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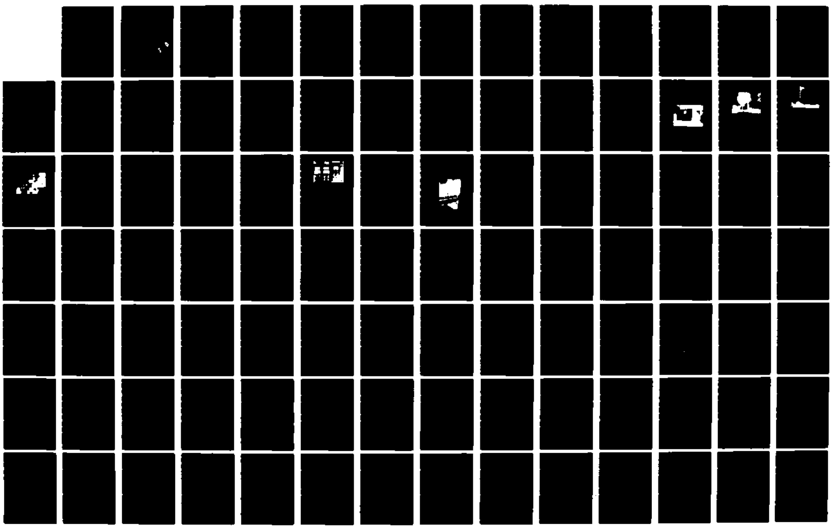

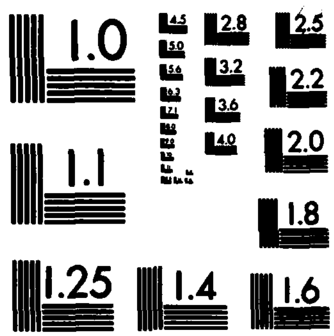

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STUDY OF CCD EYEPIECE ON T-4 THEODOLITE

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Final Report
July 1977 - November 1982

November 1982

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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 astro-position 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 galvenometer 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 intermittant 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 efficency 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

Eyepiece 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 Eyepiece System enclosure and the astrolabe building. Note the power generator on the back of the Array Eyepiece System enclosure.

Figure 1

Array Eyepiece 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.

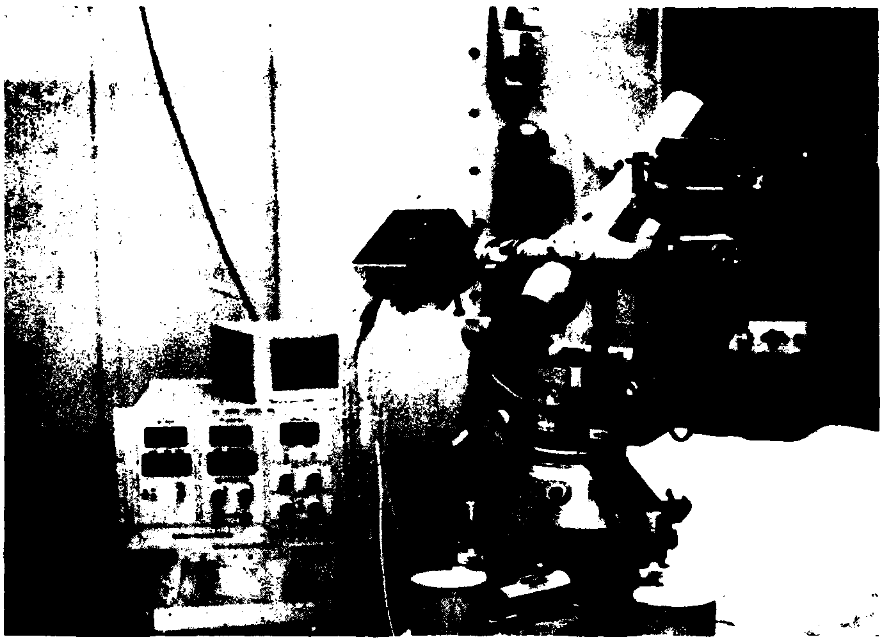


Figure 4

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 Cheyeene, 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 ambiant 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 specifiaction 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 configurtions. 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 precedure 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 $-05^{H}\ 07^{M}\ 18\overset{S}{.}9$

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°03 58.23 W + 0.0086 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.	No. of Stars 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 Instrument: Wild T4-120741

Chronometer: Datametrics 231

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	$77^{\circ}03'58''.190$	$77^{\circ}03'58''.180$	$0''.010$
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 eyepeice 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 anamolous 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 that 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

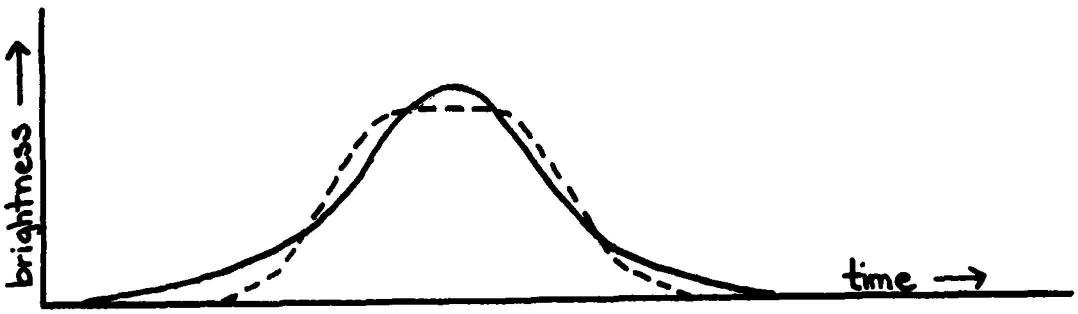


Figure 7

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.

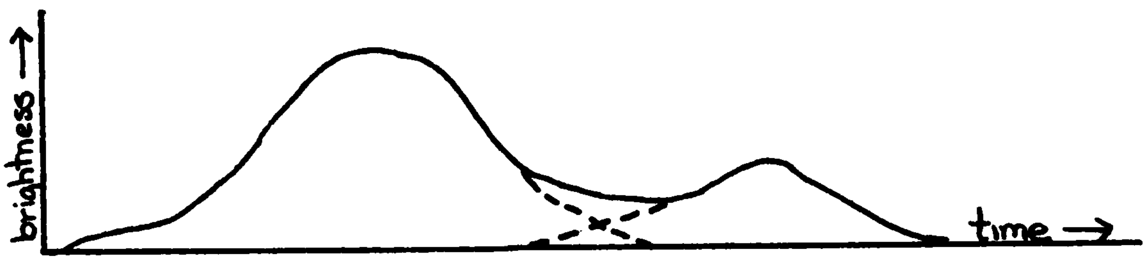


Figure 8

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(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, CCDTAPE, 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.

TABLE OF CONTENTS

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.

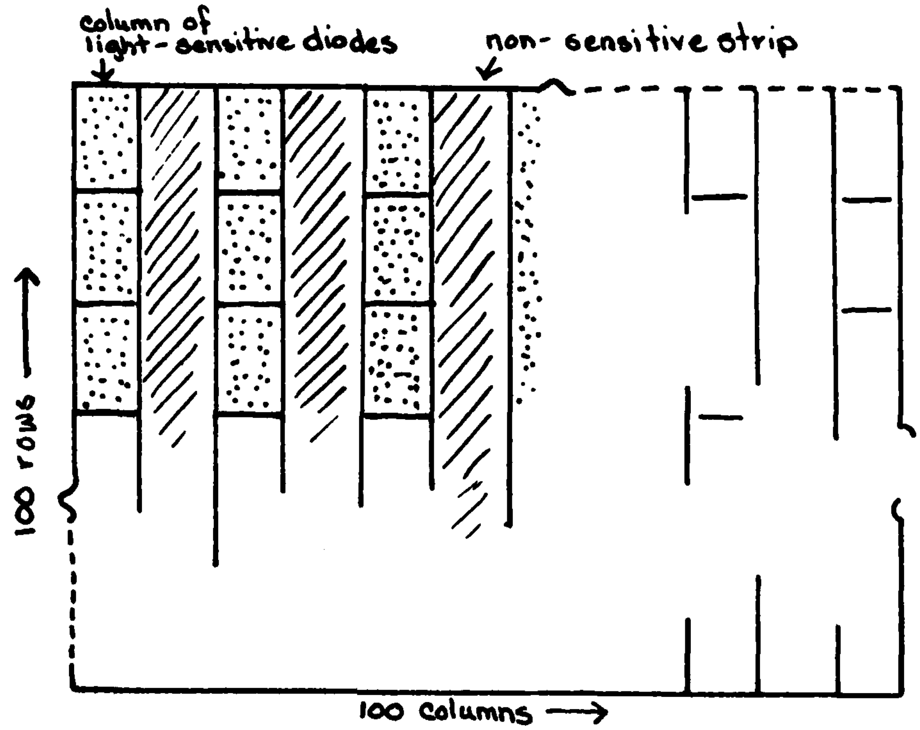


FIGURE 1

Geometry of the CCD Array

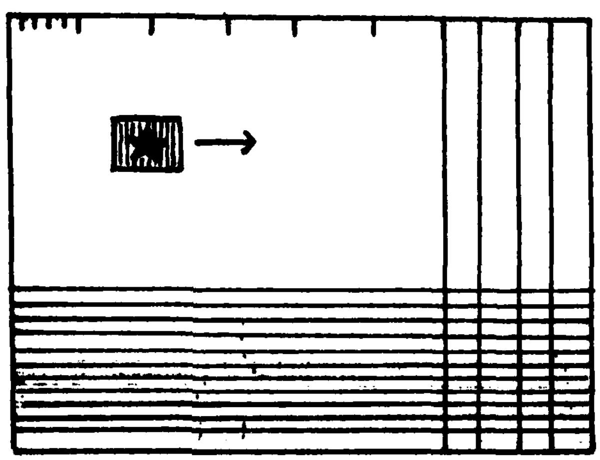


FIGURE 2

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 hadled 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 δ.

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 backgound. 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.

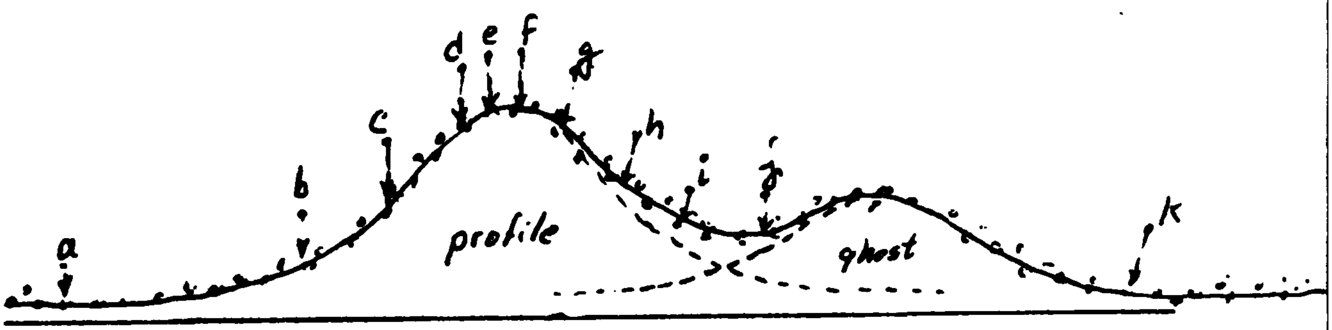


FIGURE 3

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 $E(t) = \Sigma\, a_i\, t^{e_i}$, 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.

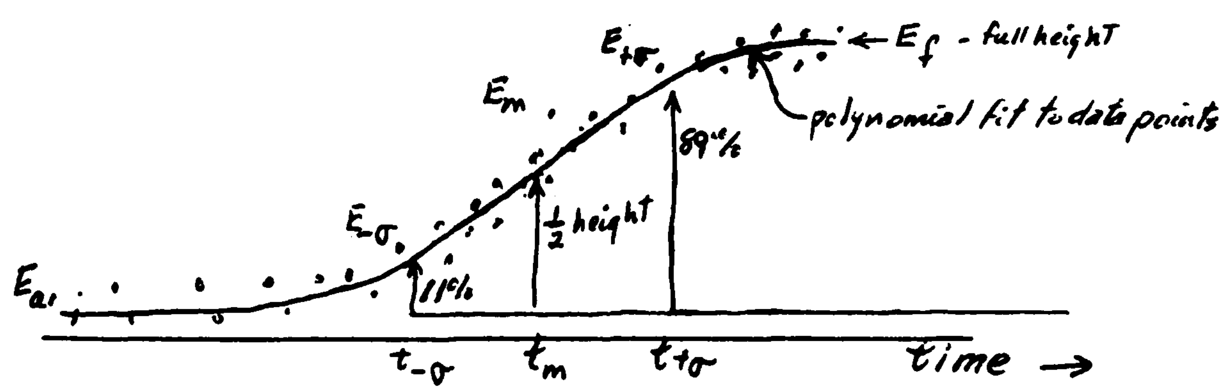


FIGURE 4

Detail of Fit to One Side of a Profile

The function E is evaluted 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 $E(t_{right\ end}) - E(t_{left\ end})$ 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(col.# - 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 adviseable 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 intrument meridian as indicated in Fig. 5.

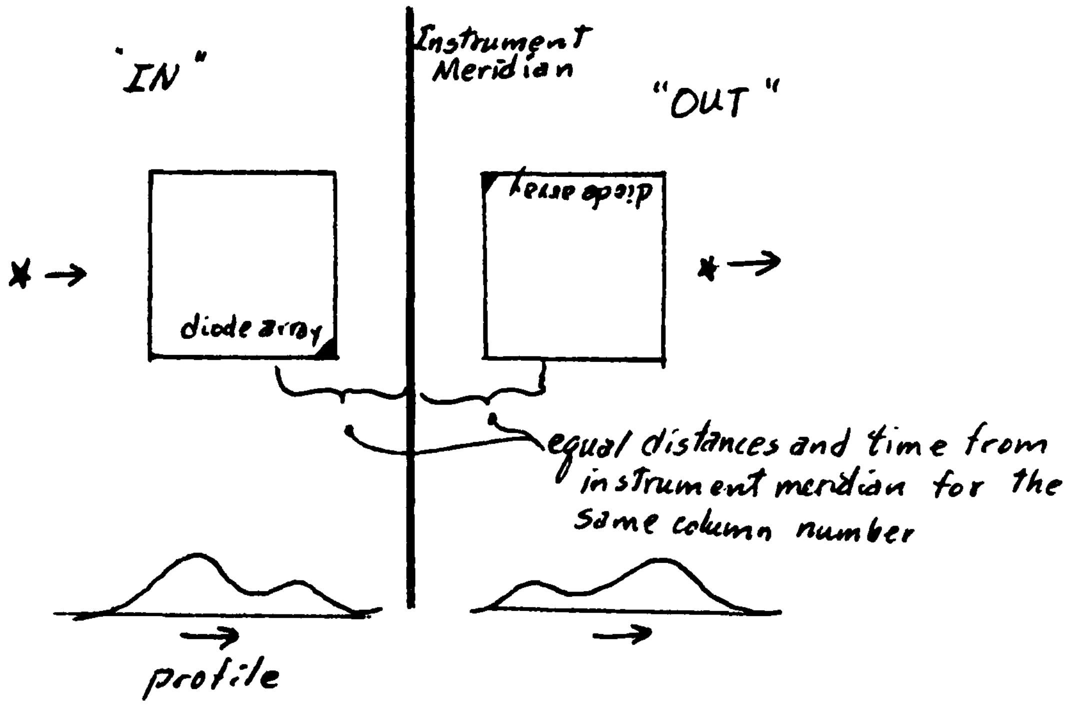


FIGURE 5

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.

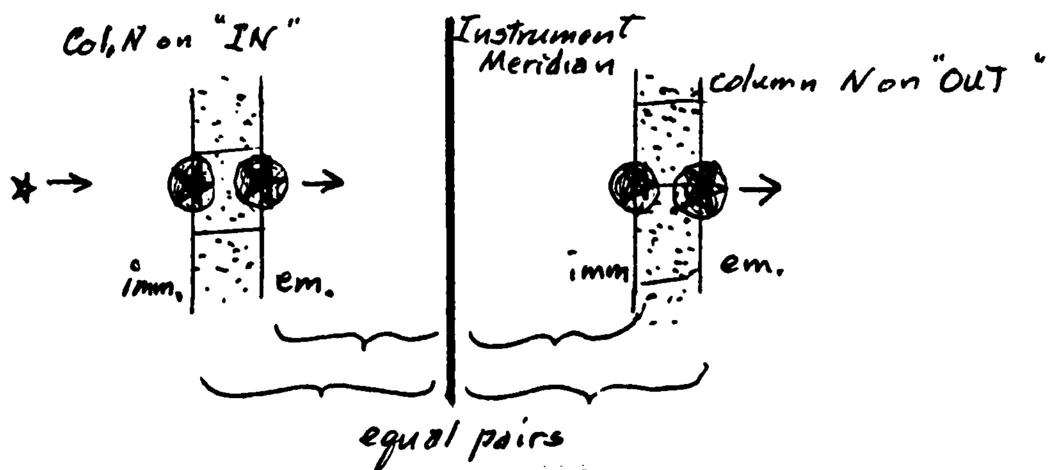


FIGURE 6

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.

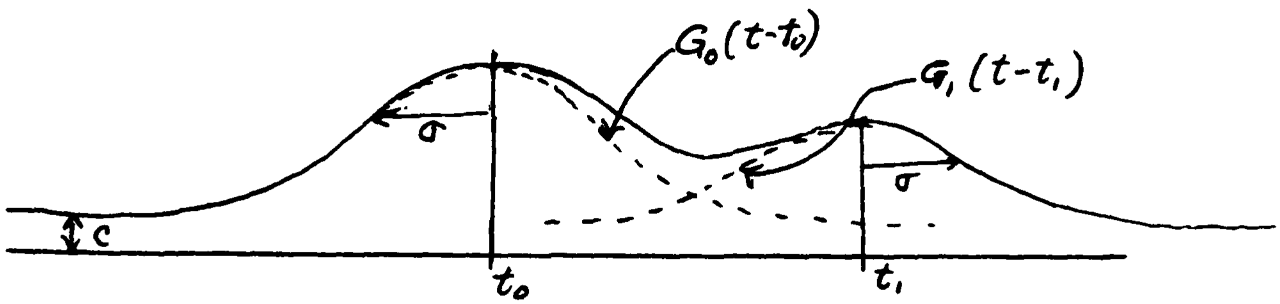


FIGURE 7

Gaussian Representation of the Profile

In mathematical terms, the profile height is

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

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 descibed 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.

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

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 $H_{observed} - H_{computed}$ 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 TO, 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, TO 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 TO 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.

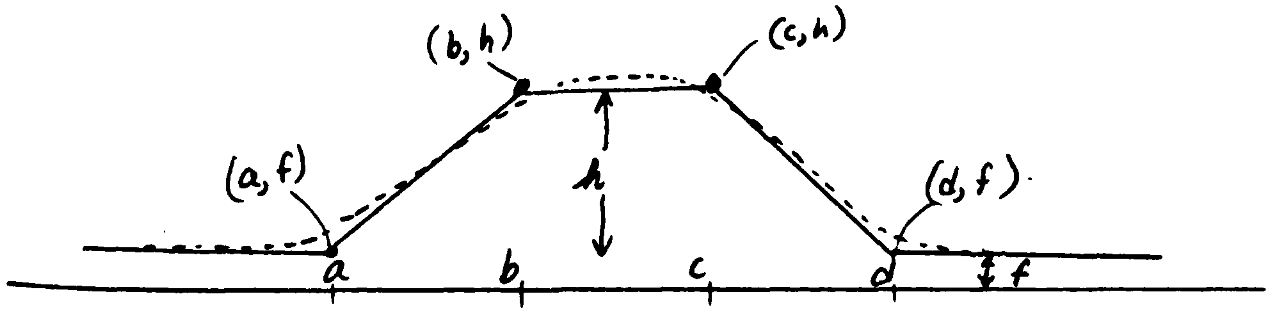


FIGURE 8

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.	IMMERSION:CONST.RATE	ERRORS OF CONST.	RATE	ST.ERROR COL.	EMERSION!
106.0001	33.0000	37.0000	49.0000	20.3760	1.0219	0.0064	0.0006	0.0383	49.0000
20.9208	1.0227	0.0056	0.0005	0.0324				

FILENAME: T4DEC09:09DEC409.SM

BASE TIME	FIRST COL	NO. OF COLS	MID COL NO.	IMMERSION:CONST.RATE	ERRORS OF CONST.	RATE	ST.ERROR COL.	EMERSION!
106.0001	180.0001	40.0000	46.0000	-16.8843	-1.0233	0.0029	0.0003	0.0159	46.0000
-16.3263	-1.0213	0.0051	0.0004	0.0319				

MEAN TIME DIFFERENCE BETWEEN IMMERSION & EMERSION = 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-D	II/OI+DA
35 1 1 1 0	39.03	39.59	174.36	0.00	0.00	106.98	106.70	0.00	106.97	0.00	106.93
36 1 1 1 1	40.11	40.68	173.38	173.92	107.02	107.03	106.74	107.30	107.02	107.03	106.97
37 1 1 1 1	41.08	41.63	172.33	172.89	106.98	106.98	106.70	107.26	106.98	106.98	106.94
39 1 1 1 1	43.13	43.67	170.28	170.80	106.97	106.97	106.70	107.24	106.98	106.96	106.93
40 1 0 1 1	44.21	0.00	169.27	169.82	107.02	0.00	106.74	0.00	107.02	0.00	106.97
41 1 1 1 1	45.18	45.69	168.23	168.75	106.97	106.96	106.71	107.22	106.98	106.94	106.94
42 1 1 1 1	46.21	46.78	167.19	167.77	106.99	106.98	106.70	107.27	106.98	107.00	106.93
45 1 1 1 1	49.26	49.87	164.11	164.65	106.95	106.99	106.68	107.26	106.96	106.98	106.91
46 1 1 1 1	50.37	50.87	163.09	163.65	107.01	106.98	106.73	107.26	107.01	106.99	106.96
49 1 1 1 1	53.44	53.92	160.03	160.56	107.00	106.97	106.74	107.24	107.01	106.96	106.97
50 1 1 1 1	54.46	54.98	159.03	159.60	107.03	107.00	106.75	107.29	107.02	107.01	106.98
52 1 1 1 1	56.47	57.02	156.99	157.56	107.01	107.01	106.73	107.29	107.01	107.01	106.96
54 1 1 1 1	58.51	59.06	154.93	155.47	106.99	106.99	106.72	107.26	107.00	106.99	106.95
55 1 1 1 1	59.49	60.02	153.91	154.51	107.00	106.97	106.70	107.26	106.98	106.99	106.93
56 1 1 1 1	60.45	61.06	152.91	153.49	106.97	106.98	106.68	107.28	106.96	107.00	106.91
57 1 1 1 1	61.54	62.09	151.86	152.50	107.02	106.97	106.70	107.29	106.97	107.02	106.93
58 1 1 1 1	62.55	63.18	150.85	151.47	107.01	107.02	106.70	107.33	106.98	107.05	106.93
59 1 0 1 1	63.66	0.00	149.80	150.35	107.00	0.00	106.73	0.00	107.01	0.00	106.96
60 1 1 1 1	64.57	65.18	148.77	149.34	106.96	106.97	106.67	107.26	106.95	106.98	106.90
61 1 1 1 1	65.67	66.23	147.78	148.36	107.01	107.01	106.72	107.29	107.00	107.02	106.95
63 1 1 1 1	67.67	68.25	145.71	146.26	106.97	106.98	106.69	107.25	106.97	106.98	106.92
64 1 1 1 1	68.69	69.28	144.71	145.31	107.00	106.99	106.70	107.29	106.98	107.02	106.93
	0.000	0.000	0.000	0.000	50.667	50.000	49.955	50.789	49.955	50.789	49.955
	0.000	0.000	0.000	0.000	106.994	106.987	106.711	107.271	106.987	106.995	106.941
	0.000	0.000	0.000	0.000	0.023	0.018	0.021	0.026	0.021	0.026	0.021
	0.000	0.000	0.000	0.000	0.005	0.004	0.005	0.006	0.005	0.006	0.005

LONGITUDE RECORD

Field	Value
2-30 Station	AIP ASTRO
32-50 Project	CCD
52-60 Location	G.O.R.F.
Set	3/4/1 of 4
2-12 Observer	J. Bernard
14-24 Recorder	R. Salwemaser; OP: O. Leatherman
25-35 Instrument	T-4 #120741
36-46 Chronometer	D.M-231
47-58 Local Date	9 DEC 81
60-80 Weather	CLEAR, WIND FR. NNW, 20-MPH
2-6 No.	883
7-13 Temp.	331
2-11 Latitude	39 01 15 N
14-24 Longitude	005 07 18.9 W

Star	N or S	Scaled Transit Time	Incl.	West (+)	East (-)	A / ZA	ZI	Sketch and Notes
F5 4.0 0902	S	23 58 19.		58.0		+.538	327 44 / 32 16	OLD CAMERA Table 5 T=33°F; BIAS ØØØ' Chip: +00°2C; NO FILE Tbl: 5
A0 2.1 0001	S	00 07 23. (76,414.0 ... 97)	100 / 1 / -0.9	58.0 / 18.2 / 39.8	17.8 / 58.5 / 40.7	+.199 / 1.126 / 1.143	349 58 / 10 02	Δα ~ 1° File(F)#1,2; Press: 29.72"
M0 +10° 4.9 1004	S	00 13 36. (86,711.265 ... 10)	102 / 3 / -0.4	58.2 / 18.1 / 40.1	17.9 / 58.4 / 40.5	+.345 / 1.007 / 1.065	341 05 / 18 55	Δα=30' F: 3,4
A2 4.5 1005	S	00 17 19. (17,009.065 ...)	104 / 4 / +2.2	18.9 ↔ 58.1 ← 39.2	59.2 / 17.8 / 41.4	+.051 / 1.246 / 1.247	357 50 / 02 20	No Δα F; 5,6
A2 44 5.2 5.1 2022	N	00 27 11.	/			-.128 / 1.391 / 1.397	05 16 / 354 44	Very dim
B0 4.2 0016	N	00 31 53. (87,380 ... 10)	106 / 7 / +0.4	18.4 ↔ 58.6 ↔ 40.2 →	58.8 / 18.2 / 40.6	.774 / 2.004 / 2.190	23 49 / 336 11	F: 7,8
B3 4.5 0018	S	00 35 51. (72,116.169 ... 14)	108 / +1.4	59.0 / 17.9 / 41.1	18.6 / 58.3 / 39.7	+.113 / 1.195 / 1.201	354 36 / 05 24	Δα = 1° F: 9,10
K0 2.5 0021	N	00 39 24.	110 / +4.9	59.5 / 16.7 / 42.8	19.2 / 57.1 / 37.9	-.541 / 1.726 / 1.809	17 25 / 342 35	F: 11,12
K0 4.3 0027	S	00 46 19.	112 / +0.1	58.2 / 17.8 / 40.4	17.9 / 58.2 / 40.3	+.281 / 1.059 / 1.096	345 09 / 14 51	Δα=30' F: 13,14

Moon 1 day before full moon

SSMFEB0.MC

File	Time of meridian (s)	Col. Pair Error	Error of Mean of Col. Pairs	No. of Col. Pairs
T4FEB11:11FEB100	90 266.739	0.056	0.010	40
T4FEB11:11FEB104	901008.819	0.001	0.000	5
T4FEB11:11FEB106	92 303.170	0.038	0.014	7
T4FEB11:11FEB108	92 591.922	0.029	0.006	25
T4FEB11:11FEB110	92 802.684	0.025	0.007	17
T4FEB11:11FEB112	93 239.654	0.027	0.012	5
T4FEB11:11FEB114	7 417.355	0.049	0.018	7
T4FEB11:11FEB116	7 680.243	0.044	0.012	15
T4FEB11:11FEB200	8 510.276	0.000	0.000	1
T4FEB11:11FEB202	8 819.216	0.024	0.004	34
T4FEB11:11FEB204	9 98.707	0.047	0.019	6
T4FEB11:11FEB206	9 783.410	0.042	0.008	29
T4FEB11:11FEB209	11 602.889	0.024	0.006	19
T4FEB11:11FEB211	12 247.100	0.039	0.008	22
T4FEB11:11FEB300	13 616.269	0.102	0.051	4
T4FEB11:11FEB302	14 121.930	0.058	0.011	30
T4FEB11:11FEB304	14 484.024	0.038	0.011	17
T4FEB11:11FEB306	14 685.008	0.051	0.018	8
T4FEB11:11FEB308	14 911.791	0.047	0.015	14
T4FEB11:11FEB310	15 388.446	0.020	0.005	22
T4FEB11:11FEB312	15 719.665	0.032	0.007	21
T4FEB11:11FEB314	15 920.886	0.039	0.009	24
T4FEB11:11FEB316	16 660.498	0.036	0.013	8
T4FEB11:11FEB318	16 925.074	0.038	0.010	17
T4FEB11:11FEB320	17 586.075	0.037	0.006	45
T4FEB11:11FEB400	19 464.617	0.028	0.006	26
T4FEB11:11FEB402	19 756.021	0.072	0.016	21
T4FEB11:11FEB404	20 289.605	0.475	0.194	9
T4FEB11:11FEB406	20 752.443	0.026	0.005	32
T4FEB11:11FEB408	21 329.937	0.049	0.022	5
T4FEB11:11FEB410	21 643.847	0.056	0.014	16
T4FEB11:11FEB416	22 628.343	0.025	0.010	7

R

APPENDIX III

OPERATIONAL SYSTEM ON THE NOVA MINICOMPUTER

FOR THE CCD EYEPIECE SYSTEM

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11454(26276)

```
( EMPTY BLOCK )
```

BLOCK: 11455(26277)

```
( EMPTY BLOCK )
```

BLOCK: 11456(26300)

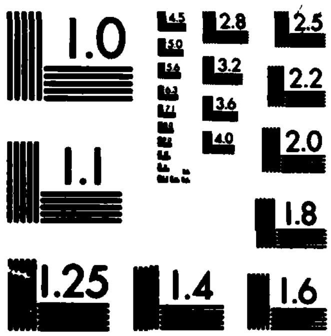
```
( T-4 THEODOLITE ASTROMETERY CONTROL ROUTINES  1/22/82 FCW ) ;S

            -------------- BLOCK MAP --------------

BLK 302 - LOAD BLOCK                BLK 304 - BUFFER MANAGEMENT
BLK 306 - PATCH PARAMETERS          BLK 310 - RATE PARAMETERS
BLK 312 - REAL TIME CLOCK           BLK 316 - EVENT TIMER
BLK 324 - AUTO PATCH STEP           BLK 330 - PATCH GENERATOR
BLK 336 - INTERRUPT ROUTINES        BLK 346 - STAR #
BLK 352 - RECORD HEADER             BLK 354 - DATA ROUTINES
BLK 360 - ALIAS SET BLOCK           BLK 362 - DATA RECORDING
BLK 366 - RATES                     BLK 370 - BACKGROUND LEVEL
BLK 372 - A-D VALUE DISP.
```

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)

```
( T4 PROGRAM COMMENTS          FCW 1/22/82 )      ;S

  ALL ODD NUMBERED BLOCKS ARE RESERVED AS COMMENT BLOCKS. MOST
EVEN NUMBERED BLOCKS ARE PROGRAM BLOCKS, ALTHOUGH IF A COMMENT
TAKES MORE THAN 1 BLOCK, IT WILL OVERFLOW TO THE NEXT EVEN
NUMBERED BLOCK. ALL COMMENT BLOCKS CAN BE LOADED WITH NO
DIFFICULTY.
```

BLOCK: 11458(26302)

```
( T4 LOAD BLOCK   FCW  1/8/82  MOD 4-22-82 )

: T4 ;

TAPE    ' TAPE LOADED' CR

DBL-PREC    ' DOUBLE PRECISION LOADED' CR

: T4-LOAD 375 304 DO I LOAD 2 +LOOP ;

T4-LOAD   ' T4 SYSTEM LOADED' CR

DECIMAL    ' BASE IS DECIMAL' CR  BELL


;S
```

BLOCK: 11459(26303)

```
( LOAD BLOCK COMMENTS      FCW 1/22/82 )      ;S

T4 - DUMMY DEFINITION TO PREVENT THE T4 SYSTEM FROM BEING
     LOADED TWICE.

TAPE - LOAD THE TAPE READ/WRITE ROUTINES

DBL-PREC - LOAD THE DOUBLE PRECISION INTEGER ROUTINES

T4-LOAD - LOAD THE REST OF THE T4 PROGRAM BLOCKS
```

BLOCK: 11487(26337)

```
( INTERRUPT HANDLER COMMENTS    FCW 1/21/82 )    ;S

  ON THE T4 PROGRAM, INTERRUPTS ARE USED ONLY TO SERVICE THE KEY
BOARD. ANY OTHER INTERRUPTING DEVICE WILL CAUSE THE PROGRAM
TO ABORT.
  'IVECT' IS AN INTERRUPT VECTOR ARRAY 64 WORDS LONG. THE VECTOR
OFFSET IS DETERMINED BY THE ASCII VALUE OF THE KEY STRUCK. THIS
ARRAY IS INITIALIZED SO ALL VECTORS POINT TO THE INTERRUPT EXIT
ROUTINE.
```

BLOCK: 11488(26340)

```
( T4 INTERRUPT EXIT         FCW   1/8/82    MOD 4-13-82  )

CODE INT-EXIT
     REGS 4 + 0 LDA,  0 0 MOV, *2  REGS 3 + 3 LDA,
     REGS 2 + 2 LDA,  REGS 1+ 1 LDA,  REGS 0 LDA,
     INTEN,  0 I) JMP,

' INT-EXIT CONSTANT IXIT

( INITIALIZE INTERRUPT VECTOR TABLE )
IXIT IVECT !  IVECT DUP 1+ 176 WORDS




;S
```

BLOCK: 11489(26341)

```
( INTERRUPT EXIT COMMENTS          FCW  1/21/82 )  ;S

   RESTORE REGISTERS AND CY
   ENABLE INTERRUPTS
   RETURN TO INTERRUPTED PROGRAM
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11490(26342)

```
( KEYBOARD INTERRUPT SERVICE ROUTINES   FCW 1/8/82 )
(  MOD  5/13/82 )

: IVCT! HERE SWAP IVECT + ! ;
CPATCH INTEGER IMV      0 INTEGER WELL

( LEFT )  061 IVCT!  IMV 2 LDA,  2 2) DSZ,  IXIT JMP,
                                 2 2) ISZ,  IXIT JMP,
( RIGHT ) 063 IVCT!  IMV 2 LDA,  2 2) ISZ,  IXIT JMP,
( UP    ) 065 IVCT!  IMV 2 LDA,  0 2) ISZ,  IXIT JMP,
( DOWN  ) 054 IVCT!  IMV 2 LDA,  0 2) DSZ,  IXIT JMP,
                                0 2) ISZ,  IXIT JMP.
( FINISHED ! )  15 IVCT!  2 2 LDA,  WELL 2 STA,
                                           IXIT JMP,

;S
```

BLOCK: 11491(26343)

```
( INTRR. SERVICE COMMENTS      FCW   1/21/82 )   ;S

   THESE ROUTINES INCREMENT OR DECREMENT THE STARTING ROW OR
COLUMN # TO CHANGE THE PATCH POSITION.
   A 'CR' SETS "WELL" TO A NONZERO VALUE TO TERMINATE DATA
TAKING.
```

BLOCK: 11492(26344)

```
( INTERRUPT CONTROL ROUTINES  FCW 1/8/82  MOD 1/11/82 )

1 ,CODE KCKA ' INTERRUPT ,
   0 S) 0 LDA,  77 DOB,  ' KCKA 0 LDA,  1 0 STA,  POP JMP,

CODE STTI 110 NIO, NEXT JMP,   CODE CTTI 210 NIO, NEXT JMP,

: KCLR  177777 KCKA CTTI ;
: KARM  177775 KCKA STTI ;

CODE DI  277 NIO,  NEXT JMP,
CODE EI  INTEN,  NEXT JMP,

: CINIT  CRATE SCA 4 WORDS  KARM  ;
: CFIN   KCLR  ;
;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11493(26345)

```
( INTERRUPT CONTROL COMMENTS      FCW 1/21/82 )    ;S

KCKA - OUTPUTS THE INTERRUPT MASK ON THE STACK AND SETS THE
        INTERRUPT VECTOR ( LOC 1 ) TO POINT TO THE T4 INTER-
        RUPT HANDLER.

CINIT - SETS UP THE SCRATCH AREA FOR THE RATE AND ENABLES THE
         TTI INTERRUPT MASK.
```

BLOCK: 11494(26346)

```
( STAR # AND OTHER STUFF   FCW  1/21/82   MOD 4/15/82 )

-1 INTEGER STAR-NMBR
: STAR-NUMBER
        BASE @ DECIMAL  WORD  NUMBER  DROP  STAR-NMBR  !
        BASE ! ;

: SN STAR-NUMBER ;

0 INTEGER LOC  5 DP +! ( ASCII STRING )
: LOCATION
      WORD  DP @ 1+  LOC  5 WORDS ;



;S
```

BLOCK: 11495(26347)

```
( HEADER AND HEADER ROUTINES COMMENTS  FCW 1/22/82 )    ;S

   THE RECORD HEADER FORMAT IS AS FOLLOWS.
    WORD #                          DESCRIPTION
    ------                          -----------
    0                               STAR NUMBER
    1                               SPARE
    2 - 3                           DMA 1 SEC CLOCK
    4 - 17                          ETBUF ( LESS PHOTOGATE )
    18 - 25                         SPARES
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11496(26350)

```
( T4 SYSTEM )  ;S
  ;S
```

BLOCK: 11497(26351)

```
( T4 SYSTEM ) ;S
  ;S
```

BLOCK: 11498(26352)

```
( CREATE THE RECORD HEADER   FCW 1/21/82   MOD 1/25/82 )
1 ,CODE HBF 0 ,
    0 S) 1 LDA,  ' HBF 0 LDA,  1 0 ADD,  PUT JMP,
( HEADER ADDRESS ON STACK  )
: RECORD-HEADER
    ' HBF !
    STAR-NMBR @  0 HBF   !
    1SEC-CLK     2 HBF  D!
    ETBUF 2 +    4 HBF  16 WORDS  ;
  ;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11499(26353)

```
( RECORD HEADER ROUTINES COMMENTS     FCW 1/21/82 )   ;S

HBF - REPLACES THE # ON THE STACK WITH THE SUM OF THE # ON THE
      STACK AND THE HEADER STARTING ADDRESS.

RECORD-HEADER
    - BUILD THE RECORD HEADER ACCORDING TO THE HEADER FORMAT.
```

BLOCK: 11500(26354)

```
( RECORD HEADER AND 1'ST FRAME OF RECORD   FCW 1/8/82 )
(  MOD 2/11/82 )

BASE @ DECIMAL

: 1'ST-FRAME
    32 GBUF  ' GBUF @ CCDINIT  TIMETAGS
    RECORD-HEADER
    PTGMICROSEC D@  26 HBF  D!
    CPATCH  28 HBF  4  WORDS
    EI  STEP  CCD-DONE  DI  ' GBUF ! ;

BASE !


;S
```

BLOCK: 11501(26355)

```
( 1'ST FRAME COMMENTS          FCW  1/21/82  )  ;S
   32 GBUF RESERVES 32 WORDS FOR THE RECORD AND FRAME HEADERS.
THE PATCH GENERATOR IS INITIALIZED FOR THE NEXT FRAME. TIMETAGS
CHECKS THE ET BOARD AND DOES NOT RETURN UNTIL THE NEW FRAME HAS
STARTED. THEN THE RECORD-HEADER IS CREATED AND THE FRAME HEADER
IS FILLED WITH THE PHOTOGATE TIME AND THE PATCH PARAMETERS.
INTERRUPTS ARE ENABLED FOR THE KEYBOARD, THE AUTO STEP ROUTINE
IS CALLED, AND THE PROGRAM WAITS UNTIL THE THE CURRENT PATCH
FRAME IS DONE. THEN INTERRUPTS ARE DISABLED AND THE NEXT FREE
BUFFER ADDRESS STORED IN GBUF.

  ;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11502(26356)

```
( FRAMES 2,3, & 4 OF TAPE RECORD  FCW  1/8/82  MOD 1/22/82 )

: REC-FRAME
   6 GBUF DUP ' GBUF @ CCDINIT  TIMETAGS
   PTGMICROSEC D@ ROT D!   CPATCH SWAP 2 + 4 WORDS
   EI  STEP  CCD-DONE  DI  ' GBUF !  ;

: 234-FRAMES  REC-FRAME  REC-FRAME  REC-FRAME ;

  ;S
```

BLOCK: 11503(26357)

```
( 2,3,4 FRAME COMMENTS          FCW 1/22/82    ) ;S

REC-FRAME - RECORD 1 CCD FRAME WITH THE FOLLOWING FORMAT:

        WORD #              DESCRIPTION
        ------              -----------
         0 , 1              PHOTOGATE IN MICROSECONDS
         2 - 5              PATCH PARAMETERS (CPATCH)
         6 - N              PIXEL DATA
```

BLOCK: 11504(26360)

```
( ALIAS SET BLOCK  FCW 06/08/81   MOD  01/21/82         )

ALIAS T4DATA  ALIAS T4EOF
: RECORD ' TWRITE ' T4DATA !  ' EOF ' T4EOF ! ;

RECORD

: NOWRT DROP DROP ;
: SIM ' NOWRT ' T4DATA ! ' NULL ' T4EOF ! ;

SIM

;S
```

BLOCK: 11505(26361)

```
( ALIAS SET BLOCK COMMENTS        FCW  1/21/82  )  ;S

T4DATA - DUMMY WRITE ROUTINE
T4EOF  - DUMMY EOF ROUTINE

RECORD - SET UP T4DATA TO THE TAPE WRITE ROUTINE AND T4EOF
            TO THE TAPE EOF ROUTINE
SIM    - SET UP T4DATA AND T4EOF TO DO NOTHING AT ALL
```

BLOCK: 11506(26362)

```
( DATA RECORDING ROUTINES     FCW  1/8/82   MOD  2/8/82 )
: 1REC
     ' GBUF @ DUP   1'ST-FRAME  234-FRAMES
     ' GBUF @  -  SWAP  T4DATA  ;

' GBUF @  GBUFMARK  GBUFST

: DATA-LOOP
     WELL ZERO!  PCNT! CINIT  ETINIT  TICK DROP
     BEGIN TICK ETSCAN END
     BEGIN  GBUFST  1REC  1REC  WELL @  END
     CFIN  T4EOF  ;

: CURSOR    SIM DATA-LOOP ;
: RUN       CURSOR  RECORD  FAST  GAP GAP DATA-LOOP ;
;S
```

BLOCK: 11507(26363)

```
( RECORDING ROUTINES COMMENTS   FCW 1/21/82  )   ;S

1REC - ASSEMBLE 1 COMPLETE RECORD IN MEMORY AND CALL T4WRITE

DATA-LOOP
      - INITIALIZE INTERRUPTS AND THE EVENT TIMER
        SET UP AN INDEFINITE LOOP, SWITCHING BETWEEN 2 BUFFERS
        DISABLE INTERRUPTS AND CALL T4EOF

CURSOR
      - DO DATA-LOOP WITHOUT WRITING TO TAPE

RUN  - DO DATA-LOOP AND RECORD DATA ON TAPE
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11508(26364)

```
( THESE ROUTINES ARE HELPFUL WHEN RUNNING THE T4 SYSTEM )
( MOD    FCW 4/15/82 )
: @TIME CR " TIME: " MST? ;
: TRUN @TIME RECORD FAST GAP GAP DATA-LOOP @TIME ;

1 ,CODE REVERSE  CRATE ,
    ' REVERSE 3 LDA,  1 3) 0 LDA,  0 0 COM,  1 3) 0 STA,
    3 3) 0 LDA,  0 0 COM,  3 3) 0 STA,  NEXT JMP,

0 INTEGER HLD-RATE 0 , 0 , 0 ,
: HALT CRATE HLD-RATE 4 WORDS STILL ;
: RESUME HLD-RATE CRATE 4 WORDS ;
: REVERSAL HOME CURSOR TRUN HALT CURSOR RESUME REVERSE TRUN
                 -1 STAR-NMBR ! ;
: R REVERSAL ;
;S
```

BLOCK: 11509(26365)

```
( RUNTIME ROUTINE COMMENTS  FCW  1/21/82 MOD 4/15/82)  ;S
TRUN - SAME AS RUN EXCEPT IT PRINTS THE TIME ON THE TERMINAL AT
       THE BEGINNING AND END OF A RUN.
REVERSE - CHANGE THE DIRECTION FLAGS IN CRATE
HALT - SAVE CURRENT RATE AND REPLACE WITH STILL
RESUME - RESTORE RATE
REVERSAL - DO THE DATA RUN IN BOTH DIRECTIONS
```

BLOCK: 11510(26366)

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

  ;S
```

BLOCK: 11481(26331)

```
( OPATCH COMMENTS                      FCW  1/22/82  )     ;S
   THE PATCH IS DEFINED IN HARDWARE BY 4 COORDINATES : 1) START-
ING LINE; 2) ENDING LINE; 3) STARTING COLUMN; & 4) ENDING COL-
UMN. THE 4 PATCH COORDINATES ARE SELECTED BY A 'DOA 7' INSTRUC-
TION. BITS 4-15 HAVE THE COORDINATE VALUE (RIGHT JUSTIFIED).
BITS 2 & 3 GO TO A DECODER TO SPECIFY WHICH PARAMETER IS BEING
OUTPUT. THIS TABLE SHOWS THE SELECTION MAPPING.
                        ------TABLE------
                BIT #                       PATCH
                2 , 3                     PARAMETER
                -----                  ---------------
                0 , 0                  STARTING LINE
                0 , 1                  ENDING   LINE
                1 , 0                  STARTING COLUMN
                1 , 1                  ENDING   COLUMN
( CONTINUED NEXT BLOCK )
```

BLOCK: 11482(26332)

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

BLOCK: 11483(26333)

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

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11484(26334)

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

BLOCK: 11485(26335)

```
( PATCH GENERATOR CTRL COMMENTS   FCW 1/21/82  )    ;S
STCCD - OUTPUT THE BUFFER ADDRESS AND WORD COUNT TO PATCH GEN-
        ERATOR CARD WHILE STARTING IT
CCDINIT - OUTPUT PATCH COORDINATES AND START PATCH GENERATOR
CCD-DONE - WAIT FOR PATCH GENERATOR TO FINISH. RETURN THE NEXT
           FREE BUFFER ADDRESS ON THE STACK
```

BLOCK: 11486(26336)

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

BLOCK: 11478(26326)

```
( AUTO PATCH STEP ROUTINES   FCW  1/20/82  MOD 1/25/82 )

   SCA DSZ,        ( COLUMN COUNTER )
   IF,
     0 3) 0 LDA,  SCA 0 STA,  SCA 1+ 0 LDA,  0 0 MOV, SPL
     IF,
       2 2) 0 LDA,  0 0 INC,  LIMITS 3 + 1 LDA,  0 1 SUB, # SNC
       1 0 MOV,  2 2) 0 STA,
     ELSE,
       2 2) 0 LDA,  0 0 DEC,  LIMITS 2 + 1 LDA,  0 1 ADC, # SZC
       1 0 MOV,  2 2) 0 STA,
     THEN,
   THEN,
   N 2 LDA, NEXT JMP,

 ;S
```

BLOCK: 11479(26327)

```
( PATCH STEP COMMENTS      FCW  1/20/82             ) ;S

   'STEP' IS CALLED ONCE PER FRAME. THE COUNTS STORED AT SCA
AND SCA+2 ARE DECREMENTED. WHEN THE COUNT ='S 0, THE COUNT IS
RESTORED AND THE DIR FLAG IS CHECKED. IF THE FLAG IS NEG, THE
STARTING LINE/COL # IS DECREMENTED AND CHECKED AGAINST THE LOWER
LIMIT. IF #<LIMIT, THE LIMIT IS SUBSTITUTED; OTHERWISE THE
DECREMENTED # IS USED. IF THE FLAG IS POS, THE STARTING LINE/COL
IS INCREMENTED AND CHECKED AGAINST THE UPPER LIMIT. IF #>LIMIT
THE LIMIT IS USED; OTHERWISE THE INCREMENTED # IS USED.
```

BLOCK: 11480(26330)

```
( SEND PATCH PARAMETERS TO CCD INTERFACE                11/25/80 )
( MOD  FCW  1/21/82 )
( USE BITS 2&3 OF 12 BIT DATA WORD AS REGISTER SELECT           )
( 2,3 = 00 START LINE, 01 END LINE, 10 START COL, 11 END COL    )

10000 INTEGER INCRM  ( REGISTER SELECT INCREMENT   )
( ADD OFFSET TO PARAMETER AND SEND IT. INC OFFSET FOR NEXT )
SUBROUTINE SEND 1 0 ADD, 7 DOA, INCRM 3 LDA, 3 1 ADD, RETURN

2 ,CODE OPATCH 0 , CPATCH ,  ' OPATCH DUP 2 STA,  1+ 2 LDA,
      1 1 SUB,  0 2) 0 LDA,  SEND JSR,  1 2) 3 LDA,
   3 3 MOV, /2   0 2) 0 LDA,  3 0 ADD,  0 0 DEC,  SEND JSR,
                 2 2) 0 LDA,  SEND JSR,
    3 2) 3 LDA,  2 2) 0 LDA,  3 0 ADD,  0 0 DEC,  SEND JSR,
                ' OPATCH 2 LDA,  NEXT JMP,
;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11475(26323)

```
( TIMETAG ROUTINE COMMENTS      FCW 1/20/82 ) ;S

?CCD - MONITOR THE CCD ADDRESS COUNTER AND DO NOT RETURN UNTIL
       IT CHANGES. THIS ENSURES THAT THE PHOTOGATE TIME AT THE
       START OF THE CURRENT FRAME IS THE ONE STORED IN ETBUF.

1SEC - HOLD THE VALUE OF THE HARDWARE 1 SEC COUNTER. THIS IS
       CHECKED AGAINST THE 1 SEC COUNTER AND IF DIFFERENT,
       '1SEC' IS UPDATED WITH THE NEW VALUE AND AN ETSCAN IS
       DONE TO MAKE SURE THE DMAMICROSEC IS UPDATED. THIS
       PREVENTS THE 2 CLOCKS FROM GETTING OUT OF PHASE.

TIMETAGS - DO ETSCAN AND UPDATE THE 1SEC CLK IF NECESSARY.
```

BLOCK: 11476(26324)

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

BLOCK: 11477(26325)

```
( PATCH STEP COMMENTS     FCW  1/20/82        ) ;S

LIMITS - THESE ARE THE UPPER AND LOWER LIMITS OF THE STARTING
         LINE/COLUMN #. THE LIMITS DO NOT GO TO 100 DUE TO THE
         HEIGHT AND WIDTH OF THE PATCH.

SCA - THIS IS A SCRATCH AREA. CRATE IS COPIED HERE.
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11472(26320)

```
( 8 CHAN. ET BOARD DRIVER ROUTINES  FCW  1/20/82 MOD 1/20/82 )
CODE ETSCAN
     NXTBUF JSR,  4205 DOC,  4005 DIB,  105 DOB,  N 0 LDA,
     0 1 SUB, SNR
       IF,
         1 1 MOV, /2 SNR
         IF,
           N 1+ 1 STA,  ETTIME JSR,
         THEN,
       THEN,
     NEXT JMP,

CODE ETINIT
     ETVAR 4 + 3 LDA,  0 3) 0 LDA,  3 3) 0 STA,  305 DOB,
     2 3) 0 LDA,  105 DOC,  NEXT JMP,
;S
```

BLOCK: 11473(26321)

(8 CHAN. ET BOARD COMMENTS   FCW 1/20/82)

'ETSCAN' IS THE MAIN ROUTINE. IT GETS THE NEXT BUFFER, RESTARTS THE ET BOARD, AND CHECK TO SEE IF ANYTHING WAS TRANS-FERRED. IF SOMETHING WAS, IT CALLS ETTIME TO SORT AND STORE THE TIMES.

'ETINIT' SETS THE BUFFER ADDRESS, OUTPUTS THE ADDRESS TO THE ET BOARD, OUTPUTS A WORD COUNT OF 26 (OCTAL) TO THE ET BOARD, AND STARTS IT.

BLOCK: 11474(26322)

```
( TIMETAG ROUTINES FOR DATA RUNS  FCW 1/8/82   MOD 1/11/82 )

ETBUF 16 + CONSTANT DMAMICROSEC
ETBUF      CONSTANT PTGMICROSEC

CODE ?CCD
   4007 DIB,  HERE  7 DIB, 1 0 SUB, SNR  JMP,  NEXT JMP,

0 INTEGER 1SEC
: TIMETAGS
   ?CCD  ETSCAN  1PPSCLK DUP 1SEC @ =
     IF  DROP  ELSE  1SEC ! ETSCAN THEN  ;

: 1SEC-CLK
   TIME D@  1SEC @ 0 D+ ;
;S
```

BLOCK: 11469(26315)

```
( REAL TIME CLOCK COMMENTS       FCW    1/22/82 ) ;S

   'ADJTIME' CALLS 'CHKBD' AND DEPENDING ON WHICH KEY WAS
PRESSED (IF ANY) DOES THE FOLLOEING: 1) '-' DECREMENTS THE
BASE TIME; 2) '+' INCREMENTS THE BASE TIME; & 3) 'CR' SETS
A FLAG TO EXIT THE LOOP IN CHKTIME;

   'CHKTIME' SETS UP A LOOP THAT PRINTS THE TIME ONCE PER
SECOND AND CALLS 'ADJTIME' TO MODIFY THE TIME IF NECESSARY.

   'MST' SETS THE BASE TIME TO THE VALUE ON THE STACK, CLEARS
THE HARDWARE COUNTER, AND CALLS CHKTIME. THE TIME IS ENTERED
AS FOLLOWS:          HH:MM:SS. MST  (CR)
BEFORE TYPING IN THE TIME MAKE SURE THE BASE IS DECIMAL.
ALSO BE SURE NOT TO FORGET THE DECIMAL PT.
```

BLOCK: 11470(26316)

```
( 8 CHANNEL EVENT TIMER BOARD DRIVER ROUTINES  04/15/81  )

0 INTEGER ETBUF HERE DUP 1- SWAP 20 DUP DP +! WORDS

26 DUP GBUF DUP INTEGER ETVAR OVER GBUF + , MINUS , 0 , ETVAR ,
   ETBUF ,

SUBROUTINE NXTBUF
     ETVAR 3 + 1 LDA,  ETVAR 1+ 0 LDA,  1 0 SUB,
     ETVAR 3 + 0 STA,  N 1 STA,  ETVAR 2 + 1 LDA,  RETURN

SUBROUTINE ETTIME
     HERE  N I) 0 LDA, 7 1 LDA,  0 1 AND, *2
     ETVAR 5 + 3 LDA,  1 3 ADD,  1 3) 0 STA,  N ISZ,
     N I) 0 LDA, 0 3) 0 STA, N ISZ, N 1+ DSZ,  JMP,
     RETURN                   ;S
```

BLOCK: 11471(26317)

```
( 8 CHANNEL ET BOARD DRIVER COMMENTS        FCW  1/20/82 ) ;S

   THESE ROUTINES TAKE THE TIMES PLACED IN MEMORY BY THE ET
BOARD, AND PLACE THEM BY ORDER OF THEIR CHANNEL # IN ETBUF.
TIMES USED BY THE PROGRAM ARE ACCESSED FROM ETBUF.

   'NXTBUF' FLIPS BACK AND FORTH BETWEEN TWO (2) CONSECUTIVE
BUFFERS. WHILE ONE IS BEING FILLED THE OTHE IS BEING PROCESSED.
THE ALGORITHM USED IS :
(NEW BUF ADDR) = 2*(1'ST BUF ADDR) + 26 - (PREV BUFFER ADDR)

   'ETTIME' SCANS THE TIMES PLACED IN THE BUFFER AND PLACES
THEM IN THEIR RESPECTIVE PLACE IN 'ETBUF'.
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

```
BLOCK: 11466(26312)

( REAL TIME CLOCK ROUTINES    06/08/81    )
( MOD   FCW  2/8/82 )
CODE C5 305 DOA, 205 NIO, NEXT JMP,
CODE STTI 110 NIO, NEXT JMP,
1 ,CODE TICK 0 , ' TICK 1 LDA, 5 DIA. 0 1 SUB, SNR
   IF, ' TICK 0 STA, 2 0 LDA, ELSE, 0 0 SUB, THEN, PUSH JMP,
CODE 1PPSCLK 5 DIA, PUSH JMP,

CODE CHKBD 10 SZB, IF, 110 DIA, #177 1 LDA, 1 0 AND, ELSE,
    0 0 SUB, THEN, PUSH JMP,

BASE @ DECIMAL
: HMS F @ -ROT 60 D/MOD -ROT 60 D/MOD -ROT 24 D/MOD -ROT DDROP
   48 F 1+ ! 2 F ! . " :" . " :" . 32 F 1+ ! F ! ;
: HMS. D@ HMS ;
BASE !                         ;S


BLOCK: 11467(26313)

( REAL TIME CLOCK ROUTINES COMMENTS   FCW 1/20/82  )  ;S

   THESE ROUTINES ARE USED TO SYNCHRONIZE THE FIRMWARE CLOCK
TO THE DATAMETRICS 1 SEC CLOCK. THE 1PPS FROM THE DMA CLOCK
CLOCKS A HARDWARE COUNTER ON THE EVENT TIMER BOARD. THIS 16
BIT COUNT IS ADDED TO A 32 BIT # IN MEMORY ( A "BASE" COUNT )
TO FORM THE CORRECT TIME-OF-DAY. THE TIME IS SET BY FIRST
CLEARING THE 16 BIT HARDWARE COUNTER, AND THEN ADJUSTING THE
"BASE" COUNT UNTIL THE SUM OF THE BASE COUNT AND THE COUNTER
IS EQUAL TO THE TIME DISPLAYED ON THE DMA CLOCK.

C5 - RESET CTR TO 0,   STOP DMA ACTIVITY

HMS. - PRINT OUT THE DOUBLE PRECISION # ON THE STACK IN THE
       FORMAT  HH:MM:SS


BLOCK: 11468(26314)

( MORE REAL TIME CLOCK ROUTINES   06/08/81 MOD 4/14/82     )

: GETTIME TIME D@ 1PPSCLK 0 D+ ;
: MST? GETTIME HMS ;
53 CONSTANT '+'      55 CONSTANT '-' 15 CONSTANT CRTN
: -TIME TIME D@ 1. D- DABS  TIME D! ;
: +TIME TIME D@ 1. D+ TIME D! ;

: ADJTIME CHKBD DUP CRTN = IF DROP 1
    ELSE DUP '+' = IF DROP +TIME 0
    ELSE DUP '-' = IF DROP -TIME 0
    ELSE DROP 0 THEN THEN THEN ;

: CHKTIME STTI BEGIN TICK IF MST? CR THEN ADJTIME END ;
: GMT C5 TIME D! CHKTIME ;
;S
```

BLOCK: 11463(26307)

```
( PATCH PARAMETER COMMENTS      FCW 1/22/82 ) ;S

CPATCH - CURRENT PATCH

  'PATCH' IS USED TO DEFINE A WORD WHICH WHEN INVOKED WILL
PLACE A SPECIFIED PATCH POSITION AND SIZE IN 'CPATCH'. THE
PARAMETERS ARE TYPED IN THE SAME ORDER AS THEY APPEAR IN
'CPATCH'. THEN THE WORD 'PATCH' IS TYPED FOLLOWED BY WHATEVER
NAME IS TO BE USED, IN THEIS CASE 'HOME'. WHEN 'HOME' IS USED,
IT WILL PLACE 40, 10, 10, & 6 IN 'CPATCH'.
```

BLOCK: 11464(26310)

```
( PATCH RATE PARAMETER ENTRY          FCW  1/20/82 )
( HOR COUNT, HOR DIR FLAG,  VERT COUNT, VERT DIR FLAG )
0 INTEGER CRATE 0 , 0 , 0 , CRATE ,
: RATE CONSTANT , ;CODE 2 1 MOV,  CRATE 4 + 2 LDA,  0 0 SUB,
    0 2) 0 STA,  1 2) 0 STA,  2 2) 0 STA,  3 2) 0 STA,
    0 3) 0 LDA,  0 0 MOV, # *2 SNC
      IF,    3 2) 0 STA,  0 0 NEG,  2 2) 0 STA,
      ELSE,  2 2) 0 STA,
      THEN,
    1 3) 0 LDA,  0 0 MOV, # *2 SNC
      IF,    1 2) 0 STA,  0 0 NEG,  0 2) 0 STA,
      ELSE,  0 2) 0 STA,
      THEN,
    1 2 MOV,  NEXT JMP,
0 0 RATE STILL          STILL
;S
```

BLOCK: 11465(26311)

```
( PATCH RATE COMMENTS      FCW 1/22/82  )  ;S
CRATE - CURRENT RATE

  'RATE' DEFINES A WORD WHICH WILL SET UP 'CRATE' ACCORDING TO T
THE NUMBERS ENTERED WHEN THE WORD WAS DEFINED. TO USE 'RATE' DO
THE FOLLOWING: TYPE IN 2 NUMBERS, FOLLOWED BY 'RATE', THEN BY
THE NAME OF THE NEW RATE. THE 1'ST # IS THE HORIZONTAL RATE -
A POSITIVE VALUE WILL MOVE THE PATCH TO THE RIGHT, A NEGATIVE
VALUE TO THE LEFT. THE 2'ND # IS THE VERTICAL RATE - A POS.
VALUE WILL MOVE THE PATCH UP, WHILE A NEG. VALUE WILL MOVE IT
DOWN. ( SEE 'OPATCH' COMMENTS FOR VERTICAL STEP PECULIARITIES).
THE COUNTER TAKES THE ABSOLUTE VALUE OF THE # ENTERED AND COUNTS
DOWN TO ZERO. THUS A VALUE OF 1 WILL BE THE FASTEST RATE, AND A
VALUE OF 0 WILL BE THE SLOWEST. THE # IS DECREMENTED ONCE PER
FRAME. FOR EXAMPLE, IF THE FRAME RATE IS 40 HZ, A COUNT OF 40
WILL MOVE THE PATCH ONCE EVERY SECOND.
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11460(26304)

```
( BUFFER MANAGEMENT    FCW   1-8-82   MOD 5/24/82 )

1 ,CODE GBUF 0 ,
   0 3) 0 LDA, 0 S) 1 LDA, 0 1 ADD, 0 3) 1 STA, PUT JMP,

: GBUFMARK CONSTANT ;CODE
   0 3) 0 LDA, ' GBUF 0 STA, NEXT JMP,

40000 CONSTANT BUF
BUF GBUFMARK GBUFINITIALIZE
                              GBUFINITIALIZE




;S
```

BLOCK: 11461(26305)

```
( BUFFER MANAGEMENT COMMENT BLOCK      FCW 1/20/82    ) ;S

   ' GBUF ' RETURNS A BUFFER ADDRESS. WHEN GBUF IS CALLED .
THE TOP STACK ITEM IS THE # OF WORDS TO BE RESERVED. THIS
# IS ADDED TO THE NEXT FREE BUFFER ADDRESS AND SAVED FOR THE
NEXT TIME GBUF IS CALLED.

   'GBUFMARK' DEFINES A CONSTANT THAT WHEN INVOKED WILL PLACE TH
VALUE IN ITS PARAMETER FIELD IN THE PARAMETER FIELD OF 'GBUF'
INSTEAD OF ON THE STACK.
```

BLOCK: 11462(26306)

```
( PATCH PARAMETER ENTRY          FCW  1/22/82 )

( STARTING ROW, # ROWS, STARTING COLUMN, # COLS    )
0 INTEGER CPATCH 0 , 0 , 0 , CPATCH ,

: EVACO, 0 0 INC, # /2 SNC  0 0 INC, ;

: PATCH CONSTANT , , , ;CODE 2 1 MOV, CPATCH 4 + 2 LDA,
   0 3) 0 LDA, EVACO, 3 2) 0 STA, 1 3) 0 LDA, 2 2) 0 STA,
   2 3) 0 LDA, EVACO, 1 2) 0 STA, 3 3) 0 LDA, 0 2) 0 STA,
   1 2 MOV, NEXT JMP,

  40 10 10 6 PATCH HOME

HOME
;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11511(26367)

```
( HOR. RATE COMMENTS     FCW 1/21/82    )  ;S

  THESE RATES ARE SET UP IN INCREMENTS OF 5 DEG. OF DECLINATION.
AN 'EAST' RATE MOVES THE PATCH FROM LEFT TO RIGHT ON THE
DISPLAY. A 'WEST' RATE MOVES THE PATCH FROM RIGHT TO LEFT ON THE
DISPLAY. THE FRAME FREQUENCY FOR THESE RATES IS 40 HZ.
```

BLOCK: 11512(26370)

```
( BACKGROUND SETTING ROUTINES   FCW  1/8/82   2/8/82   )

24 12 47 10 PATCH CENTER

: 1-PATCH  PCNT! ' GBUF @ CCDINIT  CCD-DONE DROP ;

: AVG
   O. ' GBUF @ DUP PCNT @ MINUS + SWAP
    DO  I @ O D+ LOOP
   PCNT @ MINUS D/MOD DROP ;

: BACKGROUND
    CURSOR STTI
    BEGIN 1-PATCH " AVG= " AVG D. CR
              77777 O DO LOOP CHKBD END ;
;S
```

BLOCK: 11513(26371)

```
( BACKGROUND COMMENTS          FCW  1/21/82 )     ;S

  THE BACKGROUND ROUTINES ARE FOR SETTING THE VIDEO BIAS TO THE
PROPER LEVEL. THE LEVEL SHOULD BE IN THE RANGE OF 100-200
WITHOUT SUBTRACTION; IF SUBTRACTION IS USED, IT SHOULD BE SET
TO APPROXIMATELY 200-400, DEPENDING ON THE AMOUNT OF SUBTRACTION
USED. THE MAIN POINT IS TO GET A UNIFORM BACKGROUND AS SEEN ON
THE DISPLAY. MAKE ABSOLUTELY SURE THAT NO LIGHT ENTERS THE
CAMERA WHILE DOING THE BACKGROUND ADJUSTMENT - OTHERWISE
THE ADJUSTMENT WILL BE WRONG.
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11514(26372)

```
( A-D VALUE DISPLAY ROUTINES      FCW 1/25/82  MOD  4/15/82 )
: ADV-DUMP
          CPATCH 3 + @ COLUMNS CR 10 F !
          1-PATCH ' GBUF @ DUP PCNT @ MINUS + SWAP
          DO I @ O. CR# LOOP ;
: ADV ADV-DUMP ;
: CADV ' GBUF @ PCNT @ OVER OVER + ROT ROT MINUS + SWAP CR
              DO I @ O. CR# LOOP ;
: C CURSOR ADV ;
;S
```

BLOCK: 11515(26373)

```
( A-D VALUE COMMENTS             FCW 1/25/82       )    ;S
ADV-DUMP
        - GET SOME A-D VALUES AT THE CURRENT PATCH LOCATION. PRINT
          OUT THE VALUES WITH AS MANY COLS AS IN THE PATCH
          ( UP TO 10 COLS). THE FIELDS ARE PRINTED OUT SEPERATELY;
          I.E.- THEY ARE NOT INTERLEAVED.
ADV - NAME USED FOR BREVITY
CADV - PRINT OUT THE VALUES OF THE LAST FRAME BEFORE THE RUN OR
          CURSOR MODE WAS TERMINATED.
```

BLOCK: 11516(26374)

```
( PATCH INITIALIZATION ROUTINES   FCW  4/22/82  MOD 4-22-82 )
( SET THE STARTING 'HOME' POSITION OF THE CURSOR )
: POSITION
    HOME STILL CURSOR CPATCH @ ' HOME 3 + !
                      CPATCH 2 + @ ' HOME 1 + ! ;
( # ROWS UNDER STACK, # COLUMNS ON TOP OF STK )
: RXC  ' HOME ! ' HOME 2 + ! ;
;S
```

BLOCK: 11517(26375)

```
( PATCH INITIALIZATION COMMENTS  FCW  4/22/82  MOD 4-22-82 ) ;S

POSITION - POSITION DEFINES WHERE THE 'HOME' POSITION
           OF THE CURSOR IS. TO USE, TYPE 'POSITION' AND RETURN,
           AND MOVE THE CURSOR TO THE DESIRED PLACE. THEN TYPE
           RETURN AND THAT POSITION WILL BE SAVED.

RXC -    RXC IS USED TO CHANGE THE PATCH SIZE. TWO PARAMETERS ARE
         ENTERED: 1) THE # OF ROWS; & 2) THE # OF COLUMNS. THE #
         OF ROWS MUST BE AN EVEN #; THE # OF COLUMNS CAN BE EITHER
         EVEN OR ODD. THE FOLLOWING EXAMPLE WILL SET THE PATCH
         SIZE TO 10 ROWS BY 7 COLUMNS. THE '*' IS A PROMPT.

         *10 7 RXC <RETURN>
```

BLOCK: 11518(26376)

```
( EMPTY BLOCK )
```

BLOCK: 11519(26377)

```
( EMPTY BLOCK )
```

---
*26160 26166 SHOW

BLOCK: 11376(26160)

```
( SIMPLE MINDED TAPE HANDLER.   FCW  12/09/80  MOD 2/23/82 )
( ASSUMES ONLY TAPE UNIT #0 EXISTS                         )

OCTAL

: TAPE ;

( LTB = LENGTH OF TAPE BLOCK )
0 INTEGER LTB 0 , -1001 , -1402 ,

47 CONSTANT CUR    0 CUR !


 161 LOAD 162 LOAD 163 LOAD 164 LOAD 165 LOAD 166 LOAD
;S
;S
```

BLOCK: 11377(26161)

```
 ( USEFUL TAPE UTILITIES                             02/26/81  )
( TRDY GIVES UP CONTROL TO THE MULTITASKER AND DOES NOT       )
(      RETURN UNTIL THE TAPE STATUS IS NOT BUSY               )
SUBROUTINE TRDY HERE WAIT JSR, 1 1 SUB, 22 DIA,
     0 0 MOV, /2 1 1 MOV, *2 +C 0 0 SUB, 22 SNB, 0 0 INC,
     0 1 AND, SNR JMP, RETURN
( WRITE 3 INCH GAP ON TAPE AT CURRENT POS. OF TAPE            )
  1 ,CODE GAP 70 , TRDY JSR, ' GAP 0 LDA, 122 DOA, NEXT JMP,

( REWIND TAPE TO BEGINNING OF TAPE MARKER                     )
  1 ,CODE REWIND 10 , TRDY JSR, ' REWIND 0 LDA, 122 DOA,
                           0 0 SUB, CUR 0 STA, NEXT JMP,

( WRITE EOF AT CURRENT POSITION OF TAPE                       )
1 ,CODE WEOF 60 , TRDY JSR, ' WEOF 0 LDA, 122 DOA, CUR ISZ,
                                             NEXT JMP,  ;S
```

BLOCK: 11378(26162)

```
( MORE TAPE UTILITIES                               03/03/81 )
30 INTEGER XCOM 40 , ( FWDSPC , BCKSPC COMMANDS  )

( FORWARD SPACE # OF RECORDS ON STACK                          )
CODE FWDSPC  TRDY JSR, 0 S) 1 LDA, 1 0 NEG, SNR
        IF, 222 DOC, XCOM 0 LDA, 122 DOA, CUR 3 LDA, 1 3 ADD,
        CUR 3 STA, TRDY JSR, THEN, POP JMP,

( BACK SPACE # OF RECORDS ON STACK                            )
CODE BCKSPC TRDY JSR, 0 S) 1 LDA, 1 0 NEG, SNR IF,
        222 DOC, XCOM 1+ 0 LDA, 122 DOA, CUR 3 LDA, 1 3 SUB,
        CUR 3 STA, TRDY JSR, THEN, POP JMP,

: BKUP 1 BCKSPC 1  BCKSPC 1 FWDSPC ;
: EOF WEOF WEOF BKUP ;
;S
```

BLOCK: 11379(26163)

```
( TAPE CONTROLLER ERROR CHECKING   FCW 11/02/81  MOD 2/23/82 )
0 INTEGER TPERROR 0 , 0 , CUR ,
0 INTEGER EOFLG
053042 INTEGER ?TP       ( TAPE ERROR MASK BITS )
SUBROUTINE ?TAPE
   0 0 SUB,  EOFLG 0 STA,  22 DIA,  0 3 MOV, ><
   3 3 MOV, /2 SNC  IF,  EOFLG 0 STA,  THEN,
   ?TP 3 LDA,  0 3 AND, SNR
   IF,  222 NIO,  TPERROR 0 STA,  CUR 3 LDA,
      TPERROR 1+ DUP 3 STA,  0 0 SUB,  1+ 0 STA,
      10 0 LDA,  0 0 NEG,  ABORT I) JSR,
   THEN,  RETURN
;S
```

BLOCK: 11380(26164)

```
( TAPE READ ROUTINES   FCW  12/9/80     MOD 3/1/82 )
' TRDY INTEGER TP? ' ?TAPE ,
( BUFFER ADDRESS ON STACK. RETURNS WORD COUNT ON STACK    )
CODE TREAD  TP? I) JSR, 0 0 SUB, 22 DOA, 22 DOC, 0 S) 0 LDA,
     122 DOB, TP? I) JSR, TP? 1+ I) JSR, CUR ISZ, 222 DIB,
     0 S) 1 LDA, 1 0 SUB, PUT JMP,
( BUFFER ADDRESS ON STACK. RETURNS EOF FLAG ON STACK WITH  )
( WORD COUNT UNDERNEATH.  )
: TRDEOF TREAD EOFLG @ ;
;S
```

BLOCK: 11381(26165)

```
( TAPE WRITE ROUTINE       FCW 12/09/80     MOD 2/23/82  )
( BUFFER ADDRESS ON STACK. WC UNDER STACK                )
( RETURNS AFTER WRITE INITIATED                          )
1 ,CODE TWRITE 50 ,
     TP? I) JSR,  TP? 1+ I) JSR,
     22 DIA,  4 1 LDA,  1 0 AND, SNR
      IF,  2 0 LDA,  ABORT I) JSR,  THEN,
     CUR ISZ,  ' TWRITE 0 LDA,  22 DOA,  0 S) 0 LDA,
     22 DOB,  1 S) 0 LDA,  122 DOC,  2POP JMP,
;S
```

BLOCK: 11382(26166)

```
( FIND DOUBLE EOF ROUTINE        FCW 2/23/82  MOD  02/23/82  )

: 1FILE  77777 FWDSPC ;
1 ,CODE :?TAPE ' ?TAPE ,  ' :?TAPE I) JSR,  NEXT JMP,
1 ,CODE :TRDY  ' TRDY ,   ' :TRDY I) JSR,  NEXT JMP,

( POSITION TAPE BETWEEN DOUBLE EOF MARKERS  )
: END-OF-TAPE
   BEGIN  1FILE  1 FWDSPC  :?TAPE  EOFLG @  END  BKUP ;
;S
```

BLOCK: 11383(26167)

```
( EMPTY BLOCK )
```

BLOCK: 11384(26170)

```
( BACKUP ROUTINES   FCW  11/16/81  MOD 6-17-82         )
( THESE ROUTINES DO A DISK TO TAPE BACKUP OF A )
( BOOTABLE DISK IMAGE . )

: BFR PREV @ 1000 - ;
: COPYBOOT 3 0 DO BFR I DREAD I BFR 1000 + !
                        -1001 BFR TWRITE LOOP ;

: D-T FLUSH REWIND GAP COPYBOOT SIZE 3
  DO BFR I DREAD BFR @ IF I BFR 1000 + !
              -1001 BFR TWRITE THEN LOOP EOF ;

171 LOAD ( LOAD TAPE-DISK ROUTINES    )
;S
```

---

*26200 26214 SHOW

BLOCK: 11391(26177)

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

BLOCK: 11392(26200)

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

BLOCK: 11393(26201)

```
( VARIABLES AND CONSTANTS   FCW 6/9/81    MOD 5/24/82 )
BASE @ OCTAL   41000 CONSTANT BUF
        DECIMAL 103 CONSTANT LINEC
-2 INTEGER OFFSET
0 CONSTANT STRTBLOK   11 CONSTANT ENDBLOK
51 CONSTANT LPF  ( LINES/FRAME )
OCTAL
0 CONSTANT TOCSM      100 CONSTANT FRMCSM
BASE !
;S
```

T4 SYSTEM PROGRAM AS OF JULY 9, 1982

BLOCK: 11394(26202)

```
( CSM ALU CODES AND INSTRUCTION GENERATION ROUTINES 05/15/81 )
( MOD 5/24/82                              )

( ON FUNCTIONS, A IS CSM SIDE, B IS NOVA SIDE                       )
1 CONSTANT F=A  46 CONSTANT F=0  23 CONSTANT F=A+B
70 CONSTANT F=1  31 CONSTANT F=2A  64 CONSTANT F=B

    0 INTEGER BLK
TOCSM INTEGER DIR

( ALU FUNCTION ON THE STACK. RETURNS COMPLETED INSTRUCTION    )
(            ON STACK                                          )
CODE :CSMINSTR  0 S) 0 LDA, DIR 1 LDA, 1 0 ADD, PUT JMP,


;S
```

BLOCK: 11395(26203)

```
( CSM I/O ROUTINES    FCW  5/12/81   MOD   5/24/82  )

2000 INTEGER LBLK ( LENGTH OF BLOCK )

( DOA - ALU & DIR, DOB - BLOCK #, DOC - ADDRESS       )

SUBROUTINE CSMIO ( INSTR AC0, BUF AC1, RETS NEXT BUFF IN AC0 )
 CSM DOA, 4000 CSM + DOC, BLK 0 LDA, 100 CSM + DOB,
        LBLK 0 LDA, 1 0 ADD, RETURN

( INSTR ON STK, BUFFER UNDER STACK, RETS NXT BUF )
 CODE :CSMIO 0 S) 0 LDA, 1 S) 1 LDA, CSMIO JSR, BINARY JMP,



;S
```

BLOCK: 11396(26204)

```
( SEQUENTIAL BLOCK OUTPUT ROUTINES  FCW 5-22-81 MOD 5/24/82 )

( BLK #, INSTRUCTION, BUFFER      # OF BLOCKS TO TRANSFER    )
BLK INTEGER DATA 0 , 0 ,          0 INTEGER NBLKS
SUBROUTINE NXTBLK
        DATA I) ISZ, DATA 2 + 0 LDA, LBLK 1 LDA, 1 0 ADD,
            DATA 2 + 0 STA, RETURN

( INSERT INSTRUCTION AT DATA+1 AND BUFFER AT DATA+2 BEFORE )
(     CALLING                                               )
CODE CSMOUT
     HERE DATA 1+ 0 LDA, DATA 2 + 1 LDA, CSMIO JSR,
          NXTBLK JSR, NBLKS DSZ, JMP, NEXT JMP,

;S
;S
```

BLOCK: 11397(26205)

```
( LINE TRANSFER ROUTINES   FCW  5-24-82  MOD 5/25/82 )
0 INTEGER FLD
0 INTEGER LLCC 10000 , 20002 , 30147 ,
1 ,CODE OPATCH   ' LLCC ,
   FLD 1 LDA,  1 1 MOV, /2 SZC  1 1 MOV, +C /2  ' OPATCH 3 LDA,
   0 3) 0 LDA,  1 0 ADD,  7 DOA,
   1 3) 0 LDA,  1 0 ADD,  7 DOA,
   2 3) 0 LDA,  1 0 ADD,  7 DOA,
   3 3) 0 LDA,  1 0 ADD,  7 DOA,  NEXT JMP,
1 ,CODE TRNSFR  -146 ,
  ' TRNSFR 0 LDA,  107 DOC,  HERE  7 SZB,  JMP,
  7 DIB,  0 0 INC,  7 DOB,  NEXT JMP,
;S
```

BLOCK: 11398(26206)

```
( FRAME TRANSFER ROUTINES  FCW 5-24-82   MOD  5/25/82 )
CODE 7DOB  0 S) 0 LDA,  7 DOB,  POP JMP,
: RD-FLD
  LPF 0 DO  I LLCC !  I 10000 + LLCC 1+ !
              OPATCH  TRNSFR
        LOOP ;
: RD-FRAME  BUF OFFSET @ + 7DOB
  0 FLD ! RD-FLD   1 FLD ! RD-FLD ;
;S
;S
```

BLOCK: 11399(26207)

```
( SCALE PIXL VALUES   FCW 5-24-82  MOD 5/24/82 )
100 INTEGER AD-OFF   ( A-D OFFSET )
1 ,CODE SC-LN  146 ,
   ' SC-LN 1 LDA,  N 1 STA,  0 S) 3 LDA,  AD-OFF 1 LDA.
   HERE  0 3) 0 LDA,  1 0 SUB,  SZC
          IF,  0 0 SUB,  ELSE,  0 0 MOV, /2  THEN,
          0 3) 0 STA,  3 3 INC,  N DSZ,  JMP,  POP JMP.
: SCALE  LPF 2 *  0
          DO BUF LINEC I * + SC-LN LOOP ;
;S
```

BLOCK: 11400(26210)

```
( MISCELLANEOUS ROUTINES    FCW 5-22-81   MOD 5/24/82 )

: ALLBLOCKS :CSMINSTR 400 0 DO I BLK ! BUF OVER :CSMIO
                        DROP LOOP DROP ;

: OCSM  F=0  ALLBLOCKS ;

;S
```

BLOCK: 11401(26211)

```
( CSM OVERFLOW CHECKER AND CORRECTOR  FCW 5-15-81  MOD 5/24/82 )

: READIN FRMCSM DIR ! BUF F=A :CSMINSTR :CSMIO DROP ;
: WRTOUT TOCSM  DIR ! BUF F=B :CSMINSTR :CSMIO DROP ;

0 INTEGER OVFLO  7777 INTEGER MAXX

2 ,CODE ?EXCEED 2000 , BUF ,  0 0 SUB, OVFLO 0 STA,
 ' ?EXCEED 0 LDA, N 0 STA, MAXX 1 LDA, ' ?EXCEED 1+ 3 LDA,
 HERE 0 3) 0 LDA, 0 1 SUB, # SZC IF, 0 3) 1 STA, OVFLO 1 STA,
 THEN, 3 3 INC, N DSZ, JMP, OVFLO 0 LDA, PUSH JMP,

: OVFCHK ENDBLOK STRTBLOK DO I BLK !
          READIN  ?EXCEED
          IF WRTOUT THEN  LOOP ;
;S
```

BLOCK: 11402(26212)

```
(  SET UP ALTERNATE CHANNELS   FCW 05/14/81 MOD 5/24/82   )

( STOP SUBTRACTOR #1 AND THE INTEGRATOR                         )
1 ,CODE I1STOP F=A , ' I1STOP 0 LDA, CSM 1+ DOA, CSM 2 + DOA,
          4 0 LDA, CSM 1+ DOC, CSM 2 + DOC, NEXT JMP,

( SET UP SUBTRACTOR #2 FOR 202 OPERATION                        )
2 CONSTANT RUN-FOREVER
CODE S2A 0 S) 0 LDA, 2SUB DOA, POP JMP,
CODE S2B 0 S) 0 LDA, 2SUB DOB, POP JMP,
CODE S2C 0 S) 0 LDA, 2SUB DOC, POP JMP,
CODE S2ST 2SUB 100 + NIO, NEXT JMP,

: ST2SUB F=A S2A STRTBLOK ENDBLOK 1+ 400 * + S2B
              RUN-FOREVER S2C S2ST ;
I1STOP  ST2SUB                 ;S
```

BLOCK: 11403(26213)

```
( MAIN RUNTIME ROUTINES  FCW 5-24-82  MOD 5/24/82 )

( CSM ROUTINE SET UP )
: CRSU  TOCSM DIR !  F=A+B :CSMINSTR DATA 1+ !  BUF DATA 2 + ! ;

4 INTEGER SLC
: SUBTRACT  OCSM
   SLC @ 0 DO  CRSU  RD-FRAME  SCALE
               ENDBLOK  STRTBLOK -  NBLKS !
               CSMOUT  OVFCHK
           LOOP ;
;S
```

BLOCK: 11404(26214)

```
( EMPTY BLOCK )
```

BLOCK: 11405(26215)

```
( EMPTY BLOCK )
```

---
*26400 26405 SHOW

BLOCK: 11520(26400)

```
( 1PPS AND PHOTOGATE TIME TAG CHECKS    FCW 1/27/82 )
( NEW TAPE FORMAT    MOD FCW 5/19/82 )
BASE @ OCTAL
: D-28  D- DDUP DPOS NOT IF 2000000000. D+ THEN ;
DECIMAL
: STRP# 16 D/MOD DROP ;        : TRQ BUF TRDEOF SWAP DROP ;
BUF 26 + CONSTANT PTG-OFFSET
: PTG-STEP PTG-OFFSET 3 + DUP @ SWAP 2 + @ * 6 + ;

0. DINTEGER LSTPG

: PDFR 4 0
    DO   PTG-OFFSET I PTG-STEP * + D@ STRP# DDUP LSTPG
         D@ DSWAP LSTPG D! D-28 D. LOOP ;
OCTAL   401 LOAD 402 LOAD 403 LOAD        BASE !
" TIME-CHECKS LOADED "  CR    ;S
```

BLOCK: 11521(26401)

```
( 1PPS TIME TAG DIFFERENCES   FCW 1/27/82   MOD 2/23/82 )
BASE @ DECIMAL

0. DINTEGER LAST-1PPS      0. DINTEGER MCS
: DDFR BUF 2 + D@ LAST-1PPS D@ DOVER LAST-1PPS D!
       D- D. BUF 16 + D@ STRP# MCS D@ DOVER MCS D! D-28 D. ;

: PHOTOGATE-CHECK
         BEGIN CR STTI TRQ IF 1 ELSE PDFR CHKBD THEN END ;

: DMA-CHECK
         BEGIN CR STTI TRQ IF 1 ELSE DDFR CHKBD THEN END ;

: DMA/PTG-CHECK
         BEGIN CR STTI TRQ IF 1 ELSE DDFR PDFR CHKBD THEN END ;
BASE !        ;S
```

BLOCK: 11522(26402)

```
( 1PPS AND PTG TIME-TAG CHECKS   FCW 2/8/82  MOD 2/25/82 )
BASE @ DECIMAL
: DMA-TIME BUF 2 + D@ DDUP HMS D. BUF 16 + D@
              STRP# D. ;

: PTG-MICROSEC  4 0
       DO   PTG-OFFSET I PTG-STEP * + D@ STRP# D. LOOP ;

: MICROSECONDS BEGIN CR STTI TRQ IF 1
              ELSE DMA-TIME  PTG-MICROSEC  CHKBD THEN  END ;
: MS 10 F ! MICROSECONDS ;
: PC PHOTOGATE-CHECK ;
: DC DMA-CHECK ;
: DPC DMA/PTG-CHECK ;
BASE !
;S
```

BLOCK: 11523(26403)

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

BLOCK: 11524(26404)

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

BLOCK: 11525(26405)

```
( EMPTY BLOCK )
```

APPENDIX IV

OPERATIONAL PROGRAM LOCATED IN THE MICROPROCESSOR IN THE CAMERA CONTROL UNIT

```
00003       00CA       CHIP   EQU     202              ;CCD 202

00005                         INCLUDE 'CCDSTPXS'       ; SETUP
00009                         LIST    CND              ;LIST UNASSEMBLED SOURCE
00011       0000   >          ORG     0000H            ;STORAGE STARTING ADDRESS

00013                  ;      SYSTEM DATA VARIBLES

00015 0000 0002        DEST   BLOCK   2                ;DEST ADDR FOR MOVE
00016 0002 0010        DTBL   BLOCK   16               ;CLOCK VOLTAGE TABLE
00017 0012 0001        LCTR   BLOCK   1                ;LINE COUNTER
00018 0013 0002        SRC    BLOCK   2                ;SOURCE ADDR FOR MOVE
00019 0015 0001        INTR   BLOCK   1                ;PROGRAM MODIFIED
00020 0016 0002        VECT   BLOCK   2                ;INTERRUPT JMP VECTOR

00022                  ;      SYSTEM ADDRESS EQUATES

00024       0800       CTR1   EQU     800H             ;LATCH FOR COUNTER 1
00025       0801       CTR2   EQU     801H             ;LATCH FOR COUNTER 2
00026       0802       CAMNM  EQU     802H             ;CAMERA NO. BIT
00027       0802       CLOCK  EQU     802H             ;CLOCK SELECT
00028       0803       INCDC  EQU     803H             ;INC/DEC SWITCH
00029       1000       LEDS   EQU     1000H            ;DISPLAY LEDS
00030       0804       RCLK   EQU     804H             ;CLOCK MASK REGISTER
00031       0806       RSTAT  EQU     806H             ;CLOCK STATUS REGISTER
00032       0807       RUN    EQU     807H             ;RESTART COUNTERS
00033       03FF       STK    EQU     3FFH             ;TOP OF STACK

00035                  ;      SYSTEM MASK EQUATES

00037       0008       CAMBT  EQU     08H              ;CAMERA BIT
00038       0007       CLKBT  EQU     07H              ;CLOCK & PHASE BIT
00039       0010       CNT    EQU     10H              ;FOR DEBOUNCE
00040       0003       HR     EQU     03H              ;MASK FOR CLOCK ENABLE
00041       000B       HRP    EQU     0BH              ;  "
00042       0007       HRV    EQU     07H              ;  "
00043       000F       HRVP   EQU     0FH              ;  "
00044       0030       IDBIT  EQU     30H              ;INC/DEC BIT
00045       0010       INCBT  EQU     10H              ;INC BIT
00046       0040       STOP   EQU     40H              ;STOP CTRS BIT
00047       0040       TBENT  EQU     40H              ;TABLE ENTER BIT
00048       00F0       TBMSK  EQU     0F0H             ;TABLE NO. BIT
```

CCD DRIVER SETUP PROGRAM

```
00F0        VAR    EQU     0F0H             ;VAR TABLE POSITION

                   ;       SYSTEM CLOCK CTR EQUATES

                   ;       NOTE: ON REVISION 1 BOARD COUNTER 1 IS 10 BITS AND COUNTER 2 IS
                   ;               6 BITS. ON REVISION 2 BOARD, COUNTER 1 IS 9 BITS AND
                   ;               COUNTER 2 IS 7 BITS.

FFFF                       IF      CHIP=202

                   ;       CCD 202 ,        REVISION #2 BOARD

001C        VCNT   EQU     14*2             ;# CNTS FOR VERTICAL ON END LINE
0067        HCNT   EQU     103              ;# HORIZONTAL PULSES
007E        VRCNT  EQU     63*2             ;VERTICAL RESET COUNTS
0032        NROWS  EQU     51-1             ;# ROWS/FIELD

                   ELSE
                   SPACE   1
                   ;       CCD 211 ,        REVISION #1 BOARD
                   SPACE   1
            VCNT   EQU     63*4
            HCNT   EQU     201
            VRCNT  EQU     63*4
            NROWS  EQU     124-1
                   SPACE   2
                   ENDIF
```

```
Tektronix      M6800 ASM V3.3  CCDSTP    9/25/81              Page      3
CCD DRIVER SETUP PROGRAM
                F800    >          ORG     0F800H           ;STARTING ADDRESS FOR PROGRAM

                              ;    SETUP & INITALIZE ROUTINE

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

```
00100                          INCLUDE 'CCDCTLXS'        ; HOUSEKEEPING

00104                  ;       MAIN PROGRAM

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

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 803H            ;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 #8              ;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
```

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

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

F887 BDF951  >   DVOLT   JSR    CKADR           ;GET ADDR OF CLK TO DEST
F88A DE00    >           LDX    @DEST           ;ADDR OF CLK IN X
F88C B60803              LDA    A  INCDC        ;READ INC/DC SWITCH
F88F 43                  COM    A
F890 8410                AND    A  #INCBT
F892 2704                BEQ    DV2
F894 6C00                INC    X               ;INC +1
F896 2002                BRA    DV3
F898 6A00        DV2     DEC    X               ;DEC -1
F89A A600        DV3     LDA    A  X            ;UPDATE LEDS
F89C B71000              STA    A  LEDS
F89F BDF8AD  >           JSR    UPDAT           ;UPDAT DACS
F8A2 39                  RTS

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

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

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

F8AD 9612    >   UPDAT   LDA    A  @LCTR        ;WAIT FOR PHOTOGATE
F8AF 26FC                BNE    UPDAT           ;
                 ;
F8B1 9602    >           LDA    A  @DTBL         ;H+   CAM 1
F8B3 B70808              STA    A  808H
F8B6 9603    >           LDA    A  @DTBL+1       ;H-
F8B8 B70809              STA    A  809H
```

```
F8BB 9604    >          LDA     A  @DTBL+2       ;V+
F8BD B7080A             STA     A  80AH
F8C0 9605    >          LDA     A  @DTBL+3       ;V-
F8C2 B7080B             STA     A  80BH
F8C5 9606    >          LDA     A  @DTBL+4       ;P+
F8C7 B7080C             STA     A  80CH
F8CA 9607    >          LDA     A  @DTBL+5       ;P-
F8CC B7080D             STA     A  80DH
F8CF 9608    >          LDA     A  @DTBL+6       ;R+
F8D1 B7080E             STA     A  80EH
F8D4 9609    >          LDA     A  @DTBL+7       ;R-
F8D6 B7080F             STA     A  80FH

                  ;     CAMERA 2 DACS AND FIBER OPTIC LINK

F8D9 960A    >          LDA     A  @DTBL+8      ;H+      CAM 2
F8DB B71808             STA     A  1808H
F8DE 960B    >          LDA     A  @DTBL+9      ;H-
F8E0 B71809             STA     A  1809H
F8E3 960C    >          LDA     A  @DTBL+10     ;V+
F8E5 B7180A             STA     A  180AH
F8E8 960D    >          LDA     A  @DTBL+11     ;V-
F8EA B7180B             STA     A  180BH
F8ED 960E    >          LDA     A  @DTBL+12     ;P+
F8EF B7180C             STA     A  180CH
F8F2 960F    >          LDA     A  @DTBL+13     ;V-
F8F4 B7180D             STA     A  180DH
F8F7 9610    >          LDA     A  @DTBL+14     ;R+
F8F9 B7180E             STA     A  180EH
F8FC 9611    >          LDA     A  @DTBL+15     ;R-
F8FE B7180F             STA     A  180FH
                  ;
F901 39                 RTS

                  ;     UPDAT FRONT PANEL LEDS TO CORRESPOND TO THE
                  ;     SELECTED CAMERA AND CLOCK
                  ;
F902 BDF951  >   TOLED  JSR     CKADR           ;GET ADDR OF CLOCK
F905 DE00    >          LDX     @DEST           ;ADDR TO X REG
F907 A600               LDA     A,X             ;GET BINARY VOLTAGE VALUE
F909 B71000             STA     A  LEDS         ;WRITE TO LEDS
F90C 39                 RTS

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

F90D 5F          VTBL   CLR     B               ;FOR CAMERA 1
F90E B60802             LDA     A  CAMNM        ;READ SELECTED CAMERA
F911 8408               AND     A  #CAMBT
```

```
F913 2602                    BNE     VTB2
F915 C608                    LDA     B  #8          ;FOR CAMERA 2
F917 CB02       >  VTB2      ADD     B  #DTBL       ;COMPUTE ADDR OF PROPER TABLE
F919 D701       >            STA     B  @DEST+1
F91B 4F                      CLR     A
F91C 9700       >            STA     A  @DEST
F91E 39                      RTS

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

F91F 5F            FTBL      CLR     B              ;FOR CAMERA 1
F920 B60802                  LDA     A  CAMNM       ;READ SELECTED CAMERA
F923 8508                    BIT     A  #CAMBT
F925 2602                    BNE     FTB2
F927 C680                    LDA     B  #80H        ;FOR CAMERA 2
F929 84F0          FTB2      AND     A  #TBMSK      ;READ SELECTED TABLE
F92B 88F0                    EOR     A  #VAR        ;RET IF VAR SELECTED
F92D 2601                    BNE     FTB3
F92F 39                      RTS
F930 88F0          FTB3      EOR     A  #VAR        ;FIXED SELECTED TABLE
F932 44                      LSR     A              ;COMPUTE ADDR OF PROPER TABLE
F933 1B                      ABA
F934 C6FE       >            LDA     B  #HI(TABLE)
F936 8B00       >            ADD     A  #LO(TABLE)
F938 C900                    ADC     B  #0
F93A 9714       >            STA     A  @SRC+1
F93C D713       >            STA     B  @SRC
F93E 39                      RTS

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

F93F DE13       >  COPY      LDX     @SRC
F941 A600                    LDA     A  X
F943 08                      INX
F944 DF13       >            STX     @SRC
F946 DE00       >            LDX     @DEST
F948 A700                    STA     A  X
F94A 08                      INX
F94B DF00       >            STX     @DEST
F94D 5A                      DEC     B
F94E 26EF                    BNE     COPY
F950 39                      RTS

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

```
00292 F951 5F           CKADR  CLR    B              ;FOR CAMERA 1
00293 F952 B60802              LDA    A  CAMNM       ;READ IN CAMERA
00294 F955 8408                AND    A  #CAMBT
00295 F957 2602                BNE    CKAD1
00296 F959 C608                LDA    B  #8          ;FOR 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
```

```
                             INCLUDE 'CCDRPTXS'      ; INTERRUPT ROUTINES

                     ;       CLOCK DRIVER INTERRUPT ROUTINES

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

                     ;       UNDERFLOW CTR2, LAST DATA LINE, FIELD 2

F969 860F            INTR1   LDA     A   #HRVP
F96B B70804                  STA     A   RCLK
F96E 861E                    LDA     A   #00011110B    ;LATCH ON 1UF,CLR ON 2UF,INTR ON 1UF
F970 B70806                  STA     A   RSTAT
F973 867E                    LDA     A   #VRCNT
F975 B70801                  STA     A   CTR2
F978 CEF97E    >             LDX         #INTR2
F97B DF16      >             STX         @VECT
F97D 3B                      RTI

                     ;       UNDERFLOW CTR1, LAST DATA LINE, FIELD 2

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

                     ;       INTERRUPT CTR2, PV LINE

F989 8607            INTR3   LDA     A   #HRV
F98B B70804                  STA     A   RCLK
F98E 863E                    LDA     A   #00111110B    ;CLR ON CTR2 UF,INTR CTR2 UF,LTH CTR1 UF
F990 B70806                  STA     A   RSTAT
F993 861C                    LDA     A   #VCNT
```

```
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CCD DRIVER INTERRUPT PROGRAM

F995 B70801                STA     A  CTR2
F998 CEF9A2  >             LDX     #INTR4
F99B DF16    >             STX     @VECT
F99D 8632                  LDA     A  #NROWS
F99F 9712    >             STA     A  @LCTR
F9A1 3B                    RTI

                     ;     UNDERFLOW CTR2 DATA LINE N

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

                     ;     UNDERFLOW CTR2 LINE 51, FIELD 1

F9AD 860B       INTR5      LDA     A  #HRP
F9AF B70804                STA     A  RCLK
F9B2 861E                  LDA     A  #00011110B   ;LOAD ON CTR1 UF,CLR ON 2UF,INTR ON 1UF
F9B4 B70806                STA     A  RSTAT
F9B7 867E                  LDA     A  #VRCNT
F9B9 B70801                STA     A  CTR2
F9BC CEF9C2  >             LDX     #INTR6
F9BF DF16    >             STX     @VECT
F9C1 3B                    RTI

                     ;     UNDERFLOW CTR1, LAST DATA LINE, FIELD 1

F9C2 8620       INTR6      LDA     A #00100000B    ;UPDATE FF CTR1 UF, CLR ON CTR1 UF
F9C4 B70806                STA     A RSTAT
F9C7 CEF9CD  >             LDX     #INTR7
F9CA DF16    >             STX     @VECT
F9CC 3B                    RTI

                     ;     INTERRUPT CTR2, PHOTOGATE LINE

F9CD 8607       INTR7      LDA     A #HRV
F9CF B70804                STA     A RCLK
F9D2 863E                  LDA     A #00111110B    ;CLR CTR2 UF, INTR CTR2 UF, LATCH CTR1 U
F9D4 B70806                STA     A RSTAT
F9D7 861C                  LDA     A #VCNT
F9D9 B70801                STA     A CTR2
F9DC CEF9E6  >             LDX     #INTR8
F9DF DF16    >             STX     @VECT
F9E1 8632                  LDA     A #NROWS
F9E3 9712    >             STA     A @LCTR
F9E5 3B                    RTI

                     ;     UNDERFLOW CTR2, DATA LINE N, FIELD 2

F9E6 7A0012  >  INTR8      DEC     LCTR
```

CCD DRIVER INTERRUPT PROGRAM

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

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

;          CTR2               CTR1

;       63(HRVP)            103(HRVP)
;51 [14(HRV)                103(   )]
;       63(HRP)             103(HRP)
;51 [14(HRV)                103(   )]

;       RASTER FOR CCD 211 CHIP ( REVISION 1 BOARD )

;          CTR2               CTR1

;        63(HRVP)           201(HRVP)
;124 [63(HRV)               201( )    ]
;        63(HRP)            201(HRP)
;124 [63(HRV)               201( )    ]

;H,R = DISABLE CLOCK
;V,P = ENABLE CLOCK
```

```
00437                              INCLUDE 'CCDTBLXS'        ; VOLTAGE TABLES

00441         FE00    >            ORG     0FE00H            ;STARTING ADDRESS FOR CAMERA TABLES

00443         FFFF                 IF      CHIP = 202

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

00454         FE80    >            ORG     TABLE + 80H

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

```
                               ELSE            ;CHIP = 211
                               SPACE   1
                    ;          H+    H-    V+    V-    P+    P-    R+    R-
                    TABLE      BYTE    252,  64,  169,   27,  139,  30,   0,    0
                               BYTE    255,  64,  169,    0,  139,   0,   0,    0
                               SPACE   2
                               ORG     TABLE + 80H
                               SPACE   2
                               BYTE    252,  64,  169,   27,  139,  30,   0,    0
                               BYTE    255,  64,  169,    0,  139,  30,   0,    0
                               SPACE   1
                               ENDIF

      FFF8      >              ORG     0FFF8H              ;STARTING ADDRESS FOR INTERRUPT VECTORS

      FFF8 0015 >              WORD    INTR                ;INTERRUPT REQUEST
      FFFA 0015 >              WORD    INTR                ;SOFTWARE INTERRUPT
      FFFC 0015 >              WORD    INTR                ;NON-MASKABLE INTERRUPT
      FFFE F800 >              WORD    INITL               ;RESTART

                               END
```

Scalars

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

% (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	NEWTBL - F839	SRC ---- 0013	TABLE -- FE00
UPDAT -- F8AD	VECT --- 0016	VTB2 --- F917	VTBL --- F90D

478 Source Lines 478 Assembled Lines 46570 Bytes available

>>> No assembly errors detected <<<

FILM