P43

SMALL EXPLORER PROJECT
SUBMILLIMETER WAVE ASTRONOMY SATELLITE
(SWAS)

Contract NAS5-30702

Mission Operations and Data Analysis Plan

Principal Investigator

Dr. Gary J. Melnick

July 1990

Prepared for
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt Road
Greenbelt, Maryland 20771

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory
is a member of the
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this contract is Mr. Walter Nagel, Code 740.4, Goddard Space Flight Center, Greenbelt Road, Greenbelt MD 20771

PREFACE

This document presents the Mission Operations and Data Analysis Plan for the Submillimeter Wave Astronomy Satellite (SWAS) Project. It defines organizational responsibilities, discusses target selection and navigation, specifies instrument command and data requirements, defines data reduction and analysis hardware and software requirements, and discusses mission operations center staffing requirements.

TABLE OF CONTENTS

INTRODUCTION

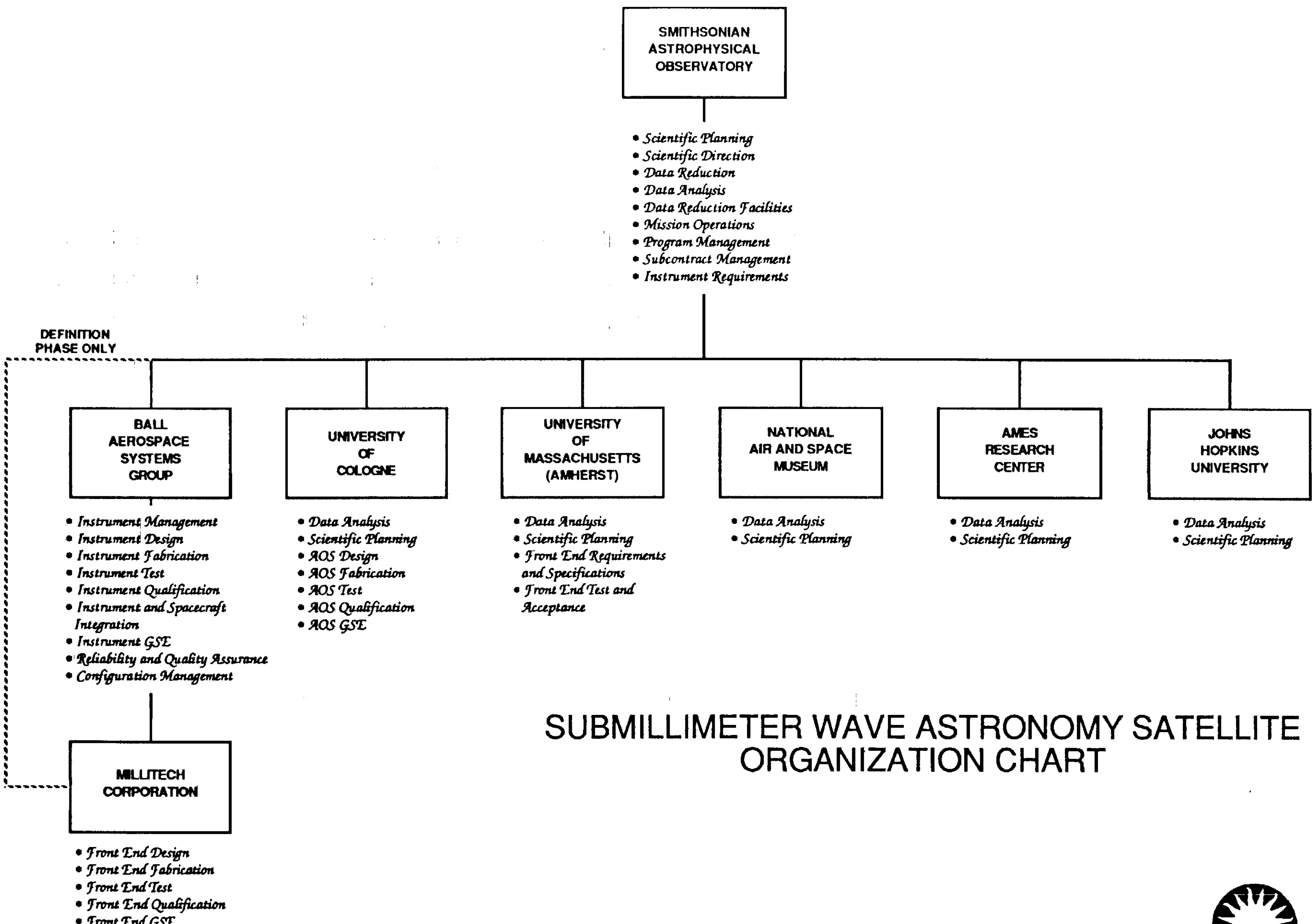
The Mission Operations and Data Analysis (MODA) Plan is the basis for the MODA planning and development effort to be undertaken during the Submillimeter Wave Astronomy Satellite (SWAS) Development Phase. Careful and complete advance planning for the on orbit operations period of the SWAS Mission is essential to assure efficient and effective completion of the proposed scientific program. Detailed planning and the development of the hardware and software systems necessary to carry out the mission is one of the two major thrusts of the Development Phase of the project. The other, of course, is the design, fabrication, test and calibration of the instrumental hardware.

This document presents the Mission Operations and Data Analysis (MODA) Plan for the SWAS project and is submitted in response to the requirements of NASA Contract NAS5-30702. All aspects of MODA requirements are considered: organizational responsibilities, instrument commands, data requirements and formats, target selection and navigation, daily data processing requirements, scientific data analysis requirements, and Science Operations Center hardware, software and staffing requirements.

In keeping with a key SMEX Project goal to keep documentation costs to a minimum, this document is organized in a viewgraph format and is based upon the MODA viewgraphs presented during the Conceptual Design Review (CoDR) held at Goddard Space Flight Center on June 8, 1990. Some additional viewgraphs have been added to cover additional topics. Viewgraphs are displayed on the right-hand pages throughout the document and text to explain and augment the viewgraphs is displayed on the facing page.

Mission Operations planning and implementation is the responsibility of SAO. Data analysis will be carried out by the entire SWAS Science Team: the University of Cologne, the University of Massachusetts at Amherst, the National Air and Space Museum, Ames Research Center and Johns Hopkins University. As the lead operations center, SAO will establish operations hardware and software requirements in consultation with the other members of the SWAS Science Team, develop the required facilities and software and operate the satellite during the mission in conjunction with Goddard Space Flight Center. SAO will coordinate the data analysis effort and fund it by subcontract to the non-government US participants and letters of agreement with the University of Cologne and ARC. Ball Aerospace and Millitech, while they have no day-to-day role in these activities, will support MODA by consulting on experiment operational and performance issues before and after launch.

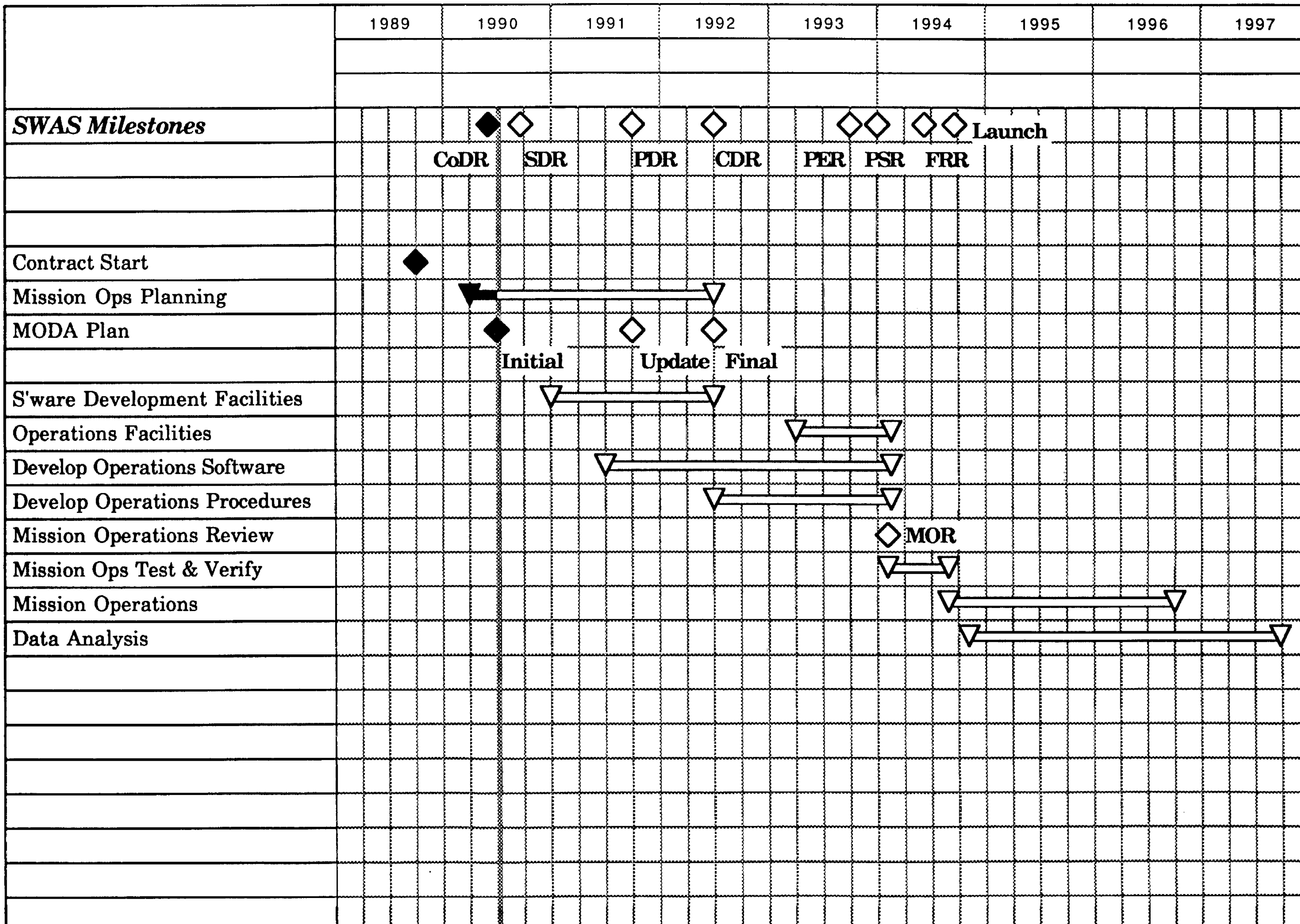
SUBMILLIMETER WAVE ASTRONOMY SATELLITE ORGANIZATION CHART



Smithsonian Astrophysical Observatory

Development of facilities and software as early in the project as practicable is vital to successful on-orbit operation. Hardware, software and procedural bugs must be worked out of the operations system well before launch. The planned MODA schedule accomplishes this goal by initiating operations planning early in the Development Phase and by providing facilities for software development and operations procedure checkout as soon as staff is available to use them. Workstations will be procured early in 1991 for the Project Scientist and Principal Investigator and additional hardware purchased as additional staff is added. These workstations will ultimately form the backbone of the Science Operations Center (SOC) facility. Procurement of the final hardware set for the SOC will be delayed until early in 1993 to take maximum advantage of the improvements in performance and reductions in cost of computer hardware that will almost certainly occur over the next few years. This plan allows twelve months for development of this facility before the Mission Operations Review (MOR) scheduled for the first quarter of calendar 1994. We plan to have all facilities and software in place by the time of the MOR and will reserve the six months remaining before launch for operational procedures and software checkout.

SWAS MISSION OPERATIONS & DATA ANALYSIS SCHEDULE



Mon, Jul 2, 1990

The division of tasks between the Science Operations Center (SOC) at SAO and GSFC is premised on the philosophy that: (1) the means by which the scientific objectives of the mission are met rest with the Investigator team, (2) the SOC and GSFC each exercise control over that portion of the experiment for which they have the greatest expertise, and (3) the required interaction between the SOC and GSFC be as efficient as possible.

Toward these ends, the following viewgraph outlines the tasks to be performed by each center. It is our intent to pre-screen all anticipated targets for the needed guide stars prior to the mission. The staff at the SOC will regularly review those sources which possess suitable guide stars for their weekly availability and a subset of these available sources, selected by the Investigator team, will be forwarded to GSFC as the weekly target list. Along with the targets, the SOC will specify: (1) the order in which the sources should be observed, based on overall observing efficiency and scientific priority, (2) the total integration time on each target, and (3) the reference position for each source to which the telescope should nod every 30 seconds. The SOC may wish to review the GSFC-constructed command timeline in order to ensure against miscommunication and the SOC will, as part of its data reduction responsibilities, review the data transmitted from GSFC for its integrity.

GSFC will assume responsibility for all functions relating to the spacecraft and the overall safety of the mission. These tasks are listed in the following viewgraph. Because maintaining the angle of the solar arrays with respect to the Sun and pointing are spacecraft responsibilities, GSFC will assume control of the selection of guide stars, spacecraft roll-angle (or azimuth), and therefore also of the reference position nod commanding. In addition, GSFC will provide the data required to determine the velocity vector of the spacecraft at all times as this will be required in order to remove the Doppler velocity of the spacecraft from the scientific data.

SWAS MISSION OPERATIONS RESPONSIBILITIES

- SAO
  - TARGET SELECTION
    - Weekly Target List (Pre-Screened for Availability)
    - Construction of Target Viewing Sequence
    - Specification of Total Integration Time per Target
    - Specification of Reference Position for each Target
  - REVIEW OF COMMAND TIMELINE
  - INSTRUMENT PERFORMANCE ASSESSMENT
  - VERIFICATION OF DATA INTEGRITY

- GSFC
  - TARGET NAVIGATION
    - Selection of Target Guide Stars
    - Selection of Target Azimuth Angle
    - Identification of Target Viewing Time
    - Orbit Determination
  - SPACECRAFT PERFORMANCE ASSESSMENT
  - SPACECRAFT COMMANDING
    - Maneuver Determination
    - Maneuver Execution
    - Target Observation
    - Reference Position Nod Commanding
    - Data Acquisition
    - Space Operation, Health, and Safety

The division of tasks between the SOC at SAO and the Co-Investigator institutions is shown in the next viewgraph. The main emphasis in establishing this division is that: (1) we create an efficient structure for both receiving and processing the data as well as planning future observations, (2) all of the preliminary data reduction occur in a single location, both to ensure standard data reduction procedures as well as to streamline archival of the data, and (3) management of the staff needed to perform these tasks is simplified by concentrating the effort in one center.

It is assumed that by one year before launch the SOC and all of the Co-Investigator institutions will be linked in a way that will permit the easy transfer of data between sites. It is our intention to perform all of the data reduction up to the final calibrated spectra on each source at the SOC. These spectra will be catalogued and then distributed to members of the Co-Investigator team at their home institutions for further scientific analysis leading to publication of the results.

The SOC will assume the responsibility of preparing the data and the attendent documentation for submission to the NSSDC.

SAO and members of the SOC will conduct regular telecons with the Co-Investigator team to review the data and to establish a source list for the following week. The SOC will compile, analyze, and catalogue all instrument housekeeping data and, whenever the data indicate, initiate a telecon with the appropriate team members to discuss corrective measures.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

DATA ANALYSIS RESPONSIBILITIES

❐ SAO

- Science Team Coordination
- Mission Operations Planning
- Receive, Archive, and Reduce Data
- Cross-Check Observations with Timeline
- Generate Instrument Health Displays and Database
- Perform Trend Analysis, Evaluate Instrument Health
- Coordinate Distribution of Data among Co-Investigators
- Data Analysis and Publication of Results
- Archive Final Data Products Prepared at Co-I Institutions
- Prepare Data for NSSDC
- Prepare Required Documentation for NSSDC

❐ UMass, NASM, NASA Ames, Univ. of Cologne, Johns Hopkins

- Data Analysis
- Publication of Results
- Consult on Instrument Health Issues
- Participate in Weekly Source Selection

The following viewgraph lists the instrument commands, divided according to whether they are single- or multiple-bit commands. For those multiple-bit commands, the number of bits required has been included.

This list is not final, but within about 20 percent it does convey the approximate number of the commands needed to operate the instrument.

SWAS INSTRUMENT COMMANDS

& Bit Requirements

SINGLE-BIT

Power On/Off
- Crystal OSC
- DRO A
- DRO B
- IF line A
- IF line B

Gunn OSC select A1
Gunn OSC select A2
Gunn OSC select B1
Gunn OSC select B2
PLL sideband select B
Blanking to AOS On/Off
Comb Generator In/Out
Flip mirror In/Out
AOS Power On/Off
AOS laser diode/CCD select
Reset AOS Averager
PLL 1 open/close
PLL 2 open/close
PLL 3 open/close
Filter Bank A Power On/Off
Filter Bank B Power On/Off

MULTI-BIT	# Bits
Frequency set A	8
Frequency set B	8
Attenuator set A	4
Attenuator set B	4
Nod position X	12
Nod position Y	12
Star Tracker	8
Tripler bias 1	8
Tripler bias 2	8
Harmonic mixer 1	8
Harmonic mixer 2	8

TOTAL INSTRUMENT BITS = 110

The following viewgraph lists the housekeeping parameters, divided according to whether they are single- or multiple-bit parameters. For those multiple-bit parameters, the number of bits required has been included.

This list is not final, but within about 20 percent it does convey the approximate number of the parameters needed to evaluate the health of the instrument.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

SWAS HOUSEKEEPING DATA

& Bit Requirements

(Recorded once per minute)

SINGLE-BIT

- Power On/Off
  - Crystal OSC
  - DRO A
  - DRO B
  - IF line A
  - IF line B
- Gunn OSC select A1
- Gunn OSC select A2
- Gunn OSC select B1
- Gunn OSC select B2
- PLL sideband select B
- AOS Power On/Off
- AOS laser diode/CCD select 1
- AOS laser diode/CCD select 2
- PLL 1 open/close
- PLL 2 open/close
- PLL 3 open/close
- Filter Bank A Power On/Off
- Filter Bank B Power On/Off
- Nod Zero X
- Nod Zero Y

MULTI-BIT	# Bits
Frequency set A	8
Frequency set B	8
Attenuator set A	4
Attenuator set B	4
Receiver biases	
- Harmonic mixer A	8
- Harmonic mixer B	8
- Cooled tripler A	8
- Cooled tripler B	8
Power supply voltages (10 values x 8 bits)	80
Temperature sensors (15 values x 8 bits)	120
Calibration load temp.	8
Laser diode current	8
Gunn OSC Voltage	8

TOTAL HOUSEKEEPING BITS/MINUTE = 301

Smithsonian Astrophysical Observatory

The process of selecting targets for each week's observing list involves four decisions. First, is a given source of interest visible to the instrument during the next week, i.e. is the source:

(1) outside of the Earth and Sun avoidance angles?

(2) on the Sun side of the orbit, is the source obtainable while keeping the solar array panels within ± 15° of the perpendicular to the Sun?

(3) is the source visible for more than 10 minutes?

Second, if some integration time has already been obtained on a source, are the co-averaged spectra sufficiently good that no further integration time is needed (e.g., have we obtained line detections that are convincing enough to publish)? If the source has not yet been observed, then the decision is to allocate observing time.

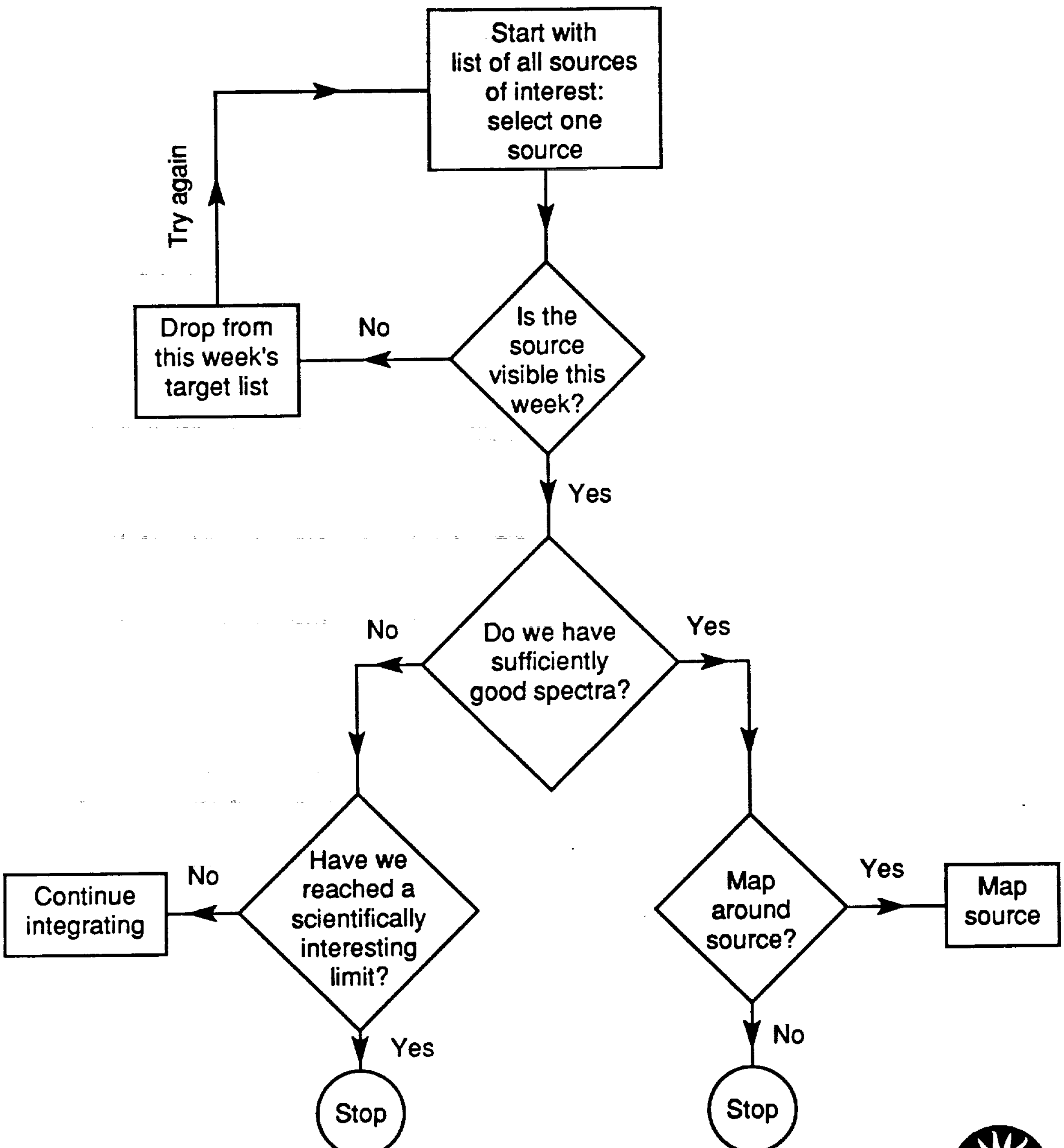
Third, if a source displays strong emission in one or more of the SWAS spectral lines, will sufficiently more be learned by performing a simple four position "map", i.e., integrations spaced 1/2 beam diameter to each side of the already observed center position?

Fourth, if last week's integrations yielded no detection in one or more of the SWAS lines, do we wish to commit further satellite time to improve the signal-to-noise of the spectra? One element in answering this question will be the amount of additional time required to reach a scientifically interesting limit on the abundance of each SWAS species. Another consideration will be whether or not the additional time on this source begins to compete with time on a potentially more interesting source.

The following flow chart summarizes this decision network.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

WEEKLY TARGET VIEWING FLOW CHART



Smithsonian Astrophysical Observatory

The following viewgraph lists the parameter set-up and observing sequences that will typically precede each source observation. After acquiring the source, it will be necessary to input the frequency shift to the receiver oscillator needed to remove the galactic Doppler shift of the source (STEP 2). This procedure preserves the maximum baseline on each side of the expected line centers (there being four lines in a SWAS spectrum). This step will be performed only once at the beginning of each source observing session. During the approximately 30 minutes of observing on this source no further frequency adjustments will be made - the shifts in the observed spectral lines due to spacecraft motion will be removed in the post-downlink data reduction. STEP 3 refers to the number of steps required of the telescope assembly stepper motors needed to place the reference beam at the desired position on the sky. STEP 4 sets the total time we wish to integrate. In most cases, this time will be solely determined by the source visibility. STEP 5 sets the time for on-source and off-source integrations. From laboratory tests of the receiver and AOS stability, this time will be approximately 30 seconds per on- or off-source position. If flight data indicate that the receiver-AOS system is more (or less) stable than ground tests, we may wish to vary this number.

STEPS 6 through 11 calibrate the receiver-AOS system. STEPS 6 through 10 will initially be performed once per source. If the system is found to be quite stable, then these steps will be performed less frequently. STEP 11 will be performed on the average of once per day.

With the above steps completed, the instrument is now ready to begin taking data (STEP 12).

TYPICAL OBSERVING SEQUENCE

1) Acquire source
2) Uplink frequency
3) Nod reference position X-Y
4) Duration of total observation
5) Duration between on-source/off-source (nom. ~30 sec.)
6) Go to reference position
7) Flip mirror up (~6 sec.)
8) Flip mirror down
9) Integrate on reference position (~6 sec.)
10) Blanking of AOS (~6 sec.)
11) Comb generator (~ 6 sec.) - verify frequency adjust
12) On-source/Off-source integrations until end of total time

Steps 7–10: Performed once per source

Step 11: Performed once per day

The composition of the downlinked data may be divided into three categories: (1) spacecraft housekeeping data, (2) instrument housekeeping data, and (3) science data. It is our approach to embed within the science data stream all of the information needed to produce reduced spectra. Thus, by stripping out the science data stream, it should be possible to procede with the data reduction without having to halt periodically to read data from either the spacecraft or instrument housekeeping data streams, thus greatly facilitating the data processing.

The following viewgraph lists the parameters and their bit requirements needed to satisfy the above goal. By construction, the AOS integrates for 2 seconds and then transfers the averaged data to the on-board recorder. As a result, it is our intent to quantize the science into 2-second packets. Thus the data shown here give the number of bits sent to the recorder every 2 seconds.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

SWAS SCIENCE DATA

Parameters and Their Bit Requirements to Be Embedded in the Data Stream

(Data Pre-Averaged for 2 Seconds)

Parameter	Bits per 2 seconds
Object Name (12 characters x 8 bits/char.)	96
AOS data output ([1400 channels x 16 bits] per 2 seconds)	22,400
Truncated Julian day	16
Seconds of day	17
S/C Attitude Quaternion (transformable to RA, DEC)	128
Orbit State Vector & Prop. Coef (where S/C is in its orbit)	896
Telescope nod position (X-Y)	24
Flip mirror position	2
Blanking to AOS On/Off	2
Comb generator In/Out	2
Continuum detector data (A)	24
Continuum detector data (B)	24
Filter Bank (32 channels x 16 bits)	512
Phase Lock Loop (PLL) status	3
(Charged particle hit detector)	2
TOTAL (per 2 seconds)	24,148

Smithsonian Astrophysical Observatory

The number of times per day that data will need to be downlinked is dependent on five parameters: (1) the spacecraft transmitter downlink data rate, (2) the on-board data generation rate, (3) the data capacity of the on-board recorder memory, (4) the degree to which the data is compressed, and (5) the time available per pass over a ground station for data transfer.

The following viewgraph presents an estimate of the required frequency of data downlinks assuming that on-board memory capacity is not an issue and that no attempt is made to compress the data. As is indicated, with a downlinked bit rate sufficient to transfer 1 orbit's data in about 1 minute and taking the conservative estimate of 8 usable minutes of Acquisition of Signal per pass over a ground station, a maximum of 8 orbits of data can be downlinked per Acquisition. With 16 orbits per day, this would imply that a data dump must occur at least every 12 hours.

In practice, there will be a careful tradeoff study of the weight and power impacts of increasing on-board memory versus the staffing needed to operate the ground station. In addition, various techniques of data compression will also be examined. Both of these studies will be conducted by GSFC and reviewed by the SWAS science team.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

RATE OF DATA DUMPS

① On-board transmitter downlink data rate = 1.25 Mbits/sec

② On-board data generation rate:
Data stream is ~ 90% Science data
1% Instrument Housekeeping data
9% Spacecraft Housekeeping data

Science data generation rate ≈ 12.1 kbits/sec
⇒ Total data generation rate ≈ 13.4 kbits/sec

③ Total data accumulated during each 95 minute orbit = 76 Mbits

④ At a transmission rate of 1.25 Mbits/sec, it will require 61 seconds to transfer one orbit's data

⑤ There are 8 - 10 minutes of usable contact during each Acquisition of Signal

⇒ Maximum number of orbits between data downlinks = 8
(= 12 hours)

(The above estimate assumes no data compression.)

The following viewgraph summarizes several of the "top-level" features of the Science Operations Center (SOC) along with a few of the more detailed aspects of its interaction with GSFC.

Our overall objective is to receive the data from the spacecraft as quickly as is feasible, archive and process this data on a daily basis, and to disseminate the processed data as efficiently as possible among the Co-Investigator team.

The number of data downlinks per day has not yet been established, but our hope is to be able to examine the health of the instrument often enough to correct any out-of-spec condition before too much time is potentially lost taking corrupted data. It is also highly desirable to obtain and process the scientific data not too long after it was taken in order to fold these results efficiently into our next week's observing schedule.

The link between GSFC and the SOC should be more capable than the existing 56 Kbit/sec link in order to be able to transfer data quickly (at 56 Kbit/sec, one day's worth of data, ~1.2 Gbits, would require approximately 6 hours to transfer on a dedicated line). An upgrade of SAO's present 56 Kbit/sec link to GSFC to a 1.5 Mbit/sec, T1, link has been requested. Such a link would cut the time needed to transfer a day's data to about 14 minutes.

Similarly, the medium employed to record the data sent from GSFC should be capable of recording the data at a rate equal to or greater than 1.5 Mbit/sec, it should have a large capacity, and it should enable the user to quickly access any portion of the data after it has been recorded. One attractive option that fulfills these requirements are Write Once Read Many (WORM) optical disks. Such an approach allows for fast recording (> 1.5 Mbit/sec) and possesses an access speed comparable to a hard disk. In addition, data received in this manner cannot be over-written and is therefore a natural archival medium. Finally, since each disk may be capable of storing ~1 week's worth of data, data archives can be quite compact.

Selecting UNIX as the SOC operating system allows for the widest choice of computer workstations and therefore keeps our hardware costs lower. UNIX is also becoming a standard among universities and will therefore allow us to share software more freely among the Co-Investigator institutions.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

SCIENCE OPERATIONS CENTER - OVERVIEW

- The Science Operations Center (SOC) will be located at SAO with computer links to GSFC, Univ. of Massachusetts, NASM, NASA Ames, Johns Hopkins Univ., and the Univ. of Cologne.
- Data will be downlinked at least every TBD (4) orbits.
- Data will be forwarded to the SOC from GSFC as quickly as possible, but not to exceed 60 minutes after receipt of data at GSFC.
- Format of data sent to SOC is to be set by GSFC and approved by SAO.
- Data link between GSFC and SOC is baselined to be a T1 ground link (data transmission rate = 1.5 Mbits/sec).
- Data will be received automatically at SOC and written directly to Write Once Read Many (WORM) optical disk. These optical disks will serve as both an archive and a "hard disk" for the first stage of data reduction.
  - Optical disk drives can currently write data to disk at a rate greater than that of the T1 transmission rate.
  - Current optical disks have a capacity of 600 Mbytes. At a data generation rate of 15,000 bits/sec, which is at the high end of the expected SWAS rate, one optical disk can receive and archive 59 orbits, or about 3.7 days, worth of data. It is expected that the capacity of commercially available optical disks will increase by a factor of 2 to 3 by 1994.
- SOC hardware will operate under UNIX.
- Incoming data will be divided into three categories: (1) Spacecraft data, (2) Science data, and (3) Instrument housekeeping data.

The following viewgraph outlines the major steps involved in processing the science data. STEP 1 starts with the data as it is received at the SOC (in units of 2 seconds of data). The incoming 2-second packets of data are first tagged as being ON-source, OFF-source, CAL data, COMB generator ON data, etc. STEP 2 automatically separates the CAL scans and performs the needed calibration. STEP 3 corrects the recorded position on the sky for any spatial offsets that are discovered during our on-orbit boresight tests. STEP 4 separates those scans obtained when the COMB generator is engaged and checks the frequency stability of the system. STEP 5 co-averages 30 seconds of ON's and 30 seconds of OFF's and STEP 6 uses these results to compute a calibrated spectrum for that ON-OFF pair. STEP 7 allows for either visual or automatic inspection of these 1-minute spectra to determine if they have been corrupted in any way and therefore should be discarded (and, thus, not co-averaged with the scans that are determined to be good). STEP 8 will break the full AOS spectrum, which still contains all four spectral lines, into four separate spectra. STEP 9 corrects each spectra for the spacecraft Doppler motion and STEP 10 then co-averages all of the spectra for that observing session. STEP 11 removes any simple baseline slope and, finally, STEP 12 co-averages the data from all observing sessions on a given source.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

DATA REDUCTION STEPS

1) Identify nature of each 2-second AOS dump (ON, OFF, CAL, COMB, Continuum, Unusable,...)
2) Select CAL data and compute calibration scans (this can be done fairly infrequently)
3) Select pointing data and correct for pointing offsets if necessary
4) Select COMB data and verify frequency calibration (also infrequent)
5) Co-average each 30 seconds of ON's and 30 seconds of OFF's
6) Form calibrated spectra out of co-averaged ON's and OFF's

$$\text{Calibrated Spectra} = \frac{\text{ON} - \text{OFF}}{\text{OFF}} T_{sys}$$

7) Inspect each 1-minute spectrum and remove bad spectra
8) Break full AOS output into 4 separate spectra
9) Compute appropriate Doppler shifts and correct spectra
10) Sum all spectra for a single observation session
11) Fit baseline and apply correction
12) Co-average with any previous observations of same source

Data analysis package needs to be able to:

1) Plot spectra, compute line parameters, and perform Gaussian fitting
2) Form spatial maps and spatial/velocity maps of line parameters

Smithsonian Astrophysical Observatory

The following viewgraph displays our concept of a daily schedule that would permit one eight-hour shift to fully process 24 hours of data. Based on discussions with GSFC, it is assumed that data is downlinked and transferred to the SOC four times per day. It is also assumed that the Data Reduction Steps given in the previous viewgraph have been automated and can be run in a batch mode. Finally, we assume that a seven-day-a-week operation can be achieved with 5 people, excluding the PI and Project Scientist. A breakdown of SOC staff members is presented in a subsequent viewgraph.

DATA & MISSION OPS - TYPICAL DAY

7 AM: Designated operator logs-in to the #1 data reduction work-station and checks to see that the data dumps from the previous night arrived successfully. Operator then submits the commands to have the batch reduction program begin for each of the two sets of data (workstation #1 performs the reduction of the first set of data, workstation #2 does the second set; if there were three data dumps during the night, workstation #3 would work on this data).

9 AM: Operators/Postdocs arrive at SOC. The batch reduction routines have finished and plots have been made. The operators spend about 1/2 hour reviewing the plots.

10 - 12 AM: Operators hand reduce problem spectra.

Sometime during the morning, another new set of data arrives from GSFC and batch reduction is started for it on workstation #3.

1 - 2 PM: Hand reduce problem cases for these latest data.

2 - 3 PM: Add data from previous four sets of data dumps to previous averages - note any "finished" sources.

3-3:30 PM: Daily group meeting to review the previous 24 hours.

3:30-5 PM: Clean up directories, etc. Prepare for tonight's data dumps. If a new set of data arrives from GSFC, submit batch process.

(Concurrent with these data reduction operations, another staff member is working on planning/scheduling for next week's observing.)

Current planning calls for the SOC to operate for 1 eight-hour shift per day, seven days per week. The SOC staffing is premised on the need to: (1) stay current with the data on a daily basis, (2) have at least one scientist present during any 8-hour shift, (3) have one person largely dedicated to the task of constructing next week's observing schedule, (4) have at least one hire that is highly skilled in computer systems management.

Five hires, in addition to the PI and Project Scientist, are required to meet the above criteria: 3 scientists and 2 computer operators, one of whom is the computer systems manager.

In most cases each shift will consist of three people, one of whom will always be a scientist. Their duties will broadly consist of reducing the scientific data, examining the housekeeping data to track instrument health, and archiving the data. A fourth member of most shifts will be a second scientist whose efforts will be focused on mission planning. It will be expected that each staff member will be trained in performing all of the daily tasks so that illness and vacation do not impair SOC operations. The PI and Project Scientist will participate in and oversee all of these efforts, though their involvement will not be required in order to carry out the above tasks. The PI and Project Scientist will lead the daily group meetings and coordinate relevant discussions with the other members of the SWAS science team.

After the Project Scientist, it is our intention to hire a computer systems manager in order to lay the groundwork for a rational SOC computer system and to begin the needed software development under the supervision of the PI and Project Scientist.

MISSION OPERATIONS STAFFING

- ANALYSIS OF PROCESSING REQUIREMENTS SHOWS THAT MISSION CAN BE PERFORMED WITH ONE SHIFT PER DAY SEVEN DAYS PER WEEK

- OPERATIONS WILL BE COVERED WITH A CORE STAFF OF FIVE:
  - 3 OPERATOR/SCIENTISTS
  - 1 SCIENTIST OPERATIONS PLANNER
  - 1 DATA SYSTEM ENGINEER

- PRINCIPAL INVESTIGATOR AND PROJECT SCIENTIST LEAD EFFORT ON A DAILY BASIS FOCUSING ON DATA REVIEW, PROBLEM RESOLUTION, AND COORDINATION OF CO-I SUPPORT

- DATA SYSTEMS ENGINEER WILL BE BROUGHT ON BOARD FIRST, OTHERS ADDED DURING PROJECT WITH FULL STAFFING ACHIEVED ONE YEAR BEFORE LAUNCH

One possible SOC staffing schedule that satisfies the requirements set forth in the previous viewgraph.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

SOC STAFFING SCHEDULE

PI	Principal Investigator
PS	Project Scientist
S1	Scientist #1
S2	Scientist #2
S3	Scientist #3 (Mission Planner)
O1	Operator #1 (Computer Systems Manager)
O2	Operator #2

Monday	S1	S2	O1	(PI/PS)	S3
Tuesday	S1	S2	O1	(PI/PS)	S3
Wednesday	S1	(PI/PS)	O1	O2	S3
Thursday	S1	(PI/PS)	O1	O2	S3
Friday	S1	S2	O1	O2	S3
Saturday	(PI/PS)	S2		O2	
Sunday	(PI/PS)	S2		O2	

(PI/PS) implies that the PI or the PS can be called on to participate in this shift if the press of work requires.

Instrument health is a science team responsibility that will be coordinated through the SOC. One of the responsibilities of the SOC is to catalogue and analyze the performance of the instrument via the housekeeping data. Along with daily reviews of all of the housekeeping parameters, long-term trends in this data will be monitored. SOC members will possess a set of "nominal" values for each parameter, and when parameters are found to be out-of-range this condition will be transmitted to members of the science team by SOC staffers. The following viewgraph summarizes the procedures that will be instituted to address instrument problems.

INSTRUMENT HEALTH EVALUATION/PROBLEMS

- Instrument health will be evaluated with each receipt-of-data at the SOC by comparing the Housekeeping parameters against a set of normal performance ranges for each parameter.

- SAO will provide GSFC with a limited set of Housekeeping parameters which should be monitored during those periods when the SOC is not manned.

    - When any of these parameters is determined to be in a sustained out-of-limits state, a designated SOC staffer will be informed by the appropriate GSFC personnel as soon as possible

- Early in the mission, all out-of-limits problems will be cause for the initiation of a conference call among appropriate hardware parties so that prudent action can be taken *as soon as possible.*

- Later in the mission, if certain out-of-limits situations become well understood, corrective action may be initiated by SOC staffers without the need to initiate group telecons.

The following viewgraph summarizes the hardware needed to operate the SOC.

DATA & MISSION OPS - HARDWARE NEEDS

- 6 Workstations
  - 3 workstations for routine (level 1) pipeline data processing
  - 1 workstation for higher level (level 2) data processing (e.g., map making - could also be used as a spare to be used for level 1 data reduction when hardware maintenance is required)
  - 1 workstation used as a network server
  - 1 workstation for database management/archive uses
- 2 Write Once Read Many (WORM) Disk Drives
- 2 Eraseable Optical Disk Drives
- 2 Gbytes of Magnetic Disk Drive Capacity
- 2 Laser Printers
- Miscellaneous
  - Modems
  - Optical Disks

The major software modules needed to process the data from their received form from GFSC to final spectra and maps are shown in the following viewgraph. Our goal is to link these modules in a way that will permit batch processing of the data.

It is our expectation that the main data reduction module can be obtained in total from one of several radio astronomy observatories whose data reduction requirements are similar to SWAS's.

SWAS CONCEPTUAL DESIGN REVIEW
JUNE 8, 1990

DATA REDUCTION - MAJOR SOFTWARE NEEDS

- ❐ Command procedure to transfer data from optical disk to magnetic disks, produce a summary of the data for the pipeline processor operator to scan, and do error checking.

- ❐ Routine to separate the incoming data into Science and Housekeeping data then organize each into appropriate bins (e.g., Science - CAL's, COMB, ON's, OFF's, etc.; Housekeeping - temperatures, voltages, frequencies, etc.).

- ❐ Routine to output (plots and hardcopy) Housekeeping data and archive this data.

- ❐ Routine to correct Science data for any boresight pointing offsets (if necessary).

- ❐ Routine to facilitate the identification of bad scans to be removed prior to co-averaging.

- ❐ Routine to re-format the science data into a form readable by main data reduction module (CLASS or UMass Data Reduction Package).

- ❐ Batch reduction command procedures to do various reductions with CLASS or UMass Data Reduction Package.

- ❐ Routine to make spatial and/or spatial velocity maps (e.g., IRAF).

The current baselined sunshade design has a 35° Earth avoidance angle and a 75° Sun avoidance angle. Given these constraints, we have calculated the average number of minutes per orbit that Jupiter, Saturn, and Mars will be visible throughout 1993, 1994, and 1995 in two-month intervals. These results are presented in the following viewgraph.

There is a strong preference to launch SWAS at a time when Jupiter is available since it is by far the strongest calibrator. Early in the mission, when boresighting and calibration activities are most intensive, the availability of a calibrator as strong as Jupiter will greatly expedite these procedures (conversely, there are times of the year when Saturn and Mars will be difficult to detect without lengthy integrations, making them unsuitable for the calibration procedures required).

AVAILABILITY OF CALIBRATORS (35°/75° Sunshade)

		Minutes of Observing Each Orbit		
Year	Month	Jupiter	Saturn	Mars
1993	January	37.5	0.0	33.0
	March	28.5	0.0	21.0
	May	27.0	7.5	37.5
	July	37.5	22.5	4.5
	September	0.0	33.0	0.0
	November	0.0	19.5	0.0
1994	January	7.5	3.0	0.0
	March	21.0	0.0	0.0
	May	33.0	4.5	0.0
	July	19.5	19.5	1.5
	September	6.0	33.0	4.5
	November	0.0	22.5	37.5
1995	January	1.5	6.0	22.5
	March	37.5	0.0	31.5
	May	27.0	3.0	16.5
	July	27.0	39.0	9.0
	September	37.5	31.5	1.5
	November	1.5	25.5	0.0

NASA National Aeronautics and Space Administration

Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
N/A		

4. Title and Subtitle
Mission Operations and Data Analysis Plan for the Submillimeter Wave Astronomy Satellite (SWAS)

5. Report Date
July 1990

6. Performing Organization Code

7. Author(s)
Dr. Gary J. Melnick, Principal Investigator

8. Performing Organization Report No.
SWAS - 224

10. Work Unit No.
N/A

9. Performing Organization Name and Address
Smithsonian Astrophysical Observatory
60 Garden Street
Cambridge, Massachusetts 02138

11. Contract or Grant No.
NAS5-30702

13. Type of Report and Period Covered
Technical Document per § B.1 of NAS5-30702

12. Sponsoring Agency Name and Address
National Aeronautics and Space Administration:
Small Explorer Project, Code 740
Goddard Space Flight Center, Greenbelt, Maryland 20771

14. Sponsoring Agency Code

15. Supplementary Notes
NASA Technical Officer for Contract NAS5-30702: Mr. Walter Nagel, Code 740.4, Goddard Space Flight Center

16. Abstract

The Submillimeter Wave Astronomy Satellite (SWAS) will map selected regions of the sky at four specific wavelengths in the 490 to 553 GHz range. This document presents the Mission Operations and Data Analysis Plan for SWAS. It defines organizational responsibilities, discusses target selection and navigation, specifies instrument command and data requirements, defines data reduction and analysis hardware and software requirements, and discusses mission operations center staffing requirements.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
submillimeter wave astronomy, gigahertz range receivers, acousto-optical spectrometer, Small Explorer Project, Submillimeter Wave Astronomy Satellite (SWAS)	Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	41	N/A

NASA FORM 1626 OCT 86

PAGE 40 INTENTIONALLY BLANK

PRECEDING PAGE BLANK NOT FILMED

PREPARATION OF THE REPORT DOCUMENTATION PAGE

The last page of a report facing the third cover is the Report Documentation Page, RDP. Information presented on this page is used in announcing and cataloging reports as well as preparing the cover and title page. Thus it is important that the information be correct. Instructions for filling in each block of the form are as follows:

Block 1. Report No. NASA report series number, if preassigned.

Block 2. Government Accession No. Leave blank.

Block 3. Recipient's Catalog No. Reserved for use by each report recipient.

Block 4. Title and Subtitle. Typed in caps and lower case with dash or period separating subtitle from title.

Block 5. Report Date. Approximate month and year the report will be published.

Block 6. Performing Organization Code. Leave blank.

Block 7. Author(s). Provide full names exactly as they are to appear on the title page. If applicable, the word editor should follow a name.

Block 8. Performing Organization Report No. NASA installation report control number and, if desired, the non-NASA performing organization report control number.

Block 9. Performing Organization Name and Address. Provide affiliation (NASA program office, NASA installation, or contractor name) of authors.

Block 10. Work Unit No. Provide Research and Technology Objectives and Plans (RTOP) number.

Block 11. Contract or Grant No. Provide when applicable.

Block 12. Sponsoring Agency Name and Address. National Aeronautics and Space Administration, Washington, D.C. 20546-0001. If contractor report, add NASA installation or HQ program office.

Block 13. Type of Report and Period Covered. NASA formal report series; for Contractor Report also list type (interim, final) and period covered when applicable.

Block 14. Sponsoring Agency Code. Leave blank.

Block 15. Supplementary Notes. Information not included elsewhere: affiliation of authors if additional space is required for block 9, notice of work sponsored by another agency, monitor of contract, information about supplements (film, data tapes, etc.), meeting site and date for presented papers, journal to which an article has been submitted, note of a report made from a thesis, appendix by author other than shown in block 7.

Block 16. Abstract. The abstract should be informative rather than descriptive and should state the objectives of the investigation, the methods employed (e.g., simulation, experiment, or remote sensing), the results obtained, and the conclusions reached.

Block 17. Key Words. Identifying words or phrases to be used in cataloging the report.

Block 18. Distribution Statement. Indicate whether report is available to public or not. If not to be controlled, use "Unclassified-Unlimited." If controlled availability is required, list the category approved on the Document Availability Authorization Form (see NHB 2200.2, Form FF427). Also specify subject category (see "Table of Contents" in a current issue of STAR), in which report is to be distributed.

Block 19. Security Classification (of this report). Self-explanatory.

Block 20. Security Classification (of this page). Self-explanatory.

Block 21. No. of Pages. Count front matter pages beginning with iii, text pages including internal blank pages, and the RDP, but not the title page or the back of the title page.

Block 22. Price Code. If block 18 shows "Unclassified-Unlimited," provide the NTIS price code (see "NTIS Price Schedules" in a current issue of STAR) and at the bottom of the form add either "For sale by the National Technical Information Service, Springfield, VA 22161-2171" or "For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-0001," whichever is appropriate.