RESEARCH STUDY TO DEFINE & RECOMMEND SYSTEM IMPROVEMENTS FOR DATA DISPLAY in the OGO OPERATIONS CONTROL CENTER

Contract # : NAS5-10515

June 1967

prepared by

WEBSTER RESEARCH CORPORATION
8115 Fenton Street, Silver Spring
Maryland 20910

for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

REPORT

RESEARCH STUDY TO DEFINE & RECOMMEND SYSTEM IMPROVEMENTS FOR DATA DISPLAY in the OGO OPERATIONS CONTROL CENTER

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Goddard Space Flight Center

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1. INTRODUCTION

As a result of increased OGO satellite operations, there has arisen the need for a more rapid presentation of live telemetry data displayed in a converted form that makes it instantly recognizable in true engineering units. Associated with this 'quick display' need, goes the desired capability to receive a rapid indication of the satellite commanded status, and to provide an immediate indication of any disagreements between actual and displayed status.

1.1. Background. Past system capabilities have been inadequate to provide the improved response time needed in satellite commanding operations. Controlling has been done in response to information received from telemetry and displayed in a non-real time mode on line printers. The alternative to this, has been the receipt of limited strip chart information output in an unconverted form. The need for real-time decision making and support of multiple OGO's has determined the necessity for an expanded and more sophisticated operational environment.

The central processor which has supported all past OGO-OCC activity, is an SDS-920 with an 8 micro-second cycle time. All existing usable software and control center peripheral equipment is designed for use with the SDS-900 computer series.

1.2. Scope & Purpose. The planned new capability is to supply rapid, visual display of spacecraft parameters in easily understood formats and to display spacecraft configurations along with computer verification data.

Contract NAS5-10515 defines effort which will directly aid the OGO Operations Control Center in the planning, design and implementation of an improved system configuration for data display, satellite control, and subsequent operations support.

As a research study, the contract purpose has been to assist OGO-OCC in exploring various ways to meet projected requirements and aid in the definition of hardware/software specifications for providing the increased flexibility of service which is needed.

This phase of the study has been directly connected with the outlining of specifications and requirements for a central processor system and associated peripheral, including a computer driven alpha-numeric Cathode Ray Tube display. Further, an overall schedule has been developed for the implementation of associated computer software.

1.3. Direction of Effort. To complete a computer processing system which will satisfy the immediate increased needs of the OGO Operations Control Center for satellite commanding and data display, the need becomes one of providing several items. These specific project sub-systems are:

a. A computer central processor with sufficient speed, core storage, I/O capability and peripheral equipment, to successfully meet the outlined requirements.

b. An array of Cathode Ray Tube units or other alternative display devices that can be put into a real time hookup for displaying converted engineering values for selected telemetry parameters.

   A special display which will give an immediate indication of the commanded status of an OGO spacecraft and a computer determined evaluation and verification of the receipt and execution of the given commands.

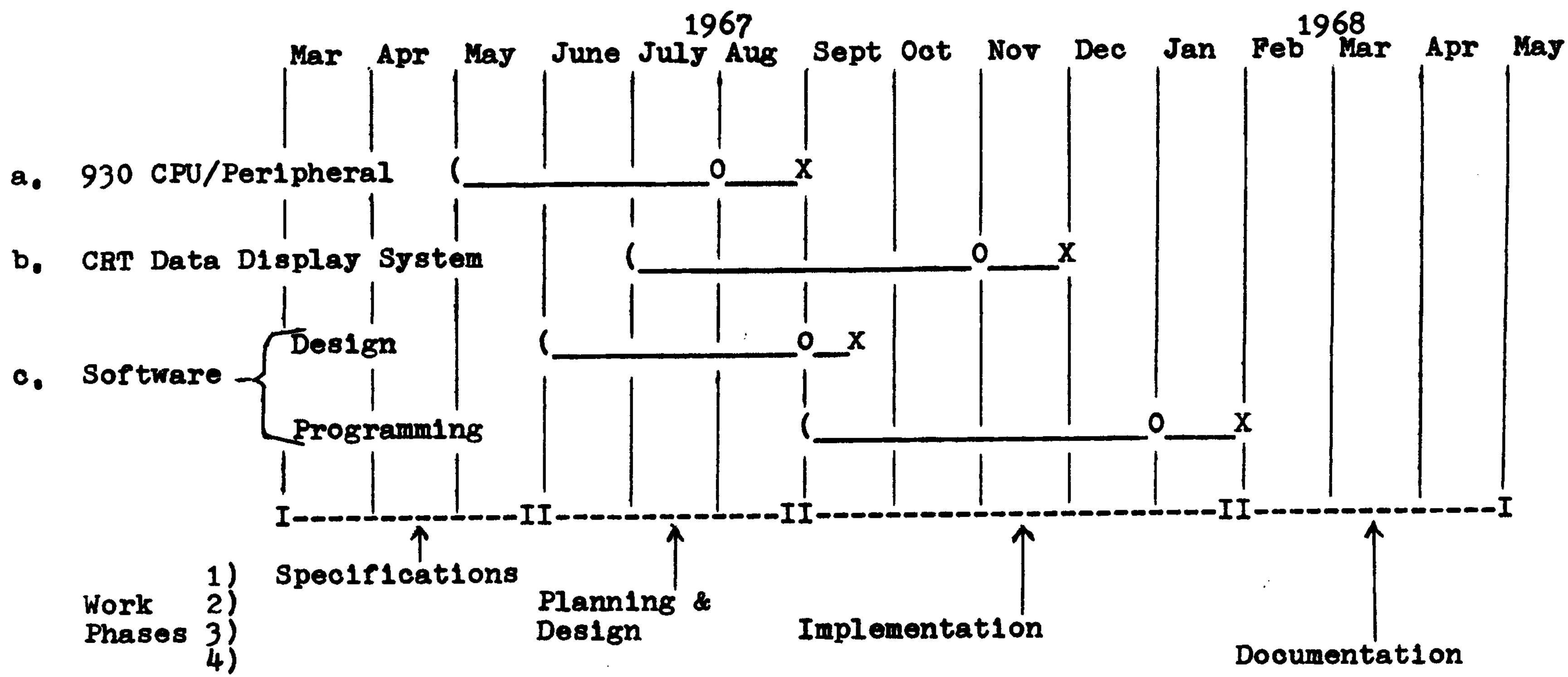
c. The computer programs which will successfully operate the various displays, do the monitoring function of data input and handling, give the necessary diagnostic and maintenance assistance for system checkouts, and provide the off-line aids necessary for the development of system programs.

Under the direction of the NASA technical monitor, contract emphasis has been channeled to fit the OGO system implementation schedule displayed in Figure 1. All effort has been carried out in conjunction with the 'specification' phase and directly applied to the sub-systems listed above.

For a more coordinated effort, some diversion from the original proposed scope of work was requested by the GSFC technical officer. The most significant deviations of emphasis involved requests for a concentration of effort toward the production of specifications and studies for use in the purchasing of necessary hardware. For this reason, contract reporting has taken a form which can be helpful for these needs, rather than belaboring many unacceptable alternative plans of action.

Software studies were oriented toward giving assistance in the development of broad requirements, work load estimates, and

OGO CRT System Implementation Schedule



Legend:
(- Equipment Ordered; activity started
0 - Equipment Delivered; activity completed
X - Equipment operational; activity documented

Figure 1.

scheduling for planning purposes. This was done instead of concentrating upon specific software items such as display device formats and computer program coding.

The net result is that most findings and recommendations have been immediately applied to their respective situations and this final reporting primarily takes on only documentary value.

1.4 Contributors. Responsibility for initial planning has been placed with a committee of NASA personnel from several different divisions at GSFC. All investigation connected with this contract has been undertaken in direct assistance to this group, and the reported material here-in represents effort to which these members have contributed significantly.

Robert Lively	-	Project Operations Branch; GSFC
Carl Tonty	-	Control Equipment Branch; GSFC
Phillip Merwarth	-	Advanced Orbital Programming Branch GSFC
Ray Hartenstein	-	OGO Project Office

Software development falls within the responsibility of Phillip Merwarth and has been implemented through the efforts of a software development committee. Persons from Computing & Software Incorporated, have contributed to these undertakings.

2. DISCUSSION

2.1 Central Processor & Peripheral. All work done in regard to the central processing unit, has been documented to allow the results to be directly usable in connection with procurement actions, the undertaking of special studies, and preparation of an ADP Plan. For convenience, all determinations, planning, and specifications have been separately presented in the form of an attachment. This approach was taken so that easy reference could be made to that portion of this study which might be of particular interest for further extraction of data.

Appended document I gives a complete description of the 'Central Processor & Peripheral Equipment' for use with an OGO CRT system.

2.1.1 Rationale - An initial study was made to arrive at requirements concerning processing speed and mass storage. Determination was made that an effective computer cycle time of 3.6 micro-seconds or faster was needed, while storage needs could be met utilizing 24K of 24 bit memory. The alternative methods of using magnetic tape or disk memory for furnishing mass storage, were examined and discarded from immediate applicability.

The major factor for the selection of the central processor which would be implemented for driving a CRT data display system, was the factor of compatibility. An early determination of the need for hardware compatibility, restricted most study to the Scientific Data Systems line of computer equipment. Of particular initial interest was the possibility of utilizing two SDS computers in a parallel effort for attaining the processing speeds required. Such hybrid configurations were discarded however, because of the special engineering and technical effort which would be necessary.

Another important factor in decision making, was the desire to conform to a schedule which would allow for use of the system in support of OGO-E from the time of launch. Schedules call for the central processing unit with peripheral, to be operational by September 1, 1967. Certain SDS computers appeared to be available within this time frame.

2.1.2 Description - An SDS-930 computer equiped with a real time interrupt system, 24K of core memory, and conventional equipment for off-line processing, became the configuration thought to most satisfactorily comply with with all major requirements.

2.2 CRT Display Hardware. Data presented in connection with the Cathode Ray Tube equipment study, is also in the form of an attachment. Appended document II, 'Commanded Status & Data Display Hardware', defines the CRT system felt to best fulfill hardware needs.

2.2.1 Rationale - The determination of CRT requirements was predicated mostly on equipment availability to meet schedules calling for a CRT system delivery by November 1, 1967. This determined a procurement action for an alpha-numeric input/output device which was off-the-shelf, and would call for a minimum amount of engineering modification or supplementation.

The consequent system becomes one which does not allow vector and video display or random updating of information. Certain advantages should show up however, in cost, availability, field tested reliability, and ease of use. An investigation was carried out to determine whether it was desireous to maintain compatibility with any other systems at Goddard. It became apparent that very little has yet been done in the installation of real time alpha-numeric display units of the CRT variety.

Specifically investigated, was the display system being planned for support of the Orbiting Astronomical Observatory Satellite. The installation for OAO appears to be based on quite different criteria and objectives than those of OGO. The effect is that the OAO system is much more expensive and developmental than what is needed by OGO.

It summarily appears then, that no useful purpose would be served by the maintenance of lateral compatibility with other CRT systems presently planned or in use at Goddard Space Flight Center.

2.2.2. Description - The particular CRT configuration that appeared most appropriate, seemed to be one that provided for the display of alpha-numeric data at primary designated stations of the control center. Such positions would contain limited selector devices for changing the channel which could be displayed at that station.

A second system would contain both Inquiry and Display capability which would allow keyboard control and update of all programs being output.

The lines of communication to and from the central processor should be a full duplex system which will prevent incoming messages from disturbing those being displayed. To allow full duplex operation, two separate data sub-channels have been recommended for use with the CRT controller complex. This duality will allow display messages to be kept on a separate channel from input and editing messages.

2.2.3. Commanded Status - A study was undertaken to determine the feasibility of utilizing the CRT equipment for the off-line storage and subsequent display and update of commanded status information. It was determined that by using three large CRT scopes and delay lines, a more expedient, versatile and less expensive application could be made, compared to the use of special engineered status display boards.

2.3 CRT Display Software. Initial work efforts involving computer software, have been carried out in assistance to equipment procurement action. These tasks have involved studies of programs similar to the ones which shall operate as resident computer processors. Efforts have provided approximations of core and cycle time needs for these several processors, determining basic requirements concerning the selection of equipment.

An estimate of the total work effort which will be required to carry out the software plan, has provided the basis for outlining a software schedule for producing computer programs to meet OGO-E launch milestones. This effort also includes the undertaking of studies and design relating to an expanded system which could later assume a larger proportion of the control center work load.

2.3.1 Software Schedule - A preliminary schedule included as Appendix A, has been broken down into choronological work phases with sub-efforts defined. Also contained, are estimates of man-power requirements together with approximate completion dates.

2.3.2 Current Activity - Present efforts of the software development committee are involved in the accumulation of reference material, system concepts and other usable techniques which might be applicable to the group objectives. Several real-time monitors, controllers and executive type routines are being examined including; a) SEB OGO Monitor b) OGO-OCC Monitor c) SIB OGO Monitor d) TOLINT e) ARTOMP f) SDS Disc Monitor system.

Apart from useful extractions which might be made from these sytems, other specific techniques and routines have been recommended for investigation and incorporation.

a. Utilization of a compression scheme for storing extra pages of display data within limited core memory.

b. Implementation of a macro language which will allow a modular and simplified coding scheme for telemetry processing.

c. Inclusion in the executive program of an orbit determination package which may be initialized by the acceptance of a minimum amount of readily available orbit parameter data and which will maintain time updated data pertaining to space-craft orbit and attitude.

d. Formulation of special displays, including graphs, plots, binary presentations and other potentially helpful output for use in real time decision making.

For purposes of this report, reference is made to the collection of data accumulated by the software committee. Software research effort under contract NAS5-10515 has been carried out in direct coordination with this group, and a complete and meaningful documentation of the effort must await the comprehensive analysis scheduled above.

3. FUTURE CONTRACT ACTIVITY

As an extension of present effort, future work should involve furnishing consultation to aid in arrival of a plan of implementation for CRT software programs. Tasks should be carried out over the up-coming three month period which is the time span designated for the design and planning stage for OGO software. In direct cooperation with a working committee for software development, the work should be applied to the following designated areas of the total effort.:

a. Executive Program. Undertake analysis of existing real time monitoring programs for the purpose of extracting techniques for inclusion within the new control center system.

Complete detailed programming specifications with concern for the handling of PCM-DHE telemetry data, equipment interfacing with the Data Sub-channels of the SDS Data Multiplex System, communication with the CRT display system, and production of a data history tape.

Produce a descriptive presentation of the executive system.

b. Common Sub-routines. Formulate a group of common sub-routines, together with a standardized method of usage, which will allow software sharing by all users and processors.

Produce macro flowcharts and a descriptive preliminary usage report.

c. CRT Display Programs. Provide specific definitions, I/O formats, and operating disciplines for real time CRT system programs. Special coverage should be given to the control routine, including channel partitioning, handling of query/response and forced reply modes of operation. A program for designating channel status and activity, should be detailed.

Outline computer programs for Continuous Limits, Commanded Status, Raw Data, and Engineering Units Display, for the purpose of specifying formats, item callup schemes, coding logic, and updating methods.

4. CONCLUSIONS

Most all of the findings, conclusions, and solutions resulting from this study, are embodied within the attachments relating to hardware configurations. Appropriate recommendation is then, that the systems be implemented as defined. WRC recommends the continuation of the development of an overall CRT System Plan, which in its entirety will represent an extensive effort to design and detail, prior to implementation, all portions of the proposed CRT system. Such a plan, would provide the framework from which coordinated and broader based development could be undertaken.

Specifically, a 'CRT System Plan' calls for the production of documents covering each of several work headings. These informational reports would be in the form of, and as a continuation of attachments I and II which are furnished here-in. Further topics would be covered during the design and planning schedule phase and would be closely associated with software effort. Specific documents which should be furnished include:

- III - CRT System Software Specifications
- IV - Executive Monitoring Program
- V - Telemetry Processing Macro Language
- VI - CRT Computer Programs
- VII - Expanded Control Center System
- VIII - Experimenter & Programmers Manual

WRC feels that February 1, 1968 represents a realistic completion date for achieving an operational system. Such a judgement is based upon the reasonableness of the various scheduled tasks of activitiy. However, timely procurement of equipment and services by governmental personnel is essential.

Major slippage in any portion of the phasing, will most probably result in a CRT system of little or no value to OGO-E.

APPENDIX A

OGO-OCC II PRELIMINARY SOFTWARE SCHEDULE

A preliminary schedule has been broken down into chronoligical work phases with sub-efforts defined. Also contained, are estimates of manpower requirements together with approximate completion dates. A more complete breakdown of Phase III must await the completion of phase II.

Phase I -Specifications (7 committee Weeks)

a. Outline OGO software functions based upon project requirements and control center needs.

   1) Review OGO-OCC current project requirements and documents (OGO-E, F etc.).

   2) Consider anticipated project requirements and/or needs.

   3) Evaluate the OGO-OCC,s present hardware capability with respect to the above requirements.

b. Request concurrence from the OGO project office and incorporate alternative acceptable proposals.

c. Study current systems for extraction of usable techniques.

   1) Examine other real-time telemetry systems which use SDS computers. (SIB, MSCC, SEB)

   2) Evaluate philosophy of real-time monitor systems for useful ideas.

   3) Examine SDS-920 OGO-OCC monitor system for useful ideas.

d. Finalize overall software requirements and define functions to be incorporated into the system.

Phase II -Design & Planning (12 committee weeks)

a. Complete specifications of hardware.

   1) PCM interface

   2) CRT system
      * Special characters
      * Data sub-channel interface
      * Remotes/slaves

3) C&D Console/time information

4) POD console

5) Command encoder

items included for a possible expandes system are,

6) DISC file/extra tape drives

7) Data plotter

b. Analyze ideas from Phase I, Section c.

c. Design new system together with macro flow charts, I/O formats and preliminary operating instructions.

d. Establish a preliminary schedule for Phases III and IV.

e. Form description of new system design.

1) Provide written or oral presentation of gross system to the project office.

2) Provide programming and operations definition for programmers and experimenters.

Phase III-Coding & Integration (47 man-months)

a. Real time executive

b. CRT processor programs

c. Ancillary routines

d. Utility routines

Phase IV -Documentation (3 man-months)

a. Complete documentation of all routines.

Completion dates - Slippage in hardware delivery dates, or delays in essential hardware interfacing will produce equivalent extensions in software completion dates.

Phases	Interpretation	Dates		
Phase I	Specifications	May 1, 1967	-	June 15, 1967
Phase II	Design & Planning	June 15, 1967	-	Sept. 1, 1967
Phase III	Coding & System Integration	Sept. 1, 1967	-	Feb. 1, 1968
Phase IV	Documentation	Feb. 1, 1968	-	May 1, 1968

C E N T R A L   P R O C E S S O R

and Peripheral Equipment

NAS5-10515

ATTACHMENT I

C E N T R A L   P R O C E S S O R

and Peripheral Equipment

Contract # : NAS5-10515

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1. BACKGROUND

Past computer processing for the OGO control center at Goddard Space Flight Center has been accomplished by use of a Scientific Data Systems 920 central processor together with peripheral equipment that has allowed non-real time data display of a conventional fashion. This system supported the launches of OGO I, OGO II, and OGO III and has provided control for these spacecraft over the last three years.

The scheduled launches of more additions to the OGO series has created a demand for an expanded capability concerning the central processor needed to operate the type of equipment which is planned for future spacecraft status and data display. The major drawbacks of the present SDS-920 computer are its processing speed, mass storage, and slow I/O facilities. The 8 micro-second cycle time of the 920 barely allows minimal data transfer functions to be carried out at the higher telemetry data rates.

This written section constitutes a descriptive treatment of the major part of what is planned to be a real-time Cathode Ray Tube display system of use with future functioning OGO spacecraft. Described within is the central processor and peripheral equipment (less actual CRT units and Controller complex) thought best to be suited for the control center needs.

2. REQUIREMENTS

Of primary concern, is the definition of the requirements for the central computing unit and its associated peripheral. The adequacy of this equipment array will determine the eventual timeliness of the system completion, and the effectiveness of the finished product to accomplish the overall primary function of providing rapid real-time data display.

2.1 Compatibility. The foremost requirement for the additional processing equipment, is that it be compatible with present OGO control center hardware. This will also result in compatibility with systems being used throughout most present orbiting observatory control centers at Goddard. The advantages are obvious. A maximum flexibility will exist in equipment inter-change, maintenance, and use of previously developed programs and techniques. Further, familiarity, past experience, and associated program development capability are not lost.

2.2 Processor Speed. Broad requirements dictate need for the ability to update display information up to a rate of once per second for changing telemetry and status data. Total speed requirements are derived from four specific basic functions which are detailed in Appendix A. These are:

a. Monitoring program - 100,000 mc/s

b. CRT Data Display - 96,000 mc/s

c. Commanded Status - 60,000 mc/s

d. CRT I/O - 33,000 mc/s

Note: mc/s -- machine cycles per second

These total 289,000 machine cycles per second, defining a critical cycle speed of 3.4 micro-seconds per machine cycle. This necessitates use of a central processor with a cycle time less than that calculated above. The alternative to this could only be the use of two or more processors operating in parallel to give the effective processing speed mentioned.

2.3 Mass Storage. Storage requirements for a control center system to provide real time display as outlined, should consist of those needs for the operation of the monitoring function of the software system, together with the simultaneous operation of the telemetry display system and a status display program. Also of significance, is the need for a storage area for common subroutines and constants together with buffer and storage areas connected with various input/output functions.

Of the total storage requirements of the system, a distinction may be made between that storage which should be immediately accessible by the central processor and that which could be relegated to an external storage device.

As calculated in Appendix B, minimal storage needs accomplishing only those functions which have presently been defined, require 24K of mass storage, of which nearly 18K should consist of immediately accessible core memory.

Any future expansion of the system to include processing of experiment and processor programs, together with maintenance and diagnostic programs, will require up to a million characters of external device storage. (This does not, however, constitute an immediate requirement).

2.4 Peripheral Equipment. The following items describe minimum peripheral needs for utilizing the central computer in software development.

a. Typewriter	-	One	(1)
b. Line Printer	-	One	(1)
c. Magnetic Tape Units with one controller	-	Three	(3)
d. Card Reader	-	One	(1)
e. Paper Tape Punch/ Reader/Spooler	-	One	(1)

The typewriter is used in the transfer of control messages for system control. For program alterations and debugging, three magnetic tape units with a controller are necessary to allow the required speed and flexibility needed for the development of sizable computer programs. One magnetic tape unit is needed to hold a multitude of 'debugging aid' programs, while the others act as I/O media for programs.

A high speed card reader and printer will allow symbolic card deck inputs, assemblies and listing. The storage of binary programs on paper tape necessitates the need for a fairly fast paper tape reader/punch/spooler and mounting rack.

2.5 I/O Interfacing; Interrupts. The real-time processing configuration requires a real-time clock and a multiple interrupt system. A data multiplexing system is required, having separate sub-channels to handle telemetry and CRT sub-systems data transfer. An optional addition to the equipment is 'External Interlace' which would allow faster data transfer through the data sub-channels. This addition is not necessary at this time, but might eventually prove desirable.

Also desirable but not essential is a power fail-safe system. Operating off an interrupt, it would provide for the storage and eventual restoration of volatile information during and subsequent to a power supply lapse or failure.

2.6 Other. The PCM Data Handling Equipment necessary for telemetry decoding and presentation to the computer interfacing equipment will be borrowed on a split signal sharing basis from the system now present in the OGO-920 Control Center.

3. SPECIFICATIONS

To satisfy the foremost requirements of system compatibility, it seems necessary that the central processor and all peripheral equipment belong to or be compatible with the Scientific Data Systems line of digital data equipment.

3.1 Central Processor. For compatibility, it further would seem necessary to require that the SDS processor belong to the 900 series. There exist computer models in the new SDS 'SIGMA' series which satisfy all requirements, and are cost attractive compared to the SDS 900 series. However, it is felt that the vast differences in the order codes and associated software would prove detrimental to a timely completion of the project. This argument also applies to the SDS 9300 central processor.

3.1.1 Possible configuration - Implementation of the outlined system might be possible by the utilization of two computers operating in parallel with an incorporated means for rapid transfer of data from one to the other. Such a machine couple might consist of an SDS-920 tied through a memory bank to an SDS-92, -910, -925 or another SDS 920. Monitoring and data gathering would be assigned to one machine which would do preliminary editing, formatting, and calculation. The data would then be passed to the other machine for output to displays, and final calculations. Such a system would cause a significant increase in software development and could lead to unforeseen problems.

3.1.2 Recommendation - The only SDS-900 series, non-time sharing computer which appears to have the core capacity and processing speed capable of performing all designated computer programs alone, is the SDS-930, and it seems a logical choice from the criteria of compatibility, cost and speed.

* Central Processor ----- SDS 930

3.2 Mass Storage. To fulfill the total storage needs set down under 'requirements' would call for a minimum of 16K of computer core storage and an additional 8K of rapid access mass storage. Possible storage devices for the extra need are:

3.2.1. Magnetic Tape System - While offering a possibility, a magnetic tape unit for use as an external storage device would badly compromise the real time effectiveness of the planned system. Not only is it slow and prevents random access to data, but the reliability is very low for sustained usage on a real-time basis.

3.2.2. SDS RAD (Disc) File- A rapid access disc or drum would make an excellent temporary storage device to be used in conjunction with the Display Software system. Ultimately, a system which might be capable of an expanded portion of control center requirements, should include an item of mass storage such as a small disc or drum. Such a device is, however, cost restrictive and also has the added disadvantage of requiring several thousand cells of computer core storage for a monitoring software control system.

3.2.3. Core Memory Extension- Memory core storage for an SDS-930, is available in units of 4K up to a maximum of 32K. For system needs, a micro-access to all data would add to efficiency, and would enhance system reliability.

The most economical way to supply presently projected mass storage needs is to simply expand main core memory to 24K. Subsequent specifications are:

a. 16K Core Memory	----	SDS	92160
b. 8K Core Memory	----	SDS	92080
Other associated items include,			
c. Memory Interlace Control	----	SDS	91210
d. Multiple Access to Memory	----	SDS	92990

3.3 <u>Peripheral Equipment</u>. The following list representa a comprehensive itemization of acceptable units. The order of listing for alternative items does <u>not</u> constitute a priority of desirability:

a. Typewriter -			
Keyboard/Printer (teletype) w punch	----	SDS	9334
or Keyboard/Printer (teletype)	----	SDS	9237
or Keyboard/Printer (IBM)	----	SDS	9137-C
b. Paper Tape Devices -			
Paper Tape Reader	----	SDS	9330
+ Paper Tape Punch	----	SDS	9132
+ Paper Tape Spooler	----	SDS	9135
+ Paper Tape Cart	----	SDS	9319
or P.T. Reader/Punch/Cart & Spooler	----	SDS	92340
c. Magnetic Tape Units & Controller-*			
Tape Transport	----	SDS	92462
+ Tape Controller	----	SDS	92482

*Note: Standard SDS tape transport units consist of either Potter or Ampex name brand. It is essential that the two brands not be mixed for a particular installation.

or Tape Transport	----	SDS	9346
+ Tape Controller	----	SDS	9348
or Tape Transport	----	SDS	9546
+ Tape Controller	----	SDS	9548
or Tape Transport	----	SDS	95463
+ Tape Controller	----	SDS	95483

d. Line Printer -

Printer, buffered 800LPM	----	SDS	9379
or Printer, buffered 1000 LPM	----	SDS	9171

3.4 I/O Interfacing; Interrupts. For the input of telemetry from the PCM DHE and the transfer of data to and from the CRT display controller, the most advantageous mode is through a Data Multiplex system with three sub-channels.

a. Data Multiplex Channel	----	SDS	91602
b. Data Subchannel II	----	SDS	91712

An interrupt system shall be operating, and the telemetry sub-channel shall have an interrupt priority over that of the CRT data system.

c. Arming for Interrupt Levels	----	SDS	92280
d. 16 Levels of Interrupt	----	SDS	93290
e. Interrupt Control System	----	SDS	93280
f. Real-time Clock	----	SDS	91880

4. ACQUISITION SCHEDULE

Existing schedules call for all computer programming to be completed, debugged and operational by January 1, 1968. Further, all hardware should be in place and tested before October, 1967. To make the main frame and peripheral available for equipment checkout and to allow at least five months of software development, it should be delivered prior to August 1, 1967.

5. PROPOSED SOURCES

The obvious source for the above items is:

Scientific Data Systems
1649 Seventeenth Street
Santa Monica, California 90404

It is doubtful, however, that a total system procurement could be made in the time frame outlined. A more timely solution may involve the acquisition of the main frame and as much of the peripheral as possible, through a Government inter-agency pool, or by some form of departmental equipment loan. For the purchase of any additional items enumerated above, SDS is the only known source.

6. RECOMMENDED PROCUREMENT ITEMS

Description		Model Number
-General Purpose Computer with Time-Multiplexed Communication Channel for six-bit I/O	---	SDS 930
-16,384 Words of Core Memory	---	SDS 92160
- 8,192 Words of Core Memory	---	SDS 92080
-Memory Interlace Control Unit	---	SDS 91210
-Multiple Access to Memory (MAM)	---	SDS 92990
-Keyboard/Printer (teletype) and Coupler	---	SDS 9237
-Photoelectric Paper-Tape Reader, 300 Character/Second: Paper-Tape Punch, 60 Char./Sec.: & Spooler, Mounted	---	SDS 92340
-Card Reader and Coupler; 400 Card/Min.	---	SDS 9152
-Control for 1-8 Tape Transports; 75 ips; 556 and 200 Char./Inch	---	SDS 9348
(3)Tape Transport: 75 ips; 556 and 200 Char./ Inch	---	SDS 9346
-Line Printer; Buffered, 600-800 line/minute, 132 Columns	---	SDS 9379
-Data Multiplex Channel	---	SDS 91602
(3)Data Subchannel II	---	SDS 91712
-Real Time Clock	---	SDS 91880
-Interrupt Control System; with Interrupt Chassis	---	SDS 93280

-Arming for 16 levels of Interrupt --- SDS 92280

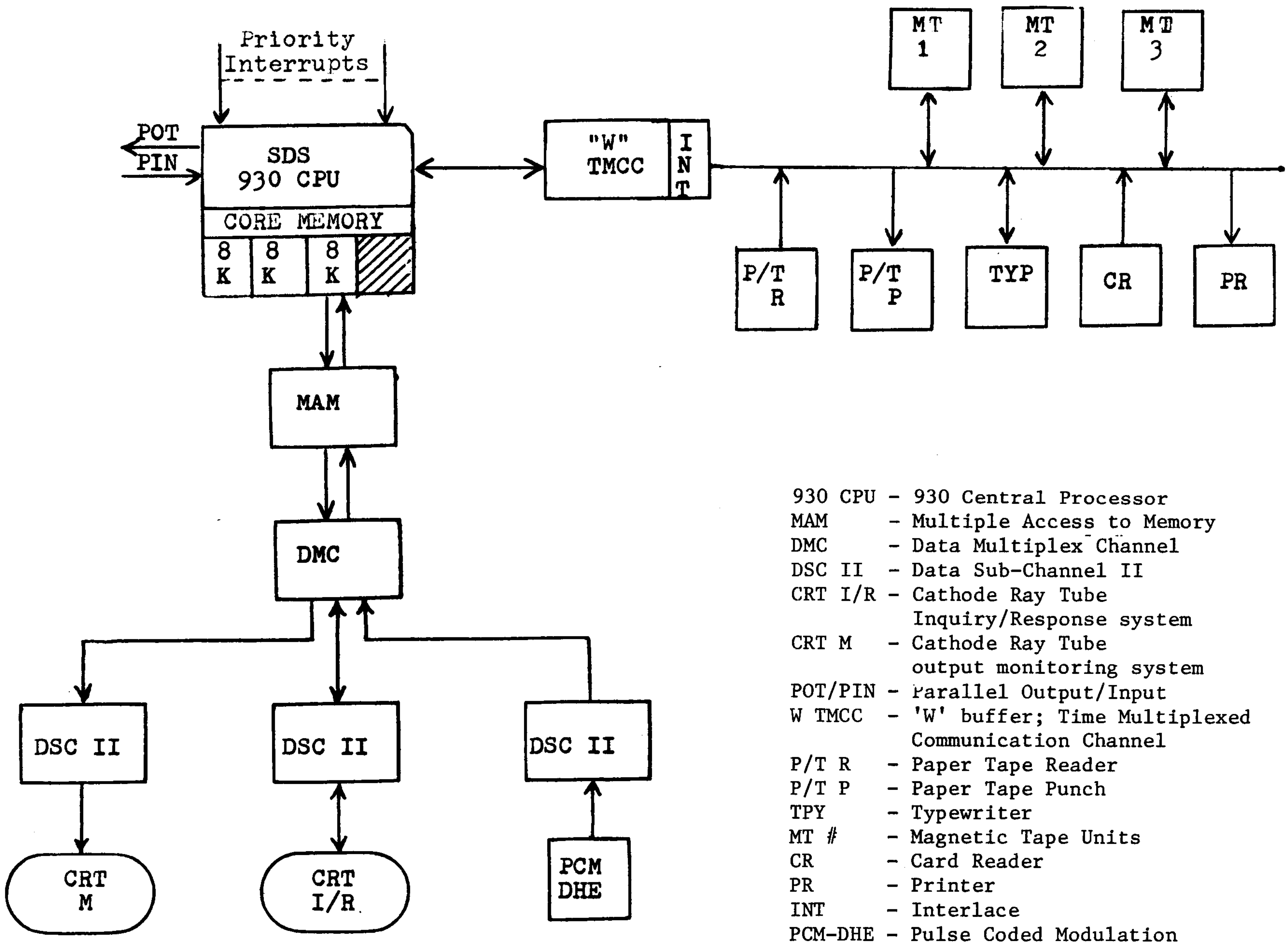
(8)Priority Interrupt; two levels --- SDS 93290

Figure 1 depicts a block diagram of the planned Processor configuration.

7. SUPPLY SCHEDULE PRICE LIST

The following prices cover items of proposed procurement plus optional and alternately acceptable equipment. Maintenance is available only on purchased equipment.

	Item	Purchases	rental/M	maint/M
930	General Purpose Computer	64,000	1,605	375
91800	External Interlace -----	5,000	125	25
91712	Data Subchannel II -----	3,600	100	20
91880	Real Time Clock --------	1,500	40	27
92160	16K core Memory --------	72,000	1,800	250
92080	8K core Memory ---------	42,000	1,050	200
91210	Memory Interlace Control	4,000	100	20
91500	Memory Interface connect	5,000	125	25
92990	Multiple Access to Mem.	2,500	65	12
9237	Typewriter -------------	6,000	180	30
9334	Typewriter w P.T. punch	7,500	225	40
9137-C	Typewriter -----------	7,850	235	65
9152	Card Reader ------------	15,000	500	75
9153	Card Reader ------------	18,500	550	100
9330	Paper-Tape Reader ------	3,500	115	40
9132	Paper-Tape Punch -------	6,000	180	60
9232	Paper-Tape Punch -------	6,000	180	60
9135	Paper-Tape Spooler -----	1,500	45	7
9319	Paper-Tape Cart --------	1,000	30	-
92340	P.T.Reader/Punch/Spooler & Cart -----------------	10,000	305	90
9346	Tape Transport ---------	27,000	730	150
9348	Tape Controller --------	12,000	360	100
9546	Tape Transport ---------	23,000	600	135
9548	Tape Controller --------	9,000	295	80
95462	Tape Transport ---------	27,000	625	150
95482	Tape Controller --------	12,000	300	100
95463	Tape Transport ---------	28,000	700	175
95483	Tape Controller --------	15,000	375	125
9379	Line Printer -----------	36,000	900	250
9171	Line Printer -----------	45,000	1,125	300
91602	Data Multiplex Channel -	10,500	260	50
92280	Arming 16 levels of Int.	2,800	70	15
93280	Interrupt Control ------	800	20	5
93290	Priority Interrupt: Two Levels -----------	500	13	3



930 CPU	-	930 Central Processor
MAM	-	Multiple Access to Memory
DMC	-	Data Multiplex Channel
DSC II	-	Data Sub-Channel II
CRT I/R	-	Cathode Ray Tube Inquiry/Response system
CRT M	-	Cathode Ray Tube output monitoring system
POT/PIN	-	Parallel Output/Input
W TMCC	-	'W' buffer; Time Multiplexed Communication Channel
P/T R	-	Paper Tape Reader
P/T P	-	Paper Tape Punch
TPY	-	Typewriter
MT #	-	Magnetic Tape Units
CR	-	Card Reader
PR	-	Printer
INT	-	Interlace
PCM-DHE	-	Pulse Coded Modulation Data Handling Equipment

Proposed SDS 930 Processor
& Peripheral Configuration

Figure 1.

8 TOTAL PROCUREMENT COST

		Purchase	rental/M	maint/M
a.	Central Processor -			
930	General Purpose Computer	64,000	1,605	375
b.	Mass Storage -			
92160	16K Core Storage --------	72,000	1,800	250
92080	8K Core Storage --------	42,000	1,050	200
91210	Memory Interlace Control-	4,000	100	20
92990	Multiple Access to Mem. -	2,500	65	12
c.	Peripheral -			
9346	Tape Transport ----------(3)	81,000	2,190	450
9348	Tape Controller ---------	12,000	360	100
9237	Typewriter (teletype) ---	6,000	180	30
92340	P.T. Reader/Punch/Spooler " & Cart ----------------	10,000	305	90
9152	Card Reader -------------	15,000	500	75
9379	Line Printer ------------	36,000	900	250
d.	I/O Interfacing; Interrrupts -			
91602	Data Multiplex Channel --	10,500	260	50
91712	Data Subchannel II ------(3)	10,800	300	60
91880	Real Time Clock ---------	1,500	40	27
92280	Arming 16 Levels of Int.-	2,800	70	15
93280	Interrupt Control -------	800	20	5
93290	Priority Interrupt: Two Levels---------------(8)	4,000	104	24
	TOTAL	374,900	9,849	2,033

APPENDIX 'A'

PROCESSOR SPEED REQUIREMENTS

Processor speed requirements of the proposed system, result from the aggragate needs of several processing functions operating concurrently within the central computer.

1. Monitor. The monitoring program, acts on an interrupt basis to bring in real time telemetry data, and respond to programming interrupts while doing basic formatting and data editing. Study of the present OGO monitoring program, has indicated a need of nearly 100,000 machine cycles for every second of time operating. This calculation represents the worst case situation of a 64 kilobit data rate.

2. CRT Data Display. The programs to operate the data display sets will have to be able to handle up to eight full unique screens of data with a maximum of twelve lines per screen. Imperical analysis of similar processing programs, has indicated that roughly 500 machine instructions are executed for the processing of any single telemetry point. In the extreme case of eight full screens each containing 12 telemetry points for processing, the approximate timing need is for (estimating 2 machine cycles per machine instruction),

   8 x 12 x 2 x 5000 = 96,000 machine cycles

3. Commanded Status. The commanded status sub-system shall be capable of executing the necessary logic for making diagnostic decisions on various telemetry points on either an 'as called' basis, or an automatic update basis. This program will service about 60 unique telemetry points, with the number of machine cycles for each point, roughly equal to the needs for the CRT data display computations.

   60 x 1,000 = 60,000 machine cycles

4. CRT I/O. Using an estimated number of display characters of 1,000 per CRT screen and assuming a system which will necessitate the output of the full array of characters per update, we get a total of 8,000 outputs for data display and 3,000 characters of output for three screens displaying commanded status. Approximating a need for three machine cycles per character output, gives a total time requirement of:

   (8,000 + 3,000) x 3 = 33,000 machine cycles

In summary, the cycle totals become:

100,000	
96,000	
60,000	
33,000	
289,000	machine cycles

To update all arrays on a once per second basis, would thus require a processor with a cycle speed of 1,000,000 divided by 289,000: or approximately,

3.4 micro-seconds per cycle

APPENDIX 'B'

MASS STORAGE REQUIREMENTS

The need arises for the simultaneous residence in core of several computer programs. The cumulative core requirements of these separate parts constitutes the total mass storage requirements for implementation of the planned CRT display system.

1. Monitor. The present OGO-920 monitor program occupies 11,000 word cells of SDS-920 core memory. Basically, the envisioned core resident monitoring program, must perform nearly all the functions contained in the present monitor plus some which will be unique to the real time display system. By careful programming lay-out, to reduce duplication of sub-routines and constants, and cutting the capability of the monitor to the minimum requirements of a display system, core needs might be cut to 6500 locations. To meet any eventualities for expanding the system, however, 8000 cells of resident core, should be reserved for this program.

2. Commanded Status. A program to operate a special display board for commanded status and verification would correspond in form, to the present commanded status & verification printout processor. This program consists of two independent parts, each of approximately 4000 cells. From an elimination of the duplication within the two parts, a combined program should be contained in about 5000 storage locations. By making use of sub-routines and constants belonging to CRT display routines, this storage requirement could be reduced to 4000 twenty-four bit words.

3. CRT Display. A statistical average over present processor printout programs reveals that, by a macro sub-routine approach to coding, the unique information and linkage needed to completely describe any one telemetry point may be reduced to 30 cell locations. Present project requirements call for access and display of any of 384 various telemetry points. Because of super-commutation of channels and duplication of logic for some points, it would seem that unique logic for 300 telemetry points would be sufficient.

4. CRT Images. The most effective approach to the display of CRT images, assuming that the eventual CRT system will not allow random updating of screen information, is the continual reserve in core of all characters constituting an image. By packing four characters per word, and assuming a CRT system which has a display capability of 1000 characters, it will require 250 storage cells to hold a single unique image display.

Capabilities should provide for up to eight image displays updated on a real time basis. Also highly desirable but not necessary, would be the capability to hold other images in core which could be called into active display upon request.

5. Sub-routines & Constants. Essentially, the above listed programs are capable of being reduced in size as indicated because of the common use of sub-routines and constants. A minimum of 2000 cells of resident core should be reserved for this purpose.

Following, is an itemization of total storage requirements. A distinction is made between that storage which should be immediately accessible in resident core, and that which could be called in from an external storage device.

	Resident	External
Monitor ----------------------	8,000	
Commanded Status -------------	4,000	
CRT Display ------------------	3,000	6,000
CRT Images -------------------	2,000	2,000
Sub-routines & Constants -----	2,000	
	19,000	8,000

It should be noted that by relating only to those requirements which have been presently outlined, 2000 cells of CRT image storage could be eliminated, plus 1500 cells from the Monitor, bringing the necessary storage to less than 24,000 words.

It seems at this time that a prior constriction of available core memory, to less than 24K, would result in a subsequent degradation of system capability.

C A T H O D E   R A Y   T U B E

spacecraft status & data display

S Y S T E M

NAS5-10515

ATTACHMENT II

C A T H O D E R A Y T U B E
Spacecraft Status & Data Display
S Y S T E M

Contract # : NAS5-10515

June 1967

by

WEBSTER RESEARCH CORPORATION
8115 Fenton Street, Silver Spring
Maryland 20910

for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

TABLE OF CONTENTS

1. BACKGROUND

Present display capabilities of the Ogo Operations Control Center allow information to be called up and output on a line printer on a delayed basis, the alternative being the viewing of strip charts for displaying raw telemetry in unconverted form. Consequently, there is a loss of current information as to satellite conditions, and a resulting lack of timely responses in commanding operations. The problem becomes more acute for POGO satellites where the 'pass time' is very short. Greater difficulties are encountered during periods when multiple (three or more) OGO's are being operated.

2. REQUIREMENTS

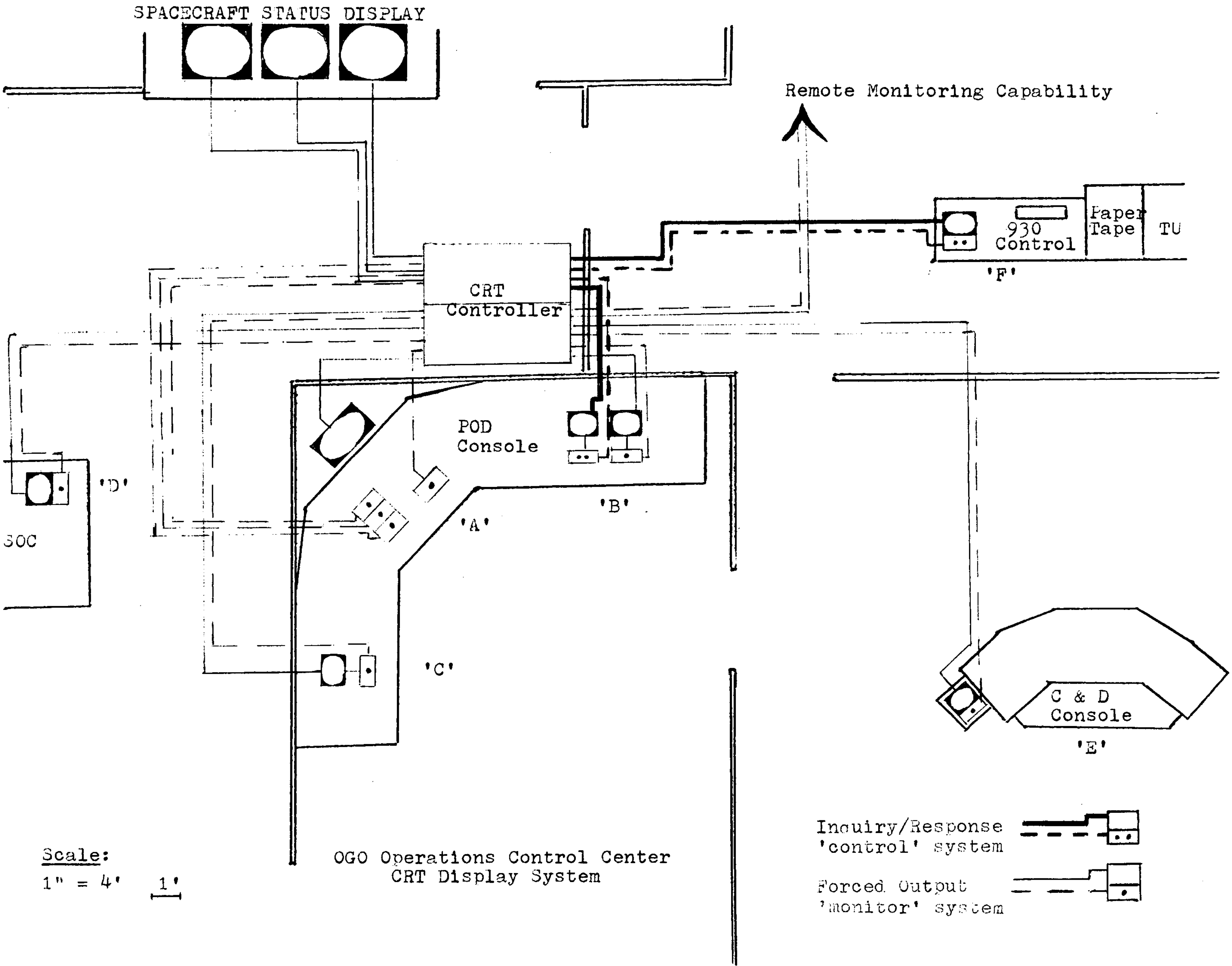
Project office requirements have defined the need for multiple real-time programs operating within a central processor where outputs are selectively viewable at various stations within the OGO control center.

The installation of a system of Cathode Ray Tubes directly coupled with an SDS-930 computer through the necessary controller units and high speed interface devices, constitutes a functional approach to providing displays and read-outs which will allow rapid access to satellite data and status. Various computer programs may be operating within the SDS-930 computer, any of which will be selectable for providing immediate data to any monitoring station.

The display equipment array will present dynamically computer updated information which can be selectively viewed at any of major control center positions (figure-1). Positions A & B, located at the POD Console, are those of the Project Operations Director and the Assistant Operations Director, respectively. Position C is that of the sub-system coordinator for the work area at position D. E specifies the station of the Data Operations Controller at the C&D Console, and F is the Computer Operator Control Station.

3. SPECIFICATIONS

A sufficient number of 'monitor' displays will be available to allow computer revised data display at any of the designated principal positions (A, B, C, D & E). All stations should allow independent display presentations with the further flexibility of selecting through keyboard or channel selectors, any of the several images which are being held in the buffer storage of the system. This monitoring capability at the various control center positions should be accomplished in an off-line manner without access to the central computer. Located within the proximity of the central processor will be the controller and interface logic for passing information between the computer and the several display units.



OGO Operations Control Center
CRT Display System

Figure 1.

Up to three other monitoring stations located at remote sites up to one mile in distance from the central processor may be specified, and the controller systems should be expandable to allow for this added capability.

In addition to the selective monitoring system outlined, a second associated 'control' network will act as a communication media between positions B and F and the central processor. Inquiry-Response CRT units will be located at these positions, which will allow the keyboard formulation of display directives for transmission to the central processor. These directives will determine the programs and images selectable on the 'monitor' system.

Further capability shall be the display and storage of the commanded status of each functioning OGO Space-craft. The proposed means of accomplishing this is by maintaining the status information within the buffer storage area associated with the CRT connected controller. The spacecraft status information would then be revised either by computer when directed through a 'control' station, or manually through one of these stations by the direct entry of keyboard data. Figure-2 depicts a block diagram of the CRT display system.

1.2 CRT Display Units. Two standard sized monitor scopes and their associated entry devices for channel selection shall be located at positions B and C at the POD console, while two other units of similar size will be at positions D and E. A larger unit at position A, will serve the general Project Director work area, with an entry device for this unit located at the POD console.

The CRTs of the 'control' system will consist of units at positions B and F, of the same general dimensions as those designated as 'monitor' scopes. Both units will consist of a standard size display scope and an alphanumeric keyboard. Three other units will be connected to the 'control' system for the expressed purpose of displaying Spacecraft Status. These units should be of sufficient screeen and character size to be readable up to a distance of 25 feet. Associated selector devices should be provided for mounting at the POD console, which will allow for the display of the spacecraft status of immediate interest. This information is to be maintained within the delay line or core buffer storage of the controller. Provision will be made to allow for both computer revision of the status displays and off-line manual revision through the keyboard at positions B and F.

The outlined CRT units should have the following characteristics:

a. Present a viewing area of 30-100 sq. in. (Standard size).

b. Present a viewing area of at least 300 sq. in. (large size).

c. Display light characters written on a dark field.

CRT Status & Data Display System
Block Diagram

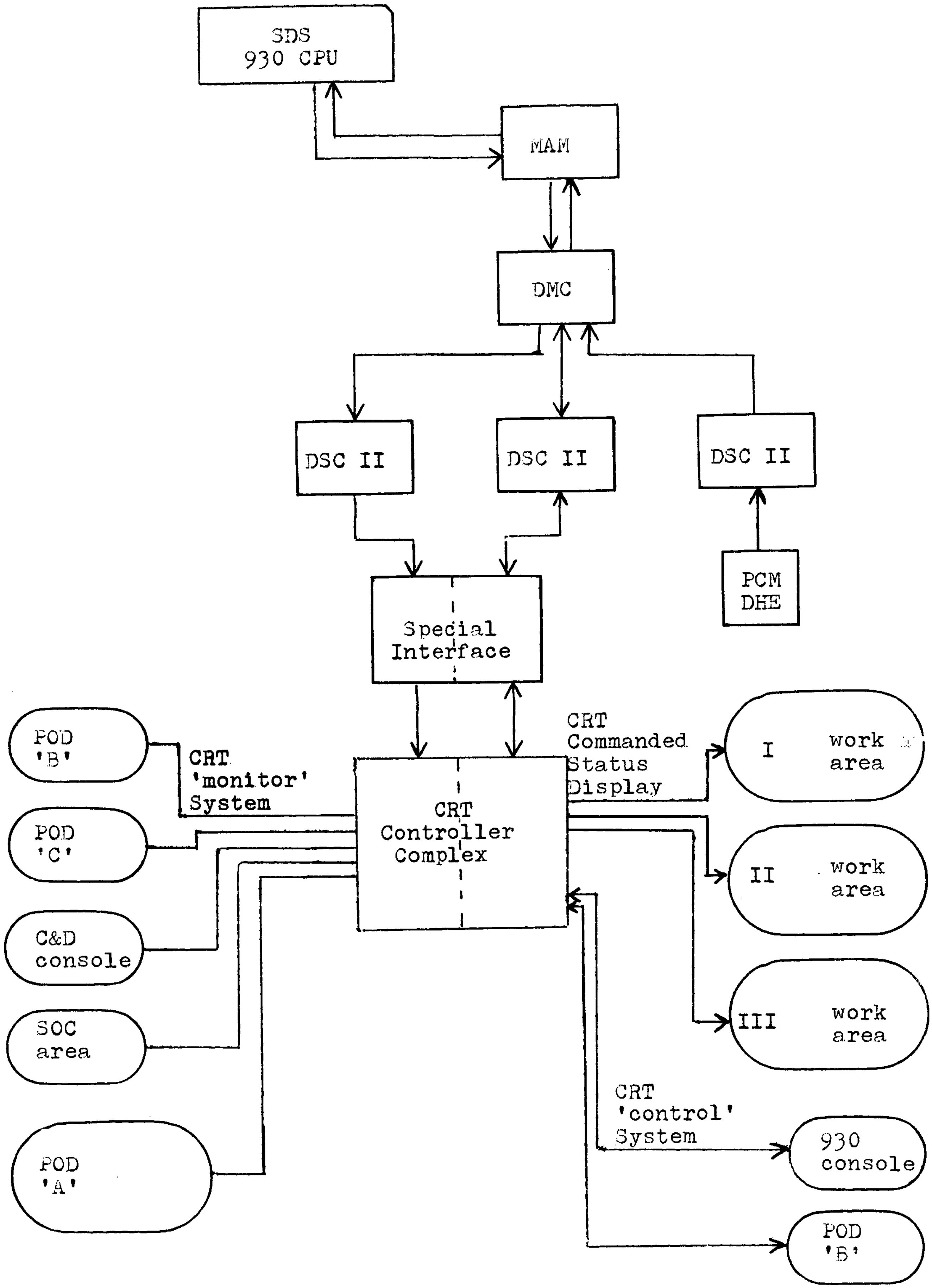


Figure ?.

d. Be free from observable jitter and drift, and have a refresh rate (30-60 cps.) sufficient to eliminate flicker.

e. Provide a character font similar to Folio Medium Extended, with a nominal height to width aspect ratio of 4:3.

f. Provide a character symbol generator to display and maintain characters of such size and definition as to be legible at distances of 10 feet for standard sized displays, and 25 feet for large sized displays.

g. Allow the attachment of slave type display units to any of the several main units for a duplicate data presentation.

h. Allow minimum acceptable input capability at each station of a selector device which will allow independent and non-interfering selection and viewing of at least seven various channels of computer updated information.

In addition to all of the above described specifications for the CRT units, the 'control' units shall have the following:

i. Allow off-line message composition and modification capability.

j. Contain full alpa-numeric keyboards with an array of special function keys and special characters, the total number of keys to be representable with a six bit coding.

k. Have a message editing capability, including, at least, a character scanning function, home return function, line feed and character step.

3.2 CRT Controller. The controller complex will consist of one or more control units capable of providing the timing, logic, storage and necessary buffering to adapt the characterisitics of the display units to a standard form for data transferral to and from a central processor. This complex will provide the housing for all special editing, conversion and storage modules not contained within the individual display units.

A separate special interface unit is described which will match the standard data transfer characteristics of the Controller system with that of the Data Subchannel connected to the Data Multiplex System of an SDS-930 central processor.

The controller complex shall provide the following characteristics:

a. Allow asyncronous data transfer rates of at least 20,000 characters per second.

b. Effectively furnish full duplex operation by allowing simultaneous transmission through the 'control' and 'monitor' systems.

c. Be capable of the transferring six bit data words (BCD code as in Appendix A) to and from an external interface in a 'bit parallel-character serial' mode; or have the capability to communicate directly with the 24 bit data register of the data multiplex channel of an SDS-930 computer.

d. Provide sufficient transmission and switching speed to allow complete update and revision of up to fourteen full channels of data within one second.

e. Give a minimum display capacity of 500 characters per screen, with a maximum display not to exceed 2,000 characters per screen.

f. Contain necessary communication lines for data requests, responses, disconnects, and other needed timing and control signals.

g. Contain a sufficient number of delay lines or core buffer storage to hold seven full pages of data for the 'monitor' system, and seven full pages of data connected with the 'control' system.

3.3 Interface. Special purpose interface hardware shall accomplish the necessary transferral of data between the character register of the controller and a four character packed word register of the SDS Data Subchannel. Literature describing interfacing operations with the Data Subchannels of an SDS-930 computer is contained in the SDS Channel Interfacing Publication 900561A.

The special interface shall:

a. Successfully connect the standard CRT controller interface to a Data Subchannel (DSC-II) attached to the Data Multiplex System of an SDS-930 computer.

b. Provide logic level conversions to match operating voltage levels between the two connected devices.

c. Allow full use of the SDS-930 interlace capability for automatic block transfer of data under hardware control.

3.4 Mounting & Physical. Two standard sized 'monitor' scopes and a 'control' scope, together with their entry devices, shall be countable in the provided 19" racks (figure-3) of the POD console. The large scope in the POD area will be housed within its own cabinet which will provide fixtures of sufficient construction to allow ceiling suspension of the unit above the general eye level of the area. A control selector for this unit will be mountable within the paneling of the POD console.

SDS CHARACTER CODES

Characters Printer/CRT	Internal SDS Code	Characters Printer/CRT	Internal SDS Code
0	00	-	40
1	01	J	41
2	02	K	42
3	03	L	43
4	04	M	44
5	05	N	45
6	06	O	46
7	07	P	47
8	10	Q	50
9	11	R	51
Blank	12	!	52
=	13	$	53
'	14	*	54
:	15	]	55
>	16	;	56
✓	17	Δ	57
+	20	Blank	60
A	21	/	61
B	22	S	62
C	23	T	63
D	24	U	64
E	25	V	65
F	26	W	66
G	27	X	67
H	30	Y	70
I	31	Z	71
?	32	ǂ	72
.	33	,	73
)	34	(	74
[	35	ɷ	75
<	36	\	76
≢	37	⧻	77

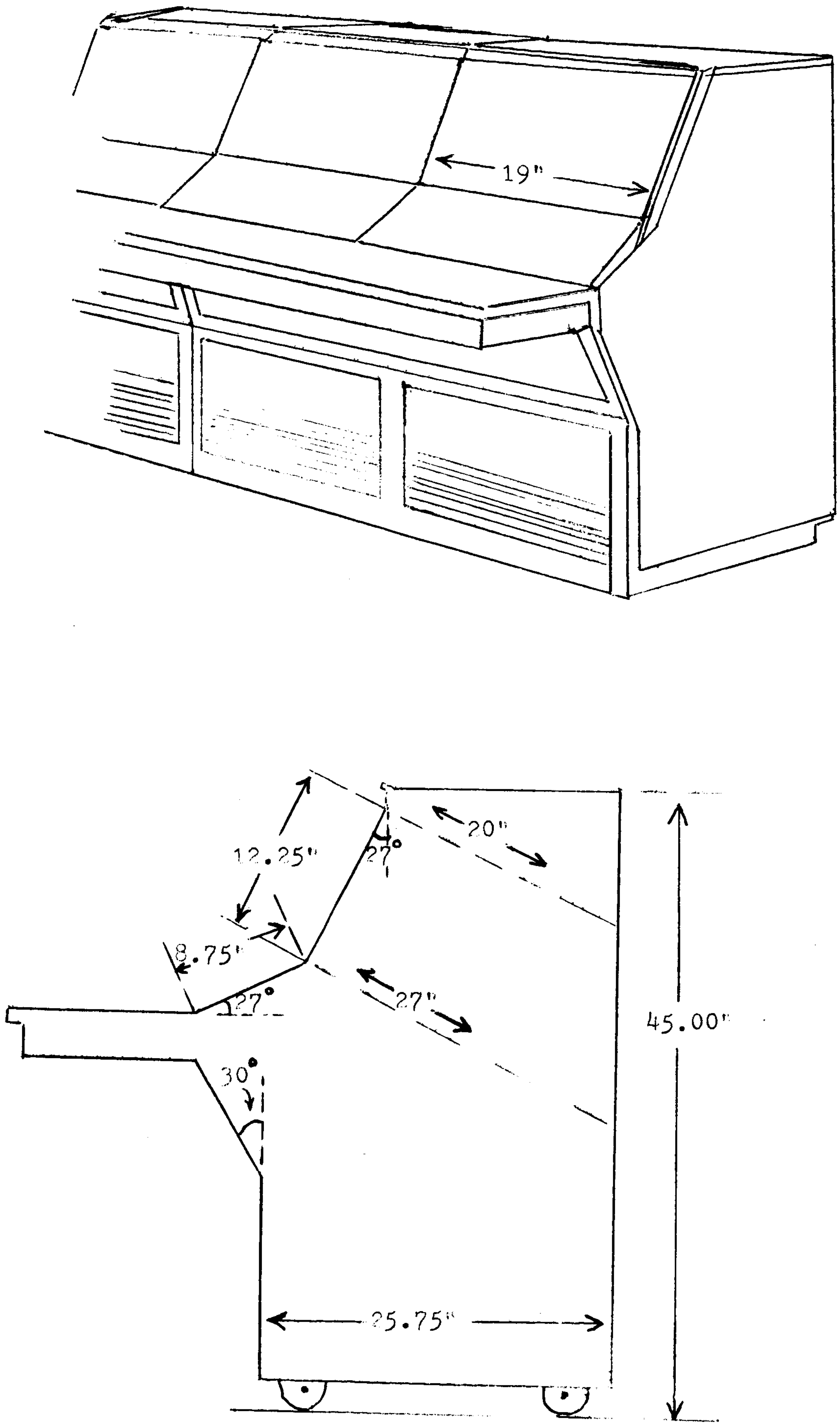


Figure 3.

All other standard sized CRTs and entry devices, will be self-contained within desk top enclosures. The three large Spacecraft Status scopes, should be box enclosed for wall mounting.

Physically, the controller unit shall be located within 30 feet of the central processor, and within 50 feet of all local display units.

All equipment shall operate on 117 volts ±10V AC. and 60 cycle ±5 cps. Test points for timing signals and character generation, necessary maintenance equipment and appropriate documentation shall be provided to allow establishment of a government furnished maintenance program.

4. PROPOSED SOURCES

Local Offices:	Home Offices:
* RAYTHEON COMPANY	
Solar Building 1000 - 16th Street, N.W. Washington, D. C. 20036	Boston Post Road Wayland, Massachusetts 01778 Attn: Indust. Sales Manager
* THE BUNKER-RAMO CORPORATION	
2001 Wisconsin Ave., N.W. Washington, D.C. 20007 Attn: Charles A. Theiss	445 Fairfield Avenue Stamford, Connecticut 06904
* STROMBERG-CARLSON CORPORATION	
1015 Wisconsin Ave., N.W. Washington, D.C. 20007	P. O. Box 2449 Data Products Division San Diego, California 92112
* SANDERS ASSOCIATES,	
Suite 420 1750 Pennsylvania Ave., N.W. Washington, D.C. 20007 Attn: Stephen R. Grayson	95 Canal Street Nashua, New Hampshire 03060 Attn: Data Systems Marketing
* SCIENTIFIC DATA SYSTEMS	
12150 Parklawn Drive Rockville, Maryland 20852 Attn: Dennis F. Straiter	1649 Seventeenth Street Santa Monica, California 90404

5. ITEMS & COST

The following breakdown of items is for price estimating purposes only. The items are not necessarily available in part, or even separately listed by various manufacturers. Cost estimates are only rough approximations for the purpose of arriving at a total dollar cost which may be used for planning purposes.

1	Standard size- 'unmounted' CRT Station with 'full alpha-numeric keyboard'		2,000
1	Standard size- 'mounted' CRT station with 'full alpha-numeric keyboard'		2,000
2	Standard size- 'unmounted' CRT Station with 'limited selector' keyboard	@ 2,000	4,000
2	Standard size- 'mounted' CRT Station with 'limited selector' keyboard	@ 2,000	4,000
4	Large size- 'mounted' CRT Station with 'limited selector' keyboard	@ 2,000	8,000
1	CRT Controller System with full duplex data transfer capability; less buffer storage		20,000
12	Buffer Storage Module; delay line or core storage	@ 3,000	36,000
1	"High speed Transfer" interface module		8,000
1	ASCII to BCD Code Translator		4,000
1	"Editing feature" module		1,000
		TOTAL	89,000

In the event that equipment is purchased instead of renting, and maintenance is to be performed by the purchaser, additional special test equipment should be bought.

1	Equipment test set	3,000