t_1)^2}{2\sigma^2} \right).$$

To reduce the number of unknowns, $(t_1 - t_0)$ is assumed to be the equatorial column crossing rate divided by cosine declination, or

$$t_1 = t_0 + 0.95 \sec \delta.$$

The width of the profile, σ , along with c , f , A , and t_1 are determined from each profile. These unknowns are determined iteratively by taking differentials with respect to each and solving for corrections to current values for each unknown. Approximate initial values are required to start the process. Values found by the profile search algorithm described in III. D. can be used for starting the differential correction iterations.

For a Gaussian function, analytical derivatives to each unknown can be written, which are faster to evaluate than numerical derivatives which may be required in more complicated functions. Formally, the correction to the computed height $H(t_0, A, f, \sigma, c)$ of the profile at any point can be written as the total derivative to the unknowns.

$$H_{\text{observed}} - H_{\text{computed}} = \frac{\partial H}{\partial t_0} \Delta t_0 + \frac{\partial H}{\partial A} \Delta A + \frac{\partial H}{\partial f} \Delta f + \frac{\partial H}{\partial \sigma} \Delta \sigma + \frac{\partial H}{\partial c} \Delta c$$

This equation can be evaluated for each frame time on the entire profile and the unknowns Δt , ΔA , Δf , $\Delta \sigma$, and Δc can be found by a least squares solution. These corrections are added to the current values of t , A , f , σ , and c . The differences $H_{\text{observed}} - H_{\text{computed}}$ are again found from the new constant, the partial derivatives are evaluated with the new constants and the cycle repeated until some convergence criterion is satisfied.

The parameters given to the subroutine for the Gaussian fit, called FITGS, are the same as those for FITAM described in III. E., except that declination is also passed in to determine the ghost displacement in time. The identifier for t_0 is T0, A is AC, c is B, f is F, and σ is S. The partial derivatives for each constant are loaded into array EQ(n, 1 - 5) for the five constants.

The value for σ is passed out in all four elements of SIGMA to keep the

subroutine compatible with the remainder of the program. Similarly, T_0 is passed out in $TIM(1)$ and $TIM(2)$; AC is passed out in $ENR(1)$ and $ENR(2)$.

Since the Gaussian fit routine uses the entire profile, with ghost, the value of T_0 should be better determined than the time of the mid-height of each profile side. Experience with a number of nights of observation has shown that the internal error of column crossing pairs was reduced by about 30 percent.

B. Trapezoidal Fit

Similar to the Gaussian fit, a trapezoidal function has been used in a differential correction algorithm for fitting the profiles. The trapezoidal model was motivated by the expectation that the top of the profile would be flat if the star diameter were small relative to the diode column width. Also, the ghost was expected to disappear with improved electronics in the diode array driving circuitry. The trapezoidal fit was written and developed on data which had little ghost effect but without a flat top.

The method of treating the trapezoid was to take derivatives with respect to the time coordinate of the points a , b , c , d , and height h shown in Fig. 8.

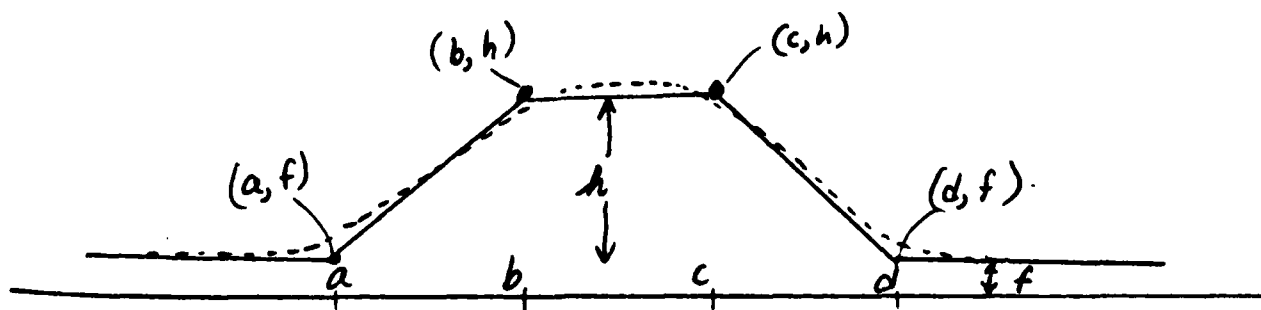


FIGURE 8

Trapezoidal Representation of the Profile

The derivatives for the straight line segments were evaluated only within their respective intervals. Extensive testing was not carried out because the flat topped profiles have not yet been produced, but the test results were comparable to the other fitting methods in accuracy.

VI. SOME EXAMPLES OF PROGRAM OUTPUT

FILENAME: T4DEC09:09DEC408.SM

BASE TIME FIRST COL	NO. OF COLS	MID COL NO.	INNERSSION:CONST.RATE	ERRORS OF CONST. RATE	ST.ERROR COL. EMERSSION!
104.0001	33.0000	49.0000	20.3740	1.0219	0.0006
20.9208	1.0227	0.0056	0.0005	0.0324	0.0383

FILENAME: T4DEC09:09DEC409.SM

BASE TIME FIRST COL	NO. OF COLS	MID COL NO.	INNERSSION:CONST.RATE	ERRORS OF CONST. RATE	ST.ERROR COL. EMERSSION!
104.0001	180.0001	40.0000	-16.8843	-1.0233	0.0003
-16.3263	-1.0213	0.0051	0.0004	0.0319	0.0159

MEAN TIME DIFFERENCE BETWEEN INNERSSION & EMERSSION = 0.553
NO. OF DIFFERENCES USED = 59.000

DIFFERENCE COMPUTED FROM RATE AND DIODE ARRAY DIMENSIONS 0.460

DECLINATION COMPUTED FROM RATES 21.72

COL	IN - I	IN - E	OUT - I	OUT - E	II/OE	IE/OI	II/OI	IE/OE	II/OI+D	IE/OE-B	II/OI+DA
35	1	1	0	39.03	39.59	174.36	0.00	106.98	106.70	0.00	106.93
36	1	1	1	40.11	40.68	173.38	173.92	107.02	106.74	107.30	106.97
37	1	1	1	41.08	41.63	172.33	172.89	106.98	106.70	107.24	106.98
39	1	1	1	43.13	43.67	170.28	170.80	106.97	106.70	107.24	106.98
40	1	0	1	44.21	0.00	169.27	169.82	107.02	106.74	0.00	106.97
41	1	1	1	45.18	45.69	168.23	168.75	106.97	106.71	107.22	106.98
42	1	1	1	46.21	46.78	167.19	167.77	106.99	106.70	107.27	106.98
45	1	1	1	49.26	49.87	164.11	164.65	106.95	106.68	107.24	106.96
46	1	1	1	50.37	50.87	163.09	163.65	107.01	106.98	107.24	106.99
49	1	1	1	53.44	53.92	160.03	160.56	107.00	106.97	107.24	106.97
50	1	1	1	54.46	54.98	159.03	159.60	107.03	106.75	107.29	106.98
52	1	1	1	56.47	57.02	156.99	157.56	107.01	106.73	107.29	106.96
54	1	1	1	58.51	59.06	154.93	155.47	106.99	106.72	107.24	106.99
55	1	1	1	59.49	60.02	153.91	154.51	107.00	106.70	107.26	106.98
56	1	1	1	60.45	61.06	152.91	153.49	106.97	106.68	107.28	106.98
57	1	1	1	61.54	62.09	151.84	152.50	107.02	106.70	107.29	106.97
58	1	1	1	62.55	63.18	150.85	151.47	107.01	106.70	107.33	106.98
59	1	0	1	63.66	0.00	149.80	150.35	107.00	106.73	0.00	106.96
60	1	1	1	64.57	65.18	148.77	149.34	106.94	106.67	107.26	106.98
61	1	1	1	65.67	66.23	147.78	148.36	107.01	106.72	107.29	106.95
63	1	1	1	67.67	68.25	145.71	146.26	106.97	106.69	107.25	106.98
64	1	1	1	68.69	69.28	144.71	145.31	107.00	106.99	107.29	106.98
65	1	1	1	69.71	70.30	143.71	144.31	107.00	106.99	107.29	106.98
66	1	1	1	70.73	71.32	142.71	143.31	107.00	106.99	107.29	106.98
67	1	1	1	71.75	72.34	141.71	142.31	107.00	106.99	107.29	106.98
68	1	1	1	72.77	73.36	140.71	141.31	107.00	106.99	107.29	106.98
69	1	1	1	73.79	74.38	139.71	140.31	107.00	106.99	107.29	106.98
70	1	1	1	74.81	75.42	138.71	139.31	107.00	106.99	107.29	106.98
71	1	1	1	75.83	76.44	137.71	138.31	107.00	106.99	107.29	106.98
72	1	1	1	76.85	77.46	136.71	137.31	107.00	106.99	107.29	106.98
73	1	1	1	77.87	78.48	135.71	136.31	107.00	106.99	107.29	106.98
74	1	1	1	78.89	79.50	134.71	135.31	107.00	106.99	107.29	106.98
75	1	1	1	79.91	80.52	133.71	134.31	107.00	106.99	107.29	106.98
76	1	1	1	80.93	81.54	132.71	133.31	107.00	106.99	107.29	106.98
77	1	1	1	81.95	82.56	131.71	132.31	107.00	106.99	107.29	106.98
78	1	1	1	82.97	83.58	130.71	131.31	107.00	106.99	107.29	106.98
79	1	1	1	83.99	84.60	129.71	130.31	107.00	106.99	107.29	106.98
80	1	1	1	85.01	85.62	128.71	129.31	107.00	106.99	107.29	106.98
81	1	1	1	86.03	86.64	127.71	128.31	107.00	106.99	107.29	106.98
82	1	1	1	87.05	87.66	126.71	127.31	107.00	106.99	107.29	106.98
83	1	1	1	88.07	88.68	125.71	126.31	107.00	106.99	107.29	106.98
84	1	1	1	89.09	89.70	124.71	125.31	107.00	106.99	107.29	106.98
85	1	1	1	90.11	90.72	123.71	124.31	107.00	106.99	107.29	106.98
86	1	1	1	91.13	91.74	122.71	123.31	107.00	106.99	107.29	106.98
87	1	1	1	92.15	92.76	121.71	122.31	107.00	106.99	107.29	106.98
88	1	1	1	93.17	93.78	120.71	121.31	107.00	106.99	107.29	106.98
89	1	1	1	94.19	94.80	119.71	120.31	107.00	106.99	107.29	106.98
90	1	1	1	95.21	95.82	118.71	119.31	107.00	106.99	107.29	106.98
91	1	1	1	96.23	96.84	117.71	118.31	107.00	106.99	107.29	106.98
92	1	1	1	97.25	97.86	116.71	117.31	107.00	106.99	107.29	106.98
93	1	1	1	98.27	98.88	115.71	116.31	107.00	106.99	107.29	106.98
94	1	1	1	99.29	99.90	114.71	115.31	107.00	106.99	107.29	106.98
95	1	1	1	100.31	100.92	113.71	114.31	107.00	106.99	107.29	106.98
96	1	1	1	101.33	101.94	112.71	113.31	107.00	106.99	107.29	106.98
97	1	1	1	102.35	102.96	111.71	112.31	107.00	106.99	107.29	106.98
98	1	1	1	103.37	103.98	110.71	111.31	107.00	106.99	107.29	106.98
99	1	1	1	104.39	105.00	109.71	110.31	107.00	106.99	107.29	106.98
100	1	1	1	105.41	106.02	108.71	109.31	107.00	106.99	107.29	106.98
101	1	1	1	106.43	107.04	107.71	108.31	107.00	106.99	107.29	106.98
102	1	1	1	107.45	108.06	106.71	107.31	107.00	106.99	107.29	106.98
103	1	1	1	108.47	109.08	105.71	106.31	107.00	106.99	107.29	106.98
104	1	1	1	109.49	110.09	104.71	105.31	107.00	106.99	107.29	106.98
105	1	1	1	110.51	111.11	103.71	104.31	107.00	106.99	107.29	106.98
106	1	1	1	111.53	112.12	102.71	103.31	107.00	106.99	107.29	106.98
107	1	1	1	112.55	113.14	101.71	102.31	107.00	106.99	107.29	106.98
108	1	1	1	113.57	114.16	100.71	101.31	107.00	106.99	107.29	106.98
109	1	1	1	114.59	115.17	99.71	100.31	107.00	106.99	107.29	106.98
110	1	1	1	115.61	116.18	98.71	99.31	107.00	106.99	107.29	106.98
111	1	1	1	116.63	117.20	97.71	98.31	107.00	106.99	107.29	106.98
112	1	1	1	117.65	118.22	96.71	97.31	107.00	106.99	107.29	106.98
113	1	1	1	118.67	119.24	95.71	96.31	107.00	106.99	107.29	106.98
114	1	1	1	119.69	120.26	94.71	95.31	107.00	106.99	107.29	106.98
115	1	1	1	120.71	121.28	93.71	94.31	107.00	106.99	107.29	106.98
116	1	1	1	121.73	122.30	92.71	93.31	107.00	106.99	107.29	106.98
117	1	1	1	122.75	123.32	91.71	92.31	107.00	106.99	107.29	106.98
118	1	1	1	123.77	124.34	90.71	91.31	107.00	106.99	107.29	106.98
119	1	1	1	124.79	125.36	89.71	90.31	107.00	106.99	107.29	106.98
120	1	1	1	125.81	126.38	88.71	89.31	107.00	106.99	107.29	106.98
121	1	1	1	126.83	127.40	87.71	88.31	107.00	106.99	107.29	106.98
122	1	1	1	127.85	128.42	86.71	87.31	107.00	106.99	107.29	106.98
123	1	1	1	128.87	129.44	85.71	86.31	107.00	106.99	107.29	106.98
124	1	1	1	129.89	130.46	84.71	85.31	107.00	106.99	107.29	106.98
125	1	1	1	130.91	131.48	83.71	84.31	107.00	106.99	107.29	106.98
126	1	1	1	131.93	132.50	82.71	83.31	107.00	106.99	107.29	106.98
127	1	1	1	132.95	133.52	81.71	82.31	107.00	106.99	107.29	106.98
128	1	1	1	133.97	134.54	80.71	81.31	107.00	106.99	107.29	106.98
129	1	1	1	134.99	135.56	79.71	80.31	107.00	106.99	107.29	106.98
130	1	1	1	136.01	136.58	78.71	79.31	107.00	106.99	107.29	106.98
131	1	1	1	137.03	137.60	77.71	78.31	107.00	106.99	107.29	106.98
132	1	1	1	138.05	138.62	76.71	77.31	107.00	106.99	107.29	106.98
133	1	1	1	139.07	139.64	75.71	76.31	107.00	106.99	107.29	106.98
134	1	1	1	140.09	140.66	74.71	75.31	107.00	106.99	107.29	106.98
135	1	1	1	141.11	141.68	73.71	74.31	107.00	106.99	107.29	106.98
136	1	1	1	142.13	142.70	72.71	73.31	107.00	106.99	107.29	106.98
137	1	1	1	143.15	143.72	71.71	72.31	107.00	106.99	107.29	106.98
138	1	1	1	144.17	144.74	70.71	71.31	107.00	106.99	107.29	106.98
139	1	1	1	145.19	145.76	69.71	70.31	107.00	106.99	107.29	106.98
140											

LONGITUDE RECORD

12-50 PROJECT										12-50 LOCATION										SETUP OF 4									
1 AIP ASTRO										G.O.R.F.										SETUP OF 4									
2 J. Bernard										D.M. 23 / 9 DEC 81										CLEAR, WIND									
3 883										D.M. 23 / 9 DEC 81										PE. NW, 20-40									
4 39,015										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 FS 4.0										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0902										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 40 2.1										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0001										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 40 4.9										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 1004										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 1005										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 2022										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0016										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0018										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0021										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									
5 0027										D.M. 23 / 9 DEC 81										D.M. 23 / 9 DEC 81									

Moon 1 day before full moon

Table 5
 Bias 888' Chip: +00.20
 No File
 40-10 File (F) #1,2
 Press: 29.72"

Box = 30' F: 3,4
 No box F: 5,6

Very dim
 F: 7,8

Ad = 1° F: 9,10

F: 11,12

Ad = 30' F: 13,14

SSMFEBO.MC

File	Time of meridian	Col. Pair Error	Error of Mean of Col. Pairs	No. of Col. Pairs
T4FEF111:11FEF100	90 266.739	0.056	0.010	40
T4FEF111:11FEF104	90 1008.819	0.001	0.000	100
T4FEF111:11FEF106	92 303.170	0.038	0.014	20
T4FEF111:11FEF108	92 591.922	0.029	0.006	100
T4FEF111:11FEF110	92 802.684	0.025	0.007	100
T4FEF111:11FEF112	93 239.654	0.027	0.012	100
T4FEF111:11FEF114	7 417.355	0.048	0.018	100
T4FEF111:11FEF116	7 680.243	0.044	0.012	15
T4FEF111:11FEF200	8 510.276	0.000	0.000	14
T4FEF111:11FEF202	8 619.216	0.024	0.004	6
T4FEF111:11FEF204	9 98.707	0.047	0.019	6
T4FEF111:11FEF206	9 783.410	0.042	0.008	100
T4FEF111:11FEF209	11 602.889	0.024	0.006	100
T4FEF111:11FEF211	12 247.100	0.039	0.008	100
T4FEF111:11FEF300	13 616.269	0.102	0.051	4
T4FEF111:11FEF302	14 121.930	0.058	0.011	100
T4FEF111:11FEF304	14 484.024	0.038	0.011	100
T4FEF111:11FEF306	14 685.008	0.051	0.018	100
T4FEF111:11FEF308	14 911.791	0.047	0.015	100
T4FEF111:11FEF310	15 388.446	0.020	0.005	100
T4FEF111:11FEF312	15 719.665	0.032	0.007	100
T4FEF111:11FEF314	15 920.886	0.039	0.008	100
T4FEF111:11FEF316	16 640.798	0.036	0.013	100
T4FEF111:11FEF318	16 925.074	0.039	0.010	100
T4FEF111:11FEF320	17 586.075	0.037	0.006	100
T4FEF111:11FEF400	19 464.617	0.028	0.006	100
T4FEF111:11FEF402	19 756.021	0.072	0.016	100
T4FEF111:11FEF404	20 289.605	0.475	0.194	100
T4FEF111:11FEF406	20 752.443	0.026	0.005	100
T4FEF111:11FEF408	21 329.937	0.049	0.022	100
T4FEF111:11FEF410	21 643.847	0.056	0.014	100
T4FEF111:11FEF416	22 628.343	0.025	0.010	100

R

APPENDIX III

OPERATIONAL SYSTEM ON THE NOVA MINICOMPUTER
FOR THE CCD EYEPIECE SYSTEM

BLOCK: 11454(26276)

1 (EMPTY BLOCK)
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BLOCK: 11455(26277)

1 (EMPTY BLOCK)
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BLOCK: 11456(26300)

1 (T-4 THEODOLITE ASTROMETRY CONTROL ROUTINES 1/22/82 FCW) :S
 2
 3 ----- BLOCK MAP -----
 4
 5 BLK 302 - LOAD BLOCK BLK 304 - BUFFER MANAGEMENT
 6 BLK 306 - PATCH PARAMETERS BLK 310 - RATE PARAMETERS
 7 BLK 312 - REAL TIME CLOCK BLK 316 - EVENT TIMER
 10 BLK 324 - AUTO PATCH STEP BLK 330 - PATCH GENERATOR
 11 BLK 336 - INTERRUPT ROUTINES BLK 346 - STAR #
 12 BLK 352 - RECORD HEADER BLK 354 - DATA ROUTINES
 13 BLK 360 - ALIAS SET BLOCK BLK 362 - DATA RECORDING
 14 BLK 366 - RATES BLK 370 - BACKGROUND LEVEL
 15 BLK 372 - A-D VALUE DISP.
 16
 17
 20

AD-A127 322

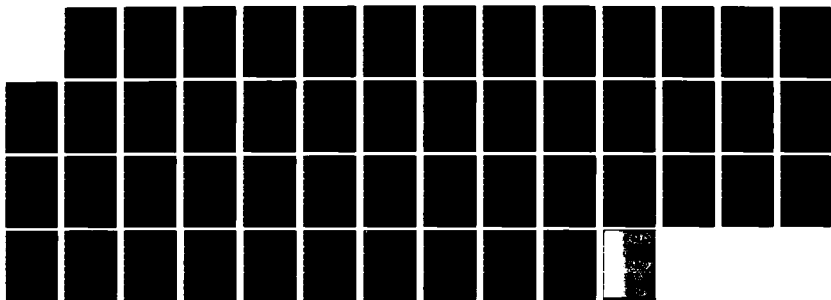
STUDY OF CCD EYEPIECE ON T-4 THEODOLITE(U) MARYLAND
UNIV COLLEGE PARK DEPT OF PHYSICS AND ASTRONOMY
D G CURRIE NOV 82 AFGL-TR-82-0184 F19628-77-C-0186

2/2

UNCLASSIFIED

F/G 17/8

NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11457(26301)

```

1 ( T4 PROGRAM COMMENTS          FCW 1/22/82 )      ;S
2
3  ALL ODD NUMBERED BLOCKS ARE RESERVED AS COMMENT BLOCKS. MOST
4  EVEN NUMBERED BLOCKS ARE PROGRAM BLOCKS, ALTHOUGH IF A COMMENT
5  TAKES MORE THAN 1 BLOCK, IT WILL OVERFLOW TO THE NEXT EVEN
6  NUMBERED BLOCK. ALL COMMENT BLOCKS CAN BE LOADED WITH NO
7  DIFFICULTY.
10
11
12
13
14
15
16
17
20
```

BLOCK: 11458(26302)

```

1 ( T4 LOAD BLOCK    FCW 1/8/82  MOD 4-22-82 )
2
3 : T4 ;
4
5 TAPE    * TAPE LOADED* CR
6
7 DBL-PREC    * DOUBLE PRECISION LOADED* CR
10
11 : T4-LOAD 375 304 DO I LOAD 2 +LOOP ;
12
13 T4-LOAD    * T4 SYSTEM LOADED* CR
14
15 DECIMAL    * BASE IS DECIMAL* CR  BELL
16
17
20 ;S
```

BLOCK: 11459(26303)

```

1 ( LOAD BLOCK COMMENTS          FCW 1/22/82 )      ;S
2
3 T4 - DUMMY DEFINITION TO PREVENT THE T4 SYSTEM FROM BEING
4   LOADED TWICE.
5
6 TAPE - LOAD THE TAPE READ/WRITE ROUTINES
7
10 DBL-PREC - LOAD THE DOUBLE PRECISION INTEGER ROUTINES
11
12 T4-LOAD - LOAD THE REST OF THE T4 PROGRAM BLOCKS
13
14
15
16
17
20
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11487(26337)

```

1 ( INTERRUPT HANDLER COMMENTS      FCW 1/21/82 )  #S
2
3   ON THE T4 PROGRAM, INTERRUPTS ARE USED ONLY TO SERVICE THE KEY
4   BOARD. ANY OTHER INTERRUPTING DEVICE WILL CAUSE THE PROGRAM
5   TO ABORT.
6   'IVECT' IS AN INTERRUPT VECTOR ARRAY 64 WORDS LONG. THE VECTOR
7   OFFSET IS DETERMINED BY THE ASCII VALUE OF THE KEY STRUCK. THIS
10  ARRAY IS INITIALIZED SO ALL VECTORS POINT TO THE INTERRUPT EXIT
11  ROUTINE.
12
13
14
15
16
17
20

```

BLOCK: 11488(26340)

```

1 ( T4 INTERRUPT EXIT      FCW  1/8/82      MOD 4-13-82  )
2
3 CODE INT-EXIT
4   REGS 4 + 0 LDA, 0 0 MOV, *2 REGS 3 + 3 LDA,
5   REGS 2 + 2 LDA, REGS 1+ 1 LDA, REGS 0 LDA,
6   INTEN, 0 1) JMP,
7
8 ' INT-EXIT CONSTANT IXIT
9
10 ( INITIALIZE INTERRUPT VECTOR TABLE )
13 IXIT IVECT ! IVECT DUP 1+ 176 WORDS
14
15
16
17
18 #S

```

BLOCK: 11489(26341)

```

1 ( INTERRUPT EXIT COMMENTS      FCW  1/21/82 )  #S
2
3   RESTORE REGISTERS AND CY
4   ENABLE INTERRUPTS
5   RETURN TO INTERRUPTED PROGRAM
6
7
8
9
10
11
12
13
14
15
16
17
18

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11490(26342)

```

1 ( KEYBOARD INTERRUPT SERVICE ROUTINES   FCW 1/8/82 )
2 ( MOD 5/13/82 )
3
4 : IVCT! HERE SWAP IVECT + ! ;
5 CPATCH INTEGER IMV      0 INTEGER WELL
6
7 ( LEFT ) 061 IVCT! IMV 2 LDA, 2 2) DSZ, IXIT JMP,
10          2 2) ISZ, IXIT JMP,
11 ( RIGHT ) 063 IVCT! IMV 2 LDA, 2 2) ISZ, IXIT JMP,
12 ( UP ) 065 IVCT! IMV 2 LDA, 0 2) ISZ, IXIT JMP,
13 ( DOWN ) 054 IVCT! IMV 2 LDA, 0 2) DSZ, IXIT JMP,
14          0 2) ISZ, IXIT JMP,
15 ( FINISHED ! ) 15 IVCT! 2 2 LDA, WELL 2 STA,
16          IXIT JMP,
17
20 IS

```

BLOCK: 11491(26343)

```

1 ( INTRR. SERVICE COMMENTS   FCW 1/21/82 )  IS
2
3   THESE ROUTINES INCREMENT OR DECREMENT THE STARTING ROW OR
4 COLUMN * TO CHANGE THE PATCH POSITION.
5   A 'CR' SETS 'WELL' TO A NONZERO VALUE TO TERMINATE DATA
6 TAKING.
7
10
11
12
13
14
15
16
17
20

```

BLOCK: 11492(26344)

```

1 ( INTERRUPT CONTROL ROUTINES   FCW 1/8/82 MOD 1/11/82 )
2
3 1 ,CODE KCKA / INTERRUPT ,
4   0 S) 0 LDA, 77 DOB, / KCKA 0 LDA, 1 0 STA, POP JMP,
5
6 CODE STTI 110 NIO, NEXT JMP, CODE CTTI 210 NIO, NEXT JMP,
7
10 : KCLR 177777 KCKA CTTI ;
11 : KARM 177775 KCKA STTI ;
12
13 CODE DI 277 NIO, NEXT JMP,
14 CODE EI INTEN, NEXT JMP,
15
16 : CINIT CRATE SCA 4 WORDS KARM ;
17 : CFIN KCLR ;
20 IS

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11493(26345)

```

1 ( INTERRUPT CONTROL COMMENTS      FCW 1/21/82 )  ;S
2
3 KCKA - OUTPUTS THE INTERRUPT MASK ON THE STACK AND SETS THE
4       INTERRUPT VECTOR ( LOC 1 ) TO POINT TO THE T4 INTER-
5       RUPT HANDLER.
6
7 CINIT - SETS UP THE SCRATCH AREA FOR THE RATE AND ENABLES THE
10      TTI INTERRUPT MASK.
11
12
13
14
15
16
17
20

```

BLOCK: 11494(26346)

```

1 ( STAR # AND OTHER STUFF  FCW 1/21/82  MOD 4/15/82 )
2
3 -1 INTEGER STAR-NMBR
4 : STAR-NUMBER
5     BASE @ DECIMAL  WORD  NUMBER  DROP  STAR-NMBR  !
6     BASE ! ;
7
10 : SN STAR-NUMBER ;
11
12 0 INTEGER LOC  5 DP +! ( ASCII STRING )
13 : LOCATION
14     WORD  DP @ 1+  LOC  5 WORDS ;
15
16
17
20 ;S

```

BLOCK: 11495(26347)

```

1 ( HEADER AND HEADER ROUTINES COMMENTS  FCW 1/22/82 )  ;S
2
3 THE RECORD HEADER FORMAT IS AS FOLLOWS.
4   WORD #      DESCRIPTION
5   -----
6   0           STAR NUMBER
7   1           SPARE
10  2 - 3       DMA 1 SEC CLOCK
11  4 - 17      ETBUF ( LESS PHOTOGATE )
12  18 - 25     SPARES
13
14
15
16
17
20

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11496(26350)

```

1 ( T4 SYSTEM ) ;S
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20 ;S

```

BLOCK: 11497(26351)

```

1 ( T4 SYSTEM ) ;S
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20 ;S

```

BLOCK: 11498(26352)

```

1 ( CREATE THE RECORD HEADER   FCW 1/21/82   MOD 1/25/82 )
2
3 1 ,CODE HBF 0 ,
4     0 S) 1 LDA,   ' HBF 0 LDA,   1 0 ADD,   PUT JMP,
5
6 ( HEADER ADDRESS ON STACK )
7 : RECORD-HEADER
10     ' HBF !
11     STAR-NMBR @   0 HBF   !
12     1SEC-CLK     2 HBF   D!
13     ETRUF 2 +    4 HBF   16 WORDS   ;
14
15
16
17
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11499(26353)

```

1 ( RECORD HEADER ROUTINES COMMENTS      FCW 1/21/82 )  IS
2
3 HBF - REPLACES THE # ON THE STACK WITH THE SUM OF THE # ON THE
4       STACK AND THE HEADER STARTING ADDRESS.
5
6 RECORD-HEADER
7       - BUILD THE RECORD HEADER ACCORDING TO THE HEADER FORMAT.
10
11
12
13
14
15
16
17
20

```

BLOCK: 11500(26354)

```

1 ( RECORD HEADER AND 1'ST FRAME OF RECORD  FCW 1/8/82 )
2 ( MOD 2/11/82 )
3
4 BASE @ DECIMAL
5
6 : 1'ST-FRAME
7   32 GRUF / GRUF @ CCDINIT TIMETAGS
10  RECORD-HEADER
11  PTGMICROSEC D@ 26 HBF D!
12  CPATCH 28 HBF 4 WORDS
13  EI STEP CCD-DONE DI / GRUF ! ;
14
15 BASE !
16
17
20 IS

```

BLOCK: 11501(26355)

```

1 ( 1'ST FRAME COMMENTS      FCW 1/21/82 )  IS
2   32 GRUF RESERVES 32 WORDS FOR THE RECORD AND FRAME HEADERS.
3 THE PATCH GENERATOR IS INITIALIZED FOR THE NEXT FRAME. TIMETAGS
4 CHECKS THE ET BOARD AND DOES NOT RETURN UNTIL THE NEW FRAME HAS
5 STARTED. THEN THE RECORD-HEADER IS CREATED AND THE FRAME HEADER
6 IS FILLED WITH THE PHOTOGATE TIME AND THE PATCH PARAMETERS.
7 INTERRUPTS ARE ENABLED FOR THE KEYBOARD, THE AUTO STEP ROUTINE
10 IS CALLED, AND THE PROGRAM WAITS UNTIL THE THE CURRENT PATCH
11 FRAME IS DONE. THEN INTERRUPTS ARE DISABLED AND THE NEXT FREE
12 BUFFER ADDRESS STORED IN GRUF.
13
14
15
16
17
20  IS

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11502(26356)

```

1 ( FRAMES 2,3, & 4 OF TAPE RECORD FCW 1/8/82 MOD 1/22/82 )
2
3 : REC-FRAME
4     6 GBUF DUP ' GBUF @ CCDINIT TIMETAGS
5     PTGMICROSEC D@ ROT D! CPATCH SWAP 2 + 4 WORDS
6     EI STEP CCD-DONE DI ' GBUF ! ;
7
10 : 234-FRAMES REC-FRAME REC-FRAME REC-FRAME ;
11
12
13
14
15
16
17
20 IS

```

BLOCK: 11503(26357)

```

1 ( 2,3,4 FRAME COMMENTS FCW 1/22/82 ) IS
2
3 REC-FRAME - RECORD 1 CCD FRAME WITH THE FOLLOWING FORMAT:
4
5     WORD #      DESCRIPTION
6     -----
7     0 , 1      PHOTOGATE IN MICROSECONDS
10    2 - 5      PATCH PARAMETERS (CPATCH)
11    6 - N      PIXEL DATA
12
13
14
15
16
17
20

```

BLOCK: 11504(26360)

```

1 ( ALIAS SET BLOCK FCW 06/08/81 MOD 01/21/82 )
2
3 ALIAS T4DATA ALIAS T4EOF
4 : RECORD ' TWRITE ' T4DATA ! ' EOF ' T4EOF ! ;
5
6 RECORD
7
10 : NOWRT DROP DROP ;
11 : SIM ' NOWRT ' T4DATA ! ' NULL ' T4EOF ! ;
12
13 SIM
14
15
16
17
20 IS

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11505(26361)

```

1 ( ALIAS SET BLOCK COMMENTS          FCW 1/21/82 ) ;S
2
3 T4DATA - DUMMY WRITE ROUTINE
4 T4EOF  - DUMMY EOF ROUTINE
5
6 RECORD - SET UP T4DATA TO THE TAPE WRITE ROUTINE AND T4EOF
7         TO THE TAPE EOF ROUTINE
10 SIM   - SET UP T4DATA AND T4EOF TO DO NOTHING AT ALL
11
12
13
14
15
16
17
20

```

BLOCK: 11506(26362)

```

1 ( DATA RECORDING ROUTINES          FCW 1/8/82   MOD 2/8/82 )
2 ; 1REC
3   ' GBUF @ DUP   1'ST-FRAME  234-FRAMES
4   ' GBUF @ - SWAP T4DATA ;
5
6 ' GBUF @ GBUFMARK GBUFST
7
10 : DATA-LOOP
11   WELL ZERO! PCNT! CINIT ETINIT TICK DROP
12   BEGIN TICK ETSCAN END
13   BEGIN GBUFST 1REC 1REC WELL @ END
14   CFIN T4EOF ;
15
16 : CURSOR   SIM DATA-LOOP ;
17 : RUN      CURSOR RECORD FAST GAP GAP DATA-LOOP ;
20 ;S

```

BLOCK: 11507(26363)

```

1 ( RECORDING ROUTINES COMMENTS       FCW 1/21/82 ) ;S
2
3 1REC - ASSEMBLE 1 COMPLETE RECORD IN MEMORY AND CALL T4WRITE
4
5 DATA-LOOP
6   - INITIALIZE INTERRUPTS AND THE EVENT TIMER
7   SET UP AN INDEFINITE LOOP, SWITCHING BETWEEN 2 BUFFERS
10  DISABLE INTERRUPTS AND CALL T4EOF
11
12 CURSOR
13   - DO DATA-LOOP WITHOUT WRITING TO TAPE
14
15 RUN  - DO DATA-LOOP AND RECORD DATA ON TAPE
16
17
20

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11508(26364)

```

1 ( THESE ROUTINES ARE HELPFUL WHEN RUNNING THE T4 SYSTEM )
2 ( MOD FCW 4/15/82 )
3 : @TIME CR * TIME: * MST? ;
4 : TRUN @TIME RECORD FAST GAP GAP DATA-LOOP @TIME ;
5
6 1 ,CODE REVERSE CRATE ,
7   ' REVERSE 3 LDA, 1 3) 0 LDA, 0 0 COM, 1 3) 0 STA,
10   3 3) 0 LDA, 0 0 COM, 3 3) 0 STA, NEXT JMP,
11
12 0 INTEGER HLD-RATE 0 , 0 , 0 ,
13 : HALT CRATE HLD-RATE 4 WORDS STILL ;
14 : RESUME HLD-RATE CRATE 4 WORDS ;
15 : REVERSAL HOME CURSOR TRUN HALT CURSOR RESUME REVERSE TRUN
16   -1 STAR-NMBR ! ;
17 : R REVERSAL ;
20 ;S

```

BLOCK: 11509(26365)

```

1 ( RUNTIME ROUTINE COMMENTS FCW 1/21/82 MOD 4/15/82 ) ;S
2 TRUN - SAME AS RUN EXCEPT IT PRINTS THE TIME ON THE TERMINAL AT
3   THE BEGINNING AND END OF A RUN.
4 REVERSE - CHANGE THE DIRECTION FLAGS IN CRATE
5 HALT - SAVE CURRENT RATE AND REPLACE WITH STILL
6 RESUME - RESTORE RATE
7 REVERSAL - DO THE DATA RUN IN BOTH DIRECTIONS
10
11
12
13
14
15
16
17
20

```

BLOCK: 11510(26366)

```

1 ( HORIZONTAL RATES FCW 12/03/81 MOD 1/26/82 )
2 BASE @ DECIMAL
3 39 0 RATE E00 39 0 RATE E05 40 0 RATE E10 41 0 RATE E15
4 41 0 RATE E20 43 0 RATE E25 45 0 RATE E30 48 0 RATE E35
5 51 0 RATE E40 55 0 RATE E45 61 0 RATE E50 68 0 RATE E55
6 77 0 RATE E60 92 0 RATE E65 114 0 RATE E70 150 0 RATE E75
7 224 0 RATE E80 447 0 RATE E85
10 -39 0 RATE W00 -39 0 RATE W05 -40 0 RATE W10 -41 0 RATE W15
11 -41 0 RATE W20 -43 0 RATE W25 -45 0 RATE W30 -48 0 RATE W35
12 -51 0 RATE W40 -55 0 RATE W45 -61 0 RATE W50 -68 0 RATE W55
13 -77 0 RATE W60 -92 0 RATE W65 -114 0 RATE W70 -150 0 RATE W75
14 -224 0 RATE W80 -447 0 RATE W85
15 BASE !
16
17
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11481(26331)

1 (OPATCH COMMENTS FCW 1/22/82) ;S
 2 THE PATCH IS DEFINED IN HARDWARE BY 4 COORDINATES : 1) START-
 3 ING LINE; 2) ENDING LINE; 3) STARTING COLUMN; & 4) ENDING COL-
 4 UMN. THE 4 PATCH COORDINATES ARE SELECTED BY A 'DOA 7' INSTRU-
 5 TION. BITS 4-15 HAVE THE COORDINATE VALUE (RIGHT JUSTIFIED).
 6 BITS 2 & 3 GO TO A DECODER TO SPECIFY WHICH PARAMETER IS BEING
 7 OUTPUT. THIS TABLE SHOWS THE SELECTION MAPPING.

-----TABLE-----		PATCH
BIT #		PARAMETER
2 , 3		
0 , 0		STARTING LINE
0 , 1		ENDING LINE
1 , 0		STARTING COLUMN
1 , 1		ENDING COLUMN

20 (CONTINUED NEXT BLOCK)

BLOCK: 11482(26332)

1 (OPATCH COMMENTS FCW 1/21/82) ;S
 2 IN ADDITION, BIT 0 OF THE 'DOA 7' INSTRUCTION HAS A SPECIAL
 3 FUNCTION. IF BIT 0 = 0, THE ODD FIELD IS THE FIRST ONE IN A
 4 FRAME. IF BIT 0 = 1, THE EVEN FIELD IS THE FIRST ONE IN A FRAME.
 5 THIS FEATURE IS NOT EXPLOITED BY THIS PROGRAM; BIT 0 IS ALWAYS
 6 SET TO 0.
 7 THE HARDWARE CAN HANDLE A CCD ARRAY OF UP TO 8192 ROWS BY
 10 4096 COLUMNS. THE PATCH SIZE CAN BE FROM 2 ROWS X 2 COLS UP TO
 11 THE SIZE OF THE CCD ARRAY. THE LIMITING FACTOR IS THE WORD
 12 COUNT REGISTER, WHICH LIMITS THE MAXIMUM PATCH SIZE TO
 13 32,767 ELEMNTS.
 14 CHECK THE CCD DATA SHEETS; THERE ARE ONE OR MORE LINES AT THE
 15 BEGINNING OF EACH FIELD THAT CONTAIN NO DATA, AND THERE ARE SEV-
 16 ERAL COLUMNS AT THE BEGINNING OF EACH LINE WITH NO DATA.
 17 THEREFORE IT IS USELESS TO SPECIFY ONE OF THESE LINES OR COLS
 20 AS THE STARTING ROW/COL. (CONTINUED NEXT BLOCK)

BLOCK: 11483(26333)

1 (OPATCH COMMENTS FCW 1/21/82) ;S
 2 THE SOFTWARE MUST MAKE SURE THE PATCH IS NOT SITUATED WHERE
 3 PART OR ALL OF THE PATCH EXTENDS PAST THE CCD BOUNDARIES. FOR
 4 EXAMPLE, SUPPOSE THERE ARE 100 PIXELS/LINE, AND THE PATCH IS
 5 20 COLUMNS WIDE. IF THE PATCH STARTING COL # IS 90, 10 COLS
 6 WILL NOT BE USED. THIS WILL ALSO AFFECT THE MANNER IN WHICH
 7 THE PIXEL VALUES ARE PUT INTO THE MEMORY BUFFER.
 10 THE HARDWARE TREATS BOTH FIELDS OF A FRAME IDENTICALLY (WITH
 11 THE EXCEPTION OF WHICH IS THE 1ST OF THE TWO). THE EFFECT OF
 12 THIS IS TO HALVE THE EFFECTIVE # OF VERTICAL STEPS. THE NET
 13 RESULT IS TWOFOLD: 1) THE PATCH MUST HAVE AN EVEN # OF LINES;
 14 & 2) AND BY CHANGING THE LINE # BY 1, YOU ARE IN EFFECT CHANGING
 15 IT BY 2.
 16
 17
 20

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11484(26334)

```

1 ( PATCH GENERATOR CONTROL ROUTINES FCW 1/8/82 MOD 1/11/82 )
2
3 0 INTEGER PCNT ( WORD COUNT FOR 1 FRAME )
4
5 ( CALCULATE WORD COUNT FOR TRANSFER )
6 : PCNT! CPATCH 1+ @ CPATCH 3 + @ * MINUS PCNT ! ;
7
10 CODE STCCD ( BUFFER ADDR ON STACK )
11 0 S) 0 LDA, 7 DOB, PCNT 0 LDA, 107 DOC, POP JMP,
12
13 : CCDINIT OPATCH STCCD ;
14
15 CODE CCD-DONE ( RETURN NEXT ADDR IN BUFFER ON STACK )
16 HERE 7 SZB, JMP, 7 DIB, PUSH JMP,
17
20 ;S

```

BLOCK: 11485(26335)

```

1 ( PATCH GENERATOR CTRL COMMENTS FCW 1/21/82 ) ;S
2
3 STCCD - OUTPUT THE BUFFER ADDRESS AND WORD COUNT TO PATCH GEN-
4 ERATOR CARD WHILE STARTING IT
5
6 CCDINIT - OUTPUT PATCH COORDINATES AND START PATCH GENERATOR
7
10 CCD-DONE - WAIT FOR PATCH GENERATOR TO FINISH. RETURN THE NEXT
11 FREE BUFFER ADDRESS ON THE STACK
12
13
14
15
16
17
20

```

BLOCK: 11486(26336)

```

1 ( T4 INTERRUPT HANDLER FCW 1/8/82 MOD 4-13-82 )
2 0 INTEGER IVECT 177 ( LEGAL CHAR DELIMITER ) DP +!
3 IVECT INTEGER IVCT 62677 CPU IORST,
4 0 INTEGER REGS 0 , 0 , 0 , 0 , ( AC0-AC3, CY )
5 CODE INTERRUPT
6 10 SND, IF,
7 REGS 0 STA, REGS 1+ 1 STA, REGS 2 + 2 STA,
10 REGS 3 + 3 STA, 0 0 MOV, 4C /2 REGS 4 + 0 STA,
11 110 DIA, #177 1 LDA, 1 0 AND, IVCT 2 LDA,
12 0 2 ADD, 0 2) I) JMP,
13 ELSE,
14 277 DIB, IORST, ABORT I) JMP,
15 THEN,
16
17 ;S
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11478(26326)

```

1 ( AUTO PATCH STEP ROUTINES   FCW  1/20/82   MOD 1/25/82 )
2
3   SCA DSZ,          ( COLUMN COUNTER )
4   IF,
5       0 3) 0 LDA,   SCA 0 STA,   SCA 1+ 0 LDA,   0 0 MOV, SPL
6       IF,
7           2 2) 0 LDA,   0 0 INC,   LIMITS 3 + 1 LDA,   0 1 SUB, # SNC
10          1 0 MOV,   2 2) 0 STA,
11      ELSE,
12          2 2) 0 LDA,   0 0 DEC,   LIMITS 2 + 1 LDA,   0 1 ADC, # SZC
13          1 0 MOV,   2 2) 0 STA,
14      THEN,
15      THEN,
16      N 2 LDA, NEXT JMP,
17
20  ;S

```

BLOCK: 11479(26327)

```

1 ( PATCH STEP COMMENTS       FCW  1/20/82           ) ;S
2
3   *STEP* IS CALLED ONCE PER FRAME. THE COUNTS STORED AT SCA
4   AND SCA+2 ARE DECREMENTED. WHEN THE COUNT = 'S 0, THE COUNT IS
5   RESTORED AND THE DIR FLAG IS CHECKED. IF THE FLAG IS NEG, THE
6   STARTING LINE/COL # IS DECREMENTED AND CHECKED AGAINST THE LOWER
7   LIMIT. IF #<LIMIT, THE LIMIT IS SUBSTITUTED; OTHERWISE THE
10  DECREMENTED # IS USED. IF THE FLAG IS POS, THE STARTING LINE/COL
11  IS INCREMENTED AND CHECKED AGAINST THE UPPER LIMIT. IF #>LIMIT
12  THE LIMIT IS USED; OTHERWISE THE INCREMENTED # IS USED.
13
14
15
16
17
20

```

BLOCK: 11480(26330)

```

1 ( SEND PATCH PARAMETERS TO CCD INTERFACE           11/25/80 )
2 ( MOD FCW  1/21/82 )
3 ( USE BITS 2&3 OF 12 BIT DATA WORD AS REGISTER SELECT )
4 ( 2.3 = 00 START LINE, 01 END LINE, 10 START COL, 11 END COL )
5
6 10000 INTEGER INCRM ( REGISTER SELECT INCREMENT )
7 ( ADD OFFSET TO PARAMETER AND SEND IT. INC OFFSET FOR NEXT )
10 SUBROUTINE SEND 1 0 ADD, 7 DOA, INCRM 3 LDA, 3 1 ADD, RETURN
11
12 2 ,CODE OPATCH 0 , CPATCH , ' OPATCH DUF 2 STA, 1+ 2 LDA,
13     1 1 SUB, 0 2) 0 LDA, SEND JSR, 1 2) 3 LDA,
14     3 3 MOV, /2 0 2) 0 LDA, 3 0 ADD, 0 0 DEC, SEND JSR,
15         2 2) 0 LDA, SEND JSR,
16     3 2) 3 LDA, 2 2) 0 LDA, 3 0 ADD, 0 0 DEC, SEND JSR,
17         ' OPATCH 2 LDA, NEXT JMP,
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11475(26323)

```

1 ( TIMETAG ROUTINE COMMENTS      FCW 1/20/82 ) ;S
2
3 ?CCD - MONITOR THE CCD ADDRESS COUNTER AND DO NOT RETURN UNTIL
4       IT CHANGES. THIS ENSURES THAT THE PHOTOGATE TIME AT THE
5       START OF THE CURRENT FRAME IS THE ONE STORED IN ETRUF.
6
7 1SEC - HOLD THE VALUE OF THE HARDWARE 1 SEC COUNTER. THIS IS
10      CHECKED AGAINST THE 1 SEC COUNTER AND IF DIFFERENT,
11      '1SEC' IS UPDATED WITH THE NEW VALUE AND AN ETSCAN IS
12      DONE TO MAKE SURE THE DMAMICROSEC IS UPDATED. THIS
13      PREVENTS THE 2 CLOCKS FROM GETTING OUT OF PHASE.
14
15 TIMETAGS - DO ETSCAN AND UPDATE THE 1SEC CLK IF NECESSARY.
16
17
20

```

BLOCK: 11476(26324)

```

1 ( AUTO PATCH STEP ROUTINES      FCW 1/20/82  MOD 4/19/82 )
2 BASE @ DECIMAL
3 1 INTEGER LIMITS 47 , 1 , 94 ,      BASE !
4 0 INTEGER SCA 0 , 0 , 0 ,
5 2 ,CODE STEP CRATE , CPATCH .
6   N 2 STA, ' STEP 3 LDA, ' STEP 1+ 2 LDA, SCA 2 + DSZ,
7   IF,      ( LINE <ROW> COUNTER )
10  2 3) 0 LDA, SCA 2 + 0 STA, SCA 3 + 0 LDA, 0 0 MOV, SPL
11  IF,
12  0 2) 0 LDA, 0 0 INC, LIMITS 1+ 1 LDA, 0 1 SUB, # SNC
13  1 0 MOV, 0 2) 0 STA,
14  ELSE,
15  0 2) 0 LDA, 0 0 DEC, LIMITS 1 LDA, 0 1 ADC, # SZC
16  1 0 MOV, 0 2) 0 STA,
17  THEN,
20  THEN,      ;S

```

BLOCK: 11477(26325)

```

1 ( PATCH STEP COMMENTS      FCW 1/20/82      ) ;S
2
3 LIMITS - THESE ARE THE UPPER AND LOWER LIMITS OF THE STARTING
4          LINE/COLUMN #. THE LIMITS DO NOT GO TO 100 DUE TO THE
5          HEIGHT AND WIDTH OF THE PATCH.
6
7 SCA - THIS IS A SCRATCH AREA. CRATE IS COPIED HERE.
10
11
12
13
14
15
16
17
20

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11472(26320)

```

1 ( 8 CHAN. ET BOARD DRIVER ROUTINES FCW 1/20/82 MOD 1/20/82 )
2 CODE ETSCAN
3     NXTBUF JSR, 4205 DOC, 4005 DIB, 105 DOB, N 0 LDA,
4     0 1 SUB, SNR
5     IF,
6     1 1 MOV, /2 SNR
7     IF,
10    N 1+ 1 STA, ETTIME JSR,
11    THEN,
12    THEN,
13    NEXT JMP,
14
15 CODE ETINIT
16     ETVAR 4 + 3 LDA, 0 3) 0 LDA, 3 3) 0 STA, 305 DOB,
17     2 3) 0 LDA, 105 DOC, NEXT JMP,
20 ;S

```

BLOCK: 11473(26321)

```

1 ( 8 CHAN. ET BOARD COMMENTS FCW 1/20/82 )
2
3     'ETSCAN' IS THE MAIN ROUTINE. IT GETS THE NEXT BUFFER,
4     RESTARTS THE ET BOARD, AND CHECK TO SEE IF ANYTHING WAS TRANS-
5     FERRED. IF SOMETHING WAS, IT CALLS ETTIME TO SORT AND STORE
6     THE TIMES.
7
10    'ETINIT' SETS THE BUFFER ADDRESS, OUTPUTS THE ADDRESS
11    TO THE ET BOARD, OUTPUTS A WORD COUNT OF 26 (OCTAL) TO THE
12    ET BOARD, AND STARTS IT.
13
14
15
16
17
20

```

BLOCK: 11474(26322)

```

1 ( TIMETAG ROUTINES FOR DATA RUNS FCW 1/8/82 MOD 1/11/82 )
2
3     ETBUF 16 + CONSTANT DMAMICROSEC
4     ETBUF     CONSTANT PTGMICROSEC
5
6     CODE ?CCD
7     4007 DIB, HERE 7 DIB, 1 0 SUB, SNR JMP. NEXT JMP,
10
11    0 INTEGER 1SEC
12    : TIMETAGS
13    ?CCD ETSCAN 1PPSCLK DUP 1SEC @ =
14    IF DROP ELSE 1SEC ! ETSCAN THEN ;
15
16    : 1SEC-CLK
17    TIME D@ 1SEC @ 0 D+ ;
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11469(26315)

```

1 ( REAL TIME CLOCK COMMENTS      FCW      1/22/82 ) ;S
2
3  'ADJTIME' CALLS 'CHKRD' AND DEPENDING ON WHICH KEY WAS
4  PRESSED (IF ANY) DOES THE FOLLOEING: 1) '-' DECREASES THE
5  BASE TIME; 2) '+' INCREMENTS THE BASE TIME; & 3) 'CR' SETS
6  A FLAG TO EXIT THE LOOP IN CHKTIME;
7
10  'CHKTIME' SETS UP A LOOP THAT PRINTS THE TIME ONCE PER
11  SECOND AND CALLS 'ADJTIME' TO MODIFY THE TIME IF NECESSARY.
12
13  'MST' SETS THE BASE TIME TO THE VALUE ON THE STACK, CLEARS
14  THE HARDWARE COUNTER, AND CALLS CHKTIME. THE TIME IS ENTERED
15  AS FOLLOWS:      HH:MM:SS. MST (CR)
16  BEFORE TYPING IN THE TIME MAKE SURE THE BASE IS DECIMAL.
17  ALSO BE SURE NOT TO FORGET THE DECIMAL PT.
20

```

BLOCK: 11470(26316)

```

1 ( 8 CHANNEL EVENT TIMER BOARD DRIVER ROUTINES  04/15/81  )
2
3  0 INTEGER ETRUF HERE DUP 1- SWAP 20 DUP DP +! WORDS
4
5  26 DUP GRUF DUP INTEGER ETVAR OVER GRUF + , MINUS , 0 , ETVAR .
6  ETRUF ,
7
10  SUBROUTINE NXTRUF
11      ETVAR 3 + 1 LDA,  ETVAR 1+ 0 LDA,  1 0 SUB,
12      ETVAR 3 + 0 STA,  N 1 STA,  ETVAR 2 + 1 LDA,  RETURN
13
14  SUBROUTINE ETTIME
15      HERE N 1) 0 LDA,  7 1 LDA,  0 1 AND, *2
16      ETVAR 5 + 3 LDA,  1 3 ADD,  1 3) 0 STA,  N ISZ,
17      N 1) 0 LDA,  0 3) 0 STA,  N ISZ,  N 1+ DSZ,  JMP,
20      RETURN                      ;S

```

BLOCK: 11471(26317)

```

1 ( 8 CHANNEL ET BOARD DRIVER COMMENTS      FCW      1/20/82 ) ;S
2
3  THESE ROUTINES TAKE THE TIMES PLACED IN MEMORY BY THE ET
4  BOARD, AND PLACE THEM BY ORDER OF THEIR CHANNEL # IN ETRUF.
5  TIMES USED BY THE PROGRAM ARE ACCESSED FROM ETRUF.
6
7  'NXTRUF' FLIPS BACK AND FORTH BETWEEN TWO (2) CONSECUTIVE
10  BUFFERS. WHILE ONE IS BEING FILLED THE OTHE IS BEING PROCESSED.
11  THE ALGORITHM USED IS :
12  (NEW BUF ADDR) = 2*(1'ST BUF ADDR) + 26 - (PREV BUFFER ADDR)
13
14  'ETTIME' SCANS THE TIMES PLACED IN THE BUFFER AND PLACES
15  THEM IN THEIR RESPECTIVE PLACE IN 'ETRUF'.
16
17
20

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11466(26312)

```

1 ( REAL TIME CLOCK ROUTINES    06/08/81    )
2 ( MOD    FCW  2/8/82 )
3 CODE C5 305 DOA, 205 NIO, NEXT JMP,
4 CODE STTI 110 NIO, NEXT JMP,
5 1 ,CODE TICK 0 , ' TICK 1 LDA, 5 DIA, 0 1 SUB, SNR
6   IF, ' TICK 0 STA, 2 0 LDA, ELSE, 0 0 SUB, THEN, PUSH JMP,
7 CODE 1PPSCLK 5 DIA, PUSH JMP,
10
11 CODE CHKBD 10 SZB, IF, 110 DIA, #177 1 LDA, 1 0 AND, ELSE,
12   0 0 SUB, THEN, PUSH JMP,
13
14 BASE @ DECIMAL
15 : HMS F @ -ROT 60 D/MOD -ROT 60 D/MOD -ROT 24 D/MOD -ROT DDROP
16   48 F 1+ ! 2 F ! . ' : ' . ' : ' . 32 F 1+ ! F ! ;
17 : HMS. D@ HMS ;
20 BASE !                               ;S

```

BLOCK: 11467(26313)

```

1 ( REAL TIME CLOCK ROUTINES COMMENTS    FCW 1/20/82    ) ;S
2
3   THESE ROUTINES ARE USED TO SYNCHRONIZE THE FIRMWARE CLOCK
4 TO THE DATAMETRICS 1 SEC CLOCK. THE 1PPS FROM THE DMA CLOCK
5 CLOCKS A HARDWARE COUNTER ON THE EVENT TIMER BOARD. THIS 16
6 BIT COUNT IS ADDED TO A 32 BIT # IN MEMORY ( A "BASE" COUNT )
7 TO FORM THE CORRECT TIME-OF-DAY. THE TIME IS SET BY FIRST
10 CLEARING THE 16 BIT HARDWARE COUNTER, AND THEN ADJUSTING THE
11 "BASE" COUNT UNTIL THE SUM OF THE BASE COUNT AND THE COUNTER
12 IS EQUAL TO THE TIME DISPLAYED ON THE DMA CLOCK.
13
14 C5 - RESET CTR TO 0,    STOP DMA ACTIVITY
15
16 HMS. - PRINT OUT THE DOUBLE PRECISION # ON THE STACK IN THE
17   FORMAT HH:MM:SS
20

```

BLOCK: 11468(26314)

```

1 ( MORE REAL TIME CLOCK ROUTINES    06/08/81 MOD 4/14/82    )
2
3 : GETTIME TIME D@ 1PPSCLK 0 D+ ;
4 : MST? GETTIME HMS ;
5 53 CONSTANT '+'    55 CONSTANT '-' 15 CONSTANT CRTN
6 : -TIME TIME D@ 1. D- DABS TIME D! ;
7 : +TIME TIME D@ 1. D+ TIME D! ;
10
11 : ADJTIME CHKBD DUP CRTN = IF DROP 1
12   ELSE DUP '+' = IF DROP +TIME 0
13   ELSE DUP '-' = IF DROP -TIME 0
14   ELSE DROP 0 THEN THEN THEN ;
15
16 : CHKTIME STTI BEGIN TICK IF MST? CR THEN ADJTIME END ;
17 : GMT C5 TIME D! CHKTIME ;
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11463(26307)

```

1 ( PATCH PARAMETER COMMENTS      FCW 1/22/82 ) ;S
2
3 CPATCH - CURRENT PATCH
4
5 "PATCH" IS USED TO DEFINE A WORD WHICH WHEN INVOKED WILL
6 PLACE A SPECIFIED PATCH POSITION AND SIZE IN "CPATCH". THE
7 PARAMETERS ARE TYPED IN THE SAME ORDER AS THEY APPEAR IN
10 "CPATCH". THEN THE WORD "PATCH" IS TYPED FOLLOWED BY WHATEVER
11 NAME IS TO BE USED, IN THIS CASE "HOME". WHEN "HOME" IS USED,
12 IT WILL PLACE 40, 10, 10, & 6 IN "CPATCH".
13
14
15
16
17
20

```

BLOCK: 11464(26310)

```

1 ( PATCH RATE PARAMETER ENTRY      FCW 1/20/82 )
2 ( HOR COUNT, HOR DIR FLAG, VERT COUNT, VERT DIR FLAG )
3 0 INTEGER CRATE 0 , 0 , 0 , CRATE ,
4 : RATE CONSTANT , ;CODE 2 1 MOV, CRATE 4 + 2 LDA, 0 0 SUB,
5     0 2) 0 STA, 1 2) 0 STA, 2 2) 0 STA, 3 2) 0 STA,
6     0 3) 0 LDA, 0 0 MOV, # *2 SNC
7     IF, 3 2) 0 STA, 0 0 NEG, 2 2) 0 STA,
10    ELSE, 2 2) 0 STA,
11    THEN,
12    1 3) 0 LDA, 0 0 MOV, # *2 SNC
13    IF, 1 2) 0 STA, 0 0 NEG, 0 2) 0 STA,
14    ELSE, 0 2) 0 STA,
15    THEN,
16    1 2 MOV, NEXT JMP,
17 0 0 RATE STILL      STILL
20 ;S

```

BLOCK: 11465(26311)

```

1 ( PATCH RATE COMMENTS      FCW 1/22/82 ) ;S
2 CRATE - CURRENT RATE
3
4 "RATE" DEFINES A WORD WHICH WILL SET UP "CRATE" ACCORDING TO T
5 THE NUMBERS ENTERED WHEN THE WORD WAS DEFINED. TO USE "RATE" DO
6 THE FOLLOWING: TYPE IN 2 NUMBERS, FOLLOWED BY "RATE", THEN BY
7 THE NAME OF THE NEW RATE. THE 1ST # IS THE HORIZONTAL RATE -
10 A POSITIVE VALUE WILL MOVE THE PATCH TO THE RIGHT, A NEGATIVE
11 VALUE TO THE LEFT. THE 2ND # IS THE VERTICAL RATE - A POS.
12 VALUE WILL MOVE THE PATCH UP, WHILE A NEG. VALUE WILL MOVE IT
13 DOWN. ( SEE "OPATCH" COMMENTS FOR VERTICAL STEP PECULIARITIES).
14 THE COUNTER TAKES THE ABSOLUTE VALUE OF THE # ENTERED AND COUNTS
15 DOWN TO ZERO. THUS A VALUE OF 1 WILL BE THE FASTEST RATE, AND A
16 VALUE OF 0 WILL BE THE SLOWEST. THE # IS DECREMENTED ONCE PER
17 FRAME. FOR EXAMPLE, IF THE FRAME RATE IS 40 HZ, A COUNT OF 40
20 WILL MOVE THE PATCH ONCE EVERY SECOND.

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11460(26304)

```

1 ( BUFFER MANAGEMENT      FCW  1-8-82  MOD 5/24/82 )
2
3 1 ,CODE GBUF 0 ,
4   0 3) 0 LDA, 0 S) 1 LDA, 0 1 ADD, 0 3) 1 STA, PUT JMP,
5
6 : GBUFMARK CONSTANT ;CODE
7   0 3) 0 LDA, ' GBUF 0 STA, NEXT JMP,
10
11 40000 CONSTANT BUF
12 BUF GBUFMARK GBUFINITIALIZE
13                                GBUFINITIALIZE
14
15
16
17
20 ;S

```

BLOCK: 11461(26305)

```

1 ( BUFFER MANAGEMENT COMMENT BLOCK      FCW 1/20/82  ) ;S
2
3   * GBUF * RETURNS A BUFFER ADDRESS. WHEN GBUF IS CALLED .
4 THE TOP STACK ITEM IS THE # OF WORDS TO BE RESERVED. THIS
5 # IS ADDED TO THE NEXT FREE BUFFER ADDRESS AND SAVED FOR THE
6 NEXT TIME GBUF IS CALLED.
7
10   "GBUFMARK" DEFINES A CONSTANT THAT WHEN INVOKED WILL PLACE TH
11 VALUE IN ITS PARAMETER FIELD IN THE PARAMETER FIELD OF "GBUF"
12 INSTEAD OF ON THE STACK.
13
14
15
16
17
20

```

BLOCK: 11462(26306)

```

1 ( PATCH PARAMETER ENTRY      FCW  1/22/82  )
2
3 ( STARTING ROW, # ROWS, STARTING COLUMN, # COLS  )
4 0 INTEGER CPATCH 0 , 0 , 0 , CPATCH ,
5
6 : EVACO, 0 0 INC, # /2 SNC  0 0 INC, ;
7
10 : PATCH CONSTANT , , , ;CODE 2 1 MOV, CPATCH 4 + 2 LDA,
11   0 3) 0 LDA, EVACO, 3 2) 0 STA, 1 3) 0 LDA, 2 2) 0 STA,
12   2 3) 0 LDA, EVACO, 1 2) 0 STA, 3 3) 0 LDA, 0 2) 0 STA,
13   1 2 MOV, NEXT JMP,
14
15   40 10 10 6 PATCH HOME
16
17 HOME
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11511(26367)

```

1 ( HOR. RATE COMMENTS      FCW 1/21/82  )  ;S
2
3   THESE RATES ARE SET UP IN INCREMENTS OF 5 DEG. OF DECLINATION.
4   AN 'EAST' RATE MOVES THE PATCH FROM LEFT TO RIGHT ON THE
5   DISPLAY. A 'WEST' RATE MOVES THE PATCH FROM RIGHT TO LEFT ON THE
6   DISPLAY. THE FRAME FREQUENCY FOR THESE RATES IS 40 HZ.
7
10
11
12
13
14
15
16
17
20

```

BLOCK: 11512(26370)

```

1 ( BACKGROUND SETTING ROUTINES  FCW 1/8/82  2/8/82  )
2
3 24 12 47 10 PATCH CENTER
4
5 : 1-PATCH PCNT! ' GBUF @ CCDINIT  CCD-DONE DROP ;
6
7 : AVG
10   0. ' GBUF @ DUP PCNT @ MINUS + SWAP
11   DO I @ 0 D+ LOOP
12   PCNT @ MINUS D/MOD DROP ;
13
14 : BACKGROUND
15   CURSOR STTI
16   BEGIN 1-PATCH ' AVG= ' AVG D. CR
17           77777 0 DO LOOP CHKBD END ;
20 ;S

```

BLOCK: 11513(26371)

```

1 ( BACKGROUND COMMENTS      FCW 1/21/82  )  ;S
2
3   THE BACKGROUND ROUTINES ARE FOR SETTING THE VIDEO BIAS TO THE
4   PROPER LEVEL. THE LEVEL SHOULD BE IN THE RANGE OF 100-200
5   WITHOUT SUBTRACTION; IF SUBTRACTION IS USED, IT SHOULD BE SET
6   TO APPROXIMATELY 200-400, DEPENDING ON THE AMOUNT OF SUBTRACTION
7   USED. THE MAIN POINT IS TO GET A UNIFORM BACKGROUND AS SEEN ON
10  THE DISPLAY. MAKE ABSOLUTELY SURE THAT NO LIGHT ENTERS THE
11  CAMERA WHILE DOING THE BACKGROUND ADJUSTMENT - OTHERWISE
12  THE ADJUSTMENT WILL BE WRONG.
13
14
15
16
17
20

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11514(26372)

```

1 ( A-D VALUE DISPLAY ROUTINES      FCW 1/25/82  MOD  4/15/82 )
2
3 : ADV-DUMP
4      CPATCH 3 + @ COLUMNS CR 10 F !
5      1-PATCH ' GBUF @ PCNT @ MINUS + SWAP
6      DO I @ 0. CR@ LOOP ;
7
10 : ADV ADV-DUMP ;
11
12 : CADV ' GBUF @ PCNT @ OVER OVER + ROT ROT MINUS + SWAP CR
13      DO I @ 0. CR@ LOOP ;
14
15 : C CURSOR ADV ;
16
17
20 IS

```

BLOCK: 11515(26373)

```

1 ( A-D VALUE COMMENTS      FCW 1/25/82      )  IS
2
3 ADV-DUMP
4      - GET SOME A-D VALUES AT THE CURRENT PATCH LOCATION. PRINT
5      OUT THE VALUES WITH AS MANY COLS AS IN THE PATCH
6      ( UP TO 10 COLS). THE FIELDS ARE PRINTED OUT SEPERATELY;
7      I.E.- THEY ARE NOT INTERLEAVED.
10
11 ADV - NAME USED FOR BREVITY
12
13 CADV - PRINT OUT THE VALUES OF THE LAST FRAME BEFORE THE RUN OR
14      CURSOR MODE WAS TERMINATED.
15
16
17
20

```

BLOCK: 11516(26374)

```

1 ( PATCH INITIALIZATION ROUTINES  FCW  4/22/82  MOD 4-22-82 )
2
3 ( SET THE STARTING 'HOME' POSITION OF THE CURSOR )
4 : POSITION
5      HOME STILL CURSOR CPATCH @ ' HOME 3 + !
6      CPATCH 2 + @ ' HOME 1 + ! ;
7
10 ( @ ROWS UNDER STACK, @ COLUMNS ON TOP OF STK )
11 : RXC ' HOME ! ' HOME 2 + ! ;
12
13
14
15
16
17
20 IS

```

BLOCK: 11517(26375)

```

1 ( PATCH INITIALIZATION COMMENTS FCW 4/22/82 MOD 4-22-82 ) ;S
2
3 POSITION - POSITION DEFINES WHERE THE 'HOME' POSITION
4           OF THE CURSOR IS. TO USE, TYPE "POSITION" AND RETURN,
5           AND MOVE THE CURSOR TO THE DESIRED PLACE. THEN TYPE
6           RETURN AND THAT POSITION WILL BE SAVED.
7
10 RXC - RXC IS USED TO CHANGE THE PATCH SIZE. TWO PARAMETERS ARE
11        ENTERED: 1) THE # OF ROWS; & 2) THE # OF COLUMNS. THE #
12        OF ROWS MUST BE AN EVEN #; THE # OF COLUMNS CAN BE EITHER
13        EVEN OR ODD. THE FOLLOWING EXAMPLE WILL SET THE PATCH
14        SIZE TO 10 ROWS BY 7 COLUMNS. THE '*' IS A PROMPT.
15
16        *10 7 RXC <RETURN>
17
20

```

BLOCK: 11518(26376)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

BLOCK: 11519(26377)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

*26160 26166 SHOW

112

BLOCK: 11376(26160)

```

1 ( SIMPLE MINDED TAPE HANDLER.   FCW  12/09/80  MOD 2/23/82 )
2 ( ASSUMES ONLY TAPE UNIT #0 EXISTS )
3
4 OCTAL
5
6 : TAPE ;
7
10 ( LTB = LENGTH OF TAPE BLOCK )
11 0 INTEGER LTB 0 , -1001 , -1402 ,
12
13 47 CONSTANT CUR    0 CUR !
14
15
16 161 LOAD 162 LOAD 163 LOAD 164 LOAD 165 LOAD 166 LOAD
17 ;S
20 ;S

```

BLOCK: 11377(26161)

```

1 ( USEFUL TAPE UTILITIES                                02/26/81 )
2 ( TRDY GIVES UP CONTROL TO THE MULTITASKER AND DOES NOT )
3 ( RETURN UNTIL THE TAPE STATUS IS NOT BUSY )
4 SUBROUTINE TRDY HERE WAIT JSR, 1 1 SUB, 22 DIA,
5     0 0 MOV, /2 1 1 MOV, *2 +C 0 0 SUB, 22 SNB, 0 0 INC,
6     0 1 AND, SNR JMP, RETURN
7 ( WRITE 3 INCH GAP ON TAPE AT CURRENT POS. OF TAPE )
10 1 ,CODE GAP 70 , TRDY JSR, ' GAP 0 LDA, 122 DOA, NEXT JMP,
11
12 ( REWIND TAPE TO BEGINNING OF TAPE MARKER )
13 1 ,CODE REWIND 10 , TRDY JSR, ' REWIND 0 LDA, 122 DOA,
14     0 0 SUB, CUR 0 STA, NEXT JMP,
15
16 ( WRITE EOF AT CURRENT POSITION OF TAPE )
17 1 ,CODE WEOF 60 , TRDY JSR, ' WEOF 0 LDA, 122 DOA, CUR ISZ,
20     NEXT JMP, ;S

```

BLOCK: 11378(26162)

```

1 ( MORE TAPE UTILITIES                                03/03/81 )
2 30 INTEGER XCOM 40 , ( FWDSPC , BCKSPC COMMANDS )
3
4 ( FORWARD SPACE # OF RECORDS ON STACK )
5 CODE FWDSPC TRDY JSR, 0 S) 1 LDA, 1 0 NEG, SNR
6     IF, 222 DOC, XCOM 0 LDA, 122 DOA, CUR 3 LDA, 1 3 ADD,
7     CUR 3 STA, TRDY JSR, THEN, POP JMP,
10
11 ( BACK SPACE # OF RECORDS ON STACK )
12 CODE BCKSPC TRDY JSR, 0 S) 1 LDA, 1 0 NEG, SNR IF,
13     222 DOC, XCOM 1+ 0 LDA, 122 DOA, CUR 3 LDA, 1 3 SUB,
14     CUR 3 STA, TRDY JSR, THEN, POP JMP,
15
16 : BKUP 1 BCKSPC 1 BCKSPC 1 FWDSPC ;
17 : EOF WEOF WEOF BKUP ;
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11379(26163)

```

1 ( TAPE CONTROLLER ERROR CHECKING   FCW 11/02/81   MOD 2/23/82 )
2
3 0 INTEGER TPERROR 0 , 0 , CUR ,
4 0 INTEGER EOFLG
5
6 053042 INTEGER ?TP      ( TAPE ERROR MASK BITS )
7
10 SUBROUTINE ?TAPE
11   0 0 SUB, EOFLG 0 STA, 22 DIA, 0 3 MOV, ><
12   3 3 MOV, /2 SNC IF, EOFLG 0 STA, THEN,
13   ?TP 3 LDA, 0 3 AND, SNR
14   IF, 222 NID, TPERROR 0 STA, CUR 3 LDA,
15       TPERROR 1+ DUF 3 STA, 0 0 SUB, 1+ 0 STA,
16       10 0 LDA, 0 0 NEG, ABORT I) JSR,
17   THEN, RETURN
20 IS

```

BLOCK: 11380(26164)

```

1 ( TAPE READ ROUTINES   FCW 12/9/80   MOD 3/1/82 )
2
3 ' TRDY INTEGER TP? ' ?TAPE ,
4
5 ( BUFFER ADDRESS ON STACK. RETURNS WORD COUNT ON STACK )
6 CODE TREAD TP? I) JSR, 0 0 SUB, 22 DOA, 22 DOC, 0 S) 0 LDA,
7   122 DOB, TP? I) JSR, TP? 1+ I) JSR, CUR ISZ, 22 DIB,
10   0 S) 1 LDA, 1 0 SUB, PUT JMP,
11
12 ( BUFFER ADDRESS ON STACK. RETURNS EOF FLAG ON STACK WITH )
13 ( WORD COUNT UNDERNEATH. )
14
15 : TRDEOF TREAD EOFLG 0 ;
16
17
20 IS

```

BLOCK: 11381(26165)

```

1 ( TAPE WRITE ROUTINE   FCW 12/09/80   MOD 2/23/82 )
2
3 ( BUFFER ADDRESS ON STACK, WC UNDER STACK )
4 ( RETURNS AFTER WRITE INITIATED )
5 1 ,CODE TWRITE 50 ,
6   TP? I) JSR, TP? 1+ I) JSR,
7   22 DIA, 4 1 LDA, 1 0 AND, SNR
10   IF, 2 0 LDA, ABORT I) JSR, THEN,
11   CUR ISZ, ' TWRITE 0 LDA, 22 DOA, 0 S) 0 LDA,
12   22 DOB, 1 S) 0 LDA, 122 DOC, 2POP JMP,
13
14
15
16
17
20 IS

```

BLOCK: 11382(26166)

```

1 ( FIND DOUBLE EOF ROUTINE          FCW 2/23/82  MOD 02/23/82  )
2
3 : 1FILE  77777 FWDSPC ;
4 1 ,CODE :?TAPE ' ?TAPE , ' :?TAPE I) JSR,  NEXT JMP,
5 1 ,CODE :TRDY ' TRDY , ' :TRDY I) JSR,  NEXT JMP,
6
7 ( POSITION TAPE BETWEEN DOUBLE EOF MARKERS  )
10 : END-OF-TAPE
11   BEGIN  1FILE  1 FWDSPC  :?TAPE  EOFLG @  END  BKUP ;
12
13
14
15
16
17
20 #S

```

BLOCK: 11383(26167)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

BLOCK: 11384(26170)

```

1 ( BACKUP ROUTINES  FCW 11/16/81  MOD 6-17-82          )
2 ( THESE ROUTINES DO A DISK TO TAPE BACKUP OF A )
3 ( BOOTABLE DISK IMAGE . )
4
5 : BFR PREV @ 1000 - ;
6 : COPYBOOT 3 0 DO BFR I DREAD I BFR 1000 + !
7   -1001 BFR TWRITE LOOP ;
10
11 : D-T FLUSH REWIND GAP COPYBOOT SIZE 3
12   DO BFR I DREAD BFR @ IF I BFR 1000 + !
13   -1001 BFR TWRITE THEN LOOP EOF ;
14
15 171 LOAD ( LOAD TAPE-DISK ROUTINES  )
16 #S
17
20

```

*26200 26214 SHOW

116

BLOCK: 11391(26177)

```

1 ( DISK HOUSEKEEPING UTILITIES FCW 03-10-81 MOD 6/17/82 )
2
3 : DISK-UTILITIES ;
4
5 ( NULL OUT UNUSED BLOCKS )
6 : ZO 1+ DUP 777 + SWAP DO 20040 I ! LOOP ;
7 : BLANK BLOCK DUP @ IF DROP ELSE ZO UPDATE THEN ;
10 : CLRDISK 464 3 DO I BLANK LOOP FLUSH ;
11
12 ( ERASE A BLOCK - BLOCK # ON STACK )
13 : ERASE-BLOCK DUP BLOCK ZERO! BLANK FLUSH ;
14
15
16
17
20 ;S

```

BLOCK: 11392(26200)

```

1 ( NEW CSM PICTURE NULLING ROUTINES FCW 5-12-81 MOD 5/24/82 )
2 ( LOAD MAP FOR ALL ROUTINES )
3 ( 231 VARIABLE AND CONSTANT DEFINITIONS )
4 ( 232 CSM INSTRUCTION GENERATION )
5 ( 233 CSM I/O ROUTINES )
6 ( 234 SEQUENTIAL BLOCK OUTPUT ROUTINES )
7 ( 235 PATCH PARAMETERS TO INTERFACE BOARD )
10 ( 241 OVERFLOW CHECKING )
11 ( 242 CHANNEL SET UP FOR SUBTEACTION )
12 ( 243 RUNTIME ROUTINE )
13
14 : CCD-SUBTRACT ; BASE @ OCTAL
15 60 CONSTANT CSM 63 CONSTANT 2SUB
16 : SUBTRACT-LOAD 244 231 DO I LOAD LOOP ; SUBTRACT-LOAD
17 BASE ! ' SUBTRACTOR LOADED' CR
20 ;S

```

BLOCK: 11393(26201)

```

1 ( VARIABLES AND CONSTANTS FCW 6/9/81 MOD 5/24/82 )
2
3 BASE @ OCTAL 41000 CONSTANT BUF
4 DECIMAL 103 CONSTANT LINEC
5
6 -2 INTEGER OFFSET
7
10 0 CONSTANT STRTBLOK 11 CONSTANT ENDBLOK
11 51 CONSTANT LPF ( LINES/FRAME )
12
13
14 OCTAL
15 0 CONSTANT TOCSM 100 CONSTANT FRMCSM
16
17 BASE !
20 ;S

```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11394(26202)

```

1 ( CSM ALU CODES AND INSTRUCTION GENERATION ROUTINES 05/15/81 )
2 ( MOD 5/24/82 )
3
4 ( ON FUNCTIONS, A IS CSM SIDE, B IS NOVA SIDE )
5 1 CONSTANT F=A 46 CONSTANT F=0 23 CONSTANT F=A+B
6 70 CONSTANT F=1 31 CONSTANT F=2A 64 CONSTANT F=B
7
10 0 INTEGER BLK
11 TOCSM INTEGER DIR
12
13 ( ALU FUNCTION ON THE STACK. RETURNS COMPLETED INSTRUCTION )
14 ( ON STACK )
15 CODE :CSMINSTR 0 S) 0 LDA, DIR 1 LDA, 1 0 ADD, PUT JMP,
16
17
20 ;S

```

BLOCK: 11395(26203)

```

1 ( CSM I/O ROUTINES FCW 5/12/81 MOD 5/24/82 )
2
3 2000 INTEGER LBLK ( LENGTH OF BLOCK )
4
5 ( DOA - ALU & DIR, DOB - BLOCK #, DOC - ADDRESS )
6
7 SUBROUTINE CSMIO ( INSTR ACO, BUF AC1, RETS NEXT BUFF IN ACO )
10 CSM DOA, 4000 CSM + DOC, BLK 0 LDA, 100 CSM + DOB,
11 LBLK 0 LDA, 1 0 ADD, RETURN
12
13 ( INSTR ON STK, BUFFER UNDER STACK, RETS NXT BUF )
14 CODE :CSMIO 0 S) 0 LDA, 1 S) 1 LDA, CSMIO JSR, BINARY JMP,
15
16
17
20 ;S

```

BLOCK: 11396(26204)

```

1 ( SEQUENTIAL BLOCK OUTPUT ROUTINES FCW 5-22-81 MOD 5/24/82 )
2
3 ( BLK #, INSTRUCTION, BUFFER # OF BLOCKS TO TRANSFER )
4 BLK INTEGER DATA 0 , 0 , 0 INTEGER NBLKS
5 SUBROUTINE NXTBLK
6 DATA 1) ISZ, DATA 2 + 0 LDA, LBLK 1 LDA, 1 0 ADD,
7 DATA 2 + 0 STA, RETURN
10
11 ( INSERT INSTRUCTION AT DATA+1 AND BUFFER AT DATA+2 BEFORE )
12 ( CALLING )
13 CODE CSMOUT
14 HERE DATA 1+ 0 LDA, DATA 2 + 1 LDA, CSMIO JSR,
15 NXTBLK JSR, NBLKS ISZ, JMP, NEXT JMP,
16
17 ;S
20 ;S

```

BLOCK: 11397(26205)

```

1 ( LINE TRANSFER ROUTINES FCW 5-24-82 MOD 5/25/82 )
2
3 0 INTEGER FLD
4 0 INTEGER LLCC 10000 , 20002 , 30147 ,
5
6 1 ,CODE OPATCH ' LLCC ,
7   FLD 1 LDA, 1 1 MOV, /2 SZC 1 1 MOV, +C /2 ' OPATCH 3 LDA,
10  0 3) 0 LDA, 1 0 ADD, 7 DOA,
11  1 3) 0 LDA, 1 0 ADD, 7 DOA,
12  2 3) 0 LDA, 1 0 ADD, 7 DOA,
13  3 3) 0 LDA, 1 0 ADD, 7 DOA, NEXT JMP,
14
15 1 ,CODE TRANSFR -146 ,
16  ' TRANSFR 0 LDA, 107 DOB, HERE 7 SZB, JMP,
17  7 DIB, 0 0 INC, 7 DOB, NEXT JMP,
20 ;S

```

BLOCK: 11398(26206)

```

1 ( FRAME TRANSFER ROUTINES FCW 5-24-82 MOD 5/25/82 )
2
3 CODE 7DOB 0 S) 0 LDA, 7 DOB, POP JMP,
4
5 : RD-FLD
6   LFF 0 DO I LLCC ! I 10000 + LLCC 1+ !
7   OPATCH TRANSFR
10  LOOP ;
11
12
13 : RD-FRAME BUF OFFSET @ + 7DOB
14  0 FLD ! RD-FLD 1 FLD ! RD-FLD ;
15
16
17 ;S
20 ;S

```

BLOCK: 11399(26207)

```

1 ( SCALE PIXL VALUES FCW 5-24-82 MOD 5/24/82 )
2
3 100 INTEGER AD-OFF ( A-D OFFSET )
4
5 1 ,CODE SC-LN 146 ,
6   ' SC-LN 1 LDA, N 1 STA, 0 S) 3 LDA, AD-OFF 1 LDA,
7   HERE 0 3) 0 LDA, 1 0 SUB, SZC
10  IF, 0 0 SUB, ELSE, 0 0 MOV, /2 THEN,
11  0 3) 0 STA, 3 3 INC, N DSZ, JMP, POP JMP,
12
13 : SCALE LFF 2 * 0
14  DO BUF LINEC I * + SC-LN LOOP ;
15
16
17
20 ;S

```

BLOCK: 11400(26210)

```

1 ( MISCELLANEOUS ROUTINES      FCW 5-22-81   MOD 5/24/82 )
2
3 : ALLBLOCKS :CSMINSTR 400 0 DO I BLK ! BUF OVER :CSMIO
4       DROP LOOP DROP ;
5
6 : OCSM  F=0  ALLBLOCKS ;
7
10
11
12
13
14
15
16
17
20 ;S

```

BLOCK: 11401(26211)

```

1 ( CSM OVERFLOW CHECKER AND CORRECTOR  FCW 5-15-81  MOD 5/24/82 )
2
3 : READIN FRMCSM DIR ! BUF F=A :CSMINSTR :CSMIO DROP ;
4 : WRTOUT TOCSM  DIR ! BUF F=B :CSMINSTR :CSMIO DROP ;
5
6 0 INTEGER OVFLD  7777 INTEGER MAXX
7
10 2 ,CODE ?EXCEED 2000 , BUF ,  0 0 SUB, OVFLD 0 STA,
11 ' ?EXCEED 0 LDA, N 0 STA, MAXX 1 LDA, ' ?EXCEED 1+ 3 LDA,
12 HERE 0 3) 0 LDA, 0 1 SUB, # SZC IF, 0 3) 1 STA, OVFLD 1 STA,
13 THEN, 3 3 INC, N DSZ, JMP, OVFLD 0 LDA, PUSH JMP,
14
15 : OVFCNK ENDBLOK STRTBLOK DO I BLK !
16       READIN ?EXCEED
17       IF WRTOUT THEN  LOOP ;
20 ;S

```

BLOCK: 11402(26212)

```

1 ( SET UP ALTERNATE CHANNELS  FCW 05/14/81 MOD 5/24/82 )
2
3 ( STOP SUBTRACTOR #1 AND THE INTEGRATOR )
4 1 ,CODE I1STOP F=A , ' I1STOP 0 LDA, CSM 1+ DOA, CSM 2 + DOA,
5       4 0 LDA, CSM 1+ DOC, CSM 2 + DOC, NEXT JMP,
6
7 ( SET UP SUBTRACTOR #2 FOR 202 OPERATION )
10 2 CONSTANT RUN-FOREVER
11 CODE S2A 0 S) 0 LDA, 2SUB DOA, POP JMP,
12 CODE S2B 0 S) 0 LDA, 2SUB DOB, POP JMP,
13 CODE S2C 0 S) 0 LDA, 2SUB DOC, POP JMP,
14 CODE S2ST 2SUB 100 + NIO, NEXT JMP,
15
16 : ST2SUB F=A S2A STRTBLOK ENDBLOK 1+ 400 * + S2B
17       RUN-FOREVER S2C S2ST ;
20 I1STOP  ST2SUB      ;S

```

BLOCK: 11403(26213)

```

1 ( MAIN RUNTIME ROUTINES FCW 5-24-82 MOD 5/24/82 )
2
3 ( CSM ROUTINE SET UP )
4 : CRSU TOCSM DIR ! F=A+B :CSMINSTR DATA 1+ ! BUF DATA 2 + ! ;
5
6 4 INTEGER SLC
7 : SUBTRACT OCSM
10 SLC @ 0 DO CRSU RD-FRAME SCALE
11 ENDBLOK STRTBLOK - NBLKS !
12 CSMOUT OVFCHK
13 LOOP ;
14
15
16
17
20 ;S

```

BLOCK: 11404(26214)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

BLOCK: 11405(26215)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

*26400 26405 SHOW

122

BLOCK: 11520(26400)

```

1 ( 1PPS AND PHOTOGATE TIME TAG CHECKS    FCW 1/27/82 )
2 ( NEW TAPE FORMAT      MOD FCW 5/19/82 )
3 BASE @ OCTAL
4 : D-28 D- DDUP DPOS NOT IF 2000000000. D+ THEN ;
5 DECIMAL
6 : STRP# 16 D/MOD DROP ;      : TRQ BUF TRDEOF SWAP DROP ;
7 BUF 26 + CONSTANT PTG-OFFSET
10 : PTG-STEP PTG-OFFSET 3 + DUP @ SWAP 2 + @ * 6 + ;
11
12 0. DINTEGER LSTPG
13
14 : PDR 4 0
15     DO PTG-OFFSET I PTG-STEP * + D@ STRP# DDUP LSTPG
16     D@ DSWAP LSTPG D! D-28 D. LOOP ;
17 OCTAL 401 LOAD 402 LOAD 403 LOAD      BASE !
20 * TIME-CHECKS LOADED * CR    $S

```

BLOCK: 11521(26401)

```

1 ( 1PPS TIME TAG DIFFERENCES    FCW 1/27/82    MOD 2/23/82 )
2 BASE @ DECIMAL
3
4 0. DINTEGER LAST-1PPS      0. DINTEGER MCS
5 : DDFR BUF 2 + D@ LAST-1PPS D@ DOVER LAST-1PPS D!
6     D- D. BUF 16 + D@ STRP# MCS D@ DOVER MCS D! D-28 D. ;
7
10 : PHOTOGATE-CHECK
11     BEGIN CR STTI TRQ IF 1 ELSE PDR CHKBD THEN END ;
12
13 : DMA-CHECK
14     BEGIN CR STTI TRQ IF 1 ELSE DDFR CHKBD THEN END ;
15
16 : DMA/PTG-CHECK
17     BEGIN CR STTI TRQ IF 1 ELSE DDFR PDR CHKBD THEN END ;
20 BASE !      $S

```

BLOCK: 11522(26402)

```

1 ( 1PPS AND PTG TIME-TAG CHECKS    FCW 2/8/82    MOD 2/25/82 )
2 BASE @ DECIMAL
3 : DMA-TIME BUF 2 + D@ DDUP HMS D. BUF 16 + D@
4     STRP# D. ;
5
6 : PTG-MICROSEC 4 0
7     DO PTG-OFFSET I PTG-STEP * + D@ STRP# D. LOOP ;
10
11 : MICROSECONDS BEGIN CR STTI TRQ IF 1
12     ELSE DMA-TIME PTG-MICROSEC CHKBD THEN END ;
13 : MS 10 F ! MICROSECONDS ;
14 : FC PHOTOGATE-CHECK ;
15 : DC DMA-CHECK ;
16 : DFC DMA/PTG-CHECK ;
17 BASE !
20 $S

```

BLOCK: 11523(26403)

```

1 ( 1PPS AND PHOTOGATE TIME TAG CHECKS      FCW 1/27/82 )
2 ( NEW TAPE FORMAT      MOD FCW  3/9/82 )
3 BASE @ DECIMAL
4 : PRT-TIMES DMA-TIME  PTG-MICROSEC ;
5 : PDFR-CHK  4 0
6      DO  PTG-OFFSET I PTG-STEP * + D@ STRP# DDUP LSTPG
7          D@ DSWAP LSTPG D! D-28 DROP DUP
10         24000 < IF CR * R#=" CUR ? CR PRT-TIMES THEN
11         26000 > IF CR * R#=" CUR ? CR PRT-TIMES THEN
12     LOOP ;
13 : PCHK  BEGIN TRQ
14         IF CR * EOF* CR 1 ELSE PDFR-CHK CHKBD THEN END ;
15 BASE !
16 : PGF RUN REWIND 12 F ! PCHK REWIND ;
17 ;S
20  ;S

```

BLOCK: 11524(26404)

```

1 ( REAL TIME CLOCK ROUTINES      06/08/81 )
2
3 CODE C5 305 DOA, 205 NIO, NEXT JMP,
4 CODE STTI 110 NIO, NEXT JMP,
5 1 ,CODE TICK 0 , ' TICK 1 LDA, 5 DIA, 0 1 SUB, SNR
6     IF, ' TICK 0 STA, 2 0 LDA, ELSE, 0 0 SUB, THEN, PUSH JMP,
7 CODE 1PPSCLK 5 DIA, PUSH JMP,
10
11 CODE CHKBD 10 SZB, IF, 110 DIA, #177 1 LDA, 1 0 AND, ELSE,
12     0 0 SUB, THEN, PUSH JMP,
13
14 BASE @ DECIMAL
15 : HMS 60 D/MOD -ROT 60 D/MOD -ROT 24 D/MOD -ROT DDROP
16     48 F 1+ ! 2 F ! . ' ;' . ' ;' . 32 F 1+ ! ;
17 : HMS. D@ HMS ;
20 BASE !

```

BLOCK: 11525(26405)

```

1 ( EMPTY BLOCK )
2
3
4
5
6
7
10
11
12
13
14
15
16
17
20

```

APPENDIX IV**OPERATIONAL PROGRAM LOCATED IN THE MICROPROCESSOR
IN THE CAMERA CONTROL UNIT**

Tektronix

M6800 ASM V3.3 CCD202 9/25/81

Page 1

00003	00CA	CHIP	EQU	202	ICCD 202
00005				INCLUDE 'CCDSTPXS'	I SETUP
00009				LIST END	ILIST UNASSEMBLED SOURCE
00011	0000	>	ORG	0000H	I STORAGE STARTING ADDRESS
00013				SYSTEM DATA VARIABLES	
00015	0000	0002	DEST	BLOCK 2	IDEST ADDR FOR MOVE
00016	0002	0010	DTBL	BLOCK 16	ICLOCK VOLTAGE TABLE
00017	0012	0001	LCTR	BLOCK 1	ILINE COUNTER
00018	0013	0002	SRC	BLOCK 2	ISOURCE ADDR FOR MOVE
00019	0015	0001	INTR	BLOCK 1	I PROGRAM MODIFIED
00020	0016	0002	VECT	BLOCK 2	I INTERRUPT JMP VECTOR
00022				SYSTEM ADDRESS EQUATES	
00024	0800	CTR1	EQU	800H	ILATCH FOR COUNTER 1
00025	0801	CTR2	EQU	801H	ILATCH FOR COUNTER 2
00026	0802	CAHNM	EQU	802H	ICAMERA NO. BIT
00027	0802	CLOCK	EQU	802H	ICLOCK SELECT
00028	0803	INDC	EQU	803H	IINC/DEC SWITCH
00029	1000	LEDS	EQU	1000H	IDISPLAY LEDS
00030	0804	RCLK	EQU	804H	ICLOCK MASK REGISTER
00031	0804	RSTAT	EQU	806H	ICLOCK STATUS REGISTER
00032	0807	RUN	EQU	807H	I RESTART COUNTERS
00033	03FF	STK	EQU	3FFH	ITOP OF STACK
00035				SYSTEM MASK EQUATES	
00037	0008	CAMBT	EQU	08H	ICAMERA BIT
00038	0007	CLKBT	EQU	07H	ICLOCK & PHASE BIT
00039	0010	CNT	EQU	10H	I FOR DEBOUNCE
00040	0003	HR	EQU	03H	IMASK FOR CLOCK ENABLE
00041	000B	HRP	EQU	0BH	I
00042	0007	HRV	EQU	07H	I
00043	000F	HRUP	EQU	0FH	I
00044	0030	IDBIT	EQU	30H	IINC/DEC BIT
00045	0010	INCBT	EQU	10H	IINC BIT
00046	0040	STOP	EQU	40H	I STOP CTRS BIT
00047	0040	TBENT	EQU	40H	ITABLE ENTER BIT
00048	00F0	TBMSK	EQU	0F0H	ITABLE NO. BIT

Tektronix M6800 ASM V3.3 CCDSTP 9/25/81
 CCD DRIVER SETUP PROGRAM

Page 2

00049	00F0	VAR	EQU	OF0H	IVAR TABLE POSITION
00051					SYSTEM CLOCK CTR EQUATES
00053					NOTE: ON REVISION 1 BOARD COUNTER 1 IS 10 BITS AND COUNTER 2 IS
00054					6 BITS. ON REVISION 2 BOARD, COUNTER 1 IS 9 BITS AND
00055					COUNTER 2 IS 7 BITS.
00057	FFFF		IF	CHIP=202	
00059				CCD 202 ,	REVISION #2 BOARD
00061	001C	VCNT	EQU	14#2	# CNTS FOR VERTICAL ON END LINE
00062	0067	HCNT	EQU	103	# HORIZONTAL PULSES
00063	007E	VRCNT	EQU	63#2	# VERTICAL RESET COUNTS
00064	0032	NROWS	EQU	51-1	# ROWS/FIELD
00066			ELSE		
00067			SPACE	1	
00068			CCD 211 ,		REVISION #1 BOARD
00069			SPACE	1	
00070		VCNT	EQU	63#4	
00071		HCNT	EQU	201	
00072		VRCNT	EQU	63#4	
00073		NROWS	EQU	124-1	
00074			SPACE	2	
00075			ENDIF		

Tektronix M6800 ASM V3.3 CCDSTP 9/25/81
 CCD DRIVER SETUP PROGRAM

Page 3

00077 F800 > ORG OF800H ;STARTING ADDRESS FOR PROGRAM

00079 ; SETUP & INITIALIZE ROUTINE

00081	F800	8E03FF	INITL	LDS	#STK	;SET STACK POINTER
00082	F803	8640		LDA	A #STOP	;STOP CTRS & INTERRUPT
00083	F805	B70806		STA	A RSTAT	
00084	F808	8667		LDA	A #HCNT	;SET UP CTS
00085	F80A	B70800		STA	A CTR1	
00086	F80D	861C		LDA	A #VCNT	
00087	F80F	B70801		STA	A CTR2	
00088	F812	8603		LDA	A #HR	;SET MASK FOR CLOCK ENABLE
00089	F814	B70804		STA	A RCLK	
00090	F817	CEF969	>	LDX	#INTR1	;SET INTERRUPT VECTOR
00091	F81A	DF16	>	STX	#VECT	
00092	F81C	867E		LDA	A #7EH	;SET PROGRAM MOD
00093	F81E	B70015	>	STA	A INTR	
00094	F821	CEFE00	>	LDX	#TABLE	;SET SOURCE ADDR
00095	F824	DF13	>	STX	#SRC	
00096	F826	863E		LDA	A #00111110B	;CLR ON CTR 2UF,INTR CTR 2UF,LCH CTR 1UF
00097	F828	B70806		STA	A RSTAT	;START IT UP
00098	F82B	B70807		STA	A RUN	

Tektronix M4800 ASM V3.3 CCDSTP 9/25/81
CCD DRIVER SETUP PROGRAM

Page 4

00100 INCLUDE 'CCDCTLXS' ; HOUSEKEEPING

00104 ; MAIN PROGRAM

00106 F82E BDF839 > HNTFP JSR NEWTBL
00107 F831 BDF859 > JSR CKVAR
00108 F834 BDF902 > JSR TOLED
00109 F837 20F5 BRA HNTFP

00111 ; SUBROUTINE NEWTBL: CHECKS FOR A NEW TABLE ENTRY

00113 F839 B60802 NEWTBL LDA A CAMNM ;CHK FOR VARYING
00114 F83C 84F0 AND A \$VAR
00115 F83E 88F0 EOR A \$VAR
00116 F840 2716 BEQ NEWEX ;EXIT IF VARYING
00117 F842 B60803 LDA A \$03H ;CHK TBL ENTER SWITCH
00118 F845 43 COM A
00119 F846 8440 AND A \$TBENT ;CHK
00120 F848 270E BEQ NEWEX ;NOT PUSHED
00121 ; SET UP NEW TABLE
00122 F84A BDF90D > JSR VTBL ;PUT ADDR OF VAR TABLE AT DEST
00123 F84D BDF91F > JSR FTBL ;PUT ADDRESS OF FIXED TABLE AT SRC
00124 F850 C608 LDA B \$B ;MOVE 8 BYTES
00125 F852 BDF93F > JSR COPY ;COPY THE 8 BYTES
00126 F855 BDF8AD > JSR UPDAT ;TO THE DACS
00127 F858 39 NEWEX RTS

00129 ; SUBROUTINE CKVAR: 1.CHECKS IF TABLE SWITCH IS SET TO VARYING
00130 ; 2.IF SET, IT CHECKS THE INC/DEC SWITCH
00131 ; 3.IF PUSHED, IT INC/DEC THE PROPER CLOCK
00132 ; AT A 4HZ RATE WHILE HELD

00134 F859 B60802 CKVAR LDA A CAMNM ;CHECK IF SWITCH SET TO VAR
00135 F85C 84F0 AND A \$VAR
00136 F85E 88F0 EOR A \$VAR
00137 F860 2624 BNE CKVEX ;NOT SET TO VARYING
00138 F862 B60803 LDA A INCDC ;CHECK IF INC/DEC SWITCH PUSHED
00139 F865 43 COM A
00140 F866 8430 AND A \$IDBIT
00141 F868 271C BEQ CKVEX
00142 F86A BDF887 > JSR DVOLT ;INC/DEC PROPER CLOCK
00143 F86D CE0190 LDX \$400
00144 F870 BDF8A3 > JSR DELAY
00145 F873 B60803 CKV2 LDA A INCDC ;CHECK IF INC/DEC STILL PUSHED
00146 F876 43 COM A
00147 F877 8430 AND A \$IDBIT
00148 F879 270B BEQ CKVEX

Tektronix M6800 ASM V3.3 CCDCTL 6/03/81
CCD DRIVER CONTROL PROGRAM

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```
00149 F87B BDF887 > JSR DVOLT      ;INC/DEC PROPER CLOCK AGAIN
00150 F87E CE0028    LDX #40
00151 F881 BDF8A3 > JSR DELAY
00152 F884 20ED      BRA CKV2
00153 F886 39        CKVEX RTS
```

```
00155 ; SUBROUTINE DVOLT: 1.INC/DEC THE CLOCK SPECIFIED BY THE
00156 ; CAMERA NO. & PHASE SWITCHES
00157 ; 2.UPDATES LEDS TO CURRENT VALUE
```

```
00159 F887 BDF951 > DVOLT JSR CKADR      ;GET ADDR OF CLK TO DEST
00160 F88A DE00 > LDX #DEST      ;ADDR OF CLK IN X
00161 F88C B60803 LDA A INCD C      ;READ INC/DC SWITCH
00162 F88F 43 COM A
00163 F890 8410 AND A #INCBT
00164 F892 2704 BEQ DV2
00165 F894 6C00 INC X              ;INC +1
00166 F896 2002 BRA DV3
00167 F898 6A00 DV2 DEC X          ;DEC -1
00168 F89A A600 DV3 LDA A X        ;UPDATE LEDS
00169 F89C B71000 STA A LEDS
00170 F89F BDF8AD > JSR UPDAT      ;UPDAT DACS
00171 F8A2 39 RTS
```

```
00173 ; SUBROUTINE DELAY: DELAYS FOR N MSEC BEFORE RETURNING
00174 ; WHERE N=NO. IN X REG.
```

```
00176 F8A3 C6FA DELAY LDA B #250      ;SET COUNTER FOR 1 MSEC
00177 F8A5 01 DEL2 NOP
00178 F8A6 5A DEC B
00179 F8A7 26FC BNE DEL2
00180 F8A9 09 DEX
00181 F8AA 26F7 BNE DELAY      ;MSECS -1
00182 F8AC 39 RTS
```

```
00184 ; SUBROUTINE UPDAT: TAKES THE CLOCK VOLTAGE VALUES FROM RAM
00185 ; AND WRITES THEM TO THE DACS AND THE
00186 ; FIBER OPTIC LINK
```

```
00188 F8AD 9612 > UPDAT LDA A #LCYR      ;WAIT FOR PHOTOGATE
00189 F8AF 26FC BNE UPDAT
00190 ;
00191 F8B1 9602 > LDA A #DTBL      ;IN CAN 1
00192 F8B3 B70808 STA A 808H
00193 F8B6 9603 > LDA A #DTBL+1      ;IN-
00194 F8B8 B70809 STA A 809H
```

Tektronix M6800 ASM V3.3 CCDCTL 6/03/81
CCD DRIVER CONTROL PROGRAM

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```

00195 F85B 9604 > LDA A @DTBL+2 IV+
00196 F85D B7080A STA A 80AH
00197 F8C0 9605 > LDA A @DTBL+3 IV-
00198 F8C2 B7080B STA A 80BH
00199 F8C5 9606 > LDA A @DTBL+4 IP+
00200 F8C7 B7080C STA A 80CH
00201 F8CA 9607 > LDA A @DTBL+5 IP-
00202 F8CC B7080D STA A 80DH
00203 F8CF 9608 > LDA A @DTBL+6 IR+
00204 F8D1 B7080E STA A 80EH
00205 F8D4 9609 > LDA A @DTBL+7 IR-
00206 F8D6 B7080F STA A 80FH

```

00208 . : CAMERA 2 DACS AND FIBER OPTIC LINK

```

00210 F8D9 960A > LDA A @DTBL+8 IH+ CAM 2
00211 F8DB B7180B STA A 180BH
00212 F8DE 960B > LDA A @DTBL+9 IH-
00213 F8E0 B71809 STA A 1809H
00214 F8E3 960C > LDA A @DTBL+10 IV+
00215 F8E5 B7180A STA A 180AH
00216 F8E8 960D > LDA A @DTBL+11 IV-
00217 F8EA B7180B STA A 180BH
00218 F8ED 960E > LDA A @DTBL+12 IP+
00219 F8EF B7180C STA A 180CH
00220 F8F2 960F > LDA A @DTBL+13 IV-
00221 F8F4 B7180D STA A 180DH
00222 F8F7 9610 > LDA A @DTBL+14 IR+
00223 F8F9 B7180E STA A 180EH
00224 F8FC 9611 > LDA A @DTBL+15 IR-
00225 F8FE B7180F STA A 180FH
00226
00227 F901 39 RTS

```

00229 . : UPDAT FRONT PANEL LEDS TO CORRESPOND TO THE
00230 . : SELECTED CAMERA AND CLOCK

```

00231 . :
00232 F902 BDF951 > TOLED JSR CKADR IGET ADDR OF CLOCK
00233 F905 DE00 > LDX @DEST IADDR TO X REG
00234 F907 A600 LDA A,X IGET BINARY VOLTAGE VALUE
00235 F909 B71000 STA A LEDS IWRITE TO LEDS
00236 F90C 39 RTS

```

00238 . : SUBROUTINE VTBL READS THE CAMERA NO. & PLACES THE ADDR
00239 . : OF THE CORRESPONDING RAM TABLE AT DEST

```

00241 F90D 5F VTBL CLR B IFOR CAMERA 1
00242 F90E B40802 LDA A CAMNM IREAD SELECTED CAMERA
00243 F911 8408 AND A $CAMBT

```

Tektronix M6800 ASM V3.3 CCDCTL 6/03/81
CCD DRIVER CONTROL PROGRAM

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```

00244 F913 2602      BNE     VTB2
00245 F915 C608      LDA     B  #B
00246 F917 CB02      > VTB2  ADD     B  @DTBL      ;FOR CAMERA 2
                                           ;COMPUTE ADDR OF PROPER TABLE
00247 F919 D701      >      STA     B  @DEST+1
00248 F91B 4F        CLR     A
00249 F91C 9700      >      STA     A  @DEST
00250 F91E 39        RTS

```

```

00252      ;          SUBROUTINE FTBL: READS THE CAMERA NO. & PLACES THE ADDR
00253      ;          OF THE CORRESPONDING RAM TABLE AT SRC

```

```

00255 F91F 5F        FTBL  CLR     B
00256 F920 B60802     LDA     A  CAMNH      ;FOR CAMERA 1
00257 F923 8508       BIT     A  @CAMBT      ;READ SELECTED CAMERA
00258 F925 2602       BNE     VTB2
00259 F927 C680       LDA     B  #80H      ;FOR CAMERA 2
00260 F929 84F0       FTB2  AND     A  @TBMSK  ;READ SELECTED TABLE
00261 F92B 88F0       EOR     A  @VAR      ;RET IF VAR SELECTED
00262 F92D 2601       BNE     VTB3
00263 F92F 39        RTS
00264 F930 88F0       FTB3  EOR     A  @VAR      ;FIXED SELECTED TABLE
00265 F932 44        LSR     A              ;COMPUTE ADDR OF PROPER TABLE
00266 F933 1B        ABX
00267 F934 C6FE      >      LDA     B  @HI(TABLE)
00268 F936 8800      >      ADD     A  @LO(TABLE)
00269 F938 C9C3      >      ADC     B  #0
00270 F93A 9714      >      STA     A  @SRC+1
00271 F93C D713      >      STA     B  @SRC
00272 F93E 39        RTS

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00274      ;          SUBROUTINE COPY: COPIES THE NO. OF BYTES IN ACC B FROM
00275      ;          THE ADDR AT SRC TO THE ADDR AT DEST

```

```

00277 F93F DE13      > COPY  LDX     @SRC
00278 F941 A600      LDA     A  X
00279 F943 08        INX
00280 F944 DF13      >      STX     @SRC
00281 F946 DE00      >      LDX     @DEST
00282 F948 A700      STA     A  X
00283 F94A 08        INX
00284 F94B DF00      >      STX     @DEST
00285 F94D 5A        DEC     B
00286 F94E 26EF       BNE     COPY
00287 F950 39        RTS

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00289      ;          SUBROUTINE CKADR: PLACES THE ADDR OF THE CLK
00290      ;          TO INC IN DEST

```

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 CCD DRIVER CONTROL PROGRAM

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00292	F951	5F	CKADR	CLR	B		IFOR CAMERA 1
00293	F952	B60802		LDA	A	CAMNH	IREAD IN CAMERA
00294	F955	8408		AND	A	@CAMBT	
00295	F957	2602		BNE	CKAD1		
00296	F959	C608		LDA	B	@8	IFOR CAMERA 2
00297	F95B	B60802	CKAD1	LDA	A	CLOCK	
00298	F95E	8407		AND	A	@CLKBT	
00299	F960	1B		ABA			
00300	F961	8B02	>	ADD	A	@DTBL	
00301	F963	9701	>	STA	A	@DEST+1	
00302	F965	4F		CLR	A		
00303	F966	9700	>	STA	A	@DEST	
00304	F968	39		RTS			

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CCD DRIVER CONTROL PROGRAM

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00306          INCLUDE "CCDRPTX"          ; INTERRUPT ROUTINES

00310          ; CLOCK DRIVER INTERRUPT ROUTINES

00312          ; THESE ROUTINES FORM A LINKED LIST FOR PROCESSING THE CLOCK COUNTER
00313          ; INTERRUPTS. EACH ROUTINE PLACES THE VECTOR FOR THE NEXT INTERRUPT IN
00314          ; 'VECT' ( A PAGE ZERO LOCATION ) WHICH IS THE ADDRESS FIELD OF A 'JMP'
00315          ; INSTRUCTION. THUS NO PROGRAM LOGIC IS NEEDED TO DETERMINE THE POSITION
00316          ; IN A FRAME OR THE APPROPRIATE ACTION.
00317          ; THE ROUTINES DO TWO THINGS: 1) LOAD LATCHES THAT DETERMINE WHICH
00318          ; CLOCKS ARE TO BE ENABLED OR CLEARED & 2) LOAD LATCHES THAT SET THE
00319          ; COUNTERS. ALL EVENTS ARE SYNCHRONIZED TO THE OVERFLOW OF EITHER COUNTER
00320          ; DETERMINED BY A STATUS BIT WHICH SELECTS THE COUNTER OF CHOICE. THERE
00321          ; IS NO 'OFF' POSITION (I.E. ONE OF THE COUNTERS WILL ALWAYS CAUSE AN
00322          ; EVENT).
00323          ; THERE ARE 4 CLOCKS TO TAKE CARE OF - OH, OR, OV, & OP (HORIZONTAL,
00324          ; RESET, VERTICAL, AND PHOTOGATE RESPECTIVELY). OH AND OR ARE ENABLED BY
00325          ; CLEARING THE APPROPRIATE FF OR SETTING IT TO 0. OV AND OP ARE ENABLED
00326          ; BY SETTING THE APPROPRIATE FF TO 1. WHATEVER IS TO BE DONE, THE LATCHES
00327          ; MUST BE LOADED >BEFORE< THE DESIRED COUNTER UNDERFLOWS; OTHERWISE THE
00328          ; INFORMATION WILL NOT BE LATCHED UNTIL THE NEXT TIME THE COUNTER UNDER-
00329          ; FLOWS.

00331          ; UNDERFLOW CTR2, LAST DATA LINE, FIELD 2

00333 F969 860F      INTR1 LDA    A  $HRUP
00334 F96B B70804    STA    A  RCLK
00335 F96E 861E      LDA    A  $00011110B  ;LATCH ON 1UF,CLR ON 2UF,INTR ON 1UF
00336 F970 B70806    STA    A  RSTAT
00337 F973 867E      LDA    A  $VRCNT
00338 F975 B70801    STA    A  CTR2
00339 F978 CEF97E    >     LDX    $INTR2
00340 F97B DF16      >     STX    $VECT
00341 F97D 3B       RTI

00343          ; UNDERFLOW CTR1, LAST DATA LINE, FIELD 2

00345 F97E 8620      INTR2 LDA    A  $00100000B  ;UPDATE FF ON CTR 1UF,CLR ON CTR 1UF
00346 F980 B70806    STA    A  RSTAT
00347 F983 CEF989    >     LDX    $INTR3
00348 F986 DF16      >     STX    $VECT
00349 F988 3B       RTI

00351          ; INTERRUPT CTR2, PU LINE

00353 F989 8607      INTR3 LDA    A  $HRU
00354 F98B B70804    STA    A  RCLK
00355 F98E 863E      LDA    A  $00111110B  ;CLR ON CTR2 UF,INTR CTR2 UF,LTH CTR1 UF
00356 F990 B70806    STA    A  RSTAT
00357 F993 861C      LDA    A  $VCNT

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Tektronix M6800 ASM V3.3 CDRPT 6/16/81
CCD DRIVER INTERRUPT PROGRAM

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00358 F995 B70801 STA A CTR2
00359 F998 CEF9A2 > LDX #INTR4
00360 F99B DF16 > STX @VECT
00361 F99D 8632 LDA A #NR0WS
00362 F99F 9712 > STA A @LCTR
00363 F9A1 3B RTI

00365 ; UNDERFLOW CTR2 DATA LINE N

00367 F9A2 7A0012 > INTR4 DEC LCTR
00368 F9A5 2605 BNE IN4EX ;MORE TO GO
00369 F9A7 CEF9AD > LDX #INTR5
00370 F9AA DF16 > STX @VECT
00371 F9AC 3B IN4EX RTI

00373 ; UNDERFLOW CTR2 LINE 51, FIELD 1

00375 F9AD 840B INTR5 LDA A #HRP
00376 F9AF B70804 STA A RCLK
00377 F9B2 841E LDA A #00011110B ;LOAD ON CTR1 UF, CLR ON 2UF, INTR ON 1UF
00378 F9B4 B70806 STA A RSTAT
00379 F9B7 867E LDA A #VRCNT
00380 F9B9 B70801 STA A CTR2
00381 F9BC CEF9C2 > LDX #INTR6
00382 F9BF DF16 > STX @VECT
00383 F9C1 3B RTI

00385 ; UNDERFLOW CTR1, LAST DATA LINE, FIELD 1

00387 F9C2 8420 INTR6 LDA A #00100000B ;UPDATE FF CTR1 UF, CLR ON CTR1 UF
00388 F9C4 B70806 STA A RSTAT
00389 F9C7 CEF9CD > LDX #INTR7
00390 F9CA DF16 > STX @VECT
00391 F9CC 3B RTI

00393 ; INTERRUPT CTR2, PHOTOGATE LINE

00395 F9CD 8407 INTR7 LDA A #HRV
00396 F9CF B70804 STA A RCLK
00397 F9D2 843E LDA A #00111110B ;CLR CTR2 UF, INTR CTR2 UF, LATCH CTR1 U
00398 F9D4 B70806 STA A RSTAT
00399 F9D7 841C LDA A #VCNT
00400 F9D9 B70801 STA A CTR2
00401 F9DC CEF9E6 > LDX #INTR8
00402 F9DF DF16 > STX @VECT
00403 F9E1 8632 LDA A #NR0WS
00404 F9E3 9712 > STA A @LCTR
00405 F9E5 3B RTI

00407 ; UNDERFLOW CTR2, DATA LINE N, FIELD 2

00409 F9E6 7A0012 > INTR8 DEC LCTR

```

Tektronix M6800 ASM V3.3 CDRPT 6/16/81
CCD DRIVER INTERRUPT PROGRAM

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00410 F9E9 2605		BNE	INDEX
00411 F9EB CEF969	>	LDX	@INTR1
00412 F9EE DF16	>	STX	@VECT
00413 F9F0 3B		INDEX	RTI

Tektronix M6800 ASM V3.3 CCDRPT 6/16/81
 CCD DRIVER INTERRUPT PROGRAM

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00416 ; RASTER FOR CCD 202 CHIP (REVISION 2 BOARD)

00418 ; CTR2 CTR1

00420 ; 63(HRVP) 103(HRVP)

00421 ;51 [14(HRV) 103()]

00422 ; 63(HRP) 103(HRP)

00423 ;51 [14(HRV) 103()]

00425 ; RASTER FOR CCD 211 CHIP (REVISION 1 BOARD)

00427 ; CTR2 CTR1

00429 ; 63(HRVP) 201(HRVP)

00430 ;124 [63(HRV) 201()]

00431 ; 63(HRP) 201(HRP)

00432 ;124 [63(HRV) 201()]

00434 ;H,R = DISABLE CLOCK

00435 ;V,P = ENABLE CLOCK

Tektronix M4800 ASM V3.3 CCDRPT 6/16/81
 CCD DRIVER INTERRUPT PROGRAM

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00437          INCLUDE "CCDtbl28"      / VOLTAGE TABLES
00441          FE00      >          ORG      OFE00H          / STARTING ADDRESS FOR CAMERA TABLES

00443          FFFF          IF          CHIP = 202

00445          /
00446 FE00 58B825CC      TABLE BYTE      H+      H-      U+      U-      P+      P-      R+      R-
00446 FE04 48C8CF39      88, 184, 37, 204, 72, 200, 207, 57
00447 FE08 3C3C3C3C      BYTE      60, 60, 60, 60, 60, 60, 60, 60
00447 FE0C 3C3C3C3C      BYTE      85, 85, 85, 85, 85, 85, 85, 85
00448 FE10 55555555      BYTE      110, 110, 110, 110, 110, 110, 110, 110
00448 FE14 55555555      BYTE      135, 135, 135, 135, 135, 200, 135, 135
00449 FE18 6E6E6E6E      BYTE      161, 161, 161, 161, 161, 161, 161, 161
00449 FE1C 6E6E6E6E      BYTE      185, 185, 185, 185, 185, 185, 185, 185
00450 FE20 87878787      BYTE
00450 FE24 87C88787      BYTE
00451 FE28 A1A1A1A1      BYTE
00451 FE2C A1A1A1A1      BYTE
00452 FE30 B9B9B9B9      BYTE
00452 FE34 B9B9B9B9

00454          FE80      >          ORG      TABLE + 80H

00456 FE80 58B825CC      BYTE      88, 184, 37, 204, 72, 200, 207, 57
00456 FE84 48C8CF39

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Tektronix M6800 ASM V3.3 CCDBL 7/14/81
 CCD DRIVER CAMERA TABLES

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00458                                     ELSE          ICHIP = 211
00459                                     SPACE          1
00460                                     ( )          H+   H-   V+   V-   P+   P-   R+   R-
00461                                     TABLE  BYTE    252, 64, 169, 27, 139, 30, 0, 0
00462                                     BYTE    255, 64, 169, 0, 139, 0, 0, 0
00463                                     SPACE          2
00464                                     ORG          TABLE + BOH
00465                                     SPACE          2
00466                                     BYTE    252, 64, 169, 27, 139, 30, 0, 0
00467                                     BYTE    255, 64, 169, 0, 139, 30, 0, 0
00468                                     SPACE          1
00469                                     ENDIF

00471      FFFB      >      ORG      OFFF8H      !STARTING ADDRESS FOR INTERRUPT VECTORS

00473 FFF8 0015      >      WORD      INTR      !INTERRUPT REQUEST
00474 FFFA 0015      >      WORD      INTR      !SOFTWARE INTERRUPT
00475 FFFC 0015      >      WORD      INTR      !NON-MASKABLE INTERRUPT
00476 FFFE FB00      >      WORD      INITL     !RESTART

00478                                     END

```

Tektronix M6800 ASM V3.3 Symbol Table

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Scalars

CAMBT -- 0008	CAMNM -- 0802	CHIP --- 00CA	CLKBT -- 0007
CNT ---- 0010	CTR1 --- 0800	CTR2 --- 0801	HCNT --- 0067
HRP ---- 0008	HRV ---- 0007	HRVP --- 000F	IDBIT -- 0030
INDCD -- 0803	LEDS --- 1000	NROWS -- 0032	RCLK --- 0804
RUN ---- 0807	STK ---- 03FF	STOP --- 0040	TBENT -- 0040
VAR ---- 00F0	VCNT --- 001C	VRNT --- 007E	

X (default) Section (10000)

CKAD1 -- F95B	CKADR -- F951	CKV2 --- F873	CKVAR -- F859
COPY --- F93F	DEL2 --- F8A5	DELAY -- F8A3	DEST --- 0000
DV2 ---- F898	DV3 ---- F89A	DVOLT -- F887	FTB2 --- F929
FTBL --- F91F	IN4EX -- F9AC	IN8EX -- F9F0	INITL -- F800
INTR1 -- F969	INTR2 -- F97E	INTR3 -- F989	INTR4 -- F9A2
INTR6 -- F9C2	INTR7 -- F9CD	INTR8 -- F9E6	LCTR --- 0012
NEWEX -- F858	NEUTBL - F839	SRC ---- 0013	TABLE -- FE00
UPDAT -- FBAD	VELT --- 0016	VTB2 --- F917	VTBL --- F90B

478 Source Lines 478 Assembled Lines 46570 Bytes available

>>> No assembly errors detected <<<

