NASA CR-144677

STUDY FOR APPLICATION OF A SOUNDING ROCKET EXPERIMENT TO SPACELAB/SHUTTLE MISSION

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Final Report

Prepared for

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland 20771

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PREFACE

This is the final report of NASA contract NAS 5-20973 entitled

STUDY FOR APPLICATION OF A SOUNDING ROCKET EXPERIMENT TO SPACELAB/SHUTTLE MISSION.

We reference and include the following previous reports as part of this report:

1. "A Preliminary Report of a Study to Adapt a University of Wisconsin Rocket Payload for use with the Spacelab on the NASA Space Shuttle" 15 April 1975.
2. "Aerobee Rocket Payload Acoustic Vibration Test" 18 July 1975.

Both of these reports went to Dr. D. Leckrone, Code 671.0 as well as to Mr. A. White, Code 726.

The tasks in our proposal of 16 January 1975 constitute the work statement of this contract and are summarized as follows:

a. Electrical, mechanical, and optical modifications necessary are reported in section I.
b. Operations and data handling are discussed in section III and Appendix A of this report.
c. Documentation of item a. was covered above. Programming requirements are discussed in sections II and IV of this report.
d. Testing and integration are discussed in section II of this report and reference is made to an undated GSFC document labelled INTEGRATION AND TEST Preliminary.
e. Electronic ground support equipment (GSE) is described in section I of this report. Calibration and optical GSE is the subject of section V of this report.
f. A management plan with cost estimate is developed in section VI.
g. A project initiation conference was held on 13-14 February 1975. A pre-acoustic vibration meeting was held on 18 June 1975. A post-acoustic vibration

review was held on 20 June 1975. A discussion of integration with a solar payload was held by telephone but no conference took place. A Final Design Review was held 20 August 1975.

INTRODUCTION

This is the final report on the Wisconsin study to determine the effort required to adapt the Wisconsin UV calibration rocket payload for use with the shuttle borne Spacelab. The purpose of this particular payload is to establish a network of 40 well calibrated stars for future use. This will require two shuttle flights approximately six months apart with orbits chosen so that spacecraft night does not occur in the South Atlantic radiation anomaly.

We have made many assumptions for this study:

1. A thermal canister on a SIPS is assumed.
2. A SIPS-provided "strongback" mounting surface is assumed.
3. A tracking device will be furnished by SIPS for installation in our instrument to utilize the zero order signal as the SIPS fine guidance signal.
4. The RAU has a parallel computer type data interface as well as A/D converters for housekeeping.
5. T & I will take no more than 2 months at GSFC.
6. Since calibration is the critical part of our package, we will be able to leave a mechanical and/or electrical duplicate with the SIPS while we recalibrate, if T & I should take more than 2 months.
7. We provide GSE for early checkout but NASA provide appropriate GOE for "quick-look" and real-time checkout.
8. Six months of programming effort on our part will suffice for both checkout programs and any simple command or control routines required for flight.
9. External vacuum lines will be provided so that an on-board vacuum system will not be needed. The latter is given as an option.

A minor portion of the effort is contained in the changes we are already planning for this payload. The major mechanical and optical work is:

1. Mounting of the evacuated package to a strongback.
2. Mounting and alignment of the fine guidance sensor.
3. Design and construction of a simple on-board calibration device.

The major electronic effort is to provide a correct interface with the RAU. Also a more flexible GSE is envisioned than now exists for the Aerobee payload.

SUMMARY AND CONCLUSIONS

Our study indicates that rocket size packages can be inexpensively adapted to Shuttle/Spacelab use. We have baselined a 2 flight project extending over 2 years and requiring 80 man months of effort for our existing rocket payload.

Our cost estimate is 290 thousand dollars with the proviso that projects of somewhat less than twice this scope be available to fill in since we require about 10 persons to do the tasks but they would not be busy all of the time.

We conclude that testing must be held to a minimum since rocket packages seem to be able to tolerate shuttle vibration and noise levels. Testing documentation should be simple with the help of NASA personnel.

In order to hold programming costs to a minimum we have suggested that a standard, flexible control and data collection language such as FORTH be used rather than a computation language such as FORTRAN. Even then programming will be a significant effort.

Formal documentation from us should be limited to drawings of optical, mechanical, and electrical aspects of our package along with some descriptive material.

Structural, thermal, and safety verification, computation, and documentation should be generated by NASA experts with our help in providing input.

Interaction between the users and the persons specifying the mechanical and electrical interfaces (particularly the RAU) would be highly desirable at this time.

The experimenter should program his portion of the NASA furnished GSE and GOE as well as aiding in the observing program generation.

For our payload the mission specialist is not a requirement; but we would feel much more comfortable if he would be available for initial operations and in case of trouble.

We envision T & I scheduling for several missions as a problem. We also estimate that operations preparation and scheduling will be another problem area.

I MECHANICAL AND ELECTRICAL MODIFICATIONS

I a The Present Payload

The existing rocket payload includes a spectrograph which feeds five detectors with sensitivities between λ600 Å and λ1500 A, each with about 90 A bandwidths, and four individual filter photometers sensitive to radiation from about λ1900 Å through the visual region with bandpasses ranging from 30 Å to about 200 Å. This package is shown in figures 7 and 8.

The spectrograph consists of an 8-inch spherical mirror (whose field of view is limited to about 2° by slat collimators) which illuminates, with a converging bundle of light, a 600 line/mm plane diffraction grating blazed at λ1200. The resulting spectrum, with a dispersion of about 17 Å/mm, is focussed on Bendix windowless channeltrons fixed in the focal plane; these detectors are operated in a pulse counting mode. The entire payload is evacuated before flight to minimize out-gassing problems.

The four photometers mentioned above are of a type we have flown many times before -- two-inch quartz refractors with six-layer MgF_2-Al interference filters to shape the ultraviolet pass bands, and EMI 6256b photomultipliers operating in a DC mode. The total package weighs about 190 pounds and is 77 inches long.

Each of the channeltron detectors has a pre-amp within the detector housing. The preamp output feeds and amplifier discriminator which in turn converts the low level signals to a fixed pulse width T^2L levels. These pulses are counted in 16 bit high speed counters which have a fixed integration time of 500 msec as gover ned by a stable 32 Hz crystal clock. The contents of the counters are jam transferred into 16 bit shift registers and shifted out serially to the telemetry by the same clock which governs integration time. The counters are then reset. The shifting sequence takes 500 msec to empty the shift registers after which another data dump is taken and the process repeated. Count rate capability is 133,000 counts/sec before overflow. The master clock is fed to telemetry in order to decode the binary bit stream to actual photon counts. This clock has a fiducial pulse interjected on it to indicate the start of the shifting sequence. All signal levels are T^2L.

The photomultipliers are operated in the DC mode. Each of the four linear DC amplifiers are two range auto switching amplifiers giving a dynamic range of 50. Output levels are 0 - +5.0 volts.

There are 25 housekeeping channels monitoring the following:

- All power supply levels - both LV and HV
- Battery voltages
- Vacuum condition (thermocouple)
- PM amplifier offsets/background (X20)
- Calibration lamp current

Toward the latter part of the flight while slewing between stars, a UV calibration lamp is turned on to check and calibrate the channeltron detectors.

The payload requires two battery voltages:

+28 Volts ± 4 Volts and

-12 Volts ± 2 Volts

Total current: 3 AMPS (28V)

.2 AMPS (12V)

Power: approx. 100 Watts.

I b Mechanical Description

The sounding rocket spectrometer instrument contains control electronics, spectrometer, slat baffle, and four two inch photometers in a seventy-five inch Aerobee can which is vacuum tight. Vacuum pumping is done externally through a valve in the nose cone. The mechanical changes to the basic instrument are minimal. The electronics section, which is about fifteen inches long and weighs twenty pounds, would be moved external to the vacuum or, thinking of it another way, the bulkhead would be moved forward between the electronics and spectrometer. This requires vacuum feed-thru connectors.

The startracker on the existing Aerobee instrument is mounted adjacent to the slat baffle and photometers, about fourteen inches aft of the fromt end of the Aerobee can. The startracker for the shuttle would be moved aft to the electronics bulkhead adjacent to the electronics. The startracker will then be external to the vacuum in a forward looking position at the zero order image of the spectrometer. This change will require a vacuum tight optical feed-thru through the bulkhead.

Additions to the present instrument include a calibration collimator section and a valve section. The collimator section will be at the forward end of the spectrometer attached where the slat baffle was. The collimator will be a ten inch diameter tube thirty-six inches long connected through a vacuum tight bulkhead ring on the forward end of the spectrometer. The vacuum pump connection can be made anywhere along the length of the collimator tube. The forward end of the collimator tube is supported by a bulkhead ring and will have a locating taper and valve seal surface. The valve section will be in a box twelve inches on a side with two ten inch diameter holes on the optical axis. The box is supported at the collimator end by a bulkhead ring. Inside the box the valve is supported, by opposite walls perpendicular to the viewing axis, on trunnions. The face of the valve carries an eight inch mirror which points into the spectrometer when the valve is sealed (for calibration purposes). When the instrument is in orbit the valve/mirror is retracted about two inches, rotated 90° CCW, and advanced two inches to a locked position leaving the viewing axis clear. When it is desired to seal the instrument the valve/mirror is retracted from its locked position, rotated 90° CW, and advanced to its sealed or calibration position. The slat baffle with the two inch photometers is mounted on the forward end of the valve box.

Mounting of the instrument to the SIPS canister will be done with the aid of a strongback or a girth ring. The instrument to strongback connection will be made at three or possibly four bulkhead rings. The bulkhead rings are located between electronics and spectrometer, spectrometer and collimator, collimator and valve box. The fourth ring, if needed, is between the valve box and slat baffle. (see Figure 1)

As an alternative to the strongback mounting, the girth ring mounting to the SIPS canister requires a narrow box kite-type frame which is held in the canister at the trunnions in the area of the pointing axis. The instrument would be supported through the center of the box kite frame with diagonal supports extending lengthwise fore and aft from the four extreme corners of the frame and radially inward to the bulkhead rings between the electronics and spectrometer sections, and to the bulkhead ring between collimator and valve sections.

The center of gravity can be adjusted by moving the instrument lengthwise within its limits or by repositioning the electronics or pump connection.

<u>Summary of Mechanical Changes</u>

1. The electronics section is atmospheric pressure and therefore, requires vacuum tight feed thrus. The electronics may have to be moved off-center to give the startracker access to zero order.

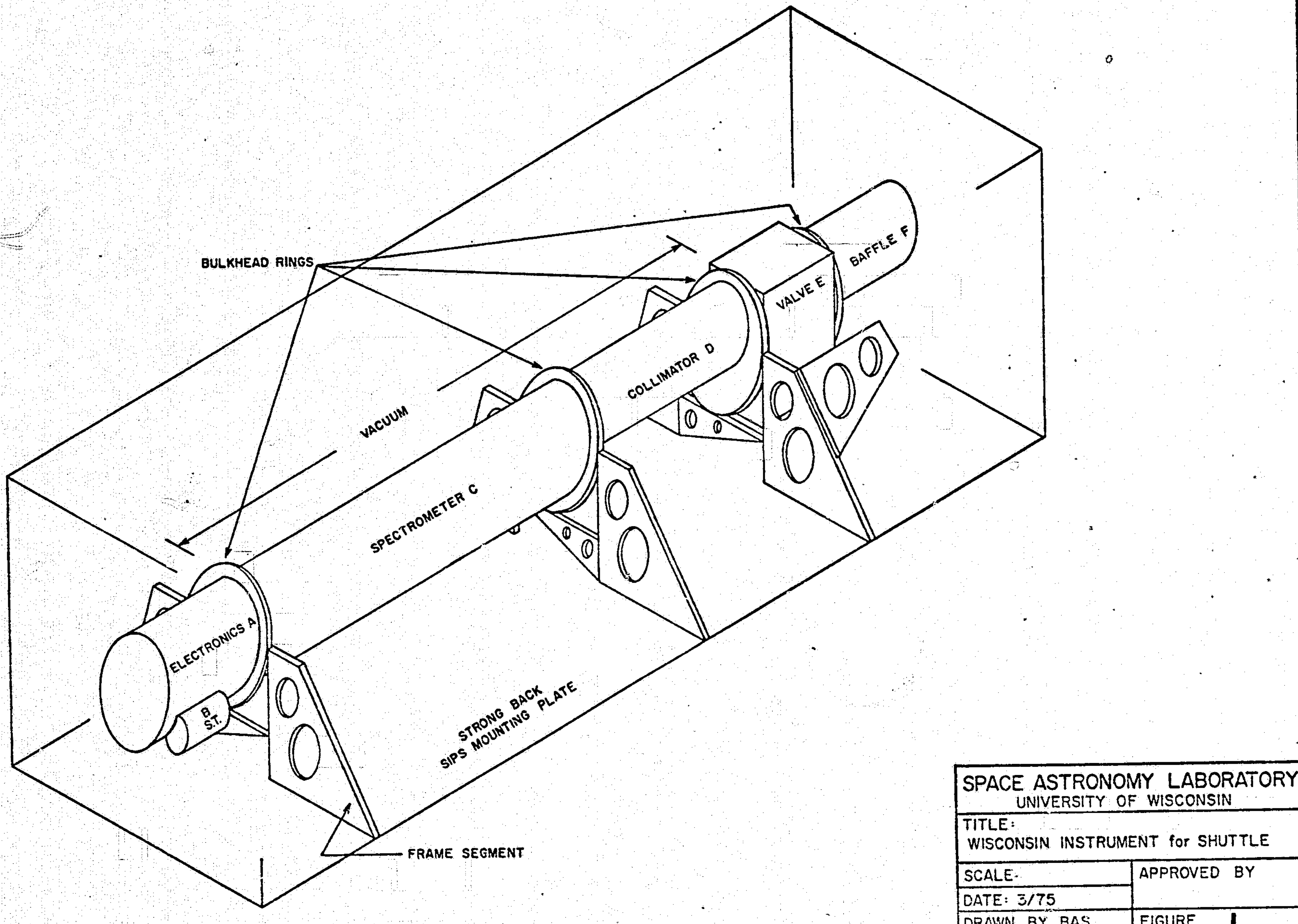

BULKHEAD RINGS
VACUUM
BAFFLE F
VALVE E
COLLIMATOR D
SPECTROMETER C
ELECTRONICS A
B
S.T.
STRONG BACK
SIPS MOUNTING PLATE
FRAME SEGMENT
SPACE ASTRONOMY LABORATORY
UNIVERSITY OF WISCONSIN
TITLE:
WISCONSIN INSTRUMENT for SHUTTLE
SCALE-
APPROVED BY
DATE: 3/75
DRAWN BY BAS
FIGURE 1

Figure 1

2. The startracker is in air, therefore the optical path will require a vacuum tight feed-thru window.

3. The spectrometer is unchanged except for a vacuum tight bulkhead connection directly to its base.

4. The collimator needs appropriate plumbing for either the vacuum connection to exterior pumping or to on-board pumping. It also provides an optical path for calibration. The pumping port can be anywhere along the axis in spectrometer or calibration collimator.

5. The valve section contains a vacuum sealing valve to which a calibration mirror is attached.

6. The baffle contains slats to limit the field of view in the dispersion direction. The two inch photometers clamp around the baffle.

7. If suitable vacuum lines are not available through an umbilical connection during the prelaunch phase it will be necessary to include some vacuum equipment as part of our package.

Frame segments can be fastened together in various configurations to form mounting stations for the bulkhead ring. The bulkhead ring is an Aerobee (or larger) male/female bulkhead connector with a flange on its periphery. The male/female connections are vacuum tight.

I c Optical Description

The experiment package consists of one objective-type grating spectrometer for the vacuum ultraviolet region and four small photometers for specific wavelengths in the near ultraviolet.

The spectrometer is a Monk-Gillieson type using a concave spherical mirror and a plane grating. The eight inch diameter mirror is illuminated by light from the star with the field being limited by a slat baffle. The wavelengths observed are determined by the positioning of individual open cathode channeltron multipliers along the direction of dispersion in the focal surface. As a rocket payload this spectrometer has been flown with five detectors defining 90 Å wide bandpasses between 600 Å and 1500 Å. For the shuttle flights an additional detector, smaller cathode areas, and a slight tipping of the grating will provide observations at six 40 Å wide bandpasses between 900 Å and 1800 Å. Because of the objective position of the grating in this instrument, the pointing accuracy necessary for good definition of the bandpasses wavelengths is ± 15 arc seconds.

The four small photometers are two inch diameter telescopes with quartz lenses and interference filters and use photomultipliers as detectors. The interference filters define bandpasses several hundred Angstroms wide in the middle ultraviolet. The pointing accuracy necessary for these instruments is ± 5 arc minutes.

Changes

There are several changes required to adapt this experiment for a shuttle flight in addition to those required for mechanical and electrical interfacing.

One change is considered necessary because of the absolute calibration required. The overall accuracy of the stellar flux measurements depends on both the accuracy of a laboratory measurement of the spectrometer sensitivity and the certainity one has that the sensitivity is the same during the flight. To monitor the stability of the spectrometer's response during the appreciable length of time between the absolute calibrations done in our laboratory before and after the flight, a field calibration system has been included as an integral part of the spectrometer.

The system consists of a sealed hydrogen lamp and a collimating mirror. The lamp will be either of the discharge type which has been used with the spectrometer on rocket flights or, hopefully, a more stable rf-excited version. The lamp is limited to wavelengths longer than 1050 Å because of the necessity of a window, but emits light throughout the rest of the vacuum ultraviolet. The eight inch diameter collimating mirror is mounted on the valve which provides the vacuum seal for the spectrometer and is completely removed from the field of view when the valve is in its open position. An off-axis parabolic figuring of the mirror allows the lamp to be mounted out of the beam without astigmatism, and is available without cost since use will be made of a mirror on hand from a developmental OAO stellar telescope.

This on-board system is designed to be used both for field calibration before launch and as an in-flight calibration source. A field calibration can be done at any time that the spectrometer is under a high vacuum. The high vacuum condition must be present to even turn on the channeltron detectors in the spectrometer for test purposes. As presently conceived the high vacuum is achieved when required by attaching an external pumping system to the experiment. This assumes that the experimenter will have access to the experiment for this purpose on several occasions, one of which would be shortly before launch. An alternative to attaching the external pumping system is to provide sufficient internal pumping to maintain a high vacuum constantly in the spectrometer, thus allowing testing of detector operation and field calibration checks to be done remotely.

Another required change is in the location of the startracker. On the shuttle the startracker will provide guidance through the spectrometer itself using the visible light in the zero order from the objective grating. This is a very direct way of assuring that the spectrometer remains aligned to the startracker and full use can be made of the startracker's pointing ability. This would limit the use of this startracker to fine pointing only. Figure 2 is an optical diagram of the package including all changes.

While we have assumed a NASA furnished strongback within the canister, it would not be difficult to furnish such a mounting plate ourselves. However, we will need such a strongback in order to mount the instrument and check our internal alignment.

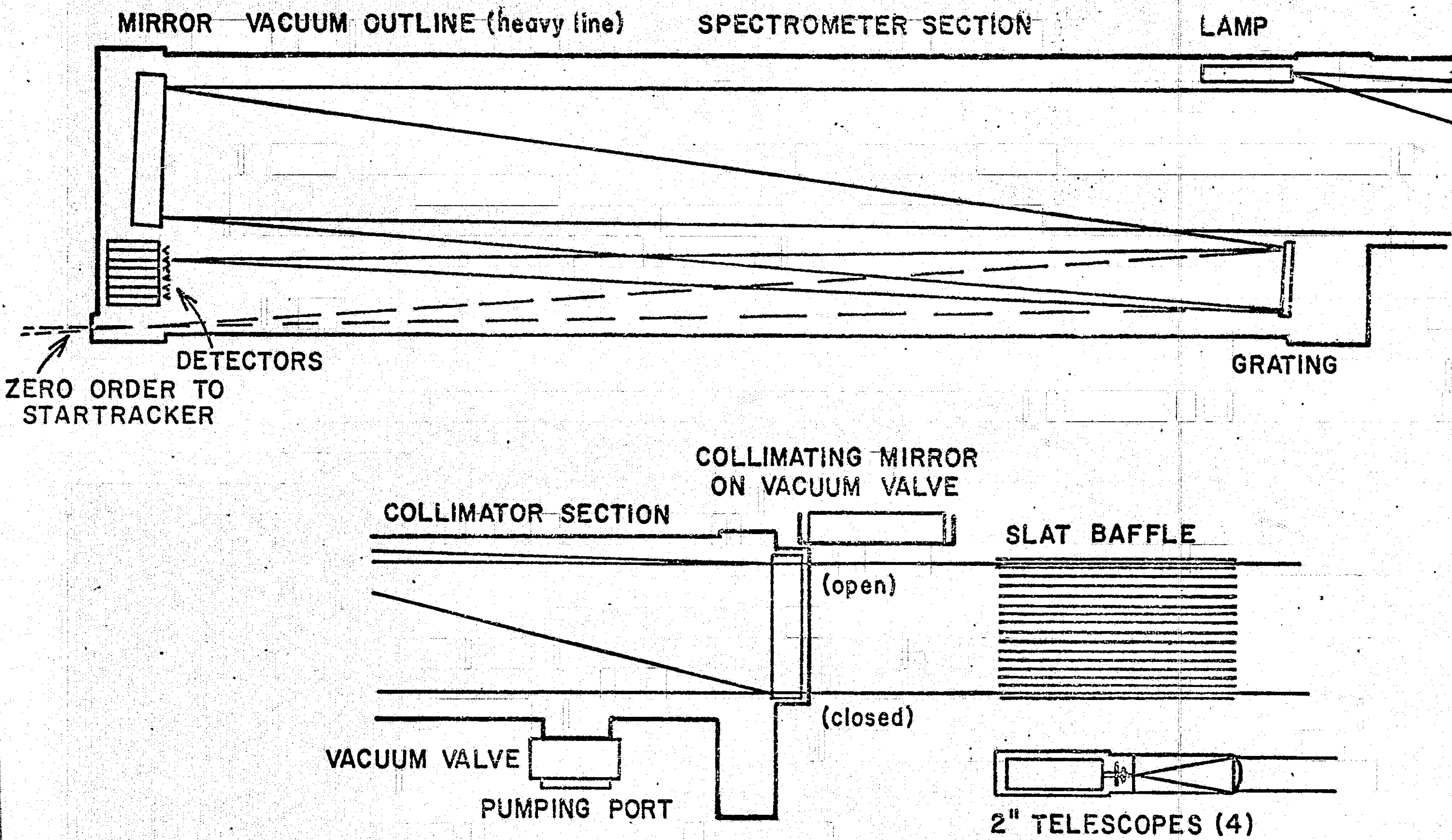
Requirements

The experiment requires a clean high vacuum environment for satisfactory operation. An upper limit of 10^{-5} torr is set by channeltron detectors. The fact that the spectrometer is vacuum tight protects it during launch phase and until actual operation from contaminants released in the initial out-gassing from the payload bay. A vacuum of 10^{-6} torr and reasonable absence of oil would be adequate for operation provided the canister protects all sections of the spectrometer from significant thermal cycling during the time that the spectrometer vacuum valve is open. This seems compatible with our expectation that the canister will provide darkness for the experiment during the sunlight portions of the orbit.

I d Electronics

All detectors will be operated in a pulse counting mode and several new channeltrons will be added. The characteristics of the RAU (at present not known) are assumed to be a computer I/O bus structure.

A flexible GSE is being designed for T & I and a new control panel for use in the Spacelab is laid out. The details of these designs are given in section I e.



OPTICAL DIAGRAM OF UV SPECTROMETER

Figure 2

I e UW ASP Electronics

Since the payload-to-shuttle electrical interface, RAU, has not been defined as yet, the following discussion of proposed hardware design and cost estimates will probably be subject to some change.

Data management and control of the UW ASP can be easily handled with an interface that allows information to be passed between the payload and the CDHS computer in a more or less standard "hand-shaking" format. This technique allows multiple experiments to operate simultaneously easily. The payload electronics requires only minor modifications and additions to operate with such a system. Figure 3 shows the proposed electronics system.

We assume that the RAU interface has a 24 bit input data bus and a 24 bit output bus. If desired, these 48 lines can be reduced to a single 24 bit 2-way bus to reduce line count. In addition there is an interrupt line which signals to the CDHS computer that attention is required and a clear interrupt (optional) which is the response. Digital data are strobed onto the 24 bit input bus in response to an Input Data command and digital status by an Input Status command. Experiment control is via the 24 bit output bus and Output command. The Master Clear line resets the experiment into a 'no operation' condition. In order to handle the analog housekeeping data, the interface can accept (at least) 32 signals (0 - +5 volts).

The 11 photon detectors within the payload are operated in a pulse counting mode. The detector output pulses are counted in 17 bit photon counters with fixed integration periods of 100 milliseconds. Counter capacity is 1.3 megaphotons per second. The counters operate in a free run mode with the only dead time (50 nanoseconds) being that of transfer of the counter contents to 17 bit storage registers followed by counter reset.

The 11 registers are gated sequentially onto a common data bus. To identify the counter, a 4 bit ID word is also strobed onto the bus with the 17 bit data word. This data frame is

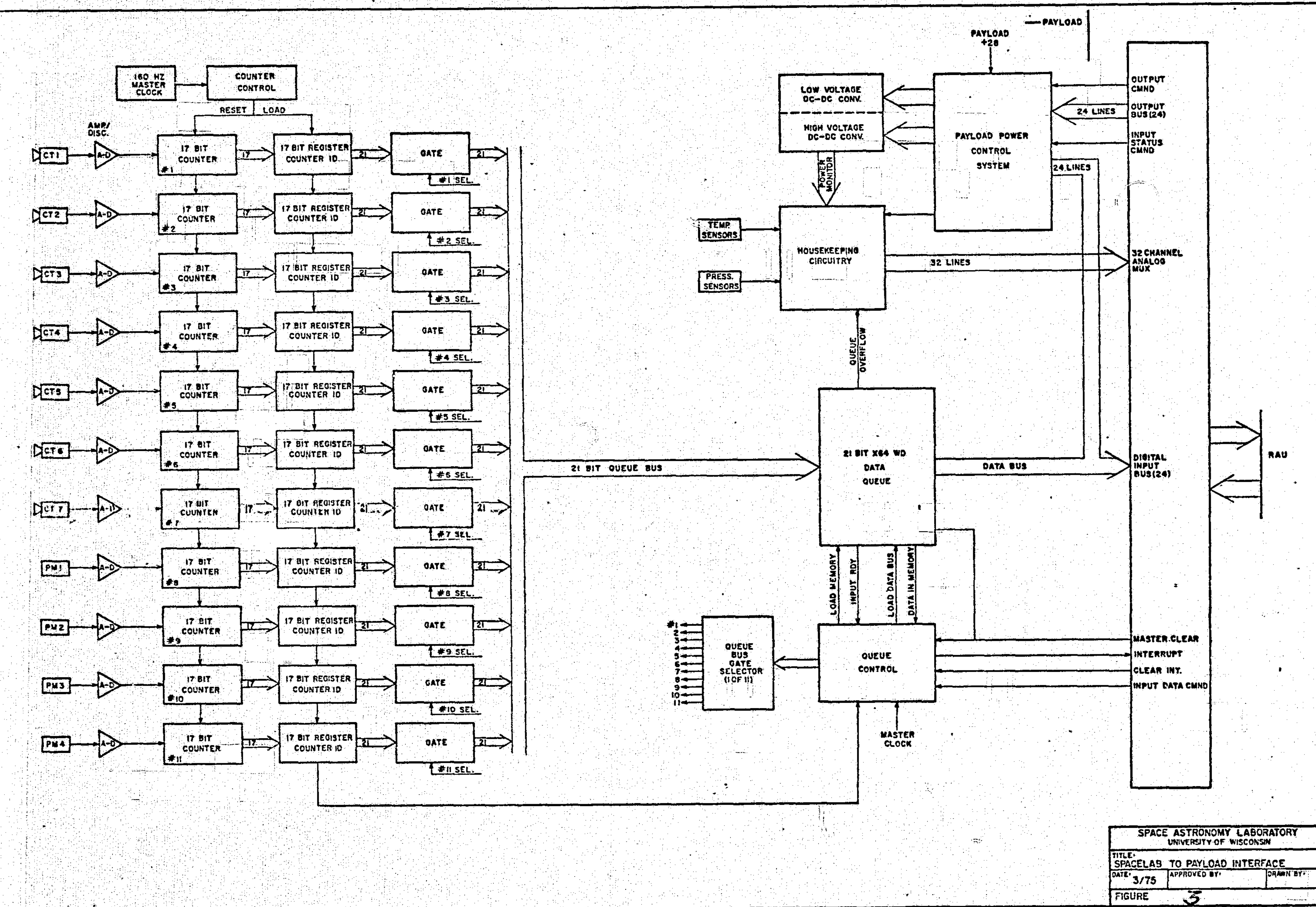

160 HZ MASTER CLOCK
COUNTER CONTROL
RESET
LOAD
AMP/DISC.
CT1
CT2
CT3
CT4
CT5
CT6
CT7
PM1
PM2
PM3
PM4
A-D
17 BIT COUNTER
17 BIT REGISTER COUNTER ID
GATE
#1 SEL.
#2 SEL.
#3 SEL.
#4 SEL.
#5 SEL.
#6 SEL.
#7 SEL.
#8 SEL.
#9 SEL.
#10 SEL.
#11 SEL.
21 BIT QUEUE BUS
PAYLOAD
PAYLOAD +28
LOW VOLTAGE DC-DC CONV.
HIGH VOLTAGE DC-DC CONV.
POWER MONITOR
PAYLOAD POWER CONTROL SYSTEM
OUTPUT CMND
OUTPUT BUS(24)
24 LINES
INPUT STATUS CMND
24 LINES
TEMP. SENSORS
PRESS. SENSORS
HOUSEKEEPING CIRCUITRY
32 LINES
32 CHANNEL ANALOG MUX
QUEUE OVERFLOW
21 BIT X64 WD DATA QUEUE
DATA BUS
DIGITAL INPUT BUS(24)
RAU
LOAD MEMORY
INPUT RDY
LOAD DATA BUS
DATA IN MEMORY
QUEUE BUS GATE SELECTOR (1 OF 11)
QUEUE CONTROL
MASTER CLOCK
MASTER CLEAR
INTERRUPT
CLEAR INT.
INPUT DATA CMND
SPACE ASTRONOMY LABORATORY
UNIVERSITY OF WISCONSIN
TITLE: SPACELAB TO PAYLOAD INTERFACE
DATE: 3/75
APPROVED BY:
DRAWN BY:
FIGURE 3

Figure 3

shown below.

CNTR ID 4 BITS	M S B	DATA WORD	L S B

DATA FRAME

A small data memory, a first in - first out 21 bit X 64 word queue, is included in between the data bus and the RAU input lines. This small addition, readily expandable, allows the RAU data-way to remain inactive or busy for up to 1/2 second before it must take data from the queue before loss of data occurs. Data in the queue would be indicated by a high level on the interrupt line. To remove data from the queue, the CDHS/RAU generates an input data command. Data will remain stable on the input lines for the duration of the command (> 100 nsec) plus > 5 nsec. The average bit rate equals 2.31 K bits/second, not counting housekeeping. Sampling rate for analog housekeeping can be 5 samples/second/channel. Assuming an 8 bit A/D conversion within the RAU, this would result in a housekeeping rate of 1.3 K bits/second or a total of 3.61 K bits/second for the payload. The digital data would be stored in raw (unprocessed) form onboard Spacelab to be transmitted whenever possible to the control center for quick-look and detailed analysis. The CDHS computer would be programmed to check the status of the experiment and warn the Payload Specialist of any anomalies.

Experiment control could be the responsibility of the Payload Specialist via a control panel furnished by us. The panel, Figure 4, can control the power to each of the 11 detectors and their associated electronics. Figure 5 shows the control system. The control panel is linked to the CDMS computer instead of directly to the experiment. The reason is that experiment control,

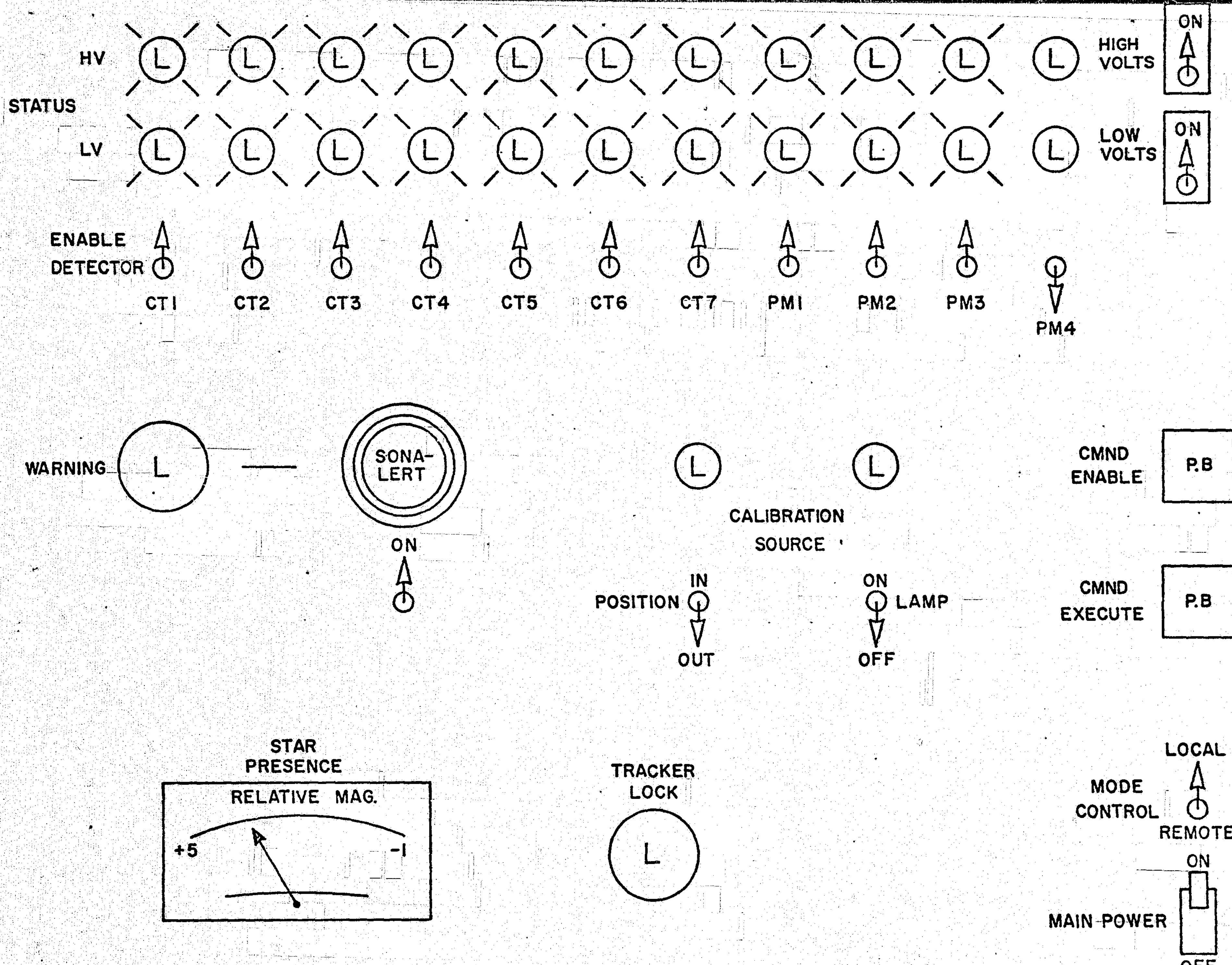


FIGURE 4 : CONTROL PANEL

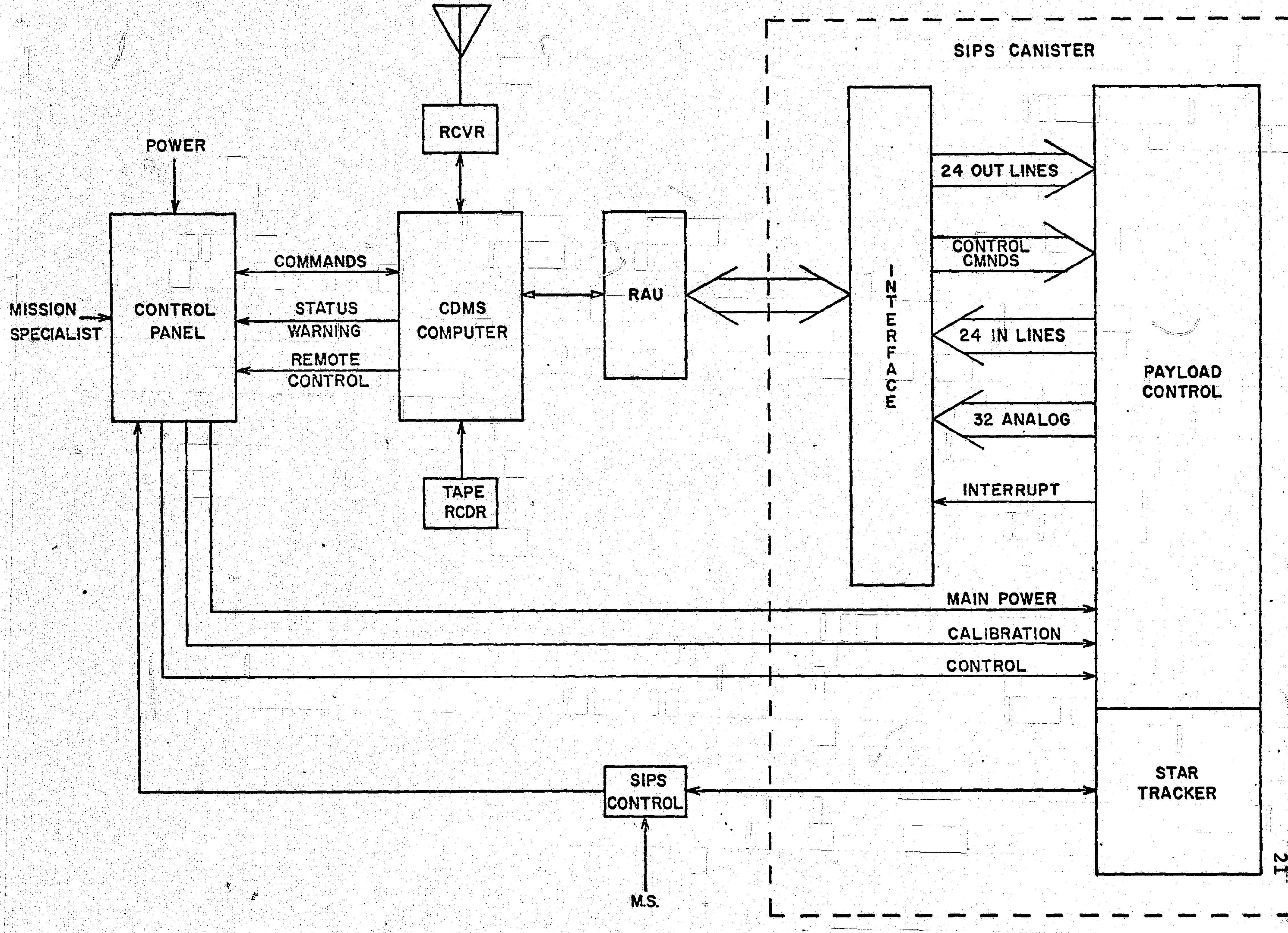


FIGURE 5 CONTROL SYSTEM

as an alternate, can be easily accomplished at the ground control center.

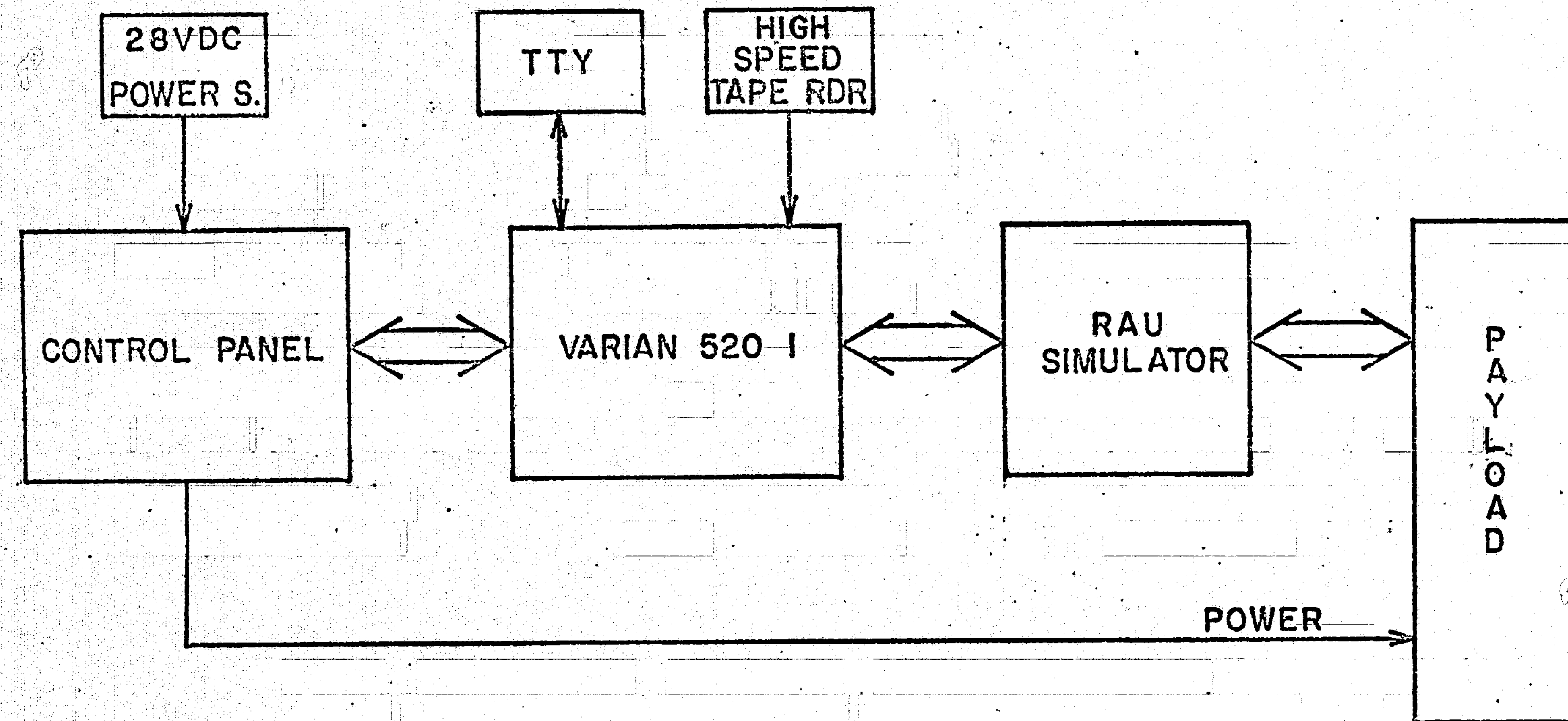
The control panel allows selective power control of individual subsystems rather than a simple +28V experiment ON/OFF switch. This method was chosen because if a malfunction should occur, the malfunctioning detector can be shut off. Power status of each detector will be fed to the RAU via the analog housekeeping lines. The computer will sample these levels and indicate the status of each detector on the control panel. Should any anomaly exist, a warning light and a possible audio tone will be generated to alert the Payload Specialist that a problem exists and corrective action is required. The faulty subsystem will be indicated by a flashing status light above the power switch of that detector and/or computer CRT console.

Ground Support Equipment

GSE is defined as equipment required to check and calibrate the payload when the payload is not integrated with the Spacelab. The assumption is made that GSFC will provide the ground experimenter with a console for payload control and data analysis when the payload is part of the Spacelab system. The GSE shown in Figure 6 was developed for operator convenience, portability and minimum cost. It can be constructed at this laboratory. A minicomputer and its peripherals already exist and therefore are not considered in the estimated cost for the GSE. The control panel is identical with the Spacelab panel previously described. The computer will control the payload, monitor status, and collect data which will be printed out on the teletype. Additional hardware required includes the control panel and RAU simulator.

Payload Simulator

Prior to payload integration at GSFC, Wisconsin will provide a payload simulator. This will allow the Space lab systems personnel to check out the software in advance of formal integration.



28VDC
POWER S.
TTY
HIGH
SPEED
TAPE RDR
CONTROL PANEL
VARIAN 520-I
RAU
SIMULATOR
PAYLOAD
POWER

FIGURE 6 GSE

The simulator can be one of two types. It may be of similar weight and dimension as the flight payload - in effect a prototype, but without detectors or optics to minimize expenses. A "photon simulator" would provide data for the counters. A less expensive alternative would be an electronic simulation only. Following formal integration, the payload is returned to Wisconsin for calibration and the simulator is remounted within the Spacelab so that as other payloads arrive T & E the Wisconsin "payload" can be checked out with the others for possible interference. We propose to furnish the less expensive simulator (functional only) but to have approximately the correct mass.

II TEST & INTEGRATION

Some T & I can take place within this laboratory and at General Environments Corporation in Morton Grove, IL. This corporation can perform complete payload vibration tests and subsystem thermal vacuum tests if required. Mass properties and acoustic vibration tests would have to be done at GSFC.

II a Testing and Integration at Goddard Space Flight Center

As has been previously reported we have subjected our Aerobee calibration payload to shuttle level acoustic noise and no damage or degradation was sustained. Our testing and integration experience includes two large satellites (OAO-A1, OAO-A2) as well as many sounding rockets with packages of various complexities.

We fully agree with the philosophy expressed in the preliminary test and integration plan for small shuttle payloads. In order to keep the cost low testing must be much more rocket-like than satellite-like.

As far as the generalities of the plan are concerned we have no argument. It seems to mention everything that needs doing. Our package is of the type III hardware and would be considered of the spacecraft class.

The tasks on table 1 are substantially the same as that furnished by GSFC. We do question items 9, 10, and 11 at level IV of table 1 since we are assuming a thermal and structural canister concept for this study.

We require a field calibration as close to launch as is practical (we suggest at level II with the functional test). Also we require a one month period at Wisconsin after alignment and EMC (level III) for final detailed calibration. During this period we would leave a dummy payload that would produce appropriate electrical responses to commands. The real payload would be back for compatibility testing before level II integration. We recommend that flight simulations be carried out independently

Table 1.

Summary of Astronomy Spacelab Payloads

Integration Sequence

Pre GSFC
    Experiment buildup, subsystem level tests

At GSFC
    Preintegration
        1. Buildup as required
        2. Electrical checkout
        3. Add pallet attachments
        4. Functional test (after every test)
        5. Modal survey
        6. Acoustics
        7. Leak test
        8. Thermal-vacuum
        9. Functional test
        10. Ambient functional test
IV)   11. Add thermal blankets

    Pallet mating
    Interface verification
    Optical alignment
    EMC
    Flight simulation (OCC option)
    Safety verification
    Combine pallets (mechanical & electrical)
    Interface verification
    Compatibility test
III) Flight Simulation (OCC)

    Mate with flight igloo
    Pack & ship to launch site

At launch site
    Mate with previously unavailable flight hardware (Spacelab)
II) Abbreviated functional test & field calibration

    Mate to orbiter
I) Orbiter integrated test

    Launch
    Flight
    Land
    Return to GSFC and deintegrate

of the hardware testing since real data need not be obtained and time can be saved by doing the jobs in parallel.

These tests must be quite abreviated since we feel that two man months is all that can be allowed in our planning for all of level IV and level II with the exception of flight simulation.

There are two areas of effort mentioned in the test plan that we strongly object to. They are:

1. experiment-supplied data for STOP and NASTRAN
2. optical calibration of our payload by GSFC

Likewise, we feel that the plan has left out two important, time consuming tasks:

3. It will be necessary for experimenters to build simple ground support equipment to simulate the CDMS and RAU in order to checkout and test their payloads before and perhaps after delivery to GSFC.

4. The computer programming effort implied on the part of the experimenter is not mentioned and is a significant item.

We shall amplify the programming problem in a project such as this in section IV of this report. Optical calibration is discussed in section V of this report.

We discuss each of the objections below.

1. We question the necessity of detailed modelling of these packages (as described in section 7 of the test plan) since they have already been through flights. Such calculations performed by the STOP program in lieu of detailed testing provide a check on design if needed. We recommend that should such calculations be required, a NASA person come to Wisconsin to gather the relevant data for the run.

2. In the case of our payloads as well as those of many other experimenters the calibration will be done by the experimenter. Any cost to duplicate this at GSFC is unnecessary. We agree that if an experimenter does not have any calibration of his own the GSFC facilities (as described in section 8 of the test plan) could be used. However, we question whether running

a facility designed to handle large satellites to calibrate a multitude of small packages would be cost effective in light of schedule and manpower considerations.

3. Each experimenter will need some simulator in order to check out this package. These could be much less elaborate than the one described in the test plan. We have already reported our GSE plans. NASA, however, might consider the possibility of furnishing correct connectors, output drivers, clocks and other common necessary parts of the electronic interface to the experimenter as GFE.

4. It will be necessary for each small payload to have a separate test routine in the spacelab simulator. Our experience indicates that this programming is best done by ourselves in order to meet time schedules and have the correct test programs. Therefore, the language available on the spacelab simulator should be as simple and flexible as possible. Based on these considerations, we strongly recommend the use of the interactive programming language, FORTH, as the standard language to be used in testing and also perhaps in operations. This language was developed at NRAO and has been adopted by KPNO, CTIO, and many other observatories. Many astronomers are already familiar with this powerful and flexible language. We suggest that a few members of the programming group to be involved in testing and operations spend a few days at KPNO trying out their FORTH system. At Wisconsin we have implemented a similar FORTH system and find it amazingly useful for quick programming.

Since we are assuming a thermal canister, we have not baselined any thermal analysis. If such is necessary, we feel that a NASA expert should run the required analysis on the STOP program.

II b Safety

There are no hazards to personnel involved with our package. The ability of the package mounted to the strongback to sustain "crash" level loads will be determined by analysis.

Hazards to our own equipment and that of other payloads consist primarily of EMI generated by failed high voltage power supplies. These conditions will be monitored and indicated on the panel in the Spacelab so that manual corrective action can be taken. It is expected that this hazard may result in loss of data but not in destruction of other instruments.

We are not carrying any high pressure systems, explosive devices, or radioactive material. The philosophy adopted for further study was that the primary structure should not suffer catastrophic failure under crash loads. The following design criteria for structural members was discussed at a meeting at GSFC:

LOADS		STRUCTURE			
		PRIMARY		SECONDARY	
		Yield	Ultimate	Yield	Ultimate
NORMAL	Test	1.65	2.2	1.65	2.2
	Analy.	2	3	2	3
CRASH	Test	<1	1.0	<<1	<1.0
	Analy.	<1	1.5	<<1	<1

The idea is that since the package should operate in orbit one would test to normal launch and landing loads at the levels given but if a calculation was performed instead, the analytical load factors would be used. Under crash loading conditions one would not test the flight hardware and secondary structures could fail but the primary structures must not fail and cause a hazard.

We do not see any problem in complying with these requirements. The flight package has been tested to sounding rocket specs and successfully launched and recovered.

We would anticipate GSFC analyzing a structural model for crash load performance of the primary structure. The following preliminary analysis indicates that no significant safety hazard exists.

To verify our structural mounting, we have calculated the requirements on our mounting bolts. We used the safety factor formula on page 350 of Machinery's Handbook, 17th Edition, the Industrial Press, F = a X b X c X d.

a is the ratio of ultimate strength to the elastic limit.

b is a factor depending upon the character of the stress.

c is a factor depending upon the manner in which the load is applied.

d is a factor to take care of unknowns.

In our case, a is 2, b is 2 for a load which varies from 0 to max., c is 2 for a suddenly applied load, and we take d = 2 for safety. This gives us a safety factor of 16 as a design requirement.

We estimate our payload weight at 400 lbs. and assume an emergency landing load as 30 g. So our required load capability is SF X W X G = 16 X 400 X 30 = 192,000 lbs.

We plan to use 6 dowel pins of 1/4" diameter to provide dimensional reproducibility. The shear strength of each is 14,400 lbs. for a total of 86,400. Furthermore, our package will be mounted to the strongback with 24 ALLEN CAP SCREWS of size 3/8 - 24. The shear strength of cap screws as taken from the tables of ALLEN CAP SCREWS is 70% of tensile strength, or 10,430 lbs. per screw or 250,320 lbs. for 24 screws.

The capability of our package then is 250,320 plus 86,400 lbs. for screws and shear pins, a total of 336,720 lbs. for a shear load which is well beyond the required 192,000 lbs. In tension our package will sustain 24 X 14,900 = 357,600 lbs. which is also above the required maximum.

II c Aerobee Rocket Payload Acoustic Vibration Test

Payload History:

This payload consists of a far ultra-violet spectrograph and 4 filter photometers designed for absolute calibration of flux from early type stars. (See figure 1.) The spectrograph is comprised of an 8 inch telescope, an off axis far UV grating, and 5 windowless channeltron detectors. The filter photometers are standard EMI 6256B detectors with narrow band interference filters and optics in front. These photometers have been used on many past payloads. This particular payload was launched successfully aboard an Aerobee 200 on November 25, 1974 from White Sands Missile Range.

Acoustic Vibration Preparations:

Aside from the obvious question of whether or not this payload can survive this severe environment, an important factor is whether or not optical alignment can be preserved. Prior to the test the spectrograph was aligned using a beam collimator via auto collimation with an optical flat affixed to the body of the package. The payload optics focused the beam at the exit of the zero order monitor. The alignment was measured to an accuracy of ~ ±1.5 arc minutes. This corresponds to a bandpass of ~ 10 angstroms with respect to the spectrograph detectors.

The payload was assembled with previously flown detectors that were functional but no longer flight qualified due to high background noise and/or reduced photocathode response. Two filter photometers, two channeltrons and all detector and support electronics were subjected to the test.

Test Format:

This was the first time a rocket payload was exposed to an acoustic test. In order to derive as much information as possible from this test, the package was subjected to 3 levels of intensity below the actual required intensity of 154 DB. A detector or subsystem that fails at a low level of intensity would require considerably more design change than one that failed at a much higher level. The payload was tested with all system and detectors under power. Vital detector signals and electrical status were transmitted to the sounding rocket branch via the rocket instrumentation section attached to the rear of the payload. In all, 31 data and housekeeping signals were monitored and recorded. The package was supported horizontally in the chamber as shown in figure 8. Experiment power was provided by DC supplies located outside the chamber. Load current was continuously monitored for purposes of detecting any anomalies. The payload was visually monitored by TV, and a video recording was made. All test personnel with control and monitoring functions had their voice recorded along with the payload data.

The test was made using high pressure nitrogen as the driving force. 20 second runs were made at 145 DB, 148 DB, and 151 DB. Each level was twice the intensity of the previous level. This was followed by the required integrated average intensity of 154 DB for a period of 2 minutes.

Test Results:

The vibration ran with only one anomaly. Just into the level of 151 DB, the technician monitoring the DC supplies powering the experiment noticed a current fluctuation on the minus 12 volt supply and aborted the test. After a minute of investigation it was discovered that the AC line cord had wiggled out of the socket due to the vibration. The test was resumed at the 151 DB level and ran through completion with no further problems.

Following the test the chamber lights extinguished and the photomultiplier sensitivities were checked and compared with the data taken prior to the test. No change in sensitivity was noticed. Immediate visual inspection showed no damage to the structure. Aside from the power supply drop out, the oscillograph record of the 31 data channels indicated no anomalies. The post optical alignment check showed the instrument remained within the original ±1.5 arc minutes. The individual detectors were carefully inspected for any breakage. There was none. Both channeltrons remained functional. The electronics systems and structure were also carefully checked and no anomalies were discovered. Figure 9 shows the GSFC predicted shuttle internal acoustic levels. Figures 10 through 13 are the computer plots of the actual intensity versus frequency for each of the 4 levels. Due to the chamber characteristics it was not quite possible to achieve the desired intensity at the very low end of the spectrum.

The Space Astronomy Laboratory wishes to thank the General Electric Space Division for their valuable assistance in executing this test.

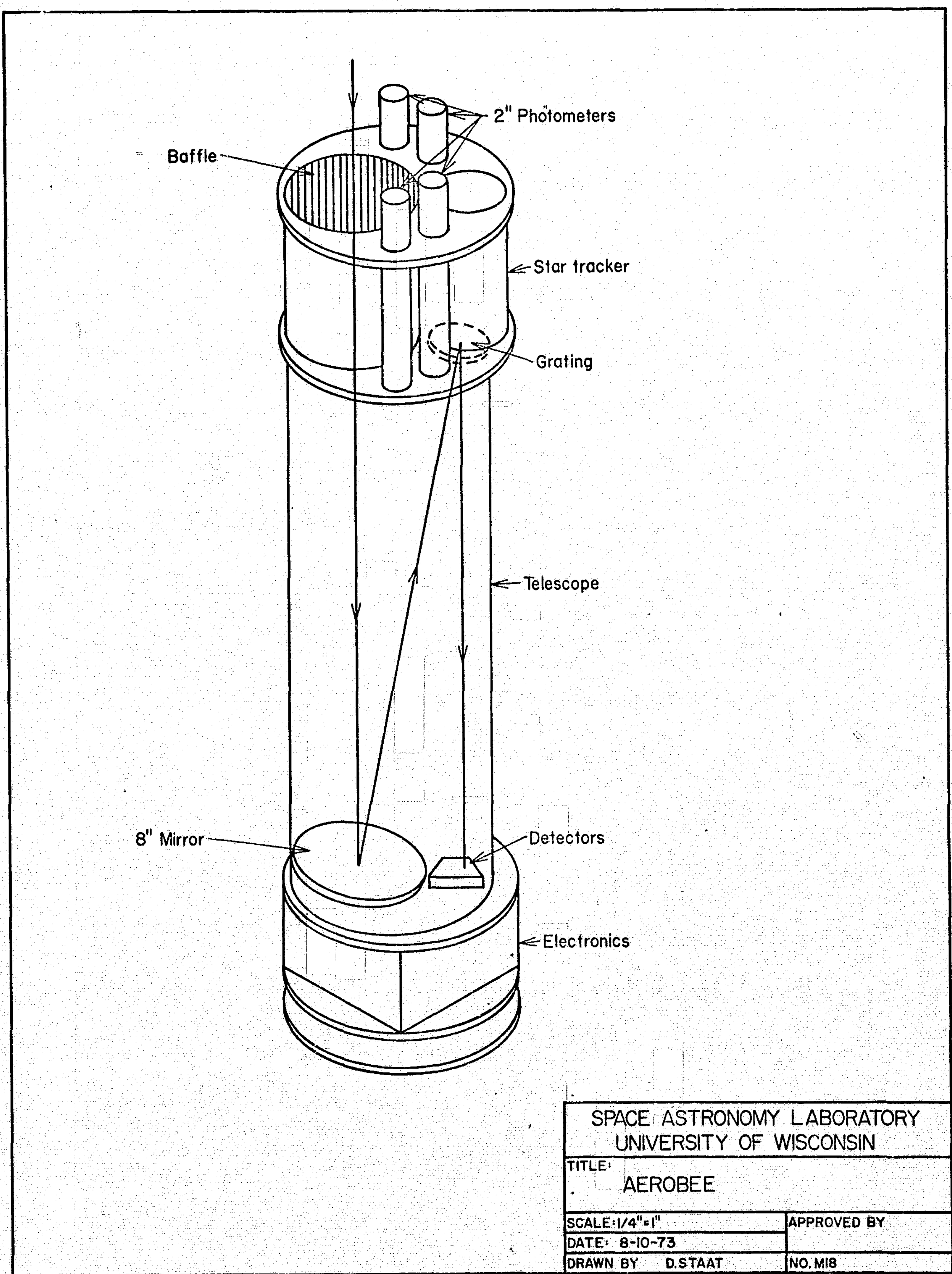

2" Photometers
Baffle
Star tracker
Grating
Telescope
8" Mirror
Detectors
Electronics
SPACE ASTRONOMY LABORATORY
UNIVERSITY OF WISCONSIN
TITLE: AEROBEE
SCALE: 1/4"=1"
DATE: 8-10-73
DRAWN BY D.STAAT
APPROVED BY
NO. M18

Figure 7

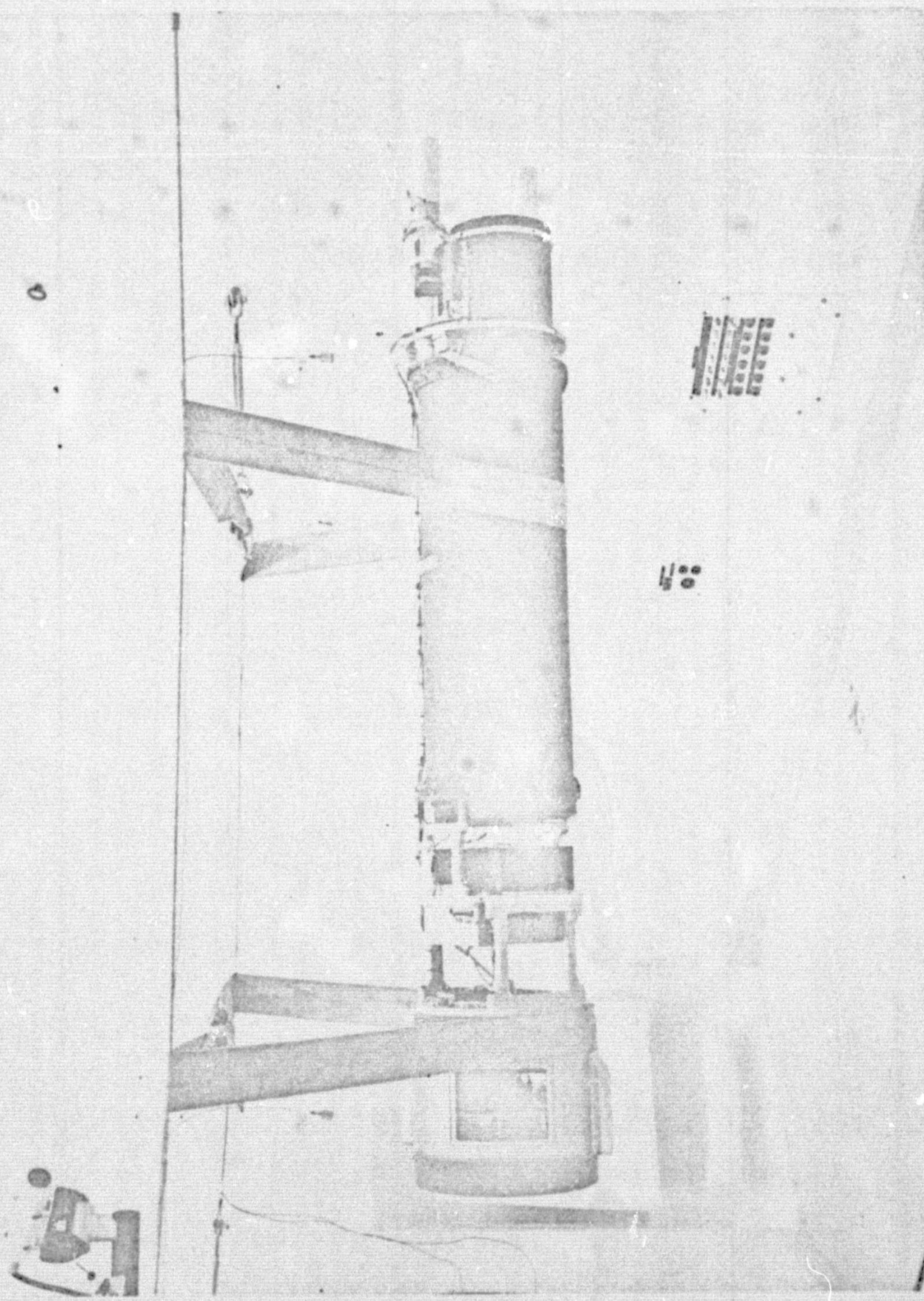


Figure 8

ORIGINAL PAGE IS
OF POOR QUALITY

COMPARISON OF SHUTTLE & DELTA ACOUSTICS (5/7/75)

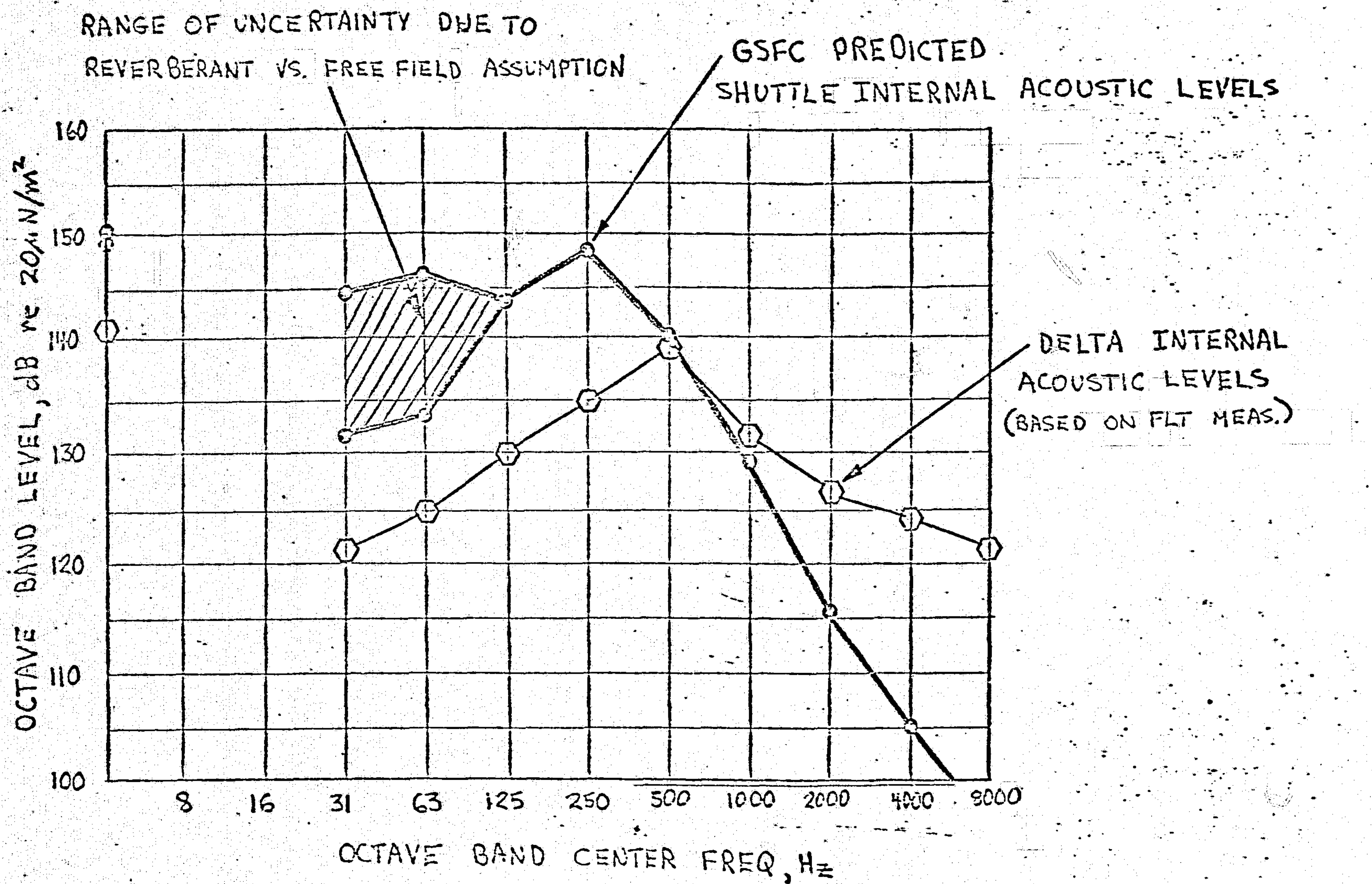


Figure 9

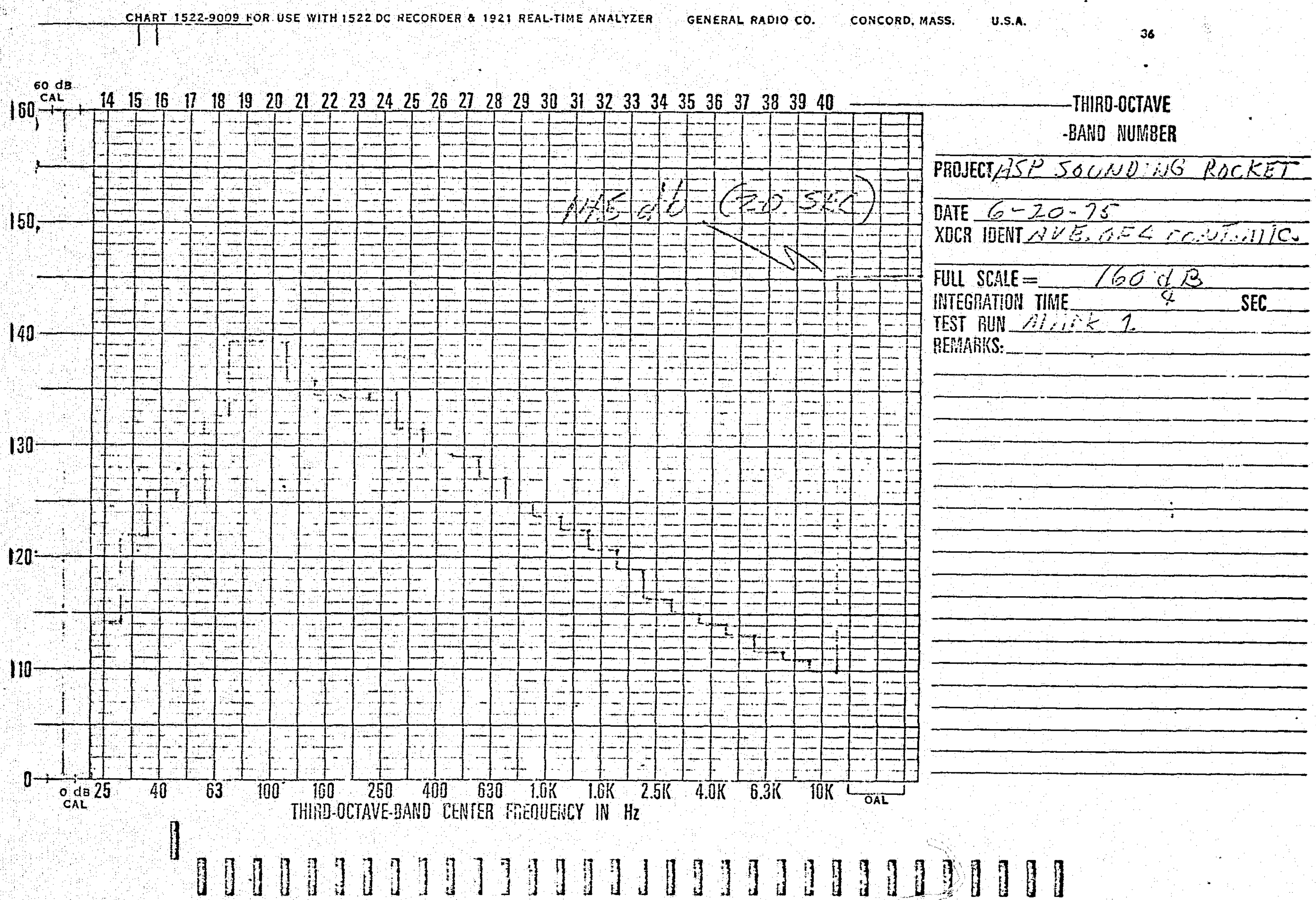


CHART 1522-9009 FOR USE WITH 1522 DC RECORDER & 1921 REAL-TIME ANALYZER GENERAL RADIO CO. CONCORD, MASS. U.S.A.
60 dB CAL
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
THIRD-OCTAVE -BAND NUMBER
160
150
140
130
120
110
0
0 dB CAL
25 40 63 100 160 250 400 630 1.0K 1.6K 2.5K 4.0K 6.3K 10K
OAL
THIRD-OCTAVE-BAND CENTER FREQUENCY IN Hz
PROJECT ASP SOUNDING ROCKET
DATE 6-20-75
FULL SCALE = 160 dB
INTEGRATION TIME 4 SEC
TEST RUN
REMARKS:

Figure 10

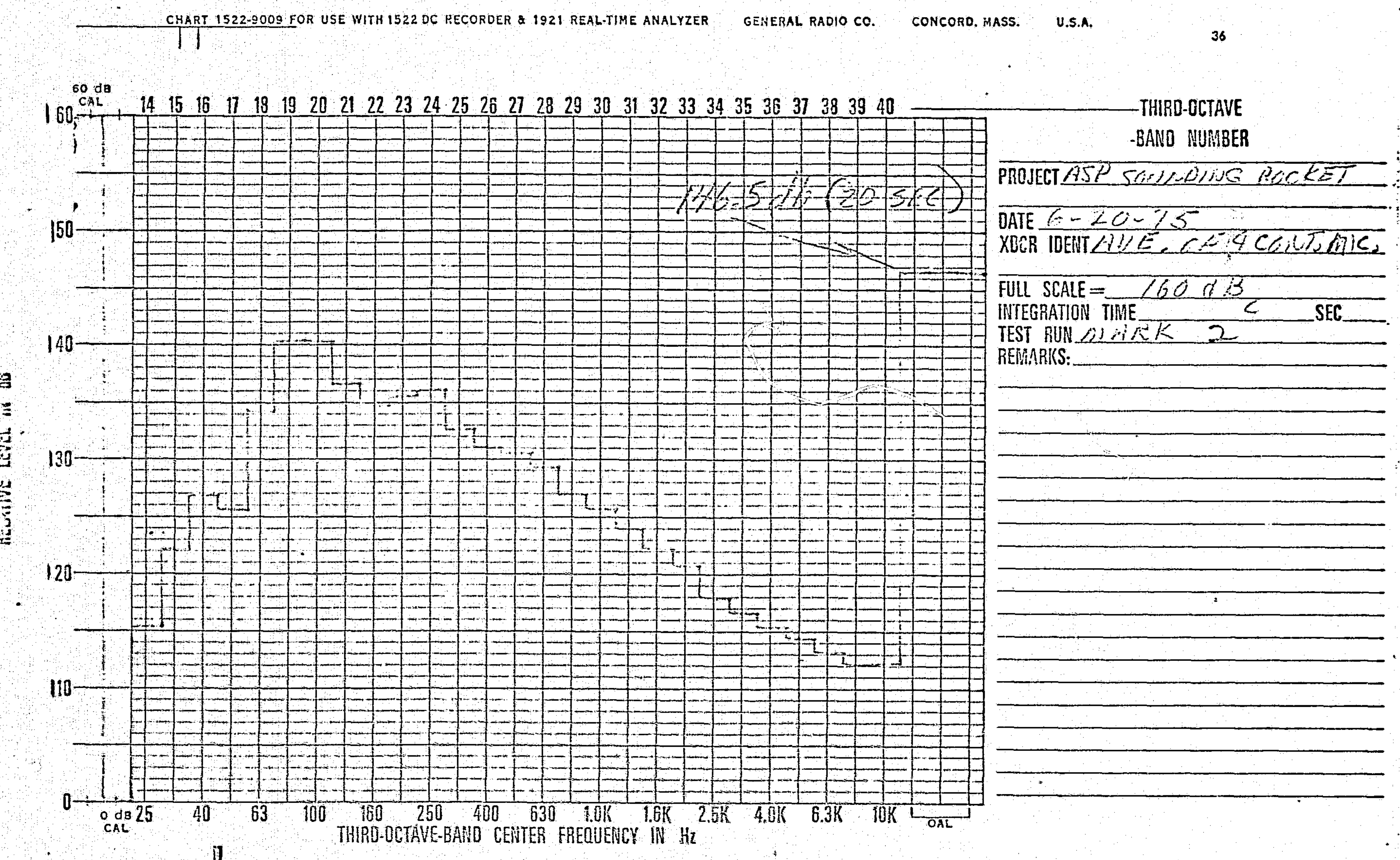


CHART 1522-9009 FOR USE WITH 1522 DC RECORDER & 1921 REAL-TIME ANALYZER
GENERAL RADIO CO.
CONCORD, MASS.
U.S.A.
60 dB CAL
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
THIRD-OCTAVE -BAND NUMBER
146.5 dB (20 SEC)
160
150
140
130
120
110
0
RELATIVE LEVEL IN dB
0 dB CAL
25 40 63 100 160 250 400 630 1.0K 1.6K 2.5K 4.0K 6.3K 10K
OAL
THIRD-OCTAVE-BAND CENTER FREQUENCY IN Hz
PROJECT ASP SOUNDING ROCKET
DATE 6-20-75
XDCR IDENT AVE. CH 9 CONT. MIC.
FULL SCALE = 160 dB
INTEGRATION TIME C SEC
TEST RUN MARK 2
REMARKS:

Figure 11

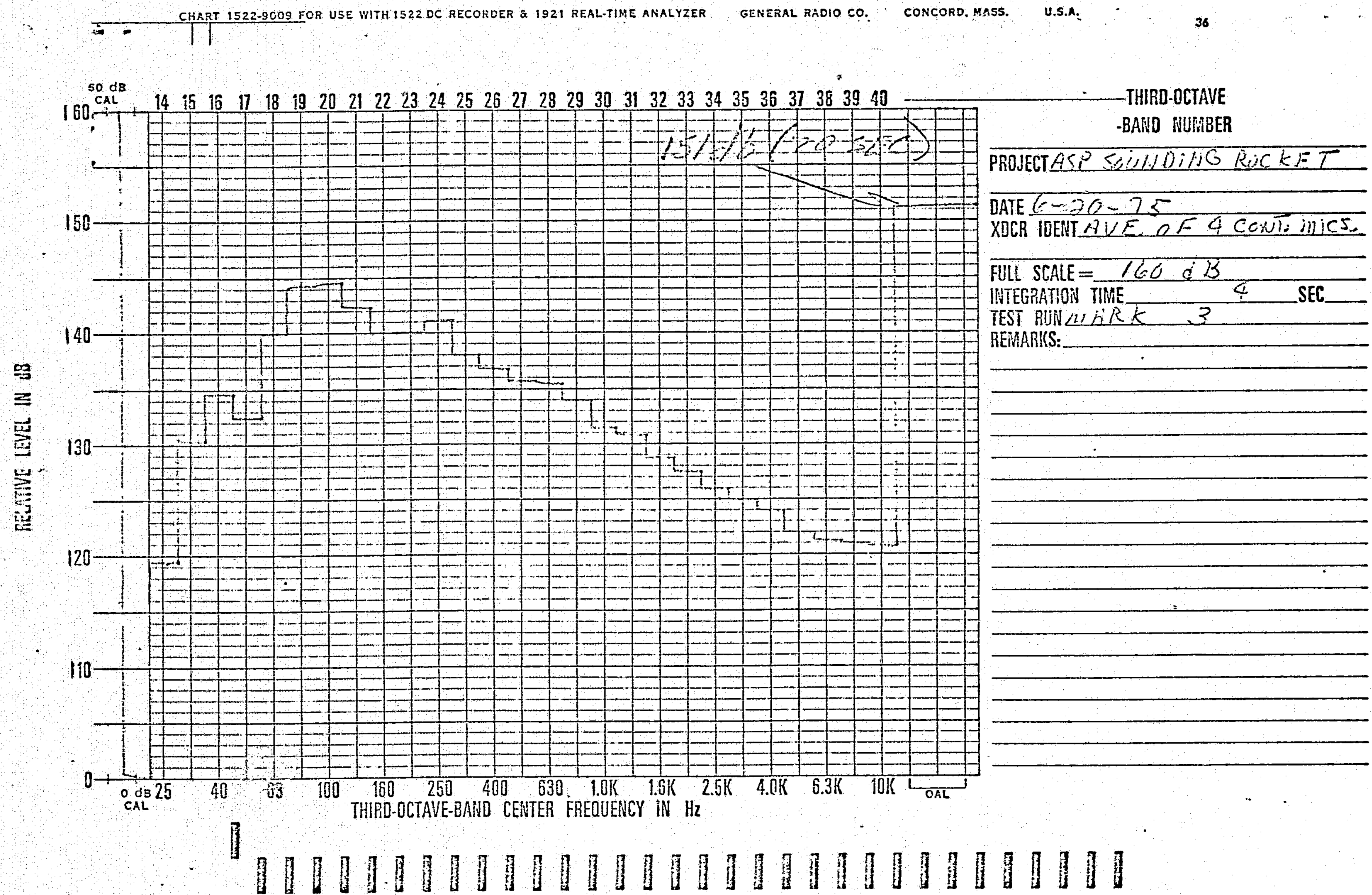
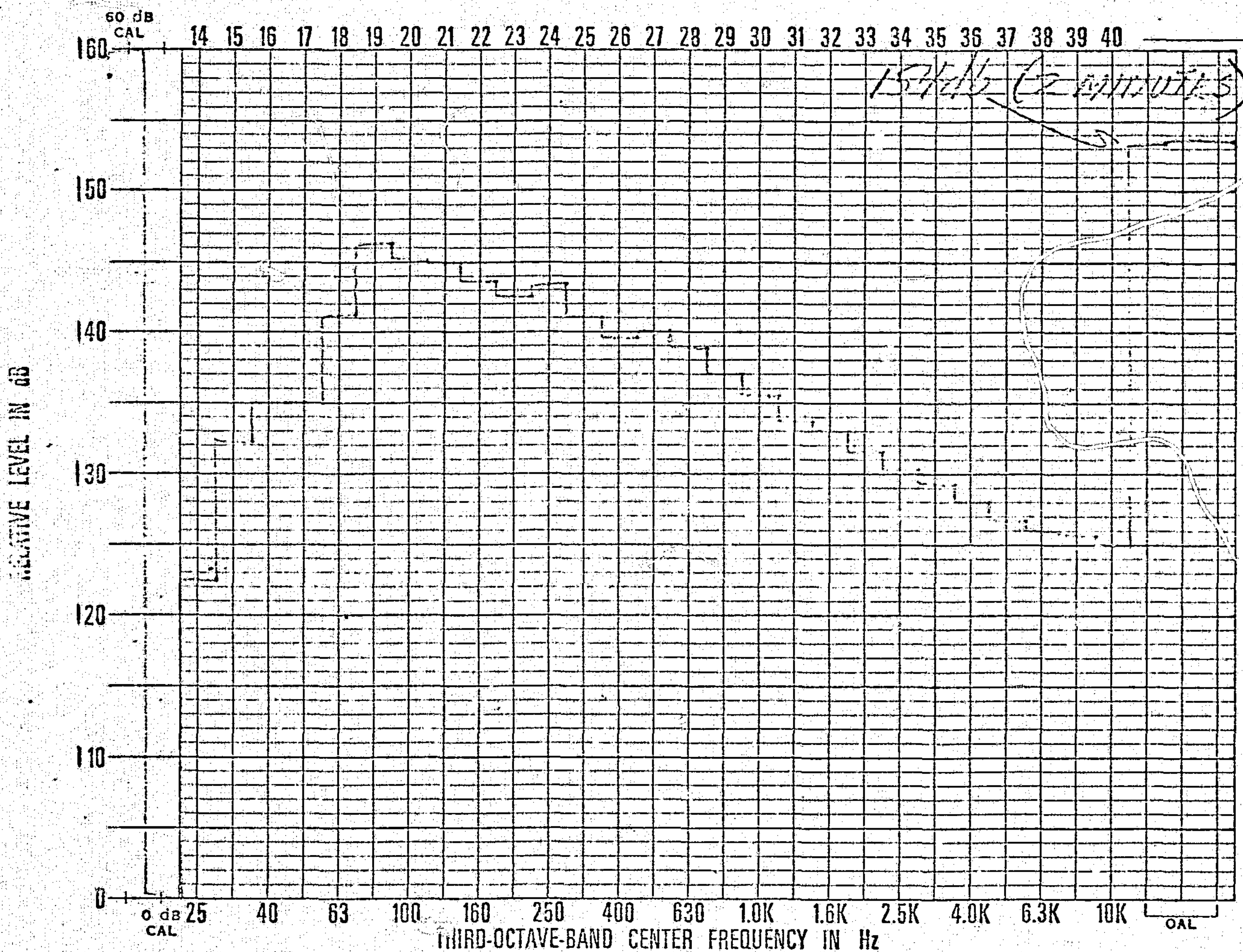


CHART 1522-9009 FOR USE WITH 1522 DC RECORDER & 1921 REAL-TIME ANALYZER GENERAL RADIO CO. CONCORD, MASS. U.S.A.
36
50 dB CAL
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
THIRD-OCTAVE -BAND NUMBER
151 dB (20 SEC)
PROJECT ASP SOUNDING ROCKET
DATE 6-20-75
XDCR IDENT AVE. OF 4 CONT. MICS.
FULL SCALE = 160 dB
INTEGRATION TIME 4 SEC
TEST RUN MARK 3
REMARKS:
160
150
140
130
120
110
0
RELATIVE LEVEL IN dB
0 dB CAL
25 40 63 100 160 250 400 630 1.0K 1.6K 2.5K 4.0K 6.3K 10K OAL
THIRD-OCTAVE-BAND CENTER FREQUENCY IN Hz

Figure 12

CHART 1522-9009 FOR USE WITH 1522 DC RECORDER & 1921 REAL-TIME ANALYZER GENERAL RADIO CO. CONCORD, MASS. U.S.A.



PROJECT ASP SOUNDING ROCKET

DATE 6-20-75

XDCR IDENT AVE. OF 4 CONT. MIC.

FULL SCALE = 160 dB

INTEGRATION TIME 4 SEC

TEST RUN MARK 4

REMARKS: BEGIN OF MARK 4 LEVEL

Figure 13

III OPERATIONS AND DATA HANDLING

III a Rationale

The purpose of this instrument is to establish a sequence of internally consistent photometric standards in the ultraviolet for use by other instruments. This sequence of standards will include UV bright stars for use by small instruments and fainter stars for use by larger instruments.

For the convenience of users of this sequence a network of about 40 standard stars will be established around the celestial sphere. For reasonably complete sky coverage two missions will be required - one in the spring or summer and one in the fall or winter. Internal consistency will be maintained among the stars observed during each mission by observing in a closed sequence so that the first star to be observed will also be the last. This sequence will be repeated twice during each mission. The program stars observed during different missions will be tied together by including an overlap of about 10 stars that each sequence will have in common.

III b Star Selection Criteria

The program stars will be carefully selected so that they will provide future user with accurate, internally consistent, unambiguous ultraviolet standards that are convenient to use. Accordingly we have established the following criteria to judge the acceptability of candidate stars.

(i) To insure an adequate ultraviolet continuum flux and to avoid stars with fluxes that change rapidly across the bandpasses, only stars with early spectral types are chosen. We have chosen, somewhat arbitrarily, B8 as the latest spectral type for this program.

(ii) Program stars are chosen to have as large a range of apparent fluxes as possible in order to be suitable for both small and large instruments. The limit on the faintest stars to be observed will probably be determined by the capabilities of zero order image star tracker (ZOIST). For the primary list of program stars we are assuming that the ZOIST will be able to track any star with a V magnitude of 6.0 or brighter. We will establish a supplementary list of fainter stars for use in the event that the ZOIST exceeds this anticipated performance.

(iii) The network was planned to have full sky coverage for the convenience of observers and to avoid having too many standards occulted by the sun, moon, and earth at any time. We intend to have, as closely as possible, one star for every 2 hours in right ascension near the celestial equator and one star for every 4 hours of right ascension at declinations $+60^{\circ}$ and -60°. In addition some stars will be chosen at intermediate declinations.

(iv) Stars with known variability were rejected. In addition stars with emission line spectra were rejected since these active stars may vary.

(v) Stars with bright companions were rejected in order to avoid error when instruments of different spatial resolution are used. This rejection occurred if a secondary or a field star nearer than 10 arc minutes contributed more than 1 percent of the combined light in the visual.

(vi) To increase the usefulness of these standards we attempt to include current ultraviolet and visual standards such as those established by Oke (1964) and Bless, Code, and Fairchild (1975). In addition we intend to include stars previously observed by satellite observatories in order to help tie together existing ultraviolet observations.

Further details of these criteria are given in Appendix A.

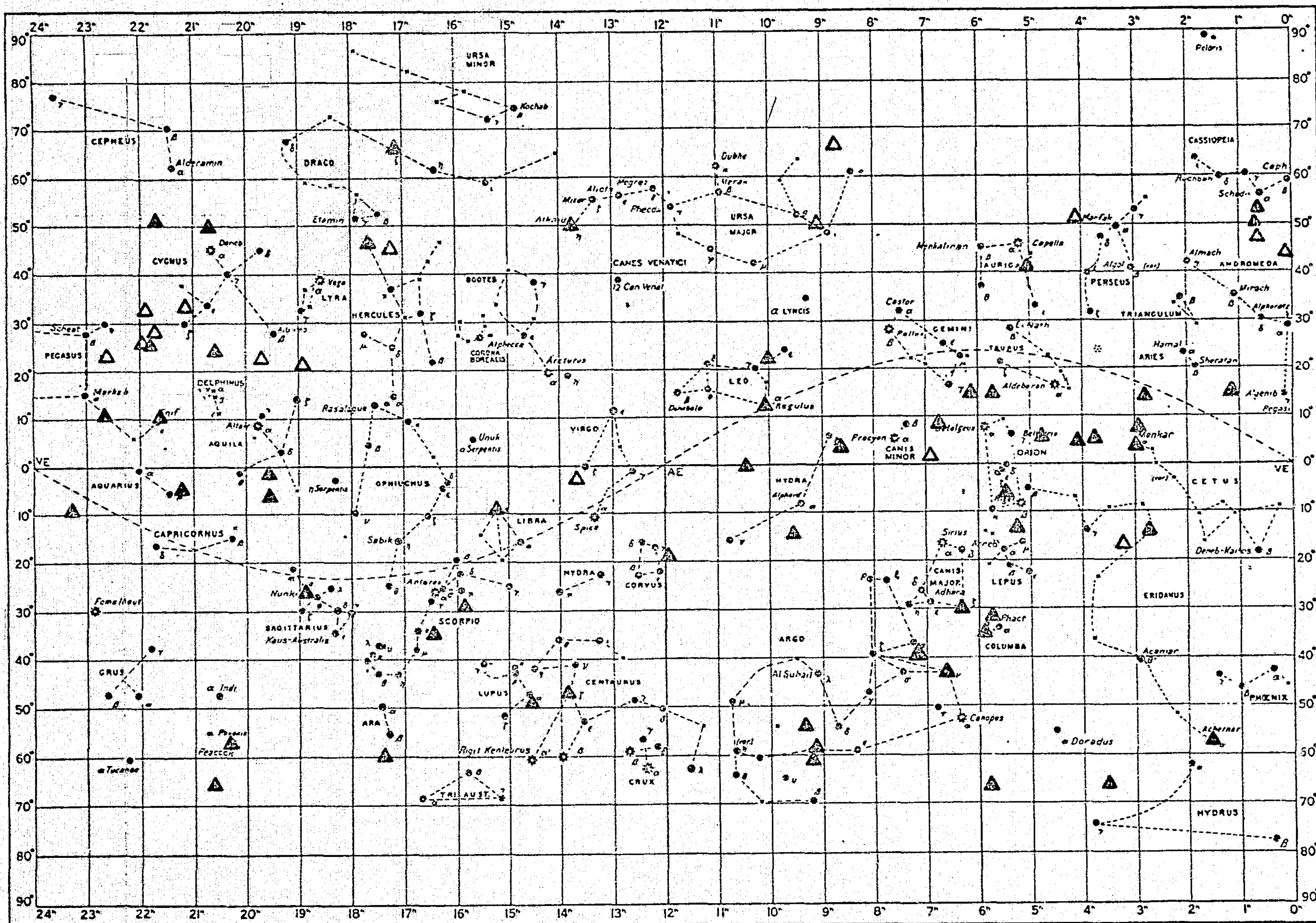
Fifty five stars satisfying these criteria are listed in table 1, Appendix A. The network of program stars will be chosen from among these and other stars after the capabilities of the ZOIST and SIPS have been better determined and after the dates and orbits of the mission have been determined.

An additional 16 stars fainter than V magnitude 6.0 are listed (table 2, Appendix A) to supplement the brighter sequence in the event that guidance on faint targets proves possible. The faint stars listed here are more likely to be undetected variables and to have bright companions than the stars in table 1, Appendix A. Neither the list in table 1 nor the one in table 2 include all stars which satisfy the selection criteria. Neither list is intended to limit the choice of standards, but rather to give examples of the types of stars under consideration.

The locations in the sky of the stars on these two lists are shown in figure 14.

III c <u>Normal Operations</u>

Each Wisconsin Mission Plan (WMP) will consist of the observation of about 25 program stars and appropriate sky light measurements during the night portion of the orbit. Each star will be observed twice during a given mission. An average of two stars and corresponding sky positions will be observed during each orbital night. The actual amount of time spent observing each star will of course depend upon its magnitude. The desired sequence of pointings, search patterns and data acquisition cycles will be pre-programmed and executed by an on-board CDMS computer. The programing will be sufficiently flexible to permit changes to be made during the mission if necessary. Internal consistency will be maintained primarily by observing in a closed sequence and by occasional observations of the field calibration lamp.



A POSSIBLE STANDARDS

△ SUPPLEMENTARY FAINT STARS

FIGURE 14. LOCATIONS OF POSSIBLE UV STANDARD STARS

During each mission there will be a period of experiment preparation, turn on, and checkout during which the assistance of the Payload Specialist (PS) via a dedicated control panel will be required. During this phase real time transmission of experiment data to the control center will be required to permit monitoring of successful completion of each step.

Experiment and housekeeping data will be stored unprocessed in the CDMS mass memory or on tape to be transmitted periodically to the control center for monitoring of possible malfunctions. The total maximum number of bits of data per orbital night will not exceed 10 Megabits. Housekeeping data will include the output of sensors within the experiment package as well as such pertinent Spacelab status data as GMT of SIPS maneuvers, tracker error signals, thruster firings, and shuttle inertial reference errors. When the experiment is on, experiment housekeeping data will be monitored continuously by the CDMS to take corrective action in event of hazards such as the failure of a high voltage power supply.

In the detailed discussions of normal operations below we assume that once the Wisconsin Mission Plan is begun experiment operation will be continuous (at night) until the WMP is completed. We make this assumption because continuous operation is simplest to plan and because such operation will require the least number of orbital nights for completion. Moreover, if because of overall mission requirements our operations are split into several segments, each segment will resemble, in miniature, the continuous WMP. This will be discussed more fully in Section III d, Abnormal and Optional Operations.

Each WMP will require 28 to 42 orbital nights (2 to 3 days) for completion.

III c, i <u>Turn On and Checkout</u>

The experiment preparation, turn on, and checkout phases are designed to permit a safe beginning of observations and to permit in-orbit adjustment of operations to insure a successful mission. Most of this work will be performed by the PS and monitored by the experimenter's staff at the control center. Early preparation will include the opening of the cargo bay, the deployment of the SIPS, and the opening of the SIPS sunshade to permit outgassing and establishment of thermal equilibrium. The schedule for these operations are to be determined by NASA. Once Spacelab and SIPS outgassing has proceeded to a sufficient extent (a length of time to be determined), the PS will retract the experiment valve/calibration mirror (VCM) by remote command to permit outgassing and to permit the interior of the experiment to reach equilibrium with the environment. During this procedure the experiment vacuum sensor should be monitored to be certain that Spacelab outgassing has proceeded sufficiently.

The first Wisconsin orbit will begin with experiment turn on by the PS. If this is to occur during the day portion of the orbit the SIPS sunshade must be closed first to eliminate stray light. Using the experimenter furnished control panel, the manual commanding of the payload will begin with turning on the main +28 volt circuit breaker. This provides power to the payload control logic and eventually to the detector electronics. Then the PS will proceed to activate sequentially the individual subsystems and detectors. Each step will be monitored by the CDMS for proper status. Status information will also appear on the control panel and be telemetered to the control center. Following a successful activation of all subsystems and shortly before the onset of orbital night the VCM will be re-inserted into the optical path and the field calibration lamp turned on to check detector response. Shortly after night begins the field calibration lamp will be turned off, the VCM will be retracted, the SIPS sunshade will be opened, and the SIPS will be maneuvered to the first target star. It is anticipated that warpages of the shuttle in orbit and misalignments of the shuttle inertial reference, the SIPS, and the Wisconsin instrument will make a raster search pattern necessary in order to locate the star. The star search will be executed by a subroutine within the CDMS computer. The first target star will be chosen to have no bright neighbors so that the acquisition of a star by the ZOIST during the search will unambiguously locate the instrument in the celestial coordinate system. The measured misalignment between the shuttle coordinate system and the celestial coordinate system can then be entered as an offset correction to the observing program. The first measurements of the star will be obtained before the end of night.

During the daylight portion of the second Wisconsin orbit it may be feasible to undertake one of the optional tests of the instrument. One test that might be executed at this time is the scattered light experiment. This will be discussed in Section III d, Abnormal and Optional Operations.

Assuming all is well at this stage, the first Wisconsin Observing Plan (WOP) will be executed during the night portion of the second Wisconsin orbit. This WOP will begin with a measurement of the field calibration lamp and then continue to measurements of the first stars. The PS should monitor whether the ZOIST acquires its guide stars at the expected times after the execution of the first sequence of SIPS maneuvers.

III c, ii Observational Techniques

To maintain flexibility in operations and to simplify planning, the WMP is divided into preprogrammed Wisconsin Observing Plans (WOP). Each WOP consists of a sequence of commands necessary to carry out observations during a single orbital night. These commands include all that are necessary for SIPS maneuvers (slews), ZOIST offsets, and data integrations to observe from one to four stars and an equal number of sky fields. There will be one WOP for each orbit of observations. Each WOP is assigned an identification code and loaded into the experiment computer prior to launch. Normally they would be executed in a predetermined order by the WMP program. But any WOP could be called up out of sequence if circumstances warrant and if restraints of shuttle attitude and adjacent payloads permit. This call up can be made by the PS or by a command load from ground by giving the computer an ID code and a GMT or Spacelab time to start execution. In order to permit execution of the WOP in this manner and to allow for possible problems of misalignment with the celestial coordinate system, the commands in a WOP will not be given an absolute execution time. The commands will have relative execution times that will be initialized by the time at which execution is started and by the time at which the ZOIST acquires its guide star.

The number of stars per WOP will vary because the available observing time depends upon the celestial coordinates of the sun and the orbital parameters of the shuttle and because the total integration time on an individual star will depend upon its anticipated ultraviolet flux.

An important feature of the observing sequence on an individual star is that episodes of star measurement will be sandwiched between episodes of sky measurement. This procedure will permit an accurate subtraction of counts due to sky light and of dark counts from the stellar data. Every star observation will begin and end with an episode of sky measurement and will include at least two episodes of star measurement. See table 2 for an example. The length of each measurement episode will be many times the 100 millisecond counter integration time (see Section I e, UW ASP Electronics) in order to monitor the time dependence of sky and dark. No measurement episode will exceed one minute because the dark counts and the sky light (primarily solar hydrogen Lyman alpha scattered in the geocorona) will change in that time scale. For each star the total time of sky measurement will about equal the total time of star measurement. During slews experiment and housekeeping data will be recorded in order to monitor conditions. Therefore the data frame rate will be constant during the orbital night regardless of the nature, magnitudes, and number of targets.

For some observations a specific shuttle attitude or a SIPS roll motion will be necessary to avoid bright field stars along the axis of dispersion of the spectrograph.

III c, iii <u>Experiment Commands</u>

The redundant procedure of Command Enable and Execute described in Section III d of the Preliminary Report provides protection against accidental and possibly damaging commands. Commands can be directed to the experiment by the computer system, by manual entry by the PS, or by ground load during real time operations. The PS will be able to switch from one commanding mode to another using the experimenter furnished control panel.

III c, iv <u>Calibration Measurements</u>

Observations of the field calibration lamp during orbital operations are required to determine instrumental sensitivity. Six such measurements should be adequate if experiment operation is continuous during the WMP. The first calibration

Table 2. Sample Wisconsin Observing Plan : W02

EPISODE	RELATIVE EXECUTION TIME (seconds)	SIPS MODE	ZOIST MODE	TARGET	INTEGRATION TIME (seconds)
A	0	SLEW	CENTER	133 Tau	-
B	72	FINE POINTING	OFFSET	SKY 1	47
C	125	FINE POINTING	CENTER	133 Tau	52
B	183	FINE POINTING	OFFSET	SKY 1	47
C	236	FINE POINTING	CENTER	133 Tau	52
B	294	FINE POINTING	OFFSET	SKY 1	47
---- REPEAT EPISODES C AND B TEN MORE TIMES ----					
D	1457	SLEW	CENTER	υ Ori	-
E	1559	FINE POINTING	OFFSET	SKY 2	33
F	1598	FINE POINTING	CENTER	υ Ori	44
E	1648	FINE POINTING	OFFSET	SKY 2	33
F	1687	FINE POINTING	CENTER	υ Ori	44
E	1737	FINE POINTING	OFFSET	SKY 2	33
F	1776	FINE POINTING	CENTER	υ Ori	44
E	1826	FINE POINTING	OFFSET	SKY 2	33
G	1865			END	

SKY 1 : offset from 133 Tau

SKY 2 : offset from υ Ori

measurement will be made during the check out phase and will provide a test that the detectors are functioning properly. The second measurement will occur during the first WOP. The remaining measurements will be made after 1/4, 1/2, 3/4, and 4/4 of the WMP has been completed. During each calibration measurement dark count data will be obtained by sandwiching episodes with the calibration lamp on between episodes with the lamp off.

III c, v <u>Housekeeping Data and Failure Monitoring</u>

Pertinent experiment and Spacelab status information will be stored in addition to the detector signals. These housekeeping data include the following:

- All LV and HV power supply levels.
- Battery voltages.
- Vacuum condition.
- PM amplifier offsets/background.
- Calibration lamp current.
- VCM status.
- ZOIST error signals.
- GMT of SIPS maneuvers.
- Thruster firings.
- Shuttle inertial reference errors.

The housekeeping data will be monitored continuously by the CDMS in order to take immediate corrective action in the event of hazardous conditions. For example, since a power supply failure might be a hazard to this and other experiments, the condition of the power supplies would be monitored and an automatic shutdown of the experiment commanded if a failure is detected. Other failures - such as failure of the star tracker - might not be hazardous. Corrective action for some such failures might require human observance and decisions. If so, the problem would be noted by the PS in real-time or by the experimenter's ground crew from playback of telemetered data.

III c, vi Ground Operations Equipment and Staff

A GOE and an experimenter's staff is necessary primarily to monitor the condition of the experiment and, if necessary, to make decisions regarding corrective actions. We assume that NASA will furnish general purpose GOE that can be easily reprogrammed to carry out the functions of command generation and data display for successive users. We assume further that users will communicate with the GOE using a simple and widely used language such as FORTH so that little time and effort will have to be spent in learning new languages. We expect to receive experiment data at the control center every one or two orbits. The telemetry of data is especially important during the sleep period of the PS. A greater delay between acquisition and examination of data will result in a potentially greater loss of data in the event of a malfunction. A three man experimenter's staff is large enough to monitor the experiment 24 hours a day during operations and to permit consultations and task-sharing or task-splitting if a malfunction forces reprogramming.

III c, vii Advance Planning

When preliminary orbital elements have been decided upon for the mission, advance planning programs can be run at Madison. These programs will use subroutines from the HARUSPEX program (Heacox 1970), used for OAO-2 WEP operations, to provide important information such as the time available to observe each star, the times when the Spacelab will be in the South Atlantic Anomaly, slewing distances between target stars, and the location of the moon. With this information available, we can begin detailed planning of the primary and contingency observing programs. This second stage of planning will require NASA coordination of shuttle attitude demands by the different experimenters. An example of a possible WMP is given in Appendix A.

III c, viii Miscellaneous

This experiment will not obtain meaningful data in the South Atlantic Anomaly (SAA). Although the flux of energetic protons decreases at low altitudes (Stassinopoulos 1970), these fluxes will be sufficient to swamp our experiment at the altitudes of Shuttle operation. Therefore, the orbital elements should be chosen so that orbiter night is not in the SAA.

The observation of very bright stars may result in loss of photoevents due to near coincidence (counter dead time). A correction for dead time to be made to the measurements of bright stars will be determined during the laboratory calibration before and after launch.

III d Abnormal and Optional Operations

Although we anticipate that not all malfunctions and unusual circumstances will be foreseen, we intend to formulate contingency plans for as many of these occurrences as we can. This preparedness will enable us to have the quick response necessary for such short orbital missions. Furthermore, in this examination we will evaluate the likelihood of a malfunction causing a failure of our portion of the mission. Some of the possible malfunctions are named and briefly discussed below. Some operations will be planned for the first mission primarily to extend our knowledge of the capabilities of the instrument to improve planning for the second mission and to provide information to simplify data reduction. These operations are called "optional" since some of them will require the participation of the PS and they will proceed at his option. These operations also are named and briefly discussed below.

III d, i Variable Misalignment Offsets

It is possible that the differences between the spacecraft centered coordinate system and the celestial coordinate system will be dependent upon such factors as the attitude of the shuttle, the SIPS altitude and azimuth, or the length of time since launch. If so, the ZOIST may fail to acquire its star at the commanded pointing. In this event a subroutine in the WMP will automatically begin an ever-widening search pattern. If the offsets are varying slowly, it may be sufficient to use the offsets determined empirically from the previous star to acquire the target star. If the variations in the offsets are large and random the search pattern might cover a large area of the sky and be very time consuming. In this case it would be necessary to change the WMP so that the target stars will be the brightest objects in a region much larger than the probable search region and so that more time will be allowed for maneuvering and less time for stellar measurements. This contingency WMP would be prepared in advance of launch.

III d, ii <u>Power Supply Failure</u>

A power supply which failed before operations began would be detected at turn on by the PS and the experimenter. A power supply which failed during operations would be detected by the CDMS computer and would be automatically shut down. In addition a warning indicator would be set. The redundancy in power supplies insures that data will be obtained in some wavelength intervals in spite of a power supply failure.

III d, iii <u>Detector Failure</u>

The detectors are unlikely to fail during normal operations. A failure which occurred before operations began would be detected during turn on. Because of the redundancy of detectors the loss of a detector would result in the loss of data from only one wavelength interval.

III d, iv Failure of the VCM to Retract

The failure of the VCM to retract after a calibration lamp measurement might cause a potential hazard to this experiment. With the VCM in its sealed position any outgassing within the experiment would accumulate and cause HV arcing. Therefore, the CDMS computer should monitor the vacuum condition sensor within this experiment and perform an automatic shutdown in the event that a gas pressure of 10^{-5} torr is exceeded. Even if no outgassing occurs, the sealed condition of the VCM would appear in the housekeeping data and a warning light on the experimenter furnished control panel would be triggered. If the VCM moved from the sealed position but failed to retract fully, its condition would be noted as a continual failure of the star tracker to acquire its guide star. It may be possible for the PS to release the VCM by entering repeated commands to retract on the control panel. If it is impossible to retract the mirror in orbit all of the remaining WMP will be lost. In that case the VCM should be sealed if possible and the experiment shut down.

III d, v Failure of the Zero Order Image Star Tracker

If the alignment between the spacecraft centered coordinate system and the celestial coordinate system is accurately known and repeatable it will be possible to complete the WMP in spite of a failure of the ZOIST. Since the two-inch photometers do not require as accurate pointing as the spectrometer, they might provide good data even with slightly worse alignment. Misalignment offsets could be determined even after the ZOIST failed by using the output of the detectors in the experiment to signal the presence of the target star within the field of view.

III d,vi Discontinuous Observing Runs

Discontinuous observing runs may be required for reasons of shuttle attitude, operation of other experiments, or occurrence of orbital night during the SAA due to a badly timed launch. In normal circumstances if the gap(s) in observations extend for only a small number of orbits we anticipate no problems in leaving this instrument powered up. However, if the gap(s) are long or if the operation of other experiments might result in a situation hazardous to this experiment then the experiment must be shut down during the gap. When our observations resume, the experiment must be turned on and checked out as detailed in Section III c, i. During such discontinuous operation, each segment of the WMP will be a closed loop that starts and ends on the same star. In addition for consistency each loop must contain some overlap with stars observed in other loops. Therefore, if our experiment must be turned off and on, additional observing time will be required for check out and for assuring adequate internal consistency.

III d, vii <u>Scattered Light Testing</u>

To determine whether daylight observations are practical with this instrument, the following testing procedure would be used. First the SIPS would be positioned at a Beta angle predicted to be safe for day observing. Second, during daylight, the PS would open the SIPS sunshade in steps while the experimenter monitors the detector signals to be sure they do not exceed the danger level. Real-time telemetry and a voice link between the PS and the experimenter will be required. If light levels are satisfactory, the SIPS will be slewed by joy stick to higher Beta angles while the detectors are monitored for variations. If scattered light levels prove to be a problem before the maximum predicted safe Beta angle is reached, the SIPS sunshade would be closed to avoid damage to the experiment.

III d, viii <u>In-Orbit Star Tracker Testing</u>

The sensitivity of the ZOIST will be known before launch from laboratory tests. In-orbit testing of the ZOIST on borderline stars will determine whether changes have occurred between the laboratory tests and the orbital operations. This would be done simply by pointing the experiment in turn towards each star in a sequence expected to be marginally detectable by the ZOIST and noting whether the star tracker mechanism can lock on it.

III d, ix <u>Other Experiment Testing</u>

The following tests would be useful for data reduction and could be performed without PS participation:

- Measurement of the exact alignment of the photometers and the spectrometer relative to the ZOIST.
- Measurement of the attenuation of light by the collimator by offsetting from the target star along the direction of the dispersion of the grating.
- Measurement of the intensity of star light scattered within the instrument at varied offsets perpendicular to the direction of the dispersion.
- Measurement of the response of the instrument to particle fluxes in the SAA and near the vicinity of the earth's magnetic poles.

III d, x <u>Engineering Flight</u>

If this instrument is used on an engineering flight(s), many of the optional tests can be accomplished then. The information thus obtained will help to formulate improved methods of operation for later flights.

III e <u>Data Analysis</u>

Data analysis can be divided into quick look analysis and detailed analysis. Both types of analysis will require a computer program to read the raw data tapes and interpret them to the user in terms of the signals output by the various detectors and housekeeping sensors.

III e, i <u>Quick Look Analysis</u>

The primary function of quick look analysis is to monitor the data while the flight is in progress to ascertain that no malfunctions are occurring. The examination of housekeeping data will be particularly important during this phase. The detector data will also be useful but they need not be analyzed as rigorously as in the detailed analysis. It will be adequate to average the stellar signal from each detector and compare it with the response predicted on the basis of the pre-launch calibration and the star's spectral type, magnitude, and B-V color.

III e, ii <u>Detailed Analysis</u>

The purpose of the detailed analysis is to produce accurate ultraviolet fluxes for each of the standard stars. To do this it is necessary to discard bad data, to remove the dark counts and the sky light, and to scale the measurements according to the time-dependent sensitivity of each detector. Data could be discarded if the housekeeping status exceeds certain limits or if parity errors are found. A search for gaps in the time sequence of data would be made. Next, corrections for counter dead time would be made. Then, for each sky position a smooth curve would be fit to the signal from the episodes of measurement obtained during a single orbital night. The interpolated signal would provide combined sky and dark counts to be subtracted from the corresponding stellar measurements. An additional correction may be necessary for star light scattered within the instrument. Next, a time-dependent sensitivity function would be determined for each detector using the pairs of stellar observations and the calibration lamp measurements. From these sensitivity functions and the stellar measurements we can determine accurate relative fluxes. The absolute fluxes will be determined by comparison of the response of the detectors to the field calibration lamp and to the synchrotron calibration source before and after both flights.

III f <u>Complementary Operations with Other Experimenters</u>

We make a few comments here on the benefits and possible difficulties involved in sharing a SIPS with other types of instruments.

III f, i <u>A Solar Experiment</u>

Since the efficient use of time in space would be increased by sharing a SIPS with an experiment that used the daylight portion of our orbits, a solar experiment seems to be a natural complement to the Wisconsin instrument. However, there will be some conflict over shuttle attitude if it is necessary for the cargo bay to face the sun during the day. Moreover, if the operation of the other experiment causes the Wisconsin instrument to be pointed directly at the sun, the SIPS sunshade should completely eliminate light or the instrument should be shut off to avoid damage.

III f, ii <u>A Stellar Experiment</u>

Although another stellar experiment would compete for the same observing time, there may be some advantage in simultaneous observations, especially of variable stars. Our experiment could provide accurate continuum temperatures to complement the results of spectroscopy. However, it is possible that the misalignment between the optical axes of the two experiments would be too large to permit simultaneous observations of the same source.

III f, iii <u>A High-Energy Experiment</u>

Although the ZOIST may be sufficiently sensitive to track a few X-ray sources, most sources are too faint. Optical misalignment could also prevent simultaneous observations with this instrument.

III f, iv An Earth Resources Experiment

Such an experiment would use the daylight portion of the Wisconsin orbits. Therefore, time sharing with such an experiment would result in the efficient use of time in space. Moreover, maneuvers of the shuttle between day and night would be small or unnecessary since an attitude taken to view the earth during the day will probably be good for viewing the stars at night.

IV PROGRAMMING REQUIREMENTS

Computer programming for a small payload for shuttle use will be a more significant effort than that required for a sounding rocket flight and can be broken into the following tasks:

a. Programming a small spacelab simulator built by Wisconsin (this might be necessary for a rocket also).

b. Programming the spacelab simulator (GSE) furnished by GSFC for use in integration and functional testing.

c. Preparing observing plans and detailed command sequences for a flight.

d. Programming a "quick-look" analysis and display for operations at the control center (GOE) furnished by GSFC.

e. Data reduction programming at Wisconsin (also necessary for a rocket shot).

We feel that these tasks can be accomplished in six man months on our part with the assumption that a programming language such as FORTH is available for items, a, b, d, and e. Also considerable NASA aid will be needed in item c, as well as the effort to furnish the user with FORTH on the machines to be used in items b, c, and d.

IV a We discussed a Wisconsin built simulator in the Preliminary Report. This would be constructed by adding appropriate RAU simulator hardware to an existing Varian 520I minicomputer to minimize cost while retaining the desired flexibility. Since we have already brought FORTH up to our PDP-8, we envision little difficulty in doing so for the 520I. Test programs will then be written in FORTH by Wisconsin personnel.

IV b Programming of the GSE for testing at NASA will be quite simple for us because the routines (words) developed for phase IV a at Wisconsin will be directly transferable to the Sigma 5 GSE provided that NASA furnished FORTH on that machine. Implementation of FORTH could be done in cooperation with KPNO or Wisconsin or can be purchased quite economically for the company, FORTH, Inc. This company is in the business of providing FORTH to any user. They are uniquely capable in this area since the owners of the company are the persons that developed FORTH for the NRAO originally. We strongly recommend this approach and are assuming it in our cost estimates.

IV c In preparing observing plans and on-board computer command sequences, use will be made of GSFC furnished programs. We have already done similar things on OAO and can aid in this, but the major task will be a NASA function. This whole area is, at present, not well defined for small astronomy payloads and will require cooperation between NASA and ESRO in program design. FORTH may be an aid in this as well, particularly for the on-board processor.

IV d GSFC will provide experimenter stations in the control center that can be used for a "quick-look" at each experimenters data on a real-time or nearly real-time basis. In order to best perform this function during flight (and also during simulation), the experimenter should be able to provide the programming. Again we see this as an area where FORTH will allow a considerable cost saving and many previously used words will be available. We are assuming that GSFC will provide FORTH on whatever GOE is furnished.

IV e Data reduction is a process that will be done at Wisconsin on our Mod Comp III. The programming will be unique to our payload. However, after many rocket shots and over four years of OAO data to reduce, we have a good idea of the problems in reduction and how to approach them. We plan to have the first data reduction programs ready by the time of the first flight but are allowing some programming effort for unforeseen problems that may arise.

In summary, we envision programming to be a significant effort, but feel it can be held to six man months if FORTH is available on most of the computers involved in the project.

V CALIBRATION

V a Relative Calibration

The purpose of this experiment is the absolute photometric measurement of the stars observed. Consequently sufficient time must be allowed for as accurate an absolute calibration of the instrument sensitivity as possible before and after each flight, on a schedule that minimized the opportunity for instrument degradation between the calibrations and the flight.

Specifically, as much of the Test and Evaluation and integration procedure as possible will be completed and then the instrument returned to Wisconsin for a final absolute calibration. This means the Wisconsin experiment will be absent from the GSFC facilities for six weeks after its initial integration. During this period either integration can continue using the electronic simulator of this payload, or integration as it includes Wisconsin will be suspended. After the absolute calibration the spectrometer will remain sealed and will be operable only during a calibration check when an external vacuum system is attached to the spectrometer. This will be done at least once as the experiment is re-integrated in the pallet at GSFC or at the Cape.

V b Absolute Calibration

The measurement of the instruments' sensitivities against an absolute radiometric standard provides the basis for interpreting the flight results in terms of absolute flux from the stars. For this experiment the absolute calibration standard used is synchrotron radiation from the Wisconsin electron storage ring and the instruments are made to view this source directly in order to avoid the use of intermediate standards.

The calibration procedure consists of an internal calibration check of the spectrometer's sensitivity, removal of the slat collimator and vacuum valve section, mounting and alignment in the vacuum calibration tank at the storage ring, direct calibration of several points on the objective with synchrotron radiation from a known number of electrons at several specific energies, and a mapping of the objective with a folding mirror system. Upon removal from the calibration tank the vacuum valve section is put in place, the spectrometer evacuated and another reading taken with the internal calibration system to serve as a baseline measurement for later calibration checks. A similar routine is followed for calibration of the four smaller photometers.

One month has been allowed for doing each absolute calibration of the instruments. This is realistic on the basis of past experience with the operation of the storage ring and the necessary sharing of time there with other synchrotron radiation users.

V c Calibration Check and Ground Support Equipment

The integral calibration system in the spectrometer will be used to do a calibration check of the instrument during re-integration of the payload to the pallet. This requires the connection of an external vacuum system to the port on the side of the spectrometer in order to achieve the high vacuum necessary during operation of the open channel detectors. At this time a calibration check of the small photometers will be done using a small field calibration unit which attaches to the end of each photometer; no vacuum is required for this calibration.

Both the external vacuum system and the small photometer field calibration unit have already been used to support this experiment for flights as a rocket payload. Some additional vacuum line may be needed depending on the proximity of the vacuum system to the pallet during this test.

One week has been allowed for completing this test although the actual calibration check itself should take only a few hours once the necessary vacuum has been achieved.

VI MANAGEMENT AND COST ESTIMATES

In addition to the assumptions made in the introduction of the Preliminary Report, we are assuming for this cost estimate the following:

1. 1975 dollars without any inflation to the 1980 time frame and also personnel costs reflect 1975 pay levels and do not include raises for key personnel that will be in addition to inflation.

2. That we will provide an electro-mechanical dummy (but not a prototype) package to be left at GSFC for integration as discussed as an option in the Preliminary Report.

3. That an on-board vacuum system is included as an option.

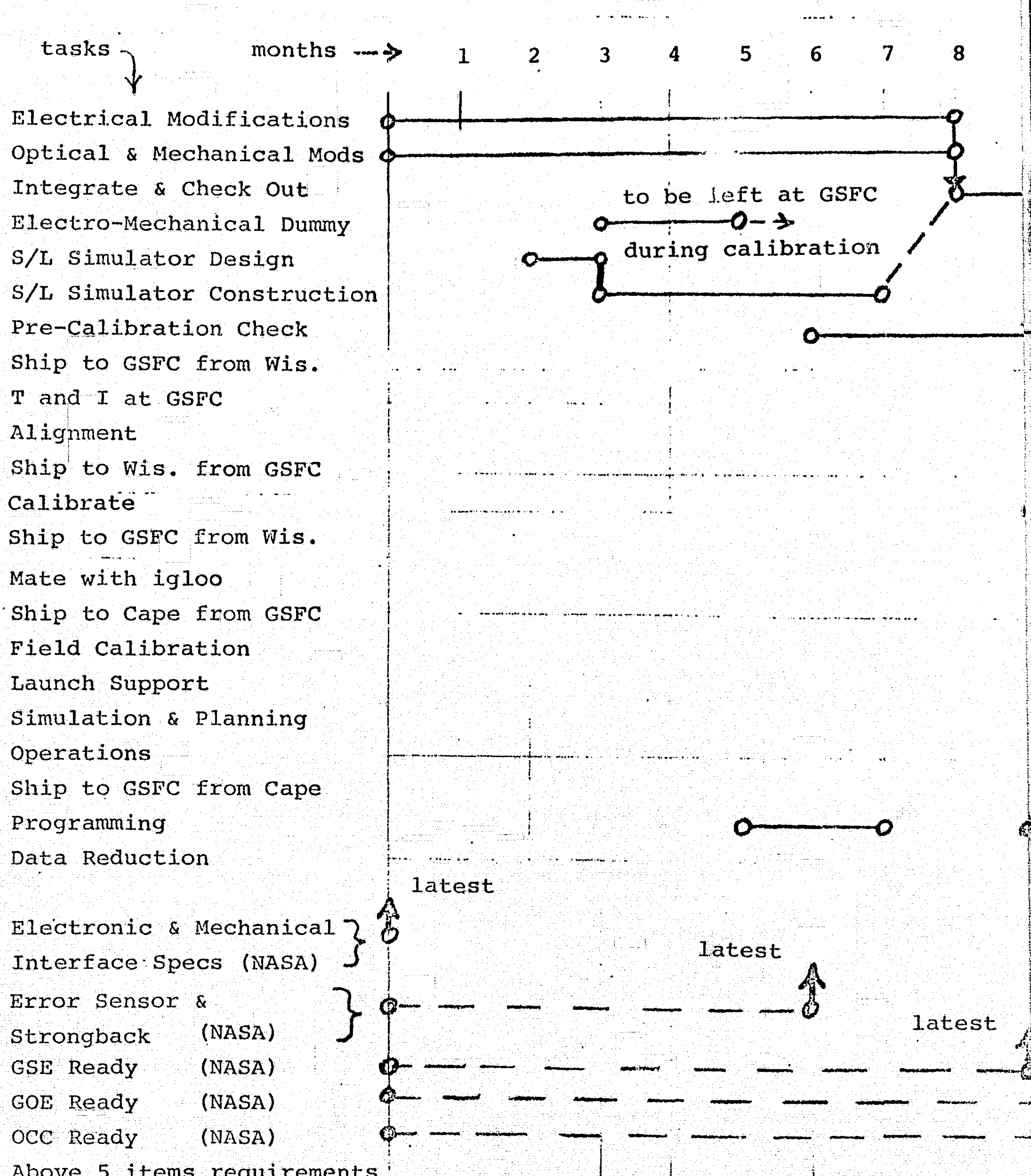
4. The programming language FORTH will be used and available on most computers.

We have developed a schedule of activities as they relate to us and NASA which reflects the time we think will be required on our part. We also show when NASA inputs would be required. The time actually required for T & I is uncertain since it is not clear how many payloads can be processed at once or whether they run sequentially. There will be a scheduling problem if many shuttle flights per year are to be supported. At the time of our first calibration we will leave an electro-mechanical dummy with the SIPS so that other packages could be integrated later. The time for the second flight integration may not be so long since many of the same packages may be flying again.

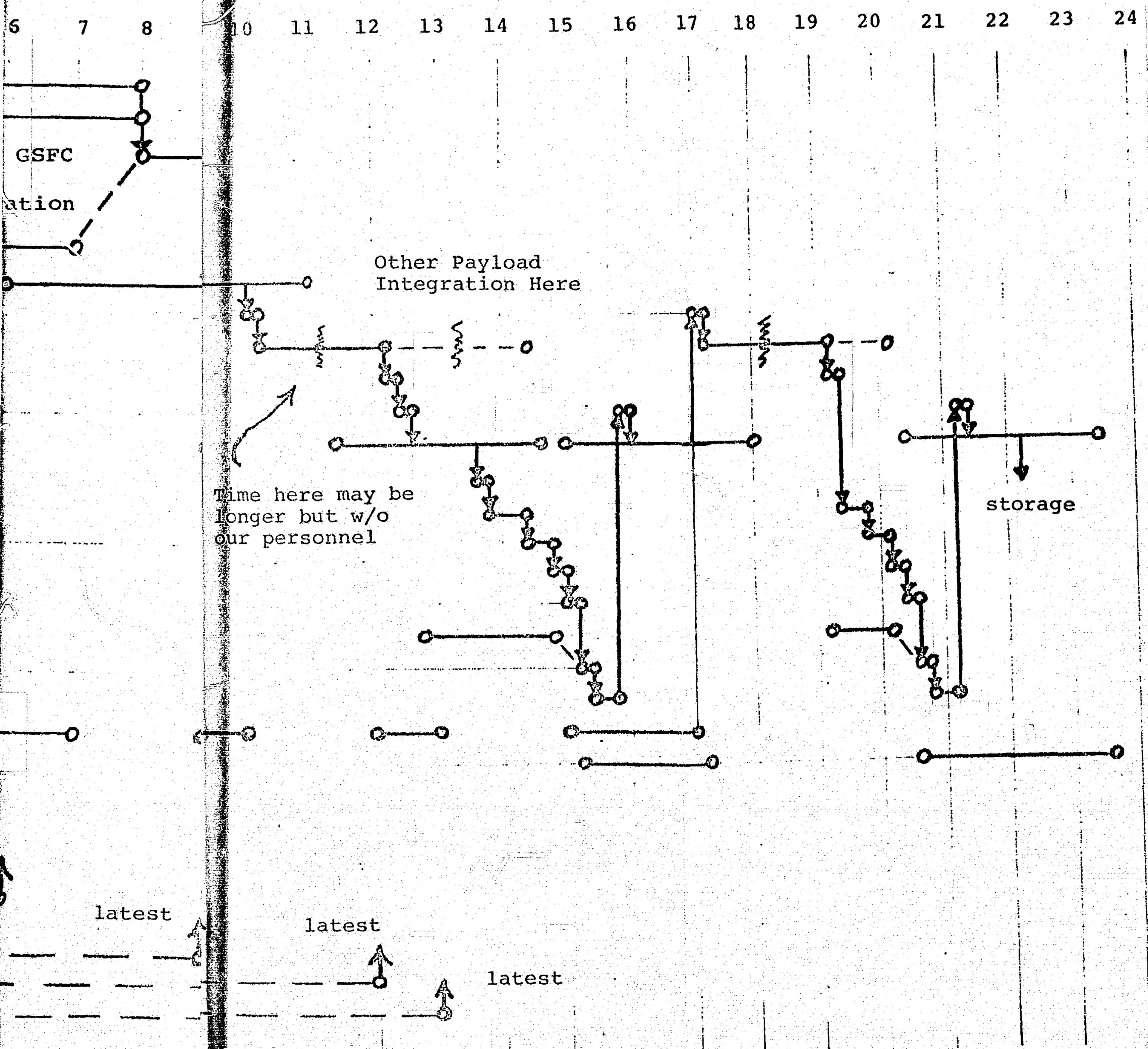
We have proposed two flights about six months apart with launch times picked so that shuttle night is out of the South Atlantic Anomaly as much as possible. Simulations of two months are shown. This represents effort on our part with the cooperation of GSFC rather than formal simulations which would be rather short.

Our six months programming effort can be split as needed to program GSE and GOE as they become available. We have indicated the latest time at which NASA inputs to us must be available.

It must be noted that not all of our staff will be busy all of the time. In fact this project would occupy our laboratory about one third of the time so other projects must be available of approximately twice the scope of this one in order to preserve the necessary group at our laboratory to do any one of them. This is the equivalent of 9 or 10 full time persons below which point we will not have the capability to sustain a project of this sort.



FOLDOUT FRAME |



WISCONSIN/SHUTTLE SCHEDULE

FOLDOUT FRAME 2

Cost Breakdown (overhead and fringe benefits lumped with salaries) 1975 dollars.

A. Optical-mechanical effort to modify the payload and calibrate it once before delivery to GSFC:

Construction	Cost in Thousands
Materials	4
Instrument Maker (10 MM)	20
Physicist (3 MM)	8
Calibration (up to delivery)	
Instrument Maker (1 MM)	2
Physicist (4MM)	11

B. Electronic effort required to modify and integrate the instrument for delivery to GSFC:

Design and Construction	
Materials	8
Electronic and functional simulator	8
Engineer (5 MM)	13
Electronic Technician (7 MM)	15
Integration at Wisconsin	
Engineer (1 MM)	3
Electronic Technician (1 MM)	2
Programmer (1 MM)	2
Administrative Cost	
Travel - 2 trips (1 MM)	4
Project Manager (4 MM)	15
Astronomer (planning) (3 MM)	7

TOTAL COST OF DELIVERY TO GSFC (41 MM) 122

C. Additional calibration and support of 2 flights

	Cost in Thousands
Calibration	
Physicist (9 MM)	24
Instrument Maker (1 MM)	2
Testing and Integration	
Engineer (4 MM)	10
Programmer (2 MM)	4
Physicist (1 MM)	3
Operations	
Programmer (2 MM)	6
Astronomer (4 MM)	12
Project Manager (2 MM)	7
Travel	
14 Man trips	4
4 Man months	8
Data Analysis	
Programmer (1 MM)	3
Astronomer (3 MM)	10
Students (6 MM)	8

TOTAL ESTIMATED TESTING AND FLIGHT (39 MM) 101

TOTAL PROJECT w/o OPTIONAL VACUUM SYSTEM (80 MM)	223
ON-BOARD VACUUM SYSTEM	19
	242
20% CONTINGENCY	48
TOTAL COST W/ CONTINGENCY	290

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Appendix A. Star Lists And Advance Planning

Star Lists

An important part of advance planning is the careful choice of target stars. The general star selection criteria given in Section III b of the text represent a compromise betweem the need for full sky coverage, the need for stars with strong ultraviolet continua, and the expected capabilities of the ZOIST. Some stars satisfying these criteria are listed in table A-1. Column 1 gives the star name or HD number. Columns 2 through 5 give the position of the star in 1950 coordinates. These positions were taken from the Smithsonian Astrophysical Observatory Star Catalogue. Column 6 gives the spectral type, the luminosity class, and indications of spectral peculiarities. These spectral types are taken, in order of preference, from Morgan and Keenan (1973), Lesh(1968), Hiltner, Garrison, and Schild (1969), Cowley (1972), Cowley et al. (1969), and the Yale Bright Star Catalogue (Hoffleit 1964). Spectral types from the Bright Star Catalogue are surrounded by parentheses. Columns 7 and 8 give the observed V magnitude and B-V color for each star. These quantities are taken from Cousins (1971) or from Iriarte et al. (1965) if possible. For stars not present in these sources either an unweighted average of the magnitudes tabulated in Blanco et al. (1968) or the magnitude in the Yale Bright Star Catalogue is used. Magnitudes from the Yale catalog are surrounded by

Table A-1. Possible Ultraviolet Standards

NAME	α (1950)	δ (1950)	SP.T.	V	B-V	t(1%) (sec)	REMARKS
ZET CAS	0 34.17	53 37.3	B2 IV	3.66	-0.18	1.3	1
XI CAS	0 39.26	50 14.3	B2.5V	4.81	-0.10	5.8	1
87 PSC	1 11.47	15 52.2	B8 III	5.95	-0.07	51.5	1
ALP ERI	1 35.86	-57 29.4	B3 V P	0.47	-0.16	0.1	1
PI CET	2 41.74	-14 04.2	B7 V	4.25	-0.14	5.0	1
SIG ARI	2 48.73	14 52.6	B7 V	(5.43)	-0.08	18.2	1
LAM CET	2 57.03	8 42.6	B6 III	4.70	-0.12	7.6	
93 CET	2 59.75	4 09.4	B7 V	5.62	-0.10	19.6	
22252	3 30.34	66 39.5	B8 V	5.82	-0.06	48.3	
29 TAU	3 43.01	5 53.7	B3 V	5.34	-0.11	10.1	
40 TAU	4 01.09	5 17.9	B3 V	5.32	-0.08	11.5	1
PI4 ORI	4 48.54	5 31.3	B2 III	3.67	-0.15	1.5	1
ETA AUR	5 03.00	41 10.1	B3 V	3.19	-0.18	1.0	1,4
LAM LEP	5 17.27	-13 13.6	B0.5IV	4.29	-0.25	1.2	1,4
UPS ORI	5 29.51	- 7 20.2	B0 V	4.63	-0.26	1.4	1,2,3,4
MU COL	5 44.14	-32 19.4	09.5IV	5.17	-0.27	2.4	1,4
133 TAU	5 44.88	13 53.0	B2 IV-V	5.27	-0.16	6.4	1,2
EPS DOR	5 49.94	-66 54.8	B6 V	5.10	-0.15	9.8	1,4
GAM COL	5 55.76	-35 17.3	B2.5IV	4.35	-0.18	2.6	1
XI ORI	6 09.10	14 13.3	B3 IV	4.48	-0.17	3.4	1,2,3
ZET CMA	6 18.39	-30 02.4	B2.5IV	3.02	-0.19	0.7	1,2
NU PUP	6 36.23	-43 09.1	(B8 III)	3.17	-0.11	3.2	1,2,3
16 MON	6 43.81	8 38.5	B2.5V	5.92	-0.16	12.1	
54893	7 07.17	-39 34.5	B2 IV-V	4.83	-0.18	3.9	1,2
ETA HYA	8 40.61	3 34.8	B4 V	4.30	-0.20	2.6	1,3,7,8
79351	9 09.65	-58 45.7	B2 IV-V	3.44	-0.19	1.0	2
79447	9 10.14	-62 06.7	B3 III	3.97	-0.18	2.0	2,4
KAP VEL	9 20.56	-54 47.8	B2 IV-V	2.50	-0.19	0.4	1,2
KAP HYA	9 37.91	-14 06.3	B5 V	5.05	-0.14	8.1	4
87015	10 00.03	22 11.5	B2.5IV	(5.51)	-0.19	7.2	4
ALP LEO	10 05.71	12 12.7	B7 V	1.35	-0.12	0.3	1,3,5,7,8
BET SEX	10 27.73	- 0 22.8	B6 V	5.09	-0.13	10.2	
104337	11 58.29	-19 22.8	B1 V	(5.26)	-	5.2	
ETA UMA	13 45.57	49 33.7	B3 V	1.86	-0.18	0.3	1,3,5,6
ZET CEN	13 52.41	-47 02.6	B2.5IV	2.53	-0.23	0.4	1
RHO LUP	14 34.51	-49 12.5	B5 V	4.04	-0.15	3.0	1,4
BET LIB	15 14.31	- 9 12.0	(B8 V)	2.61	-0.11	1.9	1
RHO SCO	15 53.79	-29 04.2	B2 IV-V	3.85	-0.20	1.4	1,4
148703	16 28.11	-34 35.8	B2 III	4.23	-0.16	2.4	1
ZET DRA	17 08.64	65 46.6	B6 III	3.17	-0.11	2.0	1
DEL ARA	17 26.58	-60 38.7	(B8 V)	3.61	-0.10	5.0	
IOT HER	17 38.05	46 01.9	B3 IV	3.80	-0.18	1.7	1
SIG SGR	18 52.16	-26 21.6	B2.5V	2.07	-0.22	0.3	1,3
IOT AQL	19 34.13	- 1 23.9	B5 III	4.36	-0.09	5.5	
KAP AQL	19 34.20	- 7 08.4	B0.5III N	4.95	0.00	7.2	1,8
ALP PAV	20 21.70	-56 53.8	B2.5V	1.94	-0.19	0.3	1
28 VUL	20 36.35	23 56.4	B5 IV	5.05	-0.15	7.7	1
UPS PAV	20 37.39	-66 56.3	(B8 V)	5.14	-0.06	25.8	1,3
51 CYG	20 40.67	50 09.6	B2 V	(5.38)	-	25.7	1
15 AQR	21 15.56	- 4 43.8	B5 V	5.82	-0.12	18.2	
206540	21 40.11	10 35.7	B7 III	(5.88)	-0.12	22.5	1,3
PI1 CYG	21 40.32	50 57.7	B3 IV	4.67	-0.12	5.2	1,2
16 PEG	21 50.78	25 41.3	B3 V	5.06	-0.18	5.5	1,3
ZET PEG	22 38.97	10 34.2	B8 V	3.39	-0.10	4.1	1
PSI2AQR	23 15.31	- 9 27.3	B5 V N	4.40	-0.14	4.4	1

parentheses. Column 9 gives the time in seconds estimated to be required for at least 10^4 photoevents to be recorded by each detector in the wavelength interval 1900 Å to 1300 Å. A minimum efficiency of 5×10^{-3} was assumed for each detector. The stellar fluxes were estimated from the observed stellar properties and from OAO-2 photometry of stars of the same spectral type. The numbers in column 10, "Remarks", refer to a remark in table A-4. The stars in table A-1 were checked for the absence of nearby bright stars in the SAO Star Catalogue and in the double star catalogues of Aitken (1932) and Rossiter(1955). The stars were checked for known variability in the Yale Bright Star Catalogue and in Percy (1974), Shobbrook (1972), and Hill (1967). In addition the variable radial velocities recorded by Albada and Sher (1969) and by Thackery (1966) were taken as evidence of possible light variability.

Some stars fainter than sixth magnitude but satisfying the other criteria are listed in table A-2. The first column gives the HD or BD number of the star. The quantities given in the other columns are the same as in table A-1. Most of the spectral types and magnitudes are from Guetter (1974). The data for BD+28°4211 are taken from Blanco et al. (1968). The spectral type of HD 201345 is from Walborn (1971); its magnitudes are from Blanco et al. The visual magnitude of BD+25°4655 is quoted from Richter (1971).

Table A-2. Faint Star Supplement

HD NUMBER NAME	α (1950)	δ (1950)	SP.T.	V	B-V	t(1%) (sec)	REMARKS
73	0 03.03	43 07.4	B1.5V	8.48	-0.18	89.8	
4460	0 44.51	47 32.0	B1 V	8.41	-0.16	93.4	2
20340	3 13.46	-17 00.8	B3 V	7.97	-0.13	103.1	
25787	4 03.97	51 19.2	B2 V	7.65	0.02	135.5	
51507	6 55.09	1 33.5	B3 V	8.00	-0.11	117.2	
74604	8 44.32	66 53.6	B8 V	6.15	-0.11	49.4	
77770	9 02.90	49 48.7	B2 IV	7.51	-0.21	39.7	
120086	13 44.74	- 2 11.7	B2 V	7.88	-0.18	64.3	
156110	17 12.00	45 25.8	B3 V N	7.56	-0.17	57.9	
176254	18 56.53	20 33.2	B2 V	6.74	0.03	61.6	2
186412	19 41.27	22 22.5	B5 V	6.82	-0.08	55.9	
201345	21 05.86	33 11.7	ON9 V	7.66	-0.13	109.3	
+28°4211	21 48.9	28 37.8	SDO	10.53	-0.34	231.8	1,4,9
208973	21 57.00	33 23.5	B2 V	8.22	-0.10	128.4	
+25°4655	21 57.42	26 11.6	SDO	9.67	-	162.6	1
214930	22 39.03	23 35.1	B2 IV	7.38	-0.14	49.0	

Orbit Choice

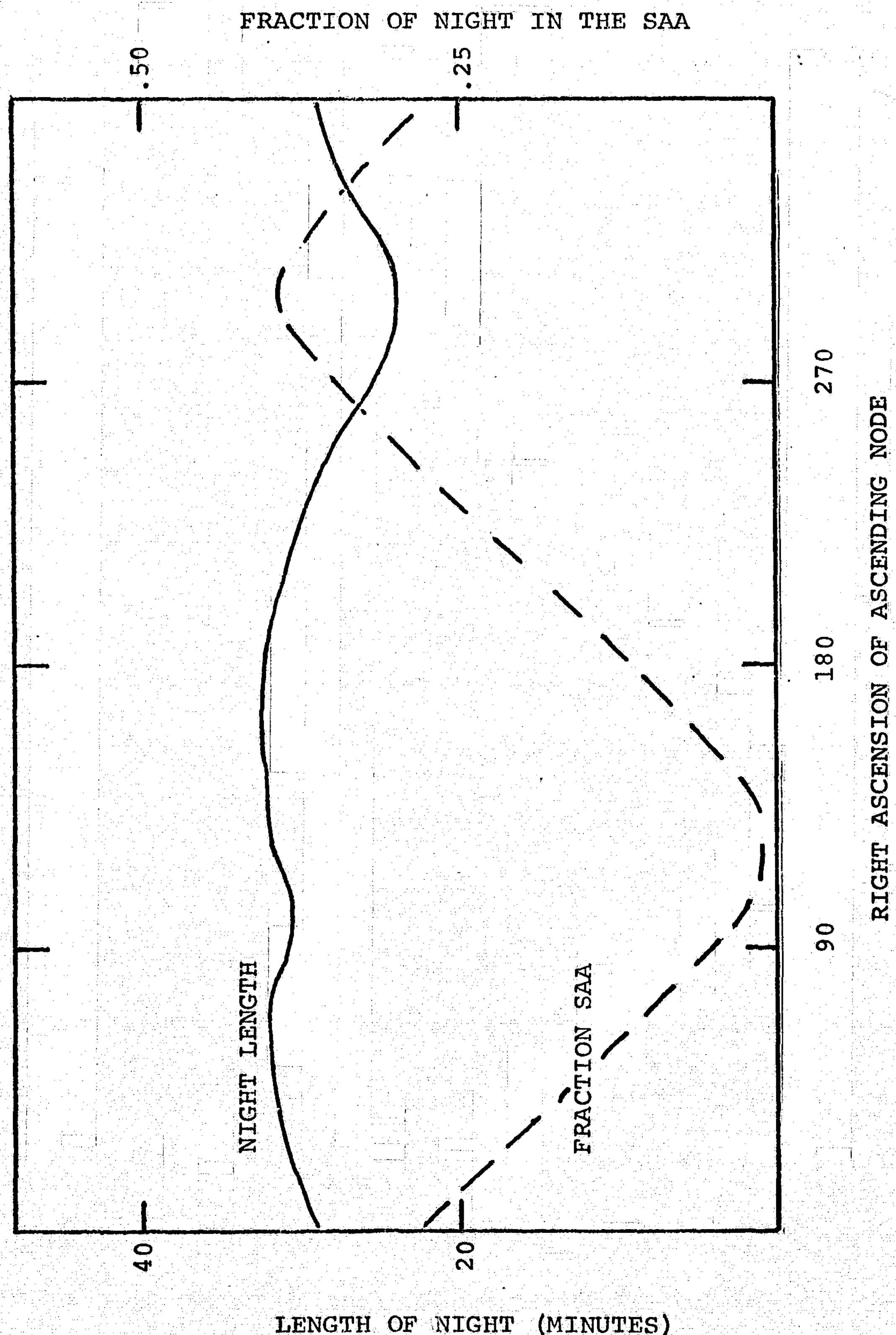
Since the Wisconsin instrument will observe only during the night, the average length of night and the average fraction of night lost to the SAA are important factors in determining the efficiency of use of time in space. We present here an example of how the efficiency might be maximized by choice of shuttle orbit. We varied the assumed Right Ascension of the Ascending Node (RA of Node) while keeping all of the other assumed orbital parameters constant. With each choice of the RA of Node, we used MAP to determine the length of night and the fraction of night time lost to the SAA during a twenty-four hour period. (MAP is a subroutine of the HARUSPEX program used in the operation of the Wisconsin Experiment Package in OAO-2 (Heacox 1970).) The assumed constant orbital parameters are:

Semi-major axis	6778.0	kilometers.
Inclination	28.5	degrees.
Eccentricity	0.0	.
Mean Anomaly	0.0	degrees.
Argument of perigee	0.0	degrees.
Change of RA of Node	-6.378	degrees/day.
Epoch	1971 January 1, GMT 00:00:00.	
Date of Launch	1971 January 15 .	

The results are shown in Figure A-1. It is clear that, in this example, the best orbit for the Wisconsin instrument would have

FIGURE A-1.

EFFECT OF THE RA OF NODE ON NIGHT LENGTH AND SAA INCIDENCE



an RA of Node in the range 90° to 150°. Such an orbit would both minimize the effects of the SAA and keep the length of the night reasonably long. We point out that the worst loss of observing time to SAA will not generally occur during the shortest nights.

Wisconsin Mission Plan

A possible WMP based on the orbital parameters and launch date given above is presented in Table A-3. For this WMP we have taken the RA of Node to be 90°. Column 1 gives the WOP ID code. Turn on and check out is assigned the ID code 00. WOP 01 would be executed in Wisconsin orbits 2 and 14; WOP 02 in orbits 3 and 15; etc. Column 2 lists the object to be observed. Column 3, "t_{night}", gives the length of night time in minutes when the target is at least 10° above the horizon. Column 4, "t_{obs}", gives the length of time in minutes that will be devoted to observing this star and its corresponding sky during the WOP. For this WMP, we have chosen t_{obs} so that approximately 10^6 counts will be recorded by each detector. Column 5, "t_{slew}", gives an estimated of the length of time that will be required for the SIPS to slew to the next star. For this estimate we assumed a SIPS maneuver rate of at least 2 degrees/second. Column 6, "Remarks", refers to the remarks listed in Table A-4.

A more detailed representation of the operations planned

Table A-3. Model Observing Schedule for 15 January Launch

WISCONSIN OBSERVING PLAN	STAR	t_{night}	t_{obs}	t_{slew}	REMARKS
0	α Leo	(	CHECK	OUT)	
1	CAL LIGHT	–	5	–	
	α Leo	30	1.3	0.7	1,3,5,7,8
	η Hya	31	9.0	1.2	1,3,7,8
	ξ Ori	31	11.7	0.2	1,2,3
2	133 Tau	31	23.2	0.7	1,2
	υ Ori	31	5.1	1.3	1,2,3,4
3	π Cet	18	17.0	1.4	1
4	α Eri	5	0.8	1.4	1
	μ Col	31	8.9	0.3	1,4
	ζ CMa	31	2.8	0.4	1,2
	ν Pup	31	11.8	0.2	1,2,3
5	54893	31	13.6	0.8	1,2
	κ Vel	21	1.6	0.2	1,2
	79351	20	3.6	0.1	2
	79447	18	7.1	1.3	2,4
6	CAL LIGHT	–	5	–	
	ζ Cen	11	1.8	1.1	1
7	104337	20	19.0	0.9	
8	β Sex	28	27.0	–	
9	β Sex	28	7.8	2.0	
	η UMa	26	1.3	0.9	1,3,5,6
	ζ Dra	31	6.7	0.6	1
	ι Her	5	4.6	1.2	1
10	π^1Cyg	12	11.0	–	1,2
11	π^1Cyg	12	10.2	0.8	1,2
	ζ Cas	20	4.8	0.1	1
	ξ Cas	20	2.0	–	1
12	ξ Cas	20	20.0	1.4	1
	η Aur	30	7.0	1.9	1,4
13	87015	31	27.1	0.3	4
	α Leo	30	1.6	–	1,3,5,7,8

for WOP 02 is given in Table 1 of the text.

Approximately one minute per star is allowed in the WMP for a possible search pattern required to acquire the star. The sequence of stars is chosen to minimize time lost due to the target star being below the horizon.

TABLE A-4.

REMARKS FOR TABLES A-1, A-2, and A-3

1. UV Photometry by OAO-2 WEP
2. UV Photometry by OAO-2 SAO (Davis et al. 1973)
3. UV Photometry by TD-1 (Swings et al. 1973; Vreux et al. 1973; Humphries et al. 1975)
4. UV Photometry by ANS (van Duinen 1975, private communication)
5. UV Standard (Bless et al. 1975)
6. UV Standard (Bohlin et al. 1974)
7. Visual Standard (Oke 1964)
8. Visual Standard (Hayes 1969)
9. Visual Standard (Stone 1974)