NRL Report 6530

ELF-VLF Propagation/Electron Density-Temperature Satellite-Borne Experiment

September 21, 1967

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NAVAL RESEARCH LABORATORY
Washington, D.C.

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C. J. Kurner, E. F. Kulikowski, and F. T. Powles

Data Processing Branch
Applications Research Division

September 21, 1967

NAVAL RESEARCH LABORATORY
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ABSTRACT

An experiment program plan for the investigation of ionospheric plasma electron density and temperature and for the ion sheath surrounding space vehicles has been developed. Subsequent efforts have broadened the scope to include the investigation of VLF radiation from spaceborne transmitting sources. The program, although originally planned for inclusion in the Manned Orbiting Laboratory program, has been made sufficiently flexible to permit conduct of the experiments aboard a broad range of launch vehicle-satellite configurations, either manned or unmanned.

PROBLEM STATUS

This is the final report on this problem. This problem is now closed.

AUTHORIZATION

NRL Problem R07-15
WEPTASK RT7045020/6521/F019-05-02

Manuscript submitted December 16, 1967.

ELF-VLF Propagation/Electron Density-Temperature
Satellite-Borne Experiment

INTRODUCTION

The investigative program which forms the basis for this report was initiated as a proposed experiment for the measurement of ionospheric (F-layer) plasma parameters, such as charged particle densities and temperature (energy), and for the investigation of interactions of space vehicles with the plasma medium.

The proposed experiment was submitted for consideration for inclusion in the Manned Orbiting Laboratory (MOL), it being reasoned that the unique capabilities of a large, well-instrumented orbital platform provided an ideal means for conduct of a comprehensive "in-situ" data collection program. The on-board presence of skilled astronaut test conductors provided the capability to optimize the collection of the experiment data over the expected (and perhaps unexpected) temporal and spatial variations encountered. It was expected that this would result in an enhanced accuracy and reliability of the experiment and its conduct.

Inclusion of the experiment in a laboratory platform of the size of the MOL gives promise of supporting data from other experiments and vehicle subsystems which may be used in the ground-based data analysis procedures. Plasma data variations may be correlated with causative effects detected by other sensors (e.g., x-ray and γ-ray monitors) or associated with vehicle orientations. These capabilities also provide an opportunity for enhanced accuracy of the experiment results.

This report will present the chronology of the definition of the experiment program, the technical development effort, and the support studies undertaken.

PROGRAM DEFINITION

The initial attempt at defining an experiment for the measurement of plasma densities and temperature suitable for inclusion in the MOL was contained in an experiment proposal submitted to the Navy MOL Experiment Selection Board (A.1).* Favorable reaction at this level resulted in the submission of the proposed experiment, in slightly more detail, to the MOL Managing Agency, Air Force Systems Command, Space Systems Division (A.2, A.3) for further review and evaluation.

Approval by DOD of a Pre-Contract Definition Phase effort and selection of the Electron Density and Temperature Experiment as a candidate experiment for the MOL resulted in a formal program effort at the Laboratory. Technical approaches, milestones and schedules, fiscal requirements, and manpower levels required were

*References are to appendix items; with letters referring to an appendix, and following numerals referring to exhibits contained within that appendix.

documented in reports submitted to the Air Force via the Navy Field Office for MOL (B.1-B.5). Periodic program reviews in the form of graphics and supporting narrative material were presented to the Navy Field Office (C.1-C.23). These reviews were instituted to provide the Air Force with a high degree of visibility on the Navy Experiment program. As a result of such reviews, several modifications to experiment configuration were effected during the Pre-PDP period, in keeping with vehicle limitations (e.g., size, weight, power), which were defined to the experiment sponsors during this period. These changes to the Electron Density and Temperature Experiment are evident in the Program Review material prepared for this period (C.1-C.3). Additional supporting information was presented through memoranda prepared on specific areas of program effort, for example, the Memorandum For File dealing with the initial definition of data storage and data rate requirements occasioned by operation of the Plasma Measurements Experiment (D.1).

With the conclusion of the Pre-PDP effort and in anticipation of a formal go-ahead on the PDP itself, project effort was concentrated on the procurement planning for a laboratory model of the proposed plasma measurement instrumentation. A draft copy of a Request for Proposal was prepared (D.8), with the intention of updating it and releasing the final version to industry when program approval was received. It shortly became apparent that obtaining such approval would be delayed. With the intent to continue a meaningful program effort without the procurement of significant amounts of equipment, an effort was initiated to develop data collection and analysis techniques which could be used for the test and evaluation of system components to be procured after program approval had been given. Similarly, consideration was given to simulation tasks which could be employed to evaluate the performance of the proposed experiment configuration (D.5).

At about this time, the objectives of the several candidate experiments were re-examined and the experiment sponsors were asked to redefine their programs to emphasize the support of an ultimate operational need and/or capability. Since one of the original objectives of the plasma measurements experiment was to provide data of use to a VLF propagation experiment (also a candidate for inclusion in the MOL program), it was determined that the two experiments be merged and redefined in terms of their ultimate operational capability. This redefinition was performed and presented to the Navy Field Office for MOL in the form of program reviews and progress reports (C.10-C.14). The Request for Proposal was redrafted and held while awaiting the necessary funding (D.10).

It became increasingly evident that the Navy-sponsored MOL Military Technology Experiments (of which the consolidated VLF Propagation/Electron Density Temperature Experiment was one) would not be funded as part of the MOL PDP effort. With this in mind, a further redefinition of the experiment program was conducted with the goal of achieving a program which was sufficiently flexible to be accommodated by a wide variety of launch vehicle-satellite configurations in either a manned or unmanned environment (C.16). The overall performance objectives were not significantly changed; they were limited in scope, however, by the capabilities of the parent satellite and its instrumentation (e.g., attitude sensors, data storage and telemetry, power sources).

This most recent approach has been incorporated in a document submitted to the Naval Air Systems Command to aid them in the preparation of a Proposed Technical Approach for a submarine communication system using a spaceborne VLF transmitter (D.11).

A more detailed presentation of the work done under this program is given in the July 1966 Progress Report (C.23) which is also the fiscal year 1966 final report.

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6. Final Technical Documentary Report (FTDR), Navy Experiment Program for Manned Orbiting Laboratory: Experiment S-23, Electron Density and Temperature, Navy Field Office for MOL Report TR-65-2, Vol. 3, Jan. 8, 1965

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APPENDIX A

PRELIMINARY DOCUMENTATION PREPARED IN SUPPORT OF CANDIDACY OF ELECTRON TEMPERATURE AND DENSITY EXPERIMENT FOR MANNED ORBITING LABORATORY PROGRAM

Contents

Exhibit A.1	Electron Density and Temperature
Exhibit A.2	The MOL-Electron Density and Temperature Experiment
Exhibit A.3	Electron Density and Effective Temperature

EXHIBIT A.1

ELECTRON DENSITY AND TEMPERATURE

I. Experiment Description

A satellite moves through plasma, a partially ionized medium composed of neutral molecules, positive ions, and electrons. For comparable ion and electron temperatures, i.e., thermal equilibrium,* the electron velocity will be about a hundred times the ion velocity. Specific calculations show that the ion velocity is one-tenth that of the satellite, while the electron velocity is 10 times greater than the satellite velocity. This means, in effect, that the satellite plows into a stationary distribution of positive ions while it is bombarded from all directions by the much faster electrons. Electrical equilibrium is achieved when the incoming ion current is balanced by the electron current, and this occurs when the satellite reaches a negative potential such that only electrons having energies greater than this potential can reach the satellite. Because of the negative charge around the satellite electrons are repelled. Thus, near the satellite and extending outward for several centimeters there is a charge sheath around the satellite wherein there are fewer electrons than positive ions. As one moves away from the satellite it is observed that the electric field due to the satellite is neutralized by the excess positive charge near the vehicle so that at a few centimeters away from the surface the satellite field drops to zero and the normal unperturbed plasma again exists.

Calculations made via the indicated route show that the satellite will normally be charged to a negative 3 to 5 volts. Under certain conditions it is possible that the satellite potential may go as low as -60 volts, although this has never been observed. This condition would be expected to obtain when the electron energy distribution has an appreciable high energy tail. It is interesting to note that at a height of 200 km, where the electron density now is about $2 \times 10^5 /cm^3$, a satellite will accumulate a charge of about 3.2×10^2 coulombs, for a satellite potential of about 3-5 volts. There may thus be problems associated with moving equipment from or to the MOL as well as rendezvous with other vehicles which may have different charges.

The plasma sheath formed about the satellite will markedly affect the propagation of VLF signals as well as the impedance of both VLF and UHF antennas. One of the least understood problems at the present time is the effects of such sheaths on VLF propagation and antenna characteristics.

In order to better understand the behavior of radiating devices on the MOL as well as the environment in which the vehicle moves, it is desirable to study the properties of the plasma and plasma sheath about the MOL. In particular the experimental program is:

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*For a fairly complete set of references see R. E. Bourdeau, "The Temperature of Charged Particles in the Upper Atmosphere," presented at COSPAR, held May 8-20, 1964 in Florence, Italy; Goddard Space Flight Center Preprint.

(1) To study the electron energy distribution in the plasma surrounding the MOL.

(2) To determine the electron and ion densities in the plasma and plasma sheath.

(3) To study the size and the formation of the plasma sheath around the MOL and determine how such sheaths are affected by vehicle heading, etc.

(4) To correlate this information with the VLF experiments to determine how VLF propagation and antenna impedance are affected.

Basically the experiment is carried out by the astronaut who extends several retractable probes placed at five different positions from nose to tail of the craft. Each probe will be of a modified Langmuir type designed to be extended from the vehicle at will and (perhaps) the orientation varied slightly. The astronaut will utilize a multichannel electrometer to record the plasma currents. The data can be stored until the astronaut's return to earth or be telemetered down; the latter is preferable. Analysis of the data will permit determination of ion density, electron density, and electron energy distribution as a function of distance from the satellite. This information should be sufficient to define the plasma and plasma sheath so that its effects can be determined.

II. Work Plan

At the present time NRL is in phase zero of the program and the experimental details are being defined as far as possible with available information. This includes specific tasks as described below:

1. An evaluation and determination of the charge and potential of the satellite as well as the sheath thickness is being made in accordance with existing experimental data. Estimates of the effects of photoelectric currents as well as (VXH) voltages are also being included.

2. A preliminary design of the probe system is being made including estimates of the probe current -- which may vary from 10^{-7} to 10^{-10} amp. The satellite potential will probably be of the order of 5 volts negative.

3. Preliminary design of the recording system is also being made: this includes amplifier, summing amplifiers, compression amplifier, filters, demodulator timing devices, and programmed logic and control.

III. Schedule

A preliminary design of the experimental package has been made. The present schedule is such that as complete an experiment as possible will be designed and documented by 15 August. In general the overall schedule for the program is somewhat as follows:

C.Y. 64	C.Y. 65	C.Y. 66	C.Y. 67	C.Y. 68
Start planning: Phase zero complete by 15 August	Initiate laboratory work and models	Complete and test laboratory models	Fabricate final models and start installation in vehicles	Final installation and test

IV. Organization

The development program will be carried out within the existing organization of the Naval Research Laboratory with Dr. W. C. Hall as coordinator. This specific project is assigned to the Data Processing Branch of the Applications Research Division of the Laboratory.

Personnel assigned to this project are: E. F. Kulikowski (project manager), C. J. Kurner, F. T. Powles, and R. A. Beaulieu.

V. Fiscal

Fiscal estimates for phase zero amount to about $35K and will be completed by 15 August as indicated above. The overall costing for the experiment is estimated as follows:

	FY 65	FY 66	FY 67	FY 68	FY 69	FY 70
Cost per year (millions)	0.2	0.2	0.6	0.4	0.1	0.1

VI. Problems and Accomplishments

The general techniques of this experiment are well understood and have been fairly well documented in the literature. However, because of the size of the craft, some problems may arise that normally could be neglected. Examples of the problems solved or under consideration are listed below:

1. Calculations have been made of the satellite potential and the thickness of the plasma sheath.

2. Estimates of the probe currents (ion and electron) have been made in order to design the electrometer system and recording devices.

3. A major problem remaining is design of the probes.

4. Miniaturization of the electrometer and recording equipment is also an essential problem.

5. A schedule of experimental operation has been formulated. Each orbital measurement will include, as far as practicable, two series of probe measurements at each of four selected points in the orbit for a minimum of 40 data points per orbit.

EXHIBIT A.2

Title of Experiment: The MOL -- Electron Density and Temperature Experiment

1. SCOPE

The purpose of this experiment is to study the plasma environment in the vicinity of the MOL by means of manned observations of various kinds and to correlate these observations with physical laws. Specifically, this experiment is intended to evaluate the properties of the plasma sheath and the extent to which it will interfere with the propagation of electromagnetic energy through it.

2. BACKGROUND

These experiments are required so that a knowledge of the environment of the MOL can be obtained which will provide information to be used in the design of electromagnetic equipment aboard space vehicles. Specifically, how the plasma sheath around a space vehicle affects the design and operation of antennas (especially VLF) as well as the radar cross-section.

Such experiments can only be carried out in space where the proper plasma conditions exist on a sufficiently large scale. A study of the plasma state near the MOL is essential to provide a working knowledge of the conditions of the environment in which man must live and work.

3. GENERAL CRITERIA

3.1 Manned Laboratory Characteristics

3.1.1 MOL Vehicle:

The actual physical dimensions of the ultimate MOL design will be used insofar as it is practical for the installation and utilization of the equipment and facilities related to this experiment.

3.1.2 Mission Duration:

Since a complete understanding of the plasma sheath phenomena is desired, it presently appears that a series of measurements should encompass a full earth-solar cycle to provide an opportunity to measure possible effects related to latitude and seasonal variations and unusual solar activity. If the scheduled duration is limited to less than a calendar year, this experiment will be limited accordingly.

3.2 MOL Performance Criteria

A possible MOL orbit with the following characteristics has been suggested:

Altitude - 100-250 nautical miles
Inclination - 40°
Pitch, Roll, and Yaw - Less than ± 1°

Insofar as it is practical, the rates of pitch, roll, and yaw should be held to a minimum in order to preserve the uniformity of the accompanying plasma sheath volume and to minimize the perturbing effects incident to solar photoelectric excitation of the MOL and Langmuir probes.

3.3 Description of the Experiment

(a) To study the electron energy distribution in the plasma surrounding the MOL.

(b) To determine the electron and ion densities in the plasma.

(c) To relate the above factors to the propagation and reception of electromagnetic waves.

(d) To study the formation and size of the plasma sheath around the MOL, and to determine how this affects (if any) the currents flowing in the MOL as well as in the medium and the ability of the astronauts to leave the MOL.

(e) To determine the potential of the satellite.

(f) To determine the across-the-plasma sheath potential distribution.

(g) To determine the plasma sheath thickness.

(h) To determine the concentration gradient of protons and electrons at plasma sheath edge.

(i) To determine the directional properties and motion of the plasma sheath.

(j) Correlate the data with radar ground stations and NAVSPASUR to determine the effective radar cross-section of MOL.

3.4 Configuration of Test Items

Retractable probes will be placed at the five corners of two equivalent abutting tetrahedrons to provide essentially spherical coverage. Each probe will be generally of the Langmuir type and designed so that its direction relative to the MOL can be varied (20° - 160°) and extended to 100 meters from the craft. A programmed multichannel recording electrometer will be required on board the MOL so that essentially simultaneous recordings of the probe currents may be obtained. The degree of perturbation introduced by the probes must be kept to a small value.

3.5 How Experiment Will Be Done

3.5.1 Measurements:

On either a preplanned program basis or subject to certain alert conditions, the astronaut will manipulate the equipment to perform proton, electron, and calibration experiments.

3.5.2 Equipment Description:

As indicated by the accompanying functional chart, the equipment aboard the MOL for this experiment will consist of the following:

3.5.2.1 Probes:

Five probes designed to interchangeably measure proton or electron currents and calibration signals by means of applied programmed signals.

3.5.2.2 Amplifiers and Gates:

Amplifier/Gates associated with each probe will be programmed to either sequentially deliver an amplified probe current or to simultaneously deliver their amplified probe outputs to a summing amplifier.

3.5.2.3 Summing Amplifier:

The summing amplifier will, on a programmed basis, accept and amplify sequentially the outputs of the individual amplifier/gates or their combined output.

3.5.2.4 Compression Amplifier:

The range of measured probe currents may extend over 10^{-7} to 10^{-13} amp. The compression amplifier delivers a logarithmic output to maintain the six-decade dynamic range to the demodulator.

3.5.2.5 Filter:

The filter is intended to prevent extraneous signals, due to the programmed sweep and pulse signals, from entering the demodulator.

3.5.2.6 Demodulator:

The demodulator delivers the detected probe signal output for evaluation and study.

3.5.2.7 Time Clock:

The time clock delivers a time signal for identifying the time of occurrence of registered probe currents and other phenomena.

3.5.2.8 Programmed Logic and Control:

The programmed logic and control provides the means whereby the probes or calibration signals are sampled on the basis of a prearranged semiautomatic program of instructions, an alert signal to the astronaut as a result of some significant change in space conditions, or specific instructions received from a ground command station.

The programmed logic and control operates in conjunction with a sweep/pulse modulator, proton/electron selector sensing mechanism, amplifier/gates/summing amplifier, level set control, time clock, encoder, store, monitor display, and data link.

3.5.2.9 Calibration:

Calibration signals are provided to permit assessment of operating conditions of this experiment either by the astronaut or on command from the ground.

3.5.2.10 Encoder:

The encoder translates the analog output of the demodulator into digital form suitable for storage and the resultant display and processing by the astronaut.

3.5.2.11 Store:

The store holds the series of probe measurements and the following calibration signal measurements included in one experimental run. The store also holds this information for subsequent transmission to a ground station if it is deemed desirable at the time.

3.5.2.12 Monitor Display:

The monitor display permits the astronaut to visually observe the resultant measurement of current due to either protons or electrons specifying particle energies, densities and temperature. Additionally, the monitor display will permit the astronaut to inspect test points within the experimental system related to the calibration signals, and relative to the programmed sweep and pulse signals. The monitor display will include a "Level Set Control" by which the astronaut may set an alert alarm when conditions relative to the plasma sheath (i.e., particle energies, densities, temperature) exceed some minimum value. It is hoped that once the normal conditions for the plasma have been established, the astronaut may be called upon to perform duties related to this condition, only when abnormal conditions arise.

3.5.2.13 Data Link Interface:

The data link interface provides the mechanism for transmitting experiment information, held in store, to the ground.

3.5.2.14 Ancillary Equipment:

Additional information to supplement that derived from the probes is needed: magnetometer, temperature, and pressure. These may be made available as a result of other experiments carried aboard MOL.

3.6 Test Support Equipment Required

None

4. TASKS

4.1 Test Procedure-General

When the MOL is in position to allow experiments to be performed, the probes will be extended to a given distance and set at a prescribed angle. Recordings will be made as a function of probe voltage. Observations will be repeated for different

probe lengths at the same angle. All observations should be made as near to one point in space as possible as the plasma conditions may change as a function of position and time.

4.2 Astronaut Functions

The astronaut will operate and position the probes. He additionally will observe, record, and interpret the results of the experiment together with the examination of calibration and test signals sequentially following each set of experimental measurements.

The astronaut will conduct the experiment on the basis of prearranged programmed instructions, on command instructions from the ground, or on the basis of alert signals related to space environmental conditions. Man is essential to a proper functioning of the experiments as a judgment must be made as to when or (determined by sampling) how much data must be taken.

The experiment will require the coordination and attention of two astronauts; one astronaut essentially full time during the experiment for the measurement, calibration, recording, and reporting of the experiment results, and one astronaut part time for the manipulation of the probes.

4.3 Frequency and Duration of Experiments

For discussion purposes, it is assumed that the MOL orbital period will be of the order of 100 minutes. It is desired that, for other than ground command instructions or alert signals, measurements be taken over two successive orbits once each day. Each orbit measurement will include, insofar as practical, two series of five probe measurements and one calibration measurement at each of four selected points in the satellite's orbit, for a minimum of 48 measurements per orbit. It is desired that measurements be relative to the earth's poles and equator on the first orbit and at the corresponding intermediate points on the succeeding orbit. Since measurements, based on the above 100 minute orbit, will occur in general every 20 minutes, suitable store and monitor displays are essential to help the astronaut in his tasks of probe manipulation, monitoring, interpreting, and reporting.

4.4 Measurements

This experiment will measure particle energies extending over approximately the range of 0-3 kev giving rise to probe currents of 10^{-7} amp. to 10^{-13} amp.

4.4.1 Protons:

Proton measurements will be made in accordance with programmed or manually applied voltages to either each of the five probes, one at a time, or to all probes so as to operate essentially in parallel.

4.4.2 Electrons:

Measurements similar to the proton measurement will be made on electrons. The decision for one or the other measurement will be accomplished by a proton/electron sensing mechanism. It is expected that in the "alert" operating condition

this mechanism will be set to electron measurement and the set level control will be set by the astronaut.

4.4.3 Calibration:

It is planned that a monitor operation, involving the use of internally generated signals after each set of five probe measurements, be initiated to establish and verify normal operation of the experiment. The calibration will be established by means of a programmed set of test signals and observations made at several test points. The test observation will be recorded and sent to ground on command.

4.5 Program Planning

4.5.1 Phase I:

Phase I will include preliminary engineering design with a target date of mid-August 1964.

4.5.2 Phase II:

Phase II will include a refinement of Phase I, the design, test, and evaluation of certain critical elements such as probes, amplifier/gate, compression amplifier, program logic and control, and demodulator. This should be completed during Fiscal Years 1965-66.

4.5.3 Instructions:

Suitable instructions on equipment operation and maintenance will be developed for instructing the astronauts. Aids such as nomographs will be developed to assist the astronauts in the recording, reduction, and interpretation of experimental data.

4.6 Manpower Requirements

4.6.1 Astronauts:

(a) Number required: Two

(1) Man's function: As technicians conducting tests.

(b) Crew skill requirements:

Some briefing will be required to acquaint the astronauts with the objectives of the experiment. A brief training period should be all that is required to provide sufficient information to the astronauts to operate the equipment.

(c) Manpower profile:

It is expected that approximately the full time of an astronaut for two complete orbits, together with the part-time assistance of a second astronaut, should be sufficient time to complete an experiment.

(d) Training requirements:

See (b) above.

4.6.2 Ground Personnel:

(a) Number required: 2 - 3

(1) Man's function: To set up and test equipment.

(b) Crew skill requirements:

Crew must have intimate knowledge of equipment.

(c) Manpower profile:

It is expected that the crew will be required 6 weeks before shot time to finish installation, and do checkout experiments.

(d) Training Requirements:

Technicians from the Laboratory will be sent to install and test apparatus.

5. REPORTS

5.1 Program Plan

The general program plan is reported in this document. Future plans will be reported under Phases I and II, indicated above.

5.2 Program Progress Letter Report

Subsequent to the actual launching of MOL, tentative experimental data will be issued in the form of letter reports as quickly as practical.

5.3 Final Report

The final report will describe the conditions of the actual experiment together with the data. Data interpretation, deductions, conclusions, and relations to known physical laws will be reported.

6. PROGRAM MANAGEMENT

6.1 Participating Government Agencies

Sponsor - NRL.

6.2 Category of Experiment

Category (b).

6.3 Cost

FY-65, $67 K; FY-66, $100 K; FY-67, $200 K; FY-68, $50 K; FY-69, $50 K.

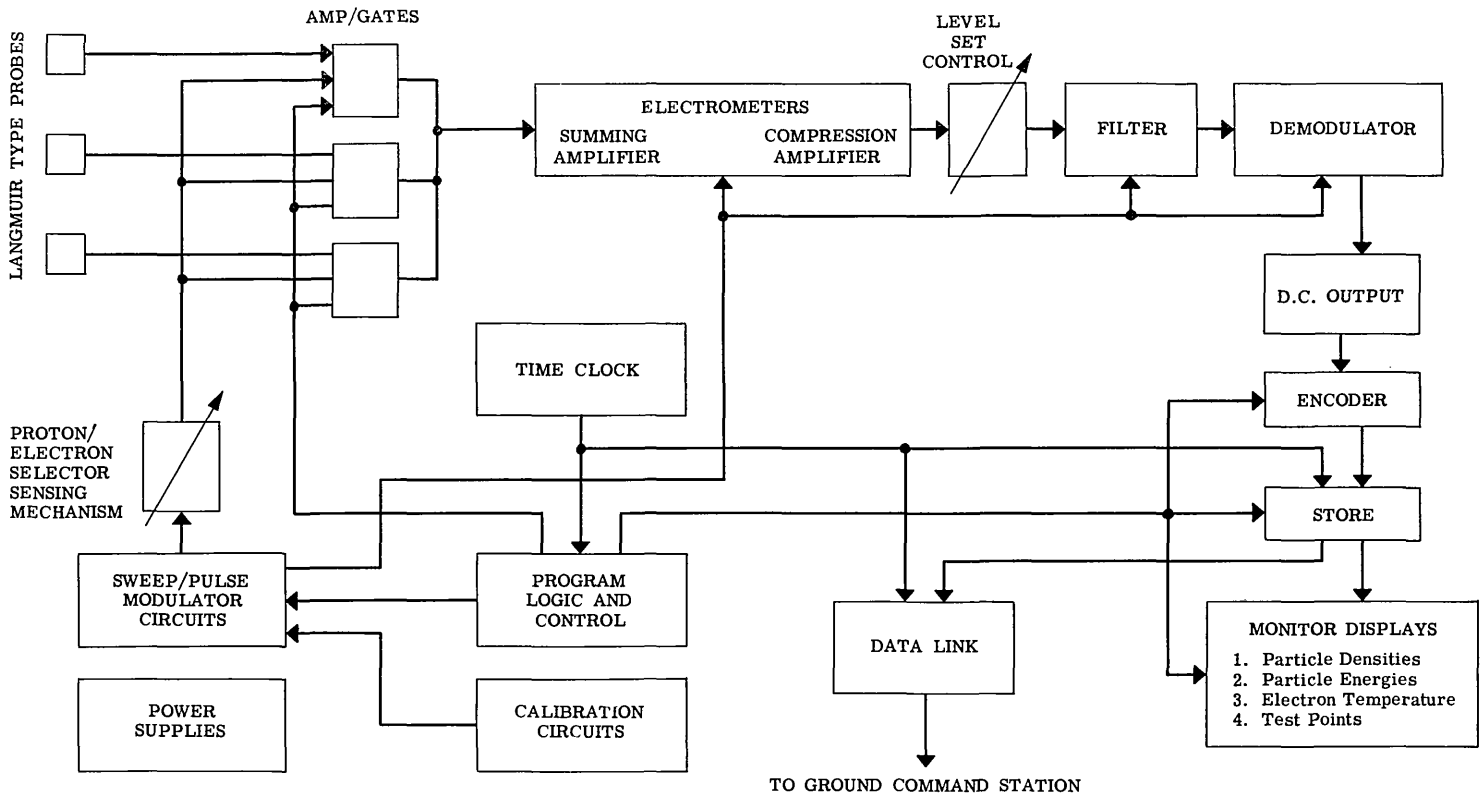
6.4 Schedule

Not available as yet.

6.5 Security

No special security

THE MOL-ELECTRON DENSITY AND TEMPERATURE EXPERIMENT
TENTATIVE BLOCK DIAGRAM



ANCILLARY EQUIPMENT:

1. Magnetometer
2. Temperature
3. Pressure

EXHIBIT A.3

Title of Experiment: Electron Density and Effective Temperature

I. Test Objective: The purpose of this experiment is to study the plasma environment in the vicinity of the MOL. Information obtained here has a direct bearing on the operation of all electromagnetic equipment on the MOL having to do with transmission and reception of signals as well as the detectability of the MOL by radar.

II. Importance of Test: These experiments are required so that a knowledge of the environment of the MOL can be obtained which will provide information to be used in the design of electromagnetic equipment aboard the vessel. Specifically, how the plasma sheath around the craft affects the design and operation of antennas (especially VLF) as well as the radar cross-section.

Such experiments can only be carried out in space where the proper plasma conditions exist on a sufficiently large scale. A study of the plasma state near the MOL is essential to provide a working knowledge of the conditions of the environment in which man must live and work.

The observations to be determined and recorded in these experiments are related in a great degree to phenomena of extraterrestrial origin. Because of this there is uncertainty in the nature of physical conditions attending planned observations. It is considered that the timeliness of personal observation, initiative, and interpretation on the part of the astronaut will contribute significantly to the value and success of the experiments. Since the astronaut in general will be moving at a rate of approximately 300 miles a minute and traversing a changing magneto-ionic medium, it is apparent that the judgment and skill of the astronaut would make a contribution to the experiment that could not be achieved without his help.

The course of future similar and related experiments might be best determined and accomplished by other means only as a result of the flexibility provided by the astronaut in these initial MOL experiments.

III. Description of the Experiment

A. Detailed Experimental Program

1. To study the electron energy distribution in the plasma surrounding the MOL.

2. To determine the electron and ion densities in the plasma.

3. To relate the above factors to the propagation and reception of electromagnetic waves.

4. To study the formation and size of the plasma sheath around the MOL and determine how this affects (if at all) the currents flowing in the MOL, as well as in the medium, and the ability of the astronauts to leave the MOL.

5. Correlate the data with radar ground stations and NAVSPASUR to determine the effective radar cross-section of MOL.

B. Configuration of Test Items

Retractable probes will be placed at (5) different equispaced positions from nose to tail of the craft. Each probe will be generally of the Langmuir type and designed so that its direction relative to MOL can be varied (20-160°) and extended to 100 meters from the craft. A multichannel recording electrometer will be required on board the MOL so that simultaneous recordings of the probe currents may be obtained.

C. Test Support Equipment Required

None

D. Test Procedure

When the MOL is in position to allow experiments to be performed, the probes will be extended a given distance and sit at a prescribed angle. Recordings then will be made of probe currents as a function of probe voltage. Such observations will be repeated for different probe lengths at the same angle. After a complete set of observations is made for one probe angle another may be chosen and the experiments repeated. All observations should be done as near to one point in space as possible as the plasma conditions may change as a function of position and time.

(1) Man is essential to a proper functioning of the experiments as a judgment must be made as to when or (determined by sampling) how much data should be taken.

(2) Experiments will be essentially manual and require the complete attention of one astronaut at a time.

E. Category of Experiment

(1) Category (b).

F. Cost

FY 65	FY 66	FY 67	FY 68	FY 69
100K	200K	300K	150K	50K

G. Schedule

Not available as yet.

IV. Participating Government Agencies: Sponsor - NRL

V. Additional Requirements

A. Security: No special security.

B. Manning Description

1. ASTRONAUTS

a. Number required: one

(1) Man's function: As technician conducting test.

b. Crew skill requirements

Some briefing will be required to acquaint the astronaut with the objectives of the experiment. A brief training period of an hour should be all that is required to provide sufficient information to the astronaut to operate the equipment.

c. Manpower profile

It is expected that approximately the full time of an astronaut for two complete orbits should be sufficient time to complete the experiments.

d. Training requirements

See (b) above.

2. GROUND PERSONNEL

a. Number required: 2 - 3

(1) Man's function: To set up and test equipment.

b. Crew skill requirements

Crew must have intimate knowledge of equipment.

c. Manpower profile

It is expected that the crew will be required 6 weeks before shot time to finish installation and do checkout experiments.

d. Training Requirements

Technicians from Laboratory will be sent to install and test apparatus.

ATTACHMENT A

DESIGN CHARACTERISTICS TEST EQUIPMENT

1. Langmuir probe equipment
2. 10 lbs.
3. Vol. 1 cu. ft.
4. Power: 25 watts continuous
5. Spares: None
6. Tools: Usual
7. Heat Output: 25 watts
8. Stability: Normal
9. Vibration Limits: Normal
10. Shock Limits: Normal
11. Hazards: Usual for electronic equipment.

APPENDIX B

DOCUMENTATION SUBMITTED TO NAVMOL IN FULFILLMENT OF REQUIREMENTS FOR PRE-PDP EFFORT

Contents

Exhibit B.1	Specific Tasks - Experiment S-23
Exhibit B.2	Experiment S-23 Data Book of 8/13/64
Exhibit B.3	Experiment S-23 Data Book of 9/23/64
Exhibit B.4	Pre-Requisite Data Report (PDR) of 9/24/64
Exhibit B.5	Mission Analysis Report of 9/23/64
Exhibit B.6	PTDP Input Data Report
Exhibit B.7	Final Technical Documentary Report (FTDR)

EXHIBIT B.1

SPECIFIC TASKS EXPERIMENT S-23

4. Specific Tasks

4.1 Definition of Experiment

4.1.1 This experiment is required so that a knowledge of the environment of the MOL can be obtained. It will provide information to be used in the design of electromagnetic equipment to be used aboard space vehicles. The plasma sheath formed about the satellite will markedly affect the propagation of V.L.F. signals as well as the impedance of both V.L.F. and U.H.F. antennas. Such experiments can only be carried out in space where the proper plasma conditions exist on a sufficiently large scale.

4.1.2 The experiment will involve the measurement of electron and ion currents over the range 10^{-7} to 10^{-12} Amps. as a function of probe voltage over the range -40 to +40 volts, in order to determine:

(a) The electron energy distribution in the plasma surrounding the MOL.

(b) The electron and ion densities in the plasma.

(c) The formation and size of the sheath around the MOL.

(d) The potential of the satellite.

(e) The across-the-sheath potential distribution.

(f) Additionally, the effects of V×H EMF's induced in the MOL structure and its relation to the plasma sheath will be studied.

The above quantities will lead to the determination of:

(g) The refractive index of the environment.

(h) The propagation constant; i.e., the attenuation and phase characteristics.

(i) The surface currents on the MOL.

The long range plan is to determine seasonal, diurnal and spatial

variations of the plasma under ordinary and extraordinary conditions. For any particular MOL mission, the experiment will be directed insofar as practical to determine diurnal and spatial variations of the plasma. An implicit purpose of this experiment is to determine the range, validity, and accuracy of the measured quantities to be used in correlating and establishing physical principles for engineering applications.

4.1.3 Experimental testing will be conducted over two orbits to satisfy the diurnal and spatial requirements with regard to latitude, sunlight and darkness. Each orbital measurement will include, as a minimum insofar as practical, two series of probe measurements at each of four selected points in the orbit for a minimum of 40 data points per orbit.

4.2 Preliminary Analysis

4.2.1 The astronaut

To initiate, control, maintain and monitor the experiment.

In-flight equipment

To measure, calibrate, record, display, store and transmit experimental data.

Ground support equipment

(a) To maintain communications between astronaut and ground support facilities.

(b) To collect, record and store experimental data transmitted from the MOL.

Ground support personnel

(a) To maintain and operate ground support equipment.

(b) To monitor and process incoming data.

(c) To provide in-flight support.

4.2.2 The astronaut, in general, will perform the following:

(a) Selects experiment program and initiates measurements.

(b) Inspect the resultant measurements.

(c) If data appears satisfactory, will enable transmit to ground on given command.

(d) Modify program as instructed on command.

(e) Repeat above at stated intervals.

(f) Control the attitude of the MOL.

Specifically, the experiment is carried out by an astronaut who extends five probes and controls their orientation. The astronaut will utilize a multi-channel electrometer in conjunction with the probes to record plasma currents. The astronaut will be required to perform in-orbit alignment and calibration by the use of check-off procedures and instructions, and by use of standard internal inputs and visual inspection of outputs. One alignment procedure will be conducted per test sequence. Four sets of measurements and associated calibrations will be made per test sequence. The astronaut will be involved in on-board data processing by monitoring experimental progress and reading and correlation of outputs with pre-flight furnished nomographs. The astronaut will evaluate on-board displays to determine existence of abnormal test environmental conditions and report same to ground. The astronaut will maintain log and complete check-out list.

4.2.3 In-Flight Equipment.

The in-flight equipment will consist of:

(a) Five externally mounted probes, controllable in length and orientation on a semi-automatic programmed basis.

(b) A multi-channel electrometer amplifier and associated selection gates (electrometer will be capable of 10^{-7} - 10^{-12} ampere measurement in one range).

(c) Electronics used for conditioning electrometer output prior to encoding and storage.

(d) The programmed logic and control circuitry which provides the means whereby the probes or calibration signals are sampled on the basis of a pre-arranged semi-automatic program of instructions, an alert signal to the astronaut as

a result of some significant change in space conditions or specific instructions from a ground command station.

(e) The circuitry necessary to provide calibration signals for the assessment of operating conditions of the experiment, either by the astronaut or on command of the ground.

(f) Encoding and storage devices for holding of experiment data for subsequent transmission and utilization.

(g) Display and control panel suitable for effecting the program instructions and modification thereto and for the observation of results.

(h) Data link interface which provides the mechanism for transmitting experiment information, held in store, to the ground.

(i) Power conversion and regulation devices.

(j) Ancillary equipment to provide additional information to supplement that derived from the probes, such as magnetometer, UV and X-ray radiometers. These may be made available as a result of other experiments carried aboard the MOL.

The experiment has the following physical factors:

	Weight	Vol.	Power
Probes	75 lbs. (external)	1 cu. ft.	
Electronics	63 lbs. (internal)	2.5 cu. ft.	

Power per test: Stand-by; 40 Watts
Average operating; 100 Watts
Peak operating; 150 Watts

Heat output: External; zero watts
Internal; Standby, 40 Watts
Average operating, 75 Watts
Peak operating, 135 Watts

Reliability Goals: 1,000 hrs. MTBF.

4.2.4 Ground Support Equipment.

This experiment will utilize planned ground-MOL-ground data links to:

(a) Maintain communications with the astronaut so as to provide him with instructional control and command information.

(b) Collect, record and store the experimental data from the MOL. Preference is expressed for this experiment for standard IRIG telemetry techniques or for Gemini PCM data links. Ultimate choice or choices is dependent upon trade-off analysis of equipment simplicity aboard MOL vs. data handling on MOL and data processing on the ground as well as on the overall data link configuration chosen for MOL, reflected as an interface problem.

A minimum of one ground support system will be required for the reception of data twice a day. For this experiment this frequency of reporting is adequate. Since the ground support equipment will be common to other users, any increase in the frequency of data reporting will result in decreased MOL storage requirements. Such a trade-off must be examined in terms of the cost of additional ground support facilities versus added weight due to the increased storage in the MOL.

4.2.5 Ground Support Personnel.

Personnel responsible for operation and maintenance of ground terminal receiving and transmitting equipment. They must have intimate knowledge of the philosophy and operation of the on-board experiment. They must be capable of relaying to the astronaut instructions and information relative to the conduct of the experiment in a changing environment. They will monitor and process the experimental data transmitted from MOL in response to an appropriate command. The monitoring and processing functions are limited to the extent of insuring the reception of transmitted information. Specific analysis of this information will be accomplished at the Naval Research Laboratory.

4.3 Vehicle Requirements and Interfaces

Requirements and other interface considerations that will be imposed on the MOL vehicle, the MOL sub-systems and experiments by the electron density and temperature experiment will include in general the following:

(a) Commonality of Equipment:

Power supplies

Time standards

Data processing

- Standards
  - Format
  - Word length
  - Data rate
- Storage

Data links

Equipment

Simultaneity of use of astronaut

(b) Environmental Considerations:

Temperature, pressure, humidity, accommodations for space needs and accessibility as affected by all on-board experiments.

Minimization and elimination of interference; space, electrical, magnetic, acoustic, optical.

(c) Common Data Requirements:

Magnetometer.

UV Radiometer.

X-Ray Radiometer.

Vehicle attitude as a function of time.

Vehicle Requirements:

(a) Stabilization:

Attitude control ± 1.0° in each axis.

Rate stabilization ± 0.1° per second.

Rate control in roll 360° per minute

(b) Weight, volume, power, heat dissipation and reliability:

See paragraph 4.2.3(j).

Astronaut Accommodation Requirements:

Astronaut must be within viewing and working distance of display and control panels while experiment is in process.

4.4 Equipment Description

4.4.1 Design Synthesis:

(a) Sensors

Five sensors, each comprising a boom, probe and ancillary servo-mechanism drive system, will be employed. The boom-probe combination will be extendible over a range from the MOL surface to a distance of ten feet. Additionally, the boom-probe combination will be adjustable about three axes to permit controlled orientation of the probe. The drive system should be capable of orienting the boom-probe assembly in a specified direction and length within thirty seconds, (subject to the requirements of weight and size and the exchange of angular momentum with the MOL). It is estimated that a sensor assembly, comprising boom, probe, and drive will weigh approximately fifteen pounds and occupy approximately 0.2 cu. ft. Sensor assemblies will be mounted one fore, one aft and three equally spaced amid-ship the MOL structure.

(b) Controls

In general, the following controls will be employed in the conduct of the experiment:

(1) On-off-standby for control of primary power.
(2) Electrometer calibration.
(3) Probe voltage adjustment.
(4) Program selection for boom-probe erection and generation of sensory, logic and calibration voltages.
(5) Display adjustments for controlling scales, intensity and monitoring voltages.
(6) Data recording and readout for initiation and reporting.
(7) Interface switching for the selection of ancillary equipments used in other experiments.

(c) Displays

(1) Boom-probe status indicators.

(2) Probe voltage monitor.

(3) Electrometer currents.

(4) Maintenance test.

The following displays, while not considered essential to this experiment, would nevertheless provide useful data for interpreting experimental results:

(5) Ancillary devices such as time, magnetometer, U.V. and X-ray.

(6) Interface indicators.

(7) Vehicle attitude.

(d) Data Handling

The data handling system will provide the means for selection, sample and hold, encode, store and transmit of the following information:

(1) Experiment identification.

(2) Boom-probe orientation.

(3) Probe voltage vs. current characteristic.

(4) Calibration data.

(5) Attitude of vehicle.

(6) Time code.

(7) Magnetometer.

(8) U.V. radiation.

(9) X-ray radiation.

(10) Parity bits.

The store should have a capacity for holding 50,000 bits during two orbits, estimated here as totaling 200 minutes.

(e) Communications Equipment

Insofar as practical, consistent with other experiment requirements, the IRIG telemetry standards will be used for analog data and the Gemini PCM data system for digital data. Data links will be provided for ground-astronaut-ground communications for purpose of instruction, control and commands. These latter links will be consistent with requirements imposed on the MOL by other experiments.

(f) Equipment weight and size estimates

(1) Weights

a.	Boom-probe assembly(s)	75 lbs.
b.	Electrometers (5)	10 lbs.
c.	Program logic, control and store	25 lbs.
d.	Function control and displays	14 lbs.
e.	Power conversion and regulation	2 lbs.
f.	Data link interface	2 lbs.
g.	Miscellaneous	10 lbs.
	TOTAL WEIGHT	138 lbs.

(2) Size

a.	Boom-probe assemblies (5)	1.0 cu.ft.
b.	Electronics	2.0 cu.ft.
c.	Displays	0.5 cu.ft.
	TOTAL SIZE	3.5 cu.ft.

(3) Reliability

Design goal 1,000 hours MTBF.

EXHIBIT B.2

EXPERIMENT S-23

I. Test Objective

Evaluate the properties of the plasma sheath in the vicinity of the MOL and determine its relation to the propagation of electromagnetic energy.

II. Description of Experiment

a. Experiment description summary:

The experiment is carried out by an astronaut who extends five (5) probes and controls their orientation. The astronaut will utilize a multi-channel electrometer in conjunction with the probes to record plasma currents. Analysis of the data will permit the definition of the plasma and sheath so that their effects can be determined.

b. Experiment equipment design characteristics and requirements:

1. Description:

Experiment consists of (a) five adjustable probes mounted external to the MOL and requiring approximately 1 cu. ft.; and (b) electronic measuring, control, display, and recording equipment mounted in a pressurized cabin and requiring approximately 2.5 cu. ft.

2. Weight:

Probes - Total 75 lbs. (external)
Electronic - Total 63 lbs. (internal)

3. Power per test:

(a) Continuous - zero
(b) Stand-by - 40 Watts
(c) Average operating - 100 Watts
(d) Peak - 150 Watts

4. Heat output:

   (a) External - zero

   (b) Internal

      (1) Continuous - zero

      (2) Standby - 40 Watts

      (3) Average operating - 95 Watts

      (4) Peak - 135 Watts

5. Spares for In-orbit Maintenance:

   Replacement items - spares

   (a) Electrometer Tubes - 2

   (b) Electrometer Amplifier - 1

	Electrometer Tube	Electrometer Amplifier
Volume	12 cu. in.	36 cu. in.
Quantity	2	1
Weight	0.5 lbs.	1.5 lbs.

6. Stability:

   Attitude Stability ± 1° in each axis

   Rate Stabilization ± .1°/second

   Rate Control 360°/minute

7. Vibration Limits:

   (NOT AVAILABLE)

8. Launch Environment Vibration and Shock Limit:

   (NOT AVAILABLE)

9. Hazards Peculiar to Equipment:

   (NOT AVAILABLE)

10. Temperature Limitations:

    (NOT AVAILABLE)

11. Special Environmental Requirements:

    (NOT AVAILABLE)

12. Ephemeris Data:

    (NOT APPLICABLE)

13. Equipment Location Requirements:
Requirement exists for five probes to be mounted external to the vehicle at the following general positions; fore, aft, and equally spaced amid ships.

14. Special Mounting Requirements:
Five (5) external booms capable of being oriented in length and angle.

15. Pressure Vessels:
(NOT APPLICABLE)

16 Electro-Magnetic Interference:
Magnetometer readings taken simultaneously with this experiment are necessary, i.e., interference to magnetometer readings by other devices and equipments should be eliminated.

c. Alignment & Calibration Equipment Design Characteristics:
Alignment and calibration equipment will be an integral part of experiment equipment described under paragraph II(b).

d. In-Orbit Alignment and Calibration Procedures:

1. Description Alignment and Calibration of Function:

(a) Alignments:
Use of standard inputs and visual inspection of outputs by astronaut.

2. Number of alignments and calibrations to be performed:
One alignment per test sequence.
Four sets of measurements per test sequence.
Automatic calibrations are made within each set of measurements.

3. Specific Times for Alignments and Calibration:
Alignment will be made prior to start of experiment. Measurements and calibrations will be made so as to provide data in the northern and southern latitudes, each during sunlight and darkness.

4. Targets or source of calibration signals:
Built-in signal generators.

5. Data Processing Requirements:

(a) Computations:
Nomographs.

(b) Displays:
Meters.

(c) Recorded or stored data:
Alignment and operating instruction.

e. Test and Evaluation Procedures:

1. Total number of Tests:
Tests will be conducted over two orbits to satisfy the latitude and sunlight requirements. Each orbital measurement will include, as a minimum insofar as practical, two series of probe measurements at each of four selected points in the orbit for a minimum of 40 data points per orbit.

2. Parameters to be varied:
Boom length and probe orientation.
Probe voltages.

3. Target types and description:
(NOT APPLICABLE)

4. Target locations:
(NOT APPLICABLE)

5. Test procedure:

(a) Spacecraft events:
See paragraph e.1.

(b) Ground events:
Command and control for initiation of tests and data readout.

6. Evaluation Procedure:
(NOT AVAILABLE)

7. Data to be Recorded:

(a) Description:

Boom-Probe-Attitude

Voltage vs. Current Characteristics

Calibrations

Attitude of vehicle

Time Code

Experiment identification

Parity bits

Magnetometer

U. V. Radiation

X-Ray Radiation

(b) Recording Media:

Either/both magnetic core and tape.

(c) Amount of data per test per medium:

Minimum of 12,000 bits per orbit (see par. e.1.)

8. On-board data processing:

(a) Description and purpose of processing:

Monitoring of experimental progress by astronaut.

(b) Computing requirements:

Reading and correlation with nomograph by astronaut.

(c) Readout and storage or recording requirements:

Data to be read out automatically and stored automatically (see par. e.7.).

9. Communication data requirements to ground (during flight):

(a) Types and amount:

See paragraphs e.7 and e.8.

(b) Allowable delay time:

Flexible.

(c) Required security:

(NOT APPLICABLE)

10. Physical Data Recovery Requirements:

(a) Description of data in terms of type and amount:
Data indicated in par. e.7(a) and e.7(c) will be telemetered over an available MOL data link to a ground recovery site. No physical recovery of generated experimental data is anticipated at this time, but see par. f.1(e).

(b) Frequency of Recovery:
(NOT APPLICABLE)

(c) Required security:
(NOT APPLICABLE)

11. Communication Requirements to Spacecraft:

(a) Types and amounts of data or commands:
Instructional information to astronaut to initiate or modify experiment program.

(b) Frequency per test and allowable delay time:
One instruction and command per orbit. Delay time up to one-orbit period may be expected.

(c) Required security:
(NOT APPLICABLE)

f. Manning Data (Astronauts):

1. Task descriptions per man per test:

(a) Test Operations:
Astronaut will follow a pre-arranged instruction or modify such an instruction on command to initiate an experiment sequence. Instructions will include check-off list and alignment procedures. Time required - minimum 5 minutes per test sequence.

(b) Calibration Operations:
Calibration to be done automatically, but will require visual monitoring by the astronaut. Time required - estimated that four one-minute monitoring intervals during one orbit.

(c) Data Processing:

Covered under paragraph f.1(b).

(d) Evaluation:

Astronaut will evaluate on board displays to determine existence of abnormal test environmental conditions. Time required - continually during course of experiment, but on a cursory basis.

(e) Communication and Reporting:

Astronaut will maintain log and complete check-out list. Astronaut will report via data link existence of unusual environmental conditions. Time required - five minutes per special report, and five minutes per test sequence for experiment status report.

2. Work Positions relative to above tasks:

Astronaut must be within working and viewing distance of display and control panels.

3. Basic Skill Requirements:

(a) Alignment and Calibration:

Astronaut will be required to recognize misalignment, as indicated by displays, and to take measures by means of instructions to establish suitable experimental conditions.

(b) Operations:

See paragraph f.3(a).

(c) Maintenance:

See paragraph f.(e).

(d) Data Analysis:

See paragraph f.1(d).

4. Training Requirements:

Some briefing will be required to acquaint the astronaut with the objectives of the experiment. A one-week training period should be all that is required to provide sufficient information for the operation and maintenance of the equipment and to develop familiarity with the control and display devices.

5. Other Selection Criteria:
   (NOT AVAILABLE)

6. Maximum Work Periods:
   Five minutes.

EXHIBIT B.3

EXPERIMENT S-23

I. Test Objective

Evaluate the properties of the plasma sheath in the vicinity of the MOL and determine its relation to the propagation of electromagnetic energy.

II. Description of Experiment

a. Experiment description summary:

The experiment is carried out by an astronaut who extends three (3) probes and controls their orientation. The astronaut will utilize a multi-channel electrometer in conjunction with the probes to record plasma currents. Analysis of the data will permit the definition of the plasma and sheath so that their effects can be determined.

b. Experiment equipment design characteristics and requirements:

1. Description:

Experiment consists of (a) three adjustable probes mounted external to the MOL, requiring approximately 1 cu. ft. The probe and current measuring assemblies may be placed in unpressurized compartments, and (b) control, display, and recording equipment mounted in a pressurized cabin and requiring approximately 2.5 cu. ft.

2. Weight:

Probes - Total 40 lbs. (external)
Electronic - Total 40 lbs. (internal)

3. Power per test:

(a) Continuous - zero
(b) Stand-by - 10 Watts
(c) Average operating - 75 Watts
(d) Peak - 100 Watts

4. Heat output:

   (a) External - zero

   (b) Internal

      (1) Continuous - zero

      (2) Standby - 10 Watts

      (3) Average operating - 70 Watts

      (4) Peak - 90 Watts

5. Spares for In-orbit Maintenance:

   Replacement items - spares

   (a) Electrometer Amplifier Module - 1

	Electrometer Amplifier Module
Volume	36 cu. in.
Quantity	1
Weight	1.5 lbs.

6. Stability:

   Attitude Stability: ± 1° in each axis

   Rate Stabilization: ± .1°/second

   Rate Control: 360°/minute maximum

7. Vibration Limits:

   Equipment will meet environmental conditions as stated in Section 1-A MOL Experiments Environment of Aerospace Corp. Memo 1784.0-007 dated 19 June 1964.

8. Launch Environment Vibration and Shock Limit:

   Same as Par. IIb7

9. Hazards Peculiar to Equipment:

   None

10. Temperature Limitations:
Same as Par IIb7.

11. Special Environmental Requirements:
None

12. Ephemeris Data:
Will be used in post-flight analysis.

13. Equipment Location Requirements:
Requirement exists for three probes to be mounted external to the vehicle at the following general positions; fore, aft, and amid ships.

14. Special Mounting Requirements:
Three (3) external booms capable of being oriented in length and angle.

15. Pressure Vessels:
Control and Display Equipment will be mounted within pressurized compartment.

16. Electro-Magnetic Interference:
Magnetometer readings taken simultaneously with this experiment are necessary, i.e., interference to magnetometer readings by other devices and equipments should be eliminated.

c. Alignment & Calibration Equipment Design Characteristics:
Alignment and calibration equipment will be an integral part of experiment equipment described under paragraph IIb.

d. In-Orbit Alignment and Calibration Procedures:

1. Description Alignment and Calibration of Function:

(a) Alignments:
Use of standard inputs and visual inspection of outputs by astronaut.

2. Number of alignments and calibrations to be performed:
One alignment per test sequence.

Four sets of measurements per test sequence.
Automatic calibrations are made within each set of measurements.

3. Specific Times for Alignments and Calibration:
Alignment will be made prior to start of experiment. Measurements and calibrations will be made so as to provide data in the northern and southern latitudes, each during sunlight and darkness.

4. Targets or source of calibration signals:
Built-in signal generators.

5. Data Processing Requirements:

(a) Computations:
Nomographs.

(b) Displays:
Meters.

(c) Recorded or stored data:
Operation and alignment instruction.

e. Test and Evaluation Procedures:

1. Total number of Tests:
Tests will be conducted over a minimum of two orbits to satisfy the latitude and sunlight requirements. Each orbital measurement will include, as a minimum insofar as practical, two series of probe measurements at each of four selected points in the orbit for a minimum of 24 data points per orbit.

2. Parameters to be varied:
Boom length and probe orientation.
Probe voltages.
Measurement range.

3. Target types and description:
(NOT APPLICABLE)

4. Target locations:
(NOT APPLICABLE)

5. Test procedure:

(a) Spacecraft events:
See paragraph e.1.

(b) Ground events:
Command and control for initiation of tests and data readout.

6. Evaluation Procedure:
Astronaut uses established procedures and initiative based on instruction, training and experience to operate equipment during standard and/or anomalistic conditions.

7. Data to be Recorded:

(a) Description:
Boom-Probe-Attitude
Voltage vs. Current Characterisitcs
Calibrations
Attitude of vehicle
Time Code
Experiment identification
Parity bits
Magnetometer
U. V. Radiation
X-Ray Radiation
Temperature-Equipment and Ambient

(b) Recording Media:
Either/both magnetic core and tape

(c) Amount of data per test per medium:
Minimum of 12,000 bits per orbit (see par. e.1.)

8. On-board data processing:

(a) Description and purpose of processing:
Monitoring of experimental progress by astronaut.

(b) Computing requirements:
Reading and correlation with nomograph by astronaut.

(c) Readout and storage or recording requirements:
Data to be read out and stored automatically (see par. e.7).

9. Communication data requirements to ground (during flight):

(a) Types and amount:
See paragraphs e.7 and e.8.

(b) Allowable delay time:
Flexible.

(c) Required security:
(NOT APPLICABLE)

10. Physical Data Recovery Requirements:

(a) Description of data in terms of type and amount:
Data indicated in par. e.7(a) and e.7(c) will be telemetered over an available MOL data link to a ground recovery site. No physical recovery of generated experimental data is anticipated at this time, but see par. f.1(e).

(b) Frequency of Recovery:
(NOT APPLICABLE)

(c) Required security:
(NOT APPLICABLE)

11. Communication Requirements to Spacecraft:

(a) Types and amounts of data or commands:
Instructional information to astronaut to initiate or modify experiment program.

(b) Frequency per test and allowable delay time:
One instruction and command per orbit. Delay time up to one-orbit period may be expected.

(c) Required security:
(NOT APPLICABLE)

f. Manning Data (Astronauts):

1. Task descriptions per man per test:

(a) Test Operations:
Astronaut will follow a pre-arranged instruction, modify such an instruction on command, or initiate an experiment sequence. Instructions will include check-off list and alignment procedures. Time required - minimum 5 minutes per test sequence.

(b) Calibration Operations:
Calibration will be done by visual monitoring of displays by the astronaut. Time required - estimated that four one-minute monitoring intervals during one orbit.

(c) Data Processing:
Covered under paragraph f.1(b).

(d) Evaluation:
Astronaut will evaluate on board displays to determine existence of abnormal test environmental conditions. Time required - continually during course of experiment, but on a cursory basis.

(e) Communication and Reporting:
Astronaut will maintain log and complete check-out list. Astronaut will report via data link existence of unusual environmental conditions. Time required - five minutes per special report, and five minutes per test sequence for experiment status report.

2. Work Positions relative to above tasks:
Astronaut must be within working and viewing distance of display and control panels.

3. Basic Skill Requirements:

(a) Alignment and Calibration:
Astronaut will be required to recognize misalignment, as indicated by displays, and to take measures by means of instructions to establish suitable experimental conditions.

(b) Operations:

See paragraph f.3(a).

(c) Maintenance:

See paragraph f.3(a).

(d) Data Analysis:

See paragraph f.1(d).

4. Training Requirements:

Some briefing will be required to acquaint the astronaut with the objectives of the experiment. A one-week training period under simulated conditions using operational type equipment should be all that is required to provide sufficient information for the operation and maintenance of the equipment and to develop familiarity with the control and display devices.

5. Other Selection Criteria:

None.

6. Maximum Work Periods:

Five minutes.

EXHIBIT B.4

PREREQUISITE DATA REPORT (PDR)

INTRODUCTION

I. SCOPE:

This attachment is provided to answer the seven basic questions of paragraph V.C of Attachment 1 to AFR 375-5, dated 4 May 1964.

II. DESCRIPTION:

The purpose of this experiment is to study the plasma environment of MOL by means of manned observations of various kinds and to correlate these observations with physical laws. Specifically, this experiment is intended to evaluate the properties of the plasma sheath and the extent to which it will interfere with the propagation of electromagnetic energy through it.

No critical equipments are involved in the system experiments. All items are currently available on an engineered basis.

III. ATTACHMENTS:

No additional study summary reports as described in paragraph 3.3.4.2 of Management Plan For MOL Experiments, Revised, dated 22 July 1964, exist.

SECTION I
ENGINEERING STATUS

1. State-of-the-Art:

The measurement of plasma characteristics has a considerable background, especially in the area of gaseous electronics and related devices, and theory and techniques have been developed for these applications. With moving vehicles in space, similar techniques can be employed, with modifications to adapt them to the varying conditions encountered. No new break-throughs are required to obtain desired results.

2. Experiment Requirements:

The requirements imposed by this experiment on the state-of-the-art deal primarily with interpretation of experimental methods and the validity of measurements made under conditions of motion which introduce variations and transitions in the plasma surrounding the vehicle as opposed to equilibrium beyond the immediate environs. A space charge sheath immediately surrounding the vehicle must be considered, as well as currents flowing in the surface material from external magnetic and other phenomena. The particle flow around the moving vehicle causes different concentrations and directions to exist at locations relative to the vehicle having changing flow patterns. The difference in velocities of electrons and ions relative to the vehicle velocity introduce problems in particle collection. An adequate assessment of these effects on the experiment is necessary.

3. Summary:

This experiment requires no extension of the state-of-the-art for plasma measurements. The design of measurement probes is well documented from past investigations, and the problem is a matter of selection of the most effective type for the application. Electrometer amplifiers and associated signal conditioners are available in different forms and the reduction of size and power requirements constitutes the primary design requirement, as do other conventional components for data conversion and storage, system programming, and monitor and control.

4. References:

(a) "Studies of Electric Discharges in Gases at Low Pressures", Dr. Irving Langmuir, Harold Mott-Smith, Jr.:

(1) General Electric Review, Vol. 27, No. 7, July 1924, pg. 449
(2) General Electric Review, Part II, Vol. 27, No. 8, Aug 1924, pg. 538
(3) General Electric Review, Part III, Vol. 27, No. 9, Sep 1924, pg. 616
(4) General Electric Review, Part IV, Vol. 27, No. 11, Nov 1924, pg. 76[illegible]
(5) General Electric Review, Part V, Vol. 27, No. 12, Dec 1924, pg. 810

(b) "Dynamic Probe Measurement in the Ionosphere", Gunnar Hok, N. W. Spencer, A. Reifman, W. G. Dow; Univ. Mich. Res. Inst. Scientific Report FS-3, Nov 1958

(c) "Atmospheric Drag on the Satellite", R. Jastrow, C. A. Pearse; Jour. Geophysical Res., Vol. 62, No. 3, Sep 1957, pg. 413

(d) "Measurement of Positive Ion Density in the Ionosphere", Torao Ichimiya, Kazuo Takayama, Yuichiro Aono; Report of Ionosphere and Space Research in Japan, Vol. 13, 1959

(e) "Exploration of Upper Atmosphere with Third Soviet Satellite", V. I. Krassovski; Prox. Inst. Radio Eng., 47, No. 2, pg. 289, Feb 1959

(f) "Interactions of Rapidly Moving Bodies in Terrestrial Atmosphere" K. P. Chopra; Rev. Modern Physics, 33, No. 2, pg. 153, Apr 1961

(g) "Ionospheric Research from Space Vehicles", R. L. Bourdeau; Space Science Review, 1, pg. 683, 1962-3

(h) "Measurement and Interpretation of Ion Density Distributions in Daytime F Region", R. C. Sagalyn, M. Smiddy, J. Wisnia; Jour. Geo. Res., Vol. 68, No. 1, pg. 199, Jan 1, 1963

(i) "Explorer 8 Satellite Measurements in the Upper Ionosphere", R. L. Bourdeau, J. L. Donley; NASA TN D-2150, Jun 1964

(j) "Explorer 10 Plasma Measurements", A. Bonetti, H. S. Bridge, A. J. Lazarus, B. Rossi, F. Scherb; Jour. Geo. Res. Vol. 68, No. 13, pg. 4017, July 1, 1963

(k) "Effects Produced by an Artificial Satellite Rapidly Moving in the Ionosphere or in an Interplanetary Medium", Ya. L. Al'pert, A. V. Gurevich, L. P. Pitaevski; Soviet Physics Uspekhi, Vol. 6, No. 1, pg. 13, Jul-Aug 1963

SECTION II

BUILDING BLOCK COMPONENTS AND TECHNOLOGY

1. Critical Components:

With the exception of the probes and booms, which must be fabricated to fit the installation, building block components of basic design are available for a system of this type. Both probes and booms have been designed and built for other projects and techniques are well established. Depending upon the location of the installation, i.e., temperature and pressure ranges, mechanical conditions, volume and weight limits, the design characteristics may have to be modified to meet space and vehicle needs. However, design performance has been proven for similar experiments, including the probes, and no development problems are anticipated. Components include electrometer amplifier, signal conditioner, multiplexer, encoder, magnetic memory, programmer, calibrator, monitor and display, and power convertor.

2. Technology:

Since conventional techniques exist for the complete system, no research problems or break-throughs are required.

3. References:

(a) "An Instrument for the Investigation of Interplanetary Plasma", H. S. Bridge, C. Dilworth, B. Rossi, F. Scherb; Jour. Geo. Res. Vol. 65, No. 10, pg. 3053; Oct 1960

(b) "Two Instruments for Measuring Distributions of Low Energy Charged Particles in Space", M. Bader, T. B. Fryer, F. C. Wittebom; NASA TN D-1035

(c) "Mariner A Plasma Probe", H. S. Bridge, B. Rossi, F. Scherb, R. H. Baker, R. S. Cuikay, E. F. Lyon; Lincoln Lab. Tech. Report 337; 5 Dec 1963

(d) "An Instrument for the Measurement of Interplanetary Solar Plasma", C. Josias, J. Lawrence; Jet Propulsion Lab. TR 32-492; 1 May 1964

(e) "High Speed Electrometers for Rocket and Satellite Experiments", J. Praglin, W. A. Nichols; Proc. IRE, Vol. 48, No. 4, pg. 771; Apr 1960

(f) Proc. IRE, Vol. 50, No. ; Sep 1962:

(1) "Negative Impedance Electrometer Amplifiers - Introduction", E. F. MacNichol, Jr., pg. 1909

(2) "Cathode Follower and Negative Capacitance as High Impedance Input Circuits", Christian Guld, pg. 1912

(3) "Stabilized Wide-Band Potentiometric Preamplifiers", J. W. Moore, J. H. Gebhart, pg. 1928

(4) "Bandwidth Limits for Neutralized Input Capacity Amplifiers", R. L. Schoenfeld, pg. 1942

(g) "Solid State Electrometers with Input-Capacitance Neutralization", H. Fein; IEEE Transactions on Bio-Medical Engineering; Jan-Apr 1964

(h) "Put FETs to Work in Electrometers", Robert Munoz; Electronic Design; May 11, 1964

SECTION III
TRADE-OFF ANALYSIS

1. Conducted Analysis:

From the standpoint of logistics, personnel, training, and operations, there is very little in the way of trade-offs to be accomplished. The technical approach is based on a considerable amount of background experience as discussed in other sections of this PDR (Sections I, IV).

2. Directed Activity:

(NOT APPLICABLE)

3. Summary:

No further analysis is contemplated. A continuing review of the trade-off analyses is not expected to provide a better man-machine configured experiment than that proposed here.

SECTION IV
TECHNICAL APPROACH SELECTION

1. Technical Approach:

The probe technique to be used here was selected on the following bases:

(a) It provides direct exploration and analysis of the plasma environment of the MOL.

(b) It leads directly to the determination of electron density and temperature which is essential for the derivation of the propagation constant (α, the attenuation factor and β, the phase velocity factor).

The technical approach selected involves a system by which an astronaut can position several plasma probes on the vehicle to collect charged particles of different characteristics. By means of program selection, he can apply voltages to the probes which result in currents being generated at the input to electrometer amplifiers which serve to transform the signals to levels suitable for recording. Through control and monitoring of calibration and output conditions, he can adjust the operation of the system in accordance with environmental plasma change. As multiple channels of data become available, the astronaut sets up interface conditions to record the data on magnetic tape which is time-shared by other experiments. Also, he selects parameters from other measurement sources such as radiation monitors, magnetometers, pressure and temperature devices, and connects them through a multiplexer to the recorder. As each part of an experiment is completed, the astronaut shifts probes to new positions and repeats the measurements for a new set of conditions, selecting orbital and solar positions which enable limits to be determined. This approach allows the reasoning and visual monitoring powers of the astronaut to be utilized, thus affording more complete experimental results than could be obtained by other means of control.

2. Alternatives:

The choice of alternatives, with respect to man, does not change appreciably the basic functions but the degree that will be required of him in setting up experiment conditions and monitoring and assessing the results. Other approaches in general allow determination of particle density but not particle thermal energy.

For example, other possibilities are rf impedance probes, plasma resonance at electron gyrofrequency, electromagnetic transmission or reflection, ionization gauges, the Bremsstralung experiment employing electron beam and X-ray detectors, or diffusion, scattering, absorption in the plasma. The method selected is considered the most straightforward in technique, affords optimum use of man's observation and reasoning on results, provides the most characteristic data, and does not introduce interference or hazardous operations.

SECTION V

MISSION AND PERFORMANCE

1. Description:

The experiment mission is to enable an astronaut to perform the tasks necessary for measuring the properties of the plasma in the vicinity of the vehicle. The variations caused by motion of vehicle and particles require multiple measurements to be made by means of movable probes at different locations in a short time interval. The astronaut must position the probes to explore conditions around antennas and similar protuberances extending from the vehicle, and monitor results shown on electronic displays. Calibration of system performance must also be included. Each measurement for a fixed set of conditions should require no more than 5 minutes. Several of these may be necessary to define boundaries at any one time. As general conditions change from day to night, or with latitude or altitude, or solar activity, additional sets of measurements will be needed. The timing is not critical and can be worked in with other experiments. Vehicle conditions such as attitude need not meet a specific value at time of a set of measurements but must be known to establish probe directions. Location of probe booms may need correlation with other extensions.

It is anticipated that output of sensors for other purposes such as magnetometer, radiation indicators, time, can be shared with other experiments. Also data recorders, data links, and ground facilities available can be used on a mutual basis.

Space: External probes, 1 cu. ft.; internal electronics, 2.5 cu. ft.

Weight: External probes, 40 lbs.; internal electronics, 40 lbs.

Power: Average 75 volts, peak 100 watts; standby 10 watts; intermittent.

2. Degradation:

The space limitations aboard the MOL on the positioning and number of probes could limit an optimum experiment design. Additionally, the orbit selected for MOL will restrict measurements to given altitude and latitude conditions.

3. Reference:

It is understood that Space Systems Division will supply the required material on MOL design and performance criteria.

SECTION VI

COST EFFECTIVENESS

1. Competitive Items:

This experiment has been designed to permit the extension of the probe-boom assemblies in such a manner as to provide contours of the plasma environment surrounding the MOL vehicle. Previous and current experiments designed to examine the plasma make use of fixed probes generally at the surface of a rocket or satellite vehicle. This provides restricted data which is not considered to be adequate for the goals set for this experiment. Additionally, this experiment, by directly supporting experiments S-1 and S-22, does so both in space and time, providing a unique opportunity for correlating basic scientific information with measured electromagnetic wave propagation properties.

2. Criteria for Comparison:

The cost effectiveness of this experiment is difficult to determine in a quantitive manner. This is so because:

(a) A unique method has been chosen for the determination of electron density and temperature.

(b) The engineering accomplishment of the design is limited by the availability of a few unique and selectable components and subsystems, i.e., DeHaviland booms, assemblies, and electrometer amplifier modules.

Man's impact on the experiment has been established on the basis of testing man's skill in space. For instance, going to one extreme such as the complete automation of the experiment, which would require a minimum participation on the part of the man, would lead both to a fiscally expensive system and to one with a low reliability factor. On the other hand, a completely manual system, with full control by the man, would limit the results of the experiment by requiring an inordinate amount of time for the collection of each datum point. This experiment has been designed to make the best use of man and at the same time collect adequate amounts of data in a given unit of time and space.

3. Comparison:

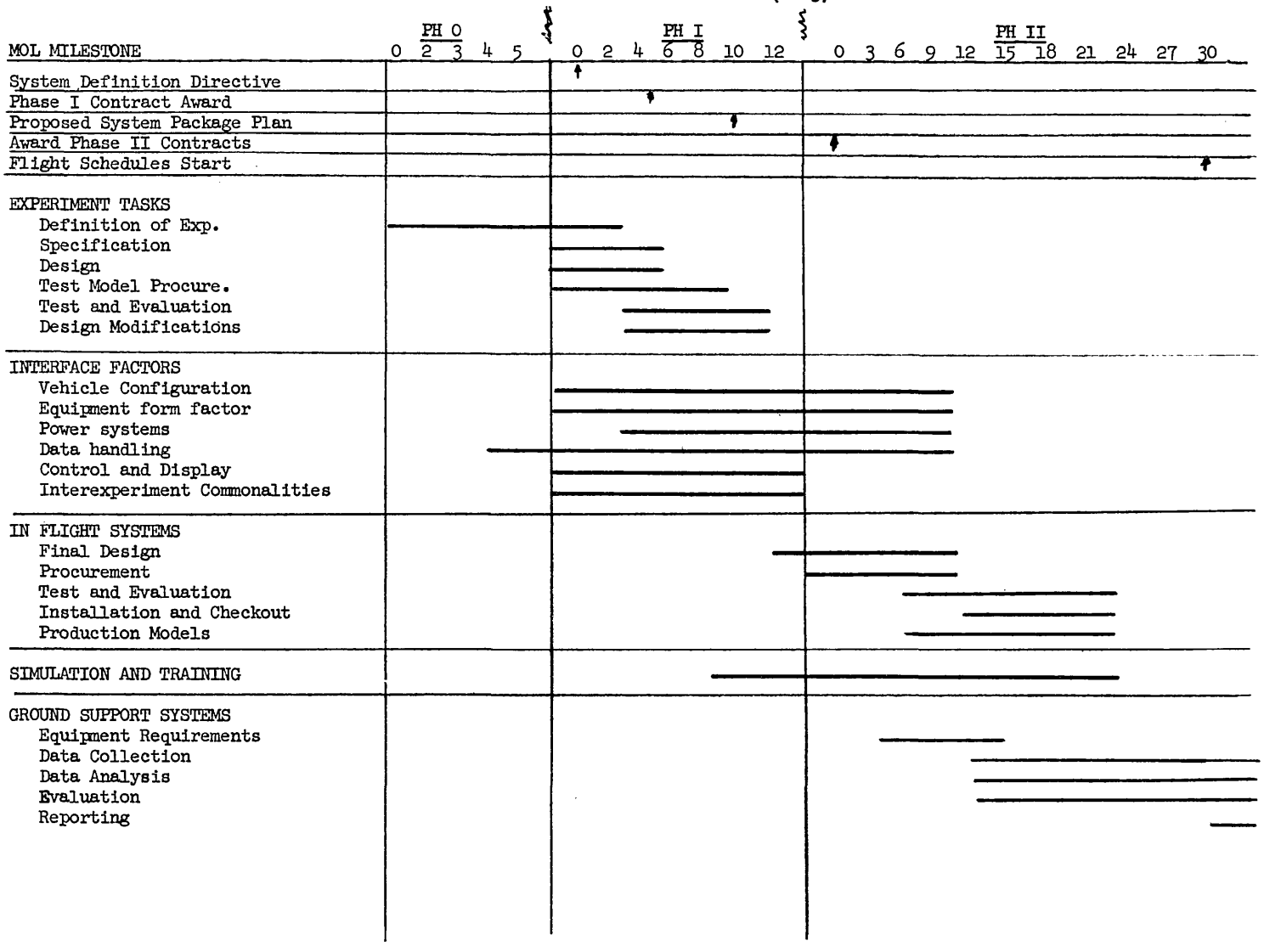
Since other techniques or experiment designs do not lead directly to the

objectives of this experiment, i.e., electron density and temperature, it is difficult to provide cost-effectiveness comparison with these other techniques.

SECTION VII -- SCHEDULE

FTDR - ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23) - SCHEDULE II

9/28/64



SECTION VII - COST SCHEDULE

	Fiscal Year			
	1965	1966	1967	1968
Current Authorized	35 K			
Expend. to 1 Oct 1964	16 K			
ESTIMATED FUTURE REQUIREMENTS:				
Procurement	250 K	1250 K	1050 K	-
Salary	50 K	150 K	150 K	150 K

SECTION VIII - BIBLIOGRAPHY

Management Plan for MOL Experiments; AFSSD; 22 July 1964.

System Program Management in USAF; Booz-Allen Applied Research, Inc.; 1 Aug 1964.

Statement of Work for MOL Experiment S-23 (Secret); Plasma Investigation by Measurement of Electron Temperature and Density; 30 July 1964.

Preliminary Technical Development Plan for MOL (Secret); AFSSD-50A; 30 June 1964.

EXHIBIT B.5

MISSION ANALYSIS REPORT

1. Experiment Description

The purpose of this experiment is to study the plasma environment in the vicinity of MOL by means of manned observations of various kinds and to correlate these observations with physical laws. Specifically, this experiment is intended to evaluate the properties of the plasma sheath and the extent to which it will interfere with the propagation of electromagnetic energy through it.

A satellite moves through plasma or partially ionized medium composed of neutral molecules, positive ions and electrons. For comparable ion and electron temperatures, i.e., thermal equilibrium, the electron velocity will be about a hundred times the ion velocity. Specific calculations show that the ion velocity is one-tenth that of the satellite while the electron velocity is 10 times greater than the satellite. This means in effect that the satellite plows into a stationary distribution of positive ions while it is bombarded from all directions by the much faster electrons. Electrical equilibrium is achieved when the incoming ion current is balanced by the electron current and this occurs when the satellite reaches a negative potential such that only electrons having energies greater than this potential can reach the satellite. Because of the negative charge around the satellite electrons are repelled. Thus near the satellite and extending outward for several centimeters, there is a charge sheath around the satellite wherein there are fewer electrons than positive ions. As one moves away from the satellite, it is observed that the electric field due to the satellite is nautralized by the excess positive charge near the vehicle so that at a few centimeters away from the surface the satellite field drops to zero and the normal unperturbed plasma again exists.

Calculations made via the indicated route show that the satellite will normally be charged to a negative 3 to 5 volts. Under certain conditions, it is possible that the satellite potential may go as low as -60 volts, although this has never been observed: This condition would be expected to obtain when the electron energy distribution has an appreciable high energy tail. It is interesting to note that at a height of 200 km where the electron density now is about $2x10^5/cm^3$, a satellite will accumulate a charge of about $3.2x10^{-7}$ coulombs, for

a satellite potential of about 3-5 volts. There may thus be problems associated with moving equipment from or to the MOL as well as rendezvous with other vehicles which may have different charges.

In order to better understand the behavior of radiating devices on the MOL as well as the environment in which the vehicle moves, it is desirable to study the properties of the plasma and plasma sheath about the MOL. In particular, the experimental program is:

(1) To study the electron energy distribution in the plasma surrounding the MOL.

(2) To determine the electron and ion densities in the plasma and plasma sheath.

(3) To study the size of the formation of the plasma sheath around MOL and determine how such sheaths are affected by vehicle heading, etc.

(4) To correlate this information with the V.L.F. experiments to determine how V.L.F. propagation and antennae impedance are affected.

2. Man's Role

Man's purpose in space in a military capacity is related to his ability to achieve objectives accomplished through directed activities, perception and observation, monitoring and calibration, reasoning power and initiative. This experiment provides an opportunity to evaluate these characteristics as related to man's performance.

Based on his experience acquired through previous instruction and training as related to this experiment, the man will use the above mentioned characteristics in adapting the experiment to the environment.

His contributions will be measured and evaluated in terms of how the experiment is enhanced by his participation and also by delays encountered while performing experimental tasks.

3. Man as Test Conductor

As a test conductor, man will initiate the experiment according to a prearranged sequence. Unusual environmental conditions may require modification of

the test sequence by the man based on his observation and preliminary evaluation of data. In connection with other on-board experiments, the test conductor may be required to manipulate the external sensors to positions dictated by operating conditions of the other experiments.

During the test sequence, the test conductor monitors the experiment displays, recognizes misalignments and takes the necessary corrective action. Experimental procedures include the completion of alignment check-off lists and the preparation of narrative log in which special conditions, observations, and results are noted.

4. Space Test Requirement

V.L.F. experiments will be conducted on the MOL. The electron density and temperature experiment supports the V.L.F. experiments. It is desired that both be performed simultaneously to achieve the maximum correlation of results. In this connection the electron density and temperature experiment would:

(a) Determine basic information relative to formation of plasma sheath around large orbiting vehicles and study effects of supersonic flow.

(b) Determine characteristics of unperturbed plasma as related to V.L.F. propagation.

(c) Determine electron density and potential distribution across the plasma sheath in order to relate the sheath characteristics to V.L.F. and U.H.F. antenna impedance characteristics.

(d) Study effects of VXH emf's induced in the satellite vehicle structure and its relation to the plasma sheath.

5. Military Importance

The electron density and temperature experiment will contribute to the knowledge of the environment of space vehicles. This will be of prime importance in the development of techniques and equipment for achieving reliable communications from manned space missions to cognizant command and control centers, both earth-based or on other vehicles.

Determination of the plasma state near MOL is essential to provide a working knowledge of the conditions of the environment in which man must work and live while on a space mission.

6. Technological Importance

Technologically, the experiment will provide the engineering information for launching or coupling electromagnetic energy from a transmitter/antenna complex to the magneto-ionic medium and, similarly, from the medium to an antenna/receiver complex. Engineering information related to these problems is scant or unavailable. Man will provide a mechanism for the determination of these engineering parameters which would not be as directly available by other means.

This experiment supports directly the technological exploitation of Experiments S-1 and S-22.

7. Scientific Importance

This experiment will provide for an increase in the fund of knowledge related to the magneto-ionic environment. Specifically from the standpoint of determining electron and ion densities and temperatures over ranges of altitude, latitude, diurnal variations. Also the determination in the anisotropic characteristic of the medium as influenced by the earth's magnetic field, solar flares, and other extraterrestial phenomena.

Man's contribution will be related to a determination and responsiveness, to such items as boundary conditions, anomalies, and changing plasma conditions.

8. Technical Feasibility

No major engineering or technical problems are envisioned in meeting the objectives of this experiment. Experiments of a similar character have been conducted on unmanned satellites, but have been limited in scope such that the scientific data obtained was of meager proportions relative to that expected from the conduct of this experiment aboard MOL.

Space-qualified techniques and components composed of solid state devices are available to meet the engineering and contraction requirements of this experiment. The equipment is expected to have a maximum weight of 80 lbs., an average power requirement of 110 Watts when in use, and occupying a volume of 3.5 cu. ft. Reliability in terms of MTBF calls for a design goal of 1000 hours. Equipment, with the exception of control and display devices, will be suitable for mounting in unpressurized spaces.

Engineering building blocks for this experiment are available with no long lead-time developments necessary, thus insuring availability of the experiment on a timely basis.

9. Cost Effectiveness

The cost estimates for the definition, development and documentation of the experiment, up to but not including integration, is $3.1 million.

The cost effectiveness of this experiment relative to other DOD efforts is not applicable in this instance.

EXHIBIT B.6

PTDP INPUTS

SECTION 6 - ACQUISITION:

1. Title of Experiment

Electron Density and Temperature

2. Objective

The purpose of this experiment is to study the plasma environment in the vicinity of MOL by means of manned observations of various kinds and to correlate these observations with physical laws. Specifically, this experiment is intended to evaluate the properties of the plasma sheath and the extent to which it will interfere with the propagation of electromagnetic energy through it.

3. Description

A satellite moves through plasma of partially ionized medium composed of neutral molecules, positive ions and electrons. For comparable ion and electron temperatures, i.e., thermal equilibrium*, the electron velocity will be about a hundred times the ion velocity. Specific calculations show that the ion velocity is one-tenth that of the satellite while the electron velocity is 10 times greater than the satellite. This means in effect that the satellite plows into a stationary distribution of positive ions while it is bombarded from all directions by the much faster electrons. Electrical equilibrium is achieved when the incoming ion current is balanced by the electron current and this occurs when the satellite reaches a negative potential such that only electrons having energies greater than this potential can reach the satellite. Because of the negative charge around the satellite, electrons are repelled. Thus near the satellite and extending outward for several centimeters, there is a charge sheath around the satellite wherein there are fewer electrons than positive ions. As one moves away from the satellite, it is observed that the electric field due to the satellite is neutralized by the excess positive charge near the vehicle so that at a few centimeters away from the surface the satellite field drops to zero and the normal unperturbed plasma again exists.

Calculations made via the indicated route show that the satellite will normally be charged to a negative 3 to 5 volts. Under certain conditions,

* For a fairly complete set of references see R. E. Bourdeau, "The Temperature of Charged Particles in the Upper Atmosphere". Preprint May 1964, Goddard Space Flight Center, presented at COSPAR.

it is possible that the satellite potential may go as low as -60 volts although this has never been observed: This condition would be expected to obtain when the electron energy distribution has an appreciable high energy tail. It is interesting to note that at a height of 200 km where the electron density now is about $2 \times 10^5/cm^3$, a satellite will accumulate a charge of about 3.2×10^{-7} coulombs, for a satellite potential of about 3-5 volts. There may thus be problems associated with moving equipment from or to the MOL as well as rendezvous with other vehicles which may have different charges.

In order to better understand the behavior of radiating devices on the MOL as well as the environment in which the vehicle moves, it is desirable to study the properties of the plasma and plasma sheath about the MOL. In particular, the experimental program is:

(1) To study the electron energy distribution in the plasma surrounding the MOL.

(2) To determine the electron and ion densities in the plasma and plasma sheath.

(3) To study the size of the formation of the plasma sheath around MOL and determine how such sheaths are affected by vehicle heading, etc.

(4) To correlate this information with the V.L.F. experiments to determine how V.L.F. propagation and antennae impedance are affected.

4. Importance

The experiments are required so that a knowledge of the environment about the MOL can be obtained and understood so as to provide information to be used in the design of electromagnetic equipment to be used aboard satellites. Such experiments can be carried out only in space where the proper plasma conditions exist on a sufficiently large vessel such as the MOL which typifies future-generation vehicles.

V.L.F. experiments will be conducted on the MOL. The electron density and temperature experiment supports the V.L.F. experiment. It is desired that both be performed simultaneously to achieve the maximum correlation of results. In this connection, the electron density and temperature experiment would:

(a) Determine basic information relative to formation of plasma sheath around large orbiting vehicles and study effects of supersonic flow.

(b) Determine characteristics of unperturbed plasma as related to V.L.F. propagation.

(c) Determine electron density and potential distribution across the plasma sheath in order to relate the sheath characteristics to V.L.F. and U.H.F. antenna impedance characteristics.

(d) Study effects of VXH emf's induced in the satellite vehicle structure and its relation to the plasma sheath.

5. <u>Vehicle Interfaces</u>

a. Commonality Problems
   - (1) Power Supplies
   - (2) Time Standard
   - (3) Data Processing
     - Standards
       - Format
       - Word Length
       - Data Rate
     - Storage
   - (4) Data Link
   - (5) Equipment Interface
   - (6) Simultaneous use of astronaut for several experiments

b. Environmental Problems
   - (1) Accommodation for space needs and accessibility as affected by all on-board experiments
   - (2) Minimization and elimination of interference problems: space, electrical, magnetic, acoustic, optical

c. Common Data Requirements related to all or several experiments
   - (1) Pressure
   - (2) Magnetometer
   - (3) X-Ray
   - (4) Vehicle attitude and position as functions of time

6. Test Concepts

Basically the experiment is carried out by the astronaut who extends several retractable probes placed at three different positions from nose to tail of the craft. Each probe will be of a modified Langmuir type designed to be extended from the vehicle at will and (perhaps) the orientation varied slightly. The astronaut will utilize a multichannel electrometer to record the plasma currents stored until the astronaut's return to earth or be telemetered down: The latter is preferable. Analysis of the data will permit determination of ion density, electron density and electron energy distribution as a function of distance from the satellite. This information should be sufficient to define the plasma and plasma sheath so that its effects can be determined.

SECTION 7 - CIVIL ENGINEERING:

(NOT APPLICABLE)

SECTION 9 - MANPOWER REQUIREMENTS:

5 Man-years for Phase 1.

12 1/2 Man-years for Phase 2.

SECTION 10 - PERSONNEL TRAINING:

Some briefing will be required to acquaint the astronaut with the objectives of the experiment. A one-week training period should be all that is required to provide sufficient information for the operation and maintenance of the equipment and to develop familiarity with the control and display devices. A similar training period should be adequate for ground support personnel.

SECTION 11 - FINANCIAL:

FY 1965 - $250 K		Procurement Items
FY 1966 - $1250 K		
FY 1967 - $1200 K		
FY 1965 - $ 40 K		Salary
FY 1966 - $150 K		
FY 1967 - $150 K		

SECTION 12 - REQUIREMENTS:

(NOT AVAILABLE)

SECTION 15 - SECURITY:

(SEE ATTACHMENT)

SECTION 16 - BIOMEDICAL:

1. Task description per man per test

(a) Test Operations:

Astronaut will follow a pre-arranged instruction or modify such an instruction on command to initiate an experiment sequence. Instructions will include check-off list and alignment procedures. Time required - minimum 5 minutes per test sequence.

(b) Calibration Operations:

Calibration to be done automatically, but will require visual monitoring by the astronaut. Time required - estimated that four one-minute monitoring intervals during one orbit.

Astronaut will be required to recognize misalignment, as indicated by displays, and to take measures by means of instructions to establish suitable experimental conditions.

(c) Evaluation:

Astronaut will evaluate on board displays to determine existence of abnormal test environmental conditions. Time required - continually during course of experiment, but on a cursory basis.

(d) Communication and Reporting:

Astronaut will maintain log and complete check-out list. Astronaut will report via data link existence of unusual environmental conditions. Time required-five minutes per special report, and five minutes per test sequence for experiment status report.

2. Work Positions relative to above tasks:

Astronaut must be within working and viewing distance of display and control panels.

3. Support Requirements:
   None

4. Potential Problems:
   None

5. Time-Line Considerations:
   (NOT APPLICABLE)

SECTION 17 - PDP PLAN
(NOT AVAILABLE)

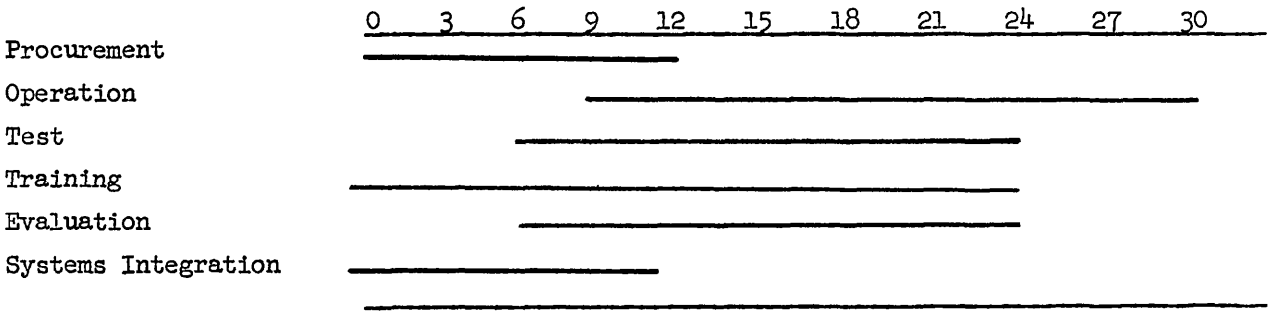
SECURITY CLASSIFICATION FOR ELECTRON DENSITY ON TEMPERATURE EXPERIMENT (S-23)

INFORMATION REVEALING	CLASSIFICATION	AFR 205-2 GROUP CODE
1. Experiment titles	U	
2. Experiment titles associated with the MOL Program.	U	
3. Complete lists or partial lists of experiments associated with the MOL Program.	U	
4. The experiments which will be conducted on a particular MOL flight will be classified.	C	
5. Experiment objectives	U	
6. Experiment equipments (itemized)	U	
a. Flight equipments		
b. Simulator equipments		
7. Equipment specifications	U	
8. Equipment drawings	U	
9. Equipment performance, capability, tolerances, accuracies, etc.	U	
10. Experiment procedures	U	
11. Test results and final reports	U	
12. Interface documents	U	
13. Experimental development and programs	U	
14. Experiment budget estimates	U	
Experiment System Security	N.A.	
Vulnerability and threat		
Countermeasures		
Physical Security	N.A.	
Contractor facilities		
During movement		
At launch site		

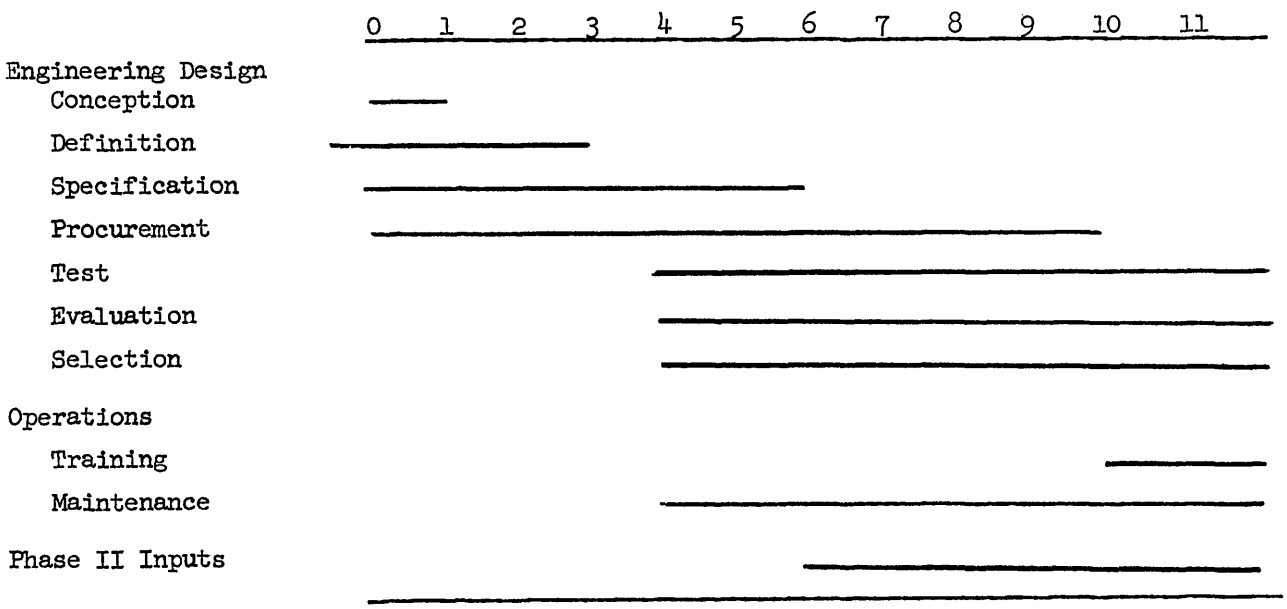
SECTION II -- SCHEDULE

FTDR
ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)
SCHEDULE I

PHASE II (ACQUISITION)
Months from go-ahead



PHASE I (PROGRAM DEFINITION PHASE)
Months after go-ahead



EXPERIMENT MANAGEMENT ORGANIZATION

ELECTRON DENSITY AND TEMPERATURE

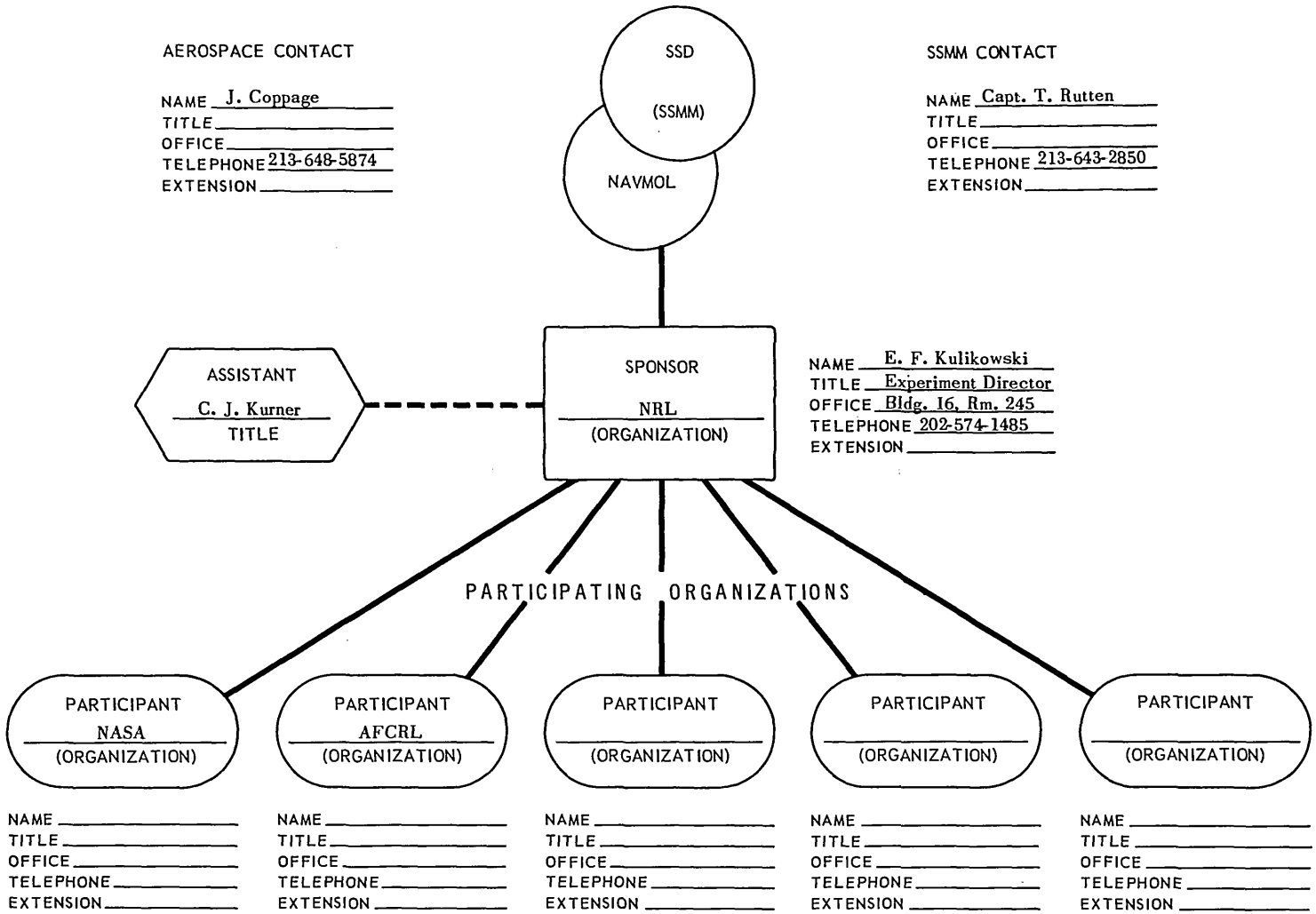


EXHIBIT B.7

ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)

FINAL TECHNICAL DOCUMENTARY REPORT (FTDR)

I. Specific Tasks

A. Definition of Experiment:

1. This experiment is required so that a knowledge of the environment of the MOL can be obtained. It will provide information to be used in the design of electromagnetic equipment to be used aboard space vehicles. The plasma sheath formed about the satellite will markedly affect the propagation of V.L.F. signals as well as the impedance of both V.L.F. and U.H.F. antennas. Such experiments can only be carried out in space where the proper plasma conditions exist on a sufficiently large scale.

2. The experiment will involve the measurement of electron and ion currents over the range 10^{-7} to 10^{-12} Amps. as a function of probe voltage over the range -40 to +40 volts, in order to determine:

(a) The electron energy distribution in the plasma surrounding the MOL.

(b) The electron and ion densities in the plasma.

(c) The formation and size of the sheath around the MOL.

(d) The potential of the satellite.

(e) The across-the-sheath potential distribution.

(f) Additionally, the effects of VXH EMF's induces in the MOL structure and its relation to the plasma sheath will be studied.

The above quantities will lead to the determination of:

(g) The refractive index of the environment.

(h) The propagation constant; i.e., the attenuation and phase characteristics.

(i) The surface currents on the MOL.

The long range plan is to determine seasonal, diurnal and spatial variations of the plasma under ordinary and extraordinary conditions.

For any particular MOL mission, the experiment will be directed insofar as practical to determine diurnal and spatial variations of the plasma. An implicit purpose of this experiment is to determine the range, validity, and accuracy of the measured quantities to be used in correlating and establishing physical principles for engineering applications.

3. Experimental testing will be conducted over two orbits to satisfy the diurnal and spatial requirements with regard to latitude, sunlight and darkness. Each orbital measurement will include, as a minimum insofar as practical, two series of probe measurements at each of four selected points in the orbit for a minimum of 24 data points per orbit.

B. Preliminary Analysis:

1. The astronaut

To initiate, control, maintain and monitor the experiment.

In-flight equipment

To measure, calibrate, record, display, store and transmit experimental data.

Ground support equipment

(a) To maintain communications between astronaut and ground support facilities.

(b) To collect, record and store experimental data transmitted from the MOL.

Ground support personnel

(a) To maintain and operate ground support equipment.

(b) To monitor and process incoming data.

(c) To provide in-flight support.

2. The astronaut, in general, will perform the following:

(a) Selects experiment program and initiates measurements.

(b) Inspect the resultant measurements.

(c) If data appears satisfactory, will enable transmit to ground on given command.

(d) Modify program as instructed on command.

(e) Repeat above at stated intervals.

(f) Control the attitude of the MOL.

Specifically, the experiment is carried out by an astronaut who extends three probes and controls their orientation. The astronaut will utilize a multi-channel electrometer in conjunction with the probes to record plasma currents. The astronaut will be required to perform in-orbit alignment and calibration by the use of check-off procedures and instructions, and by use of standard internal inputs and visual inspection of outputs. One alignment procedure will be conducted per test sequence. Four sets of measurements and associated calibrations will be made per test sequence. The astronaut will be involved in on-board data processing by monitoring experimental progress and reading and correlation of outputs with pre-flight furnished nomographs. The astronaut will evaluate on-board displays to determine existence of abnormal test environmental conditions and report same to ground. The astronaut will maintain log and complete check-out list.

3. In-Flight Equipment

The in-flight equipment will consist of:

(a) Three externally mounted probes, controllable in length and orientation on a semi-automatic programmed basis.

(b) A multi-channel electrometer amplifier and associated selection gates (electrometer will be capable of 10^{-7} - 10^{-12} ampere measurement in one range).

(c) Electronics used for conditioning electrometer output prior to encoding and storage.

(d) The programmed logic and control circuitry which provides the means whereby the probes or calibration signals are sampled on the basis of a pre-arranged semi-automatic program of instructions, an alert signal to the astronaut as a result of some significant change in space conditions or specific instructions from a ground command station.

(e) The circuitry necessary to provide calibration signals for the assessment of operating conditions of the experiment, either by the astronaut or on command of the ground.

(f) Encoding and storage devices for holding of experiment data for subsequent transmission and utilization.

(g) Display and control panel suitable for effecting the program instructions and modification thereto and for the observation of results.

(h) Data link interface which provides the mechanism for transmitting experiment information, held in store, to the ground.

(i) Power conversion and regulation devices.

(j) Ancillary equipment to provide additional information to supplement that derived from the probes, such as magnetometer, UV and X-ray radiometers. These may be made available as a result of other experiments carried aboard the MOL.

The experiment has the following physical factors:

	Weight	Vol.	Power
Probes	40 lbs. (external)	1 cu. ft.	
Electronics	40 lbs. (internal)	2.5 cu. ft.	

Power per test: Stand-by; 10 Watts
Average operating; 75 Watts
Peak operating; 100 Watts

Heat output: External; zero watts
Internal; Standby, 10 Watts
Average operating, 70 Watts
Peak operating, 90 Watts

Reliability Goals: 1,000 hrs. MTBF.

4. Ground Support Equipment

This experiment will utilize planned ground-MOL-ground data links to:

(a) Maintain communications with the astronaut so as to provide him with instructional control and command information.

(b) Collect, record and store the experimental data from the MOL. Preference is expressed for this experiment for standard IRIG telemetry techniques or for Gemini PCM data links. Ultimate choice or choices is dependent upon trade-off analysis of equipment simplicity aboard MOL vs. data handling on MOL and data processing on the ground as well as on the overall data link configuration chosen for MOL, reflected as an interface problem.

A minimum of one ground support system will be required for the reception of data twice a day. For this experiment this frequency of reporting is adequate. Since the ground support equipment will be common to other users, any increase in the frequency of data reporting will result in decreased MOL storage requirements. Such a trade-off must be examined in terms of the cost of additional ground support facilities versus added weight due to the increased storage in the MOL.

5. Ground Support Personnel

Personnel responsible for operation and maintenance of ground terminal receiving and transmitting equipment. They must have intimate knowledge of the philosophy and operation of the on-board experiment. They must be capable of relaying to the astronaut instructions and information relative to the conduct of the experiment in a changing environment. They will monitor and process the experimental data transmitted from MOL in response to an appropriate command. The monitoring and processing functions are limited to the extent of insuring the reception of transmitted information. Specific analysis of this information will be accomplished at the Naval Research Laboratory.

C. Vehicle Requirements and Interfaces:

1. Requirements and other interface considerations that will be imposed on the MOL vehicle, the MOL sub-systems and experiments by the electron density and temperature experiment will include in general the following:

(a) Commonality of Equipment:

Power supplies

Time standards

Data processing

Standards

Format

Word length

Data rate

Storage

Data links

Equipment

Simultaneity of use of astronaut

(b) Environmental Considerations:

Temperature, pressure, humidity, accommodations for space needs and accessibility as affected by all on-board experiments.

Minimization and elimination of interference; space, electrical, magnetic, acoustic, optical.

(c) Common Data Requirements:

Magnetometer.

UV Radiometer.

X-Ray Radiometer.

Vehicle attitude as a function of time.

2. Vehicle Requirements

(a) Stabilization:

Attitude control ± 1.0° in each axis.

Rate stabilization ± 0.1° per second.

Rate control in roll 360° per minute.

(b) Weight, volume, power, heat dissipation and reliability:

See paragraph B3(j).

3. Astronaut Accommodation Requirements:

Astronaut must be within viewing and working distance of display and control panels while experiment is in process.

D. Equipment Description:

1. Design Synthesis

(a) Sensors

Three sensors, each comprising a boom, probe and ancillary servo-mechanism drive system, will be employed. The boom-probe combination will be extendible over a range from the MOL surface to a distance of ten feet. Additionally, the boom-probe combination will be adjustable about three axes to permit controlled orientation of the probe. The drive system should be capable of orienting the boom-probe assembly in a specified direction and length within thirty seconds, (subject to the requirements of weight and size and the exchange of angular momentum with the MOL). It is estimated that a sensor assembly, comprising boom, probe, and drive will weigh approximately thirteen pounds and occupy approximately 0.2 cu. ft. Sensor assemblies will be mounted one fore, one aft, and one amid-ship the MOL structure.

(b) Controls

In general, the following controls will be employed in the conduct of the experiment:

(1) On-off-standby for control of primary power.
(2) Electrometer calibration.
(3) Probe voltage adjustment.
(4) Program selection for boom-probe erection and generation of sensory, logic and calibration voltages.
(5) Display adjustments for controlling scales, intensity and monitoring voltages.
(6) Data recording and readout for initiation and reporting.
(7) Interface switching for the selection of ancillary equipments used in other experiments.

(c) Displays

(1) Boom-probe status indicators.

(2) Probe voltage monitor.

(3) Electrometer currents.

(4) Maintenance test.

The following displays, while not considered essential to this experiment, would nevertheless provide useful data for interpreting experimental results:

(5) Ancillary devices such as time, magnetometer, U.V. and X-ray.

(6) Interface indicators.

(7) Vehicle attitude.

(d) Data Handling

The data handling system will provide the means for selection, sample and hold, encode, store and transmit of the following information:

(1) Experiment identification.

(2) Boom-probe orientation.

(3) Probe voltage vs. current characteristic.

(4) Calibration data.

(5) Attitude of vehicle.

(6) Time code.

(7) Magnetometer.

(8) U.V. radiation.

(9) X-ray radiation.

(10) Parity bits.

The store should have a capacity for holding 50,000 bits during two orbits, estimated here as totaling 200 minutes.

(e) Communications Equipment

Insofar as practical, consistent with other experiment requirements, the IRIG telemetry standards will be used for analog data and the Gemini PCM data system for digital data. Data links will be provided for ground-astronaut-ground communications for purpose of instruction, control and commands. These latter links will be consistent with requirements imposed on the MOL by other experiments.

(f) Equipment weight and size estimates

(1) Weights

a.	Boom-probe assembly(s)	40 lbs.
b.	Electrometers (3)	6 lbs.
c.	Program logic, control and store	20 lbs.
d.	Function control and displays	10 lbs.
e.	Power conversion and regulation	2 lbs.
f.	Data link interface	2 lbs.
	TOTAL WEIGHT	80 lbs.

(2) Size

a.	Boom-probe assemblies (3)	1.0 cu.ft.
b.	Electronics	2.0 cu.ft.
c.	Displays	0.5 cu.ft.
	TOTAL SIZE	3.5 cu.ft.

(3) Reliability

Design goal 1,000 hours MTBF.

E. Program Planning:

1. The Program Plan for the Electron Density and Temperature Experiment (S-23) is expected to follow the general outline of Schedule I for the conduct of the Project Definition Phase (Phase I) and the Acquisition Phase (Phase II).

2. More detailed scheduling for this experiment is presented in Schedule II. As can be seen, the principal product of the Phase I effort will be a laboratory model of the experiment equipment. This model will reflect the information available on equipment form factor as it is affected by the MOL vehicle configuration. The laboratory model will be subjected to environmental and performance testing to validate its suitability for the MOL environment.

Final specifications and layout drawings for experiment on-board equipment will be set forth following the test and evaluation of the

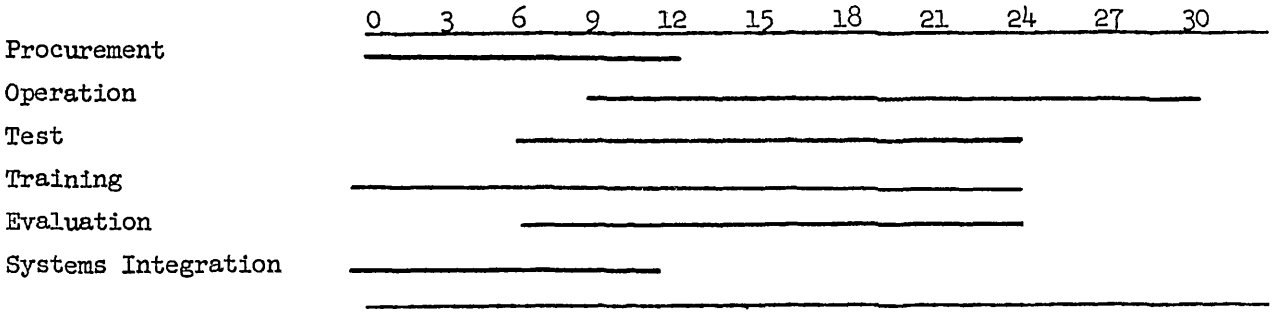
laboratory model. This documentation will reflect any necessary design modification.

The laboratory model will be used to initiate the training program for conduct of the experiment. Astronaut tasks relative to this experiment will be studied and routines determined to permit the rapid and efficient completion of test sequences.

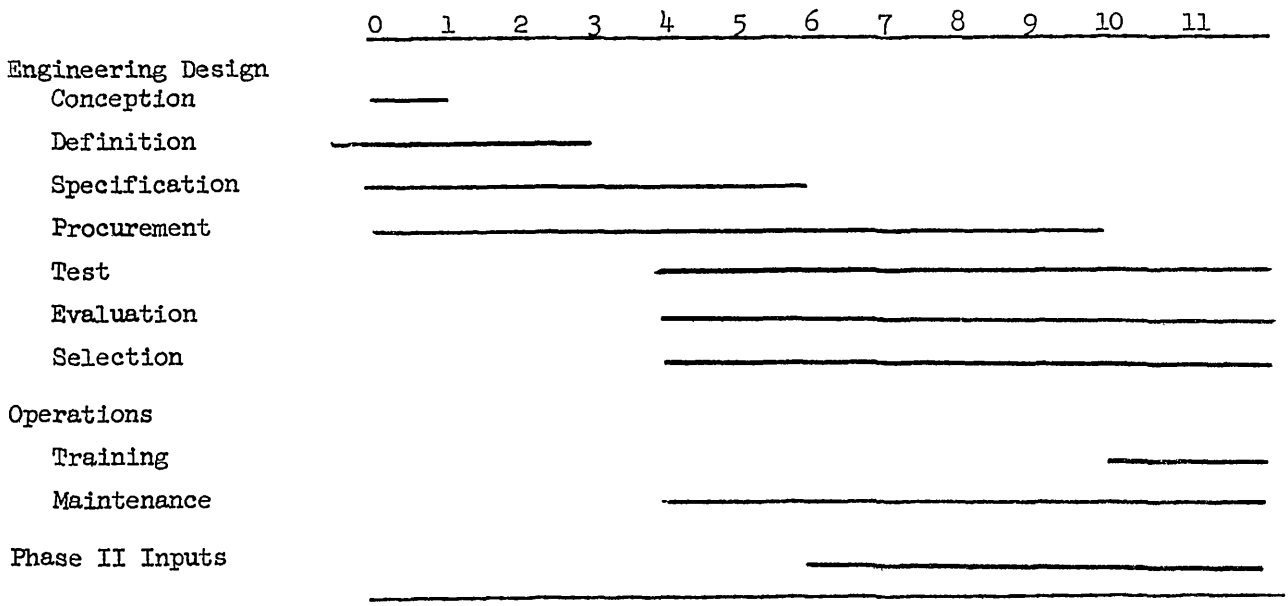
Manpower and cost schedules for Phase I and Phase II are shown in Schedule III.

FTDR
ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)
SCHEDULE I

PHASE II (ACQUISITION)
Months from go-ahead

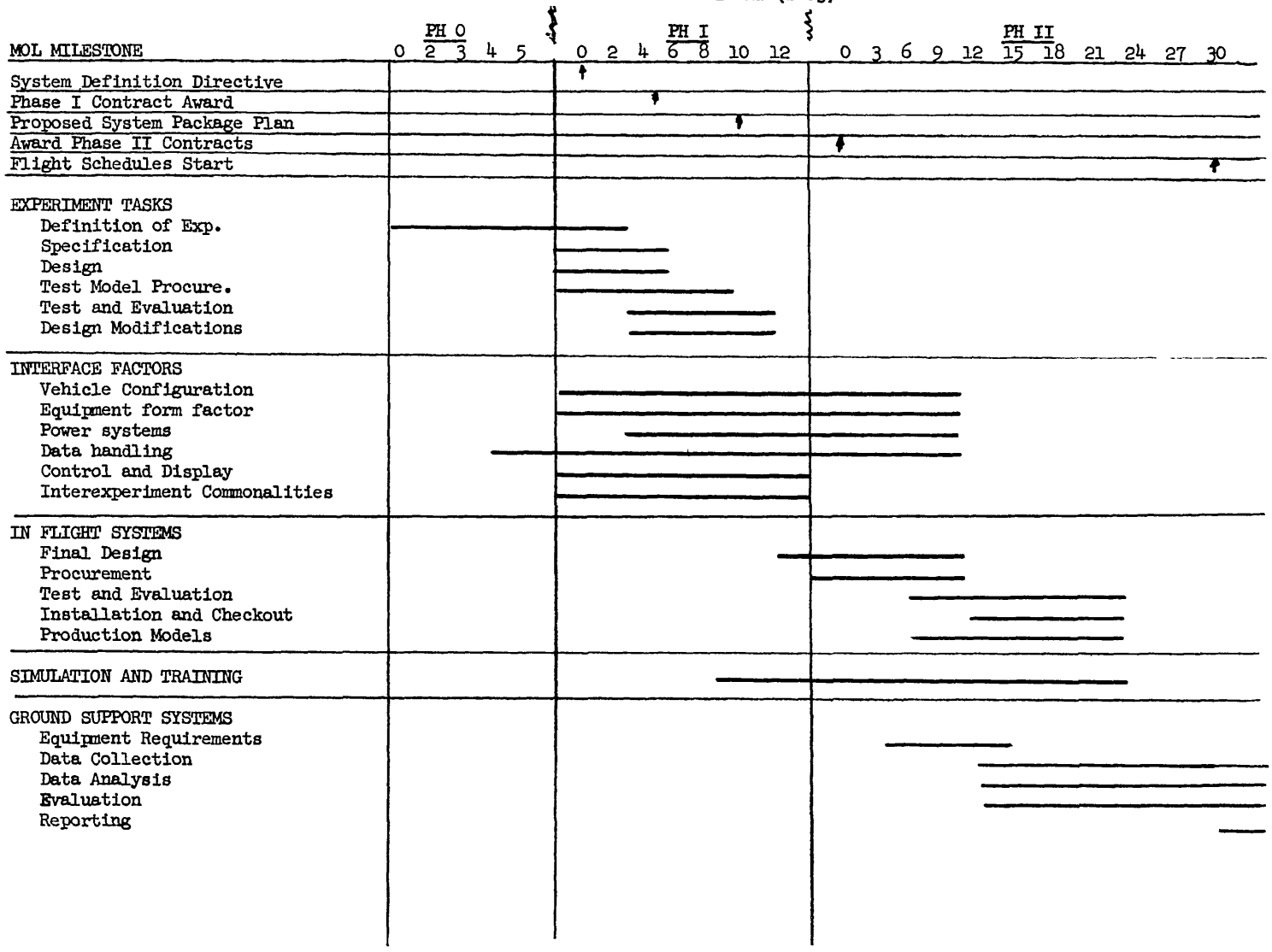


PHASE I (PROGRAM DEFINITION PHASE)
Months after go-ahead



FTDR - ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23) - SCHEDULE II

9/28/64



FTDR
ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)
SCHEDULE III

	Phase I	Phase II
Manpower	5 man years	12.5 man years
Cost	$660 K	$2390 K

APPENDIX C

MONTHLY PROGRAM REVIEW GRAPHICS AND/OR PROGRESS REPORTS

Contents

Exhibit C.1	Program Review Graphics for August 1964
Exhibit C.2	Program Review Graphics for September 1964
Exhibit C.3	Program Review Graphics for October 1964
Exhibit C.4	Program Review Graphics for December 1964
Exhibit C.5	Program Review Graphics for January 1965
Exhibit C.6	Program Review Graphics and Supporting Narrative for February 1965
Exhibit C.7	Program Review Graphics for March 1965
Exhibit C.8	Program Review Graphics for April 1965
Exhibit C.9	Program Review Graphics for May 1965
Exhibit C.10	Program Review Graphics for June 1965
Exhibit C.11	Progress Report for August 1965
Exhibit C.12	Program Review Graphics for September 1965
Exhibit C.13	Progress Report for September 1965
Exhibit C.14	Progress Report for October 1965
Exhibit C.15	Progress Report for November 1965
Exhibit C.16	Progress Report for December 1965
Exhibit C.17	Program Review Graphics and Supporting Narrative for January 1966
Exhibit C.18	Progress Report for January 1966
Exhibit C.19	Progress Report for February 1966
Exhibit C.20	Progress Report for March 1966
Exhibit C.21	Progress Report for April 1966
Exhibit C.22	Progress Report for May 1966
Exhibit C.23	Progress Report for July 1966

EXHIBIT C.1

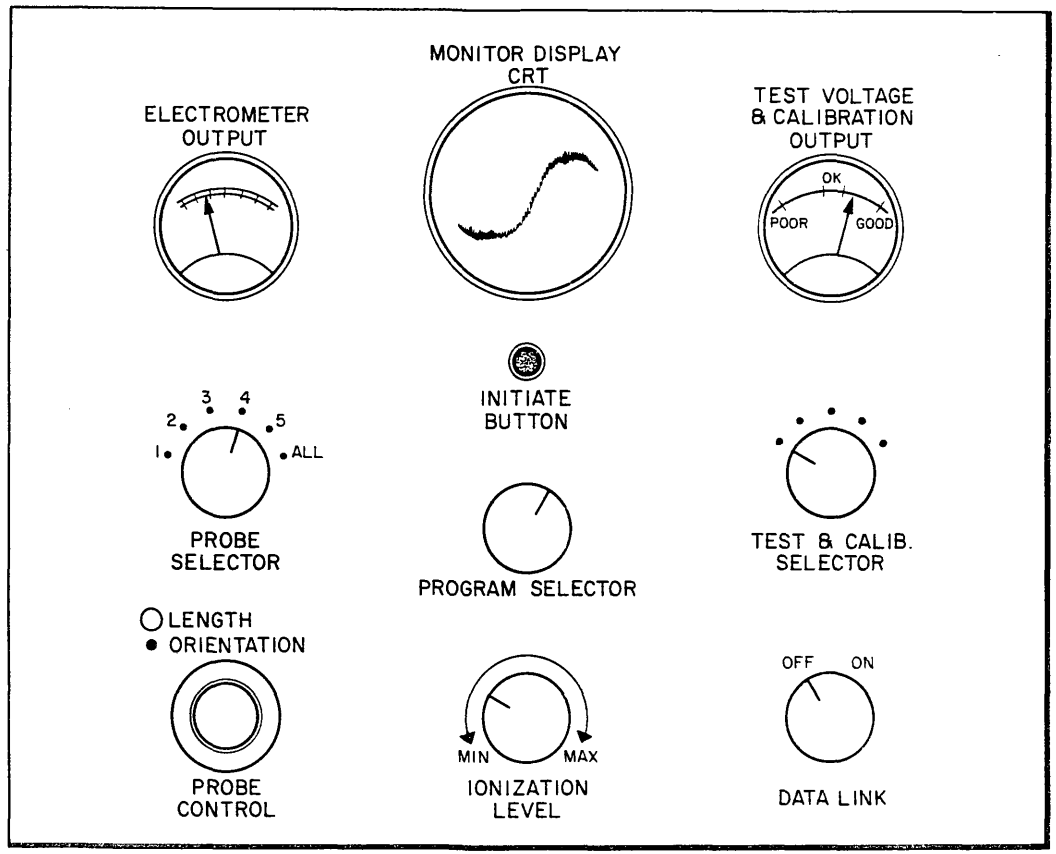
NATURE OF EXPERIMENT

1. Study Plasma Environment
2. Evaluate Properties of the Plasma
3. Determine Effect of the Plasma on Electromagnetic Wave Propagation

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

-- Astronaut's Function --
Tasks to be performed

1. Selects program and initiates measurements.

   Selected program automatically establishes the following:

   (a) Sets probe routine for length and angle
   (b) Sets monitoring level
   (c) Test and calibration
   (d) Makes measurements
   (e) Encodes and stores data

2. Inspect resultant measurements.

3. If data appears satisfactory initiate transmit to ground on given command.

4. Repeat above at stated intervals.

5. Modify program as instructed on command.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

PROGRAM PLAN

I PROBE CONFIGURATION

A. Langmuir Type (guarded and unguarded)
B. Faraday cup collector

II BOOM MECHANISM

A. Extensor means (deHaviland, telescoping, erectable)
B. Control (manual, motor driven)
C. Probe attitude control
D. Boom and probe status indicators

III ELECTROMETERS AND AMPLIFIERS

A. Range of input variables
B. Scaling of outputs
C. Time constant analysis of internal and external (plasma) transients
D. Effects of photo-ionization on data levels

IV PROBE ELECTRICAL CONTROL

A. Programmed sweep or step voltage range and rate
B. Probe system calibration techniques

V DATA ENCODING STORAGE AND TRANSMISSION

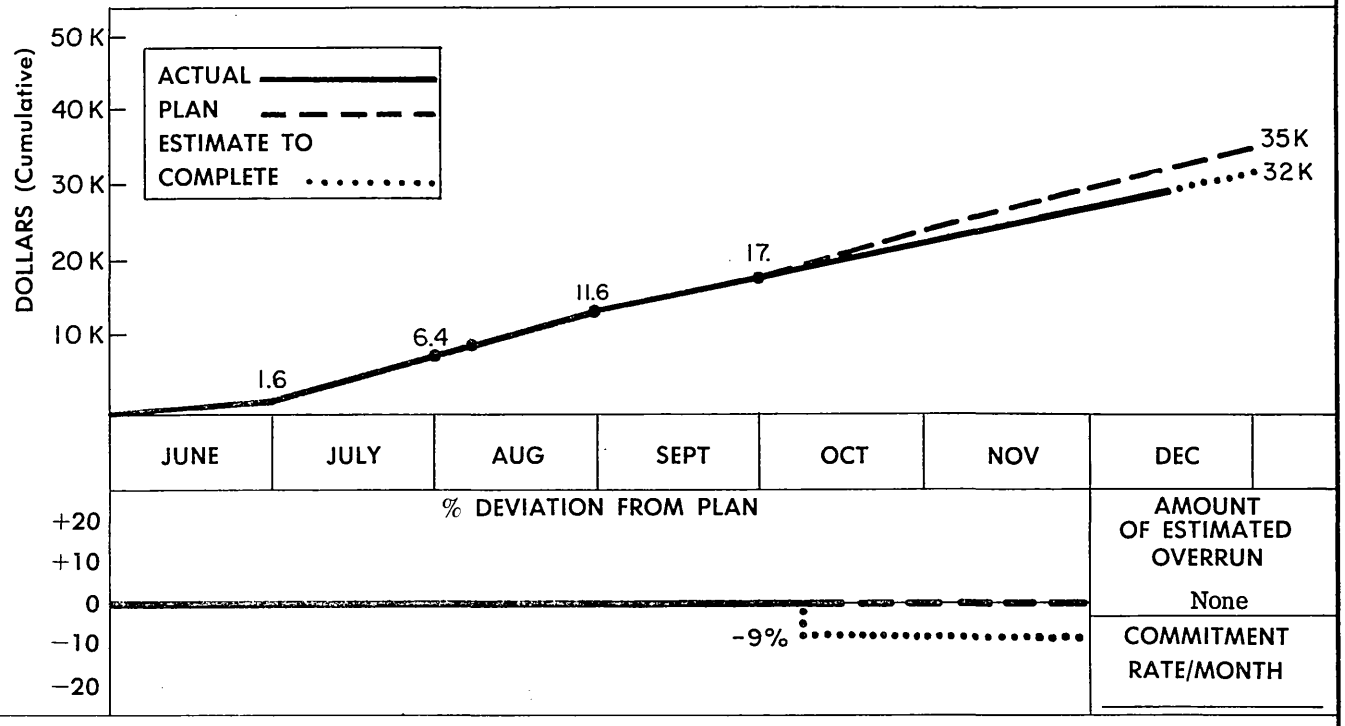
A. Standards
B. Multiplexing
C. Recording and storage medium

VI POWER SUPPLIES

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

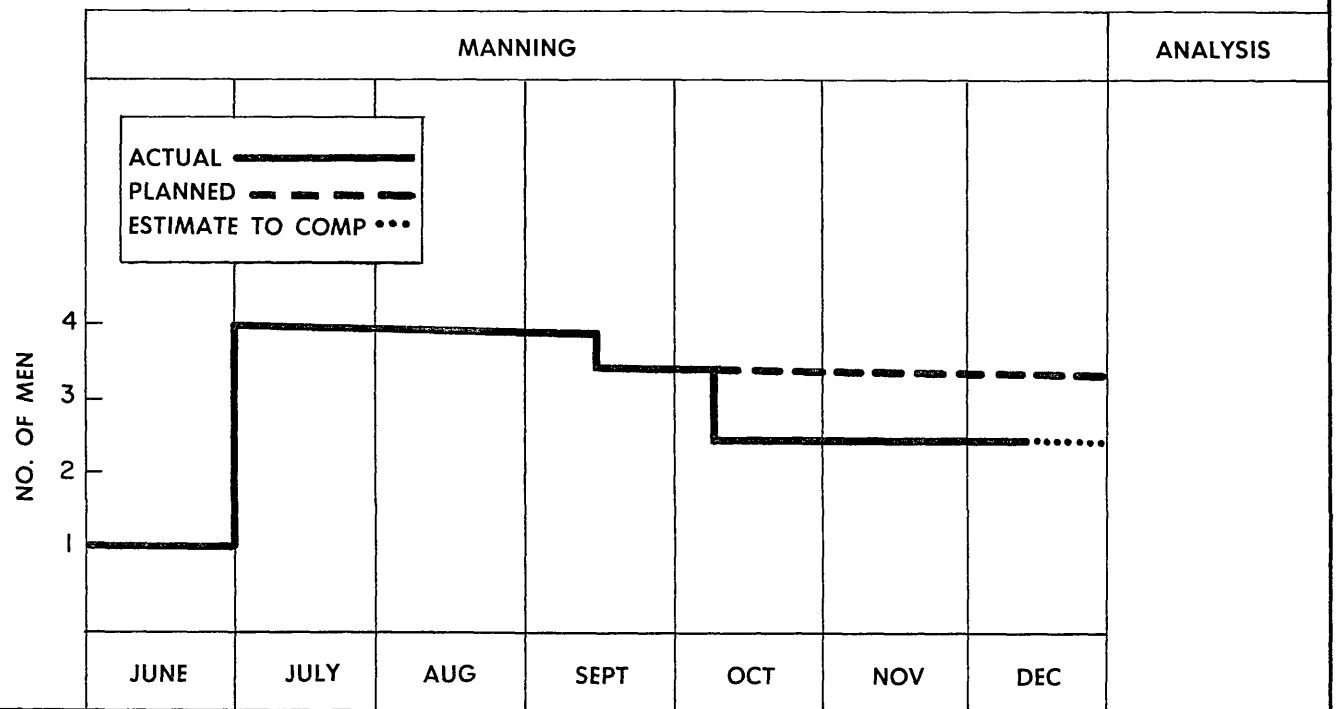
FUNDING PLAN SUMMARY REPORT
Commitments



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

MANPOWER PLAN REPORT



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
1. Definition of Experiment									
2. Preliminary Analysis									
3. Vehicle Requirements and Interfaces									
4. Equipment Description									
5. Program Plan									
Reports									
Program Reviews									

Now +1 Month

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

Integration Factors

1. Commonality Problems
   - (a) Power supplies
   - (b) Time standard
   - (c) Data processing
     - Standards
       - Format
       - Word length
       - Data rate
     - Storage
   - (d) Data link
   - (e) Equipment interface
   - (f) Simultaneous use of astronaut for several experiments

2. Environmental Problems
   - (a) Accomodation for space needs and accessibility as affected by all on-board experiments
   - (b) Minimization and elimination of interference problems: space, electrical, magnetic, acoustic, optical

3. Common Data Requirements Related to All or Several Experiments
   - (a) Pressure
   - (b) Magnetometer
   - (c) X-Ray
   - (d) Vehicle attitude and position as functions of time

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

1. Experiments are required so that a knowledge of the environment about the MOL can be obtained and understood so as to provide information to be used in the design of electromagnetic equipment to be used aboard satellites.

2. Such experiments can be carried out in space where the proper plasma conditions exist on a sufficiently large vessel such as the MOL which typifies future-generation vehicles.

3. Simultaneity of experiments: VLF experiments will be conducted on the MOL. The MOL electron density and temperature experiment supports this experiment. It is desirable that both be performed simultaneously to achieve the maximum correlation of results. In this connection the electron density and temperature experiment would:

   (a) Determine basic information relative to formation of plasma sheath around large orbiting vehicles and study effects of supersonic flow.

   (b) Determine characteristics of unperturbed plasma as related to VLF propagation.

   (c) Determine electron density and potential distribution across the plasma sheath in order to relate the sheath characteristics to VLF and UHF antenna impedance characteristics.

   (d) Study effects of $V \times H$ emf's induced in the satellite vehicle structure and its relation to the plasma sheath.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

SPECIFIC SYSTEM PERFORMANCE GOALS

PROBE SYSTEM

- 5 Booms and assembly
- 5 Probe mechanism
- Probe status indicators
- Control mechanism
- Programming mechanism
- Probe sweep power supply

ELECTROMETERS AND AMPLIFIERS

TIMING DEVICE (CLOCK)

DIGITAL LOGIC AND CONTROL
Storage, including input/output for look bits/or bits

TAPE RECORDING STORAGE

MONITOR DISPLAY AND CONTROL PANEL

PRIME POWER CONVERSION AND REGULATION

ANCILLARY INTEGRATING INSTRUMENTATION
(PE cells, magnetometer, X-Ray, monitors, etc.)

DATA LINK INTERFACE

MISCELLANEOUS (Cable, clamps, etc.)

Total Weight - 138 lb

Total Volume - 3.5 cu ft

Power { 75 w (avg.) / 125 w (peak) }

STABILIZATION REQUIREMENTS
Attitude control to ±1°
Rate Control ±0.01° sec
Maneuver Rate - 360°/min (subject to analysis of plasma and instrumentation time constants)

ENVIRONMENTAL LIMITATIONS
Boom and probe sensors suitable for external environment
Measurement and control equipment to be operable and maintainable within pressurized cabin

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 10 August 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

EXHIBIT C.2

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

1. Experiments are required so that a knowledge of the environment about the MOL can be obtained and understood so as to provide information to be used in the design of electromagnetic equipment to be used aboard satellites.

2. Such experiments can be carried out in space where the proper plasma conditions exist on a sufficiently large vessel such as the MOL which typifies future-generation vehicles.

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   (a) Determine basic information relative to formation of plasma sheath around large orbiting vehicles and study effects of supersonic flow.

   (b) Determine characteristics of unperturbed plasma as related to VLF propagation.

   (c) Determine electron density and potential distribution across the plasma sheath in order to relate the sheath characteristics to VLF and UHF antenna impedance characteristics.

   (d) Study effects of $V \times H$ emf's induced in the satellite vehicle structure and its relation to the plasma sheath.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 18 September 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

STATUS SUMMARY REPORT

Experiment Progress is Proceeding as Planned

Current Effort is Directed Toward:

- Pre Phase I Final Documentation
  - Data Book
  - PTDP Inputs
  - Prerequisite Data Report
- Equipment Weight and Complexity Analysis
  - Reduction in Number of Probes
- MOL Interface and Environment
  - Consultation with Aerospace Corporation
  - Liaison with other Experiments
- Ionospheric Environment Studies

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
Preparation of Mission Analysis Summary					↑				
Preparation of PTDP Input Requirements					↑				
Preparation of PDP (Sec. 17 of PTDP)					↑				
Final Technical Document Report						↑			
RFP (Data Book) for Phase Ib						↑			
Prerequisite Data Report						↑			
Specifications						↑			
EXPERIMENT TASKS					O				
Definition of Experiment					O			*	Redistribution of effort
Experiment scope and application anal.				Ø	⊠				
Experiment data time-line analysis					O				
Define Experiments					O				
PRELIMINARY ANALYSIS					O				
Requirement Imposed by Experiment on:					O				
Astronaut			Ø						
Space Vehicle					O				
Ground Support Equipment					O				
Ground Support Personnel					O				
Training and Equipment Programs					O				

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
PRELIMINARY ANALYSIS (Con't)									
Define Functions of Astronaut in:					O				
Operation and control of sensors									
and displays			Ø						
Data evaluation, storage, and									
transmission					O				
Equipment maintenance			Ø						
Equipment checkout			Ø						
In-Flight Equipment Performance Specs.			Ø						
Probe sensors			Ø						
Control and display devices			Ø						
Data handling and processing			Ø						
Calibration and maintenance			Ø						
MOL VEHICLE REQUIREMENTS									
AND INTERFACES					O				
Vehicle attitude and rate control			Ø						
Weight, volume, mounting and geometry					O				
Input power sources					O				
Data handling, computing and telemetry			Ø						
Commonality of control and display			Ø						

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

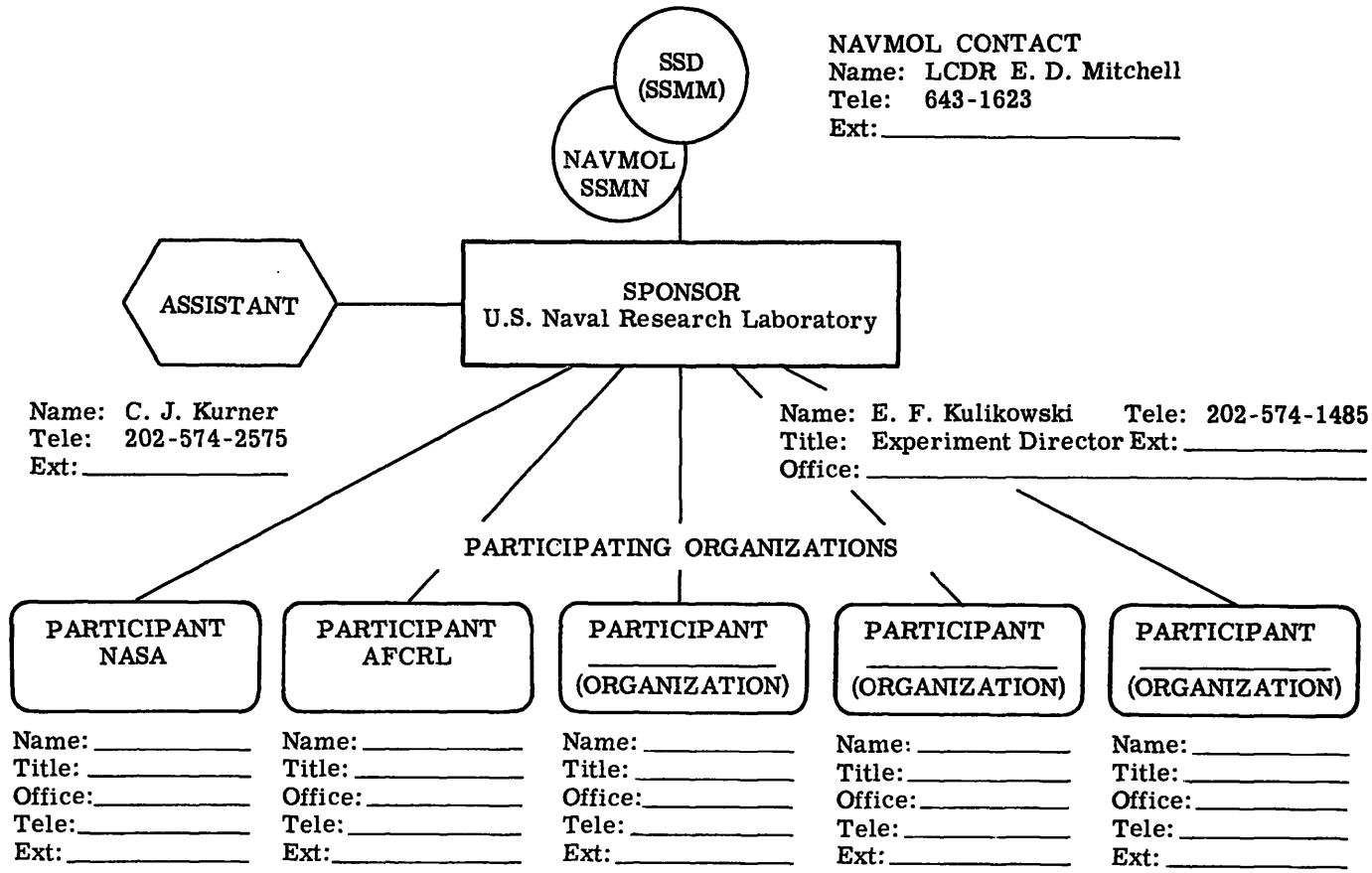
SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
MOL VEHICLE REQUIREMENTS									
AND INTERFACES (Con't)									
Heat Dissipation and Shielding									
Inter-experiment interfaces					O				
S-1					O				
S-22					O				
EQUIPMENT DESCRIPTION					O				
Preliminary in-flight equipment			Ø						
base-line design									
Preliminary ground support base-line			Ø						
design									
Cost/effectiveness and trade-off analysis					O				
					O				
PROGRAM PLANNING						⊗		*	Rescheduled
Phase I					O				
Pre-Phase II						⊗		*	Rescheduled
Phase II						⊗		*	Rescheduled
					O				

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

EXPERIMENT MANAGEMENT ORGANIZATION



EXPERIMENT: S-23

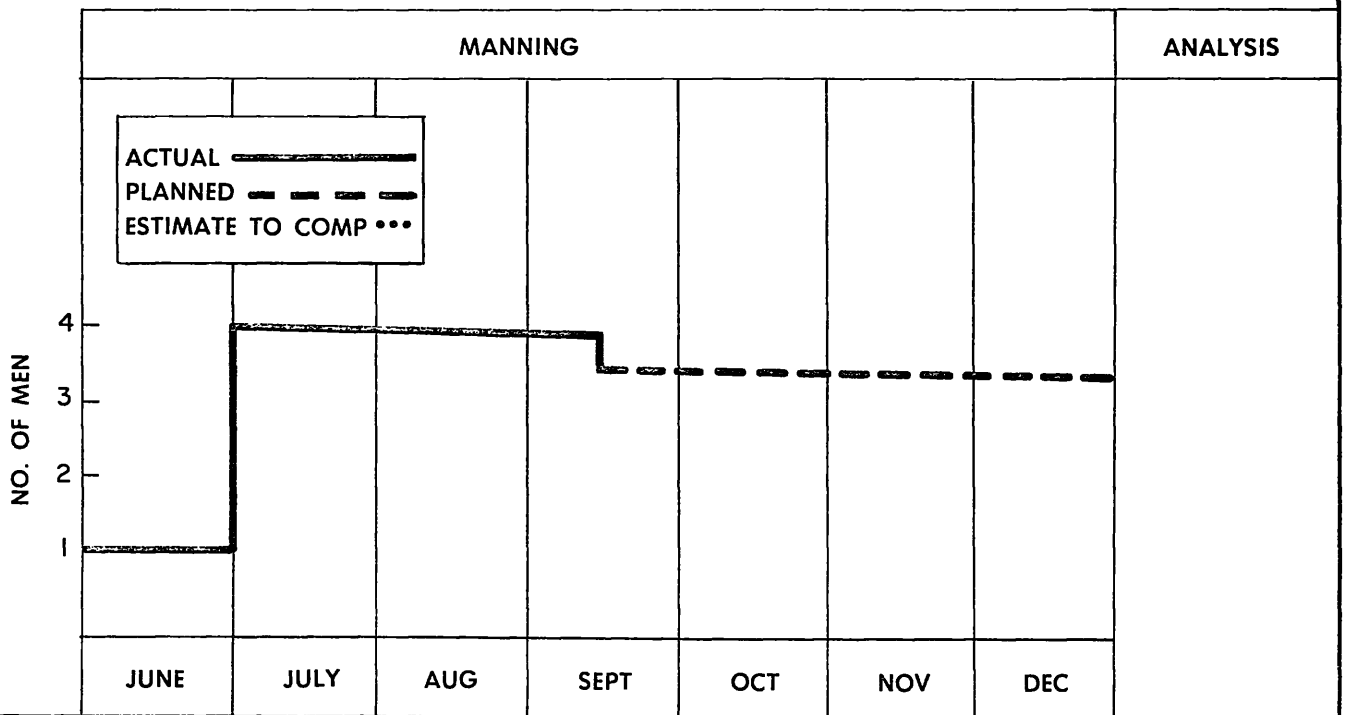
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964

AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

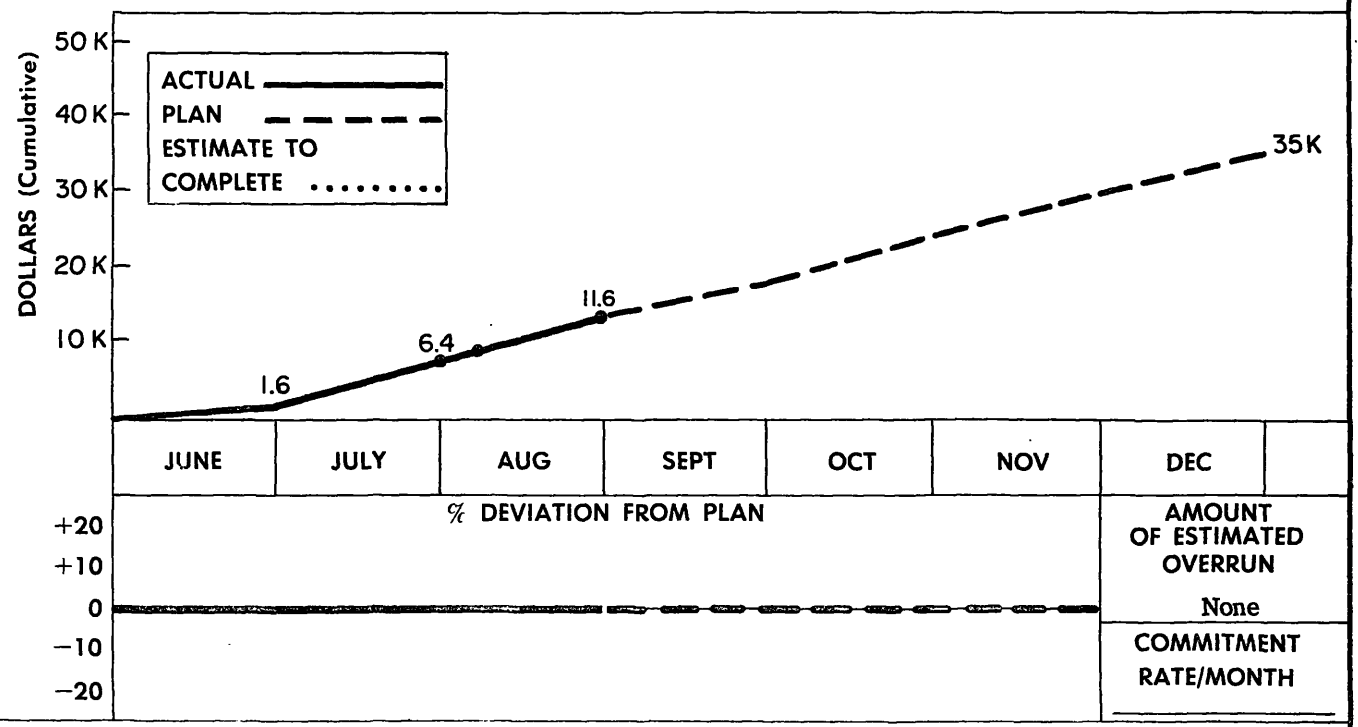
MANPOWER PLAN REPORT



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 18 Sept. 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

FUNDING PLAN SUMMARY REPORT
Commitments



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 18 Sept. 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

ACTION ITEM REPORT

ACTION	STATUS
Rough Draft of Aerospace Corp. Interoffice Correspondence dated 4 September 1964 Subj: Navy Review of MOL Experiment S-23 From: Rudolf X. Meyer "6. Action Item: It was agreed at the executive session that NRL should explore the possibility of obtaining space for this experiment on an unmanned satellite."	1. The Electron Density and Temperature Experiment (S-23) will test and evaluate man's skill in space through direction, perception, calibration, and action as related to the accomplishment of the experiment. 2. In deriving basic scientific information in the immediate vicinity of MOL, this experiment directly supports Experiments S-1 and S-22. 3. Experiment S-23 must be performed in a manned vehicle.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 20 September 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

EXHIBIT C.3

THE MOL ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

1. Experiments are required so that a knowledge of the environment about the MOL can be obtained and understood so as to provide information to be used in the design of electromagnetic equipment to be used aboard satellites.

2. Such experiments can be carried out in space where the proper plasma conditions exist on a sufficiently large vessel such as the MOL which typifies future-generation vehicles.

3. Simultaneity of experiments: VLF experiments will be conducted on the MOL. The MOL electron density and temperature experiment supports this experiment. It is desirable that both be performed simultaneously to achieve the maximum correlation of results. In this connection the electron density and temperature experiment would:

   (a) Determine basic information relative to formation of plasma sheath around large orbiting vehicles and study effects of supersonic flow.

   (b) Determine characteristics of unperturbed plasma as related to VLF propagation.

   (c) Determine electron density and potential distribution across the plasma sheath in order to relate the sheath characteristics to VLF and UHF antenna impedance characteristics.

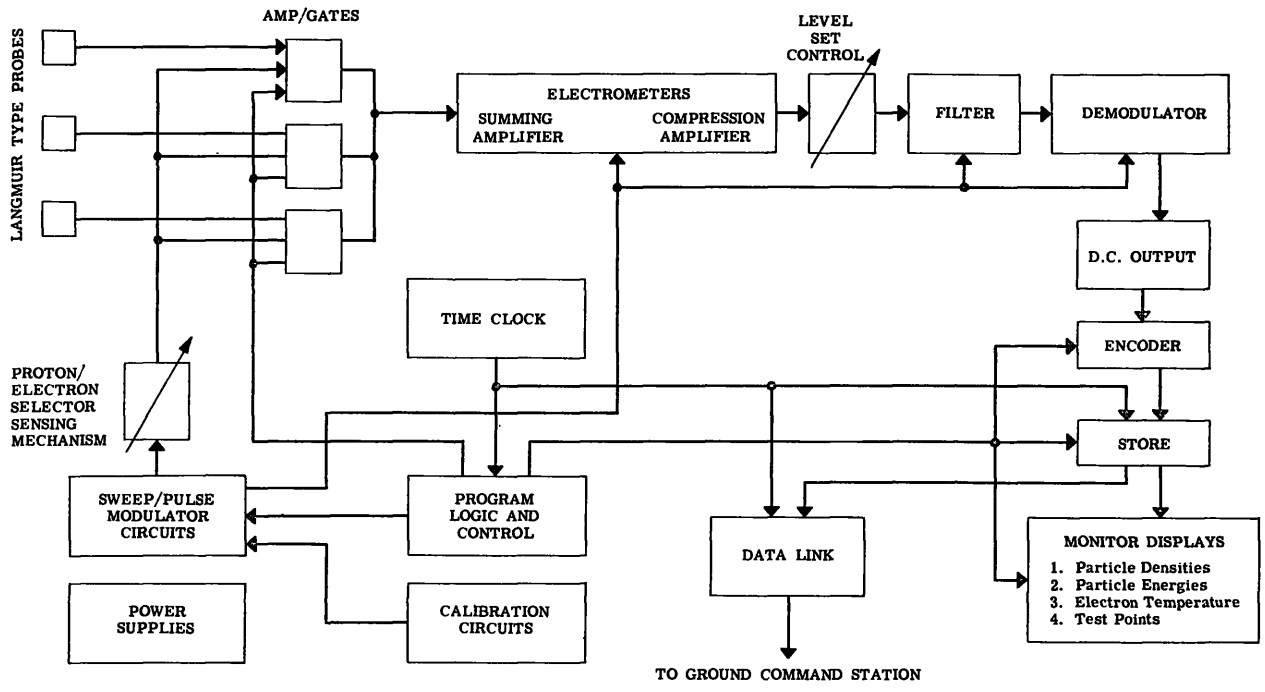
   (d) Study effects of $V \times H$ emf's induced in the satellite vehicle structure and its relation to the plasma sheath.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

THE MOL-ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

TENTATIVE BLOCK DIAGRAM



ANCILLARY EQUIPMENT:

1. Magnetometer
2. Temperature
3. Pressure

EXPERIMENT: S-23

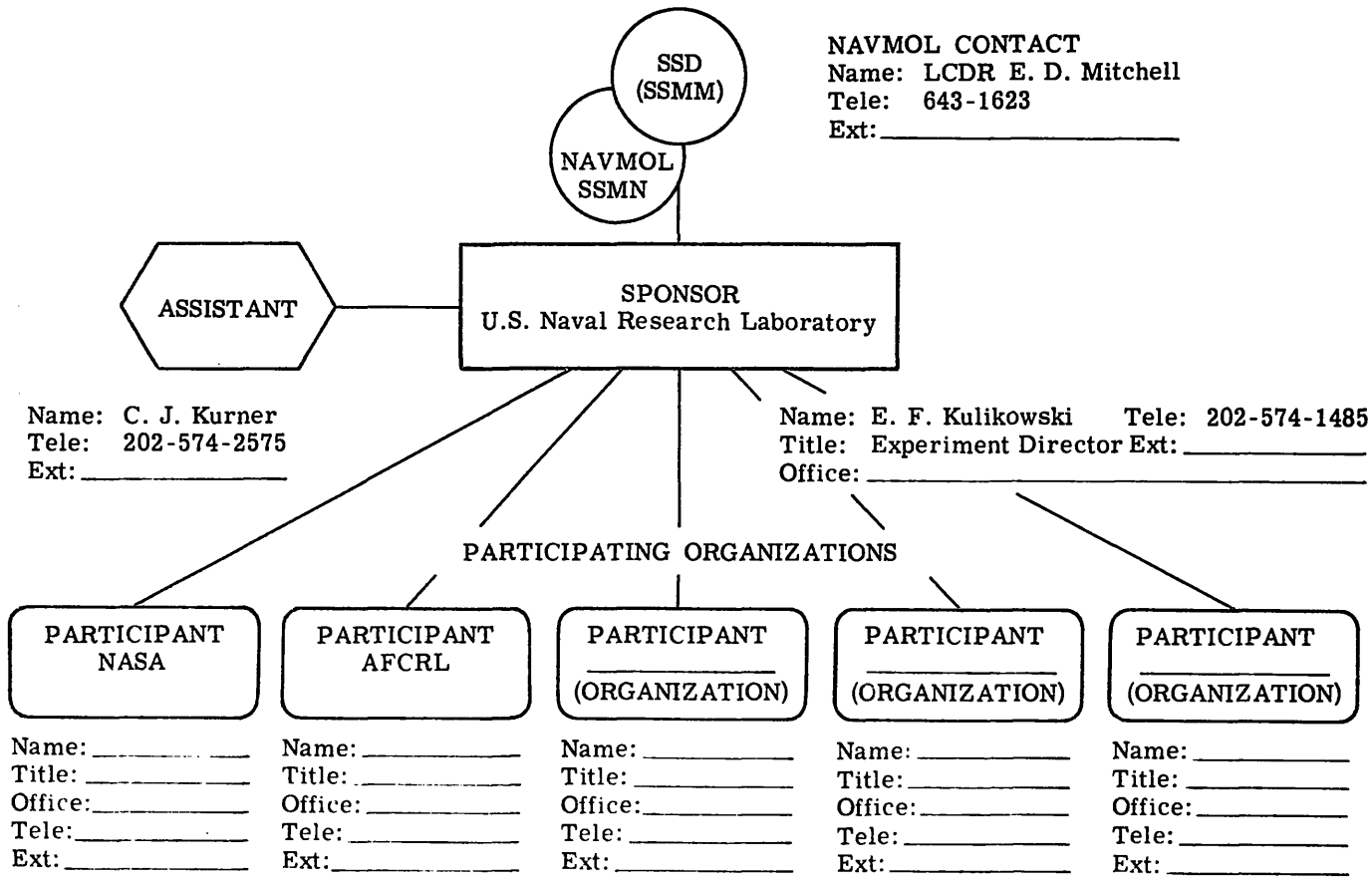
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964

AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

EXPERIMENT MANAGEMENT ORGANIZATION



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
Preparation of Mission Analysis Summary					↑				
Preparation of PTDP Input Requirements					↑				
Preparation of PDP (Sec. 17 of PTDP)					↑				
Final Technical Document Report						↑			
RFP (Data Book) for Phase Ib						↑			
Prerequisite Data Report						↑			
Specifications						↑			
EXPERIMENT TASKS	■	■	■	■	Ø				
Definition of Experiment	■	■	■	■	Ø				
Experiment scope and application anal.	■	■	■	Ø					
Experiment data time-line analysis	■	■	■	■	Ø				
Define Experiments	■	■	■	■	Ø				
PRELIMINARY ANALYSIS	■	■	■	■	Ø				
Requirement Imposed by Experiment on:	■	■	■	■	Ø				
Astronaut	■	■	Ø						
Space Vehicle	■	■	■	■	Ø				
Ground Support Equipment	■	■	■	■	Ø				
Ground Support Personnel	■	■	■	■	Ø				
Training and Equipment Programs	■	■	■	■	Ø				

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
PRELIMINARY ANALYSIS (Con't)									
Define Functions of Astronaut in:					Ø				
Operation and control of sensors									
and displays			Ø						
Data evaluation, storage, and									
transmission					Ø				
Equipment maintenance			Ø						
Equipment checkout			Ø						
In-Flight Equipment Performance Specs.			Ø						
Probe sensors			Ø						
Control and display devices			Ø						
Data handling and processing			Ø						
Calibration and maintenance			Ø						
MOL VEHICLE REQUIREMENTS									
AND INTERFACES					Ø				
Vehicle attitude and rate control			Ø						
Weight, volume, mounting and geometry					Ø				
Input power sources					Ø				
Data handling, computing and telemetry			Ø						
Commonality of control and display			Ø						

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

SCHEDULE REPORT

MILESTONE – TASK	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	Change	ANALYSIS
MOL VEHICLE REQUIREMENTS									
AND INTERFACES (Con't)									
Heat Dissipation and Shielding					Ø				
Inter-experiment interfaces					Ø				
S-1					Ø				
S-22					Ø				
EQUIPMENT DESCRIPTION					Ø				
Preliminary in-flight equipment			Ø						
base-line design									
Preliminary ground support base-line			Ø						
design									
Cost/effectiveness and trade-off analysis					Ø				
PROGRAM PLANNING					Ø				
Phase I					Ø				
Pre-Phase II					Ø				
Phase II					Ø				

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

MOL PROGRAM SCHEDULE

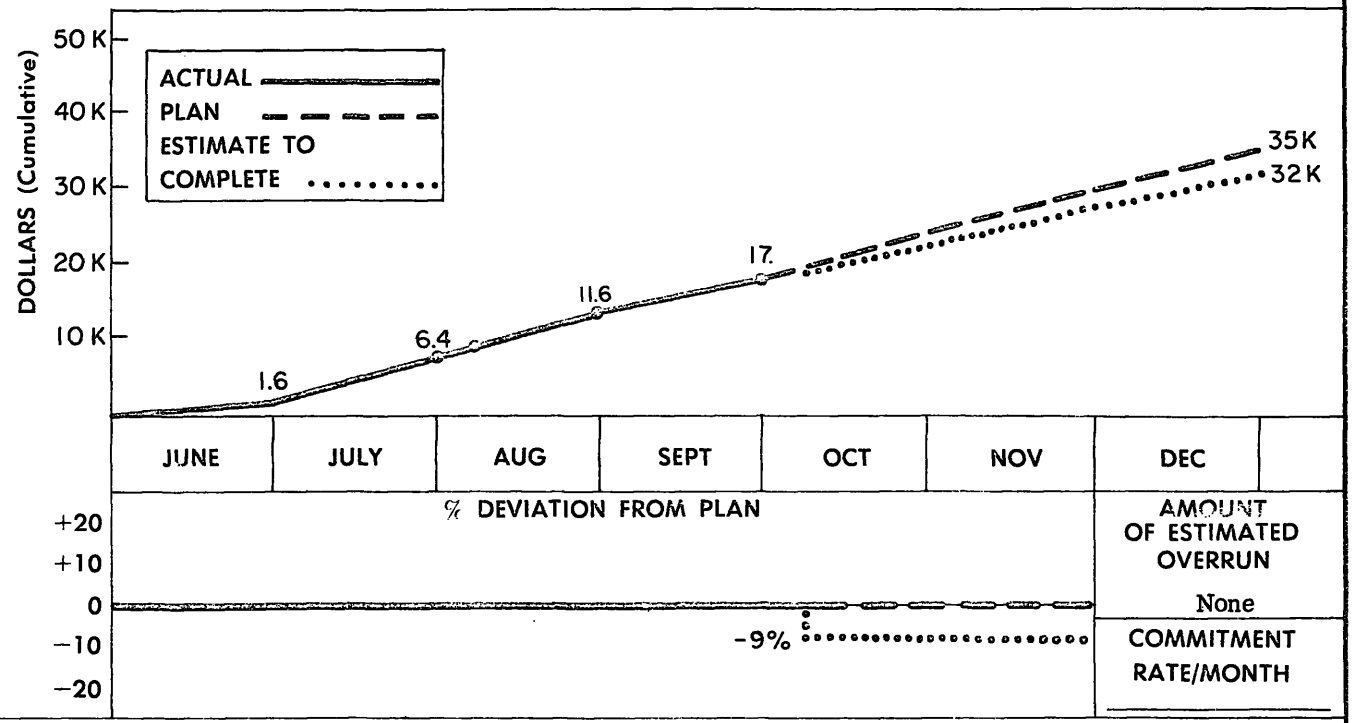
MILESTONES	1964	1965
Phase I a System Definition Directive Phase I Contract Award		
Phase I b Proposed System Package Plan		
TASKS		
Definition of Experiment		
Specifications		
Design		
Test Model Procurement		
Test and Evaluation		
Design Modifications		
Vehicle Configuration		
Equipment Form Factor		
Power Systems		
Data Handling		
Control and Display		
Interexperiment Commonalities		

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

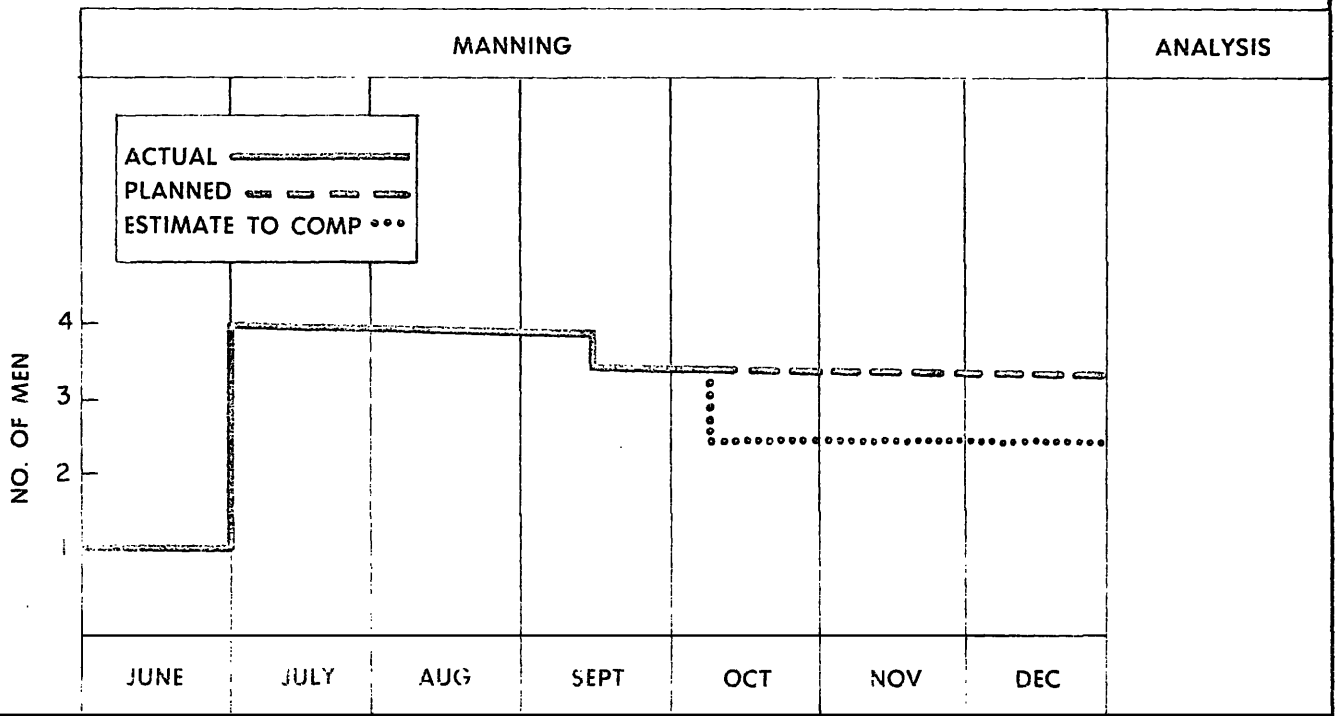
FUNDING PLAN SUMMARY REPORT
Commitments



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

MANPOWER PLAN REPORT



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

ACTION ITEM REPORT

ACTION	STATUS
Rough Draft of Aerospace Corp. Interoffice Correspondence dated 4 September 1964 Subj: Navy Review of MOL Experiment S-23 From: Rudolf X. Meyer "6. Action Item: It was agreed at the executive session that NRL should explore the possibility of obtaining space for this experiment on an unmanned satellite."	1. The Electron Density and Temperature Experiment (S-23) will test and evaluate man's skill in space through direction, perception, calibration, and action as related to the accomplishment of the experiment. 2. In deriving basic scientific information in the immediate vicinity of MOL, this experiment directly supports Experiments S-1 and S-22. 3. Experiment S-23 must be performed in a manned vehicle.

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

STATUS SUMMARY REPORT

Experiment Progress is Proceeding as Planned

Recent Effort Has Resulted in:

- Pre Phase I Final Documentation
  - Data Book
  - PTDP Inputs
  - Prerequisite Data Report
- Equipment Weight and Complexity Analysis
  - Reduction in Number of Probes
- MOL Interface and Environment
  - Consultation with Aerospace Corporation
  - Liaison with other Experiments
- Ionospheric Environment Studies

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 16 October 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

EXHIBIT C.4

STATUS SUMMARY REPORT

Experiment effort is currently directed toward further detailing of:

Equipment Definition

- Probe Configuration
- Boom Mechanical Assembly
- Electrometer Amplifiers
- Control and Display Devices

Interface Problems

- On-Board Data Handling and Usage
  (Memorandum to Aerospace Corporation via NAVMOL)
- Inter-Experiment Commonalities

Plasma Physics

- Ionospheric Environment
- Near-Vehicle Ion Sheath

Documentation

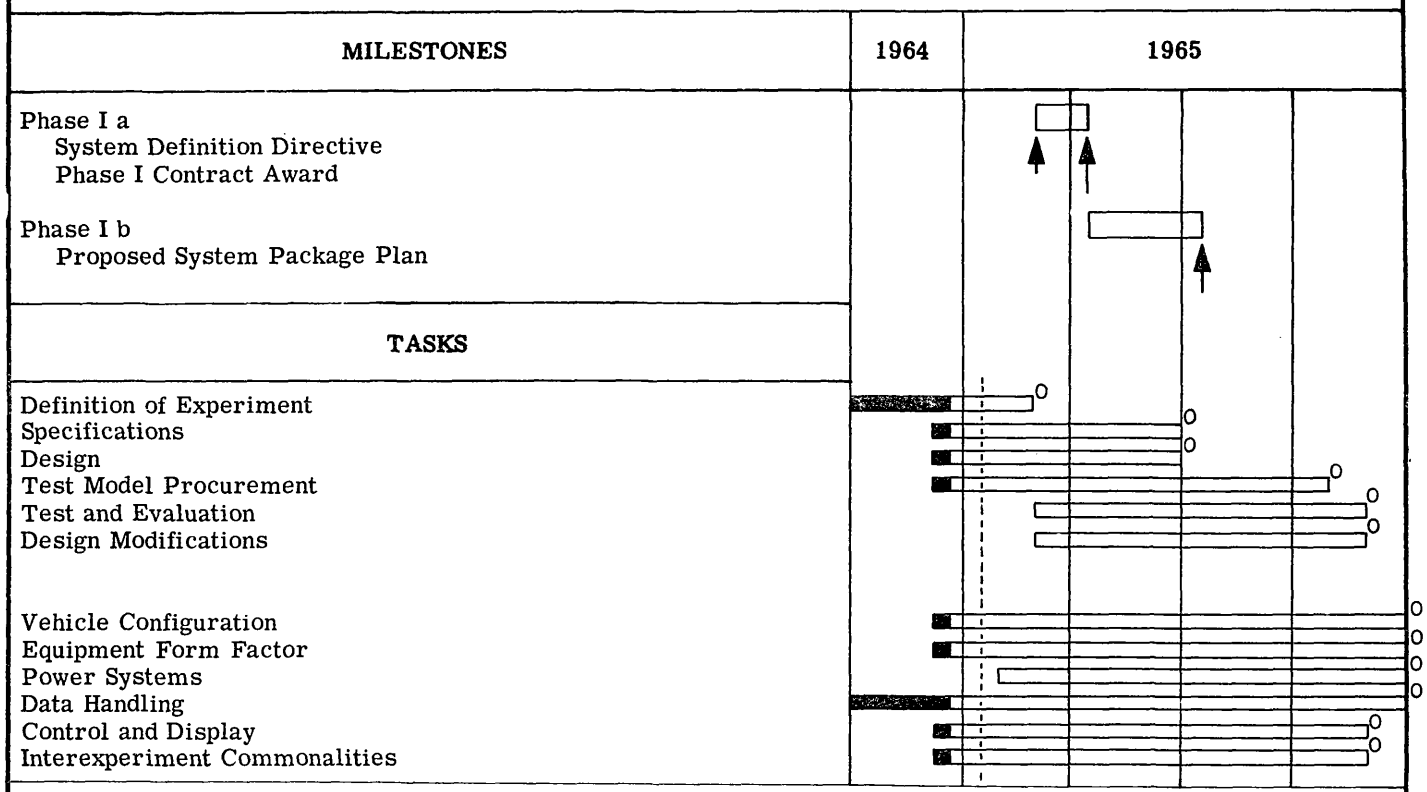
- Updating of Experiment Data Book
- Familiarization with PDP Requirements

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 15 December 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

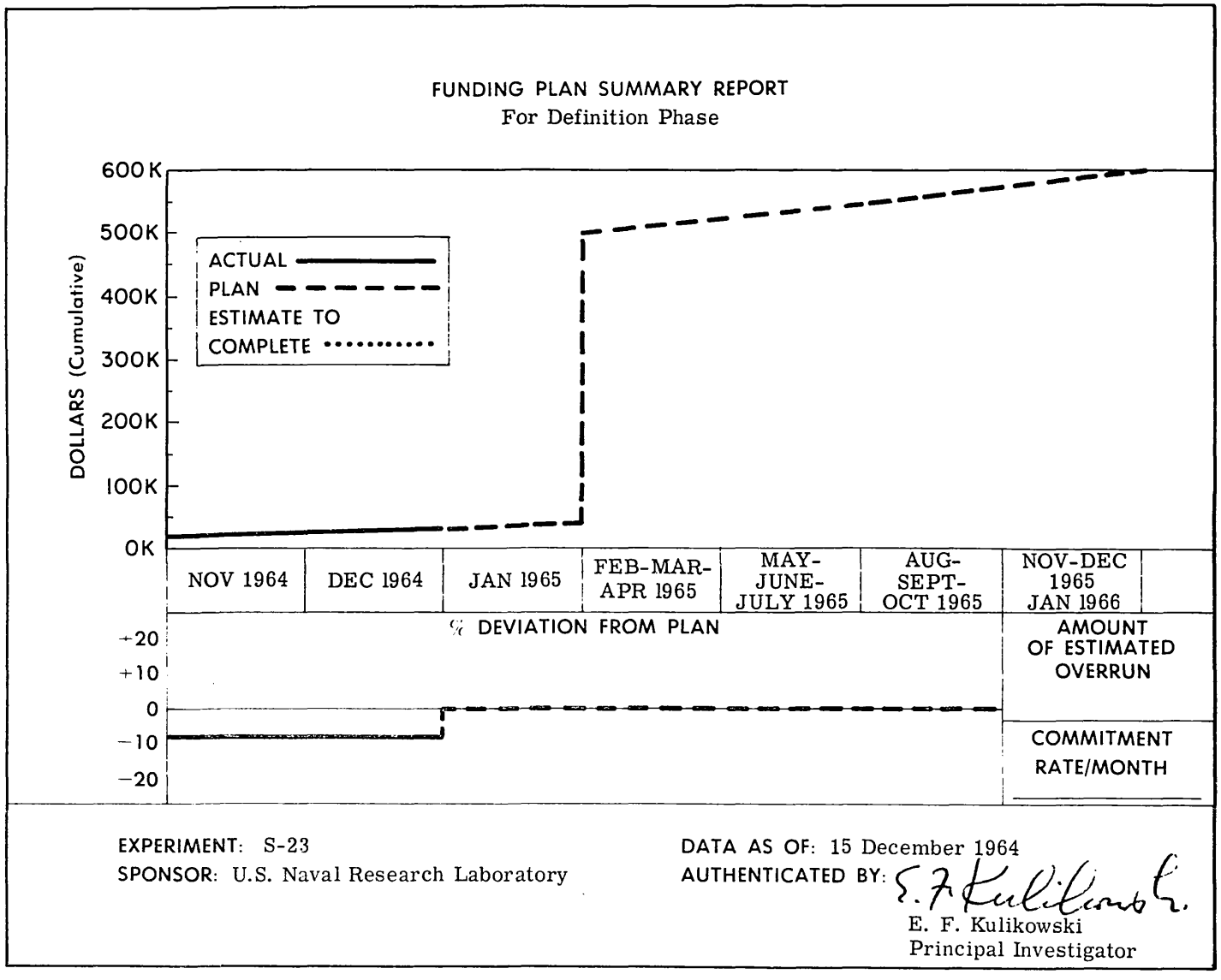
MOL PROGRAM SCHEDULE



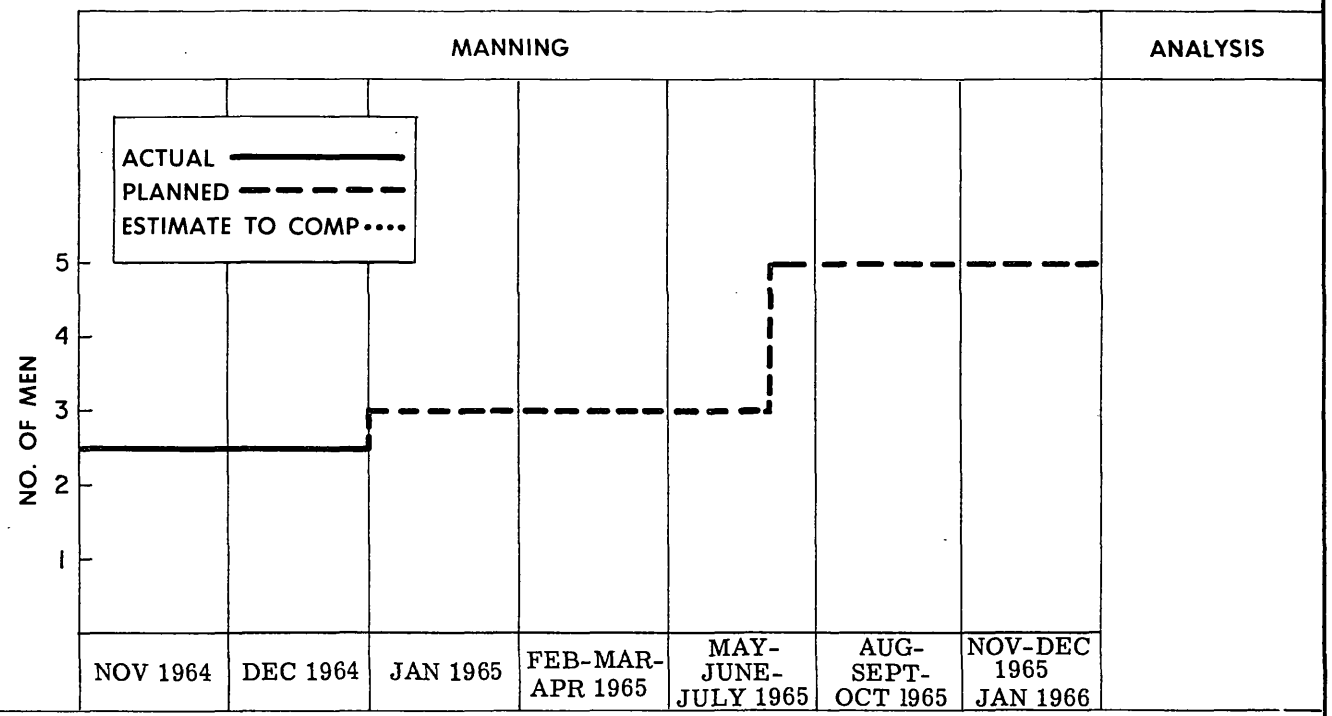
EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 15 December 1964
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

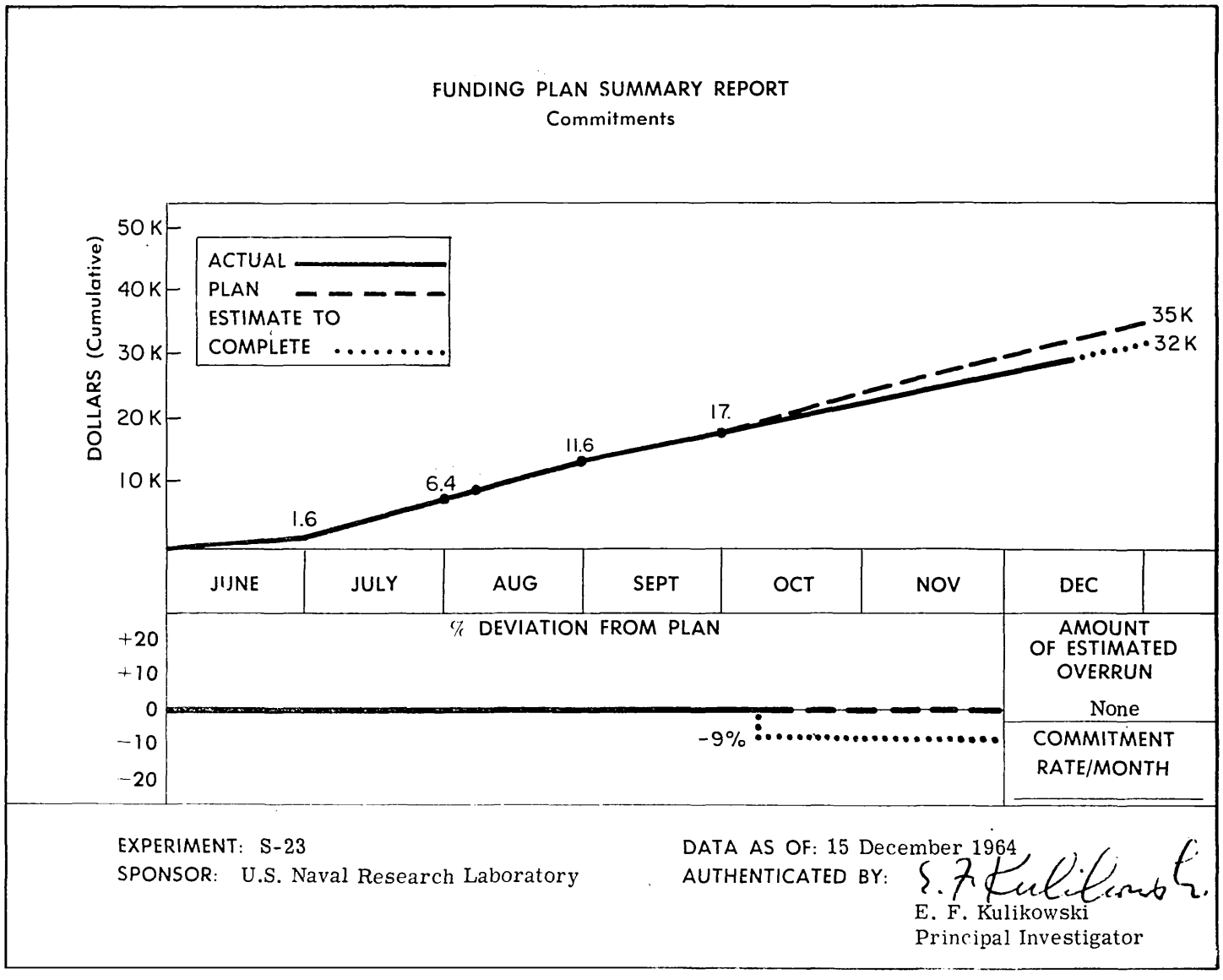

FUNDING PLAN SUMMARY REPORT
For Definition Phase
DOLLARS (Cumulative)
600K
500K
400K
300K
200K
100K
0K
ACTUAL
PLAN
ESTIMATE TO COMPLETE
NOV 1964
DEC 1964
JAN 1965
FEB-MAR-APR 1965
MAY-JUNE-JULY 1965
AUG-SEPT-OCT 1965
NOV-DEC 1965 JAN 1966
% DEVIATION FROM PLAN
+20
+10
0
−10
−20
AMOUNT OF ESTIMATED OVERRUN
COMMITMENT RATE/MONTH
EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory
DATA AS OF: 15 December 1964
AUTHENTICATED BY:
E. F. Kulikowski
Principal Investigator

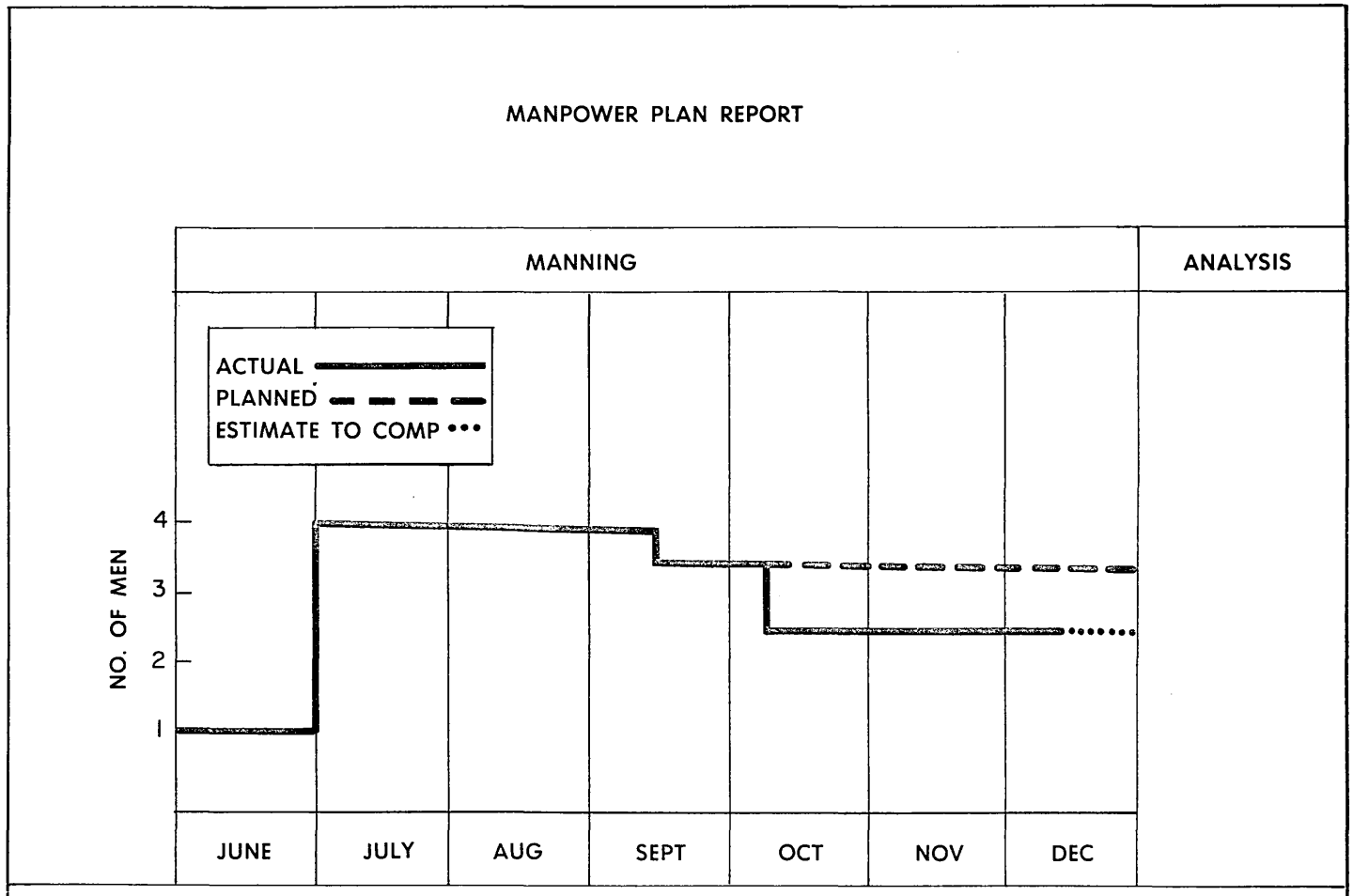
MANPOWER PLAN REPORT
For Definition Phase



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 15 December 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator


FUNDING PLAN SUMMARY REPORT
Commitments
DOLLARS (Cumulative)
50 K
40 K
30 K
20 K
10 K
ACTUAL
PLAN
ESTIMATE TO COMPLETE
1.6
6.4
11.6
17.
35K
32K
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
% DEVIATION FROM PLAN
+20
+10
0
−10
−20
-9%
AMOUNT OF ESTIMATED OVERRUN
None
COMMITMENT RATE/MONTH
EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory
DATA AS OF: 15 December 1964
AUTHENTICATED BY:
E. F. Kulikowski
Principal Investigator



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 15 December 1964
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

EXHIBIT C.5

STATUS SUMMARY REPORT

Current experiment effort is directed toward:

Experiment Definition

Investigation of Probe Techniques (Resonance Probes)
Preliminary Trade-Off Study of Representative Probe-Boom Configurations
Experiment Parameter Limit Determination

Interface Problems

Continuing Study of On-Board Data Conditioning, Storage and Transmission Requirements
Review of P-Experiments to Determine Availability of Ancillary Data

Plasma Physics

Vehicle Sheath Effects (Photoelectric, Vehicle Configuration, and VXB Effects)
Review of Ionospheric Small Scale Inhomogeneities

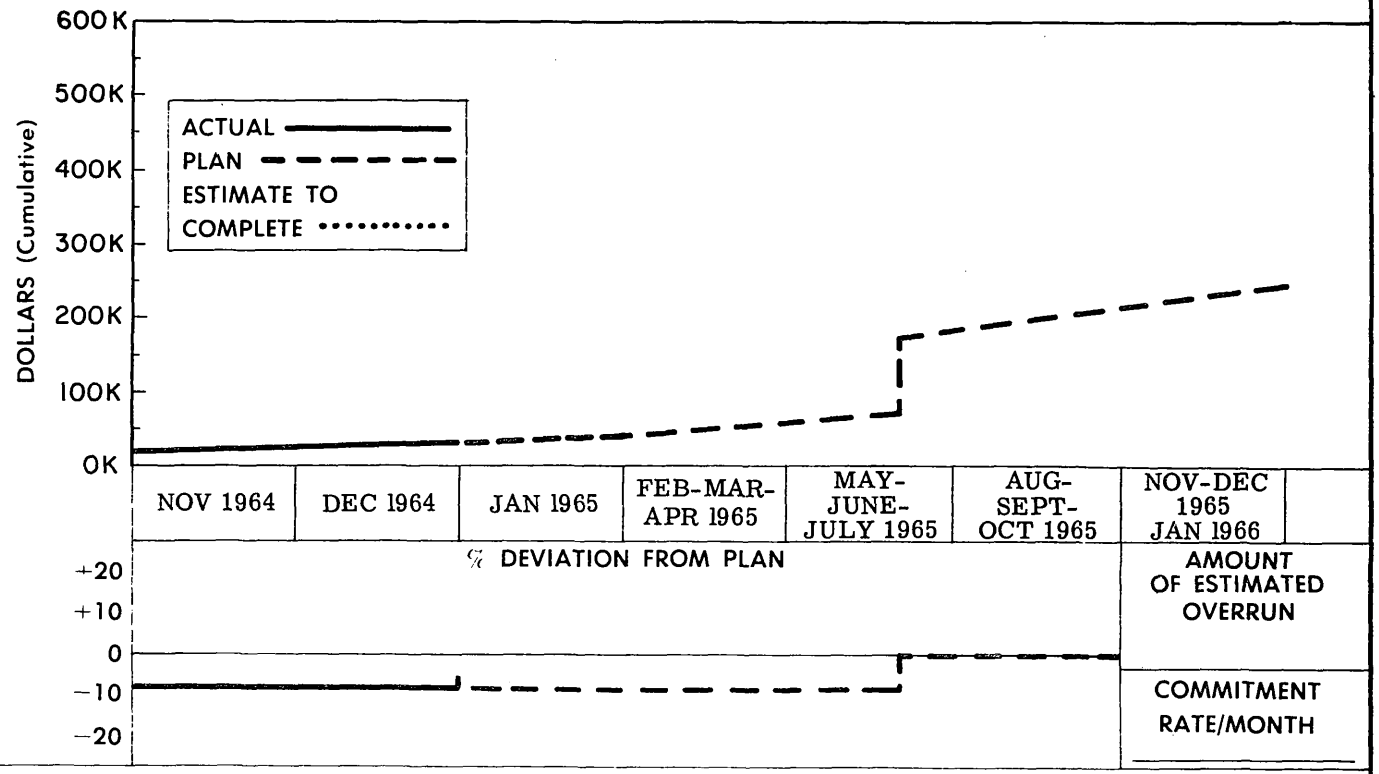
Documentation

Art Work and Write-Up for MOL Navy Brochure

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 1 January 1965
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

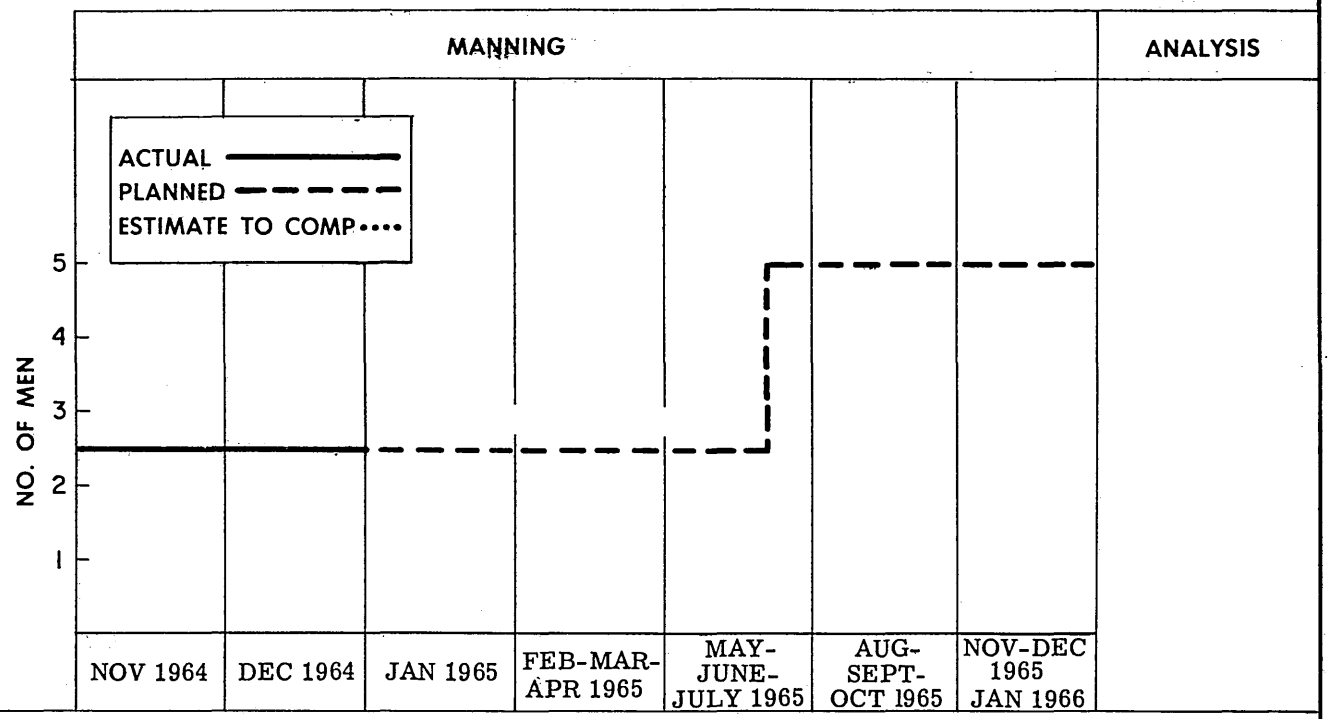
FUNDING PLAN SUMMARY REPORT
For Definition Phase



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 1 January 1965
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

MANPOWER PLAN REPORT
For Definition Phase



EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 1 January 1965
AUTHENTICATED BY: E. F. Kulikowski
E. F. Kulikowski
Principal Investigator

MOL PROGRAM SCHEDULE

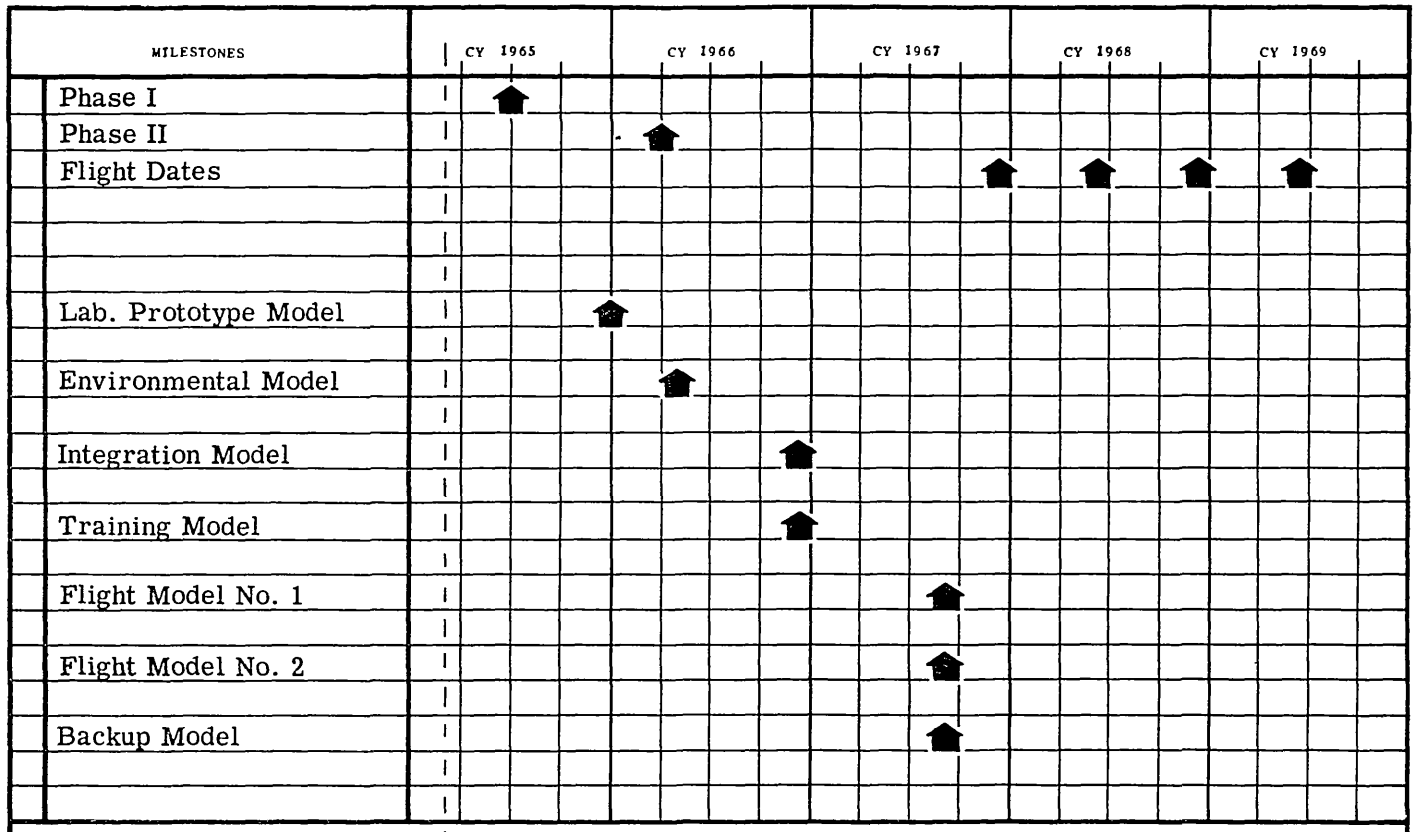
MILESTONES	1964	1965
Phase I a System Definition Directive Phase I Contract Award		
Phase I b Proposed System Package Plan		
TASKS		
Definition of Experiment		
Specifications		
Design		
Test Model Procurement		
Test and Evaluation		
Design Modifications		
Vehicle Configuration		
Equipment Form Factor		
Power Systems		
Data Handling		
Control and Display		
Interexperiment Commonalities		

EXPERIMENT: S-23
SPONSOR: U.S. Naval Research Laboratory

DATA AS OF: 1 January 1965
AUTHENTICATED BY: E. F. Kulikowski

E. F. Kulikowski
Principal Investigator

EXHIBIT C.6

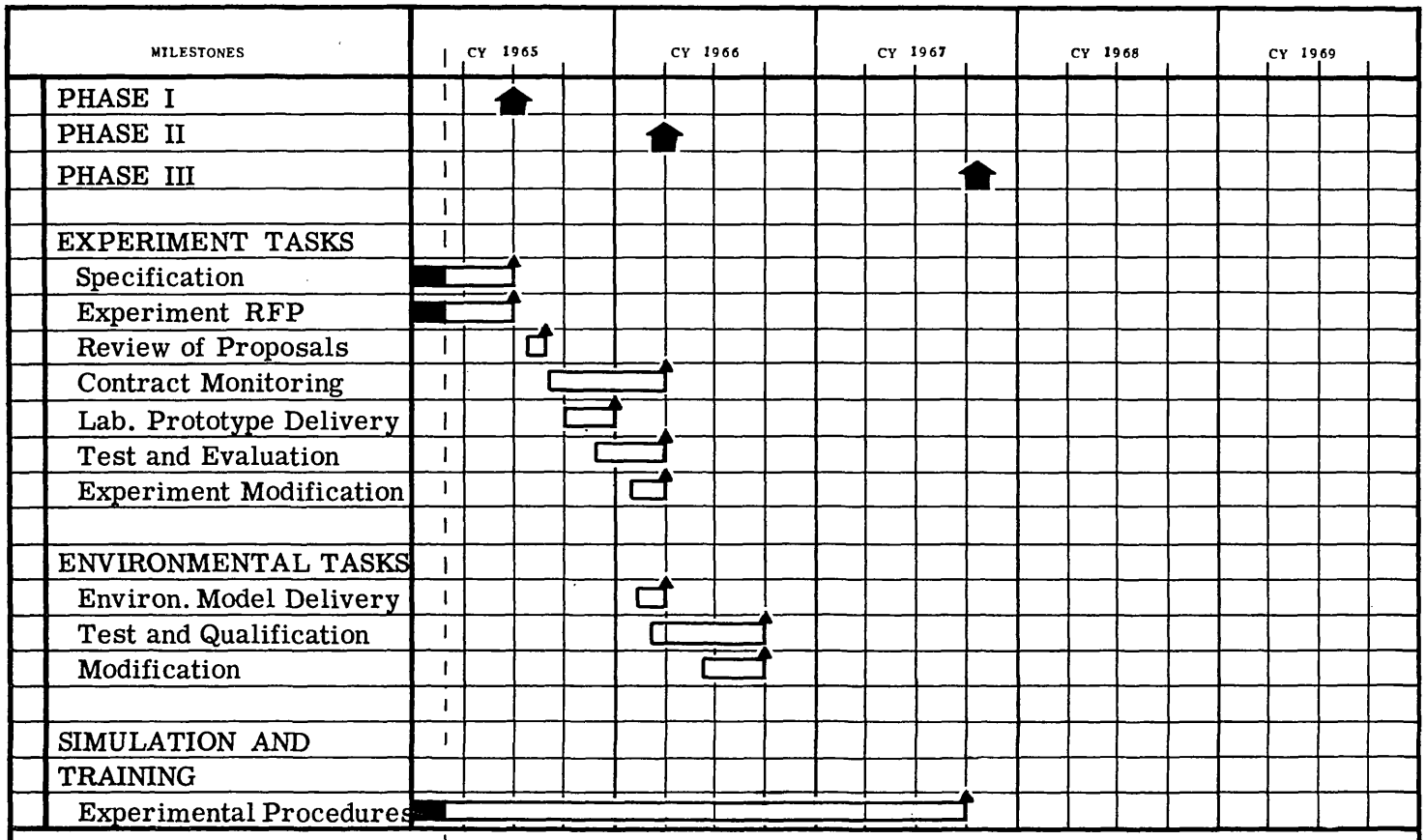


NOTES:
1. Milestones for equipment models were derived for a November 67 flight date.

PREPARED BY: C. J. Kurner
APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM
Key Milestone Schedule
S-23 Experiment
2 LEVEL
SCH'D NO. 2-S23-1

ORIGINAL SCHEDULE APPROVAL ____ DATE
LAST SCHEDULE CHANGE ____ DATE
STATUS AS OF 28 Feb 1965 DATE
PAGE 1 OF 3 PAGES



NOTES:

PREPARED BY: C. J. Kurner

APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Milestone Schedule
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-1

ORIGINAL SCHEDULE APPROVAL _____ DATE

LAST SCHEDULE CHANGE _____ DATE

STATUS AS OF 28 Feb 1965 DATE

PAGE 2 OF 3 PAGES

MILESTONES	CY 1965	CY 1966	CY 1967	CY 1968	CY 1969
Man-Machine Control Sys.					
INTERFACE TASKS					
Vehicle Configuration					
Equipment Form Factor					
Power Systems					
Data Handling					
Control and Display					
Interexp. Commonalities					
IN-FLIGHT SYS. TASKS					
Final Design					
Procurement					
Installation and Checkout					
GROUND SUPPORT					
SYSTEMS TASKS					
Equipment Requirements					
Data Collection					
Data Analysis					
Evaluation					

NOTES:

PREPARED BY: C. J. Kurner

APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Milestone Schedule
S-23 Experiment

2 LEVEL

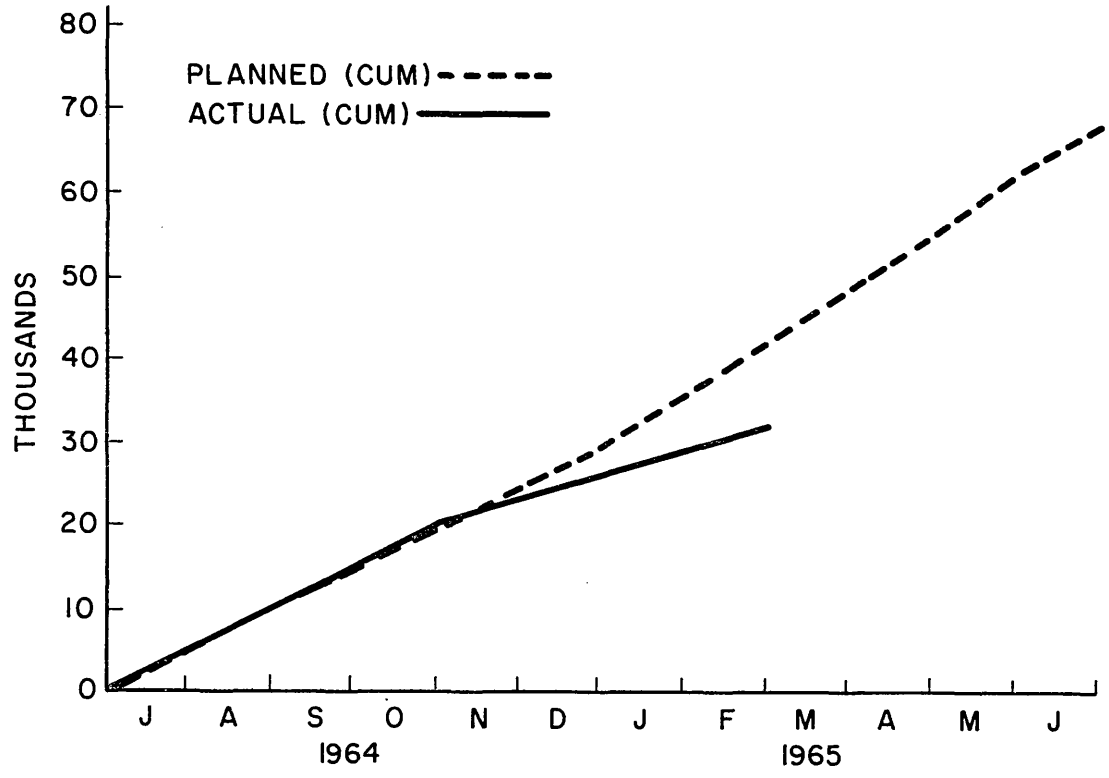
SCH'D NO. 2-S23-1

ORIGINAL SCHEDULE APPROVAL _____ DATE

LAST SCHEDULE CHANGE _____ DATE

STATUS AS OF 28 Feb 1965 DATE

PAGE 3 OF 3 PAGES



	J	A	S	O	N	D	J	F	M	A	M	J
PLANNED	5.0	10.0	15.0	20.0	24.5	29.0	35.3	41.7	48.1	54.7	61.6	68.2
ACTUAL	4.8	10.0	15.4	19.4	22.9	25.9	28.9	31.9				

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

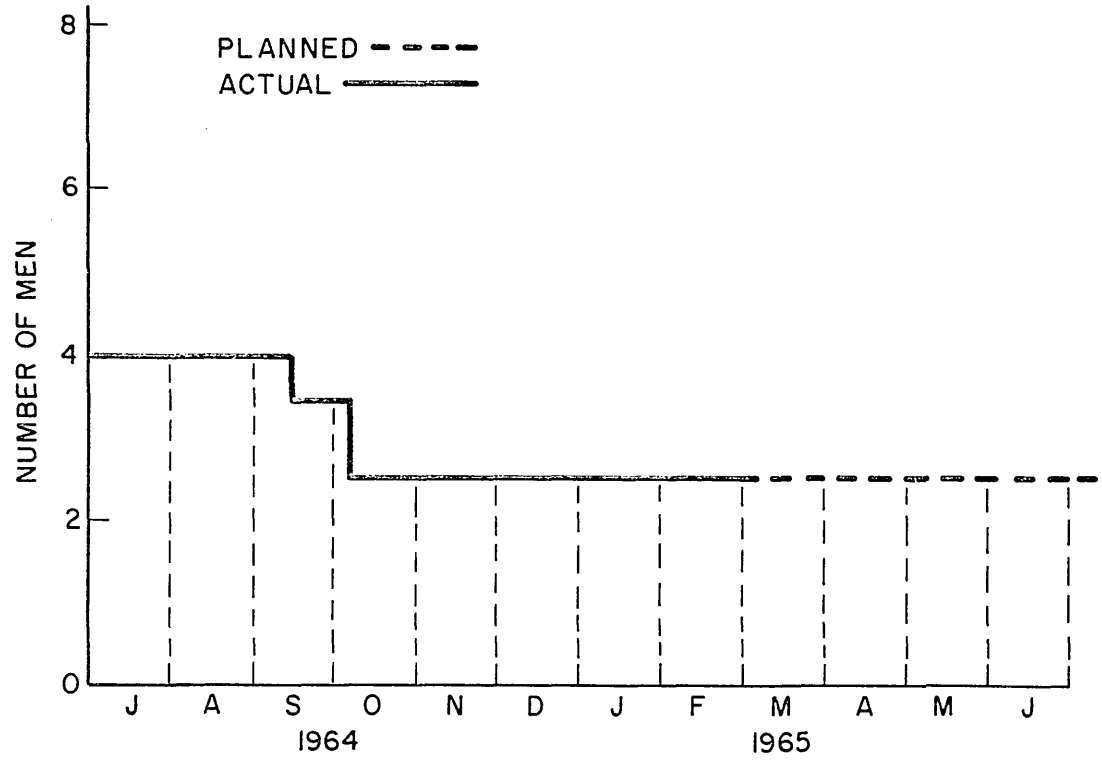
Total Expenditures
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-3

ORIGINAL SCHEDULE APPROVAL ____ DATE
LAST SCHEDULE CHANGE ____ DATE
STATUS AS OF 28 Feb 1965 DATE

PAGE 1 OF 1 PAGES



PLANNED	4.0	4.0	3.5	3.5	3.5	3.5	2.0	2.0	2.0	2.0	2.0	2.0
ACTUAL	4.0	4.0	3.5	2.5	2.5	2.5	2.5	2.5				

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

In House Civilian Manpower Level
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-4

ORIGINAL SCHEDULE APPROVAL ____ DATE
LAST SCHEDULE CHANGE ____ DATE
STATUS AS OF 28 Feb 1965 DATE

PAGE 1 OF 1 PAGES

CURRENT WEIGHT	(LB)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe-Boom Assembly(s)	40	0
Electrometers (3)	6	0
Program Logic Control & Store	20	0
Function Control & Displays	10	0
Power Control & Regulation	2	0
Data Link Interface	2	0
	80	Net Change 0

CURRENT VOLUME	(FT^3)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe Boom Assemblies (3)	1.0	0
Electronics	2.0	0
Displays	0.5	0
	3.5	Net Change 0

POWER DEMAND	(WATTS)	AMOUNT OF CHANGE SINCE LAST REPORT
Continuous	0	0
Standby	10	0
Average Operating (Peak)	75 (100)	0

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM
Weight, Volume, Power
S-23 Experiment
SCH'D NO. 2-S23-5
2 LEVEL

ORIGINAL SCHEDULE APPROVAL ____ DATE
LAST SCHEDULE CHANGE ____ DATE
STATUS AS OF 28 Feb 1965 DATE
PAGE 1 OF 1 PAGES

TECHNICAL HIGHLIGHTS

1. Develop Instrumentation for Laboratory Plasma Investigations

2. Continue Comparison Studies on Various Probe-Boom Configurations

3. Initiate State-of-the-Art Investigation of Vacuum Tube vs. Solid-State Electrometer Amplifiers

4. Refine Experiment Conduct Plan (Data Usage Profile)

5. Establish Parameter Limit Values

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM Technical Progress S-23 Experiment SCH'D NO. 2-S23-5	2 LEVEL ORIGINAL SCHEDULE APPROVAL ____ DATE LAST SCHEDULE CHANGE ____ DATE STATUS AS OF 28 February 65 DATE PAGE 1 OF 1 PAGES

OUTLINE FOR EXPERIMENT S-23
FEBRUARY 1965 PROGRAM REVIEW

5 FEB 1965

Amplification of Section 3.X. of PMP
Management or Implementation Plans for

1. Technical Design

a. Work leading to specification for each sub-system of experiment (e.g., probe, boom mechanism, program control, display, power conversion, data handling, and telemetry).

b. In-house effort on electrometer amplifiers and probe measurement techniques.

2. Contractor Effort (during Phase One)

a. Study, design and development of suitable probe-boom and erection mechanism.

b. Complementary electrometer development.

c. Effort toward weight, size, power conservation, reliability, and environmental constraints as per specifications.

3. Procurement (during Phase One)

a. One complete experimental model of the probe-boom-electrometer sub-system will be procured for laboratory test and evaluation (both electrical and mechanical).

4. Experiment Interface Control

a. In-house management as liaison between probe-boom contractor and vehicle contractor.

b. Direct liaison with data handling, recording and telemetry contractors for experiment data interfaces.

c. Liaison to effect satisfactory display configurations.

d. Liaison for efficient power usage.

e. Integration of ancillary data into experiment.

5. Equipment Test and Qualification

a. Performance and environmental spec part of contract.

b. Laboratory evaluation of experimental model to insure compliance and to revise hard spec (Phase II) where needed.

1. TECHNICAL DESIGN

Effort in this area will lead to a specification for an experimental model of the probe-boom-electrometer subsystem. This specification will suggest avenues of approach and will delineate performance limits and tolerances under conditions of temperature, vibration, and shock as specified for the MOL environment. Weight, size, and power usage limits will similarly be defined.

Specifications will also be prepared for each of the other subsystems of the experiment. Parameter values and performance limits will be assigned. These subsystems include the data conditioning package (scaling amplifiers, A/D converters, multiplexer as necessary), the probe voltage program control, the display configuration, and the power conversion and regulation package.

Continuing study of probe configurations and measurement techniques will lead to a specification for data reduction and analysis. This will include the utilization of ancillary information (X-ray radiometer data, magnetometer readings, etc.) where it is determined that this information may be available.

These specifications and studies will culminate in an RFP for the Phase One procurement of the previously mentioned experimental model probe-boom-electrometer configuration.

2. CONTRACTOR EFFORT

The contract awarded for the Phase One effort will consist of the design, development and fabrication of a probe-boom-electrometer subsystem in accordance with the specification contained in the RFP. Contractor effort will be reviewed periodically for compliance with the specification. Modification of the specification, if found necessary, will promptly be brought to the attention of the contractor. The contractor will be required to demonstrate compliance with the specification through test procedures which are deemed satisfactory to the experiment sponsor.

3. PROCUREMENT

The procurement of an experimental model of the probe-boom-electrometer sub-

system for laboratory test and evaluation under the contract described previously is considered to be the only major procurement during the Phase One period. However, procurement of time, using established facilities, to perform environment testing may be necessary.

4. EXPERIMENT INTERFACE CONTROL

Management control of the experiment interfaces will be the responsibility of the sponsor. Liaison will be maintained by the sponsor between the vehicle contractor and the experiment probe-boom contractor. Direct liaison on data and telemetry systems, display configurations, power systems, and ancillary data will be maintained.

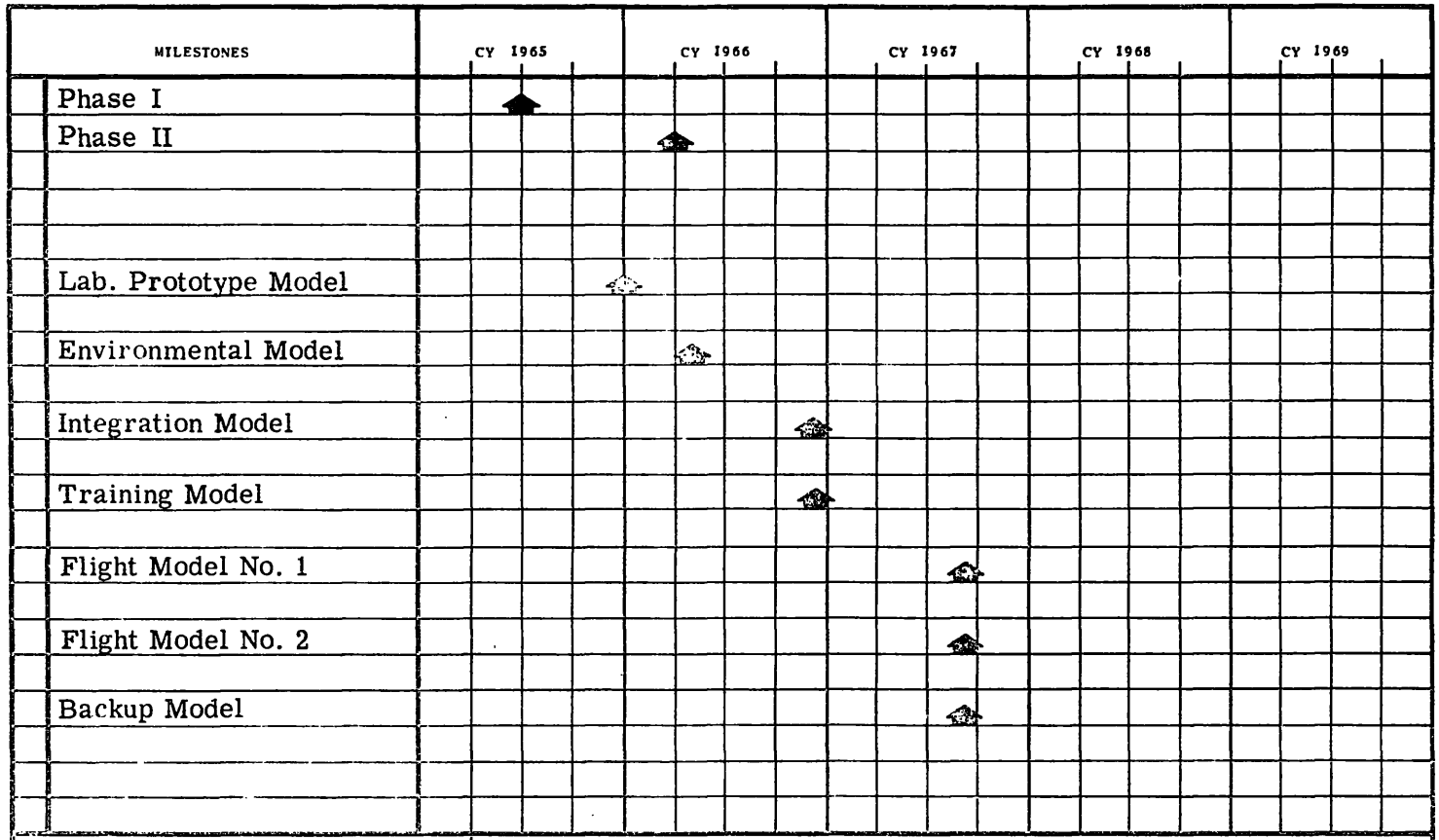
Adequate lines of communication between the systems contractors and experiment sponsors must be maintained at all times. General interface data must be forthcoming from the system managers in order that problem areas for each experiment may be isolated and more detailed information obtained for solution of the problems. The experiment sponsor will provide the experiment interface requirements to the system manager.

5. EQUIPMENT TEST AND QUALIFICATION

Laboratory test for achievement of performance goals and operation under environmental constraints will be performed both as part of the contractor effort and in the sponsors laboratory.

This test and evaluation procedure will be used to further define the data collection, reduction and analysis procedures and to form a basis for the hard specification to be used in procurement of the flight hardware during Phase Two.

EXHIBIT C.7



NOTES:

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Key Milestone Schedule
S-23 Experiment

2 LEVEL

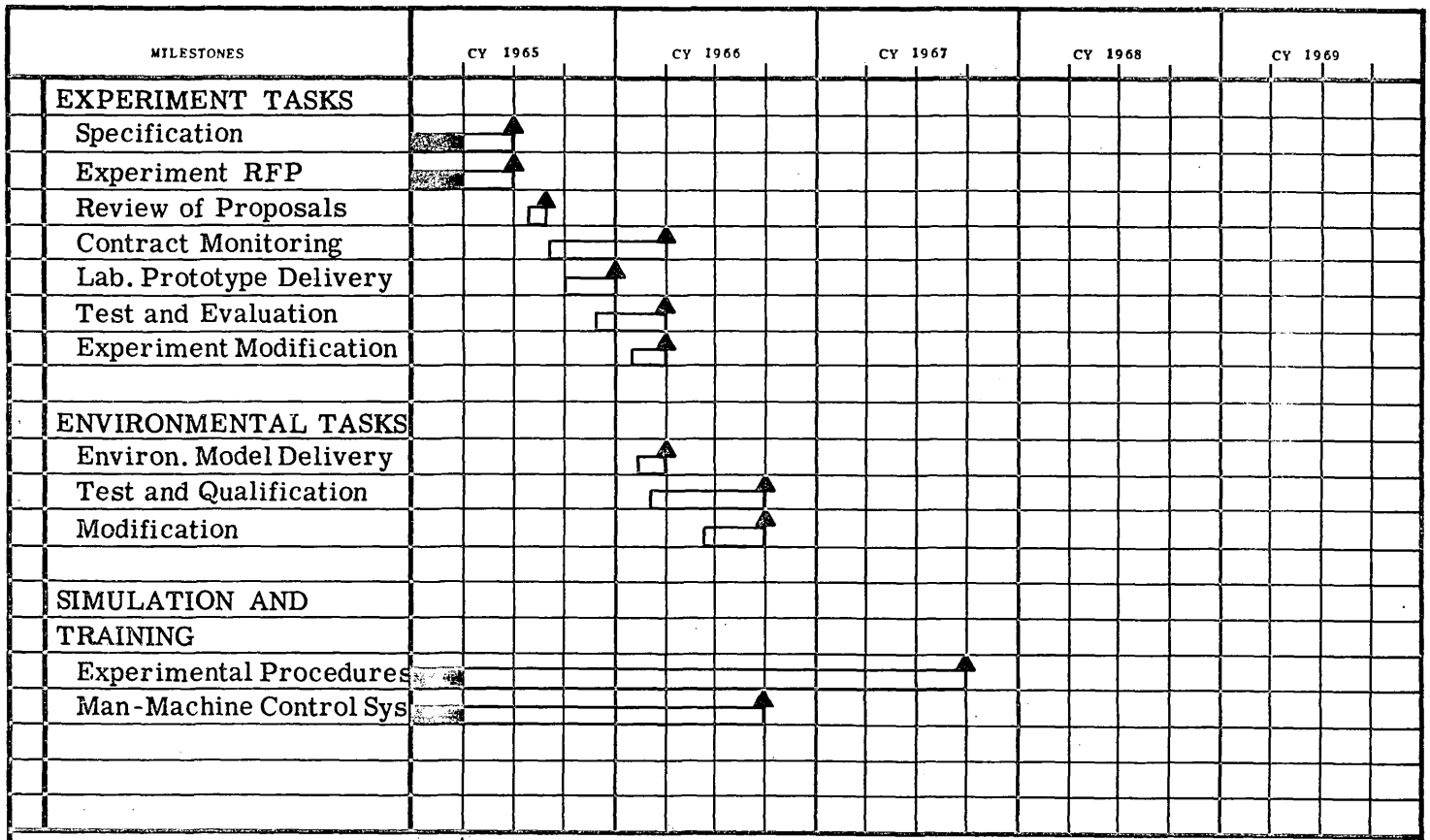
SCH'D NO. 2-S23-1-01

ORIGINAL SCHEDULE APPROVAL _____ DATE

LAST SCHEDULE CHANGE 2-28-65 DATE

STATUS AS OF 3-31-65 DATE

PAGE 1 OF 3 PAGES



NOTES:

PREPARED BY: C. J. Kurner

APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Milestone Schedule
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-1-01

ORIGINAL SCHEDULE APPROVAL 2-28 DATE

LAST SCHEDULE CHANGE 2-28-65 DATE

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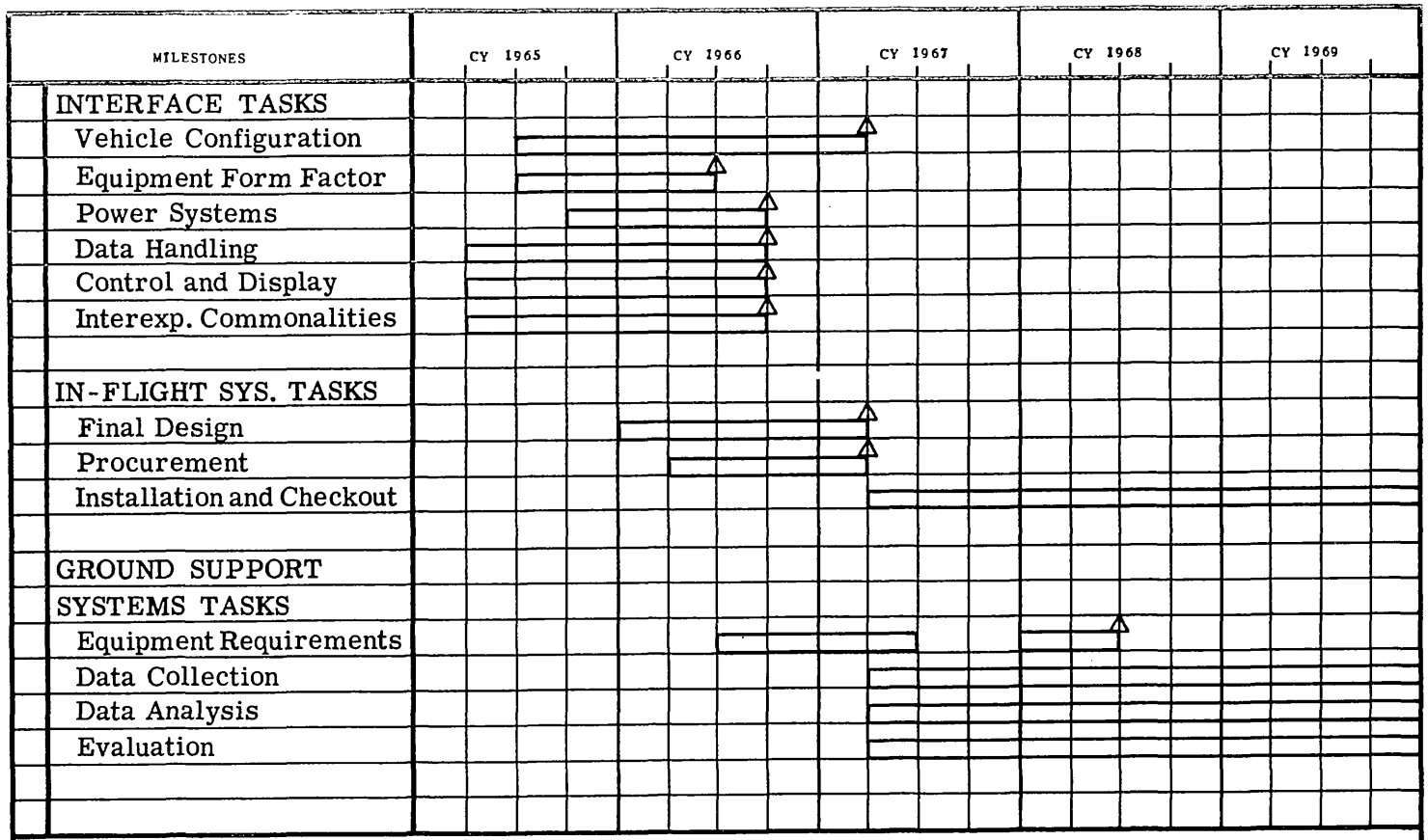

NOTES:

PREPARED BY: C. J. Kurner

APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Milestone Schedule
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-1-01

ORIGINAL SCHEDULE APPROVAL ~~1-15-65~~ DATE

LAST SCHEDULE CHANGE 2-28-65 DATE

STATUS AS OF 3-31-65 DATE

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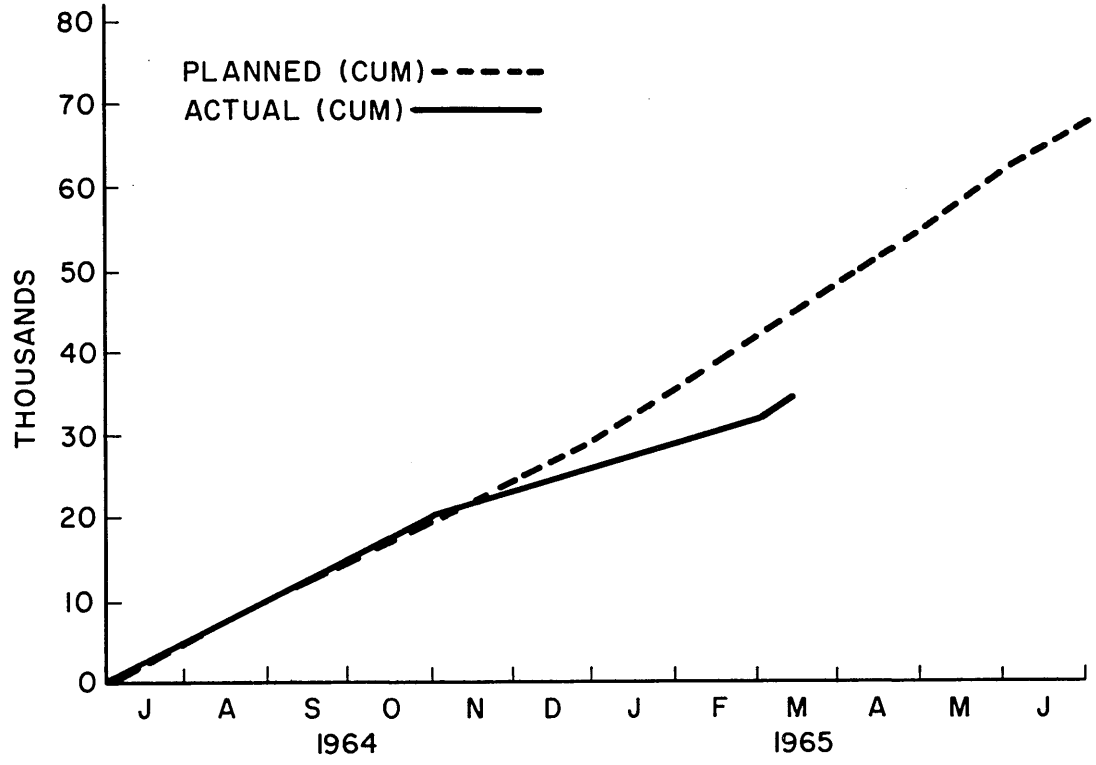


	J	A	S	O	N	D	J	F	M	A	M	J
PLANNED	5.0	10.0	15.0	20.0	24.5	29.0	35.3	41.7	48.1	54.7	61.6	68.2
ACTUAL	4.8	10.0	15.4	19.4	22.9	25.9	28.9	31.9				

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

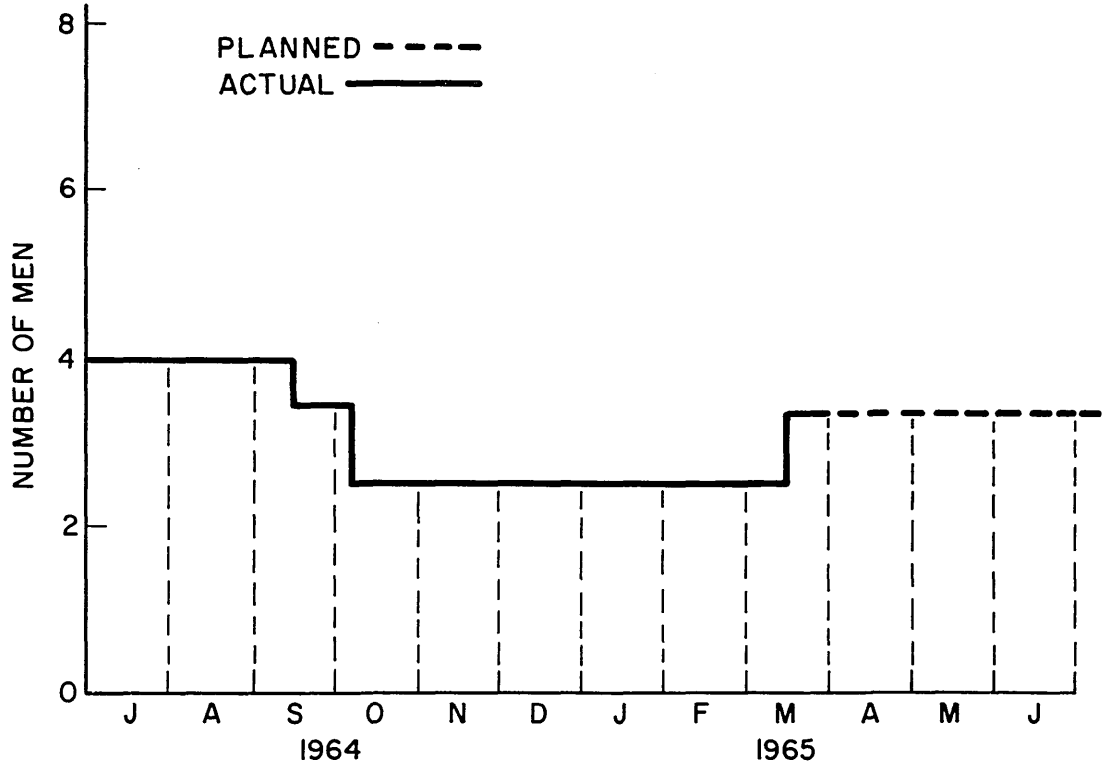
Total Expenditures
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-3-01

ORIGINAL SCHEDULE APPROVAL _____ DATE
LAST SCHEDULE CHANGE 2-28-65 DATE
STATUS AS OF 3-31-65 DATE

PAGE 1 OF 1 PAGES



	J	A	S	O	N	D	J	F	M	A	M	J
PLANNED	4.0	4.0	3.5	3.5	3.5	3.5	2.0	2.0	2.0	2.0	2.0	2.0
ACTUAL	4.0	4.0	3.5	2.5	2.5	2.5	2.5	2.5				

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

In House Civilian Manpower Level
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-4-02

ORIGINAL SCHEDULE APPROVAL DATE
LAST SCHEDULE CHANGE 2-28-65 DATE
STATUS AS OF 3-31-65 DATE

PAGE 1 OF 1 PAGES

CURRENT WEIGHT	(LB)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe-Boom Assembly(s)	40	0
Electrometers (3)	6	0
Program Logic Control & Store	20	0
Function Control & Displays	10	0
Power Control & Regulation	2	0
Data Link Interface	2	0
	80	Net Change 0

CURRENT VOLUME	(FT^3)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe Boom Assemblies (3)	1.0	0
Electronics	2.0	0
Displays	0.5	0
	3.5	Net Change 0

POWER DEMAND	(WATTS)	AMOUNT OF CHANGE SINCE LAST REPORT
Continuous	0	0
Standby	10	0
Average Operating (Peak)	75 (100)	0

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Weight, Volume, Power
S-23 Experiment

2 LEVEL

SCH'D NO. 2-S23-5-01

ORIGINAL SCHEDULE APPROVAL DATE
LAST SCHEDULE CHANGE 2-28-65 DATE
STATUS AS OF 4-1-65 DATE

PAGE 1 OF 1 PAGES

TECHNICAL HIGHLIGHTS

1. Continue Comparison Studies on Various Probe-Boom Configurations

2. Completed State-of-the-Art Investigation of Vacuum Tube vs. Solid-State Electrometer Amplifiers

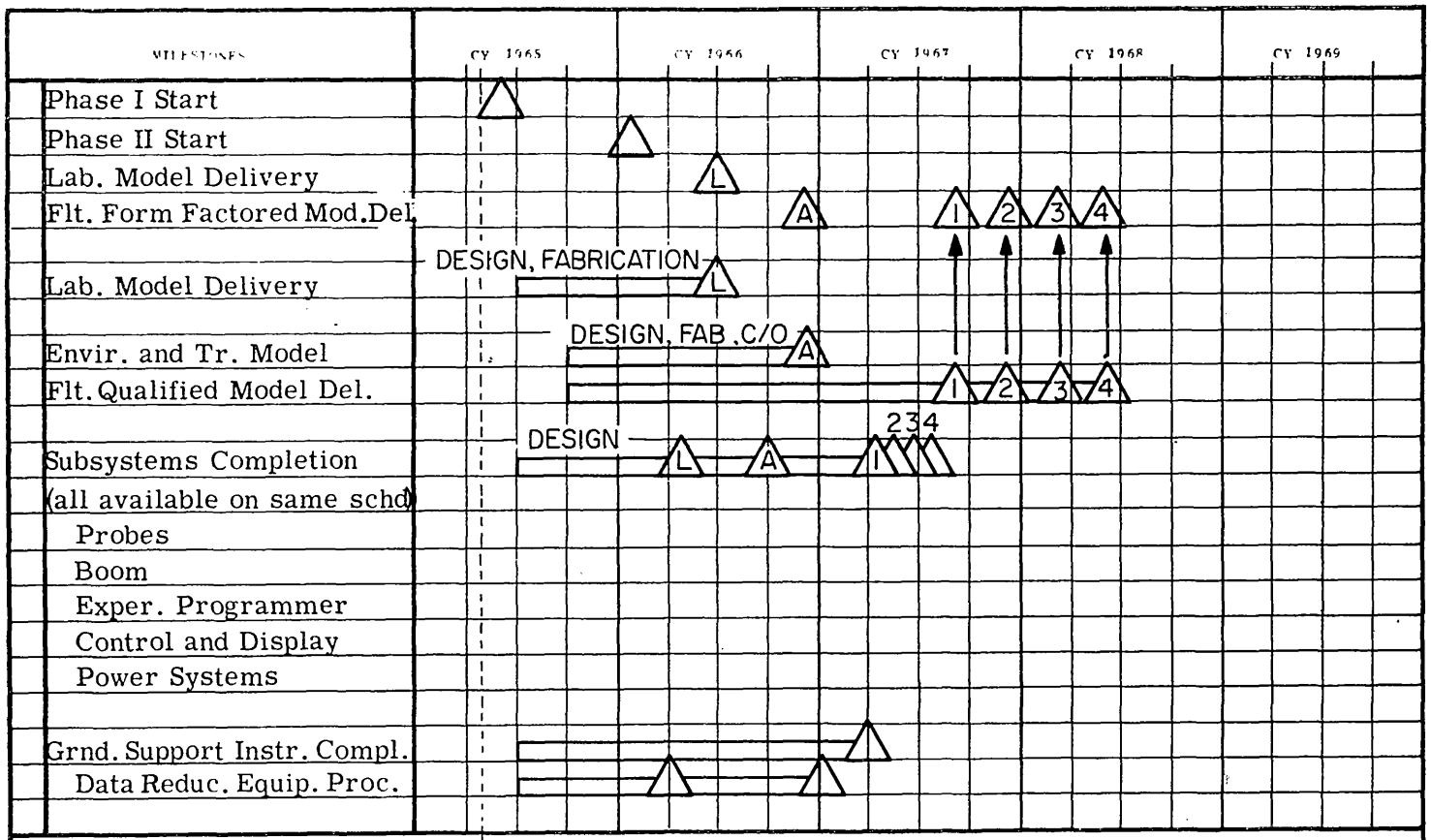
3. Continue Investigation of Solid-State Electrometer Amplifiers

4. Refine Experiment Conduct Plan (Data Usage Profile)

5. Establish Parameter Limit Values for Use in RFP

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM Technical Progress S-23 Experiment SCH'D NO. 2-S23-5-02	2 LEVEL
		ORIGINAL SCHEDULE APPROVAL 2-28 DATE LAST SCHEDULE CHANGE 2-28-65 DATE STATUS AS OF 4-1-65 DATE PAGE 1 OF 1 PAGES

EXHIBIT C.8



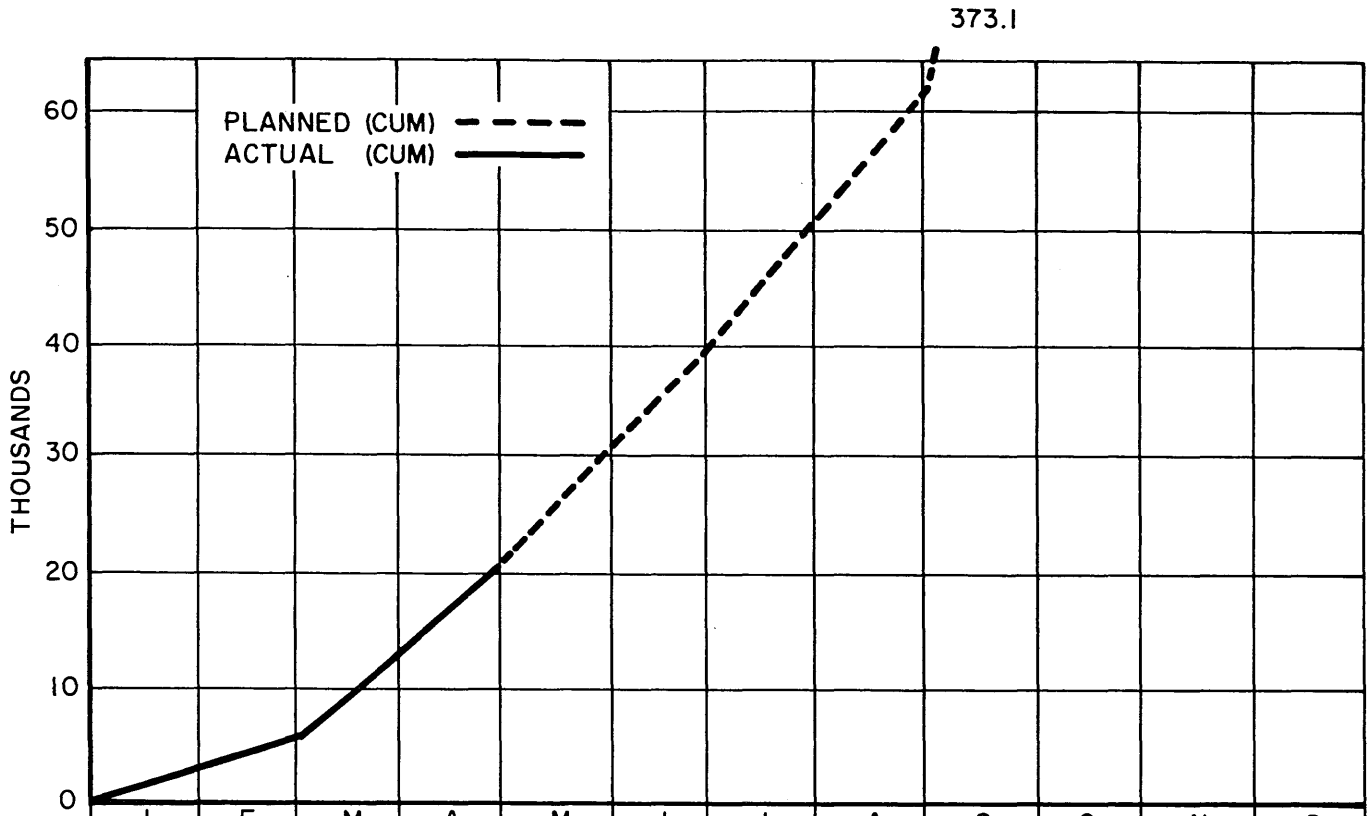
NOTES

L Laboratory Checkout Model
A Environmental Qualification and Training Model
1, 2, 3, 4 Flight Qualified Models

PREPARED BY C.J. Kurner
APPROVED E.F. Kulikowski

NAVY EXPERIMENT PROGRAM
S-23 Milestone Schedule
1 LEVEL
SCH D NO. 1-S23-1-02

ORIGINAL SCHEDULE APPROVAL _____ DATE
LAST SCHEDULE CHANGE 3-31-65 DATE
STATUS AS OF 4-30-65 DATE
PAGE 1 OF 1 PAGES



	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	6.3	12.7	19.1	25.7	32.6	39.2	50.5	61.8	373.2	384.5	395.8	407.2
ACTUAL	3.0	6.0	11.2	21.2								

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

S-23 Funding Plan

1 LEVEL

SCHED NO. 1-S23-2-00

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE 2-28-65

STATUS AS OF 4-30-65

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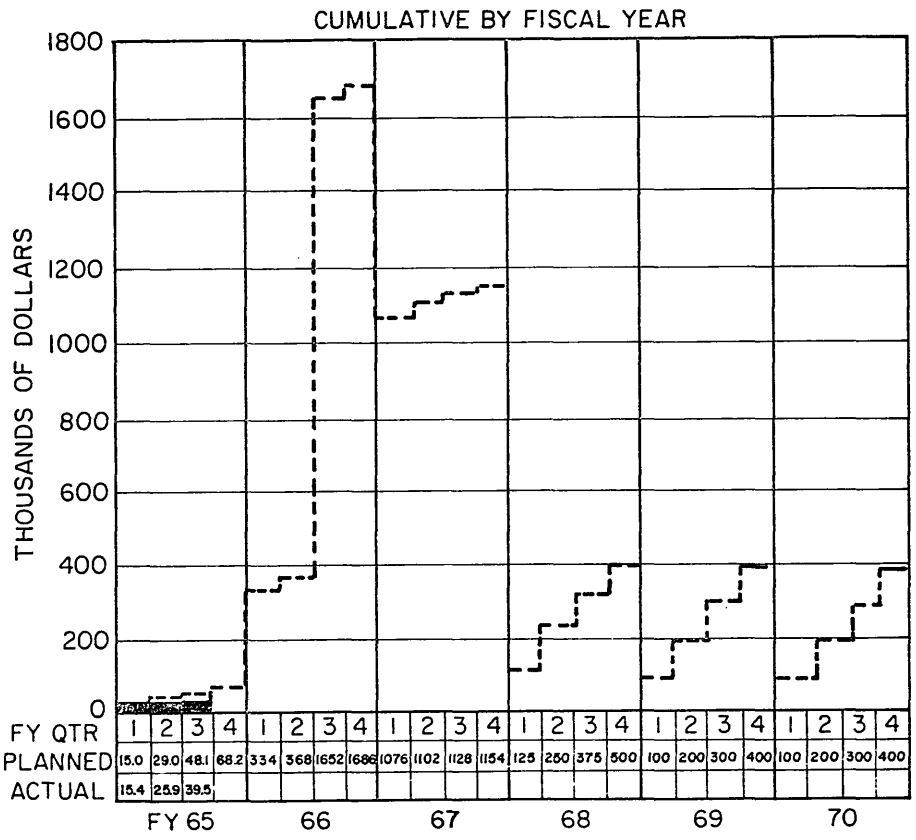
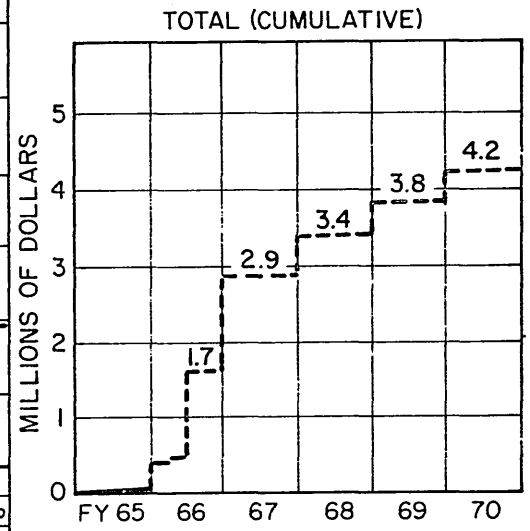
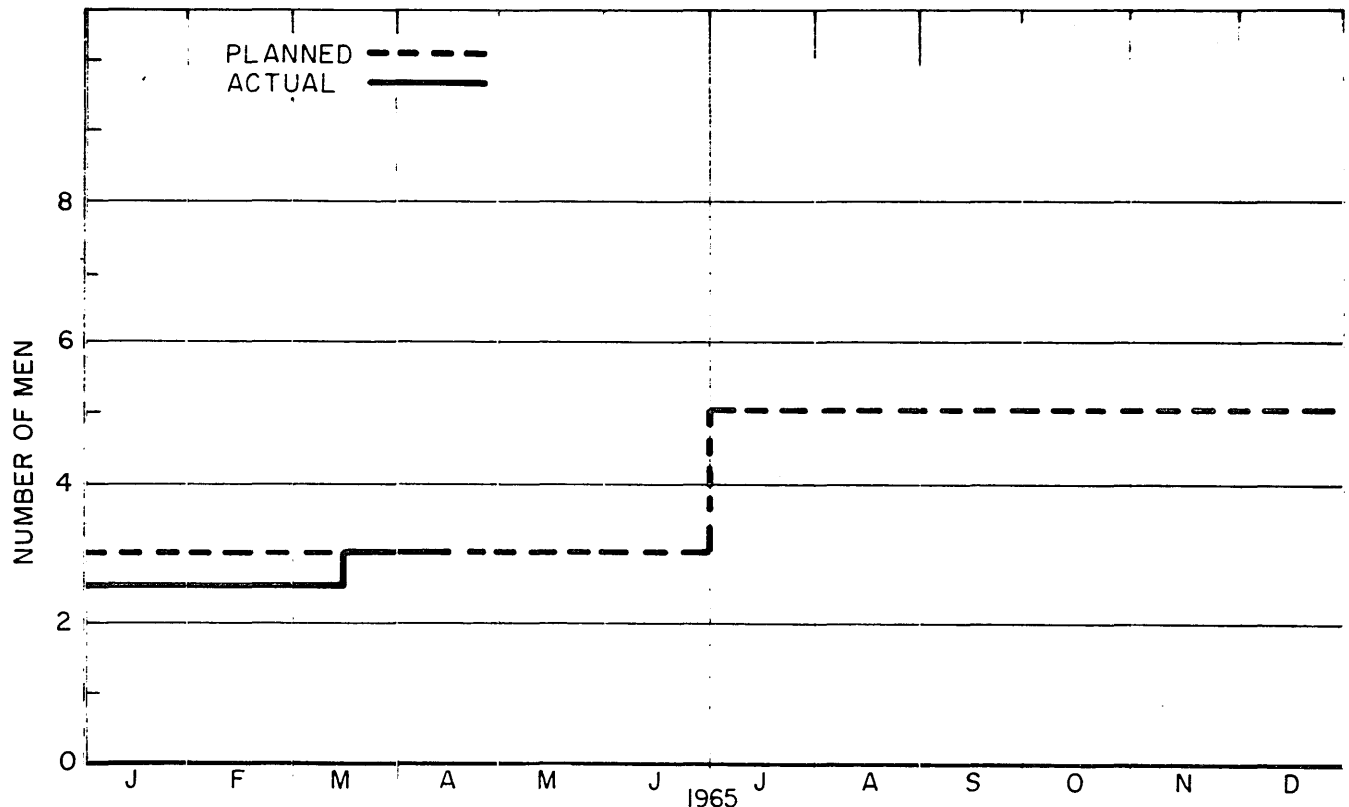




PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	S-23 Fiscal Schedule 1-S23-2-00	1 4-30-65 2 2



	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	3.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0
ACTUAL	2.5	2.5	2.5	2.5								

C. J. Kurner

E. F. Kulikowski

S-23 Manpower Chart

1

1-S23-3-00

4-30-65

1 1

PROGRAM HIGHLIGHTS

CBD Synopsis Responses have been received.

Determination and findings leading to source list are in progress.

The thermal equalization probe temperature variation study has been completed.

Draft of work statement for experiment RFP has been generated and is being smoothed

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM 1 LEVEL SCH'D NO. 1-S23-4-00	ORIGINAL SCHEDULE APPROVAL ____ DATE LAST SCHEDULE CHANGE ____ DATE STATUS AS OF 4-30-65 DATE PAGE 1 OF 1 PAGES

CURRENT WEIGHT	(LB)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe-Boom Assembly(s)	40	0
Electrometers (3)	6	0
Program Logic Control & Store	20	0
Function Control & Displays	10	0
Power Control & Regulation	2	0
Data Link Interface	2	0
	80	Net Change 0

CURRENT VOLUME	(FT^3)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe Boom Assemblies (3)	1.0	0
Electronics	2.0	0
Displays	0.5	0
	3.5	Net Change 0

POWER DEMAND	(WATTS)	AMOUNT OF CHANGE SINCE LAST REPORT
Continuous	0	0
Standby	10	0
Average Operating (Peak)	75 (100)	0

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

Weight, Volume, Power
S-23 Experiment

1 LEVEL

SCH'D NO 1-S23-5-01

ORIGINAL SCHEDULE APPROVAL DATE
LAST SCHEDULE CHANGE 2-28-65 DATE
STATUS AS OF 4-30-65 DATE

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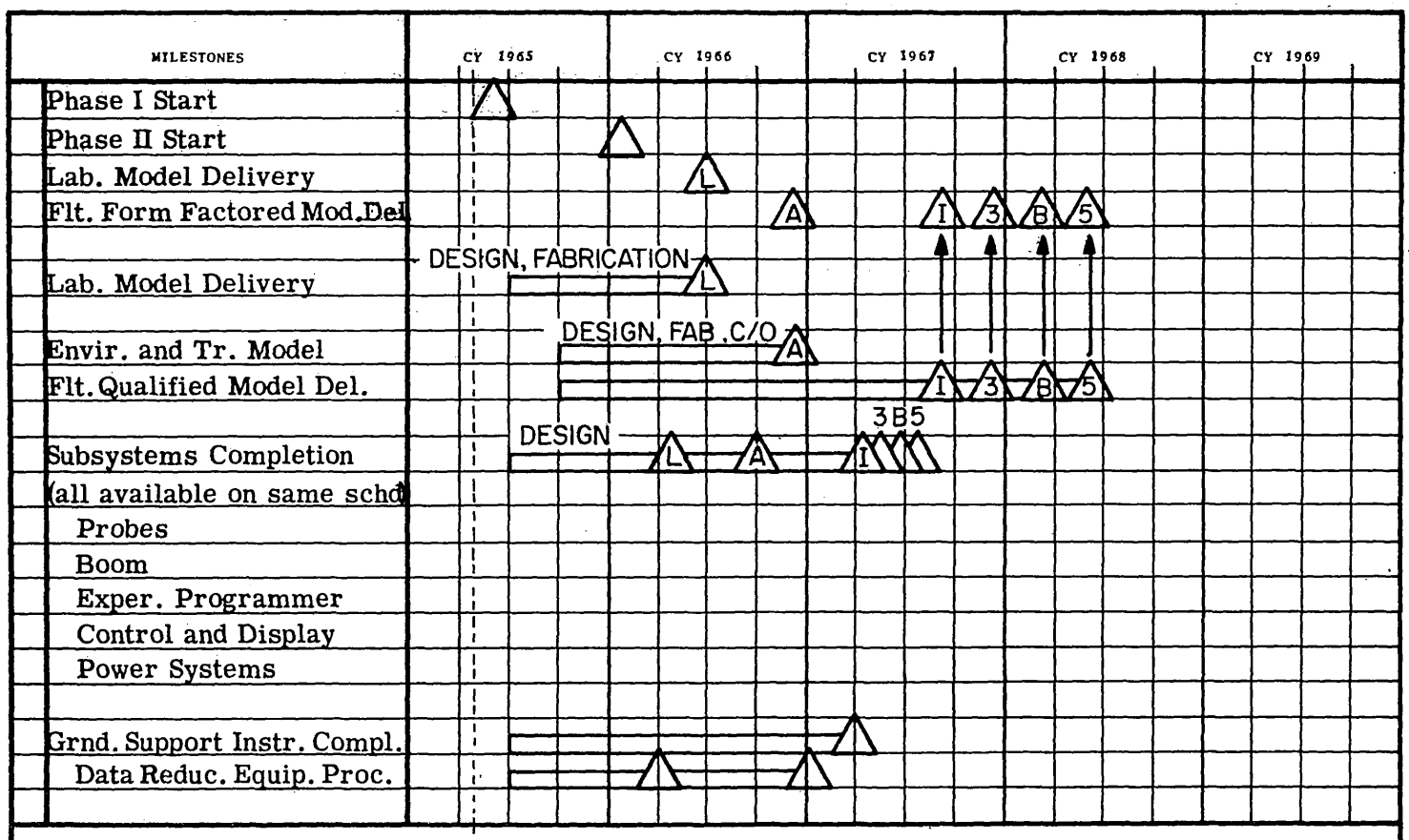
EXHIBIT C.9



NOTES:

L Laboratory Checkout Model
A Environmental Qualification and Training Model
1, 2, 3, 4 Flight Qualified Models
I Integration Model
B Backup Model

PREPARED BY: C.J. Kurner
APPROVED E.F. Kulikowski

NAVY EXPERIMENT PROGRAM
S-23 Milestone Schedule
1 LEVEL
SCH'D NO. 1-S23-1-02

ORIGINAL SCHEDULE APPROVAL
LAST SCHEDULE CHANGE 4-30-65 DATE
STATUS AS OF 5-31-65 DATE
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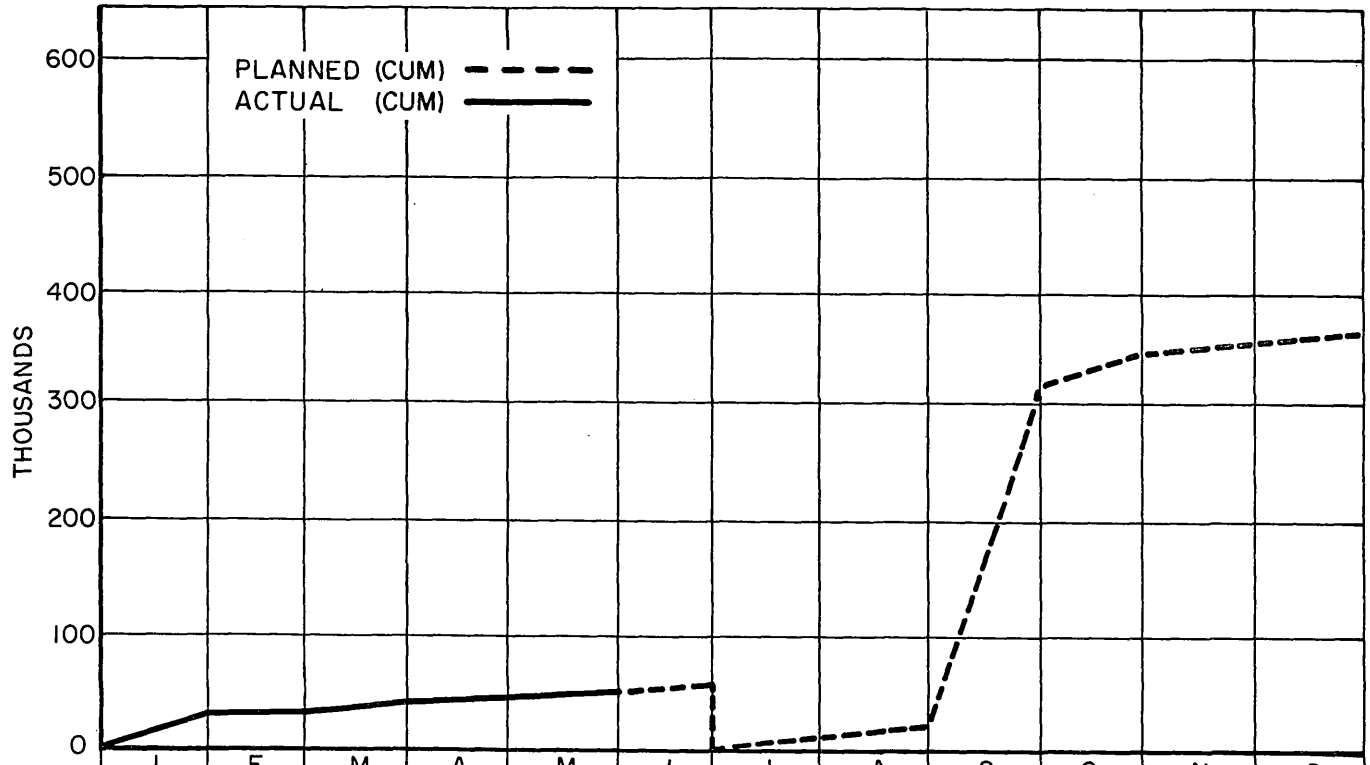

	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	30.5	33.5	41.1	47.3	53.6	60.2	11.3	22.5	333.9	345.2	356.5	367.9
ACTUAL	30.5	33.5	41.1	47.3	53.6							

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

S-23 Funding Plan

1 LEVEL

SCHED NO. 1-S23-2-00

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE 4-30-62

STATUS AS OF 5-31-65

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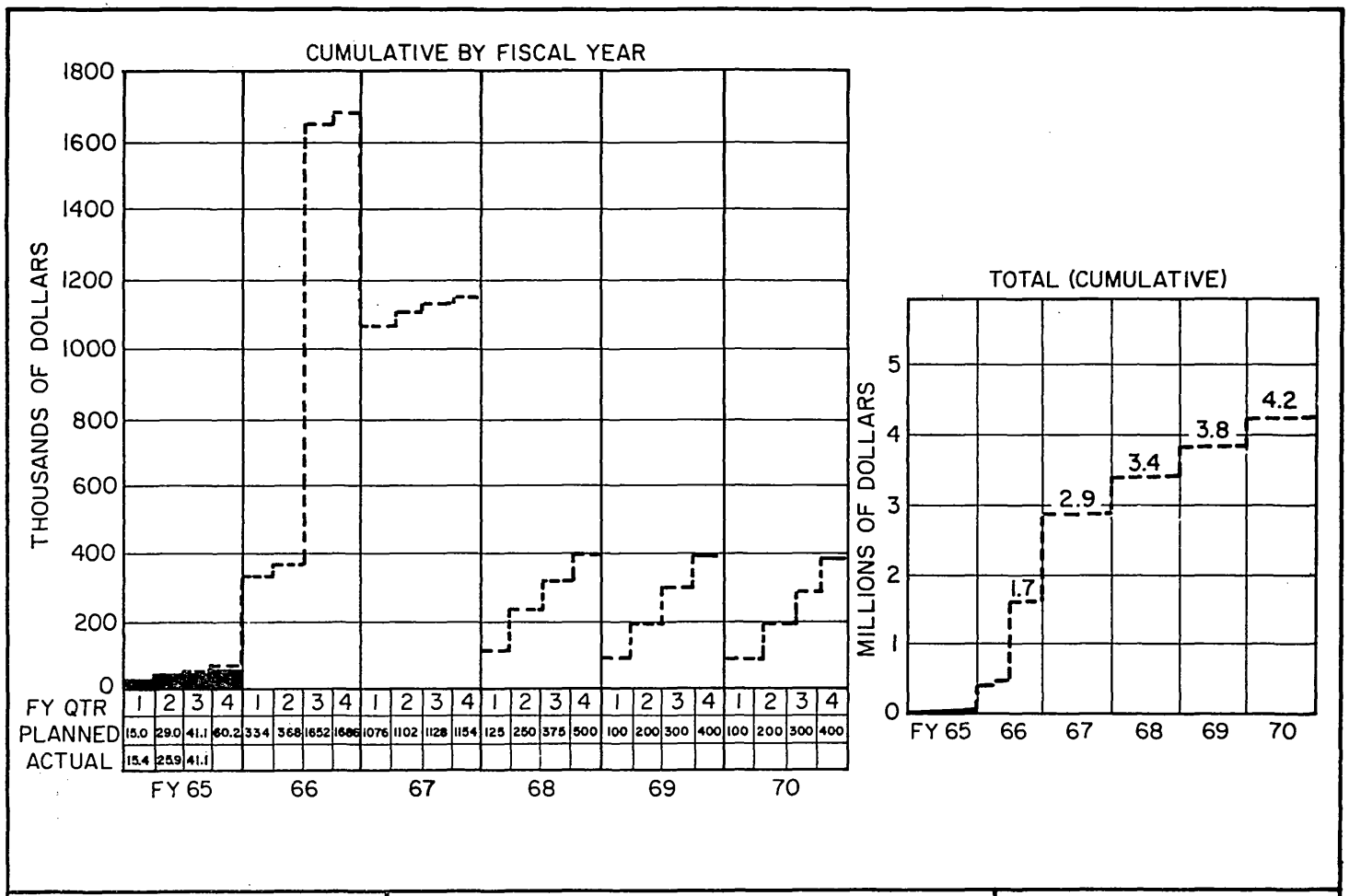
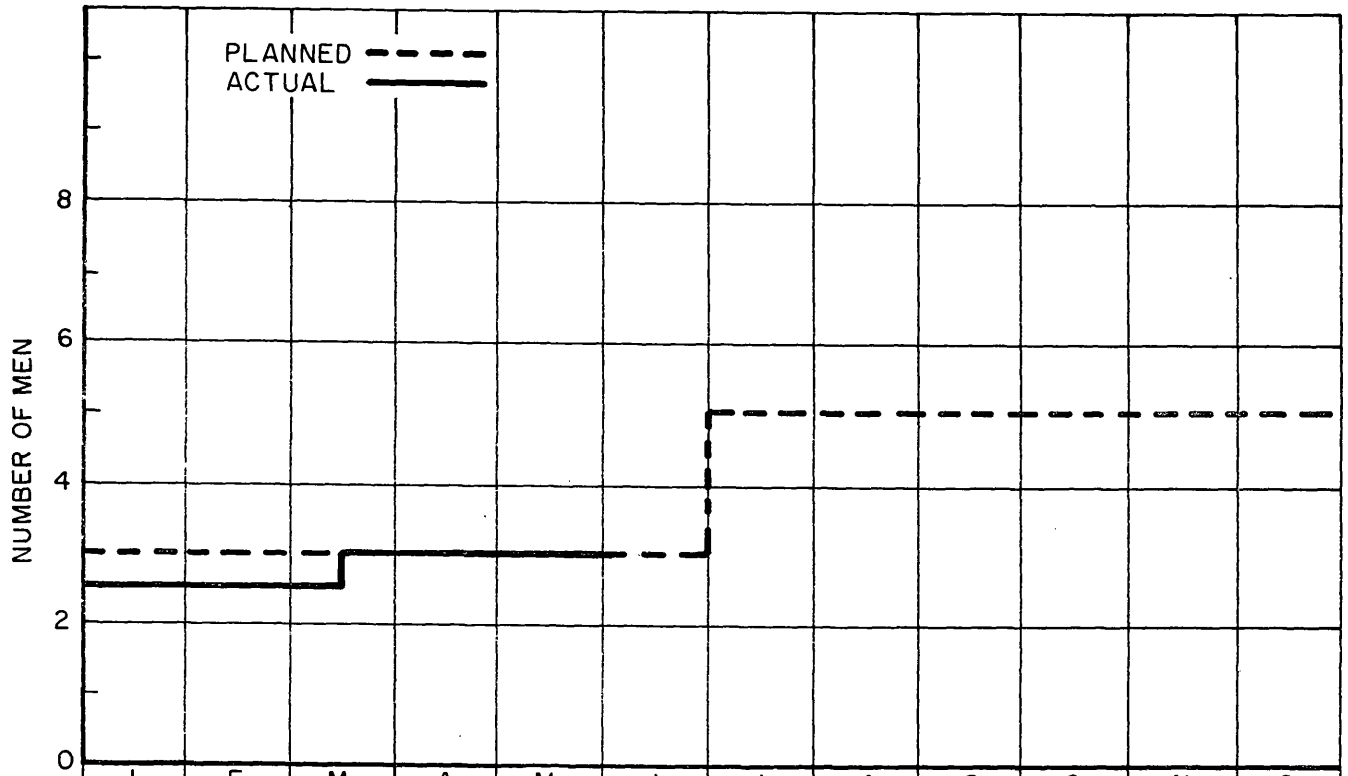


PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	S-23 Fiscal Schedule 1 LEVEL SCHED NO 1-S23-2-00	ORIGINAL SCHEDULE APPROVAL LAST SCHEDULE CHANGE 4-30-65 STATUS AS OF 5-31-65 PAGE 2 OF 2 PAGES



	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED	3.0	3.0	3.0	3.0	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0
ACTUAL	2.5	2.5	2.5	3.0	3.0							

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

S-23 Manpower Chart

1 LEVEL

SCH. NO. 1-S23-3-00

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE 4-30-65

STATUS AS OF 5-31-65

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PROGRAM HIGHLIGHTS

Continuing theoretical investigation of ionospheric plasma-plasma sheath-probe boundaries.

Preparing updated RFP draft, widening scope to encompass ancillary sensors (magnetometer, UV radiometer, etc.) and on-board support systems (data conditioning, storage, encoding, telemetry, and power sources).

Continuing determination and finding procedures in compilation of source list.

PREPARED BY: C.J. Kurner APPROVED: E.F. Kulikowski	NAVY EXPERIMENT PROGRAM 1 LEVEL SCH'D NO. 1-S23-4-00	ORIGINAL SCHEDULE APPROVAL DATE LAST SCHEDULE CHANGE 4-30-65 DATE STATUS AS OF 5-31-65 DATE PAGE 1 OF 1 PAGES

CURRENT WEIGHT	(LB)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe-Boom Assembly(s)	40	0
Electrometers (3)	6	0
Program Logic Control & Store	20	0
Function Control & Displays	10	0
Power Control & Regulation	2	0
Data Link Interface	2	0
	80	Net Change 0

CURRENT VOLUME	(FT^3)	AMOUNT OF CHANGE SINCE LAST REPORT
Probe Boom Assemblies (3)	1.0	0
Electronics	2.0	0
Displays	0.5	0
	3.5	Net Change 0

POWER DEMAND	(WATTS)	AMOUNT OF CHANGE SINCE LAST REPORT
Continuous	0	0
Standby	10	0
Average Operating (Peak)	75 (100)	0

PREPARED BY: C.J. Kurner
APPROVED: E.F. Kulikowski

NAVY EXPERIMENT PROGRAM
Weight, Volume, Power
S-23 Experiment

1 LEVEL

SCH'D NO. 1-S23-5-01

ORIGINAL SCHEDULE APPROVAL 2-28-65 DATE
LAST SCHEDULE CHANGE DATE
STATUS AS OF 5-31-65 DATE

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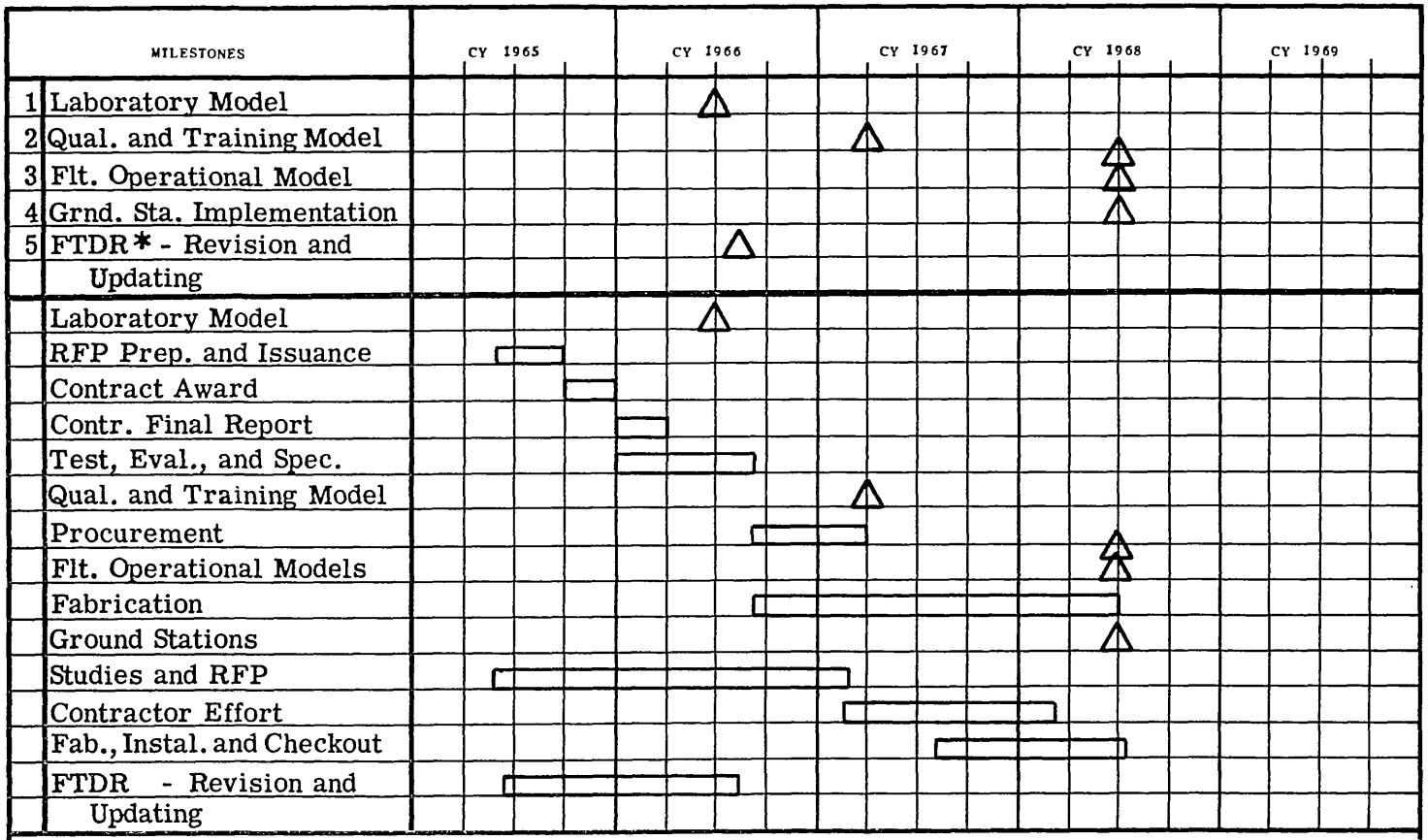
EXHIBIT C.10

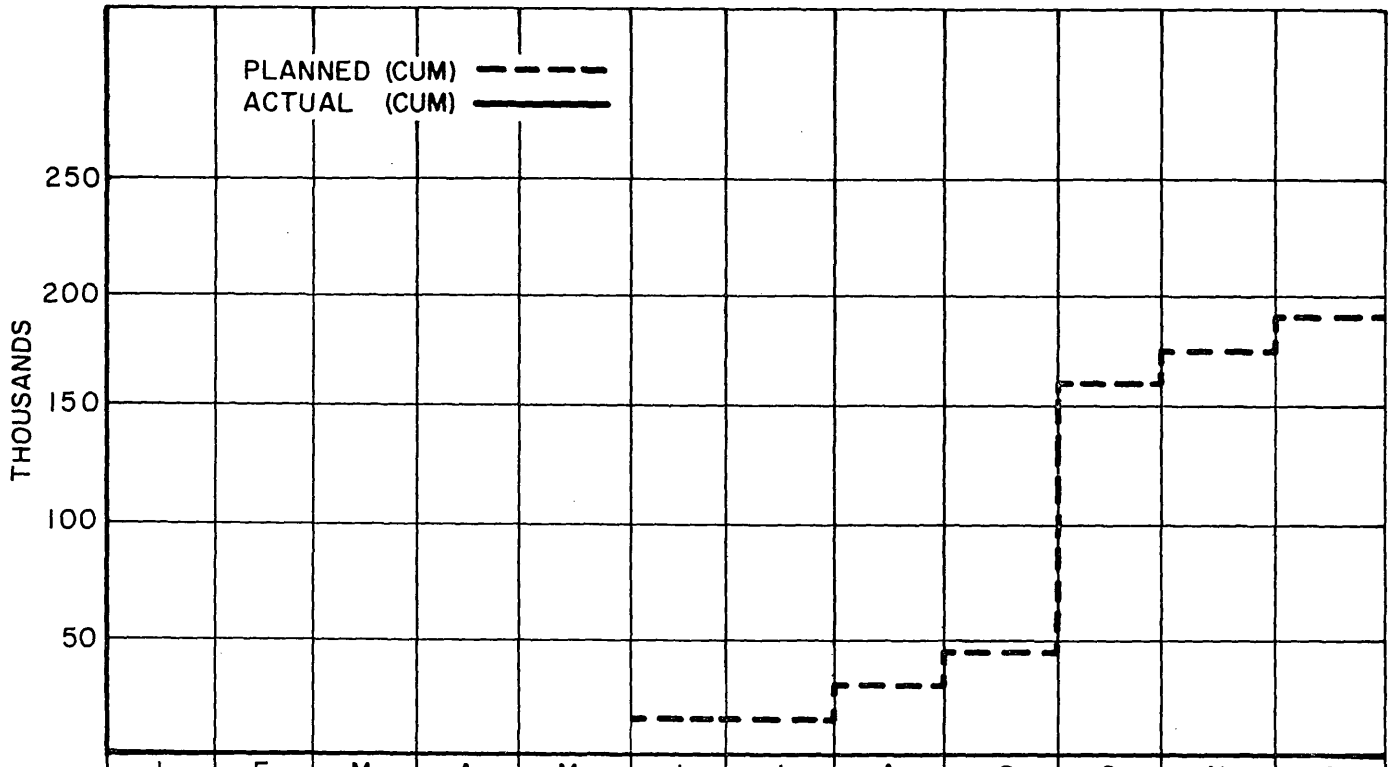


NOTES: *NAVMOL Conf. Report No. TR-65-2, Final Technical Document Report on Experiment S-1, dated 8 Jan 1965.

PREPARED BY: E. F. Kulikowski
APPROVED E. F. Kulikowski

NAVY EXPERIMENT PROGRAM
S-1 Milestone Plan
1 LEVEL
SCH'D NO. 1-S1-1-00

ORIGINAL SCHEDULE APPROVAL _____ DATE
LAST SCHEDULE CHANGE _____ DATE
STATUS AS OF 6-1-65 DATE
PAGE 1 OF 1 PAGES



	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED						15.0	15.0	30.0	45.0	160.0	175.0	190.0
ACTUAL												

PREPARED BY: E. F. Kulikowski

APPROVED: E. F. Kulikowski

S-1 Funding Plan

1 LEVEL

SCHED NO. 1-S1-2-00

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE

STATUS AS OF 6-1-65

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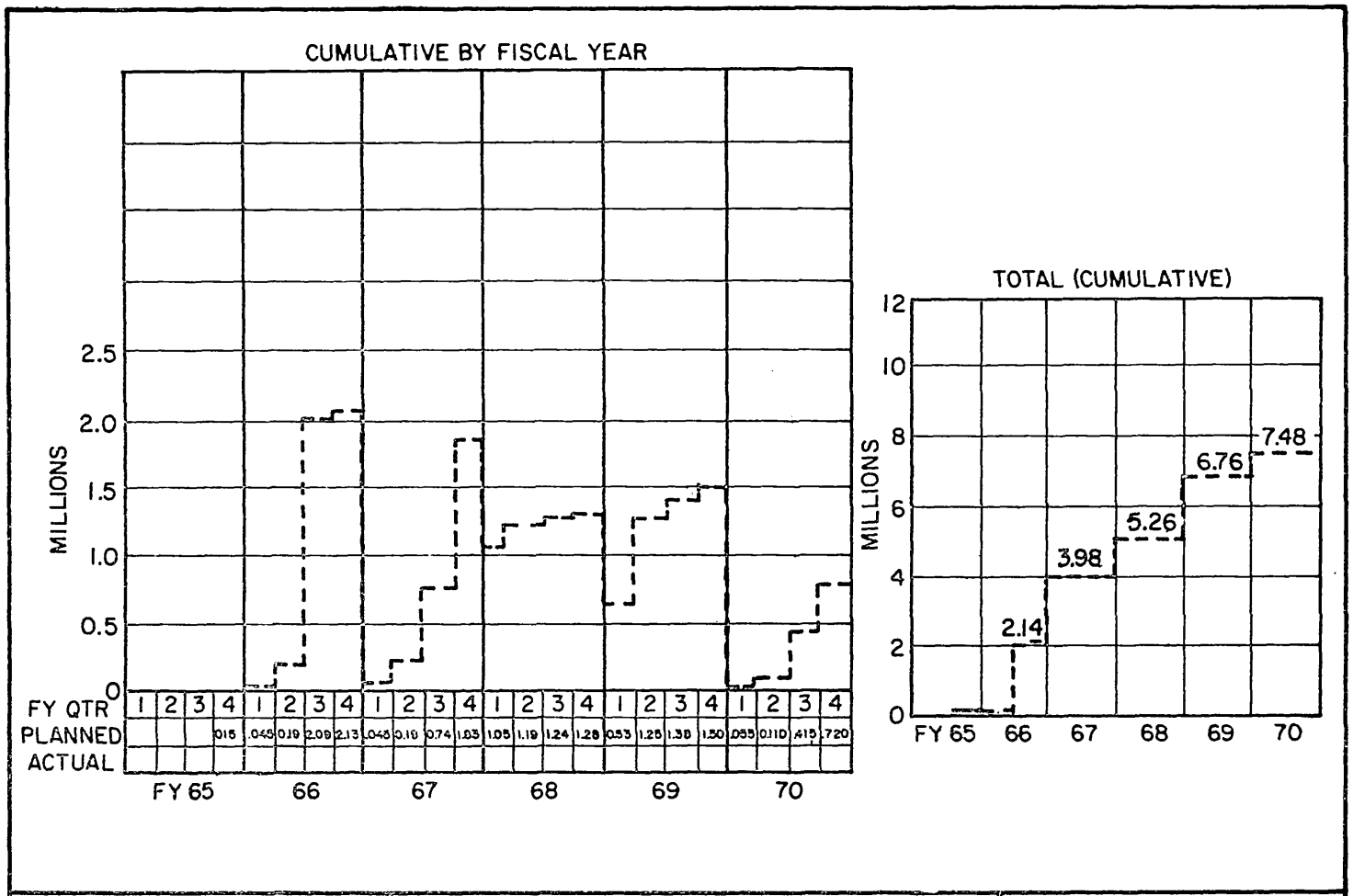
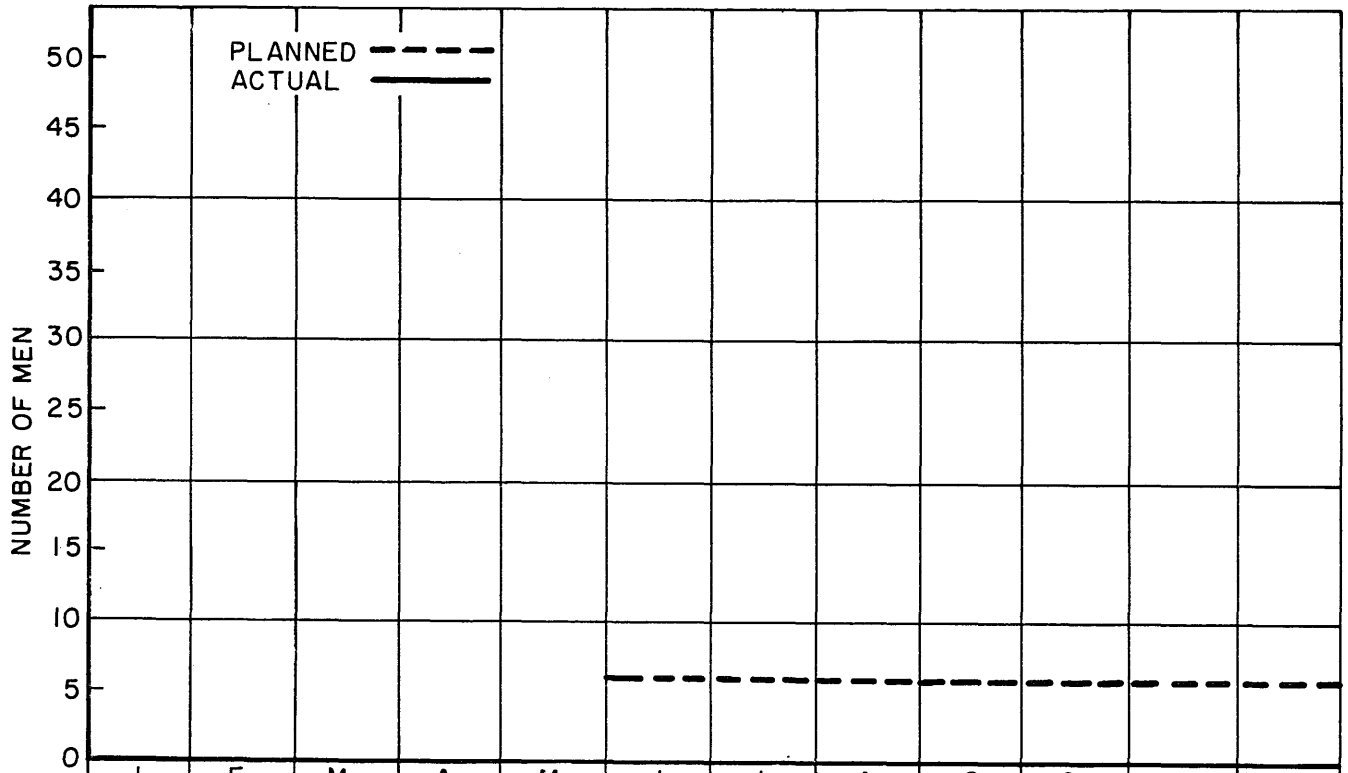


PREPARED BY: E. F. Kulikowski	S-1 Fiscal Schedule	ORIGINAL SCHEDULE APPROVAL
APPROVED: E. F. Kulikowski	1 LEVEL	LAST SCHEDULE CHANGE
	SCHED NO 1-S1-2-00	STATUS AS OF 6-1-65
		PAGE 2 OF 2 PAGES



	J	F	M	A	M	J	J	A	S	O	N	D
PLANNED						6.0	6.0	6.0	6.0	6.0	6.0	6.0
ACTUAL												

PREPARED BY: E. F. Kulikowski

APPROVED: E. F. Kulikowski

S-1 Manpower Plan

1 LEVEL

SCHED NO. 1-S1-3-00

ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE

STATUS AS OF 6-1-65

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PROGRAM HIGHLIGHTS

Old Problem	Solution	Solution Date	Action Party
Reevaluation of experiment scheduling and level of effort.	A Memorandum of Understanding (Enclosure to NRL Ltr 7000-62 Serial 0528 of 3 June 1965) has been prepared by NRL giving estimates of manpower and funds to be utilized in the prosecution of Experiment S-1.	1 June 1965	NRL

PREPARED BY: E.F. Kulikowski
APPROVED: E.F. Kulikowski

NAVY EXPERIMENT PROGRAM

1 LEVEL

SCH'D NO 1-S1-4-00

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LAST SCHEDULE CHANGE ____ DATE
STATUS AS OF 5-31-65 DATE

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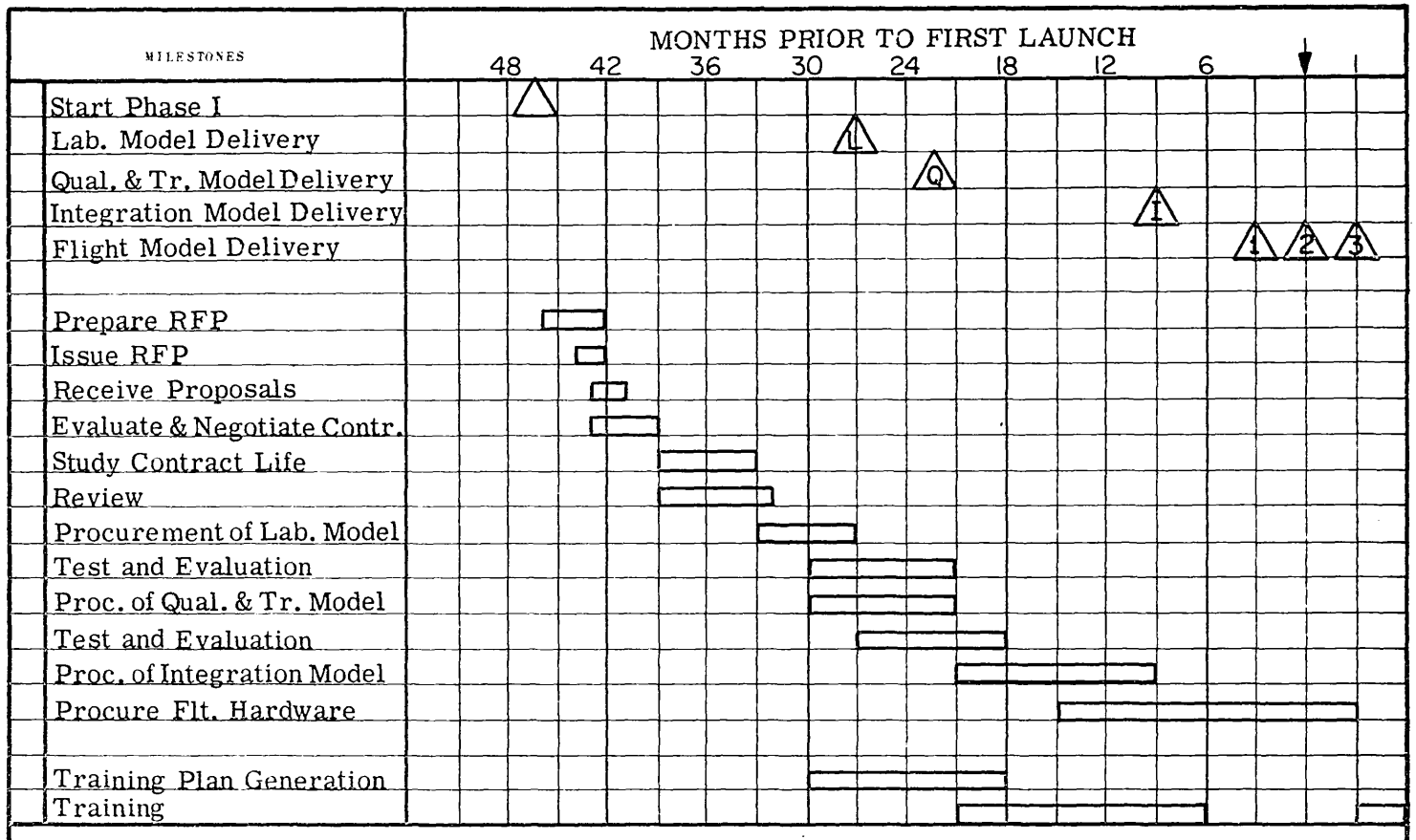
EXHIBIT C.11



NOTES: L - Laboratory Checkout Model
Q - Qualification and Training Model
I - Integration Model
1,2,3 - Flight and Backup Models

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM
ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE PROGRAM
SCHED NO
LEVEL

ORIGINAL SCHEDULE APPROVAL DATE
LAST SCHEDULE CHANGE
STATUS AS OF 15 Aug. 1965 DATE
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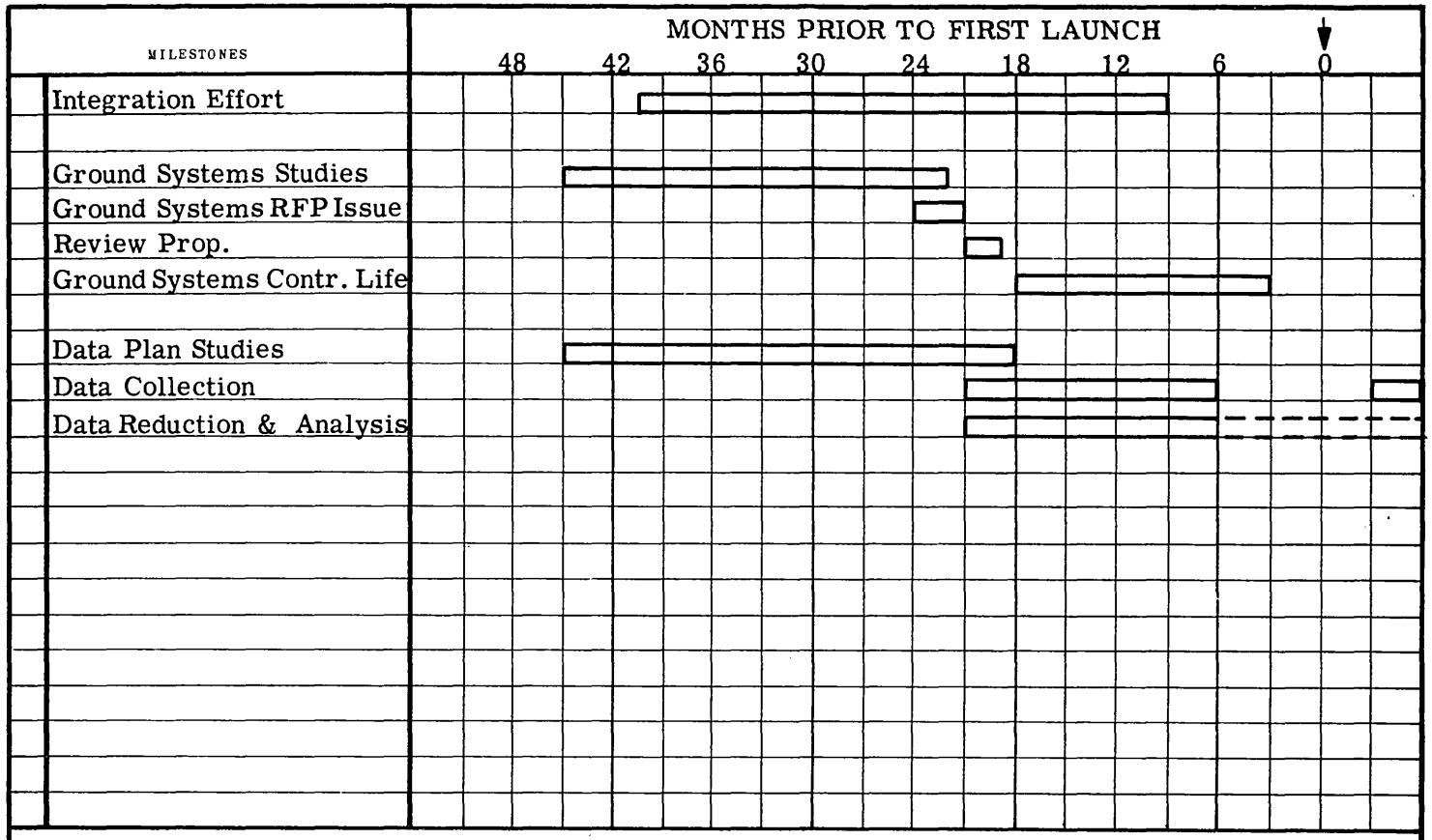


NOTES:

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE PROGRAM

LEVEL

SCH'D NO.

ORIGINAL SCHEDULE APPROVAL _____ DATE

LAST SCHEDULE CHANGE _____

STATUS AS OF 15 Aug. 1965 DATE

PAGE 2 OF 2 PAGES

U. S. NAVAL RESEARCH LABORATORY
WASHINGTON 25, D. C.

IN REPLY REFER TO

5110-126:CJK:eam
NRL Prob H03-06C
SER:

From: Director, U. S. Naval Research Laboratory, Washington, D. C. 20390
To: Chief, Bureau of Naval Weapons (Code RTO3-35)

Via: Officer in Charge, U. S. Navy Field Office for Manned Orbiting Laboratory

Subj: Revised Milestone Schedule for ELF-VLF Propagation/Electron Density-Temperature Program

Ref: (a) BUWEPS WEPTASK RT 7045020/6521/F019-05-02 Ser 08985 dtd 1 Jul 1965

Encl: (1) ELF-VLF Propagation/Electron Density-Temperature Program Milestone Schedule
(2) Preliminary Cost Requirements for ELF/VLF Propagation/Electron Density-Temperature Program

1. Enclosures (1) and (2) are submitted in fulfillment of the requirements of paragraph 4 of the referenced WEPTASK.

2. Schedule dates in the milestone charts represent current estimates of program advances which may be attained based on a program approval date of 1 September 1965.

3. Cost estimates of enclosure (2) reflect the funding level required to achieve the milestone schedule dates.

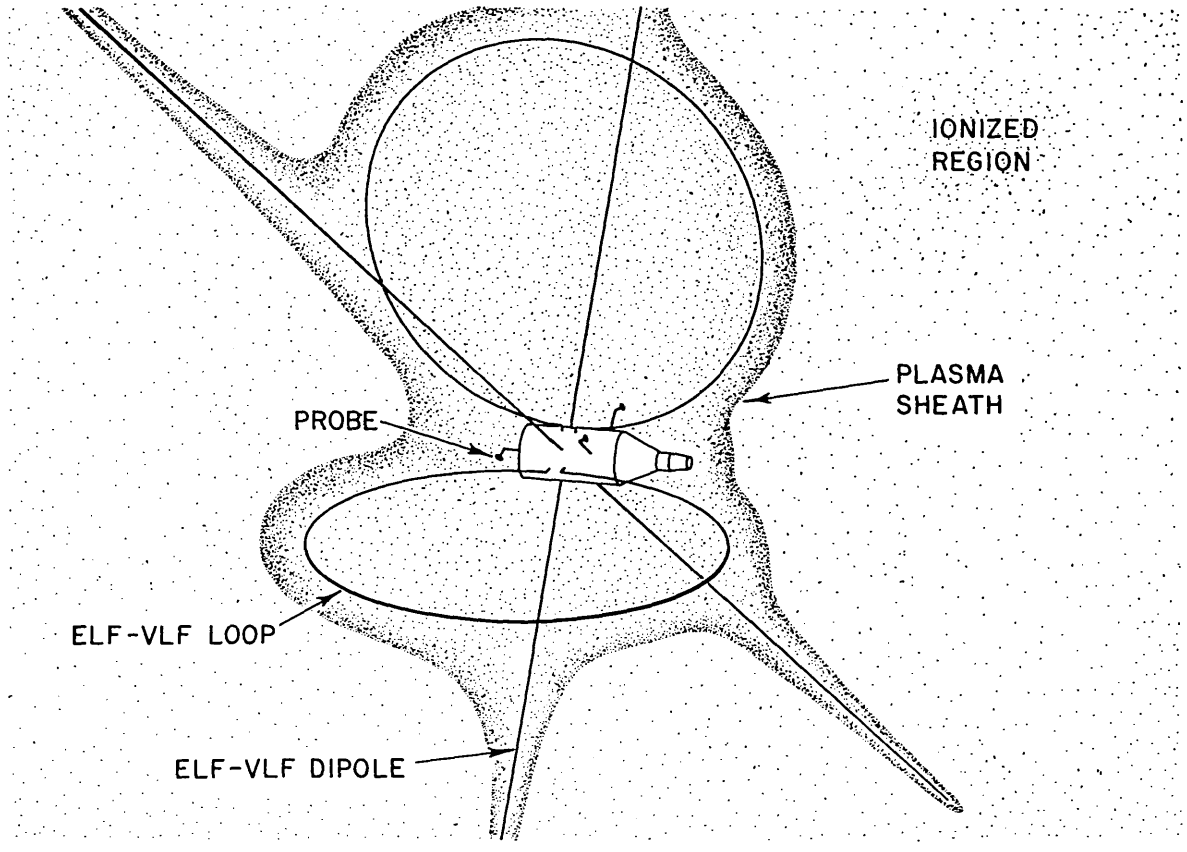
PRELIMINARY COST ANALYSIS OF
ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE PROGRAM

FISCAL YEAR	COST ITEM	COST	IN-HOUSE MANPOWER COST**	FY TOTALS
1966	Study Contract (2)	350 K	185 K	535 K
1967	Lab Model Procurement	2000 K	210 K	
	Qual. & Tr. Model Procure.	1250 K		
	Qualification Testing & Facilities	200 K		3660 K
1968	Integration Model Procurement	750 K	210 K	
	Gnd. Systems Study & Test	100 K		
	Training Costs	125 K		
	Data Handling	200 K		1385 K
1969	Flight Models	1800 K	210 K	
	Gnd. System Implementation	1800 K	140 K *	
	Training	125 K		
	Data Handling	300 K		4375 K
1970	Data Handling	500 K	210 K	
			140 K *	850 K
TOTAL				10805 K

* Indicates additional salary requirements for personnel for operation and maintenance of ground station equipment preceding and during flights of program-equipped vehicles.

** In-House Manpower Cost as tabulated is predicated on the delivery of Flight Articles in calendar year 1969. Acceleration of the program will require the assignment of additional personnel to meet the accelerated delivery schedules.

EXHIBIT C.12



PREPARED BY: C.J. Kurner APPROVED: E.F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT SCH'D NO.	LEVEL ORIGINAL SCHEDULE APPROVAL DATE LAST SCHEDULE CHANGE DATE STATUS AS OF 15 Sept. 1965 DATE PAGE ___ OF ___ PAGES

EXPERIMENT OBJECTIVES

1. Demonstrate a world-wide ELF/VLF communications capability
   a. Space-to-ground
   b. Ground-to-space
   c. Space-to-space
2. Add to the knowledge of the charged particle composition of the ionosphere and the effects of space vehicle motion in the medium
3. Investigate the propagation and detection of magneto hydrodynamic waves
4. Investigate the ELF/VLF noise spectral density within the ionosphere
5. Additional goals may be generated as program definition continues

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON DENSITY - TEMPERATURE EXPERIMENT SCH'D NO	LEVEL
	ORIGINAL SCHEDULE APPROVAL ____ DATE LAST SCHEDULE CHANGE ____ DATE STATUS AS OF 9-15-65 DATE PAGE ___ OF ___ PAGES	

MAJOR TASKS IN SUPPORT OF OBJECTIVES

1. Provide ELF/VLF transmission capability on MOL
2. Receive and record ground-based ELF/VLF signals on MOL
3. Receive and record magnetohydrodynamic wave modes launched as a result of MOL motion and antenna excitation
4. Receive and record ELF/VLF Ionospheric noise environment
5. Measure charged particle density of ambient Ionosphere and near-vehicle plasma
6. Measure vehicle potentials and gradients for spatial and temporal variation
7. Receive and record MOL transmitted ELF/VLF signals at suitably located ground sites

PREPARED BY: C. J. Kurner APPROVED: E. F. Kuilikowski	NAVY EXPERIMENT PROGRAM ELF/VLF PROPAGATION/ELECTRON DENSITY - TEMPERATURE EXPERIMENT SCH'D NO	LEVEL ORIGINAL SCHEDULE APPROVAL ___ DATE LAST SCHEDULE CHANGE ___ DATE STATUS AS OF 9-15-65 DATE PAGE ___ OF ___ PAGES

RESULTS TO BE OBTAINED FROM EXPERIMENT

1. Propagation parameters for ELF/VLF space-ground link, space-space link, and ground-space link
2. Effects of frequency, power level, antenna configuration, antenna orientation and orbit position on antenna impedance and transmission efficiency
3. Spectral power density profile of ionospheric ELF/VLF noise background
4. Magnetohydrodynamic wave effects caused by vehicle and antenna excitation
5. Electron and Ion densities and temperatures along MOL orbit
6. Plasma sheath particle densities and sheath geometry
7. Effects of high-power transmission on sheath and on vehicle potential
8. Specifications for an operational ELF/VLF communications terminal

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REASONS FOR EXPERIMENT IN MOL

1. Needs effort of man to monitor and adjust antenna/coupler for optimizing in the presence of unknown and varying environmental conditions.
2. Man provides preprocessing capability in search of ELF/VLF receiver spectrum
3. Man can be responsive to sudden anomalous conditions and can take action to effect useful data collection during these conditions

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON DENSITY - TEMPERATURE EXPERIMENT SCH D NO	LEVEL ORIGINAL SCHEDULE APPROVAL ____ DATE LAST SCHEDULE CHANGE ____ DATE STATUS AS OF 9-15-65 DATE PAGE ___ OF ___ PAGES

SYSTEM CONCEPT

Astronaut performs controlled deployment of ELF/VLF antennas

On-board transmitter operated at preselected set of frequencies, power level, vehicle attitude

Special transmissions based on Astronauts interpretation of on-board displays

Astronaut monitors and records ELF/VLF signals received at spacecraft (manual surveillance)

Instrumented ground sites receive and record ELF/VLF transmissions from satellite

Data reduction and analysis to determine world wide communication capability of space-generated ELF/VLF

PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON AENSITY-TEMPERATURE EXPERIMENT SCH'D NO.	LEVEL
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SYSTEM CONCEPT II

Electron density and temperature probes make measurements on charged particle concentration vehicle plasma sheath, and vehicle potentials to complement ELF/VLF propagation measurements

Magnitude and direction of magnetic field is recorded for correlation with propagation characteristics

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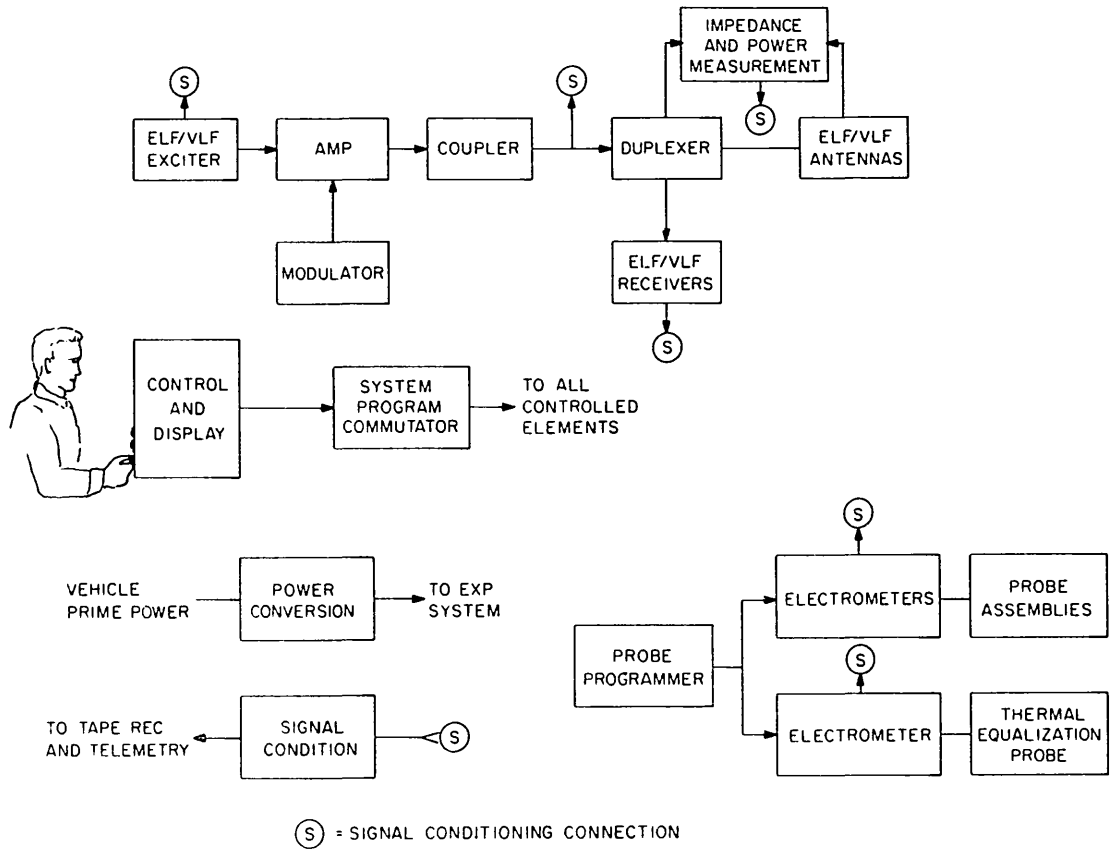
EXPERIMENT SUPPORT STUDIES

1. Coupling of Energy from Antenna to Magneto-Ionic Medium
   a. Loop vs dipole antenna
   b. Orientation of antenna with respect to magnetic field lines
   c. Antenna impedance in ionospheric medium
   d. Antenna size and weight studies

2. Measurement of Electron Density and Temperature
   a. Optimum technique for probing near-vehicle environment
   b. Techniques for measurement of vehicle potential
   c. Effect of ELF/VLF transmission on near vehicle ED & T

3. Magneto Hydro Dynamic Waves
   a. Vehicle effects in the production of
   b. Techniques for on board detection

4. Noise Environment
   a. Amplitude and frequency spectrum of noise environment
   b. Sources of ionospheric ELF/VLF noise



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APPROVED: E.F. Kulikowski

NAVY EXPERIMENT PROGRAM
ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT
Functional Block Diagram
LEVEL
SCH'D NO.

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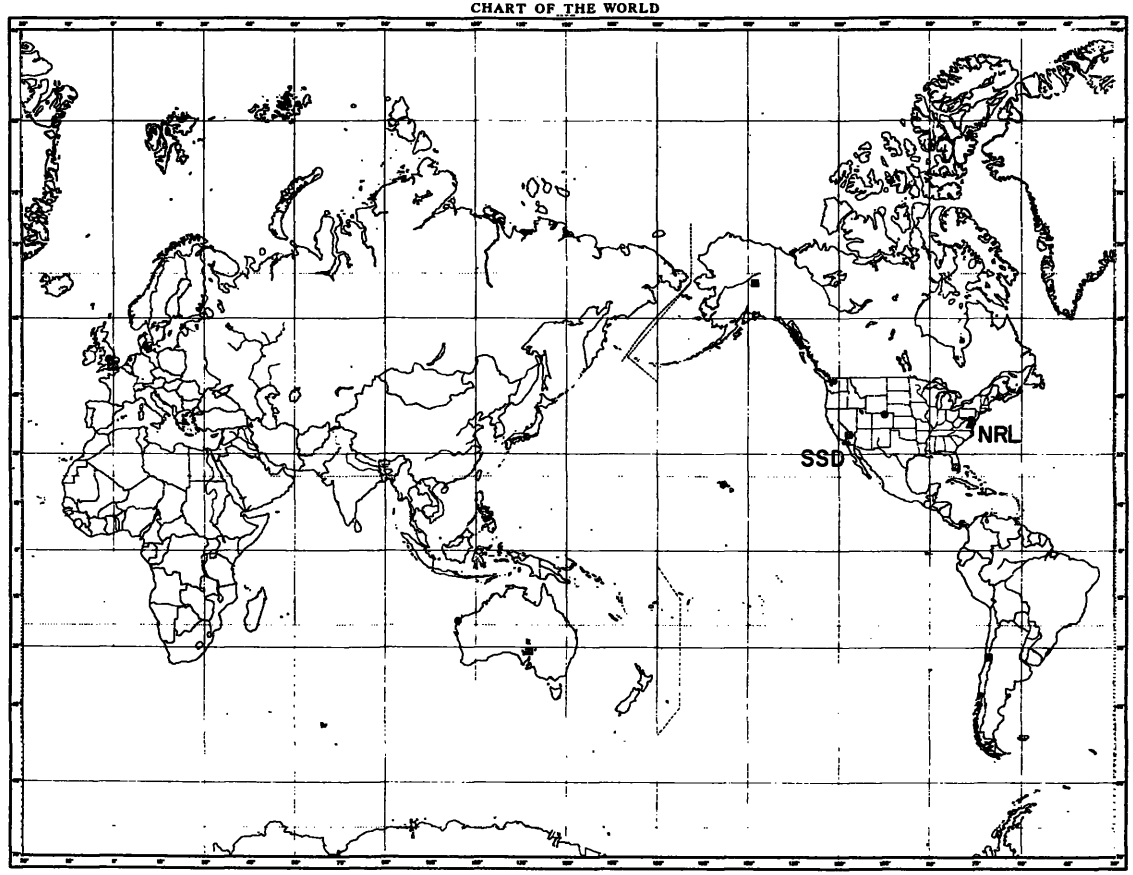
CHART OF THE WORLD



● VLF TRANSMITTERS
■ VLF RECEIVERS

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● Transmitters								
Balboa	9.0°N	79.6°W						
Rugby	52.4°N	1.3°W						
Ft. Collins	40.7°N	105.0°W						
Lualualei	21.3°N	158.2°W						
Jim Creek	48.3°N	121.9°W						
Annapolis	39.0°N	76.5°W						
Cutler	44.7°N	67.2°W						
N.W. Cape								
Yosami	35°N	137°E						
■ Receivers								
College	65°N	148°W						
Santiago	33.4°S	70.8°W						
Ft. Myers	26.7°N	81.8°W						
Slough	51.5°N	0.6°W						
Woomera	31.1°S	137.0°W						
Mojave	35.1°N	118.2°W						
▲ Data Red. Center	33.8°N	118.2°W						
SSD, Los Angeles								
NRL	38.9°N	77.0°W						

PREPARED BY: C.J. Kurner
APPROVED: E.F. Kulikowski

NAVY EXPERIMENT PROGRAM
ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT
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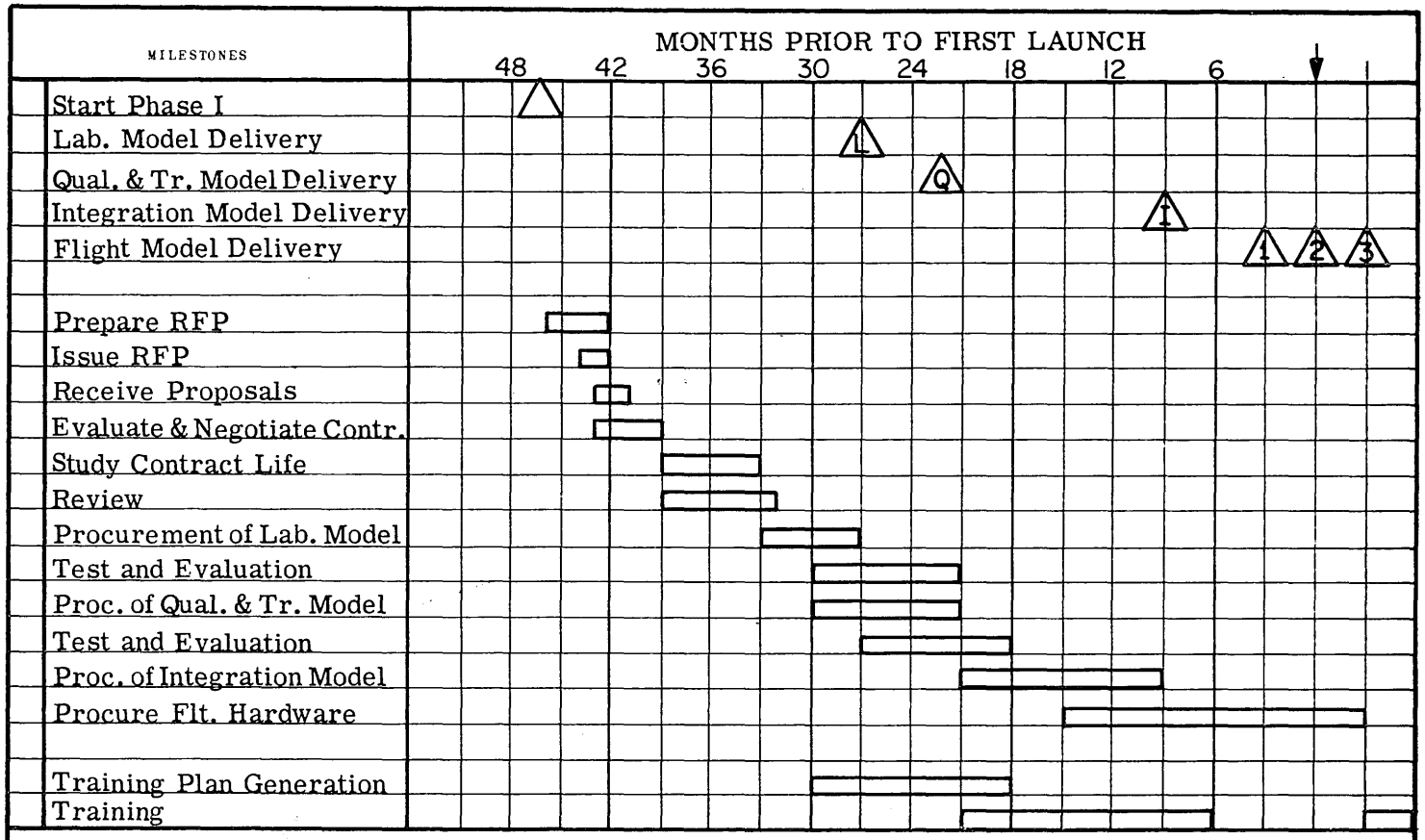

NOTES: L - Laboratory Checkout Model
Q - Qualification and Training Model
I - Integration Model
1,2,3 - Flight and Backup Models

PREPARED BY: C. J. Kurner
APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM
ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE PROGRAM
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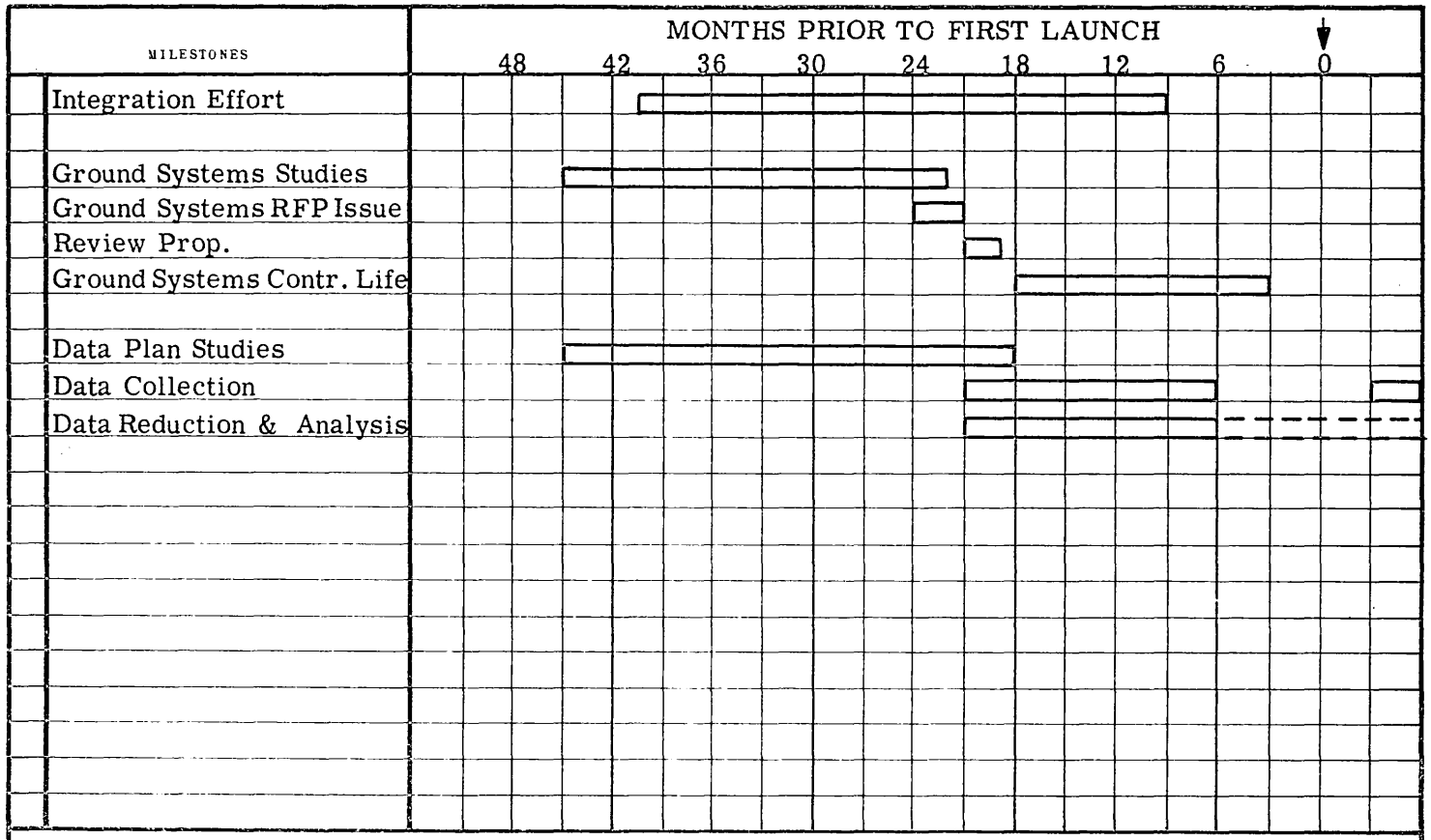

NOTES:

PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

NAVY EXPERIMENT PROGRAM

ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE PROGRAM

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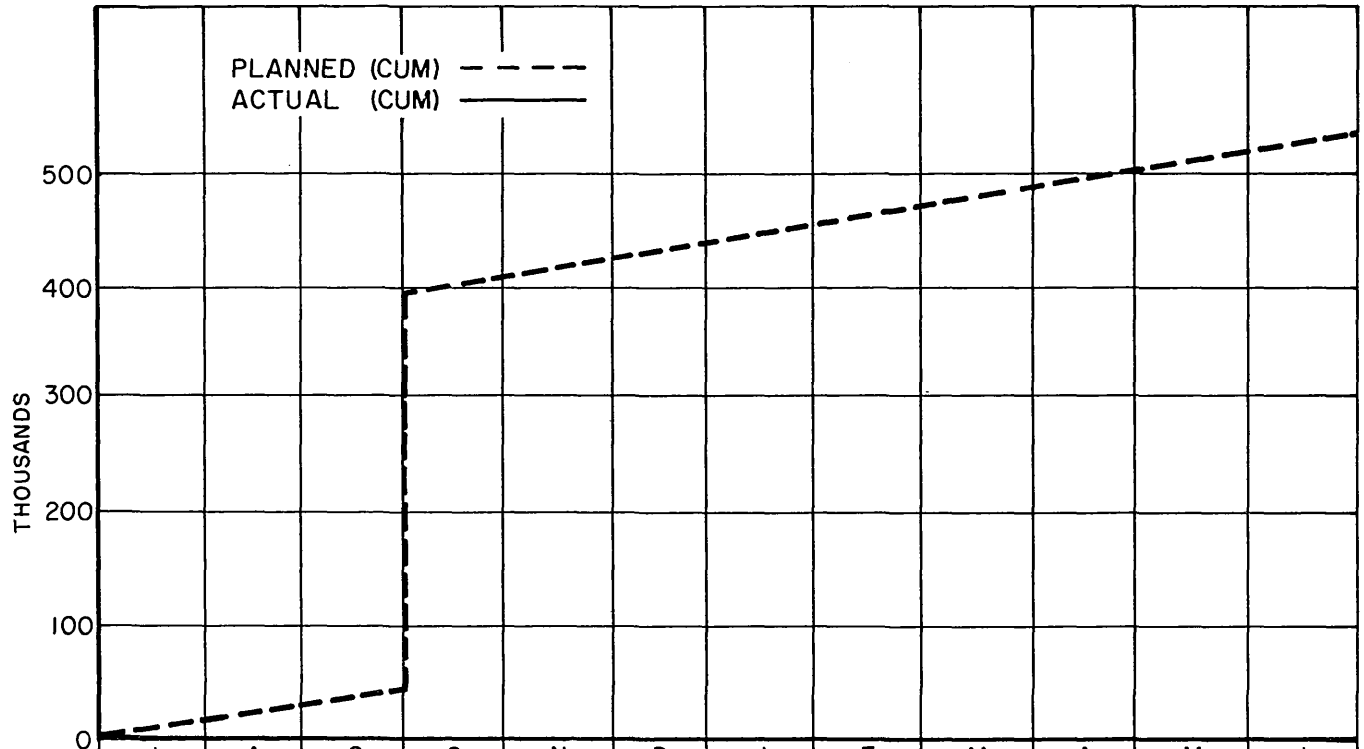

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			1965					1966				
PLANNED	15.0	30.0	45.0	410.0	425	440	455	470	485	500	515	535
ACTUAL												

PREPARED BY: C.J. Kurner

APPROVED: E.F. Kulikowski

ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT
Fiscal 1966 Funding Plan

LEVEL

SCHED NO.

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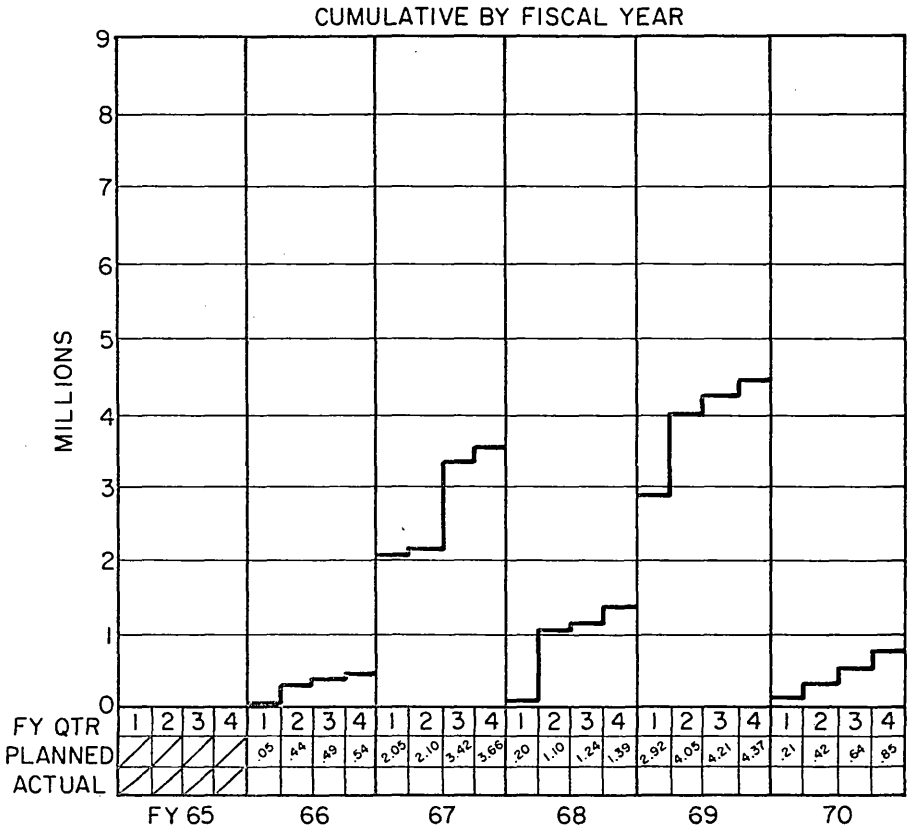
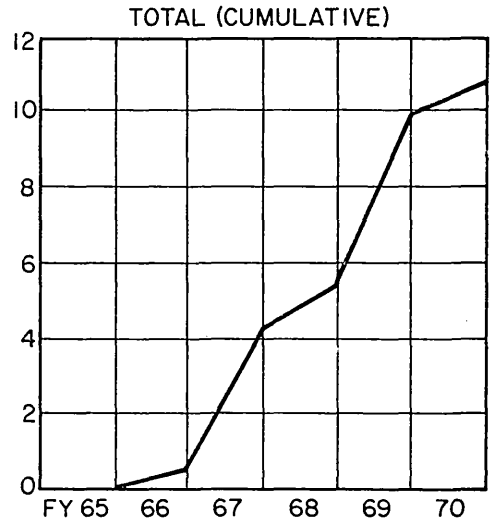
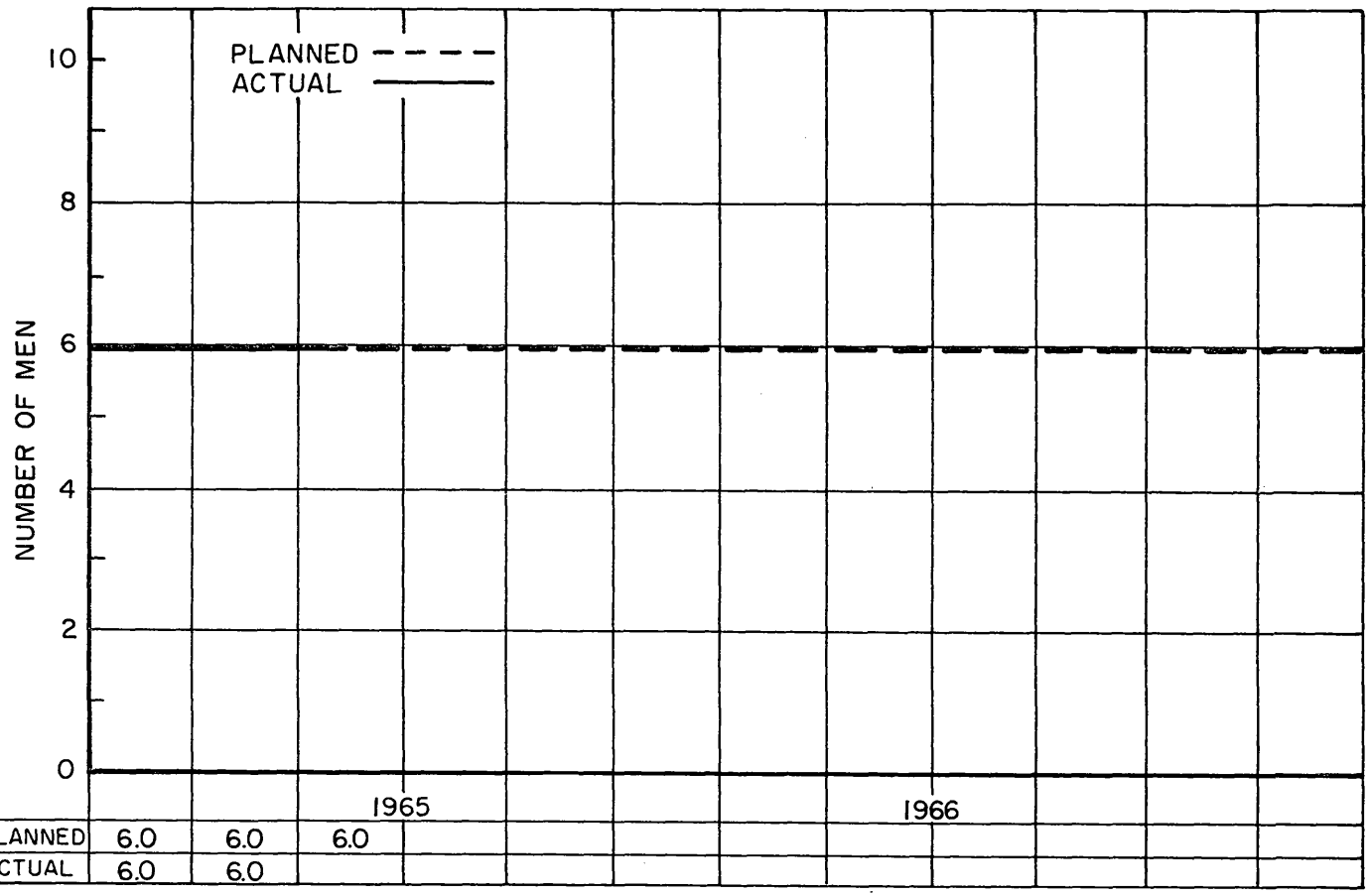




PREPARED BY: C. J. Kurner APPROVED: E. F. Kulikowski	ELF-VLF PROPAGATION/ELECTRON DENSITY - TEMPERATURE EXPERIMENT CUMULATIVE FUNDING PLAN (LEVEL)	ORIGINAL SCHEDULE APPROVAL LAST SCHEDULE CHANGE STATUS AS OF 9-15-65 PAGE OF PAGES



PLANNED	6.0	6.0	6.0									
ACTUAL	6.0	6.0										

PREPARED BY: C.J. Kurner

APPROVED: E.F. Kulikowski

ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT

Fiscal 1966 Manpower Plan

LEVEL

SCHED NO.

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EXHIBIT C.13

7000-101:WCH:jak
NRL Prob R03-06
SER: 7175

From: Director, U. S. Naval Research Laboratory, Washington, D. C. 20390
To: Officer-in-Charge, Navy Field Office for MOL (MP-11)
SSD, Air Force Unit Post Office, Los Angeles, California 90045

Subj: Monthly progress report on Manned Orbiting Laboratory program (U)

Ref: (a) BUWEPS WEPTASK RT 7045020/6521/F019-05-02 Ser 08985 of 1 Jul 1965

Encl: (1) One copy "Preliminary Redefinition of Objectives and Configuration for Consolidated ELF-VLF Propagation/Electron Density and Temperature Experiment"
(2) One copy definition of objectives of and equipment configurations for the "Orbital Plasma Characteristics (S-22)" program

1. Enclosures (1) and (2) are submitted in partial fulfillment of the requirements of reference (a), particularly with respect to Tasks I and II.

2. Work will continue to define further each one of the subtasks.

Copy to:
BUWEPS (RT) (w/encls)
5110
53203

Unclassified when enclosures are removed.

PRELIMINARY REDEFINITION OF OBJECTIVES AND CONFIGURATION FOR CONSOLIDATED ELF-VLF PROPAGATION/ELECTRON DENSITY AND TEMPERATURE EXPERIMENT

TASK I - REDEFINITION OF OBJECTIVES

The ELF-VLF Communication Propagation Experiment (S-1) and the Electron Density and Temperature Experiment (S-23) have been consolidated into a single undertaking. In addition, the scope of the experiment has been broadened to include the investigation of the generation, detection and characteristics of magnetohydrodynamic waves in the ELF-VLF spectrum. The decision to effect this consolidation was based primarily on the complementary nature of the two earlier experiments, and the similarity of the ancillary needs for both (e.g., magnetometer data, vehicle attitude data.).

The consolidated experiment has been redefined to emphasize the military technology aspects of the system and to provide a basis for an operational communication system.

The principal objective in the conduct of the experiment is to demonstrate a world-wide ELF/VLF communications system employing an orbital vehicle as one of the terminals. Long-range transmission at VLF has long been utilized by the Navy for communications among widely dispersed forces. The location of an ELF-VLF transmitter in a space vehicle is expected to enhance this capability and afford a world-wide service from a relatively small mobile platform. The ELF-VLF transmissions should also provide a means for communicating between widely separated earth orbiting vehicles.

Coupling of electromagnetic waves from antennas to a magneto-ionic medium at ELF-VLF is currently not well understood. The effects of the motion of space craft in this medium are similarly only partially known. For these and other reasons, it is felt desirable that, concurrently with the conduct of the propagation experiment, measurements be made on the nature of the ionosphere, the plasma sheath surrounding the vehicle and its outboard structures (antennas), and on the spatial and temporal variation of these quantities. In addition, the excitation of the antennas at relatively high power levels may produce changes in the near-vehicle charged particle concentration, and such perturbations should be monitored and measured for correlation with the propagation characteristics.

The motion of the MOL in the ionosphere may result in the launching of magnetohydrodynamic (MHD) wave modes which are in the ELF-VLF spectrum. Excitation of the transmitting antenna may similarly launch wave modes other than the electromagnetic waves at the excitation frequency. It is proposed that the on-board ELF-VLF receiver complex be utilized to detect such waves and thus to provide a means for observing the motion of vehicles in the ionosphere. (Detection of MHD waves at other frequencies has similarly been proposed.) Theoretical and experimental investigations related to the generation and propagation of these MHD wave modes

are still in their infancy and much remains to be learned. As part of the investigation of the MHD waves, the ELF-VLF noise spectrum present in the ionosphere needs to be examined. The receivers in MOL as part of the consolidated experiment are also expected to provide valuable information on the nature, origin and spectral density of the ELF-VLF noise trapped within the ionosphere.

The experiment program as currently defined is flexible in approach and configuration. Additional study is under way to determine whether additional objectives can be established and whether the current objectives are fully responsive to the MOL Program goals.

The consolidated experiment has evolved into five major areas. A brief summary of each of these areas is presented to provide a word picture of the scope of the experiment.

1. PROVIDE ELF-VLF TRANSMISSION CAPABILITY ON MOL

This area has as its principal effort the definition, design, implementation, and operating concepts of the ELF-VLF signal transmission capabilities from the MOL. This includes the generation and amplification of ELF-VLF signals at suitable power levels, the matching of the signals to an antenna(s), and for providing effective monitoring and control of the experiment variables.

2. RECEIVE AND RECORD SIGNALS ON MOL

This area is concerned with providing a capability to observe the ELF-VLF spectrum and to record both known ground-based signal sources and those observed but not necessarily expected. Implicit in this is the capability to receive, detect and record magnetohydrodynamic waves in the frequency spectrum of interest and to receive and record samples of the ELF-VLF noise background of the ionosphere which may be present.

3. PLASMA MEASUREMENTS

This deals with the instrumentation required for the measurement of ionospheric charged particle concentrations, particle temperatures, near-vehicle sheath effects, vehicle potentials and potential gradients. The system will be sensitive to changes in the measured quantities caused by spatial and temporal effects, the effects produced by ELF-VLF transmitter power level and frequency, and by effects of vehicle motion and attitude in the medium.

4. GROUND STATION RECEPTION OF MOL ELF-VLF TRANSMISSIONS

This is associated with the instrumentation required at suitably located ground stations for the determination of propagation characteristics for MOL transmitted signals. This

instrumentation will also reflect the possible existence of MOL-excited MHD waves and will attempt their detection. The selection of receiving sites will consider the MOL orbit, surface conditions, and antipodal effects.

5. INTERFACE OF EXPERIMENT WITH MOL PROGRAM

Effort under this area will ensure that the mechanical, electrical, human factor, and ground support elements which contribute to the satisfactory conduct of the experiment have been considered. The interface of the consolidated experiment with other on-board experiments, with signal conditioning and recording facilities will be part of this area. Provision will be made for recovery of the data from the telemetry receiving sites in a format suitable for processing.

This brief tabulation of Experiment areas provides a measure of the scope of the consolidated experiment. Effort is currently directed toward defining the parameters of interest in each area and in establishing the limit values for these parameters.

The conduct of the ELF-VLF Propagation/Electron Density-Temperature Experiment will yield a considerable amount of data recorded on the MOL vehicle and at the ground receiving sites. Data reduction, analysis and interpretation are expected to yield, for example, the following results:

1. The propagation parameters of an ELF-VLF space-to-ground link will be determined. If possible, space-to-space communications at these frequencies will also be investigated. Ground-to-space paths will yield information on propagation in reverse direction and will reflect non-reciprocity of the path, if such is the case.

2. Optimum antenna configurations for communication in the 300 cps - 30,000 cps frequency range will be determined, as will the dependence of propagation efficiency on antenna orientation with respect to the earth's magnetic field. Antenna impedance will be monitored over the range of variation of the frequency, power level, antenna configuration and orientation.

3. A comprehensive survey of the ELF-VLF signal environment at MOL orbital altitudes will be conducted. This will include measurement of background noise level.

4. Electron and ion concentrations in the ionosphere will be determined as a function of vehicle position. This will provide day-night, seasonal, and to a limited degree, height variation of these concentrations.

5. The plasma sheath surrounding the orbiting vehicle will be investigated. Charged particle concentrations, sheath potentials and potential gradients will be determined. The effects on the sheath of antenna and boom deployment, vehicle attitude and position and on-board electromagnetic radiation of various frequencies and power levels will be determined.

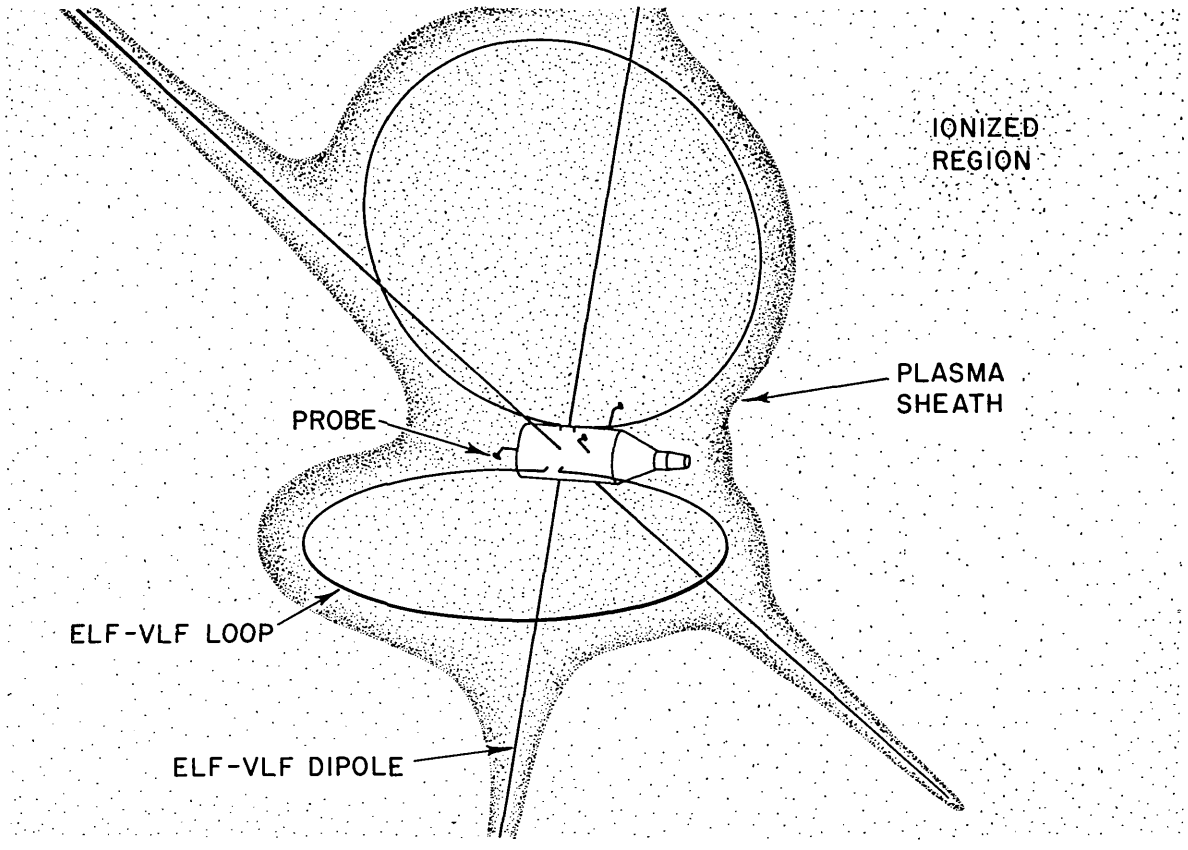
TASK II - REDEFINITION OF EQUIPMENT

The preliminary redefinition of the equipment configuration for the consolidated experiment has resulted in two classes of experiment equipment: those components which must interface with the vehicle exterior and the space environment (e.g., antennas, booms, sensors); and those components which form part of the MOL electronics complement.

Figure 1 is an artist's conception of the MOL on orbit with deployed ELF-VLF antennas and plasma sensor booms. Although many combinations of antenna-boom configurations are possible, ultimate selection of a particular set will reflect trade-offs of physical and economic factors against performance. Work is currently under way to determine the performance of each combination and to define the weight, size and power requirements of the various combinations considered.

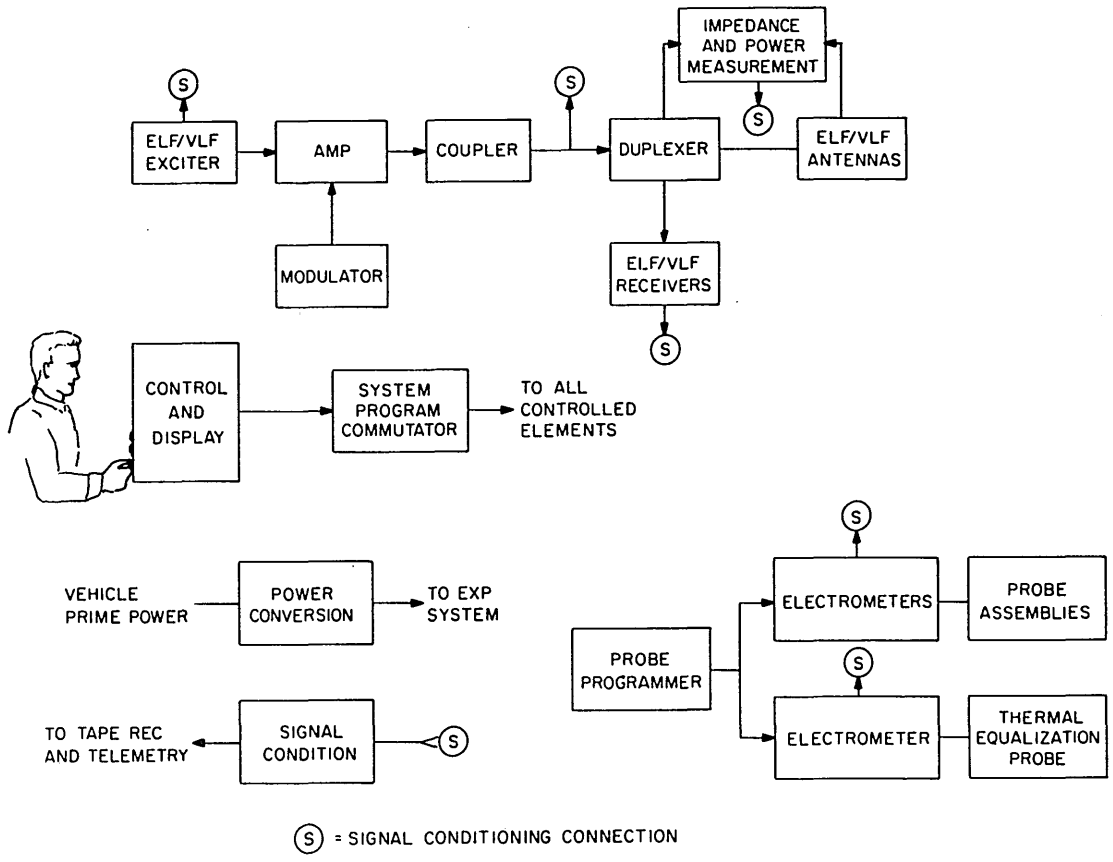
The block diagram of Figure 2 presents a functional analysis of the control, display and data collection portions of the experiment. Detail definition of each of the functions outlined in the block diagram, and determination of parameter limit values is being pursued. The interface of the various blocks with power systems, data conditioning, recording and telemetry will be considered as details of the MOL system are further defined. Interface effects resulting from common usage of on-board display and control devices must similarly be considered.

D. J. KURLER
NRL, Code 5115-A



PREPARED BY: C.J. Kurner APPROVED: E.F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT SCH'D NO.	LEVEL
		ORIGINAL SCHEDULE APPROVAL DATE LAST SCHEDULE CHANGE DATE STATUS AS OF 15 Sept. 1965 DATE PAGE ___ OF ___ PAGES

Figure 1



PREPARED BY: C.J. Kurner APPROVED: E.F. Kulikowski	NAVY EXPERIMENT PROGRAM ELF-VLF PROPAGATION/ELECTRON DENSITY-TEMPERATURE EXPERIMENT Functional Block Diagram SCH'D NO.	LEVEL ORIGINAL SCHEDULE APPROVAL DATE LAST SCHEDULE CHANGE DATE STATUS AS OF 15 Sept. 1965 DATE PAGE ___ OF ___ PAGES

Figure 2

EXHIBIT C.14

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27
5010-108

UNITED STATES GOVERNMENT

Memorandum

5110-166:CJK:eam

TO : Code 7000
Via : Code 5100

DATE: 22 October 1965

FROM : Code 5110

SUBJECT: October 1965 Monthly Progress Report on WEPTASK RT 7045020/6521/F0-19-05-02; Exploitation of Space Plasma Effects for Satellite Communications, Command and Control and Anti-Detection Capabilities in a Satellite Surveillance System (U)

1. The principal effort during the month has been the continuation of the redefinition of the consolidated ELF-VLF Propagation/Electron Density-Temperature and Magnetohydrodynamic (MHD) Wave Experiment. Particular emphasis has been placed on the enhancement of the operational capabilities of the system. This report presents a summary of the factors under consideration toward achieving this enhanced capability.

2. The limitations of UHF and microwave transmissions to line-of-sight distances or to longer ranges at the expense of large, carefully-oriented antennas precludes the use of this portion of the frequency spectrum as a world-wide communication link to widely dispersed naval forces. The HF region, though widely used, requires frequent changes in operating frequency, is subject to rapid and severe fading and, at times of solar disturbances, is almost completely unusable. Furthermore, atmospheric nuclear bursts can prevent HF communications for many hours following the burst.

3. The need for a reliable long-range communications capability for the naval service has led to the development of a system utilizing the VLF portion of the radio spectrum. To achieve this long range capability and the ability to communicate with submerged vessels, extremely high power transmitters are employed, together with large antenna array installations. The major part of this experiment is to demonstrate that this long range capability may be achieved utilizing space vehicles carrying relatively low power transmitters and reasonable antenna structures.

4. Numerous rocket probes and satellites instrumented with VLF receivers and antennas (e.g., LOFTI I, LOFTI II-A, ALOUETTE, FOGO), have shown that VLF propagation from ground to space can be effected. Propagation in the reverse direction, from space to ground, has also been shown to exist, even though no known flights of VLF transmitter instrumented space vehicles have been made. Observations of "whistler" signals and other VLF astropheric phenomena have been made. They are known to have been propagated within the magnetosphere prior to arrival at ground receiving sites. The VLF reception aboard space vehicles indicates that the frequency of occurrence of these signals within the ionosphere is at least an order of magnitude greater than that observed at ground level. The investigation of the ELF-VLF signal and noise environment within the ionosphere, and the coupling mechanisms by which this energy reaches the free-space conditions of the atmosphere forms a major part of the propagation experiment. Included in this investigation will be the effects of frequency, wave polarization and direction of propagation relative to the orientation of the earth's magnetic field.

5. In addition to its role as a communication terminal, the utilization of the experiment ELF-VLF receiver complex as a means for the detection of MHD waves will be studied. It has been postulated that the movement of spacecraft at orbital velocity through a magneto-ionic medium may excite and launch such MHD wave modes. Interaction of electric fields, such as are produced by satellite radio transmissions, with the ionospheric plasma may similarly excite such waves. Although these concepts are currently untested, their potential application as satellite detection techniques should not be overlooked.

6. In support of the propagation aspect of the experiment, a number of complementary investigations are required. These include antenna impedance measurements and a diagnostic probing of the plasma environment of the vehicle.

7. Theoretical studies have been conducted which show that the effective length of an antenna in a magneto-ionic medium such as the ionosphere may be several orders of magnitude greater than that of the same antenna in free space. Thus, highly efficient VLF antennas of reasonable size may be possible in the ionosphere. Impedance measurements made on receiver-equipped space probes have been somewhat conflicting and further investigation, both theoretical and experimental, is necessary. The effects of antenna orientation with respect to the magnetic field lines also needs further study. The behavior of antenna impedance as frequency and excitation power levels are varied is completely unknown for an ionospheric environment. Impedance variation may be experienced due to alteration in the bounding plasma medium (e.g., breakdown, field-induced ionization) as the frequency and excitation levels are varied.

8. The complementary investigation of the plasma environment of the vehicle and its attendant antenna structures will provide needed data for effecting optimum matching of antennas to the propagating medium and will provide the data for correlation of path loss calculations with the nature of path along which the energy is propagated. Information is needed on the magnitude and variation of the ambient plasma densities in which the antennas are imbedded, the nature of the plasma sheath immediately surrounding the vehicle, the potentials and potential gradients which exist on the vehicle and their variation with changes in transmitter frequency, power level and antenna lengths.

9. Studies designed to provide insight into some of the aforementioned problem areas are under way. A mathematical analysis of the coupling of energy from an antenna to an anisotropic plasma medium is being conducted. From this analysis it is hoped that an optimum antenna configuration and orientation can be deduced and incorporated into the experiment plan for in situ verification during the flight program. This is a continuation of work originally reported under references (a) and (b).

10. A comprehensive survey of plasma diagnostic probe techniques is being conducted to ensure that the experiment instrumentation is best suited for the determination of those parameters which affect the launching and propagation of the VLF transmissions.

5110-166:CJK:emm
22 October 1965

11. The results obtained from these and subsequent efforts which are designed to provide an enhanced capability for the experiment will be reported as they become available.

12. In addition to the "in-house" efforts toward providing a meaningful investigation in the several areas discussed, it is planned to contract for a design study conducted by an independent source. The Request for Proposal for this design study is nearly complete.

References:

(a) Electromagnetic Research Corporation Report No. ONR-4250-1 of 30 April 1965, "Satellite Antenna Radiation Properties at VLF in the Ionosphere".

(b) Ament, W. S.; Katzin, J. C.; Katzin, M.; and Koo, B. Y. C.; "Impedance of a Cylindrical Dipole having a Sinusoidal Current Distribution in a Homogeneous Anisotropic Ionosphere"; Radio Science Journal of Research, NBS/USNC-URSI, Vol. 68D, No. 4; April 1964.

C. J. KURNER

EXHIBIT C.15

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

5110-188:EVK:esm

TO : Code 7000

DATE: 24 November 1965

Via : Code 5100

FROM : Code 5110

SUBJECT: Progress Report for November 1965 - NDL Experiments 81/823; forwarding of

Ref : (a) BUSHIPS Conf Ser 08985 of 1 July 1965

Encl : (1) NDL Memorandum for File 5110-186:EED of 24 Nov 1965
(2) Progress Report for Month of November 1965; 5110-187:CJK:esm of 24 Nov 1965

1. In accordance with paragraph 5 of reference (a), enclosures (1) and (2) are forwarded.

E. F. KULIKOWSKI

Unclassified when enclosure (2) is removed.

5110-187:CJK:eam
NRL Prob R07-15
24 November 1965

PROGRESS REPORT FOR THE MONTH OF NOVEMBER 1965

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02 (U)

1. The redefinition of the experimental tasks which have evolved as a result of the consolidation of the ELF/VLF Propagation Experiment, the Electron Density and Temperature Experiment and the Magnetohydrodynamic Wave Investigation continues. Work has continued on the analysis of probe techniques for plasma diagnostics, and on the mathematical treatment for describing the coupling of energy from an antenna to a surrounding magneto-ionic medium. Work initiated during this reporting period has been directed toward the determination of the data requirements of the experiment, and on the investigation of the ELF-VLF signal and noise environment which may be expected at a ground receiving station.

2. The investigation of probe techniques suitable for conducting "in-situ" measurements of the ionospheric plasma and of the plasma sheath in the immediate vicinity of space craft and its attending outboard structures (antennas, etc.) has resulted in the preparation of a memorandum for file 5110-186:RND:eam, which provides a summary description of several of the currently used probe techniques, together with a brief description of the operating principles involved for each type. The memorandum is not to be considered as an all-inclusive listing of probe types, but merely as an indication of those types which have enjoyed considerable usage in rocket and satellite ionospheric plasma investigations. In the continuing study of this aspect of the experiment, other probe techniques will be examined and the merits and disadvantages of each considered in achieving the aims of the experiment.

3. The theoretical analysis of the coupling (radiation) of energy from an antenna to the surrounding magneto-ionic medium is progressing slowly. Uncertainty in the form of suitable antenna source energy distributions, the effect of the plasma sheath on these distributions and the complexity of integrations required, suggest that any solutions that may be obtained may be only partially representative of the physical nature of the problem. Any additional knowledge of these effects will, so far as is mathematically tractable, be incorporated in this analysis as they become available in the literature.

4. During the past month a review of the data requirements for the consolidated experiment has been initiated. As a first step the data associated with the propagation portion of the experiment will be assessed. Consideration is being given to all parameters of the experiment which require measurement. Among the items considered will be amplitude and frequency content of the parameters, sampling rates required to provide adequate digital coding of the data and constraints which may be imposed by the central on-board data collection facility.

5. Analysis of the data requirements is also expected to indicate the amount, if any, of permanent analog data storage which must be provided on board the vehicle to achieve experiment goals. It is conceivable that sampling rates available from the central processor for digitizing of the experiment data may be inadequate (or perhaps marginal) for reconstruction of the original sensory data after receipt at ground stations via telemetry. If this proves to be the case, a requirement would exist for recording this experiment data on board the vehicle, in analog fashion on magnetic tape, for eventual physical recovery. Such data may be required to complete and/or validate that obtained via telemetry.

6. The data analysis conducted on the propagation subsystem will be incorporated as part of the overall ELF-VLF Propagation/Electron Density-Temperature/MHD Wave Experiment Data Plan. The Data Usage Profile generated for the original Electron Density and Temperature Experiment establishes the format planned for use and is expected to guide in the preparation of the usage profile for the consolidated experiment.

7. Elements of a ground receiving system for use at ELF/VLF have been installed in the laboratory. These provide the basis for conduct of preliminary experimental investigation of the signal and noise environment which may be encountered at a field site in this frequency range. The instrumentation currently installed (a LOFTI VLF ground station terminal) consists of a broadband receiver front end, local oscillators and i.f. amplifiers to provide narrow band reception at 10.0 KC/sec and 18.0 KC/sec. This equipment will be used to conduct a spectrum analysis of the band and to identify additional instrumentation requirements for the ground receiving sites to be operated as part of the experiment.

8. A design study to be conducted on award of a contract is planned to provide for an independent approach to achievement of the experiment goals. A Request for Proposal for such a contract has been prepared in rough draft form. Preparation of a smooth RFP and its issuance will be deferred pending further direction regarding experiment status and the necessary funding has been received.

C. J. KURNER

5110-186:RND:eam
NRL Prob R07-15
24 November 1965

MEMORANDUM FOR FILE

INTRODUCTION TO PLASMA PROBE FUNDAMENTALS

INTRODUCTION:

This paper is an introduction to the operation of some of the standard probes used in determining the characteristics of plasmas. The literature existing on each probe is both voluminous and complex. As an introductory survey, this paper avoids the mathematics and electronics and tries to concentrate on the fundamental principles of operation of the probes. Thus many things will be stated without mathematical justification, with the aim being to give the reader a feeling for the physical processes involved in the probe operation.

The five probes discussed are:

1. Electrostatic (Langmuir) Probe
2. Double Probe
3. Modified Double Probe
4. Resonance Probe
5. Thermal Equalization Probe

Before discussing each probe, a general introduction to the interaction of a conducting body with a plasma is given.

Consider an imaginary cube in a neutral plasma, Figure 1. The random motion of the charged particles leaves the net current flow across any surface of the cube zero. That is, the random current density $\bar{J}$ of particles crossing from one side of a surface to the other is

$$\bar{J} = \frac{n\bar{u}}{4} \qquad (1)$$

where n is the particle density and $\bar{u}$ is the average particle velocity.

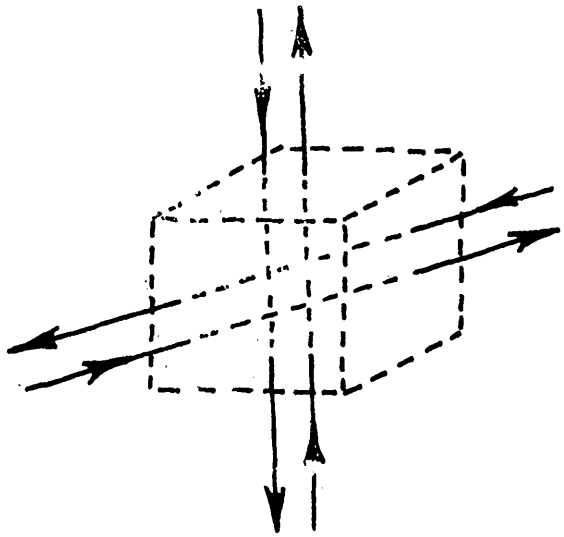


Figure 1

But since this is an imaginary surface, an equal current density exists for particles crossing in the opposite direction. This is true regardless of the charge of the particles. Since the mass of the ions are greater than the electrons, then in thermal equilibrium the average velocity of the electrons is higher than the average velocity of the ions.

Now all of a sudden let the walls of this imaginary cube become conductors, see Figure 2.

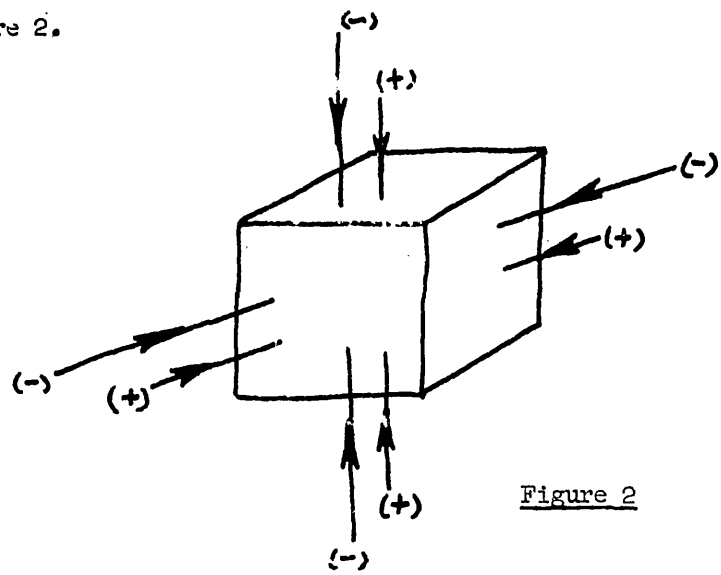


Figure 2

Then each wall sees only particles arriving from the outside, so that there is a net flow to each wall of electrons and ions. But since the average velocity of the electrons is higher than the ions, shown in Figure 3 by longer vectors, the walls receive a net flow of electrons and begin to become negatively charged, see Figure 3.

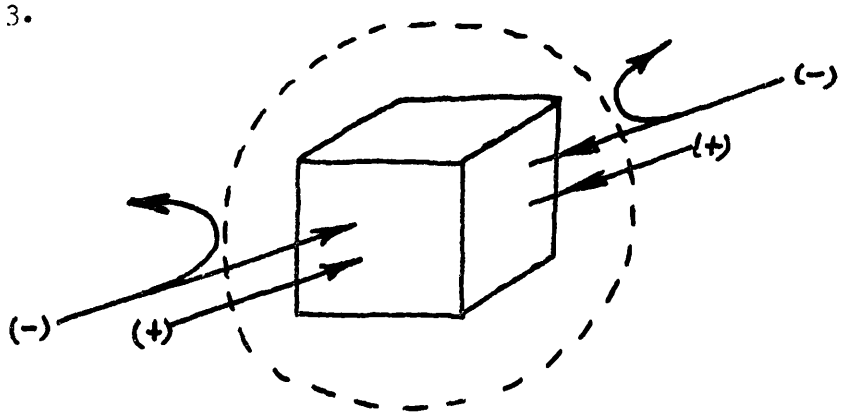


Figure 3

The potential of the walls now begins to repel the low energy electrons but allows some of the high energy electrons to collect on the wall. Eventually, an equilibrium condition will develop in which the small electron current to the walls will just cancel the ion current, resulting in a zero net current flow to the walls, see Figure 4.

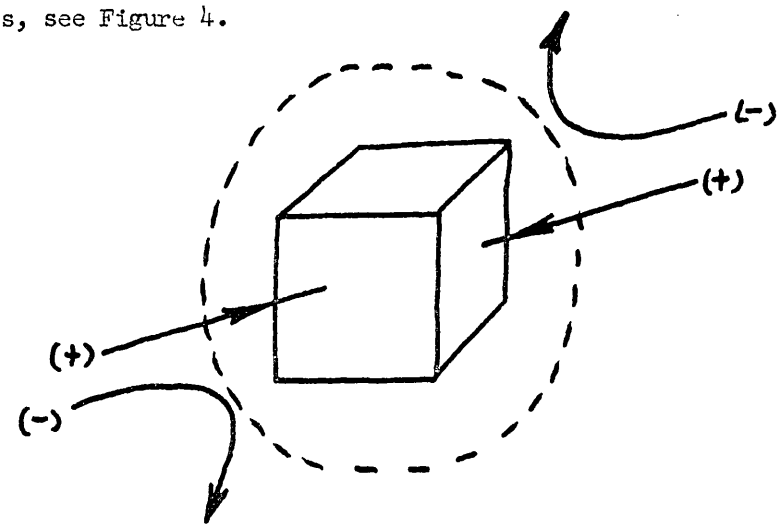


Figure 4

In this equilibrium state a sheath has developed around the cube which consists mainly of ions which shield the plasma from the negative potential of the walls.

ELECTROSTATIC PROBE:

The circuitry of this probe is shown in Figure 5.

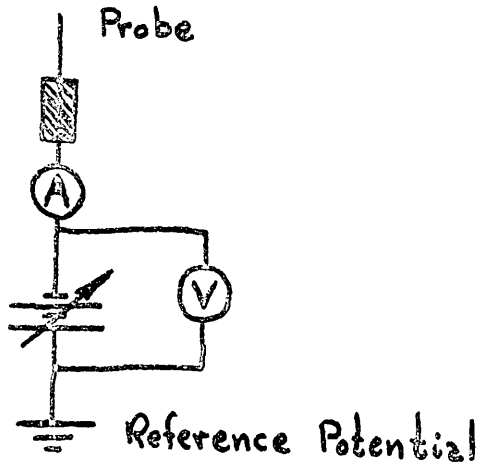


Figure 5

The voltage of the probe is varied while the current to the probe is measured. The geometry of the probe may be planar, cylindrical or spherical. In general, the probe characteristic will appear as shown in Figure 6.

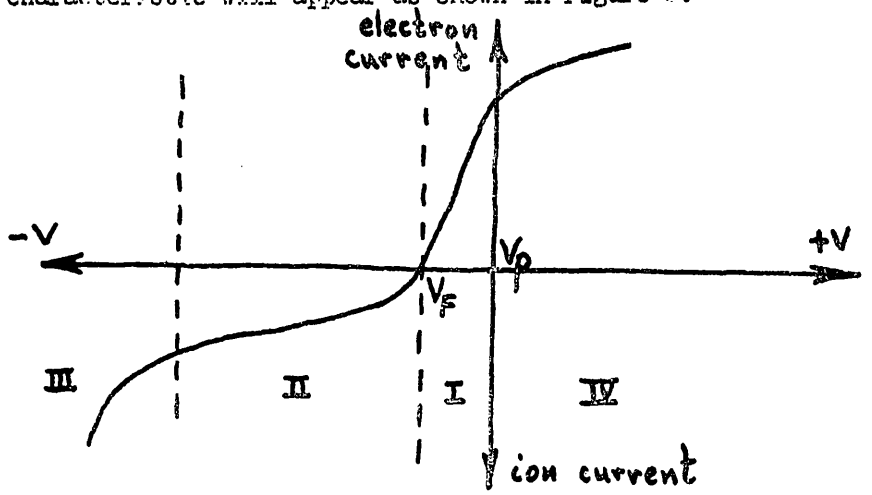


Figure 6

This current-voltage curve can be explained in the following way. Starting in region I, the probe is at some negative potential V_F (floating potential) with the net current to the probe being zero, as discussed in the introduction. As the potential of the probe is made more negative (region II), more electrons are repelled allowing a net ion current to flow to the probe. Increasing the negative potential increases the ion current. In this region the probe is said to be in ion-sheath operation; that is, the probe is operating with a sheath consisting mainly of ions (see Figure 4). In region III the negative potential becomes so great that the accelerated ions begin to knock electrons out of the wall which are naturally repelled from the wall, so that the added electron flow away from the wall appears as a positive flow to the wall, or tends to cancel the small electron current to the wall and the curve dips down sharply.

Again starting at V_F in region I, when the probe potential is made less negative, more electrons are allowed to be collected by the wall. When the probe potential becomes equal to the plasma potential V_P, there is no sheath and consequently no electrical forces on the particles. Then the higher random velocity of the electrons results in a net electron current to the probe. This current has to be continuously conducted away by the circuit for the wall potential to remain zero with respect to the plasma. As the probe potential is made positive (region IV), the positive charges are repelled and an electron sheath is formed preserving the neutrality of the plasma. In this region the probe is said to be in electron-sheath operation; that is, the probe is operating with a sheath consisting mainly of electrons (Figure 4 with signs of charges reversed).

If the probe is operating at a potential which is slightly negative with respect to the plasma potential, some of the electrons will have sufficient energies to penetrate the sheath and be collected by the probe. If the electron distribution is assumed to be Maxwellian, then analysis shows

$$\frac{d}{dV}\left(\ln |J_e|\right) = -\frac{e}{kT_e} \qquad (2)$$

where J_e is the electron current density, so that a linear dependence of $\ln |J_e|$ on voltage indicates a Maxwellian distribution and the slope of this straight line gives the electron temperature while the bend in the curve gives the density.

DOUBLE PROBE:

It was assumed that with the single electrostatic probe a convenient reference potential was available. In some cases this is not so, and a double probe may be used. The circuitry for this probe is shown in Figure 7.

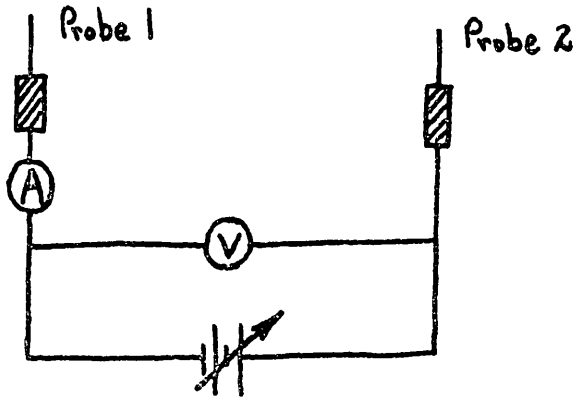


Figure 7

It is first assumed that the two probes are identical and the separation of the probes is such that there will be no mutual interference. When the potential difference V is varied, a characteristic curve results as shown in Figure 8.

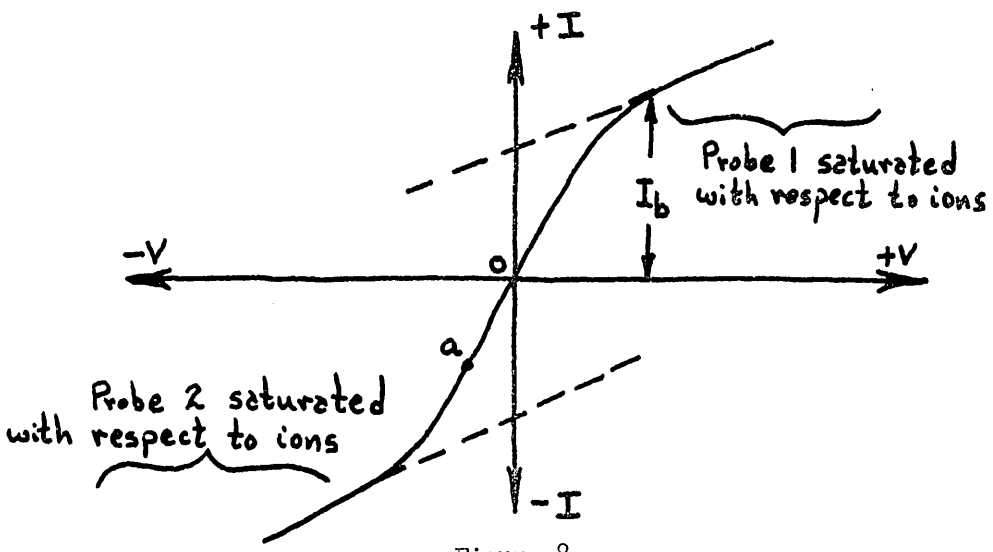


Figure 8

When the potential difference V between the two probes is zero, each probe will assume the same floating potential and the net current will be zero, see Figure 9.

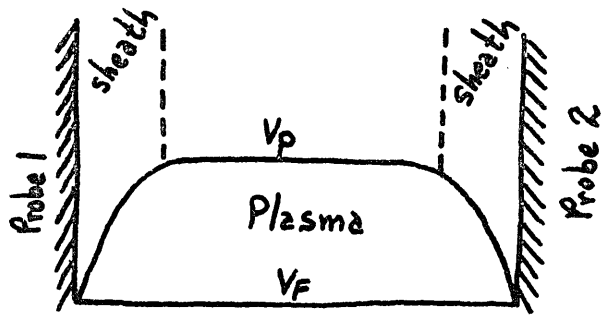


Figure 9

When the potential of probe 2 is made more negative, Figure 10, probe 1 moves closer to the plasma potential and allows more electrons to be collected while probe 2 repels more electrons.

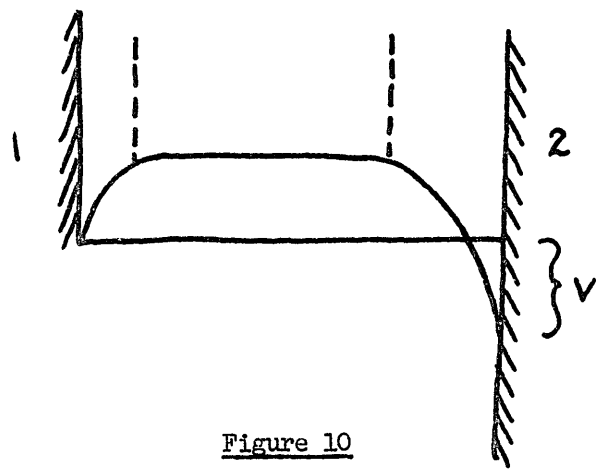


Figure 10

Thus the surplus electrons in probe 1 flow to probe 2 resulting in a current flow shown as some point "a" in Figure 8.

When probe 2 is driven very negative, Figure 11, the sheath around probe 1 is collapsed even more allowing more electrons of the plasma to be collected. Likewise probe 2 will receive practically no electrons and a high current flow from probe 1 to probe 2 will result.

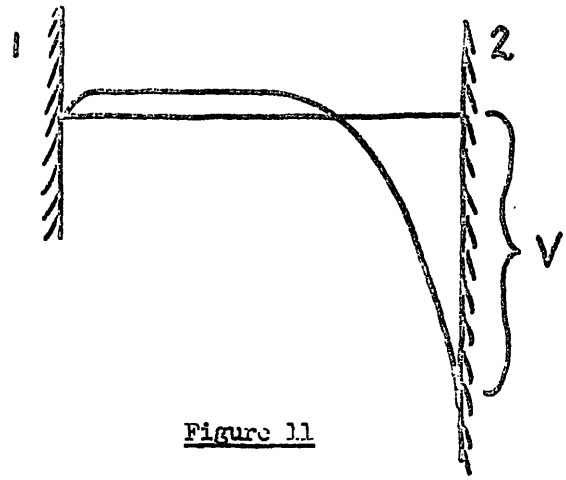


Figure 11

A further increase in the potential difference of the probes will have little effect on the current flow between them, for no more electrons can be collected by probe 2; therefore no more electrons need flow from probe 1. Thus, in this saturated condition, the current changes very little while the potential of probe 1 remains constant with respect to the plasma and the potential of 2 goes more negative along with V. Under these conditions probe 2 is considered saturated with respect to positive ions, see Figure 8.

Because the two probes are identical, the curve is symmetric about the origin. If the potential of the plasma differs at the two probes, the I = 0 point will be displaced along the V axis. Analysis of this probe gives

$$\ln\left[\frac{2I_b}{I_e} - 1\right] = -\frac{eV}{kT_e} \qquad (3)$$

where I_b is the probe current at the break point and I_e is the electron current. Since only electron current at potentials close to V_F can be accepted, the main contribution to the measured electron current will be from the high energy tail of the distribution. If the distribution function f(E) appears as shown in Figure 12, then the potential V_F of the probe repels the particles with energy below V_F but accepts those with greater energy.

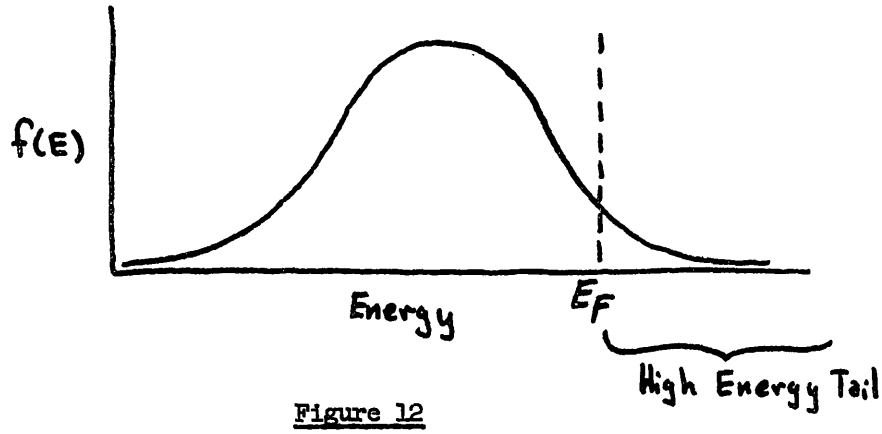


Figure 12

Thus from equation (3) the electron temperature can be determined while the bend in the curve at saturation levels gives the density.

MODIFIED DOUBLE PROBE:

As stated for the double probe, most of the electrons collected by the double probe will come from the high energy tail of the distribution. If the distribution is nearly Maxwellian, this type of probe is undesirable. This difficulty can be overcome by use of a double probe with the dimensions of one probe (collecting area) much greater than the other probe, see Figure 13.

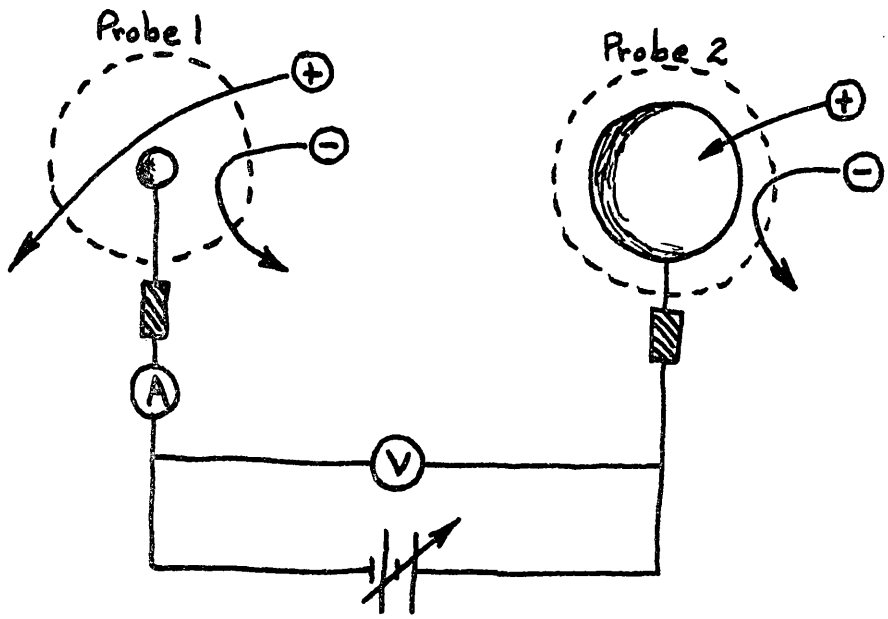


Figure 13

If the dimensions of the sheath with respect to the probe area are large (probe 1), the ion current collected by the probe will depend on the orbital motion of the ion. For example, if the velocity of the ions is very high when they enter the sheath region, many will merely be deflected and not collected. Under these conditions, the current is referred to as orbital-motion-limited. If, on the other hand, the sheath dimensions with respect to the probe area is small (probe 2), then practically all ions will be collected regardless of their orbital motion. Under this condition the current is referred to as sheath-area-limited. Through expressions for these two currents the characteristic curve for this probe system can be obtained which results in a curve very similar to the single electrostatic probe characteristic. Thus the problem of collecting only high energy electrons is greatly reduced, and the electron temperature and density can be determined as with the electrostatic probe.

RESONANCE PROBE:

The resonance probe consists of a small r.f. voltage superimposed upon the constant potential of the probe. The circuitry is shown in Figure 14.

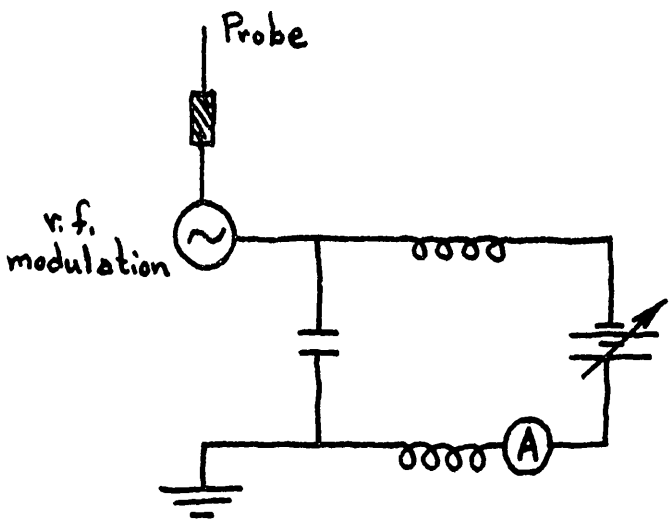


Figure 14

When the frequency of the modulation is swept through the plasma frequency, a characteristic curve results as shown in Figure 15.

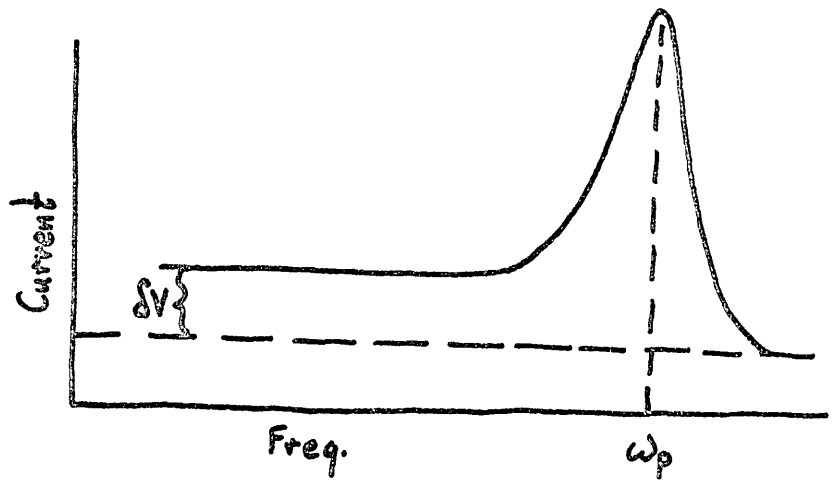


Figure 15

The peak of the curve appears at the plasma frequency ω_p while the half-width of the peak depends on the collision frequency. The distance δV of the curve from the reference line is proportional to the amplitude of the r.f. modulation. The curve can be explained in the following way, going from left to right in Figure 15.

In addition to the plasma parameters the radius of the sheath around the probe is primarily determined by the static potential applied to the probe, while the penetration depth of the r.f. modulation into the plasma depends on the frequency. Considering the dielectric constant of the sheath to be nearly the same as free space, then at frequencies below the plasma frequency the penetration depth of the r.f. modulation is less than the sheath radius resulting in the electric field of the modulation being shielded out within the sheath. Thus the incident current to the sheath will be unaffected by the modulation, and only when the particles get near the surface of the probe are they affected by the electric field of the modulation. This leaves the current practically independent of frequency. As the frequency approaches the plasma frequency, the penetration depth increases allowing the electric field of the modulation to enter the plasma and disturb the motion of the incoming particles. This fluctuating current will be superimposed on the steady current and its time average thereby increasing the current through the circuit.

consistent with any resonance phenomenon, this effect will have a maximum at the plasma frequency. As the frequency is further increased, the effect of the oscillating electric field of the modulation on the incoming electrons will diminish and eventually have no effect at all. That is, the frequency will be so high that the electrons will not see any fluctuations and behave as if they were in the original static field with no r.f. modulation.

From the characteristic curve the temperature of the electrons can be determined from the first part of the curve while the peak will give the plasma frequency. From the plasma frequency the density can be determined and the collision frequency measured by the half-width of the peak.

THERMAL EQUALIZATION PROBE:

This probe is designed to measure the potential acquired by a conductor immersed in a plasma. As discussed in the introduction, a conducting body placed in a plasma will assume a floating potential such that the flux of the incoming electrons and ions will equate resulting in a zero net current to the walls. This leaves a sheath around the body causing a potential difference to exist between the walls and the plasma.

The Thermal Equalization Probe (T.E.P.) is attached to, but electrically insulated from, the body whose potential with respect to the plasma is to be determined, see Figure 16.

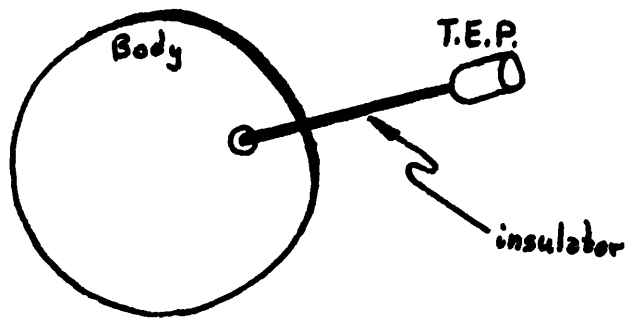


Figure 16

The T.E.P. consists of a hollow conductor in which is a heater. Initially, the probe is at the floating potential with zero net current to the probe (equal

vector lengths in Figure 17a). When the heater is turned on, the temperature of the T.E.P. rises and begins to emit electrons like the cathode of a vacuum tube. This out-flowing electron current tends to cancel the incoming electron current allowing the incoming ion current to make the probe potential less negative, see Figure 17b.

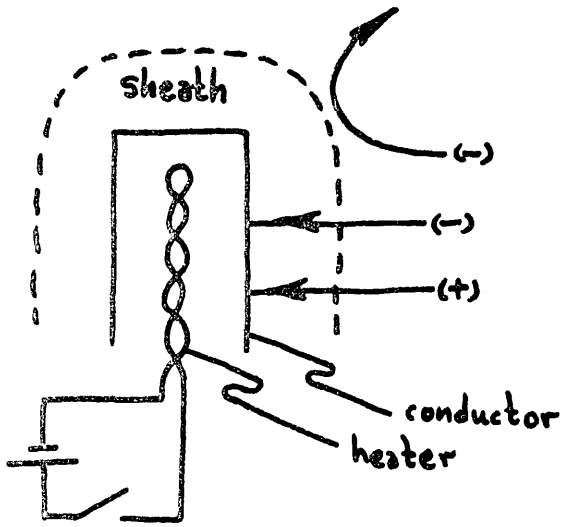


Figure 17a

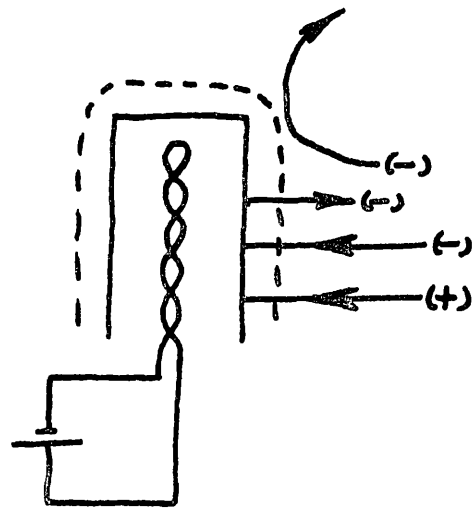


Figure 17b

As the temperature of the probe is increased, the probe potential and sheath thickness decrease. Constantly increasing the temperature will cause the probe potential to approach the plasma potential. When this happens, a further increase in temperature will force the probe positive with respect to the plasma, at which point the potential versus temperature curve (Figure 18) makes a sharp bend, after which it slowly rises as the temperature increases.

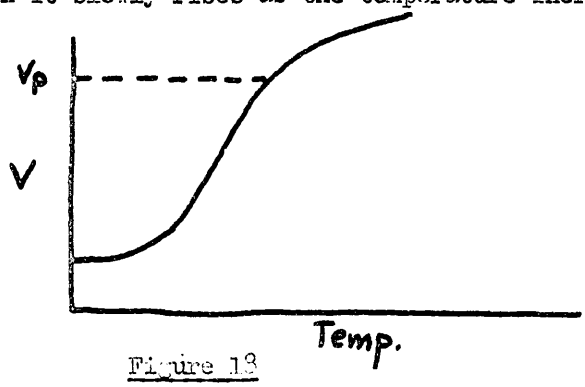


Figure 18

If the potential between the probe and the body is monitored, then a probe whose temperature is set to operate slightly above the bend of the curve will provide a continuous measure of the body to plasma potential. Analysis of the dependence of the voltage-temperature curve on the plasma parameters results in the following conclusions:

1. The T.E.P. voltage emission characteristics are nearly independent of all parameters except the plasma density.

2. The slope of the curve above the bend is uniform and proportional to probe temperature.

3. The electron density determines where the voltage-temperature curve crosses the plasma potential axis.

PROBE DIFFICULTIES:

Each probe has its own operational problems, but there are also many difficulties that are common to all types. The probe characteristic curves are explained through theoretical analyses of the probe-plasma interactions. This necessitates the postulation of parameters and processes that govern the probe operation and then formulating these mathematically. Hopefully, this leads to solution which correspond to the measured characteristics. If these probes are to operate in the ionosphere where the plasma parameters and processes not only differ greatly from the laboratory plasmas, but are also naturally occurring and thus uncontrolable, then the formulation of the analyses of the probe operations must be reviewed carefully. The effects of such things as ultra-violet radiation causing photoelectric effects, high probe velocities (since they will be attached to satellites), disturbances by other experiments near by, the earth's magnetic field, etc., must be looked into.

As stated before, the main difficulty of the electrostatic probe is the unavailability of a reference potential. For a satellite-mounted probe, this will usually mean the satellite potential itself will act as the ground. This implies that not only its potential should be known, but also its potential changes with environmental changes (day-night lighting, ionospheric changes with height, etc.). This problem can be reduced by using the modified double probe; however, the analysis of the characteristic curve is much harder since the probe combination

is operating between two extremes (sheath-orbital-limited and sheath-area-limited). In a low density plasma, the determination of the bend in the characteristic curve becomes very difficult.

The resonance probe seems promising for ionospheric studies, but recent literature raises the question of whether the peak really occurs at the plasma frequency. Rocket flights with the T.E.P. have been successful; however, none have as yet been employed on satellites. This would imply that the effects of additional environmental characteristics associated with satellite operation would have to be incorporated into the theory and design. This would include such things as high probe velocities and wakes, long operation times, secondary emission of electrons by bombarding electrons, ions and photons (photoelectric effect), and the earth's magnetic field. For example, if the point of operation were set, but some unforeseen condition forced the satellite potential positive, then the resultant data would be useless.

Regardless of the probe or probes used, there will always be the structural, electronic and telemetry problems as well as the effects of other experiments on the probe and vehicle environments.

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Robert N. DeWitt

ROBERT N. DEWITT

EXHIBIT C.16

STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

5110-208:EWK:cam
DATE: 21 December 1965

TO : Code 7000
Via : Code 5100
FROM : Code 5110

SUBJECT: Progress Report for December 1965 - MOL Experiments S1/S23; forwarding of (U)

Ref : (a) BUWEPS Conf Ser 08985 of 1 July 1965

Encl : (1) Progress Report for Month of December 1965; 5110-207:CJK:cam of 21 Dec 1965
(2) NRL Memorandum for File 5110-206:FTP:cam of 20 Dec 1965

1. In accordance with paragraph 5 of reference (a), enclosures (1) and (2) are forwarded.

E. F. KULIKOWSKI

5110-207:CJK:eam
NRL Prob R07-15
21 December 1965

PROGRESS REPORT FOR THE MONTH OF DECEMBER 1965

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02 (U)

1. Previous reports on this WEPTASK have discussed the redefinition of tasks associated with the consolidation ELF-VLF Propagation Experiment, the Electron Density and Temperature Experiment, and the Magnetohydrodynamic Wave Investigation. Such redefinition has been directed primarily to the technological and operational aspects of the program. In contrast, the effort during this reporting period has been directed toward an examination of the milestone/schedule planning for the experiment.

2. The delays in approval and funding of the experiment has resulted in a situation in which adherence to the previously prepared schedules (Sept. 1965) would require that the experiment be conducted on the latter phases of the launch schedule. However, guidelines received from NAVMOL indicate that the military technology experiments must be planned for inclusion in the first manned flights in order to enhance their consideration for the program. It is with this constraint in mind that the consolidated experiment has been rescheduled, while still encompassing the scope considered necessary to achieve all of the previously described goals. It is considered that this schedule represents the minimum time in which the experiment can be planned in detail, and equipment produced and delivered to the vehicle contractor for integration with the orbital laboratory, consistent with the current moderate funding and staffing plans. Additional delays in program go-ahead must result in the utilization of additional resources and/or the curtailment of some of the experiment objectives.

3. A preliminary investigation into the data requirements of the consolidated ELF-VLF Propagation/Electron Density-Temperature Experiment has been completed. A memorandum, "Experiment Data Considerations; Exploitation of Space Plasma Effects - WEPTASK RT 7045020/6521/F019-05-02", NRL 5110-206:FTP:eam of 20 December 1965, has been prepared in which the parameters of the experiment and those of other on-board systems germane to the conduct of this experiment are identified. A first estimate of sensor sampling and encoding rates and accuracies are presented. Similar first estimates of total data quantities and rates are obtained, based on a previous and now somewhat obsolete Data Usage Profile.

4. A revised Data Usage Profile and Power Budget Plan for the experiment is in preparation, and will reflect the results contained in 5110-206:FTP:eam Memorandum.

5. The draft copy of the Request For Proposal for an Engineering Design Study contract has been updated to be in accordance with the newly generated milestone/schedule plan. Final modifications and submission await formal approval of the experiment program.

ENCL (1) TO NRL MEMO 5110-208:EFK:eam

6. The investigation of probe techniques, analyses of ELF-VLF Propagation, and the theoretical treatment of energy coupling from an antenna to the ionospheric medium has been pursued sporadically during this period and no results of significance can be reported at this time. Effort on these tasks will continue.

7. The ground station instrumentation has been augmented by the acquisition of a one meter square loop antenna which will be used to further define the signal environment of a VLF receiving site. Additionally, instrumentation is planned for the near future and spectral analysis of the VLF region will be conducted.

C. J. KURNER
NRL, Code 5112

5110-206:FTP:eam
20 December 1965

MEMORANDUM FOR FILE

Subj: Experiment Data Considerations; Exploitation of Space Plasma Effects
BUWEPS WEPTASK RT 7045020/6521/F019-05-02 Ser 08985 of 1 July 1965 (U)

1. The stable phase characteristics of VLF waves and their long range propagation capability in the earth-ionosphere cavity provide reliable communication and precise frequency comparison between ground-based stations and to a lesser degree to subsurface receiving stations. An extension of this capability to space stations in the ionosphere would provide operational advantages not presently existent. Toward this end, an investigation of space conditions in the environment of a manned orbiting vehicle as related to electromagnetic wave transmission is being planned. The tasks to be included in the experimental investigation would include measurement of VLF/ELF transmissions from space-to-ground and from ground-to-space, characteristics of space plasma around the vehicle and its effect on electromagnetic wave coupling, magnetohydrodynamic (MHD) wave effects, and an assessment of interface relations and astronaut performance and influence in conducting the experimental operations. Various types of sensing devices are needed to measure the desired parameters, and their outputs must be recorded with suitable accuracy and correlation in time and position to provide data completeness without superfluity.

2. In any experiment involving the collection of quantities of data, a primary problem is created in the processing and interpretation of the data to obtain usable results in a reasonable period of time. Some experiments provide measured parameters which are readily reduced by automatic techniques to a form suitable for entering in a computer to obtain desired functions. In other experiments, the measurement conditions are so highly variable that the data does not respond readily to means for extracting automatically the parameters to be processed. Measurement of electromagnetic wave propagation is an example of the latter. In many cases, to derive meaningful results, it has been necessary to make continuous records, over long periods of time, of received waveforms from sources of interest, and then to scan these records visually to locate conditions which could be related to other parameters. This procedure involves much manual effort and time.

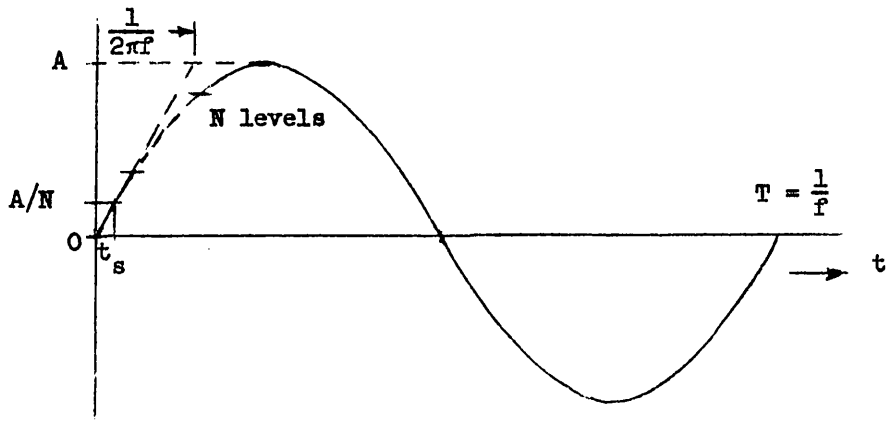
3. In the experiment on space plasma and propagation conditions to be conducted aboard the MOL, an attempt is being made to condition the experimental data in different ways so as to permit the desired parameters to be evaluated in the most effective manner through the elimination of undesired effects. A sampling process over pertinent time intervals is employed in conjunction with encoding to provide an output in digital form for high speed tape recording. An analysis was made earlier of data handling to be employed for plasma measurement, so emphasis here is on propagation. In digitizing the data, one approach would be

ENCL (2) TO NRL MEMO 5110-208:EFK:eam

to reconstruct complete waveforms. As will be shown, this procedure entails a tremendous encoding capability, both from the standpoint of digital rates as well as total quantities of data, even for the low frequencies and narrow bandwidths of this experiment. Thus it becomes more advantageous to select portions of filtered waveforms and take discrete samples no more frequently than necessary to include the desired information. As a backup provision for special monitoring, an analog tape recording of selected waveforms would be desirable. For the frequencies and conditions involved, the required recording bandwidths would be narrow. The tape recordings could be returned to earth upon completion of the mission.

4. In reproducing a signal by a sampling process, either in conjunction with encoding or not, it is necessary, for continuous quantizing with a desired degree of accuracy, to consider the highest frequency components in the wave in determining the sampling rate and the number of samples. By Nyquist theory, it is possible to reproduce a waveform by sampling at only twice the highest frequency component present. However, it is necessary to apply mathematical procedures to reconstruct the waveform and this method is not too satisfactory for convenient and rapid processing. The more straight-forward continuous sampling method can be applied to a waveform in accordance with the maximum frequency required, and the rate and number of samples determined. For a given reading accuracy, 1/N, the number of sampled levels is the inverse or N. During the interval in which a level is sampled, a range of values is covered by the variable, and in order to remain within the desired accuracy, the sampling interval must be no greater than the time for the variable to change through one level of quantization. The uncertainty of the precise time of sampling is introduced by variations in switching and circuit parameters during the gating period, particularly for high speed sampling devices.

5. An example of sampling conditions for reconstruction of a waveform can be provided by a sine wave which can be the equivalent of the highest frequency included in a waveform to be analyzed.



The sampling rate is determined by the most rapid change of value, which occurs at the zero crossing. By differentiating with t=0, the maximum slope is obtained and is given by

$$S = A \times 2\pi f$$

If N levels are desired, where 1/N is the accuracy of measurement, then for element A/N sampled in time t_s, slope S holds and

$$2\pi f A = \frac{A}{N\, t_s}$$

Having assumed that the sampling time is equal to the quantization interval, the sampling rate is given by

$$R = \frac{1}{t_s} = 2\pi f N$$

6. Employing this formula, for an accuracy of 1%, or N = 100, and f = 1 cps, the sampling rate becomes 628 values per second, or per cycle, since f = 1. The VLF waveforms from a LOFTI receiver have a maximum frequency of 35 cps, requiring a sampling rate of 21980 per second for reconstruction of the entire waveform. For a few minutes of reception, the number of values runs into the millions, and when encoded, the required digital recording capacity of about 175,000 bits per second is many times the permissible limit. However, by selecting portions of the received signals which will yield data on the desired parameters, it should be possible to reduce the data load considerably without losing pertinent information.

7. Typical of the VLF signals to be processed at the orbiting vehicle are pulses of continuous wave 300 milliseconds in duration repeated at 1 second intervals. The transmitted radio frequency can be any value from 300 kc to possibly 0.3 kc with the majority falling between 10 and 20 kc. Doppler shift variations of up to several cycles per second per second cause changes in the base frequency. Pulse phase delays of an appreciable fraction of a second can occur in signal arrival. Received signal amplitudes can vary up to a few decibels in times up to one minute, and up to a maximum of 40 db with changing conditions over longer periods of time. Noise background levels also fluctuate from minimum quiet conditions to values greater than signal levels during disturbances. The signals available from LOFTI receivers are at IF frequencies of about 1000 cps with a bandwidth of 28 cps, and 25 cps with bandwidth of 20 cps, or as detected envelopes.

The output amplitude varies from 0 to 5 volts. These receiver characteristics serve only as an example, as it will be possible in other receivers to choose values which will afford the best signal conditioning.

8. In sampling the waveform values to obtain the desired parameters, different sections can be selected and processed so as to present the best condition for the particular measurement. The frequency of sampling and the required accuracy are established on the basis of anticipated variations in the values and the desired limits, such as whether average, peak, maximum or minimum, and the associated periods during which they occur.

9. A parameter of primary concern is the amplitude of the received signal. An example of this signal can be a CW pulse of 300 ms duration repeated each second. It is available from a LOFTI receiver as a 25 cps IF or as a detected envelope. For strong signals with little fading, a single sampling of the envelope would provide a value typical of the full duration. However, as the signal-to-noise ratio decreases and multi-path effects enter in, the amplitude varies during the pulse which must then be sampled several times, say every 50 ms for a reasonable average. Low pass filtering can provide some improvement of signal. In addition to the main pulse, echo and delayed transmission signals occur during the interval between pulses, and sampling must be frequent enough to distinguish these forms from bursts of noise. The same rate of one sample each 50 ms or 20 samples for each keying cycle of 1 second should be adequate.

10. In order to determine the received signal-to-noise ratio (SNR), measurements must be made of the noise levels in frequency bands of interest. Noise of a random nature is made up of peaks of many amplitudes which can be integrated over a period of time to obtain an average value. A quasipeak value can also be obtained by sampling the higher levels. At times, bursts of noise from discrete sources are added to the normal level. These bursts, e.g., from lightning discharges, occur at random times and are of various durations. Although the noise level can be measured intermittently with signal reception, employing the same receiver, the narrow bandwidth discriminates against most of the noise frequencies. Thus a special wide-band receiver provides a more representative measure of noise conditions. Sampling of noise waveforms will depend upon the degree of detail desired. Integrated outputs from detection of a wideband channel will provide average or quasi-peak values from a waveform of normal distribution sampled, say, 20 times per second. Bursts of shorter duration than the sampling period of 50 milliseconds will probably be missed, and the number of samples must be increased to the desired rate if this information is needed.

11. The frequency of the received signals is another parameter of interest. Although the frequency at the VLF ground transmitter is held to a high degree of precision by comparison with observatory standards, the received signals can vary by several cycles from changes in the propagation medium between ground and the space vehicle. A direct method of determining frequency is to measure the time between zero crossings of the radio-frequency wave by means of a precision counter.

For measurement of time between zero crossings, the base frequency to be used, and the counter rate can be selected on the basis of desired time intervals and accuracy. Either intermittent or continuous sampling can be used, dependent again on detail desired. Perhaps 5 consecutive crossings to provide an average value, repeated every 50 ms would be adequate for representative conditions. A second method employs phase comparison between a precision standard in the vehicle and the incoming signal in a phase locked circuit. The rate of change of phase, or slope of the comparator output is a measure of the frequency and can be sampled for Doppler shifts and related changes. In many cases, the change during a 300 ms pulse will be less than a single phase-cycle, and 10 samples should provide an average slope value. During occasional extreme variations in the medium, the value of slope may increase by a factor of three, giving up to three phase-cycles per pulse.

12. In making phase delay measurements of VLF signals, it is possible to obtain relative values of phase change employing a precision frequency standard for comparison, but difficult to measure absolute values unless some means exists of establishing a satellite reference time corresponding to the time of radiation of a signal from the transmitter. Short duration pulses are used in systems for timing purposes, but the narrow bandwidth, or high Q, of a VLF antenna does not permit fast-rising signal transmission. In fact the slow rise time may pose a question as to the actual time of radiation of a signal. Perhaps a frequency at VHF or UHF might be synchronized to serve this purpose but the range is then limited to line-of-sight and not suitable for long distance VLF transmissions. An alternative is to use zero crossings of the continuous wave as a reference. The particular crossing must be identified, and one way of doing this is to transmit a second wave displaced slightly in frequency from the first one. The times at which the positive crossings are in phase can be used as reference points, with a differential phase comparator employing phase-locked signal techniques in a receiver, providing the relation between the two carriers. For locating specific crossings with common phase, a clock standard would be needed as a gross time indicator. Where real time telemetering of data is employed as in LOFTI, a comparison of time-of-arrival of VLF signals from the satellite and from the ground VLF transmitter at a ground receiving station gives a measure of delay. Here the transmission delay between ground stations is assumed to be small relative to that in space.

13. It is found in measuring phase variations of VLF signals between ground stations that the maximum change is normally less than the time of a single cycle, for example, 50 microseconds at a frequency of 20 kc. This value is a relative phase change obtained by comparing an incoming VLF signal with a local standard frequency. Transmissions within a daytime area or a night-time area show small phase variations, but a transition from day to night or vice versa gives a change of tens of microseconds. Sudden ionospheric disturbances also cause considerable change, but of a random nature. Thus most VLF phase comparators available on the market have a full scale range of 50 microseconds for signals near 20 kc and one-third of this value for transmissions such as WWVB on 60 kc.

14. For VLF transmissions between space vehicles and ground stations, a much greater range of values is encountered, since the signals must pass through an ionized medium whose characteristics vary with altitude and solar radiation, among other effects. Short term phase changes of up to 400 microseconds per second have been observed equivalent to a Doppler shift of 8 cps/s. In comparison, maximum Doppler shift for vehicle forward motion is a few tenths of a cycle per second, depending upon transmission frequency. Time delays of VLF signals from 10 to 200 milliseconds have been observed in the LOFTI project, also signal echoes occurring 2/3 and 4/3 of a second after transmission.

15. It is noted in LOFTI recordings of some of the VLF signal characteristics that limitations in the operation of the receivers cause a decrease in the quantity of usable data that could be obtained. In determining signal amplitude, especially at medium ranges, saturation of the receiver prevents a measure of the received signal level. The receiver has a dynamic range of 40 db and it appears that a higher value, possibly twice the present one, would be advisable. The phase delay of the received signal, from radiation at the transmitter to reception in the satellite, is subject to some uncertainties. The bandwidth of the second IF amplifier is 20 cps to allow passage of signals shifted by expected Doppler effects. The phase variations in the receiver can change up to the order of 10 milliseconds, and thus measurements are limited to this order of accuracy. A possible solution where more precise values are desired might be use of a phase locked receiver for this kind of measurement. Problems which would be encountered would be first, a capability for locking-on to a varying signal, and second, a response time suitable for following these variations. The control of bandwidth to obtain optimum tracking would be required.

16. In planning the plasma measurement experiment, four measurement periods, each of 15 minute duration, were scheduled for one orbit. Within each interval of 15 minutes, about 6 minutes were devoted to monitoring or recording experimental data, with the remainder of 9 minutes given to changing experiment conditions by repositioning the booms and probes. A limit of 500 bits per second was set on the data rate by recording requirements given at that time. The maximum data possible in 6 minutes under this restriction is 180 kilobits. With the consolidation of the propagation and plasma experiments, an opportunity is afforded for utilizing the remaining 9 minutes for receiving and transmitting measurements. The time would be divided up into intermittent intervals of several seconds depending upon the repositioning time requirements of the booms and probes. In List A, typical data which might be included in one of three sequences making up the 15 minute period is shown. Assuming the same data rate as before, the total quantity of data in 15 minutes becomes 450 kilobits, and for four positions in orbit a total of 1.8 megabits. Since a much higher capability for data handling now appears in the system plan, it may become possible to increase the data rate to enable both experiments to be conducted in the same available time, and also to provide other advantages. If the data rate could be increased several times, say to 5000 bits per second, measurements of various receiver outputs could be made simultaneously with the charged particle measurements, thus allowing correlation between more related parameters, as well as making more effective use of

the time available. Transmitter operation would be conducted during sequential intervals intermittently with other measurements, and at times when sensors would be desensitized to avoid damage. Transmission data would be essentially of status type for discrete fixed conditions, except insofar as loading effects on the antenna from changing plasma conditions would cause impedance variations and changes in excitation power from the transmitter. It would be necessary to sample such parameters as transmitter input power, loading coil setting, antenna feed current, and antenna impedance. For special tests, transmitter and receiver would be operated as a pair to detect signal returns immediately following a transmitted pulse, employing a T-R device similar to radar. Several receivers or channels could be made available to share functions for monitoring and measuring purposes.

17. In order to correlate the various measurements in time, and to establish accurate reference times for required intervals, standards of adequate precision must be available for recording with the data. It is understood that elapsed time in the MOL system will be recorded in 0.1 second intervals, with provision for short term event timing of 1 millisecond where necessary. A complete time indication may be of the order of 28 or 32 bits, but for a given experiment where repeated recordings are required, the values can be expressed as partial codes defining short intervals of a sequence, with the full time code only at the beginning and end. As has been mentioned, high precision standards of time or frequency are available in the vehicle, and measurements relative to them are no problem. However if absolute measurements relative to signals in other locations are made, a method of synchronizing and identifying the times at which certain outside events occur, e.g., the initiation of a signal, must be employed and made part of the data recording. The frequency with which values must be recorded is dependent upon desired measurement accuracy. If intervals of the order of a cycle or less of a VLF wave are being considered, special provision may have to be made to record the tens of microseconds included in these intervals.

F. T. POWLES
NRL, Code 5113

LIST A

TYPICAL DATA FOR PLASMA/PROPAGATION EXPERIMENT

The following tentative list gives an estimate of digital data recorded in a five minute sequence.

Sequence Status Frame once each five minutes to define general experiment conditions.

Experiment Identification	4 bits
Block Identification	2 bits
Attitude Control Mode	2 bits
Vehicle Attitude (3 axes)	15 bits
Equipment Temperature	5 bits
Magnetometer	3 bits
Ultraviolet Radiation	3 bits
X-Ray Radiation	3 bits
Concurrent Experiments	( )

Sub-sequence Calibrate Frame once each 50 seconds to define measurement reference conditions.

Experiment Identification	4 bits
Block Identification	2 bits
Probe Attitude	2 bits
Voltage Scan Range	2 bits
Electrometer Voltage (3 points)	24 bits
Electrometer Currents (3 points)	72 bits
Data Channel Identification	3 bits
Receiver Calibrate (4 channels)	320 bits
Antenna Impedance Reference (5 points)	80 bits
Other data	( )

Data Set Status Frame repeated eight times in each 50 second interval to define specific measurement conditions.

Experiment Identification	4 bits
Block Identification	2 bits
Boom Length Mode	1 bit
Boom Length	8 bits
Collection Mode	1 bit
Probe Bias Voltage	8 bits
Boom-Vehicle Voltage	24 bits
Receiver Type	2 bits
Receiver Bandwidth Mode	2 bits
Receiver Antenna Type	2 bits
Receiver Antenna Orientation	4 bits

Transmitter Frequency	4 bits
Transmitter Dummy Load Input	4 bits
Transmitter Modulation	2 bits
Transmitter Antenna Type	2 bits
Transmitter Antenna Length	4 bits
Transmitter Antenna Orientation	4 bits
Other Data	( )

Experiment Data Frame repeated eight times in each 50 second interval to measure experimental parameters for each preceding data set status frame.

Probe Voltage	120 bits/sec	
Probe Currents (3)	360 bits/sec	
Signal Amplitude	320 bits/sec	
Signal Frequency	1600 bits/sec	
Signal Phase	160 bits/sec	
Noise Amplitude	160 bits/sec	
Receiver Antenna Impedance	160 bits/sec	
Reference Time	800 bits/sec	
Paralleled Data		3680 bits/sec total
Transmitter Input Power	160 bits/sec	
Loading Coil Setting	160 bits/sec	
Antenna Current	160 bits/sec	
Antenna Impedance	160 bits/sec	
Output Signal Monitor	160 bits/sec	
Reference Time	800 bits/sec	
Sequential Data		1600 bits/sec total

EXHIBIT C.17

A MINIMAL VLF PROPAGATION EXPERIMENT FOR AN IONOSPHERIC SATELLITE

Previous program planning has been directed toward the design of a comprehensive experimental effort suitable for investigation of the parameters which effect propagation of ELF/VLF energy in the ionosphere. These investigations include radiation of ELF/VLF energy from an antenna imbedded in a magneto-ionic medium; spectral analysis of the noise environment in this frequency domain; the launching and detection of magnetohydrodynamic wave modes which may accompany the motion of an orbiting vehicle in the ionosphere; the determination of charged particle densities and temperatures in the near-vicinity of the vehicle and the interactions between these particles and the ELF/VLF power radiated from the vehicle antennas.

Achievement of the primary objective of this investigation, i.e., the propagation of VLF energy from a space vehicle to ground, can be accomplished with a considerable reduction in the scope of the experiment design. Such a reduction can result in a number of short term advantages. The mechanical interfacing of experiment instrumentation with the parent vehicle is minimized. The electrical interfaces can be similarly reduced. Weight, volume and power savings can be effected from the estimates presented for the comprehensive experiment. In addition, the flight instrumentation units for such a reduced experiment should be available for an earlier flight date as a result of the reduction in the interface tasks, the number of devices involved, and the fabrication and testing time requirements.

An experiment for the sole purpose of demonstrating space-to-ground VLF transmission would consist of, as a minimum; a VLF source of adequate power, a coupling mechanism to match the source to an antenna, a simple transmitter programmer, and the antenna element(s) and the deployment mechanism. In addition, it is likely that power system buffering to isolate the experiment from the prime vehicle power will be required. Signal conditioning (data sampling, hold, multiplex and encode) to ensure compatibility with the vehicle telemetry system must be supplied. The block diagram shown in Fig. 1 depicts the elements of such a minimal system. As a result of the reduction in the scope of the flight equipment, considerable simplification of the supporting instrumentation will be effected. The environmental qualification procedures, the pre-launch check-out and monitoring equipment all reflect the effects of experiment simplification. Only the ground VLF receiving sites remain relatively unchanged from the configuration proposed for the comprehensive experiment.

It should be pointed out, however, that a minimal VLF propagation experiment cannot be purchased without incurring penalties in performance. A minimal experiment provides no data which will give an insight into the conditions which prevail during the conduct of the experiment. In particular, data relative to ionospheric charged particle densities, magnetic field strength and directions (relative to the transmitting antenna elements), reciprocity of the propagation medium, effects of transmitted power level and transmitter frequency variation are not obtained. The results obtained from a minimal experiment thus must stand by themselves. Interpretation of results with respect to the aforementioned effects can at best only be inferred.

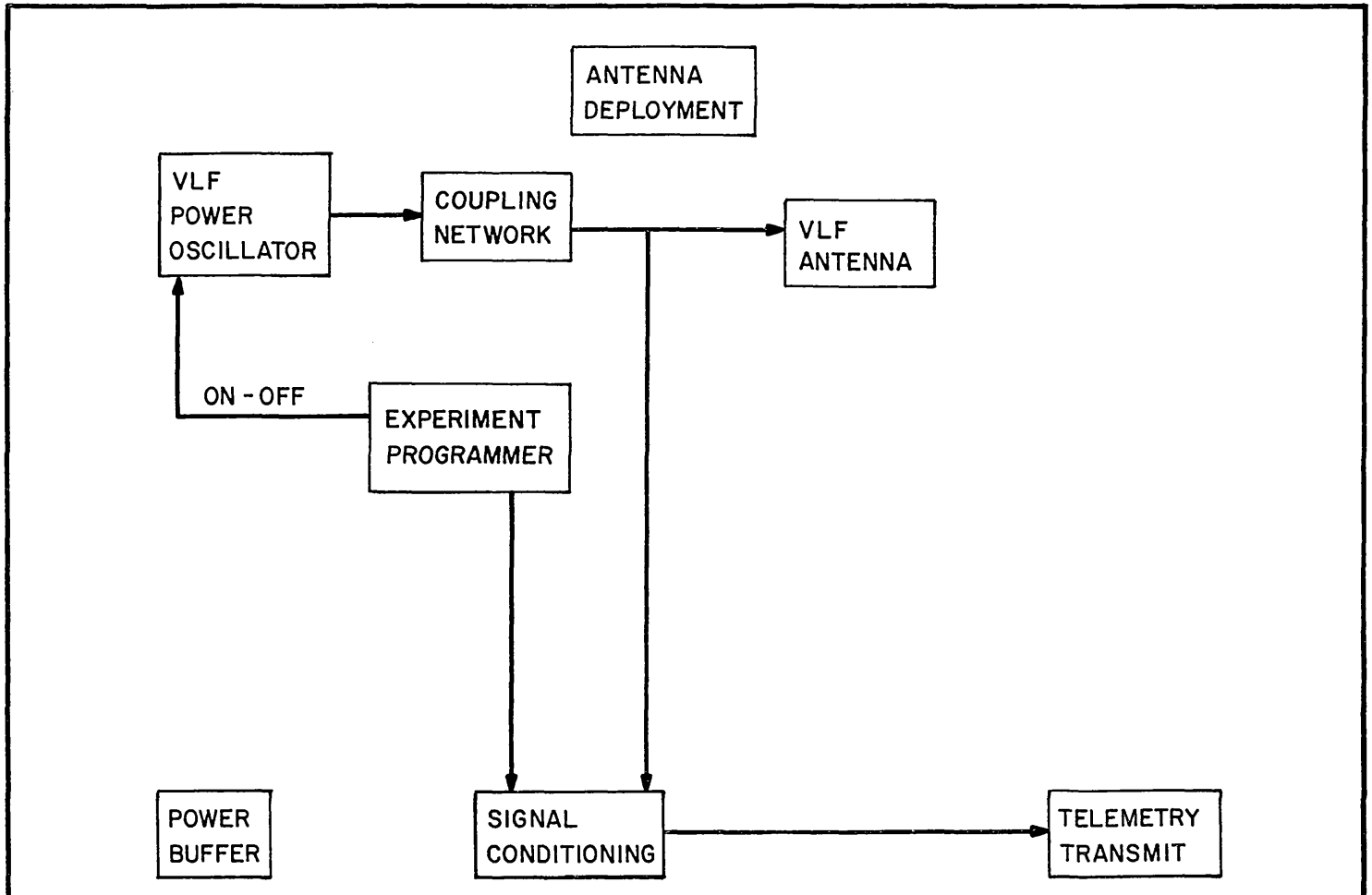
The limitations imposed by a minimal experiment has resulted in a stepwise improvement program for the experiment. A series of modifications and additions have been considered. They are depicted, in Figures 2 through , in order of increasing complexity and in decreasing order of importance of the ensuing data (in support of the VLF propagation task). Figure 2 adds to the experiment the capability for measurement of antenna impedance, a quality which is related to the transmitted frequency, antenna dimensions, the local plasma density and the antenna orientation relative to the earth's magnetic field. To provide for the correlation of the impedance data, a plasma probe for determination of charged particle densities has been included and a magnetometer added (if it is not already included in the vehicle instrumentation for attitude determination). The inclusion of these elements of the flight instrumentation make possible the correlation of ground received signal strengths with the nature of the environment at the transmitting satellite. Figure 3 shows the addition of a command receiving unit which controls the degree of antenna deployment. This will provide a capability to match the antenna impedance for optimum radiation at the VLF frequency employed in the ionospheric medium. The inclusion of the command receiver also can provide for the variation of transmitter power level and/or frequency. These quantities provide additional data on the effects of the medium on propagation.

The experiment as planned to this point provides for the essentially continuous transmission of signals throughout the orbit. However, the determination of the vehicle derived quantities such as antenna impedance, plasma densities and magnetometer data are obtainable only when the satellite is in range of a telemetry receiving station. To provide a full measurement capability, the inclusion of a record/playback tape recorder, as shown in Figure 4, is recommended. Environmental conditions can then be correlated with received VLF signal strengths at all points in the orbit.

The final planned addition to the satellite instrumentation consists of the addition of a receiving facility on the vehicle. This facility, shown in Figure 5, would provide a means for conducting a spectral investigation of the background noise in the ELF/VLF region. The same receiving equipment would be utilized to detect the existence of locally or remotely generated magnetohydrodynamic waves which may be intercepted by the satellite antenna.

The program of additions and/or modifications as outlined in this memorandum need not proceed in the order given, nor must each such addition consist of those elements outlined for a given step. The equipment configuration for any given flight may depend on the priority of information required, the time scale on which the equipment must be obtained, the financial limitations imposed, and the result of previous flights conducted under this or other programs.

C. J. KURNER



PREPARED BY: _____

APPROVED: _____

NAVY EXPERIMENT PROGRAM

LEVEL

SCH'D NO. _____

ORIGINAL SCHEDULE APPROVAL _____ DATE

LAST SCHEDULE CHANGE _____ DATE

STATUS AS OF 1/15/66 DATE

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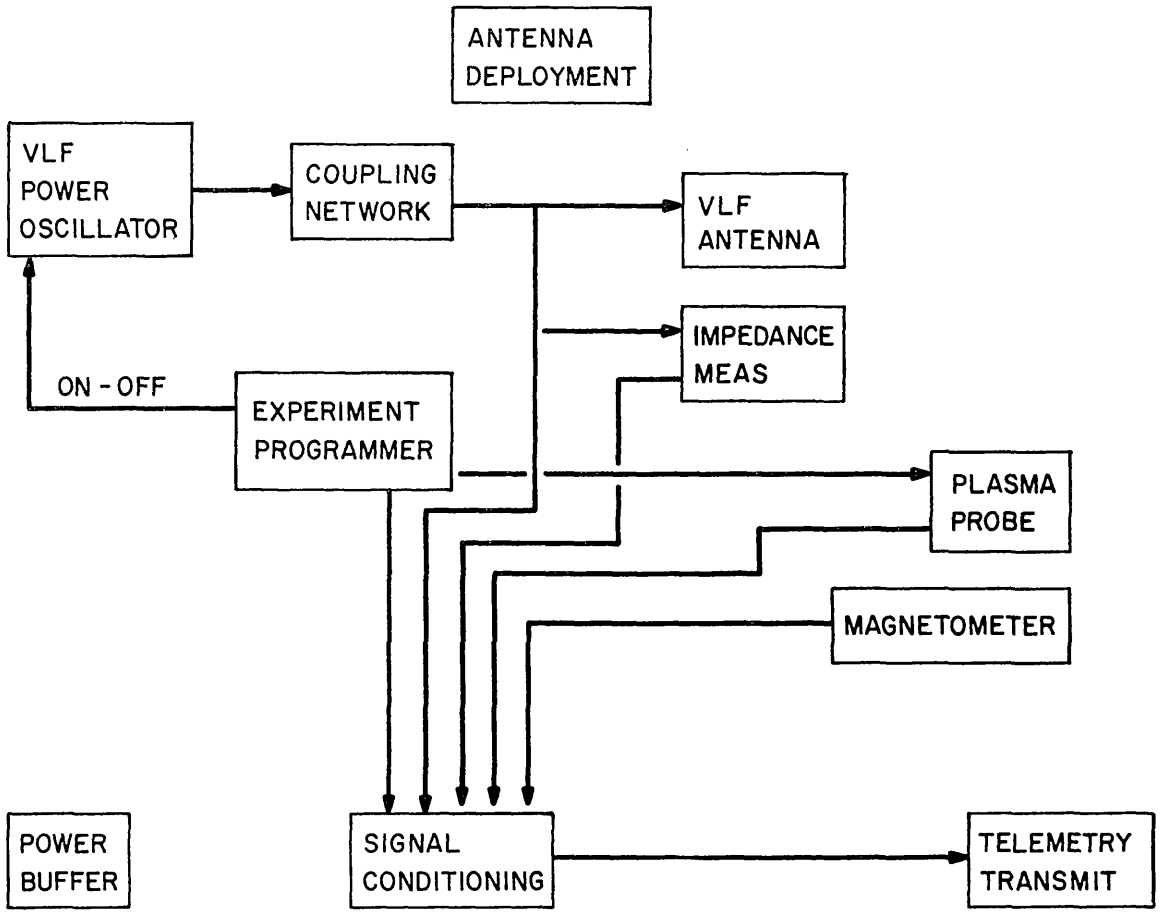

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NAVY EXPERIMENT PROGRAM

LEVEL

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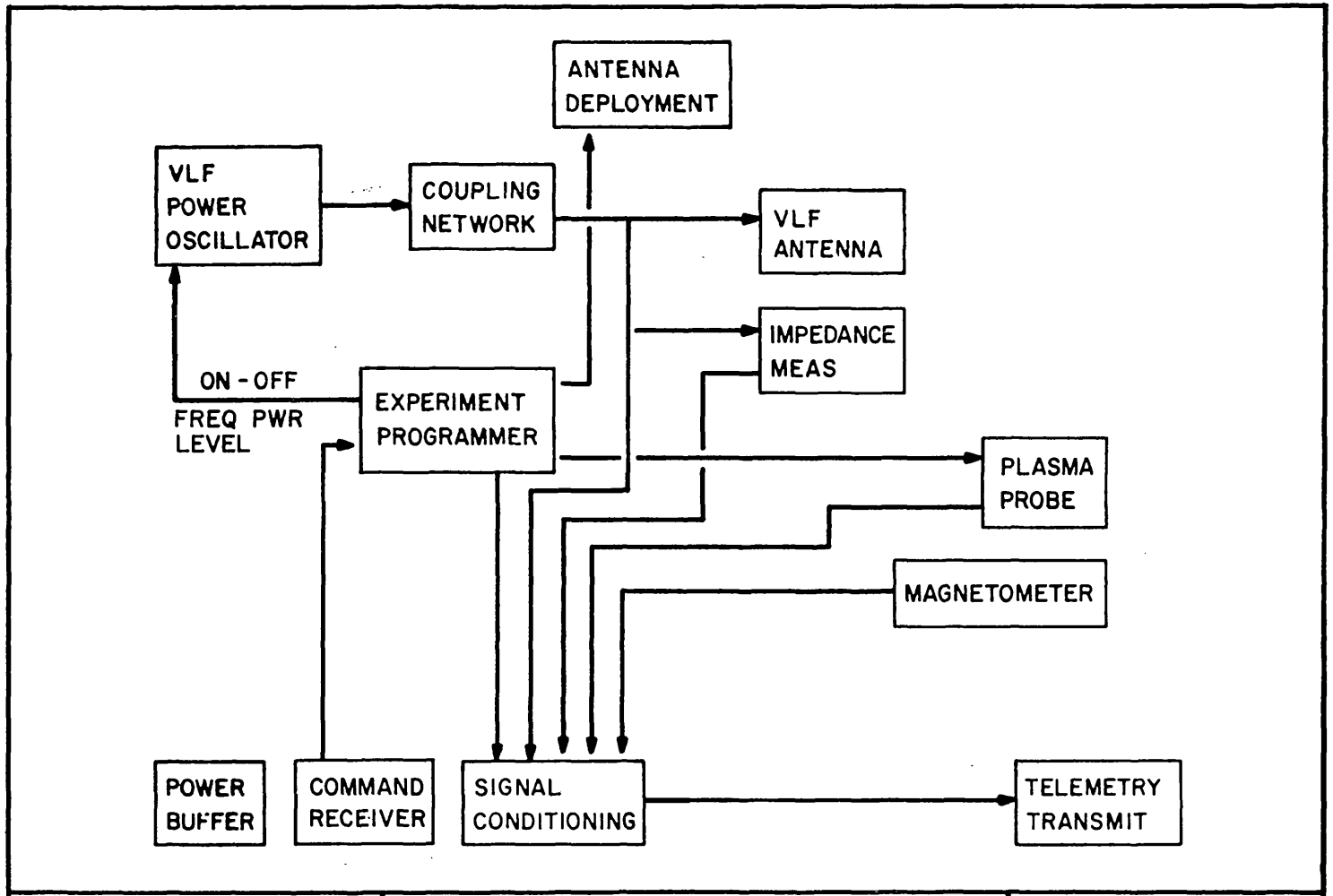

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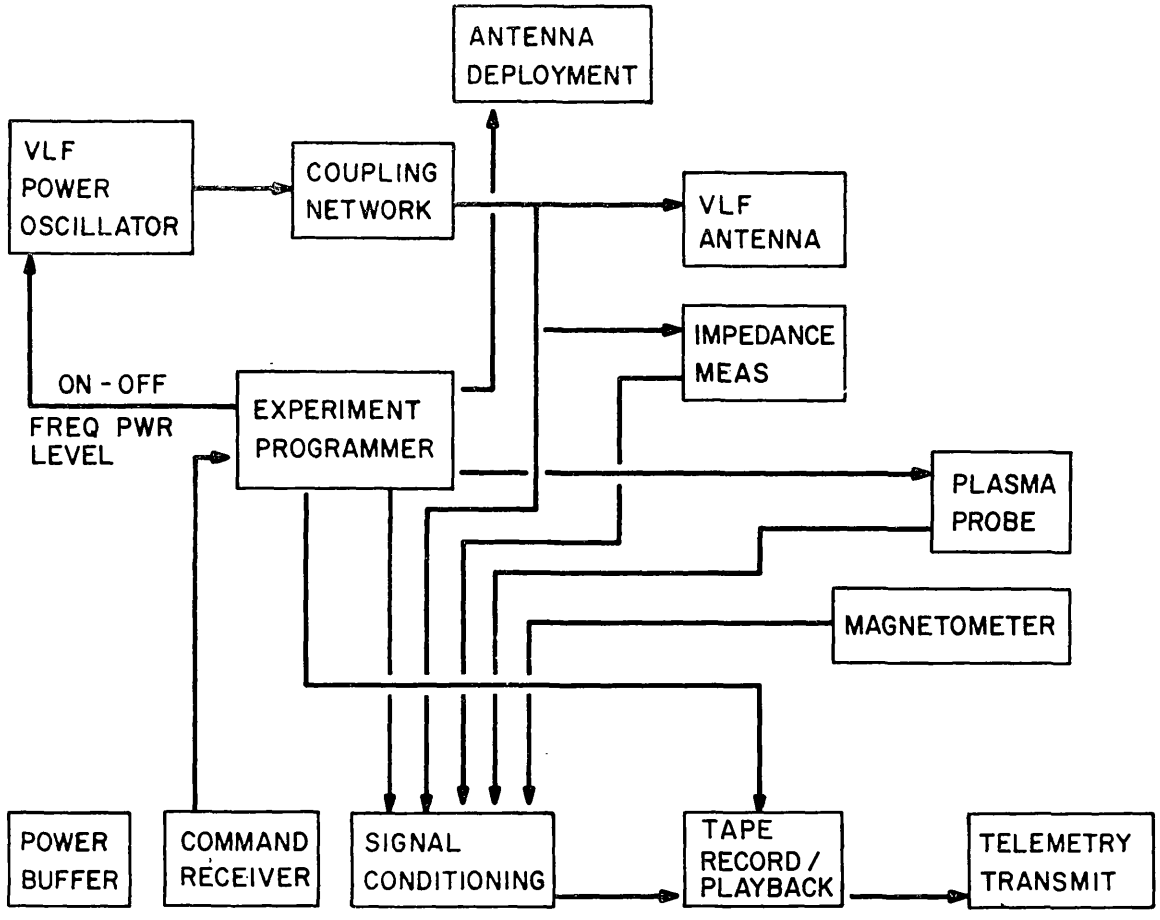

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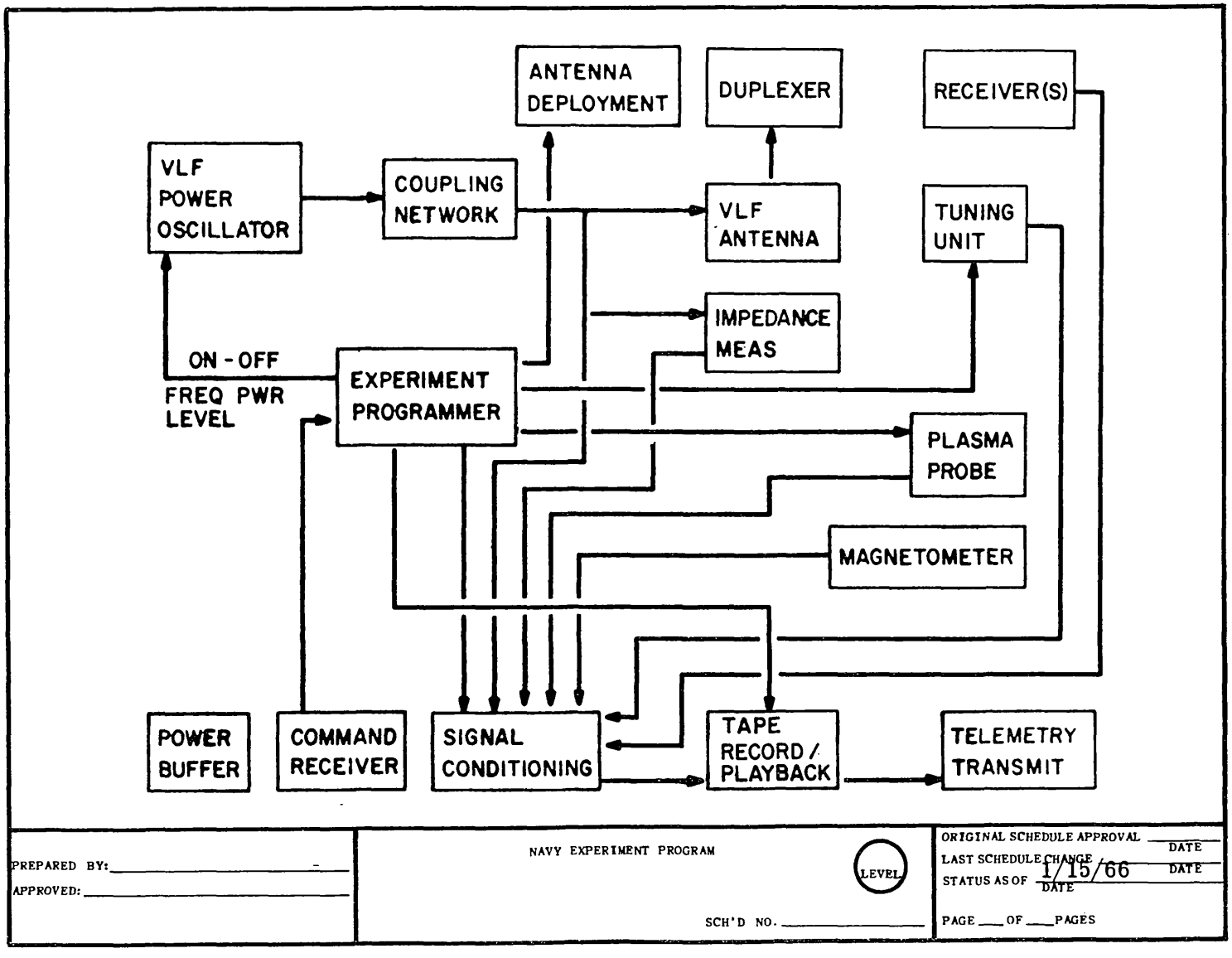
ANTENNA DEPLOYMENT
DUPLEXER
RECEIVER(S)
VLF POWER OSCILLATOR
COUPLING NETWORK
VLF ANTENNA
TUNING UNIT
IMPEDANCE MEAS
ON - OFF
FREQ PWR LEVEL
EXPERIMENT PROGRAMMER
PLASMA PROBE
MAGNETOMETER
POWER BUFFER
COMMAND RECEIVER
SIGNAL CONDITIONING
TAPE RECORD / PLAYBACK
TELEMETRY TRANSMIT
PREPARED BY:
APPROVED:
NAVY EXPERIMENT PROGRAM
LEVEL
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ORIGINAL SCHEDULE APPROVAL DATE
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PROGRAM EFFORT

A. VLF PROPAGATION

1. Antennas: review of techniques for deployment of large antennas in space:
   (a) Stored Tubular Extensible Member (DeHavilland Type)
   (b) Inflatable Structure

2. Theoretical Studies on nature and behaviour of antennas in magnetoplasma

3. Prepare Draft Versions of Request For Proposal
   (a) Engineering Design Study for Comprehensive Experiment
   (b) Engineering Design Study for Minimal Experiment

4. Conducted Analysis on Data Requirements from vehicle-borne experiment equipment

5. Instrumented VLF receiving rack for evaluating VLF receiving techniques, conduct antenna study, develop techniques for spectral analysis

B. PLASMA INVESTIGATION

1. Review of Probe Techniques
2. Procurement of Plasma Tube for evaluation of Probes and Measurement Techniques
3. Procurement of Logarithmic Electrometer Amplifiers for Plasma Diagnostics

C. CONSULTATION WITH NASA AND AF FACILITIES

1. Prior NASA Ionospheric Rocket and Satellite Experiments
2. AFCRL Rocket and Satellite Experiments

PROGRAM EFFORT (continued)

3. Experiment Conduct and Data Analysis Techniques used for Electron Density and Temperature Measurements
4. Design of space-borne electronics (power supplies, telemetry etc.)
5. VLF electronics for satellite use (Alouette, Alouette B, FR-1, ISISA)

D. PREPARE DOCUMENTATION TO PROVIDE EXPERIMENT DATA TO AEROSPACE CORP. VIA NAVMOL

E. VLF ANTENNA MODELING

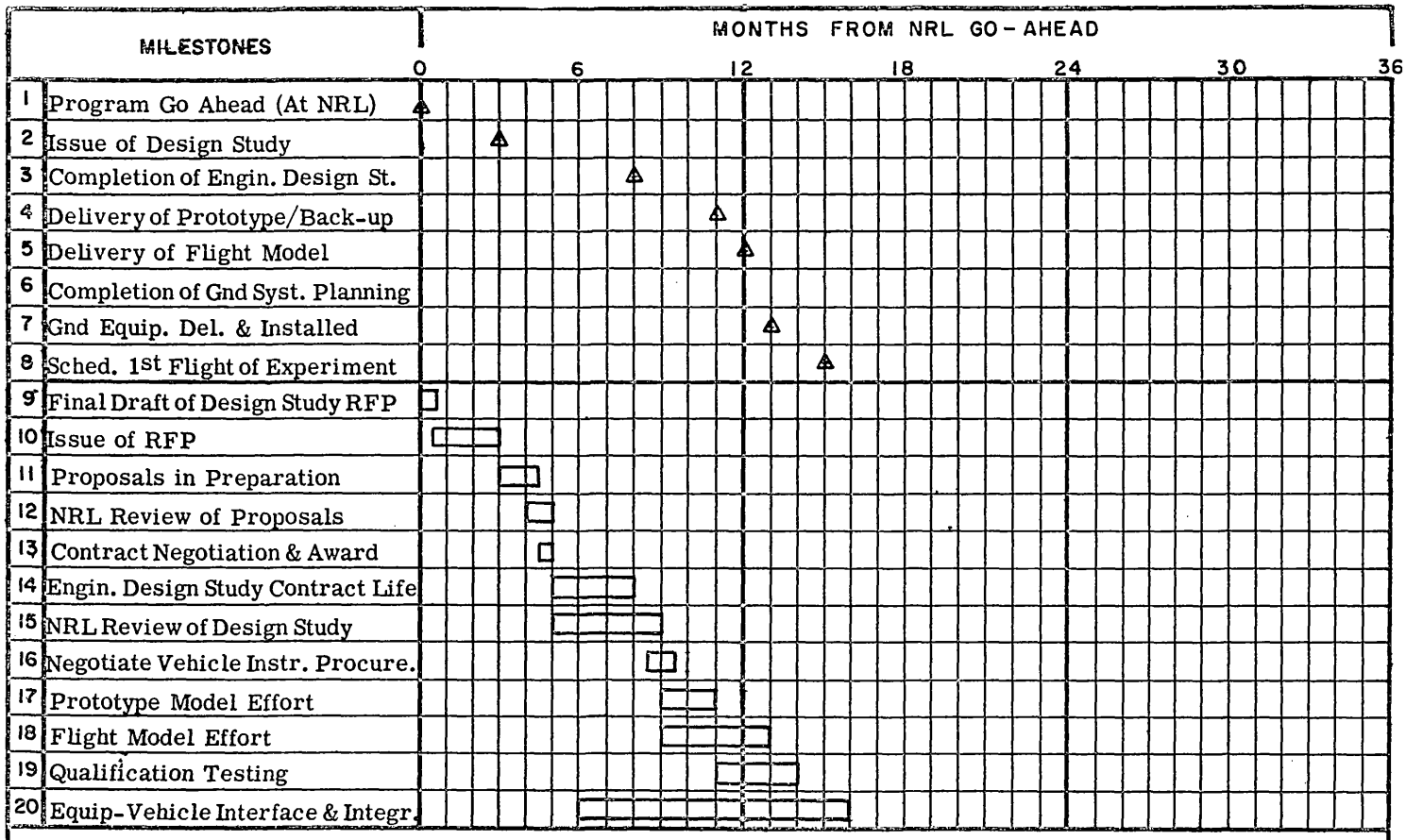
ADDITIONAL SUPPORT DATA (If Available)

A. VEHICLE

1. Solar Radiation
   x-ray
   ultra violet
2. Attitude
3. Internal Timing

B. GROUND

1. Orbit ephemeris (position)
2. Ionograms
3. VLF signals via T/M from other satellites
4. Voluntary reports of experiment VLF reception w/time, signal str and position



PREPARED BY: C. J. Kurner

APPROVED: E. F. Kulikowski

Minimal VLF Propagation Experiment for Ionospheric Satellite

Milestone/Schedule Plan

SCHED NO.

LEVEL

STATUS AS OF 15 January 1965

PAGE 1 OF 2 PAGES

	MILESTONES	CY 1966												CY 1967												CY 1968											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Gnd Systems Studies																																				
2	Gnd Systems Equip Procurement																																				
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PREPARED BY:

APPROVED:

Minimal VLF Propagation Experiment
For Ionospheric Satellite

Milestone/Schedule Plan

LEVEL

SCHED NO.

STATUS AS OF 15 Jan 1966

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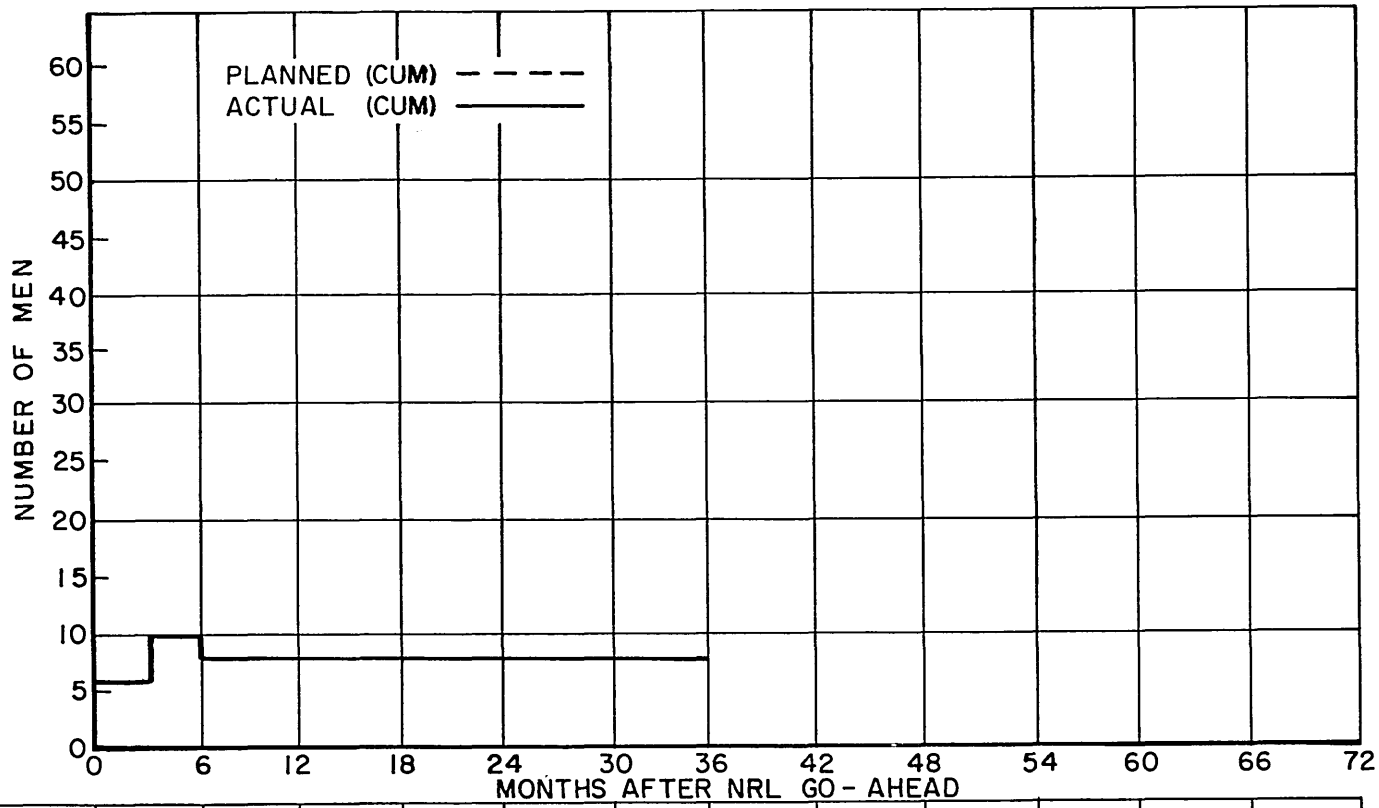

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ACTUAL												

PREPARED BY:

APPROVED:

Minimal VLF Propagation Experiment
For Ionospheric Satellite

Preliminary Manpower Plan SCHED NO.

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ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE

STATUS AS OF 15 Jan 1966

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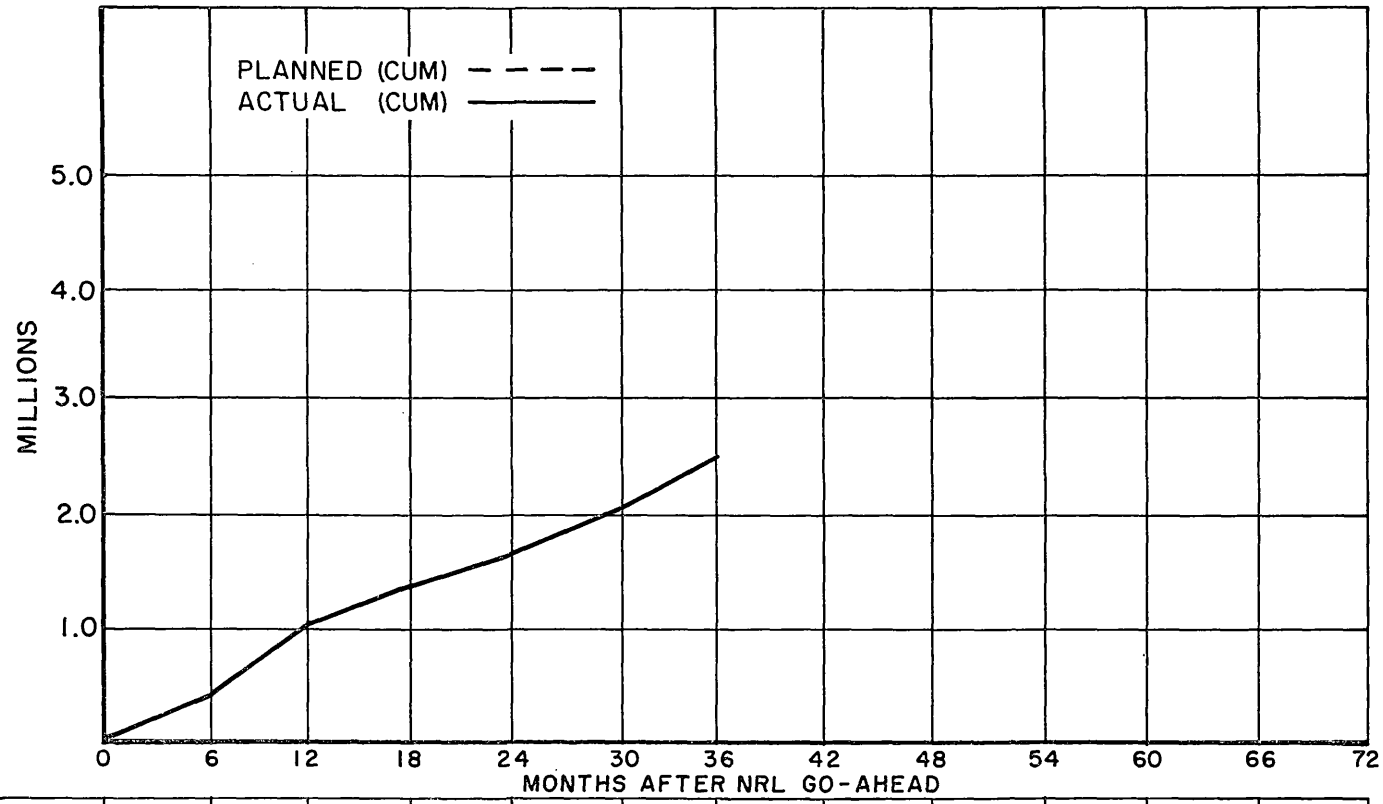

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ACTUAL												

PREPARED BY:

APPROVED:

Minimal VLF Propagation Experiment
For Ionospheric Satellite

Milestone/Schedule Plan

SCHED NO.

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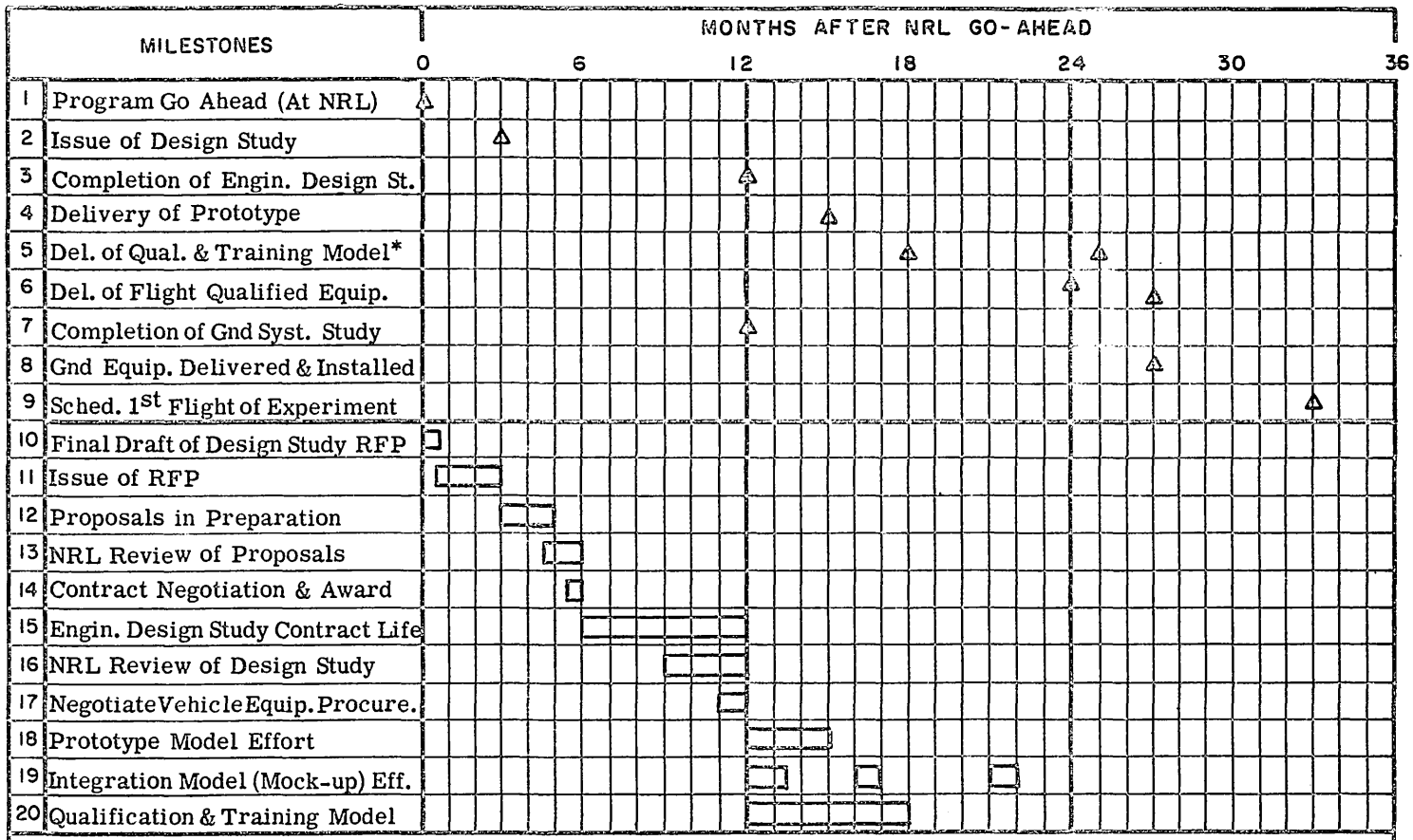


*Qualification model serves as training model after space qualification testing and refurbishment.

PREPARED BY:

APPROVED:

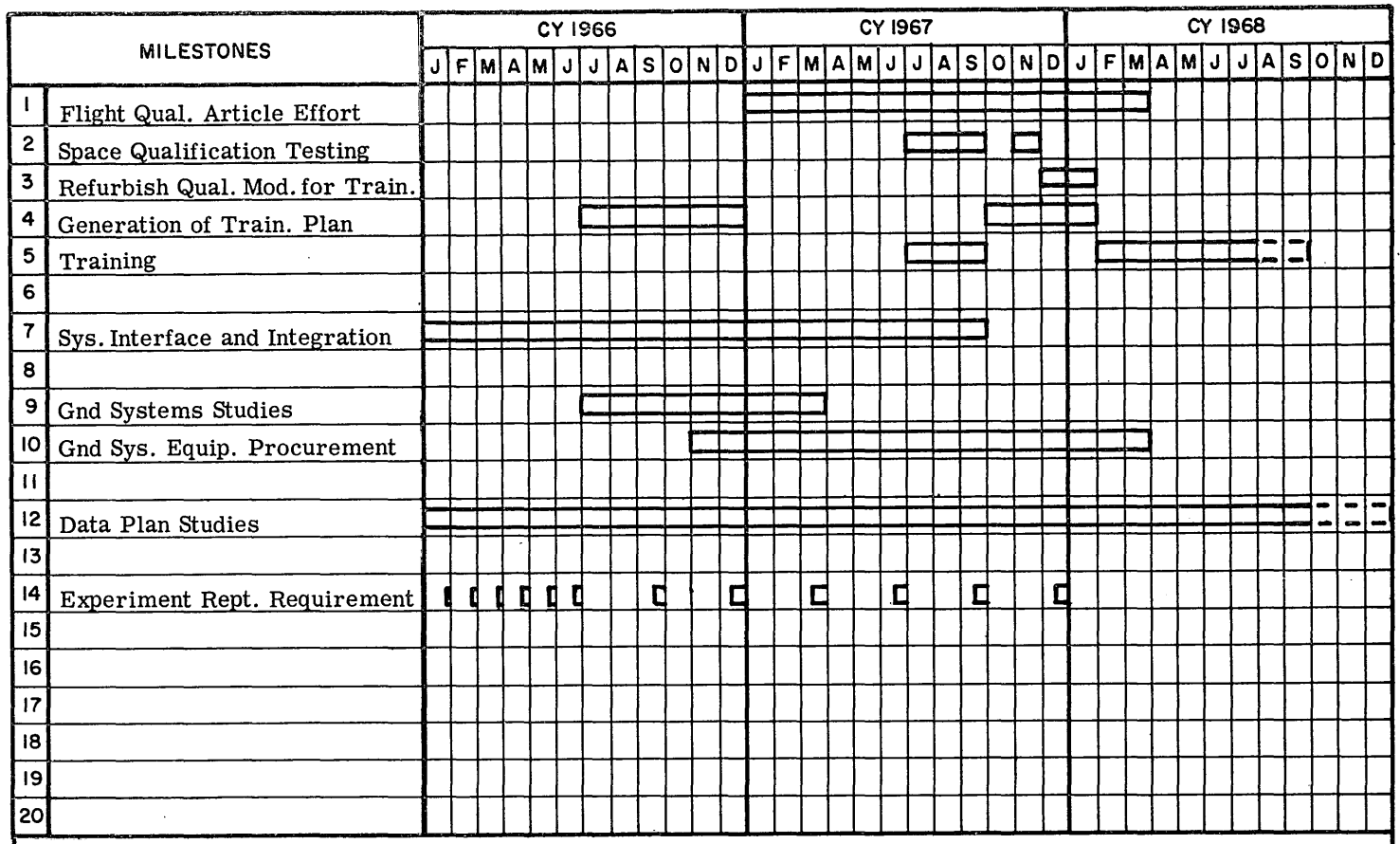
Consolidated S-1/S-23 Experiment
Revised Milestone/Schedule

2 LEVEL

SCHED NO.

STATUS AS OF 1 January 1966

PAGE 1 OF 2 PAGES



PREPARED BY:

APPROVED:

Consolidated S-1/S-23 Experiment
Revised Milestone/Schedule

2 LEVEL

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STATUS AS OF 1 Jan 1966

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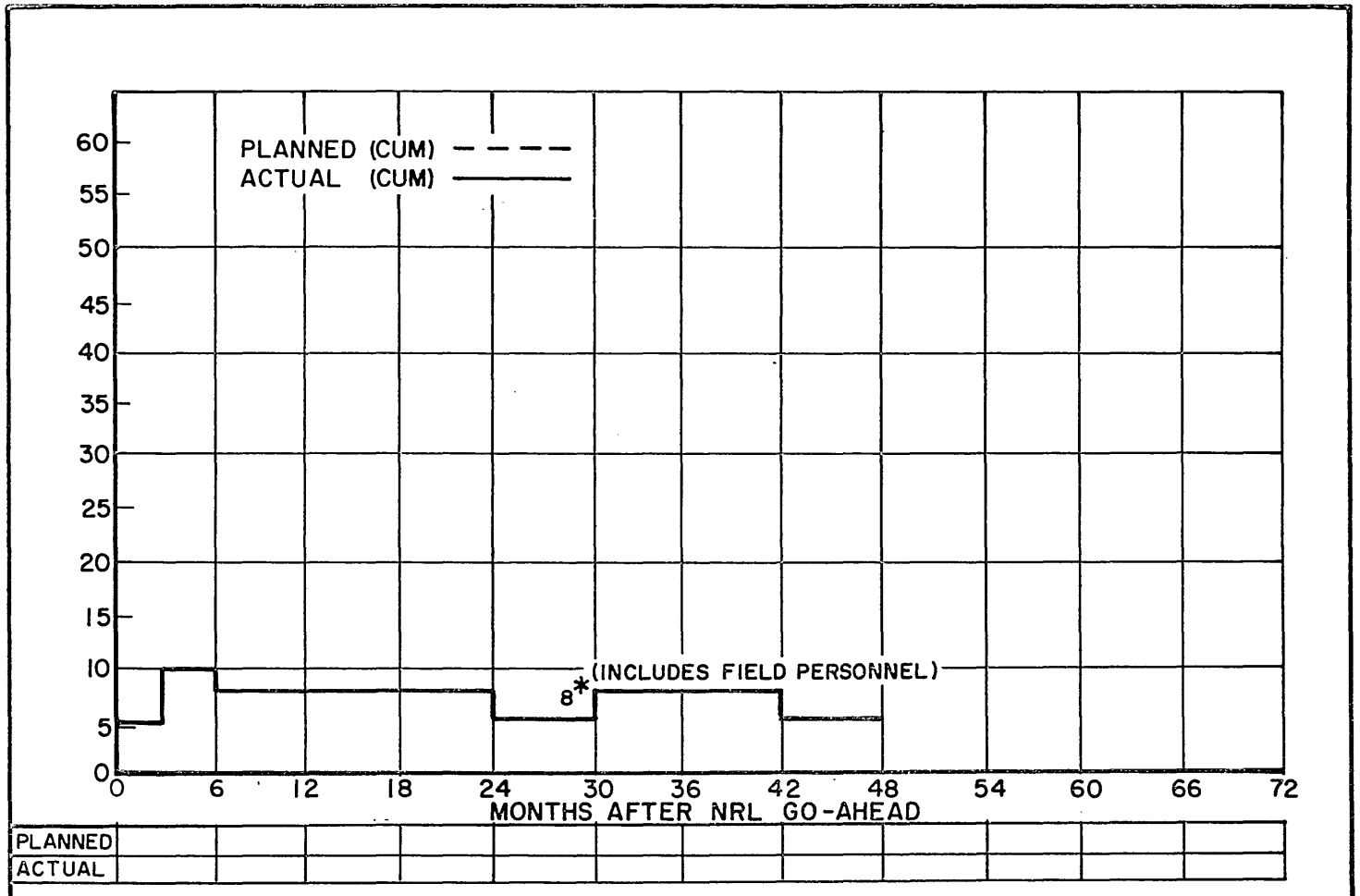

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APPROVED:	Revised Manpower Plan SCHED NO. LEVEL	STATUS AS OF 1 Jan 1966
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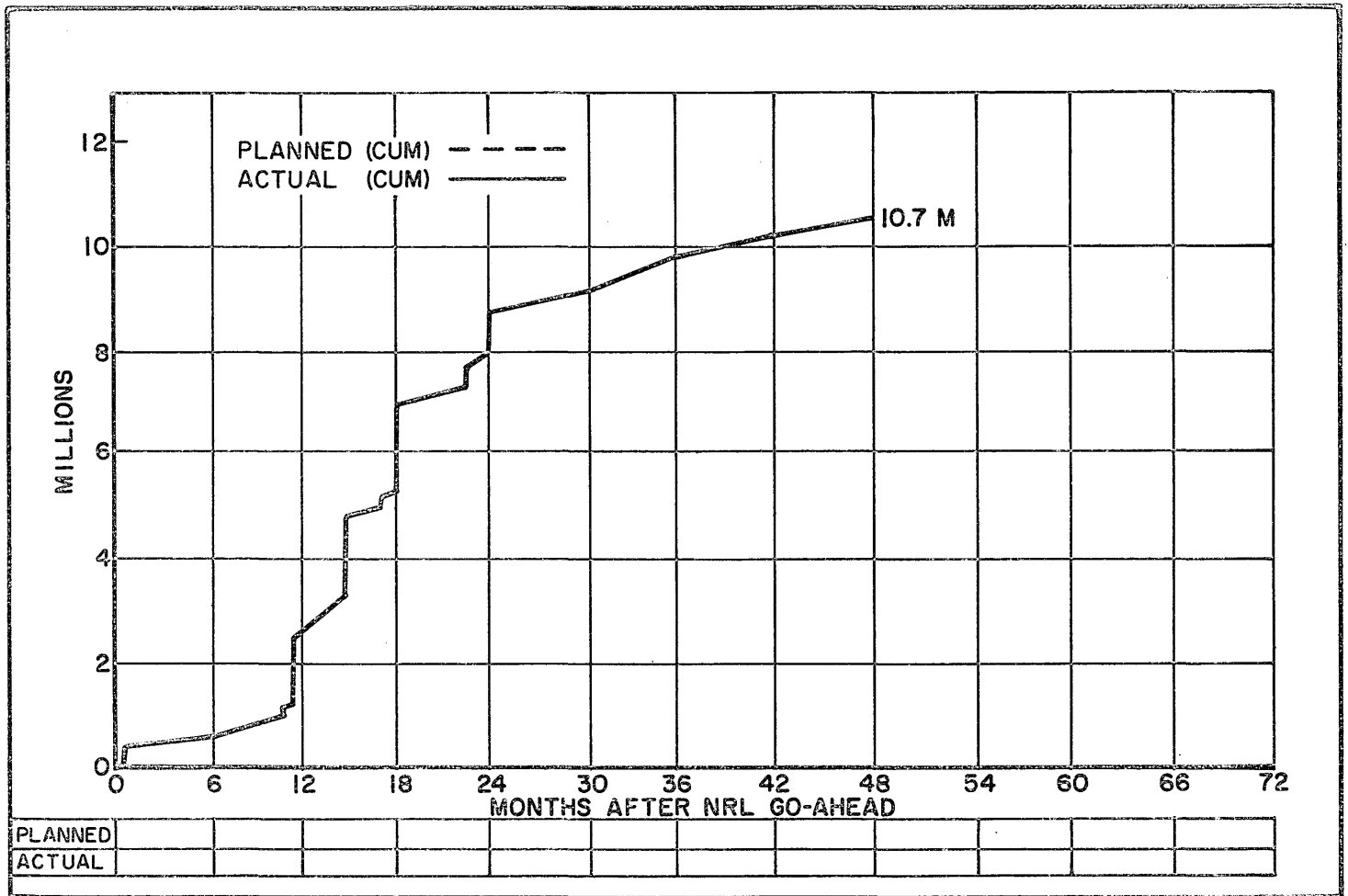

PREPARED BY:	Consolidated S-1/S-23 Experiment	ORIGINAL SCHEDULE APPROVAL
		LAST SCHEDULE CHANGE
APPROVED:	Revised Funding Plan	STATUS AS OF 1 Jan 1966
	SCHED NO.	PAGE OF PAGES

LEVEL

EXHIBIT C.18

STANDARD FORM NO. 64

Office Memorandum • UNITED STATES GOVERNMENT

5110-9:EFK:oam

TO : Code 7000

DATE: 2 February 1966

Via : Code 5100

FROM : Code 5110

SUBJECT: Progress Report for January 1966 - MOL Experiments 81/823; forwarding of (U)

Ref : (a) BUWEPS Conf Ser 08983 of 1 July 1965

Encl : (1) Progress Report for Month of January 1965; 5110-9A:EFK:oam of 2 February 1966

1. In accordance with paragraph 5 of reference (a), enclosure (1) is forwarded.

E. F. KULIKOWSKI

Unclassified when enclosure is removed.

5110-9A:EFK:eam
NRL Prob R07-15
2 February 1966

PROGRESS REPORT FOR THE MONTH OF JANUARY 1966

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02 (U)

Encl: (1) Milestone/Schedule, Manpower and Funding Charts for Reduced Scope VLF Experiment

Encl: (2) VLF Propagation Experiment Options

Encl: (3) VLF Propagation/Electron Density and Temperature Comprehensive Experiment (U)

1. The principal effort during the month was the preliminary design of an experiment which is considerably reduced in scope from that of the comprehensive experiment. The sole objective of the reduced scope effort is to demonstrate the propagation of VLF energy from satellite-borne antennas to the ground. A milestone/-schedule plan was devised, and manpower and fiscal requirements for a reduced scope experiment outlined. These form enclosure (1) to this report.

2. A series of options and/or additions to the reduced scope experiment were considered and the benefits accruing as a result of these additions described. The effort resulted in a set of five configurations which might be employed in an experiment complex. These configurations outline the various program elements required to conduct investigations ranging from the sole objective of demonstration of VLF propagation from a satellite to the total effort of the previously detailed comprehensive experiment program. The block diagrams and descriptive material for the various optional experiment configurations are presented as enclosure (2). The data on the Comprehensive Experiment is included as enclosure (3) and is classified SECRET.

3. For the investigation of the VLF ground environment a narrow-band (50 cps) VLF receiver was borrowed to permit a detailed study of the VLF signal population being received by the broad-band (5 cps - 200 Kcps) receiver. The narrow-band receiver data is expected to aid in the interpretation of spectrum analysis data obtained from the broad-band data. The broad-band receiver in conjunction with an external local oscillator has been used to receive signals of 17.8 KC (NAA), 21.4 KC (NSS), 64 KC, 87 KC, and 10.2 KC. These signals were received using a yagi antenna on the roof. A small loop antenna is available and will be installed on the roof with a rotor in the near future. The broad-band output of the receiver was filtered to pass frequencies from 600 - 6000 cps in an attempt to receive whistlers, but as yet none have been received.

4. Material was prepared and presented at NRL to the program sponsors (Bureau of Naval Weapons, Code RT) on 28 January 1966. This presentation outlined the experiment programs proposed by the Laboratory and summarized the accomplishments to date.

Confidential upon removal of enclosure (3).

5110-9A:EFK:eam
NRL Prob R07-15
2 February 1966

5. Some thought has been given to the possibility of measuring characteristics of a transmitting antenna for space applications, in a simulated environment. Initial considerations toward a scaling technique, point up a situation in which the factors involved in antenna performance in the VLF band below plasma and cyclotron frequencies are so interdependent that a straightforward analysis becomes very difficult. Wide variations in the electromagnetic wave radiation for a given applied frequency occur in different directions from the antenna with changes in electron density and magnetic field direction. Further study of some of these effects is being continued.

C. J. KURNER
NRL, Code 5112

REDUCED SCOPE EXPERIMENT
(VLF PROPAGATION)
PRELIMINARY FUNDING PLAN

3 Month Intervals	Cost Item	Cost	In-House Manpower	Period Cost Total
1	Design Study	200 K	60 K	260 K
2			60 K	60 K
3	Procurement of prototype and flight equipment (1st pay)	125 K	80 K	335 K
	Ground Systems Procurement	100 K		
	Pre-launch Checkout Rack	30 K		
4	Procurement of prototype and flight equip. (completion)	125 K	80 K	380 K
	Ground Systems Procurement	100 K		
	Qualification Testing	25 K		
	Data Analysis	50 K		
5	Qualification Testing	25 K	*100 K	175 K
	Data Analysis	50 K		
6		50 K	* 80 K	130 K
7	Data Collection, Reduction,	100 K	* 80 K	180 K
8	Analysis, Interpretation	100 K	* 80 K	180 K
9	and Reporting	100 K	* 80 K	180 K
10		100 K	* 80 K	180 K
11		100 K	* 80 K	180 K
12		100 K	* 80 K	180 K
			TOTAL	2.420 M

* Indicates cost of field personnel included.

COMPREHENSIVE S-1/S-23 EXPERIMENT
ESTIMATED FUNDING PLAN

6 Month Intervals	Cost Item	Cost	In-House Manpower	Period Cost Total
1	Engineering Design Study Contr.	350 K	120 K	470 K
2	Prototype Equipment and Integration Mock-up	2000 K	150 K	2250 K
	Ground Systems Support Study	100 K		
3	Qualification and Training Model (Includes Pre-Launch Monitor and Checkout Equipment)	1800 K	165 K	2865 K
	VLF Ground Stations Instrum.	900 K		
4	Flight Qualified Equipments(3)	1800 K	165 K	2565 K
	Refurbish Qualification Model	250 K		
	Qualification Testing	200 K		
	Training Costs	50 K		
	Data Collection, Processing, Analysis	100 K		
5	Ground Station Instrum., Installation & Checkout	900 K	105 K	1305 K
	Training	100 K		
	Data Handling	200 K		
6	Training	100 K	*175 K	475 K
	Data Handling	200 K		
7	Data Handling	250 K	*175 K	425 K
8		250 K	105 K	355 K
			TOTAL	10710 K

* Indicates cost of field personnel included.

EXHIBIT C.19

PROGRESS REPORT FOR THE MONTH OF FEBRUARY 1966

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02

ELF/VLF Propagation/Electron Density-Temperature Experiment

Copies of the program presentation made to the task sponsors (BUWEPS, Code RT) were submitted as part of the monthly progress report.

The activity during the month consisted primarily of investigation of techniques and facilities suitable for laboratory simulation of space plasma phenomena. It has long been recognized that such simulation can provide a valuable tool for the evaluation of satellite-borne experiment components and for the development of improved diagnostic techniques suitable for future space application.

A discussion was held with personnel from NASA with respect to simulation facilities currently being used or planned. NRL groups utilizing space simulation chambers have also been contacted. Further discussions are planned to insure a thorough familiarity with what is available, limitations of such facilities, and improvements which would be desirable for future systems.

If simulation of space conditions were to be attempted for the minimum altitude specified for an orbiting vehicle, the necessary dimensions of a chamber, which approximate the length of the mean free path of the space particles between collisions, is in the order of a hundred meters. A chamber of this size would be too expensive to be feasible. However, simulation can be accomplished by operating at a higher pressure than that of space, thus achieving a shorter mean free path.

A study has been initiated on the scaling methods applicable to magneto-ionic plasma parameters suitable for model studies in limited size chambers. Parameters such as plasma density, pressure, temperature, magnetic field intensity, and frequency must be considered in the scaling process. Simultaneous scaling of all relevant parameters does not at present seem feasible; therefore the studies are expected to result in a series of scaled experiments, each of which will provide data on one or more of the significant parameters.

A loop antenna and rotor were installed at NRL so that continued investigation of the VLF ground environment may be carried out.

The specification of the plasma source and simulation chamber requirements, which if met, will satisfy the testing needs of the comprehensive experiment program.

C. J. KURNER
NRL, Code 5112

ENCL (1) TO NRL MEMO 5110-39:EFK:eam

UNCLASSIFIED

EXHIBIT C.20

PROGRESS REPORT FOR THE MONTH OF MARCH 1966

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02

ELF/VLF Propagation/Electron Density-Temperature Experiment

The study of plasma sources and space simulation chambers suitable for the test and evaluation of experiment components and subsystems has continued. Also considered in the study is the capability for evaluation of models of antennas in suitably scaled plasmas and operating frequency regions.

Work continues on the study of magnetohydrodynamic (MHD) wave modes which may be stimulated by the satellite-ionosphere interaction. The relationship of vehicle size and velocity parameters, together with the physics of the medium is being studied to establish the conditions necessary for the generation of these MHD waves. A general review of MHD waves is being prepared for presentation to Laboratory personnel and to a group of Reserve Officers who will be visiting NRL.

The studies related to the behavior of a radiating antenna in a magneto-ionic medium have progressed to a point where the results can be reported. The report is currently in preparation.

During this period, it was learned that the problem in its present form is planned for termination at the end of the current fiscal year. The task sponsor has requested that we examine the program to identify those elements which can satisfy an operational need and to supply material for justification of this need. To this end, the Navy VLF Communications System is being reviewed and past efforts in satellite and rocket instrumentation for VLF studies is being examined. A memorandum summarizing these reviews and outlining the areas deserving of additional effort is being prepared.

C. J. KURNER
NRL, Code 5112

ENCL (1) TO NRL MEMO 5110-65:EFK:eam

8 March 1966

MEMORANDUM FOR FILE

Antenna Impedances in the Ionosphere

Purpose: The aims of this program are to develop mathematical methods for calculating impedances of antennas in the magnetosphere; to predict impedances for practical antennas as far as possible; to provide physical interpretations of unusual behaviors of these impedances. This investigation is intended to provide a background of physical understanding and of mathematical method to serve as basis both for the interpretation of experimental results and for more realistic antenna calculations, taking account of the yet-to-be-specified nature of the plasma sheath and the satellite wake.

Background: Present NRL personnel had earlier developed a complex power formulation expressing the impedance Z of an antenna in a homogeneous (i.e., sheath- and wake-free) incompressible magnetosphere. The method entailed assuming a parametrized antenna current, and calculating antenna impedance as a double integral, over the antenna surface, of an expression involving the antenna current and the dyadic Green's function for the surrounding medium. The formulation was of the variational type, permitting accurate determination of the current's parameters and from this, a best estimate of Z. The impedance Z was then calculated for thin dipole and loop antennas arbitrarily oriented in the magnetosphere. The radiation resistance of these antennas came out after evaluation of a numerical integral. The term that expressed the reactance of the dipole, for free-space conditions, turned out to change from capacitative to resistive to inductive, depending on ionospheric parameters and dipole orientation. The "resistive" reactance occurred when the dipole was oriented normal to directions in the collisionless ionosphere for which plane-wave phase velocity fell to zero. The numerical integrations failed to converge for practical VLF antennas of practical lengths in some regions of the ionosphere. This work had been done with the support of NASA and of NRL under the LOFTI program.

Progress: The problems recently considered have included: (a) Find the impedance for an infinitely long, thin dipole. The immediate aim here was to provide a limiting case of the finite dipole so that one would have some basis of estimate in case one could not solve: (b) Find an asymptotic or other numerical procedure for evaluating impedances in cases where the existing numerical integration program fails to converge. (c) Explain physically, in terms of ionospheric processes, the appearance of the resistive and inductive reactances. (d) Extend prediction capability for antennas in the ionosphere in general.

Problem (a) was readily solved by existing methods, but no progress was made with (b).

Under (c) the geometric explanation of the occurrence of the resistive reactance was extended slightly, and a physical explanation was found as follows:

ENCL (2) TO NRL MEMO 5110-39:EFK:eam

One assumes finite collision frequency (finite ohmic losses in the medium) and considers electron motions along the cone of low-phase-velocity directions. Here the electrons have large-amplitude "resonant" motions, and therefore this cone is a region of large relative losses. The losses increase in magnitude over a narrowing region as one lets collision frequency decrease, until, in the collisionless limit, one has infinite loss in an infinitely narrow region, the net loss being finite in any unit area on the cone. From this "resonance" interpretation one concludes that the appearance of a corresponding "resistive reactance" does not correspond to a condition useful for signalling purposes.

Under (d) we have examined predictions from other sources and found that the present methods clarify or improve on other results examined. For instance, the Weil-Walsh calculations of radiation resistance for e and o waves can be extended to lower frequencies where their methods are inapplicable. The loop antenna has a more stable reactance, as function of orientation, than the dipole because it is affected primarily by the constant permeability of the medium rather than by the varying tensor dielectric properties. Some plausible reasons were also advanced that the loop would also be electrically quieter in the satellite wake and ion-impact environment; this effect was suggested in the LOFTI data.

Future Plans: The positive aspects of the foregoing developments have been assembled in rough order for a journal writeup which would have to open with a summary of the analytic method. Some machine calculations should be undertaken to examine to what extent the infinitely long dipole approximates the electrically long ones where calculations now fail to converge. The one untried extension of the present impedance formulation appears to be to the case of simple antennas in a homogeneous compressible ionosphere capable of supporting electroacoustic waves. Available physics does not permit guesses as to whether this would give more realistic predictions, however.

W. S. AMENT
NRL, Code 5104

EXHIBIT C.21

PROGRESS REPORT FOR THE MONTH OF APRIL 1966

MOL EXPERIMENTS S1/S23

WEPTASK RT 7045020/6521/F019-05-02

ELF/VLF Propagation/Electron Density-Temperature Experiment

The effort during the month was directed primarily toward obtaining a more complete understanding of the Navy's VLF communications system. Current capabilities of the system, its limitations, and future plans are being reviewed in order to obtain a proper perspective for the determination of the ultimate operational capabilities of the proposed experiment program.

An outline of the historical development of the experiment approach, similar or related efforts by other investigators, trade-off analyses to be conducted, and proposed techniques for conduct of the program has been prepared. This outline will be employed in the preparation of a Proposed Technical Approach document, prepared in conjunction with the Bureau of Naval Weapons task sponsor. A meeting of those responsible for generating the PTA was held and the outline material reviewed to assure compliance with the requirements for its preparation.

The theoretical studies being conducted under the task, i.e., the magnetohydrodynamic wave stimulation and propagation study, and the study relative to the radiation from a VLF antenna in a magneto-ionic medium are continuing. Technical papers relevant to these areas at URSI and the American Physical Society meetings held during the month were attended by personnel working on the task.

C. J. KURNER
NRL, Code 5112

ENCL (1) TO NRL MEMO 5110-81:EFK:sam

EXHIBIT C.22

PROGRESS REPORT FOR THE MONTH OF MAY 1966

WEPTASK RT 7045020/6521/F019-05-02

ELF/VLF Propagation/Electron Density-Temperature Experiment

The effort during the month continued along the lines outlined in the previous progress report. A more specific determination of the operational requirements which are not fully met with existing techniques or systems is being pursued. Similarly, potential future communications requirements are being investigated to assess the capabilities of the satellite-borne VLF instrumentation in meeting such requirements.

In examining the operational capabilities of the VLF satellite program in a communications-to-submarine environment, it was found that the HF satellite program (S-22) was also being oriented to a submarine communications system. Since the two programs are complementary to one another, it appears advantageous to determine system elements common to both approaches. As a result of preliminary discussions with the HF program sponsors, further study in this direction is indicated.

The theoretical studies of the magnetohydrodynamic (MHD) wave mode generation as a result of high power antenna excitation, or of interaction of the vehicle and plasma medium are continuing. It is expected that available parameter values relating to the medium, and the vehicle can be used to provide "quick-look" numerical estimates of MHD wave power levels which may be generated under the assumed conditions.

The study of the radiation from VLF antennas in a magneto-ionic plasma (the ionosphere) is continuing. A report on the results of the study to date is in preparation.

C. J. KURNER
NRL, Code 5112

ENCL (1) TO NRL MEMO 5110-113:CJK:eam

EXHIBIT C.23

FINAL REPORT: MOL EXPERIMENT PROGRAM S-1/S-23 (U)
(Progress Report for the Month of July 1966)

Background

The investigative program which is the subject of this final report had its inception early in 1964 with the call for proposals of experiments which could exploit the unique capabilities of the Manned Orbiting Laboratory concept. The responses of the several naval laboratories and activities were evaluated by the Navy MOL Experiment Selection Panel and those considered of the greatest value from a scientific or military operational point of view were submitted to the Air Force Systems Command, Space Systems Division, for further consideration. As a result of the selection processes, several of the experiment sponsors were directed to document their programs more fully in order to provide the Air Force contractor with the necessary preliminary technical and logistics program planning data relevant to the particular experiment. The "Plasma Investigation by Electron Density and Temperature Measurement" candidate experiment was one of several sponsored by the Naval Research Laboratory (1) which were selected for further definition as part of the Pre-Phase One PDP effort under which the MOL Program was to be conducted.

The Electron Density and Temperature Experiment, designated as MOL Military Technology Experiment S-23 (2,3), underwent a preliminary technical and operational definition in accordance with the documentation requirement of the Air Force Space Systems Division, as coordinated for the Navy experiments by the Navy Field Office for Manned Orbiting Laboratory (NAVMOL). This documentation, together with supporting and amplifying data supplied to NAVMOL as program review material and technical memoranda during the Pre-Phase One program effort, are summarized in the preliminary portion of this report. The results of subsequent efforts, occasioned by the redirection of experiment objectives and consolidation of several NRL-sponsored experiments, will also be presented.

Introduction

The investigation of the nature and behavior of the ionospheric plasma which surrounds the earth has been pursued utilizing a number of techniques with varying degrees of success. The determination of electron density vs height profile up to the region of the F_2-layer peak electron density value using vertical-incidence ionosound recordings is routinely done at many points throughout the world. Relatively recently developed oblique-incidence sounding techniques provide additional data on lateral and vertical distributions of localized concentration of electrons (such as are often associated with Sporadic-E and Spread-F wave propagation phenomena).

The advent of rocket and satellite technology has provided the first opportunity for "in-situ" investigations of the ionosphere. Numerous rocket vehicles instrumented for the determination of ionospheric charged particle density and temperature

(energy) levels of the several radio wave reflecting layers of the ionosphere have been launched. Satellites using similar instrumentation are regularly placed in orbits which sample the F layer. Much useful data on the variation of ionospheric parameters as a function of local solar time, latitude, season and solar activity level has been obtained.

The "in-situ" plasma diagnostic techniques which have been employed are quite varied. The predominant technique employs an electrostatic "Langmuir" probe concept in which the current flow to the probe is measured as a function of the probe voltage. Many probe geometries such as planar, cylindrical, and spherical have been employed. Guard electrodes are frequently used to minimize "end-effect" due to the boundary of the probe, and gridded structures have been utilized to eliminate photoelectric or secondary emission phenomena from contaminating the desired probe data. In addition to the Langmuir probe efforts, resonance rectification probes and capacitance probes have been employed for ionospheric measurements. The resonance rectification technique utilizes the phenomena that the d.c. current collected by the probe reaches a well defined maximum as the frequency of a superimposed radio frequency is varied through the region containing the local plasma frequency. The d.c. current peak level and the associated radio frequency at which the peak occurs can be interpreted in terms of the electron number density. The capacitance probe technique enables the determination of densities in terms of the variation in reactance of a capacitor for which the plasma medium forms the dielectric material.

Though the agreement between results obtained from the various probe methods has frequently been quite acceptable, it has been noted by most experimenters that perturbing influences often make the data of questionable value. These perturbations, considered to be associated with the motion of the vehicle in the medium, are quite variable both in extent and character. The shape and size parameters of the vehicle, its attitude along the orbit track, and its location in the orbit seem to be the predominant factors in the generation of the data perturbations. The ion sheath which normally surrounds the vehicle is modified by the process of "sweeping-out" of additional essentially stationary (with respect to vehicle motion) ion species in the path of the spacecraft. An attendant wake of rather large dimensions, compared to those of the space vehicle, make the probe collection process attitude sensitive. Similar ion sheath modification effects may be attributed to induced vehicle potentials resulting from the motion of conducting surfaces through the earth's static magnetic field. Photoelectric current yield from the sunlit portion of the satellite may cause circulating currents on the vehicle surface and may be a factor in sheath distortion. The effects due to these and perhaps other effects are likely to be magnified with increased satellite size. The effects resulting from the use of large antennas, long instrument booms, and large manned spacecraft capable of supporting long duration missions are currently unknown and need careful investigation.

The effects discussed have been credited with causing much of the variability and disagreement in the data collected by "in-situ" ionospheric plasma probes. However, a full understanding of these and possibly other as yet unidentified phenomena is currently lacking, and only fragmentary experimental evidence is available for validating existing analytical treatment or postulating new approaches.

One of the primary objectives defined for the S-23 Electron Density and Temperature Experiment was to obtain a comprehensive set of data on the near-vehicle ion sheath and disturbed plasma environment of a large satellite oribiting at

ionospheric altitude. The results of this program are to be used in improving the accuracy with which probe measurements of the undisturbed plasma can be made. Additionally, it is planned to use the near-vehicle data to improve satellite communication technology by providing a better understanding of antenna-to-medium electromagnetic wave coupling parameters. The general level of knowledge of the processes which accompany the passage of a vehicle through a magneto-plasma will be raised by the successful conduct of this experiment program.

Technical Definition

The preliminary technical definition of the experiment program was done principally from a performance point of view. That is, the size, weight, and power limitations imposed by a satellite environment was considered only secondary to the achievement of the experiment objectives. It was recognized that in subsequent iterations of the technical effort compromises in performance might have to be effected in order to satisfy other constraints.

An artist's concept of the external vehicle instrumentation for the preliminary program is shown in Figure 1. The five probe-boom assemblies are deployed about the surface of the vehicle to permit essentially simultaneous observations from all portions of the near environment. This will enable a mapping of the charged particle concentrations through observations along the velocity vector of the satellite, in the wake region, and at several circumferential points. The control of probe attitude provides particle velocity directional data. Variation of boom lengths enables a programmed sampling of the ion sheath surrounding the satellite from close to the external skin of the vehicle to distances as great as 10 feet, which should, for the circumferentially located probes, then be sampling the plasma medium undisturbed by the passage of the satellite.

The probe-boom sensors are controlled from a common programmer assembly. This unit supplies the probe electrode potentials which determine the operating mode (i.e., electron or positive ion collection), direct the probe attitudes and boom extension lengths, and provide the necessary timing and calibration signals for collection of data in a useful form. In addition to the programmed functions, it is possible for the astronaut/test conductor to provide manual control of the probe voltages, probe attitudes, and boom lengths for the purpose of providing additional information on particular situations of interest as determined from interpretation of the data display on board the vehicle or from "quick-look" analysis of the telemetered data on the ground.

Weight, size, and power requirements estimated for the equipment configuration arrived at in this preliminary technical definition are: weight, 140 pounds; size, 3.5 cubic feet; power, 150 watts peak, 100 watts average. The estimates are exclusive of the prime power source needed for the experiment; the data encoding, storage, and telemetry equipment; and the ancillary housekeeping data (e.g., time, vehicle attitude) which are necessary to the experiment but are assumed to be available from other spacecraft systems.

The preliminary technical definition was transmitted to the MOL managing agency for review by them and by their technical advisory staff. As a result of the review, it was learned that the experiment program submitted was excessively

heavy and power consuming for an experiment in the military technology (S-experiment) group. Some guidelines were made available as to the availability of space, both internal and on the vehicle surface; data multiplex, encoding, and storage capabilities; ancillary (to this experiment) data availability and accuracies; and tentative schedules of major MOL program milestones.

Armed with this additional information and cognizant of the relatively tight scheduling for the program, it was decided to redefine the S-23 Electron Density and Temperature Experiment in an effort to be more responsive to the guidelines suggested. It was also learned at about this time that the results obtained from the S-23 program were highly complementary to Experiments S-1, a very low frequency propagation program, and S-22, a high frequency plasma investigation program. The redefinition of Experiment S-23 was conducted with the further goal of enhancing the data utilization of this program by the complementary ones. The experiment concept thus evolved consisted of a three probe-boom complex situated along the length of the vehicle with uniform angular separation about the periphery. Physical constraints eliminated the availability of the nose region of the vehicle, and direct placement of a probe in the rear-facing structure was considered undesirable due to exposure to propulsion system exhaust products. Probe attitude and boom length positioning is adequate to retain the capability for resolving the directional properties of the collected particles and for probing the wake region created by vehicle motion. Additionally, it was planned to permit location of a probe in the near vicinity of the VLF transmitting dipole of Experiment S-1 to monitor the change, if any, in plasma parameters under the influence of strong VLF electromagnetic field intensities. The on-board display and control facility remains essentially the same. Figure 2 shows the conceptual view of the deployed probe-boom installation on the external surface of the vehicle, and Figure 3 is a tentative block diagram of the experiment vehicle instrumentation. As a result of the redefinition of the experiment a significant reduction of weight and power requirements was achieved. Estimates of these quantities for this configuration are: weight, 80 pounds; power, 75 watts average operating, 100 watts peak.

An on-orbit operating procedure for the conduct of the experiment has been devised. The procedure takes into account the limited time available for the conduct of the military technology (S) experiments and the restricted availability of data storage and telemetry for this program. Operation of the S-23 instrumentation is planned as a semiautomatic function which is initiated by the astronaut/test conductor and monitored by him for correct operation. The probe attitude, boom length, and data sampling process is normally under the control of a preprogrammed controller. In addition to the semiautomatic mode provision for manual control of the experiment is planned to enable the astronaut to investigate unusual or special interest conditions (e.g., occurrence of high levels of solar radiation, detailed probing in the vicinity of a radiating antenna).

It is planned that the minimal set of semiautomatic plasma data encompassing the conditions of day-night, latitude, and altitude variation occasioned by the vehicle orbit can be collected over eight ten-minute data intervals spaced over two consecutive orbit periods of the satellite. An additional 80 minutes of operating time is planned for the manual data collection mode in support of the VLF wave propagation experiment and for the on-board investigation of anomalous conditions. Additional operating time, if available, can supply useful validating information.

Data multiplexing, encoding, storage, and telemetry requirements for the experiment have been kept within the guidelines which were (informally) established for the S-series of experiments. The sensory data and "housekeeping" data generated by the S-23 experiment can be represented as a binary digital bit stream at a rate of less than 500 bits/second during operation. This data rate, however, does not include the ancillary data requirements which have been previously mentioned.

In anticipation of approval of the Phase-One MOL Program effort in general, and of the Electron Density and Temperature (S-23) Experiment in particular, a specification for an engineering design and procurement was drafted. A synopsis of the planned program objectives was published in the Department of Commerce Business Daily and a determination and finding procedure initiated. A draft copy of a Request for Proposal was prepared and held for final modification until the experiment program was approved and funded for participation in the Definition Phase (Phase-One) of the MOL Program.

It had been expected that with the generation of the several reports required by the MOL Program Management Office and the RFP, the Pre-Phase One effort would be complete. However, a program stretch-out, coupled with a redirection of experiment objectives to support an ultimate operational need and capability, resulted in further experiment definition. The principal operationally oriented function exhibited by the S-23 experiment program was in the support of the S-1 VLF Propagation Experiment. It was decided at this time that experiments S-1 and S-23 should be consolidated into a single program, with the S-23 objectives modified to emphasize the role of providing environmental plasma parameter data which could be used to determine optimum VLF radiation from a space vehicle. The S-1 program, independently documented in the Pre-Phase One period through the same report format prepared for the Electron Density and Temperature Experiment, is basically a program for quantitatively defining the conditions for which VLF radiation from an ionospheric-imbedded antenna can be effected and for the measurement of the magnitude of the propagated signals at ground receiving sites. The details of the S-1 program may be obtained from the referenced documents. The material presented here will be limited to the details of the combined S-1/S-23 program approach.

At about the same time as the consolidation of the two approaches was begun, it was learned that funding of the Navy S-experiment for the MOL program might not be available. As a result, the definition of the merged experiment was undertaken to provide an instrumentation concept which was sufficiently flexible to permit its inclusion in a wide variety of launch vehicle-satellite configurations. Operation in an unmanned satellite was considered as well as in the MOL.

The primary objective of the merged program is a feasibility demonstration of VLF propagation from a space-borne transmitter to widely separated ground receiving sites. A minimal configuration suitable for achieving this goal has been defined and is shown in Figure 4. Additional "building blocks" have also been defined which are desirable for purposes of providing the type of support information which may be used for enhancing and optimizing the performance of the basic system. Examples of the supporting instrumentation include plasma probe facilities and magnetometer installations. A typical set of add-on configurations to the system of Figure 4 is shown in Figures 5 through 8. Combinations other than those shown are possible, depending on vehicle capabilities and overall objectives of the mission.

A draft copy of a Request for Proposal containing the specifications for the engineering design, fabrication, environmental testing, and space qualification of an integrated system of the type shown in Figure 4 has been prepared. No further work on this aspect of the program is planned until approval and funding for equipment procurement is received.

Support Studies

Adequate technical definition of the experiment program has required that supporting studies on several of the aspects of the program be conducted. These have been carried out to ensure that state-of-the-art in techniques for data collection, processing, and interpretation is considered in the determination of the experiment performance requirements and specifications.

A review of probe techniques suitable for ionospheric plasma investigations was conducted, and the merits and limitations of the several methods were compared. The results of this review will be used in assessing the expected performance of any one or combination of the probe types in support of a particular mission. In anticipation of a considerable laboratory testing program for evaluation of representative probes, a facility for displaying and recording the characteristics of probe-electrometer amplifier combinations was devised. A small glow discharge tube, with several simple probes in the glow space, was used as a plasma source to successfully demonstrate the concept of the test instrumentation.

A part of the VLF space-to-ground propagation program is the reception of the signals transmitted from the satellite. Since the detection of these signals must be effected amid the competing VLF interference sources frequently observed at receiving sites, it was felt that an investigation of the received VLF spectrum should be conducted to locate a frequency or frequencies most immune to other signals or noise sources. A receiving system originally used in the LOFTI I program was obtained and installed. Operation was verified but no data for analysis purposes has been recorded.

A theoretical study of the radiation behavior of VLF antennas in a magneto-ionic medium is currently nearing completion. This study is of prime importance to the VLF Propagation program. Since there has been no known prior experimental program dedicated to the demonstration of radiation from a space vehicle in this frequency range, theoretical studies provide the only guide to selection of engineering design parameters. Although a number of studies of radiation from antennas in plasma have previously been conducted by others, the differing analytical models of the plasma environment used and the assumptions made for purposes of mathematical tractability have made the results inconclusive and, on occasion, contradictory. It is hoped that the present study will provide a firm basis for the prediction of performance of the satellite-borne transmitting system.

Future Plans and Recommendations

This is the final report to be issued on the MOL S-1/S-23 Experiment Program. Based on the understanding that no further funding will be made available for this program, it is planned to discontinue further effort upon completion of the report

relating to the study of antenna radiation properties in an ionospheric plasma. It is recommended, however, that in light of the serious lack of knowledge of an experimental nature on the effects of high power VLF transmitters in space, this or a similar program be pursued at an early date.

C. J. KURNER
NRL, Code 5112

References:

1. Hall, W. C. and Faust, W. R.; "Possible Experiments for Manned Orbiting Laboratory," IEEE Trans. Vol AES-1, No. 2; Oct. 1965

2. Final Technical Documentary Report (FTDR), Navy Experiments Program for Manned Orbiting Laboratory (Unclassified title); Navy Field Office for MOL Report TR-65-2, Vol 1 (S-1), Vol 3 (S-23), 8 Jan 1965 (Conf.)

3. Glasser, R. L., "Data Addendum for MOL Technology Experiments" (U), Aerospace Corp. Report TOR-469 (5107-32)-2, 20 Oct 1964 (Secret)

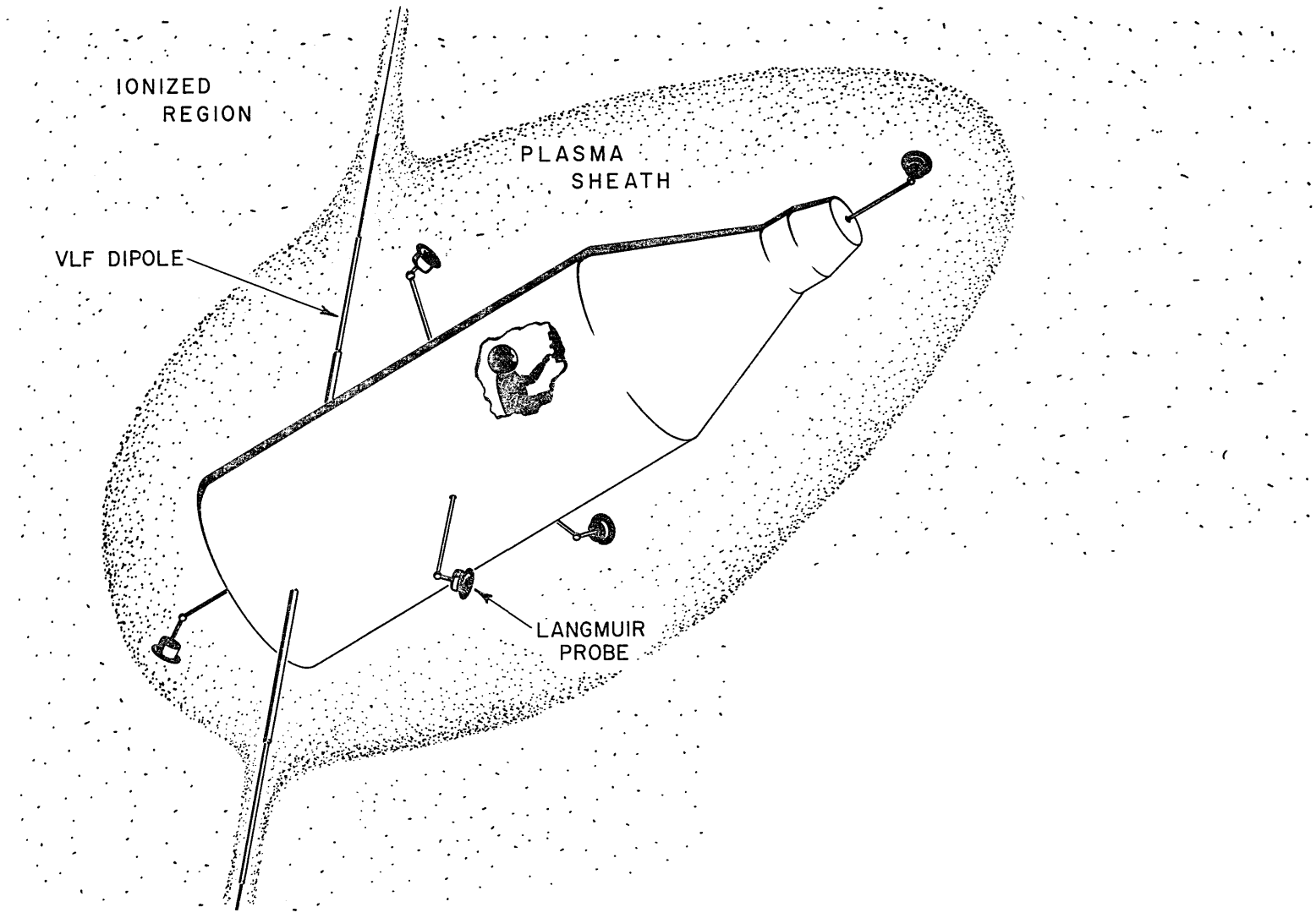

Fig. 1 - External instrumentation

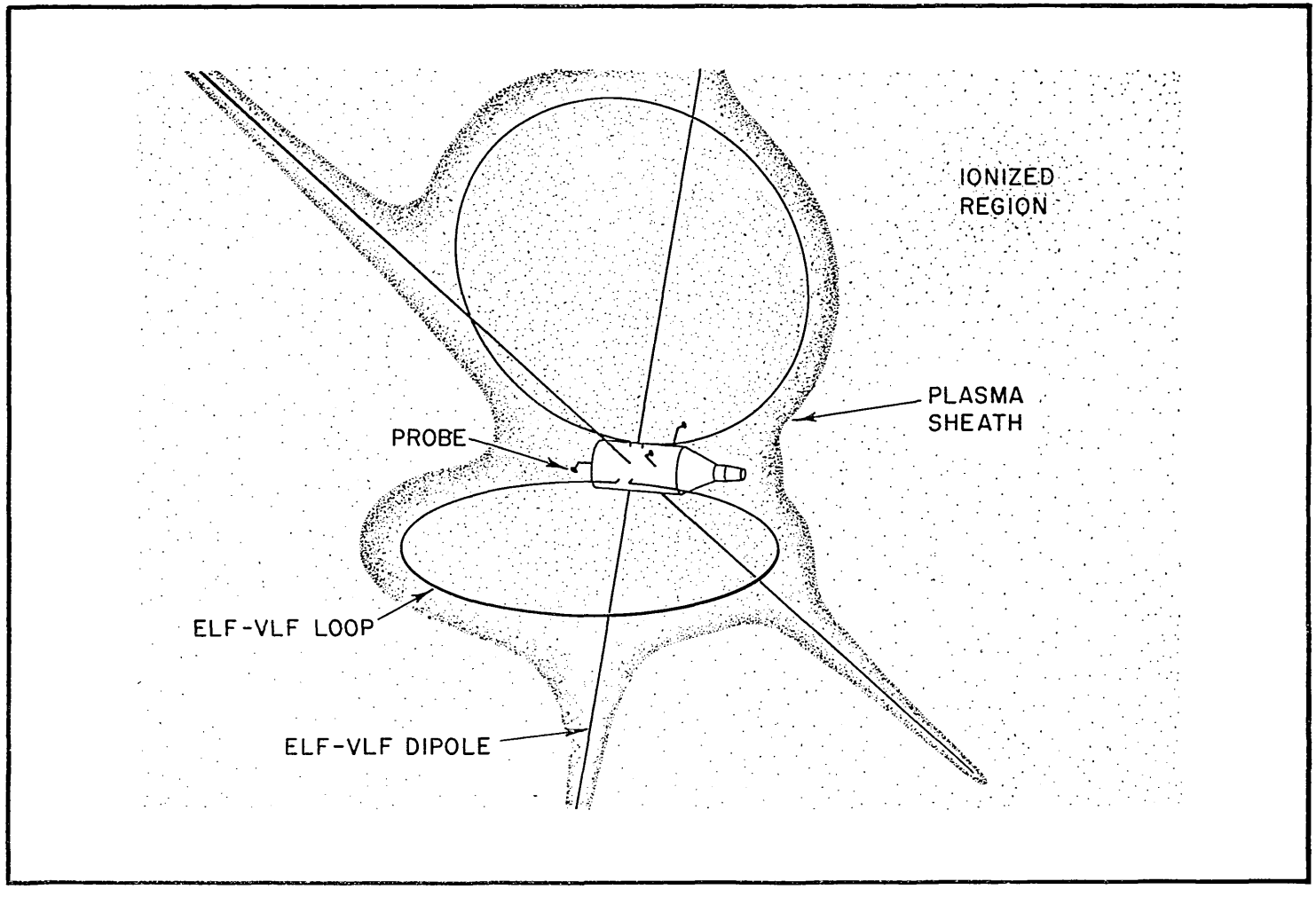

Fig. 2 - Deployed probe-boom installation

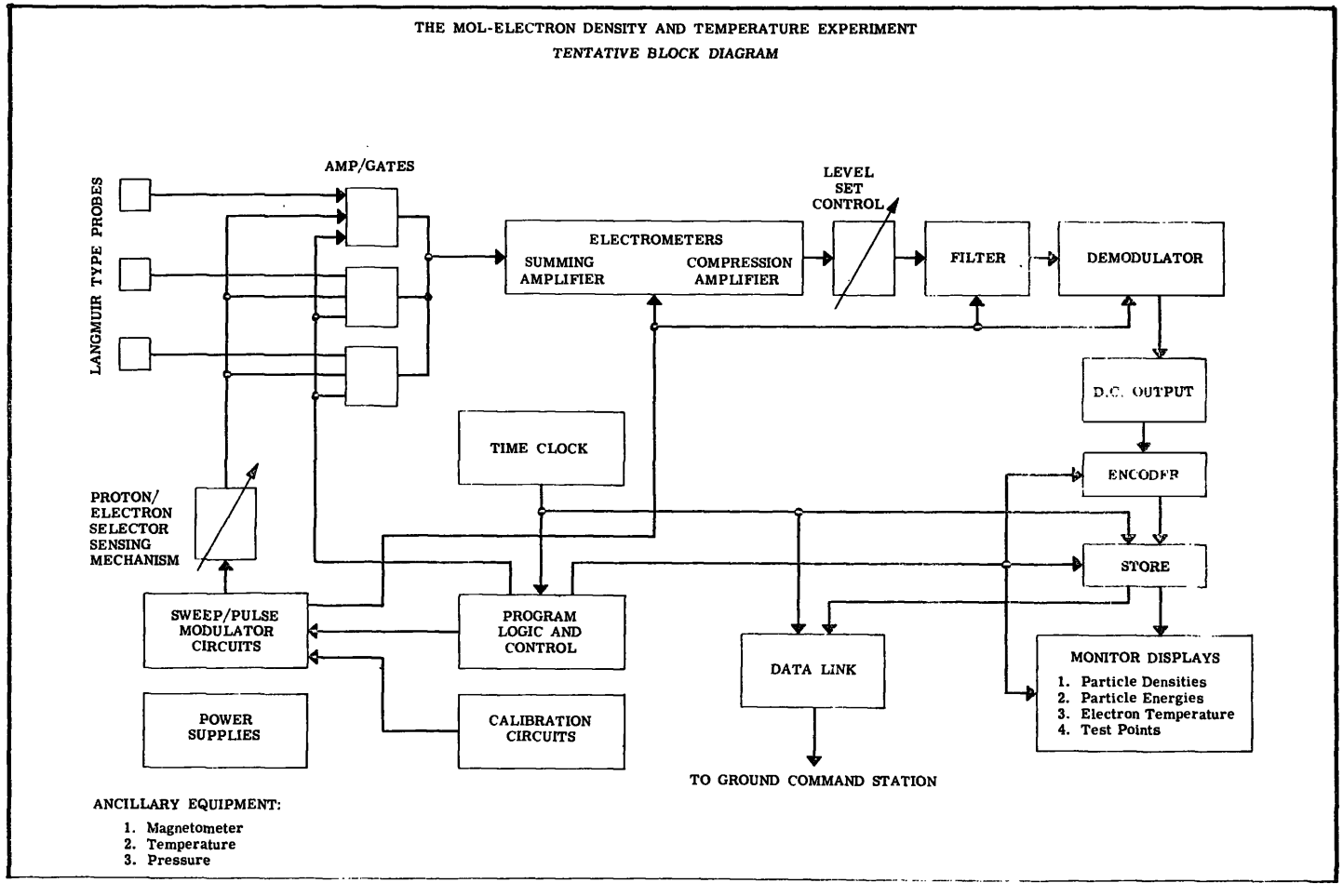

Fig. 3 - Experiment vehicle instrumentation

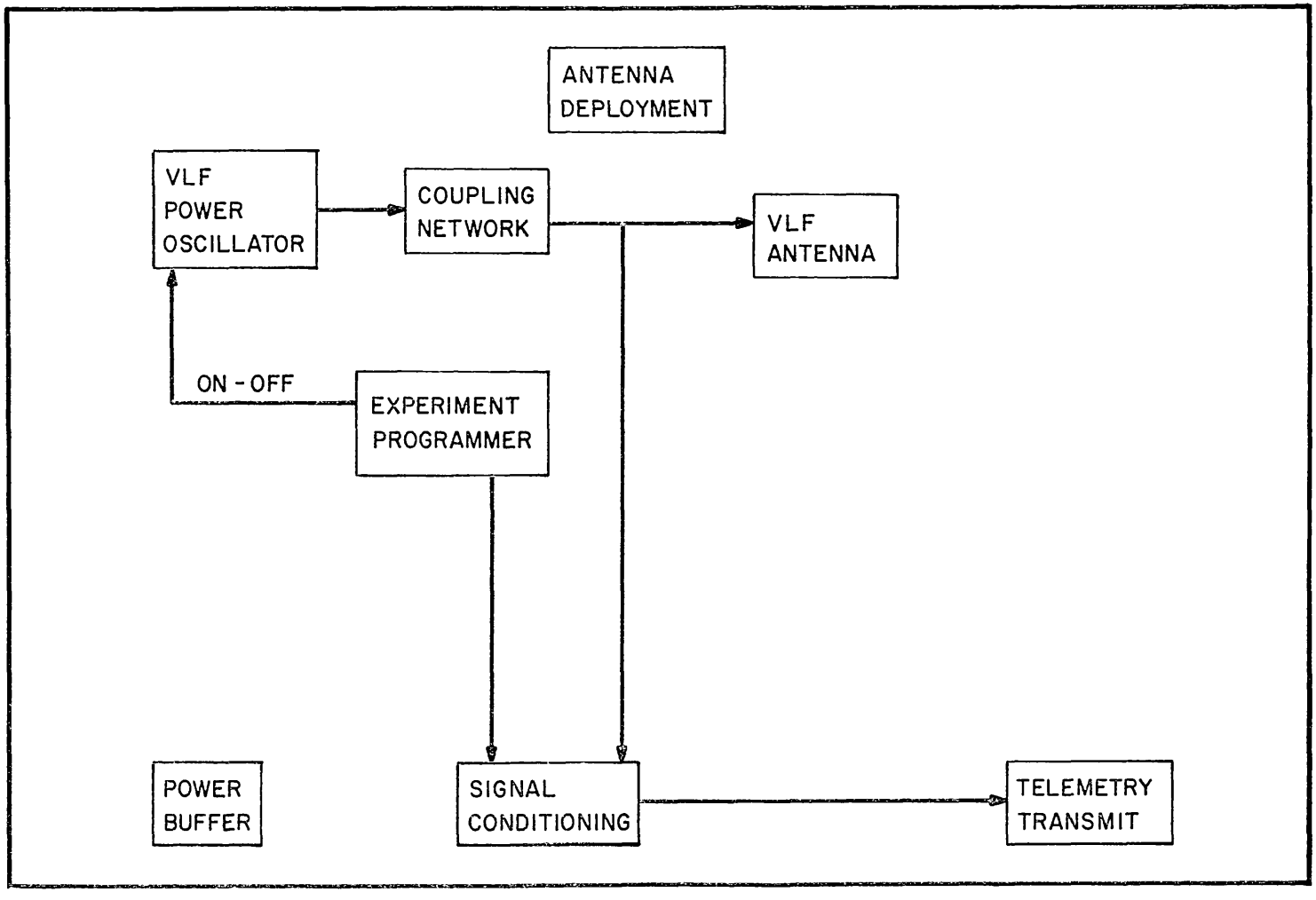

Fig. 4 - VLF propagation experiment -- minimal configuration

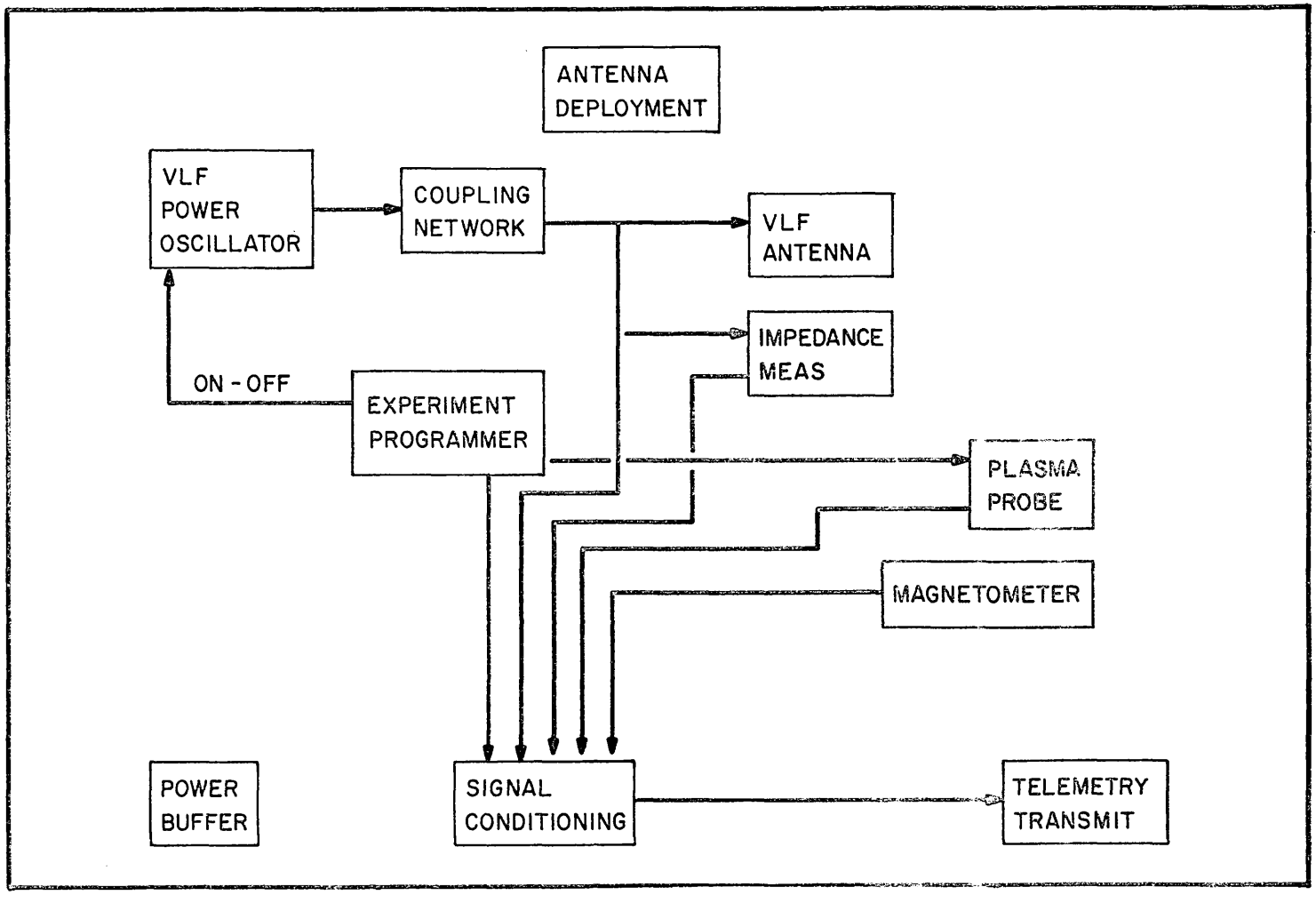

Fig. 5 - Add-on configurations to Fig. 4

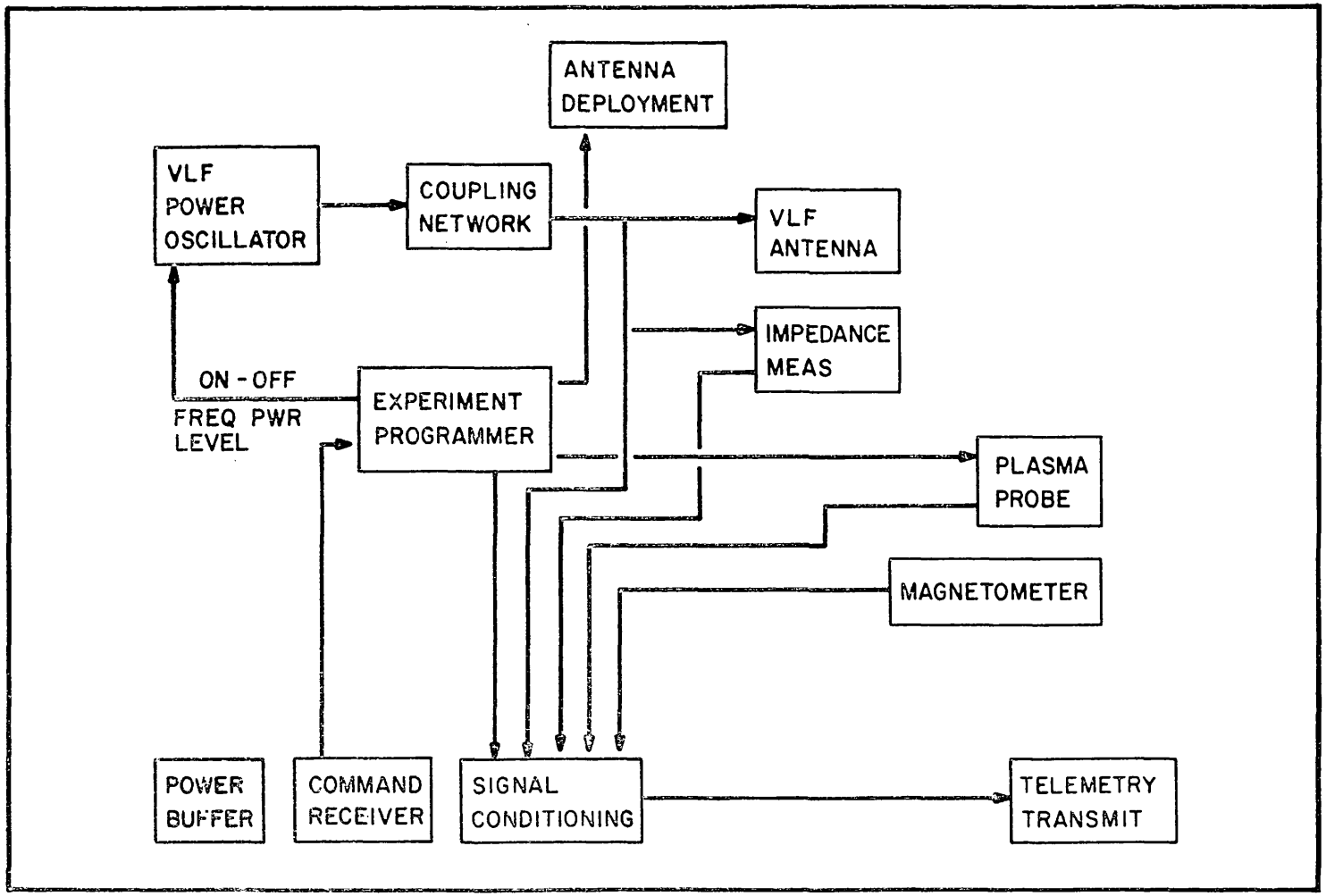

Fig. 6 - Add-on configurations to Fig. 5

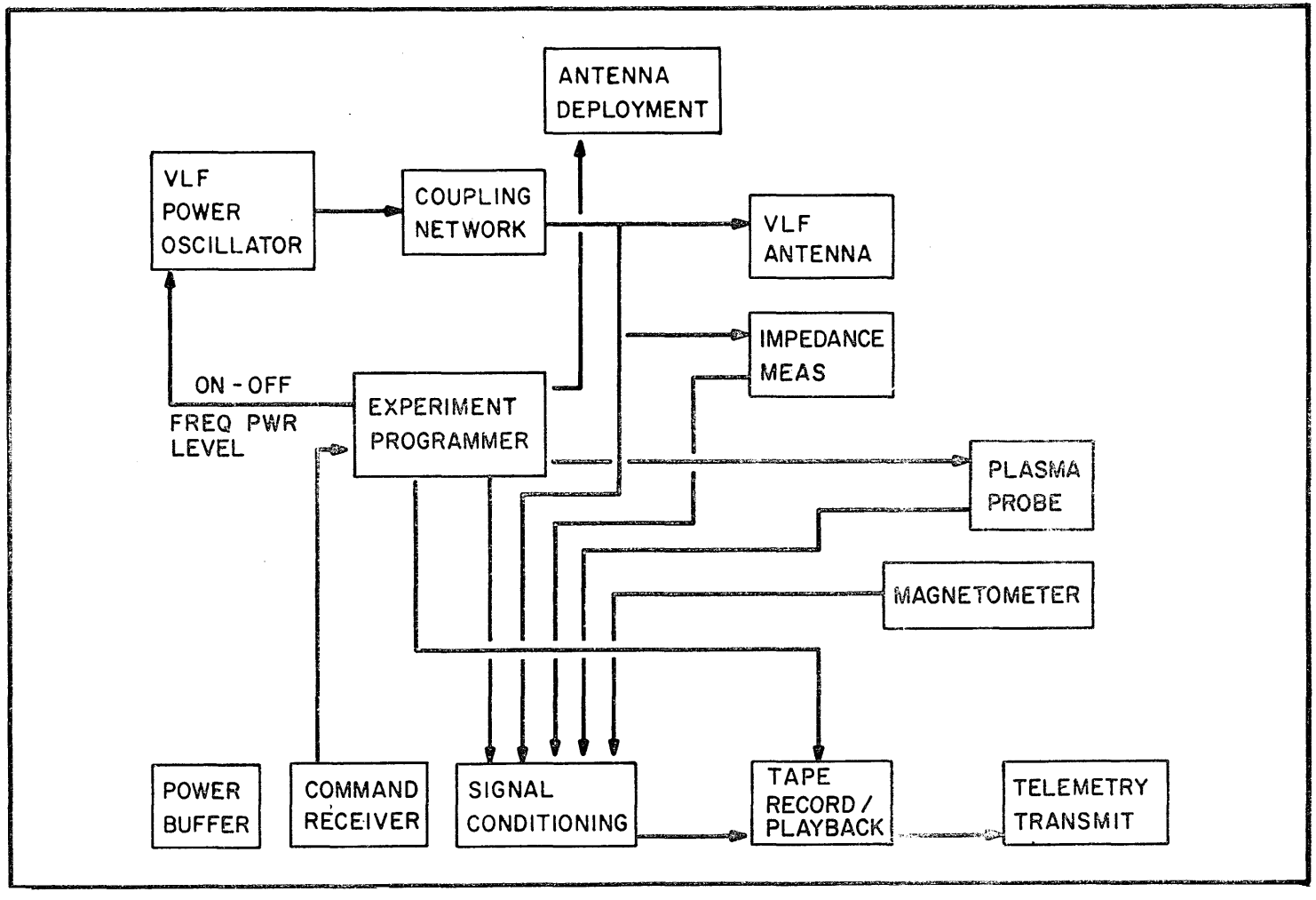

Fig. 7 - Add-on configurations to Fig. 6

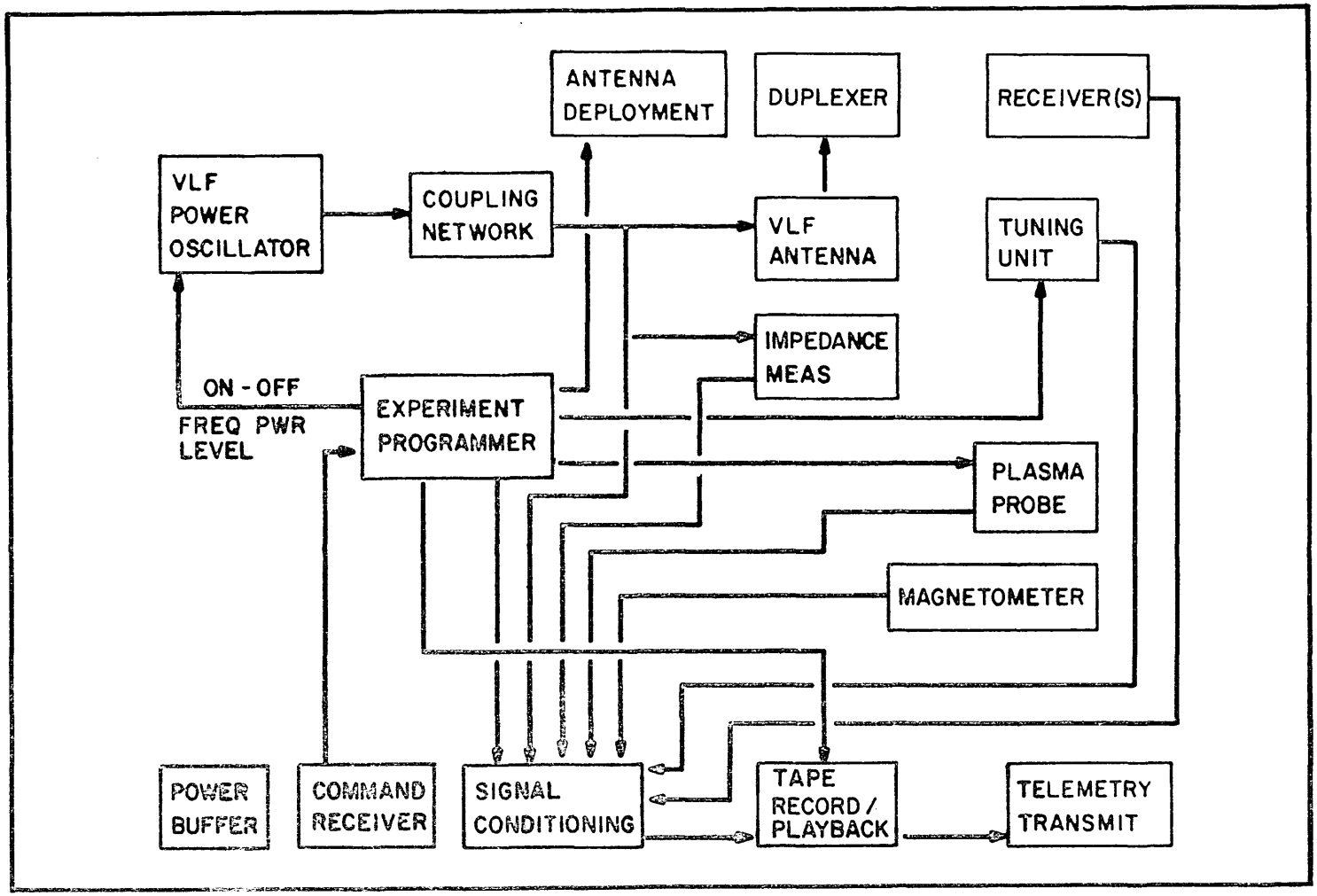

Fig. 8 - Add-on configurations to Fig. 7

APPENDIX D

ADDITIONAL SUPPORTING DOCUMENTATION OF EXPERIMENT PROGRAM*

Contents

Exhibit D.1	Memorandum for File - Project MOL Experimental Procedure for Plasma Measurements S-23
Exhibit D.2	Utilization of Magnetohydrodynamic Waves
Exhibit D.3	Interactions of Space Vehicles with Plasma
Exhibit D.4	Transmittal of Preliminary Data Rate and Data Storage Requirements for Experiment S-23 to NAVMOL
Exhibit D.5	Simulation Tasks for Experiment S-23
Exhibit D.6	Electron Density and Temperature Experiment (S-23) Justification for Inclusion in MOL
Exhibit D.7	Synopsis of Experiment Program as published in Dept. of Comm. Business Daily of 3/19/65
Exhibit D.8	Memorandum - Draft Copies of "General Procurement Plan for the Electron Density and Temperature Experiment" and "Request for Proposal for Electron Density and Temperature Experiment (S-23)"
Exhibit D.9	Memorandum - "A Look at the Solar Heating of the Thermal Equalization Probe"
Exhibit D.10	Draft copy of "Request for Proposal - Exploitation of Space Plasma Effects MOL/S1/S23 and MHD"
Exhibit D.11	Rough Draft of Material Prepared for Use by BUWEPS Code RTOS-3 in Their Preparation of a Related PTA

* Additional supporting material has been supplied as attachments to several of the progress reports of Appendix C.

EXHIBIT D.1

5110-102:FTP:eam
NRL Prob K03-06A
10 August 1964

MEMORANDUM FOR FILE

Subj: Project MOL - Experimental Procedure for Plasma Measurements S23

In obtaining experimental data from the plasma probes in the MOL project, the following sequence of operation is anticipated.

A series of step voltages are applied to differently positioned probes simultaneously, to collect ions and electrons of different energy levels for current measurement. It is believed that 8 steps, plus zero, of positive and negative voltages up to 40 volts maximum should cover the majority of particles found between altitudes of 100 and 250 miles. The sequence of voltages are obtained from a programmed power supply or amplifier fed from a gated matrix driven by 4 stage counter circuit which is triggered by a clock pulse from the time standard. As each voltage is applied, currents between 10^{-12} and 10^{-7} amperes are obtained from the probes and are amplified logarithmically to produce output voltages from each of 5 amplifiers. The 5 values are applied to sample-and-hold circuits of a multiplexer unit which maintain the levels during commutation. The length of time for measurement will be at least 1 millisecond and sometimes more depending on the current value, so there is no problem of settling time of the sample-and-hold. The multiplexer cycle time is set by the longest time for any current measurement, which for the smallest value of 10^{-12} amperes may be 1 second, the time constant of the electrometer amplifier. Thus the multiplexer is triggered not more than once a second, although the sampling rate can be much faster, say 1,000 cycles per second, to afford essentially simultaneous values on all probes.

An alternate means of applying variable voltage to the probes is the use of a linear ramp by which a continuous range change can be obtained. The time duration of the ramp would be equivalent to the total of the step voltages or about 10 seconds. Because of the time constant involved, some delay occurs in readings of the amplifier output, giving an offset to the resulting curve. However, this could be compensated and the result of this approach would be a greater number of points for plotting a curve. Here the sampling rate could be selected to provide an optimum distribution of values. If certain parts of a range are more critical, a non-linear voltage might be used to put more points into regions of greatest change. Simultaneous readings of the applied voltage to the probe, and of the resultant current, would be fed to sample-and-hold circuits of a multiplexer which would then transfer all readings sequentially to a recording medium in analog or digital form as desired. The sampling rate can be high, while the cycle time corresponds to the interval required to obtain a reading of the lowest current value. For best results from the ramp sweep, analog recording is desirable since a continuous function of E-I is possible without the quanta introduced by digitizing.

These estimates of measurement times and cycling rates are based on the premise that the major elements are the time constants of the electrometer amplifier. For the values of currents mentioned, it has been determined that the estimated times are valid. However, if smaller levels of current are to be measured, the time constants increase into the range of seconds. An unknown factor at the present time, and one which may require environmental simulation during design, is the effect of input parameters associated with the probe and its configuration in relation to the satellite. There may exist capacity conditions ahead of the amplifier which require charging times which must be added to the other values. Also with some particle types such as electrons having random velocities greater than that of the satellite, and also in cases where particle density is low, an integration time may be involved in collecting enough particles to insure accurate reading of the currents produced by them. These are some of the factors which must be considered in making measurements of this type, and will require some experimental confirmation prior to a final design.

The voltages from the multiplexer are fed into an analog-to-digital converter, when digital storage is desired. Each value is encoded into 8 bits, giving 256 increments. In addition to each voltage value, other words must be recorded to provide probe identity, position, and angle, calibration levels, and time of measurement. The total number of bits given is a possible minimum. Other additions may be desired.

For each probe, per measurement,

9 current steps of 8 bits each	72 bits
3 calibration steps	24
Probe identity	3
Probe position	3
Probe angle	3
	105
	5
For 5 probes	525
9 voltage steps at 8 bits	72
Attitude of vehicle	24
Time code	48
One second steps, 2 minute period	7
	676 bits stored each set
	4
Four sets of measurements per orbit	2704 bits per orbit
	2
Two orbits	5408
Parity bits, misc. parameters (est.)	1220
	6628 bits total

The input data rate required is relatively slow, corresponding to the multiplexer and encoder. For example, the 105 bits for a measurement can be stored in groups at 1000 bits per second, but requiring several seconds total to accommodate the multiplexer cycle time and number of groups. The readout rate for transmission is determined by the normal clock rate on the telemetry link.

For the method employing a ramp voltage on the probes, the number of bits required is as follows:

For each probe, one position	
20 current values of 8 bits each	160 bits
3 calibration values	24
Probe identity, position, angle	9
	193
	5
For 5 probes	965
Time code, begin and end	48
Time marks, 1 second intervals	7
20 voltage values	160
Attitude of vehicle	24
Measurement set	1204
	4
Four sets of measurement per orbit	4816
	2
Two orbits	9632
Parity, miscellaneous parameters (est.)	2400
	12032 bits total

The total bit values are for one probe position, and must be multiplied by the number of different settings required during a selected time interval. For storage purposes, the frequency with which stored data is dumped, determines the total accumulation from a series of measurements.

The data may also be recorded in analog form on magnetic tape if a transport is made available. This approach would permit a saving in equipment required for multiplexing, encoding, and digital storage. Using standard 7-track half-inch tape common to telemetry links, the five probe voltages could be FM-recorded in parallel on five tracks along with calibration levels and identity marks for each channel. Time code marks would appear simultaneously with the measurements on one of the extra tracks. A considerable simplification of circuitry is believed possible in this case since the digital timing and synchronization to insure the correspondence of all measurements in time during storage and readout can be eliminated. Necessary changes in system operating parameters could be better accommodated when required.

In setting up desired conditions, monitoring of successive steps of the experiment is required of the astronaut. For this purpose a display unit is to be provided showing such factors as positions of the various probes, voltage conditions on the probes for the successive measurement steps, corresponding current output values in analog form from the amplifiers, and a comparison, during recording for transmission in either digital or analog form, of recorded values with known standards. Manual selection of certain conditions and scale factors in addition to the automatic sequencing of other functions should enable optimum experimental results to be obtained.

In conducting the experiment, the astronaut must follow a prescribed sequence for establishing desired conditions and monitoring results. A set of instructions describing the functions to be performed and providing tables of control settings and readings to be expected will be provided, and with which personnel must be familiar.

At the start, the particle collecting probes must be positioned in distance from the vehicle and in pointing angle. The attitude of the satellite will affect this last factor and so must be recorded for each experiment. If attitude varies at times by astronaut control during associated experiments, the rate of variation and the axes of motion should be recorded since the resultant probe modulation can introduce additional measurement data. The controls for setting probe position may have several discrete detents to establish a limited number of known conditions. In angle, a capability should exist for complete spherical coverage by different probes. In distance from the shell, short steps when near the vehicle can provide a measure of the plasma sheath immediately surrounding it, with longer steps beyond.

With the probes positioned, the sequence of voltages which permit the selection of either positive or negative particles of different energy levels, can be applied. This is an automatic process in which a clock pulse triggers a driving circuit which introduces a series of fixed elements into the control circuit of a power supply, producing voltage steps of desired level and duration at the output. A sequence number for each step appears on a monitor display, along with the voltage value. The duration of each reading is 1 second, and enables the astronaut to observe the successive values being used for a set of measurements. As each voltage is applied, a corresponding current reading appears on the indicator. Calibration voltages on some steps enable necessary adjustments to be made. Since 5 decades are covered in these readings, separate scales are desirable for accuracy, and selection of the best range should be an objective if changes are not too rapid. A single range scale requiring no switching can be accepted for overall monitoring, and an indicator is provided on the control unit for each probe channel. The simultaneous readings on different probes will depend on the look angle, the position on the satellite, and other factors, and may vary considerably from each other.

If a ramp voltage is applied to the probes, it may be desirable to employ a different type of monitor device, for example a cathode ray tube with a high persistence screen. The voltage sweep can be applied to the horizontal axis while the current levels appear as vertical deflections, resulting in a plot of the E-I function. Calibration voltages are applied as required to the inputs and are used to establish the zero and scale conditions.

Recording of the various parameters starts after the application of voltages to the probes has allowed necessary adjustments. If the recorder is common to other experiments, for example a shared magnetic tape unit, proper time sequences must be established to avoid conflict. Other interface relations for common use of system elements must also be arranged in advance.

The time duration for a set of measurements as outlined should not exceed some tens of seconds at the most, so that a couple of minutes of an astronaut's time should suffice for setting up and running the experiment.

In brief, the following listed functions are to be performed by the astronaut:

1. Review instructions on experiment procedure.
2. Adjust probe positions and angles using tables in instructions for desired measurement conditions and attitude of satellite.
3. Turn on switch for sweep voltages to probes and monitor level and timing. Adjust range to conditions.
4. Check calibration levels on electrometer amplifiers and set zero adjustment and scales as necessary.
5. Set up interface connections for requirements common to other experiments.
6. At start of measurement sequence, turn on recording equipment and allow to run until cycle is completed, as indicated on monitor panel.
7. Log time of experiment and any special conditions observed.

Since many experiments are to be conducted by the astronauts either sequentially or concurrently, the sharing of time and effort among them to obtain the optimum quantities of data from each experiment is a matter subject to mutual agreements. This and other factors relating to integrated operation of system elements must be established early in system development to insure success of the various projects.

F. T. POWLES
Code 5113
U.S. Naval Research Laboratory

EXHIBIT D.2

5100:WRF:wdw
25 Sept 1964

"UTILIZATION OF MAGNETO-HYDRODYNAMIC WAVES"

Magneto-hydrodynamic waves occur in a conducting medium containing a static magnetic field such that wave propagation takes place when the positions of the static field lines are perturbed. A disturbance in the medium displaces the magnetic lines from their equilibrium position and a wave will be created which travels along the line of force. Such propagation can be visualized as waves traveling along a stretched rubber band. At the same time that the displacement in the magnetic field takes place, a corresponding change in the density of the medium also occurs because the field is "frozen in" the conducting medium, i.e., the magnetic field pulls the conducting medium along with it because forces are set up that tend to resist the movement of the field line through the conductor.

It is proposed to study different methods of producing hydromagnetic waves from a space craft and evaluate their usefulness as a communication and detection mechanism. It should be noted that transmission of such waves are not general in nature but are limited to directions near the magnetic field lines, so that the possibility of a secure communication system exists.

Specifically the following points will be studied:

(a) Methods of generating magneto-hydrodynamic waves:

One possibility is to extend a conducting sphere a few meters from the space craft and apply an oscillating voltage between the vessel and sphere. Oscillation of the plasma between the sphere and craft will set up plasma waves, the precise type of which will depend upon orientation relative to magnetic field, ambient density, ionization; in which case a certain portion of energy will go into the current mode.

(b) Methods of detecting magneto-hydromagnetic waves:

Variation of density, magnetic field strength and local charge variations will be considered. Detection devices should be aboard a space craft as well as on earth.

(c) Interaction of hydromagnetic waves with space craft:

The interaction of hydromagnetic waves with spacecraft will be studied to determine the effect of such waves on the "supersonic flow" about the vehicle, and as to whether drag on the device may be changed.

(d) Astronaut functions in experiment:

Current theoretical estimates indicate that a large craft is desirable to produce a sufficiently large disturbance (in conjunction with the sphere, above) in the ionosphere so that wave propagation can be initiated. Man is essential to experiment in order to carry out the complicated experimental details and to operate, observe and record.

It is proposed to assign the design of this experiment to a group involving about two people for development. Any theoretical aid will be obtained from the consultants to the Laboratory. It is anticipated that funds of $50K will be required for support of the group (neglecting any large equipment purchases).

EXHIBIT D.3

INTERACTION OF SPACE VEHICLES WITH PLASMA

The development of satellites and utilization of space has stimulated interest in the interaction of a space vehicle with its plasma environment, e.g., plasma wakes and waves produced by passage of a satellite may affect the viscous and electrodynamic forces acting as well as the response to electromagnetic waves. There appear to be many interesting and important effects that take place when a high speed object, such as a satellite, moves through the ionosphere, some of which may be of military significance in the future. An example of such an effect is the disturbance that appears before and after a space craft and has been detected by scattering of electromagnetic signals; such phenomena may provide information for possible long range detection of space craft and missiles (e.g., Experiment S-22 proposed for MOL).

Some of the phenomena that take place can be described briefly as follows:

Neutral particles (molecules, etc.) are reflected elastically from the surface of the vehicle and create a "condensation region" in front of the craft where an excess of such particles exists, while behind the craft a rarefaction region exists where there is a deficiency of such particles. In addition to the elastic interaction of the neutral particles with the craft, inelastic collisions may also occur, so that excited and possibly ionized particles may also rebound from the front surface of the space craft. This effect will lead to the emission of radiation which can possibly be detected.

Charged particles interact not only with the surface of the space craft but with the electric field (due to satellites) and the magnetic field (earth's) so that the distribution and effect of the electrons is profoundly different from the neutrals. Because the electron velocity is greater than both the ion and satellite velocities, the satellite will accumulate a negative charge which gives rise to an ion sheath about the vessel and affects the behavior of electromagnetic equipment.

Particles reflected from the vehicle can ionize the gas further in front of the vehicle and produce a large disturbance in the ionosphere. Somewhat related to this disturbance is the production of hydromagnetic and magnetoacoustic waves, which may account for the effects that appear before and after the space vehicle.

Phenomena mentioned above are thought to occur near a space craft; there are other related phenomena that have not been studied. All the effects mentioned above are postulated effects, and very few experiments (if any) have been performed to observe the details of the various interactions.

It is proposed that a small theoretical study and survey be initiated so that the various phenomena associated with the operation of space craft be defined and those of operational or military significance evaluated for a possible experimental program in a satellite. It is anticipated that the study will involve one theoretical physicist full-time at NRL and will be carried out over a period of two to three years. The money involved is about $25,000 per man year.

Specifically, the following areas relative to satellite motion will be studied:

(a) Reflection of particles from the surface of the space craft and the radiation emitted. By a study of the radiation it may be possible to deduce the speed and the altitude of the space craft.

(b) Plasma Sheath Formation: Studies should be devoted to the effects of sheaths on satellite antennas (impedance, propagation, directional pattern) as well as upon the modification of the radar cross-section (if any). Apparently there should be little effect on transmission at the usual radar frequencies for normal sheaths; however, it may be possible to disguise a satellite from radar by producing a shielding or absorbing plasma about the satellite by charging the satellite positively.

(c) Wave Propagation: The general features of wave propagation in the ionosphere at VLF and UHF seem to be understood in a general way but a great deal of detail remains to be filled in. However, the propagation of general magnetohydrodynamic waves in the ionosphere has not been examined in any detail at all. Some problems of interest are: (1) penetration of VLF signals into the ionosphere and subsequent propagation in Whistler mode, (2) propagation of waves from antennas, (3) excitation of modes of propagation other than electromagnetic such as hydromagnetic waves, (4) excitation of electromagnetic waves by plasma waves and vice versa, (5) interaction of the solar wind with the ionosphere so as to affect electromagnetic propagation and production of magnetic storms, (6) production of magnetohydrodynamic waves by satellites and their possible use as a mechanism for detection and tracking.

(d) Interaction with Magnetic Field: Relative motion of an object with respect to a magnetic field induces emf's in the object. This will result in additional drag on the satellite as well as a distortion of the electric field distribution. The latter effect will change the characteristics of the plasma sheath, and affect operation of electromagnetic equipment aboard the satellite.

(e) Supersonic Flow: A study of the effects produced by supersonic flow about the space craft will be made. This study will be related to some items mentioned above but carried out from a somewhat different viewpoint.

EXHIBIT D.4

5110-158:CJK:wdw

Code 7000 17 Nov 1964

Code 5110

Via: Code 5100

Transmittal of Preliminary Data Rate and Data Storage Requirements for Experiment S-23 to NAVMOL

Encl: (1) CSR 5110-157:CJK:wdw (4 copies)
(2) Data Usage Profile Diagram and Tables (4 copies)

1. The phone conversation reported in enclosure (1) indicates the Aerospace Corporation has need of additional information concerning the data rate and data storage requirements for Experiment S-23. In response to a request from Mr. Frank Yates of Aerospace Corporation, copies of a rough draft (working paper) of a planned addition to the Experiment Data Book (enclosure (2)) are forwarded. It is requested that a copy of enclosure (2) be provided Mr. Yates at the earliest possible date.

2. The material contained in enclosure (2) must be considered as preliminary and is forwarded in its present form only because of the pressing need for additional information on Experiment S-23 data requirements by Aerospace Corporation. Formal updating of the S-23 Experiment Data Book will be effected when the data requirements are further refined.

E. F. Kulikowski
Head, Data Processing Branch

CONSULTATIVE SERVICES RECORD
PRNC-NRL-10-631 (Rev. 4-55)

DATE	SERIAL NUMBER	FILE NUMBER
November 1964	5110-157:CJK:wdw	

1. INSTRUCTIONS - This form is to be prepared in duplicate and signed by the conferee after each conference between Laboratory personnel and outside persons. Route both copies to Division Head, cognizant Associate Director of Research and Codes 1505 (retains one copy), 4010. 1020, 1530, and to 1523 for file.

2. CONFERENCE DATA

(a) DATE OF CONFERENCE	(b) PLACE
12 Nov. 1964	Phone conversation

(c) NAME(S) OF LABORATORY PERSONNEL	(d) DIVISION AND CODE NUMBER
F. T. Fowles	ARD, Code 5113
C. J. Kurner	ARD, Code 5113A

(e) NAME(S) OF OUTSIDE PERSONS	(f) ACTIVITY REPRESENTED
Frank Yates	Aerospace Corp.
	Phone 213-648-6170

(g) PURPOSE OF CONFERENCE
Discuss experiment data rates and data handling

(h) TIME CONSUMED IN CONFERENCE
10 minutes

(i) HIGHEST CLASSIFICATION OF MATERIAL DISCUSSED OR SHOWN	(j) NRL PROBLEM NUMBER
Unclassified	51K03-06A

BRIEF OF RESULTS

A call was placed to Aerospace Corporation as a result of a request by Mr. Yates for additional information concerning the data requirements for Experiment S-23. During the conversation Mr. Yates indicated a need for data rate requirements for the experiment and a usage plan for the on-board recording media. He also asked for information detailing which experiment parameters were digital and which were analog. The precision to which analog voltages are to be encoded was also requested.

Mr. Yates was informed that a first model of a usage profile has been completed. This profile describes the experiment parameters, the ancillary information desired and the data rates associated with each of the data intervals associated with Experiment S-23. A copy of the usage profile and data rate considerations is attached.

According to Mr. Yates, current thinking at Aerospace indicates vehicle attitude will be available with 10-12 bit precision in each axis. Time will be coded in approximately I msec intervals. Analog voltage encoding will be available to 8 bit precision (for 0-5 v level). It is expected that experiment data (both analog & digital) will be routed to a central encoding and multiplying facility common to all experiments. The data format will likely take the form of interspaced data from the several experiments with sorting done at the ground stations after telemetry.

SIGNATURE
Charles J. Kurner

NAVY-DPPO PRNC, WASH., D.C.

13 November 1964

EXPERIMENT S-23 DATA REQUIREMENTS

		No. of Bits	
SEQUENCE STATUS FRAME	Experiment Identification	4	
	Block Identification	2	
	Attitude Control Mode	2	one frame per
	X-ray	*3	test sequence
	Ultra Violet	*3	(4 boom positions
	Magnetometer	*3	at each of 3
	Equip. Temp.	*5	probe attitudes)
	Vehicle Attitude (5 bits/axis)	*15	
	Concurrent Experiments	( )	
SUB-SEQUENCE CAL. FRAME	Experiment Identification	4	
	Block Identification	2	
	Probe Attitude	2	
	Voltage Scan Range	2	one frame
	Electrometer cal. volt. (3 points)	*24	for each
	Electrometer cal. currents (3 points)	*72	probe attitude
	Other, currently undefined	( )	
DATA SET STATUS FRAME	Experiment Identification	4	
	Block Identification	2	
	Time Code	28	one frame
	Boom Length Mode	1	preceding each
	Boom Length	*8	data set
	Collection Mode	1	
	Bias Voltage	*8	
	Boom Vehicle Voltage	*24	
	Other, currently undefined	( )	
EXPERIMENT DATA FRAME	Voltage	*8	15 samples each
	Current (3 probes)	*24	1 sec. data set

* Require analog-to-digital encoding; others are digital quantities.

13 November 1964

EXPERIMENT S-23 DATA RATE REQUIREMENTS

STATUS	37^+ bits of data read out within one sec. (37^+/sec) readout required once each 5 minutes.
SUB SEQUENCE CAL.	106^+ bits of data read out within 1 sec. (106^+b/sec) readout required once each 50 seconds.
DATA SET STATUS	76^+ bits of data read out within one second (76^+b/sec) readout required twice in each 10 second interval.
EXPERIMENT DATA	15 samples of 32 bits each readout within one second (480 b/sec) 2 seconds of data readout each 10 seconds.

In addition to the prescribed experimental tasks outlined in the profile diagram, it is expected that an equivalent time period (eight ten-minute intervals) will subsequently be available for special experiments conducted directly under astronaut control. These could include, but not be limited to, the detailed probing of the environment within one foot of the vehicle surface; the conduct of experiments during conditions of abnormal solar or magnetic activity, and experiments resulting from ground based data reduction which indicates additional effort be directed toward gathering data at specific probe locations and/or times.

Although an experiment usage profile has not yet been defined for these special tasks, the data handling requirements for these tasks has been considered and is included, as is practical at this time, in the data requirements outlined for the experiment in general.

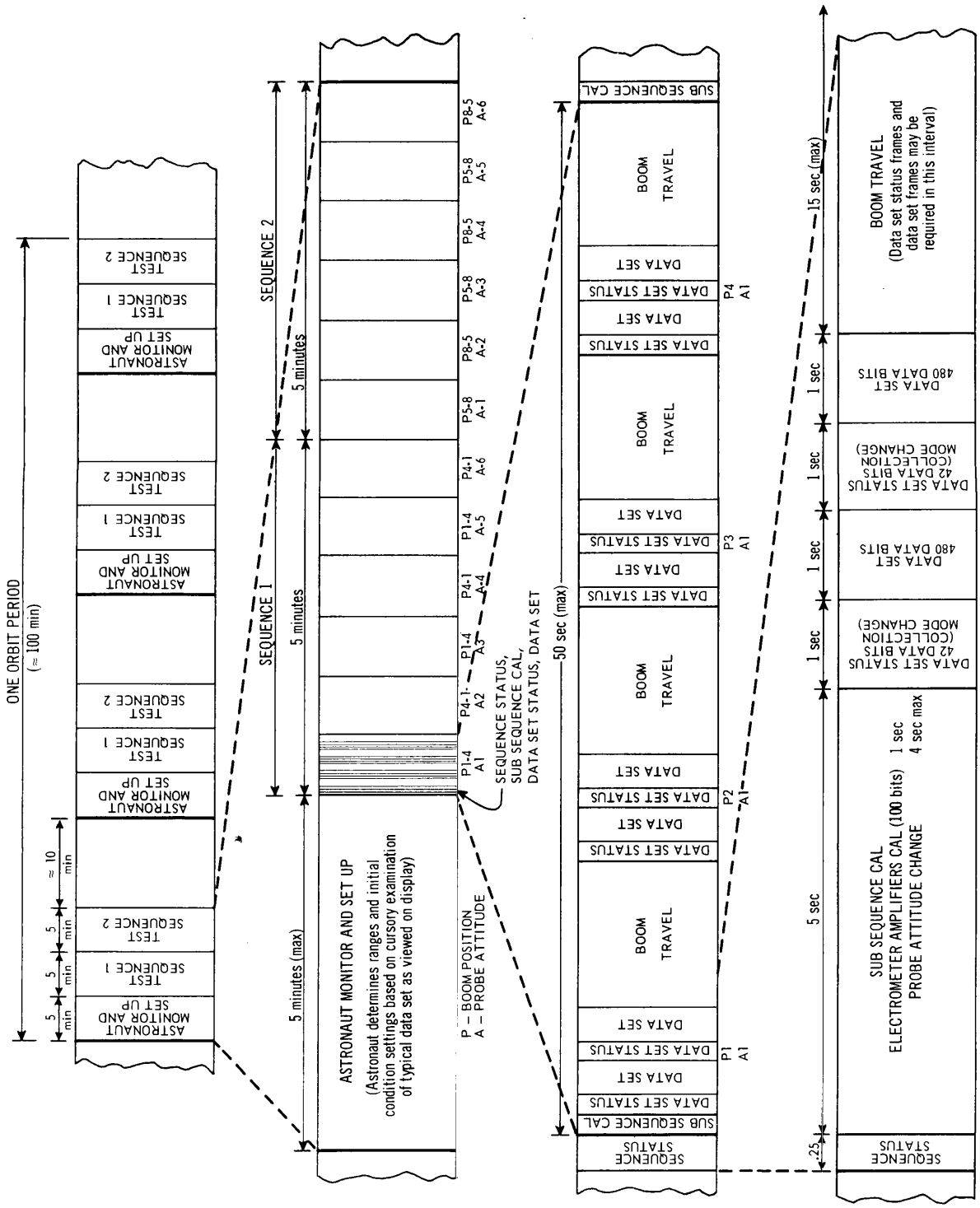
ONE ORBIT PERIOD
(≈ 100 min)
ASTRONAUT MONITOR AND SET UP
TEST SEQUENCE 1
TEST SEQUENCE 2
5 min
≈ 10 min
SEQUENCE 1
SEQUENCE 2
5 minutes
5 minutes (max)
ASTRONAUT MONITOR AND SET UP
(Astronaut determines ranges and initial condition settings based on cursory examination of typical data set as viewed on display)
P – BOOM POSITION
A – PROBE ATTITUDE
P1-4 A1
P4-1 A2
P1-4 A3
P4-1 A-4
P1-4 A-5
P4-1 A-6
P5-8 A-1
P8-5 A-2
P5-8 A-3
P8-5 A-4
P5-8 A-5
P8-5 A-6
SEQUENCE STATUS, SUB SEQUENCE CAL, DATA SET STATUS, DATA SET
50 sec (max)
SEQUENCE STATUS
SUB SEQUENCE CAL
BOOM TRAVEL
DATA SET STATUS
DATA SET
P1 A1
P2 A1
P3 A1
P4 A1
15 sec (max)
.25
5 sec
1 sec
BOOM TRAVEL
(Data set status frames and data set frames may be required in this interval)
DATA SET 480 DATA BITS
DATA SET STATUS 42 DATA BITS (COLLECTION MODE CHANGE)
SUB SEQUENCE CAL
ELECTROMETER AMPLIFIERS CAL (100 bits) 1 sec
PROBE ATTITUDE CHANGE 4 sec max

EXHIBIT D.5

SIMULATION TASKS FOR EXPERIMENT S-23

Insofar as it is practical, it is desired that Experiment S-23 be considered for inclusion in the simulation program being developed by NADC for Experiment P-13.

Availability of a simulated laboratory vehicle is considered beneficial to the development of the Electron Density and Temperature experiment. Advantages of such a simulation include:

(a) Resolution of MOL vehicle structure and S-23 Experiment interface problems by consideration of such things as aiding in the location of the probe-boom assemblies on the vehicle surface attitude control jet exhaust streams, astronaut escape routes, and shadowing by other vehicular projections;

(b) Resolution of the general inter-experiment interface problems such as the determination of the commonalities of operation with other on-board experiments, such as P-13, S-1 and S-22;

(c) The determination of the extent to which data from ancillary on-board devices such as magnetometer and ultra-violet or X-ray radiometers may be used in conjunction with the conduct of the electron density and temperature experiment.

A simulated laboratory cabin would be desirable to assess and optimize the plan for conduct of the experiment. Operation and calibration controls and subsequent display of simulated results of these operations can establish the task sequence for the astronaut for obtaining a maximum of data in a minimum of time.

Experimental realism can be achieved through the control of displayed results as a function of simulated external conditions (e.g., day-night, solar flare conditions) and as a function of the boom-probe attitude as controlled by the astronaut-test conductor.

Although the display devices currently being considered for use by Experiment S-23 are meters, the simulation task may indicate the availability and/or desirability of other displays such as cathode ray oscilloscopes for monitoring of data from this experiment.

EXHIBIT D.6

5 January 1965

ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)

JUSTIFICATION FOR INCLUSION IN MOL

The electron density and temperature experiment has been designed to provide a knowledge of the near environment of the MOL as well as to further the definition of the ionospheric medium through which the satellite travels. Among the quantities to be determined from the experiment are the electron and ion densities in the ionosphere, electron temperature, the charged particle densities in the plasma sheath surrounding the vehicle, the energy distribution of the charged particles, the vehicle potential and sheath potential gradient.

The inclusion of the experiment on a manned vehicle enhances the probability of obtaining high quality data under both normal and anomalous (e.g., solar flare or magnetic storm) environmental conditions. Man's capability for evaluating a situation and establishing the appropriate experiment parameters can make available data which could otherwise be lost.

A considerable background of rocket and satellite measurement of plasma characteristics exists(1). Numerous experiments designed to measure ionospheric electron density and temperature have been conducted. However, these experiments generally utilize fixed probes at or near the surface of a small satellite vehicle and are designed for the measurement of the properties of the undisturbed ionosphere, i.e., the effect of the vehicle passing through the medium is considered to be an undesired perturbation of the medium. Furthermore, the small size of past satellites means that near-vehicle effects, when determined, cannot readily be meaningfully associated with a vehicle the size of the MOL.

The electron density and temperature experiment proposed for MOL is intended to exploit the large vehicle size in the determination of the near-vehicle plasma environment. The maneuverable probe-boom assemblies provide a capability for "mapping" the charged particle density profile. Multiple sensors obtain, essentially simultaneously, data relating to the directional properties of the plasma and sheath, the effect of photo-ionization yield and temperature variation on the sunlit and shadowed portions of the vehicle, and the effect of magnetic field interactions (VXB) with various portions of the vehicle structure.

The complementary nature of this experiment to the several electromagnetic wave propagation experiments (S-1, S-22) for the MOL (which it supports) should be stressed. The simultaneity of measurements of experiments S-1 and S-23, and S-22 and S-23, will provide improved correlation of experimental data and conclusions, particularly with reference to wave propagation characteristics and antenna impedance. The behavior of the ionosphere in the presence of strong fields is not known completely. Similar uncertainty surrounds the sheath structure. The probes of Experiment S-23 may be positioned to "map" the vicinity of antennas during both "on" and "off" periods of a transmitter. The information

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(1) See list of references for Experiment S-23 Prerequisite Data Report (PDR), Section I, 9/24/64.

obtained during this time may be used to improve design techniques for space-vehicle antennas and for improving the understanding of ionospheric physics.

In summary, the Electron Density and Temperature Experiment (S-23) is designed to provide previously unavailable data on the size and structure of the ion sheath attached to a vehicle moving through the ionosphere at orbital velocity, provide additional data on the spatial and temporal variation of charged particle characterisitcs of the ionosphere, and provide experimental data relative to the design of radiating antenna structures on man-carrying satellites. Determination of these qualities can be enhanced in a space environment by using the knowledgeable efforts of an astronaut/test conductor.

EXHIBIT D.7

Drafted and submitted
for Comm. Bus. Daily
3/19/65

CAPABILITIES TO DESIGN, FABRICATE AND INSTRUMENT AN EXTENDABLE AND RETRACTABLE PROBE MECHANISM FOR THE MEASUREMENT OF CHARGE DENSITIES AND PARTICLE TEMPERATURE FROM SPACE VEHICLES

Factors to be included in consideration of source selection for which respondants should elaborate are (a) prior pertinent design and construction experience that demonstrates potential skill for providing equipment of this kind and any other devices whose mechanical design operation and construction are considered potentially applicable to this requirement; (b) experience in designing any of the following probes e.g., Langmuir type, Faraday cage, Resonance probe, and their signal processing and recording techniques; (c) facilities for testing such devices under simulated space conditions, and for checking ability to withstand shock and vibration, (d) indicate methods employed to assure quality control; (e) level and experiences of project design engineers (include resume) that would be assigned to such a project. A security clearance may be required.

EXHIBIT D.8

OPTIONAL FORM NO. 10 5010-108
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

5110-92:CJK:eam

TO : Code 1910 (Mrs. Bivins) DATE: 18 June 1965

FROM : Code 5110

SUBJECT: Electron Density and Temperature Experiment

Encl : (1) Memorandum draft copy, "General Procurement Plan for Electron Density and Temperature Experiment"
(2) Draft copy of Request for Proposal for Electron Density and Temperature Experiment

1. Enclosures (1) and (2) are forwarded as working papers for review and comment by Code 1910 prior to providing smooth copy when program approval is received.

2. The RFP has been prepared in accordance with instructions contained in Air Force Manual AFSC-PMI-1-9. Our understanding is that this is the preferred format for RFP's issued in connection with Air Force Program 632A.

3. Paragraph heading numbers are those used in AFSC-PMI-1-9. It is expected that the applicable information required in Part I (par. 1-28) will be prepared by the Supply Division as needed when the smooth copy of the RFP is submitted.

4. Those items in the RFP headed by OMIT represent paragraphs in PMI-1-9 which are considered not applicable to this proposed contract.

5. It is hoped that sub mission of this draft copy for review and comment will result in a formal RFP which can be issued expeditiously when program approval is received.

E. F. KULIKOWSKI

GENERAL PROCUREMENT PLAN FOR THE ELECTRON DENSITY AND TEMPERATURE EXPERIMENT (S-23)

This RFP is being issued as part of the task of providing space qualified experiment equipment for use in the MOL Program (Space Project 632A).

The general requirements of the experiment have been advertised as Synopsis No. 26 in the Department of Commerce Business Daily of 25 March 1965. A determination and finding has been done and a source list prepared.

It is expected that the end item of the contract will consist of a set of four flight qualified instrument systems suitable for conduct of the subject experiment.

The current program plan calls for the contract to be conducted in three phases. The first phase, which is covered by the current work statement, is intended to produce a firm set of specifications for a system suitable for the conduct of the experiment. Estimates of delivery time and cost for laboratory and flight qualified systems will also be produced under this phase of the contract.

It is conceivable that, based on the proposals received under this RFP, several contractors may be selected for the concurrent conduct of this phase of the contract. Parallel design studies may be indicated on the basis of different, yet appealing, technical approaches as presented in the proposals. Alternatively, if among the proposals received, it appears that individual offerors have superior capabilities in the field of only part of the experiment system, contracts will be awarded in the several areas required to develop an optimum system.

The design study phase of the contract(s) is expected to be completed in a ninety day period, culminating in a report covering the contract objectives.

Based on the results of this first stage of the contract, an extension is expected to be negotiated with one of the offerors for the procurement of a laboratory model of the experiment system. This model will be utilized to insure performance at or exceeding specification level, and for initial evaluation of the experiment data collection and reduction plan. In addition, this model can be used to verify the man-machine interactions associated with the various manual and semi-automatic experiment procedures.

Information gained from testing of the laboratory model will be used to

modify and update the system specification provided the vehicle contractor for use by him in the integration of the experiment into the orbiting vehicle. It is expected that final decisions regarding weight, volume, power demands and equipment form factor will be made as a result of the evaluation of the laboratory model of the experiment system.

The contract will then be further extended to provide for the procurement of six models of the experiment in its essentially final form. The first of these will be used for environmental test purposes for qualification of the system for the space mission. This qualification model will be subjected to the necessary shock and vibration testing, operated in a simulated space environment and subjected to the thermal stresses which can be expected during the actual mission. This model will be tested sufficiently in advance of the flight articles that minor changes can be effected in the flight models if necessary.

The second model of the flight-configured hardware is scheduled for use, as a training aid. It will be installed in the simulation of the laboratory vehicle and used in the astronaut/test conductor training program. It is expected that sensor stimuli of the type encountered in a space environment will be simulated and used to condition the test conductor to the displays which he will encounter and the control capability which he must exercise to conduct a valid and meaningful experiment.

The third model will be delivered to the vehicle contractor for use in the mechanical and electrical integration into the laboratory vehicle. Delivery of this model will be effected in time to insure that late modifications to the overall vehicle systems properly reflect the requirements of this experiment form factor and interface effects.

The remaining three models are designed for use on two of the early manned flights with one model as a back-up for both flights.

The scheduling proposed for the conduct of the experiment program is one which provides an acceptable balance between development of optimum experiment components and delivery of flight qualified systems to the vehicle contractor for final installation into the laboratory complex.

Current cost estimates for the experiment contract are summarized briefly as follows:

Design study phase, two 90-day contracts at $100K per contract	$ 200 K
Laboratory model procurement, 1 system	400 K
Flight form-factored models, 6 at $300K/model (includes qualification testing of environmental model)	1800 K

Form AFSC PMI-1-9

REQUEST FOR PROPOSAL

Electron Density and Temperature Experiment (S-23)
Part I - Administrative and General Information

1. Number
2. Issuing Office
3. Date
4. Closing Date: (Proposal submission 60 days)
5. Table of Contents
6. Accounting Data
7. Late Proposals
8. Priority
9. Payments
10. Shipping, marking, FOB point
11. Inspection and Acceptance
12. Availability of records and cost data
13. Certification
14. Incurring costs
15. Specifications
16. Base Support
17. Economy of preparation
18. Preproposal briefing and information
19. Acceptance Time: (30 day proposal review time)
20. System Source Selection Board
21. Facility Survey
22. Security
23. Classified or restricted information: No disclosures
24. News release: None
25. Rejection of proposals
26. Disposition of documents
27. Contract clauses
28. Type of contract

ENCL (2) TO NRL MEMO 5110-92:CJK:eam

Part II - Technical Proposal

29. Technical Plan

(a) Delineate your overall concepts of the project, provide a program plan, and present a clear explanation of how you plan specifically to accomplish the objectives and tasks set forth in the work statement. Provide graphics as appropriate.

(b) Isolate the technical problems which you expect to encounter, and indicate the methods by which you propose to solve them. Identify areas of technical risk. Suggest where simplification of requirements could reduce costs or time without detracting from system/equipment effectiveness. Suggest alternate technical proposals.

OMIT
- (c) Inter-related efforts schedule
- (d) Summary Program Plan
- (e) Simplicity of design and value analysis
- (f) Control over sub-contractors and managers

(g) Within the Technical Plan, furnish the following:

(1) Reliability Program Plan, outlining scope, requirements, management, testing, demonstration, reviews, and reporting.

(2) Quality Assurance Program Plan, outlining scope, requirements, management, controls, inspection, testing, calibration, and vendor quality assurance.

OMIT
- (3) Maintainability Program
- (4) Materiel Support Plan

(5) Technical Data Plan, which outlines proposed plan and requirements for technical data, engineering drawings, system specifications, check lists, utility manuals and handbooks.

OMIT
- (6) System Safety Engineering Plan
- (7) Configuration Management Plan
- (8) Aerospace Ground Equipment Plan
- (9) Transportability Program Plan
- (10) Personnel Subsystem Program Plan

OMIT (h) Cost Breakdown

30. Work Statement

(a) Purpose

(1) The objective is to devise a system by which measurements of the plasma environment can be made from a manned space vehicle. Although suggestions toward a tentative system are included in this RFP, it is desired that the proposal not be limited by these preliminary considerations, but should present approaches and techniques which take into account trade-offs between various means of accomplishing the objectives. Particularly the type of plasma probes, their location, and the means of positioning them are of major importance to the success of the project. A thorough discussion of the factors affecting the performance of different configurations should be given. Likewise, other comparative analyses involving technical results, convenience, costs, time, or other factors are necessary.

(2) Proposals are to be submitted within 60 days. Following review of proposals, a contract may be negotiated for an engineering design study to establish a Proposed System Package Plan (PSPP). An extension of contract or separate contract utilizing the findings of the design studies toward completion of a laboratory model may follow. This model serves to prove performance and establish specifications for final designs. Subsequently, a prototype suitable for final evaluation and training purposes may be procured, with up to 4 flight systems. The estimated time periods for these anticipated stages are as follows:

Submission of Proposal - 60 days

Submission of PSPP Final Report - 90 days after contract

Completion of Laboratory Model - 6 months after go-ahead

Completion of Evaluation and Training Model - 5 months additional

Completion of first flight qualified system - 9 months additional with additional systems at 3 month intervals.

(3) The object of the design study is to define the capabilities and limitations of a system that can be built at the present state of

the art. The specifications governing a proposed system in this category shall be defined. Estimates of weight, space required, power consumption, and cost are to be provided. The study is to include a complete system which will enable the various functions listed in succeeding paragraphs to be accomplished.

(4) A report is to be furnished which will include the following material, with the addition of any other that the contractor considers desirable:

a. Description of the proposed system and all component units, including types of circuits. Consideration of standard module packaging and also miniaturization should be given.

b. Specify ranges of environmental conditions (temperature, vibration, shock, humidity, atmospheric pressure) for guaranteed satisfactory operation without need for recalibration or adjustment. Also non-operating limits without damage.

c. Describe procedures for setting up the system, and making routine adjustments and performance checks, including how often required and estimated time to accomplish.

d. Estimate system reliability as mean time between failure of any major unit.

e. Discuss advisability of critical module spares for replacement.

(5) The function of the subject measurement system is to afford a means by which an astronaut can determine the characteristics of the space plasma and related factors such as magnetic field and solar radiation immediately surrounding his vehicle while orbiting the earth. The characteristics to be measured include the electron energy distribution (temperature), the electron and ion densities, the vehicle-to-plasma voltage, the shape and size of the sheath around the vehicle, the potential distribution across the sheath, and the VxH EMF induced effects in the vehicle structure. Simultaneous measurements are to be made fore, aft, and amidship of the vehicle, and sequentially at selected distances from it, which will encompass the sheath limits as well as turbulent conditions in the

immediate environment of the vehicle and out to plasma equilibrium. At a selected position in orbit, this group of measurements at predetermined locations around the vehicle will be completed as rapidly as possible. Groups will be repeated several times in one orbit to include light and dark conditions in north and south latitudes. The intent is to define diurnal, seasonal, and spatial variations in plasma conditions under ordinary and extraordinary circumstances. Observations are also required of the magnetic field strength, and of UV and X-ray radiation, and equipment temperature.

(6) In order to accomplish these objectives, it is anticipated that the measurement system may include typical components as listed here:

a. A set of plasma sensing probes mounted on extended booms.

b. Electrometer amplifiers and associated conditioning devices for probe currents.

c. A system programmer to provide, in timed sequence, the various operating conditions in accordance with selectable modes.

d. A control and monitor panel for selecting desired program modes and observing measurement results.

e. Interface equipment to accommodate a separate data handling and recording system shared with other experiments.

f. Power conversion and regulation devices between the vehicle common source and the measurement system.

g. Ancillary equipment such as magnetometer, UV and X-ray radiometers, and equipment temperature indicators.

h. Interconnecting and matching units to adapt to positioning requirements of different parts of the experiment system as necessary in the vehicle.

This is a tentative listing based on a preliminary analysis of requirements but is subject to modification by the offeror in accordance with his study of the problem.

(b) Background

This experiment is to be one of several to be conducted aboard a manned orbiting vehicle. In order to evaluate the effectiveness of a man in performing various functions in space, it is planned to utilize his capabilities of observation, control, reasoning, and decision-making, in critical phases, while providing automatic means of accomplishing routine tasks in short time intervals to expedite the measurement procedures. In order to conserve space, weight, and power, the maximum common usage must be made of equipment and instrumentation of general type aboard on a time-sharing basis. It is anticipated that sub-systems in this category could include data handling and recording, timing standards, display and indicating devices, power supplies, and ancillary sensors such as magnetometer, UV and X-ray radiometers. Consideration must be given to problems relating to mutual operation of such sub-systems and the avoidance of interference between experiments. Likewise, the location of experiment equipment, within the vehicle for accessibility needed by the astronaut, and outside the vehicle on available desired areas avoiding conflict with other external devices, must be determined by mutual agreement of users. Since the final configuration of vehicle and equipment is subject to modification as development plans progress, the experiment design in areas relating to interface conditions may also require change, and adaptability to these requirements should be given consideration.

(c) Requirements and Objectives

(1) The plasma characteristics listed in paragraph 30(a) as requiring measurement can be determined from plasma probes extending out from the vehicle. These probes are mounted on booms to allow the orientation and the position relative to the vehicle to be controlled. The number of positions to afford adequate definition of plasma conditions must be determined. The orientation is to be adjustable around any axis, and the position, from flush with the vehicle surface out to a specified limit. The positioning should be accomplished in the shortest time commensurate with other design limits.

(2) The probes which may be of the Langmuir type, Faraday cup, or similar, consist of one or more electrodes by means of which the flow of either electrons or ions to a collector electrode can be controlled and measured. A constant voltage adequate to attract the charged particles of a given type, is applied to the collector, while a sweep voltage sufficient to swing the particle currents from maximum negative to maximum positive, is applied to a grid adjacent to the collector, and can control the flow of current to it. By employing positive and negative potentials successively, a curve of current versus sweep voltage is obtained over a range of values which allow various parameters describing the space plasma conditions to be derived. An additional type, called a thermal equalization probe, which operates on a different principle to provide an independent measure of plasme-to-vehicle potential, should also be included. This TEP contains a heated emitter which discharges electrons into the surrounding plasma until its potential equals that of the surroundings. This condition is determined from the change of slope of the curve of probe voltage vs. emitter temperature. A direct voltage measurement between probe and vehicle can then be made. In the design of probes, various factors must be considered toward reducing errors in measurement caused by sheath effects, motion of vehicle, time constants of system, solar radiation, and others. For completeness, recommendations should be made for a magnetometer to measure field strength frequently, and for a solar radiation sensor.

(3) Electrometer amplifiers are needed for amplifying currents from the probe collectors, and providing a standard range of output voltages to be processed by a separate data system. Several decades of input currents, corresponding to the particle densities encountered by the space vehicle, require an amplifier of adequate dynamic range. Precautions are necessary to minimize input capacity and leakage, such as feedback between stages, and high quality components affording a high input impedance. Uniform characteristics of performance over the range of environmental conditions are obtained by adequate circuit compensation, e.g., temperature variations.

(4) The system programmer serves the purpose of relieving the astronaut of routine tasks by automatizing the accomplishment of desired functions, while enabling him to make best use of his abilities in controlling the experiment and monitoring the performance of the system and the measurement results for selected conditions. Timed from a source common to other parts of the system, the programmer establishes the sequence and time intervals of operating functions in accordance with settings of controls by the astronaut. These functions include movement of booms and probes, fixed and sweep voltages applied to the probes, switching of calibrating and operating inputs, generation of gates for data readout and data sampling times, and status codes to be recorded for indicating the conditions during measurements. Programming modes should be selectable to permit either an automatic sequence independent of control settings or a manual type corresponding to the panel controls set by the astronaut for special conditions. Other desirable operating modes can also be recommended.

(5) A control and monitor unit is to be provided by means of which the astronaut can set up the desired experiment conditions and observe the results as the selected program sequences the various operations. Controls are required for primary power, program selection, boom-probe positions, probe bias and sweep voltages, system alignment adjustments, display and monitoring scales and intensity, data readout and recording initiation, and interface conditions for equipment common to other experiments. For monitoring experiment conditions, indicators are required for the various parameters subject to control listed above. In addition, consideration should be given to the usefulness of display of relative conditions such as time, vehicle attitude, magnetic fields, solar radiation, and temperature. Where conventional indicators are employed, consideration may be given to joint usage with other experiments of a common display.

(6) It is anticipated that a central power source will be available to all systems on the vehicle. To adapt the output to the specific requirements of this experiment, provision should be made for necessary converters, regulators, and filters.

(7) It is anticipated that the data processing system will not be a part of this experiment equipment. As part of the vehicle auxiliary subsystems, it will provide digital recording on magnetic tape, and it can be employed by all experiments on a time selectable basis. Interface devices must be provided by which this experiment can be connected and coordinated with the data conversion and recording system as required. The timing of data units such as signal sampling, multiplexing, encoding, formating, sequencing, and recording, must be correlated with the experiment programmer time gates and control logic to enable the experiment data to be processed in accordance with the requirements of the overall systems. Data from the experiment to be recorded includes experiment and group identity, boom-probe positions, probe voltages and currents, calibration data, vehicle-boom potential, vehicle attitude, time code, magnetometer, UV radiation, X-ray radiation, and equipment temperature.

(8) In deriving the quantities and rates of data to be handled, primary considerations are the number of output samples to be taken in a given time, and the number of probe positions at which measurements are made. The first is governed by the number of points for a satisfactory E-I characteristic, and the probe voltage sweep rate which must be a function of system response time factors. The second is determined by the degree of assessment of the range of plasma conditions surrounding the vehicle. Values for these variables are to be recommended, based on a minimum time interval for completing a set of measurements at a given position of the vehicle in orbit and on a reasonable limit for data requirements.

(9) In order to insure a complete experiment system, it is desired that a data processing package that would match the interface devices included in the system, be planned as part of the system study, should need arise for development of such a unit at a later time. The data unit must accept experiment analog values from several probe amplifiers and auxiliary sensors such as magnetometer, solar radiation, equipment temperature, and other sources. Also digital words defining operating categories, data identities, time, and similar factors must be accepted. For analog forms, a sample-and-hold multiplexer having flexibility in scanning rates and channel selection can feed an analog-to-digital converter. Its output can be combined with the direct digital input into a formatter which sorts the data and sets up the word sequencing and timing to the magnetic tape recorder. The recorded data is transmitted to ground stations at periodic intervals over a standard telemetry link.

NOTE: All material on a data processing sub-system should be complete and self-contained so as to be separable from remainder of proposal.

(10) Suggested Preliminary Operating Factors
(Performance Specifications to be determined by design study.)

Probe

Number: 3 mounted fore, aft, amidship, of vehicle; 1 TEP

Orientation: adjustable around 3 axes

Voltages: bias up to 300 volts; sweep up to ± 40 volts

Boom

Extension: flush with vehicle surface to 10 feet maximum

Position: discrete steps or continuous

Rate of Extension: High as commensurate with other factors

Electrometer

Current range: 10^{-7} to 10^{-12} amperes

Output: 0 to 5 volts dc

Feedback compensation temperature range: Dependent on location

Drift: Adjustment if necessary

Programmer: To be specified on basis of design study

Control and Monitor Unit: To be specified by design study

Power Supply

Governed by on-board source

Total power: Objective less than 75 watts average during experiment run

Reliability MTBF to be based on missions of considerable duration with little opportunity for rectifying malfunctions.

Vehicle environment (Aerospace Corp 1784.0-007, 6/19/64)

Vehicle orbital altitude range: 100 to 250 miles

(d) Reporting Requirements

DD Form 1423

(e) Program specifications, drawings, exhibits, etc.

List standard specs.

(f) Program schedules

Attachment from Program Plan

OMIT [(g) Program documentation and control of schedules and allotments

(h) Exhibits, annexes, etc.

(i) Other

Program funding objectives and procedures

OMIT [Deployment plans
Production Plan
Documentation and control of configuration and status accounting.]

Part III - Management Proposal

31. Personnel, organization, and management

(a) Indicate names of key management, scientific, and engineering personnel who would be assigned to this program. Give percentage of time each would spend. Provide personnel qualification and experience resumé.

(b) Indicate organization of assigned group and relation to present organization.

OMIT [(c) Plan of company operation.

(d) Identify potential conflicts with other work in areas of personnel capability.

32. Related Experience

Indicate experience of company in similar or related efforts. State whether you are now performing or negotiating for similar or related work with other government organizations or contractors. Show industrial and theoretical backgrounds of your firm, and give evidence of quality of your commercial and military products.

OMIT [33. Subcontracting

34. Current Government contracts

List contracts with all agencies of government. Give program identification, dollar amount, manpower, scope, and time period of performance for each. Also, graph current and projected workloads.

OMIT [35. Program Organization and Management (Contractors)
36. Scope of Work (Contractors)
37. Disaster or Labor Surplus Area]

38. Performance Time

Indicate a starting date, after receipt of award, and time schedule for accomplishment of Milestones or Tasks.

OMIT [39. Government furnished property (GFP)
40. Liability for damage to GFP]

OMIT

41. Facilities provided
42. Production advanced planning
43. General logistics considerations
44. Program Evaluation and Review Techniques (PERT)

Part IV - Cost Proposal

45. Cost estimate breakdown

(a) Submit cost estimates for program outlined, including summary cost breakdown on form attached. Include detailed estimate of each of tasks in work statement. Include costs for all equipment, deliverable or non-deliverable, required to perform the program, whether or not equipments are listed in RFP.

OMIT [(b) Other costs

(c) Indicate in cost proposal any work to be done at other locations of company divisions, describing work and related cost.

(d) An attachment to this RFP is included, entitled "Instructions and Definitions for Preparation of Cost Proposals." Deviations should be cleared with contracting officer.

(e) Cost breakdown must be in separate detachable form from rest of proposal.

(f) Failure to furnish cost estimates and supporting information may render your proposal nonresponsive.

(g) Breakdown of direct engineering effort by job classification and corresponding rates and by task will be furnished.

OMIT [(h) Multiple contract effort and related costs

46. Financial statements (Part I, Par. 21)

47. Other financial information

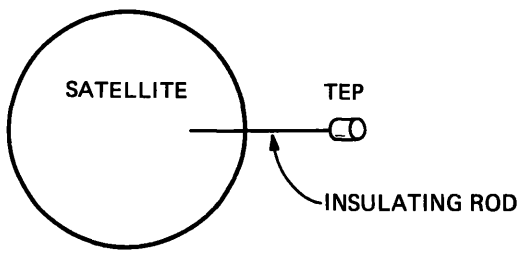
(a) Budget and financial capability.

(b) Funding requirements to complete program.

EXHIBIT D.9

A LOOK AT THE SOLAR HEATING OF THE THERMAL EQUALIZATION PROBE

Bettinger's Thermal Equalization Probe (TEP) is being considered as a probe device for the measurement of the satellite potential with respect to the ionospheric plasma. The TEP is an electron emitter mounted away from the satellite, shown schematically in the figure.



The emitting of electrons produces an outward electron current which tends to cancel the inward plasma electron current leaving the inward plasma ion current to lower the original negative TEP potential acquired when it was placed in the plasma. The potential difference between the satellite and the TEP is monitored, and when the TEP potential is lowered to zero with respect to the plasma, the satellite potential with respect to the plasma is then known.

The TEP emits electrons by heating a cathode; then the current emitted is governed by Richardson's equation

$$i = AT^2 e^{-e\phi/kT} \tag{1}$$

where

i = emitted current [amps/cm^2]

T = cathode temp. [°K]

$e\phi$ = work function of the cathode

A = constant for the cathode material

This is a rapidly increasing function of temperature, changing about twelve orders in magnitude as the temperature increases from 10^3 °K to 2×10^3 °K. Because of the sensitivity to temperature and the fact that, as a satellite probe, it will spend long periods of time in sunlight and darkness, it seems important to take a close look at the effect of solar heating on the TEP.

For small changes in temperature Eq. (1) will give

$$\delta i = AT^2 e^{-e\phi/kT} \left\{ \frac{2}{T} + \frac{e\phi}{kT^2} \right\} \delta T \tag{2}$$

or

$$\frac{\delta i}{i} = \left\{ 2 + \frac{e\phi}{kT} \right\} \frac{\delta T}{T} \tag{3}$$

Thus, for example, a 1% change in temperature of a tungsten cathode at 1.5×10^3 °K give about a 37% change in emitted current.

Let

H = radiant energy/unit area/unit time received at the surface of the TEP,

α = absorptivity = fraction of received energy that is absorbed,

R = radiant emittance = radiant energy/unit area/unit time emitted by the TEP, and

P = internal power supplied to the TEP.

Then the net heat dQ transfered to the TEP in time dt is

$$\frac{dQ}{dt} = a_p \alpha H + P - a_s R \tag{4}$$

where a_s is the total surface area and a_p is the area of the TEP projected on to a plane perpendicular to the direction from which the radiant energy flux H is received. Using the Stefan-Boltzmann (S-B) law

$$R = \epsilon \sigma T^4 \tag{5}$$

where ϵ is the emittivity and σ the S-B constant. Thus Eq. (4) for the temperature T becomes

$$C_p \frac{dT}{dt} = a_p \alpha H + P - a_s \epsilon \sigma T^4 \tag{6}$$

where C_p is the heat capacity of the TEP. The desire to solve and apply this equation to the TEP poses a few problems.

In applying this equation to the TEP, the parameters α must be evaluated. This is not only a function of the metal used, but also of the finish of the surface (polished, rough, etc.), and it should be evaluated for the case where the incident energy flux is solar radiation.

The parameter ϵ depends on the metal used and is a weak function of temperature. Because of the weak dependence on temperature, its evaluation should not pose much of a problem.

The projected area is a function of time since it depends upon the orientation of the TEP with respect to the incident radiation. Its evaluation will require averaging with respect to orientation.

The parameter H can be split into a number of terms; for example

$$H = H_{\odot} + H_{RE} + H_{rE} + H_{RS} + H_{rs} \tag{7}$$

where

$H_{\odot}$ = solar energy flux

H_{RE} = energy flux reflected by earth

H_{rE} = radiant energy flux from the earth

H_{RS} = energy flux reflected by the satellite

H_{rs} = radiant energy flux from the satellite

It will be assumed that H_{RE} and H_{rE} can be neglected with respect to the other terms. The H_o is just the solar constant while the H_{RS} is the solar constant adjusted by a reflection coefficient for the satellite and the geometry of the reflection from the satellite to the TEP. The term H_{rs} is a function of the temperature of the satellite which is again a function of time and obeying an equation similar to (6). Also, for this term, the parameter α must be adjusted since the energy absorbed will be in a different part of the spectrum.

Thus Eq. (6) can be written as

$$C_p \frac{dT}{dt} = a_p \alpha H_{\odot} + a_p' \alpha H_{RS} + a_p'' \alpha' H_{rs} + P - a_s \epsilon \sigma T^4 \tag{7}$$

where the primes denote the parameters are adjusted to correspond to the type of radiant energy.

Assuming that some sort of averaging is done leaving the first three terms of the R.H.S. independent of both T and t, Eq. (7) could be written as

$$C_p \frac{dT}{dt} = F^4 - (GT)^4 \tag{8}$$

where

$$F^4 = a_p \alpha H_{\odot} + a_p' \alpha H_{RS} + a_p'' \alpha' H_{rs} + P$$

$$G^4 = a_s \epsilon \sigma .$$

Integrating (8) gives

$$t = -\frac{C_p}{4GF^3} \left\{ \log \frac{GT - F}{GT + F} - 2 \tan^{-1} \frac{GT}{F} \right\} \Bigg|_{T_o}^{T} \tag{9}$$

which is a closed form solution, but awkward to use.

The best approach is probably in studying numerical solutions of (7) where each solution is for a set of parameters. Certain cases allowing rough calculation of the parameters could be run which would provide guides to varying the parameters. For example, the case where the orbit plane is always perpendicular to the direction to the sun and the TEP always broadside to the solar rays would serve as an upper limit for the solar heating effect. Then the case could be run for the orbit plane parallel to the direction of the sun which, for a circular orbit, would give the maximum duration of the satellite in the shadow, thus representing the case of maximum temperature fluctuation.

It seems that if the satellite to which the TEP is attached is both large and manned, the H_{RS} and H_{rs} terms may not be negligible and definitely not straight forward to evaluate for the size would imply significant reflected and radiated energy and being manned would imply the satellite surface designed to control the inside temperature. Also, there would be times when the satellite would be in sunlight but, shadowing the TEP.

EXHIBIT D.10

Form AFSC PMI 1-9

REQUEST FOR PROPOSAL

EXPLOITATION OF SPACE PLASMA-EFFECTS MOL/S1/S23 AND MHD

PART I - ADMINISTRATIVE AND GENERAL INFORMATION

1. Number
2. Issuing Office
3. Date
4. Closing Date (Proposal submission 60 days)
5. Table of Contents
6. Accounting Data
7. Late Proposals
8. Priority
9. Payments
10. Shipping, Marking, FOB Point
11. Inspection and Acceptance
12. Availability of Records and Cost Data
13. Certification
14. Incurring Costs
15. Specifications
16. Data Support
17. Cost of Preparation
18. Preproposal Briefing and Information
19. Acceptance Time: (30 day proposal review time)
20. System Source Selection Board
21. Facility Survey
22. Security
23. Classified or Restricted Information: No Disclosures
24. News Release: None
25. Rejection of Proposals
26. Disposition of Documents
27. Contract Clauses
28. Type of Contract

PART II - TECHNICAL PROPOSAL

29. TECHNICAL PLAN

a. Delineate your overall concepts of the project, provide a program plan, and present a clear explanation of how you plan specifically to accomplish the objectives and tasks set forth in the work statement. Provide graphics as appropriate.

b. Isolate the technical problems which you expect to encounter, and indicate the methods by which you propose to solve them. Identify areas of technical risk. Suggest where simplification of requirements could reduce costs or time without detracting from system/equipment effectiveness. Suggest alternate technical proposals.

(Omit) c. Interrelated efforts schedule

(Omit) d. Summary Program Plan

(Omit) e. Simplicity of design and value analysis

(Omit) f. Control over subcontractors and managers

g. Within the Technical Plan, furnish the following:

(1) Reliability Program Plan, outlining scope, requirements, management, testing, demonstration, reviews, and reporting.

(2) Quality Assurance Program Plan, outlining scope, requirements, management, controls, inspection, testing, calibration, and vendor quality assurance.

(Omit) (3) Maintainability Program

(Omit) (4) Materiel Support Plan

(5) Technical Data Plan, which outlines proposed plan and requirements for technical data, engineering drawings, system specifications, check lists, utility manuals and handbooks.

(Omit) (6) System Safety Engineering Plan

(Omit) (7) Configuration Management Plan

(Omit) (8) Aerospace Ground Equipment Plan

(Omit) (9) Transportability Program Plan

(Omit) (10) Personnel Subsystem Program Plan

(Omit) h. Cost Breakdown

(Omit) g. (1) to (10)

30. WORK STATEMENT

a. Purpose

(1) An experimental system is required which will enable measurements to be made of wave transmission effectiveness in the VLF/ULF/ELF bands between a manned orbiting space vehicle and other stations on the ground or in other space vehicles. An associated system is also required to measure the plasma environment around the vehicle in order to correlate its characteristics with the performance of the transmission system, particularly its effects on antenna radiation efficiency and dimensions, and the sheath effects on voltage excitation. Although the two systems serve a mutual objective, and must be integrated for a common application, there is considerable difference in the design technique and knowledge required in formulating an end-product. For clarity and readability, the transmitter-receiver-antenna complex is in separate paragraphs in this description from the electron probe-boom assembly. The end result must be a package in which the various requirements are coordinated, and joint usage must be made to the fullest extent of component units which can be made common to both subsystems toward saving space and weight. Certain suggestions toward a tentative system are included in this RFP, but it is desired that proposals not be limited by these preliminary considerations, and should present approaches and techniques which take into account trade-offs among various means of accomplishing the objectives. A thorough discussion of factors affecting the performance of different configurations should be given. Likewise, other comparative analyses involving technical results, convenience, time, cost, and other factors are desired.

(2) Proposals are to be submitted within 60 days. Following review of proposals, a contract may be negotiated for an engineering design study to establish a Proposed System Package Plan (PSPP). An extension of contract or separate contract utilizing the findings of the design studies toward completion of a laboratory model may follow. This model serves to prove performance and establish specifications for final designs. Subsequently, a prototype suitable for final evaluation and training purposes may be procured, with up to 4 flight systems. The estimated time periods for these anticipated stages are as follows:

Submission of proposal	60 days
Submission of PSPP final report	6 months after contract
Completion of laboratory model	6 months after go-ahead
Completion of evaluation and training model	(6 months additional)
Completion of integration model	12 months additional
Completion of first flight qualified system	(6 months additional)

with additional systems at 3 month intervals.

(3) The object of the design study is to define the capabilities and limitations of a system that can be built at the present state of the art. The specifications governing a proposed system in this category shall be defined. Estimates of weight, space required, power consumption, and cost are to be provided. The study is to include a complete system which will enable the various functions listed in succeeding paragraphs to be accomplished.

(4) A report is to be furnished which will include the following material, with the addition of any other that the contractor considers desirable.

(a) Description of the proposed system and all component units, including types of circuits. Consideration of standard module packaging and also miniaturization should be given.

(b) Specify ranges of environmental conditions (temperature, vibration, shock, humidity, atmospheric pressure) for guaranteed satisfactory operation without need for recalibration or adjustment. Also non-operating limits without damage.

(c) Describe procedures for setting up the system, and making routine adjustments and performance checks, including how often required and estimated time to accomplish.

(d) Estimate system reliability as mean time between failure of any major unit.

(e) Discuss advisability of critical module spares for replacement.

Paragraphs 30a(5) and 30a(6)

SECTION I (WAVE PROPAGATION PHASE)

(5) The propagation measuring subsystem affords a means by which an astronaut, in coordination with other stations, can set up conditions under which signal propagation at various frequencies in the VLF/ULF/ELF bands can be determined. In the transmission condition, signals of known characteristics are radiated from the space vehicle and received at stations on the ground where the signals are recorded for measurements of frequency, field strength, phase, Doppler shift, and multipath effects. Also, for determination of specific MHD effects, signals of short duration are radiated, and the radiated frequency immediately monitored. In the reception condition, signals in related bands from ground stations are monitored and recorded in the space vehicle by the astronaut to provide, in the reverse direction of transmission, the same signal characteristics as on the ground. Also wide band receptions for noise level determination are made. Transmissions from the vehicle are made intermittently for short intervals at selected positions in an orbit to provide day and night conditions in north and south latitudes. Signal reception can be made both alternately with transmissions, and on a scheduled basis when the transmitter is off, by the astronaut as time permits. In support of these propagation tests, measurements are made of the impedances of the transmitting and receiving antennas related to their orientation in the earth magnetic field, and to the plasma conditions. These measurements can be made at low excitation levels for all antennas, and for the transmitting element additional measurements at higher power levels are desirable. In order to obtain optimum results in all related phases of the experiment, time intervals for the various tasks must be specified, as well as the positions in orbit to afford the desired range of conditions in latitude, light-dark, diurnal or seasonal, and plasma environment related to solar activity and magnetic fields. In all phases, consideration must be given to the control of radio frequency interference (RFI) effects, both those generated by the experimental system and interfering with other sensors, and those from outside sources capable of affecting sensitive local devices.

(6) In order to accomplish these objectives, it is anticipated that the propagation measurement system may include, but not be limited to, typical components as listed here:

(a) A transmitter having variable frequency and power level capability.

(b) Transmitting antennas of crossed loops or dipoles of adjustable length.

(c) Matching unit to couple transmitter to antenna.

(d) Dummy load for transmitter tune-up.

(e) Tunable receiver having narrow bandwidth for signal reception.

(f) Tunable receiver having wide bandwidth for noise measurement.

(g) Receiving antennas.

(h) Antenna impedance measuring equipment.

(i) Power conversion and regulating devices between the vehicle common source and the measurement system.

(j) Interconnecting and matching units to adapt to positioning requirements of different parts of the experiment system as necessary in the vehicle

The following items may be designed to serve functions of both propagation and plasma experiments as a common unit:

(k) A system programmer to provide, in timed sequence, the various operating conditions in accordance with selectable modes.

(l) A control and monitor panel for selecting desired program modes and observing measurement results.

(m) Interface equipment to accommodate a separate data handling and recording system shared with other experiments.

(n) Ancillary equipment such as magnetometer, UV and X-ray radiometers, and equipment temperature indicators.

In addition to the space vehicle equipment, provision is to be made for

receiving equipment at the ground stations. The number of ground stations necessary, and their location based on present tracking stations should be considered.

This is a tentative listing based on a preliminary analysis of requirements and is subject to modification by the offerer in accordance with his study of the problem.

There are a number of constraints which are placed on transmitter-antenna characteristics in space vehicles and these must be weighed and compared in designing a system. Since space operations involve unknown conditions in various areas, the extent of the constraints must be estimated to serve as a guide in establishing performance characteristics. Thus a feasibility study is to be included under the contract to set the limits which must be placed on desired operating factors.

A prime example is the transmitting system. Both variable output power, and variable frequency coverage is required in determining the capability for radiating VLF/ELF energy into space and for propagating through that space. Power levels from watts to kilowatts would be desirable for measuring antenna excitation effects, either on a continuous or pulsed basis. However, size and weight restrictions on the power supply, transmitter, antenna tuning unit, dummy load, and antenna must be considered in attaining these levels. A particularly critical factor is the antenna loading condition. Antenna lengths at these frequencies are a small fraction of a wavelength, resulting in radiation resistances of a fraction of an ohm and capacitive reactances of thousands of ohms. Thus antenna currents up to tens of amperes flow through a high tuning inductance to produce tens of kilovolts of radio-frequency potential, creating a considerable hazard in a confined space. Also generated fields capable of affecting sensors and instruments in the vehicle, and currents flowing in the vehicle structure constitute interference sources. As the transmitted frequency is decreased, these conditions become worse. Longer antennas are a help but the length is limited by various factors. Thus a feasibility limit, based on an investigation of conditions of operation, is needed for maximum allowable transmitter power, and for minimum frequency of transmission in the ELF band. Related factors affecting the system and its performance objectives, must also be considered in specifying the values which will provide the best balance in overall experimental results.

Paragraphs 30a(5) and 30a(6)

SECTION II (PLASMA MEASUREMENT PHASE)

(5) The function of the plasma measurement system is to afford a means by which an astronaut can determine the characteristics of the space plasma and related factors such as magnetic field and solar radiation immediately surrounding his vehicle while orbiting the earth. The characteristics to be measured include the electron energy distribution (temperature), the electron and ion densities, the vehicle-to-plasma voltage, the shape and size of the sheath around the vehicle, the potential distribution across the sheath, and the V x H EMF induced effects in the vehicle structure. Simultaneous measurements are to be made fore, aft, and amidship of the vehicle, and sequentially at selected distances from it, which will encompass the sheath limits as well as turbulent conditions in the immediate environment of the vehicle and out to plasma equilibrium. At a selected position in orbit, this group of measurements at predetermined locations around the vehicle will be completed as rapidly as possible. Groups will be repeated several times in one orbit to include light and dark conditions in north and south latitudes. The intent is to define diurnal, seasonal, and spatial variations in plasma conditions under ordinary and extraordinary circumstances. Observations are also required of the magnetic field strength, and of UV and X-ray radiation, and equipment temperature.

(6) In order to accomplish these objectives, it is anticipated that the measurement system may include typical components as listed here:

(a) A set of plasma sensing probes mounted on extended booms.

(b) Electrometer amplifiers and associated conditioning devices for probe currents.

(c) Power conversion and regulation devices between the vehicle common source and the measurement system.

(d) Interconnecting and matching units to adapt to positioning requirements of different parts of the experiment system as necessary in the vehicle.

The following items may be designed to serve functions of both propagation and plasma experiments as a common unit:

(e) A system programmer to provide, in timed sequence, the various operating conditions in accordance with selectable modes.

(f) A control and monitor panel for selecting desired program modes and observing measurement results.

(g) Interface equipment to accommodate a separate data handling and recording system shared with other experiments.

(h) Ancillary equipment such as magnetometer, UV and X-ray radiometers, and equipment temperature indicators.

This is a tentative listing based on a preliminary analysis of requirements but is subject to modification by the offeror in accordance with his study of the problem.

b. Background

This experiment is to be one of several to be conducted aboard a manned orbiting vehicle. In order to evaluate the effectiveness of a man in performing various functions in space, it is planned to utilize his capabilities of observation, control, reasoning, and decision-making, in critical phases, while providing automatic means of accomplishing routine tasks in short time intervals to expedite the measurement procedures. In order to conserve space, weight, and power, the maximum common usage must be made of equipment and instrumentation of general type aboard on a time-sharing basis. It is anticipated that sub-systems in this category could include data handling and recording, timing standards, display and indicating devices, power supplies, and ancillary sensors such as magnetometer, UV and X-ray radiometers. Consideration must be given to problems relating to mutual operation of such sub-systems and the avoidance of interference between experiments. Likewise, the location of experiment equipment, within the vehicle for accessibility needed by the astronaut, and outside the vehicle on available desired areas avoiding conflict with other external devices, must be determined by mutual agreement of users. Since the final configuration of vehicle and equipment is subject to modification as development plans progress, the experiment design in areas relating to interface conditions may also require change, and adaptibility to these requirements should be given consideration.

Paragraphs 30c(1), c(2), c(3)

SECTION I (WAVE PROPAGATION PHASE)

c. Requirements and Objectives

(1) In accomplishing the objectives listed in paragraph 30a, the astronaut must follow a sequence of tasks established on a prearranged schedule coordinated with ground transmitting and receiving stations. Under certain circumstances, special observations may be required to meet unusual conditions which have arisen, and the astronaut can arrange with the stations for short-term schedules during which the experimental procedures will be governed by the conditions. During the regular schedules, the astronaut will operate alternately for short intervals, the transmitter phase and the plasma-receiver phase of the experiment. The transmitter is initially tuned to the desired frequency, and the power level adjusted using the dummy load. The antenna is extended and connected in place of the dummy load, and the matching unit is adjusted, using reduced power when necessary. The power is then increased to the desired level. The transmitter can be left in standby mode until ready for the radiation interval. The receiver can be pretuned to the scheduled frequency and the plasma measurement run prepared for operation. With the transmitter energized, provision should be made for protecting various components of experiments which might be damaged by stray radiation. The successive test sequences for any one group of measurements should occur as close together as possible to avoid changes in environmental conditions during different parts of a group. A plan should be proposed for the range of measured parameters to be included, and for the division of these conditions among desired orbit positions in order to obtain the optimum data for the anticipated environmental ranges in a minimum of time.

(2) In transmitting from the vehicle, the antenna is the most critical item. If satisfactory characteristics can be obtained, the transmitter and tuning coil present little problem, mainly shielding and heat dissipation. Thus a major effort is needed to provide antennas of long effective length, affording low reactance and high radiation resistance for efficient coupling.

(3) The receiving system can be of conventional design, with components to minimize size. A three decade tuning range as listed under suggested operating conditions is desired.

Paragraphs 30c(1), c(2), c(3)

SECTION II (PLASMA MEASUREMENT PHASE)

c. Requirements and Objectives

(1) The plasma characteristics listed in paragraph 30a as requiring measurement can be determined from plasma probes extending out from the vehicle. These probes are mounted on booms to allow the orientation and the position relative to the vehicle to be controlled. The number of positions to afford adequate definition of plasma conditions must be determined. The orientation is to be adjustable around any axis, and the position, from flush with the vehicle surface out to a specified limit. The positioning should be accomplished in the shortest time commensurate with other design limits.

(2) The probes which may be of the Langmuir type, Faraday cup, or similar, consist of one or more electrodes by means of which the flow of either electrons or ions to a collector electrode can be controlled and measured. A constant voltage adequate to attract the charged particles of a given type, is applied to the collector, while a sweep voltage sufficient to swing the particle currents from maximum negative to maximum positive, is applied to a grid adjacent to the collector, and can control the flow of current to it. By employing positive and negative potentials successively, a curve of current versus sweep voltage is obtained over a range of values which allow various parameters describing the space plasma conditions to be derived. An additional type, called a thermal equalization probe, which operates on a different principle to provide an independent measure of plasma-to-vehicle potential, should also be included. This TEP contains a heated emitter which discharges electrons into the surrounding plasma until its potential equals that of the surroundings. This condition is determined from the change of slope of the curve of probe voltage vs. emitter temperature. A direct voltage measurement between probe and vehicle can then be made. In the design of probes, various factors must be considered toward reducing errors in measurement caused by sheath effects, motion of vehicle, time constants of system, solar radiation, and others. For completeness, recommendations should be made for a magnetometer to measure field strength frequently, and for a solar radiation sensor.

(3) Electrometer amplifiers are needed for amplifying currents from the probe collectors, and providing a standard range of output voltages to be processed by a separate data system. Several decades of input currents, corresponding to the particle densities encountered by the space vehicle, require an amplifier of adequate dynamic range. Precautions are necessary to minimize input capacity and leakage, such as feedback between stages, and high quality components affording a high input impedance. Uniform characteristics of performance over the range of environmental conditions are obtained by adequate circuit compensation, e.g., temperature variations.

(4) The system programmer serves the purpose of relieving the astronaut of routine tasks by automatizing the accomplishment of desired functions, while enabling him to make best use of his abilities in controlling the experiment and monitoring the performance of the system and the measurement results for selected conditions. Timed from a source common to other parts of the system, the programmer establishes the sequence and time intervals of operating functions in accordance with settings of controls by the astronaut. For plasma measurement, these functions include movement of booms and probes, fixed and sweep voltages applied to the probes, and switching of calibrating and operating inputs. For propagation measurement, the functions include extension of antennas, tuning and switching of transmitter, tuning and switching of receivers, and connection and adjustment of impedance measuring equipment. Generation of gates for data readout and data sampling times, and generation of status codes for indicating the conditions during measurements enable data to be recorded and identified. Programming modes should be selectable to permit either an automatic sequence independent of control settings or a manual type corresponding to the panel controls set by the astronaut for special conditions. Other desirable operating modes can also be recommended.

(5) A control and monitor unit is to be provided by means of which the astronaut can set up the desired experiment conditions and observe the results as the selected program sequences the various operations. Controls are required for primary power, program selection, boom-probe positions, probe bias and sweep voltages, antenna extension, transmitter standby-operate, transmitter tuning, receiver tuning, impedance assembly switching and adjustment, system alignment adjustments, display and monitoring scales and intensity, data readout and recording

initiation, and interface conditions for equipment common to other experiments. For monitoring experiment conditions, indicators are required for the various parameters subject to control listed above. In addition, consideration should be given to the usefulness of display of related conditions such as time, vehicle attitude, magnetic fields, solar radiation, and temperature. Where conventional indicators are employed, consideration may be given to joint usage with other experiments of a common display.

(6) It is anticipated that a central power source will be available to all systems on the vehicle. To adapt the output to the specific requirements of this experiment, provision should be made for necessary converters, regulators, and filters.

(7) It is anticipated that the data processing system will not be a part of this experiment equipment. As part of the vehicle auxiliary subsystems, it will provide digital recording on magnetic tape and it can be employed by all experiments on a time selectable basis. Interface devices must be provided by which this experiment can be connected and coordinated with the data conversion and recording system as required. The timing of data units such as signal sampling, multiplexing, encoding, formatting, sequencing, and recording, must be correlated with the experiment programmer time gates and control logic to enable the experiment data to be processed in accordance with the requirements of the overall systems. Data from the experiment to be recorded includes experiment and group identity, boom-probe positions, probe voltages and currents, calibration data, vehicle-boom potential, transmitter antenna length and orientation, receiver antenna type and orientation, transmitter frequency and input power, type of modulation, antenna impedances, receiver bandwidth, signal characteristics, vehicle attitude, time code, magnetometer, UV radiation, X-ray radiation, equipment temperature.

(8) In deriving the quantities and rates of data to be handled for the plasma measurements, primary considerations are the number of output samples to be taken in a given time, and the number of probe positions at which measurements are made. The first is governed by the number of points for a satisfactory E-I characteristic, and the probe voltage sweep rate which must be a function of system response time factors. The second is determined by the degree of assessment

of the range of plasma conditions surrounding the vehicle. Values for these variables are to be recommended, based on a minimum time interval for completing a set of measurements at a given position of the vehicle in orbit and on a reasonable limit for data requirements. For propagation measurements, the degree of detail to be analyzed in the VLF/ELF signal characteristics will be a governing factor. Comparison of analog as against digital recording should be made to determine advantages to be gained from an overall system viewpoint.

(9) In order to insure a complete experiment system, it is desired that a data processing package that would match the interface devices included in the system, be planned as part of the system study, should need arise for development of such a unit at a later time. The data unit must accept experiment analog values from several probe amplifiers and auxiliary sensors such as magnetometer, solar radiation, equipment temperature, and other sources. Also digital words defining operating categories, data identities, time, and similar factors must be accepted. For analog forms, a sample-and-hold multiplexer having flexibility in scanning rates and channel selection can feed an analog-to-digital converter. Its output can be combined with the direct digital input into a formatter which sorts the data and sets up the word sequencing and timing to the magnetic tape recorder. The recorded data is transmitted to ground stations at periodic intervals over a standard telemetry link.

Note: All material on a data processing sub-system should be complete and self-contained so as to be separable from remainder of proposal.

(10) Suggested tentative operating factors (performance specifications to be determined by design study.

Transmitter frequency range:

Tunable from 30 kc to 0.3 kc - feasibility of low end of band to be determined; crystal-controlled fixed frequencies of 30, 10, 3, 1, 0.3 kc.

Transmitter power output:

Peak power of 1 KW if feasible; duty cycle such as to hold average power below 100 watts.

Transmitting antenna:

As long as feasible to increase radiation resistance and reduce reactance.

Transmitter loading coil:

Adjustable for predicted antenna reactance variations induced by plasma environment. Shielded to reduce radiated fields and insulated for high voltage protection.

Receivers:

Tunable from 300 kc to 0.3 kc.

Signal reception bandwidth up to 25 cps.

Noise measurement bandwidth up to 5 kcps.

Antenna impedance measuring equipment

Plasma Probe:

Number: 3 mounted fore, aft, amidship, of vehicle; 1 TEP.

Orientation: Adjustable around 3 axes.

Voltages: Bias up to 300 volts; sweep up to ± 40 volts.

Boom:

Extension: Flush with vehicle surface to 10 feet maximum.

Position: Discrete steps or continuous.

Rate of extension: High as commensurate with other factors.

Electrometer:

Current range: 10^{-7} to 10^{-12} amperes

Output: 0 to 5 volts dc

Feedback compensation temperature range: Dependent on location

Drift: Adjustment if necessary

Programmer: To be specified on basis of design study.

Control and Monitor Unit: To be specified by design study.

Power supply:

Governed by on-board source.

Total power: Objective less than 75 watts average during experiment run.

Reliability MTBF: To be based on missions of considerable duration with little opportunity for rectifying malfunctions.

Vehicle environment: (Aerospace Corp 1764.0 - 007 6/19/64)

Vehicle orbital altitude range: 100 to 250 miles.

d. Reporting Requirements

DD Form 1423

e. Program specifications, drawings, exhibits, etc.

List standard specs.

f. Program schedules

Attachment from Program Plan

(Omit) g. Program documentation and control of schedules and allotments

h. Exhibits, annexes, etc

i. Other

Program funding objectives and procedures

(Omit) Deployment plans

(Omit) Production plan

(Omit) Documentation and control of configurations and status accounting

PART III - MANAGEMENT PROPOSAL

31. PERSONNEL, ORGANIZATION, AND MANAGEMENT

a. Indicate names of key management, scientific, and engineering personnel who would be assigned to this program. Give percentage of time each would spend. Provide personnel qualification and experience resume.

b. Indicate organization of assigned group and relation to present organization.

(Omit) c. Plan of company operation

d. Identify potential conflicts with other work in areas of personnel capability

32. RELATED EXPERIENCE

Indicate experience of company in similar or related efforts. State whether you are now performing or negotiating for similar or related work with other government organizations or contractors. Show industrial and theoretical backgrounds of your firm, and give evidence of quality of your commercial and military products.

(Omit) 33. SUBCONTRACTING

34. CURRENT GOVERNMENT CONTRACTS

List contracts with all agencies of government. Give program identification, dollar amount, manpower, scope, and time period of performance for each. Also, graph current and projected workloads.

(Omit) 35. PROGRAM ORGANIZATION AND MANAGEMENT (CONTRACTORS)

(Omit) 36. SCOPE OF WORK (CONTRACTORS)

(Omit) 37. DISASTER OR LABOR SURPLUS AREA

38. PERFORMANCE TIME

Indicate a starting date, after receipt of award, and time schedule for accomplishment of milestones or tasks.

(Omit) 39. GOVERNMENT FURNISHED PROPERTY (GFP)

(Omit) 40. LIABILITY FOR DAMAGE TO GFP

(Omit) 41. FACILITIES PROVIDED

(Omit) 42. PRODUCTION ADVANCED PLANNING

(Omit) 43. GENERAL LOGISTICS CONSIDERATIONS

(Omit) 44. PROGRAM EVALUATION AND REVIEW TECHNIQUES (PERT)

PART IV - COST PROPOSAL

45. COST ESTIMATE BREAKDOWN

a. Submit cost estimates for program outlined, including summary cost breakdown on Form _____ attached. Include detailed estimate of each of tasks in work statement. Include costs for all equipment, deliverable or non-deliverable, required to perform the program, whether or not equipments are listed in RFP.

(Omit) b. Other costs

c. Indicate in cost proposal any work to be done at other locations of company divisions, describing work and related cost.

d. An attachment to this RFP is included, entitled "Instructions and Definitions for Preparation of Cost Proposals". Deviations should be cleared with contracting officer.

e. Cost breakdown must be in separate detachable form from rest of proposal.

f. Failure to furnish cost estimates and supporting information may render your proposal nonresponsive.

g. Breakdown of direct engineering effort by job classification and corresponding rates and by task will be furnished.

(Omit) h. Multiple contract effort and related costs.

46. FINANCIAL STATEMENTS (Part I, Par. 21)

47. OTHER FINANCIAL INFORMATION

a. Budget and financial capability.

b. Funding requirements to complete program.

EXHIBIT D.11

MEMORANDUM

To: Code 7000

Via: Code 5100

From: Code 5110

Subj: Rough draft of material prepared for use by BUWEPS Code RTOS-3 in their preparation of a related PTA (U)

FOREWORD:

This proposed technical approach presents one means for attacking the problem of communicating with a submerged submarine via the VLF (ELF) receiving facilities currently used for receipt of Navy Communications System traffic. The proposed approach employs a near-earth orbiting vehicle containing a VLF transmitting facility at relatively low power level to demonstrate the feasibility of generating, launching, and propagating VLF (ELF) signals from the space environment to a submerged submarine. A subsidiary goal is to demonstrate a communication capability via VLF between widely separated (beyond line-of-sight) satellite vehicles.

A brief summary of the current VLF system capabilities and limitations may prove advantageous in identifying the nature and extent of the operational problem which full exploitation of the proposed approach may alleviate.

The need for rapid and reliable communications from a tactical command and control center to the world-wide deployment of naval forces afloat is obvious. Through the implementation of several high power VLF transmission facilities near world-wide communication can be affected for much of the time. However, there remain selected areas with which communications at VLF are not reliable at any time, due to the limited number of transmitting installations currently available and the coverage patterns of the transmitting antenna systems. Additionally, local climatic effects such as thunderstorm activity can negate communications for prolonged periods of time.

The development of the nuclear submarine, with its capability for long periods of submerged operation, has imposed further demands on the VLF system. For conventional submarines, which are forced to operate at or near the surface for significant periods of time, the transmitted VLF signal penetration depths were

adequate for use by these vessels. The increased attenuation of radio waves in sea water over that in air restricts the operating depth of the submarine at those times when VLF message reception is being attempted.

Since only that portion of the radio frequency spectrum below about 30 kcs is available for communication with submerged submarines, and the need for reliable communications with these vessels is high, it is imperative that alternate transmission paths be available at all times to allow for conditions of malfunction or destruction of the primary transmission facilities. These facilities may take the form of additional high power facilities paralleling the coverage of present installations, or may be in the form of smaller, more numerous reduced coverage facilities strategically located to satisfy the communications need. Trade-off analyses of the costs, effectiveness, and vulnerability elements of alternatives available can be used to indicate desired approaches for specific tactical considerations.

For the specific problem of improved communications with submarines at increased operating depths, several approaches appear immediately evident. One is to increase the transmitter power level. This approach, however, cannot significantly improve the existing situation. The antenna system voltages currently in use are at or near the corona breakdown levels and further increases in transmitter effective radiated power would prove difficult to accomplish. Another approach to increase in submerged receiving capability would be the reduction in transmitter frequency since the attenuation rate of electromagnetic waves in sea water is an inverse function of the wave frequency. This approach, however, is not directly applicable to existing transmitting antenna facilities since a reduction in frequency would have to be accompanied by a reduction of the allowable maximum potential at the antenna terminals. This is necessary since the corona breakdown voltage is reduced as the frequency is reduced. The reduction in input power to the antenna together with the reduced antenna efficiency at the lower frequency would have a net effect of a reduction in the signal strength at the range of the receiving vessel.

Simply stated, the problem consists of improving the reliability of VLF communications to submarines at ever increasing depths of operation. Improved

reliability can be effected through an increase in signal level at the received location, while for increased depth receiving capability it may be necessary to augment the increased signal strength at the surface with operation at lower frequencies. As has been noted, little improvement in communications through either of these approaches can be effected by modification to existing facilities.

The approach proposed herein will serve to demonstrate that a low altitude ionospheric satellite may be employed to effect an improvement in the received signal levels and may perhaps provide data which indicates still lower frequency transmissions (ELF) may be efficiently radiated and propagated from a satellite.

R&D IN SUPPORT OF PROGRAM:

A considerable amount of supporting research and exploratory development effort has been conducted in the field of VLF propagation using satellite instrumentation. All of the previous work, sofar as is known, has been restricted to reception in the satellite of ground transmitted VLF signals. Examples of efforts of this type are to be found in the LOFTI I, LOFTI II-A, Alouette I, Injun III satellite instrumentation programs. Of these, the LOFTI I series were designed primarily for the investigation of VLF communication phenomena; i.e., received signal strengths as a function of distance, location, antenna attitude, etc. The constraint of the orbit of these satellites limited the data collection to regions within 30° latitude from the equator. The other satellite programs mentioned provide a greater geographical coverage, but the instrumentation employed was primarily designed to investigate the "whistler-type" VLF signal; a naturally occurring atmospheric and ionospheric signal. Much of the current knowledge of propagation characteristics of VLF signals has been derived from analysis of these whistler mode signals. Although no known experiment program for transmission of VLF energy from a satellite has been conducted, several studies of this approach have been performed. A very simple satellite experiment designed to excite a VLF wave by application of direct current pulses to an antenna in the ionosphere is planned for the ISIS-A space craft program. Transmission from aerial platforms to submerged submarines at VLF has been demonstrated from aircraft utilizing trailing wire antenna techniques.

The instrumentation developed for use in the previously mentioned programs form a sound basis for the satellite hardware which would be employed in the

conduct of the proposed effort. Several areas of uncertainty which appear to be resolvable only by actual experiment, must be considered as risk items of the program. These have to do with coupling of the transmitter to the antenna, the coupling of the antenna to the medium (radiation), and the directional properties of the radiated energy. These elements will be considered further in subsequent section of this proposal.

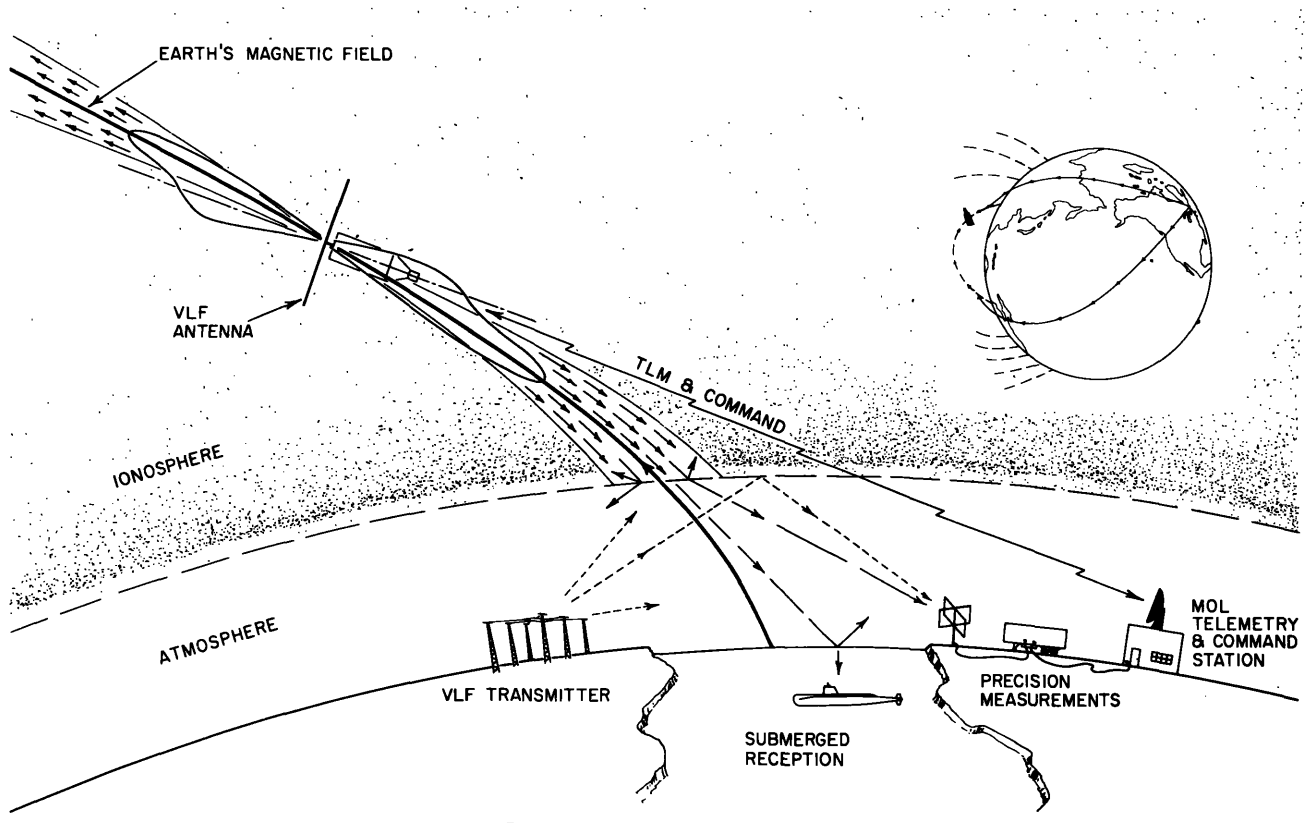
OPERATIONAL BRIEF:

In considering the scope of the proposed program effort several levels of system complexity and resultant data collection and analysis tasks are uncovered. The simplest satellite instrumentation package would consist of a transmitter coupler-antenna configuration which would be operated at a single frequency and power level and would be internally programmed to operate in an on-off modulated fashion for short periods of time over several portions of each orbit. Existing ground-based VLF receiving facilities would be requested to monitor and record the received signal for subsequent analysis to determine the level and reliability of coverage of the radiation from the satellite. A minimal amount of telemetry data (real-time) would be employed to sense the status of the on-board VLF system for correlation with the received signal levels. The block diagram of Figure 1 is representative of such a minimal system.

The system of Fig. 1, though capable of demonstrating the primary objective of the proposed effort provides little opportunity for determination of those system parameters which optimize the communications capability. In order to obtain the supporting data necessary for such an optimization, the satellite VLF systems shown in Figures 2 through 5 should be considered. Each of these systems, shown in order of increasing complexity and data sophistication, adds a measurement and/or analysis capability not included in the ones preceding it. The system of Fig. 2 adds to the basic transmitter system an ionospheric plasma diagnostic-technique to enable measurement on the characteristics of the medium into which the antenna is attempting to radiate. The impedance measuring system, shown in the same figure, provides information on the radiation behavior of the antenna.

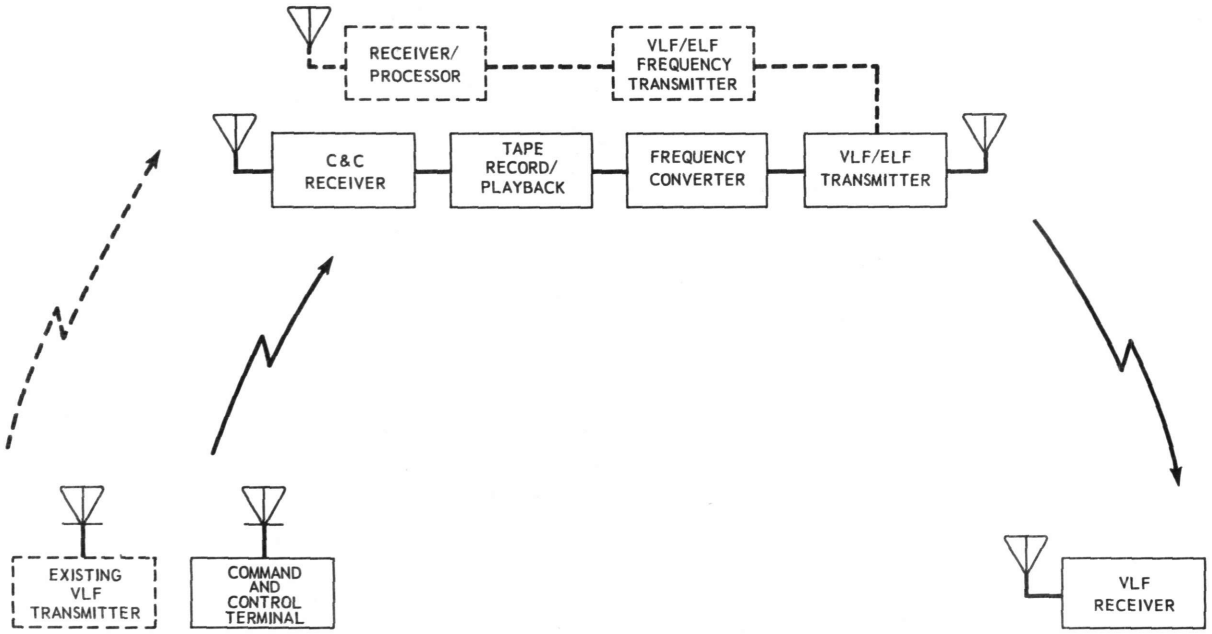
The further capability added by the system of Fig. 3 is the inclusion of a command receiver aboard the satellite. This will provide for a ground controlled

ELF/VLF PROPAGATION AND COMMUNICATION



OPERATIONAL DIAGRAM

OPERATIONAL BLOCK DIAGRAM



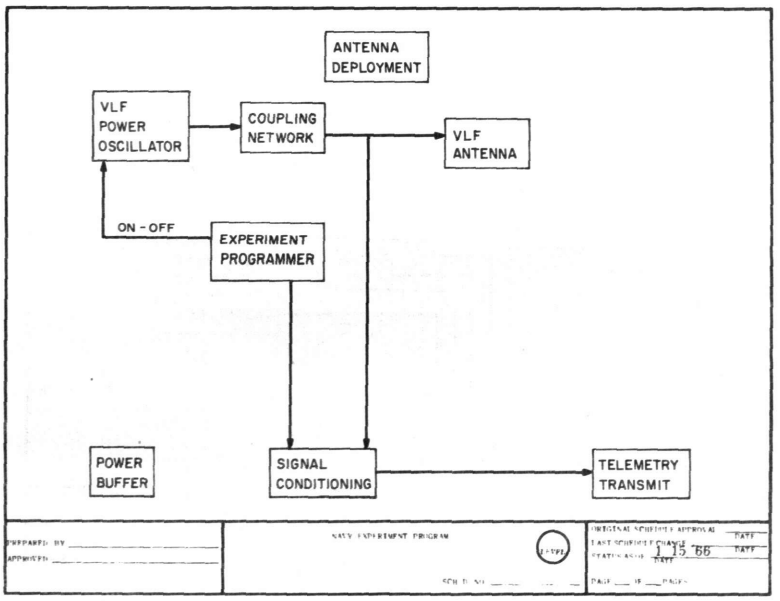


Fig. 1 - Satellite VLF system -- minimal configuration

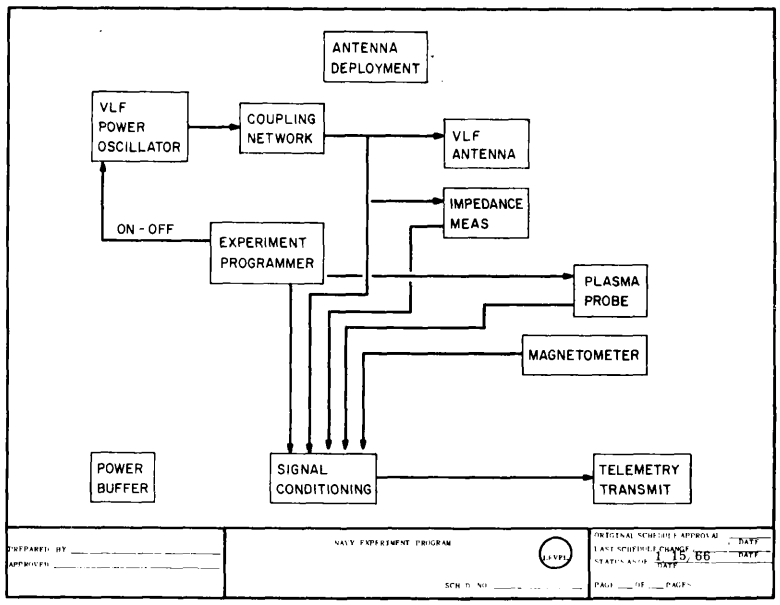


Fig. 2 - Satellite VLF system -- add-on configuration

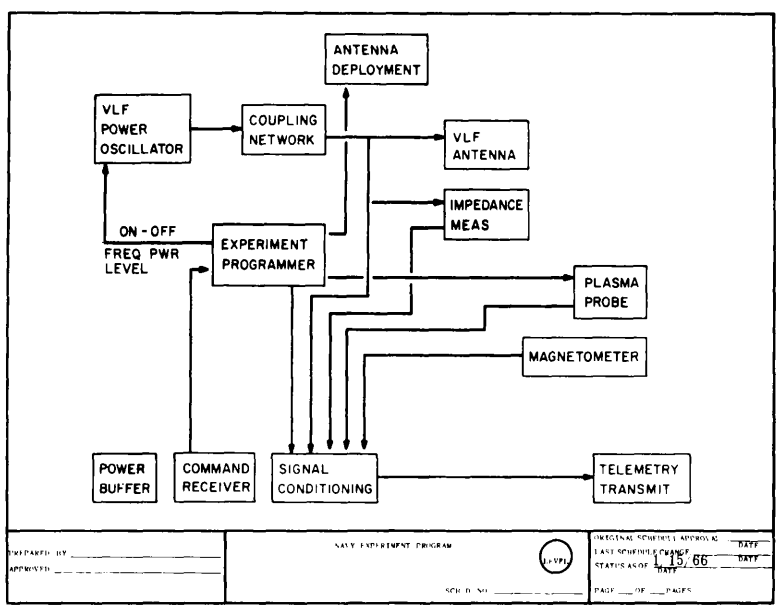


Fig. 3 - Satellite VLF system -- add-on configuration

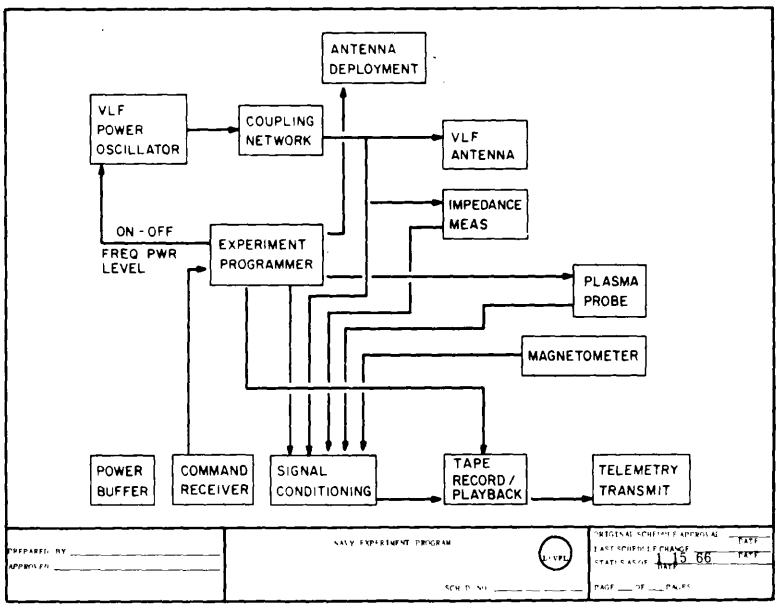


Fig. 4 - Satellite VLF system -- add-on configuration

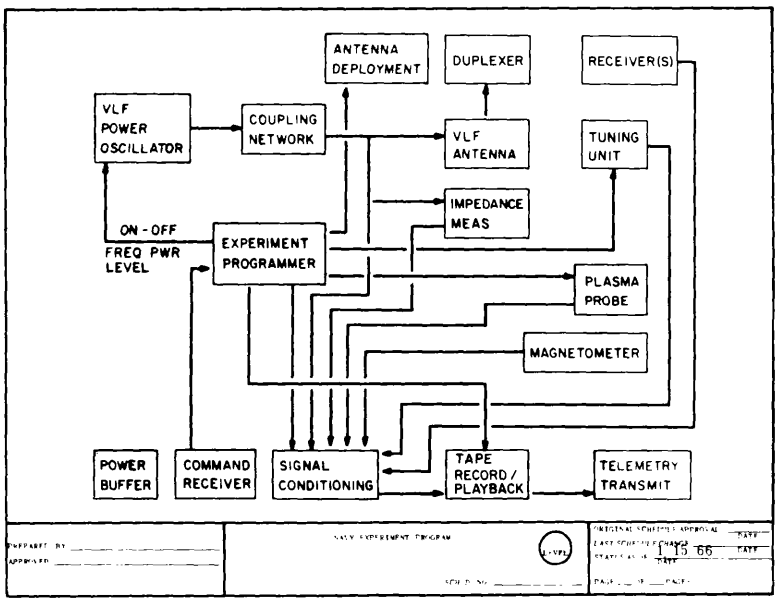


Fig. 5 - Satellite VLF system -- add-on configuration

programming of the VLF transmitting frequency, power level and period of operation and can be used to modify these parameters in accordance with recommendations based on analysis of previously received data. The tape record/playback mechanism, as added in Fig. 4, provides a means for recording the conditions of the transmitter and environment at all points in the orbit and for subsequent telemetry of the stored data when the satellite is within range of a suitable tracking station. The previous system was capable of providing such environmental data only for that period of time for which telemetry capability existed. This record/playback facility will enable the correlation of received signals with the local conditions of the ionosphere at the time the signals were received.

The final block diagram, Fig. 5, depicts the inclusion of a VLF receiving facility on the satellite. This facility adds an ability to examine the VLF signal environment at orbital altitudes. This includes a background noise investigation as well as a capability to measure the received signal strengths of earth-based transmitters. The reciprocal properties of ground-to-satellite propagation paths may be investigated by near simultaneous reception and transmission at the satellite and at a receiving terminal located at a ground-based VLF transmitter. The on-board receiving facility would also be employed to search for the existance of magnetohydrodynamic wave mode which might be excited by the motion of the space craft through the ionosphere or by nonlinear interaction of the VLF transmitted energy with the ionospheric medium.

In summary, it may be stated that demonstration of the feasibility of the proposed technique can be accomplished with relatively simple satellite instrumentation. It would be desirable, however, in an attempt to optimize the ultimate operational capability, to include a degree of sophistication which would enable the measurement of performance as a function of frequency, time, satellite location, and ionospheric condition. The following table provides a summary listing of the operational tasks which a satellite-borne VLF transmission facility might perform and the primary reasoning by which it is felt it could augment the existing VLF Navy Communication System.

OPERATIONAL TASKS

PROBLEM	PROPOSED SYSTEM APPROACH
1. Lack of full worldwide tactical coverage	1. Selection of orbit to provide coverage. Additional satellites reduces waiting time.
2. Improved reliability of coverage	2. Reduction in propagation path ranges (from satellite to submarine) could increase S/N ratio of received signal.
3. Increase in operating depth requirements	3. Combination of 2 (above) and possible use of lower frequency.
4. Long range communication to other satellites	4. Use of intra-ionospheric whistler-mode propagation.

COST, TIME AND PERFORMANCE ENVELOPES:

For the purposes of discussion in this section, the minimal proposed approach as shown in Fig. 1 will be considered as the base line system. The basic cost estimates and milestone/schedule charts presented are applicable to the base line system. It should be emphasized that these estimates consider only that portion of the satellite instrumentation which apply directly to the proposed VLF program effort. The cost and schedule elements which are attributable to the launch vehicle, prime power source, and general satellite "housekeeping" instrumentation are explicitly excluded from these estimates. This approach has been taken to allow the most general development of the VLF transmission program, so that the inherent flexibility may permit adaptation to a wide class of launch vehicles. Power, weight and size requirements of the various system configurations can be qualitatively obtained from the parametric trade-offs which are presented.

The basic milestone/schedule chart for the minimal program approach is given in Fig. 6. As is shown in the schedule the end items of the program are a primary flight-qualified satellite VLF transmitting system and a prototype which after the necessary qualification testing has been refurbished to provide a back-up system.

Cost estimates for the base-line effort are shown in Fig. 7. These estimates reflect the costs associated with the engineering design and acquisition of the flight equipment, the integration and test of the equipment with the space craft, the acquisition of specialized ground instrumentation, and the costs associated with data collection, reduction and analysis. A cumulative funding chart is shown in Fig. 8. Estimates of inhouse manpower requirements are shown in Fig. 9.

The qualitative curves shown in Fig. 10 are representative trade-off behavior of several of the significant parameters associated with the proposed program. In each case a triangle is used to identify the base-line system level and the comparative cost of added performance can be determined.

In the frequency vs. weight trade-off shown in Fig. 10a, the rapid increase in weight associated with progressively lower frequencies is caused by the increase in antenna size and antenna matching network weight incurred at the ELF end of the spectrum. In Fig. 10b, the weight penalty for increasing system complexity, i.e., system performance capability, is shown. Weight increases result directly from the inclusion of the additional functional black boxes as outlined in

Figures 1 through 5. Careful management of the power-time usage plan can minimize the impact of these additional functions on the vehicle prime power source. Figure 10c and 10d illustrate the expected cost and delivery time dependance for inclusion of the increased performance functions of the more complex instrumentation.

The preliminary estimates of weight, size, and power requirements for the base-line system are shown in Fig. 11. These estimates are based on state-of-the-art components and techniques which have previously been used in a spacecraft or which are planned for near future application.

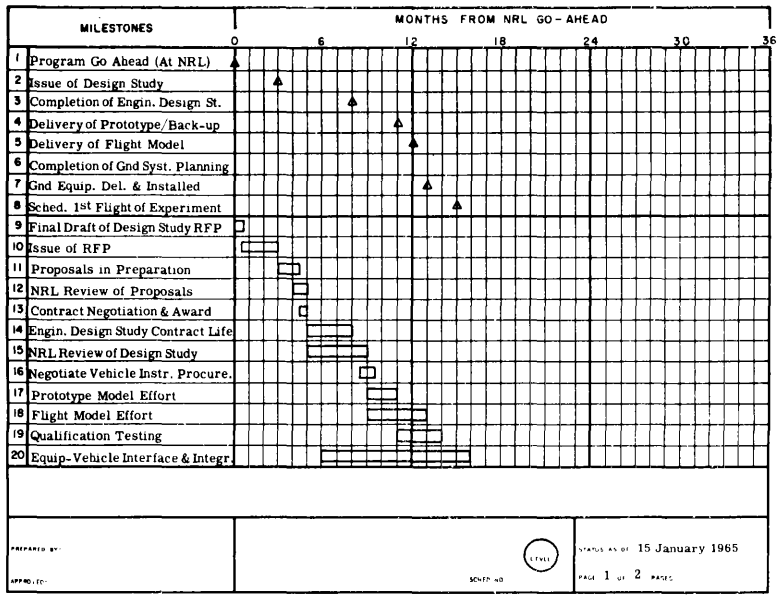


Figure 6a

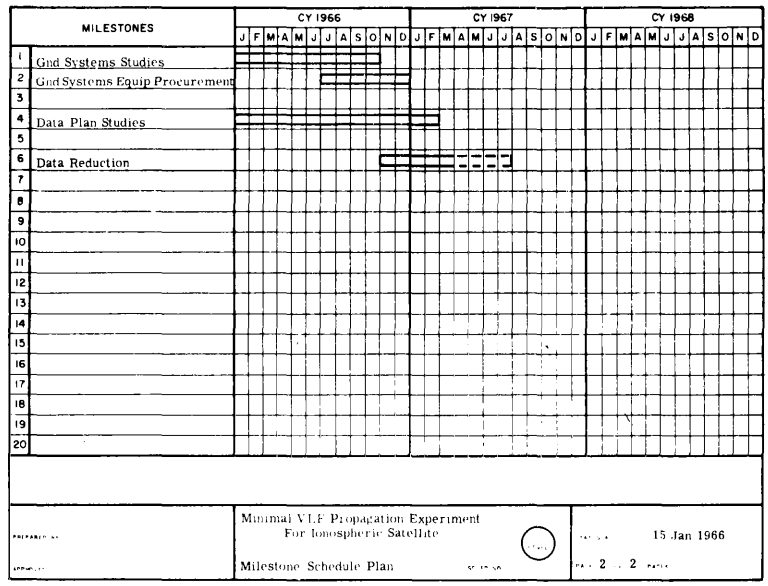


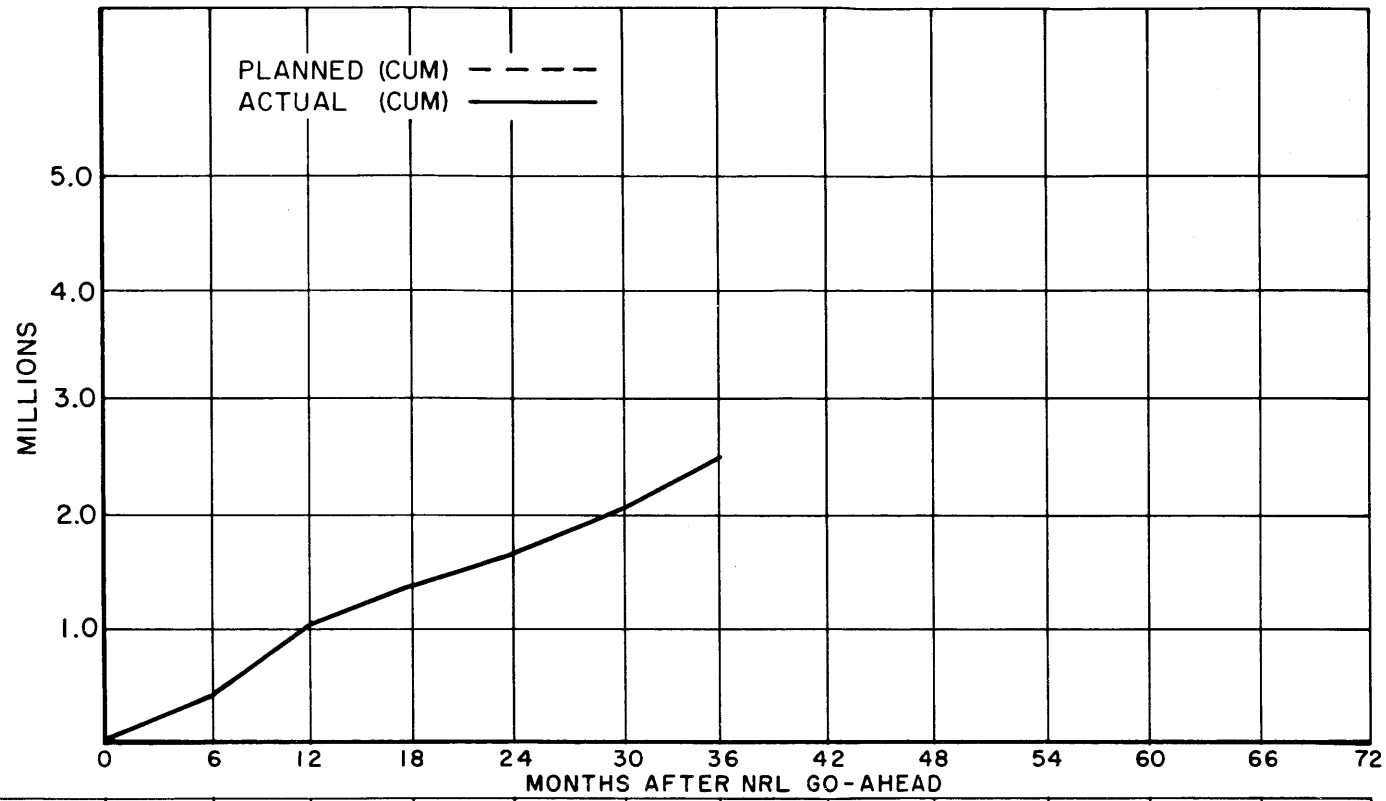
Figure 6b

PRELIMINARY FUNDING PLAN

3 month intervals	Cost Item	Cost	Inhouse Manpower	Period Cost Total
1	Design Study	$200 K	$ 60 K	$260 K
2			$ 60 K	$ 60 K
3	Procurement of prototype and flight equip. (1st pay)	$125 K	$ 80 K	$335 K
	Ground Systems Proc.	$100 K		
	Pre-launch checkout rack	$ 30 K		
4	Procurement of prototype and flight equip. (compl.)	$125 K	$ 80 K	$380 K
	Ground Systems Proc.	$100 K		
	Qualification Testing	$ 25 K		
	Data Analysis	$ 50 K		
5	Qualification Testing	$ 25 K	$100 K*	$175 K
	Data Analysis	$ 50 K		
6	Data collection, reduction, analysis, interpretation and reporting	$ 50 K	$ 80 K*	$130 K
7		$100 K	$ 80 K*	$180 K
8		$100 K	$ 80 K*	$180 K
9		$100 K	$ 80 K*	$180 K
10		$100 K	$ 80 K*	$180 K
11		$100 K	$ 80 K*	$180 K
12		$100 K	$ 80 K*	$180 K
			TOTAL	$2.420 M

* Indicates cost of field personnel included.

Fig. 7 - Reduced scope experiment (VLF propagation)



PLANNED	.320	1.035	1.340	1.700	2.060	2.420						
ACTUAL												

Minimal VLF Propagation Experiment
For Ionospheric Satellite

Milestone/Schedule Plan

SCHED NO.

LEVEL

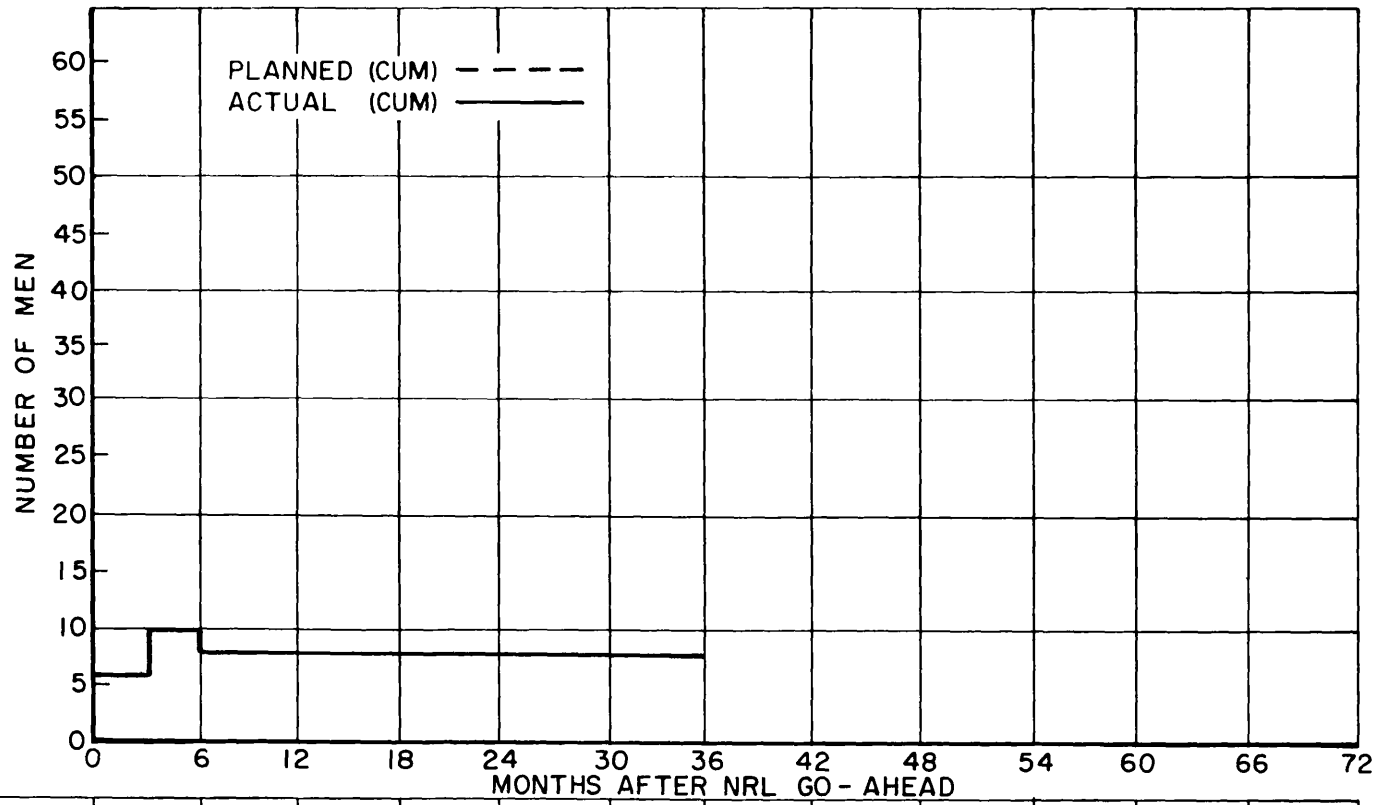
ORIGINAL SCHEDULE APPROVAL

LAST SCHEDULE CHANGE

STATUS AS OF 15 Jan 1966

PAGE OF PAGES

Figure 8



PLANNED	8	8	8	8	8	8						
ACTUAL												

Minimal VLF Propagation Experiment
For Ionospheric Satellite

Preliminary Manpower Plan SCHED NO.

LEVEL

ORIGINAL SCHEDULE APPROVAL
LAST SCHEDULE CHANGE
STATUS AS OF 15 Jan 1966
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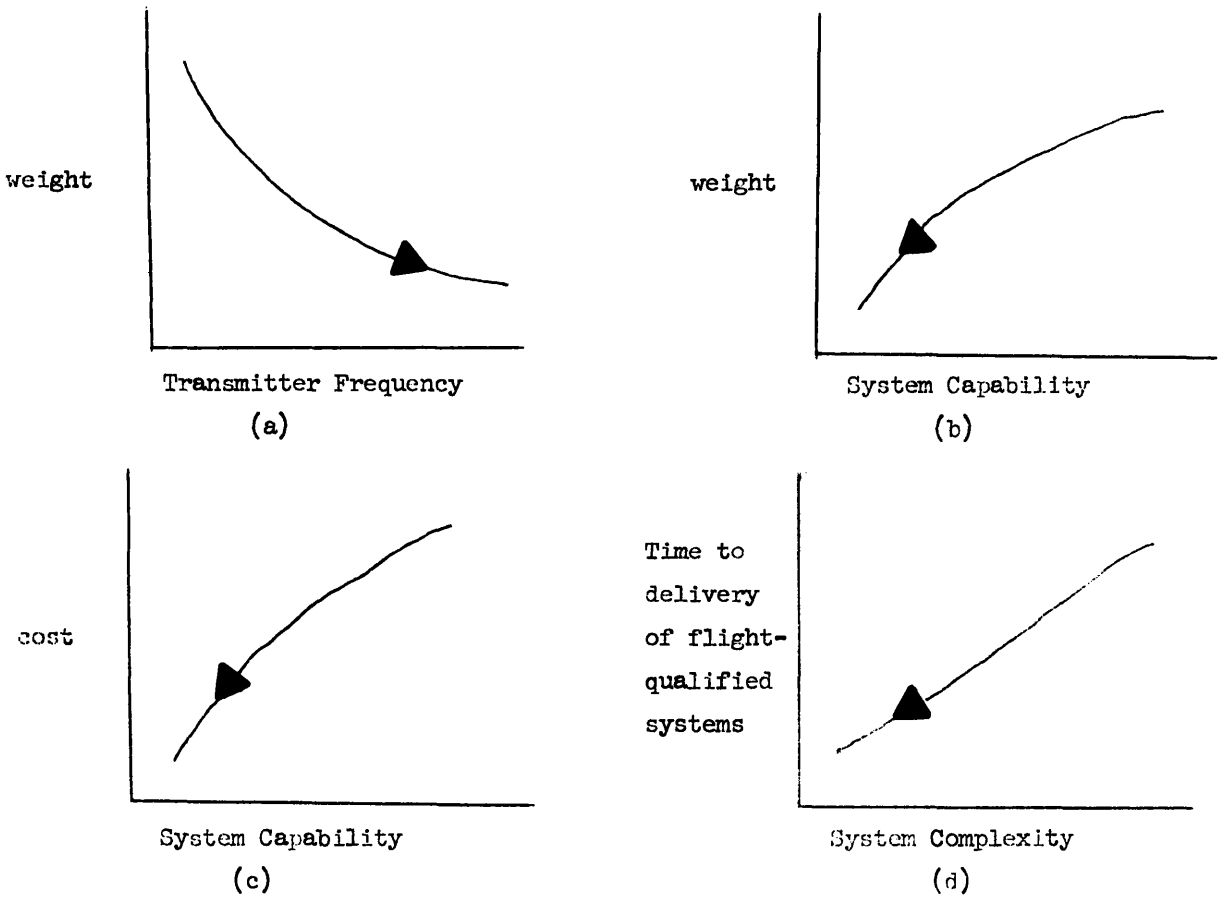

▲ Indicates status of Base-Line System

Fig. 10 - Qualitative trade-offs of base-line approach against alternatives

Item	Weight	Volume	Power
Internal Package	115 lbs.	12x12x21 (3024 cu. in.)	1 Kw (Pk) 100 W avg. operating
Antennas	10 lbs.	3x12x12 (432 cu. in.)	- - -

Fig. 11 - Base-line configuration

DEGREE OF RISK:

The elements of the proposed system approach have been examined for the purpose of identifying those components and/or techniques which exhibit an element of risk associated with the successful conduct of the program.

In examining the building block components of the satellite VLF transmitting baseline configuration, several questionable areas of operation are apparent. One of these is the matching network which delivers the transmitter power to the antenna. Since the properties of this network are dependent upon the impedance of the antenna, it is important that the properties of an antenna in the ionospheric plasma be known. The results obtained from the LOFTI I program, among others, have provided some quantitative results, but it is not known definitely that a transmitting antenna will exhibit the same properties. There is, for instance, considerable uncertainty about the effect of the relatively high VLF field intensity in the vicinity of the antenna on the surrounding ion sheath and the undisturbed plasma. The effects of such sheath and plasma disturbances on the antenna impedance is currently unknown. Theoretical approaches to the problems of antenna radiation in a plasma have been pursued, but none, sofar as is known, have considered the presence of the ion sheath or the disturbing influence of the electric field intensities generated. The final determination of the applicability of the theory and receiving antenna results must await the conduct of a VLF ionospheric transmission program.

Other components to be employed in the system are essentially off-the-shelf items. Transmitters and antennas suitable for use in space craft are available, and the additional components or sub-systems which might be added for the more complex program which have been described are all within the state-of-the-art.

The proposed program has been devised to enhance the visibility of a number of decision end-points. These include a flexible approach to systems complexity, which broadens the range of suitable launch vehicles which can be employed. Similarly, the successively more comprehensive program options permit the conduct of a basic program with the configuration of subsequent systems determined in part by previous results. The proposed system can provide an early answer to the operational capability of the concept and provide timely guidance in the determination of future effort to improve the VLF/ELF communication structure.

COMPATIBILITY:

The proposed satellite VLF transmission program imposes no unique compatibility requirements on the parent satellite or on other systems carried aboard. The ever-attendant problems of mechanical and electrical interfaces between all affected subsystems do not appear severe.

The mechanical interfaces of primary interest are the mating of the transmitting antenna with the exterior of the space craft and the availability of adequate size and weight allocations. Physical location and distribution of the internal electronics package is flexible, in keeping with overall aim of the system.

Electrical interfaces with the vehicle prime power source are not expected to create any problems, provided only that the 100 W average power level can be served while the transmissions take place. Interfacing with telemetry and programmer subsystems should not pose any problems.

It would be desirable to utilize data available from other on-board systems charged with housekeeping functions. Spacecraft attitude, power systems checks and other ancillary data which may be available may prove extremely useful in analysis and interpretation of data collected from the satellite VLF transmission program.

Electromagnetic interferences can be minimized through a thorough ground check-out of spurious radiations and by a careful selection of frequencies which may be used. This requires that the possible effects of all on-board systems be considered in the selection of the final design parameters. The effects that the VLF transmission equipment may have on other satellite systems must similarly be considered.

No consideration is currently being given to use of specific techniques to reduce the vulnerability of the proposed system to intelligent application of ECM, nor to any ECCM which might be used. In fact, it is considered that the vulnerability to such interference be tested during the active life of the satellite VLF programmed orbit time. Data obtained in this manner can be applied to optimize the invulnerability of the ultimate operational system.

The satellite VLF system is expected to be fully compatible with existing ground receiving facilities. No unique modulation or signal processing facility

would be required at the normal receiving sites, although special-purpose, mobile, receiving installations would be assembled and manned, as necessary, in support of the proposed program.

SPECIAL MANPOWER REQUIREMENTS:

The proposed base-line configuration is expected to be operable in conjunction with regular Navy VLF Communications System operations, but to have a minimum impact on such operations. The satellite transmission programming would be scheduled in a manner which would not affect the current usage of the VLF system. Existing ship and shore receiving facilities would be requested to monitor the satellite transmission frequency at selected times on a not-to-interfere basis with their regular duties.

Personnel training requirements would consist of a simple statement of transmission frequency(s), monitor times, and a statement of the modulation characteristics of the transmissions.

C. J. KURNER
NRL, Code 5112

APPENDIX I

VLF PROGRAM AS RELATED TO BROADER SCOPE OF OVERALL PROPOSED TECHNICAL APPROACH

The material presented in the accompanying report has been prepared to assist the Bureau of Naval Weapons (Code RTOS-3) in their preparation of a Proposed Technical Approach (PTA) document. The VLF program proposal outlined herein constitutes only part of the overall program to be presented by the PTA document.

It is the intent of this Appendix to underscore the commonality of approach and the compatibility of equipment consideration for the VLF system and for the HF communications system (described in a separate report) which will also be presented in the PTA.

Although the programs have evolved essentially independently, they each address themselves to the same primary objective; that of providing a reliable communications circuit between a command and control terminal and the tactical naval forces deployed throughout the oceans of the world.

The use of the VLF system for transmission of traffic to submerged submarines with subsequent relay of the reply via the HF circuit illustrates the complementary nature of the proposed approaches. The reductions of path lengths which can be effected through the use of a satellite terminal gives promise of increased communication reliability and with careful transmitted power management, particularly for the HF links, may provide additional communication security through reduced probability of signal interception.

Since it is intended that the two proposed approaches be integrated for use on a single satellite vehicle, it is important that the systems maximize the common usage of on-board equipment. Comparison of the two approaches reveals that power, telemetry and "housekeeping" data requirements are similar. Thus much of the on-board equipment serves both systems and eliminates the need for duplication of similar devices. It appears that the satellite operations of the systems can readily be time-shared, thus insuring that data for all temporal and spatial conditions will be available

for both approaches. Since it is not planned to operate the VLF and HF systems simultaneously, the electrical interface problem should be minimized as will be the effects of electromagnetic interference of one system on the other.

Mechanical interfacing will consist primarily of allocating space on the vehicle structure for the antenna assemblies for the two systems. Since both are reasonably large in the deployed position (though compactly packaged prior to attaining orbit), thorough study will be needed to allow unobstructed deployment sequences to be initiated when the on-orbit operating conditions are achieved. State-of-the-art techniques appear capable of providing the antenna configuration planned for the program.

Ground systems integration of the two approaches poses no problem in equipment, and manning requirements for monitoring of the two systems performance are such that with suitable training both approaches can be served by the same personnel.

Thus it is seen that the two proposed systems provide complementary approaches to a common operational objective; can employ a considerable fraction of equipment in common; have a minimum interface impact on each other and can be operated with common support, both in terms of satellite data management and in terms of ground station monitoring operations.

APPENDIX II

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	MILESTONES
1	Program Go-Ahead at NRL
2	Eng. Design Study RFP Released to Industry
3	Proposals Received
4	Eng. Design Study Contract Effort Begins
5	Design Study Completed
6	Vehicle Equipment Procurement Negotiations Completed
7	Prototype Model Delivery to NRL
8	Flight-Qualified Model Delivered for Integration
9	Refurbished Prototype Delivered as back-up
10	Ground System Planning Complete
11	Ground Equipment Delivered and Installed
12	Vehicle Launch Date
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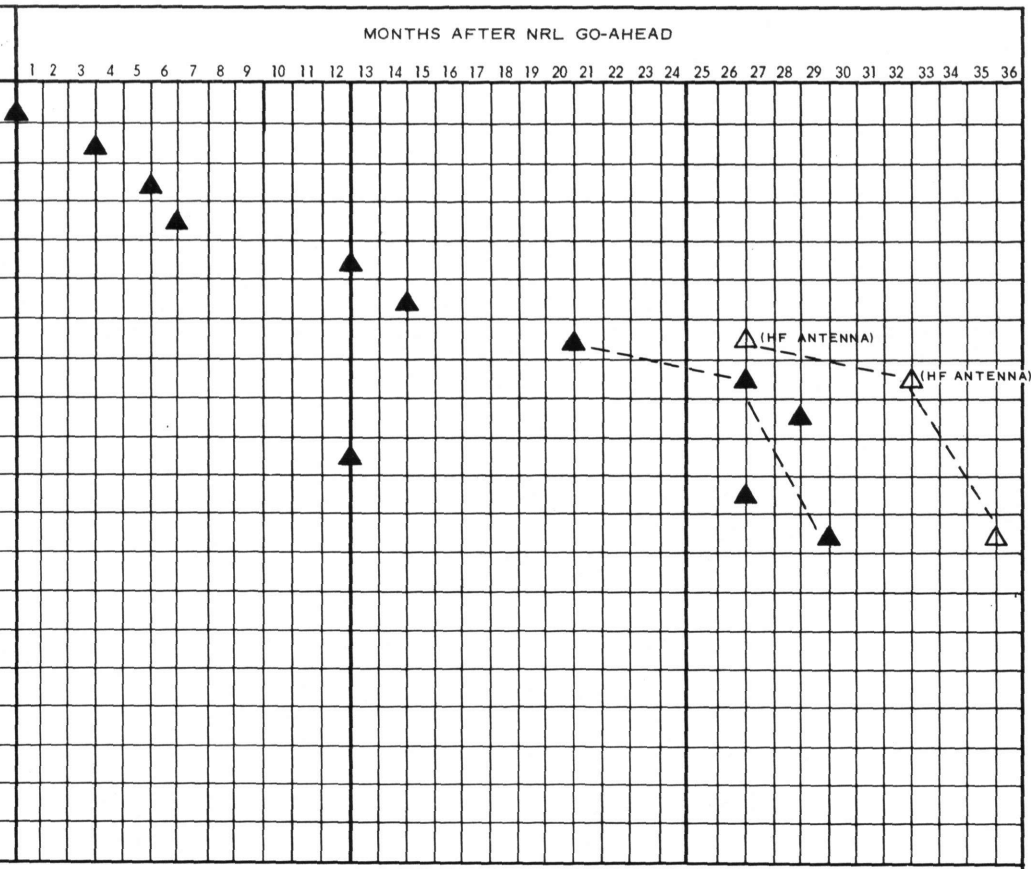

NOTE: HF antenna development and fabrication may be limiting factor in delivery time.

PREPARED BY:

APPROVED:

CONSOLIDATED VLF-HF SPACE-GROUND COMMUNICATION PROGRAM

MAJOR MILESTONE CHART