20405-6001-R0-81

DEFINITION OF EXPERIMENTS AND INSTRUMENTS FOR A COMMUNICATION/NAVIGATION RESEARCH LABORATORY

VOLUME III

LABORATORY DESCRIPTIONS

STUDY REPORT
DR MA - 04

JULY 1972

PREPARED FOR MARSHALL SPACE FLIGHT CENTER
UNDER CONTRACT NO. NAS.8 - 27540

TRW
SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH CALIFORNIA 90278

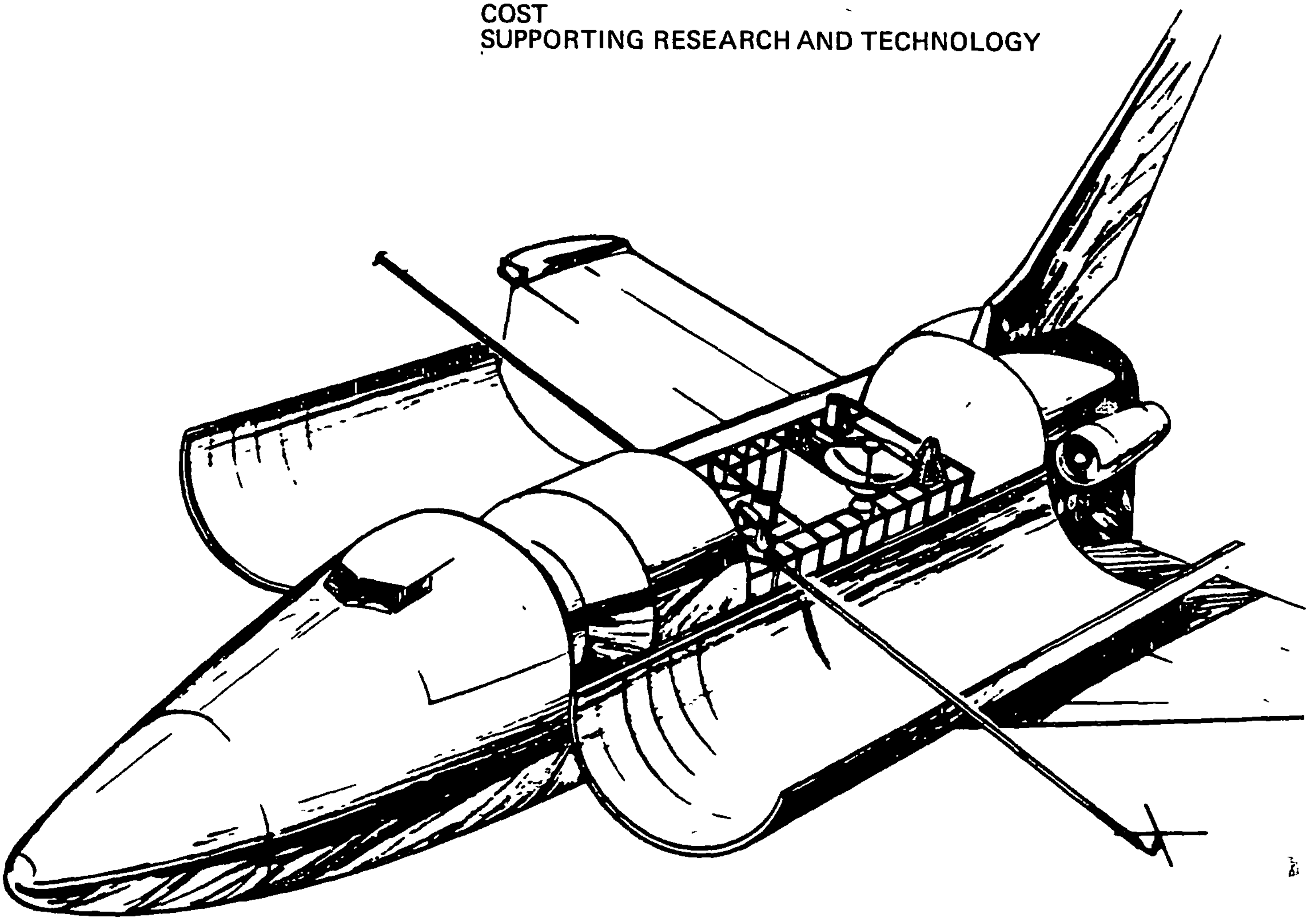
INSTITUTE FOR
TELECOMMUNICATION
SCIENCES

MCDONNELL DOUGLAS
ASTRONAUTICS
COMPANY

COMMUNICATIONS
SATELLITE
CORPORATION

THE STUDY REPORT CONSISTS OF FOUR VOLUMES AS FOLLOWS

VOLUME I - EXECUTIVE SUMMARY
VOLUME II - EXPERIMENT SELECTION
APPENDIX - EXPERIMENT DESCRIPTIONS
VOLUME III - LABORATORY DESCRIPTIONS
VOLUME IV - PROGRAMMATICS
DEVELOPMENT SCHEDULE
COST
SUPPORTING RESEARCH AND TECHNOLOGY



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1.0 INTRODUCTION

This volume is part of a four volume Interim Report on a phase A study entitled: "Definition of Experiments and Instruments for a Communication/Navigation Research Laboratory." The purpose of the study was to develop conceptual designs for a manned communication/navigation research laboratory capable of supporting various experiments in the field of communication and navigation. Volume I is an Executive Summary. Volume II, with its Appendix, describes the selection and definition of candidate experiments and the associated experiment instrumentation requirements. Volume III covers the following study objectives:

- Identification of major laboratory equipment.
- Systems and operations analysis in support of the laboratory design.
- Conceptual design of the Comm/Nav Research Laboratory.

The cost, schedule, and SRT requirements are presented in Volume IV.

1.1 ASSUMPTIONS AND GUIDELINES

The contract Statement of Work contained certain assumptions and guidelines which were utilized for the initial study effort. Most of these original guidelines have been substantially changed during the course of the study. The following are some of the major guidelines which were in effect during the principal decision-making phases of the study.

1.1.1 The Comm/Nav Research Laboratory will be designed to be compatible with the Sortie Can, now called Sortie Module.

1.1.2 The IOC date for the initial Comm/Nav Laboratory is assumed to be 1980.

1.1.3 A Data Relay Satellite System (DRSS) will be available concurrent with the implementation of the Comm/Nav Research Laboratory.

1.1.4 Stability limits of 0.5 degree attitude control dead bands and 0.01 deg/sec maximum limit cycle rate for each axis shall be provided by the Shuttle Orbiter.

1.1.5 The Orbiter crew shall consist of two (2) payload crewmen.

1.2 STUDY METHODOLOGY

Figure 1.2-1 reflects the general flow of the six principal study tasks. Two key events not reflected on this flow diagram are worth mentioning since they did have a major impact on the study. The first event was the solicitation from all known sources (government, the academic community, industry, and foreign) for candidate laboratory experiments. The screening process, and the results of this endeavor are described in Volume II. The second major event was the survey of commercial hardware for possible use in a manned orbiting vehicle. The results of this survey are reported below in Section 4.4 of this volume.

The concept of three laboratory versions (Early, Growth, and Total) was carried throughout most of the study period, but was deemphasized in the latter phase of the study. Instead, the Early Lab version was selected for detailed study and this detail is reflected in this report.

1.3 EXPERIMENT DEFINITION

An extensive survey, following the plan shown in Figure 1.3-1, was conducted to identify candidate experiments for the laboratory. The survey was made via the solicitation letter and followup actions as outlined in Figure 1.3-2. A total of 114 individual experiments were submitted by various elements of government, industry, and the academic community as shown on Figure 1.3-3. Further details of this solicitation activity may be found in Volume II.

The 114 individual experiments were subsequently grouped into two broad categories - those related to the natural environment and those related to hardware. Under these broad categories, 18 investigative areas were defined as shown in Figure 1.3-4. The 18 areas were, in turn, evaluated and ranked for consideration as Early Lab experiments. The suitability of an experiment for a low earth orbit laboratory was one of several factors involved in the selection process; a tabulation of the tradeoffs involved are presented in Tables 1.3-1 through 1.3-6. Other factors considered included:

- Potential usefulness and timeliness of experiment results.
- Usefulness of man.

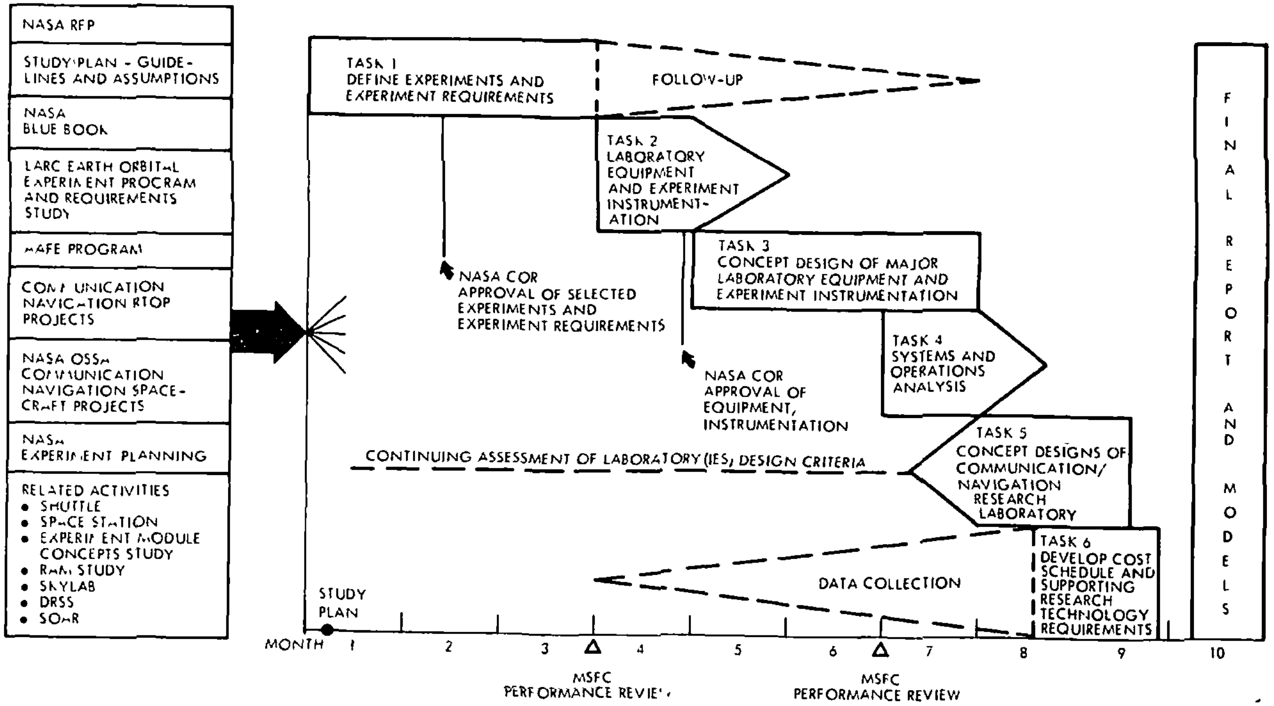


Figure 1.2-1. Comm/Nav Laboratory Study Task Flow

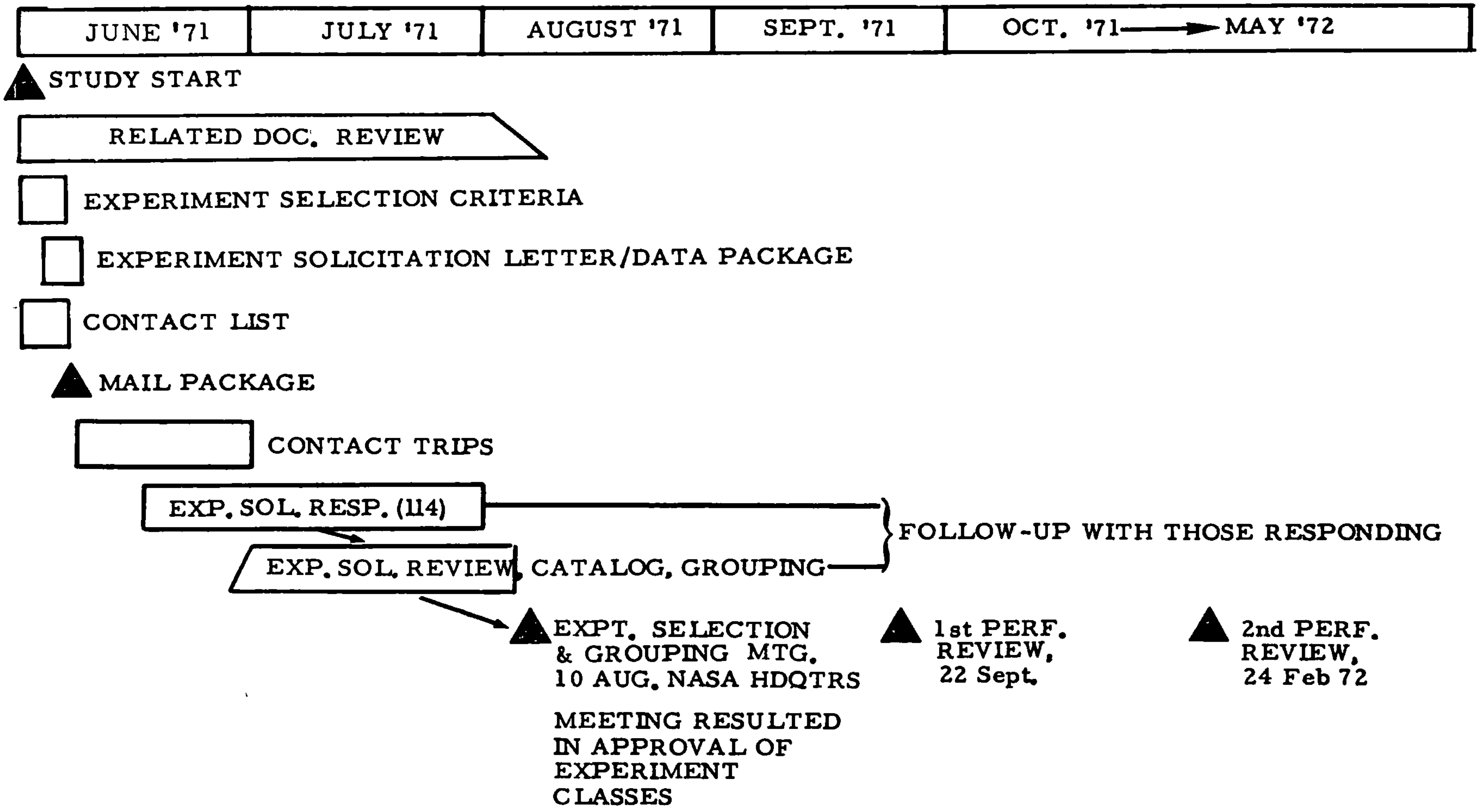
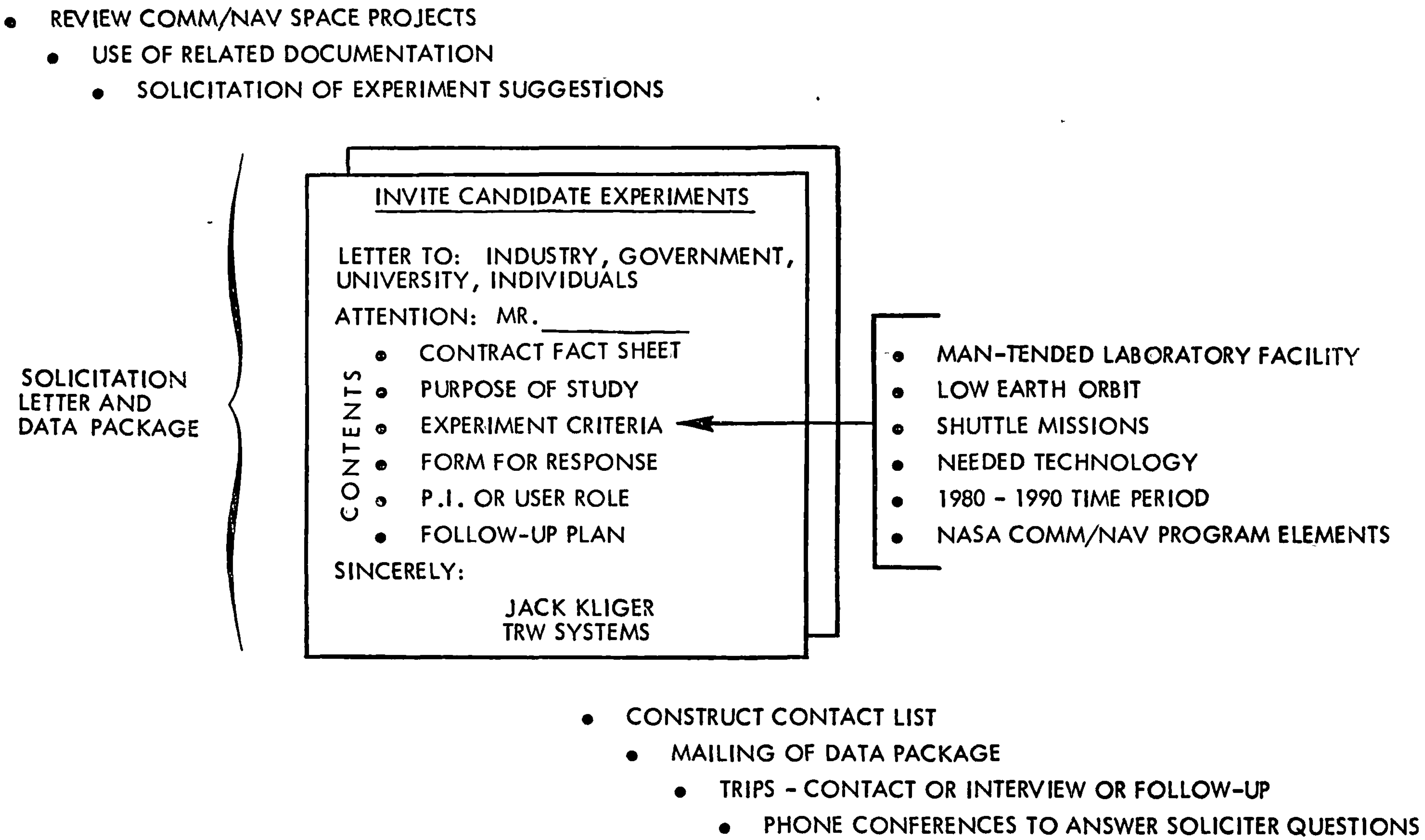


Figure 1.3-1. Comm/Nav Experiment Selection Plan



- REVIEW COMM/NAV SPACE PROJECTS
  - USE OF RELATED DOCUMENTATION
    - SOLICITATION OF EXPERIMENT SUGGESTIONS

SOLICITATION LETTER AND DATA PACKAGE

INVITE CANDIDATE EXPERIMENTS

LETTER TO: INDUSTRY, GOVERNMENT, UNIVERSITY, INDIVIDUALS

ATTENTION: MR.__________

CONTENTS
- CONTRACT FACT SHEET
- PURPOSE OF STUDY
- EXPERIMENT CRITERIA
- FORM FOR RESPONSE
- P.I. OR USER ROLE
- FOLLOW-UP PLAN

SINCERELY:

JACK KLIGER
TRW SYSTEMS

- MAN-TENDED LABORATORY FACILITY
- LOW EARTH ORBIT
- SHUTTLE MISSIONS
- NEEDED TECHNOLOGY
- 1980 - 1990 TIME PERIOD
- NASA COMM/NAV PROGRAM ELEMENTS

- CONSTRUCT CONTACT LIST
  - MAILING OF DATA PACKAGE
    - TRIPS - CONTACT OR INTERVIEW OR FOLLOW-UP
      - PHONE CONFERENCES TO ANSWER SOLICITER QUESTIONS

Figure 1.3-2. Comm/Nav Experiment Survey Methodology

GOVERNMENT: NASA – HEADQUARTERS, MSFC, GSFC, LRC, MSC, ARC, JPL

GOVERNMENT: OTHER – ESSA (ITS)*, DEPARTMENT OF TRANSPORTATION, SAMSO, NRL, FAA, USAF

INDUSTRY:

- TRW*
- MDAC*
- BELL LABS
- HONEYWELL
- RAYTHEON
- HUGHES
- GE
- WESTINGHOUSE
- RADIATION SYSTEMS
- NATIONAL SCIENTIFIC LABS
- FAIRCHILD HILLER
- HEWLETT PACKARD
- RCA
- WESTERN UNION
- ATT
- ITT
- CORP. FOR PUBLIC BROADCASTING
- CONVAIR
- BENDIX
- SYLVANIA
- BECKMAN
- LOCKHEED
- PHILCO FORD
- IBM

UNIVERSITY: ILLINOIS, PENNSYLVANIA, HOUSTON, MIT, STANFORD, ALASKA

INTERNATIONAL: ESRO, HAWKER-SIDDELEY

OTHER ORGANIZATIONS: MITRE CORP, AEROSPACE CORP, COMSAT CORP.* APPLIED PHYSICS LAB, LISTER HILL NATIONAL INSTITUTE OF HEALTH

INDIVIDUALS: (CONSULTANT) DR. B. LUSIGNAN, STANFORD AND DR. A. MALLINCKRODT

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* MEMBERS OF THE TRW CONTRACTOR TEAM

Figure 1.3-3. Solicitation of Comm/Nav Candidate Experiments

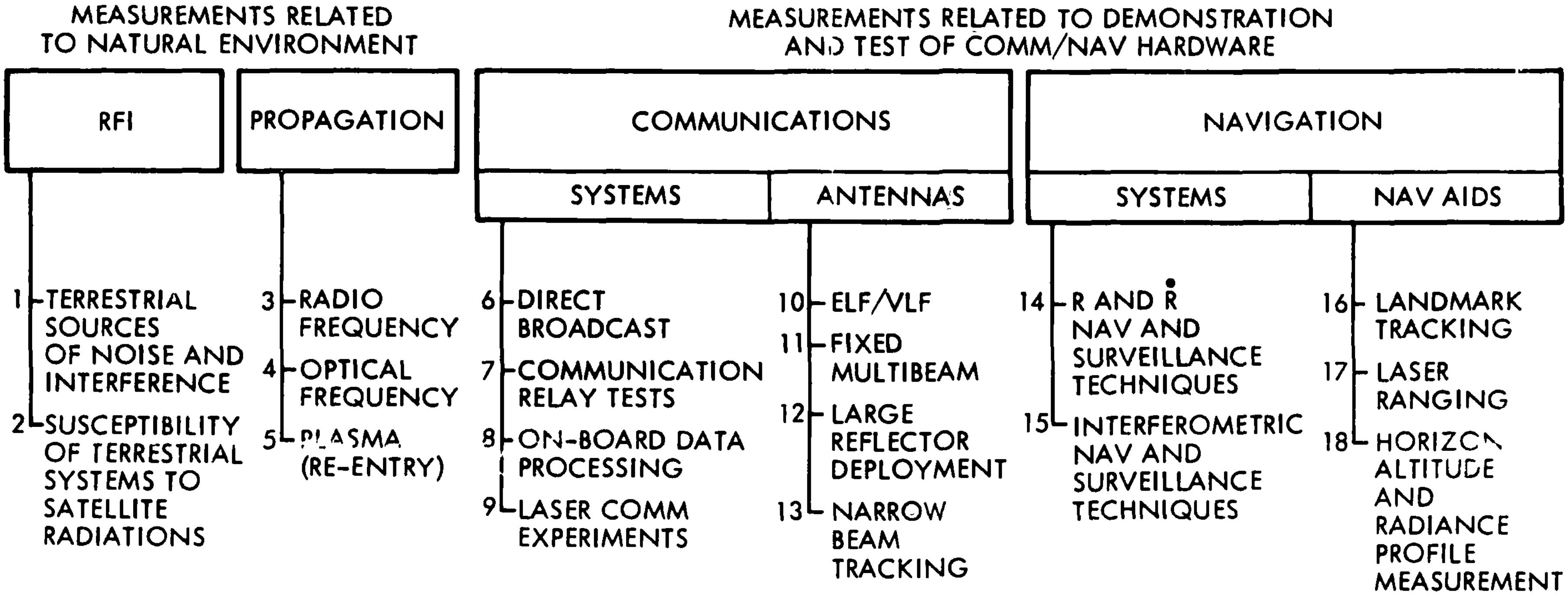

Figure 1.3-4. Class Grouping of Candidate Experiments

Table 1.3-1. Experiments Related to Natural Environment (RFI)

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB AIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
TERRESTRIAL SOURCES OF NOISE AND INTERFERENCE	• MAP NATURAL AND MAN MADE TERRESTRIAL NOISE & RADIO FREQUENCY SIGNALS IN OPERATIONAL AND PROJECTED FREQUENCY BANDS	• L-O PROVIDES SPATIAL ISOLATION • GROUND ALLOCATION ARE REPEATED • IDENTIFICATION & LOCATION OF SOURCES THEREFORE MUCH EASIER • SHORT RANGE ENHANCES SIGNAL LEVEL FOR MAPPING LOW LEVELS • L-O MAKES POSSIBLE POSITION LOCATION WITH MODEST ANTENNA • DOPPLER USEFUL FOR LOCATION	• VERY HELPFUL TO EVALUATE OPERATOR FUNCTIONS • EXPECT HIGHER (RF) NOISE LEVEL • GEOMETRY MAKES SIGNAL DENSITY & LEVEL DIFFERENT
SUSCEPTIBILITY OF TERRESTRIAL SYSTEMS TO SATELLITE RADIATIONS	• EVALUATE THE MAGNITUDE OF THE INTERFERENCE EXPERIENCED BY TERRESTRIAL COMMUNICATION SYSTEMS DUE TO TRANSMISSION FROM SPACECRAFT	• L-O LIMITS SERVICE AREA AFFECTED • ALLOWS USE OF SMALLER TX POWER • DOPPLER PERMITS GROUND TEST POINTS TO DERIVE OVERFLIGHT GEOMETRY	• HELPFUL • WOULD SPEED PROGRAM BY PROVIDING EARLY EXPERIENCE • DWELL CAN BE SIMULATED WITH SPIRAL ROUTE OR SLOW AIRCRAFT (CHOPPER)

L-O = LOW ORBIT

Table 1.3-2. Experiments Related to Natural Environment (Propagation)

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB ACIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
RADIO FREQUENCY	• ACCUMULATE DATA ON RF PROPAGATION EFFECTS INCLUDING - MULTIPATH - SCINTILLATION - FARADAY ROTATION • QUANTITY EFFECTS TO ALLOW DESIGN OF OPTIMUM SATELLITE COMM/NAV SYSTEMS	• PROPAGATION EFFECTS ARE ASSOCIATED WITH IONOSPHERE • L-O AT 200-300 NMI IS JUST OUTSIDE IONOSPHERE • SELECTED L-O GIVE MINIMUM RANGE LOSS WHILE PROVIDING TRANS-IONOSPHERIC TEST PATH TO EARTH • L-O GIVES MINIMUM RANGE LOSS FOR MULTIPATH TESTS WITH GOOD COMPROMISE ON VISIBILITY FOOTPRINT • NEED NARROW BEAM TO INVESTIGATE ANOMALIES	• NOT WORTHWHILE. ALREADY HAVE DATA FROM AIRCRAFT ON SOME PARAMETERS (WPAFB) • TOO LOW FOR TRANS-IONOSPHERIC TESTS
OPTICAL FREQUENCY	• EXTEND KNOWLEDGE OF OPTICAL WAVELENGTH PROPAGATION PHENOMENA IN THE ATMOSPHERE AND FREE SPACE	• OFFERS REALISTIC COMMUNICATION RANGE AND ATMOSPHERIC PATH • MINIMAL TRANSMIT POWER • CONVENIENT FOR MEASUREMENTS WITH VARIABLE ELEVATION ANGLE • ATMOSPHERIC GRAZING EFFECT INVESTIGATIONS EASILY CONDUCTED	• MODESTLY HIGH-ATTITUDE (50K) AIRCRAFT TESTS CAN INVESTIGATE LIMITED ATMOSPHERIC PROPAGATION PHENOMENA
PLASMA (RE-ENTRY)	• INVESTIGATE PLASMA SHOULD RE-ENTRY SIGNAL LOSS, ANTENNA MISMATCH AND ENHANCED NOISE TEMPERATURE • EVALUATE LOSS VERSUS FREQUENCY • DEFINE AND DEMONSTRATE RELIABLE SYSTEMS	• L-O SUB SATELLITE DATA COLLECTION EXPERIENCES ABSOLUTE MINIMUM RANGE LOSS TO RE-ENTRY VEHICLE ALLOWING EXTENDED ATTEN/FREQ. MEASUREMENTS • MINIMIZES POINTING ACCURACY	• NOT APPLICABLE

Table 1.3-3. Measurements Related to Communication Systems

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB AIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
DIRECT BROADCAST	• EVALUATE & QUANTIFY PARAMETER SENSITIVITY FOR DIRECT TV AND RADIO TRANSMISSION • DEMONSTRATE FEASIBILITY OF HOME RECEPTION WITH SIMPLE ANTENNA IN UHF BAND	• MINIMUM POWER NEAR EARTH • REDUCED COVERAGE FOOTPRINT ALLEVIATES RFI TO OTHER TERRESTRIAL SERVICES • ALLOWS SIMPLE SUPPORT COMM SYSTEM TO EARTH • LIMITED 'DWELL' IS ADVANTAGE IN NOT COMPETING WITH COMMERCIAL TV PROGRAMS	• VERY HELPFUL • LEVELS DIFFERENT BUT CAN PAD • DWELL CAN BE SIMULATED BY SPIRAL ROUTE OR CAN USE SLOW (HELICOPTER) AIRCRAFT
COMMUNICATION RELAY	• EVALUATE AND DEMONSTRATE EQUIPMENT AND PROCEDURES TECHNIQUES ETC RELATED TO COMM VIA A DATA RELAY SATELLITE (TDRS)	• SHORT RANGE TO EARTH GIVES LOW LOSS FOR MOST UNPREDICTABLE PORTION OF LINK (WEATHER & IONOSPHERE) • SHUTTLE NEED DRS FOR EARTH DATA DUMP	• ALREADY ADEQUATELY COVERED BY CLASSIFIED PROGRAM TESTS
ON-BOARD DATA PROCESSING	• DEMONSTRATE TECHNIQUES THAT WILL CONSIDERABLY IMPROVE COMM/NAV SATELLITE SERVICES, INCLUDING - ALLEVIATE MULTIPATH - PROVIDE DIRECT USER CONTROL - REDUCE INTERFERENCE - IMPROVE FLEXIABILITY	• CLOSELY APPROXIMATES LOW ORBIT EARTH RESOURCES WEATHER & POLLUTION SATS - AN IMPORTANT APPLICATION	• STRONGLY RECOMMENDED • DESIRABLE STEP TO EXERCISE CONCEPTS EARLY & SECURE SUPPORT FOR POTENTIAL IMPROVEMENTS
LASER COMMUNICATIONS	• REFINE AND EXTEND LASER TECHNOLOGY IN SPACE APPLICATIONS AT VARIOUS OPTICAL FREQUENCIES	• AMPLE SIGNAL LEVELS ENHANCE PERFORMANCE OF EXPERIMENT • RAPID AND RELIABLE DEVELOPMENT TEST BED (MINIMUM LEAD-TIME) • PROVIDES REALISTIC CONTROLLED SIMULATION OF SATELLITE-TO-SATELLITE LASER COMMUNICATIONS • RELATIVELY MODEST REQUIREMENTS FOR TRANSMIT POWER AND RECEIVER SENSITIVITY • INCREASED EQUIPMENT COMPLEXITY TO ACCOMMODATE DOPPLER SHIFT • EVOLUTIONARY NATURE OF THIS CLASS IMPLIES MULTIPLE FLIGHTS • IDEAL SIMULATION OF LOW ALTITUDE USER SPACECRAFT	• SUITABLE FOR DEMONSTRATING OPERABILITY OF EQUIPMENT AND PROCEDURES • CANNOT SIMULATE LONG RANGE COMMUNICATION LINK • STRUCTURAL VIBRATION INTRODUCED JITTER WHICH DISTRUBS POINTING AND TRACKING EXERCISES

Table 1.3-4. Measurements Related to Communication Antennas

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB AIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
ELF/VLF	• EXTEND OUR KNOWLEDGE OF RADIATION PHENOMENA IN ELF/VLF REGION - PERMIT REAL TIME R&D TESTING OF ANTENNAS & SPECIAL DEPLOYMENT DEVICES - SUPPLEMENT EXISTING THEORY WITH HARD TEST DATA - DEMONSTRATE LF/MF COMM	• PROXIMITY TO OUTER LAYER OF IONOSPHERE IS IDEAL • NON-STATIONARY ORBIT IS ESSENTIAL FOR MAPPING GEOGRAPHIC VARIATIONS (POLAR EFFECTS, & LATITUDE DEPENDENCE)	NOT APPLICABLE (BELOW IONOSPHERE)
FIXED MULTIBEAM ANTENNA	• DEMONSTRATE AND EVALUATE RELATIVE PERFORMANCE OF COMPETING MULTIPLE BEAM CONCEPTS IN A SPACE ENVIRONMENT FOR FREQUENCY REUSE, POLARIZATION ISOLATION AND BEAM AND SIDE LOBE CONTROL	• MINIMAL INTERFERENCE TO TERR. SYSTEMS • MINIMIZES TRANSMITTER POWER REQUIREMENTS • REALISTIC SPACE/THERMAL ENVIRONMENT • MULTIPLE FLIGHTS POSTULATED TO MEET OBJECTIVES • COST EFFECTIVE EVALUATION METHOD • QUICK REACTION FLIGHT TEST CAPABILITY • DOPPLER EFFECT IS IRRELEVANT TO DESIRED OBJECTIVES - NO CORRECTION REQUIRED	• AIRCRAFT ANTENNA RADOME REQUIRED • DOES NOT SIMULATE OPERATIONAL ENVIRONMENT IN SPACE
LARGE DEPLOYABLE REFLECTOR	• EVALUATE THE PERFORMANCE OF LARGE DEPLOYABLE ANTENNAS IN FREE SPACE • DEVELOP NEEDED EVA SKILLS NEEDED FOR FUTURE SPACE STATION • DEVELOP MEASUREMENT TECHNIQUES FOR PATTERN/REFLECTOR APPRAISAL IN EVA ENVIRONMENT	• L-O MINIMIZES BOOSTER COSTS TO ORBIT PAYLOAD	NOT APPLICABLE
NARROW BEAM TRACKING	• ACCUMULATE PRACTICAL TEST DATA ON MANUAL TRACKING PERFORMANCE USING ULTRA NARROW BEAM ANTENNAS DEFINE LIMITS NEEDED FOR FUTURE SPACE/SPACE AND GROUND HIGH GAIN ANTENNA COMM LINKS	• SHORT RANGE FROM SHUTTLE TO EARTH GIVES MINIMUM SPACE LOSS FOR MOST UNPREDICATABLE PORTION OF LINK (DUE TO WEATHER & IONOSPHERIC EFFECTS)	• HELPFUL • WOULD SPEED UP PROGRAM & YIELD EARLY DATA ON HUMAN PERFORMANCE • ACOUSTIC NOISE LEVEL MUST BE TREATED.

Table 1.3-5. Measurements Related to Navigation Systems

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB AIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
RANGE AND RANGE RATE NAVIGATION AND SURVEILLANCE TECHNIQUES	• DEMONSTRATE AND EVALUATE RANGE AND RANGE RATE MEASUREMENT TECHNIQUES FOR FUTURE TERRESTRIAL NAVIGATION, SURVEILLANCE AND SEARCH/RESCUE SYSTEMS	• IDEAL SIMULATION OF LOW-ALTITUDE USER • DOPPLER IS DESIRABLE FOR RANGE RATE MEASUREMENTS • MODEST TRANSMIT POWER AND RECEIVER SENSITIVITY REQUIREMENTS	AIR FORCE IS CURRENTLY PURSUING RELATED TESTS
INTERFEROMETRIC NAVIGATION AND SURVEILLANCE TECHNIQUES	• DEMONSTRATE AND EVALUATE THE LINE-OF-SIGHT MEASUREMENT ACCURACY OF A LONG BASELINE SPACECRAFT RECEIVING INTERFEROMETER AS A CANDIDATE FOR FUTURE NAVIGATION AND SURVEILLANCE SYSTEMS.	• FACILITIATES EVALUATION OF BOOM DEPLOYMENT MECHANISMS IN SPACE ENVIRONMENT • STABILITY OF BOOM SYSTEMS IN OPERATIONAL ENVIRONMENT MAY BE OBSERVED AND MODIFIED BY ASTRONAUT	NOT APPLICABLE TO AIRCRAFT IMPLEMENTATION BECAUSE OF RIGID, STABLE BASELINE (BOOM) REQUIREMENT

Table 1.3-6. Measurements Related to Navigation Aids

EXPERIMENT CLASS	EXPERIMENT CLASS OBJECTIVES	REMARKS ON EXPERIMENT CONDUCT IN SHUTTLE SUPPORTED LABORATORIES IN LOW EARTH ORBIT	REMARKS ON PRE-LAB AIRCRAFT FLIGHTS TO ACQUIRE EARLY DATA
LANDMARK TRACKING	DETERMINE THE FEASIBILITY AND ACCURACY OF AUTONOMOUS NAVIGATION USING UNKNOWN EARTH LANDMARKS	• ALL FORESEEABLE USER APPLICATIONS ARE IN LOW ORBIT • TRACKER HAS BEEN DESIGNED FOR LOW ORBIT	• CAN CHECKOUT THE CORRELATION MECHANIZATION AND LOGIC • LIMITED CAPABILITY TO SCALE FROM AIRCRAFT TO OPERATIONAL (LOW EARTH ORBIT) ALTITUDES
LASER RANGING	EVALUATE UTILITY AND ACCURACY OF SPACE-BORNE LASER RANGING SYSTEMS FOR APPLICATION WITH COOPERATIVE AND UNCOOPERATIVE TARGETS	• CAPABILITY TO ALTER RANGE TO COOPERATING LOW ALTITUDE SATELLITE • ONLY LOW-ORBIT TESTS ARE PRACTICAL WITH AVAILABLE TECHNOLOGY • REALISTIC SIMULATION OF TOPOGRAPHIC MAPPER	• LIMITED ALTIMETRY TESTS CAN PROVIDE PRELIMINARY PERFORMANCE ESTIMATES
HORIZON ALTITUDE AND RADIANCE PROFILE MEASUREMENTS	MEASURE THE SPECTRAL RADIANCE OF THE EARTH PARTICULARLY THE HORIZONS) FOR APPLICATION TO EARTH-POINTING SYSTEMS	• PROVIDES DESIRED GLOBAL COVERAGE • DESIRED COVERAGE ATTAINED MORE RAPIDLY THEN AT HIGHER ALTITUDE • ASTRONAUT CAN MAKE BENEFICIAL VISUAL CONTRAST MEASUREMENTS FOR CORRELATION WITH AUTOMATED DETECTOR DATA - AID TO DATA REDUCTION	• NOT SUITABLE - NEED TO GET ABOVE ATMOSPHERE FOR REALISTIC MEASUREMENTS

- Effect of mission duration.
- Cost effectiveness of using a manned laboratory.

As a result of this process, the following seven experiments were selected as candidates for the Early Lab:

- Terrestrial Sources of Noise and Interference
- RF Propagation
- Communication Relay Tests
- Laser Communication
- Fixed Multibeam Antenna
- Interferometric Navigation and Surveillance Techniques
- Landmark Tracking

1.4 SCALE MODEL

A 1/20 scale model of the Comm/Nav Research Lab was constructed and delivered to MSFC per the contract requirement. The model was constructed with various plug-in components to depict the two major configurations developed during the study. Figure 1.4-1 illustrates the in-bay or pallet configuration with the interferometer and communication relay antennas deployed. See Section 5 for definition of the elements and the derivation of this configuration.

Figures 1.4-2, 1.4-3, and 1.4-4 show the deployed or out-of-bay laboratory design which evolved from the desire to provide better antenna look angles. The laboratory is shown in various phases of deployment. Figure 1.4-2 depicts the lab stowed in the Orbiter cargo bay. Figure 1.4-3 shows the laboratory deployed but with the antenna mounting arms folded. Finally, Figure 1.4-4 shows the lab deployed, the arms unfolded, and the interferometer antenna booms extended. Other features of the Sortie Module design such as the life support system and the equipment birdcage structure are visible via cutouts in the Module exterior.

The interior of the Sortie Module has been included in the model and is shown in Figure 1.4-5. Note that only the laboratory-peculiar consoles are included in this model.

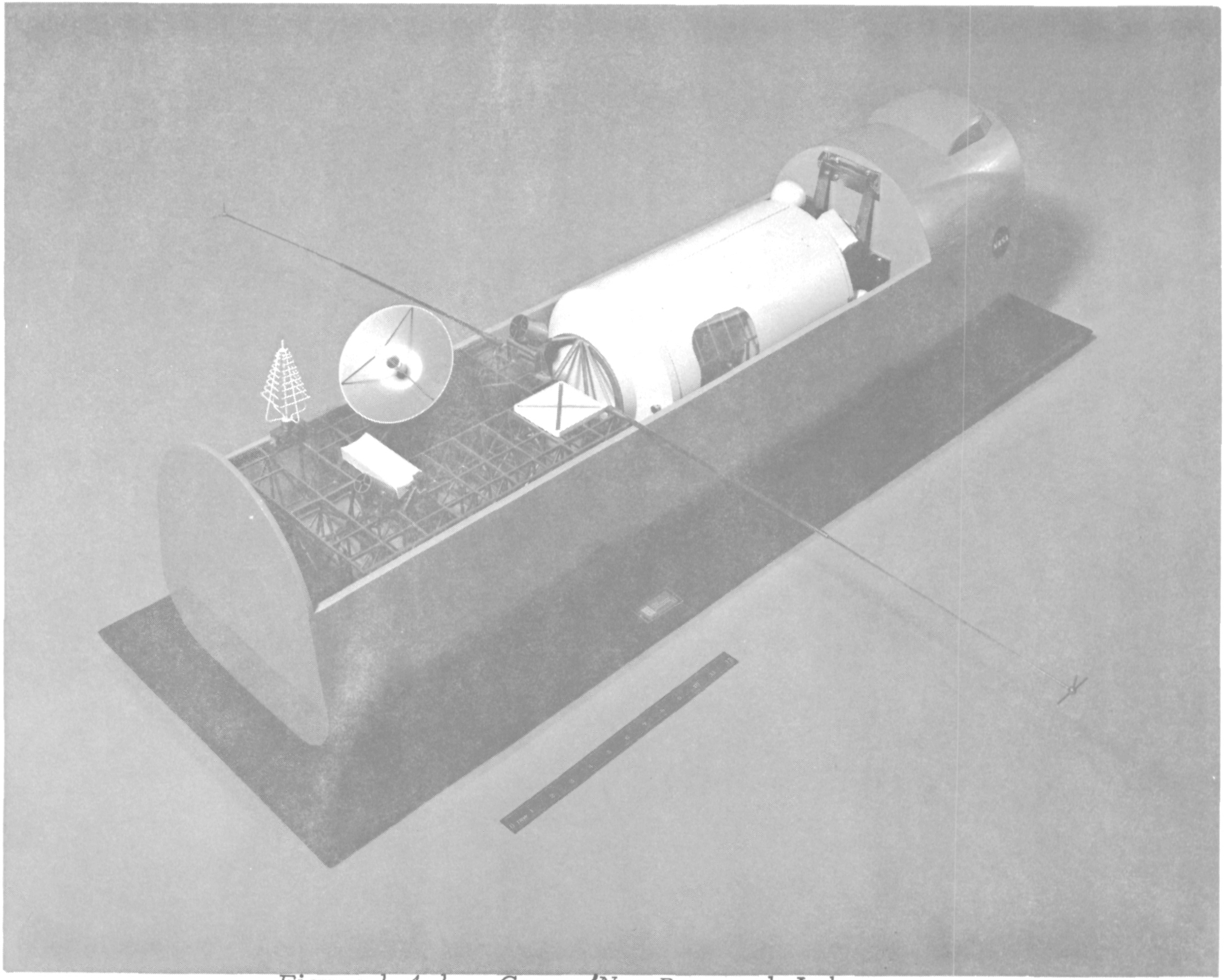

Figure 1.4-1. Comm/Nav Research Lab
(In-Bay Configuration)

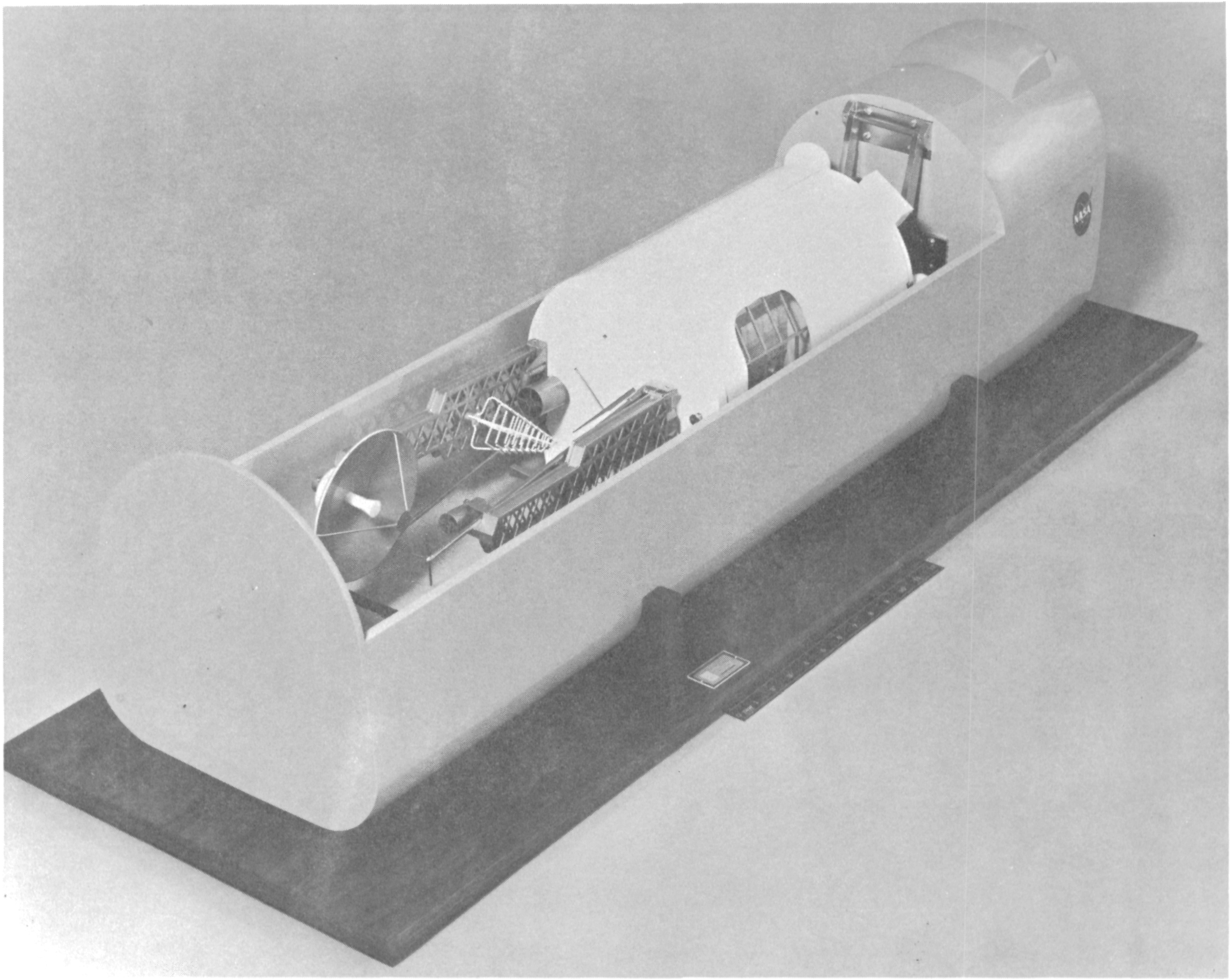

Figure 1.4-2. Out-Of-Bay Configuration (Stowed)

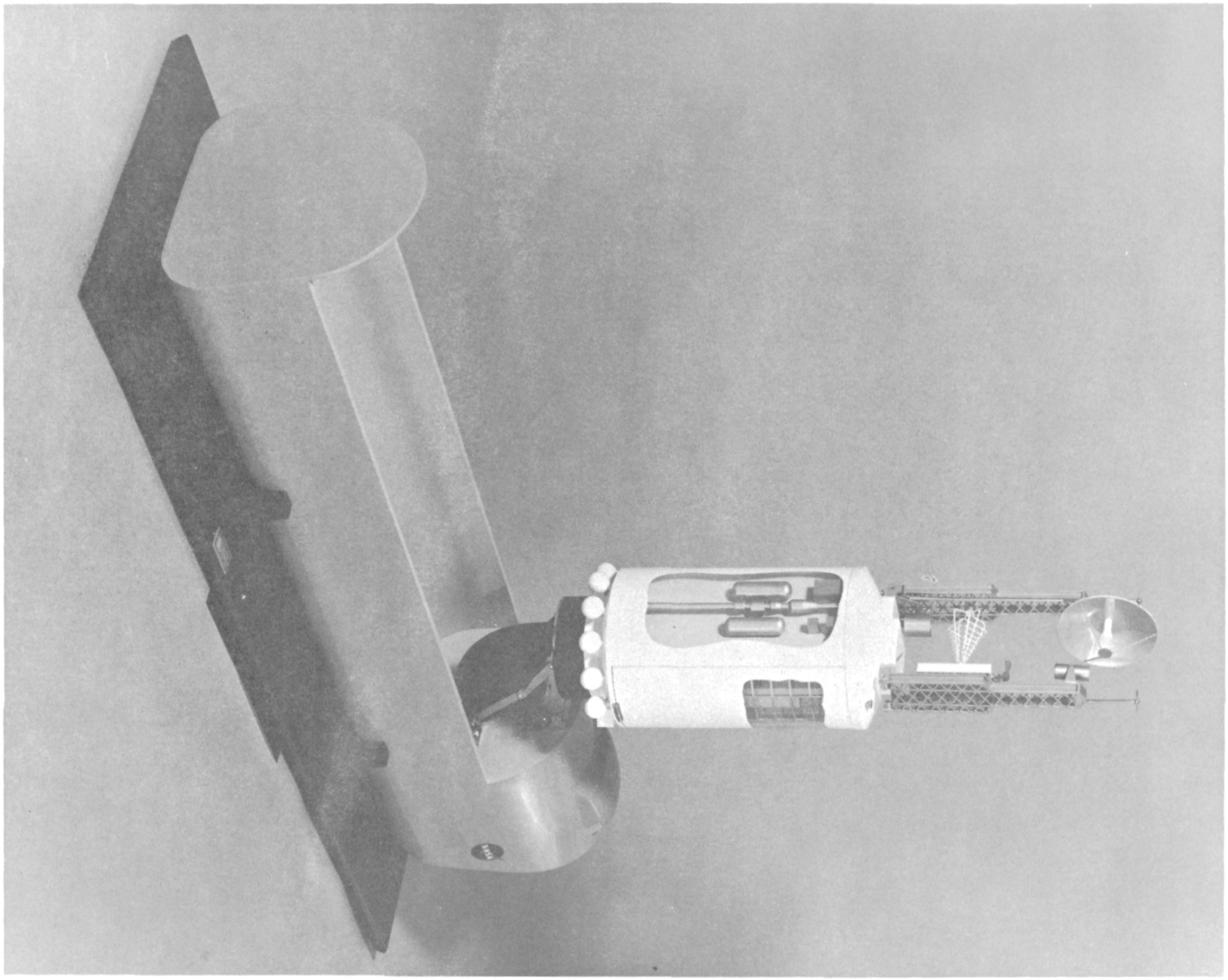

Figure 1.4-3. Out-Of-Bay Configuration
(Deployed and Folded)

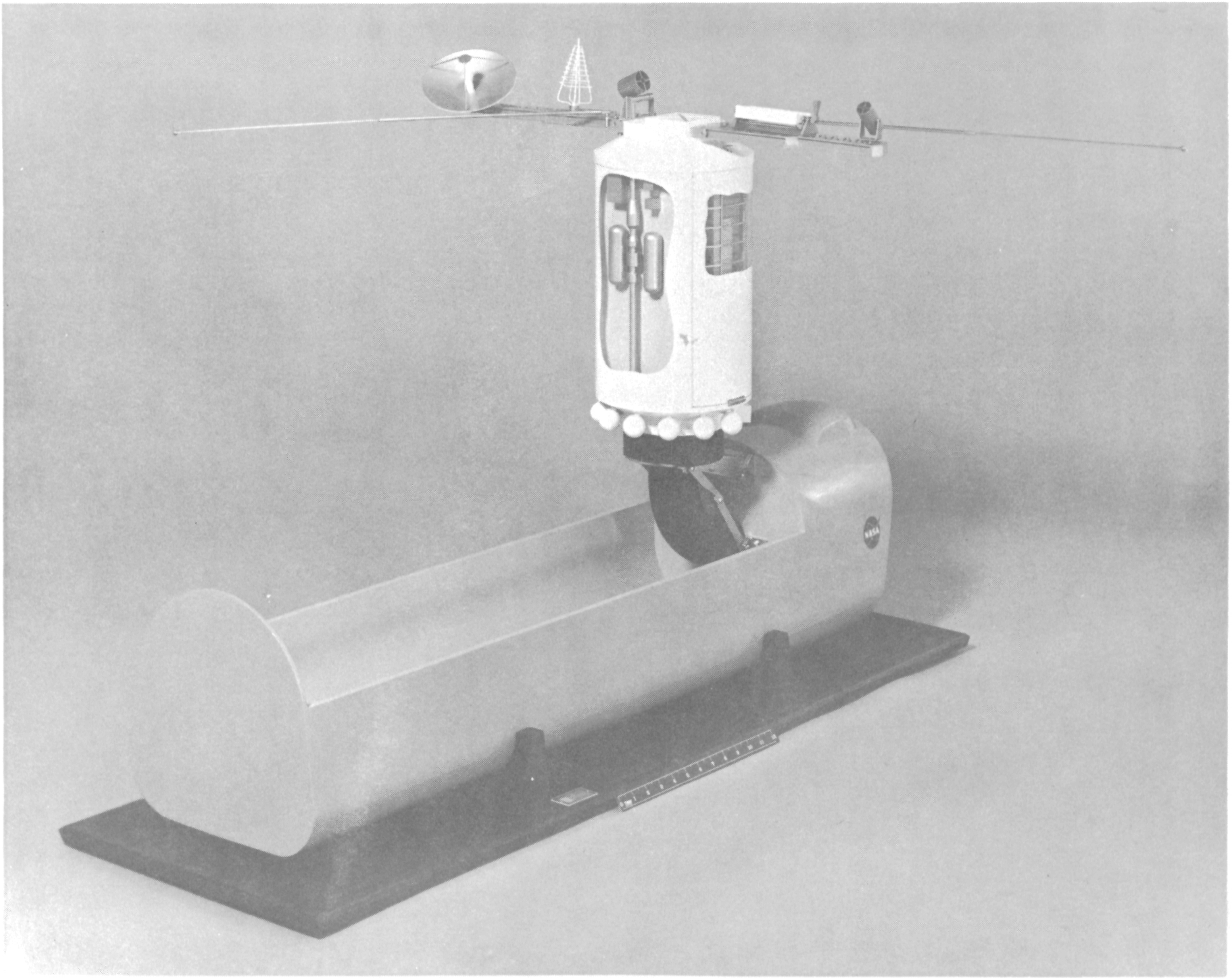

Figure 1.4-4. Out-Of-Bay Configuration
(Deployed and Unfolded)

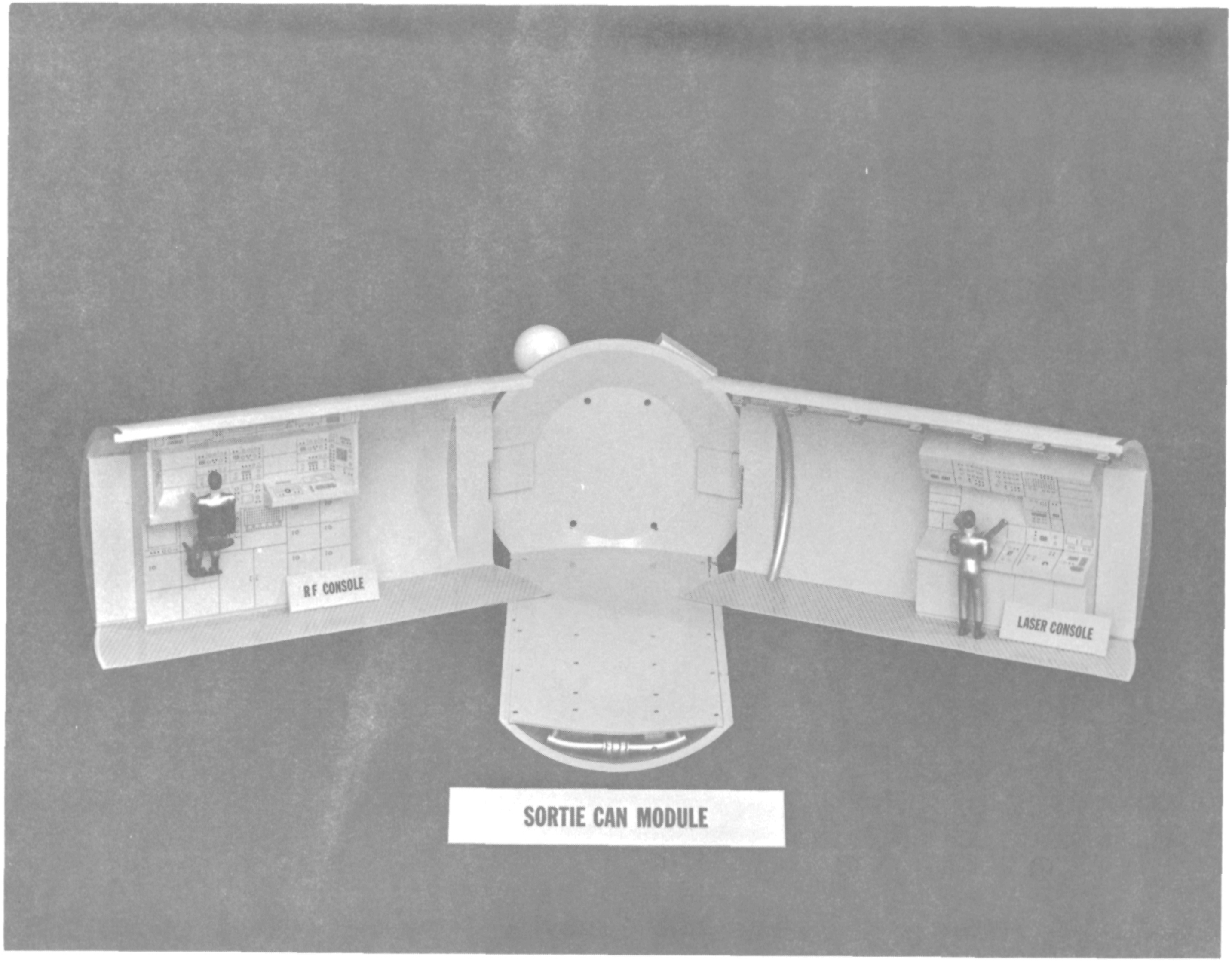

Figure 1.4-5. Sortie Module Interior (Comm/Nav Lab Consoles)

2.0 EQUIPMENT IDENTIFICATION

The recommended payload of seven experiments selected for early implementation on Sortie Can missions was evaluated to identify the kinds and key performance characteristics of the major equipment and instrumentation required to conduct and support each experiment. Supplementary information pertaining to quantity, functional/technical description, mass properties, and power consumption was also derived. Commercial equipments with performance characteristics similar to those required for the Comm/Nav Laboratory application are cited by vendor name and model number. In some cases a potential source is given based on their known capabilities in that discipline. Derivation of measurement requirements is given in Volume II.

2.1 Equipment Grouping

Predicated on the equipment definition discussed above, these lists were analyzed to identify common equipment characteristics compatible with performance requirements and minimum cost. "Common-core" and "equipment-unique" equipment lists were synthesized. Common core designates those items of equipment characterized by similar performance specifications which may be shared by the multiple experiments utilizing them, providing the operational usage requirements do not conflict. The experiment-unique category includes equipment which is peculiar to a single experiment in the payload.

In addition to the common-core and experiment-unique categories, a "control and display" group consolidates equipments characterized by their role in supporting the man-equipment interface; namely, monitoring the real-time performance and exercising the necessary control functions for the integrated payload. The caution-warning display and laser telescope gimbal controls illustrate the types of equipment associated with these two functions.

Tables 2.1-1 through 2.1-7 identify equipment for each of the seven candidate experiments. Table 2.1-8 contains the common-core equipment while Table 2.1-9 lists experiment-unique items. The control and display equipment is itemized in Table 2.1-10.

Table 2.1-1. Terrestrial Sources of RF Noise and Interference Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs)	Power (W)
ANTENNA	1	Signal Collection	Dual Orthogonally Polarized, Dual Beamwidth, Log Periodic VHF-UHF Assembly	TRW or RF Systems Inc	60 x 60 x 120	38	N/A
CALIBRATED ATTENUATOR UNIT	3	Dynamic Range Adjustment	0 - 60 dB, 50 Ohms Remote Electrical Control Digital Readout of Value, Manual Over-ride	Merrimac	3 x 3 x 4	1 0	N/A
RECEIVER	5*	Signal Selection	100 - 1000 MHz, Sweep Mode or Tunable	Singer NM37/57	16-3/4 x 18-1/2 x 8-3/4	65	35
DISPLAY (SPECTRUM ANALYZER/ OSCILLOSCOPE)	2	RF Density & Waveforms	Single Design Functions As Power Spectral Density Display for Quicklook and as Modulation Monitor	Tektronix R556	14 x 19 x 23	88	840
SCAN PROGRAM UNIT	3	Directs Sweep Receiver	Generates Digital Control Signals for Receiver and Supplies Digital Readout of Frequency and Level	Singer P-7	10 x 19 x 20 ← Available Fall of 1972 →	30	50
POWER CALIBRATION OSCILLATOR UNIT	2	Provides Known Power Levels	5-Spot Frequencies, Known, Incrementally Controllable Power Level for Standardization	TRW	4 x 2 x 6	0 75	2
SIGNAL FORMATTING UNIT	2	Data Formatting	Accumulates Pre/Post Amble, Clocks Start of Each Test and Data Acquisition	TRW	4 x 2 x 6	5 0	2
ANTENNA DIRECTIVITY SWITCH ASSEMBLY	3	Antenna Beamwidth and Polarization Selection and Calibration Control	Three-Pole-Six Way Coax. Matrix		4 x 4 x 4	2	0 2
WIDEBAND POWER DIVIDER	4	Divide Antenna Power Output	One 50 Ohm Input Port Three 50 Ohm Output Ports	Merrimac Research and Development Co PDM 30 Series	2-1/4 x 1-3/4 x 1	0 1	
MULTI-FUNCTION DEMODULATOR	1	Demodulate All Anticipated Signal Forms (incl FM PM, AM, PSK, etc)	Receiver Module Extracts Intelligence from Modulation Waveform		3 x 4 x 1	0 5	0 5
NOISE FIGURE TEST SET	1	Measure System Noise	See Data Sheet for Gen Microwave Automatic Noise Figure Meter	General Microwave Model 551	19 x 8 x 4	25	35
COMPUTER	1	Commands Experiment On and Off	General Purpose				
TAPE RECORDER, DIGITAL	1	Records Data	General Purpose				
RECEIVER INPUT/ OUTPUT ASSIGNMENT SWITCH	2	Selects Required Receivers for Experiment	Four Pole-Three Way Coax. Matrix		3 x 3 x 3	1 5	0 2
ASSIGNMENT SWITCH SCAN PROGRAM GENERATOR	1	Interconnects Scan Program Generators with Receivers	Three Pole-Four Way Multi-Bank High Density Matrix Switch		4 x 4 x 4	2	1
TIMER, PRECISION CLOCK	1			DATATRON	5 x 5 x 18	19	18
OSCILLOSCOPE FUNCTION CONTROL SWITCH	1	Permits Astronaut Monitoring of Power Density and/or Selected Test Points	Two Pole-N Way Coax. Switch		3 x 3 x 3	1	0 1

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* 2, Regular Channels with *Optional Assignment to E & H, 2E, or 2H Polarization Synchronized or Antiphased Sweeps*
1, Regular for Astronaut Signal Analysis
1, Switchable to Replace Any of Above Functions
1, Switchable to Replace Any of Above Functions

Table 2. 1-2. RF Propagation, Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs.)	Power (W)
ANTENNA	1	Signal Collection	Dual Orthogonally Plarized, Dual Beamwidth, Log Periodic VHF-UHF Assembly	TRW or RF Systems Inc.	60 x 60 x 120	38	N/A
RELAY	4	Directivity Selection	3-Position, Coaxial 50 Ohm, for Broad Narrow and EMI/ Calibration		2-1/4 x 1-3/4 x 1	0 4	N/A
RELAY	4	Resolver Selection	3-Position Coaxial 50 Ohm, for Selecting One of Three Narrow Band Polarization Resolver Assemblies		2-1/4 x 1-3/4 x 1	0 4	N/A
RELAY	4	Resolver Selection (Output)	Same as Above		2-1/4 x 1-3/4 x 1	0 4	N/A
RELAY	2	Resolver Selection (Servo Drive)	3-Position As Above, Selects Correct Resolver for Application of Servo Control Signal		2-1/4 x 1-3/4 x 1	0 4	N/A
ATTENUATOR CALIBRATION UNIT	4	Dynamic Range Adj	0 - 60 dB, 50 Ohms, Remote Electrical Control Digital Readout of Atten Value Manual Over-ride	Merrimac	3 x 3 x 4	1 0	N/A
RECEIVER	3*	Signal Selection	100 - 1000 MHz, Sweep Mode or Tunable	Singer NM37-57	16-3/4 x 18-1/2 x 8-3/4	65	35
SCAN PROGRAM GENERATOR	3**	Directs Receiver	Generates Digital Control Signals for Receiver and Provides Digital Freq Readout	Singer P-7	10 x 19 x 20 ←Available Fall of 1972→	30	50
POWER CALIBRATION UNIT	2	Power Level Calib	Provides 5-Spot Freqs with Known and Variable Power Levels for System Calibration	TRW	4 x 2 x 6	0 75	2
SIGNAL FORMATTING UNIT	2	Data Formatting	Provides Timing Commands and Formats Both Preamble and Experiment Data and Drives Lines	TRW	4 x 2 x 6	5 0	2
RELAY	2	Input Receiver/Spare	2-Position Coaxial Relay 50 Ohm Selects Regular or Spare Receiver for Each Channel		2-1/4 x 1-3/4 x 1	0 3	
RELAY	2	Output Receiver/Spare	2-Position Coaxial Relay 50 Ohm, Selects Output from Regular or Spare Receiver		2-1/4 x 1-3/4 x 1	0 3	
POLARIZATION RESOLVING SUBSYSTEM	6	Antenna Orientation	Phases Outputs from Orthog Antennas to Simulate Rotation Measures Incident Polarization Incorporates Servo Tracking Loop	Anaren Microwave or Merrimac	19 x 7 x 4	2 0	2
DIRECTIONAL COUPLER	1	Provides Calibration Input Port	Insertion Loss ≈0 5 dB Isolation ≈10 - 20 dB	Anaren Microwave 10014-20	3-1/4 x 1-1/4 x 3/8	1	-
WIDEBAND POWER DIVIDER	4	Splits Antenna for Two Channels	-3 dB Power Wideband Divider 50 Ohm	Anaren Microwave or Merrimac PDM 30	2-1/4 x 1-3/4 x 1	0 1	-
TAPE RECORDER	1	Records Data					
COMPUTER	1	Commands Experiment On and Off etc					

* Two Assigned for Regular Use in Data Acquisition for Each of Two Experiment Channels, One is Spare Common to Both Channels

** Two for Use with Data Acquisition Receivers, One Is Spare Switchable to Replace Either

Table 2.1-3(a). Communications Relay Experiment (VHF) Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs)	Power (W)
126 - 138 MHz VHF HEMISPHERICAL COVERAGE ANTENNAS	2	VHF Communications with TDRS Providing some Antenna Discrimination Against Ground Based RFI by Switching to Appropriate Antenna	Crossed Slot Antennas Backed by Shallow Cavity Design as in Lincoln Laboratory 250 MHz Antenna but Scaled to 126 - 138 MHz	None	70 x 70 x 5 (Twice Size of Original Lincoln Lab Design)	≈280	To Handle 100 W Max.
126 - 138 MHz DIRECTIONAL ANTENNA WITH PEDESTAL AND DRIVE MOTORS	1	Directional Antenna Providing Optimum Communications Capability for Given Size.	Yagi or Log Periodic Designed for 6 - 9 dB Gain with Best Side Lobe and Back to Front Ratio to Provide Standard for Comparison. Computer Driven Pedestal.	None	85 x 50	3 lb Antenna Pedes TBD	To Handle 100 W Max.
DIPLEXER, SWITCHING AND SUMMING UNIT	1	For Switching Antennas for Different Altitudes, Use of RFI Cancellation Forming Omni Pattern etc	Changeover of Top to Bottom Hemispherical Coverage. Summing to Provide Omni Pattern. Switching Antennas to Cancellation Receiver.	New Unit	18 x 8 x 12	15	5
VHF TRANSMITTER	1	Provides Medium Power Output for Transmission to TDRS	Power Amplifier in 60 - 100 Watt Range Driven from a Modem with Standard 70 MHz Interface	Similar to ECI Model 935 Modified for Use at 136 - 138 MHz	6 x 8 x 18	35	400
VHF RECEIVER	5	Provides a Number of Standard Receiver Front Ends Which Can Be Connected Up In Different Receive Configurations		Similar to ECI Model 936 Modified for Use at 126 - 128 MHz	6 x 5 x 15	13	150 W
MINIATURE TELETYPE TERMINAL ALL SOLID STATE	1	To Send or Receive Teletype at Speeds Up to 30 Characters/Sec (150 bps)	Consists of Solid State Keyboard Solid State Thermal Printer Expandable Message Memory	Similar to AN/GGC-46	6 x 13 x 17	33	150 W
MODEM	1	To Modulate and Demodulate Voice or Data Transmissions with or without Spread Spectrum Capability	Provides Baseline Communication System Analog or Digital Voice, and Digital Data Variable Data Rate (75 - 50 kbs) and Movable SS Bandwidth Up to 2 MHz	None Assumed Equivalent to TATS Modem for size, weight, and power.	20 x 10 x 8	45	90
DEMODULATOR	3	To Demodulate Voice or Data Transmissions With or Without Spread Spectrum Capability	Provides a Number of Receivers Connected to Different Antennas		20 x 5 x 8	30	50
BIT ERROR COUNTER	4	To Measure Error Rates from Various Demodulators	Range of 1 in. 10^4 seconds to 1 in 10^{-3} seconds	HP 5376A	16-3/4 x 4 x 11-3/4	10	50

Table 2.1-3(b). Communications Relay Experiment (Ku-Band) Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs)	Power (W)
TRACKING ANTENNA ASSEMBLY	1		8 ft Dish with S-Band Horn and Ku-Band Monopulse Feed. 2-Axis Gimballed with Paramps, Diplexers, Actuators, Pedestal and Waveguide, and Ku-Band Beacon	None Space Qualified. Could be Developed from TDRS User Ku-Band Antenna System.	96 Dia x 72	100	70
WIDEBAND KU-BAND TRANSMITTER	1		High Gain TWTA-35 Watts, 40 dB Gain at 15 GHz (Assumed Developed from WJ-1049 for Other Programs) and Up-Converter from Modem Output.	Watkins-Johnson TWTA WJ1049 W/O Pressurized Case	4 x 5 x 11	14 W/O Pressurized Case	250 W/O Pressurized Case
WIDEBAND MODEM (Digital and WBFM)	2	To Modulate and Demodulate Wide Band FM or Digital Signals.	Wideband FM Detector with Threshold Extension Digital Demod with Bit and Synch and Error Correction Coding Modulator Portion Has Complimentary Characteristics	No Off-The-Shelf Items Experimental Units May Be Available	20 x 15 x 8	50	250
WIDEBAND KU-BAND RECEIVER AND CONTROL UNIT	1	Ku-Band Receiver with Adjustable Parameters for Optimization of Frequency Acquisition Process	Monopulse Receiver, LO, Sweep and AFC or PLL. Control Unit to Set Center LO Frequency, Sweep Rate and Coverage and Lock-up Capability	No Off-The-Shelf Item. Experimental Units May Be Available	15 x 8 x 5	15	150
HIGH DATA RATE D/A CONVERTER AND A/D CONVERTER	1	A/D and D/A Conversion	A/D Converter with Sampling Rates Up to 15 Megasamples/Sec and Data Rates Up to 105 MBS Complimentary D/A Converters to 6 MHz BW	Units Under Development.	16-3/4 x 5-1/4 x 10	15	20
ANTENNA CONTROL UNIT		To Control Angular Sweep Patterns and Lock-Up	Provides Variable Angular Sweep Patterns (Spiral Rectangular Scans, etc) of Variable Angular Coverage	TRW	5 x 5 x 4	4	15
DATA BIT STREAM GENERATOR, AND DATA ERROR RATE RECORDER		Provides Test Patterns for Transmission and Measures Errors in Received Bit Streams	Provides Test Bit Streams at Data Rates of 1 - 105 Mbs Measures Data Rate Errors Over Range 10^{-2} to 10^{-8} for Above Data Rates	Units Under Development.	20 x 11 x 8	40	150
WIDEBAND S-BAND RECEIVER			Similar to Ku-Band Receiver Capabilities		17 x 10 x 6	20	150

Table 2.1-4. Laser Communications, Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs)	Power (W)
OPTICAL ANTENNA	1	Optical Telescope and Gimbal Platform	3 Mirror Coude' Type, 18-24" dia F/5, ±60° Elevation, ±90° Az	Perkin-Elmer Model 700	36 x 36 x 36	150	10
SERVO ELECTRONICS	1	Antenna Positioning and Control Electronics	Type II Servo 100 Hz Bandwidth	TRW	6 x 8 x 12	19	75
COARSE TRACKER	1	Ground Beacon Acquisition and Course Track	FOV - 1° x 1°; Accuracy 200 µrad sensitivity to 53µ	ITT	4 x 4 x 8	8	5
FINE TRACKER ELECTRONICS	2	Fine Dynamic Tracker	Image Dissector Tracker FOV +300 µrad Accuracy 0 5 µrad, Sensitivity to 1 06µ or 10 6µ	TRW, ITT Ball Brothers	4 x 7 x 10	10	8
LASER LINK, CO_2	1	Optical Transmitter Including Beamwidth Control, Optical Modulator, Doubler (As Required) Cooling System	CW Output at 5 watt avg power	Hughes	2 x 2 x 12	10	200
LASER LINK, Nd YAG	1		CW Output at 1 watt avg power	Sylvania	2 x 2 x 12	12	200
LASER LINK, DOUBLED Nd YAG	1		CW Output 0 1 watt avg power	Holobeam, Sylvania	2 x 2 x 12	12	200
LASER BEACON, DOUBLED Nd YAG	1	Q-Swtiched Doubled Nd YAG	Pulsed at 5 pps, 20 msec pulse width 20 mj @ 58µ Energy Output	Korad	2 x 2 x 12	12	100
TRANSMITTER ELEC	1	Data Formatting	Multiplexing, A/D Conversion Formatting	TRW	4 x 6 x 6	6	44
LASER POWER SUPPLY	2	Common Power Supply for All Lasers	Prime Laser Power Conditioner and Distribution Up to 100 watts	Wilmor Elect	12 x 3 x 10	15	50
LASER RECEIVER	1	Data Deformatting	Demultiplexing, D/A Conversion	TRW	4 x 16 x 14	16	20
COLLIMATORS	2	Optical Alignment	Continuous and Pulsed Alignment Checks for Laser, Telescope	Davison/D600	6 x 5 x 23	10	20
LASER POWER METER	1	Measure Output Laser Power	Capable of Measuring 0 53, 1 06 and 10 6µ Energy, ±5% Accuracy	Hadron/99	3 x 3 x 4	1	3
BEAM EXPANDER OPTICS	2	Provides Variable Beam Divergence Control for Laser Transmitter and the Optical Beacon, to Facilitate Acquisition	Input Beam Size ≈ 1/4" Diameter Exit Beam Size ≈ 1" Diameter Adjustment Response Times ≈0 5 Sec Output Beam Divergence CO_2 Laser Xmtr – 200 Arc-Sec Nd YAG Laser Xmtr – 50 Arc-Sec Optical Beacon – 2 Arc-Min. to 1°		3 x 3 x 6	1	5
BEAM DEFLECTOR	4	Provide Vernier Pointing Control with Faster Response and Greater Precision Than the Main Optic Gimbal	2-Axis Deflection Capability Deflection Range ±200 µrad Precision ±0 2 µrad Spectral Range Accommodate Xmtr, Receiver and Beacon		3 x 3 x 6	2	4
TELEVISION CAMERA	1	Provides Astronaut with View of Earth Scene		Westinghouse	9 x 6 x 6	13	16
CAMERA	1	Maintain Photographic Record of Telescope Field-of-View	Motion Picture Camera, Color Film, Various Frame Rates, Remote Operation	J A Maurer Co Model No SEB 33100100	6 x 5 x 1	3	15
RECORDER, TAPE	1	Hard Copy Storage for Measured Data					
COMPUTER	1	Compute Gimbal Angles for Telescope Pointing Computation of Point-Ahead Angle Program Execution of Experiment Procedural Steps					

Table 2.1-5. Fixed Multibeam Antenna, Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs.)	Power (W)
MULTIBEAM ANTENNA	1	Signal Collection	2 Spatially Separated Beams, Each with 2 Orthogonal Polarizations. Beamwidth 2.5 x 3 5 Deg , 11 - 14 GHz.	N/A	75 x 25 x 25	100	N/A
DUAL AXIS MOUNT	1	Antenna Positioning	X - Y or EL/AZ Tracking Pedestal, ±70° Each Axis, Velocity to 5°/Sec, with Servo System, Digitally Pointed from On-Board Computer Pointing accuracy 0 2°	Scientific - Atlanta Model No 3081	13 x 20 x 22		
POLARIZATION REF HORN	1	Polarization Tracking Signal Antenna for Beacon	Pyramidal Horn with Waveguide Input (WR 75)	Scientific-Atlanta Model No. 12-12	15 x 6 x 5	1	N/A
REF. SIG SOURCE (TRANSMITTER)	1	Transmit Downlink Beacon Signal for Ground Station Tracking	100 MW Solid State Voltage Controlled Oscillator	RCA Series 400	8 x 4 x 2	1	0.2
MATCHED DETECTORS	4	Detect Uplink Signals in Each Output Channel	Waveguide - Mounted Crystal Detector	Hewlett-Packard HP-M424A	1 x 2 x 1 5	0 5	N/A
LOG AMPLIFIER	8	Amplifies Uplink Received Signals for Input to Recorders	DC Logarithmic Amplifiers, Dynamic Range 110 dB, with DC Output	Hewlett-Packard HP-7563	3 5 x 7.7 x11.5	8	40
PREAMPLIFIER	1-8 Ch	Antenna Temp Meas. Amplification	Simple Low Gain DC Amplifier	Hewlett-Packard HP-8820	7.5 x 21 x 15	25	40
A/D CONVERTER	1-16Ch	Antenna Temp. Meas. Conversion	Multichannel Analog-to-Digital Converter	Hewlett-Packard HP-5416B	8 x 5-1/4 x 10	6	10
TAPE RECORDER, DIGITAL	1	Records Antenna Data		Ampex AR/700	16 x 12 x 12	48	175
TAPE RECORDER, VIDEO	1	Records TV Camera Information					
TV CAMERA	1	Monitors Antenna Position					
COMPUTER	1	Provides Data Used to Position Antenna					

Table 2.1-6. Interferometer Navigation and Surveillance, Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs.)	Power (W)
ANTENNA, DUAL DIPOLE	2	Signal Reception	L-Band Circular Polarized Omni Antenna		6 dia x 4	2	N/A
ANTENNA BOOM	2	Establish Interferometer Baseline	TBD by SR&T		4 dia. x 384 ea	25	N/A
PHASE-LOCK RECEIVER	*2*	*Track Signal Phase*	*1570 MHz Tunable Phase Lock* Receiver	*Electrac*	*19 x 7 5 x 5* ea	*15*	*15*
PROGRAMMED FREQ SYNTHESIZER	1	Receiver First Local Oscillator	See Hewlett-Packard Spec.	HP5100B - Freq Synthesizer HP5110B - Synth Driver	16.8 x 16.4 x 10.5 16.8 x 5.2 x 16 4	84 54	50 35
CALIBRATION SIGNAL GENERATOR	1	Calibrate Receiver Sensitivity & Phase Meter	See Hewlett-Packard Spec	HP8614A - Signal Generator	16 8 x 5.5 x 18 4	63	210
DIGITAL PHASE METER	1	Measure Relative Phase Angles of Received Signals	Generates 13 bit Phase Measurement Based on Two 60 MHz Sinusoids at 10 dBm.		16.8 x 7 x 4	7	10
COAXIAL SWITCH	1	Connects Calib Sig. Gen. to Receiver Inputs	50 Ohm, Co-Axial DPDT, Electrically Actuated	Amphenol	3 dia. x 3	3	-
TIME OF DAY CLOCK	1	Measure Time at Which Phase Meas Occurs	24 Bit Digital Clock with 1 Hr. Time Period, 10^{-6} Accuracy	Datatron Model 3030	5 x 5 x 18	19	18
COMPUTER	1	Position Measurement	General Purpose				
RECORDER	1	Raw Data Storage	Digital Tape Recorder				

Table 2.1-7. Landmark Tracking, Equipment Listing

ITEM	Qty	FUNCTION	TECHNICAL DESCRIPTION	Commercial Equivalent Item	Size (Inches)	Weight (lbs)	Power (W)
OPTICAL ANTENNA	1	Optical Telescope and Gimbal Platform	Two Axis Gimbal Platform, ±60° Pitch, ±50° Az., Slew Rate 1°/Sec.	Aeroflex	10 x 20 x 20	25	8 0
SERVO ELECTRONICS	1	Antenna Positioning and Control	Type II Servo, Arc-Second Accuracy	TRW	4 x 4 x 6	6	8 0
FINE TRACKER ELECTRONICS	1	*Combined Landmark and Star Tracker*	*Image Dissector Tracker*, FOV 0 5° x 0.5°, Accuracy 30 arc-sec, Wavelength Response from 0.4µ to 0 85µ.	*TRW, ITT*	4 x 7 x 10	10	8 0
CORRELATION ELEC	1	*Video Processor*	*Processing* & Correlation Based upon Scene Contrast, Data Frame 16K Bits, Frame Rate 1 sec, Orbit Coordinates	TRW	1 x 8 x 8	3	10 0
COLLIMATORS	2	Optical Alignment Checks	Telescope Alignment Check Over Visual Spectrum	Davison/*6000*	3 x 3 x 8	5	0 5
TAPE RECORDER	1	Records Data					
KALMAN FILTER	1	Special Purpose Processor	Iterative Processor for Navigation Information		4 x 6 x 10	17	27 0
COMPUTER	1	Provides Position Information, etc.					
CAMERA	1	Documents Earth Scene	Motion Picture Camera, Color Film Various Frame Rates, Remote Operation	J. A. Maurer Co Model No. SEB 33100100	6 x 5 x *1*	*3*	*15 0*
SPECTRUM ANALYZER/ OSCILLOSCOPE	1	Signal Monitoring	Main Frame with Wide Band Sampling, High Sensitivity, Delayed Sweep, Variable Persistence	Tektronix R556	19 x 14 x 23	88	840
MONITORING TELESCOPE	1	Used to Monitor and Document Scene and Target Area	±60 deg. pitch, ±45 deg azimuth, Slew Rate 2 deg/sec	Perkin-Elmer Model 700	36 x 36 x 36	150	10

Table 2.1-8. Common Core Equipment List, Early Laboratory

Component	Experiment Class 1	3	7	9	11	15	16	Location External	Internal	Source/Similar Characteristics	Dimensions (W x H x D In)	Weight (lb)	Power (w)	Volume (cu In)	Qty	Remarks
Camera (Scope)	X	X			X				RF	HP 197A	8 x 7 1/2 x 12	10 5	N/A	720	2	(Polaroid C-27E w/ Tektronix)
Frequency Counter	X	X	X		X	X			RF	HP 5240A	16 3/4 x 5 1/4 x 16 3/8	34	90	1445	1	
RF Power Meter		X	X		X				RF	Weinchel PB-1B	19 x 11 3/4 x 8	30	90	1785	2	1 UHF 1 S/X Band
AC/DC Voltmeter	X	X	X		X	X			RF	HP 3450A	16 3/4 x 3 1/2 x 21 3 /8	36	75	1240	2	
Bit Error Counter			X	X					RF	HP 5376A	16 3/4 x 4 x 11 3/4	10	50	754	1	
A/D Converter	X	X		X	X				RF	HP 5416B	8 x 5 1/4 x 10	6	10	420	2	
Camera, 16 mm						X	X		L	J.A Maurer Co., SEB 33100100	6 x 5 x 1	3	15	30	2	
Antenna, LPDA, VHF/UHF	X	X	X					X			60 x 60 x 120	38	N/A	250*	1	
• Antenna Directivity Switch Assembly	X	X	X					X			2 x 2 x 2	0 5	N/A	8	1	
Optical Antenna-18"				X			X	X		Perkin Elmer	36 x 36 x 36	150	10	27*	1	
•Servo Electronics				X			X		L		6 x 8 x 12	19	75	576	1	
Receiver, Swept-Band, VHF/UHF	X	X							RF	Singer NM 37/57	16 3/4 x 8 3/4 x 18 1/2	65	35	2710	4	No. 1 - 4 units No 3 - 2 units plus 1 spr
•Demodulator, Multifunction	X							-	RF		3 x 4 x 1	0 5	0.5	12	4	
Attenuator Calibration Unit	X	X							RF	Merimac	3 x 3 x 4	1	N/A	36	4	No 1 - 3 units No. 3 - 4 units
Scan Program Generator	X	X							RF	Singer P-7	10 x 19 x 20	30	50	3800	3	No 1 - 3 units No 3 - 2 units plus 1 spr
Signal Formating Unit	X	X							RF	TRW	4 x 2 x 6	5	2	48	2	
Wideband Power Divider	X	X						X		Merimac PDM 30	2 1/4 x 1 3/4 x 1	0 1	N/A	4	4	
RF Variable Power Supply (with Power Conditioner)	X	X	X		X	X			RF		5 x 10 x 13	20	215	650	2	
Power Calibration Unit	X	X							RF	TRW	4 x 2 x 6	0.75	2	48		2 each
Fine Tracker Electronics				X			X		L	TRW	4 x 7 x 10	10	8	280		2 Alternate - ITT, Ball Brothers

Note
RF = RF Console
L = Laser Console
* = Cu. Ft

Table 2.1-9. Unique Equipment List, Early Laboratory

Component	Experiment Class 1	3	7	9	11	15	16	Location External	Internal	Source/Similar Characteristics	Dimensions (W x H x D In.)	Weight (lb)	Power (w)	Volume (cu in.)	Qty	Remarks
Antenna, Dual Dipole, L-band						X		X			6 dia. x 4	27	N/A	432	2	Boom
•Boom Support						X		X			4 dia. x 384					
•Interferometer Boom Drive Elec.									RF		4 x 4 x 6	6	8	96	1	
Antenna, Multi-beam					X			X			75 x 25 x 25	100	N/A	27*	1	
•Mount								X			13 x 22 x 20			3.3*	1	
•Servo Electronics									RF		4 x 4 x 6	6	8	96	1	
Antenna Polarization Reference Horn					X			X		Scientific Atlanta 12-12	15 x 6 x 5	1	N/A	450	1	Mounted with lens antenna
Antenna, VHF Crossed Slot			X					X		Lincoln Labs	70 x 70 x 5	280	N/A	14*	2	Hemispherical Coverage, Capable of Handling 100W
Parabolic tracking antenna			X					X		TDRS User Ku-Band Ant.	96 dia. x 72	100	70	288*	1	8-ft Parabola
•Drive Servo-Electronics									RF		4 x 4 x 6	6	8	96	1	
Landmark Tracker							X	X		Aeroflex	10 x 20 x 20	25	8	4000	1	
•Servo Electronics							X		L		4 x 4 x 6	6	8	96	1	
Receiver, L-Band						X			RF	Electrac	19 x 7 1/2 x 5	15	15	702	2	
Crystal Detector					X			X		HP-M424A	1 x 2 x 1 1/2	0.5	N/A	3	4	
Receiver, VHF			X						RF	ECI Model 936	6 x 5 x 15	13	150	450	5	
Receiver, Ku-Band			X					X	RF		15 x 8 x 5	15	150	600	1	
Receiver, S-Band			X						RF		17 x 10 x 6	20	150	1020	1	
Receiver, Electronics, Laser				X					L		4 x 6 x 14	16	20	336	1	
Transmitter, VHF			X						RF	ECI Model 935	6 x 8 x 18	35	400	864	1	
Reference Signal Source (Transmitter)					X			X		Omni Spectra A30258	8 x 4 x 2	1	0.2	64	1	Solid State VCO
Transmitter, Ku-Band			X					X		Watkins-Johnson WJ-1049	4 x 5 x 11	14	250	220	1	Wideband, 35 watts, 40 dB gain
Laser Assy CO_2				X					L	Hughes	2 x 2 x 12	10	200	48	1	
Laser Assy Nd YAG				X					L	Sylvania	2 x 2 x 12	12	200	48	1	
Laser Link, doubled Nd YAG				X					L	Holobeams, Sylvania	2 x 2 x 12	12	200	48	1	
Laser Beacon, doubled Nd·YAG				X					L	Korad	2 x 2 x 12	12	100	48	1	
Polarization Resolver		X						X	RF	Anaren Micro-wave or Merimac	19 x 7 x 4	2	2	532	6	

* = Cu. Ft.

Table 2.1-9. Unique Equipment List, Early Laboratory (Continued)

Component	Experiment Class							Location		Source/Similar Characteristics	Dimensions (W x H x D in.)	Weight (lb)	Power (w)	Volume (cu in)	Qty	Remarks
	1	3	7	9	11	15	16	External	Internal							
Directional Coupler		X						X		Anaren Micro-wave 10014-20	3-3/4 x 1-1/4	1	N/A	2	1	
Frequency Synthesizer and Driver						X			RF	HP 5100B	16-3/4 x 10-1/2 x 16-3/8	82	--	1860	1	
										HP 5110B	16-3/4 x 5-1/4 x 16-3/8	54	35	1400	1	
Log Amplifier					X				RF	HP 7563	3-1/2 x 7-7/10 x 11-1/2	8	40	310	8	
Preamplifier					X			X		HP 8820	7-1/2 x 21 X 15	25	40	2360	1	Eight Channel
Noise Figure Test Set	X								RF	General Microwave Model 551	19 x 8 x 4	25	35	610	1	
Switching Diplexing and Preamplification Unit			X					X			18 x 8 x 12	15	5	1730	1	
Modem			X						RF		20 x 10 x 8	45	90	1600	1	
Demodulator			X						RF		20 x 5 x 8	30	50	800	3	
Modem, Wideband			X						RF		20 x 15 x 8	50	250	2400	2	
D/A and A/D Converter			X						RF		16-3/4 x 5-1/4 x 10	15	20	880	1	15 Megasamples/Sec -A/D 6 MHz Bandwidth - D/A
Antenna Scan Control Unit			X						RF		5 x 5 x 4	4	15	100	1	
Data Bit Stream Generator			X						RF		20 x 11 x 8	40	150	1760	1	1-105 Mbps Test Bit Patterns
Correlation Electronics							X		L	TRW	1 x 8 x 8	3	10	64	1	
Coarse Tracker				X					L	ITT	4 x 4 x 8	8	5	128	1	
Transmitter Electronics, Laser				X					L	TRW	4 x 6 x 6	6	44	144	1	
Optical Collimator							X		L	Davison D/6000	3 x 3 x 8	5	0 5	72	2	
Optical Collimator				X					L	Davison D600	6 x 5 x 23	10	20	690	2	
Laser Power Supply				X					L	Wilmor Elect	12 x 3 x 10	15	50	360	2	
Beam Expander Optics				X					L		3 x 3 x 6	1	5	54	2	
Beam Deflector				X					L		3 x 3 x 6	2	4	54	4	
Laser Power Meter				X					L	Hadron 99	3 x 3 x 4	1	3	36	1	
Kalman Filter							X		L		4 x 6 x 10	17	27	240	1	
Calib Signal Gen						X			RF	HP8614A and HP2650A	16-3/4 x 5-1/2 x 18-3/4	63	210	1690	1	

Table 2.1-10. Control and Display Equipment List, Early Laboratory

Component	Internal Location		Dimensions W x H x L (in)	Weight (lb)	Power (Watts)	Volume (cu in)	Quantity	
	RF	Laser						
Power Distribution	X	X	19 x 20 x 5	60	--	1,900	3	
ECLS Display	X		19 x 14 x 6	25	--	1,600	2	
X-Y Plotter	X		20 x 20 x 6	24	85	2,400	1	
Caution/Warning Display	X		8 x 16 x 6	30	25	768	2	
RF Sensor Control Panel	X		19 x 9 x 6	20	--	1,025	1	
RF CRT Displays/Controls	X		19 x 6 x 20	20	125	2,280	2	
Signal Patching Panel	X		19 x 6 x 6	15	--	1,685	1	
RF Console Mainframe	X		116 x 124 x 45	185	--	389,200	1	
Laser Console Mainframe		X	96 x 108 x 30	145	--	265,900	1	
Telescope Gimbal Cont		X	10 x 10 x 5	6	50	500	1	
Visual Optics Controls		X	19 x 6 x 5	20	50	570	1	
Tracking Display X-Y		X	12 x 10 x 10	10	100	1,200	1	
Boresight Align. Cont		X	12 x 10 x 10	15	10	1,200	1	
GNC Reference Display		X	6 x 18 x 18	32	20	1,944	1	
Horizontal Sensor Monitor		X	19 x 10 x 20	40	60	3,800	1	
TV Video Camera		X	9 x 6 x 6	13	16	324	4	1 Ext Telescope - Mounted, 1 Ext Boresight, 1 Internal Laser, 1 Spare
Timer, Precision Clock	X		5 x 5 x 18	19	18	450	1	
Computer, General Purpose	X		24 x 24 x 38	250	1,000	21,888	1	
•Input/Output Keyboard	X	X	19 x 8 x 10	10	--	1,520	3	
Teleprinter	X		6 x 13 x 17	33	150	1,326	1	
Tape Recorder, Digital	X		16 x 12 x 12	48	175	2,304	2	
Tape Recorder, Video	X		29-7/8 x 14-5/8 x 17-3/8	100	400	7,600	1	
Tape Recorder, Rotating Head	X		19 x 20 x 30	50	150	11,400	1	
Intercom	X	X	4 x 6 x 5	2	5	120	3	
Phase Meter, Digital	X		16-4/5 x 7 x 4	7	10	470	1	
Spectrum Analyzer/Oscilloscope	X		19 x 14 x 23	88	840	6,050	2	
Oscillograph	X		11 x 13 x 17-1/4	40	150	2,470	1	

3.0 INTERFACE AND SUPPORT REQUIREMENTS

Two segments of the Shuttle system have been the principal influences on the definition of a Comm/Nav Research Laboratory. They are the payload host vehicle and the Shuttle orbiter.

The Shuttle operational characteristics and design data used in this effort are based on study results which were available at a point in time, and may not be entirely compatible with the concepts which may evolve from the RFP requirements.

Study results from two separate NASA host vehicle contracts were considered in the definition of the laboratory-host vehicle interface. They were the Research and Applications (RAM) study performed by General Dynamics/Convair Aerospace Division under contract NAS8-27539 and the Shuttle Orbital Applications and Requirements (SOAR) study performed by McDonnell Douglas Astronautics Company-West under contract NAS8-26790. * In addition, the MSFC-defined Sortie Module was introduced in the latter phase of the Comm/Nav study as the host vehicle for the Early lab.

3.1 RAM INTERFACE DEFINITION

In the case of the RAM interface definition (Reference 1), a RAM support module (RSM) will provide the necessary support functions for the Shuttle attached payload. This module is designed to furnish the following capabilities as derived from a survey of multi-discipline payloads described in NASA's "Blue Book" of manned space experiments. When appropriate, these primary subsystems are designed for modular additions to expand the system capacities necessary to meet more demanding payload requirements:

EC/LS. An independent system sized for four-man capability. It supplies and conditions the atmosphere for the payload laboratory and contains provisions for storing water generated by the power fuel cells. Its functions are CO_2 removal, pressure control, maintenance of a two-gas 14.7 psi atmosphere, and humidity control.

Thermal. The RSM thermal control subsystem supplies a water/freon dual loop sublimator coolant to the laboratory via a fluid interface. A radiator surface area of 440 square feet is provided along the cylindrical 10 foot sidewall.

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* TRW is subcontractor on both RAM and SOAR Studies

Electrical Power. This subsystem provides generation, distribution, storage, conditioning and control independently of the orbiter power. It includes RAM fuel cells and cryogenic tank stores attached externally to the forward end dome. The electrical main power distribution and fuel cell water byproducts are stored internally. A 7-Kw average and 35 Kw 0.5 hr peak sizing is provided with a 775 Kw-hr 7-day maximum energy rating. Ag-Zn peaking batteries are supplied to provide up to 42 kilowatt-hours of energy in the Shuttle-supported mode of operations. Ni-Cad peaking batteries with 4.1 Kw-hr at 20 percent depth of discharge are provided for space station-attached mode of operations.

Control and Display. A crew console has been indicated featuring limited integrated controls and displays to handle both payload and RAM communications/data management requirements.

Communication/Data Management. Hardwired communications support is provided to the payload for command and data mangement. Voice (two duplex channels) and 10 Kbps command links are made at VHF via the Tracking and Data Relay Satellite, and data transmissions up to 1 Mbps are accomplished by S-band data links to MSFN stations. Onboard magnetic tape recorders are provided in the Sortie-RAM configuration with storage of up to 2 x 10^{12} bits and video recording at 5 MHz bandwidth to 5 hours maximum. A data bus and computer capability is available for data acquisition, control, scheduling and formatting. No processing is planned for scientific data.

Structure. Several alternative RSM/RAM configurations are proposed ranging from an integral shell to independent 2 + 2 in the Sortie 7-day mission mode to 2 + 2 + 4 based on mission requirements. The minimum Sortie-RAM vehicle configuration is shown in Figure 3.1-1.

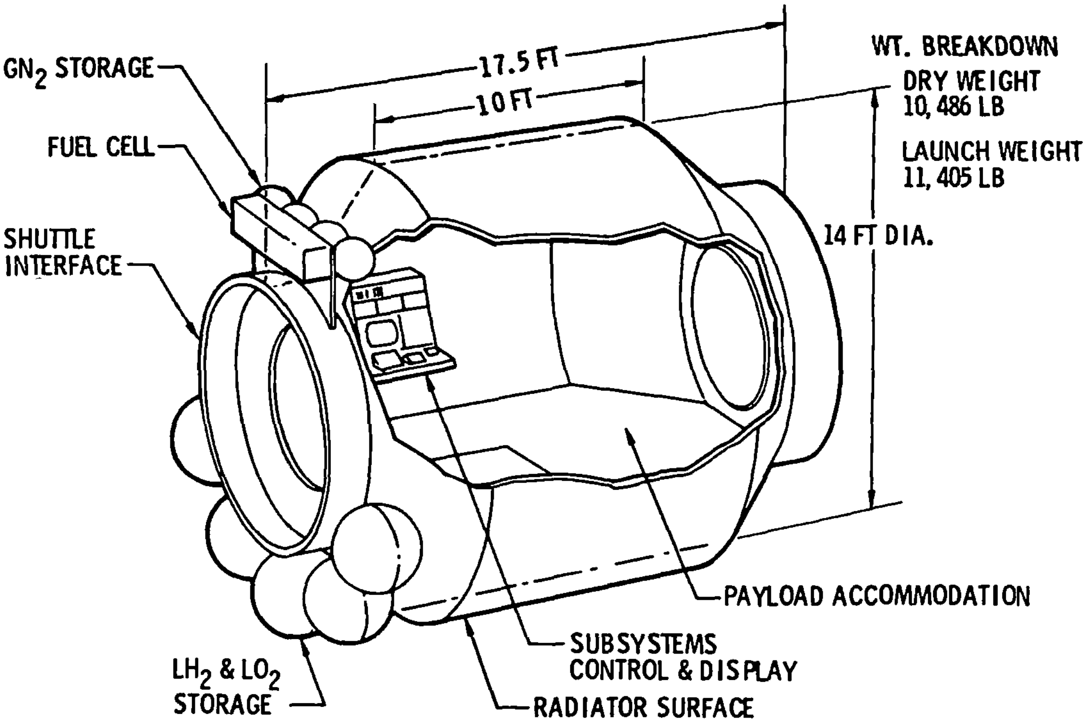
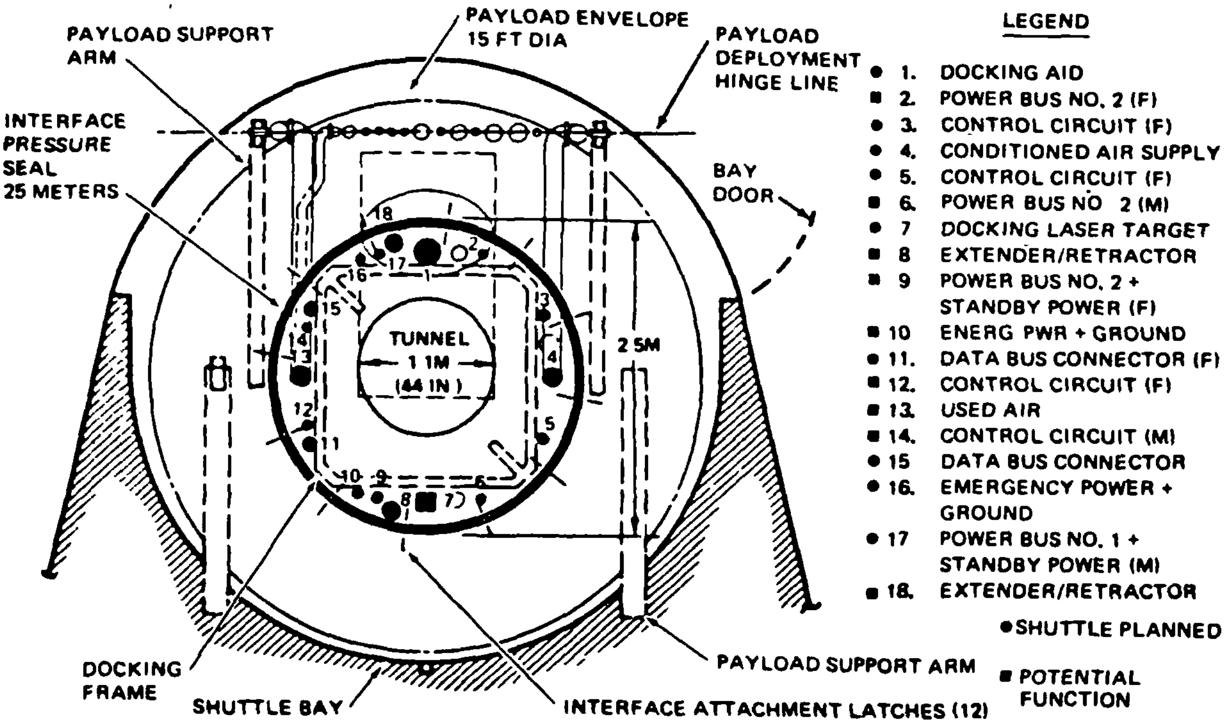


Figure 3.1-1. Sortie RAM

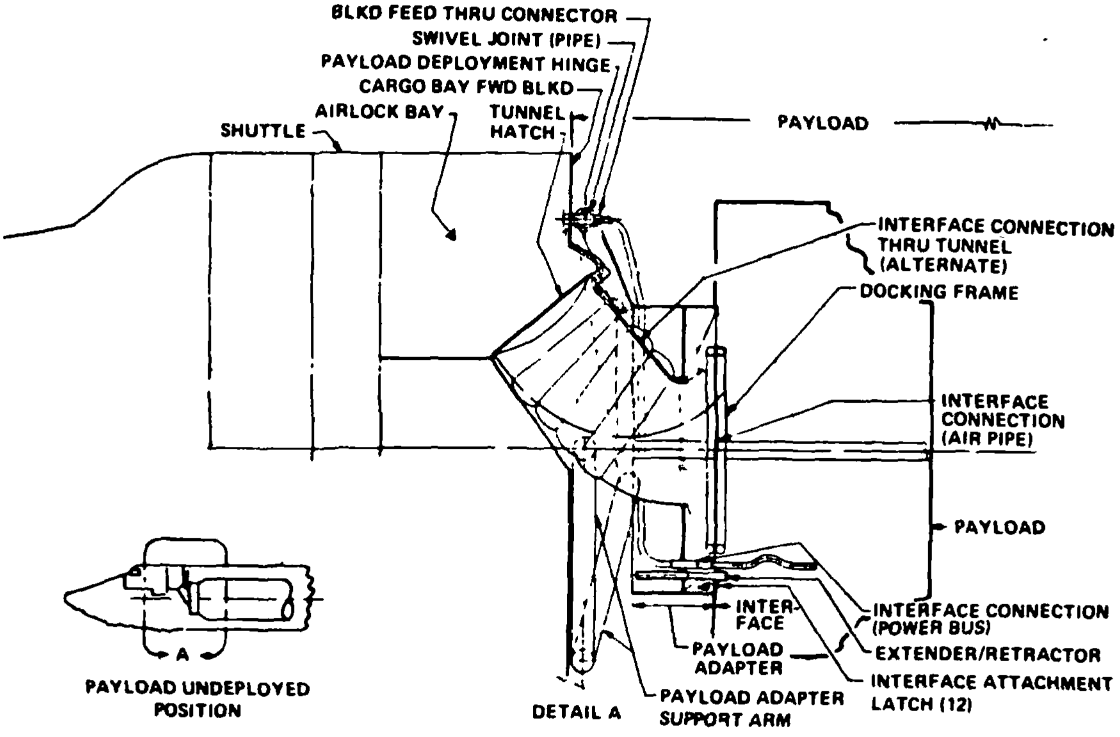
3.2 SOAR MISSION SUPPORT MODULE (MSM) INTERFACE DEFINITION

In the SOAR Phase A study recently completed for MSFC, a variety of Sortie 7-day missions were examined. A total payload, as defined in this study, consists of the particular payload experiment equipment and selected SOAR equipment needed to complete the mission objectives. In the case of communications and navigation experiment payload definition, SOAR equipment includes a Manned Support Module (MSM) plus selected elements of ancillary equipment. This MSM configuration is generally to the Sortie RAM structure just described, with significant variance only in subsystem sizing and design philosophy. The baseline orbiter interfaces for SOAR were taken from MDAC Phase B studies conducted for NASA under separate contract. In this design approach the orbiter is expected to provide most of the subsystem support requirements. Additionally, a mechanical interface is described utilizing a flexible tunnel for crew access to the MSM. An orbiter docking frame and 90 degree deployment mechanism provides MSM structural interface, with a variety of hardline interconnects. This concept is illustrated in Figure 3.2-1. The SOAR study (Reference 2) produced a large number of payload recommendations for modification to the MDAC Shuttle orbiter design baseline of June 30, 1971, as listed in Table 3.2-1. Payload services anticipated include those shown in Table 3.2-2.

Later orbiter definition study introduced variations on the baseline design to replace the mechanism for rotating the MSM payload out of the cargo bay. The payload either remained attached and fixed in the cargo bay, or was deployed by means of manipulators to a nose docking position. This design was a major departure from the original baseline and was not seriously incorporated in conceptual planning for the Comm/Nav laboratory accommodation. Later design studies may prove it necessary to do so, since either Mark I or Mark II concepts could influence the final orbiter specifications. For example, the earliest planned shuttle vehicle design provided a nominal flight deck payload remote monitoring console volume allocation of 2.12 cu ft. The Shuttle study Phase B extension resulted in a modification to this allowance (Figure 3.2-2). The revised passenger cabin area allocated 42.8 cu ft to experiment usable volume, with 18 sq ft provided for remoted displays and controls. In the case of



Recommended Standardized Interface Space Allocations for Maximum Potential Functions



Recommended Shuttle Standard Deployment Mechanism-in Cargo Bay

Figure 3.2-1. Orbiter-Payload Interfaces (SOAR)

Table 3.2-1. Suggested Modifications of the Standard Shuttle

Function	Suggested Modifications	Standard Shuttle
Payload mounting	• 5-point mount - no coupling • Provide 90-degree extension mount system	• 5 points with coupled loads • Not specified
Standard interface connector terminus	• Orbiter payload adapter • Interface connector terminus* with hard-wire and piping outside of tunnel*	• Not specified • Hardware and pipes individually in flexible tunnel
Utilities services		
Electrical power	• 550 kwh, 3.5 kw average, 9 kw peak 2 power buses	• 20 kwh, 500 w average, 800 w peak bus not specified
Attitude control	• ±0.1 degree pointing - igniter mode • Payload command	• ±0.7 degree pointing Not provided
Thermal fluid	• Fluid supply return - 7,000 Btu/hr	• Not provided
Optical alignment	• Payload extended	• Not specified
Effluent control	• Fuel cell reactants hold tank	• Not provided
Payload control panel (PCP)	• Cabin dedicated space 2.12 ft^3	• Displaces hygiene materials
PCP supp panel	• Cabin dedicated space 16.0 ft^3	• Not specified
Shuttle data bus	• Payload panel in cabin • Standard interface terminus	• Not specified • 2 buses in flexible tunnel
Dedicated payload data bus	• 2 (payload panel in cabin to terminus)	• 2 coaxial cables not specified
Illumination	• Bay and extended payload*	• Not provided
TV coverage	• Bay, extended payload, and docking*	• Not specified
Payload purge	• Allowable payload envelope dedicated purge system	• Residual flow from hydrogen tank purge
Umbilicals	• 6 side-bay and aft-bay wall	• 6 side-bay positions
Propellant dump	• Aft-bay wall*	• Not provided
Payload jettison	• Provide as part of mount*	• Not provided
Tunnel hatch	• Hatch closing tunnel at standard interface*	• Not provided

*Safety associated provisions

Table 3.2-2. Summary of Major Services Available to Experimenters Using the MSM

Item	Service Capability
Laboratory Facilities	• 1 Deck - 80 ft^2 (clear area) • Total volume 1850 ft^3
Crew	• Two passengers plus limited services from Shuttle crew
Gravity Available	• 10^{-3} to 10^{-5}
Atmosphere	• Shirtsleeve
Lighting/Observation	• Internal/External with TV for viewing (commercial 2.9 MHz). Four viewports.
Duration	• Up to 7 days on orbit at altitude up to 1200 nmi.
General Subsystem Services	• Voice communications to ground (S-band)
	• Dedicated Data Management system with dedicated communications systems (S-band) to ground. - 1.7 x 10^{11} BPD digital recording at 200 KBS - Video Recording - 12 MHz - Data Bus - 2 MBPS - Computer - 400 IOPS/sec and 32 word - Checkout (800 parameters)
	• Control - Alpha numeric keyboard - Multifunction keyboard
	• Displays - Multipurpose - 525 lines - Video monitor - 800 lines - Stripchart - Caution and warning - 20 legends
	• Scientific Airlock
	• Optical Window
	• Electrical Experiment Power ~ 1.5 kw Avg - Peaks - 9 kw (excluding supporting subsystems). 115 vdc/28 vdc
	• 0-8500 Btu/hr Heat removal
	• Pointing and Stabilization: All attitude capability inertial, earth controlled = 0.1 deg (deadband), ±0.001 deg/sec 0.5 deg total error (deployed position)
	• Navigation - position 1-3 nmi - velocity 1-8 fps

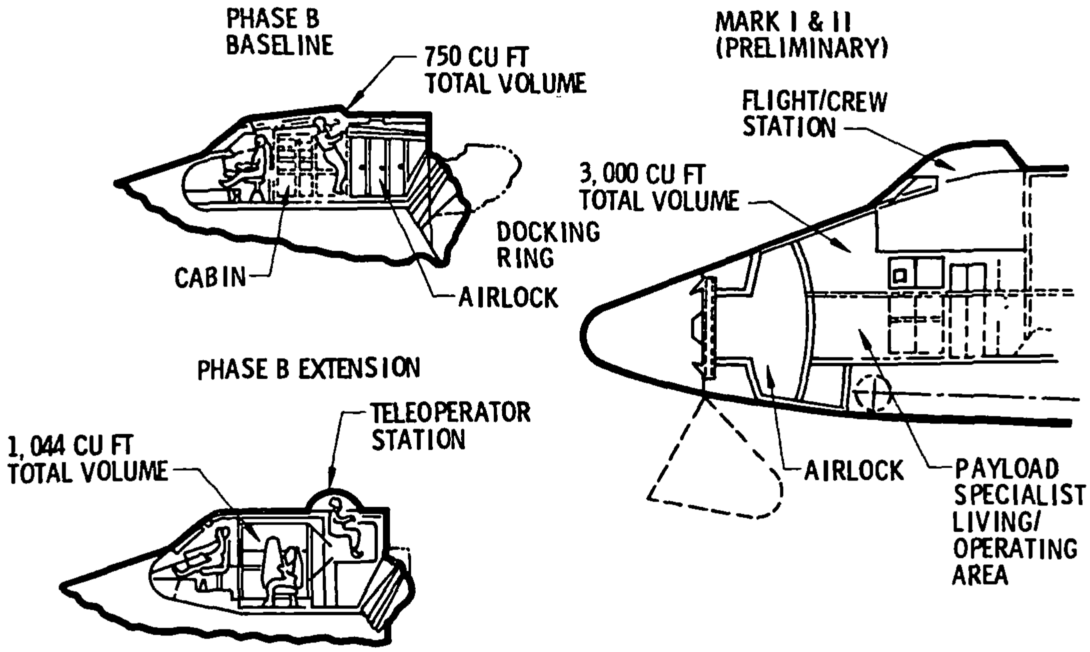


Figure 3.2-2. Past and Future Shuttle Passenger Compartments

Mark I and II designs, the payload accommodation provided display and control space on the crew flight deck, and the total Shuttle cabin volume expanded to about 3000 cu ft. A secondary feature of importance is the introduction of a manipulator deployment mechanism, nose docking ring and airlock. Thus, crew transfer into the laboratory module during initiation of Comm/Nav experiments is accomplished only after the laboratory is docked to the orbiter forward docking ring, using cargo bay manipulators. In the earlier orbiter versions, crew transfer is through the expandable tunnel after the MSM research laboratory is erected in a vertical position out of the cargo bay. This change in orientation from a vertical to horizontal plane with respect to the orbiter longitudinal axis will have a definite design impact on the module and the antenna equipment layouts. As mentioned earlier, the present study approach considers only the reference vertical orientation shown in the baseline Shuttle. When the final Phase C/D Shuttle design criteria becomes better defined, undoubtedly the external laboratory structure would also require modification. A selection of the module's on-orbit alignment either normal to or along the longitudinal Shuttle axis would be critical to the deployment configuration and operation of the various antennas needed by the experiments.

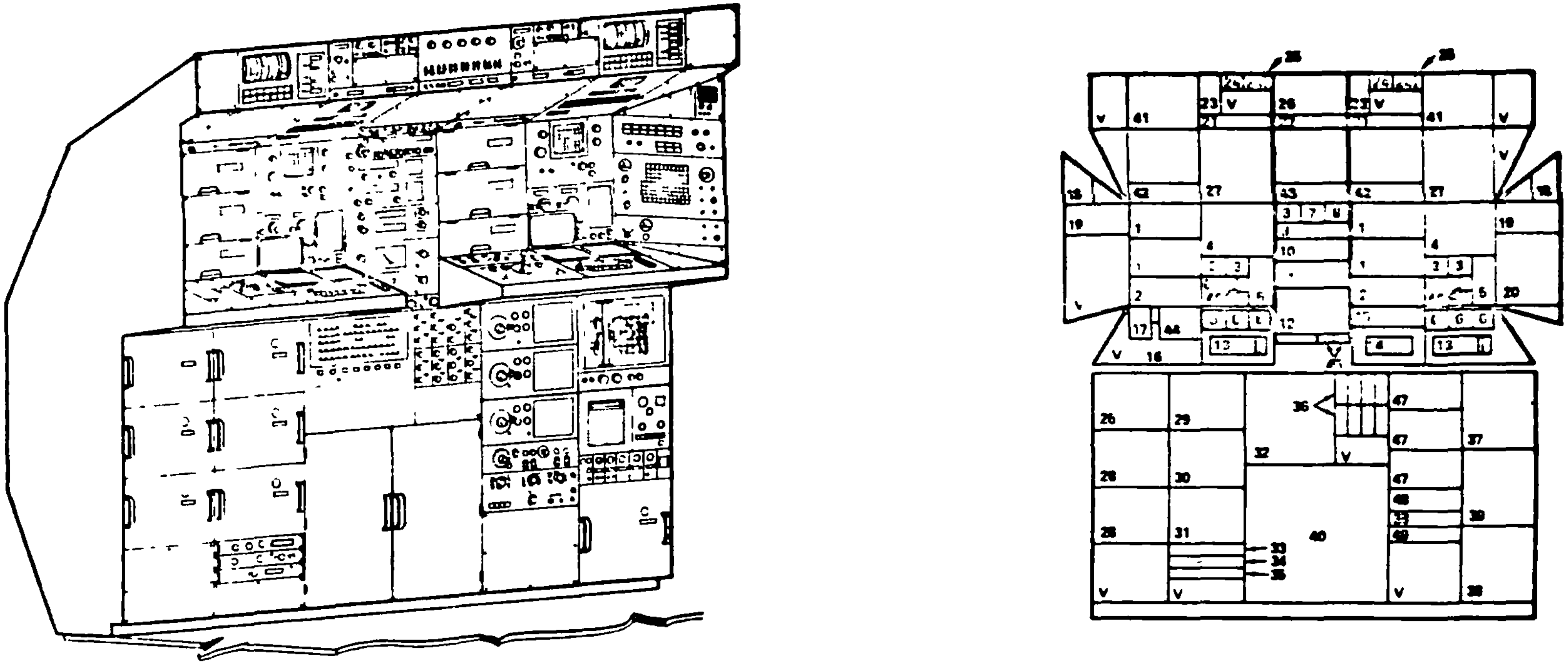
3.3. WEIGHT, POWER AND VOLUME

The study design approach used has resulted in establishing the requirement for experiment accommodation employing a "short" sortie can, with a single 120-inch long cylindrical pressurized shell. Baseline MSFC preliminary weight estimates were available for the "standard" sortie can design of 240 inches. The standard sortie can weights 11,727 pounds plus mission configuration weights unique to the various payloads. The following is a weight estimate in pounds for the Comm/Nav laboratory facility housed in a short sortie can, with experiment Data Management and Crew Station Networks and Displays accounted for in experiment equipment:

Standard Sortie Can Baseline Weight	11,727		
● Mission Support Consumables	2,391	14,118	
● Data Management, Networks and Display (Standard)		(1,423)	
● Structure at 60 percent standard Sortie Can Weight		(1,373)	
Basic Net Weight:		11,322	
● Comm/Nav Console mainframes, Common/Unique Equipment, Instrumentation (including DMS, Networks and Display)		3,230	
Total Module Weight:			14,552
● 30-ft Pallet Structure (estimated)		800	
● Antennas, Drive Systems, Electronics		1,185	1,985
Total Laboratory Payload:			16,537

With regard to pressurized laboratory module volume requirements, the configuration layouts are divided between two integrated test consoles. The RF console volume is approximately 377,570 cu in (218.5 cu ft). All of the experiment common and unique equipment, data handling, subsystem and signal displays and controls are housed within these consoles. In the case of the RF console, about 145,440 cu in (84.2 cu ft) are filled with apparatus. To this amount is added such items as thermal cold plates, ventilation ducting and cooling fans, cable conduit and interconnectors, RFI shielding material and grounding straps, etc. In the lower portion of the optical console is housed a light-tube laser cabinet capable of achieving good thermal control. Test equipment, displays, and optical boresighting are provided for easy accessibility and viewing by the crew. Final configuration views of both consoles are portrayed in Figures 3.3-1 and 3.3-2.

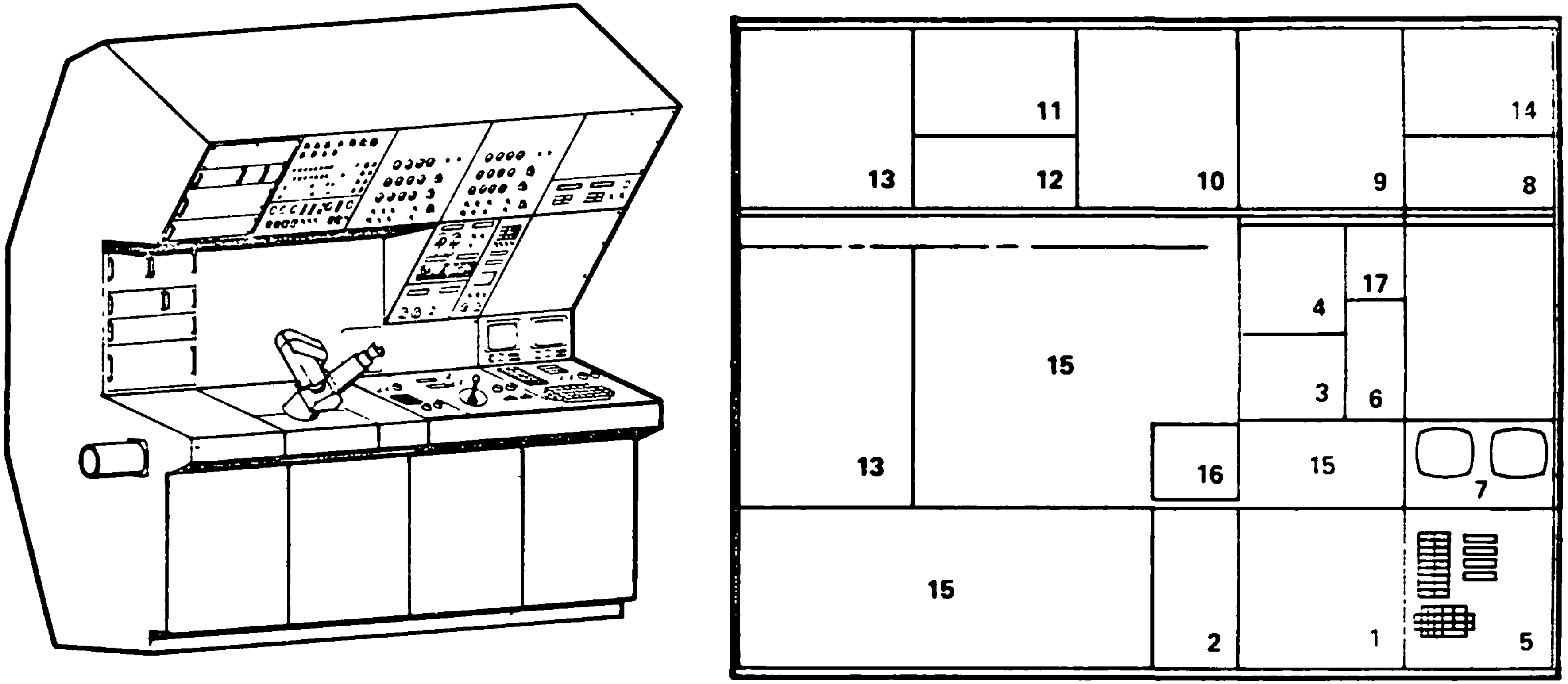
Connected prime power to experiment equipment is accomplished through power interlocks, regulators, circuit breakers and fuses contained in the secondary power panels on the consoles. This power is fed from the main distribution box located below the floor of the sortie can module. Secondary power distribution to the exterior pallet/antenna gimbal drive systems and critical RF components is performed by



1. RECEIVER - SWEPT BAND
2. RECEIVER - "L" BAND
3. RECEIVER - VHF
4. SPECTRUM ANALYZER
5. TELEPRINTER
6. C. R. T. DISPLAY
7. RECEIVER "S" BAND
8. TIMER
9. BIT ERROR COUNTER
10. FREQUENCY COUNTER
11. DIGITAL PHASE METER
12. R. F. POWER METER
13. COMPUTER KEYBOARD
14. SENSOR CONTROLLER
15. RECORDER CONTROLS
16. TRANSMITTER K_U BAND
17. TRANSMITTER VHF
18. INTERCOM
19. CAUTION AND WARNING
20. FREQUENCY SYNTHESIZER AND DRIVER
21. AC/DC VOLTMETER
22. GENERATOR-DATA BITSTREAM
23. POWER SUPPLY-VARIABLE
24. POWER DIVIDER
25. POWER CALIBRATOR UNIT
26. PREAMPLIFIER
27. ELECTRICAL POWER MONITOR AND DISTRIBUTION
28. TAPE RECORDER - DIGITAL
29. TAPE RECORDER - ANALOG
30. TAPE RECORDER - C. R. T.
31. RECORDER - LOOP
32. GENERAL PURPOSE COMPUTER
33. MODEM
34. MODEM WIDEBAND
35. DEMODULATOR
36. AMPLIFIER - LOG
37. X-Y PLOTTER
38. RECORDER - ROTATING HEAD
39. VISICORDER
40. GENERAL STORAGE
41. EC/LS CONTROL PANEL
42. A/D CONVERTERS
43. CIRCUIT PATCH PANEL
44. D/A AND A/D CONVERTER
45. SIGNAL FORMATTING
46. VHF ATTENUATOR
47. SCAN PROGRAM GENERATOR
48. CALIBRATION SIGNAL GENERATOR
49. NOISE FACTOR TEST SET

V VACANT PANEL SPACE (GROWTH)

Figure 3.3-1. Final Configuration Primary Operator Console



LASER CONSOLE

1 TELESCOPE AND GIMBAL CONTROLS
2 VISUAL OPTICS CONTROLS
3 TRACKING (X, Y) DISPLAY AND CONTROLS
4 ALIGNMENT DISPLAY AND CONTROLS
5 COMPUTER/PROGRAMMER AND REFERENCE DATA ACCESS
6 NAVIGATION REFERENCE DISPLAY
7 REFERENCE DATA DISPLAY
8 HORIZON SENSOR MONITOR AND CONTROL

9 LASER POWER SUPPLY (CO_2 SYSTEM)
10 LASER POWER SUPPLY (Nd: yAG SYSTEM)
11 CIRCUIT BREAKER/FUSE PANEL
12 SUPPORT ELECTRONICS MONITOR AND CONTROL
13 SUPPORT ELECTRONICS
14 PANEL GROWTH SPACE
15 LASER SYSTEM ACCESS
16 OPTICAL FILTER ACCESS (CO_2 CIRCUIT)
17 INTERCOM

Figure 3.3-2. Final Configuration Laser Facility multiconductor cables. The summed power of all experiment components found in equipment lists is 9.96 KW. This does not present an accurate pictue of the laboratory power requirements since duty cycling is not estimated. See Section 3.4.4 below for a typical power profile.

3.4 SUPPORT SUBSYSTEM INTERFACES

3.4.1 Data Management

Laboratory interfaces fall into two categories, those which exist to monitor the astronauts' environment or whose purpose is to support the experiment operation but which do not constitute an intrinsic part of the experiment hardware, and those which are a part or are directly concerned with the experiments. As shown on the left side of Figure 3.4-1, interfaces in the first category allow a determination of equipment status by providing access to checkout facilities on the orbiter. Interfaces in the second category, as shown on the right side of Figure 3.4-1, are involved with acquisition, transfer, storage, analysis and control of experimental data.

Subsystem Interfaces

Subsystem monitor and checkout equipment within the laboratory will consist of remote acquisition units (RAU's) providing differential inputs for analog and digital or discrete signals. Each analog and digital input channel will be directly addressable; discretes are addressed in groups of eight. Programmable signal conditioning will allow the input of high and low level analog signals in various ranges while programmed offsets establish proper range starting points. After quantization of analog inputs to 8 bits or ±1/4 percent accuracy, the data is transferred in serial format to an orbiter/laboratory interface adapter for buffer storage prior to acceptance by the orbiter instrumentation computer at 25 Kbps rate. The RAU's will also output command discretes or digital control or data signals to the subsystems under computer direction. Software contained within the 5,000 word instrumentation computer memory and allocated to the laboratory will periodically schedule the checkout of the subsystems.

Hardwire caution and warning signals generated within the laboratory area will be acquired by a caution and warning conditioning unit which is capable of limit comparison and which, in turn, drives visual and aural annunciators. It also drives three master caution and warning

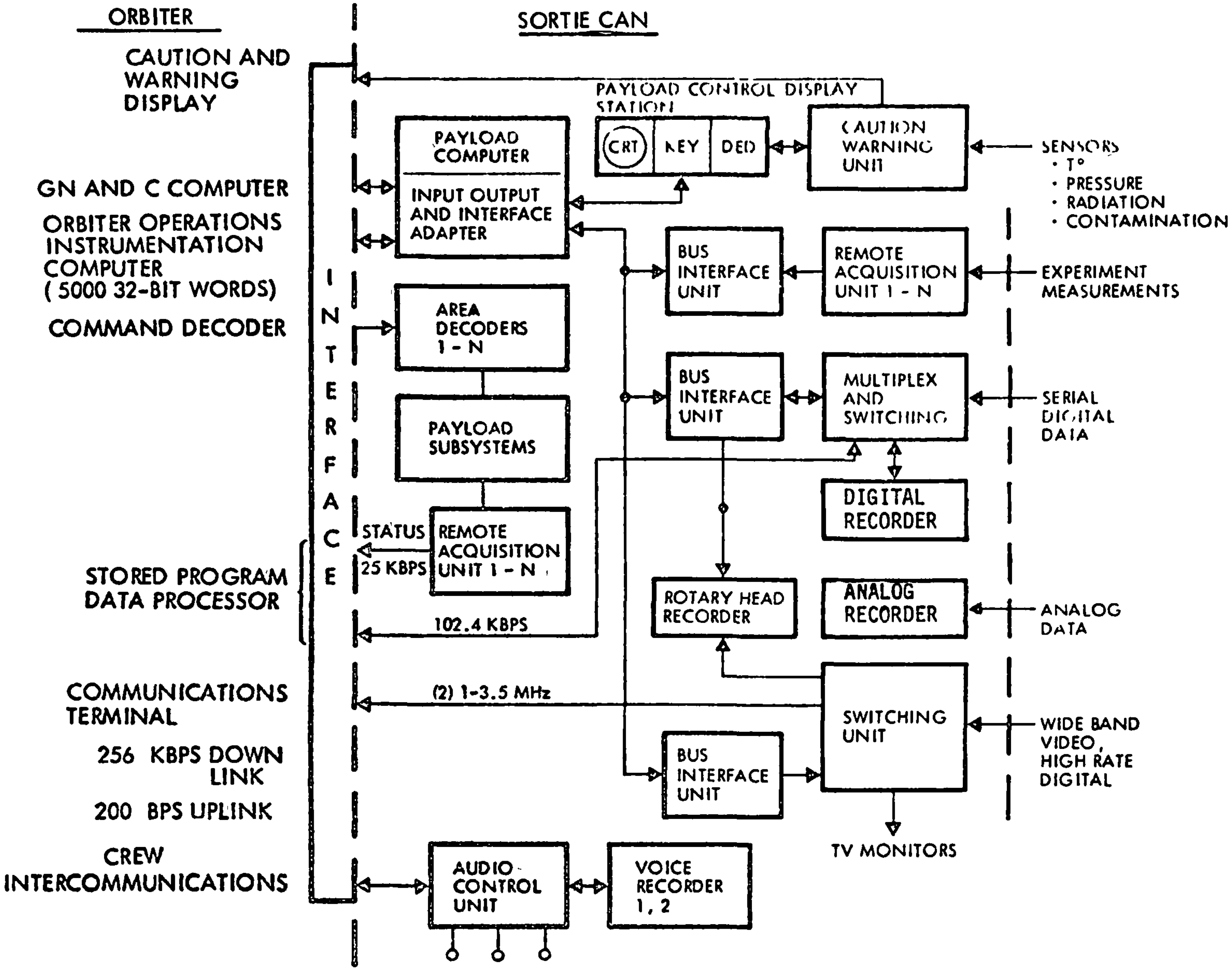


Figure 3.4-1. Data Management Laboratory Interfaces

and 10 twisted shielded pair signal lines interfacing through a connector with the orbiter pilot's and payload monitor station's C& W panels.

Three intercom crew stations interface through a connector with the orbiter's intercom system. These stations provide the standard audio controls, headsets and microphones and the additional controls necessary to operate audio recorders used for storing voice commentary during experiment observations.

Experiment Interfaces

Each of the experiment designers submitted information regarding their requirements for data management in terms of instrumentation signal outputs, control/display, processing and external data, e.g., system time, attitude, ephemeris, etc. This information is summarized in Table 3.4-1. Tables 3.4-2 through 3.4-10 show the detail data management requirements for each point experiment. Each of the seven point experiments was examined to determine the more desirable data retrieval mode; hard copy in the form of magnetic tape, photographic film strip chart, etc. or RF transmission to ground via MSFN or TDRS. The RAM study (reference 1) concluded that for Sortie missions the cost of data retrieval via TDRS would be two to three times more costly than via hard copy magnetic tape. Because most of the experiment data runs are of short duration (five minutes orless) as forced by contact with cooperative ground stations, data is accumulated only during a small percentage of the orbit. Also, since the mission duration is relatively short (seven days), in general the timeliness of the retrieval data is not critical. The predominant mode selected is hard copy. One exception is in the case of the Landmark Tracking Experiment where the data rate is approximately 200 B/S, continuously. To record this data on magnetic tape continuously during the mission would require a great number of reel changes and a very slow speed recorder. The preferred mode in this case is real time RF transmission via TDRS or buffer storage and dump to MSFN.

Although not a specific requirement, it is desirable to include a high rate data dump capability to MSFN for PI quick look to enable him to make appropriate recommendations in performing the experiment.

Table 3.4-1. Data Management - Early Laboratory Experiment Onboard Data Management Requirements Summary

Experiment	Permanent Digital	Temporary Digital	Permanent Analog	Film	Processing/ Computer	Control/ Display
1. Terrestrial Sources of Noise	1.3×10^{8}	3.2×10^{6} (display refresh)	1.8 Hrs Analog 3.5 Hrs Voice	35 mm	-	600 B/S
3. RF Propagation	1.2×10^{8}	-	3.5 Hrs Voice	-	1.1 KB/S	100 B/S
7. Communications Relay	1.6×10^{7}	-	-	35 mm	-	600 B/S
9. Laser Communication	8×10^{7}	-	-	-	-	10 B/S
11. Fixed Multi-Beam Antenna	7.7×10^{8}	-	3.3 Hrs Voice	-	-	248 B/S
15. Interferometric Navigation and Surveillance	5.4×10^{6}	-	1.3 Hrs Voice	16 mm	910 B/S	272 B/S
16. Landmark Tracking	5.7×10^{7}	-	1 Hr Voice	-	-	1.8 KB/S (132 B/S if TDRS is available)
	1.2×10^{9} Bits					

Table 3.4-2. Measurement Requirements - Early Laboratory Terrestrial Sources of RF Noise and Interference Experience

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Data Period Per Orbit	Number of Orbits/Mission	Data Storage/ Mission
Swept Receiver Video-Digitized	1	8 (7 + parity)	3.3×10^3 B/S per Receiver	Permanent File + Temporary File (call file for display refresh)	16 min. (max.) "	36 Tape capacity for 1 orbit with erase/rewrite	1.14×10^8 bits (perm.) 3.17×10^6 bits (temp.)
Panoramic Display	1	Visual		35 mm film camera	<1 roll	36	-
Monitor Receiver	1	NB Analog	10 kHz	Permanent File + CRT Display	3 min. (avg.)	36	1.8 hrs video tape, 1.8 hrs analog tape
Monitor Display	1	Visual		35 mm film	<1 roll	36	-
Voice Log	1	Analog	Voice	Permanent File	Calibration 15 min. First Orbit: 15 min. All Other. 5 min/orbit	36	3.5 hrs audio tape
Status/Housekeeping	1	Digital	500 B/S	Permanent File + Display	16 min. (max.)	36	1.73×10^7 bits (perm.)
Experiment Control	1	Digital	100 B/S	Experiment Equipment from Control Console	10 sec.	36	-

Table 3.4-3. Measurement Requirements - Early Laboratory RF Propagation Experiment

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm Storage** Bits/Mission
Receiver AGC (Received Power Level)	1	9 + Parity	100 KB/S	Perm Storage, Display	6×10^7	
Polarization Rotation	1	9 + Parity	1 KB/S	Perm Storage, Computer	6×10^5	
S/C Attitude	3	16	48 B/S	Perm Storage, Computer	2.9×10^4	
S/C Ephemeris	6	16	96 B/S	Perm Storage	$5\ 8 \times 10^4$	
Timing Reference	1	36	36 B/S	Perm. Storage, Computer	$2\ 2 \times 10^4$	
Event Number	1	8	Discrete	Perm. Storage, Control, Display	-	
Antenna Selector	1	2	Discrete	Perm. Storage, Control, Display	-	
Polarization Unit	1	2	Discrete	Perm. Storage, Control, Display	-	
Receiver Select	1	2	Discrete	Perm. Storage, Control, Display	-	
Freq Conv Range	1	3	Discrete	Perm. Storage, Control, Display	-	
Frequency ID	1	16	Discrete	Perm. Storage, Control, Display	-	
Calibration Level	1	6	Discrete	Perm Storage, Control, Display	-	
Voice Commentary Flag	1	3	Discrete	Perm. Storage, Control, Display	-	
Voice Log	1	Analog	Voice	Perm. File	-	3 5 hrs audio tape
TOTALS					$6\ 1 \times 10^7$	$1\ 22 \times 10^8$ bits

Note Requires duplex voice link to cooperative aircraft during experiment performance

* 2-5 min data runs/orbit
** 4 orbits/day - 5 days

Table 3.4-4. Measurement Requirements - Early Laboratory Communications Relay Experiment (S-Band vs Ku-Band Error Rate Measurements)

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm Storage** Bits/Mission
Antenna Gimbal Angles	2	14	2.8 B/S	Storage, Display	1 36 x 10^4	
Freq. & Angle Lock Ind.	3	Discrete	0.3	Storage, Display	1 46 x 10^3	
Bit Rate Ind	3	Discrete	0.3	Storage, Display	1.46 x 10^3	
Error Rate	2	8	160	Storage, Display	7.78 x 10^5	
Wideband Quality	1	(Film)	-	-	-	
Equipment Mode/Status	31	Discrete	3.1	Storage, Display	1.51 x 10^3	
Time	1	24	24	Storage	1 16 x 10^5	
TOTALS					9.12 x 10^5	4.66 x 10^6

* Assumes operation during 90% of each orbit.

** 5 days @ 90%

Table 3.4-5. Measurement Requirements - Early Laboratory Communications Relay Experiment (Ku-Band Acquisition)

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm Storage** Bits/Mission
Antenna Gimbal Angles	2	14	2.8 B/S	Storage, Display	1.36×10^4	
Scan Mode	10	Discrete	0 1	Storage, Display	$4\ 86 \times 10^2$	
Acquisition Time						
Frequency Lock	1	8	0.8	Storage, Display	3.89×10^3	
Spatial Lock	2	8	1.6	Storage, Display	7.78×10^3	
Error Signals, Az and El	2	8	1.6	Storage, Display	7.78×10^3	
Freq. & Angle Lock Ind.	3	Discrete	0.3	Storage, Display	1.46×10^3	
Time	1	24	24	Storage	1.16×10^5	
TOTALS					1.51×10^5	7.55×10^5

* Assumes operation during 90% of each orbit

** 5 days @ 90%

Table 3.4-6. Measurement Requirements - Early Laboratory Communications Relay Experiment (VHF Error Rate Measurements)

Instrument/Signal Identity	No. of Chan- nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm Storage** Bits/Mission
Yagi Ant Gimbal Angles	2	8	1.6 B/S	Storage, Display	7 78 x 10^3	
Antenna Switch Mode	8	Discrete	0.8 B/S	Storage, Display	3.89 x 10^3	
RFI Level	1	10	100 B/S	Storage, Display	4.86 x 10^5	
Error Rate (10 sps)	4	8	320	Storage, Display	1.55 x 10^6	
Equipment Mode/Status	35	Discrete	3 5 B/S	Storage, Display	1.7 x 10^4	
Time	1	24	24 B/S	Storage	1.16 x 10^5	
TOTALS					2.2 x 10^6	1.1 x 10^7

* Assumes operation during 90% of each orbit.

** 5 days @ 90%.

Table 3.4-7. Measurement Requirements - Early Laboratory Laser Communications Experiment

Instrument/Signal Identity	No. of Channels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm. Storage** Bits/Mission
Receiver Sig Strength	1	8	8 KB/S	Perm. Storage	2.4 x 10^6	
Transmitted Power	1	8	80 B/S	Perm. Storage	2.4 x 10^4	
Fine Tracker #1 Err Sig	4	8	640 B/S	Perm. Storage	1.9 x 10^5	
Beam Deflector #1 Angles	2	8	320 B/S	Perm. Storage	9.5 x 10^4	
Beacon Output Power	1	8	40 B/S	Perm. Storage	1.2 x 10^4	
Tracker Sig. Strength	1	8	800 B/S	Perm. Storage	2.4 x 10^5	
Transmitter Beamwidth	1	2	Discrete	Exp. Control	-	
S/C Attitude Data	3	16	48 B/S	Perm. Storage	1.4 x 10^4	
Optic Antenna #1 Angles	2	16	320 B/S	Perm. Storage	9.5 x 10^5	
Receiver Bit Err. Rate	1	8	80 B/S	Perm. Storage	2.4 x 10^4	
Event Number	1	3	Discrete	Storage, Display	-	
Background Brightness	1	8	80 B/S	Perm. Storage	2.4 x 10^4	
Transmitter Head Temp	1	8	8 B/S	Perm. Storage	2.4 x 10^3	
Laser Transmit	1	2	Discrete	Control, Display	-	
Laser ON/OFF	1	2	Discrete	Control, Display	-	
Beacon ON/OFF	1	2	Discrete	Control, Display	-	
Beacon Receiver	1	8	160 B/S	Perm. Storage	4.8 x 10^4	
Timing Reference	1	36	36 B/S	Perm. Storage	1.1 x 10^4	
Comm Data Source	5	10	50 B/S	Perm. Storage	1.5 x 10^4	
TOTALS			Discretes ≈10 B/S (random)		4 x 10^6	8 x 10^7

* 5 min data run/orbit

** 4-orbit/day-5 days

Table 3.4-8. Measurement Requirements - Early Laboratory Fixed Multibeam Antenna Experiment

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm. Storage** Bits/Mission
Detector Output	8	8	64 KB/S	Perm Storage + Chart Recorder	3.84×10^7	
S/C Attitude and Rate	6	16	96 B/S	Perm. Storage	5.76×10^4	
S/C Ephemeris	6	16	96 B/S	Perm. Storage	5.76×10^4	
Timing Reference	1	36	36 B/S	Perm. Storage	2.16×10^4	
X-Y Gimbal Angles	2	12	240 B/S	Perm. Storage & Control/ Display	1.44×10^5	
Temperature Sensors	8	8	6.4 B/S	Perm. Storage	$3\ 84 \times 10^3$	
Strain Gauges	8	8	6.4 B/S	Perm. Storage	3.84×10^3	
Beacon Power Level	1	8	8 B/S	Perm. Storage & Control/ Display	$4\ 84 \times 10^3$	
Beacon Polarization	1	10	10 B/S	Perm. Storage	6×10^3	
Voice Log	1	Analog	Voice	Analog Tape		3.3 hrs tape
TOTALS					$3\ 85 \times 10^7$	$7\ 7 \times 10^8$

* 10 min data run/orbit

** 4 orbits/day--5 days

Table 3.4-9. Measurement Requirements - Early Laboratory Interferometric Navigation Experiment

Instrument/Signal Identity	No of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits* Per Orbit	Perm. Storage** Bits/Mission
CNRL Location	3	18	540 B/S	Computer, Storage	1.62×10^5	
Time of Day	1	24	240 B/S	Computer, Storage	7.2×10^4	
Phase Angle	1	13	130 B/S	Computer, Storage	3.9×10^4	
Interferometer Receiver						
Lock Status	1	2	20 B/S	Storage, Display	6×10^3	
Tuning State	1	3	30 B/S	Storage, Display	9×10^3	
Signal Strength	1	5	50 B/S	Storage, Display	1.5×10^4	
G-Matrix	4	10, 30, 30, 8	152 B/S	Storage, Display	4.56×10^4	
LOS Angle Error	1	10	20 B/S	Storage, Display	6×10^3	
Voice Log	1	Analog	Voice	Analog Tape		1.3 hrs tape
TOTALS					3.6×10^5	5.4×10^6

* 5 min. data run/orbit

** 3 passes/day - 5 days

Table 3.4-10. Measurement Requirements - Early Laboratory Landmark Tracking Experiment

Instrument/Signal Identity	No. of Chan-nels	Data Form A or D (Bits)	Bandwidth or Bit Rate	Onboard Destination	Bits Per Orbit	Bits/Mission
Error Signals	2	8	160 B/S	Control, Display	-	
Gimbal Angles	2	16	1.6 KB/S	Control, Display	-	
Receiver Video SNR	1	8	8 B/S	Control, Display	-	
Track Command	1	2	Discrete	Control, Display	-	
Slew Command	2	16	32 B/S	Control, Display	-	
Timing Reference	1	36	36 B/S	Perm. Storage	Continuous	
Spacecraft Attitude	3	16	48 B/S	Perm. Storage	Continuous	
Computed S/C Position	3	16	48 B/S	Storage, Display	Continuous	
Voice Log	1	Analog	Voice	Analog Tape		1 hr tape
TOTAL						5.7×10^{7}*

* Recommended near-realtime data transmission via TDRS.

The majority of experiments also required tape annotation data which included the "time of day," spacecraft altitude and location and ground track weather. Since time, altitude and location data are all quantities available from the orbiter guidance and navigation (G&N) computer, an interface exists between the input/output (I/O) units of the G&N and laboratory computers. Data on local weather conditions would be obtained via the orbiter uplink and then stored in the orbiter instrumentation computer, resulting in a similar laboratory/orbiter computer interface.

The experiments themselves are highly automated both for closed loop control as well as data analysis. Computer control is exercised through bus interface units directly connected to the experiment equipment or indirectly in conjunction with RAU's similar to those described under subsystem interfaces. The bus itself would consist of separate request/response twisted shielded line pairs operating in conjunction with a 2 Mbps synchronization line. Digital data received by the I/O would be operated on by the computer and the results transferred to a linear recorder, this would be the primary operational mode for experiments such as the Interferometer Surveillance Experiment. Digital data from experiments not requiring crew onboard analysis would be transferred directly to a linear recorder or output at 100 Kbps to an orbiter/laboratory connector interfacing with a stored program data processor for downlink transmission.

Experiment analog data from 0 to 10 kHz would interface directly with subcarriers and be recorded in an FM mode. Wideband video or high rate digital data is accepted by a switching unit for either recording on the wideband recorder or transfer to the orbiter's communication terminal via an orbiter/laboratory interface connector.

Table 3.4-11 presents a summary of data handling requirements. All recording requirements are met with three conventional recorder types--a serial digital recorder capable of data rates to 100 Kbps, a parallel analog or FM record mode machine with a response of 10 kHz per channel, and a wide band rotary head recorder with a bandwidth of 10 MHz. In addition, solid state buffers for continuous low rate data would be required allowing one buffer to always be on-line while the other was being unloaded. A table containing pertinent characteristics for the three major recorder types is presented in Table 3.4-12.

Table 3.4-11 Data Handling

Exp No.	Experiment	Selected Accommodation	Implementation
1	Terrestrial Noise	Digital recorder for permanent record, digital recorder for temporary storage, WB video recorder and NB analog recording.	Digital Record Rate ≈ 3.3 Kbps WB Video - 5 MHz { 1 8 hr/ NB Analog - 10 KHz { mission
3	VHF/UHF RF Propagation	Digital recorder at each end of RF link, at the Lab and at an experiment equipped aircraft or cooperative land or sea terminal.	Digital Recorder ≈ 100 Kbps Computer I/O ≈ 1.2 Kbps
16	Landmark Tracking	Very low rate (< 200 B/S) continuous data for permanent storage requires buffer prior to recording.*	a. Dual Solid State Buffers-86 Bps total b. Digital Recorder - TBD c. Computer I/O - 2 Kbps
15	Interferometric Surveillance	Raw experiment data and computed results put into temporary storage during pass. After pass, operator calls up computed results for post-real time evaluation of data run. If the data run is valid, raw data and computed results put into permanent storage.	a Computer Memory - 1200 Bps b. Digital Recorder - TBD
11	Fixed Multibeam Antenna	Digital recorder and strip chart recorder.	a Digital Recorder ≈ 100 Kbps b. Strip Chart Recorder - 24 Channels
7	Communication Relay	Wide band video and high rate digital buffer storage	a. WB Video - 10 MHz b. Digital - 10 Mbps
9	Laser Communication	Low data recorded on tape - High rate data to CRT and filmed	a. Digital Recorders - 10 Kbps

* Initial selection of R.F transmission rather than storage.

Table 3.4-12. Recorder Characteristics

Type	Bandwidth or Data Rate (MHz or Mbps)	Speed (IPS)	Reel Diam. (In)	No. of Channels (-)	Record Time (Min.)	Volume (Ft^3)	Weight (Lbs)	Power (W)
Helical Scan	4.2 MHz	3.7	12.5	1	300	4.6	100	400
Analog (FM Record)	DC to 10 KHz	$1\frac{7}{8} - 15$	$10\frac{1}{2}$	14	32	0.6	48	133
Digital	100 Kbps	$1\frac{7}{8} - 15$	$10\frac{1}{2}$	7	32	0.6	46	123

3.4.2 Communications Requirements

The real-time information transmission and reception capabilities required to support the early Sortie Can Laboratory are quite minimal. Two-way voice communications between the Laboratory and cooperating ground facilities have been identified for experiment classes 3, 7, 9, 11 and 15. No requirement for real-time voice has been identified for Experiment 1; however, a real-time voice link would allow cooperative Emitter ON-to-Emitter OFF tests to be performed. These tests could be utilized for system calibration checks. Experiment classes 3 and 16 are the only two experiments which may require real-time data transmissions via the Orbiter S-Band link. Delayed data transmissions may also be required for several of the other experiments.

Communications Interfaces

The communications subsystem interfaces between the Early laboratory and the Shuttle orbiter will probably consist of simple hard-wired two-way voice communications. Direct hardwire access to the orbiter telemetry encoder is required for sortie can digital data transfer. The 25 Kbps allocated by the Orbiter DMS for payload data is more than adequate to support the Early laboratory payload status data requirements. Although a requirement for wideband (high rate digital or television) transmission of experiment information has not been identified, the orbiter television transmission capability could be utilized for monitoring crew activities and providing experiment support. The capability to access the orbiter wideband transmitters will be provided in the payload bay. Since the orbiter RF communications system will be utilized for communications direct to the ground stations, no operational RF interfaces are required in the Sortie Can Laboratory. The interfaces between the Shuttle Orbiter/Sortie Can Laboratory and the TDRS/ground are illustrated in Figure 3.4-2. Since many of the experiments are recommended to be performed while within the field-of-view of the NASA ground STADAN/MSFN stations, a potential conflict between operational and experiment voice communications may arise. This could be avoided by providing at least one dedicated experiment support voice channel as part of the orbiter RF system.

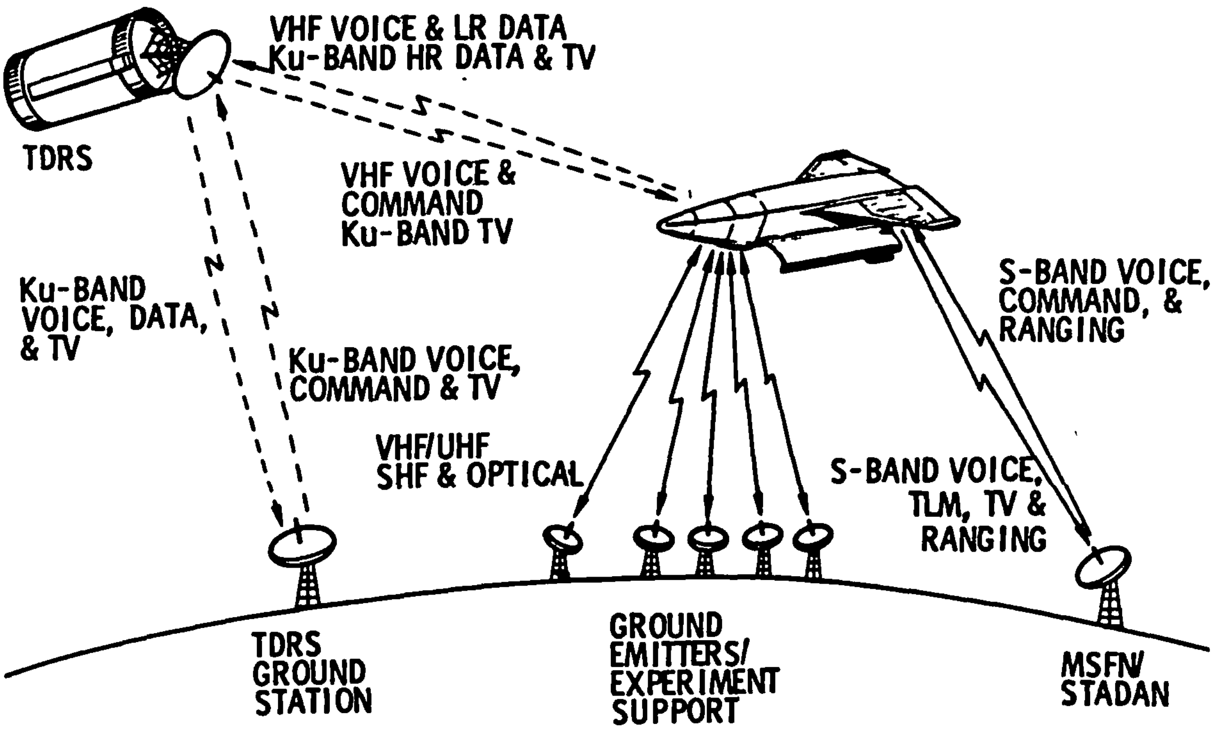


Figure 3.4-2. Shuttle Orbiter/Sortie Can Laboratory

As the experiment program evolves into growth and fully capable Laboratory operations, the baseline orbiter communications system capability may be exceeded. The capability to transmit wideband video or high rate digital data directly to the ground could be provided by incorporating a hardwired RF interface between the attached laboratory and the orbiter antenna system as shown in Figure 3.4-3. This will require the addition of an S-band wideband transmitter within laboratory, coaxial cables, and an access port in the orbiter S-band multiplexer. These changes would have minimal effect on the baseline orbiter RF system.

The current Shuttle orbiter baseline provides the capability for two-way voice and up to 2 Kbps of digital data transfer between the orbiter and a free-flying payload considered as a Growth laboratory mode of operations. A free-flyer version of the laboratory would require a complete narrow S-band RF transmission and reception system for the line of sight two-way voice and digital data communications links. In addition, a wideband video or high rate digital data transmitter would also be required for relaying transmissions directly to the ground from the free-flyer.

Since the Orbiter baseline does not provide the capability for wideband communications links with the TDRS at Ku-band, the Communication/Navigation sortie can could be utilized as a development test bed for verifying acquisition and handover procedures and validating hardware concepts.

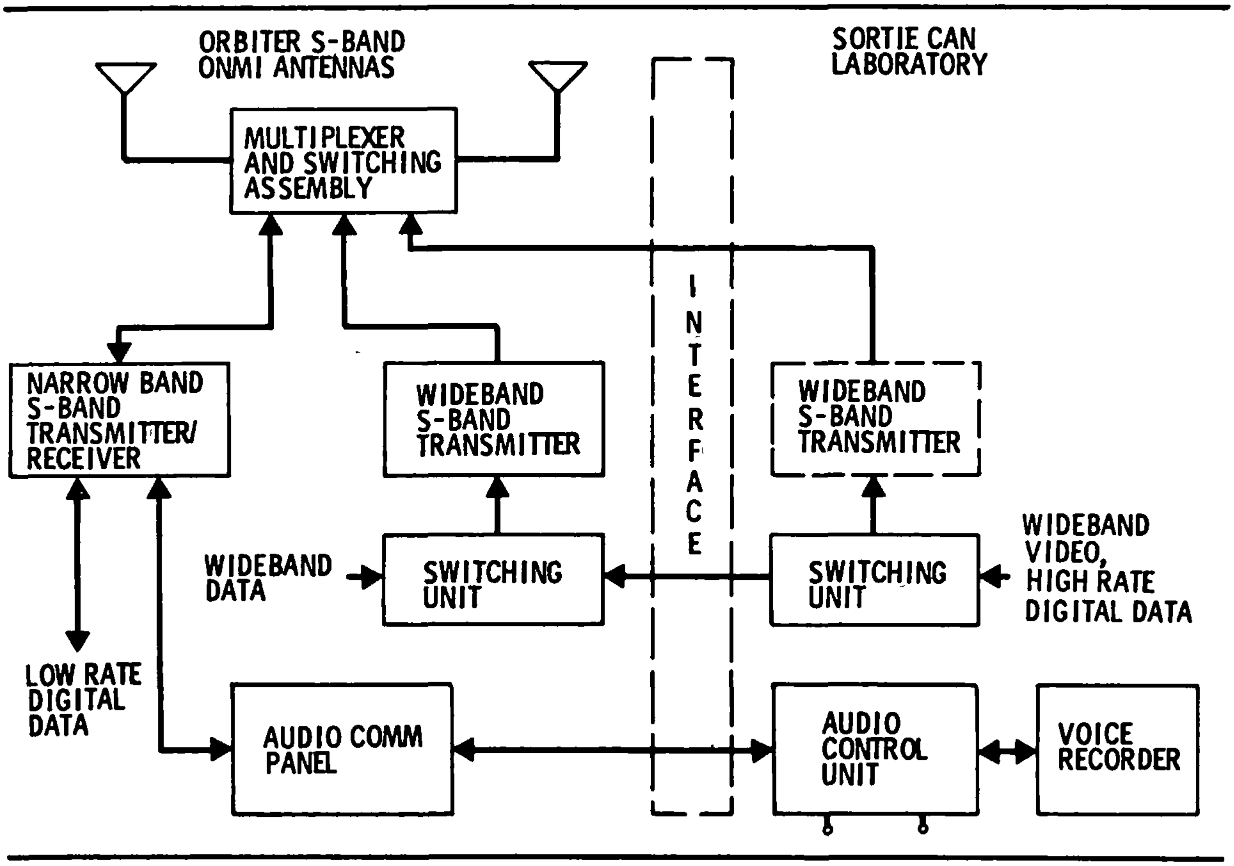


Figure 3.4-3. Orbiter/Laboratory Communications Interfaces

Heavy emphasis should be placed on the Terrestrial RF Sources, RF Propagation, and Communication Relay experiments in the Early laboratory. While early sortie can missions proposed are for VHF/UHF noise surveys, the Terrestrial RF Source experiment should be modified or expanded to include at a minimum the 1.5 - 1.7, 3.7 - 4.2, and 5.9 - 6.4 GHz frequency bands. It would be highly desirable to also cover the 11 - 15 GHz band early in order to provide timely data required for the development of future commercial relay satellite systems.

In order to maximize the effectiveness of early flights, it is recommended that an elliptical orbit having an apogee over the northern hemisphere and a perigee over the southern hemisphere be seriously considered in order to improve the circular low orbit field-of-view and CONUS ground station contact times. Another factor that must be incorporated in the sortie can interfaces for the Laser Communications, Multi-Beam Antenna, and the Landmark Tracking experiments is the ability of the orbiter attitude control system to maintain the precision attitude control required for beam pointing, acquisition and lock-on. In the case of the multi-beam antenna experiment, it may be necessary to initially use only two beams instead of the four presently proposed. This would alleviate the stringent pointing requirements and would allow NASA ground stations located on the CONUS East and West Coasts to be utilized.

3.4.3 Stabilization and Attitude Control Subsystem Interface

The presently defined stabilization and attitude control subsystem of the orbiter has the capability to provide Earth-centered and inertial or solar references. This capability is provided by a sensor complement of star trackers, horizon sensors and a 3-axis attitude gyro package. The gyro package and horizon sensors are used in a gyrocompassing mode to provide the Earth-centered reference. The star tracker, which provides the reference updating, and the gyro package are utilized to provide the inertial or solar references. Preliminary attitude reference accuracies for the Earth-centered and inertial references have been established as ±0.17 degree for both references. The ability of the orbiter to point to a particular point in either an Earth-centered or inertial reference will be the sum of the attitude reference accuracy (0.17 degree) and the attitude deadband of the control actuators.

The ability of the orbiter to hold to a reference is determined by the attitude deadband. Presently, the orbiter utilizes reaction control jets (RCJ) for the control actuation. With RCJ, the smaller the deadband, the larger the attitude control propellant required.

The pointing accuracy of attached payloads to the orbiter is computed as the attitude deadband plus the RSS of the payload alignment error and the attitude reference error (0.17 degree). Assuming a rigid structural connection between the payload and the orbiter, the attitude hold capability provided to the payload is just the deadband of the orbiter.

A requirement has been specified for the orbiter to provide a pointing capability for the payload of ±0.5 degree for one orbit every other orbit over a period of 24 hours. It is assumed that this pointing requirement of the payload is analogous to the definition of the attitude hold or deadband of the orbiter. It is noted that a requirement for the orbiter is to provide the capability for determining the mechanical alignment of the payload with respect to the reference frame of the orbiter to an accuracy of 0.5 degree in all axes while the payload is attached to the payload bay and the orbiter is in orbit. With this and the attitude reference accuracy of the orbiter, a true pointing accuracy requirement for the payload in the payload bay is at least ±0.53 degree $(\pm \sqrt{.5^2 + .17^2})$. Hence, the pointing capability of the payload is taken as the attitude deadband of the orbiter.

An alternate concept considered by the orbiter for the pointing acquisition of the payload is to mechanically erect the payload from the orbiter bay. One particular erection mechanism was evaluated to determine the attitude error. This error source was evaluated by determining the error in erecting the payload due to linkage length variations and variations in the linkage attach points and was calculated to be approximately ±1.6 degrees, 3σ.

As long as the payload alignment errors, whether due to the erection system or the non-deployed system, are relatively constant and the payload sensors have sufficient field-of-view to overcome the payload alignment and the attitude reference errors, the attitude hold capability of the payload is the same as the attitude deadband of the orbiter. For the non-deployed payload, conflicting payload pointing requirements, such as Earth-centered and data relay synchronous satellite (DRSS) targets, may require separate orbiter attitude orientations. The deployed payloads possess the capability of simultaneously satisfying conflicting experiment pointing requirements from a single orientation.

It may be cost effective to isolate those sensitive experiments rather than impose the fine pointing control on the reaction jets of the orbiter. Figure 3.4-4 shows the attitude control propellant requirements for the orbiter as a function of the attitude deadband. These requirements are shown for two orientations which are the X-axis perpendicular to the orbit plane (X-POP) and the X-axis in the orbit plane (X-IOP). The time duration and limit cycle rates are given on the figure. The data for these computations was obtained from MDAC-East dated 10 April.

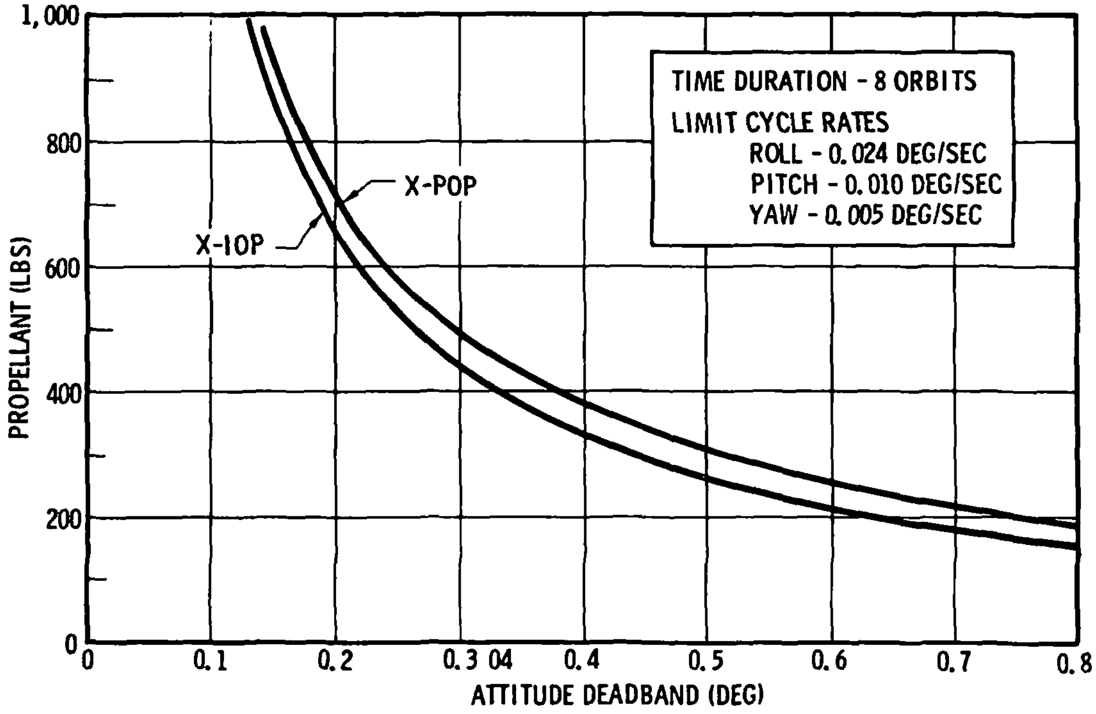


Figure 3.4-4. Orbiter Attitude Control Propellant

For those payloads that require an attitude reference better than that of the orbiter (0.17 degree), the payload must be isolated by a gimbal system and the payload must provide its own attitude reference system.

A solution to eliminate the payload alignment error is to use an attitude reference sensor mounted on the payload. This sensor could control the Shuttle or the experiment itself. In this latter case, the experiment would be gimballed with respect to the Shuttle. This requires an interface with the Shuttle control system. The Shuttle attitude reference can be compared to the experiment attitude reference and the Shuttle attitude biased to make the attitude agree with the experiment reference. This comparison could be made automatically through an electrical interface from the experiment sensor to the Shuttle.

The sortie GNC subystem is shown in Figure 3.4-5. This GNC subsystem consists of a strapdown gyro package, a pair of gimballed star trackers and the software required to process the sensor outputs.

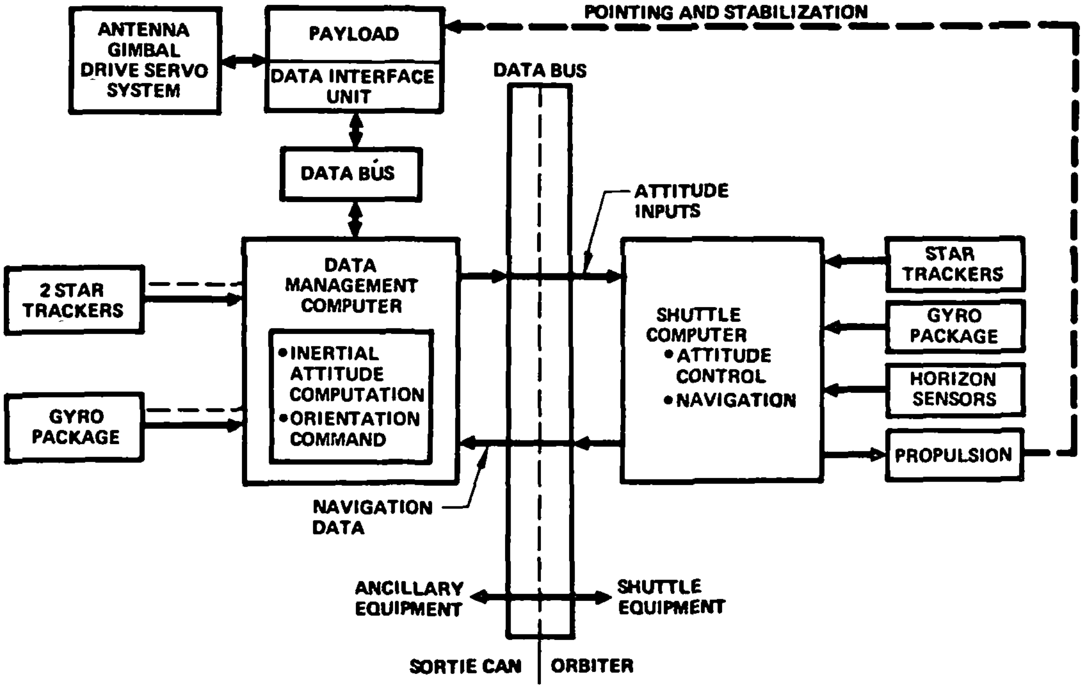


Figure 3.4-5. Sortie GNC Subsystem

During orbital operations, the GNC sensor data is processed within the DMS computer of the sortie to determine the inertial attitude of the payload. This sensor information is sent via the data bus to the Shuttle GNC subsystem. The initial attitude of the Shuttle reference is compared to the inertial reference of the payload which gives a continuous knowledge of the relative alignment between the two reference systems. This information is used by the Shuttle control system to eliminate the major portion of the payload/Shuttle alignment errors and to provide the required pointing accuracy to support the sortie mission. For payloads which require pointing relative to an Earth-centered coordinates using the available navigation parameters.

This design approach offers complete flexibility in the orientation of the payload with respect to the Shuttle attachment mechanism with no change in the Shuttle support software. The sortie attitude reference information allows the Shuttle to automatically determine the orientation of the payload and the desired pointing direction.

Figure 3.4-6. summarizes the payload attitude control requirements as a function of attitude performance. For those payloads requiring

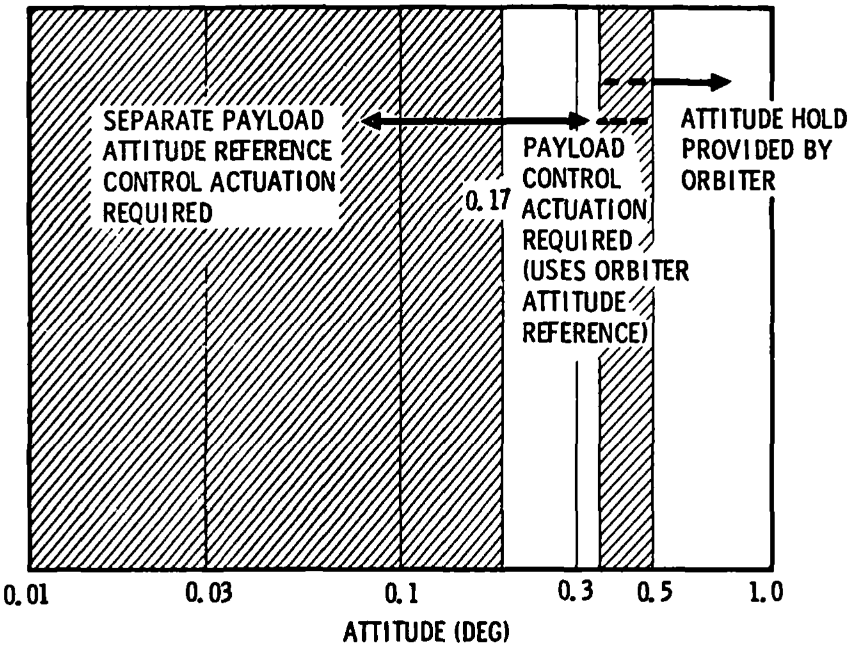


Figure 3.4-6. Payload Attitude Control Requirements

an attitude accuracy less than 0.17 degree, the payload must provide its own attitude reference system and control actuation. For those payloads with an attitude accuracy requirement greater than 0.17 degree up to 0.3 to 0.5 degree, the payload must provide its own control actuation but may use the attitude reference of the orbiter. For an attitude accuracy above the range of 0.3 to 0.5 degree, the Orbiter can provide the attitude accuracy requirement. The range of 0.3 to 0.5 degree is specified since the attitude capability of the orbiter is not that well known. If the orbiter utilized momentum storage for control actuation, the orbiter could provide the attitude accuracy of 0.17 degree for the payloads.

3.4.4 Power Subsystem Interface

The NASA/MSFC design requirement for "minimum Shuttle interface" suggests an autonomous design, with independent fuel cells, reactant tanks, and radiators mounted on the exterior of the Comm/Nav sortie can. This baseline has been adopted for the Comm/Nav sortie can mission and is reflected by the design reported here.

The recent shuttle orbiter Phase B Definition Study indicates that a sustained power level of 6 KW with 640 KWHr of energy are available for payload support. The power level would be constrained to 5 KW, however, if the thermal equivalent of 5 KW of electrical power is collected and transferred back to the Shuttle orbiter radiator. Although this option for Shuttle support is not baselined, it is an attractive alternative for future study as the orbiter Phase C/D development evolves and these available resources are verified.

The autonomous fuel cell power system design requires a number of control, display, and instrumentation functions, which are associated with the auxiliary systems for reactant and fuel cell control. These include purging, thermal control, water recovery, and pressure regulation. Fuel cell electrical systems are also provided for voltage regulation, power switching, startup and shutdown. These requirements are shown on the electrical schematics and will duplicate those within the orbiter, because identical fuel cells and reactant tanks are selected for the conomy benefits derived from commonality. The present MDAC design utilizes fuel cells with 7.5 KW sustained and 10 KW peak capability, and MOL-design reactant tanks of 44 inches (H_2) and 36 inches (0_2) holding

79 pounds of H_2 and 695 pounds of 0_2, respectively, and providing 860 KWHr of fuel cell electrical energy.

The electrical power load profile for the most active day (Mission Day 5, Experiment Day 4) is shown in Figure 3.4-7. The 24-hour average power level is 2, 800 watts. The average power during the active experimentation period of 13. 9 hours is 3, 638 watts. The highest peak load is 7, 753 watts for nine (9) minutes. Other significant sustained loads are 6, 643 watts for 24 minutes. The energy requirement for 24 hours is 67.19 KWHr. The MDAC orbiter fuel cell is capable of providing 10 KW at 26 vdc output voltage, or 7. 5 KW continuous power. In support of an orbiter payload, in the alternative design described previously, the orbiter can supply 9 KW for 20 minutes or 6 KW sustained, with a total energy of 640 KWHr. These specifications clearly satisfy Comm/Nav mission requirements, using either the baseline dedicated fuel cell, reactant tanks and radiator, or using electrical support from the MDAC Shuttle orbiter.

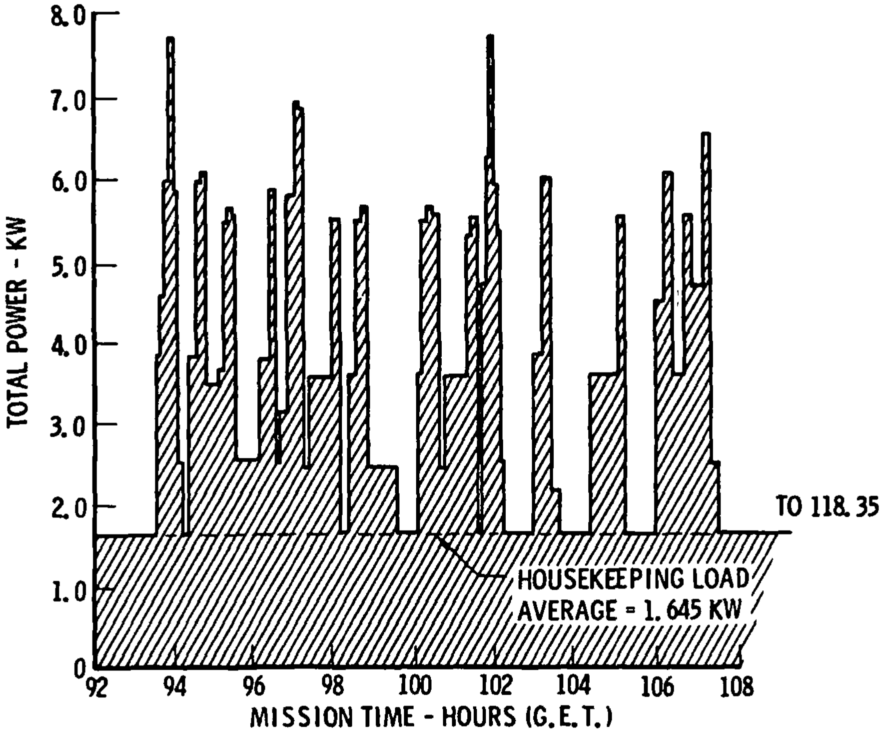


Figure 3.4-7. Electrical Power Load Profile

The fuel cell regulation system is sufficient for many Comm/Nav sortie can loads, such as lighting or heating, and these will only require primary switching control in the Main Power Distributor (under-floor assembly) and load distribution control in the console Electrical Power Panel, see Figure 3.4-8. Other loads will require special regulation, such as instruments or calibrated scientific equipment. This function is performed by DC voltage regulators located at the Electrical Power Panel near the loads. Fans and pumps and some high voltage DC loads will require AC power input for direct usage or for supply to high voltage transformer-rectifiers. Two inverters supply 115/200 V ±2-1/2% at 400 ±1 Hz, three phase AC from a location near the main power distributor. A single-phase inverter also provides 115 V ±2-1/2% at 60 ±1 Hz AC from the under-floor power center for commercial laboratory equipment.

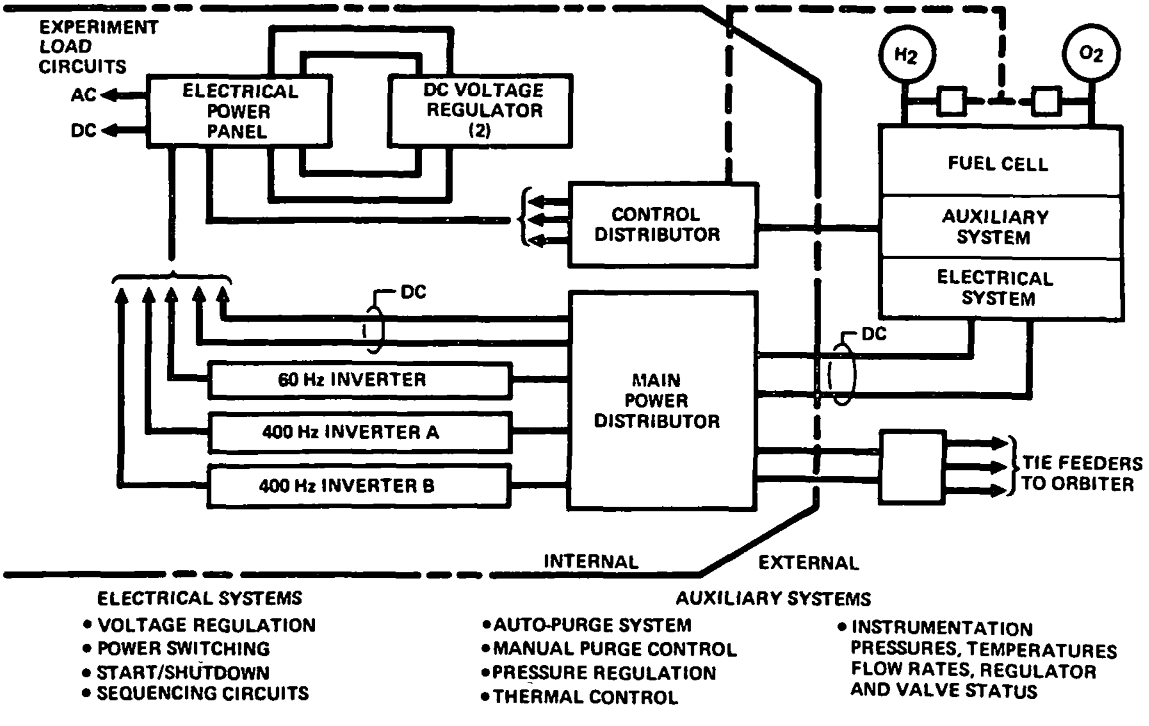


Figure 3.4-8. Power Subsystem Functional Block Diagram

The control, displays, and load circuit protection are in the Electrical Power Panel. Remote control circuit-breakers (RCCB) are located in the Main Power Distributor and at the fuel cell electrical system panel for major circuits and power feeders (see Figure 3.4-9).

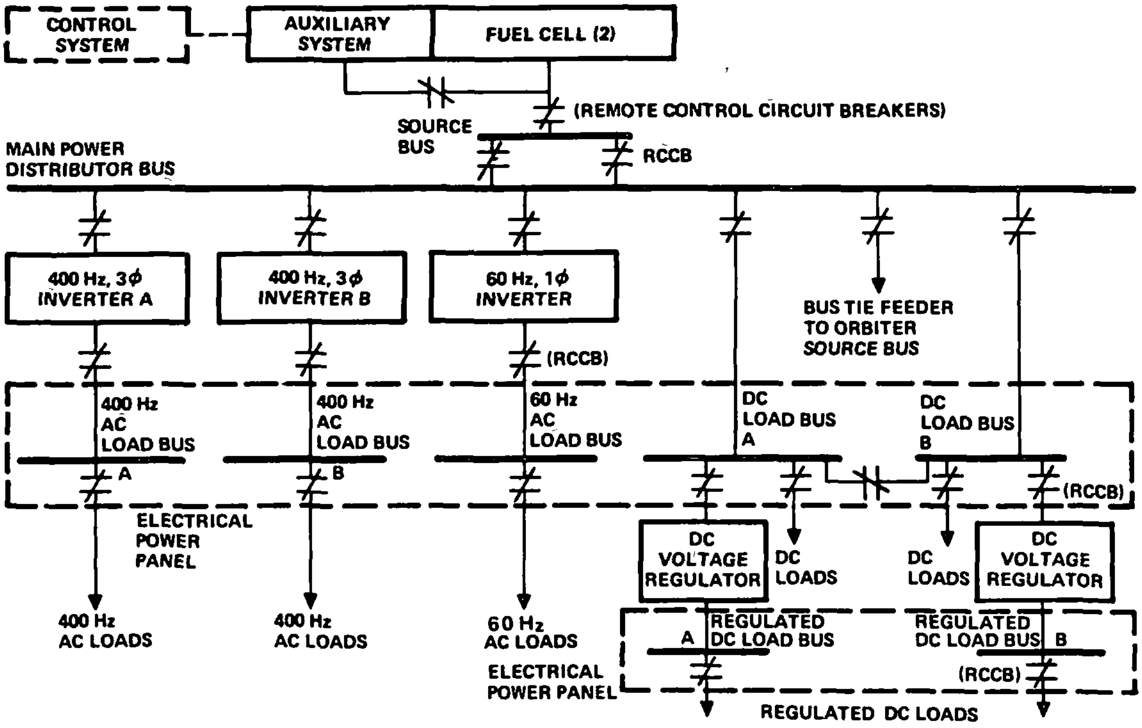


Figure 3.4-9. Power Distribution Schematic

3.4.5 Thermal Subsystem Interface

Introduction

Experimental and support equipment in the laboratory must be maintained within the allowable temperature range during all mission phases. This function is particularly critical when the equipment is operating and producing heat which must be removed and rejected to space.

The most efficient means of heat removal is to mount the equipment on a cold plate through which a cold fluid is circulated. This approach is more efficient than forced air convection due to the high heat transfer coefficients in liquid systems and the capability of cooling the equipment at higher temperatures. Normally forced air systems are limited to about 75 degrees F due to crew comfort considerations in the cabin and they require high power for circulating the air. Cold plated electronic equipment normally can operate with 105 degrees F coolant outlet temperatures; higher outlet temperatures simplify the heat rejection function.

Therefore, a desirable guideline for design of laboratory equipment is to cold plate mount the equipment wherever practical. In cases where this approach is not practical, forced air convection should be used.

Definition

The laboratory thermal conditioning design is shown in Figure 3.4-10. The system is entirely contained within the laboratory, no Shuttle interfaces are required. A two loop design is provided, a water loop circulates cold fluid to the equipment inside the pressurized volume and freon heat rejection loop rejects the heat to space via a space radiator. Heat from the water loop is transferred to the freon loop for heat rejection by means of an interface Freon/H_20 heat exchanger. This component also contains passages and connections for ground cooling fluid. Each loop contains a pump and accumulator package for circulation and to account for leakage and thermal expansions/contractions.

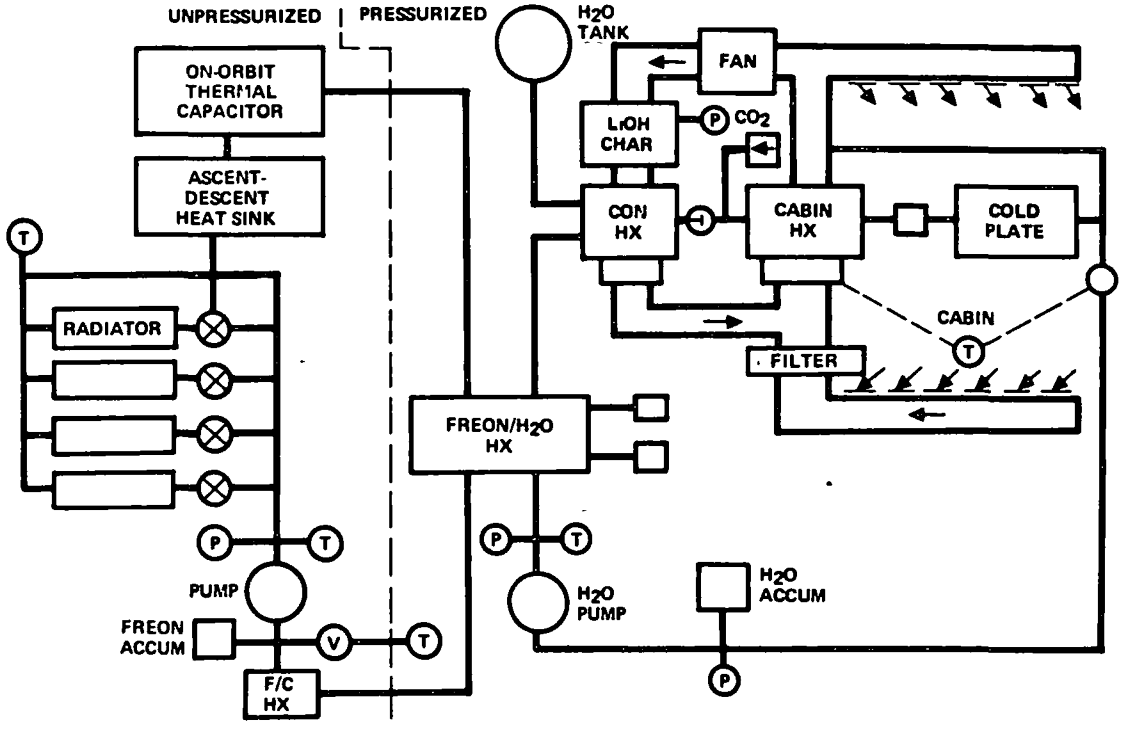


Figure 3.4-10. Thermal Control Block Diagram

Additional equipment in the freon loop is provided to obtain the desired performance. An ascent/descent heat sink is used to provide cooling during mission phases when the space radiator is inside the Shuttle bay. The on-orbit thermal capacitor stores cooling capacity during cold orbital positions for use during hot orbital conditions. The unit contains a phase change material which freezes during shade side positions and melts when the radiator is exposed to direct or earth reflected solar radiation. The freon loop also provides cooling to the fuel cell power system.

The water loop provides cooling to a condensing heat exchanger and a cabin heat exchanger. The condensing best exchanger condenses latent heat loads in the cabin due to crew generated water vapor and from experiment latent loads. Cabin heat exchanger sensible loads are derived from crew heat and equipment loads which cannot reasonably be cooled by cold plates. The bulk of the electrical load in the laboratory is removed by cold plates through which the cool circulating water is circulated.

Due to the lack of gravity in the laboratory, care must be exercised to ensure sufficient air circulation for equipment cooling. The bulk of the equipment will be located within the consoles. Forced convection is obtained by drawing air through the console with the cabin heat exchanger fan as shown in Figure 3.4-11. Temperature controlled air is distributed throughout the manned volume by a diffuser system. The air passes through the volume and then enters the consoles through filters and returns grills. The air then passes across equipment in the console, the flow passage being controlled as required by baffles. Near the top of the consoles, the air is drawn through the return duct by the circulation fan before passing through the cabin heat exchanger where the air is cooled prior to recirculation.

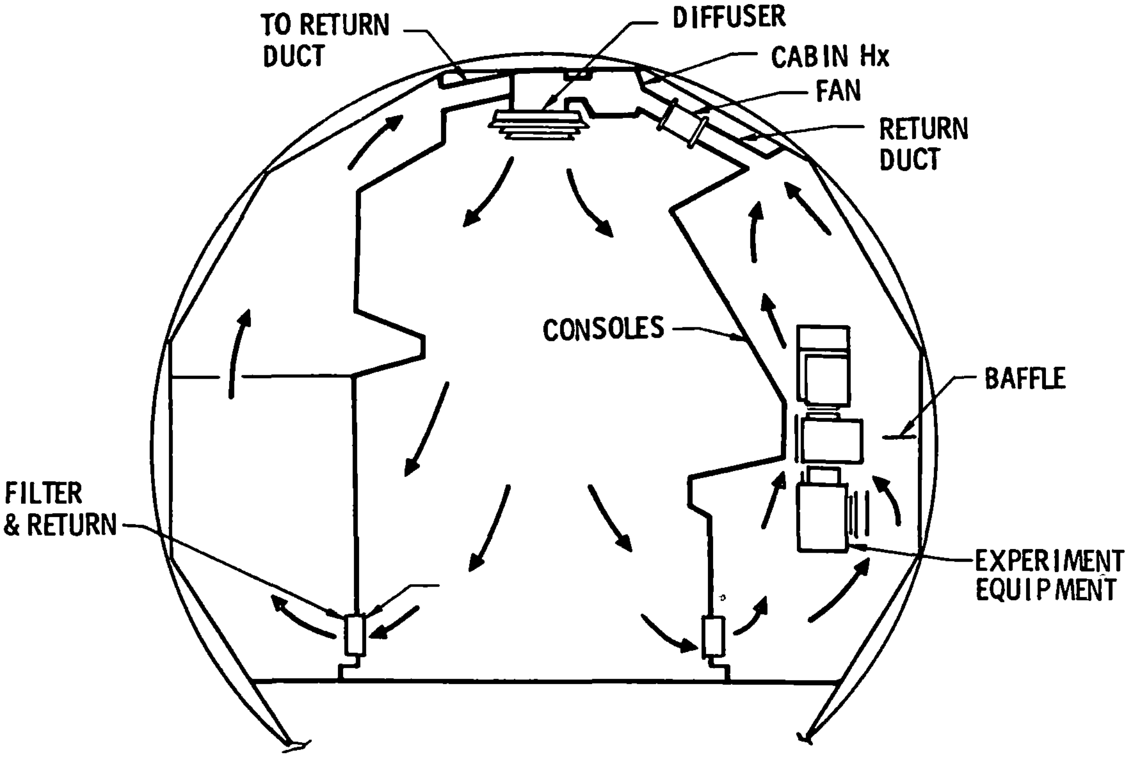


Figure 3.4-11. Laboratory Thermal Design

References

1. Research and Applications Modules (RAM), Phase B Study, Task 4.2/4.3 Review (Technical Data Summary Briefing Brochure), Convair Aerospace Division, General Dynamics Report No. GDCA-DDA71-005, 1 December 1971.

2. Final Report, Vol. VI, System Interface Definition, Shuttle Orbital Applications and Requirements (SOAR), McDonnell Douglas Astronautics Company Report MDC G2545, December 1971.

4.0 SPECIAL DESIGN CONSIDERATIONS

In addition to the orbiter-payload interfaces discussed in Section 3 above, a number of other factors, or special design considerations, were instrumental in influencing the laboratory design. These include such things as equipment maintenance, human engineering, orbital effects, and the use of commercial equipment.

Because of the short duration (seven days) of the early sortie missions, maintenance requirements will be minimal. However, as mission duration increases to 30 days or more, the need for maintenance of laboratory equipment will increase. Ultimately the maintenance function on the space station-attached laboratory may demand a dedicated crewman to perform this function.

The layout of the laboratory to insure compatibility with the crewman involves questions of safety, ease of operation, zero g effects, as well as the physical and psychological constraints of the crew. Data from past studies (RAM, SOAR, MOL) as well as current programs (APOLLO, SKYLAB) were utilized in structuring the Comm/Nav Lab.

The selection of an orbit for operation of the laboratory may not be a simple task. Orbital selection involves the Shuttle (payload capability, attitude control performance, etc.), the configuration of the ground stations (location, number, capability), and finally the experiment data which can be acquired. The interaction between the orbit characteristics and ground station coverage, as well as experiment needs, is briefly discussed.

Commercial equipment cannot generally be used in spacecraft because of the operating environment, and in particular the hard vacuum of space. For Sortie Can missions, where an atmosphere is provided for the equipment and crew, the potential benefits of using commercial equipment are many. The cost savings inherent in using commercial equipment are significant, but other important advantages such as the availability of the equipment and the established familiarity of the lab crew with such equipment should not be overlooked. Modifications to existing equipment will be required, primarily to meet flight safety requirements; some modification may also be necessary to survive the ascent/descent environment or to meet other lab interface constraints. While initial contacts with vendors of such equipment have been encouraging, further effort in this area is required to better define the approach to adapting commercial equipment for use in the Comm/Nav Lab.

4.1 MAINTENANCE

The main effort of the maintenance task was to define a maintenance philosophy for the Early, Growth and Total Comm/Nav Labs and to define crew tasks which should be performed for each of the three labs. These tasks were broken down into two main areas, 1) scheduled maintenance and calibration and 2) unscheduled maintenance. The first is involved with how often certain types of equipment should be scheduled for periodic maintenance and calibration while the latter deals with returning a failed unit to an operational condition by either repair or replacement with a spare (or redundant unit). Tables 4.1-1 and 4.1-2 summarize the maintenance tasks for the three versions of the Comm/Nav Laboratory.

4.1.1 Scheduled Maintenance and Calibration

The maintenance philosophy for the Early and Growth Comm/Nav Labs are similar. Experiment peculiar spares will only be carried for items that have limited lifetimes or wear out for the Early Lab. An example of this would be laser flash bulbs which have a limited lifetime. For the Growth Lab additional spares will be provided for experiment peculiar equipment which are known to be unreliable. Other spares that will be considered for the Early and Growth Labs are for certain in-line equipments that serve all experiments such as tape recorders for data storage and possibly items like oscilloscopes which are needed to monitor and adjust the experiments. Additional spares will be selected based upon optimizing the reliability of the Comm/Nav Lab within the cost, weight and volume constraints. In some cases an experiment will be designed to have a redundant unit that can be switched on in the event of a unit failure. The Terrestrial RF Sources and Noise experiment requires three receivers, two for 2 channel operation and one for the astronaut as an analysis receiver. Failure of any one of these three receivers will degrade the experiment. A standby spare receiver is proposed for this experiment which can be switched in to replace any one of the three primary receivers in the event of a failure. This is a cost effective approach since the three primary receivers will be essentially identical and the only cost involved would be the the manufacturing costs associated with four receivers instead of three receivers. If a failure does result in a complete loss of one experiment more time can be allocated to the remaining experiments.

Table 4.1-1. Summary of Comm/Nav Maintenance Tasks

MAINTENANCE TASKS FOR COMM/NAV EQUIPMENT	COMM/NAV LAB VERSION		
	EARLY	GROWTH	TOTAL
1. Installation of Specially Packaged Equipment	X	X	
2. Check-Out and Minor Adjustments	X	X	X
3. Scheduled Maintenance and Calibration			X
4. Unscheduled Maintenance	X	X	X
5. Fault Isolation		X	X
6. Repair of Failed Equipment			X

Table 4.1-2. Comm/Nav Maintenance Tasks

MAINTENANCE TASKS FOR COMM/NAV EQUIPMENT	COMM/NAV LAB VERSION		
	EARLY	GROWTH	TOTAL
1. Installation of Specially Packaged Equipment	Commercial equipment may not survive the launch environment without special packaging These items will be packaged separately then installed and checked out at the beginning of the mission	Commercial equipment may not survive the launch environment without special packaging These items will be packaged separately then installed and checked out at the beginning of the mission	None
2 Check Out and Minor Adjustments	During the Initial set-up of each experiment the equipment will be checked to verify it is functional and it will be adjusted if required to bring it in to spec	During the Initial set-up of each experiment the equipment will be checked to verify it is functional and it will be adjusted if required to bring it in to spec	During the Initial set-up of each experiment the equipment will be checked to verify it is functional and it will be adjusted if required to bring it in to spec.
3 Scheduled Maintenance and Calibration	None	None	Design Goal is for scheduled maintenance and calibration every 6 months except for items with limited life times of less than 6 months. These items will be scheduled on a shorter time interval.
4 Unscheduled Maintenance	Mission ciritical and limited life spares will be provided in case of failure	Mission critical and limited life spares will be provided in case of failure	Mission critical and limited life spares will be provided in case of failure
5 Fault Isolation	None	Only done to unit level to determine which unit is not working, replace unit if spare is available	May be done to circuit board level Replace with spare if available
6 Repair of Failed Equipment	None	None	Provisions may be made to repair certain failures

In general no scheduled maintenance or calibration should be required for the Early or Growth Labs since all commercial equipment should be capable of functioning for 30 days without any major maintenance or calibration activities being required. In this context calibration refers to the adjustment of equipment which requires the use of secondary standards as references.

During the checkout of the lab once it has arrived "on station" certain adjustments will be made to the equipment before the experiments are started. Boresighting and alignment checks will be required for the Laser Propagation Experiment and the sensisitivity of the receiving equipment will have to be adjusted for the Terrestrial RF Sources and Noise Experiment. In some cases some commerical equipment may not survive the launch environment without special packaging. These items will be packaged separately then installed and checked out at the beginning of the mission. Examples of this could be the CRT for the oscilloscopes or other fragile items. Requirements for special packaging will have to be analyzed to limit the amount of hardware placed in this category to avoid too much time being spent by the crew installing sepcially packaged equipment. The amount of specially package equipment for the Growth Lab can be greater than for the Early Lab since the mission time is longer thus allowing more time for the set-up and checkout of experiments.

The maintenance philosophy for the Total Lab assumes that all equipment will be specially designed for the COMM/NAV mission. The design life of this equipment should be 5 to 10 years as a goal with a minimum of scheduled maintenance and calibration being required. The 5 - 10 year design life was selected because the RAM Phase B Study uses 5 year missions but also considers extending the mission time to 10 years. Scheduled maintenance and calibration should be limited to 6 month intervals except for items with limited life times of less than 6 months. Additional spares will be available for items with limited life times and they will be replaced when they fail unless the item is critical to a continuing or long duration experiment. If the equipment is critical to a continuing or long duration during experiment it will be scheduled for replacement once it has accumulated sufficient operating time to warrant replacement. The item will then be replaced at the earliest convenient time that the experiment is shut down.

For equipment that requires calibration the design goal is to add an internal calibration circuit to this equipment where possible. If this is not possible then secondary standards will have to be provided on the Total Lab to calibrate this equipment or it will have to be returned to Earth for calibration. In order to evaluate the time required for on-board calibration of equipment an analysis was performed based upon experience at TRW Systems on typical equipment that requires calibration. Table 4.1-3.

Table 4.1-3. Calibration Intervals for General Support Equipment for Terrestrial Sources of Noise and Interference

ITEM	Calibration Interval in Weeks		AVERAGE HOURS PER CALIBRATION
	QA	MAINTAINED	
1. DC Voltmeter	16	80	1.5
2. Frequency Counter	28	52	2.2
3. Spectrum Analyzer	16	28	4.1
4. RF Signal Generator	28	52	1.2
5. Noise Generator	29	52	1.5
6. Strip Chart Recorder	28	52	2.4
7. Tape Recorder	12	28	7.5
8. Oscilloscope	12	40	2.4

lists calibration intervals and the average hours per calibration for commercial support equipment that would be required for the Terrestrial Sources of Noise and Interference Experiment. The QA Calibration interval is one that assures that the equipment is operating within manufacturer's specification while the Maintained Calibration interval is one that maintains the equipment in an operational condition. Since all the equipment for the Total Lab will be specially designed and built in the late 1980's we have assumed that we can utilize the maintained interval for our calibration requirements and that this equipment will operate within specification. The reason for extending the calibration interval is because of the technology improvements that will be implemented in this equipment which will make it more reliable then the current equipment.

The reliability improvement in the equipment is based upon a study done by TRW[1] which indicates that the failure rate or anomalies per unit (black box) decrease at a rate of 6.8% per year. The decrease is based upon over 6 years of data on different Spacecraft. Figure 4.1-1 shows the linear regression line thru these data points. Based upon this failure rate decrease some typical reliability growth curves were generated showing reliability vs time for 15 years based upon unit reliabilities of .75, .80, .85 and .90 in 1975. The curves in Figure 2 show that the reliability would increase to between .92 to .97 for these units in 1990.

The reliability growth is probably due to two major factors. One being that more reliable parts are being obtained thru better screening and technology improvements and secondly that the design is inherently more reliable because design defects are corrected and this knowledge is retained and incorporated into subsequent designs.

Extending the maintenance and calibration intervals so that the equipment is scheduled for maintenance either on a semi-yearly or yearly basis results in the following Table.

Table 4.1-4. Calibration Hours for General Support Equipment for Terrestrial Sources of Noise and Interference

	Number of Calibrations per Year	Average Hours per Calibration	Total Calibration Hours
1. DC Voltmeter	1	1.5	1.5
2. Frequency Counter	1	2.2	2.2
3. Spectrum Analyzer	2	4.1	8.2
4. RF Signal Generator	1	1.2	1.2
5. Noise Generator	1	1.5	1.5
6. Strip Chart Recorder	1	2.4	2.4
7. Tape Recorder	2	7.5	15.0
8. Oscilloscope	1	2.4	2.4
TOTALS	10		34.4

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[1] "Orbital Reliability of TRW Spacecraft," February 1971, Document No. 99900-7454-R0-00.

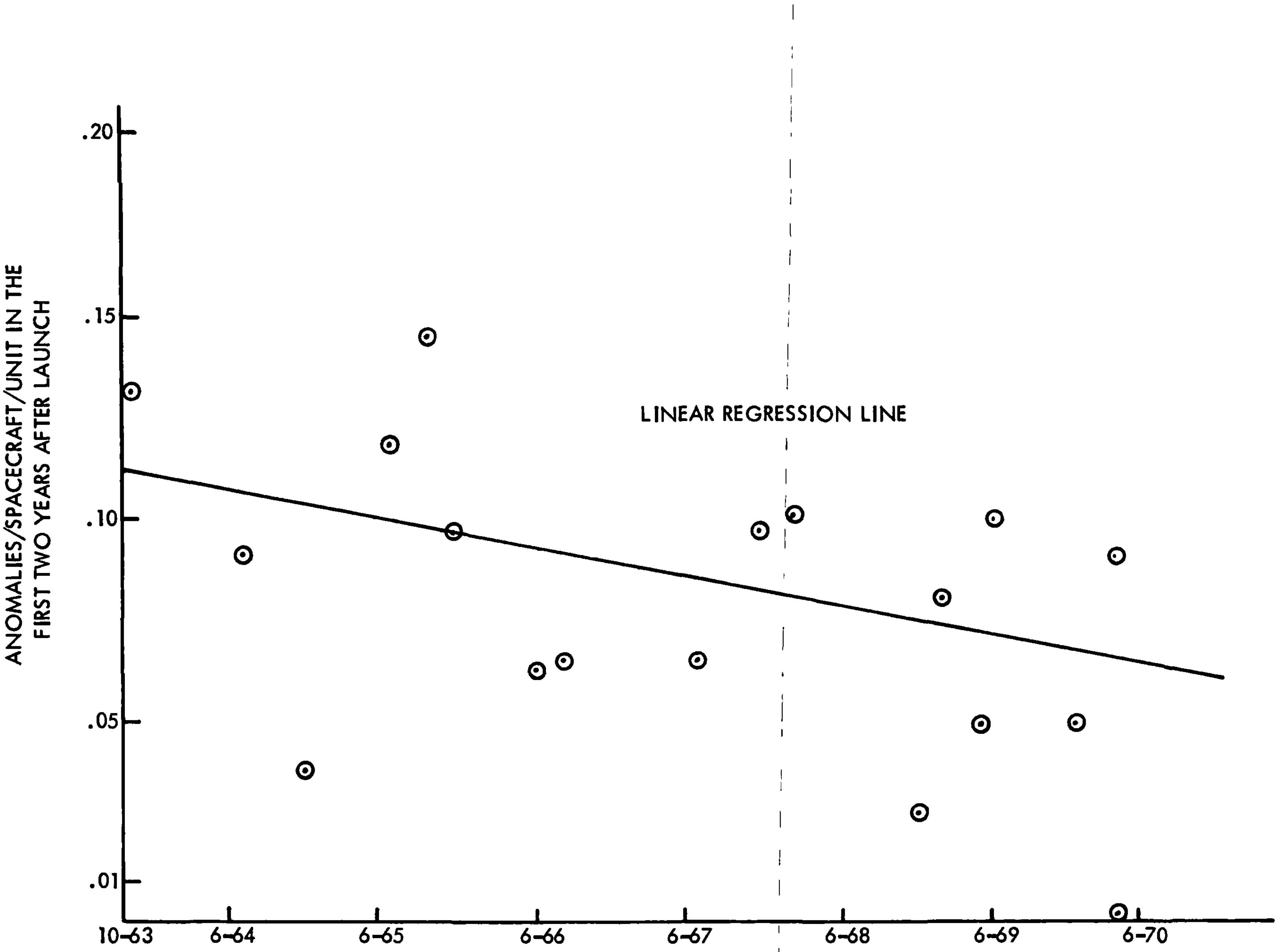


Figure 4.1-1. Linear Regression Line Showing a 6.8 Percent Decrease In Anomalies Per Year for Spacecraft Units Based on Launch Dates

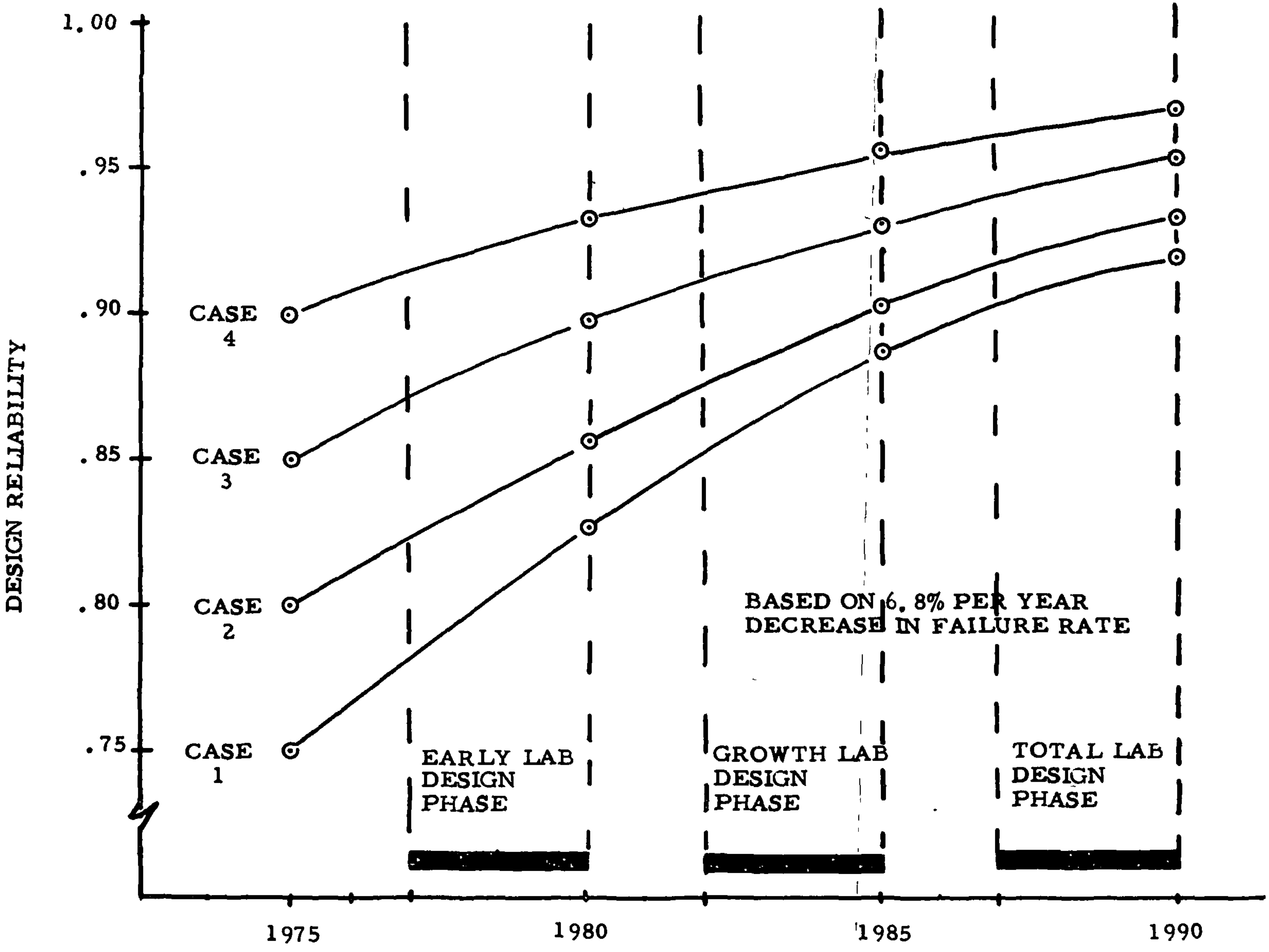


Figure 4.1-2. Reliability vs Design Date if a 6.8 Percent Decrease in Failure Rate is Projected for 15 Years

For the eight types of general support equipment we require 10 calibration actions per year or an average of 1.25 scheduled calibration actions for each item and each calibration action takes an average of 3.4 hours to complete. If we assume that we have approximately 60 items that must be calibrated for the Total COMM/NAV Lab then we have to allocate approximately 255 hours (60 items x 1.25 scheduled calibrations per item x 3.4 hours/calibration) per year to scheduled calibration. This assumes that the astronaut has the same skill as a calibration technician and that he can perform the task within the same time in space as on the ground. We know that it will take longer to perform these maintenance and calibration tasks in space than it does on the ground. Currently the best estimate is that it will take about 50% longer so for the Total COMM/NAV Lab it would require 382.5 hours (225 hrs. x 1.5) per year for scheduled calibration on 60 items of general support equipment.

4.1.2 Unscheduled Maintenance

The Early and Growth Labs will have a limited capability to provide unscheduled maintenance activities. These activities will be limited to replacing failed units or switching to a redundant unit. Mission critical spares will be provided for the equipment which can be replaced in the event of a failure. Some of these items have been previously discussed in the Scheduled Maintenance and Calibration section but will be discussed briefly. Spares will be provided for items with limited lifetimes such as laser flash bulbs, or ones that are in line to more than one experiment. Examples of the latter are oscilloscopes for experiment set up and monitoring and tape recorders for data storage.

The Total Lab will carry additional spares for critical items (those which are unreliable) and ones that have limited life times of less than 6 months. These items will be replaced when they fail unless the item is critical to a continuing or long duration experiment. In these cases the items will be scheduled for replacement once it has accumulated sufficient operating time to warrant replacement. The item will then be replaced at the earliest convenient time that the experiment is shut down.

4.1.3 Summary

An in depth quantitative analysis of the maintenance activities for the COMM/NAV Lab was not feasible during this study due to the lack of exact equipment definition and adequate reliability and maintenance data on this equipment. A preliminary quantitative analysis would be worth considering during future studies on the COMM/NAV Lab by defining equipment classes (oscilloscopes, tape recorders, receivers, transmitters, etc) and analyzing these generic classes of equipment for the required maintenance activities that would be applicable. An estimate of the reliability of each equipment class could be utilized to determine the spares required along with an estimate of equipment availability. This information could then be utilized to perform tradeoffs involving on-board vs. ground spares. Ground spares would only be considered for the Total Lab because of the periodic resupply visits available. It is assumed that every 30 days a visit would be made to the Lab that would have the capability to bring spares. These resupply visits could also be used to return equipment requiring calibration that can not be performed in the COMM/NAV Lab. Here again some trade-offs could be made involving on-board calibration vs. ground calibration. Another consideration is to delete all calibrations which require secondary standards as references. This could be accomplished for the Total Lab by designing internal calibration circuits for all equipment that require periodic calibration.

4.2 HUMAN ENGINEERING

4.2.1 Lab Sizing and Configuration Guidelines

Within the constraints imposed by the carrier host vehicle (e.g., Shuttle) and the environment within which it must operate, the size and configuration layouts of the Sortie Can Comm/Nav Laboratory design are dictated by such considerations as:

- Equipment which must occupy the facility (e.g., experiment equipment and instrumentation, vehicle subsystems equipment, such as tools and spares, crew equipment).
- Crew occupancy and crew activities (number of crewmen, periods of laboratory occupancy, types of crew activity including non-experiment related activities such as personal hygiene, suit donning, eating).
- Accessibility requirements (including visual access within and outside the vehicle, physical access to equipment within the laboratory, physical access to equipment exterior to the laboratory, and accessibility to the Shuttle crew compartment).
- Ground checkout and test requirements (involves configuration of interior and equipment for ease of launch pad inspection, checkout and test).

4.2.2 Equipment Characteristics

The first step in determining lab sizing and configuration guidelines was to define equipment characteristics and functions. The basic data for this task were available from the experiment description sheets found in Volume II. Where data were missing, catalog references were used or preliminary estimates were made. These data are summarized in Section 2.1 above, providing details such as component nomenclature, cross-reference of experiment classes, candidate commercial items and a listing of external dimensions, weight, power and volume of each item.

Analysis of crew interface requirements indicates that about 55 percent of the total console equipment require crew interface, while the remaining 45 percent does not require frequent direct crew interaction. These preliminary data help to establish gross sizes for the crew work stations. Further, the data suggest that much of the auxiliary equipment can be located in equipment bays and need not be in sight of the crew.

Additional instrumentation must be provided to the experiment crew regarding certain orbiter subsystems. These parameters are summarized in Table 4.2-1. EC/LS and attitude and stabilization instruments and meters will require a display panel area of approximately 270 sq. in. (18w x 15h). Power level indicators can be monitored on general purpose alphanumeric CRT displays. *Communication channel assignment readouts and controls* space requirements are integrated into the experiment communications/data management patch panel. This basic interface approach is shown schematically in Figure 4.2-1.

Table 4.2-1. Orbiter Interface Parameters to be Displayed

EC/LS	Power
Cabin Pressure	Circuit Protection and Reset
0_2 Partial Pressure	Illumination Control
$C0_2$ Partial Pressure	Voltage Monitors
0_2 Flow Rate	Power Bus Status Monitor
N_2 Flow Rate	Power Conditioner Monitor
Temperature	
Humidity	
Out-of-tolerance Warning	
Attitude Control and Stabilization	Communications
Attitudes (R, P, Y)	Intercomm
Rates ($\dot{R}$, $\dot{P}$, $\dot{Y}$)	Ground Link
Vertical Error	

4.2.3 Crew Occupancy and Crew Activity

The Comm/Nav Laboratory must be sized and configured for two crewmen working simultaneously, although for short periods of time there could be as many as four crewmen in the laboratory. Laboratory occupany will begin toward the end of the first day and terminate early

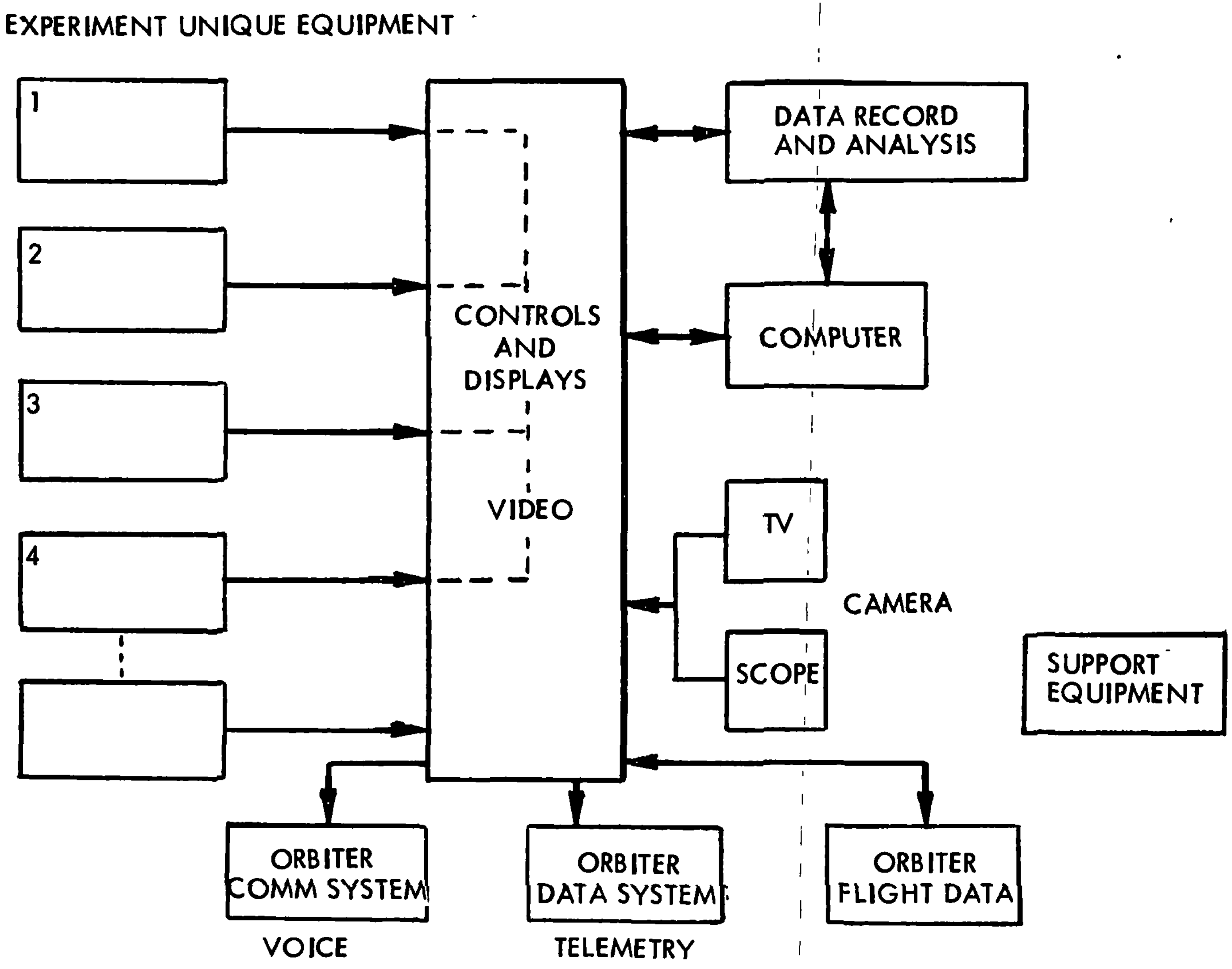


Figure 4.2-1. Orbiter-Experiment Equipment Interface

on the 7th day. The assumed crew operations are summarized below.

- Basic work day for crew

- Sleep period	8 hours
- Hygiene and food	4-1/2 hours
- Mission briefing	1 hour
- Not scheduled	1/2 hour
- Work period	10 hours

- Assumptions
  - Two crewmen available for Sortie mission
  - Orbital operations days begin on 2nd mission day, end on 6th mission day.
  - Crew does not have to eat together; however, it would be preferable.

Since each scientific crewman will be on a 10-hour workday, the maximum planned occupancy on any day will be 20 hours, though it is anticipated that with simultaneous crew operations this will actually be somewhere between 10 and 15 hours. Sleep, personal hygiene, food, mission briefing, and free time activities will be performed in the Shuttle crew compartment. This implies from 6-10 crew transfers per crewman each day between the laboratory and Shuttle crew compartment. Such activity suggests a conflict in successfully operating a "closed hatch" Sortie Can interface with the orbiter, as currently proposed by NASA. No crew EVA is anticipated in connection with the experiments for the Early Laboratory. If EVA is conducted for any reason, EVA suit storage, donning and doffing, and servicing will be performed in the Shuttle crew compartment area. The laboratory configuration must accommodate two crewmen working simultaneously but must also permit operation of the laboratory when occupied by only one crewman.

4.2.4 Accessibility and Ground Checkout/Test Requirements

Laser assemblies and closed tube light pipes must be located conveniently for crew use, but not interfere with traffic patterns within the laboratory. Light pipes provide optical pathways to the laboratory exterior. This laser equipment is to be located separate from either of the previously defined console activities and be mounted through a sealed porthole in the laboratory pressure hull.

Using crew activities as a base, a method was developed for locating equipment/instrumentation items on the display/control console or elsewhere in the lab. Table 4.2-2 shows the analysis as performed for the Landmark Tracking Experiment. As indicated in the chart, each item of equipment was assigned to an appropriate panel area (lower, center, upper) based on the established criteria of dexterity, viewing accuracy and anthropometric requirements. Recommendations for locating items external to the laboratory or not on the console are also indicated. Finally, common equipment items are identified as a part of the overall core equipment/instrumentation categorization task. The latter step is important since core equipment will no doubt have a higher frequency of use than the more specialized unique equipment items. Therefore, core equipment would receive preferential placement on the console. The assignment technique was expanded for use in the development of crew equipment interface requirements.

Certain experiment operations require visual observation of laboratory external equipment. This requirement suggests that the experiment operations consoles be located convenient to laboratory visual porthole(s) or that remote TV be provided for console display. Also laboratory interior free space clearance for maneuverability of two crew members must be available.

For ground checkout and test requirements the interior configuration must permit access to equipment while the laboratory is in the Shuttle cargo bay, either in the horizontal position before transfer to the launch pad or in the vertical position on the launch pad.

4.2.5 Crew Operations and Work Station Design

This section describes the analyses performed in developing a Sortie Can conceptual experiment control/display console and crew operating station for the Early Comm/Nav Laboratory. It also describes the implications for crew training resulting from these analyses. This analytical effort proceeded through the following steps:

- Crew functions and skills analysis
- Console design
- Training requirements analysis

Table 4.2-2. Console Location (Bay) (Dimensions in Inches)

EXPERIMENT: LANDMARK TRACKING

Equipment Description	Lower	Center	Upper	Exterior to Laboratory	Not On Control/ Display Console	Laboratory Common Equipment
1. Optical Antenna				X		
2. Servo Electronics					6 x 8 x 8 X	
3. Fine Tracking Sensor with Video Channel (Camera)					5 x 5 x 21 X	
4. Beam Deflection (Small Vernier Mirror				X		
5. Correlation Electronics					1 x 8 x 8 X	
6. Collimators & Controls — Vernier — thru Porthole (a)	3 x 3 x 8 X					X
7. Kalman Filter — Special Processing Computer					4 x 6 x 10 X	X
8. Camera (16 mm Motion Picture)					X	
9. Oscilloscope		X			X	X
10. Video Tape Deck (2) One with Active Audio Channel — Microphone	(Microphone Only) X		X			
11. Computer — General Purpose					X	X
12. Video Monitor and Controls	X					
13. Magnetic Tape Deck — Digital Data Recording			(Control Only) X		X	X
14. Inertial Measurement Unit (IMU)					X	X

Evolution from the Early Laboratory facilities to the Growth and Total Laboratories must build on the concepts developed for the Early Lab. Therefore, these conceptual designs and requirements were reviewed for growth and total lab implications. Because of the study's groundrule specifying that commercially available equipment be employed for the Early Laboratory, and consequent emphasis on manual experiment accomplishment, it was necessary to subject the equipment/man interface to careful examination to assure that functional efficiency would not be seriously compromised by operational orbital constraints. The reference material employed in the crew analysis included experiment descriptions provided by principal investigators, experiment equipment lists and specifications, and data on static and dynamic anthropometry as provided in NASA CR-1726, Handbook of Human Engineering Design Data for Reduced Gravity Conditions.

4.2.6 Crew Functions Analysis

Identification of Functions

Experiment descriptions were examined in all 18 classes to identify operations requiring crew participation. These were limited to manned activities necessary to the accomplishment of experiments, assuming nominal equipment performance. Maintenance functions were not included in the Sortie Can payload since, for the Early Laboratory concept, orbital maintenance has been omitted as an operational requirement. The 15 functions listed below were found sufficient to describe all experiment demands on the crew.

1. Checkout
2. Calibrate/align
3. Configure
4. Enable
5. Monitor (digital) status
6. Monitor (analog) status
7. Monitor (analog-digital) status
8. Assemble
9. Communicate
10. Photograph
11. Position
12. Record
13. Select
14. Adjust
15. Diagnose

Development of Crew Timelines

A typical sequence of crew functions was derived to serve as a classification framework for further timeline analysis of each experiment. The resulting typical flow sequence is shown in Figure 4.2-2 and reveals that generalized experiment flows are straightforward and highly similar. Time-phased flow diagrams were prepared for each of the first payload experiments to provide a top level summary of the crew functions required. These diagrams, Figures 4.2-3 through 4.2-10, also provided a basis for estimating crew time and number of crewmen required to accomplish the experiments and are used later as timeline reference sequences in mission planning. Each of the individual blocks which indicate crew participation are coded and numbered for easy reference purposes. The first digit identifies the experiment class number and the second digit indicates the sequencing of crew activity functions within each experiment class.

Preliminary timelines were then revised and updated in an effort to provide sequential orbital operations descriptions making maximum utilization of available crew time and with maximum space-to-ground contact time for each experiment. An initial mission earth orbit of 260 nmi circular with 35 degree inclination was finally chosen to provide maximum repeatable continental United States overflights, reference Section 6, dealing with mission analysis.

Analysis of Functions and Crew Skills

A worksheet format was developed to permit correlation of crew functions and mission timelines with experiment equipment and crew skills. A worksheet was completed for each of the seven experiments to be conducted in the Early Comm/Nav Laboratory. These forms identified for each crew function:

- Experiment equipment
- Support equipment
- Control and information requirements
- Task frequency and duration
- Crew skills required

As an example, it appears that first day on-orbit operations of unpackaging, inspection, assembly, and checkout will probably require between 7 and 8 hours of crew time. For at least some of these preparatory activities, the experiment crewmen can be assisted by one or both members of the flight crew.

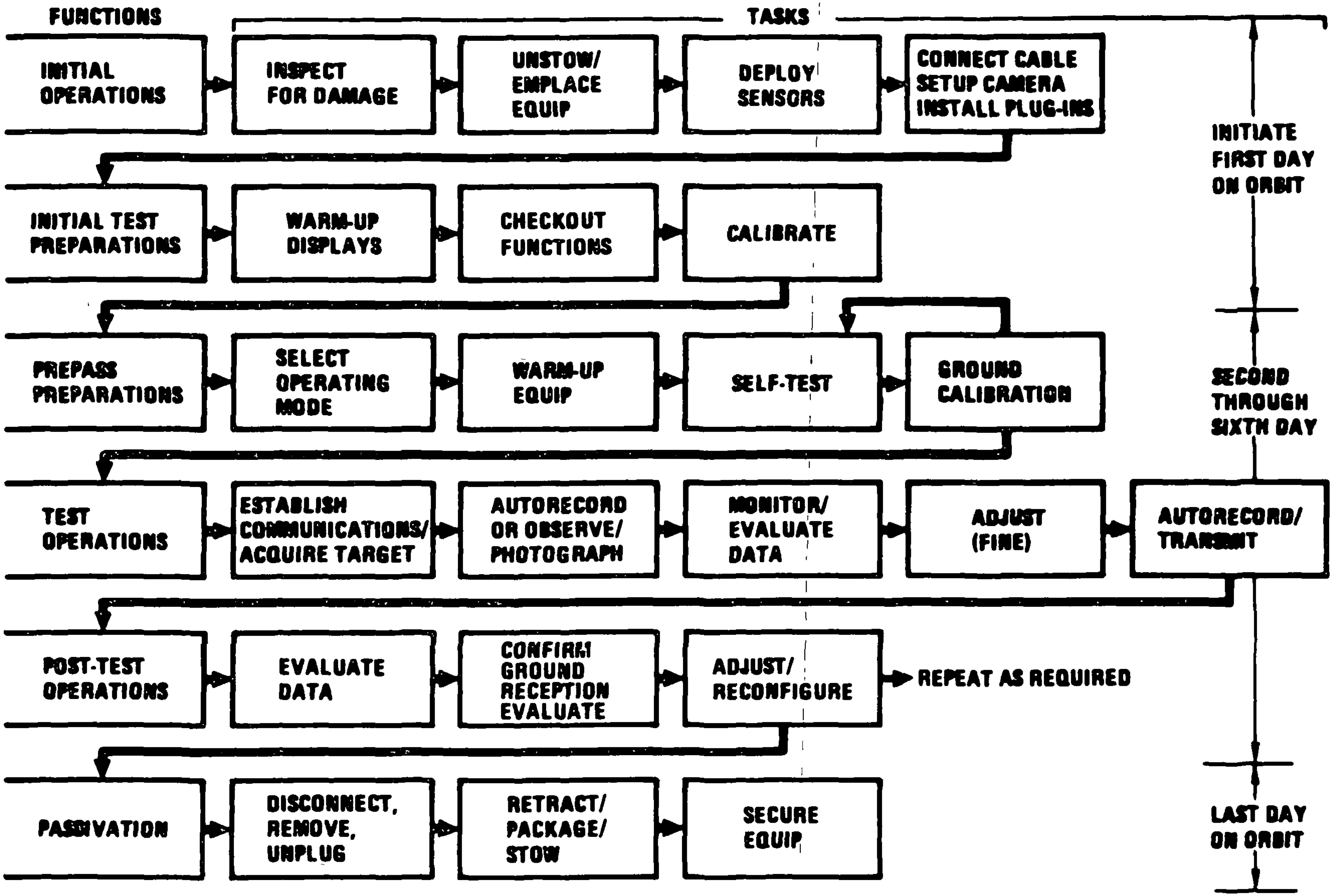


Figure 4.2-2. Typical Experiment Function Flow

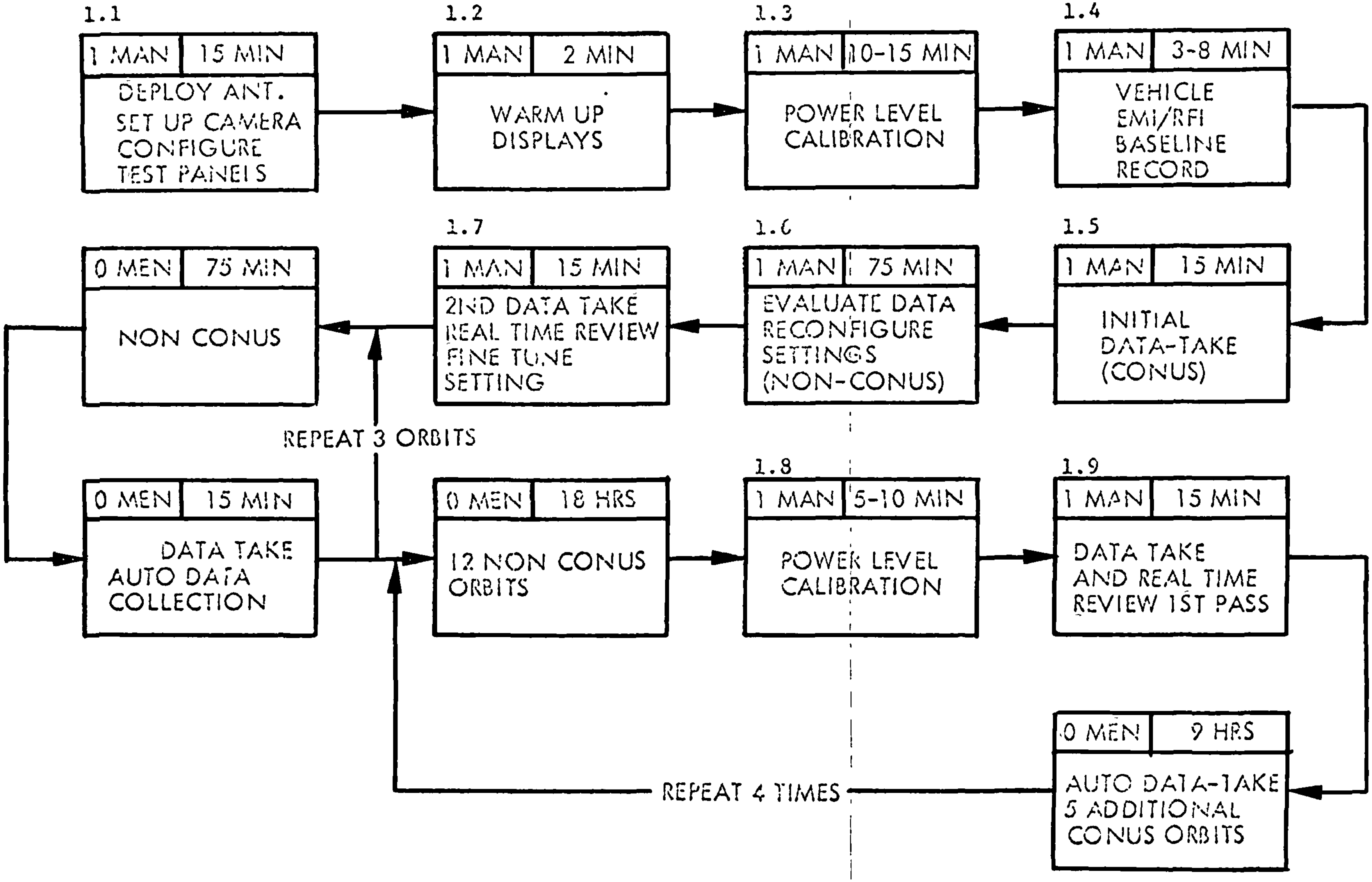


Figure 4.2-3. Experiment No. 1 - Terrestrial Sources of Noise and Interference

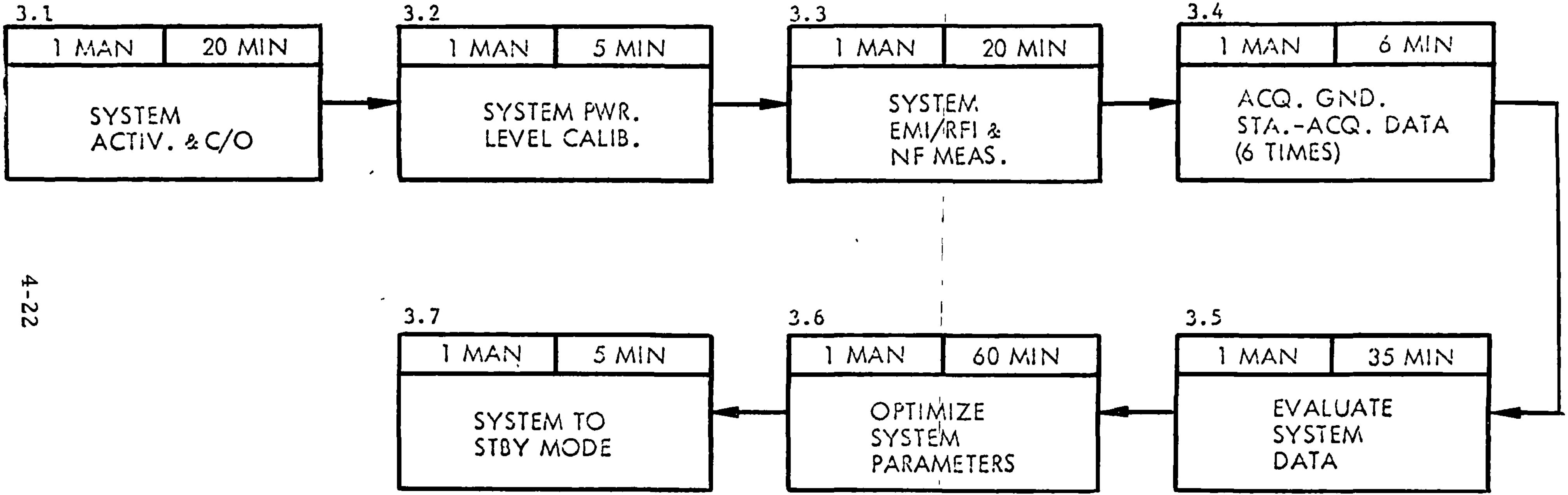


Figure 4.2-4. Experiment No. 3 - RF Propagation System Optimization (NASA Ground Station)

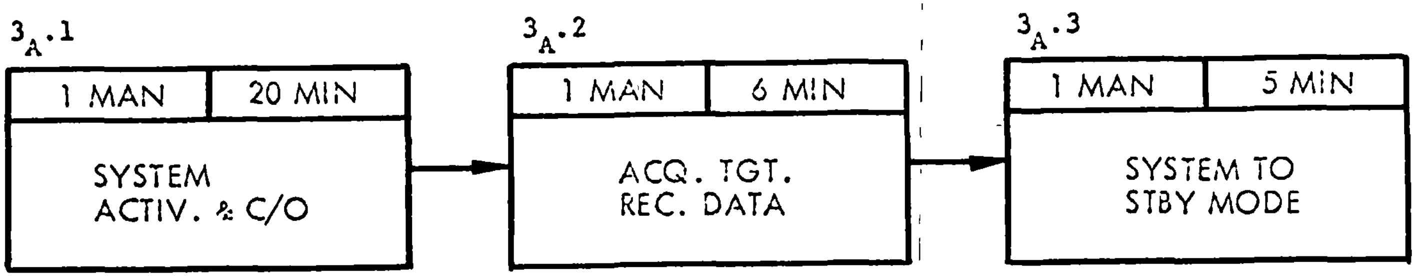


Figure 4.2-5. Experiment No. 3 - RF Propagation Test

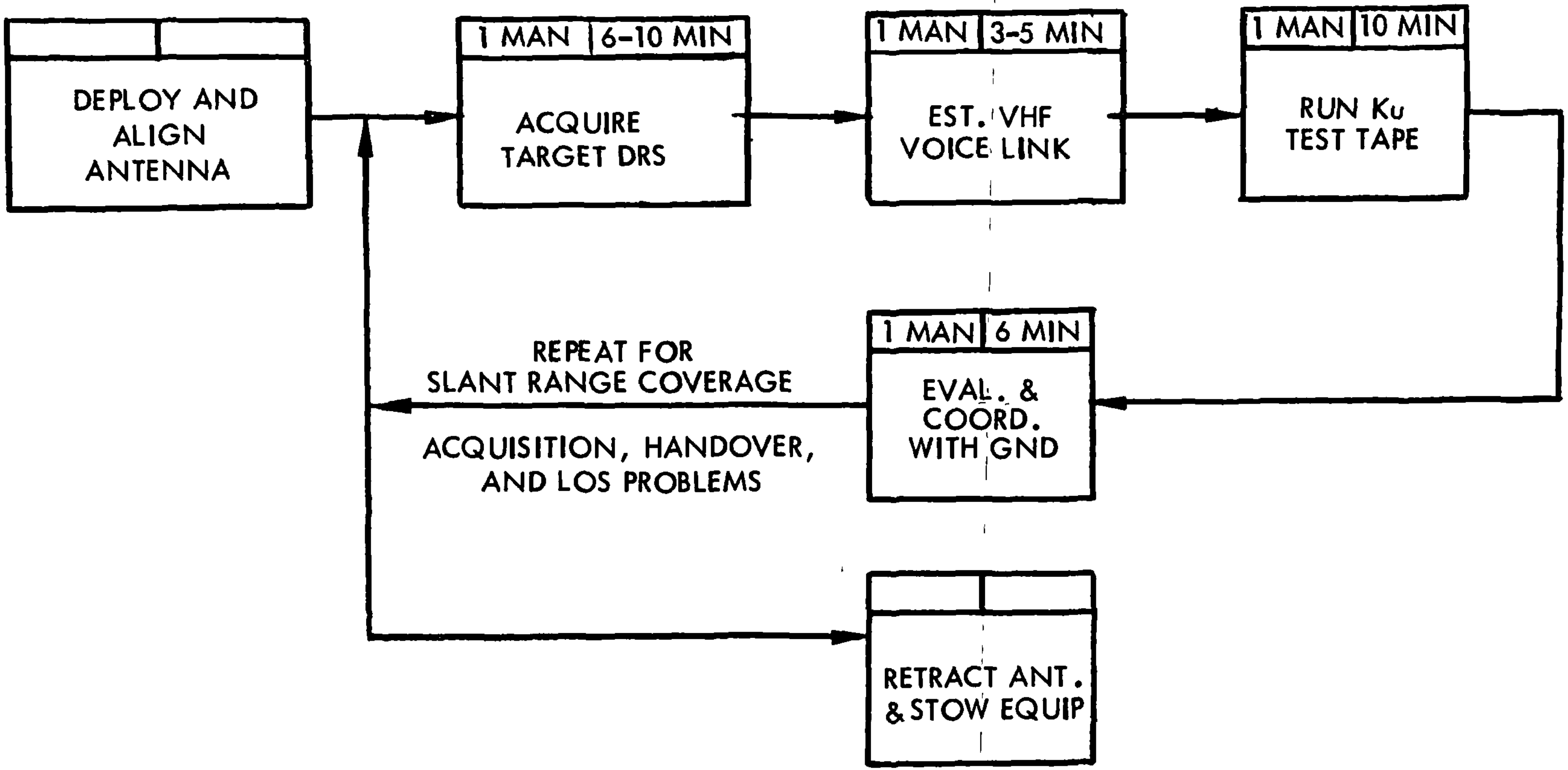


Figure 4.2-6. Experiment No. 7 - Communications/Navigation Data Relay

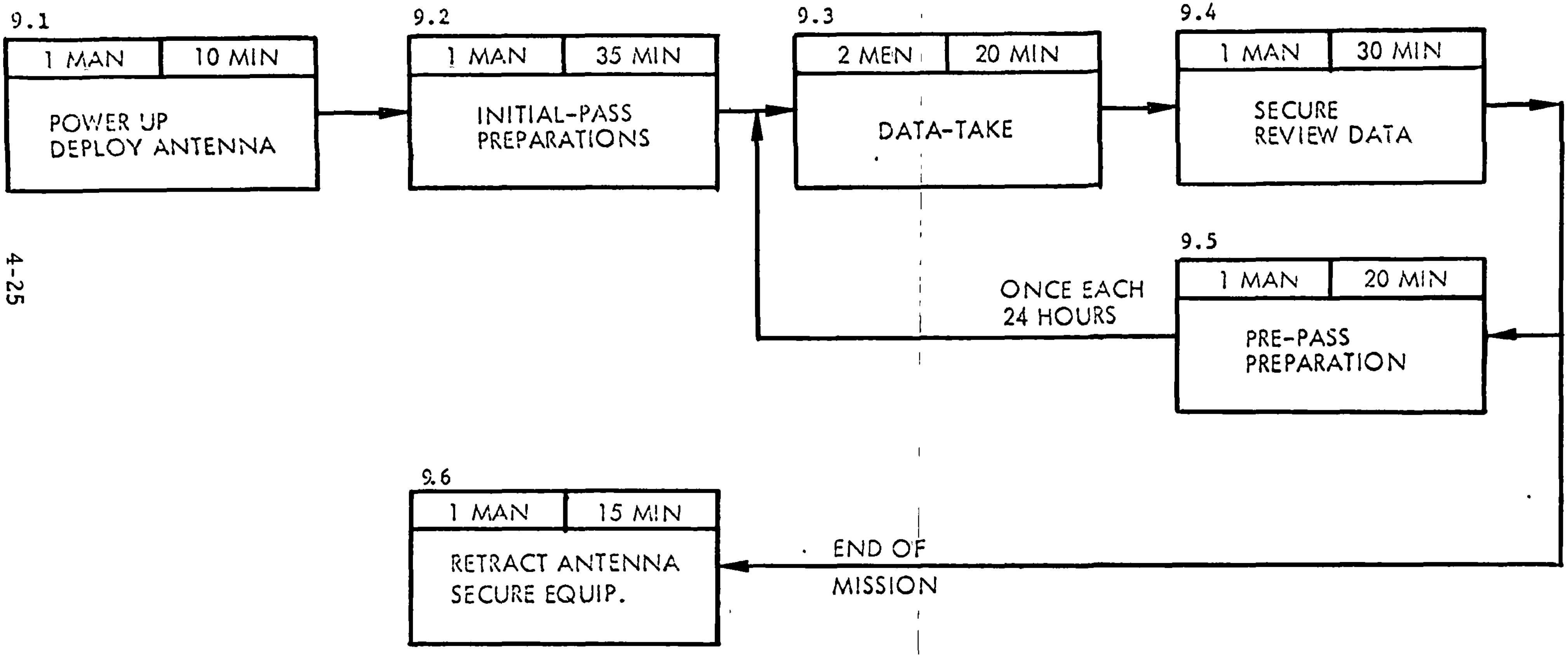


Figure 4.2-7. Experiment No. 9 - Laser Communications

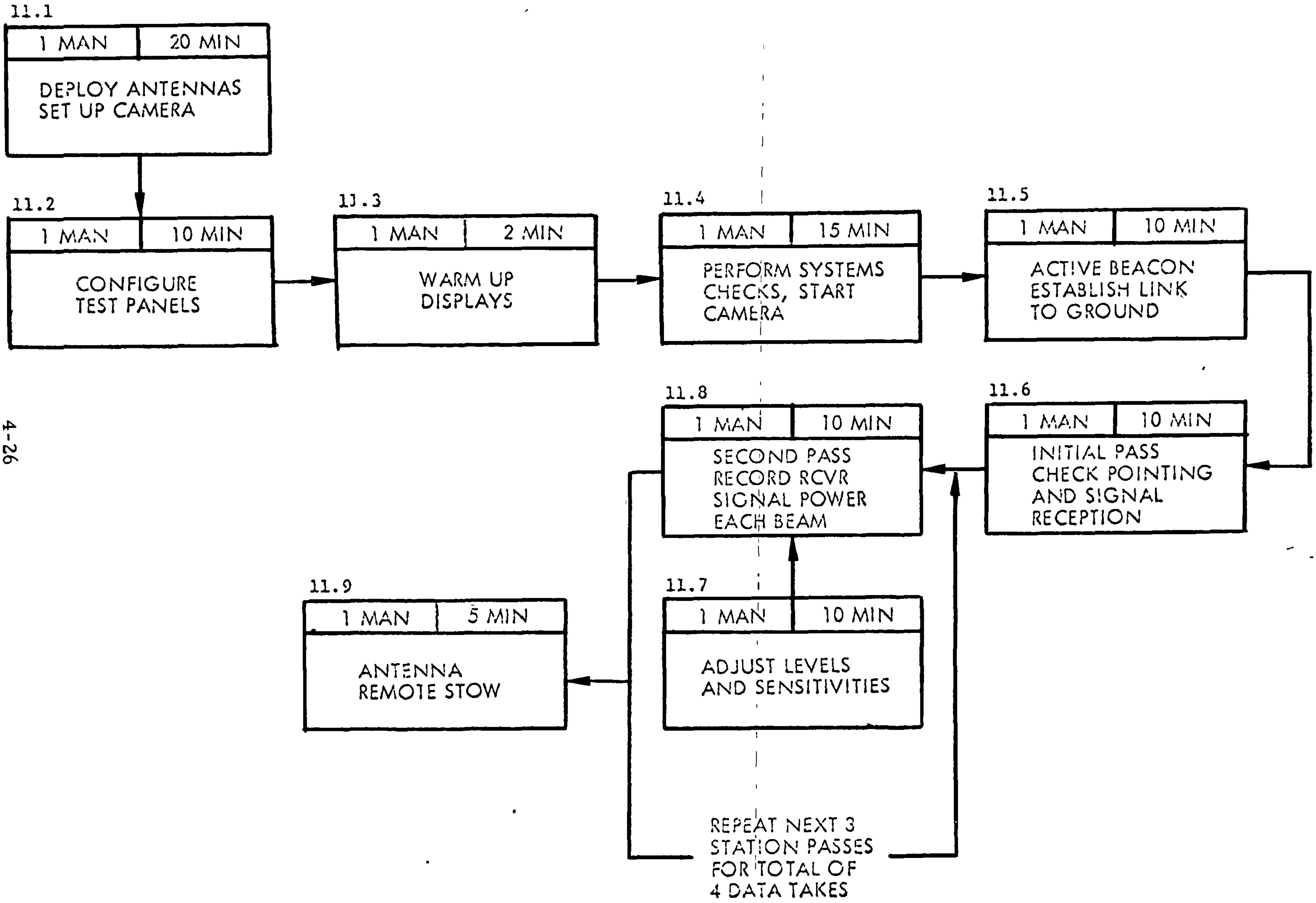


Figure 4.2-8. Experiment No. 11 - Satellite-Fixed Multi-Beam Antenna (First Phase)

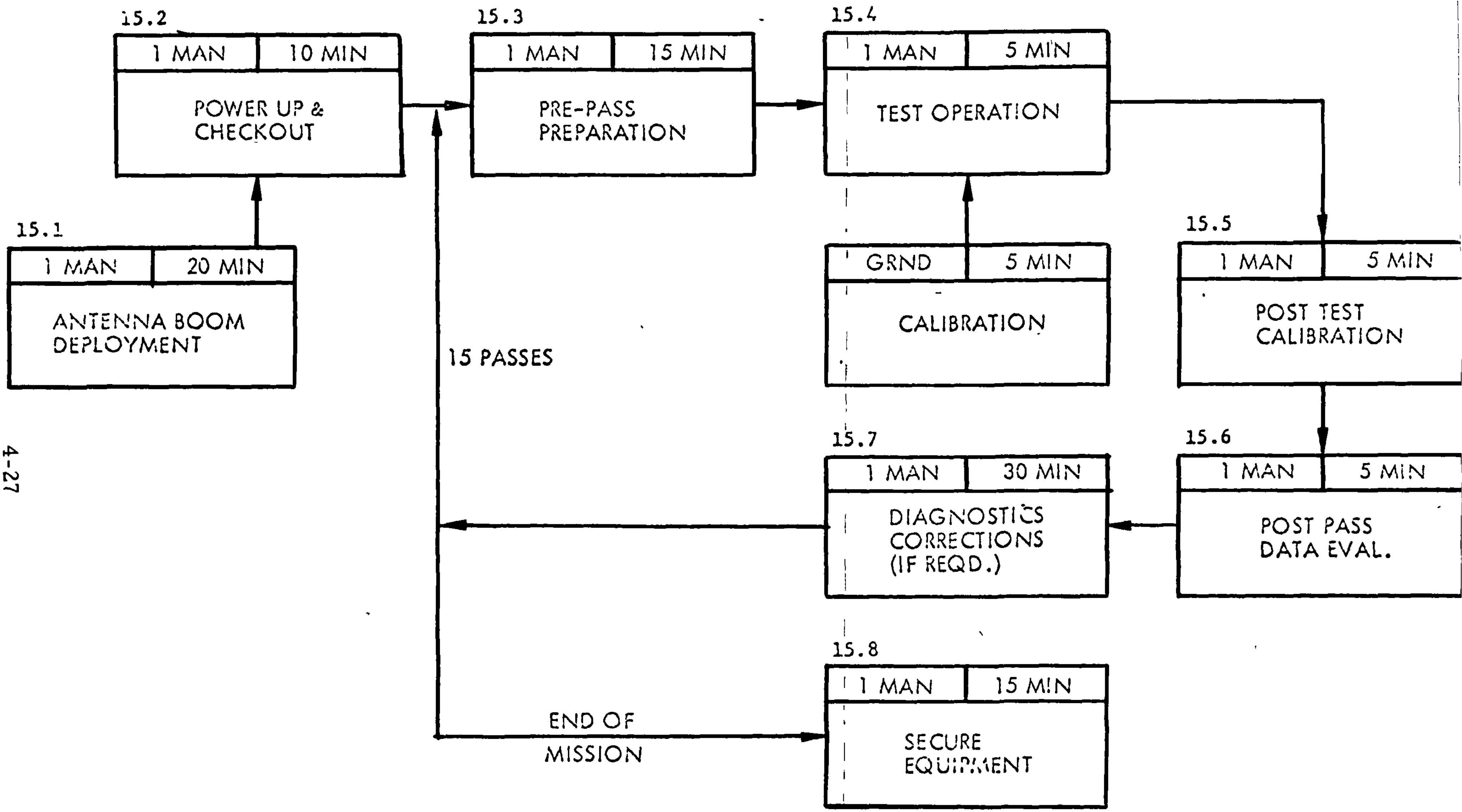


Figure 4.2-9. Experiment No. 15 - Interferometric Surveillance and Navigation

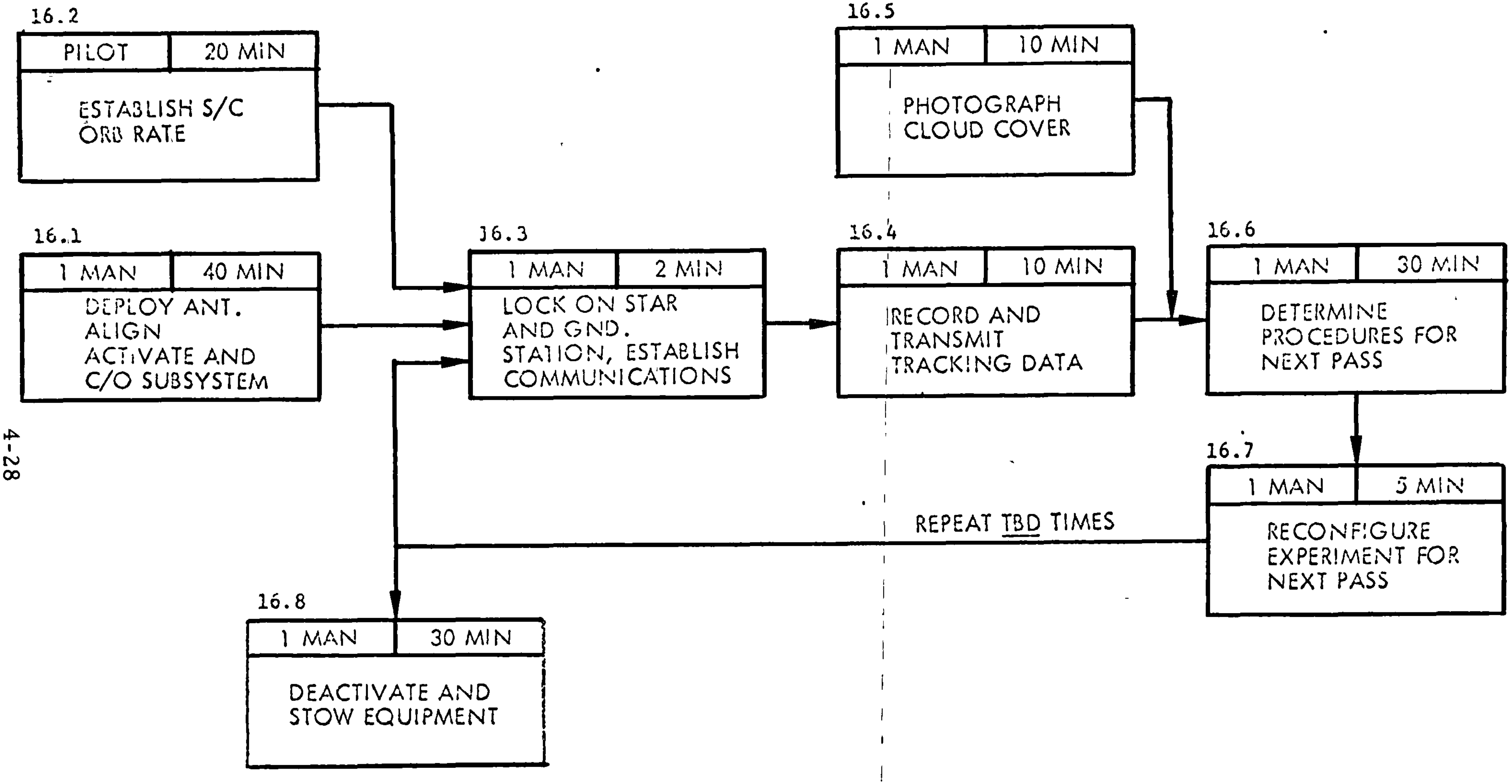


Figure 4.2-10. Experiment No. 16 - Landmark Tracking

Each of the identified crew functions was reviewed to determine the skill requirements which these functions impose on the flight crew. As used in this study, skills are defined as capabilities required to perform a function, and include both knowledge and proficiency. Knowledge can be gained by format education or training, reading, or experience and, from a pragmatic viewpoint, consists of storage of information and relationships in the memory of the individual (e.g., knowledge of the theory of electricity). Proficiency, on the other hand, is generally acquired by practice or actual performance of a task, whether it be a mental or motor task. Skills (knowledge and proficiency) may also be classified as unusual or specialized in the sense that some skills exist in all or most of the members of a given population (e.g., language skills).

The first step was to generate a list of applicable crew skills required to accomplish the identified crew functions. Skills were assigned to one of two categories. Category A includes those specialized skills which are developed through formal education or experience on the job. Category B includes those universal physical and mental skills which are of the nature of innate capabilities. High proficiency in all these was assumed to exist within the trained technical crew under consideration, and therefore require no further analysis. Crew skills categories and the identifying numerical code numbers are tabulated below.

- Skill Code - Category A - Experience
    - Optical test instrumentation
    - Electronics test instrumentation
    - Mass transfer
    - Safety procedures
    - Experimental procedures
    - Data management
    - Optical maintenance (diagnose, repair)
    - Electronic maintenance (diagnose, repair)
    - Signal performance characteristics
    - Malfunction identification and correction
    - Electromagnetic spectrum phenomena
    - Tool handling

- Skill Code - Category B - Capabilities
    - Manual dexterity
    - Visual acuity
    - Auditory acuity
    - Tactile sensitivity
    - Rapid learning
    - Rapid reaction time
    - Proprioception
    - Skeleto-muscular strength
    - Verbal facility
    - Depth perception
    - Eye-hand coordination
    - Spatial relations

Analytical Results of Crew Activities

Frequency counts of skill entries in the functions analysis worksheets were made across and within experiments. From these statistics was constructed a frequency profile of Category A skill requirements for each experiment and a rank order profile of requisite crew skills for the experiment operations portion of the overall mission. These are summarized in Table 4.2-3, and indicate that, in terms of frequency of skills per experiment, the most demanding research is R. F. Propagation, Experiment Class 3, while the least demanding from the same standpoint is Terrestrial Sources of Noise and Interference, Experiment Class 1. Approximately twice the number of skills are required for Experiment 3 as opposed to Experiment 1.

As expected for this discipline, the most frequently appearing skill across all experiments is Electronics Test Instrumentation. This skill refers to proficiency in operating electronics instrumentation. It infers a high training level consistent with crew independent operation and minimal recourse to supporting documentation or other sources of information. While performance time requirements do not appear to be excessively demanding, it is nevertheless desirable, from the standpoint of overall mission accomplishment, to assure that significant amounts of time are not spent in unnecessary tasks. This is especially true in view of the relatively short 5-day research duration and with the expectation that crew activities will become even more time consuming as the mission evolves.

Table 4.2-3. Skill Frequency Summary (A Skills versus Experiments)

A SKILLS EXPERIMENT NO.	1	2	3	4	5	6	7	8	9	10	11	12	TOTALS	RANK
1	–	13	–	3	3	2	–	1	4	11	6	3	46	7
3	1	20	–	9	2	5	–	1	7	22	10	3	80	1
7	–	17	–	2	5	2	–	1	4	13	7	3	54	5
9	18	14	2	4	2	2	–	–	2	11	6	4	70	2
11	1	11	1	8	1	5	–	–	4	12	6	3	50	6
15	–	16	–	8	1	5	–	2	5	16	6	1	60	4
16	12	14	2	8	2	1	–	–	6	11	4	3	61	3
Σ	32	105	5	42	22	19	–	5	32	96	45	20		
RANK	5.5	1	10.5	4	7	9	–	10.5	5.5	2	3	8		

The second most frequently appearing skill is Malfunction Identification and Correction. This skill can be described as the ability, when working with test instrumentation, to rapidly recognize and act to rectify any equipment operating characteristics which have departed from nominal. In view of the design requirement to use commercially available equipment and thus accepting the increased likelihood of deviation from nominal performance, this ability becomes important to the success of the mission. This skill is desirable for all onboard technical crew members and can be a significant portion of the early training of the crew.

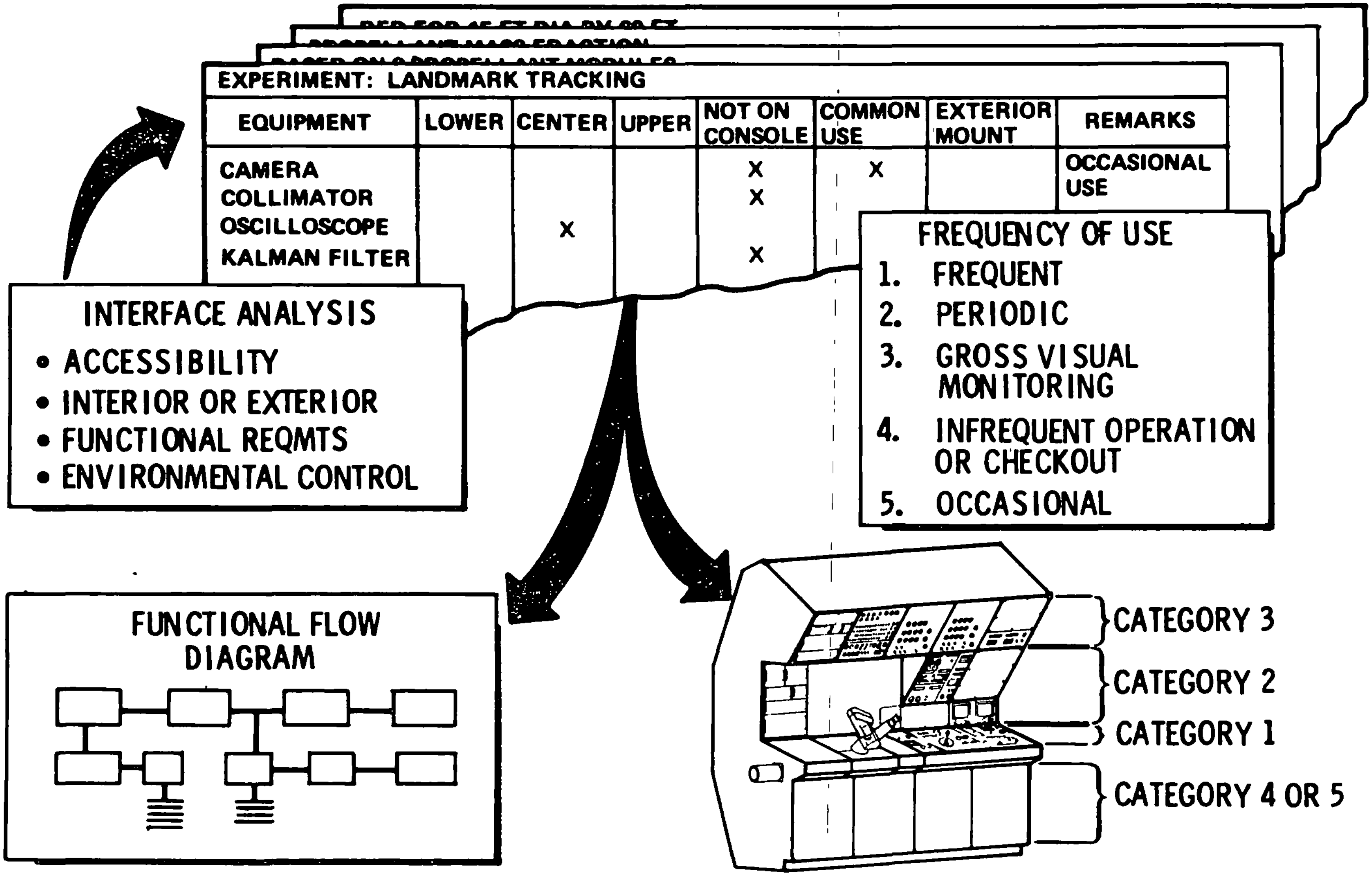
The third most frequently appearing skill is Electromagnetic Spectrum Phenomena. It refers to the capability within crew members to recognize the phenomena likely to be encountered during the mission about which decisions would be required. Typically, it involves deciding the best course of action to take to assure experiment accomplishment and to determine alternative courses of action with available resources in the event of serendipitous occurrences. It is a highly desirable specialized characteristic of the crew for the Early Laboratory, but is probably the most difficult to achieve through training. Other skill requirements include a full knowledge of operating safety procedures to assure safe conduct of equipment operation. Careful and well-trained crewmen may also prevent operating interactions which would degrade the performance of individual equipment items.

4.2.7 Console Design Concepts

Conceptual design for the Comm/Nav laboratory interior facilities concentrated on the integrated control and display consoles which experimenters will use. Figure 4.2-11 shows the layout approach, which began with a preliminary conceptual design and carried through to a final design. From equipment descriptions and sizing estimates, those items expected to provide displayed information or be manipulated by the crew were identified. Placement categories were determined and assigned based on importance and frequency of use. If fine sensorimotor activities are required, equipment units are placed on surfaces affording maximum visual and motor access.

Preliminary Design

The overall effort to develop a conceptual display-control console



EXPERIMENT: LANDMARK TRACKING

EQUIPMENT	LOWER	CENTER	UPPER	NOT ON CONSOLE	COMMON USE	EXTERIOR MOUNT	REMARKS
CAMERA				X	X		OCCASIONAL USE
COLLIMATOR				X			
OSCILLOSCOPE		X					
KALMAN FILTER				X			

INTERFACE ANALYSIS

- ACCESSIBILITY
- INTERIOR OR EXTERIOR
- FUNCTIONAL REQMTS
- ENVIRONMENTAL CONTROL

FREQUENCY OF USE

1. FREQUENT
2. PERIODIC
3. GROSS VISUAL MONITORING
4. INFREQUENT OPERATION OR CHECKOUT
5. OCCASIONAL

Figure 4.2-11. Man/Machine Console Layout Approach was aimed at assuring maximum flexibility for the accommodation of the 15 previously listed crew functional requirements. Specific goals for console design included provisions for:

- One- or two-man operation.
- Equipment access and access to vehicle pressure shell.
- The accomplishment of fine visual-motor tracking tasks.
- Visual monitoring of large numbers of diverse displays.
- Manual operations of varying frequency on all displays.
- Accommodation (dimensional) of all equipment with which crew members would be expected to interact.
- Operator needs for relatively unrestricted visual access to other vehicle areas and equipment.
- Egress envelopes consistent with rapid and unimpeded relocation of operating crew members.
- Access for preflight assembly and checkout.

To accommodate these diverse requirements, the following assumptions were made:

- Preflight assembly and checkout of the laboratory will be accomplished with the laboratory in a horizontal mode; i.e., the long axis will be parallel to the ground.
- Orbital crew experiment operations will be accomplished under "seated" restraint conditions.
- Equipment, especially for the Early Laboratory concept, will be removable at the modular level.
- Restraints, handholds, and control guards will be integral to the console and will thus not be a feature of individual commercial units.

Gross ratings of crew difficulty and use frequency of each of the identified function/experiment/equipment combinations were made. Crew difficulty refers to whether crew operating capabilities might be expected to be taxed in order to satisfactorily perform the required function. If the crew operational difficulty (time demands, complexity of procedure) level was expected to be "high," a rating of H was assigned for that function. A rating of "low," or L, was assigned if the expected difficulty was easily within performance capability expectations. This initial rating classification scheme ultimately affects placement of equipment within the overall laboratory, but may have no immediate impact upon control display console design. On the other hand, "Use Frequency" has high relevance to placement locations. "Use Frequency" entries reflect expected use repetitions of each specified function, experiment, or equipment combination. Anticipated use frequency was further categorized into High (H) and Low (L) on the basis of use frequency information provided in the experiment descriptions. These ratings are shown in Table 4.2-6 found in Paragraph 4.2.8, "Growth Lab Evolution."

A review was made of equipment specifications to generate a list of equipment which could be expected to interface with crew members during the nominal performance of each experiment. The resulting list reveals that only a relatively limited number of equipment items within the laboratory can be expected to be operated by or provide information to crew members. Examples include various manually operated switches, the computer keyboard, receivers, and the teleprinter.

Remaining are equipment items requiring few or no manual operations or infrequent visual examination. Examples of such items are the general purpose computer electronics, external equipment such as antennae, and various other items such as A/D converters, and power sources. These analyses indicate that all experiment equipment can be divided into two conceptual groupings: (a) that requiring frequent astronaut interactions, and (b) that requiring little or no such interactions. The 34 equipment classes falling within the first category are called experiment operations equipment and are housed within an experiment crew operations work center or console. Equipment within the second category can be thought of as being separately housed within an equipment storage area or bay.

The crew functions identified through the operations analysis and the equipment analysis were correlated for the seven experiment classes in the Early Lab version. All of the equipment/instrumentation items involving direct, routine crew interface were then assumed to be located on a primary display/control console. Table 4.2-4 presents an alphabetized list of all equipment reviewed and identifies those 34 items requiring active crew interface.

Table 4.2-4. Experiment Equipment List

		Interface	No Interface
1.	Amplifier, log	X	
2.	Analyzer, spectrum	X	
3.	Antenna, lens		X
4.	Antenna, LPDA, VHF, UHF		
5.	Antenna, optical-5"		X
6.	Antenna, optical-18"		X
7.	Antenna, star dipole, L-band		X
8.	Antenna, tracking		X
9.	Antenna, VHF		X
10.	Assembly, laser, CO_2		X
11.	Assembly, laser Nc: YAG		X
12.	Beam deflector		X
13.	Beam expander		X
14.	Calibration attenuator unit	X	
15.	Camera, scope	X	
16.	Camera, video		X
17.	Camera, 16mm	X	
18.	Collimator, optical (Experiment 9)		X
19.	Collimator, optical (Experiment 16)		X
20.	Control unit, antenna		X
21.	Converter, A/D and D/A		X
22.	Counter, bit error	X	
23.	Counter, frequency	X	
24.	Demodulator	X	
25.	Detector, crystal		X
26.	Electronics, correlation		X
27.	Filter, kalman		X
28.	Formatting unit, signal		X
29.	Generator, calibration signal	X	
30.	Generator, scan program	X	
31.	Generator, stream data bit	X	
32.	Input/output keyboard	X	
33.	Laser beacon, doubled Nd:YAG		X
34.	Laser link, doubled Nd:YAG		X
35.	Meter, digital phase	X	
36.	Meter, laser power		X
37.	Meter, RF power	X	
38.	Modem	X	
39.	Modem, wideband	X	
40.	Noise factor test set		X
41.	Oscilloscope		X
42.	Preamplifier	X	
43.	Polarization reference horn		X
44.	Power calibration unit	X	
45.	Power divider, wideband	X	
46.	Power supply, laser		X
47.	Power supply, variable with conditioner	X	
48.	Receiver, Ku-band	X	
49.	Receiver, laser		X

Table 4.2-4. Experiment Equipment List (Continued)

		Interface	No Interface
50.	Receiver, phase lock, L-band	X	
51.	Receiver, S-band	X	
52.	Receiver, swept band	X	
53.	Receiver, VHF	X	
54.	Recorder, oscillograph	X	
55.	Resolver, polarization		X
56.	Synthesizer, frequency and driver	X	
57.	Tape recorder, analog	X	
58.	Tape recorder, digital	X	
59.	Tape Recorder, Video/Audio		X
60.	Teleprinter	X	
61.	Timer, precision clock	X	
62.	Tracker, coarse		X
63.	Tracker, fine		X
64.	Transmitter, Ku-band	X	
65.	Transmitter, laser		X
66.	Transmitter, reference signal		X
67.	Transmitter, VHF	X	
68.	Voltmeter, AC/DC	X	

Dimensions and volumes of all equipment items were then examined to determine gross sizings. This was separately determined for equipment with and without crew functional interfaces. Disregarding redundant items, all equipment requiring crew interface would require approximately 40 cubic feet. Noninterfacing equipment would require a similar volume. Thus, two consoles or cabinets could be used to house all of the experiment equipment/instrumentation. One console would be employed as the primary RF work station, containing all of the operational controls and displays. This console would be approximately 116 inches wide and would provide over 200 cubic feet of volume. On the assumption that crew stabilization would be required to accomplish certain experiment tasks, the console would be configured for the restrained (seated) position. The lower equipment bay, would be designed for the "standing" position since neither continuous surveillance nor fine motor tasks are expected to be involved. It would house the seldom-used equipment.

Use frequency, dimensions, and equipment functional similarities were combined and used to develop a concept of equipment placement. The console design sequence is illustrated in Figure 4.2-12. An attempt was made to combine all similar crew functions and to place related equipment on a

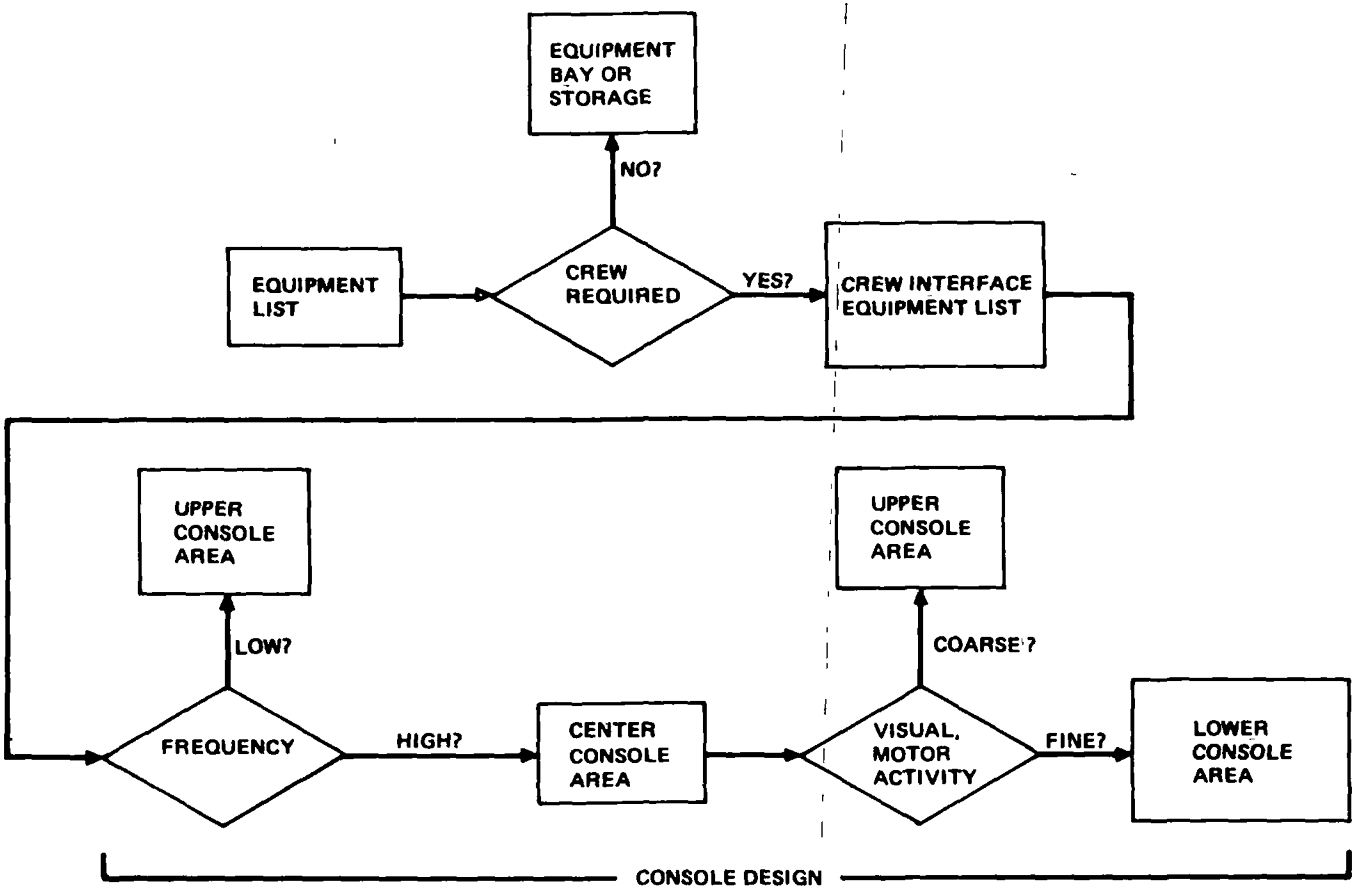


Figure 4.2-12. Console Design Sequence

panel oriented to the required crew reach envelope. In order to do this, it was necessary to further define crew/equipment functions into more specific categories. Thus, equipment/instrumentation items were categorized on the basis of characteristics of expected crew performance into four categories from most frequently used by crew to least frequently used. Items within each of the categories were conceptually placed into locales promoting the efficient accomplishment of man/machine functions.

All of the primary design features of this concept meet the requirements of the Comm/Nav laboratory facility stated earlier. As currently configured (size and volume), it will readily accommodate all experiment equipment/instrumentation thus far identified. Panel surface area is available for installation of handholds and control guards as required. Also, the conceptual console provides access to the pressure shell through a console-swingout feature which can be accomplished in either shirtsleeve or pressur-suited mode. An additional feature, consistent with cost constraints of the Early Laboratory, is that both consoles can be assembled from standard 19-inch racks. Further discussion and drawings may be found in Section 5, which covers the facility layouts.

The preliminary concept of the primary crew console was refined later to reflect the specific equipment requirements developed for the seven selected experiments. The first step was to finalize the experiment equipment list and then to determine which items require direct crew interface. The latter were placed in the console generally based upon the five location criteria summarized in Figure 4.2-13. Casual (infrequently used or non-critical) displays and controls are placed outside the operator's optimum work envelope (Areas A, B and E), while critical displays and controls or those requiring fine sensorimotor activity are located within the optimum envelope (Areas C and D).

Figure 4.2-13 also indicates station reference points for the console. The points were determined by measuring from the "floor" level to the center of the uppermost panel (109 inches). Also shown is the operator's direct line of sight well above the floor at the 95-inch level. These reference points aid in the allocation of panel area to specific tasks. A zero-g condition permits freedom in this layout design, and yet remains consistent with terrestrial floor to ceiling orientation familiar to the research crew.

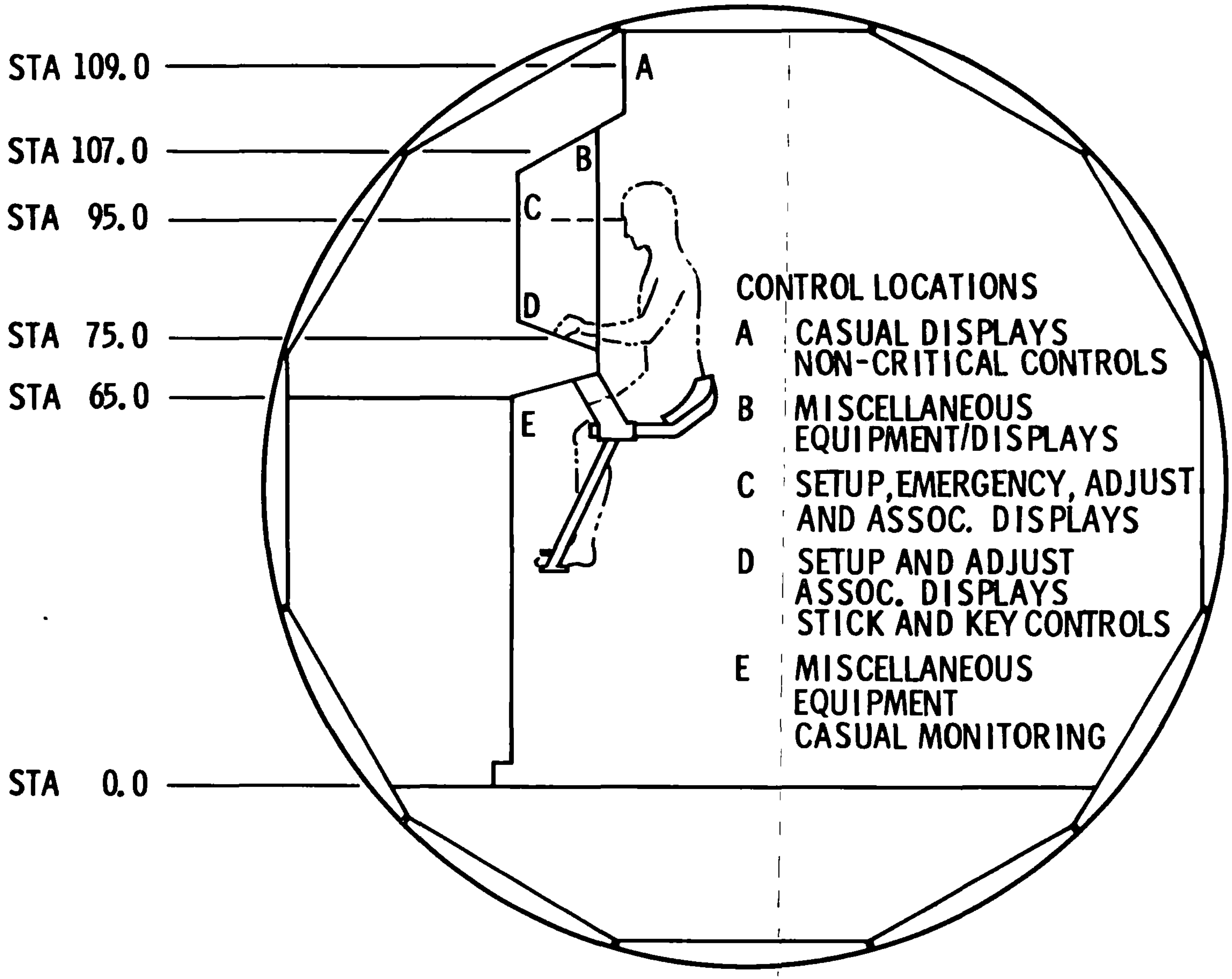


Figure 4.2-13. Primary Console Configuration

In addition to the criteria outlined above, equipment location was significantly influenced by results of the crew skill analysis discussed previously. These data include task frequency and difficulty, sequence of events and crew skill requirements. For example, the spectrum analyzer and the associated oscilloscope were located in Area C to facilitate the removal and placement of plug-in modules and the fine sensorimotor tasks required to operate the equipment. The teleprinter keyboard is located on panel D where stick or key controls can be easily activated. Casual displays, and non-critical controls such as the AD/DC voltmeter, are located above the operator's primary field of view. Orbiter subsystem monitoring displays are duplicated at each station. Less critical displays are located near the center of panel Area C so they can be shared by the two operators.

The final step in the development of the 119-inch RF console was to prepare a detailed layout of displays and controls and to show the location of storage and growth areas. The drawing was used to verify the final arrangement as being compatible with crew anthropometry. As designed, the console is configured for two operators restrained at the pelvis and feet. This position is recommended since it allows the greatest freedom in movement (reach, stretch, lean, etc.) while providing sufficient restraint for performing fine tuning or module replacement tasks. To access the equipment in Area E, the operator disconnects the restraint, grasps an appropriate handhold and propels himself to the lower region, i.e., below STA 65.

The final conceptual facility design layouts for the primary operator console and the optical laser console are presented in Fig. 3.3-1 and Fig. 3.3-2. It will be evident that laser equipment presented a slightly different layout requirement. The laser assembly is enclosed in a sealed light tube arrangement and housed in the entire lower cabinet of the 96-inch wide console. Only equipment uniquely related to the two optical experiments, Laser Communications and Landmark Tracking, are included in the design. Additionally, after considering the crew timeline functional flow diagrams it became evident that cooperative interaction between the two crew members was mandatory. This is reflected in the final two position console arrangement.

A summary of interior layout results is presented in Table 4.2-5.

Table 4.2-5. Interior Laboratory Layout Equipment Summary

	Weight	Average Dimensions	Usable Volume	Panel Surface Area
Mainframes:				
RF Console	185 lbs.	116 x 124 x 30 in.	377, 570 in^3	15, 770 in^2
Optical Console	145 lbs.	96 x 108 x 30 in.	265, 900 in^3	11, 420 in^2

	Weight		Volume	Power
Total Experiment Equipment:				
RF Console	2, 493 lbs.	-	145, 440 in^3	8, 515 watts
Optical Console	407 lbs.	-	15, 790 in^3*	1, 603 watts

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*Does not include light tube assembly.

4.2.8 Growth Lab Evolution

The typical experiment flow shown earlier indicates in a general sense the manual operations required in the Early Lab. It reflects the use of commercially available equipment similar to that used in Earth-based laboratories. After the first five years of the program, much experience will have been gained in orbit regarding the absolute requirement for manual intervention in the sequencing of tasks on orbit. Further, with the advent of specially-designed equipment and the use of larger on-board computer facilities, a much greater degree of automation will be possible. The reduction of manned participation in detailed task accomplishment is reflected in Table 4.2-6 which indicates the degree of crew participation for the Early, Growth and Total Lab concepts. Since exact data are unavailable for the later experiment programs, the experiment equipment and procedures slated for the Early Lab were used as a basis for estimating crew participation in the later versions. As shown in the table, task difficulty and use frequency of equipment is significantly reduced. The conclusion which can be drawn here is that more experiments can be performed by the same size crew.

These activities will be limited to critical override functions with such routine tasks as monitoring of analog/digital status and manual positioning of sensors being unnecessary. Thus, more equipment items can be placed onboard to gather and analyze more data within the same time period as the Early Lab concepts.

Other considerations for the Growth Lab should include provisions for EVA and free-flying modules. Longer duration mission (30 days) are also presumed.

A significant impact on crew operations would be the requirement to man free-flying modules for periods from 6-12 hours. These requirements will in turn impact the training program and perhaps the selection criteria for later crews.

4.2.9 Training Requirements Analysis

Training requirements for the early Comm/Nav laboratory crewmen were derived through analysis of required crew functions and their associated skill requirements. The scope of this analysis was limited to the Early

EARLY LAB												GROWTH LAB									TOTAL LAB									
CREW/EXPERIMENT FUNCTION		APPLICABLE EXPERIMENT(S)	EQUIPMENT NO.	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	EQUIPMENT IDENTIFICATION	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	EQUIPMENT IDENTIFICATION	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	COMMENTS
				H	L	H	L						H	L	H	L						H	L	H	L					
1	CHECKOUT	1 3, 11 16	76 75, 19	X			X	X	X	X	X	SCOPE	X			X	X	X			COMPUTERIZED-MANUAL MODE SELECT		X		X	X				
2	CALIBRATE/ALIGN	1, 3, 9, 16	77 NOT ON CONSOLE 45, 35, 46, 34, 24	X			X				X	SIGNAL GENERATOR		X		X	X				COMPUTERIZED-MANUAL MODE SELECT		X		X	X				NO 77 VSWR METER AND SLOTTED LINE - NOT ON EXPT CONSOLE
3	CONFIGURE (SET UP)	3,9	14, 15, 16		X		X		X			PRECONFIGURED BUS PANEL (REDUNDANCY)		X		X	X				PRECONFIGURIZED BUS PANEL (REDUNDANCY)		X		X	X				NO 14, 15, 16 NOT ON CONSOLE
4	ENABLE (ACTIVATE, INITIATE, RECEIVE, TRANSMIT)	3, 9, 11	36 72 71 51 53 49 25 74		X		X	X				INTEGRATED MANUAL ACTIVATOR		X		X		X			INTEGRATED MANUAL ACTIVATOR		X		X		X	X		NO 25 KEYBOARD ONLY - COMPUTER ELECTRONICS NOT ON CONSOLE
5	MONITOR (DIGITAL) STATUS	15	67, 28, 42 29, 23, 3, 40		X		X		X			SEE 7 BELOW									SEE 7 BELOW									
6	MONITOR (ANALOG) STATUS	1, 15	4, 56, 44, 32		X		X		X			SEE 7 BELOW									SEE 7 BELOW									
7	MONITOR (ANALOG-DIGITAL) STATUS	9, 15, 16	57		X		X		X			INTEGRATED ANALOG DIGITAL DISPLAY	X		X				X		INTEGRATED ANALOG DIGITAL DISPLAY	X		X				X		
8	ASSEMBLE	11	LSS, LOCOMOTION AIDS, SAFETY PROVISIONS, WORK-SITE AIDS. NOT ON CONSOLE	X			X	N/A	N/A	N/A	N/A	PREASSEMBLE AND INSTALL									PREASSEMBLE AND INSTALL									
9	COMMUNICATE (CREW, GND RECORDER)	3, 15	SPEAKER, MICRO-PHONE, HEADSET		X	X				X		SPEAKER MICRO-PHONE		X		X		X			SPEAKER MICROPHONE		X		X		X			
10	PHOTOGRAPH (EARTH, SCOPE, ANTENNA)	1, 9, 11, 16	20, 22	X			X			X		CAMERA FILM		X	X				X		CAMERA FILM		X		X				X	NO 20 NO DISPLAY AREA REQ'D (STORAGE ONLY) NO 22 NO DISPLAY AREA REQ'D (STORAGE ONLY)
11	POSITION (ANTENNA)	3, 11	AUTOMATED		X		X			X		SERVO ACTUATION COMPUTER									SERVO ACTUATION COMPUTER									
12	RECORD (MAGNETIC TAPE, PAPER, MANUAL)	1, 3, 11	62, 66, 61, 63, 57	X		X				X		MULTIPLE HEAD RECORDER		X		X		X			MULTIPLE HEAD RECORDER		X		X		X			
13	SELECT (RECEIVER, SIGNALS, OP MODE, ETC)	1, 3, 11	11		X	X			X			INTEGRATED MANUAL ACTIVATOR - SEE 4 ABOVE									INTEGRATED MANUAL ACTIVATOR-SEE 4 ABOVE									
14	ADJUST (VERNIER, GAIN, ATTENUATE)	1, 9, 11	43, 24 NOT ON CONSOLE		X	X				X		DIAL DISPLAY/ CONTROL		X		X			X		COMPUTERIZED-MANUAL REDUNDANCY		X		X			X		
15	DIAGNOSE MALFUNCTION (SAME AS FUNCTION 1.)		SEE 1 ABOVE	X			X	X	X	X	X	IMPROVED RELIA-BILITY SEE 1 ABOVE									IMPROVED RELIABILITY SEE 1 ABOVE									

LEGEND

H = HIGH
L = LOW
U = UPPER REACH ENVELOPE
M = MIDDLE REACH ENVELOPE
L = LOWER REACH ENVELOPE

Table 4.2-6. Crew Equipment Interfaces (Common Functional Requirements)

Laboratory and to the two experiment crewmen who will perform the majority of functions in that laboratory, although it is recognized that the Shuttle flight crew will require a certain amount of training regarding experimental activities in the Comm/Nav laboratory mission.

The training required to assure proficiency of the experiment crew is a function of the skill requirements imposed by the Early Laboratory experiments and the backgrounds of the individuals selected for this assignment. Training requirements would be much different for crewmen selected from the astronaut group than for crewmen selected from the scientist/engineer population. In the analysis described herein, the assumption was made that they would be selected from the scientist/engineer population. In the analysis described herein, the assumption was made that they would be selected from the scientist/engineer population.

The Comm/Nav experiment crew must be considered basically a part of the 4-man Shuttle crew and as such they will have responsibilities to the Crew Commander, especially prior to and following laboratory occupancy. In addition to specialized Comm/Nav laboratory skills, the crew must either have or acquire during training the skills identified below:

1. Knowledge of Shuttle subsystems and proficiency in monitoring and controlling status of selected subsystems.
2. Knowledge of Shuttle mission sequences and proficiency in monitoring selected operations, such as cargo bay door and radiator deployment, teleoperator operations, and on-orbit shutdown operations.
3. Proficiency in zero-g activities including locomotion, restraints, use of zero-g equipment.
4. Proficiency in techniques of orbital living (e.g., sleeping, eating, personal hygiene).
5. Knowledge of and absolute proficiency in Shuttle safety procedures, reaction to contingencies, and use of safety/contingency equipment (oxygen masks, pressure suits, survival gear).

Specialized training for the experiment crewmen will be required relative to the Comm/Nav laboratory and the experiments conducted therein. General skills which they must acquire include the following:

1. Knowledge of laboratory operational systems and proficiency in monitoring and controlling them. (Includes the autonomous systems in the laboratory such as electrical power, atmosphere supply and control, thermal control, and data management.)

2. Knowledge of and proficiency in operation and maintenance of experiment equipment. Requires knowledge of each equipment item: its configuration and location in the laboratory; its use and applicability to each specific experiment; its operating characterisitcs and its potential modes of malfunction; the tools and instruments associated with checkout, calibration, maintenance, and operation of the equipment item; the displays on which its outputs are presented; and the controls which provide input to the equipment. Requires ability to perform assembly and disassembly of the equipment, calibration and adjustments, checkout and some troubleshooting, and maintenance; ability to interpret and evalute output signals from the equipment; and proficiency in deployment and monitoring of external experiment equipment.

3. Knowledge of laboratory to Shuttle interfaces and proficiency in activities required to cross that interface. Requires practice in Shuttle to laboratory personnel transfer, communication with Shuttle flight crew, stowage of laboratory data and equipment in the Shuttle, and use of Shuttle payload deployment equipment.

4. Knowledge of and absolute proficiency in response to hazards and contingencies within the laboratory.

Table 4.2-7 provides preliminary estimates of the time required for each experiment crew member in specialized training on the Comm/Nav laboratory, its operational subsystems, and the experiments and experimental equipment. Detailed estimates have not been made for acquisition of skills required as a member of the Shuttle crew. It is assumed that such training will precede experiment unique training and will require a total time of approximately six months.

Training equipment requirements include part task trainers and a full-scale Comm/Nav laboratory simulator.

Part task trainers are required for orientation and practice on the operational subsystems, Shuttle to lab interfaces, and each of the specific experiments. These can be relatively inexpensive trainers, but must present to the trainee realistic configurations of equipment and operability of those aspects of the equipment to which part task training is addressed.

Table 4.2-7. Experiment Crew Training Requirements Comm/Nav Laboratory Configuration and Operation

		Hours	Weeks
Operational Subsystems			5
Theory		80	
Practice		120	
Shuttle to Lab Interfaces			4
Theory		80	
Practice		80	
Experiment Theory and Procedures			9 1/2
Experiment No. 1		40	
Experiment No. 3		80	
Experiment No. 7		40	
Experiment No. 9		60	
Experiment No. 11		40	
Experiment No. 15		60	
Experiment No. 16		60	
Experiment Equipment and Procedures			10
- Common Equipment		160	
- Experiment Unique Equipment			
Class Experiment No. 1 -	Theory	10	
	Practice	10	
Class Experiment No. 3 -	Theory	10	
	Practice	40	
Class Experiment No. 7 -	Theory	10	
	Practice	20	
Class Experiment No. 9 -	Theory	10	
	Practice	30	
Class Experiment No. 11 -	Theory	10	
	Practice	20	
Class Experiment No. 15 -	Theory	10	
	Practice	30	
Class Experiment No. 16 -	Theory	10	
	Practice	30	
Integrated Training with Shuttle Crew and Lab		320	8

A whole task Comm/Nav Lab simulator which can be interfaced with the Shuttle simulator is required to permit integrated crew training, practice, and mission rehearsal. This most critical training facility will be a high fidelity, operational, hard mockup and hybrid computer facility. All potential signal and control characteristics will be possible of presentation to the crew and vehicle orbital data will be provided.

4.3 ORBITAL EFFECTS

4.3.1 Ground Station Viewing Time

Operation of 4 of the 5 early lab RF experiments are predicated upon an RF communication link between the laboratory and a terrestrial station or source, the exception being the communication relay experiment where the link is with a data relay satellite.

Three categories of ground station configurations may be envisioned to support the various experiments. They are:

a) A complex of existing MSFN and STADAN stations comprising a coverage network.

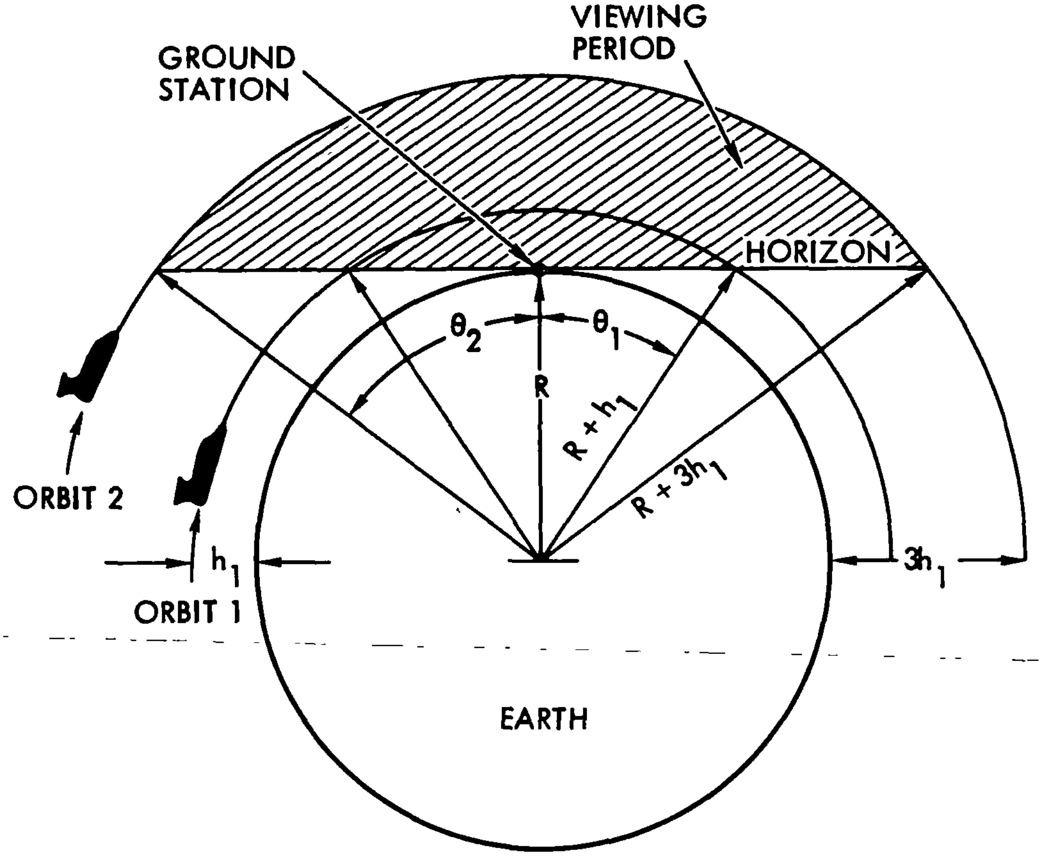
b) One or two special stations or specially-modified MSFN/STADAN stations.

c) A multiplicity of sources within a specific geographical area.

In all cases, the experiment data can be maximized by maximizing the contact time between the laboratory and the ground station complex. Orbital parameters are a major factor in determining the viewing time available per pass as well as for a typical mission duration of 7 days.

The inclination of the orbit plane to the equator is the most obvious way (but not the only way) of obtaining coverage at latitudes removed from the equator. However, orbital inclination (especially at low altitudes) subjects the orbit to certain gravitational forces which tend to disturb the orbit relative to the earth. Thus the orbit plane (line-of-nodes) may move about the axis of rotation (regression) or the orientation of the line of apsides may change (precession), or the orbit inclination may change due to the oblateness of the earth.

The altitude of the orbit is directly related to the viewing time from any one ground station as shown by Figure 4.3-1. For the example illustrated, a threefold increase in altitude results in (approximately) twice the viewing period. In general it is not possible for a ground station antenna to view the horizon, being limited either by multipath reflections or obstructed by local terrain. Minimum elevation angles are generally restricted to ≥10 degrees.



FOR CIRCULAR ORBITS, THE ORBITAL PERIOD (T_P) IS:

$$T_P = 1.41 \left(\frac{R+h}{R}\right)^{3/2} \text{ HOURS}$$

FOR h_1 = 200 N MILES, T_{P_1} = 1.54 HOURS = 92.4 MINUTES

FOR $3h_1$ = 600 N MILES, T_{P_2} = 1.8 HOURS = 108.0 MINUTES

$$\text{VIEWING TIME} = \frac{2\theta}{\omega} = \frac{\cancel{2}\theta}{\cancel{2}\pi} T_P = \left(\frac{2\theta^\circ}{360^\circ}\right) T_P = t$$

$$t_1 = \frac{38.5}{360} \times 92.4 = 9.88 \text{ MINUTES}$$

$$t_2 = \frac{63.3}{360} \times 108 = 19.0 \text{ MINUTES}$$

Figure 4.3-1. Viewing Time vs. Altitude

It is possible to increase the orbital altitude (and the viewing time) over a portion of the orbit without increasing the orbital period. Such orbits are referred to as elliptical orbits and are measured by their eccentricity (E) where:

$$E = \frac{h_a - h_p}{h_a + h_p + R} \qquad \left.\begin{array}{l} h_a = \text{apogee altitude} \\ h_p = \text{perigee altitude} \\ R = \text{earth's radius} \end{array}\right\} \text{Same Units}$$

For such orbits, the orbital period (T_p) is:

$$T_p = 1.41 \left(\frac{a}{R}\right)^{3/2} = 1.41 \left(\frac{h_a + h_p + 2R}{2R}\right)^{3/2} \quad \text{hours}$$

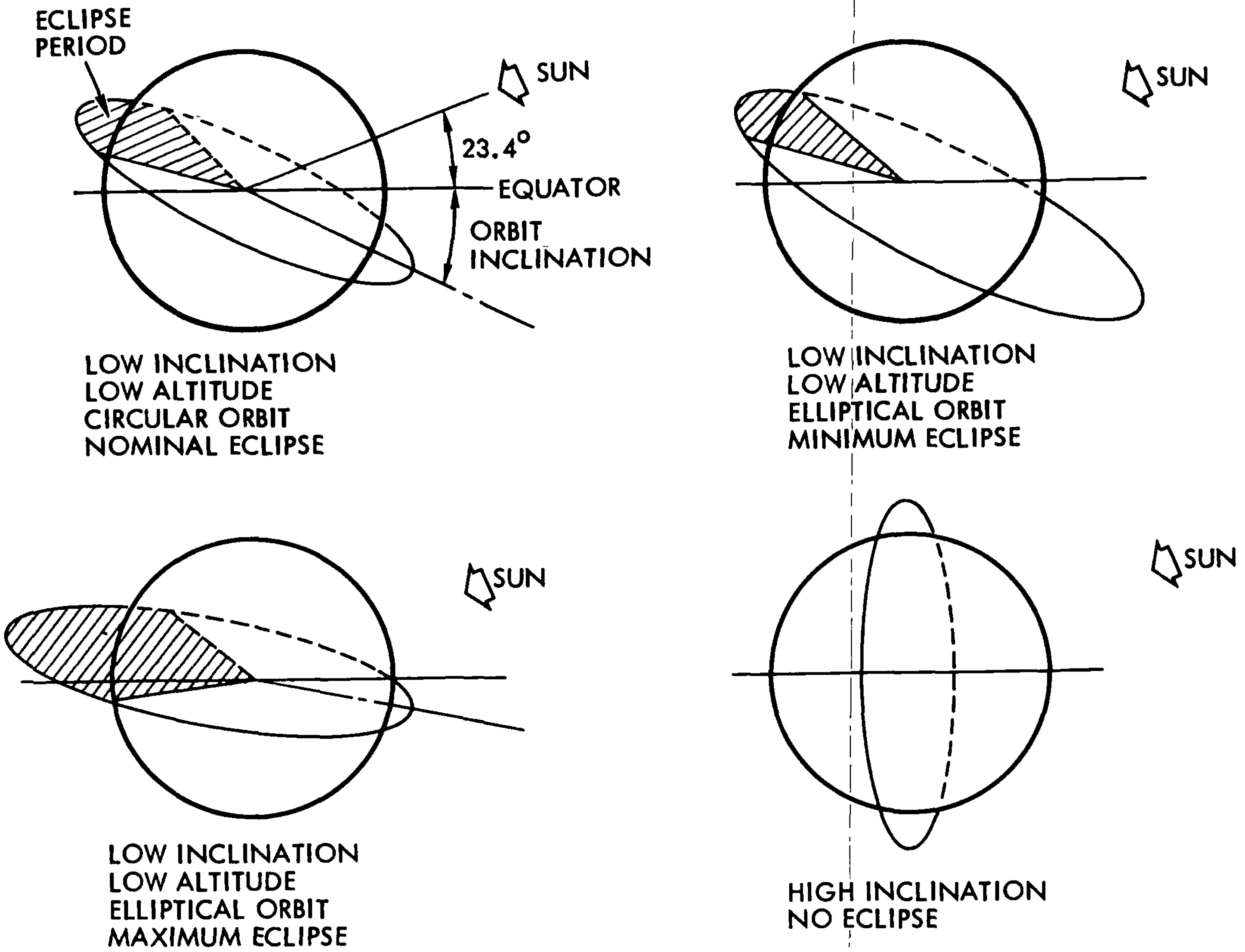
Many peripheral factors must be considered in selecting an optimum orbit or in bounding acceptable orbital parameters. These may include such factors as:

- Aerodynamic drag
- Gravity-gradient torques
- Maximum doppler frequency
- Radiation levels
- Eclipse periods
- Range safety constraints
- Geographical coverage
- Booster capabilities

The first four factors will nominally vary as some inverse function of altitude although eccentricity and inclination may also be significant. Drag is also influenced by atmospheric density which varies with the sunspot activity. The last four factors deserve further comment.

4.3.2 Eclipse Periods

The amount of time which a satellite spends in darkness is an orbital parameter of significance for many low altitude spacecraft. During this eclipse period, the sun is not visible as a source of energy for solar arrays or for solar heating nor as a source of attitude or position data, nor finally as a source of noise or interference for spacecraft/experiment sensors. By varying the orbit inclination eccentricity and line-of-nodes, it is possible to minimize or maximize the eclipse period (Figure 4.3-2).



LOW INCLINATION
LOW ALTITUDE
CIRCULAR ORBIT
NOMINAL ECLIPSE

LOW INCLINATION
LOW ALTITUDE
ELLIPTICAL ORBIT
MINIMUM ECLIPSE

LOW INCLINATION
LOW ALTITUDE
ELLIPTICAL ORBIT
MAXIMUM ECLIPSE

HIGH INCLINATION
NO ECLIPSE

Figure 4.3-2. Eclipse Variation vs Orbital Parameters

There is a special class of orbits whereby the inclination, altitude, and eccentricity are chosen to always keep the orbit plane at a fixed angle to the sun. These sun-synchronous orbits are of considerable interest to many earth-coverage systems since they do provide total viewing of the earth with a constant source of solar array power.

4.3.3 Geographical Coverage

There are numerous tradeoff factors which must be considered in the design of a ground station network and a cooperating satellite orbit. These include cost, available sites, feasibility of all-weather operation, and so forth for the ground complex plus the orbital parameters noted above. For example, the orbital period could be selected (or adjusted) to an integral sub-multiple of the earth's rotational period (nominally 24 hours). This can guarantee two contacts per day (even integers and polar orbit) for a single ground station providing the proper launch trajectory can be flown, or appropriate in-flight orbit adjustments are made. The terrestrial sources of noise and interference experiment represents a class of experiments where a specific geographical area (e.g., the continental U.S. or CONUS) represents the ground target. If the location of the ground stations (A, B, C, D) are chosen to cover successive orbits (1, 2, 3, 4), it is possible to guarantee at least one ground station contact for every orbit (see Figure 4.3-3). Where a specified "swath width" of antenna coverage is desired, the problem of achieving areal coverage may become difficult with a mission duration limited to 7 days. Reducing the orbit ground trace separation implies reducing the orbit period hence reducing the orbit altitude. This solution is not feasible below 100 miles (approximately) because of aerodynamic drag. The other strategy is to adjust the orbit to avoid repetitive ground tracks so that the antenna swath width coverage patterns interleave to minimize coverage gaps.

4.3.4 Safety Constraints

Two important safety constraints on orbit selection are worth noting. First is the Range Safety regulations governing flights on the Eastern Test Range (ETR). Because of the proximity of nearby population, the launch

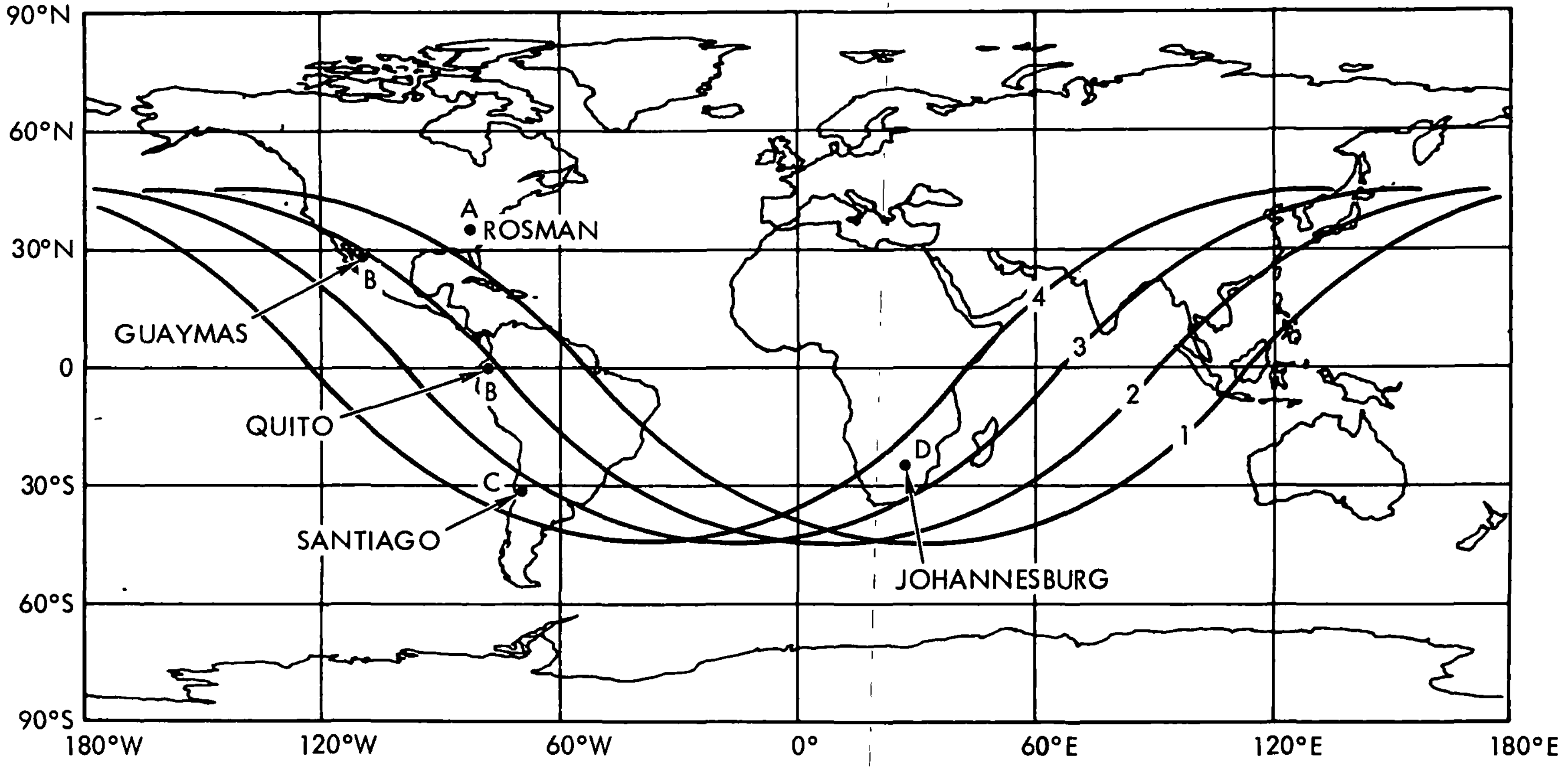


Figure 4.3-3. Geographic Coverage

azimuths allowed from ETR are severely limited (see Figure 4.3-4). Thus, in order to inject a spacecraft in a very high inclination orbit, a "dog-leg" maneuver is necessary. Such a maneuver is also required to achieve orbit inclinations lower than the latitude of KSC which is approximately 28.5°N. This maneuver is inefficient in that some additional velocity increment (ΔV) is required to achieve orbit.

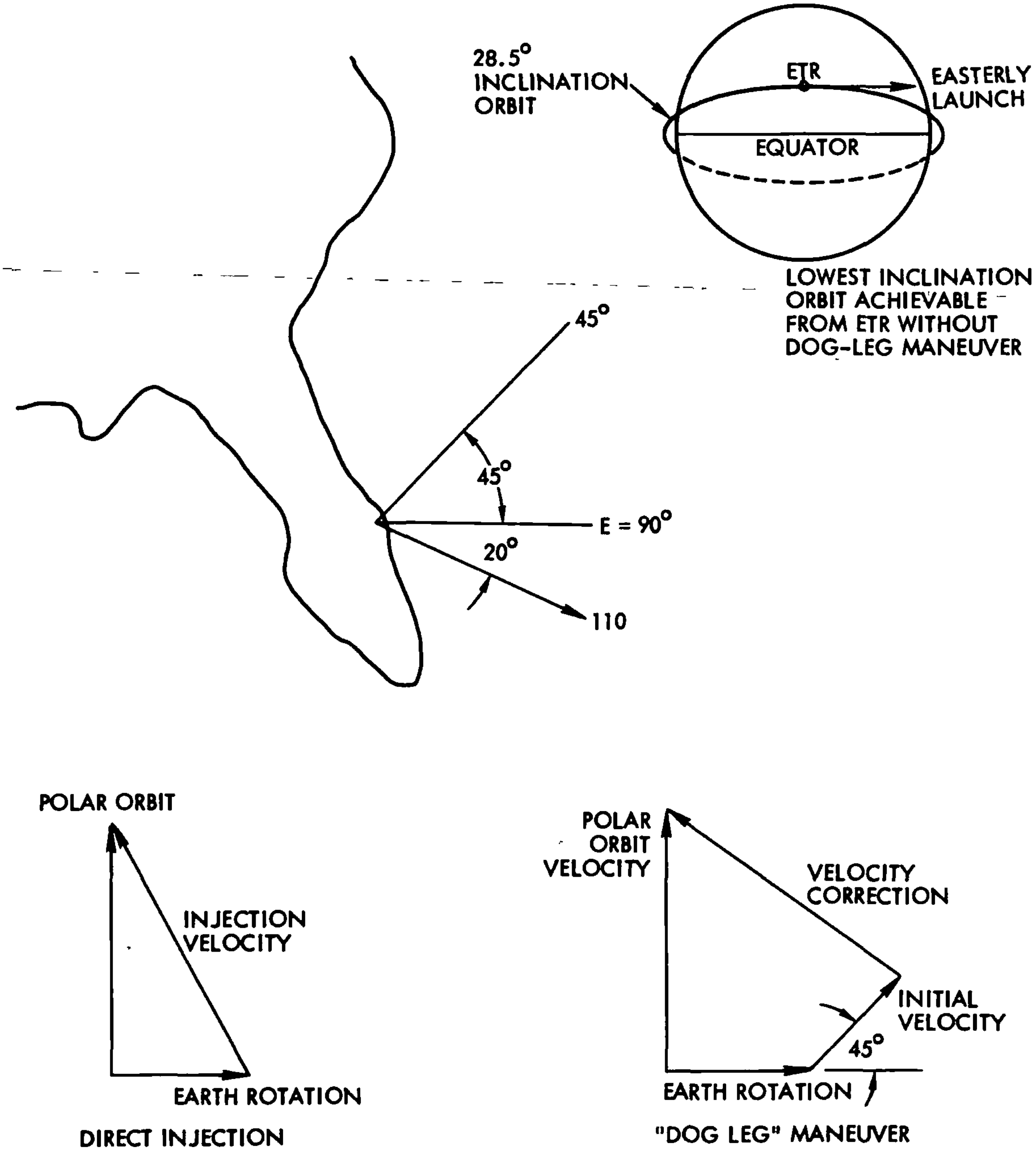
In addition to the launch azimuth limits, the orbital altitude is constrained by the potential radiation hazards presented by the Van Allen belts. Orbiter design as well as total crew exposure over multiple flights are factors in setting an altitude limit. Other factors such as the level of sunspot activity, the ellipticity of the orbit, the orbit inclination, and the transit time through the South Atlantic anomally are factors which can influence the selection of a safe orbital altitude.

4.3.5 Booster Constraints

Orbit constraints attributable to the boost vehicle are largely established by the propulsion capability although some orbits may be excluded by guidance, tracking system, sensor, or attitude control system performance. Figure 4.3-5 is representative of the anticipated Shuttle booster capability to inject payloads into various (circular) orbits.

4.3.6 Preferred Experiment Orbit

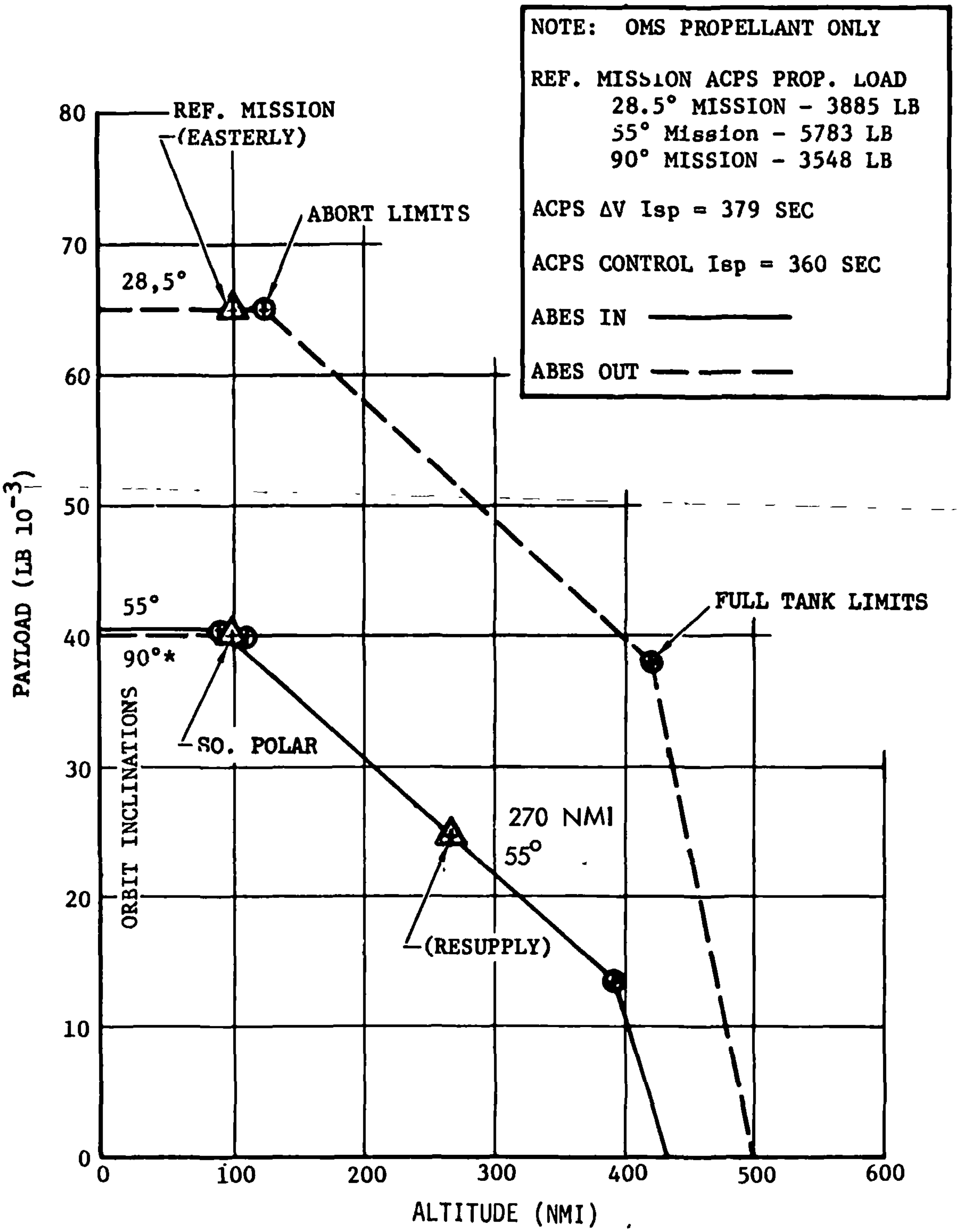
The desires of each individual experiment, insofar as orbit parameters are concerned, will vary widely. To carry a multiplicity of experiments on any single spacecraft (that is in any single orbit) requires some compromise on the part of one or all experiment principal investigators. The following discussion of several early lab experiments is intended to identify or suggest the extent of the compromises, penalties, and tradeoffs required.



DIRECT INJECTION

"DOG LEG" MANEUVER

4.3-4. ETR Range Safety and Launch Constraints



*FULL OMS TANKS WITH OMS USED FOR ASCENT

Figure 4.3-5 Shuttle Delivery Performance to Altitude

Terrestrial Sources of Noise and Interference

Objectives: Survey, identify, and characterize RF noise sources within the CONUS under various (day/night, seasonal, annual) conditions.

Solution: Select a set of orbital parameters which will guarantee a maximum of CONUS coverage under selected time-of-day conditions; see Table 4.3-1 for one possible set to meet the experiment objectives.

RF Propagation

Objectives: Measure RF propagation elements under various weather conditions (clear, cloudy, rain, snow) at various latitudes, and various ionospheric (sunspot activity) conditions using a limited number of pre-selected ground stations; one contact per orbit desired.

Assumptions: A minimal set of 4 existing ground stations (STADAN/MSFN) plus a minimum number (2) of special stations per Figure 4.3-6. below.

Solution: The selection of orbital parameters and of ground stations are inter-dependent. The tendency will be to utilize existing stations as much as possible. Special stations would be utilized to extend latitude coverage or to improve contact time. Table 4.3-2 summarizes the orbital parameters for the ground station complex shown in Figure 4.3-6.

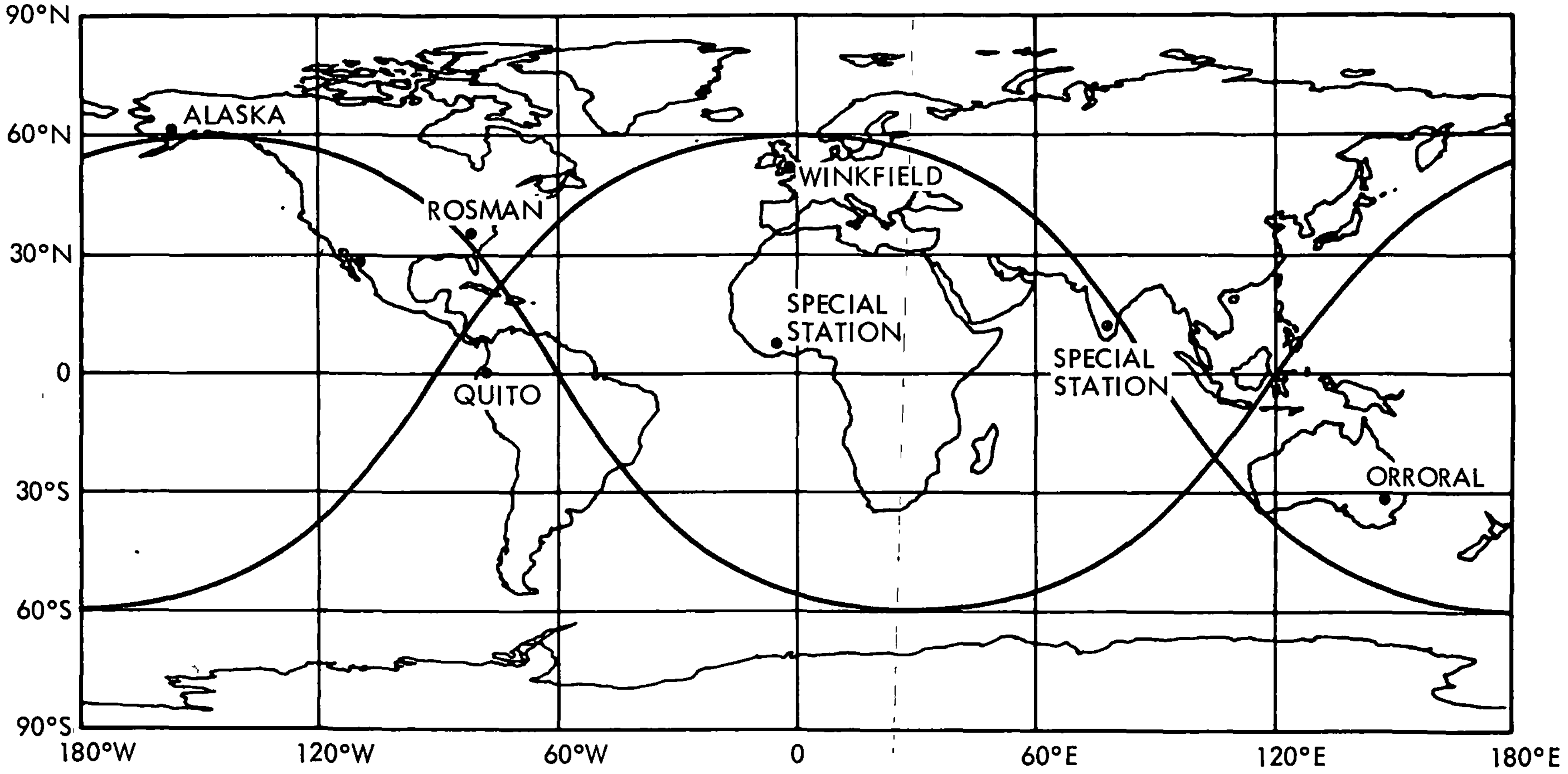


Figure 4.3-6. Ground Station Configuration for RF Propagation Experiment

Table 4.3-1. Selection of Orbital Parameters For Terrestrial Sources of Noise and Interference

ORBITAL PARAMETER	REASON FOR SELECTION	PENALTIES FOR OTHER PARAMETER VALUES
i = 55 Degrees	CONUS Coverage; Low Precession of Perigee	< 55° may lose Northern U.S. coverage due to increase rate of precession > 55° involves payload weight penalty. < 48° does not cover CONUS.
$h_p \leq 100$ NMI	Target Resolution (Spatial and Energy)	Degraded resolution or Larger Antenna/More Sensitive Receiver
Perigee in North	Same As Above	Same As Above
Line of Nodes	Preferential Day or Night Coverage	Non-Optimum Time-of-Day coverage
Orbital Period (Apogee Altitude)	Adjust for ≈90 Minute Period (Interleaved Ground Track - 10°/Day Regression)	Non-Optimum CONUS coverage

Table 4.3-2. Selection of Orbital Parameters For RF Propagation

ORBITAL PARAMETER	REASON FOR SELECTION	PENALTIES FOR OTHER PARAMETER VALUES
$i \geqq 60^{\circ}$	High Latitude Coverage Important	$< 60^{\circ}$ would lose important Geographic and Geomagnetic Variations.
$h_p = h_A = 200$ NMI	Constant Altitude (Circular Orbit) Simplifies Data Reduction	Lower Altitudes May Not Include F_2 Layer Variable Orbit Altitude Will Complicate Data Processing
Orbital Period	Adjust Altitude and Inclination and Maintain to Insure Repetitive Ground Trace	Lost Contact Time or Unfavorable Space-To-Ground Geometry
Line of Nodes	Maximum and Minimum Ionosphere Density (Noon and Midnight)	Terminator Orbit Would Not Reflect Diurnal Variations In Ionosophere.

4.4 USE OF COMMERCIAL HARDWARE

One of the study guidelines contained in the Statement of Work involved consideration of "off-the-shelf" hardware to minimize cost wherever required safety standards could be satisfied. To test the feasibility of using readily-available equipment, a limited survey of commercial hardware suppliers was undertaken. The survey request (see Appendix I) was sent to a selected group of potential commercial-grade hardware manufacturers. Those vendors who replied and those who completed the questionnaire are identified in Table 4.4-1. A summary of the questionnaire responses is presented in Table 4.4-2. Subsequent discussions with two vendors (Hewlett-Packard and Tektronix) revealed the unfamiliarity of commercial vendors with the space environment. Thus the data presented in Table 4.4-2 are qualitative expressions of concern on the part of the commercial vendor. Further quantitative definition of the modification task will require the following steps:

a. Definition of Shuttle Orbiter/host vehicle environment.

b. Definition of safety standards.

c. Detailed analysis of specific hardware to define the exact modifications required. Figure 4.4-1 illustrates typical items of concern which may require modification.

d. Definition of an acceptable qualification-type test philosophy, procedures, and test requirements.

e. Detailed cost analysis of the proposed modifications.

This program for analysis of the feasibility of utilizing off-the-shelf hardware is recommended as a task for follow-on work.

Table 4.4-1. Commercial Hardware Survey

QUESTIONNAIRES SENT – 35
REPLIES RECEIVED – 22

*AIRBORNE INSTRUMENTS LABORATORY
BECKMAN INSTRUMENTS INC.
COMMUNICATIONS ELECTRONICS INC.
*DAVIDSON OPTRONICS INC.
ELECTRO DATA INC.
EMR INSTRUMENTS
*JOHN FLUKE MFG. CO. INC.
GENERAL MICROWAVE CORPORATION
*HRB-SINGER
HAMMARLUND MFG. CO.
*HEWLETT-PACKARD

HONEYWELL
MELPAR
NELSON ROSS ELECTRONICS
POLARAD ELECTRONIC INSTRUMENTS
*RCA
RHG ELECTRONICS INC.
RYKA SCIENTIFIC INC.
SANDERS ASSOCIATES
TEKTRONIX INC.
*WATKINS JOHNSON
WESTERN MICROWAVE LABS

*Filled out questionnaire.

Table 4.4-2. Commercial Hardware Survey

		Factors Rendering Eqpt Unsuitable for CNRL Use								Redesign Required			Cost Impact		
Vendor	Instrument	Outgassing	Flammability	Load Factor	Vibration	Safety	Temperature	RFI	Pressure	Substantial	Moderate	Minor	Exorbitant	Substantial	Inconsequential
1. Airborne Instruments Lab.	Spectrum Analyzer	X	X								X			X	
2. Watkins-Johnson Co.	Pan/Man Receiving System	X			X			X			X			X	
3. John Fluke Mfg.	Digital Voltmeters, Synthesizers	X	X	X		X					X		X		
4. Davidson Optronixs, Inc.	Optical Instruments	X		X			X				X			X	
5. HRB-Singer	Swept Receiver								X		X	X		X	
6. RCA	Nav. Receiver			X		X	X		X	X			X		
7. Hewlett-Packard	Synthesizer Generator	X	X	X		X					X			X	
8. Hewlett-Packard	Digital Voltmeter	X	X	X		X		X			X			X	
9. Hewlett-Packard	Frequency Counter	X	X	X	X	X		X			X			X	
10. Hewlett-Packard	Oscilloscope	X	X	X	X	X		X			X			X	
11. Hewlett-Packard	Spectrum Analyzer	X	X	X	X	X	X		X		X			X	

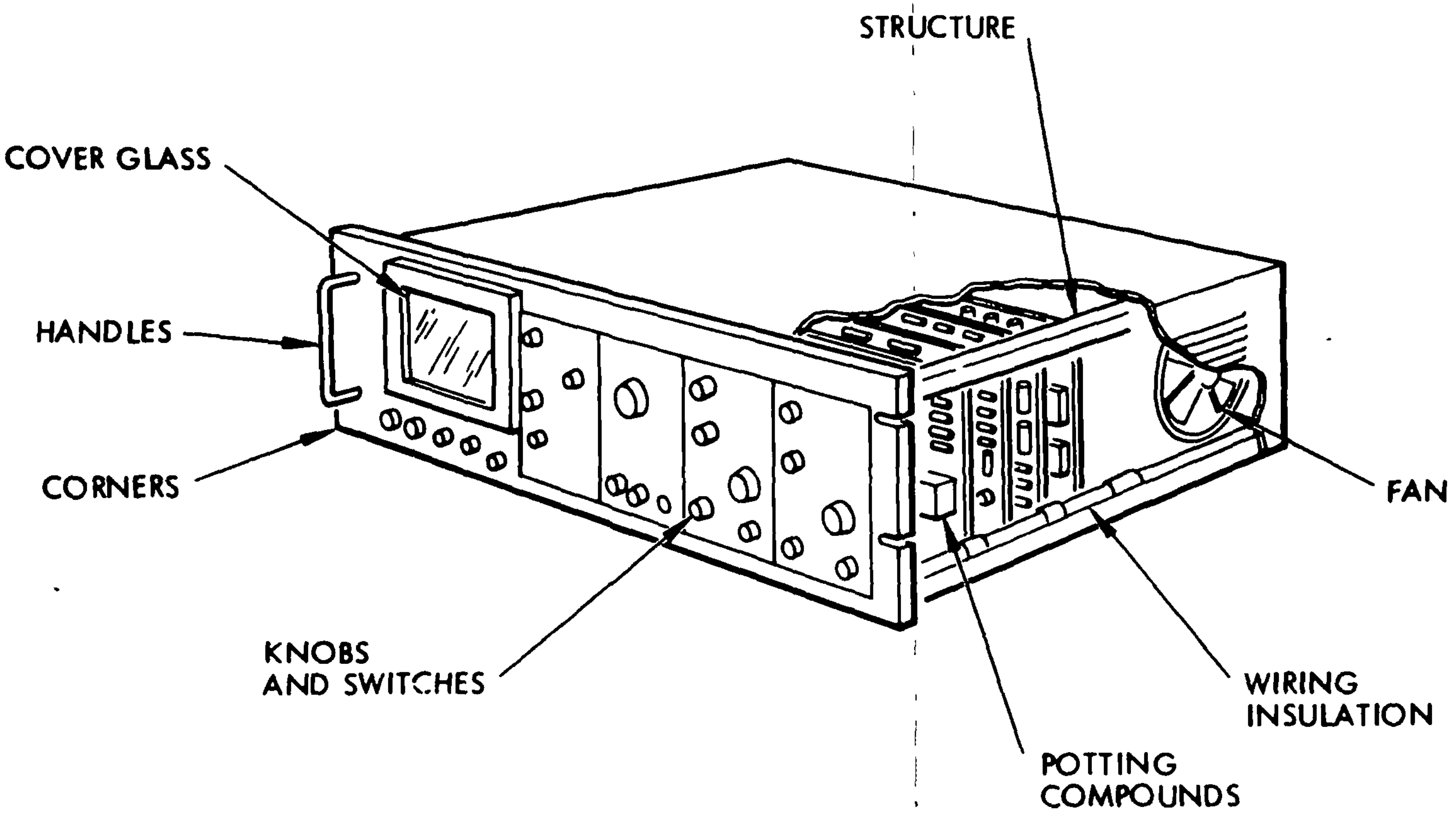


Figure 4.4-1. Commercial Hardware Modification

APPENDIX I

COMMERCIAL EQUIPMENT VENDOR SURVEY DATA PACKAGE

Gentlemen:

In support of NASA plans for future manned Shuttle/space station activities, the George C. Marshall Space Flight Center, Huntsville, Alabama, has contractually engaged TRW Systems Group to develop conceptual designs of a manned communications/navigation research laboratory. The objective of this study is to conceive laboratory designs capable of supporting a wide variety of experiments leading to the application of space technology to advanced operational systems of direct benefit to mankind. Anticipated operational systems include those planned for multiple access communications, data collection, data relay, direct broadcast TV, and information networking as well as for satellite navigation techniques for terrestrial users, surveillance, search and rescue, all traffic control, position fixing, collision avoidance, and autonomous navigation. The time assumed for an "Initial Operational Capability" of the laboratory is 1980 although interim demonstration of selected experiments and experimental techniques aboard balloon, aircraft and automated (unmanned) satellites are also being considered.

The initial laboratory configuration for Communications/Navigation research would be limited in scope with flight mission duration not exceeding seven days. Experiments in the communications/navigation investigative area would be selected from the eighteen experiment classes shown in Attachment 1. Specific experiments in each experimentation class have been developed and preliminary (hardware) performance requirements are being identified. All equipment and instruments (hardware) associated with the performance of Comm/Nav experiments on the low altitude (below 400 nmi) earth orbital manned laboratories of the 1980 - 1990 time period is related to one of the following functional categories: antennas, receivers, transmitters, optical devices, controls/displays and general support. In the category of general support we means items such as test and checkout equipment, calibration devices, data recorders, computers, clocks (event timing) cameras, and crew member equipment for restraints, safety, writing, etc. It is now appropriate to ask whether commercially available (in contrast to space-qualified) hardware might be suitable or adaptable for use in such a lab. Four questions appear to dominate the feasiblity of using commercial hardware:

(1) Is it suitable for use by man in a zero g environment ?

(2) Is it safe to put into a habitable, pressurized compartment ?

(3) Would it survive the launch, orbit, deboost, and landing environment?

(4) Could it be readily adapted for use in such a laboratory - either in a separate pressurized compartment with remote controls or in an unpressurized area ?

If your organization would be interested in addressing these questions, we have included some background material and a questionaaire as Attachments. We have attempted to simplify your task in responding to this request to minimize the effort required on your part as well as to insure a timely response. However, if you should wish to pursue this problem in further detail, please feel free to contact the undersigned.

The Shuttle and Space Station programs being developed by NASA represent an ambitious space effort over the next 20 years. The quantities of equipment involved to support this program are substantial. We believe that the potential use of commercial equipment would have a significant impact on current NASA thinking if such potential usage could be established. Your serious consideration of this request for information may be an important step in establishing that potential.

We welcome any additional data on your equipment which would assist in clarifying your capability. We also welcome your comments and specific suggestions as to methods for adapting the laboratory environment to accommodate commercial hardware. When we use your information in study products associated with verbal presentations or written reports, we will acknowledge and reference your organization as having provided the source material. Please address replies to the undersigned no later than 22 December 1971.

TRW Systems

C. W. Renn
Bldg R5/Room 1080, Telephone No. (213) 535-3477

CWR:bev

Attachment I	Project Summary
Attachment II	Shuttle/Space Laboratory Design Requirements
Attachment III	Equipment (Unit Specification)
Attachment IV	Questionnaire

ATTACHMENT I

Project Title: DEFINITION OF EXPERIMENTS AND INSTRUMENTS FOR A COMMUNICATION/NAVIGATION RESEARCH LABORATORY

Project Summary

Purpose: Study to develop conceptual designs for a manned communications/navigation research laboratory capable of supporting a wide variety of experiments in the field of communications and navigation.

Contract Details:
$300,000, Phase A Study
FFP, 10 months duration
Start date 14 June 1971

Prime Contractor:
TRW Systems Group
Space Vehicles Division (G. A. Harter, Gen. Mgr.)
Project Management: Don Waltz/Jack Kliger of SVD Advanced Systems (C. D. Graves, Mgr.)

Subcontractors to TRW:

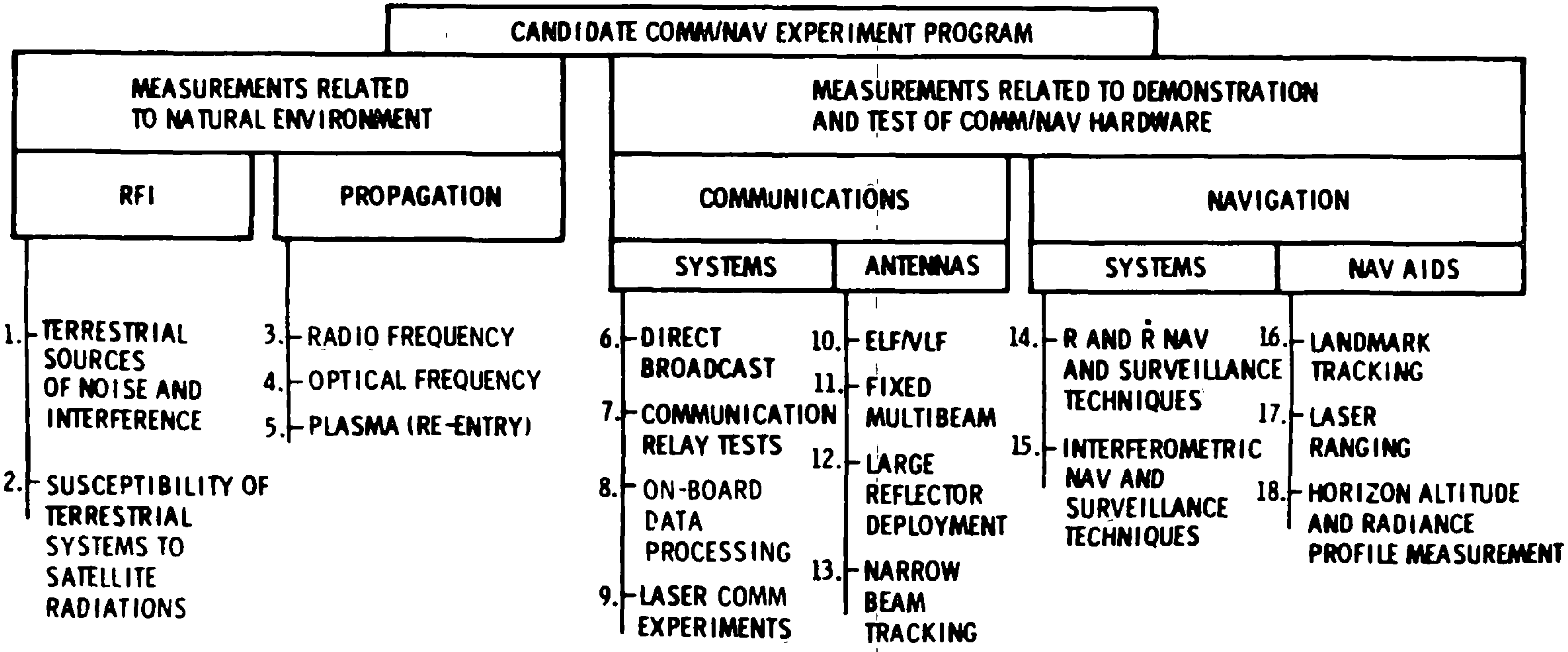
- McDonnell Douglas Astronautics Company
- Communications Satellite Corporation (COMSAT)
- Institute for Telecommunication Science

Consultant to TRW: Dr. Albert J. Mallinckrodt, Communications Research Laboratory, Santa Ana, California

Study Tasks:

- Define Communications and navigation experiments and experiment requirements.
- Identify major laboratory and experiment equipment and instrumentation.
- Develop conceptual designs of major laboratory and experiment equipment and instrumentation.
- Perform systems operations analysis in support of the communications/navigation research Laboratory design.
- Develop conceptual designs of the Communications/ Navigation Research Laboratory.
- Develop cost, schedule and Supporting Research and Technology requirements (SRT).

INVESTIGATIVE AREA GROUPING



ATTACHMENT II

TITLE: SHUTTLE/SPACE LABORATORY DESIGN REQUIREMENTS

Mission duration - 7 to 30 days.

Reliability - No quantitative value required.

Maintainability - Simple crew maintenance tasks may be considered.

Crew support - 2 pilots plus 2 experimenters.

Environment - per Table I (attached)

Safety - The following examples are illustrative of the safety criteria which will be used for manned compartments:

A. Material Outgassing - The materials, potting compounds, paints and finishes used shall not outgas toxic chemicals when exposed to on-orbit cabin pressures or temperatures, or when the space vehicle is open to free space environments. Polyvinyl Chloride (PVC) shall not be used on manned spacecraft if exposed to temperatures above 120°F and pressures less than 3 psia under normal or emergency conditions. Material outgasses are hazardous and corrosive.

B. Mechanical Design-

1. Equipment containers, and/or enclosures for use within pressurized compartments shall be designed to withstand rapid decompression of the spacecraft without damage.
2. Electrical and mechanical items shall be provided with debris-proof covers or containers for protection from conducting and non-conducting debris or foreign material floating in a gravity free state.
3. Materials and accessories associated with wiring, such as potting, heat shrinkable tubing, insulation, solder, etc., shall not be capable of sustaining combustion in the cabin atmosphere in the event short circuits or circuit breaker failure occurs.

4. Material which can shatter, such as glass, shall not be used unless positive protection is incorporated to prevent fragments or dust from entering the cabin environment, or where protection by suitable covers is employed.

5. Use of cadmium and cadmium plating should be avoided in equipment containers subject to elevated temperatures (above 450°F) or where exposed cadmium in contact with breathing gas could reach temperatures that would generate toxic fumes. Overheating could result from electrical short circuit, fire, or from dissipated electrical power in components installed with a cadmium plated fastener.

C. General - Safety - Unit equipment shall be designed for inherent safety through the selection of appropriate design features and operating principles. Suitable safety and warning indicators shall be incorporated to reduce hazards which cannot be eliminated. Crew shall be protected from effects of potentially hazardous equipment and materials, voltages, pressures, temperatures, irradiation, gasses, noise, explosive, flammable or toxic substances. There shall be no exposed sharp edges or corners on equipment.

TABLE I - PRELIMINARY DESIGN ENVIRONMENT

		HABITABLE PRESSURIZED COMPARTMENT	UNMANNED PRESSURIZED COMPARTMENT	UNPRESSURIZED COMPARTMENT
LOAD FACTOR-NORMAL	(g)	3.0 MAX	3.0 MAX	3.0 MAX
TEMPERATURE	(^{o}F)	65 - 85	50 - 90	-100 TO +150
PRESSURE	(PSIA)	10 - 14.7	10 - 14.7	0 - 15
CABIN MIXTURE	- -	$O_2 + N_2$	(NOTE 1)	- - - -
ACOUSTIC SPL	(db)	145 OVERALL	147 OVERALL	150 OVERALL
VIBRATION (RANDOM)	(g)	←	SEE FIGURE 1	→
VIBRATION (SINUSOIDAL)	(g)	(14-35HZ) = 8 →	→	→
RFI		MIL-E-6051 D →	→	→
POWER		SUPPLIED BY FUEL CELL AT BASIC VOLTAGE OF +28 VDC		
RELATIVE HUMIDITY	(%)	40	10 - 60	- - - -

NATURAL ENVIRONMENTS PER NASA TMX 53865, 53872, 53957

NOTE: 1 - PRESSURANT GAS SELECTABLE TO MINIMIZE COMBUSTION, MAXIMIZE THERMAL TRANSFER, ETC.

2 - SPECIAL PROVISIONS (PACKAGING, ISOLATION) ARE ACCEPTABLE TO SURVIVE SEVERE ENVIRONMENTS DURING LAUNCH AND REENTRY.

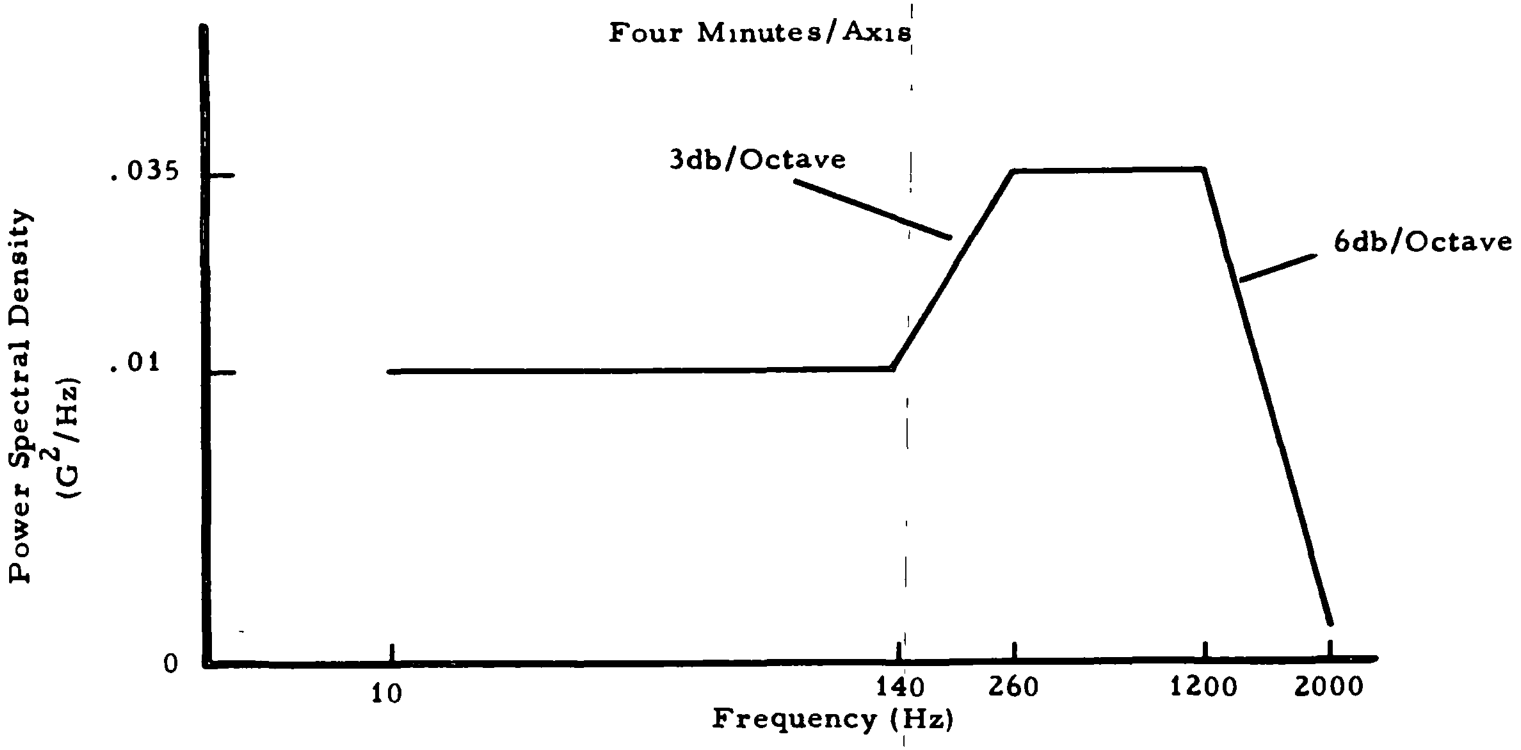


Figure 1 - Random Vibration Qualification Level
(Non-Operating)

ATTACHMENT III

PRELIMINARY SPECIFICATION

1.0 SWEPT RECEIVER, DISPLAY AND RELATED ACCESSORIES

1.0 FUNCTIONAL PURPOSE

The receiver is used to obtain a spectral power density profile of terrestrial transmitters and noise from an orbiting laboratory.

2.0 CONCEPTUAL DESIGN

- High quality, multiple conversion superheterodyne with a large dynamic signal range and well suppressed spurious signals.
- A modular design offering interchangeable front end units for a wide range of frequencies, and ease of future adaptation if desired.
- For the initial test phase, an existing commercial or military equipment will be considered, providing that it meets safety requirements.
- This specification describes the total test package, but items that perform only a portion of the total process are of interest.
- The closest commercial products identified are modern modular avionic equipment used in commercial airlines.

3.0 CONFIGURATION

- The receiver and display test subsystem configuration is illustrated in Figure 1. It comprises the following elements:
    - Input Attenuator
    - Frequency Converter
    - Sweep Receiver
    - Operator Monitor Receiver
    - Panoramic Display
    - Scan Program Generator
    - Calibration Unit
    - Operator Waveform Display

4.0 SPECIFICATIONS

The following parameter values have been established as a preliminary specification. They are to be interpreted as guidelines.

4.1 INPUT ATTENUATOR

The input attenuator allows the operator to control the level of signals applied to the sweep receiver and use an optimum output signal range.

- Frequency Range = 100 - 1000 MHz
- Total Atten. 0 - 60 dB and open (term) *
- Incremental Atten. = 3 dB
- Accuracy (any setting) = 1 dB
- Repeatability = 0.25 dB (all operating environmental conditions)
- Control = Remote Digital with Manual Over-ride.
- Readout = Binary Coding of Attn. Setting

4.2 FREQUENCY CONVERTER

This unit provides the initial RF selectivity and frequency conversion. It establishes the noise factor of the receiving system. It could adapt a conventional existing receiver to the Space-Lab requirement. Modular interchangeable units are assumed to cover the desired frequency range.

- Frequency Ranges = (a) 100 - 1000 MHz (immediate)
  (b) 1 - 10 GHz
  (c) 12, 15, 20 and 30 GHz Bands
  Future Systems
- Noise Factor = (a) 5 dB (max.) (immediate)
  (b), (c) T.B.D. (future)
- Input Impedance = 50 . ohms

4.3 SWEEP RECEIVER

Provides facilities for automatically tuning (sweeping) across any specified portion of the band available with the selected frequency converter. Incorporates remote control, and remote readout of control settings.

- Outputs Available = IF, Video
- Bandwidths = 3, 10, 30, 100 KHz, 1 MHz
- Signal Transfer Function = Logarithmic
- Video Output Signal = 10 V Peak (Nom.)

---

* This position used to calibrate the baseline RFI/EMI level within the Lab itself.

4.4 OPERATOR MONITOR RECEIVER

Provides astronaut with ability to investigate unusual signals or interaction phenomena. Incorporates multiple demodulators to accommodate most sources.

- Frequency Range = Same as sweep receiver
- Bandwidths Available = (a) Narrow 100, 300 Hz, 1, 3, 10 KHz
  (b) Wide 30, 100, 300 KHz, 1, 3, 10 MHz
- Signal Transfer Function = Logarithmic for carrier, and linear for modulation
- Demodulation Facilities = (a) Narrow C. W., AM, FSK, SSB.
  (b) Wide, F. M. AM Peak (Radar) AM and Sync Sep (TV)
- BFO: ± 3KHz
- Sensitivity: 0.75 uv 10dB S+N/N (in 2.4 KHz) NF ≈12 dB
- RF Impedance = 50Ω unbalanced
- Spurious Responses: Image rejection, IF rejection and secondary image rejection = >90 dB each
- Auto Gain Control = < 10 dB change in output for input levels from 3 uv to 1.0 volt
- AGC Time Constant: Attack Time = 15. msecs
  Decay Time = 0.1, 0.5, or 2.0 secs (selectable)
- Audio Output: (a) 1 watt to speaker at <10% T.H.D
  (b) 100 MW to phones at < 2.5 T.H.D
- Audio Response: Within 3 dB from 200 Hz to 4.5 KHz
- Cross Modulation: TBD
- Impulse Protection: TBD

4.5 PANORAMIC DISPLAY

This unit provides a "quick-look" facility allowing the astronaut to examine the spectral power density profile and make real time decisions on the conduct of the remainder of the experiment.

It features a conventional two axis deflection system with the "X" axis used for frequency and the "y" for signal power. A film camera is used to record the data. This unit is also used to view and record signal outputs from the operators monitor receiver, including T.V.

- Sweep Rates = 1, 10, 100μsecs, 1, 10, 100 M secs, 1, 10 secs.
- Screen Size = 5 inch diagonal (min)
- Synchronization = External or Signal
- Sensitivity (Y) = 1, 10, 100 mV, 1, 10 Volts/inch
- Sensitivity (X) = 2 Volts/Inch (nom)
- Bandwidth (Y) = 10 MHz, 3 dB (min)
- Bandwidth (X) = 10 MHz, 3 dB (min)
- Film Camera = 35 MM, F = 1.0, 50 Frames (1 meter film length)
- Sweep Rates = TBD

4.6 SCAN PROGRAM GENERATOR

This modest automation accessory unit provides the means whereby the sweep receiver can be programmed to gather data over one or more specified portions of the complete spectrum. It generates the commands that remotely control the sweep receiver functional controls, including sweep rate, bandwidth, etc. It would also accept inputs from the laboratory clock, for experiment start time (an orbit dependent parameter).

- Timing = Recognize arrival of operator set experiment start time
- Frequency = Generate start and stop frequency commands
- Sweep = Generate ramp or incremental code to establish sweep rate
- Bandwidth = Select processing bandwidth chosen
- Attenuator = Provide control signals needed to set selected attenuation
- Calibrate = Issue command signals to local power calibrator to set level
- Antenna = Generates control signals to coaxial relays to select beamwidth and polarization

4.7 CALIBRATION UNIT

This unit provides a reference power RF signal for checking the absolute sensitivity of the sweep receivers.

- Frequency = 5 spot frequencies
- Frequency Stability = Non-critical (TBD)
- Power Level = -160 to -80 dBW
- Level Uncertainty = 1 dB (max, all causes)
- Prime Power = Built-in Battery
- Output Impedance = 50 ohms, coaxial

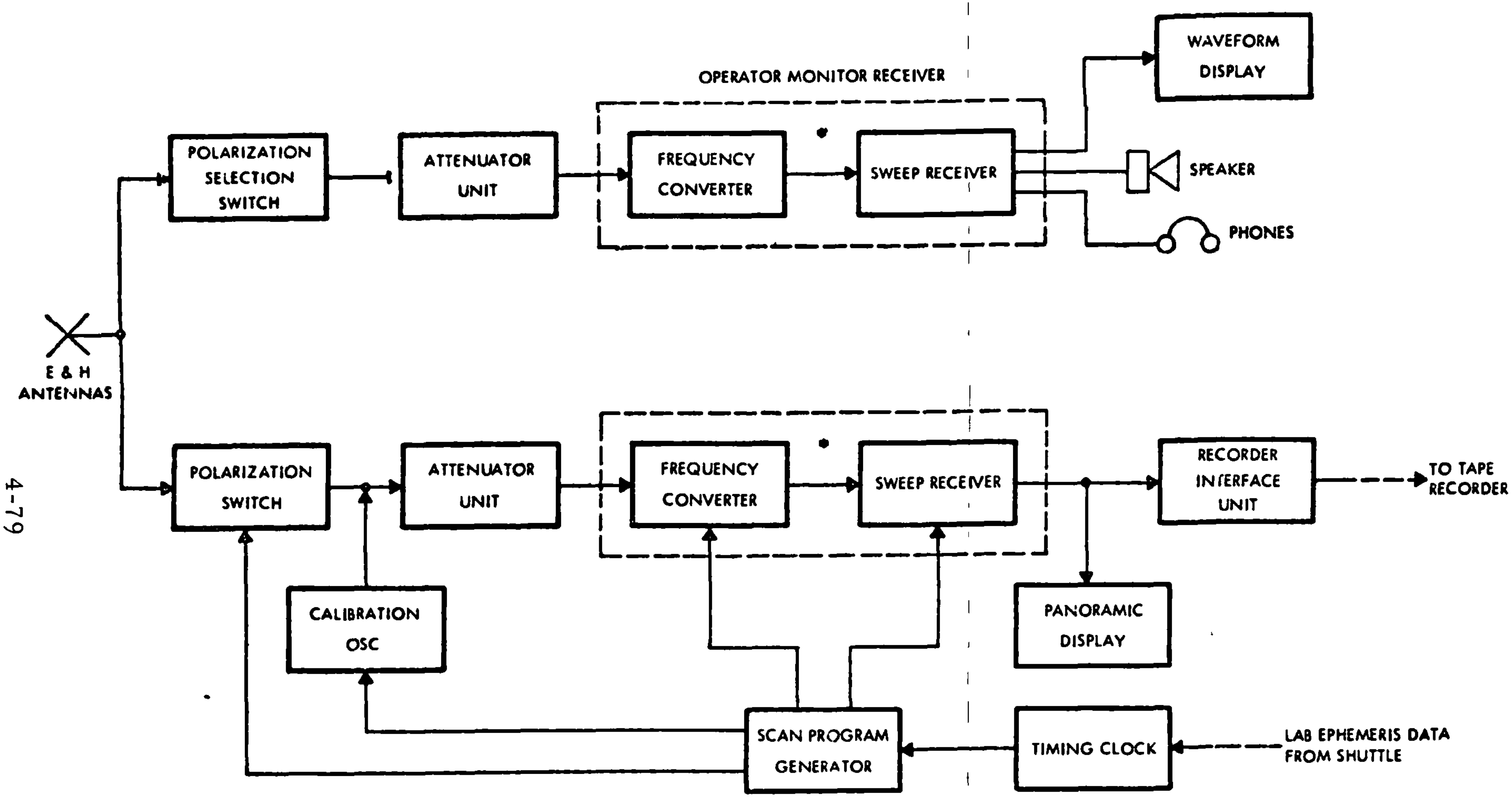
4.8 OPERATOR WAVEFORM DISPLAY

This operator display is used for the occasional analysis and examination of modulated signals available from the demodulators of the operator's monitor receiver. It is proposed that a standard single design display be used for both this function and the panoramic display. Dual units will allow photography of spectra to proceed while the operator evaluates a specific signal wave shape. It provides 100% spare backup for either single function.

4.9 COAXIAL RELAYS

Coaxial relays are used to assign the antennas and to inject the power level calibration signal.

- VSWR (100 - 1000 MHz) = 1.05:1 Max
- Open Circuit Isolation = 60 dB (100 -- 1000 MHz)
- Control Power = 100 MW max
- Control Voltage = TBD



*NOTE RECEIVER AND CONVERTER CAN BE COMBINED INTO SINGLE UNIT IF DESIRED

FIGURE 1. BLOCK DIAGRAM - SPECTRAL POWER DENSITY AND NOISE MONITORING SYSTEM

ATTACHMENT IV

COMMERCIAL HARDWARE SURVEY FOR A COMMUNICATIONS AND NAVIGATION RESEARCH LAB

PREPARED BY ______________________ REPRESENTING ________________

DATE __________ EQUIPMENT ITEM ______________________________

MODEL NO. ______________

1. Is the specific equipment/model identified above directly usable in:
   - (a) Pressurized Habitable Compartment ☐
   - (b) Pressurized Remote Compartment ☐
   - (c) Unpressurized Compartment ☐
   - (d) None of the above ☐

2. Which factor(s) makes your equipment unsuitable for Shuttle/Lab use? Describe.
   - ☐ Safety
   - ☐ Vibration
   - ☐ Temperature
   - ☐ Flammability
   - ☐ Outgassing
   - ☐ Acoustic
   - ☐ Load Factors
   - ☐ Human Factors
   - ☐ RFI
   - ☐ Pressure
   - ☐ Other ________________

3. What would be the redesign necessary to meet the requirements for lab usage? Describe.
   - ☐ Substantial
   - ☐ Moderate
   - ☐ Minor

4. On future development of similar hardware items, would your firm consider the space laboratory requirements as design standards?

   ☐ Yes

   ☐ No

5. How would you characterize the impact of the space laboratory requirements on future equipment cost?

   ☐ Exorbitant in terms of a commercial product line

   ☐ Substantial

   ☐ Inconsequential

6. What factor(s) in the laboratory requirements do you feel could be modified to accommodate commercial hardware?

7. Can you suggest alternate equipment which would satisfy the functional and performance requirements specified on Attachment 3?

8. If you are not interested in modifying your equipment for use in the space laboratory, would you consider licensing others to produce such equipment?

   ☐ Yes

   ☐ No

9. What special precautions would have to be taken to accommodate your equipment?

   ☐ Package during launch/reentry

   ☐ Shock isolation

   ☐ Other; describe ______________________

5.0 LABORATORY CONFIGURATIONS

While the ultimate space laboratory may accommodate a large list of experiments, the first (Early) Comm/Nav Research Laboratory (CNRL) may be small and rudimentary. A prime objective should be to conceive a laboratory design which can evolve in time, and grow in size and diversity as new experimental needs and capabilities arise. This laboratory evolution can take place in two dimensions: 1) within an existing configuration and size, expansion or extension of the laboratory's capability to accommodate a particular class of experiment to new frequencies, new parameters, and increased accuracies, and 2) laboratory configuration and subsystem changes to allow for the addition of new types of experiments not previously included.

An Early Communication/Navigation Research Laboratory is contemplated as a Space Shuttle supported, general purpose, reusable, laboratory that could accommodate a wide variety of Communications and Navigation experiments.

Present testing programs in this discipline rely heavily on using unmanned satellites, such as the Applications Technology Satellite (ATS) and the proposed Small Applications Technology Satellite (SATS). The Communication/Navigation Research Laboratory would be a space laboratory in which man could effectively increase experiment efficiency by certain observations, modifications, instrumentation setup/calibration and limited equipment maintenance. In addition, man may monitor experiment progress and perform preliminary data evaluation to verify proper equipment functioning and may terminate or redirect experiments to obtain the most desirable end result. The flexibility and unique capabilities of man as an experimenter in such a laboratory could add to the simplification of space experiments, and this provides the basis for commonality in many of the support subsystems thus reaping the benefits of reusability and reduced experiment costs. It is anticipated that such a laboratory could complement the various unmanned research programs in this discipline by providing a facility for testing and evaluating portions of future automated experiments.

The Comm/Nav Research Laboratory will be transported to space and returned to Earth by the Space Shuttle. Initial missions will be characterized by the laboratory remaining attached to the Shuttle Orbiter. On later flights, the laboratory could be Space Station attached.

The use of the Space Shuttle as an orbiting platform for short duration, Sortie missions, with a manned laboratory attached, will offer a substantially different concept in the acquisition of research data. The guidelines and assumptions opens the possibility of several laboratory options for configuration design, equipment lay out, crew size, and mission planning.

5.1 CNRL GUIDELINES AND ASSUMPTIONS

The following general guidelines and assumptions relative to CNRL configuration design were used during the study:

1. For study purposes, the Initial Operating Capability (IOC) date for the initial Communications/Navigation Research Laboratory is assumed to be 1979.

2. Since orbital altitude, orbital inclination and payload weight are interrelated, the orbit obtainable for a given mission is a function of the total Communications/Navigation Research Laboratory design and its host vehicles. For planning purposes, the altitude limits are between 100-470 nautical miles, and the inclination may vary from 0° to 90°; however, the total mission payload weight will determine if one or both of these parameters must be constrained.

3. Shuttle orbital pointing accuracy is assumed to be $+0.5^{\circ}$ with 0.01°/sec. maximum drift rates in each axis. If increased accuracy is required for the experiment, the necessary equipment shall be provided either by the experiment or by the Communications/Navigation Research Laboratory.

4. Length of each sortie mission from launch to landing is seven days.

5. All crew members must be in orbiter cabin for launch and landing.

6. An 0_2 - N_2 cabin atmosphere of 14.7 psi will be provided with an 0_2 partial pressure of 3.1 psi.

7. Scientific instrumentation and laboratory equipment should be designed for both in-orbit replacement and retrofitting, and return to earth for possible refurbishment and updating.

8. All in-orbit maintenance and servicing activities shall be accomplished in a shirt-sleeve environment to the maximum practical extent.

9. Use of "off-the-shelf" hardware shall be considered when it minimizes development costs and adheres to the required safety standards.

10. All materials selected for use in pressurized areas will be non-toxic, non-inflammable and non-explosive in accordance with established safety standards.

11. A Data Relay Satellite System (DRSS) shall be assumed to be available.

12. Launch and Earth return shall be by Shuttle.

13. The Comm/Nav Research Laboratory will be accommodated in either a Sortie Module or the Space Station - it is a laboratory, not a spacecraft.

5.2 EARLY COMMUNICATION/NAVIGATION LABORATORY

Laboratory Objective. Conduct low altitude orbit point experiments within the discipline areas of communications and navigation which involve astronaut participation in a meaningful way and which yield data immediately useful in contributing to the solution of communication/navigation problems.

Design Approach

- Launch and earth return by Space Shuttle
- Space Shuttle Orbiter supported
- Minimum Space Shuttle interface
- Fail safe design criteria
- Laboratory removable from Space Shuttle Orbiter bay for ground operations
- Experiment pallet detachable from laboratory
- 1980 - 1985 time period
- Seven-day Sortie missions
- Two experimenter crew
- Accommodate seven experiment classes
- Off-shelf subsystems
- Minimum automation
- No scheduled EVA
- Some commercial equipment
- No planned maintenance
- Some on-board data processing

Experiment Classes Accommodated

Experiment Class Number From Page	Experiment Class Title
1	Terrestrial sources of noise and interference
3	Radio frequency propagation
7	Communication relay
9	Laser communication
11	Fixed multibeam antenna
15	Interferometric navigation and surveillance techniques
16	Landmark tracking

5.2.1 Early Laboratory - Shuttle Orbiter In-Bay Operation

Considering equipment weight, volume, and needed services and also taking into account the two-man experimenter crew time available on a seven-day Sortie mission for experiment related activities, an Early Laboratory baseline configuration accommodating the above seven experiment classes, is suggested in Figure 5-1.

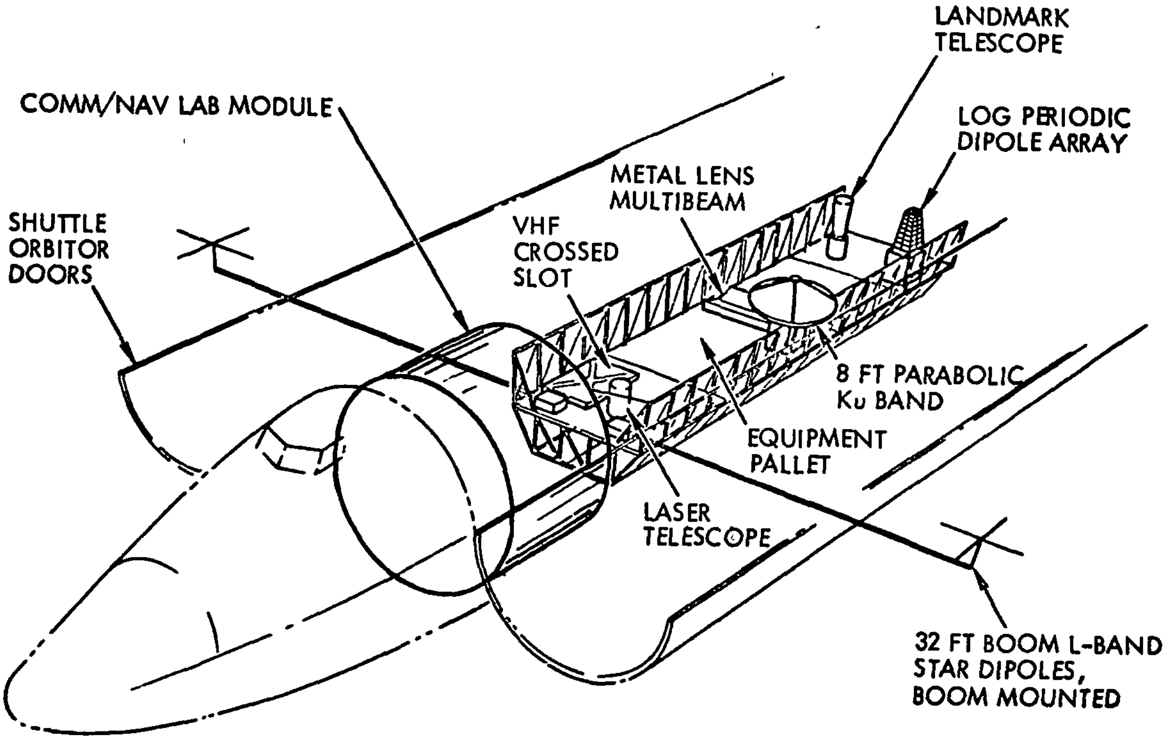


Figure 5-1. Comm/Nav Research Laboratory Operating from In-Bay Position with the Shuttle Orbiter. Pallet Shows Possible Antenna Locations

The laboratory features two major configuration elements, a pressurized habitable Sortie Module and a support structure Pallet for external equipment. Configurations of the equipment layout were examined utilizing the NASA/MSFC provided concept of the Sortie Module (or Sortie Can) and its Pallet to MSFC's available definition, Figures 5-2 and 5-3.

The important features of this laboratory are:

- 25 ft. long, 14 ft. diameter pressurized module which houses the crew station experiment operation displays and controls; experiment unique transmitters and receivers; laboratory common core equipment, and laboratory supporting subsystems. These subsystems consist of structure, environmental control/life support, thermal control, electrical power, communications and data management.

- 8 ft. diameter entry hatch for access of the crew to the Shuttle Orbiter flight deck.

- Removable end dome with an observation window for viewing the bay area.

- 30 ft. long (of the 60 ft. available) experiment pallet attached to the pressurized module end dome. Figure 5-1 indicates the distribution of the antenna farm for the seven experiment classes designated for early missions. The attached points for the various antenna mounts are provided by cross truss supporting members. This elevation is necessary in order to improve the antenna field of view from the cargo bay. The eight foot parabolic antenna is launched in a stored position pointing down into the pallet and then erected on orbit. This antenna field of view covers a 54 degree cone of rotation about its boresight normal axis. The 18 inch reflective laser telescope is gimbal mounted in a thermally insulated stable housing with a sealed light pipe system passing through the pressurized module end dome and into the laser console installed in the pressurized module. The critical length of waveguide runs for X-band (and above) antenna systems imposes a requirement to detect and down convert or amplify in housings placed at the base of the antenna. Lower RF signals will then be brought into the pressurized module via coaxial cable.

  The Figure 5-1 configuration is designed to keep the payload (pressurized module plus pallet) within the Orbiter cargo bay. Only the interferometer booms, with the L-band star dipoles at each end, are extended from the bay with all other systems attached at fixed points to the pallet. In this configuration the overall payload length is 55 feet. The cargo bay dimensions permit growth up to 60 feet in length, if required.

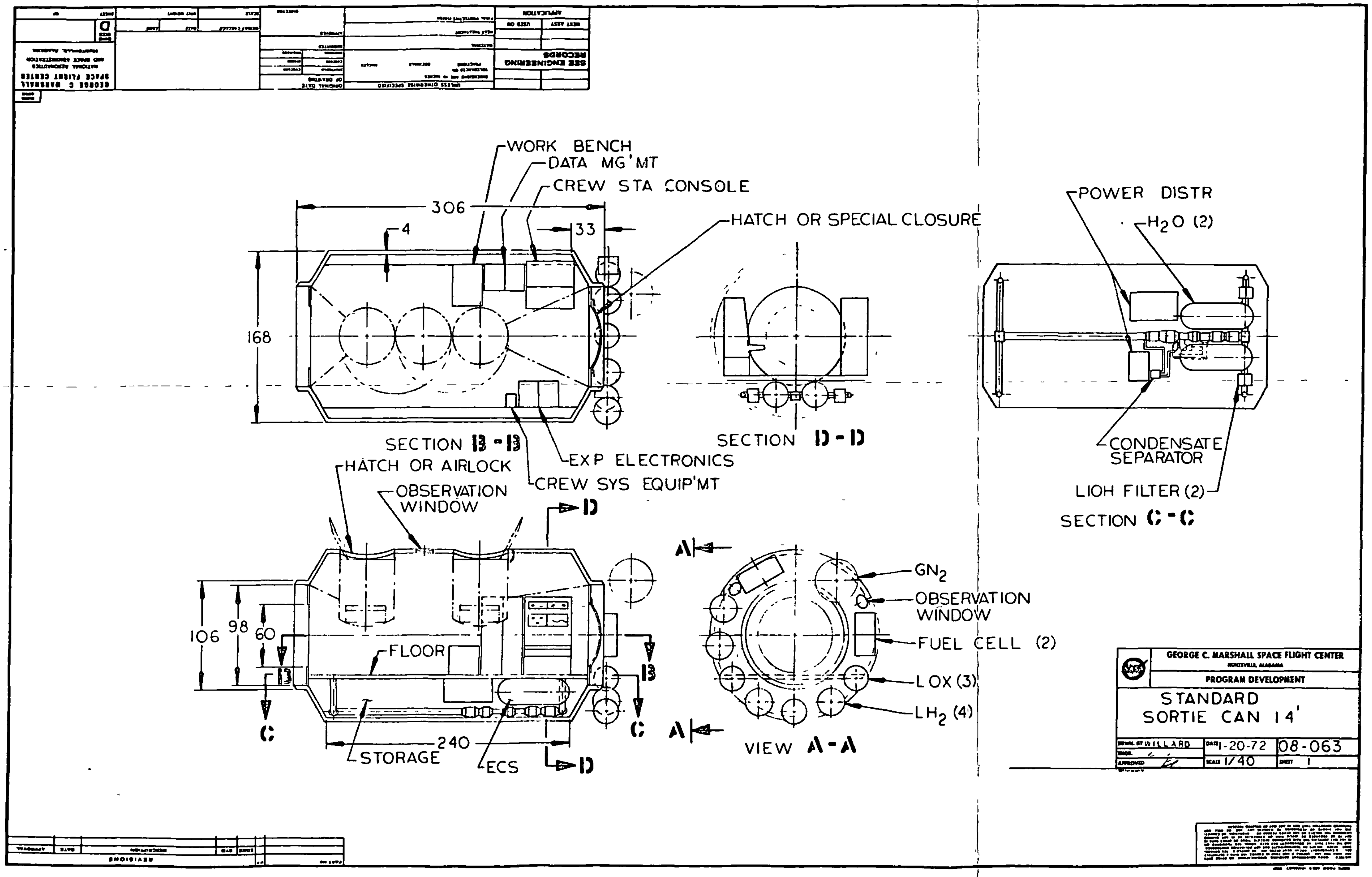


Figure 5-2. Standard Sortie Can 14'

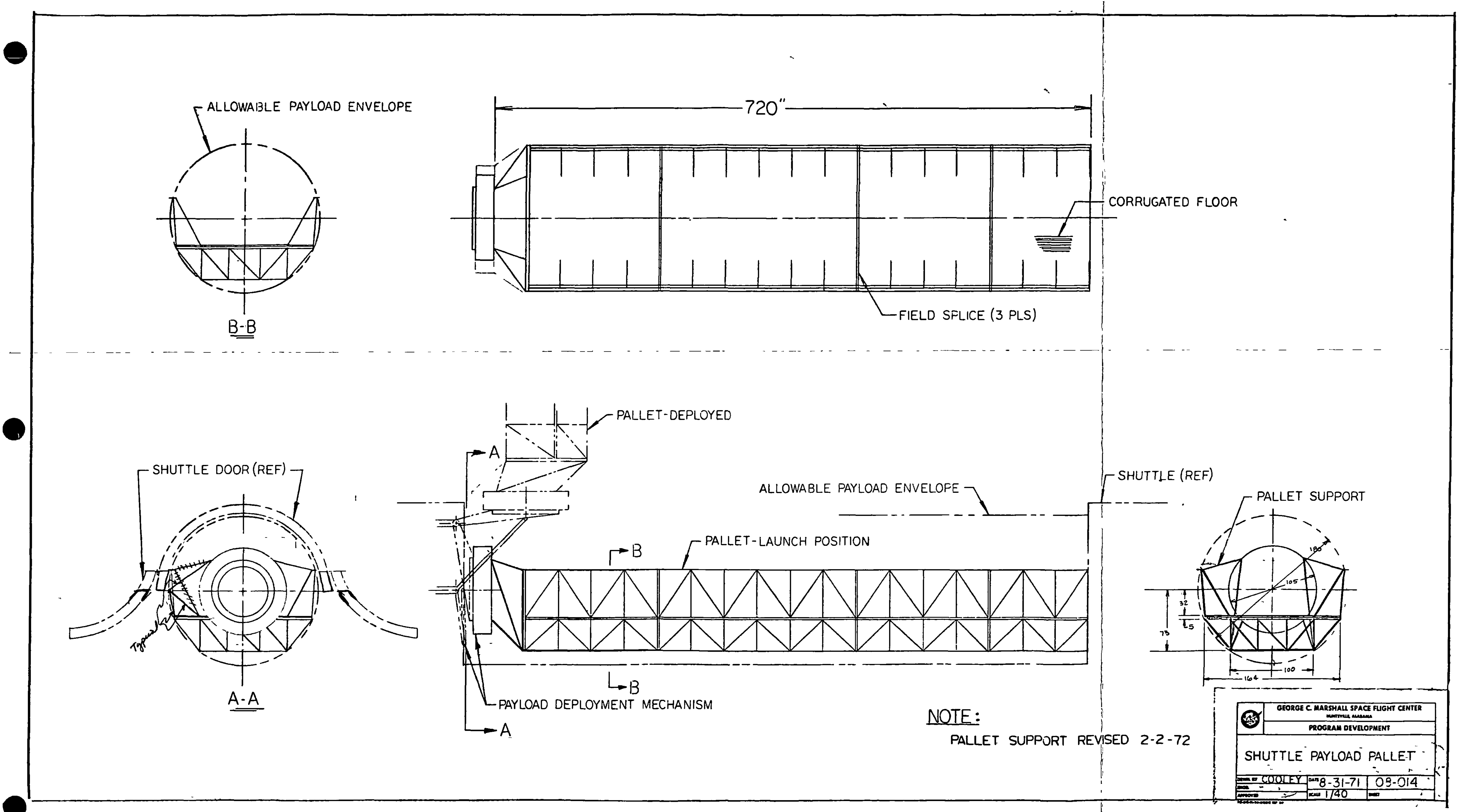


Figure 5-3. Shuttle Payload Pallet

Internal Experiment Accommodation

At the time the experiment accommodation task was performed, the available definition of the Sortie Module was minimal. Many dimensional characteristics had to be estimated. The definition of the Sortie Module may therefore change as information becomes available. The Sortie Module geometry used is shown in Figure 5-2. The length dimensions of the Module have been retained from the avilable definition. However, where that description indicates an external skin diameter of 15 feet (the maximum envelope allowed), the outer skin diameter selected for this study is less than 15 feet. Past studies have shown a high frequency of occurrences for external protuberances for manned laboratories, i.e., antennas, vent valve deflectors, window covers, etc., therefore an external skin diameter of 14 feet has been used in concjunction with a 160 inch diameter pressure shell. The length of the Module is composed basically of either a 20 foot long or a 10 foot long cylinder with end structures 33 inches long. The shorter 10 foot long alternate size could accommodate the Early Laboratory Comm/Nav equipment, but the Standard Module 20 foot long sidewall length is selected as it offers the growth potential necessary for future laboratory development.

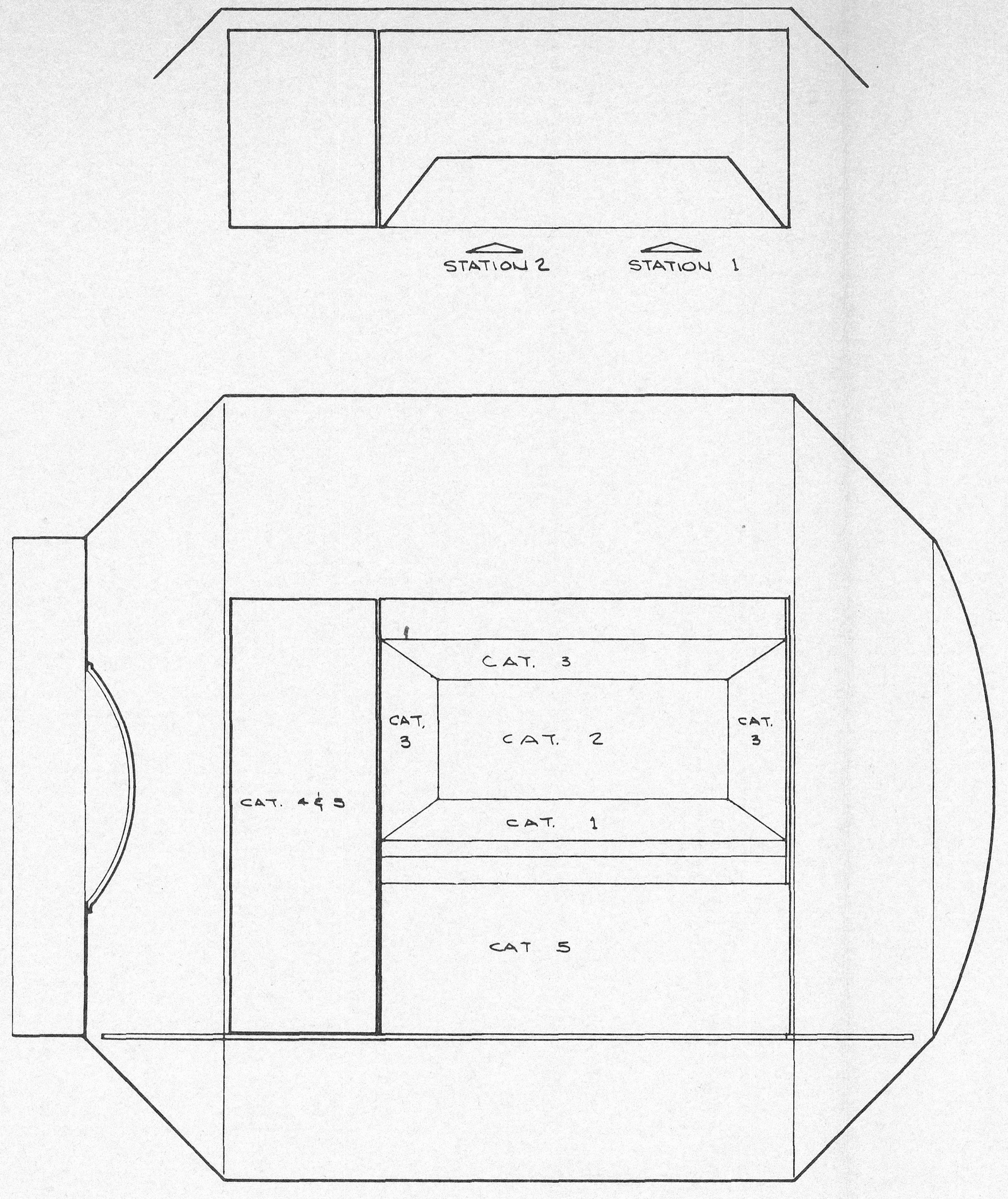
The interior of the Sortie Module includes a basic floor, environmental control equipments, electrical power distribution equipment, a standard operator console and a workbench. The operator console and workbench descriptions were unavailable and were omitted as a part of the basic Module definition in this report. The longitundinal floor is located 50 inches off the Module centerline and includes an open mesh "isogrid" panel. No description is avilable of the method proposed in the MSFC Sortie Module documents for supporting and mounting console cabinets in the vehicle. The method used in the study is the well-known birdcage support structure.

Subsystems included in the MSFC Sortie Module definition are the electrical power system and the EC/LS atmosphere storage tanks. The electrical power system consists of two fuel cells and the cryogenic storage tanks for the hydrogen-oxygen fuels. Included in the tank farm is oxygen and nitrogen for the atmospheric makeup. These systems are located around the conical end structure of the Module that interfaces with the Shuttle Orbiter.

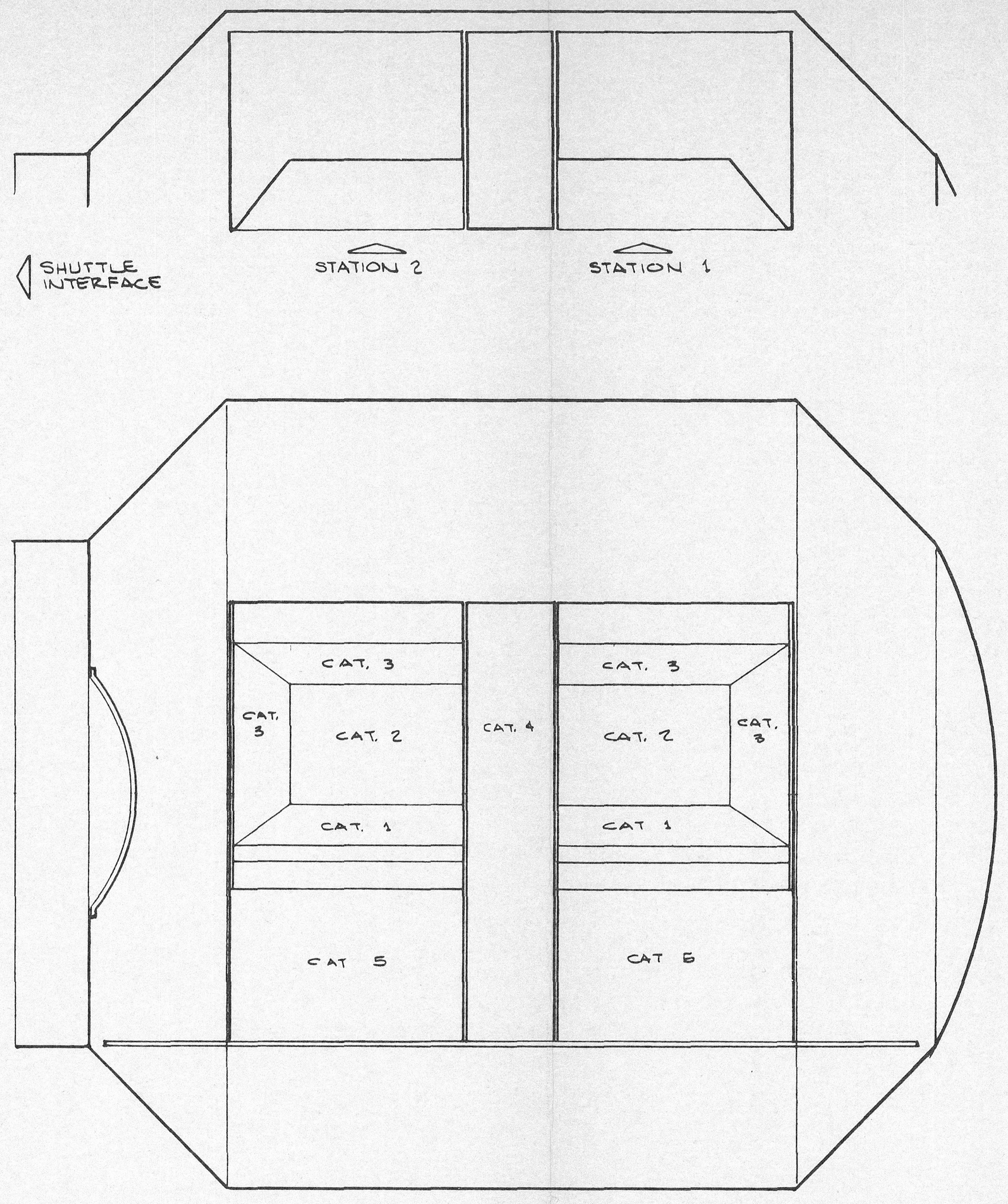
The interior volume was examined for two basic approaches to equipment placement; namely, an arrangement which is "G" oriented and comparable to console functional arrangements synonymous with Earth bound equipment and a zero "G" approach in which fixed body relationship to floor are not used. Sketches were made for both concepts for one two-man console and two one-man consoles, Figures 5-4 and 5-5, are evaluated for effectiveness. The conclusion was in favor of the zero "G" approach for compactness and for two separate operator positions rather than a dual operator console. This latter selection was favored as the cost of duplicating some multipurpose equipment was minimal being largely satisfied by a redundancy or backup quantity criterion. Initial equipment estimates produced an upper level multi-surface "Reach Envelope" console of 116 inches and a lower single surface equipment cabinet of 48 inches length. Updating of the equipment list eventually filled in many vacant panel areas of the upper console (Figure 5-6) and extended the lower cabinet to the same 116 inch length as the upper. Figure 5-7 shows the final configuration of the primary operator console. Two experiment classes use laser systems which in themselves are extensive enough to need a discrete facility and work console. This laser console, see Figure 5-8, is primarily an enclosing cabinet for the protection and conditioning of the laser equipment network. This laser system is builtin to the bird-cage support structure. One end of this cabinet and an "over-handing" cabinet contains the supporting and controlling equipment and appropriate control and display panels.

Much of the equipment is installed in drawer-style main frame structures. However, the main operator consoles are hinged to each other for general access to their back sides and to the pressure wall. The normal method, with the upper console and the lower cabinet having a common hinge system on the face nearest the Can's certerline, is to unlatch and swing either segment away from the wall while being supported by the other, see Figure 5-9.

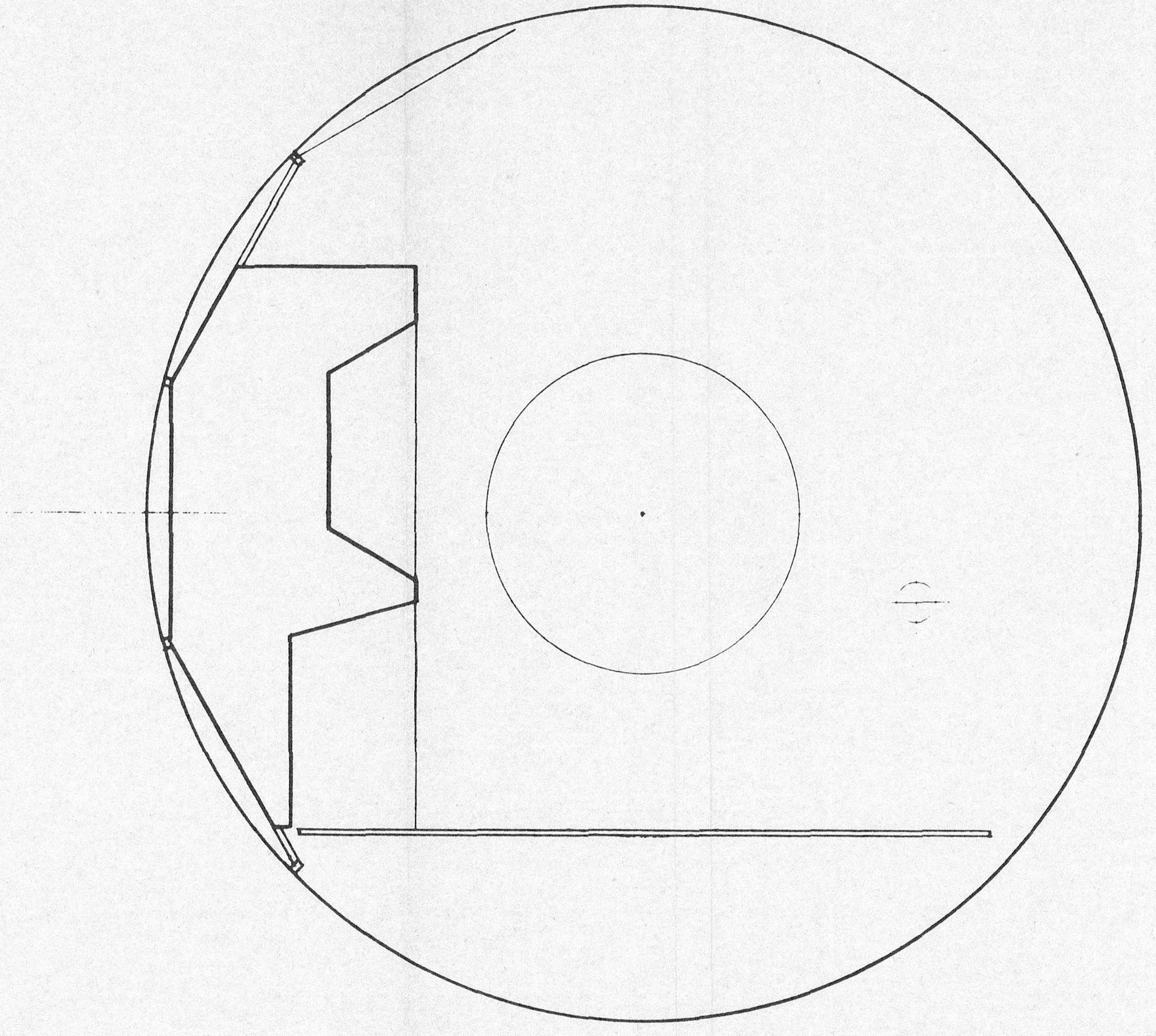
Other than a light tube for the laser telescope passing through the end dome no additional devices or equipments are required internally to accommodate the selected experiments.



ONE TWO-MAN DUTY STATION ARRANGEMENT



TWO ONE-MAN DUTY STATION ARRANGEMENT



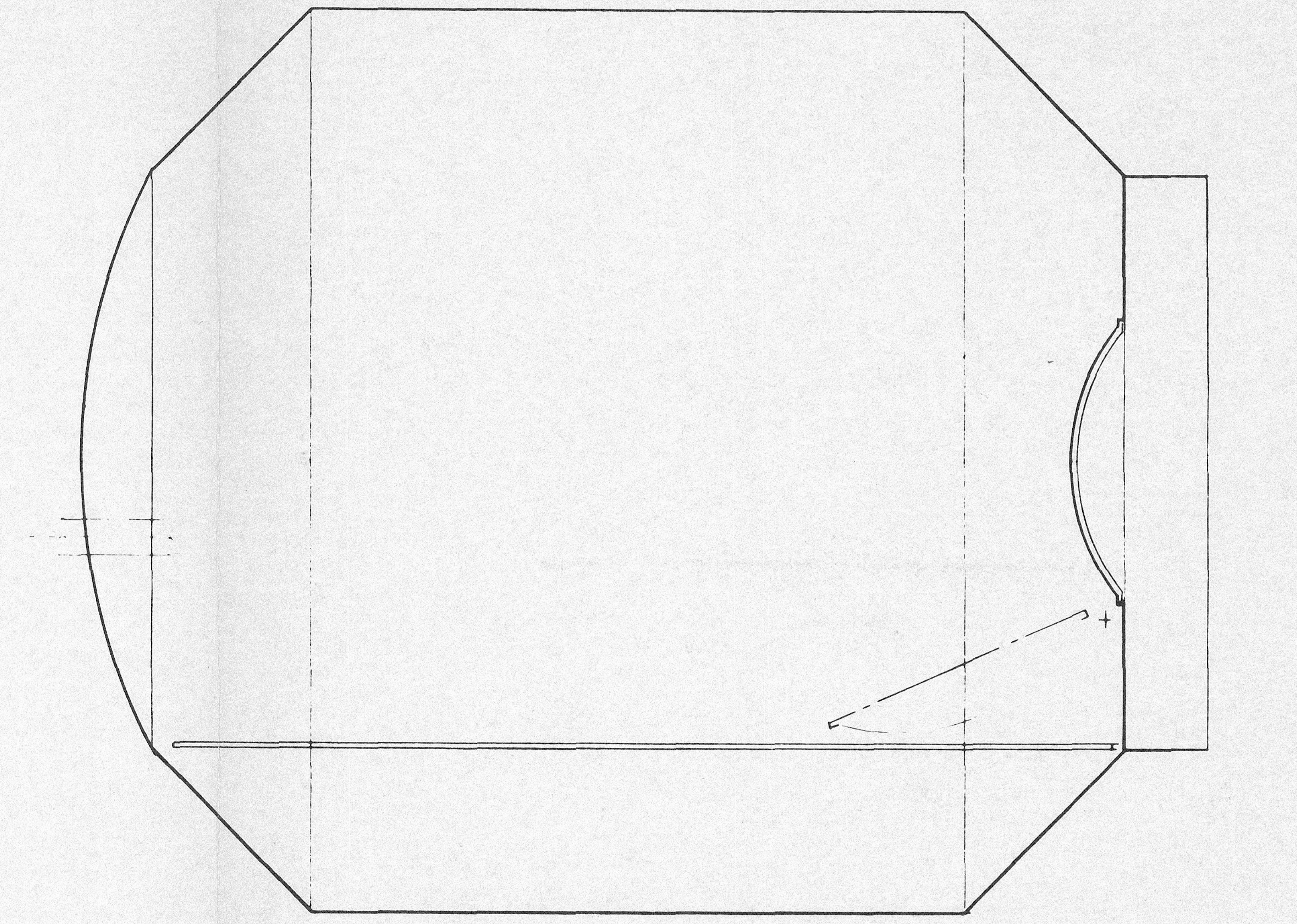
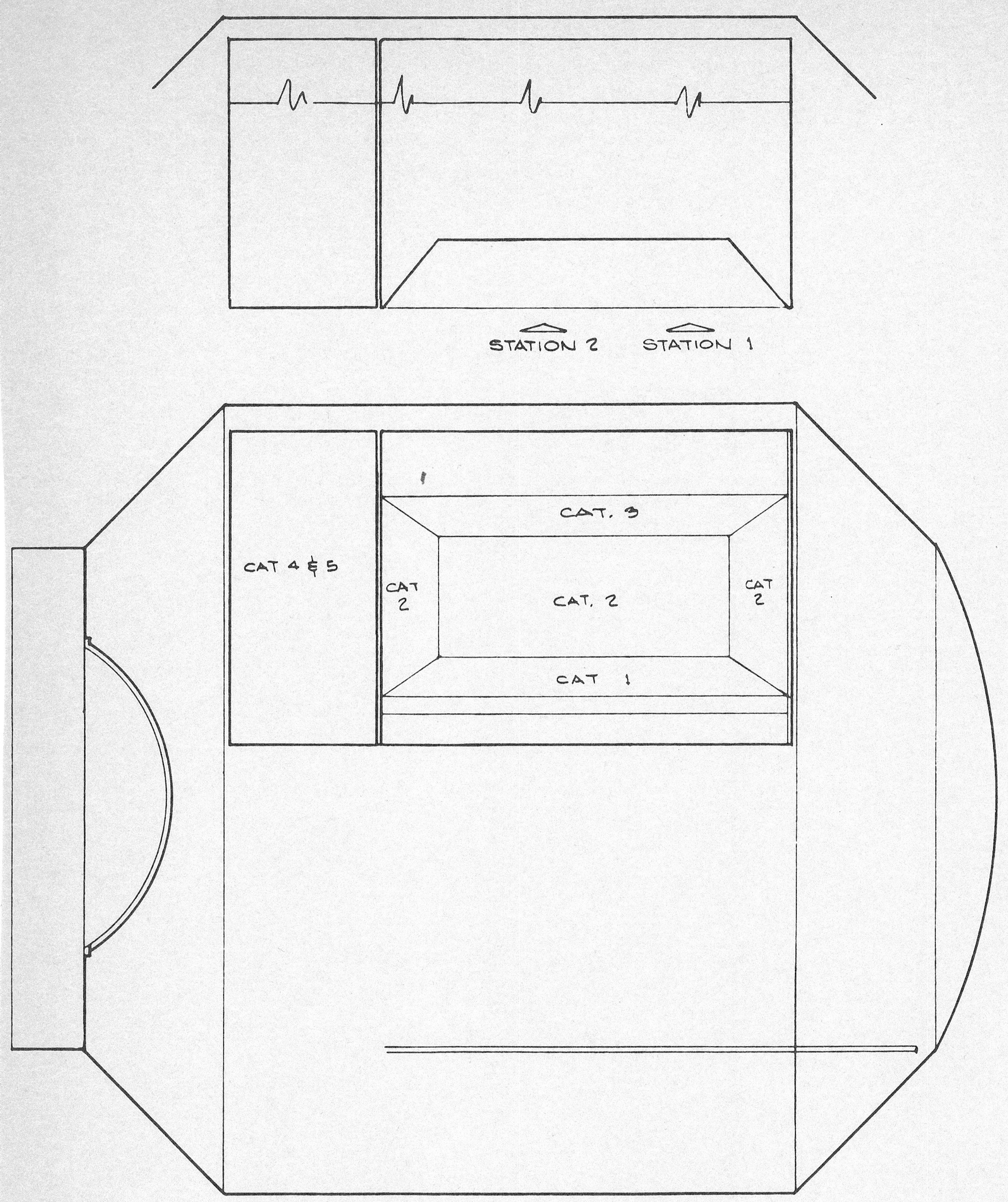
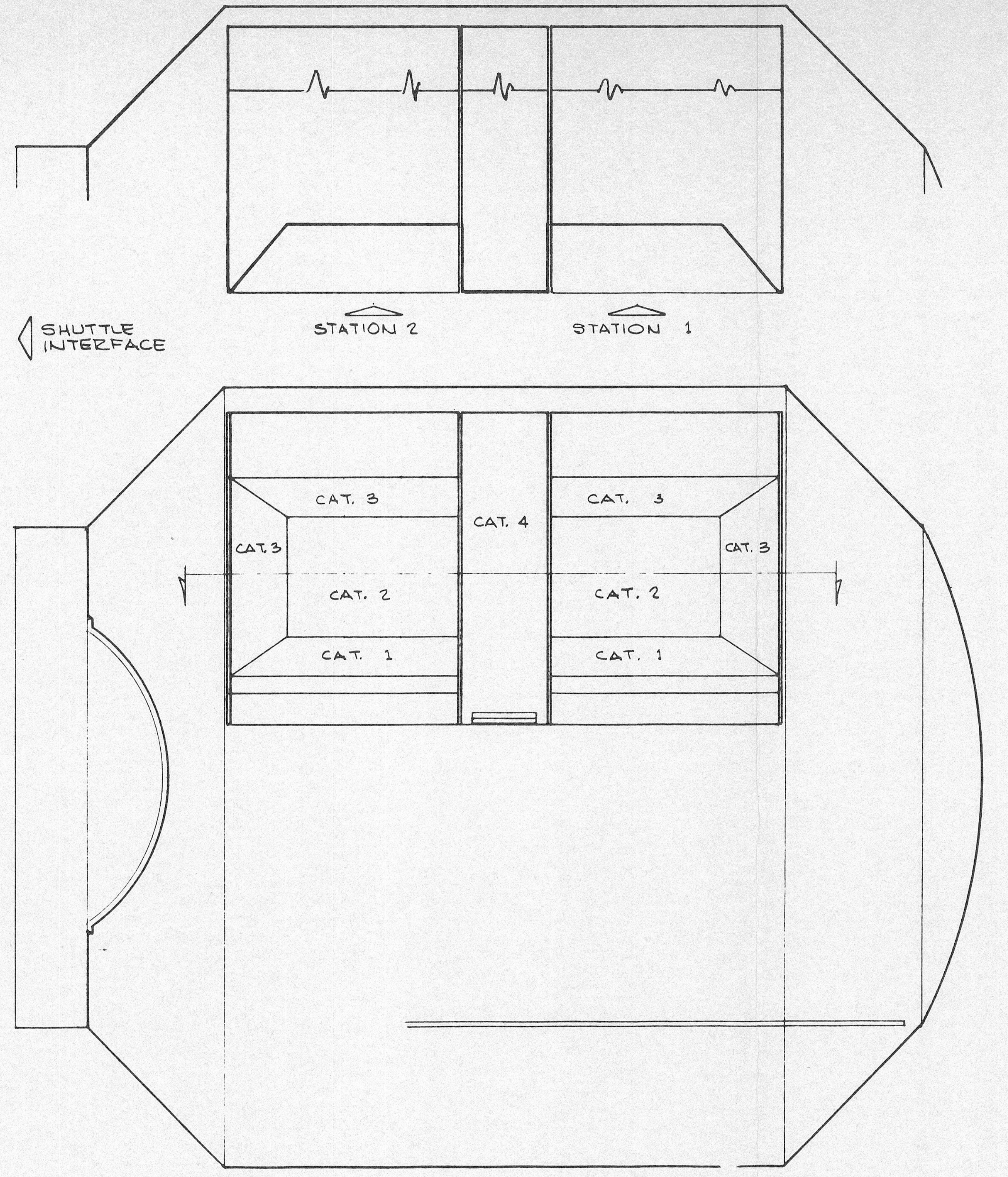


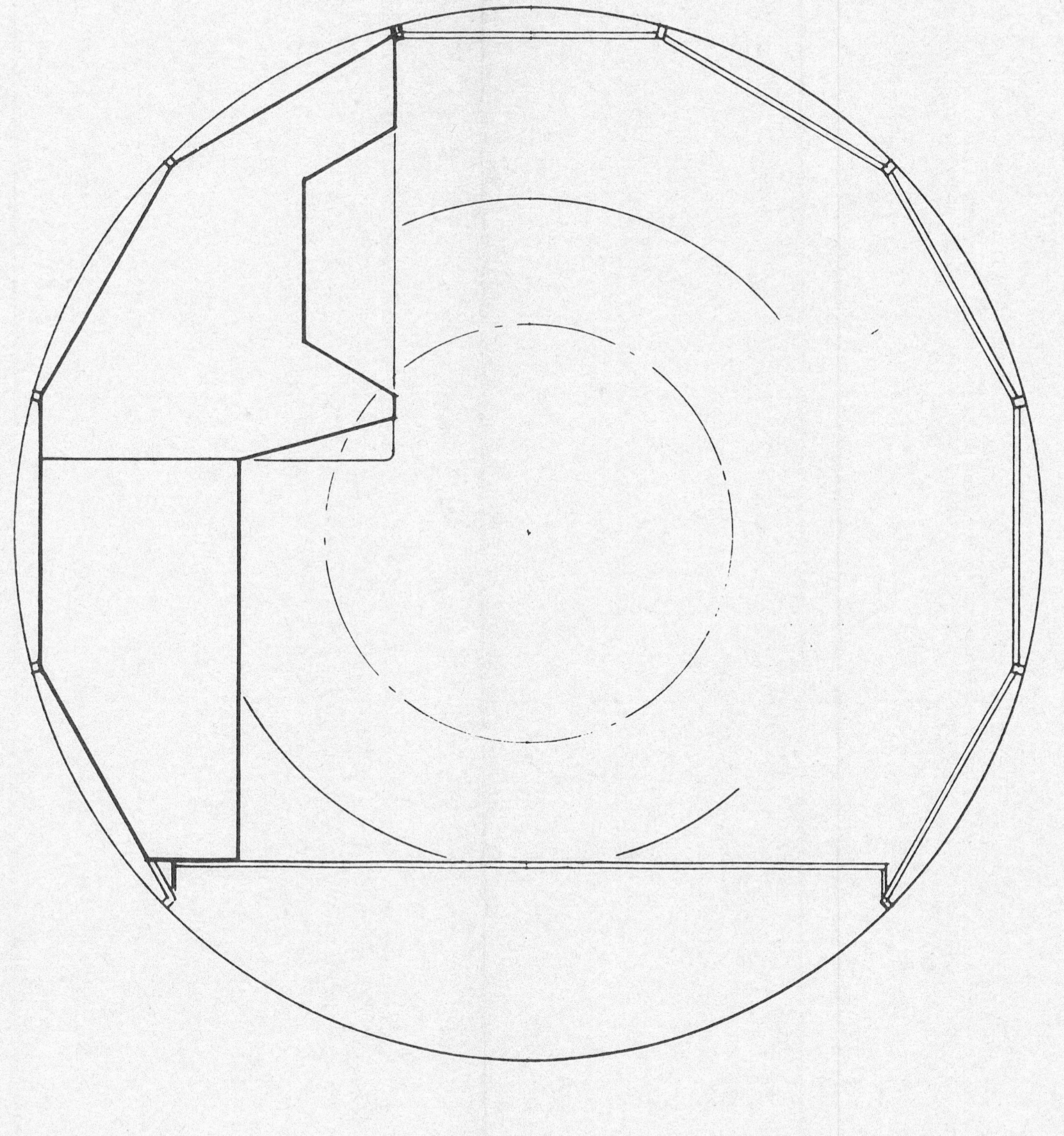
Figure 5-4. Layout-Inboard
Preliminary Space Allocation
Sortie Console



ONE TWO-MAN DUTY STATION
ARRANGEMENT



TWO ONE-MAN DUTY STATION
ARRANGEMENT



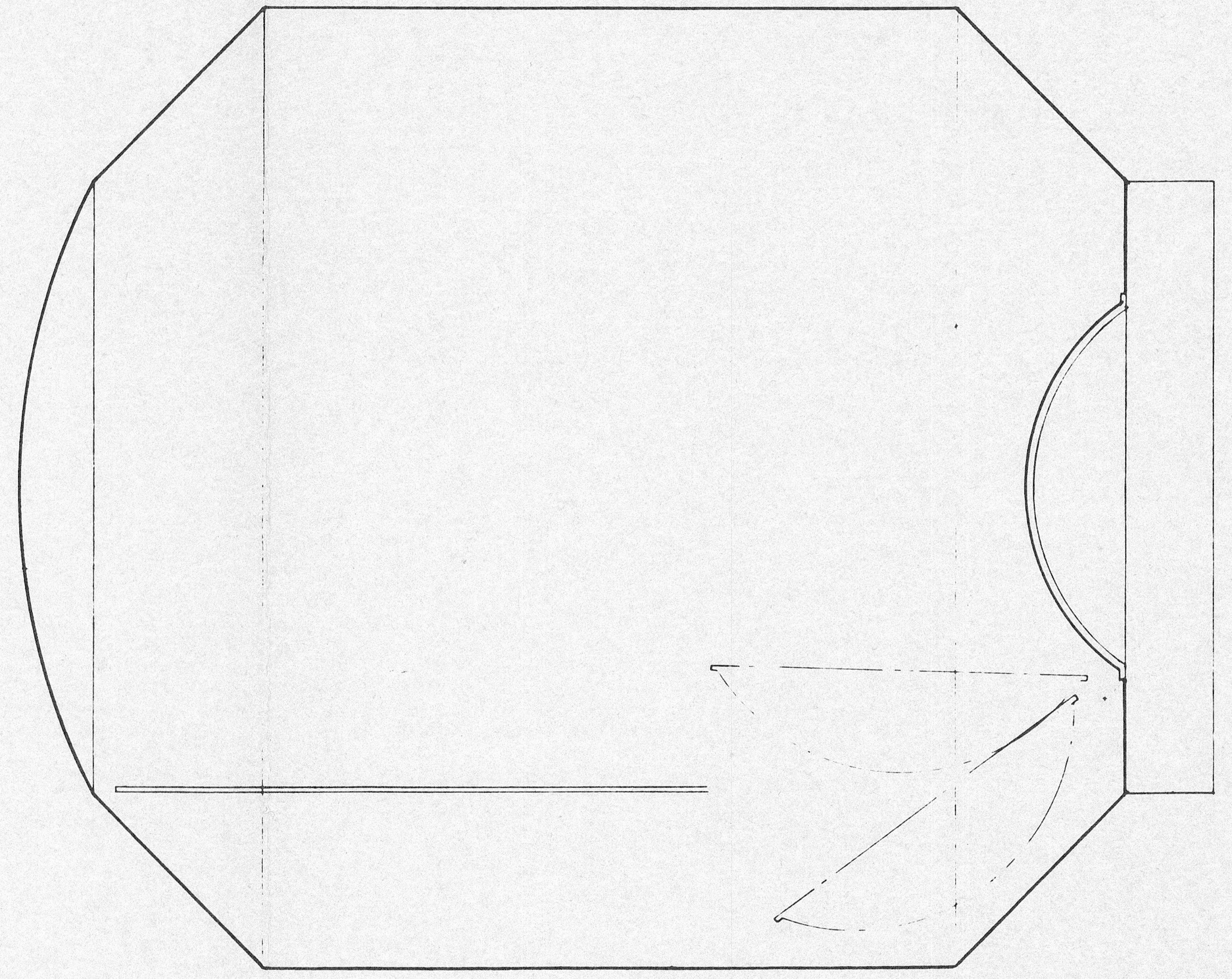


Figure 5-5. Layout-Inboard
Preliminary Space Allocation
MSM Console

1 RECEIVER - SWEPT BAND
2 RECEIVER - "L" BAND
3 RECEIVER - VHF
4 SPECTRUM ANALYZER
5 TELEPRINTER
6 C.R.T. DISPLAY
7 RECEIVER "B" BAND
8 TIMER
9 BIT ERROR COUNTER
10 FREQUENCY COUNTER
11 DIGITAL PHASE METER
12 R.F POWER METER
13 COMPUTER KEYBOAD
14 SENSOR CONTROLLER
15 RECORDER CONTROLS
16 TRANSMITTER KU BAND
17 TRANSMITTER V.H.F.
18 INTERCOM
19 CAUTION AND WARNING
20 FREQUENCY SYNTHESIZER AND DRIVER
21 AC/DC VOLTMETER
22 GENERATOR-STREAM DATA BIT
23 POWER SUPPLY - VARIABLE
24 POWER DIVIDER
25 POWER CALIBRATOR UNIT
26 PREAMPLIFIER
27 ELECTRICAL POWER MONITOR AND DISTRIBUTION
28 TAPE RECORDER - DIGITAL
29 TAPE RECORDER - ANALOG
30 TAPE RECORDER - C.R.T.
31 RECORDER - LOOP
32 GENERAL PURPOSE COMPUTER
33 MODEM
34 MODEM WIDE BAND
35 DEMODULATOR
36 AMPLIFIER -LOG
37 X-Y PLOTTER
38 RECORDER - ROTATING HEAD
39 VISICORDER
40 GENERAL STORAGE
41 EC/LS CONTROL PANEL
42 A/D CONVERTERS
43 CIRCUIT PATCH PANEL
44 D/A AND A/D CONVERTER
45 SIGNAL FORMATING UNIT
46 VHF ATTENUATOR
47 SCAN PROGRAM GENERATOR
48 CALIBRATION SIGNAL GENERATOR
49 NOISE FACTOR TEST SET

V VACANT PANEL SPACE (GROWTH)

LASER CONSOLE

1 TELESCOPE AND GIMBAL CONTROLS
2 VISUAL OPTICS CONTROLS
3 TRACKING (X,Y) DISPLAY AND CONTROLS
4 ALIGNMENT DISPLAY AND CONTROLS
5 COMPUTER/PROGRAMER AND REFERENCE DATA ACCESS
6 NAVIGATION REFERENCE DISPLAY
7 REFERENCE DATA DISPLAY
8 HORIZON SENSOR MONITOR AND CONTROL
9 LASER POWER SUPPLY (CO_2 SYSTEM)
10 LASER POWER SUPPLY (Nd:YAG SYSTEM)
11 CIRCUIT BREAKER/FUSE PANEL
12 SUPPORT ELECTRONICS MONITOR AND CONTROL
13 SUPPORT ELECTRONICS
14 PANEL GROWTH SPACE
15 LASER SYSTEM ACCESS
16 OPTICAL FILTER ACCESS (CO_2 CIRCUIT)

LASER SYSTEM

a LIGHT TUBE TO TELESCOPE
b COLLIMATING MIRROR
c LASER RECEIVER
d LASER TRANSPONDER BEACON
e LASER OUTPUT POWER MONITOR
f COLLIMATING MIRROR
g EXPANDER OPTICS
h LASER TRANSMITTER (Nd:YAG)
i FINE TRACKER
j COARSE TRACKER
k T.V. CAMERA
l EYE (VISUAL) OPTICS
m RECORDING CAMERA
n COLLIMATING MIRROR
o COLLIMATING MIRROR
p LASER TRANSMITTER (CO_2)
q LASER OSCILLATOR
r RECEIVER FILTER
s LASER RECEIVER

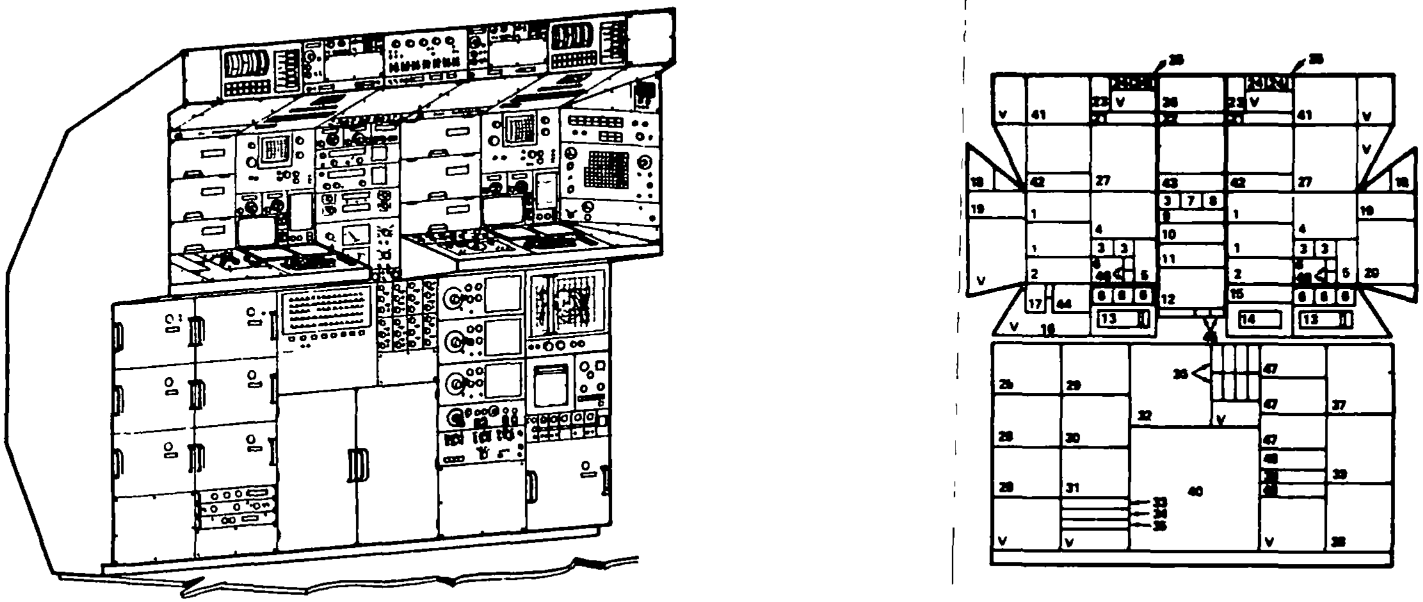
CONTRACT NO.
ORIGINAL DATE OF DRAWING
PREPARED Westenberger 2-9-72
CHECKED
ENGINEER
DESIGN ACTIVITY APPROVAL
CUSTOMER APPROVAL

MCDONNELL DOUGLAS ASTRONAUTICS CO.
WESTERN DIVISION
HUNTINGTON BEACH, CALIFORNIA
MCDONNELL DOUGLAS

EXPERIMENT ACCOMMODATION
INTERNAL CONFIGURATION
COMM. /NAV MISSION

SIZE
CODE IDENT NO. 18355
DRAWING NO.
SCALE 1/20

Figure 5-6. Experiment Accommodation Internal Configuration



1. RECEIVER - SWEPT BAND
2. RECEIVER - "L" BAND
3. RECEIVER - VHF
4. SPECTRUM ANALYZER
5. TELEPRINTER
6. C. R. T. DISPLAY
7. RECEIVER "S" BAND
8. TIMER
9. BIT ERROR COUNTER
10. FREQUENCY COUNTER
11. DIGITAL PHASE METER
12. R. F. POWER METER
13. COMPUTER KEYBOARD
14. SENSOR CONTROLLER
15. RECORDER CONTROLS
16. TRANSMITTER K_U BAND
17. TRANSMITTER VHF
18. INTERCOM
19. CAUTION AND WARNING
20. FREQUENCY SYNTHESIZER AND DRIVER
21. AC/DC VOLTMETER
22. GENERATOR-DATA BITSTREAM
23. POWER SUPPLY-VARIABLE
24. POWER DIVIDER
25. POWER CALIBRATOR UNIT
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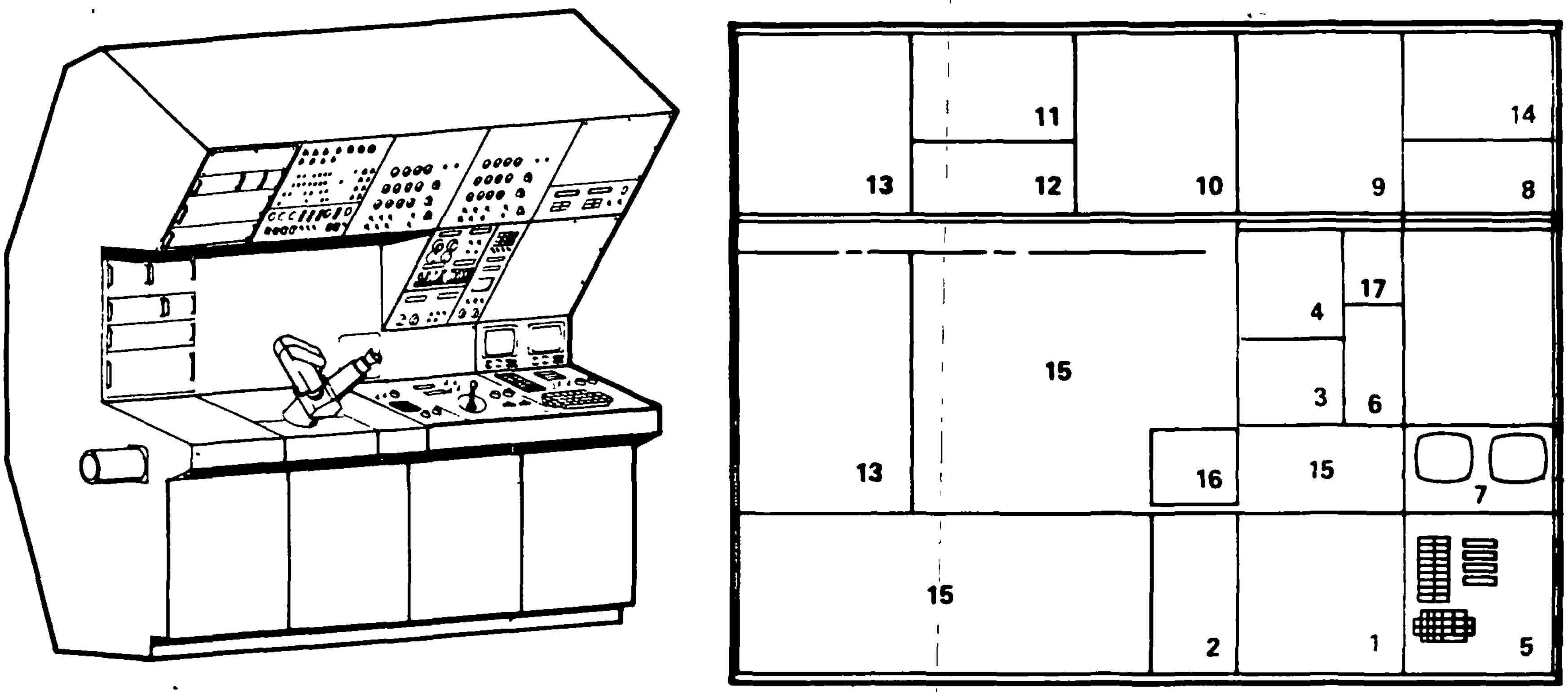
36. AMPLIFIER - LOG
37. X-Y PLOTTER
38. RECORDER - ROTATING HEAD
39. VISICORDER
40. GENERAL STORAGE
41. EC/LS CONTROL PANEL
42. A/D CONVERTERS
43. CIRCUIT PATCH PANEL
44. D/A AND A/D CONVERTER
45. SIGNAL FORMATTING
46. VHF ATTENUATOR
47. SCAN PROGRAM GENERATOR
48. CALIBRATION SIGNAL GENERATOR
49. NOISE FACTOR TEST SET

V VACANT PANEL SPACE (GROWTH)

Figure 5-7. Final Configuration - Primary Operator Console



LASER CONSOLE

1 TELESCOPE AND GIMBAL CONTROLS
2 VISUAL OPTICS CONTROLS
3 TRACKING (X, Y) DISPLAY AND CONTROLS
4 ALIGNMENT DISPLAY AND CONTROLS
5 COMPUTER/PROGRAMMER AND REFERENCE DATA ACCESS
6 NAVIGATION REFERENCE DISPLAY
7 REFERENCE DATA DISPLAY
8 HORIZON SENSOR MONITOR AND CONTROL
9 LASER POWER SUPPLY (CO_2 SYSTEM)
10 LASER POWER SUPPLY (Nd: yAG SYSTEM)
11 CIRCUIT BREAKER/FUSE PANEL
12 SUPPORT ELECTRONICS MONITOR AND CONTROL
13 SUPPORT ELECTRONICS
14 PANEL GROWTH SPACE
15 LASER SYSTEM ACCESS
16 OPTICAL FILTER ACCESS (CO_2 CIRCUIT)
17 INTERCOM

Figure 5-8. Final Configuration Laser Facility

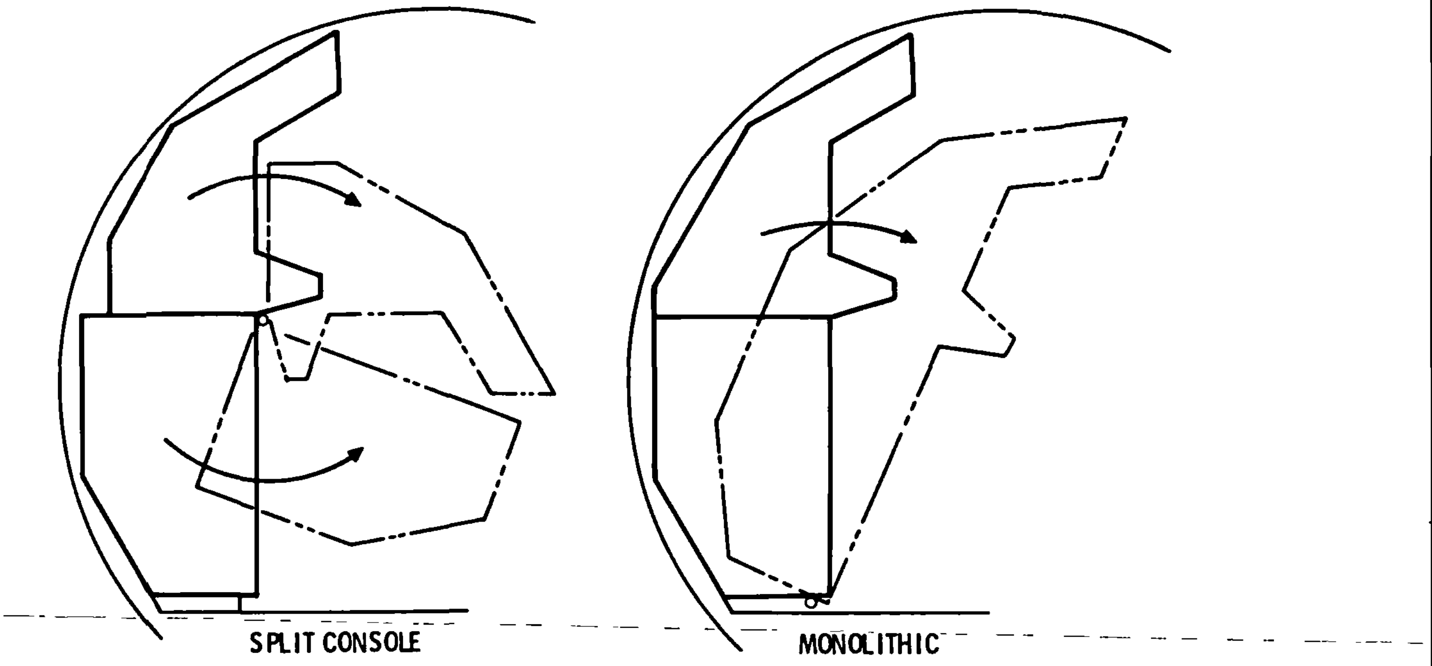


Figure 5-9. Console Pivot Alternates

External Experiment Accommodation

For the selected communications and navigation experiments all external experiment components are devices having a field of view requirement, antennas and telescopes. The specific components consists primarily of six RF antennas and two telescopes, one imaging and one spectral. The directed external support structure is the Sortie Module pallet which is a trusswork structure with a corrugated panel, see Figure 5-3, and which consits of four elements together totaling 60 feet long. For this mission only two sections of the pallet are necessary and in fact, when coupled with the Sortie Module, no more than two will fit within the Shuttle Cargo Bay. Also directed as baseline is the undeployed location of the pallet. Examination of several arrangements of the sensors on the pallet identifies that at least two of the antennas, the eight foot diameter parabolic and the log periodic dipole, will require accessory deployment to provide either a field of view or a dynamic clearance envelope. The example arrangement is shown in Figure 5-10 and visually demonstrates potential interferences between antennas in the form of beam obscuration

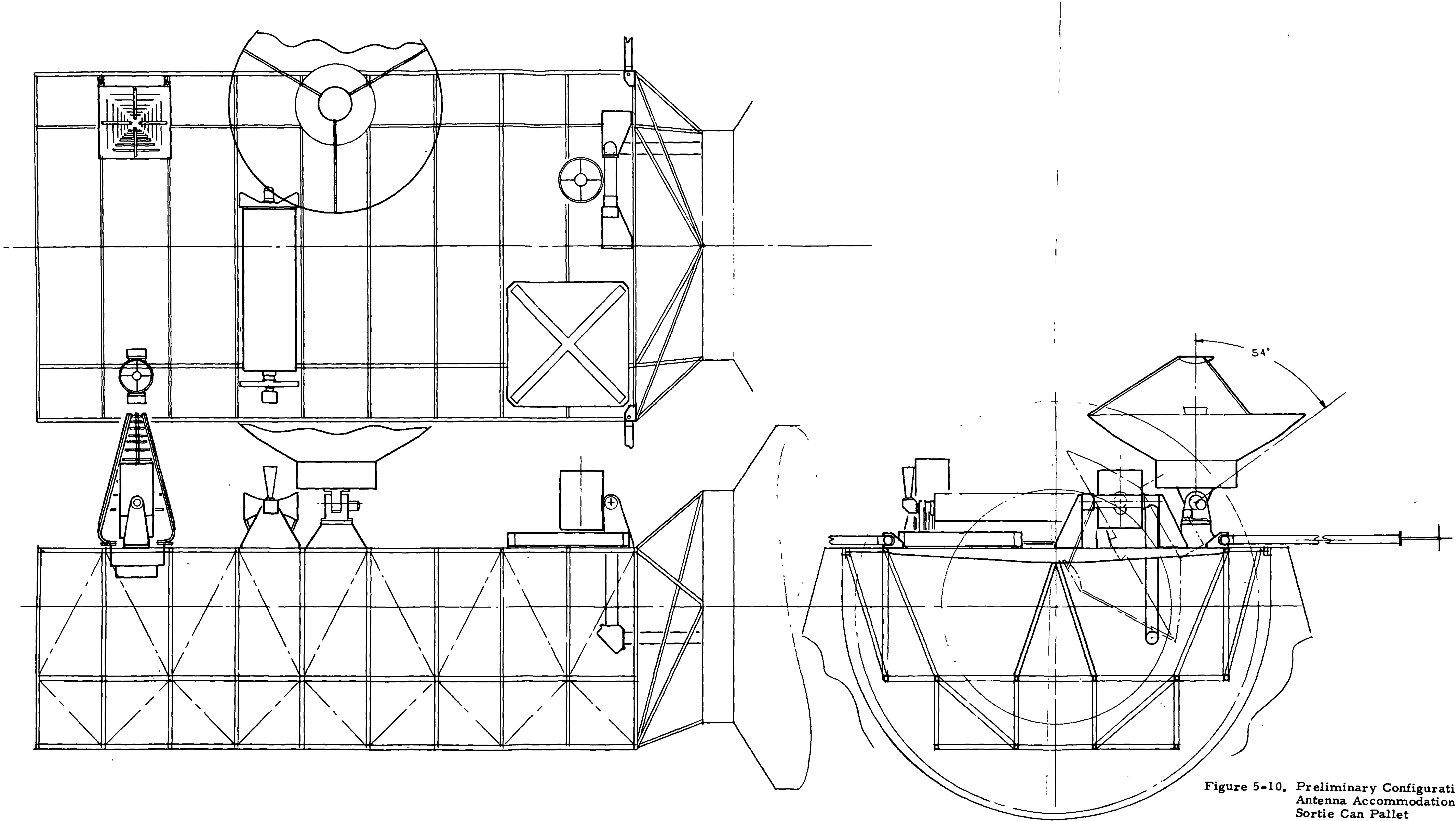


Figure 5-10. Preliminary Configuration
Antenna Accommodation
Sortie Can Pallet
(Scale 1/20)

or potential beam field effects. Continued examination of the pallet size convinces that insufficient space exists to seprate the selected sensors far enough to preclude some degree of mutual influences. The use of the Sortie Module and its pallet within the bay is certainly feasible but for the identified experiments might produce a degradation in data or data quality. It also appears that the optimum approach for this mode would fly the orbiter inverted and broadside to the line of flight.

5.2.2 Early Laboratory-Shuttle Orbiter Out-of-Bay Operation

The orbital configuration of the Sortie Module, shown in Figure 5-1 allows the Shuttle Orbiter to fly in a more propellant-optimum flight attitude. This approach, however, tends to place the sensors/antennas in or near the door-sill plane of the Orbiter. This allows adequate field of view for the antennas for Earth sites within 40 degrees to 60 degrees of Nadir, but restricts the field of view for some antennas in the vicinity of the horizone and of any antenna required for relay satellites. Maneuvers to make other satellites visible to the antennas would have an impact on stabilization propellant consumption and on simultaneous earth-ward fields of view. Configurations based on deploying the NASA Sortie Module and pallet were not considered.

In recognition of the potential antenna blockage, thermal control, and wave guide run problems with an in-the-bay payload antenna farm, an alternate design approach was studied. The pressurized module end dome ring was modified to accept a 16-foot boom structure operated by a double spline gear drive motor system. After a 90 degree rotation of pressurized module out of the Orbiter bay, the antenna boom is erected and oriented normal to the Shuttle longitundinal axis. This orientation offers several advantages. It permits antenna placement well above the Shuttle for fuller RF field of view and at the same time shortens antenna transmission coaxial cable runs to approximately one half that of the in-bay concept. Secondly, this version will permit antenna boresight error adjustments to be made. A precision optical target boresight system is anticipated for this concept. The modified dome mounting would be provided as another experiment unique device equivalent to other exterior hardware.

The disadvantage of this concept relates to fail safe operations. Positive means would have to be employed to insure that the pressurized module with its antenna boom would retract and rotate back into the Shuttle Orbiter bay so that the bay doors could be closed for Earth entry/landing.

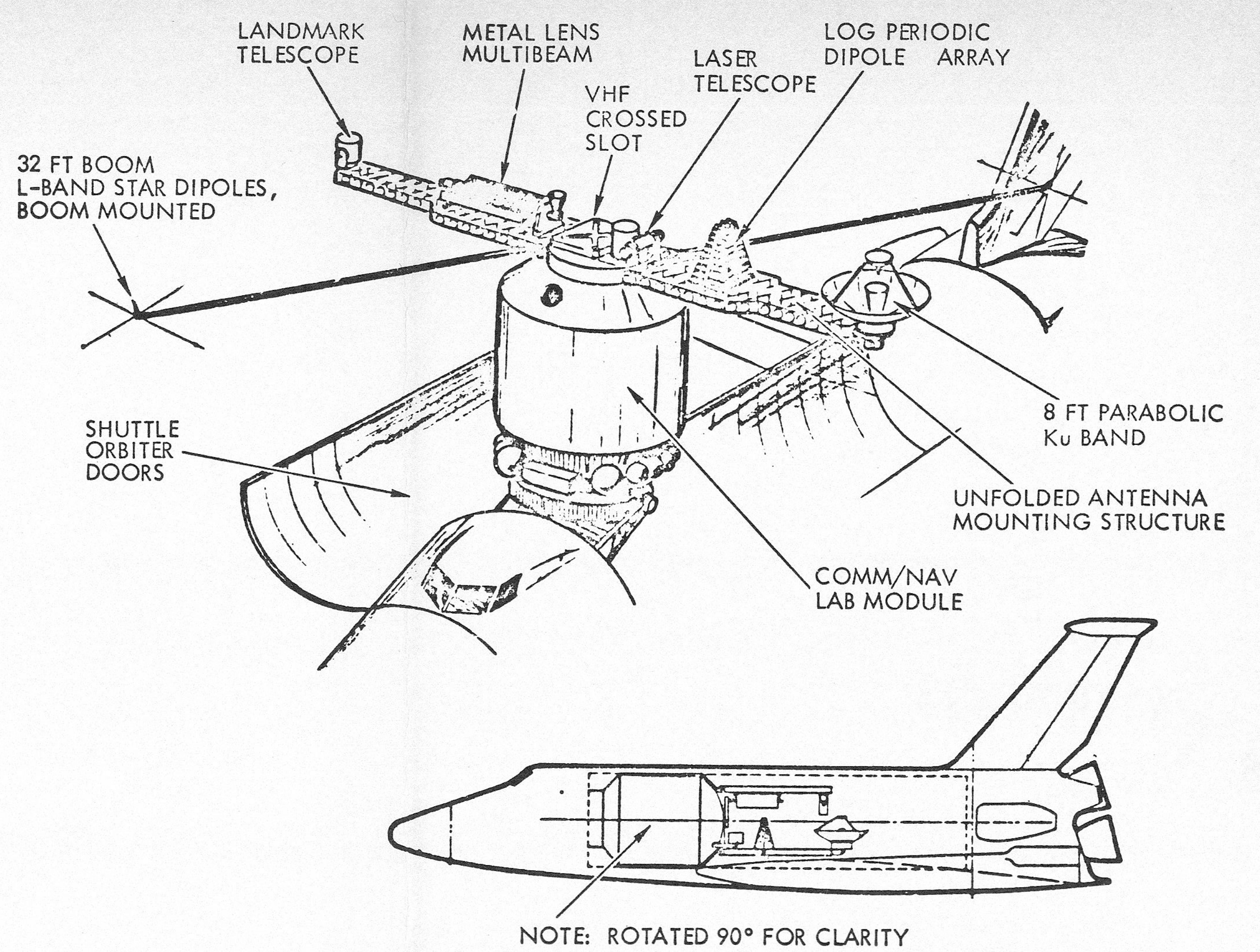
An external support structure was generated which is customized to the requirements of the experiment sensors/antennas. One of the key influences lies in the fact that most of the sensors have larger field-of-view requirements along the line of flight than transverse to it. This would indicate some form of support structure that arrays the sensors/antennas transverse to the line of flight for minimum interferences. The only way to achieve adequate array span and optimum orbiter attitude is to deploy the system out of the Shuttle bay.

The deployed (out of the Orbiter bay) laboratory case considered was based on a specially designed sensor support. Figure 5-11 shows the orbital configuration of this approach for a tilt (90°) table mode.

Several concepts were considered and layouts of a folding beam (butterfly) were generated. A feasible arrangement was accomplished but no attempt was made to optimize beam size and sensor arrangement. Figure 5-11 shows this system. The end dome closing structure of the Sortie Module has been replaced by a shallow membrane dome and a cylindrical beam support ring. This ring incorporates the support and hinge fittings for the folding beams. This ring also supports within it the VHF crossed slot antenna. On opposing sides of the ring are the hinge fittings, the beam deployment drives and the vernier drives for beam alignment. Each beam has two hinge points with drives in each for redundancy. The drive consists basically of a double ended drive motor on the beam centerline, a drive shaft (from each end of the motor) and two harmonic systems in the hinges, see Figure 5-12. The circular spline is eight inches in diameter and the pitch diameter between the circular spline and the flex spline is 7.25 inches. The wave generator is driven by the double ended motor.

Span wise the beamwidth is stepped and the beam structure consists of two channel beams approximately 15 feet long and spaced 24 inches apart. These two channel beams are flanked by two more beams approximately 8 feet long and spaced 12 inches outboard. The four channel beams are formed into a box structure by facing panels which are an open laticework of a triangular pattern. This structure should yield a reasonably minimal weight and have good thermal stability, a prerequisite for pointing alignment stability.

The sensors are located on the two beam structures to minimize mutual interferences both deployed and stowed. One beam mounts the 5-inch optical telescope and the 2 foot x 6 foot (approximate) microwave lens antenna. The optical telescope is mounted on a 2-axis gimbal and has



COMM/NAV RESEARCH LABORATORY OPERATING OUT-OF-BAY
BUT ATTACHED TO THE SHUTTLE ORBITER

Figure 5-11. Sensor Accommodation
Comm/Nav Sortie Module
Out-of-Bay Configuration

CONTRACT NO.			MCDONNELL DOUGLAS ASTRONAUTICS CO. WESTERN DIVISION HUNTINGTON BEACH, CALIFORNIA MCDONNELL DOUGLAS	
ORIGINAL DATE OF DRAWING			SENSOR ACCOMMODATION COMM/NAV SORTIE	
PREPARED	VESTERPEAL	1-25		
CHECKED				
ENGINEER				
DESIGN ACTIVITY APPROVAL			SIZE	CODE IDENT NO. 18355	DRAWING NO.
CUSTOMER APPROVAL			SCALE 1/20	SHEET 1 OF 1

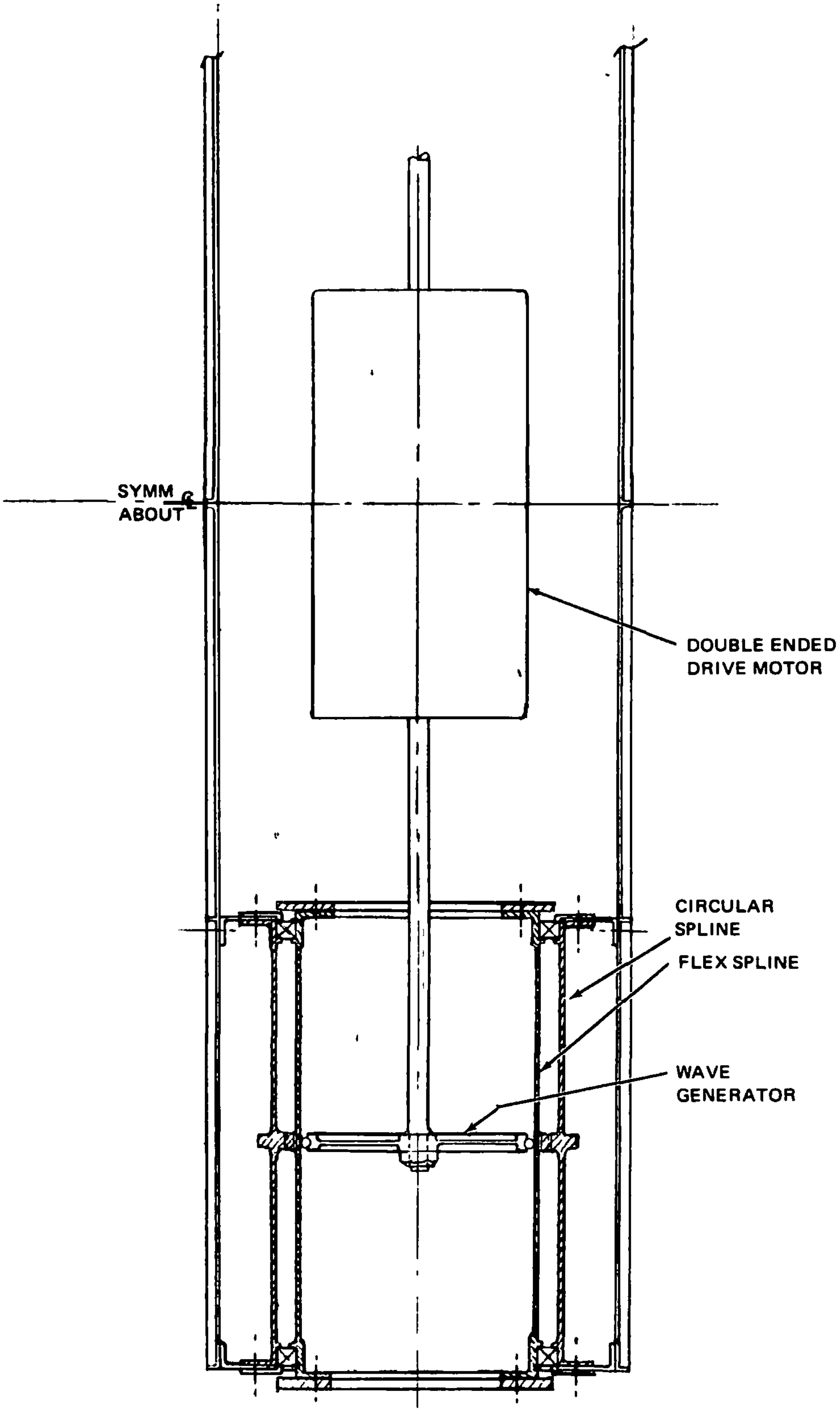


Figure 5-12. Beam Deployment Drive

a field of view available ± 90 degrees along the flight path and 90 degrees to one side of the flight path but only 75 degrees to the other side. All parameters exceed the goals of the sensor. The lens antenna is mounted on a single axis gimbal providing ± 90 degrees sweep along the flight path but lateral scanning is done electronically by the sensor itself. Again all pointing goals are exceeded. The other beam structure mounts the 8-foot diameter parabolic antenna, the 5-foot (approximately) log periodic dipole antenna and the 18-inch optical telescope for the laser systems. The large parabolic antenna needs to establish contact with both ground sites and orbiting satellites. For this field of view requirement, the 2-axis gimbal mount was located at the end of the beam such that the allowed hemispherical field of view has a "horizontal" axis and lateral to the flight path, see Figure 5-13 for obscuration map. .p. The laser telescope is mounted at the inboard end of the beam structure. It is mounted on a 2-axis gimb al system which incorporates light tube elements. The light tube segments pass the laser signal from any gimbal deflection position to the feed through in the pressure bulkhead and to the internal laser equipment. The laser telescope has a full hemispherical field of view, with its axis to Nadir, except for lateral intrusion by the other antennas on the two beam structures. The full horizon to horizon Earth surface remains unobscurred. Two crossed dipole antennas are boom mounted (separately) to booms which are hinge mounted to the outside channel beam in the plane of the main beam assembly. The booms are folded (two segments) along side the beam assemblies for stowage and deploy to angle of approximately 45 degrees with respect to the main beam assembly for use. The extended booms are approximately 32 feet long.

In general, when a significant number of antenna or telescope type sensors are to be flown on a common mission, the large line of flight viewing requirements would place them in a transverse and external (to the Shuttle) array. The concept presented here is not an optimized one and may not necessarily be appropriate to all groups of sensors but is representative of the kind of solution needed.

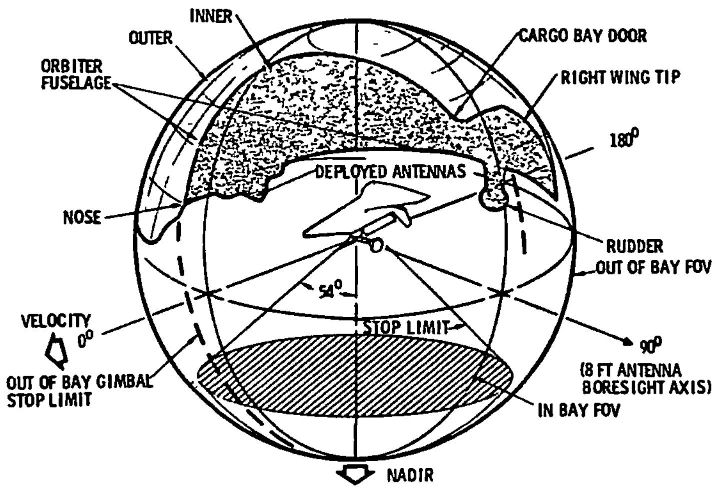


Figure 5-13. Antenna Obscuration-Data Relay Experiment

5.2.3 Early Laboratory Systems Summary

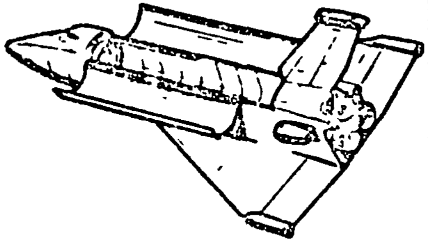
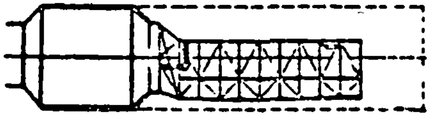
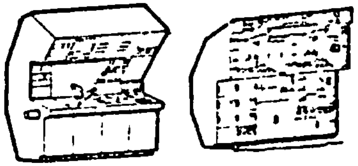
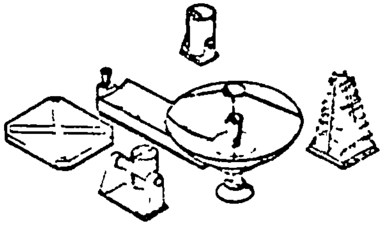
The major elements of the CNRL Orbital system consist of the Shuttle Orbiter, the Sortie Module/Pallet, and the CNRL equipment. The latter may be divided into the console equipment installed within the Sortie Module, and externally mounted antennas, etc., accommodated on the pallet.

Figure 5-14 summarizes the major functions performed by each element of the system for a conceptual baseline case together with some of the options which may be appropriate to consider in the future.

This conceptual baseline has been developed to allow the definition of overall mission requirements and operational characteristics of the Laboratory. The primary operator console accommodates the common core and experiment unique equipment needed to conduct investigations in all of the seven candidate, Early Lab experiment classes with the exception of Laser Communications. The nature of the Laser Comm equipment is such that it requires a console dedicated exclusively to investigations in this experiment class.

In addition to antennas and optical devices, other equipment mounted on the pallet includes selected receivers and transmitters (to maximize signal/data quality) and the equipment necessary to interface this equipment with the Sortie Module/Shuttle. As defined at this point in the Study, the CNRL equipment has essentially autonomous capability with regard to experiment control and display, and data management including computer support. The Sortie Module provides the resources of atmosphere, thermal control, data management and electrical power while the Shuttle provides crew services (hygiene, eating, sleeping, waste management), uplink/downlink communications and guidance/navigation/control.

Results of the study show the capability of this orbital system to be highly responsive to the mission requirements developed for the candiate experiment program. To enable NASA planners to identify the most effective mission plan however, it is appropriate to identify and discuss a variety of options or alternatives to the conceptual baseline. The interfaces between the CNRL and the Host system will certainly change as the Shuttle Program enters Phase C and the MSFC Sortie Module Project

	SHUTTLE	SORTIE MODULE	CNRL EQUIPMENT	
				

CONCEPTUAL BASELINE	• TRANSPORTATION
	• USER CREW SYSTEMS
	• COMMUNICATIONS
	  • VOICE
	  • DIGITAL DATA
	  • ANALOG/VIDEO
	• DATA MANAGEMENT
	  • STATUS MONITOR
	  • CAUTION/WARNING
	• STABILIZATION/CONTROL
	• GUIDANCE/NAVIGATION
		• HABITABLE VOLUME
		• ATMOSPHERE SUPPLY/CONTROL
		• THERMAL CONTROL
		• ELECTRICAL POWER/ENERGY
		• DATA MANAGEMENT (NON EXP)
		• STORAGE
			• PRIMARY OPERATOR CONSOLE
			  • DISPLAY/CONTROL
			  • DATA MANAGEMENT
			  • EXP EQUIPMENT
			• LASER CONSOLE
			  • LASER TRANSMITTERS
			  • VIDICON
			  • CONTROLS/DISPLAYS
			• INTERFACE EQUIPMENT
				• ANTENNAS
				• LOW NOISE RECEIVERS
				• TRANSMITTERS
				• OPTICS
				• INTERFACE EQUIPMENT

OPTIONS	• ELECTRICAL POWER/ENERGY
	• ATMOSPHERE SUPPLY/CONTROL
	• HEAT REJECTION
	• GENERAL PURPOSE CONTROLS/DISPLAYS
		• DEPLOYMENT (TILT TABLE)
		• MODIFIED END DOME
		• ATTITUDE SENSING
		• EXPERIMENT SUPPORT EQUIPMENT
		• ADDITIONAL CREW
		• DATA MANAGEMENT (EXP)
		• GENERAL PURPOSE CONTROLS/DISPLAYS
			• USE OF HOST VEHICLE STANDARD SERVICES
			  • COMPUTATION
			  • DATA MANAGEMENT
			  • DISPLAY/CONTROL
			• ALTERNATE INTERIOR CONFIGURATIONS
				• REDUCED CAPABILITY
				  • PALLET ONLY
				  • MIXED PAYLOAD
				• DEPLOYED MODE
				• ADDITIONAL ANTENNAS

Figure 5-14. CNRL Orbital System Description

enters Phase B. For example, data currently available suggests possible operational constraints in the areas of heat rejection and pointing duration. The ultimate capability of the host system in these areas may influence the design and operational characteristics of the CNRL. Conversely, the importance of defining the candidate experiment program as early as possible should also be emphasized in order to identify critical Shuttle interface areas while it is still possible to influence the design of the various elements of the orbital system.

As noted earlier, the CNRL baseline is nearly autonomous with respect to experiment control and display, data management and computer support. The option of utilizing Sortie Module support in these areas has the attractive potential of reducing CNRL equipment cost, size, and complexity. Development of such an interface will require verification of compatibility with crew usage requirements.

Of all the alternatives to be considered, the impact of "mission modes" on the CNRL configuration is critical. The current configuration fits the "dedicated mission" category. The nature of the CNRL orbital investigations program and equipment fully utilizes the crew, supporting resources, and operational capacity of the host systems as defined for the study. The possibility exists that the payload community may choose to emphasize missions other than the dedicated mode, particularly during the early phase of Shuttle operations. The "pallet only" and "mixed discipline" modes are two to be considered. In the former, only un unpressurized pallet is available in the cargo bay with crew functions performed from the Orbiter cockpit. In the latter, the capability of the Sortie Module/ Shuttle is shared with a number of experiments representing two or more disciplines (e.g., Earth Observations/Material Science). In both cases, the definition of compatible CNRL mission requirements will change significantly compared to the dedicated mission definition.

With the current interest in early CNRL mission opportunities (including aircraft programs), serious considerations should be given to examining alternate CNRL missions of this kind..

In summary, the CNRL conceptual baseline, together with examination of the options identified, will allow NASA planners to assess alternative mission plans and develop the most cost effective total system operation.

Inboard/Outboard Profile - Pertinent dimensional relationships are shown in Figure 5-15 for the Standard Sortie (26 foot side wall length) Module together with a 30 foot pallet. The "short" Sortie Module (16 foot side wall length) was examined to determine compability of this configuration with CNRL console installation requirements. Compatibility was judged marginal. Insufficient volume exists in the "short" Module to accommodate Sortie Module console and subsystem installations together with CNRL consoles. Conversely, redefinition of the CNRL equipment to maximize use of Sortie Module services (e.g., computer, data management, control and display) may result in sufficient size reduction of the CNRL primary operator console to achieve compatibility with the "short" Module. Furthermore, deletion of the laser console would achieve compatibility while allowing investigations in six of the seven Early Lab experiment classes to be accommodate.

The conclusion, however, is accommodation of CNRL equipment in the 306 inch "Standard" Sortie Module results in adequate installation volume for all known requirements, and allows for potential growth of Module equipment, Module services, and/or Module experiments and is, therefore, selected as the CNRL baseline concept.

Sortie Module Assembly Concept - Figures 5-16 and 5-17 illustrate the technique of experiment equipment installation in the Sortie Module utilizing the equipment support structure or "birdcage" concept. Figure 5-15 noted the Sortie Module hatch size as 60 inches. If experiment equipment installation is limited to this method of access, modular console design would be required and reconfiguration of the Sortie Module between flights could conceivably exceed the time available.

By utilizing bolted and sealed end sections on the Sortie Module, as opposed to a welded joint, full diameter access to the Sortie Module interior is provided. If desired, the pressure shell may be removed allowing back access to equipment for maintenance, modification or reconfiguration without requiring console removal.

CNRL Subsystem Interfaces - Figure 5-18 summarizes the major interfaces between the Shuttle, Sortie Module and Early Laboratory CNRL equipments.

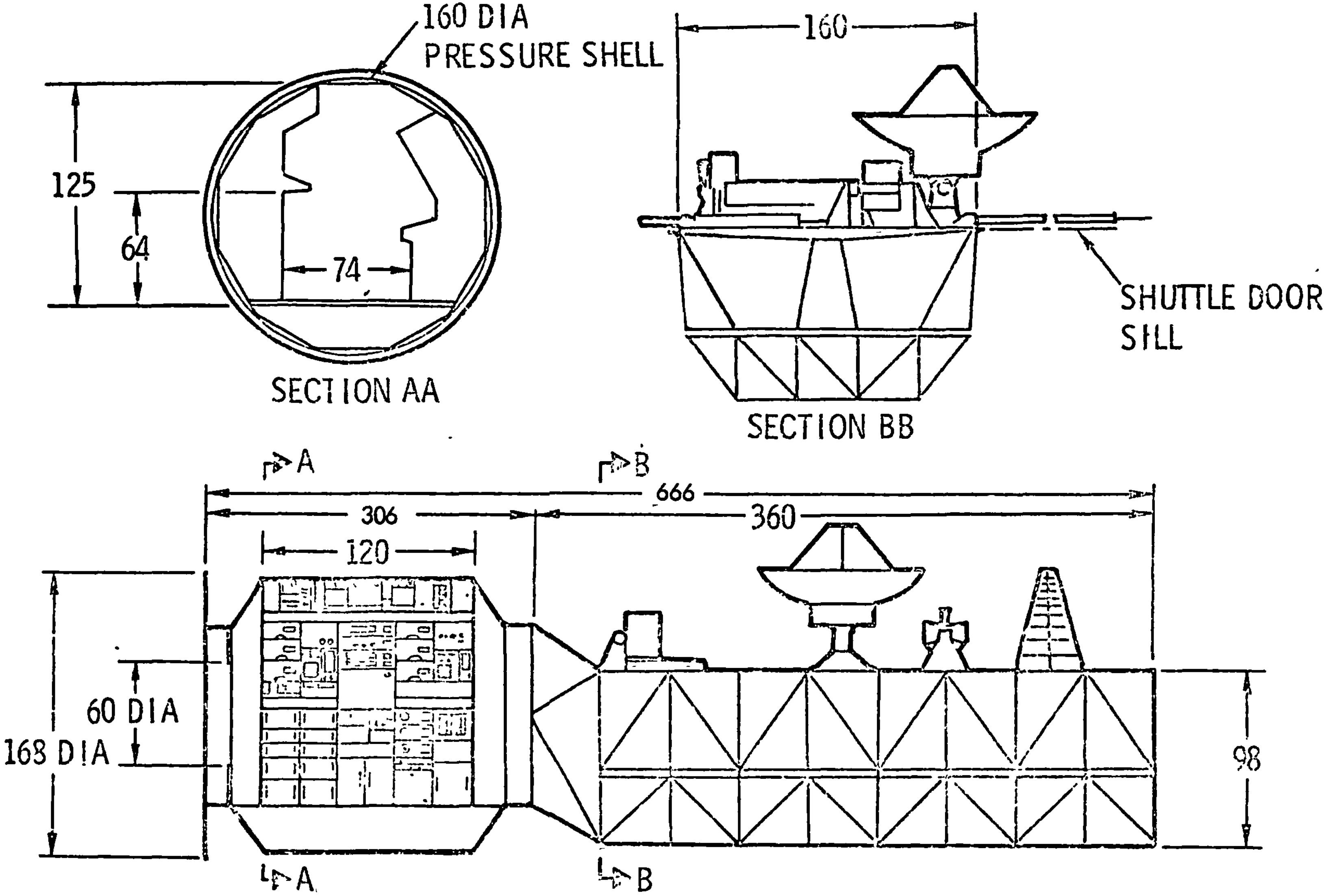


Figure 5-15. Communication/Navigation Research Laboratory Inboard Outboard Profile

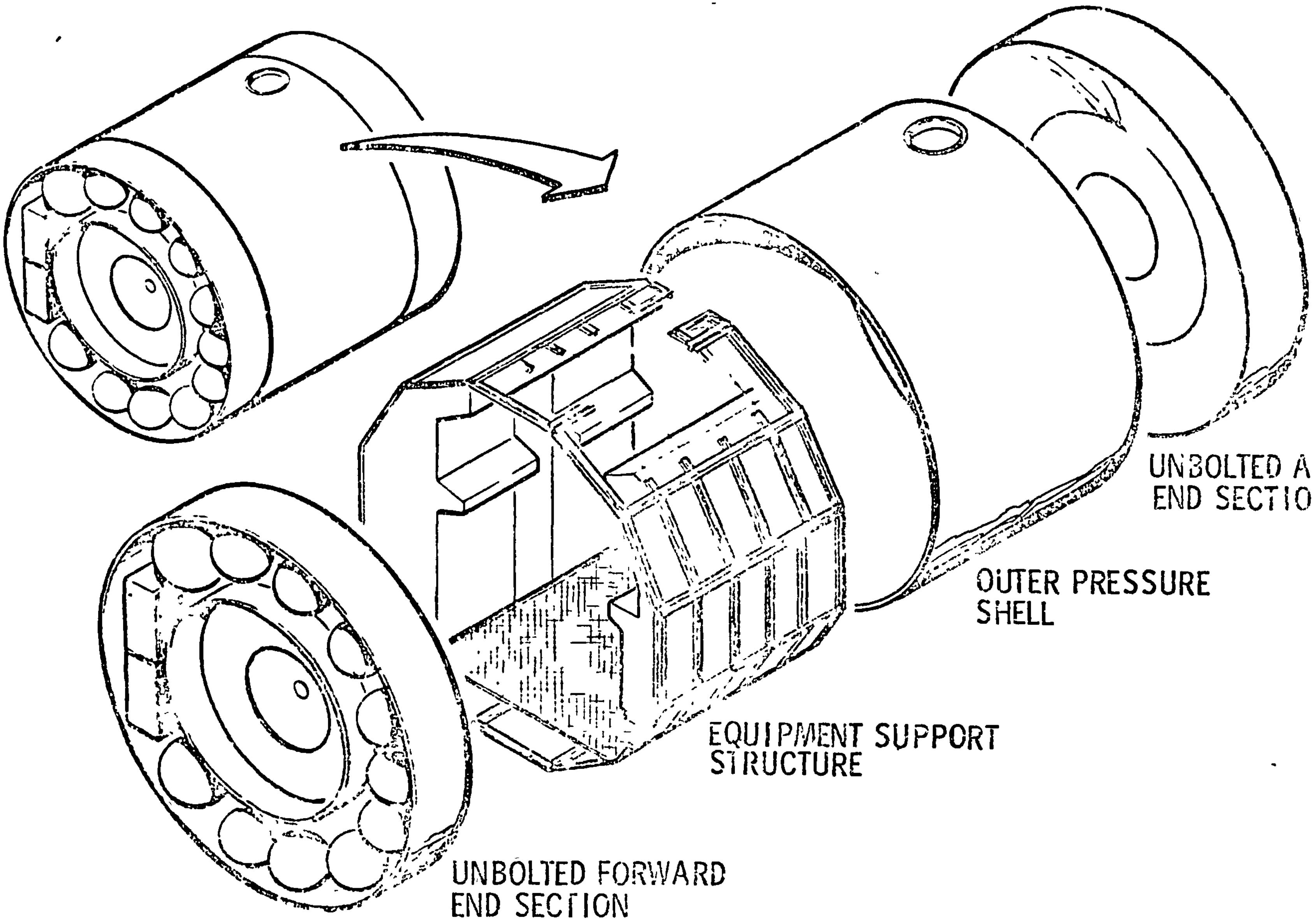


Figure 5-16. Sortie Module Assembly Concept

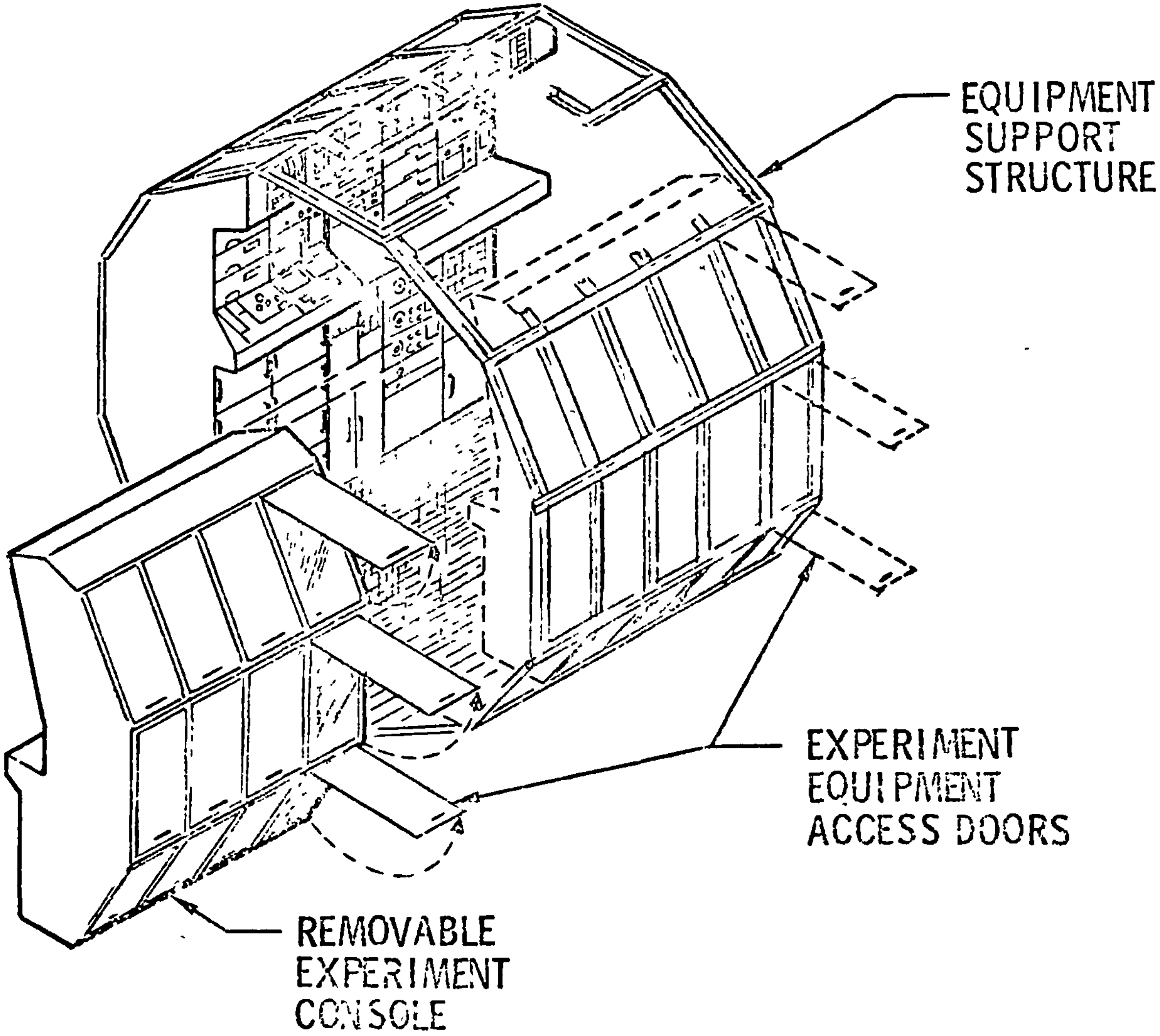


Figure 5-17. Sortie Module Experiment Equipment Installation

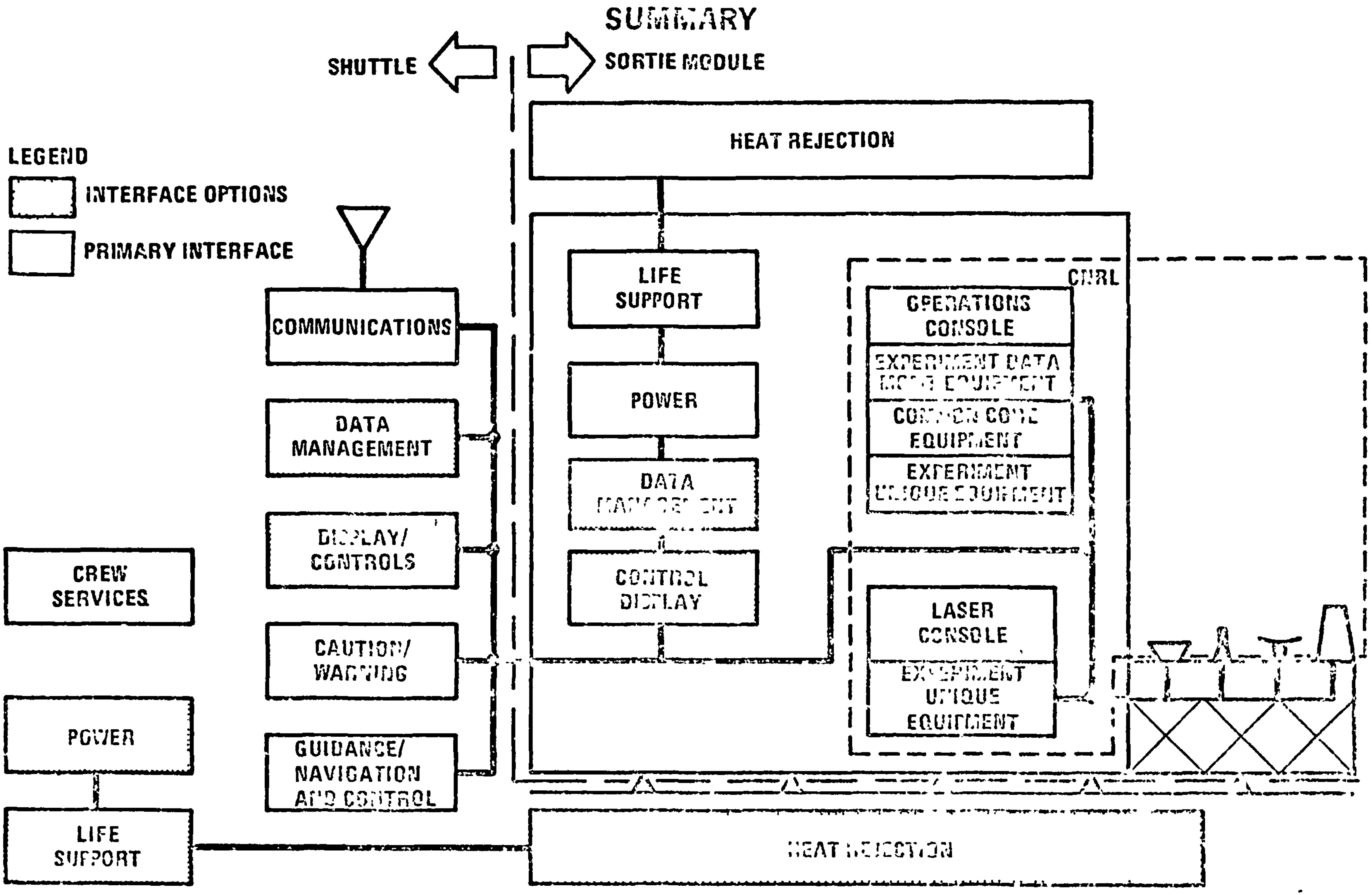


Figure 5-18. CNRL Subsystem Interfaces

Weight Summary - The table below gives summary weight data on the various CNRL Early Laboratory configurations.

Comm/Nav Laboratory Weight Summary

ITEM / CONFIGURATION	WEIGHT (LBS)		
	Short Sortie Mod/ In-Bay Config.	Std. Sortie Mod/ In-Bay Config	Std. Sortie Mod/ Out-of-Bay Config
1. Std. Sortie Can Baseline Wt.	- - -	11, 727	11, 727
2 Short Sortie Can Baseline Wt. (60% of Standard Sortie Can Structure Wt.)	10, 354	- - -	- - -
3. Mission Support Consumables	2, 391	2, 391	2, 391
4. Data Management, Networks, and Display (Standard)	[1, 423]	[1, 423]	[1, 423]
5. Basic Net Module Weight	11, 322	12, 695	12, 695
6. Comm/Nav Console Main-Frames, Common/Unique Equipment, Instrumentation (Including DMS, Networks, and Display)	3, 230	3, 230	3, 230
7. Total Module Weight	14, 552	15, 925	15, 925
8. 30-Ft. Pallet Structure	800	800	- - -
9. External Sensor Mounting Structure (Including Folding Booms and Drive Mechanism)	- - -	- - -	400
10. Antennas, Drive Systems, Electronics	1, 185	1, 185	1, 185
11. Total Laboratory Payload	16, 537	17, 910	17, 510

5.3 FUTURE OPTIONS

5.3.1 Growth Laboratory

In the time (1985-1990) between Early Laboratory flights and the advent of the Total Laboratory, there could be a period of laboratory evolution as mission duration increases and experiment lists expand. The implementation of Comm/Nav research in this time frame may have these characteristics:

- New experiment complement
- Extension of Early Laboratory experience
- Precursor to Total Laboratory
- Free-flyer capability
- Improved geographic coverage
- Extended mission time on orbit
- Exploit/evaluate EVA capability
- Deliver automated spacecraft (subsatellites) to orbit for advanced cooperative experiments

with the following consequences:

- Revised laboratory interior and exterior configuration
- Evolutionary equipment development
- Increased equipment complement and crew size
- Docking adapter required plus an autonomous module and support subsystems
- Additional crew/life support
- Airlock required
- Mounting, checkout, ejection systems

A conclusion of this is that the Growth Laboratory will assume several forms, some of which are shown in Figure 5-19.

Growth Laboratory operational assumptions:

- 1985 - 1990 time period
- 1 month to 1 year mission duration
- 2 to 4 experimenter crew
- Growth Laboratory is Shuttle Orbiter supported or serviced
- Laboratory accommodates up to 12 experiment classes. Candiate list could be seven experiment classes on the Early Laboratory plus
  - Susceptibility of Terrestrial Systems to Satellite Radiation (Class Number 2, page 1-7)

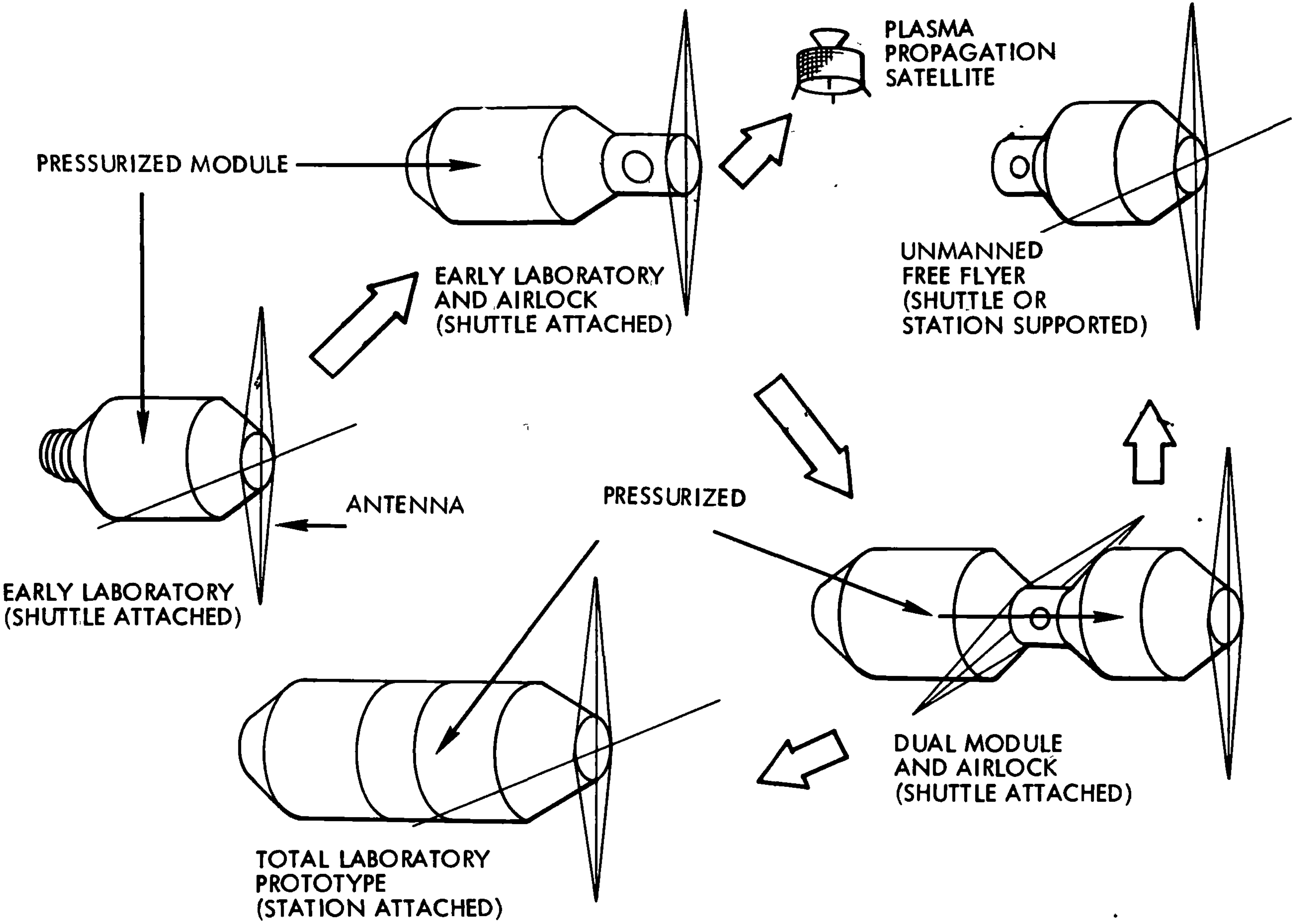


Figure 5-19. Growth Laboratory Evolution

  - Plasma Propagation (Class Number 5, page 1-7)
  - On-Board Data Processing (Class Number 8, page 1-7)
  - Narrow Beam Tracking (Class Number 13, page 1-7)
  - Range and Range Rate Navigation and Surveillance Techniques (Class Number 14, page 1-7)
  - Horizon Altitude and Radiance Profile Measurement (Class Number 18, page 1-7)
- Early lab subsystems with component update
- Increased automated events
- Some EVA
- Increased commercial equipment
- Some scheduled maintenance
- Increased on-board data processing and analysis

5.3.2 Total Laboratory

This is envisioned as a completely furnished space facility having a large complement of common core and experiment unique Comm/Nav research equipment and apparatus, Figure 5-20. The Space Station attached laboratory is constrained primarily by available volumetric work areas within the module envelope of about 14 ft. diameter and 50 ft. length. The ultimate design concept for a laboratory capability to accommodate the total research program, as an evolutionary development, must be approached cautiously. It is apparent that a meaningful definition of the Total Laboratory may not "evolve" from the 18 experiment classes. Some alternate starting point must be established to use as a basis for generating design characteristics and mission plans.

One approach is to define the various missions or tasks to be assigned to the Total Lab. A list of such specific tasks might include:

1) Conduct unique experiments on Comm/Nav related questions. These experiments could vary from 10 days in duration to 90 days. Most experiments of this type would probably involve demonstration of Comm/Nav hardware. The equipment would arrive at the laboratory and be installed or assembled by a special crew (not

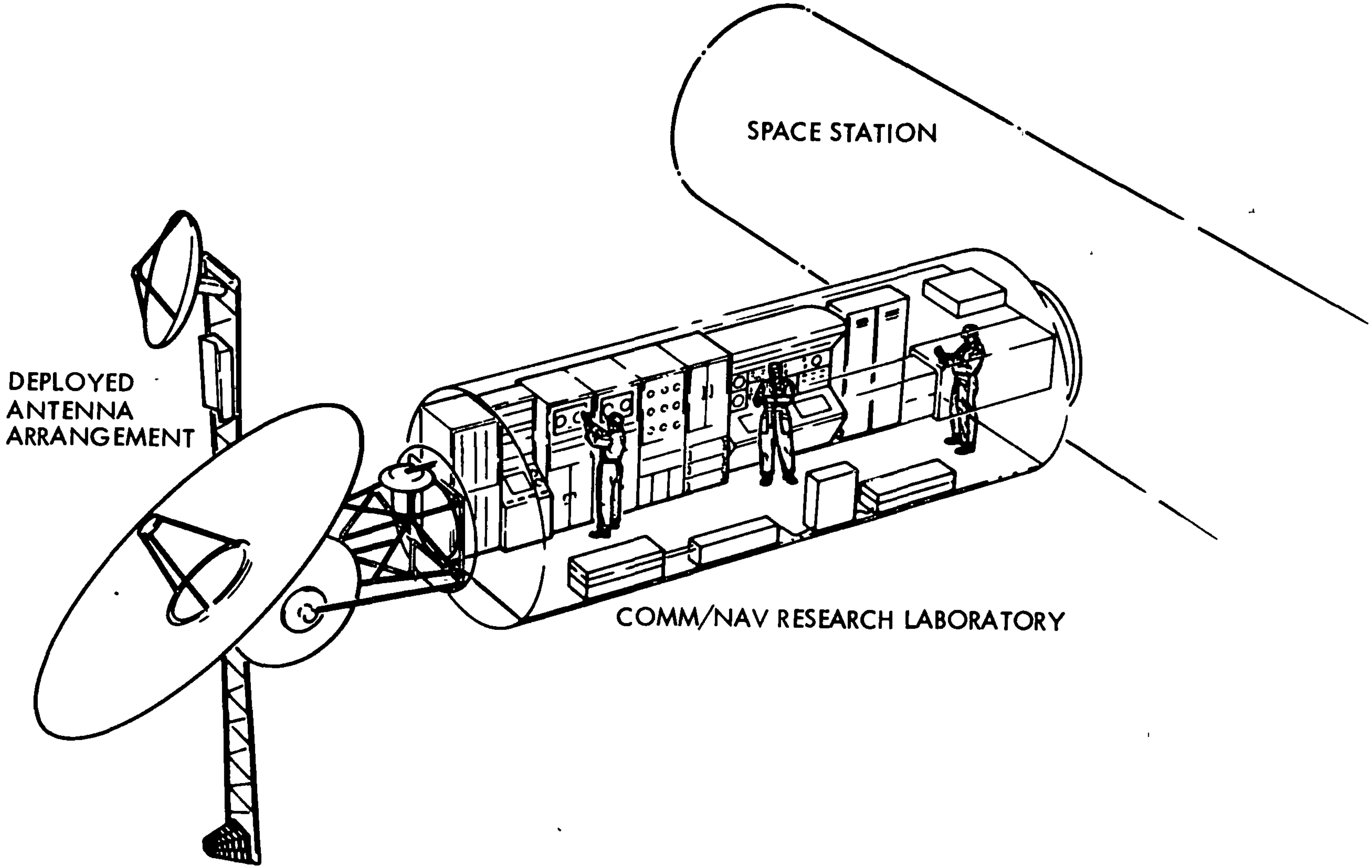


Figure 5-20. Concept of a Total Comm/Nav Research Laboratory Attached to the Space Station. Carries all Experiments. Is Flexible/Multipurpose. Maximum Commonality.

laboratory personnel). The principal scientist would check out the experiment and verify the installation before dismissing the special crew.

2) Provide data and/or other services in support of experiments in other disciplines. This might involve surveys of terrestrial noise in support of radio astronomy, measurement of propagation effects in support of earth observation sensors, etc. Many of these missions would involve a cooperating satellite.

3) Conduct long-term/routine surveys of the natural environment. This might be classified as a quasi-operational mission. It would utilize the large laboratory capabilities (power, space, weight, manpower) to conserve downlink bandwidth.

4) Provide emergency or backup services in support of other space activities.

5) Monitor the performance of operational satellite systems where the unique geometry or other capabilities of the laboratory can be employed.

The assumption that a single Total Laboratory design able to meet unlimited mission conditions is probably unrealistic. This is due to incompatible operational considerations which also must be inserted into the design approach. A mixture of operational conditions for measurements, such as an elliptical or low polar orbit, may not be cost effective to combine with a synchronous orbit requirement although the baseline instrumentation and crew skills are almost identical. This suggests careful screening of all relevant measurement accommodation parameters to determine their true operational feasibility. In addition to the specific measuring techniques and appropriate equipment selected, such items as orientation and pointing, duration of measurement, repeatability of data, location of ground support sites, altitude and inclination, and crew involvement, will be blended together into a total capability. If design compromises exceed reasonable limits, the design approach must be altered to the point of maximum accommodation and this does not necessarily infer total accommodation. The initial analyses of total requirements should be extended and iterated to a "best fit" solution or set of solutions in the course of developing the configuration and layout of the Total Laboratory.

Total Laboratory operational assumptions:

- 1990 ——→ time period
- 2 to 10 year mission duration
- 6 experimenter crew
- Delivered to orbit by Shuttle Orbiter, then attached to the Space Station during the mission, resupplied by Shuttle
- All (18) experiment classes accommodated (page)
- Highly automated
- Scheduled EVA
- Significant use of commercial equipment
- Routine maintenance and repair. Fault isolation
- Extensive on-board data processing and analysis

5.3.3 Equipment and Crew Considerations for Future Option Missions

The information to follow is summary compilations of the Maintenance (Figure 5-21), Antenna Requirements (Figure 5-22), Receiver Requirements (Figure 5-23), Transmitter Requirements (Figure 5-24), Optical Devices Requirements (Figure 5-25) and Crew Equipment Interfaces (Figure 5-26) for all experiment classes. Therefore this information can be applied to both Early and Future Options Comm/Nav Laboratory.

Maintainability/Reliability	Early Lab (7 days)	Growth Lab (30 days)	Total Lab (1 year)
a) Schedule Maintenance	None required - equipment should not require maintenance during this mission.	No more than one scheduled maintenance per equipment. Design goal is no scheduled maintenance.	Design goal for maintenance intervals is 90 days, minimum acceptable is 60 days.
b) Unscheduled Maintenance	Time to repair failed equipment should not exceed 2.0 hours.	Time to repair failed equipment should not exceed 1.0 hours.	Time to repair failed equipment should not exceed 0.5 hours.
c) Calibration*	None required - equipment should not require calibration during this mission.	No more than one scheduled calibration per equipment. Design goal is no calibration required for this mission.	Design goal for calibration intervals is 90 days, minimum acceptable is 60 days.
d) Electronic Parts	Commercial	Military JANTX and ERMIL	Military JANTX and ERML
e) Derating of Parts	Standard Commercial Practice	Derate highly stressed parts to 75%	All parts derated to 25 to 50%
f) Mission Reliability	0.99	0.99	0.99
or			
Mean Time Between Failures	16,800 hrs.	72,000 hrs.	876,000 hrs.

---

* All equipment will be calibrated and the necessary scheduled maintenance performed on the ground before each flight. These activities will be accomplished within 30 days before each flight.

Figure 5-21. Future Options - Maintenance

CLASS EXPMT. NO.	FREQUENCY RANGE (GHZ)	ANTENNA TYPE	GAIN (dBi)	HALF POWER BEAMWIDTH (DEGREES)	FEED TYPE	POLARIZATION	SIZE (DIA. x LGH)	COMMENTS
1 2, 6 3, 5 7 14	0.13 -1.7 0.62 -0.79 0.1 -0.7 0.136-0.162 1.54 -1.66	LPDA* No. 1 0.1-1.7GHz	Variable 3 - 13	Variable 30-100	N/A	RHCP LHCP HORIZ. VERT.	96" x 120"	Fixed, but must be deployed
1 2 5, 8 6	1.7 -6.4 2.5 -4.2 2.0 -2.3 2.5 -2.7	LPDA*No. 2 1.7 - 6.4GHz	Variable 3-13	Variable 30-100	N/A	RHCP LHCP HORIZ. VERT.	12" x 12"	Fixed.
15	1.5 & 5.0	Crossed Dipoles	3	90-100	N/A	RHCP	5" x 3" and 1.5" x 2"	Antennas deployed 60 feet apart during EVA
1 3, 5 6 8	14 - 14.5 10 - 15 11.7 - 12.2 13.4 - 15.35	HORN 8.0 - 15.0GHz	12-15	30-40	N/A	RHCP LHCP HORIZ. VERT.	5" x 12"	Positionable, Azimuth, Elevation, and Polarization
1	11 - 14	Open-End Waveguide	0	120	N/A	RHCP LHCP	2.0" x 6"	Fixed
7 11	11 - 14 GHz 2.5 - 2.7 3.7 - 4.2 17.7 - 21.2	Parabola	22 - 40	1.5 - 11.0	Multihorn Focal Point Interchangable	RHCP LHCP	30" x 15"	Positionable, Azimuth and Elevation requires computer positioning
7, 13	13.25 - 15.35	Parabola 13.25-15.35 GHz	42	1.2	Cassegrain Monopulse	RHCP LHCP	48" x 24"	Positionable, Azimuth, Elevation. Computer drive and Autotrack
3	17.7 - 31.0	HORN 17.7-31.0 GHz	12 - 15	30 - 40	N/A	RHCP LHCP HORIZ. VERT.	1.5" x 4"	Positionable, Azimuth, Elevation and Polarization
3	59 - 64	Parabola 59-64 GHz	58	0.2	Cassegrain Monopulse	RHCP LHCP	72" x 36"	Positionable, Azimuth and Elevation Computer drive and Autotrack
10	3.0 - 30 KHz ELF/VLF	Long Wire	-13 to -20	90 - 180	N/A	LINEAR	Up to 0 8 mi	Deployable Long Wire

Figure 5-22. Comm/Nav Laboratory Antenna Requirements Summary

Experiment Number and Class	Receiver Frequencies												Receiver Type								Pre-Detection BW	Post-Detection BW(s)	Sensitivity	Dynamic Range	Demodulation Type	Sweep Rate
	3 KHZ	30 KHZ	100 - 200 MHZ	200 - 400 MHZ	400 - 800 MHZ	800 - 1700 MHZ	1.7 - 2.7 GHZ	5.0 - 10.0 GHZ	10 - 15.3 GHZ	17 - 20 GHZ	27.5 - 31 GHZ	60 GHZ	Superheterodyne	Phase Lock	Linear	Tracking	Transponder	AGC	Fixed Frequency	Swept Frequency						
Band	1	2	3	4	5	6	7	8	9	10	11	12														
1. Terrestrial Sources of Noise and Interference			x	x	x	x	x	x	x				x		x			x		x	Adjustable(1)	≥pre-detection BW	-120 dBm	60 dB instantaneous, 120 dB	AM, PM envelope	Two receiver BW/minute
3. Radio Frequency Propagation			x	x	x				x	x	x	x	x	x(2)	x	x(3)	x(4)	x		x	20 mBps data	Multiple 10 HZ to 1 KZ	-120 dBm	40 dB instantaneous, 120 dB total	envelope coherent, IF	Two receiver BW/minute
5. Plasma Propagation							x	x		x			x		x			x		x	10 percent	≥pre-detection	-120 dBm	120 dB	Envelope	N/A
10. ELF/VLF	x	x											x		x				(5)		100 HZ	Nominal	-120 dBm	40 dB instantaneous, 120 dB total	Envelope	N/A
13. Narrow Beam Tracking Antenna									x				x			x		x		x	Nominal	Nominal	-120 dBm	40 dB instantaneous, 120 dB total	PM PLL	N/A
14. Range and Range Rate Navigation and Surveillance						x							x	x				x	x		20 MHZ	Various	-120 dBm	40 db instantaneous, 100 dB total	Five channels PSK or FSK	Tune range ±3 ppm of carrier freq.
15. Interferometric Navigation and Surveillance						x							x	x				x	x		5 MHZ	Various	-120 dBm	40 dB instantaneous, 100 dB total	Four maximum channels PCM	Tune 3 ppm of carrier freq.

(1) 1-10 MHZ-millimeter frequencies, 10, 100, 1000 KHz - VHF/UHF
(2) Band 3, 4, 5
(3) 60 GHZ only
(4) 11, 14, 20, 30 GHZ
(5) Tunable

Figure 5-23. Comm/Nav Laboratory Receiver Requirements Summary

Experiment Class	Operational Frequency Band(MHZ)	Frequency Bands								Transmitter Power (Watts) Maximum	Antenna Gain (db)	Effective Radiated Power (dbw) Maximum	Xmtr Duty Cycle		Maximum Signal Bandwidth, MHZ	Modulator						Modulating Signal				
		3 KHZ-30 KHZ	117-162 MHZ	620-790 MHZ	1535-2300 MHZ	2500-4200 MHZ	5000-7750 MHZ	10.95-14.2 GHZ	17.7-21.2 GHZ				Continuous	Gated/Pulsed		Phase	Frequency	Amplitude	Pulse	None (CW)	Special	Digital Data	Analog Data	Noise	PN Sequence	Special
1. Susceptibility of Terrestrial Systems	3700-4200 2500-2600 620-790			 x		x x				50 50 50	13 13 13	30 30 30	x x x	x x x	10 10 10	x x x	x x x	x x x	x x x	x x x			TV TV TV	x x x	x x x	x x x
3. Radio Frequency Propagation	117-138 620-790 1535-1660 10.95-11.2(1) 17.7-21.2(1)		x	 x	 x			 x	 x	0.01 0.1 1.0 5 0.5	0 0 3 13 13	-20 -10 3 20 10	x x x x x	x x x x x	0.1 10 20 500 500	x x x x x				x x x x x						x x x x x
6. Direct Broadcast	620-790 2500-2690 11.7-12.2(1)			x		 x		 x		2000 50 100	13 13 13	46 30 33	x x x		12 12 12		x x x	x x x				 x	TV TV x			
7. Communication Relay Test	117.975-138 136-138 161.9625 1535-1660 1790-2300 13.25-14.2(1)		x x x		 x x			 x		10 10 10 100 100 100	0 0 0 13 13 13	10 10 10 33 33 33	x x x x x x		0.1 0.1 0.1 20 20 500	 x	x x x	x x x				x x x x x x	x x x x x x		 x x x	x x x x
10. ELF/VLF	3-30(2)	x								1000			x		100(3)	x	x			x		x			x	
11. Fixed Multibeam Antenna (Two beams)	2500-2690 3700-4200 17.7-21.2(1)					x	 x		 x	0.001 0.001 0.001	30 30 30	0 0 0			CW CW CW					x x x						
14. Range and Range Rate Navigation and Survey	1535-1660				x					2	3	6	x	x	10	x									x	x
15 Interferometric Navigation and Survey	1535-1660 5000-5250				x		 x			2 10	3 3	6 13	x x	x x	20 20	x x					x x					x x

(1) GHZ
(2) KHZ
(3) HZ

Figure 5-24. Comm/Nav Laboratory Transmitter Requirements Summary

ITEM	DESCRIPTION	USAGE	COMMENTS
1. ANTENNAS, GIMBALLED	~18" Dia. Cassegrain, ±60° x 90° Gimbal Freedom	4. Optical Frequency Propagation 9. Laser Communication 16. Landmark Tracking 17. Laser Ranging	Used for all wavelengths from visible to LWIR
	Radiometer telescope, 80° half-angle cone gimbal freedom	18. Horizon altitude & radiance measurements	Separate optics for UV spect rum
2. SERVO CONTROL ELECTRONICS	Controls line-of-sight pointing for large Cassegrain antenna	Same as antenna above	
	Controls radiometer pointing	Same as antenna above	
3. TRACKING SENSORS	Quadrant sensor, 0.01° tracking accuracy	4. Optical Frequency Propagation 9. Laser Communication (Acquisition) 17. Laser Ranging	Operates in visible or near IR; pulsed input
	Image dissector fine tracking sensor	4. Optical Frequency Propagation 9. Laser Communication (fine 16. Landmark Tracking	Visible wavelength sensor, dual mode for point source/landmark tracking
4. LASERS (incl. modulators)	CO_2, wideband PCM Nd:YAG, 1.06 μ, PCM Nd:YAG, 0.53μ, PCM	4. Optical Frequency Propagation 9. Laser Communication	Share common power supply
	Nd:YAG, Q-Switched	4. Optical Frequency Propagation 9. Laser Communication 17. Laser Ranging	Serves as optical beacon and as ranging transmitter
5. RANGING ELECTRONICS	Performs timing, counting, gating, and thresholding for laser rangefinder	9. Laser ranging (experiment unique)	
6. BEAM DEFLECTORS	Vernier deflection, 0.1 arc second precision, 50 arc second dynamic range	4. Optical Frequency Propagation, 9. Laser Communication 16. Landmark Tracking	Reflective type to serve all wavelengths
7. TRANSMITTER ELECTRONICS	Multiplex, A/D, format for wideband laser communications	4. Optical Frequency Propagation 9. Laser Communication	Can be used for all wavelengths if desired bit rates are provided
8. RECEIVER ELECTRONICS	Video amp, bit sync, demultiplex, D/A	4. Optical Frequency Propagation 9. Laser Communication	Same as transmitter electronics

Figure 5-25. Comm/Nav Laboratory Optical Requirements Summary

EARLY LAB												GROWTH LAB									TOTAL LAB									
CREW/EXPERIMENT FUNCTION		APPLICABLE EXPERIMENT Classes	EQUIPMENT NO.	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	EQUIPMENT IDENTIFICATION	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	EQUIPMENT IDENTIFICATION	CREW DIFFICULTY		USE FREQUENCY		U	M	L	EQUIPMENT BAY	COMMENTS
				H	L	H	L						H	L	H	L						H	L	H	L					
1	CHECKOUT	1,3,7,11,15	68	X			X	X	X	X	X	SCOPE	X			X	X	X			COMPUTERIZED-MANUAL MODE SELECT		X		X	X				
2	CALIBRATE/ALIGN	1,3,15	14,29,44	X			X				X	SIGNAL GENERATOR		X		X	X				COMPUTERIZED-MANUAL MODE SELECT		X		X	X				NO 77 VSWR METER AND SLOTTED LINE NOT ON EXPT CONSOLE
3	CONFIGURE (SET UP)	1,3	45		X		X		X			PRECONFIGURED BUS PANEL (REDUNDANCY)		X		X	X				PRECONFIGURIZED BUS PANEL (REDUNDANCY)		X		X	X				NO 14, 15, 16 NOT ON CONSOLE
4	ENABLE (ACTIVATE, INITIATE, RECEIVE, TRANSMIT)	1,3,9,11,15,16	47,56		X		X	X				INTEGRATED MANUAL ACTIVATOR		X		X		X			INTEGRATED MANUAL ACTIVATOR		X		X		X	X		NO 25 KEYBOARD ONLY - COMPUTER ELECTRONICS NOT ON CONSOLE
5	MONITOR (DIGITAL) STATUS	ALL	22,23,31,35,37, 61, 68		X		X		X			SEE 7 BELOW									SEE 7 BELOW									
6	MONITOR (ANALOG) STATUS	ALL	2,30,48,50,51, 52,53,67		X		X		X			SEE 7 BELOW									SEE 7 BELOW									
7	MONITOR (ANALOG-DIGITAL) STATUS	1,3,7,11,16	60		X		X		X			INTEGRATED ANALOG DIGITAL DISPLAY	X		X				X		INTEGRATED ANALOG - DIGITAL DISPLAY	X		X				X		
8	ASSEMBLE	APPLICABLE TO EVA, IF REQD	LSS, LOCOMOTION AIDS, SAFETY & WORKSITE AIDS, NOT ON CONSOLE	X			X	N/A	N/A	N/A	N/A	PREASSEMBLE AND INSTALL									PREASSEMBLE AND INSTALL									
9	COMMUNICATE (CREW, GND RECORDER)	ALL	SPEAKER, MICROPHONE, HEADSET		X	X				X		SPEAKER, MICROPHONE		X		X		X			SPEAKER MICROPHONE		X		X		X			
10	PHOTOGRAPH (EARTH, SCOPE, ANTENNA)	1,3,9,11,15,16	15,17	X			X			X		CAMERA, FILM		X	X				X		CAMERA, FILM		X		X				X	NO 20 NO DISPLAY AREA REQ'D (STORAGE ONLY) NO 22 NO DISPLAY AREA REQ'D (STORAGE ONLY)
11	POSITION (ANTENNA)	7	JOYSTICK OVERRIDE		X		X			X		SERVO ACTUATION COMPUTER									SERVO ACTUATION COMPUTER									
12	RECORD (MAGNETIC TAPE, PAPER, MANUAL)	1,3,9,11,15,16	54,57,58	X		X				X		MULTIPLE HEAD RECORDER		X		X		X			MULTIPLE HEAD RECORDER		X		X		X			
13	SELECT (RECEIVER, SIGNALS, OP MODE, ETC)	ALL	24,32,38,39		X	X			X			INTEGRATED MANUAL ACTIVATOR SEE 4 ABOVE									INTEGRATED MANUAL ACTIVATOR-SEE 4 ABOVE									
14	ADJUST (VERNIER, GAIN, ATTENUATE)	1,3,11	1,14,42		X	X				X		DIAL DISPLAY/ CONTROL		X		X			X		COMPUTERIZED-MANUAL REDUNDANCY		X		X			X		
15	DIAGNOSE MALFUNCTION (SAME AS FUNCTION 1)		SEE 1 ABOVE	X			X	X	X	X	X	IMPROVED RELIABILITY SEE 1 ABOVE									IMPROVED RELIABILITY SEE 1 ABOVE									

LEGEND

H = HIGH
L = LOW
U = UPPER REACH ENVELOPE
M = MIDDLE REACH ENVELOPE
L = LOWER REACH ENVELOPE

Figure 5-26. Crew Equipment Interfaces (Common Functional Requirements)

6.0 OPERATIONS ANALYSIS

Mission Planning - A manned Earth orbital program of Comm/Nav Research has the following objectives:

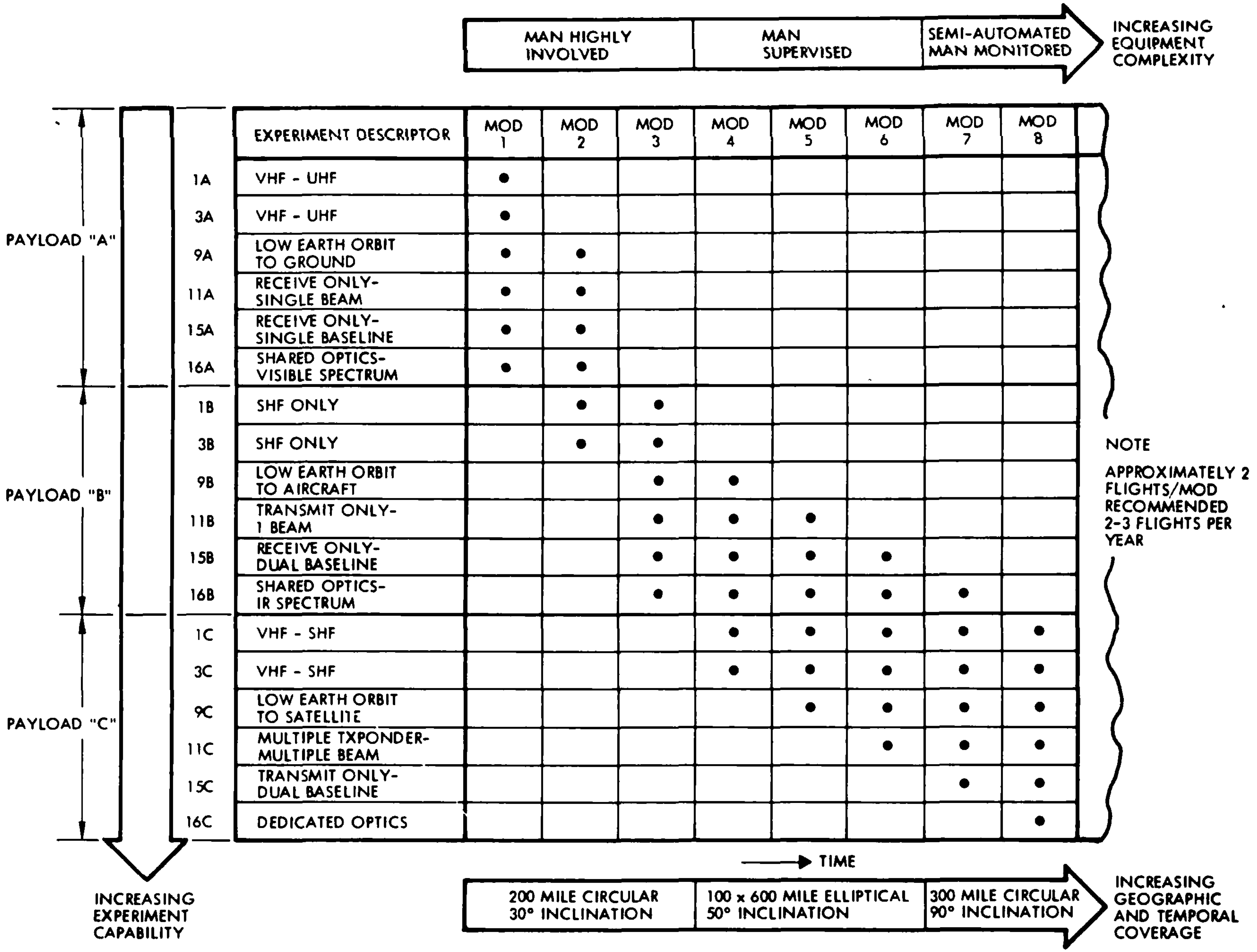
- Perform useful experiments in (1) natural environment measurements as related to RFI and propagation and (2) measurements to demonstrate and test Comm/Nav hardware related to future operational systems.
- Provide scientifically responsive space laboratories that are accessible, versatile, economical, and sensitive to research requirements.
- Provide programmatically flexible laboratories in terms of funding, schedule, and priorities.
- Complement and supplement related programs where unmanned missions, aircraft flights, and ground based research are employed in Comm/Nav research.

The experiment classes and the laboratory configurations previously listed and described are the suggested starting points toward meeting the above objectives. Assuming that Comm/Nav manned laboratories do evolve to conduct space research, the success of the program will depend to some degree, on the care given to mission planning. This element is discussed briefly in this section - concentrating on the aspects of flight schedules, timelines, and orbit considerations of the Early Laboratory.

6.1 EARLY LABORATORY - TYPICAL FLIGHT SCHEDULE

The key features of a possible flight schedule for Early Laboratory mission are shown in Figure 6-1 for six (of the seven) experiment classes selected for the Early Laboratory. Modest changes in crew involvement, geographic coverage and experiment unique equipment are shown as the flight schedule proceeds in easy steps or modifications until Early Laboratory objectives are achieved.

It is assumed that data derived in some of the early experiments may contribute to the definition of operational systems. Thus, Figure 6-1 shows a series of mission modifications, say eight, where man's participation is gradually changed. The natural consequence of this, plus the desire to expand experiment coverage, will lead to increased use of automated equipment.



		EXPERIMENT DESCRIPTOR	MOD 1	MOD 2	MOD 3	MOD 4	MOD 5	MOD 6	MOD 7	MOD 8
PAYLOAD "A"	1A	VHF - UHF	●							
	3A	VHF - UHF	●							
	9A	LOW EARTH ORBIT TO GROUND	●	●						
	11A	RECEIVE ONLY-SINGLE BEAM	●	●						
	15A	RECEIVE ONLY-SINGLE BASELINE	●	●						
	16A	SHARED OPTICS-VISIBLE SPECTRUM	●	●						
PAYLOAD "B"	1B	SHF ONLY		●	●					
	3B	SHF ONLY		●	●					
	9B	LOW EARTH ORBIT TO AIRCRAFT			●	●				
	11B	TRANSMIT ONLY-1 BEAM			●	●	●			
	15B	RECEIVE ONLY-DUAL BASELINE			●	●	●	●		
	16B	SHARED OPTICS-IR SPECTRUM			●	●	●	●	●	
PAYLOAD "C"	1C	VHF - SHF				●	●	●	●	●
	3C	VHF - SHF				●	●	●	●	●
	9C	LOW EARTH ORBIT TO SATELLITE					●	●	●	●
	11C	MULTIPLE TXPONDER-MULTIPLE BEAM						●	●	●
	15C	TRANSMIT ONLY-DUAL BASELINE							●	●
	16C	DEDICATED OPTICS								●

NOTE

APPROXIMATELY 2 FLIGHTS/MOD RECOMMENDED 2-3 FLIGHTS PER YEAR

Figure 6-1. Early Laboratory - Typical Flight Schedule

Expanding the geographic coverage may be an important element of experiment measurements. For example, the low inclination orbit might prove to be an obstacle (in establishing the propagation of RF energy through snow). An aliptical orbit could provide more station contact time and thereby enhance the experiment results. This improved temporal coverage could become a necessary element in achieving certain experiment objectives.

As Figure 6-1 indicates, experiment equipment changes could be made as the measurement sequence in each experiment class is revised and updated. A gradual evolution in equipment complexity and capability rather than "block changes" is a primary element in the schedule structure. Figure 6-1 suggests eight equipment modifications, but this is arbitrary at this point. An average of two flights per modification may be needed to meet experiment objectives. Two to three Comm/Nav Research Laboratory flights per year are recommended but this, of course, depends on funding constraints and Shuttle Orbiter availability.

The NASA document titled Updated NASA Mission Model dated 6 June 1972 from the AAD/Deputy Associated Administrator provides a planning guide for NASA and for those contractors supporting the Agency's projects. It indicates a NASA Mission Model extending from 1973 through 1990. For Communications and Navigation this model shows: one Sortie Comm/Nav experiment flight in each of the calendar years 1979, 1980, 1983, 1984, 1987 and 1990; one Comm/Nav Sortie Laboratory flight in each of the calendar years 1981, 1982, 1985, and 1989; and Comm/Nav Space Station RAM Laboratory flights of two to three months mission duration in calendar years 1986 and 1988.

Thus, this mission model, which suggests one Comm/ av mission a year (1979 through 1990), is in slight variance with this Study's recommendation of two to three missions per year. However continued mission modeling work and further Comm/Nav analysis of the experimental needs to fill technology gaps may result in revisions to the NASA model or to the recommendation.

There are various techniques available for dealing with the limitation of experiment time/data associated with the Sortie mission duration. One technique is to collapse the experiment "class" to a "point" experiment. This involves reducing the class scope in such areas as frequency coverage, operating modes, and performance.

The objectives of a point experiment can obviously be limited to a set which is compatible with a seven day mission. Or the laboratory equipment could be expanded (or duplicated) to focus on multiple sets of data. Thus the experiment class would really be implemented as a set of point experiments. Alternatively, it is reasonable to recognize the shortcomings of a limited flight duration and plan for multiple flights.

The terrestrial noise experiment involves collecting data over a wide range of frequencies. Terrestrial noise is known to have seasonal variations. It is highly correlated with the activities of man and hence it will constantly vary. Any given set of data will be perishable at some detail level and new data will always be needed. This experiment will eventually lead into an operational monitoring system after some number (N) of Sortie flights.

The fixed multibeam experiment is postulated as one which may involve difficulty in establishing satisfactory space-ground coordination. Multiple flights could be required to achieve experiment objectives.

The laser communication experiment could also have space-ground operational problems (cloud cover over the ground station). Further, the experiment involves multiple operating modes. Initially a one way space-ground link would be established. This would lead to a more complex space-aircraft link and finally to a laboratory-satellite link.

Thus, Figure 6-2 shows the possible variation in the number of flights to satisfy a research objective. As an example, it may take only one flight to demonstrate the deployment of a large antenna reflector, but maybe five flights to meet laser communications and fixed multibeam measurement goals, and N flights to map terrestrial noise.

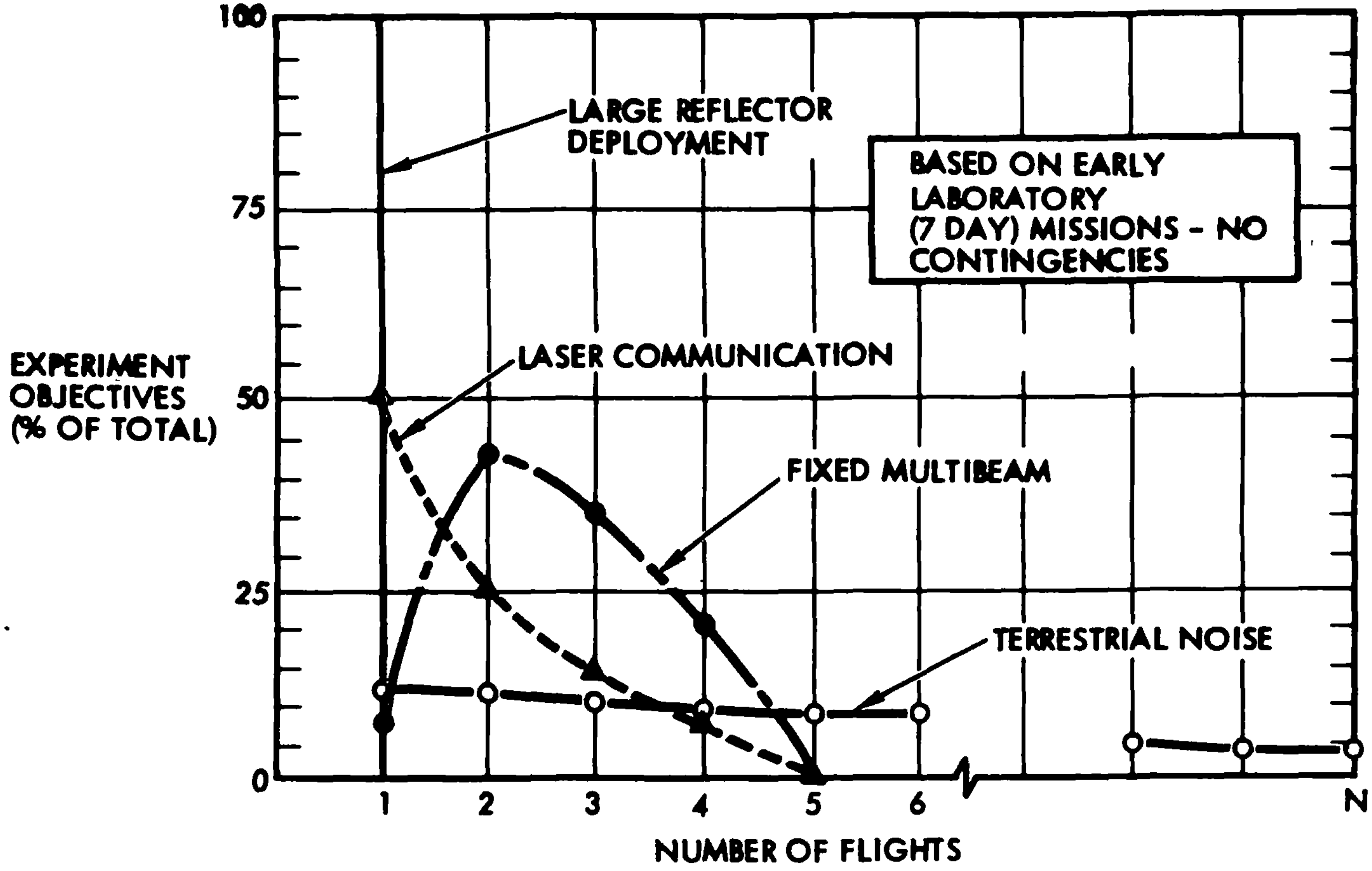


Figure 6-2. Number of Flights per Experiment

6.2 MISSION TIMELINE

During the study, prior to the second performance review, a preliminary mission timeline was developed for the Comm/Nav Research Laboratory as envisioned for an early Space Shuttle sortie flight. This preliminary timeline development was intended to verify the feasibility of this type of mission and to highlight those types of operational data (crew interactions, equipment utilization, etc.) which can be identified through this analysis technique. The preliminary timeline provided two key conclusions, as follows:

1) The experiment crew (two in number) was not fully utilized by the six experiments included in the research configuration

2) The space-to-ground contact time for some of the experiments was extremely small

Subsequent to the second performance review, the preliminary timeline has been updated with the intent to provide an orbital operations description of higher density activity. This updated mission timeline is described herein, with the revisions to the payload, the orbit, and the assumptions, along with the results of the analysis.

Two primary revisions were included in the mission timeline update. First, the original group of six experiments was expanded to a total of seven with the addition of the Communication Relay experiment. The objective of this experiment is to evaluate alternate acquisition, handover, and data transmission techniques for RF links between data relay satellites and users in low-earth orbits. The inclusion of this equipment provided a definite increase in the operations opportunities of the experiment group comprising the baselined research laboratory.

The second baseline revisions involved the selection of a more optimum earth-orbit. Several factors were involved in the selection of the new orbit, two of which were the most determinant. First, the majority of the sensors included in the research group desire maximum continental United States (CONUS) overflight, between the latitudes of 27 and 39 degrees north.

Second, those experiments desiring CONUS coverage are primarily repeaters (they desire repeated operational opportunities throughout the mission duration). As a result of these requirements, a daily-repeater orbit of 260 n. mi. circular, 35 degree inclination was chosen as the representative baseline for the research module missions.

6.2.1 Experiment and Mission Assumptions

Prior to and during the development of the mission timeline, certain assumptions were established. These assumptions are described in the following text to clarify their involvement with the development of the timeline.

Mission Assumptions

1) The experiment mission was assumed to be five (5) days in duration, leaving the first and seventh days for Shuttle ascent and descent operations, and general Comm/Nav preparatory operations.

2) The first experiment operation day was assumed to start at a ground elapsed time of 20 hours to account for the crew awake time prior to actual launch (assumed to be four (4) hours).

3) The Data Relay Satellite placement was assumed to be 145°W and 15°W, as reported in the latest NASA Headquarters planning documents.

4) It was assumed that the experiment crew would nominally schedule their sleep and food activities in parallel with the Shuttle crew wherever possible. This guideline was maintained for the sleep cycles, however, it was not rigidly adhered to for the food cycles, if that adherence would place unnecessary constraints on the experiment operations.

5) Housekeeping periods which were included in the scheduling on the preliminary mission timeline were not scheduled on the updated timeline, as they were assumed not to be of significant priority for concern at this time. The requirement for housekeeping activities is assumed to exist in the updated timeline, and thirty (30) minutes is reserved each day for these activities, but they are not shown on the timeline as rigidly scheduled activities (Item 9 below).

6) The Space Shuttle will require initial platform and state vector updates during the mission. As presently configured, if the Shuttle uses horizon sensors for the functions,

the Shuttle will be required to be in a "belly-down" local horizontal attitude for the horizon sensor operation. However, due to the lack of definition of Shuttle operation at this time, this potential orientation conflict between the Shuttle and the payload was not included in the timeline generation.

7) The ground network supporting the mission was assumed to consist of the following fround stations:

Goldstone, California	(GLD)
Guymas, Mexico	(GUY)
Corpus Christi, Texas	(TEX)
Merritt Island, Florida	(MIL)
Goddard Space Flight Center	(GSFC)
Bermuda Island	(BDA)
Grand Canary Islands	(CYI)
Ascension Island	(ACN)
Madrid, Spain	(MAD)
Carnarvon, Australia	(CRO)
Honeysuckle Creek, Australia	(HSK)
Guam Island	(GWM)
Oahu Island, Hawaii	(HAW)
Santiago, Chile	(SAN)

8) While ground coverage is shown for the total ground network (indicated by AOS-LOS Blocks on the timeline sheets) operations were assumed to occur over only those ground stations having acquisition elevation angles greater than 20 degrees (shown as darkened blocks on the timeline sheets). This approach results in a very conservative assessment of experiment operation opportunities.

9) The duty cycle assumed for the crewmen is as follows:

Sleep Period	8 hrs
Hygiene and Food	4-1/2 hrs
Mission Briefings	1 hr
Not Scheduled	1/2 hr
Work Period	10 hrs

Experiment Assumptions

To assist in the update of the mission timeline, certain assumptions were established concerning the experiments and their operational modes. These are presented in the following text for qualification.

1) Experiment Priorities

The establishment of relative priorities between the seven experiments was required for the scheduling of the mission timeline. These priorities were assumed to be the following:

Priority	No.	Title
1	1	Terrestrial Sources
2	3	RF Propagation
3	11	Multi-Beam Antenna
4	9	Laser Communications
5	7	Communication Relay
6	15	Interferometer Navigation
7	16	Landmark Tracking

2) Experiment Targets and Operations

Exp. No.	Target & Operations
1*	Operates for five passes (minimum) over CONUS
3*	Operates once for set-up over CONUS then switches to automatic mode for periodic manned operation throughout the mission
7	Initially operates over Honeysuckle with DRSS, then switches mode for acquisition, handover, and LOS operations throughout mission. This experiment is assumed to be operable with Space Shuttle in any orientation.
9	Operates once per day over Goldstone, Calif.
11	Operates four times over Texas, on one day only
15	Operates three passes over KSC, each day throughout mission
16	Operates over ground stations (Guam and Hawaii primary, MIL and CRO secondary) as often as possible

* These experiments (Nos. 1 and 3) use the same antenna. It was assumed that they could operate in parallel.

3) Experiment Operational Cycles

The operational cycles for each experiment are presented in Figures 6-3 through 6-10. Additional detail is contained in Tables 6-1 through 6-7. The coded crew skills on these tables are identified in Section 4.2.6.

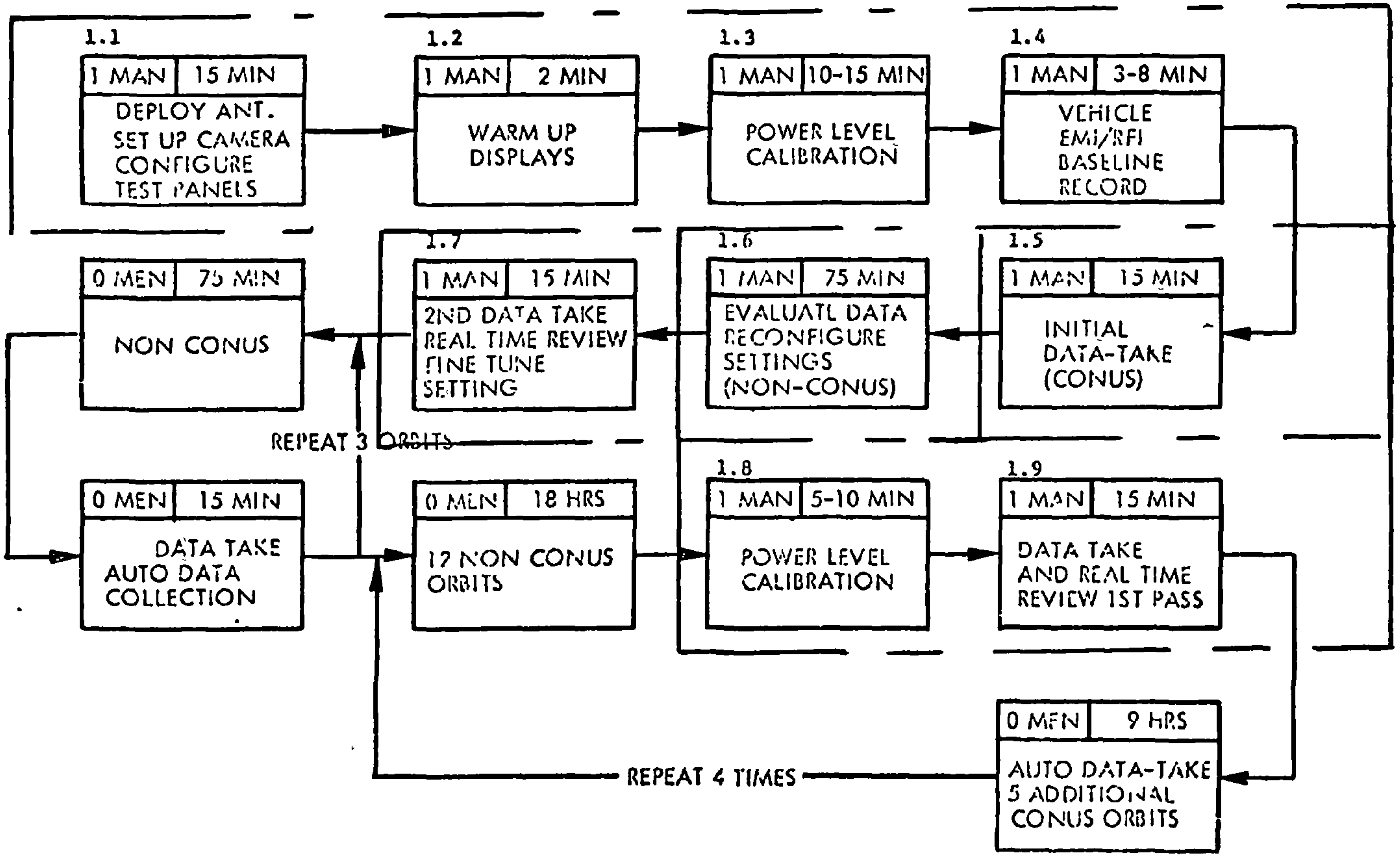


Figure 6-3. Experiment No. 1 - Terrestrial Sources of Noise and Interference

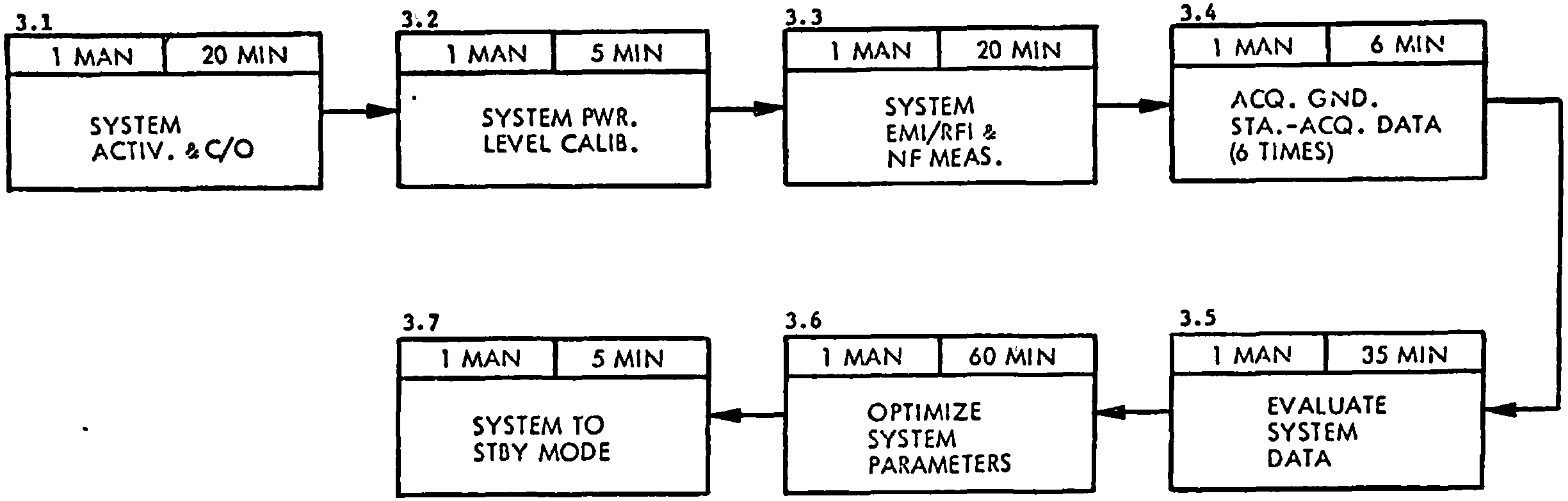


Figure 6-4. Experiment No. 3 - RF Propagation System Optimization (NASA Ground Station)

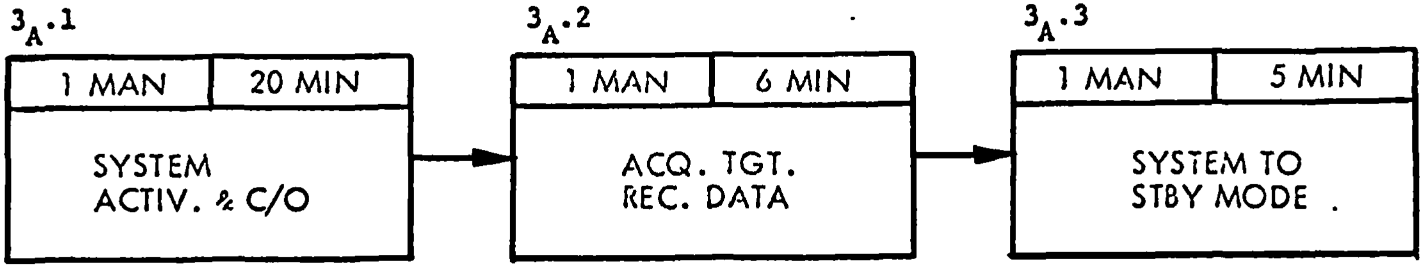


Figure 6-5. Experiment No. 3 - RF Propagation Test

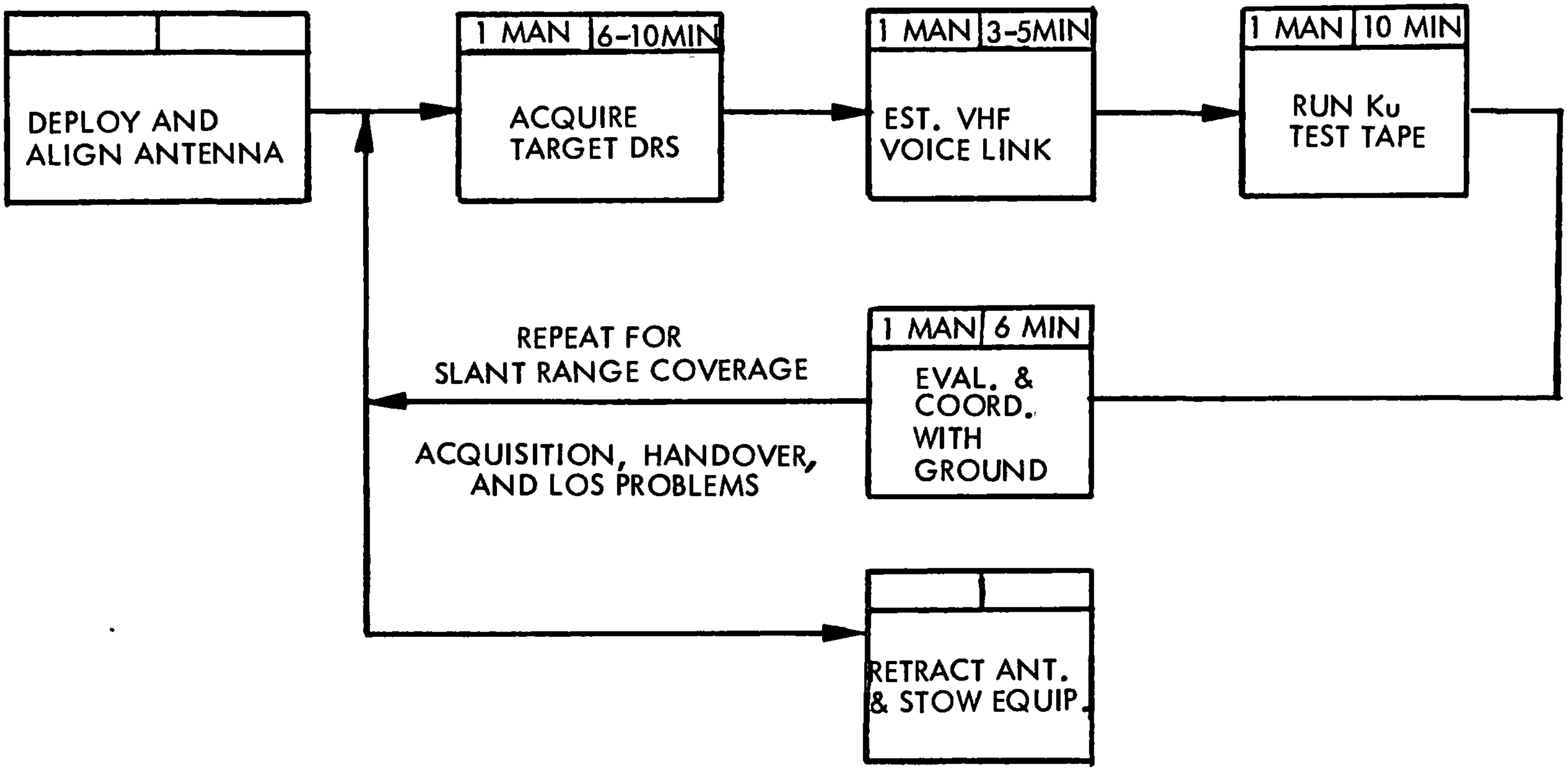


Figure 6-6. Experiment No. 7 - Communications/Navigation Data Relay

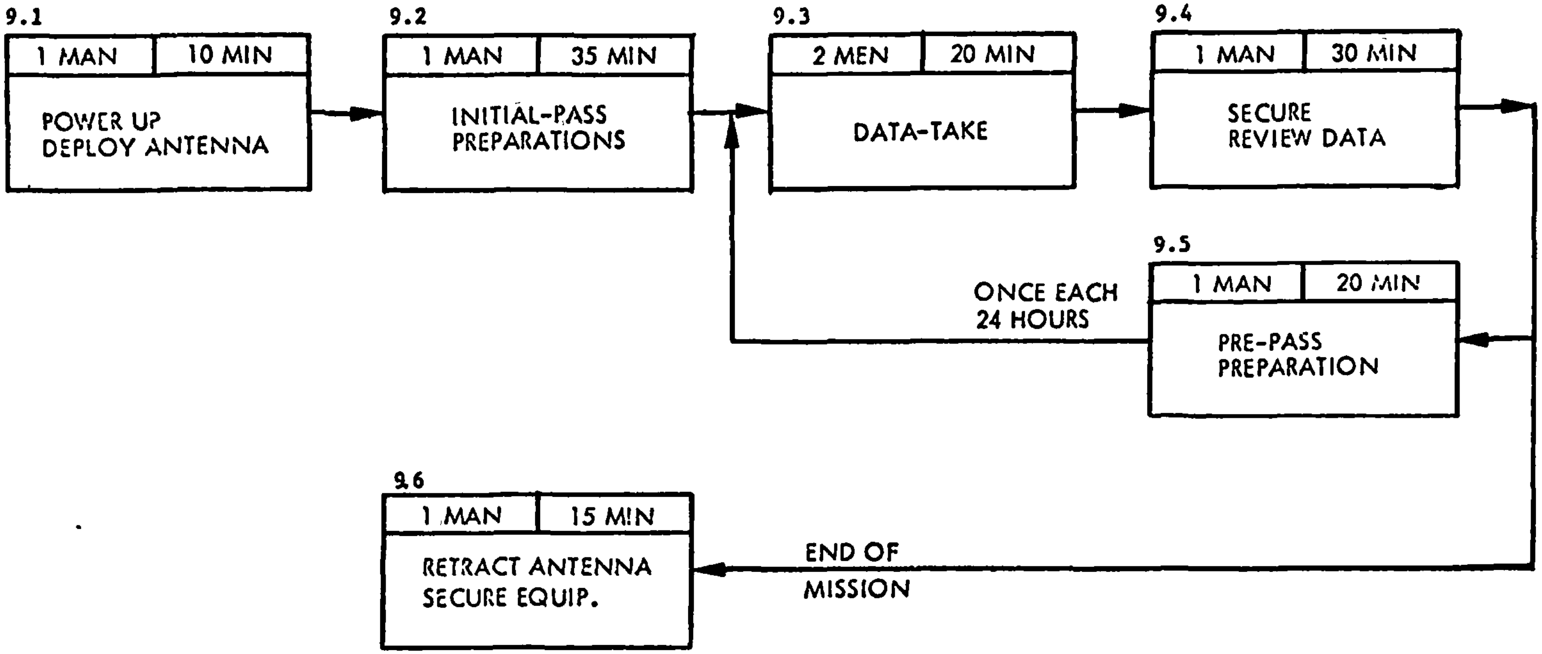


Figure 6-7. Experiment No. 9 - Laser Communications

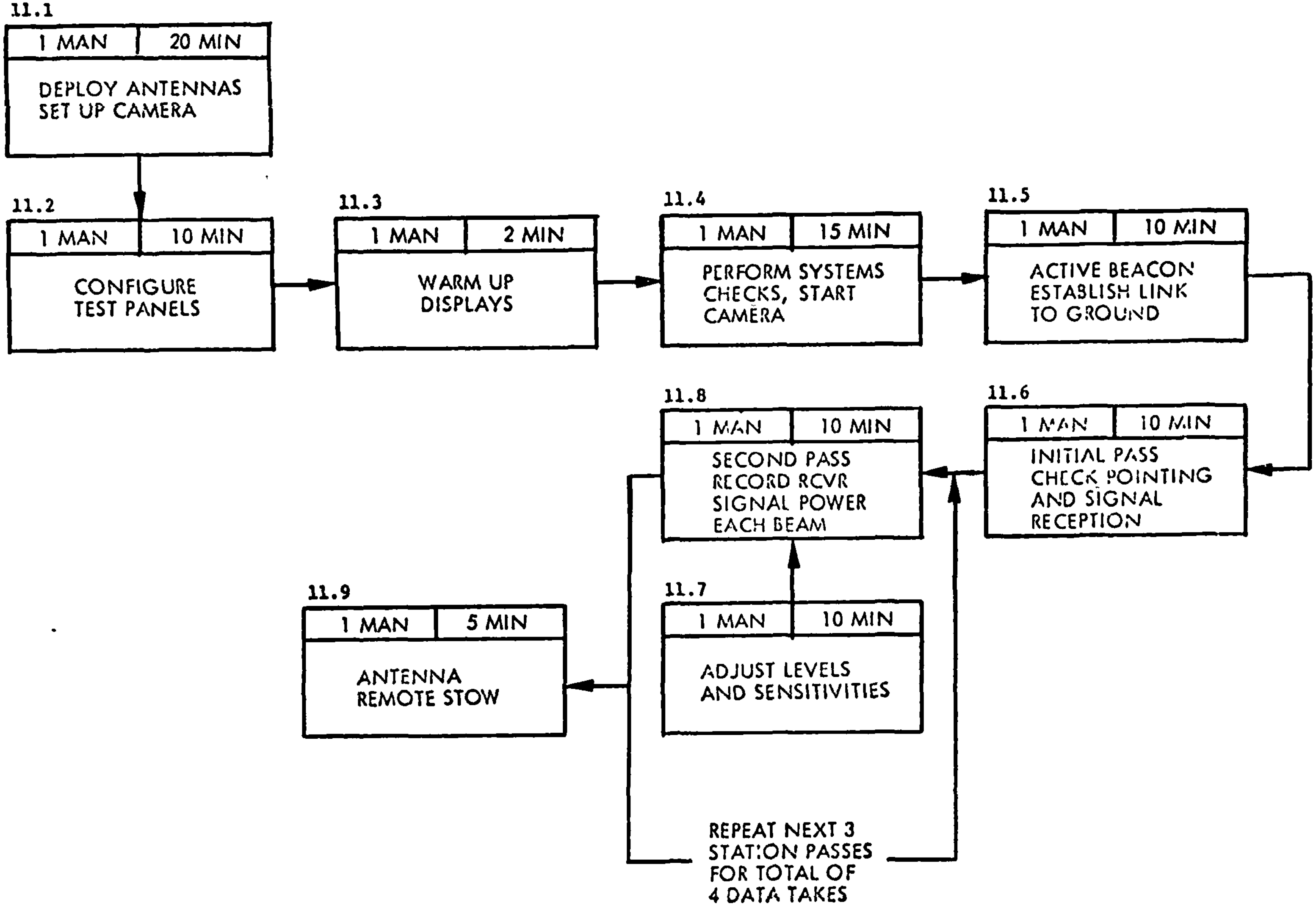


Figure 6-8. Experiment 11 - Satellite-Fixed Multi-Beam Antenna
(First Phase)

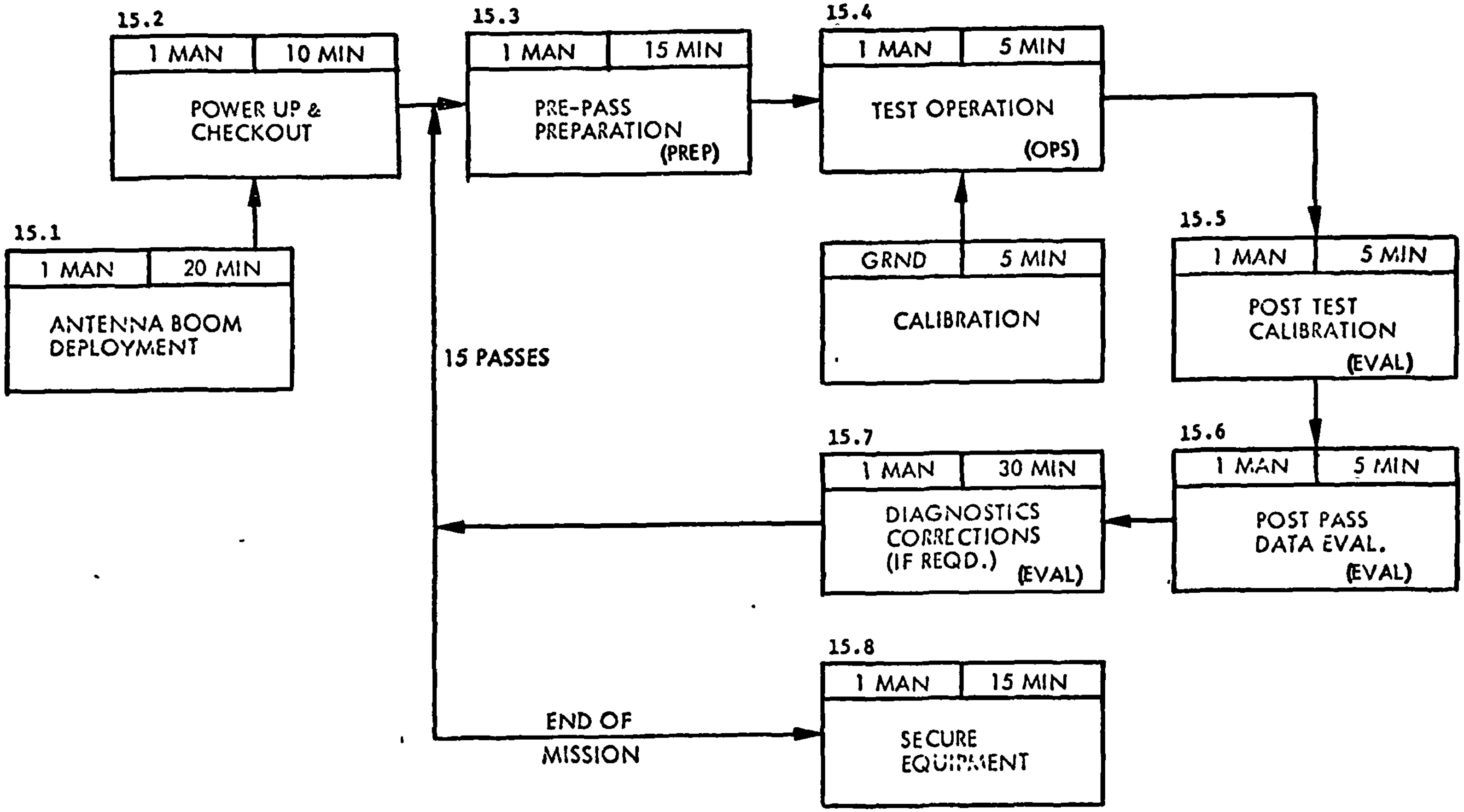


Figure 6-9. Experiment 15 - Interferometric Surveillance and Navigation

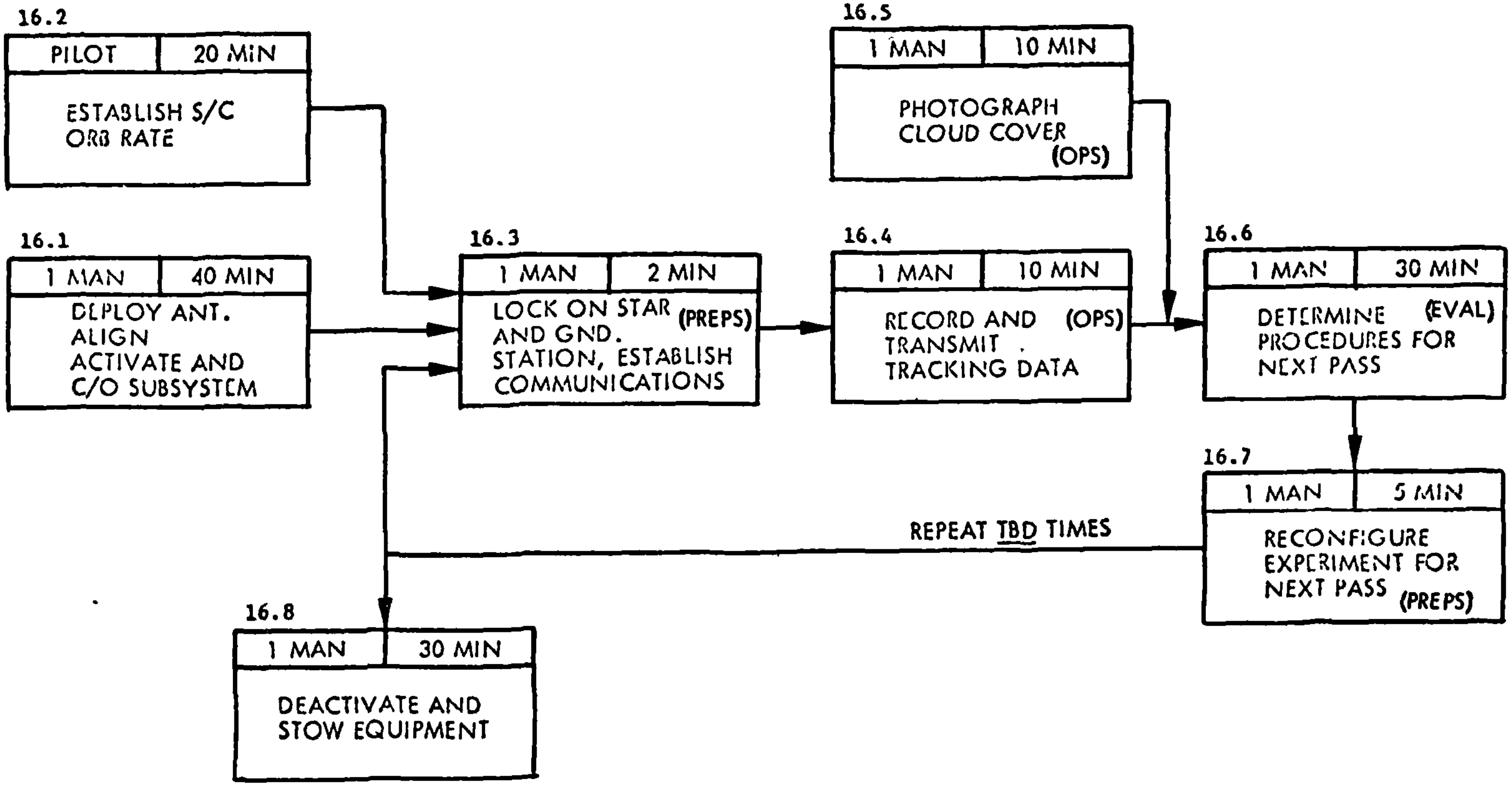


Figure 6-10. Experiment No. 16 - Landmark Tracking

Table 6-1. Experiment No. 1 - Terrestrial Sources

	REQUIREMENTS						
FUNCTION	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skill
1. INSPECT (Gross) Experiment Equip. Launch Protection	1	N/A	5	1	N/A	N/A	10
2. DEPLOY Remove Launch Protection	1	Storage	5	1	N/A	N/A	12
3. INSPECT (Fine Expt. Equipment Integrity (Visual)	1	N/A	5	1	N/A	N/A	2, 10
4. ENABLE Power on Warmup	1	Checklist	2	1	Power Swt.	Power Status	2, 4
5. CHECKOUT							
Antenna	1	Checklist	30	2	Position	Position	2, 9, 10
RCR - Synthesizer					N/A	Rcptn	2, 10, 11
Video Display					Synch,BRT,Con	Rcptn	2, 8, 10, 12
RCR - Sign. Analysis					Tuning	Frequency	2, 10, 11
Keyboard - Comp.					Select	Mode,Rcptn.	2, 6, 10
Tape Recorder					Select	Channel,Rcdg.	2, 6, 10, 11
Sig. Gen.					Select	Power, Lev.	2,,4, 9, 10
6. ENABLE Auto (Rcv.-Record)	1	Procedure	2	1	Act., Select	Mode	2, 4
7. MONITOR Signal Reception	6	Procedure	30	1	Select	Timing Sig. Strth. Waveform Freq.	9, 10, 11
8. ENABLE Data Retrieval-Display	2	Procedure	3	1	Select	Power Status	2, 5
9. MONITOR & EVALUATE Stored Data	2	N/A	30	1	Tuning	Sig. Str'th. Waveform Freq.	(9, 10, 11
10. ADJUST Signal Reception	1	N/A	30	1	Select Tuning	Spectrum Sweep Rate	2, 5, 10. 11
11. ENABLE Rcv. - Record	1	N/A	3	1	Select	Timer	2.5
12. STOW AND PPOTECT Expmt. Equipt. Reentry Protect	1	Checklist	30	1	N/A	N/A	12
13. ANTICIPATED MAINTENANCE Tape Recorder	1	Mag Tape	10	1	N/A	Tape Status	

Table 6-2. Experiment No. 3 - RF Propagation

FUNCTION	REQUIREMENTS						
	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1. INSPECT							
Launch Damage (Visual)	2	N/A	5	1	N/A	N/A	10
2. DEPLOY							
Remove Launch Protection	1	Storage	5	1	N/A	N/A	12
3. INSPECT							
Integrity (Visual)	1	N/A	5	1	N/A	N/A	2,10
4. ENABLE							
Power On	1	Checklist	2	1	Power Swt	Power Status	2,4
5. CHECKOUT							
Antenna	1	Checklist	40	1	Sel. Ptg	Position	2,9,10
RCV					Select	Rcptn	2,10,11
TRX						Pwr., Frq	2,6,10,11
Spectrum Ana					Tuning	Sig. Dynam	2,4,9,10
Freq Ctr					Select	Mode, Rcptn	2,6,10
Analog RCD					Select	Chn, Rcdg	2,6,10,11
Digital RCD					Select	Chan, RCDG	2,6,10,11
Pwr Condi					Tuning	Pwr Lev	2,4,9,10
Teleprinter					Adjust	Alphanumerics	2,10,11
DC Voltmeter					Tuning	DC Current	2,10,11
Oscilloscope					Select	Waveform	2,4,9,10
Camera, Scope					Cycle	Photo	1,5,6,10
Line Atten					Adjust	Pwr Level	2,4,10,12
Scan Prgr Gen					Tuning	Signal	2,4,8,10
Polarize Agl Rsl					Adjust	Angle	2,10
6. ENABLE							
Auto Rev, Rcd	1	Checklist	3	1	Select	Mode	2,4
					Select	Mode	2,4
7. MONITOR							
Signal Recptn	1	Checklist	40	1	Select	Sig Dynam	9,10,4
8. ENABLE							
Data Retrvl Dpl	2	Checklist	3	1	Select	Pwr Stat	2,4
9. MONITOR							
Stored Data	2	Checklist	40	1	Tuning	Sig Dynam	9,10,11
10. ADJUST							
Sig Rcptn	1	Checklist	40	1	Tuning	Sig Strength	9,10,11
11. ENABLE							
Auto. Rcv, Rcd	2	Checklist	5	1	Select	Sequen'g	2,5,10,11
12. STOW & PROTECT							
Reentry Protect.	1	Checklist	15	1	N/A	N/A	4,10,12

Table 6-3. Experiment No. 7 - Communications Relay

FUNCTION	REQUIREMENTS						
	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1. INSPECT Launch Damage (Visual)	1	N/A	5	1	N/A	N/A	10
2. DEPLOY Remove Protect. Cover	1	Storage	5	1	N/A	N/A	12
3. INSPECT Integr.	1	N/A	5	1	N/A	N/A	2,10
4. ENABLE Power On	1	Checklist	2	1	Power Swt	Power Status	2,4
5. CHECKOUT Antenna(s)	1	Checklist	30	2	Position	Position	2,9,10
Rcr - Syntzer					Adjust	Reception	2,10,11
Video Display					Synch,Bgt,Cont	Reception	2,8,10,12
Rcr - Sig Anlzr					Tuning	Freq.,Strgth	2,10,11
Keyboard - Comp					Select	Mode, Rcptn	2,6,10
Tape Record					Select	Chan.,Rcdg	2,6,11,10
Sig Generator					Select	Power Lev	2,4,9,10
Oscilloscope					Act. Select	Waveforms	2,9,10
DC Voltmeter					Act. Tuning	DC Current	2,9,10
6. ENABLE Auto Rcv, Rcd	TBD	Procedure	2	1	Act., Select	Mode	2,5
					Select	Mode	2,5,11
7. MONITOR Signal Rcptn	TBD	Procedure	45	1	Select	Sequencing Waveform Sig Strgth Freq	2,11
8. ENABLE Data Retrieval Display	TBD	Procedure	3	1	Act., Select	Power Status	2,5
9. MONITOR Stored Data	TBD	N/A	45	1	Tuning	Sig Strgth Waveform Freq	9,10,11
10. ADJUST Signal Rcptn	TBD	N/A	45	1	Tuning	Spectrum ?	2,5,10,11
11. ENABLE Auto-Rcv Record	TBD	N/A	10	1	Act., Select	SEQG	2,5
12. STOW & PROTECT Expmt EQ Reentry Project	1	Checklist	30	1	N/A	N/A	12
13. MAINTANANCE Tape Recd	1	May Tape	10	1	N/A	Tape Stat	

Table 6-4. Experiment No. 9 - Laser Communications

FUNCTION	REQUIREMENTS						
	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1. INSPECT							
Launch Damage (Visual)	1	N/A	10	1	N/A	N/A	10
2. DEPLOY							
Remove Launch Protection	1	Storage	15	1	N/A	N/A	12
3. INSPECT							
Integrity (Visual)	1	N/A	5	1	N/A	N/A	1,2,10
4. ENABLE							
Power On	1	Checklist	2	1	Power Swt.	Power Status	1,4
5. CHECKOUT	1	Checklist	90	1			
Antenna		&			Visual FOV	Position	1,2,9,10
Servo Electronics		Protocol			Adjust	Position	1,2,5,9,10
Tracking Sensors							
Fine (2)					Select	Mode	1,5,10
Coarse					Select	Mode	1,5,10
Laser (4)					Adjust	Status	1,3,12
Transmitter Elec.					Adjust	Signal Dyn.	1,2,10,11
Laser Power					Adjust	Power, Status	1,2,4
Rcvr, Elec.					Adjust	Signal Dyn.	1,2,10,11
Collimators					Adjust	Beam Direc.	1,10
Laser Power Mtr.					Select, Adjust	Power Level	1,10
Recorder					Select	Channel	1,2,6,11
6. CONFIGURE							
Expt. Opns. Setup	1	Protocol	30	1	Connect Mods.	Functional Chk	1,2,3,4,12
7. ENABLE							
Expt. Ops.	1	Checklist	5	1	Select, Adjust	Rcv-Trans Power	2,5
8. CHECKOUT							
Rcv-Trans.-Align Calib.	1	Checklist	15	1	Align, Sel, Adjust	Functionality of Expt. Conf.	1,2,4
9. RECORD (Parallel w/10							
Expt. Ops. - Semi-Auto	1	N/A	30	1	Point, Sel.	Sig. Rcv. Sig. Trans.	1,2,5,6,11
10 MONITOR (Parallel w/9)							
Expt. Ops. - Record	1	Checklist	30	1	N/A	Rec. Status Position	1,2,11
11. DISABLE							
Expt. Ops. - Power	1	Protocol	3	1	Power Swt.	Power Status	2,5
12. ADJUST	1	Checklist	30	1			
Antenna Position					Select	Antenna Posit.	(
RCV - Trans					Select	Sig. Status	(1,2,5,10,11
Power					Tune	Power Level	(
13. (RETURN TO STEP #6 FOR NEXT SUBEXPERIMENT	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14. STOW & PROTECT							
Expt. Equip. Reent. Protection	1	Checklist	30	1	N/A	N/A	12

Table 6-5. Experiment No. 11 - Multibeam Antenna

FUNCTION	REQUIREMENTS						
	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1. INSPECT Launch Damage (Visible)	1	N/A	5	1	N/A	N/A	10
2. DEPLOY Remove Protect	1	Storage	5	1	N/A	N/A	12
3. INSPECT Integrate	1	N/A	5	1	N/A	N/A	2,10
4. ENABLE Power On	1	Checklist	2	1	Power Swt	Power Status	2,4
5. CHECKOUT	1	Checklist	15	1			
Antenna					Pointing	Position	4,5,10
Camera					Select	Position	1,2,4
Recorder					Select	Channel-Rcdg.	2,6,10,11
Sig. Receiver					Select	Reptn	2,6,10,11
Amplifier (Log)					Tuning	Sig. Dynam.	2,10,11
Preamplifier					Select	Sign. Dynam.	2,4,9,10
Ref. Sign. Source					Select	Sign. Dynam.	2,4,9,10
6. CONFIGURE Exp. Ops - Grnd Link	1	Protocol	10	1	Connect Mods.	Funct. Status	2,3,4,12
7. ENABLE Exp. Ops.	4	Protocol	2	1	Select	Mode, Power	2,4
8. MONITOR Sig. Reception	4	Protocol	10	1	Select, Tune	Mode, Sig.Dynam.	9,10,11
9. ADJUST Antenna Reception	4	Checklist	10	1	Select, Tune	Sig. Levels Sensitivities	2,5,10,11
10. MONITOR Exp. Ops.	4	Protocol	10	1	Tune	Sig. Power	9,10,11
11. RETURN TO STEP #7 FOR NEXT SUBEXPT.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12. STOW & PROTECT Reentry Protect.	1	Checklist	5	1	N/A	N/A	4,10,12

Table 6-6. Experiment No. 15 - Interferometer Navigation

FUNCTION		REQUIREMENTS						
		Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1.	INSPECT							
	Launch Damage (Visual)	1	n/a	10	1	n/a	n/a	10
2.	DEPLOY							
	Remove Launch Protection	1	Storage	15	1	n/a	n/a	12
3.	INSPECT							
	Integrity (Visual)	1	n/a	5	1	n/a	n/a	2,10
4.	ENABLE							
	Power On	1	Checklist	2		Power Swt.	Power Status	2,4
5.	CHECKOUT	1	Checklist	30	1			
	Receiver					Tuning, Select	Freq. - Strgth	2,9,10
	Freq. Synth.					Adjust	Sig. Freq.	2,10,11
	Sig. Gen.					Tune, Select	Sig. Dynamics	2,4,9,10
	Dig. Phase Meter					Adjust	Phase Angle	
	Master Clock					Adjust	Time of Day	
	Antenna					Position	Position	4,5,10
	Antenna Boom					Position	Position	4,5,10
6.	CONFIGURE							
	Expt. Ops. Setup	15	Protocol	15	1	Connect Mods.	Function Stat.	2,3,4,12
7.	ENABLE							
	Expt. Ops. (Auto-Record)	15	Protocol	5	1	Select	Mode, Pwr	2,4
8.	MONITOR	15	Protocol	30	1			
	Sig. Rev./Trans. Arrival Angle Ant. & Boom Motion Trans. Power Trans. Freq. Rcvr. T° Time of Day Exp't Config. Record					Select, Tune	Mode,Sig.Dynam.	9,10,11 (Typ)
9.	(RET TO STEP #6 FOR NEXT SUBEXPT.	n/a	n/a	n/a	n/a	n/a	n/a	n/a
10.	STOW & PROTECT							
	Antenna & Boom Reentry Prot.	1	Checklist	15	1	n/a	n/a	4,10,12

Table 6-7. Experiment No. 16 - Landmark Tracking

FUNCTION	REQUIREMENTS						
	Frequency	Support Equipment	Time (Min)	No. of Crewmen	Controls	Information	Skills
1. INSPECT							
Launch Damg. (Visual)	1	n/a	5	1	n/a	n/a	10
2. DEPLOY							
Rem. Protect	1	Storage	5	1	n/a	n/a	12
3. INSPECT							
Integrity	1	n/a	5	1	n/a	n/a	1,2,10
4. ENABLE							
Power On	1	Checklist	2	1	Power Swt	Power Status	1,2,4
5. CHECKOUT	1	Checklist	40				
ANTenna					Pointing	Position	1,2,9,10,11
Star Tracker					Tuning	Pointing	1,2,4,9,10
Rcvr					Tuning	Rcptn	1,2,4,9,10
Collimator					Adjust	Beam Dir.	1,2,4,10,11
Tape Recorder					Select	Mode Rcdg.	1,2,6,10,11
Oscillosc.					Select	Waveform	1,2,4,9,10
Camera, 16mm					Cycle	Status	1,3,5,10,12
6. ENABLE							
Antenna, Rcv.,Record,Camera	TBD	Protocol	2	1	Select		2,4,1
Record, Camera					Select		2,4,1
7. MONITOR							
Sig. Rcptn. Field-op-view	TBD	Protocol	10	1	Select	Sig. Dynam.	2,9,10,11
8. PHOTO							
Cloud Cover	TBD	Protocol	10	1	Select	Position	1,2,4
9. ADJUST							
Antenna	TBD	Checklist	30	1	Select	Position	2,5,10,11
Rcv.					Select	Tune	
10. CONFIGURE							
Expt. Ops.	TBD	Checklist Protocol	5	1	Connect Position	Funct.Status	2,3,4,12
11. RETURN TO STEP #6 FOR NEXT SUBEXPT.	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12. STOW & PROTECT							
Reentry Protection	1		30	1	n/a	n/a	4,10,12

Timeline Results

The updated communication/navigation mission timeline is presented on Figures 6-11 through 6-20. These figures present the ground network coverage, the ground elapsed time, the operations of the experiments, the DRSS coverage, the special crew duties, and the total manpower requirements for the experiments. The Comm/Nav experiment operational activities summary is presented in Table 8. As shown, the experiment activities were greatly increased over the preliminary timeline.

Table 8. Experiment Activities

Experiment Title	Operational Cycles Desired	 Prel. T/L	 Updated T/L	Percent Completed
Terrestrial Source	26	5	28	100+
RF Propagation	6 + AMAP	21	6 + 13	100+
Multi-Beam Antenna	4	4	4	100
Laser Comm	5	5	5	100
Comm Relay	3 (min)	N/A	25	100+
Interferometer Nav	15	6	14	93
Landmark Tracking	AMAP	4	17	100+

The experiment crew utilization summary is presented in Table 9.

Table 9. Crew Utilization

Mission Day	Ops Day	Total Hours	Work Hours
2	1	43.9/48	15.9/20
3	2	43.7/48	15.3/20
4	3	44.7/48	16.7/20
5	4	44.5/48	16.5/20
6	5	41.9/48	13.1/20
	TOTAL	(218.7/240)	(77.5/100)

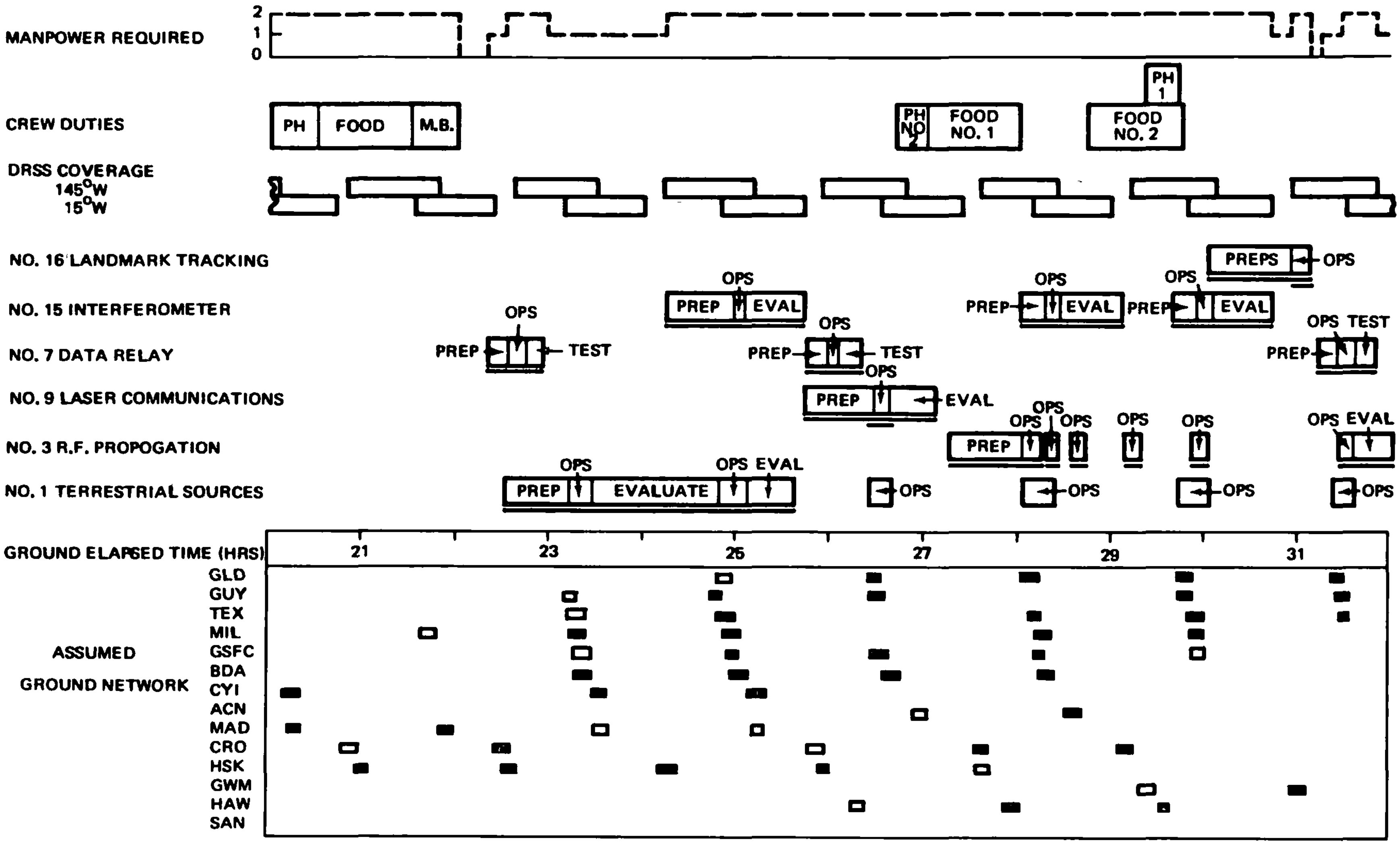


Figure 6-11. Comm/Nav Mission Timeline, Orbital Operations Day 1

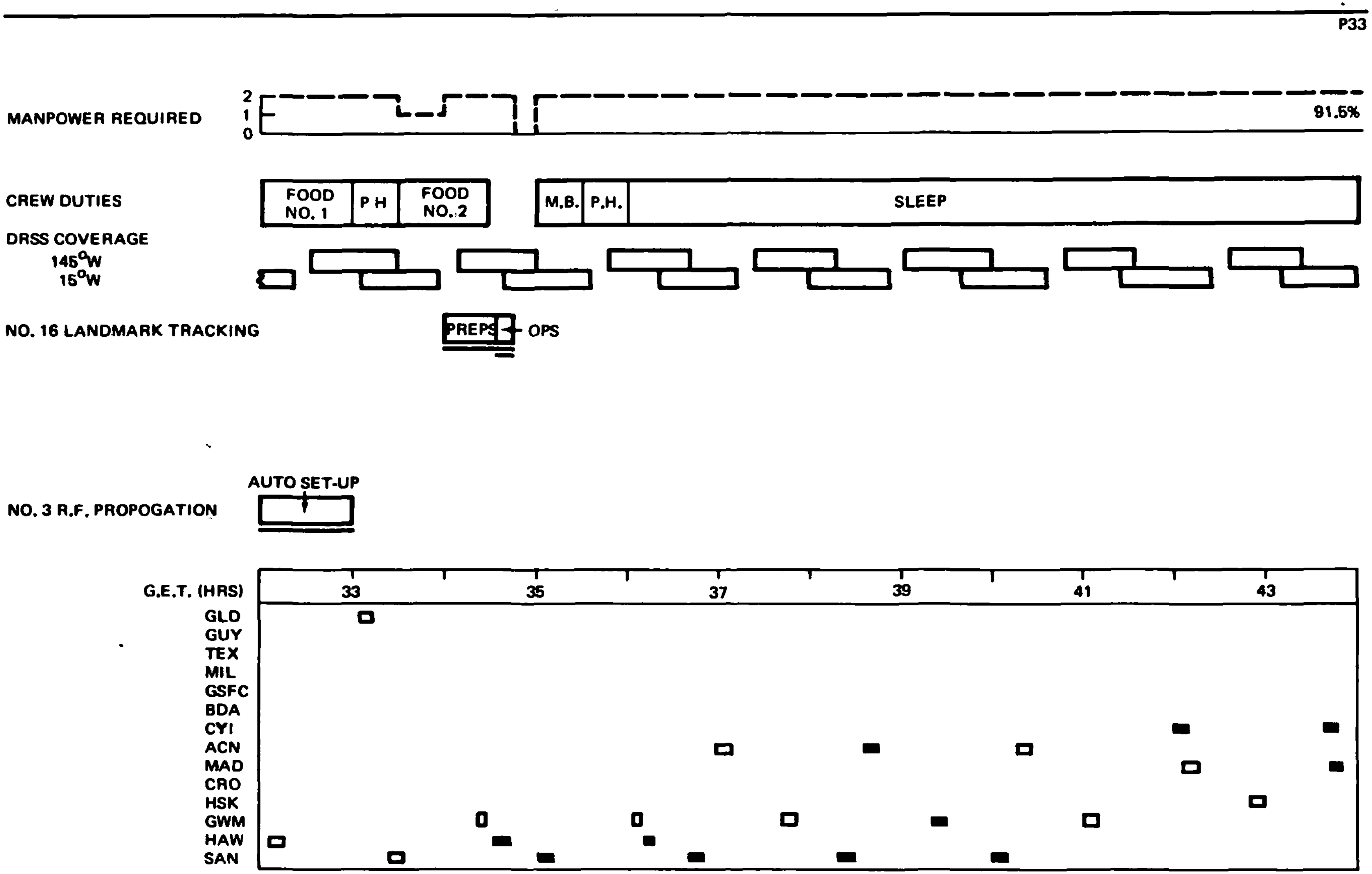


Figure 6-12. Comm/Nav Mission Timeline, Orbital Operations Day 1 (Continued)

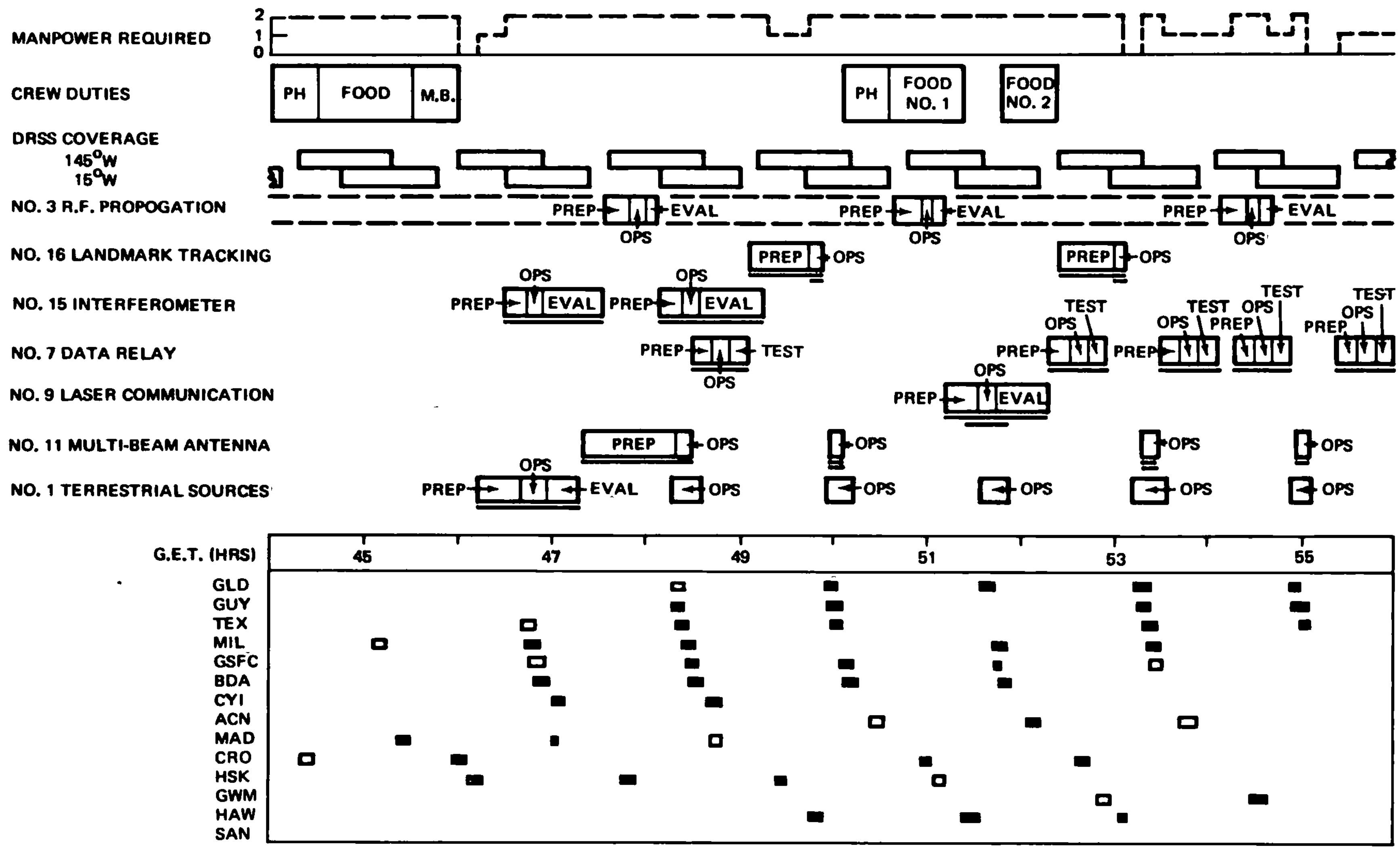


Figure 6-13. Comm/Nav Mission Timeline, Orbital Operations Day 2

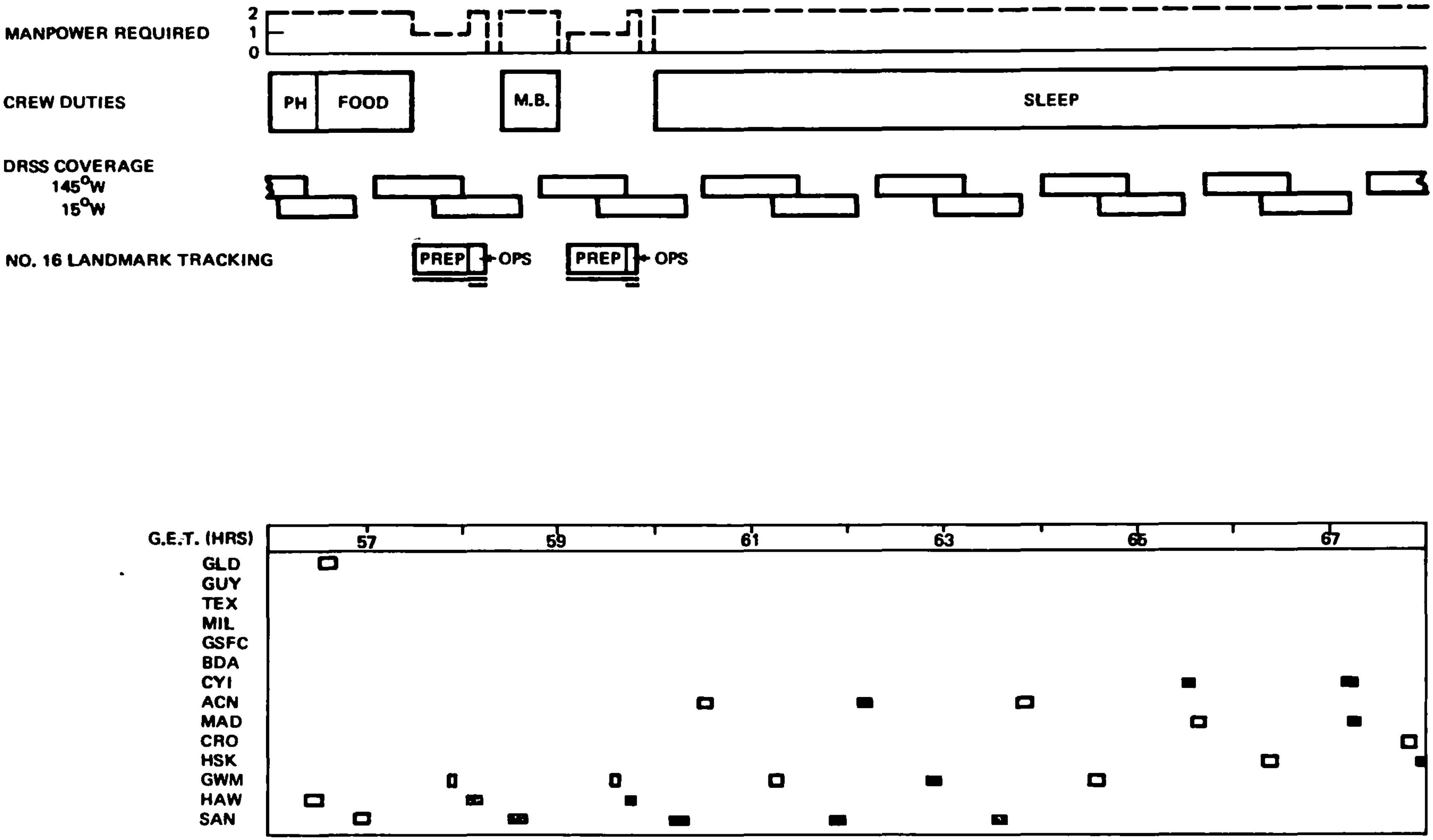


Figure 6-14. Comm/Nav Mission Timeline, Orbital Operations Day 2 (Continued)

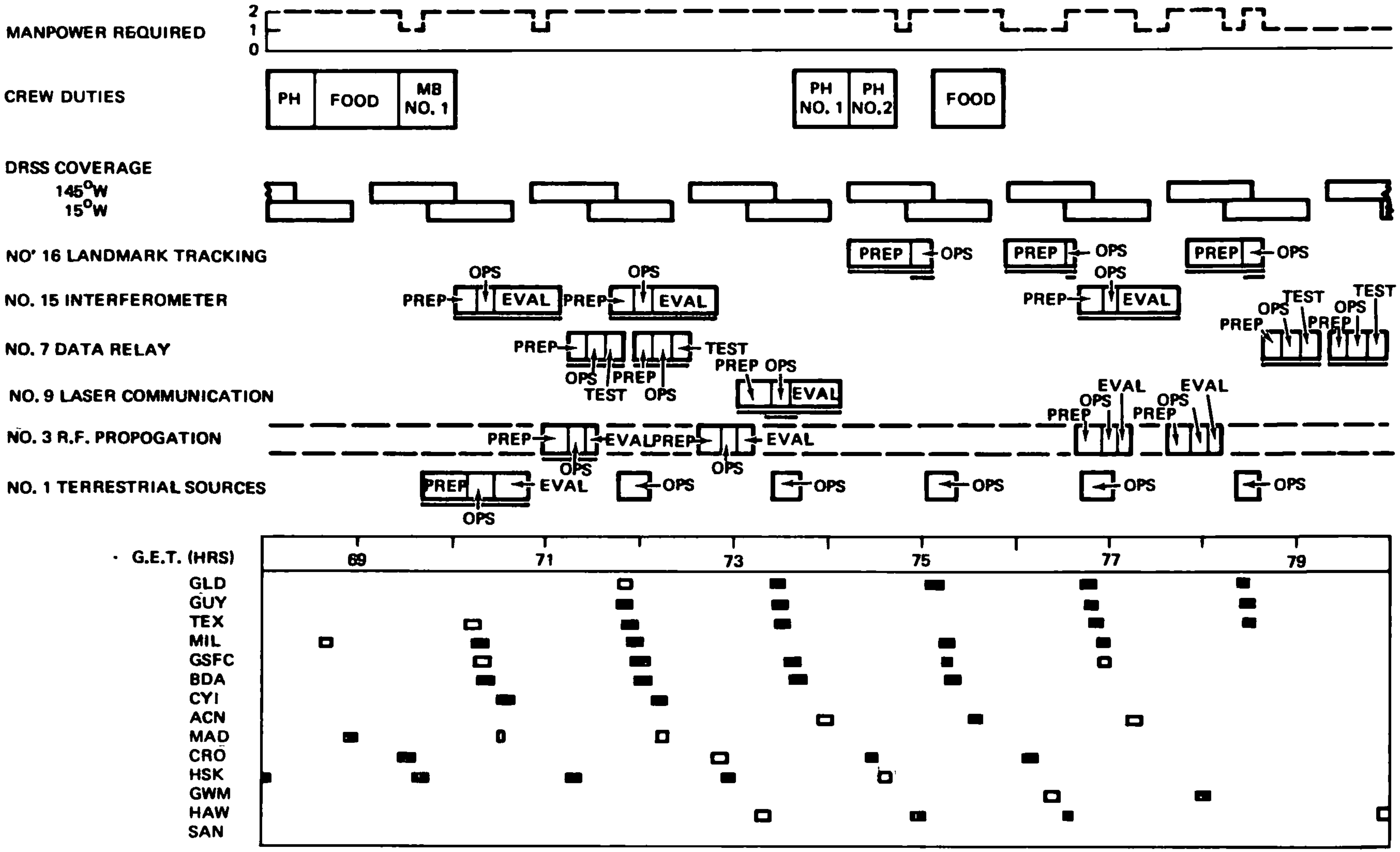


Figure 6-15. Comm/Nav Mission Timeline, Orbital Operations Day 3

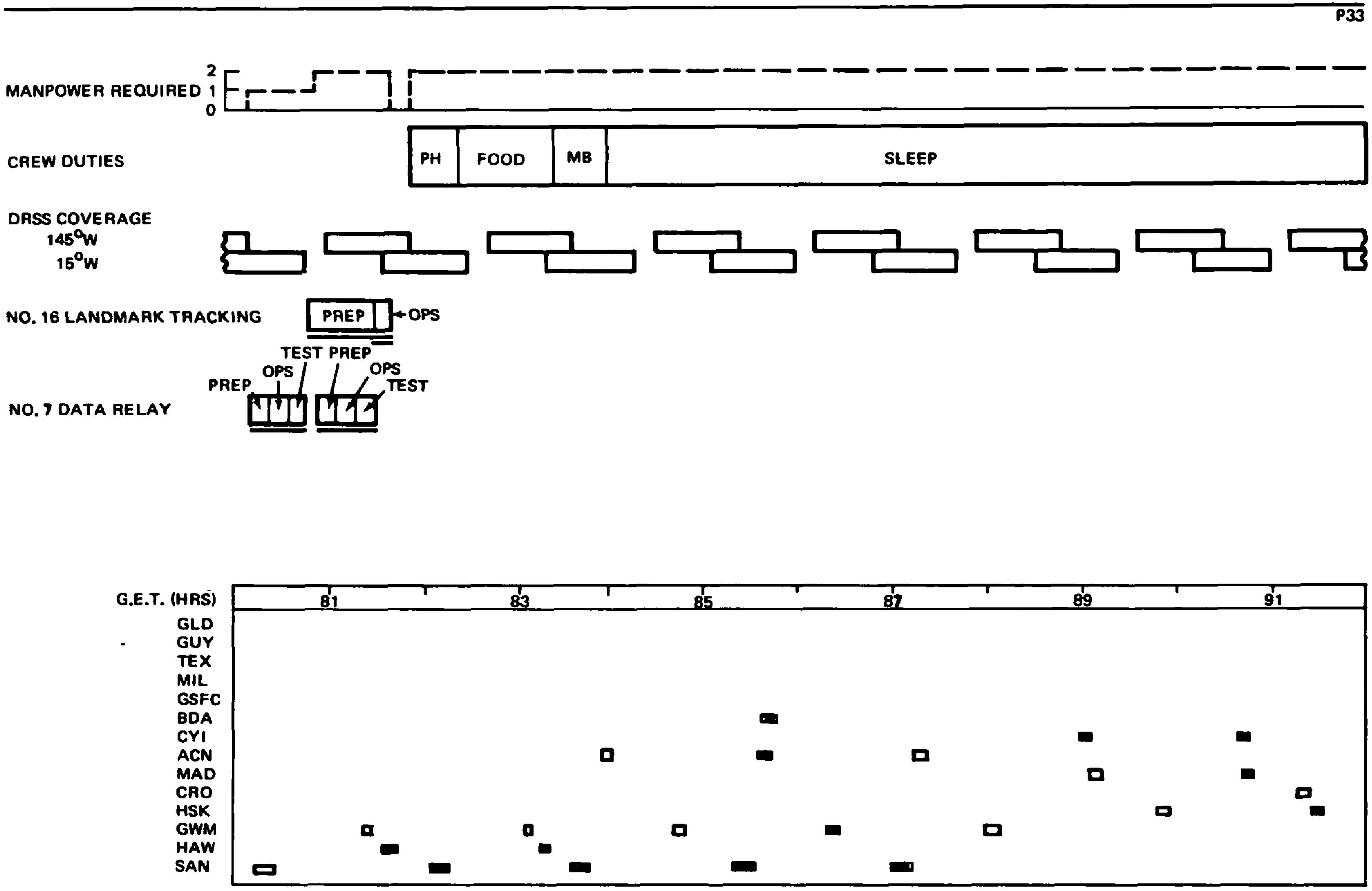


Figure 6-16. Comm/Nav Mission Timeline, Orbital Operations Day 3 (Continued)

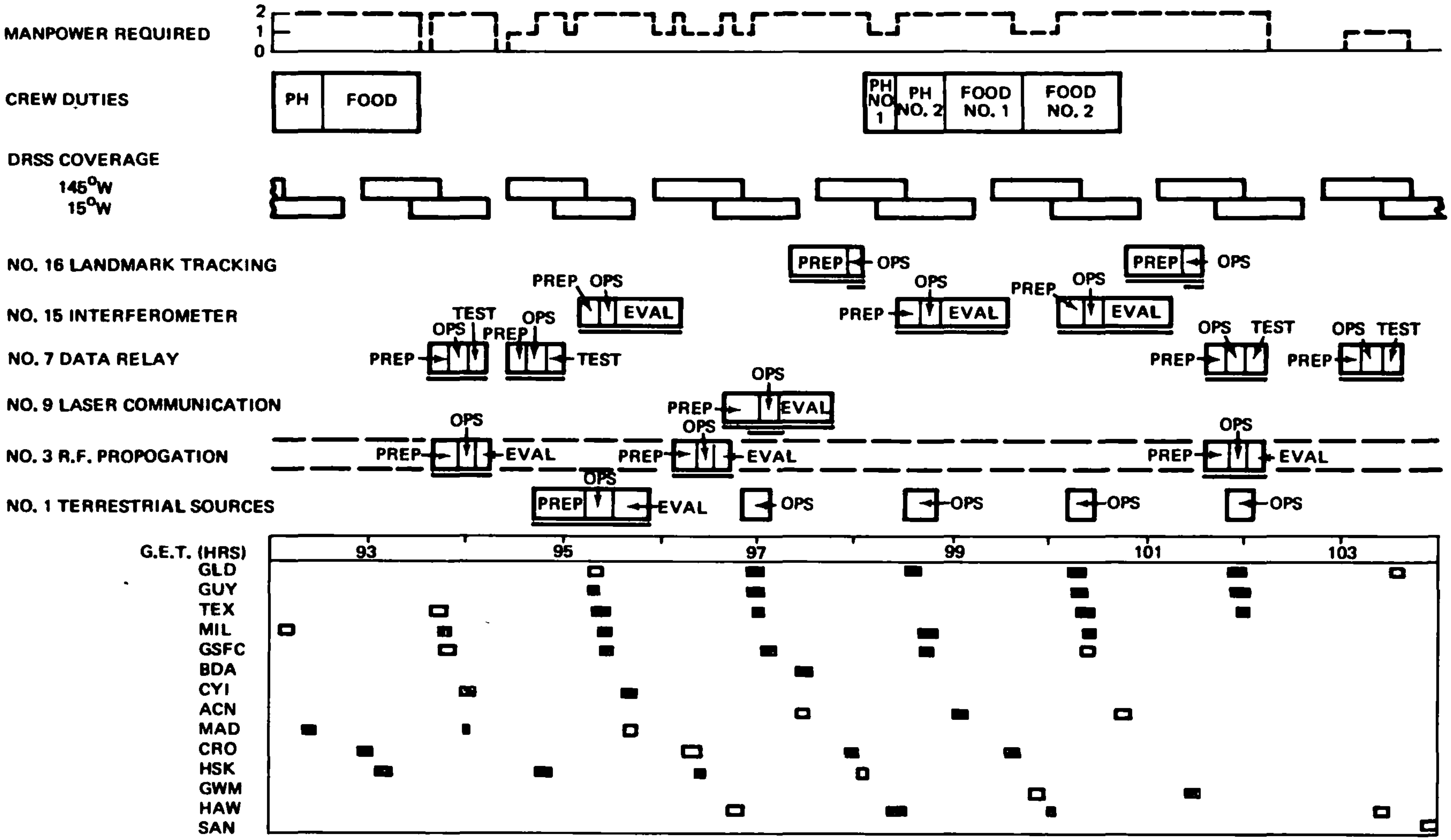


Figure 6-17 . Comm/Nav Mission Timeline, Orbital Operations Day 4

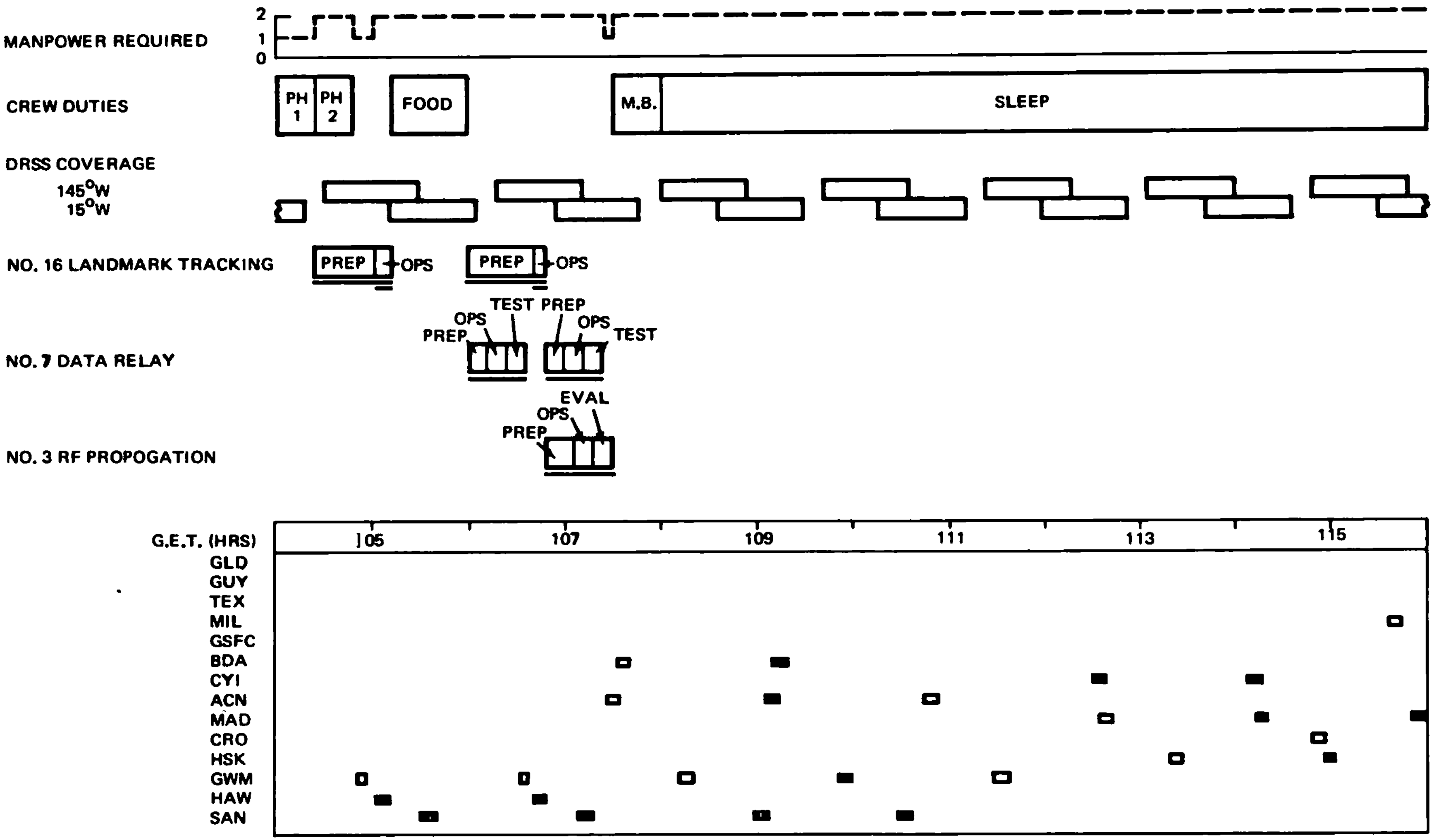


Figure 6-18. Comm/Nav Mission Timeline, Orbital Operations Day 4 (Continued)

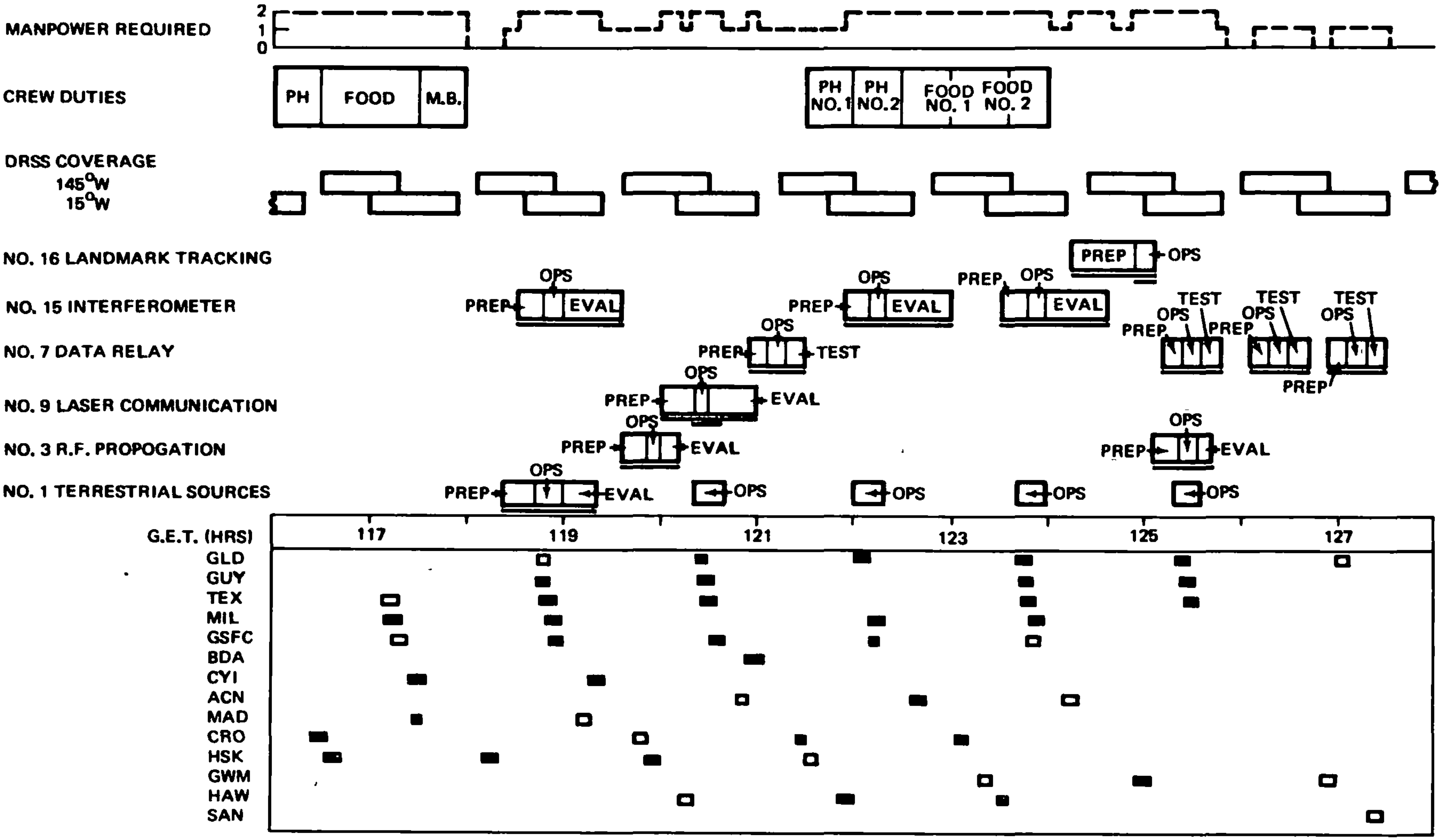


Figure 6-19. Comm/Nav Mission Timeline, Orbital Operations Day 5

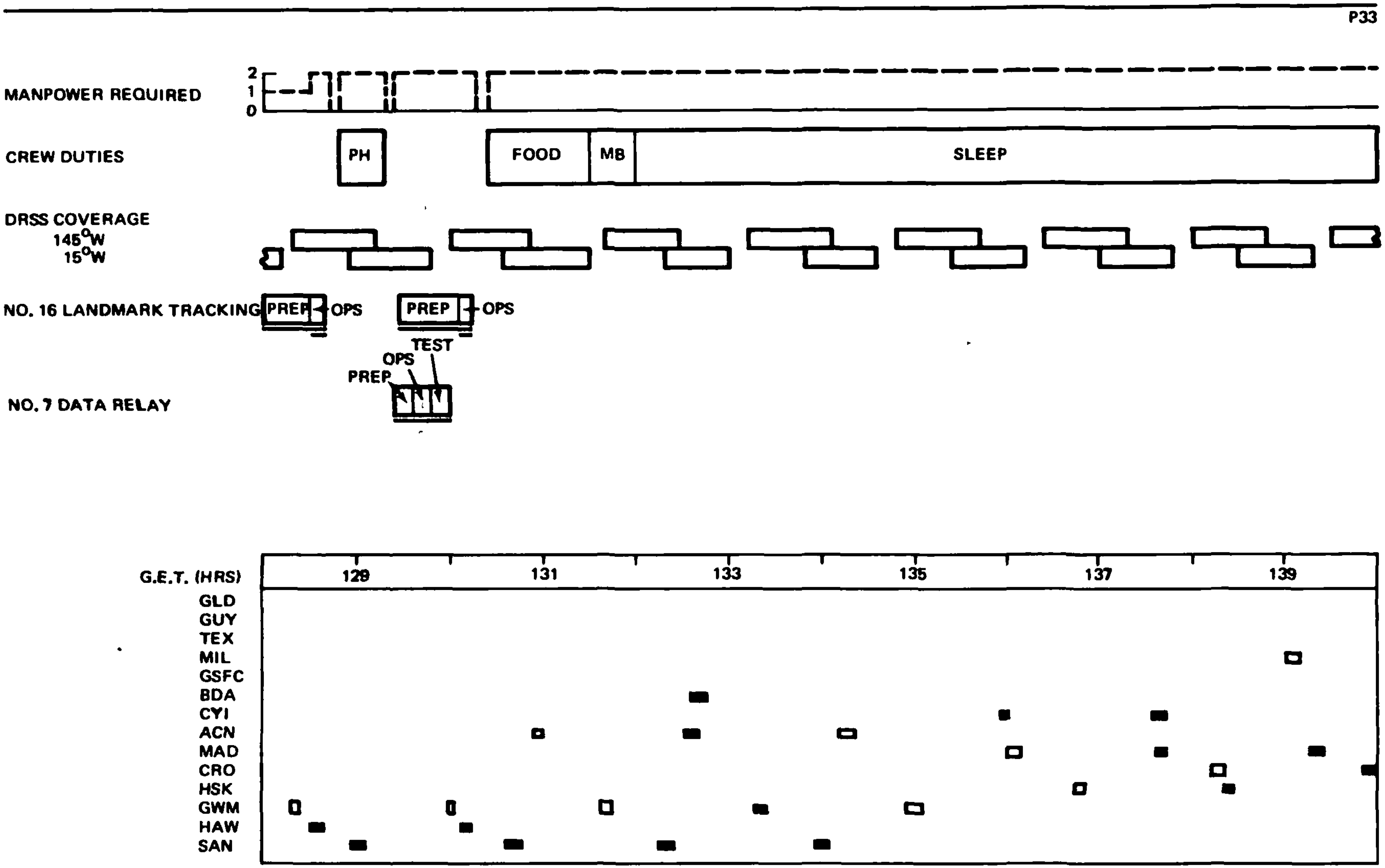


Figure 6-20. Comm/Nav Mission Timeline, Orbital Operations Day 5 (Continued)

The demands on the crew were increased considerably over those exhibited in the preliminary time line. The overall utilization numbers show 91 percent of the total crew time on-orbit utilized, with 77 percent of their work periods devoted to scheduled events. If one hour per day per crewman was scheduled for housekeeping activities, these utilization numbers would increase to 95 percent and 87 percent, respectively.

The results of the timeline update indicate several important factors, as follows:

1) A communication/navigation experiment payload, which makes full utilization of the Shuttle operational capabilities and passenger crew, can be provided.

2) As anticipated, the passenger crew can be scheduled for activities on-orbit in conjunction with the Space Shuttle crew duty cycles to eliminate interference between the crews and enhance the integrated operations of the Shuttle and payload.

3) The pre-mission planning and selection of the operations orbit is an important factor in providing the maximum mission potential to the payload.

4) The activity cycles of the two experiment crewmen indicate these personnel should be well cross-trained, such that both of the individuals are qualified for the operation of the experiments.

5) The mid-day food period of the crew should be flexible to minimize the interference with the experiment operations. The early- and late-day food periods are not as critical to the operations and possibly could be rigidized in the crew cycles.

6) If the antenna utilized for Experiment No. 1 and Experiment No. 3 is not designed for simultaneous operation of these experiments, one of the experiments will experience lost opportunities for operations in orbit.

7) Should the antenna utilized for Experiment No. 7 require special Space Shuttle orbiter orientations, this will most probably impact the operations of the other experiments, though additional data on Space Shuttle maneuver rates is required to verify this impact.

8) The operations of the experiments is "crew constrained" and should the orbiter crew be available to assist the payload crew with selected experiment operations, the orbiter crew could be utilized to increase the mission performance and return.

9) Additional analysis of orbiter and orbiter/payload interface requirements could result in providing additional time during the first and seventh mission days for experiment operations. This additional time would certainly increase the mission return. On the other hand, the integration of Shuttle required operations (such as platform updates) in orbit, once these requirements are defined, may interfere with the experiment operations and rduce the mission return.

10) The assumed constraint that the experiment must be within a 20 degree elevation acquisition cone for operation is a very conservative approach, and reduction of this constraint will afford increased experiment operations capabilities to the Comm/Nav research experiments.

6.3 MISSION ANALYSIS

During the course of work in mission analysis, a preliminary orbit model was postulated using the Laser Communications experiment proposed for Free-Flying Growth Laboratory flights. The mission description and model assumptions are specified in Table 6-10. An objective of this analysis is to identify the typical parametric data and methodology for selecting a mission orbit. A slightly elliptical orbit between 100 nautical miles perigee and 205 nautical miles apogee was examined to determine the most advantageous orbit inclination for covering five selected North American ground stations shown in the Table 6-10.

6.3.1 Orbit Lifetime

Using the assumptions of Table 6-10 and the parametric data presented in Figure 6-21, the following calculation were made to determine an orbit that will have a lifetime of seven days without requiring any maneuvers.

Average weight 15,000 lb

Ballistic Coefficient* $\frac{15{,}000 \text{ lb}}{(2.5)(200 \text{ ft}^2)} = 30 \frac{\text{lb}}{\text{ft}^2} \left[\frac{W}{C_D A} \right]$

Lifetime - 7 days

$B = \frac{7 \text{ days}}{30 \text{ psf}} = 0.234$ days/psf

for h_p = 100 n.mi e = 0.015 from Figure 3.7-1

thus,

Semi major axis** $\frac{3540 \text{ n.mi}}{1-0.015} = 3595$ n.mi

Apogee Altitude - 3595 n.mi (1.015) - 3440 n.mi = 205 n.mi

Orbit Period = 89.569 + 5(0.038) = 89.759 min.

Rev per day - (1440) ÷ (89.759) = 16

Non-Regressing Nodal Separation:

$$15 \frac{^\circ}{\text{HR}} \times \frac{\text{HR}}{60 \text{ min}} \times 89.759 \text{ min} = 22.45^\circ/\text{Rev}$$

* Assumes $C_D = 2.5$

** Assumes $R_e = 3440$ n.mi.

Table 6-10. Mission/Orbit Model Description and Assumptions

- Mission: Laser Communication Experiment
- Mission Duration: Experiment - 5 days (days 2 thru day 6)
  Total - 7 days
- Ground Stations: Five sites in North America
  - a) Goldstone, California
  - b) Cape Kennedy, Florida
  - c) Guaymas, Mexico
  - d) Corpus Christi, Texas
  - e) Goddard Space Flight Center, Maryland
- Coverage: a) <u>Objective</u>: To maximize the time spent over the ground stations.
  b) <u>Restrictions</u>: -Horizon elevation angle 10 deg.
  -Look-angle ±50 deg. from Nadir
- Launch Vehicle: Space Shuttle
- Payload Weight: (Assumed) W_{MAX} = 20,000 lb.
  W_{MIN} = 10,000 lb
- Payload Shape:
  - a) Must fit in Shuttle bay (15 d. ft. x 60 ft.)
  - b) 200 $ft.^2$ assumed (frontal area)
- Mission Profile: Deployed and retrieved by Shuttle. Payload will be stabilized and passive during rendezvous.
- Target Illumination - No Constraint.
- System Resolution - No Constraint.
- Attitude Control and Stabilization - No Constraint.
- Thermal Control (Sun Angle Orientation) - No Constraint.
- Power (Solar Cells?) - No Contraint.
- Minimum Perigee Altitude:
  - a) Sensors - No Constraint.
  - b) Man in Shuttle - 50 nmi.
- Maximum Apogee Altitude: Man in Shuttle - 500 nmi.

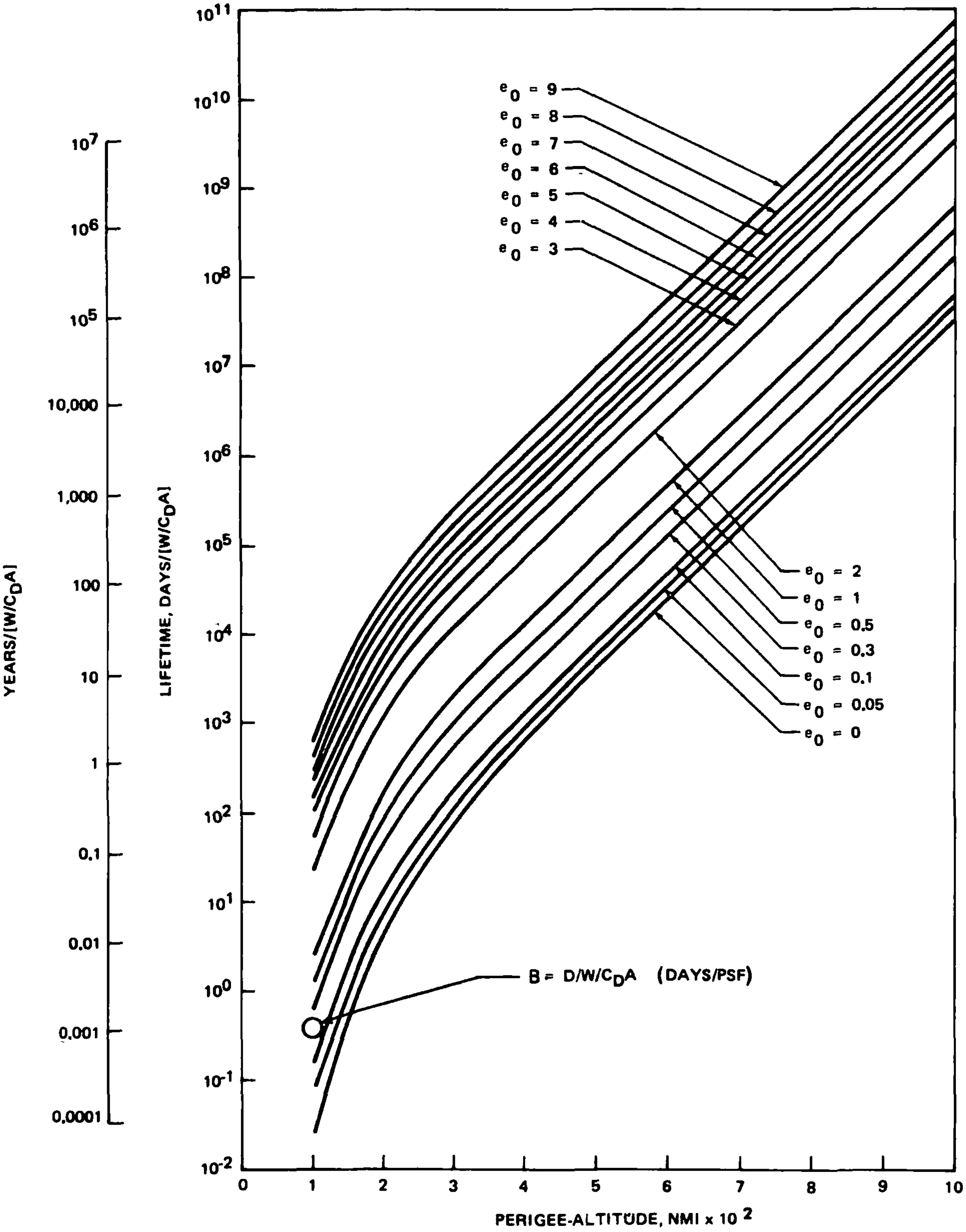
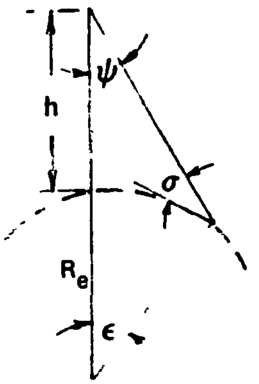


Figure 6-21. Lifetime in Days and Years Versus Perigee Altitude

6.3.2 Overfly Geometry



Two Overflight constraints are given:

(1) Maximum Sensor Look Angle = ± 50° from Nadir (Ψ)

(2) Minimum horizon elevation angle, σ, = 10°. Translating these into swath width coverage angle, ε, results in the table below for apogee and perigee.

Swath Width ε

	h = 100 nmi	h = 200 nmi
$\sigma = 10^\circ$[1]	7°	11.7°
$\Psi = 50^\circ$[2]	2°	4.6°

[1] $68^\circ \leq \Psi \leq 73^\circ$ [2] $35^\circ \leq \sigma \leq 39^\circ$

This was done with the aid of the applicable parametric data presented in Figures 6-22, 6-23, 6-24 and 6-25.

Clearly a look angle of 50° provides an ample horizon elevation angle at the target station, but a very small swath width (2° at 100 n.mi). If the look angle could be extended to 68°, an improvement of a factor of 2-1/2 could be made in the coverage angle. The swath width is directly related to the time spent over the target. Thus, the conclusion is:

EXTEND NADIR LOOK ANGLE TO 68°

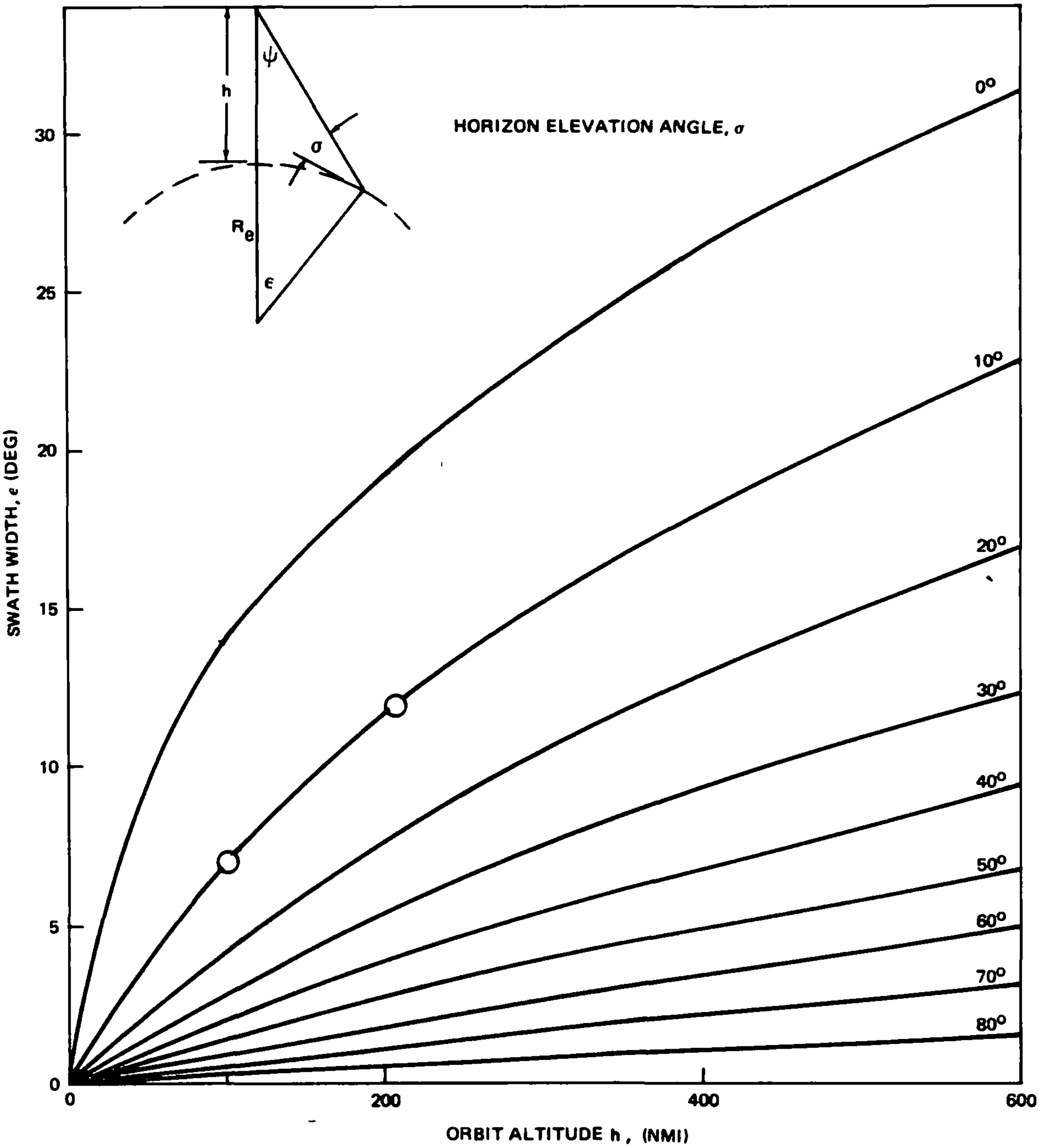


Figure 6-22. Ground Coverage from Orbit

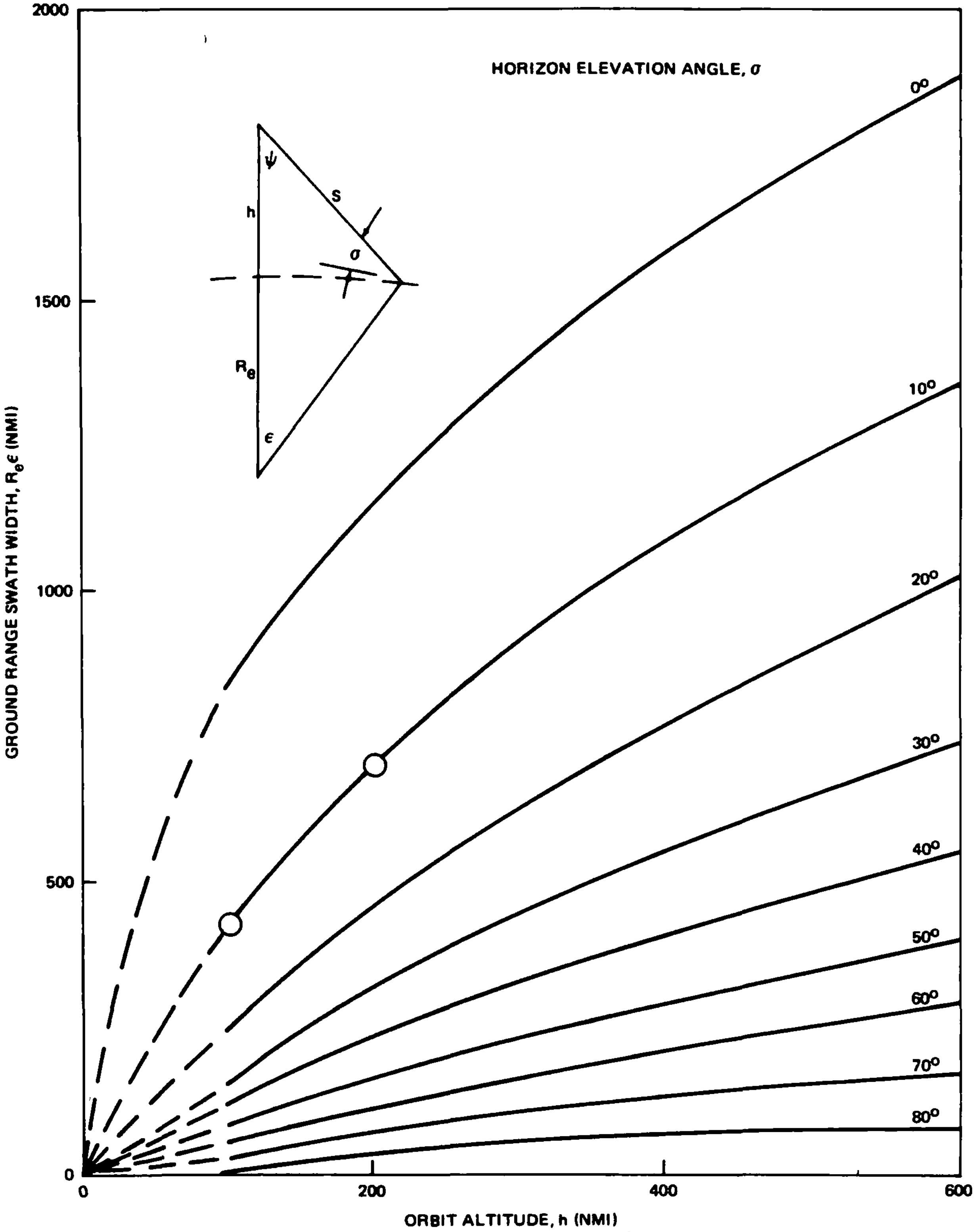


Figure 6-23. Ground Coverage From Orbit

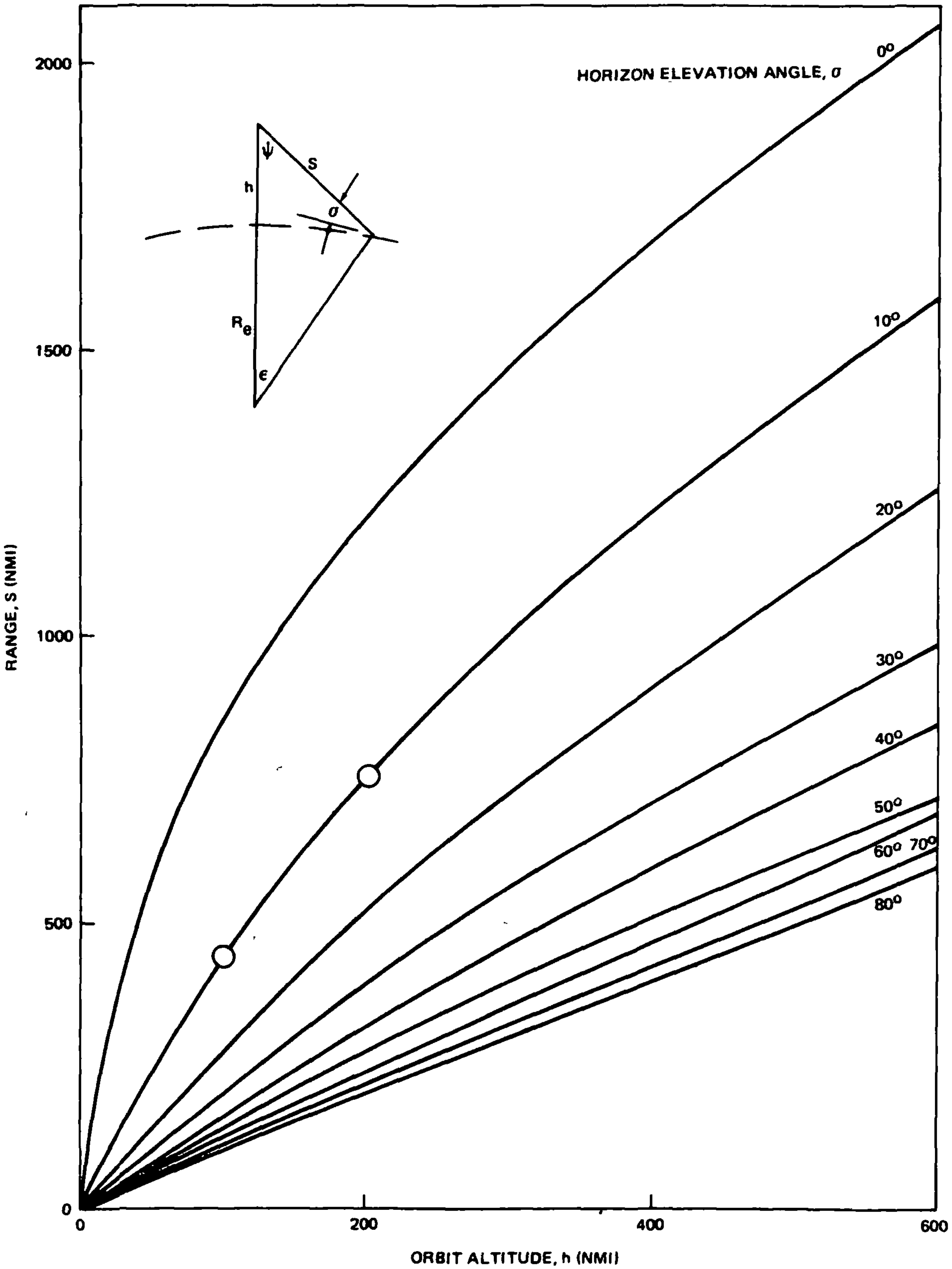


Figure 6-24. Ground Coverage From Orbit

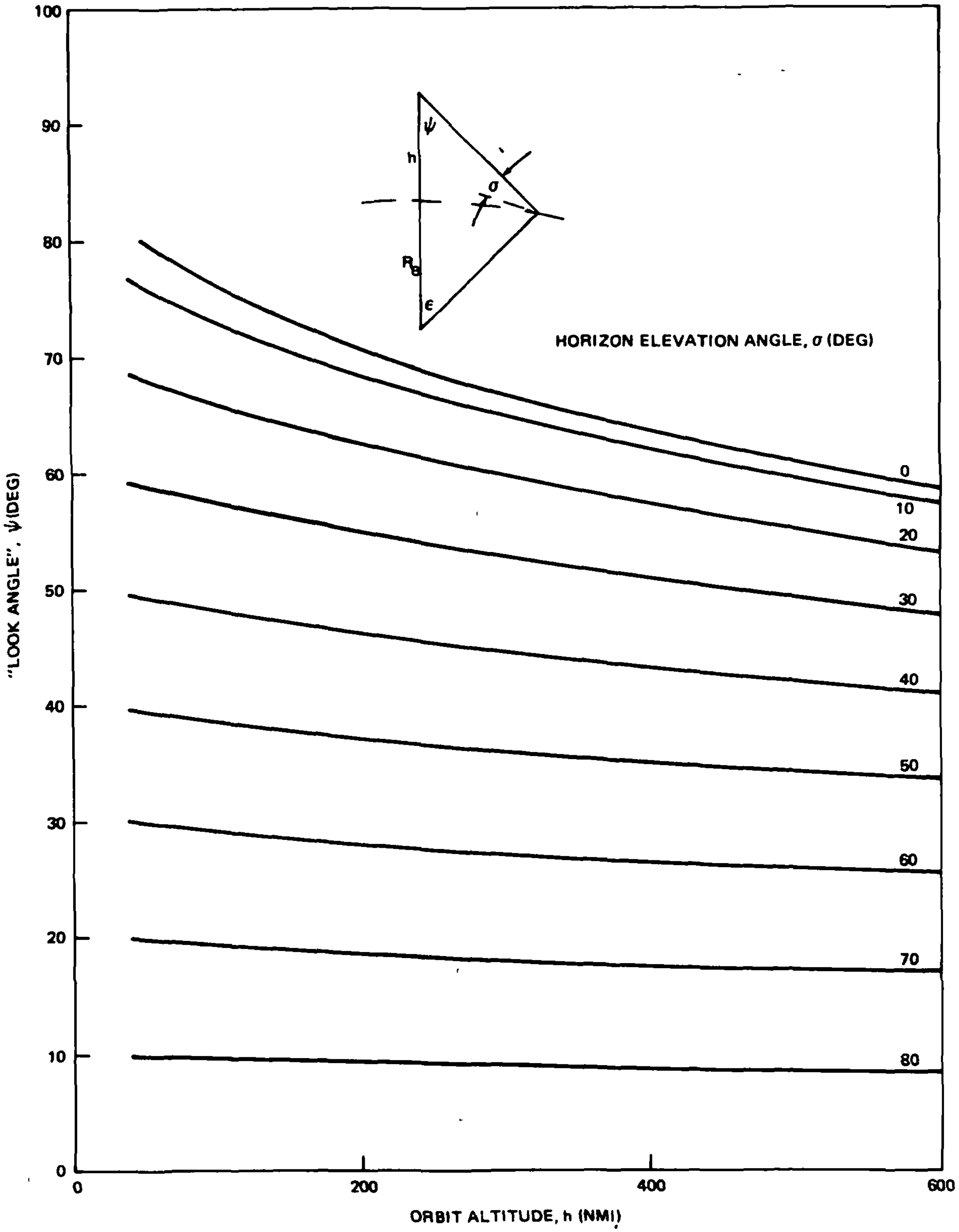


Figure 6-25. Ground Coverage From Orbit

6.3.3 Maximum Time Over Target

The maximum time spent over a target site is determined by the angular rate of the orbit and the swath width. The angular rate is found from the equation applied at apogee and perigee.

$$V_p = \sqrt{\frac{\mu}{6076}} \left(\frac{2}{3540} - \frac{1}{3595} \right)^{1/2} = 25{,}777 \text{ FPS}$$

$$W_p = \left(\frac{(3540)(6076)}{(25{,}777) \text{ FPS}} \right)^{-1} = 1.1984 \times 10^{-3} \text{ rad/sec}$$

$$V_A = \frac{3540}{3645} (25777) = 25034 \text{ FPS}$$

$$W_A = 1.1303 \times 10^{-3} \text{ rad/sec}$$

If an apogee overflight is used the net increase (maximum) in time over the target will be

$$\frac{W_p}{W_A} = 1.06 \quad \text{or} \sim 6\% \text{ more time over the target.}$$

The time spent over the target area per degree of swath width is

Perigee $\dfrac{1.7452 \times 10^{-2} \text{ rad/deg}}{1.1984 \times 10^{-3} \text{ rad/sec}} = 14.56$ sec/deg

Apogee $(1.06)(14.56) = 15.43$ sec/deg

6.3.4 Targeting

Considering the foregoing analysis the following conclusion may be drawn. The satellite should be targeted for an apogee overflight of the target station resulting in the following maximum time over the station of

$$\sigma_{min} = 10°$$

$$\Psi_{max} = 68°$$

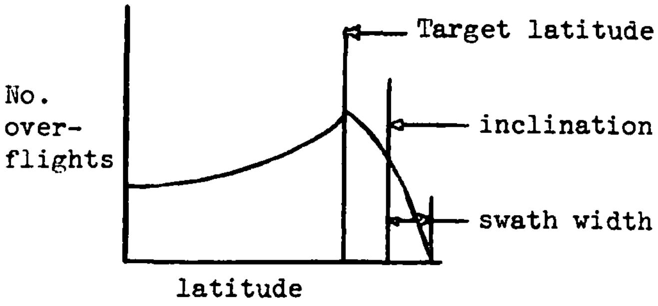
$$\varepsilon = 11.7°$$

$$\Delta t = \frac{2(11.7)(15.43)}{60} = 6.2 \text{ min}$$

6.3.5 Orbit Inclination

Orbit inclination is restricted by range safety considerations, the plane change capability of the launch vehicle, and the maximum target latitude.* According to the space shuttle ground rules, the reusable shuttle may launch at any azimuth with a corresponding degradation in payload for deviations from a due east launch. Figure 6-26 illustrates a typical variation of the effects of apogee altitude and inclination on payload for a space shuttle. The shuttle is assumed to use the OMS propellants for altitude changes.

The other factor in the selection of an orbit inclination is the location of the targets, in particular the latitude of the station. A cursory analysis will indicate that the maximum number of daily overflights of a given target can be obtained if the inclination of the orbit is equal to the target latitude plus the sensor swath width. The following sketch illustrates this point. This conclusion is valid for a long term mission where longitudinal location averages out, thus making it true for any target on that latitude circle. Since this mission is so short (7 days) the location of the orbit node will be significant in determining the number of target overflights. This is particularly true since there are several targets and optimization of the overflight history of one of them does not assure an overall optimum solution. Figures 6-27 and 6-28, present parametric data for determining the initial ascending node and nodal rate.



As a first cut, for the ground sites given, an orbit inclination of $i=\delta_{max}+\epsilon$ will be used. Since GSFC is the most northerly station $(\delta = 39^{o}N)$, placing apogee $(\sigma = 11.7^{o})$ over this target yields an inclination of $i = 50.7^{o}$.

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* Should probably be targeted by weighting the average target latitude by the number of targets above and below it.

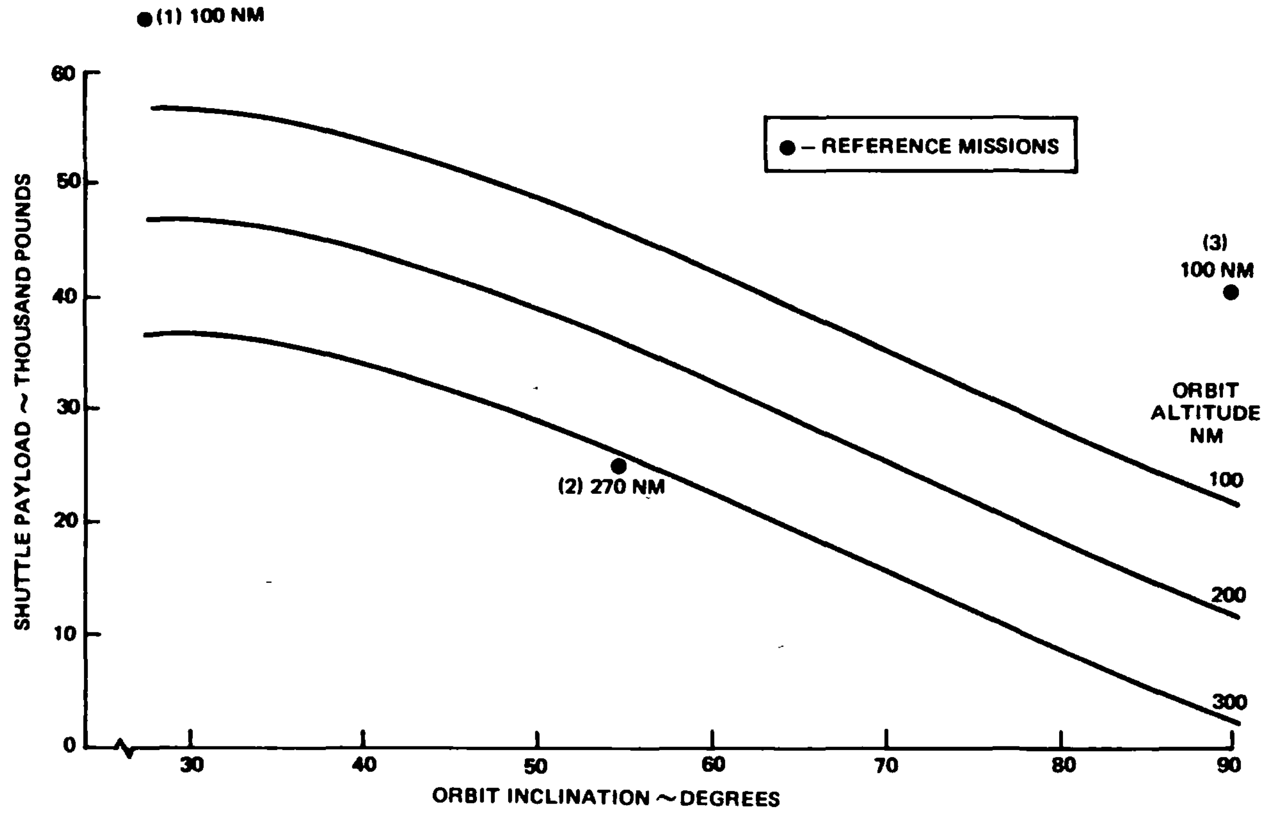


Figure 6-26. Shuttle Performance

6.3.6 Longitude of Ascending Node

The longitude of the ascending node is required to orient the orbit. Two cases are considered:

a) The nominal launch orbit node location, assuming a launch from Cape Kennedy,

b) The velocity capability required to change the orbit node in low earth orbit.

The advisability of changing the nominal node with a maneuver must be evaluated against the increased coverage it gains and the corresponding shuttle payload, altitude, and inclination penalties.

The expression relating the velocity required to change the orbit node and the angle change is

$$\Delta V = 2V \sin i \sin \frac{\Delta\Omega}{2}$$

where V is the velocity at max latitude (apogee in this case)

i is the orbit inclination

and $\Delta\Omega$ is the node shift.

Figure 6-27 presents the nominal launch orbit descending node locations. The corresponding ascending node locations are 168.58° W from these locations.

6.3.7 Nodal Regression and Apsidial Rotation

The fact that the earth is not spherical causes the orbit to be perturbed in two significant ways. The first causes the orbit plane to rotate about the North Pole a small amount each revolution. This is termed nodal regression. The second perturbation causes the line joining apogee and perigee to move in the orbit plane. These movements may be significant if a repetitive orbit is required or special sun angles or like requirements are encountered. Figure 6-28 illustrates these rates for the elliptical orbit discussed earlier.

6.3.8 Radiation

Specification of the maximum apogee altitude due to the presence of man in the shuttle is a difficult task. When considerations of the effects of corpuscular radiation on personnel are of primary concern, intensities

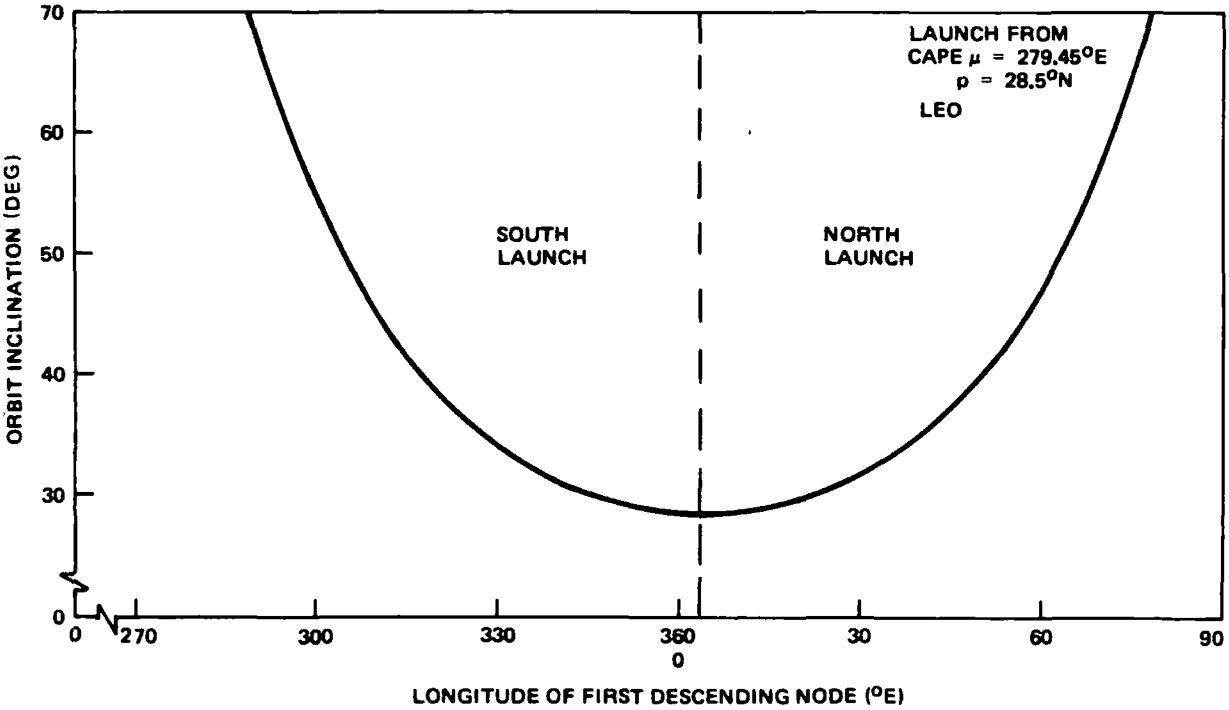


Figure 6-27. Ascending Node Versus Orbit Inclination

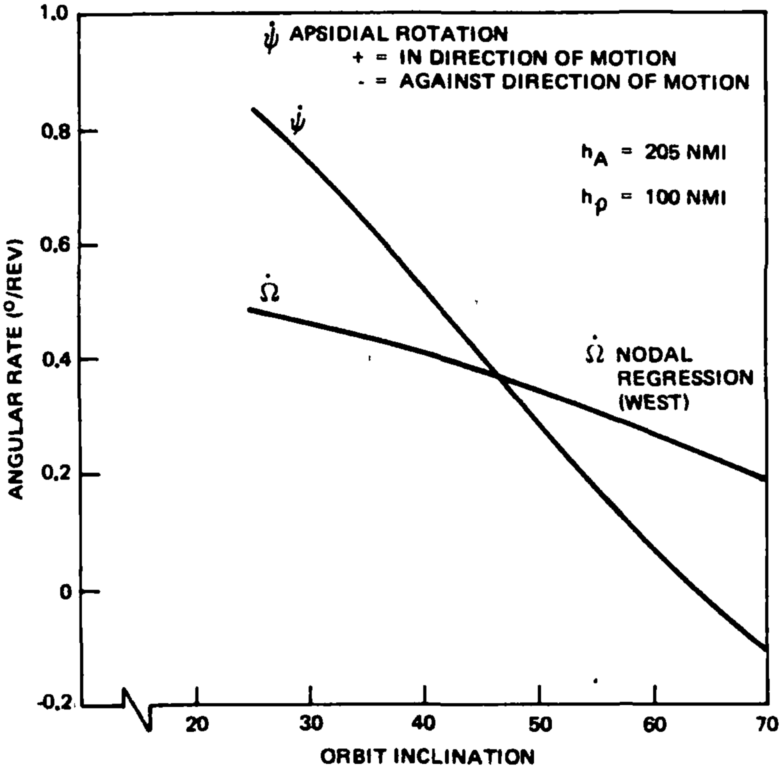


Figure 6-28. Regression and Precession Rates Versus Orbit Inclination

or counting rates must be converted to dose or dose rates. The rad is the unit of absorbed dose; one rad is 100 erg. absorbed per gram of absorbing material. Conversion of observed partical fluxes to absorbed dose rate, however, is not straightforward and is sometimes impossible for lack of necessary details. The conversion depends in a complex way on the energies and kinds of particles and on geometrical configurations of the absorbers and direction of the incident beam, as well as on the different absorbing properties of the materials.

The naturally occurring trapped electrons and protons are separated into three regions.

1. The lower edge of the inner Van Allen belt
2. The middle region, the heart of the Van Allen belt
3. The outer region or the outer Van Allen belt

The first region starts at between .15 and .17 earth radii (520 to 600 nmi) and will be used as an upper limit for the apogee altitude due to radiation and man in the Shuttle. This point is not really significant since the spacecraft is assumed non-maneuvering and the orbitor can not attain such apogee altitudes.

6.3.9 Model Mission Summary

The basic orbit selection process is based upon expressing the geometric, vehicle, mission and equipment antenna pointing constraints in terms of constraints upon the orbital elements.

The primary constraint of interest is the maximum number of minutes of viewing time between spacecraft and fixed ground locations along the Western Coast, Central Region and Eastern Seaboard of North America. The primary tool used by the model is a MDAC computer program (MZI0) that accounts for orbital decay and determines the time interval during each revolution spent over a target area, as a function of the target horizon elevation angle. Five-day viewing time data runs were analyzed for 0 and 10 degrees elevations at inclinations of 40, 50.7, 55, and 60 degrees.

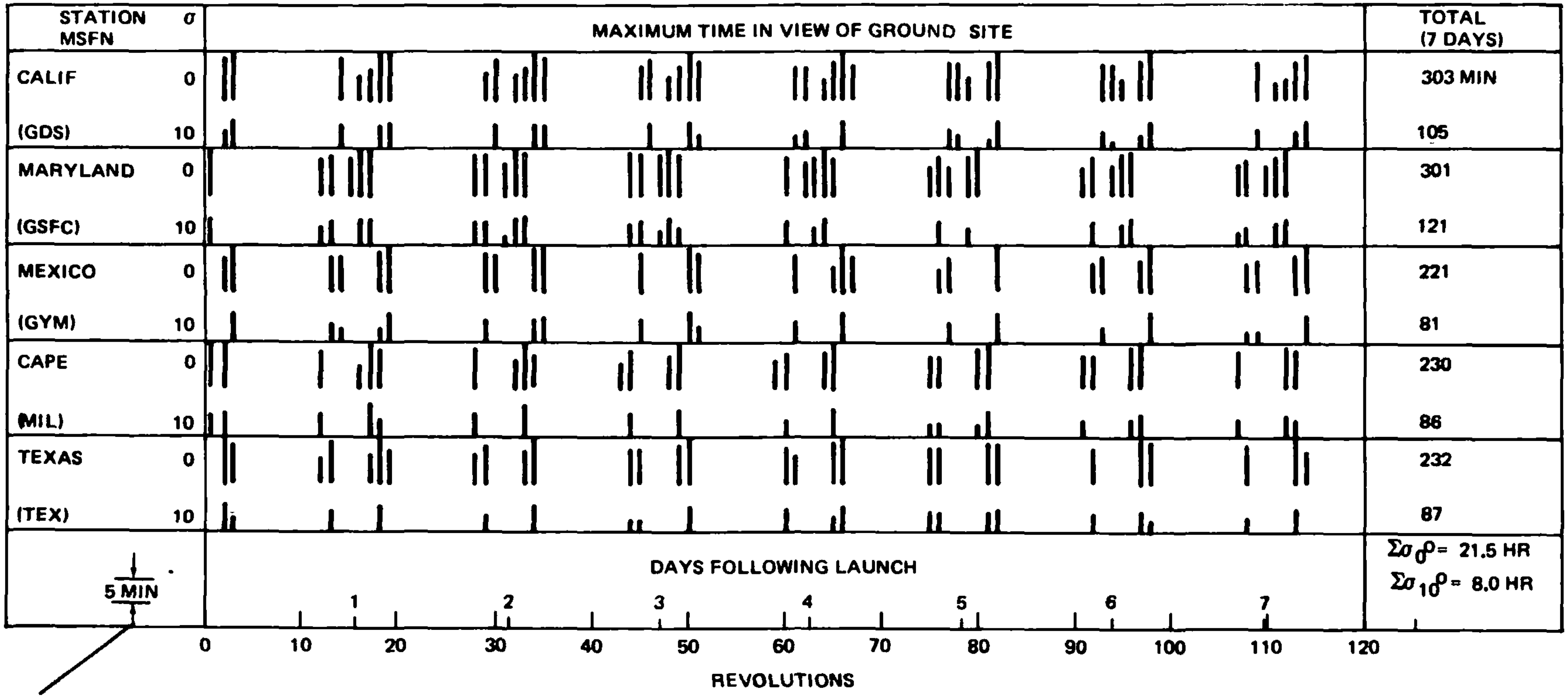
The results of seven-day orbit viewing times in minutes calculated are summarized in Figure 6-29 for 50.7 degrees inclinations. The sum results of all orbits are:

Table 6-11.

Ground Station	Total Minutes Over Site (81 Orbits)							
	0° Elevation				10° Elevation			
	Inclination							
	40°	50.7°	55°	60°	40°	50.7°	55°	60°
Goldstone, Calif.	191	210	182	159	97	72	62	53
Guaymas, Mexico	220	159	145	132	89	55	51	47
Corpus Christi, Texas	213	159	136	132	81	59	52	48
GSFC, Maryland	175	207	223	183	91	88	76	59
KSC, Florida	202	159	145	143	79	61	52	47
TOTAL (hours)	16.7	14.9	13.9	12.5	7.3	5.6	4.9	4.3

From the data results tabulated in Table 6-11, above, it appears that lower inclinations (i≤40) for the elliptical orbit example chosen gives more time over the four more southerly (attitude) station locations. Only GSFC, Maryland would lose, rather than gain, viewing time. The best balance of time over the five sites selected seemed to fall between 40 and 50 degrees inclination. Figure 6-30 depicts a ground track plot over North America for the selected orbit at 50.7 degree inclination. Superimposed are visibility circles for 0 and 10 degree elevation angle for each of the five identified ground stations. It is significant to note that approximately 5-1/2 hours of total viewing time is all that would be available during a five-day orbit mission to complete the laser research data objectives assuming perfect conditions (by not accounting for cloud cover affecting the data period). Other than the orbital lifetime discussion, paragraph 6.3.1, the remaining topics of Section 6.0 could also apply to Laser Comm experiments performed from the Space Shuttle Orbiter attached Early Comm/Nav Laboratory.

ORBIT INCLINATION	50.7°
APOGEE ALTITUDE	205 NMI
PERIGEE ALTITUDE	100 NMI
ORBIT PERIOD	89.759 MIN
REVOLUTIONS PER DAY	16



NOTE VERTICAL SCALE 1/8 IN. = 5 MINUTES

Figure 6-29. Laser Communications Orbit Model (Five North American MSFN Stations)

24 HOUR ORBIT-ALTITUDE 100 x 206 NMI
INCLINATION = 50.7°
5 GROUND SITES

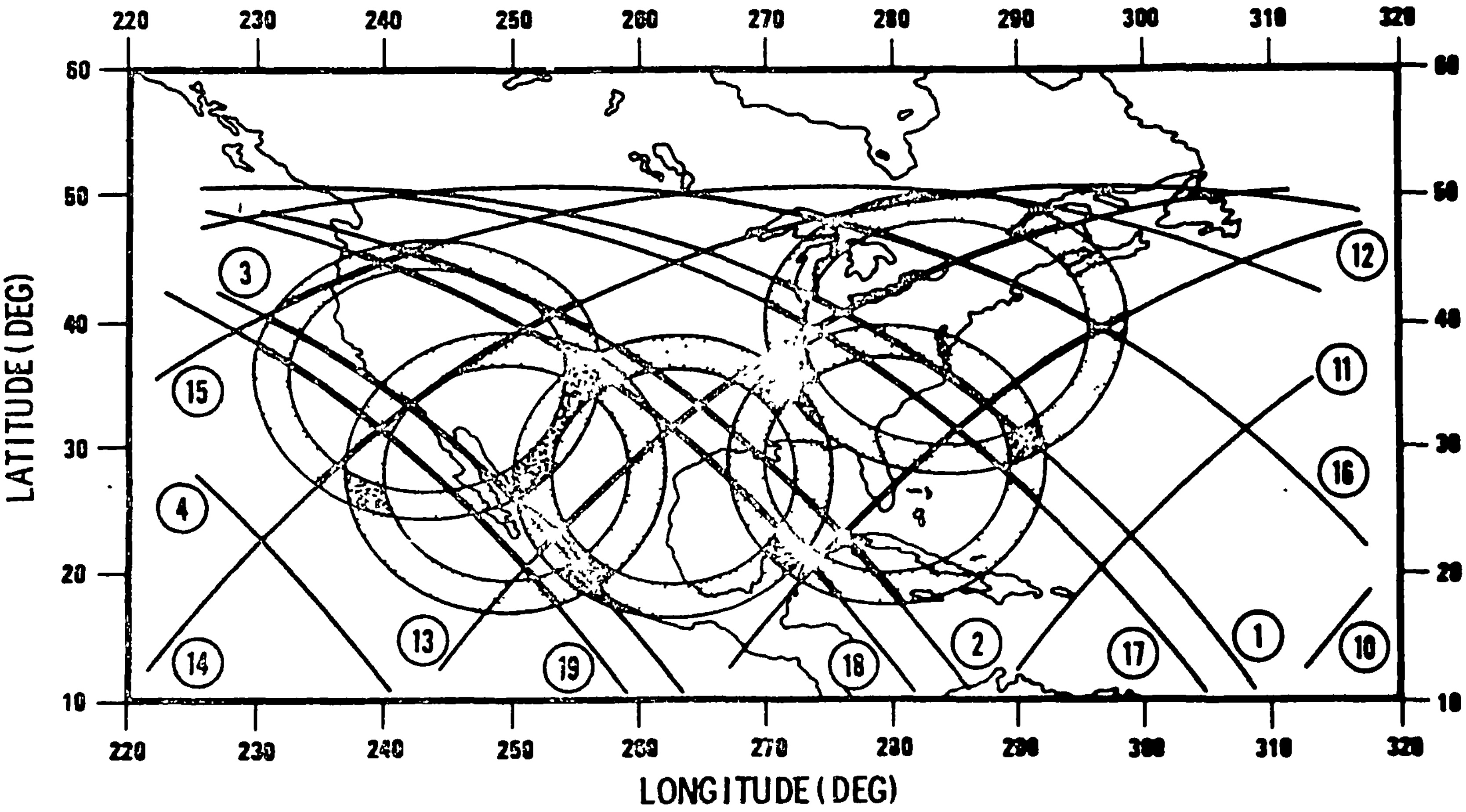


Figure 6-30. Laser Communication Mission Model