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NASA GSFC OPERATIONS PLAN 21-67
WEAPONS RESEARCH ESTABLISHMENT SATELLITE
WRESAT

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NOVEMBER 1967

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

This copy of the Goddard Space Flight Center's Operations Plan for the tracking of WRESAT was preserved by Geoff Ruck at Cooby Creek Tracking Station, Queensland.

With thanks to Mrs. Margaret Ruck.

Scanned, and PDF file assembled, by Colin Mackellar for www.honeysucklecreek.net, October 2021.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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NASA - GSFC
OPPLAN 21-67

WEAPONS RESEARCH ESTABLISHMENT SATELLITE
WRESAT

The purpose of this operations plan is to provide information for the activities concerned and guide the conduct of the WRESAT mission. Amendments and revisions will be issued, as necessary, to the concerned individuals.

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NASA-GSFC

OPPLAN 21-67

WEAPONS RESEARCH ESTABLISHMENT SATELLITE

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TABLE OF CONTENTS

SECTION 1
MISSION

SECTION 2
RESPONSIBILITIES

SECTION 3
ORGANIZATION

TABLE OF CONTENTS (Cont)

SECTION 4

PROJECT IMPLEMENTATION

SECTION 5

OPERATIONS AND CONTROL

TABLE OF CONTENTS (Cont)

SECTION 6

FIELD STATION OPERATIONS

SECTION 7

EXTERNAL AGENCY SUPPORT

SECTION 8

COMPUTING CENTER OPERATIONS

TABLE OF CONTENTS (Cont)

SECTION 9

DATA PROCESSING

SECTION 10

NASA-GSFC COMMUNICATIONS CENTER OPERATIONS

APPENDICES

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

MISSION

SECTION 1
MISSION

1.1 INTRODUCTION

The Weapons Research Establishment Satellite (WRESAT) will be the first spacecraft to be launched by Australia. The Weapons Research Establishment has been studying the climate and the climatic phenomena of the atmosphere between 30 and 100 kilometers to produce models of the fundamental atmospheric parameters of pressure, temperature density, and wind. The WRESAT experiment will provide information on the solar activity and the solar radiation flux in wavelengths which have a direct influence on the temperature between this altitude range, and will aid in the determination of the composition above 100 kilometers.

1.2 PROJECT OBJECTIVES

The objectives of the WRESAT project are to:

- Supplement and extend the range of scientific data in the field of X-ray and ultraviolet measurements being obtained from existing research programs.
- Demonstrate the capability of the WRE to develop and launch a spacecraft using existing launch facilities.
- Develop techniques relevant to spacecraft launching activities for application to present and future scientific research programs.

1.3 SCIENTIFIC OBJECTIVES

The scientific objectives of WRESAT project are to:

- Measure solar flux in the ultraviolet region between 1050 and 1660 angstrom (A).
- Measure the solar flux at 2500 A, a wavelength absorbed by ozone.
- Determine the albedo of the earth between 1050 and 1340A, and the distribution of geocoronal hydrogen.
- Determine the solar flux at 8A.

SECTION 2
RESPONSIBILITIES

SECTION 2

RESPONSIBILITIES

2.1 INTRODUCTION

The WRESAT project is a cooperative effort between Australia, the United States, and the United Kingdom. The Australian Weapons Research Establishment (WRE) has the responsibility for overall project management. The Advanced Research Projects Agency (ARPA), of the United States Department of Defense is responsible for the provision of the SPARTA launch vehicle, launch vehicle support equipment and launch operations personnel. The NASA-GSFC will be responsible for the overall United States tracking and data acquisition support and will give advice and consultation on the design and testing of the spacecraft. The Ministry of Technology manages the coordination of the support provided by the United Kingdom with the Australian Weapons Research Establishment. The major areas of responsibility are outlined in the following paragraphs.

2.2 LAUNCH VEHICLE

The United States Army Missile Command (AMICOM) is responsible for providing contractural and technical direction to Thompson Ramo Wooldridge, Incorporated, the prime contractor in the provision and launch of the launch vehicle system. Necessary launch vehicle modifications will be performed by TRW and are the technical and financial responsibility of Australia.

2.3 SPACECRAFT

The Australian Weapons Research Establishment is responsible for the design, fabrication, integration and testing of the spacecraft system. The NASA is responsible for providing spacecraft design and testing, advice and consultation.

2.4 TRACKING AND DATA ACQUISITION

Orbital tracking and telemetry data acquisition will be the responsibility of GSFC, and will be accomplished by the Space Tracking and Data Acquisition Network (STADAN).

2.5 ORBITAL COMPUTATIONS

The GSFC Mission and Trajectory Analysis Division will be responsible for all orbital computations.

2.6 DATA PROCESSING

The GSFC Information Processing Division will be responsible for periodically examining representative samples of recorded magnetic tapes from each participating STADAN stations to insure that the quality of the recorded data is in accordance with project requirements and STADAN capability. This will be accomplished prior to the tapes being shipped to WRE for final processing and analysis.

2.7 DATA REDUCTION, ANALYSIS AND PUBLICATION

The WRE will be responsible for all processing analysis and publication of the final results.

SECTION 3
ORGANIZATION

SECTION 3
ORGANIZATION

3.1 INTRODUCTION

The previous sections described the project objectives and the major areas of responsibility. This section outlines the responsibilities of the personnel directly concerned with those areas.

3.2 WRESAT MANAGER

Mr. D. Barnsley is the Principal Officer responsible to the Director of WRE for the coordination and progress of all aspects of the project.

3.3 PRINCIPAL OFFICER FLIGHT PROJECTS GROUP

Mr. B. Rofe, a member of the WRE Flight Projects Group is responsible for all scientific and technical aspects of the project.

3.4 PROJECT SCIENTIST

Professor J. Carver, a member of the University of Adelaide Physics Department, is responsible for the provision of experimental equipment to the Flight Projects Group for installation into the WRESAT spacecraft.

3.5 LAUNCH VEHICLE MANAGER

Mr. L. Johnson of the United States Army Ballistic Missile Command is responsible for the provision of the launch vehicle and associated guidance to place the spacecraft in orbit.

3.6 PROJECT OFFICER

Mr. M. H. Babcock, is the TRW Project Officer to the WRESAT project and is responsible, through the United States Army Missile Command to the Advanced Research Projects Agency, for the provision and checkout of the launch vehicle and for launch support and management.

3.7 LIAISON OFFICER AT WRE

Mr. J. South, the GSFC representative in Australia, will serve as a point of contact in arrangements at WRE.

3.8 WRESAT PROJECT MANAGER AT GSFC

Mr. G. W. Ousley of the GSFC Technology Directorate, is responsible for the organization of scientific and technical assistance given to WRE by NASA and ensuring that the WRE requirements are met.

3.9 TRACKING AND DATA SYSTEMS MANAGER

The Tracking and Data Systems Manager (T&DSM), Mr. R. Sanford, is a member of the project staff representing the T&DS Directorate. He manages the ground support effort to ensure that the ground tracking and data acquisition system meets mission requirements, and is responsible for overall utilization of all T&DS facilities.

3.10 TRACKING AND TELEMETRY ENGINEER

The Tracking and Telemetry Engineer (TATE), Mr. J. Martin of the STADAN Engineering Division, coordinates the engineering and integration of the ground equipment. He establishes necessary tests, exercises and procedures to ensure an operational ground system.

3.11 ORBITAL COMPUTATIONS ENGINEER

The Orbital Computations Engineer (OCE), Mr. L. H. Anderson of the Mission and Trajectory Analysis Division is responsible for all orbital computation activities.

SECTION 4
PROJECT IMPLEMENTATION

SECTION 4

PROJECT IMPLEMENTATION

4.1 LAUNCH VEHICLE

A refurbished Redstone missile, modified to accept two solid-propellant upper stages will be used to launch the WRESAT spacecraft. The 3-stage launch vehicle, shown in Figure 4-1, has an overall length of approximately 72 feet and a maximum body diameter of 6 feet. The vehicle produces a lift-off thrust of 78,000 pounds.

4.2 LAUNCH TRAJECTORY

The spacecraft will be launched in a northerly direction from Launching Area No. 8 at Woomera, Australia. The nominal sequence of flight events is presented in Table 4-1. After 1st-stage burn-out, the 2nd and 3rd stage/spacecraft will be separated and allowed to coast to a height of approximately 100 nautical miles. During this coast phase, the 2nd-stage inertial guidance system will pitch the vehicle axis into a horizontal position. Before 2nd-stage ignition, the vehicle is spun by spin rockets to a maximum roll rate of 2.5 to 3 rps. After burn-out, the 2nd stage is separated and the 3rd stage is ignited inserting the spacecraft into orbit at a altitude of 100 nautical miles, a latitude of 30° south and an azimuth angle of approximately 6° east of north.

4.3 ORBIT

The 3rd stage/spacecraft combination will go into a polar elliptical orbit. The subsatellite plot for the WRESAT is shown in Figure 4-2. The following are the nominal orbital elements:

- Perigee — 99.37 nautical miles
- Apogee — 714.7 nautical miles
- Period — 99.54 minutes
- Inclination — 84 ~~74.8~~ degrees
- Eccentricity — .7489
- Scientific lifetime — 14 days, approximately

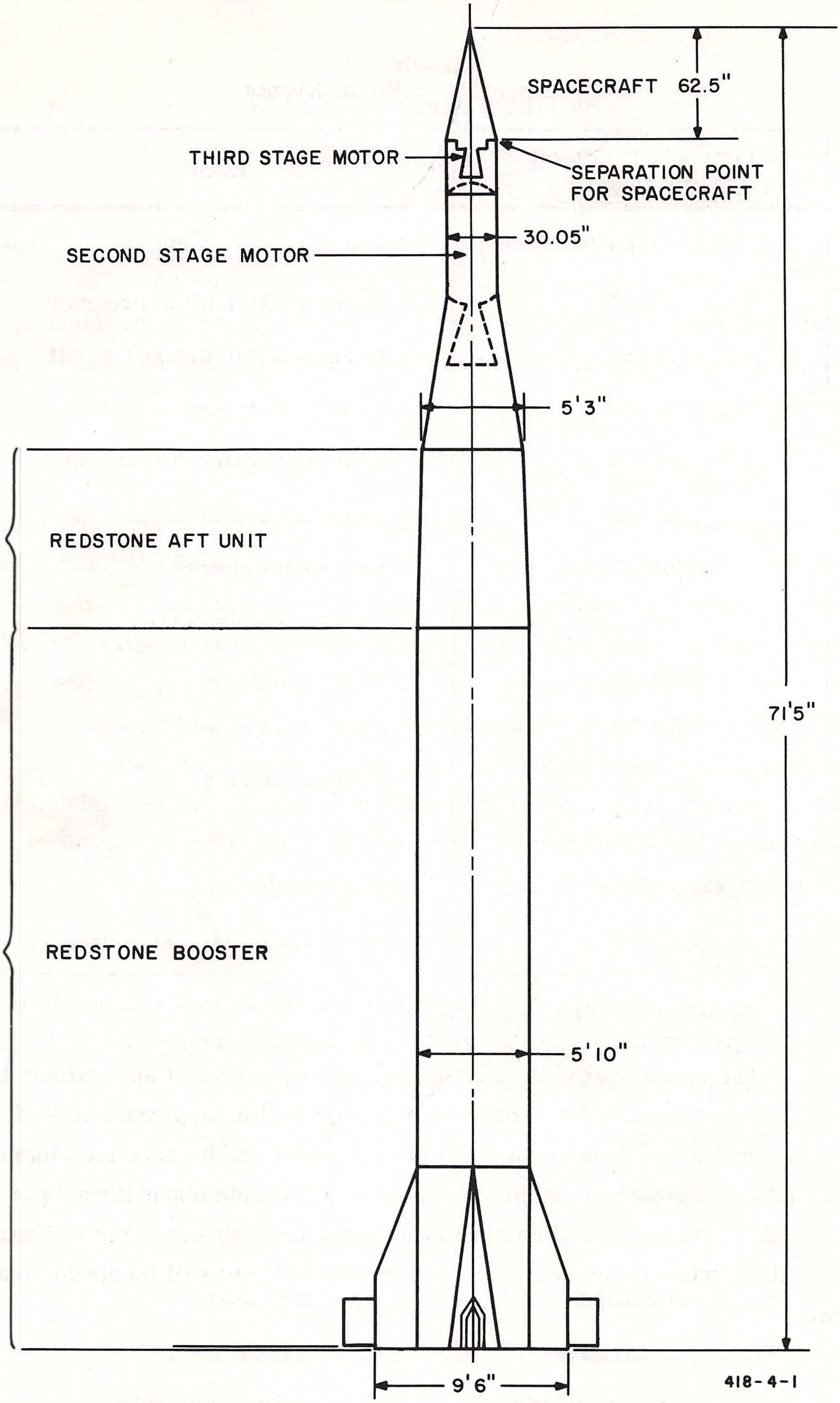


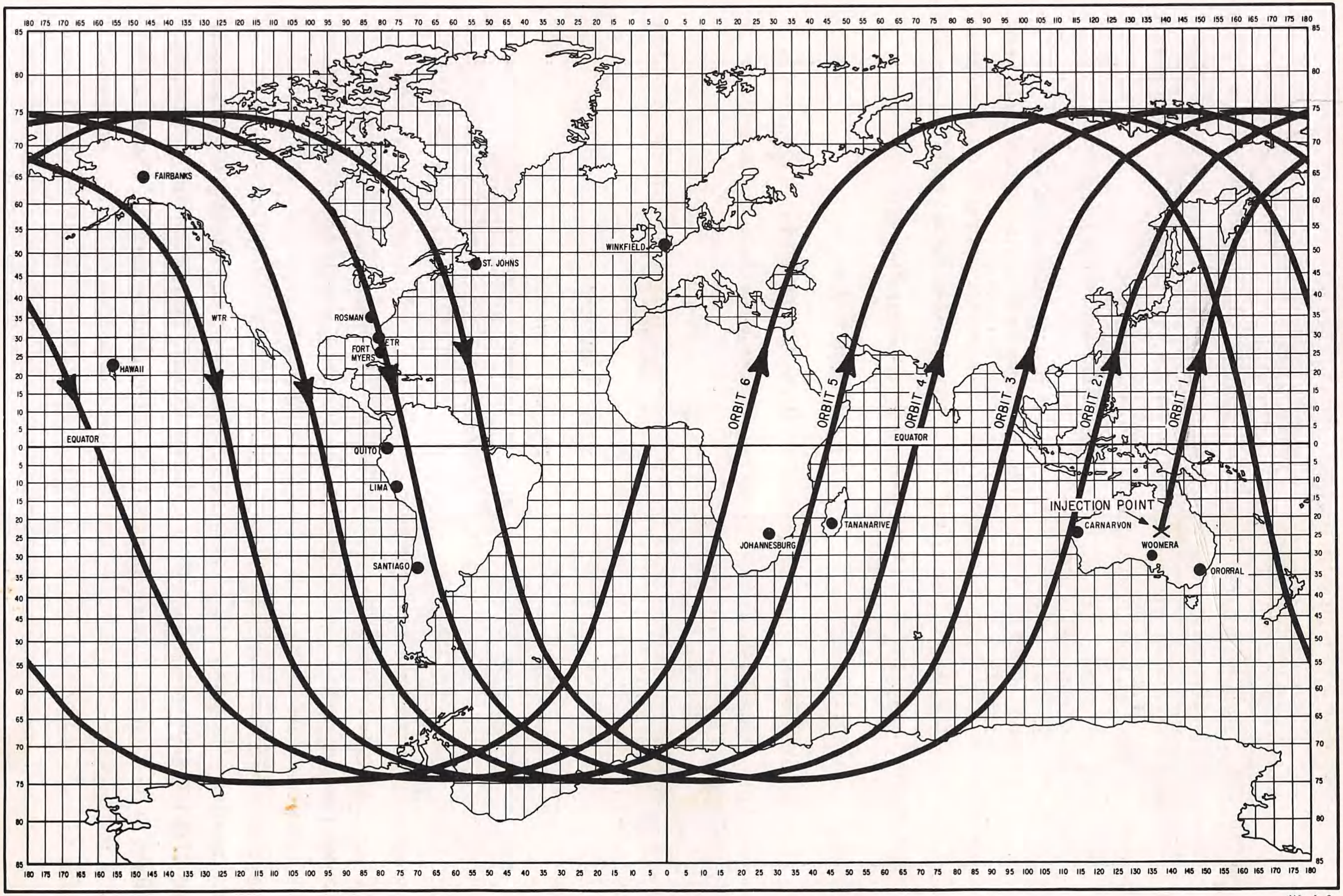
Figure 4-1. Launch Vehicle

Table 4-1
Sequence of Flight Events

Time After Lift-off (seconds)	Event
0.00	Lift-off
15.00	Begin booster pitch program
123.58	Begin booster thrust tail-off
123.98	Booster burn-out
139.00	Jettison booster thrust unit
290.91	Jettison booster aft unit
291.01	Ignite spin motors
292.91	Jettison spin motors
294.94	Stage 2 ignition
327.74	Stage 2 burn-out
327.77	Jettison stage 2
327.91	Stage 3 ignition
336.61	Stage 3 burn-out
337.23	Release experiment covers

4.4 ATTITUDE AND DYNAMICS

The spacecraft will enter orbit with a spin rate of approximately 2.5 rps about the cone axis. The attitude of this axis will be approximately 30 degrees to the rotational axis of the earth. Due to structural and balance misalignments, the spin axis will eventually nutate and assume a flat spin about the axis of maximum inertia. This axis will be normal to the spacecraft cone axis and parallel to the original spin axis at injection. The rotational rate will be approximately 30 rpm.



418-4-2

Figure 4-2. WRESAT Subsatellite Plot

4.5 SPACECRAFT DESCRIPTION

The WRESAT spacecraft, shown in Figure 4-3, consists of various spacecraft systems and seven experiments. The conical shaped spacecraft, weighing approximately 110 pounds, has a base diameter of 2.5 feet and a height of 5 feet. The 3rd-stage motor will not be jettisoned after burn-out. The total weight of the orbiting body will be approximately 160 pounds.

4.5.1 C-BAND TRANSPONDER

A Motorola SST-131 C-band transponder is installed in the spacecraft for range safety and trajectory tracking. The transponder operates on a frequency of 5850 MHz with a power output of 400 watts. Three circularly polarized antennas are mounted flush with the skin at the base of the spacecraft.

4.5.2 POWER

Batteries are used for the power source. There are no solar cells or battery charging circuitry. The capacity of these batteries are adequate to operate the spacecraft for 10 to 14 days.

A separate battery pack is used for the C-band transponder which has an expected lifetime of approximately one hour.

4.5.3 ANTENNA SYSTEM

The WRESAT spacecraft has four quarter-wave monopole antennas mounted in a turnstile configuration. Matching is accomplished by means of a parallel stub near the base of each monopole. Phasing lines are such that the antennas are fed in equal amplitude phase-quadrature. Antenna gain is +1db, including losses in the phasing network. Nulls in the radiation pattern are not expected to exceed 6 db; nulls due to cross-polarization may approach 25 db.

4.5.4 TELEMETRY SYSTEM

The WRESAT spacecraft employs a PAM/PFM/PM telemetry system to monitor the performance of the spacecraft. Thermistors and bridge circuits are used to develop the voltage signals from the various sensors. The data are time-division-multiplexed at a rate of 256 samples per second. The spacecraft transmits continuously at a frequency of 136.35 MHz with a radiated power output of 125 milliwatts. The telemetry signal will also be used as a tracking beacon.

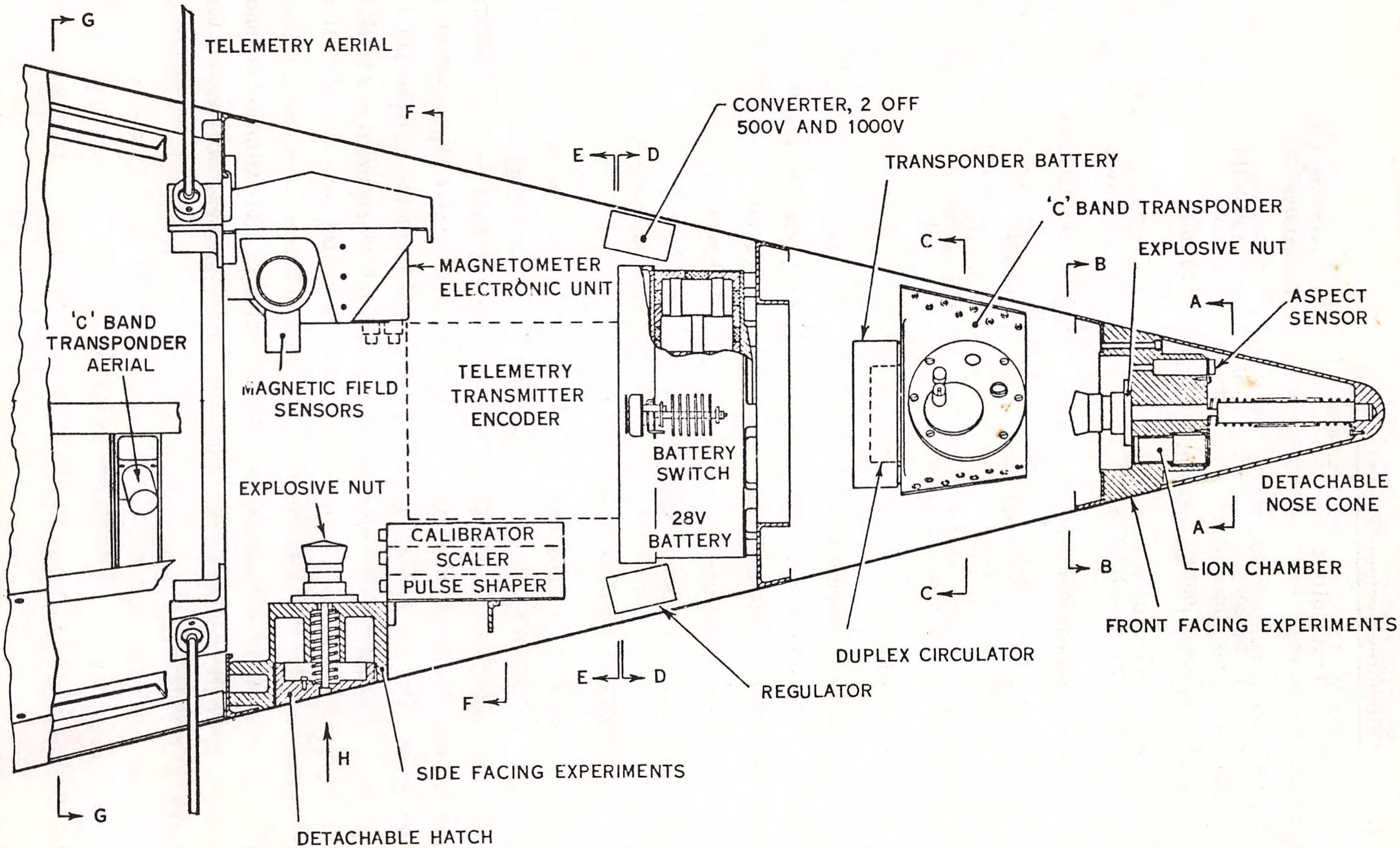


Figure 4-3. WRESAT Spacecraft

4.5.4.1 Telemetry System Characteristics

- Transmitter . . . . 1 (operating continuously)
- Frequency . . . . 136.350 MHz
- Power output . . . . 125 mw
- Modulation index . . . . $\pm$ 1 radian (approx square wave)
- Subcarrier
  - Center frequency . . . . . 10 kHz
  - Deviation . . . . $\pm$ 5 kHz
  - Synchronization . . . . . 4.5 kHz
- PFM data
  - Synchronization . . . . . 4.5 kHz
  - Rate . . . . 256 samples/sec
  - Rate stability . . . . . . 1 percent
  - Duty cycle . . . . 100 percent
  - Channel time . . . . 3 ms
  - Frame time . . . . 65 ms, approximately
  - Sequence time . . . . . . 500 ms

4.5.4.2 Telemetry Format

The WRESAT telemetry format is shown in Figure 4-3. The data are identified by channel and frame numbers. The four successive sync channels are identified as frame 1 of channel 1, frame 1 of channel 2, frame 1 of channel 3 and frame 1 of channel 4. These four sync channels have been included to permit the STADAN stations to evaluate the data using PFM equipment such as the PFM pre-pass simulator. Four channels were used to allow sufficient time for the filters (which were chosen for GSFC PFM formats) to respond. The calibrate channels, frame 2, 3, and 4 of channel 1 and frame 2 of channel 2, etc., will be used for data reduction in Australia.

4.5.5 ATTITUDE SENSORS AND CONTROL

During the day, solar aspect sensors and three magnetometers are used to determine the aspect of the spacecraft. The solar aspect sensors rely on the response of a photo diode to light reflected from a flat teflon surface, and a nipple of teflon. At night, the aspect will be determined only by the magnetometers.

It is mandatory that sensor orientation (the sensors have a 80-degree total angle of view) and final plane of spacecraft rotation must be orientated so the sun may be observed at all times when the spacecraft is in sunlight. To achieve this requirement, the spacecraft is made to tumble by wobblers (energy dissipation devices) which are released after third-stage burn-out. The transfer of motion from the original to the final rotational mode should occur within one or two orbits.

4.6 EXPERIMENT MEASUREMENTS

The measurements to be performed are divided into the following three categories:

- Sunset or sunrise measurements
- Measurements in sunlight
- Measurements toward the anti-solar point (orbit night measurements)

4.6.1 SUNSET OR SUNRISE MEASUREMENTS

The sunrise or sunset measurements depend on observing the sun with the ion chambers and the ozone sensor through the atmosphere close to the earth. From this information, profiles of molecular oxygen and ozone concentration may be determined. It is required that these measurements provide information at one latitude rather than cover a band of latitudes.

4.6.2 DAYLIGHT MEASUREMENTS

The orbital daylight measurements will provide data on the solar flux in the ultra-violet and X-ray wavelengths. Solar activity will be monitored

CHANNEL

FRAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	S	S	S	S	L_a	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
2	+5v	0v	Th_1	X	M_1	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
3	+5v	Clock	Th_2	H_b	M_2	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
4	+5v	0v	Th_3	X	M_3	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
5	0v	HK_1	Th_4	Th_6	L_a	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
6	0v	+5v	Th_5	X	M_1	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
7	+5v	HK_2	HK_3	H_b	M_2	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}
8	0v	+5v	HK_4	X	M_3	I_{1f}	I_{2f}	I_{3f}	A_{1f}	A_{2f}	0_3	I_{1s}	I_{2s}	I_{3s}	A_{1s}	A_{2s}

S = Sync. (sequence), 4.5 kHz ± 0.1%

+5v = Calibration, +5v ± 0.1%; corresponding sub-carrier, 15 kHz

0v = Calibration, 0v; corresponding sub-carrier, 5 kHz

Clock = Time code generator

Th_1 = Temperature thermistor, encoder

Th_2 = Temperature thermistor, front facing, amplifier

Th_3 = Temperature thermistor, side facing, block

Th_4 = Temperature thermistor, monitoring battery

Th_5 = Temperature thermistor, skin No. 1

Th_6 = Temperature thermistor, skin No. 2

Hk_1 = Housekeeping, monitoring 12.4 v

Hk_2 = Housekeeping, monitoring 6.2 v

Hk_3 = Housekeeping, monitoring 1.25 v

Hk_4 = Housekeeping, monitoring -7.75 v

X = X-ray measurement

H_b = Hydrogen Beta measurement

M_1 = Magnetometer No. 1

M_2 = Magnetometer No. 2

M_3 = Magnetometer No. 3

L_a = Lyman-alpha measurement

I_{1f} = Ion Chamber Experiment, (front facing No. 1)

I_{2f} = Ion Chamber Experiment, (front facing No. 2)

I_{3f} = Ion Chamber Experiment, (front facing No. 3)

A_{1f} = Aspect Sensor (front facing No. 1)

A_{2f} = Aspect Sensor (front facing No. 2)

0_3 = Ozone Experiment

I_{1s} = Ion Chamber Experiment, (side facing No. 1)

I_{2s} = Ion Chamber Experiment, (side facing No. 2)

I_{3s} = Ion Chamber Experiment, (side facing No. 3)

A_{1s} = Aspect Sensor (side facing No. 1)

A_{2s} = Aspect Sensor (side facing No. 2)

Figure 4-4. WRESAT Telemetry Format

by the X-ray sensor primarily and these measurements will be correlated with the ionosonde soundings taken at Woomera, Salisbury, and other world centers coinciding with the spacecraft pass.

4.6.3 NIGHT MEASUREMENTS

The orbital night measurements will provide data on the Lyman-alpha radiation scattered resonantly by the geocoronal hydrogen. The positions of Lyman-alpha sources in the night sky will also be determined.

SECTION 5
OPERATIONS AND CONTROL

SECTION 5

OPERATIONS AND CONTROL

5.1 INTRODUCTION

The operations and control of the GSFC Space Tracking and Data Acquisition Network ground support facilities utilized in the support of the WRESAT project will be the responsibility of the GSFC Tracking and Data Systems Directorate. The organization, facilities, and operational procedures to be utilized in discharging this responsibility are delineated below.

5.2 LAUNCH AND EARLY-ORBIT PHASE

During the launch and early-orbit phase of the mission, control of the STADAN ground facilities will be exercised by the Tracking and Data Systems (T&DS) Operations Director from the GSFC Operations Control Center (OPSCON). The following paragraphs briefly discuss the personnel who may be in attendance during the launch, the telephone communications which will be available, and the displays which will be maintained in OPSCON during the launch activities.

5.2.1 OPERATIONS CONTROL CENTER

The following personnel will assist the T&DS Operations Director and will be present in OPSCON:

- Assistant Operations Director
- Tracking and Data Systems Manager
- Tracking and Telemetry Engineer
- Orbital Computations Engineer
- NASA Headquarters Technical Liaison (if requested)
- North American Air Defense Command Liaison
- NETCON Liaison
- Operations Controller

5.2.2 TELEPHONE COMMUNICATIONS

Telephone communications for liaison, control, and coordination will be established as outlined in Figure 5-1. Internal GSFC communications circuits are not anticipated to be used.

5.2.3 DISPLAYS

Prelaunch and launch data pertaining to the mission will be displayed on illuminated screens located at the front of OPSCON. The Operations Center Branch will be responsible for the implementation and operation of these displays. The following paragraphs describe the displays shown during the launch and early-orbit phases. All the displays discussed may not be shown simultaneously; displays will be projected as appropriate data are received.

5.2.3.1 Station Status

The current status of each participating STADAN station will be shown by means of individual colored lights placed at the geographic station location on the World Map. The lights will indicate the following:

- Amber - station not reported or status unknown.
- Red - station not ready.
- Green - station ready.
- Flashing Green - acquisition of spacecraft signal.

5.2.3.2 Launch Events and Orbital Elements

This display will present the nominal sequence of events during launch, the nominal orbital elements, and other pertinent information related to the launch vehicle and spacecraft.

5.2.3.3 Teletype Message Display

This display will be used to view projected mission-oriented teletype messages to and from the supporting ground stations.

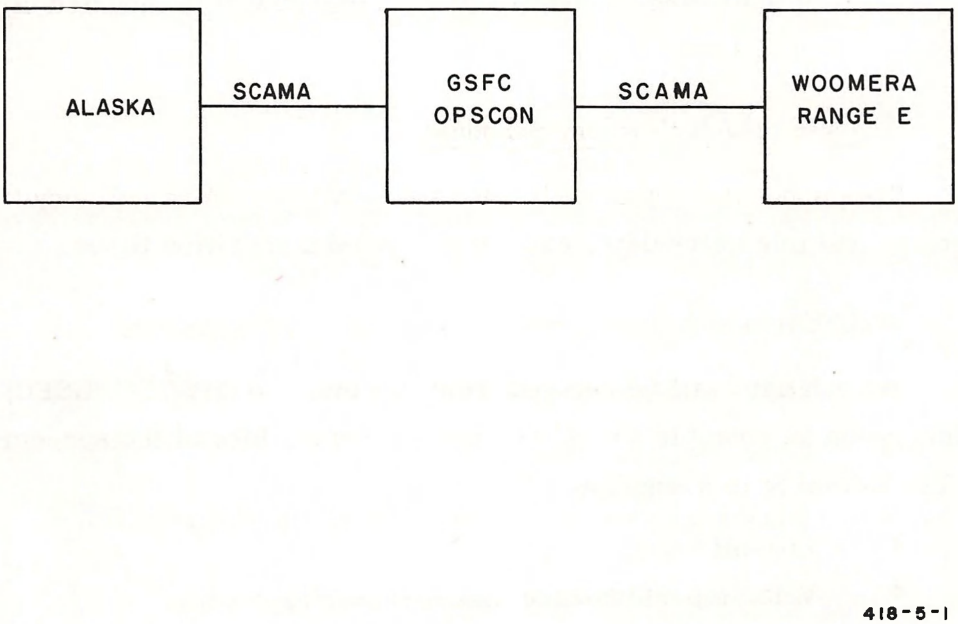


Figure 5-1. WRESAT Telephone Communications

5.2.3.4 Subsatellite Plot

The nominal subsatellite plot will be displayed. The position of the spacecraft along this plot will be indicated in real-time if near-nominal orbit is achieved. It is expected that the subsatellite plot will be maintained for no more than four hours.

5.2.3.5 Count-down Clock

The count-down clock will indicate in real-time the latest terminal count as received in OPSCON from Woomera. Hold times also will be indicated.

5.2.3.6 GMT Clock

A clock indicating Greenwich Mean Time (GMT) is mounted directly above the count-down clock.

5.2.3.7 Tracking and Telemetry Schedule

This schedule sequentially shows the stations which will acquire spacecraft tracking and telemetry data, and the predicted acquisition times.

5.2.4 LAUNCH DATA

Launch data will be relayed from Woomera to OPSCON (GSFC). As much information as possible should be obtained before loss of the spacecraft signal. The following is a suggested list:

- Lift-off time
- Vehicle performance data and staging events
- Experiment cover separation
- Injection vector from C-band radar (if available)
- Spacecraft status

5.2.5 STADAN CONTROL

During the launch and early-orbit phases, the Operations Center Branch will be responsible for the following:

a. Scheduling and monitoring the operations of the STADAN stations to ensure that:

- All available tracking data are obtained for computing an orbit at the earliest practicable date.
- All STADAN stations are scheduled to acquire and record telemetry when the spacecraft is within range.

b. Providing the Tracking and Data Systems Manager (T&DSM) with periodic reports concerning the network tracking and telemetry activities. Unusual activities will be reported in near-real-time to the Space Physics Operations Control Center (SPOCC).

A summary STADAN activity report will be prepared no later than 0600 hours local time on each of the two consecutive days following launch and transmitted to the SPOCC. This report will include such information as the number of minutes of telemetry recorded by the stations, any unusual occurrences, and the number and types of tracking messages.

c. Providing the SPOCC (GPHY) with a copy of the initial telemetry schedule and updated or new schedules as they become available.

d. Ensuring operation of appropriate displays.

e. Checking with the Network Computations Section and the Communications Operations Branch to ensure that the nominal predictions have been disseminated to all facilities participating in the WRESAT mission.

f. Confirming the nominal launch date and time to STADAN, NORAD, SAO, and NAVSPASUR at T-10 days so that early-orbit tracking support will be prepared. Follow-up notices of launch date changes will be made as required.

g. Keeping the T&DSM informed of the ability of STADAN to support the WRESAT mission when requested, beginning at T-1 day.

5.2.6 GROUND OPERATIONS CONTROL

The T&DSM will be responsible for the following:

a. Maintaining liaison with the project for the purpose of receiving and implementing changes in the project requirements if and when they arise. He will coordinate all changes to existing project requirements.

b. Verifying that the Operations Plan, station predictions, and orbital information have been distributed to those concerned, and that all ground support elements are aware of their assigned responsibilities.

c. Preparing periodic project operations and status reports concerning the WRESAT spacecraft and the ground support system.

d. Preparing the T&DS Morning Report, with the input from NETCON/OPSCON, for two consecutive days after launch.

5.3 NORMAL PHASE

The normal phase will begin when directed by the Operations Director. This phase normally begins as soon as the spacecraft orbit has been determined and updated orbital predictions have been computed and forwarded to the tracking and telemetry stations.

5.3.1 STADAN CONTROL

During the normal phase, NETCON and OPSCON of the Operations Center Branch will be responsible for the following:

a. Scheduling and monitoring the operations of the STADAN stations to provide complete station coverage in accordance with project requirements and spacecraft priority.

b. Providing the SPOCC with STADAN status information throughout the active scientific lifetime of the spacecraft. Unusual events will not be restricted to a time frame, but will be reported as dictated by the urgency of the situation and the need for a quick response.

c. Providing the SPOCC (GPHY) with a copy of the final telemetry schedule, pass summaries, telemetry reports, and any changes as they become available.

d. Scheduling the STADAN for 100 percent coverage, excluding redundant recording whenever station visibility permits.

e. Scheduling the STADAN to track the spacecraft as necessary to maintain an accurate orbit. Due to the nature of the orbit, it is felt that all available tracking passes will be needed to keep the orbit updated for the life of the spacecraft.

5.3.2 GROUND OPERATIONS CONTROL

The Tracking and Data Systems Manager, or his representative, will be responsible during the normal phase for the following:

a. Maintaining liaison with the Project for implementing changes in project requirements and handling emergency situations as they arise.

b. Maintaining an up-to-date knowledge of the spacecraft status at all times.

c. Assuring the accomplishment of all phases of the project involving the Tracking and Data Systems Directorate.

d. Keeping the appropriate Tracking and Data Systems Directorate personnel informed of the project status and ground support activities.

e. Checking to assure that maximum telemetry coverage is being obtained.

5.3.3 SPACE PHYSICS OPERATIONS CONTROL CENTER

The SPOCC will be the central point of contact for all GSFC operations regarding the WRESAT spacecraft during its active scientific lifetime. The T&DSM will be responsible for the coordination and control of all spacecraft operations. Control center operations will be under the direction of the Control Center Operations Manager. The responsibilities of the control are as follows:

- Maintaining logs of the telemetry schedule and minutes of recorded telemetry data.
- Distributing the world maps.

SECTION 6

FIELD STATION OPERATIONS

SECTION 6
FIELD STATION OPERATION

6.1 INTRODUCTION

The purpose of this section is to describe the responsibilities of the field stations from launch through the normal scientific lifetime of the WRESAT, and to outline the operational procedures that will be utilized in fulfilling mission requirements.

6.2 TRACKING

6.2.1 INTERFEROMETER TRACKING

The Space Tracking and Data Acquisition Network (STADAN) will be responsible for interferometer tracking the WRESAT spacecraft. The following STADAN stations will track the 136.35-MHz telemetry signal with their interferometer systems:

- Fairbanks, Alaska (ALASKA)
- Fort Myers, Florida (FTMYRS)
- Johannesburg, South Africa (JOBURG)
- Lima, Peru (LIMAPU)
- Quito, Ecuador (QUITOE)
- Santiago, Chile (SNTAGO)
- Orroral, Australia (ORORAL)
- Tananarive, Republic of Malagasy (MADGAR)
- St. Johns, Newfoundland (NEWFLD)
- Winkfield, England (WNKFLD)

The 136.35-MHz transmitter will transmit continuously at a power of 125 mw (see Appendix A for the signal strength calculations). The stations listed above will track the spacecraft as scheduled by OPSCON/NETCON and transmit the data to GSFC. Digital tracking data will be transmitted to COMPUT (GPUT) via teletype in accordance with standard operating procedures for near-earth-orbiting spacecraft.

6.2.2 ANGLE (X-Y) TRACKING

The ORORAL, ALASKA and ROSMAN stations will utilize the 85-foot parabolic antennas to obtain angle (X-Y) tracking data. The MADGAR, QUITOE, SNTAGO and JOBURG stations will provide X-Y tracking data using the 40-foot antennas. These stations will acquire the WRESAT telemetry signal, as scheduled by OPSCON/NETCON. The output of the X- and Y-axis angle encoders will be punched out on teletype tape and transmitted to COMPUT as soon as possible.

6.3 DATA ACQUISITION

The STADAN stations listed in paragraph 6.2.1, Rosman, North Carolina (ROSMAN), Kauai, Hawaii (KAUAIH), and Carnarvon, Australia (CARVON) have responsibility for recording the WRESAT telemetry data. All data acquisition periods for these stations will be scheduled by OPSCON/NETCON in accordance with missions requirements and spacecraft priority.

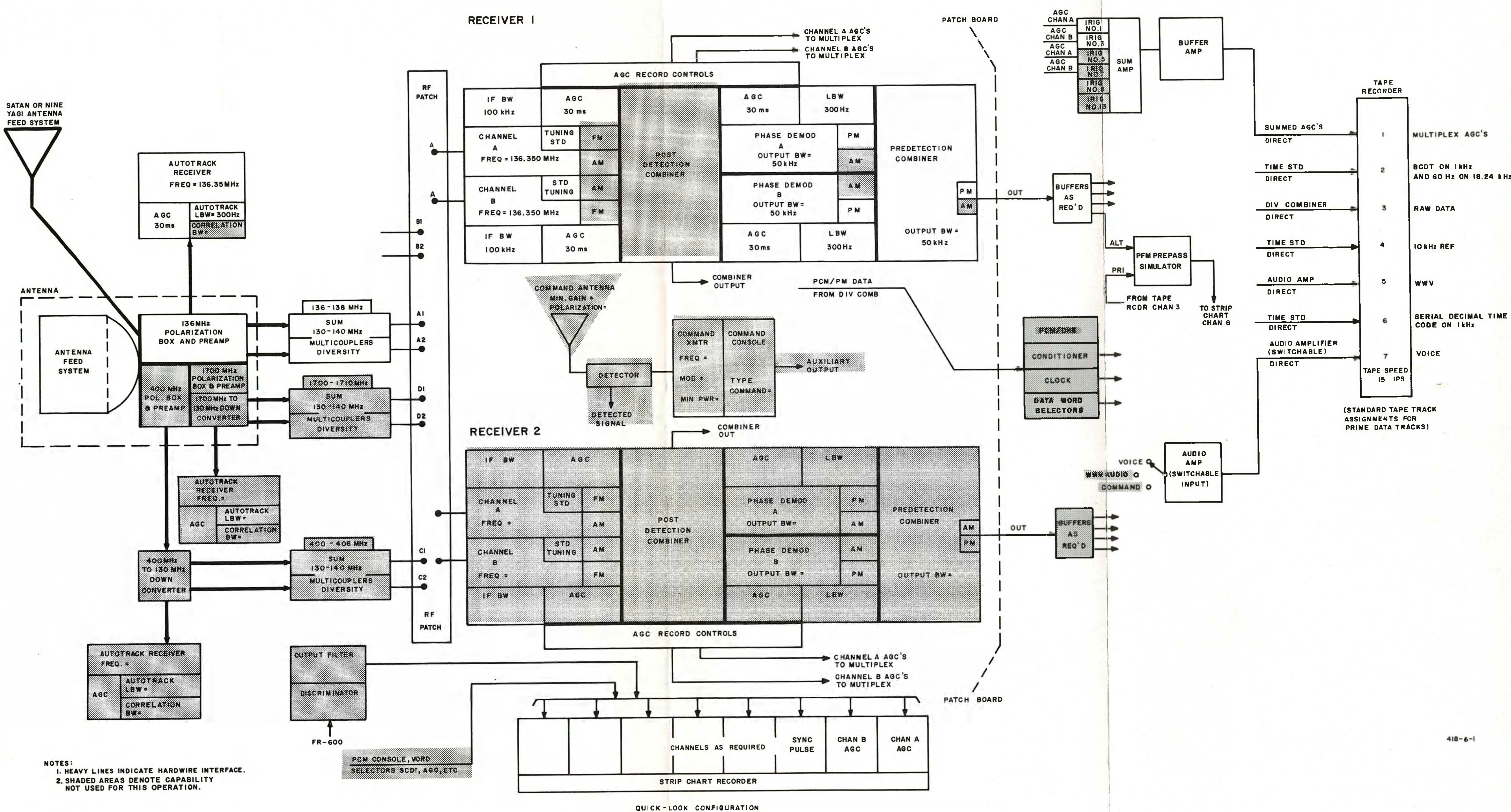
The Carnarvon station will record two magnetic tapes, containing identical data, during each pass for the 24 hours after launch. The station will send one of the tapes to WRE and forward the other to GSFC. After the first 24 hours only one tape will be recorded and forwarded to GSFC.

6.3.1 TELEMETRY EQUIPMENT CONFIGURATION

A block diagram of the basic telemetry equipment configuration to be used by the stations (with the exception of Carnarvon) is shown in Figure 6-1. The Carnarvon telemetry equipment configuration is shown in Figure 6-2. The spacecraft compatibility test will take place approximately two weeks prior to launch; therefore, last-minute equipment control settings may be teletyped to stations.

6.3.2 TELEMETRY EQUIPMENT SET-UP

The following general equipment parameters are provided for use by the STADAN stations in setting up their particular system. The controls not specifically defined may be set as specified in the individual equipment instruction manuals.



NOTES:
1. HEAVY LINES INDICATE HARDWIRE INTERFACE.
2. SHADED AREAS DENOTE CAPABILITY NOT USED FOR THIS OPERATION.

Figure 6-1. WRESAT Telemetry Equipment Configuration

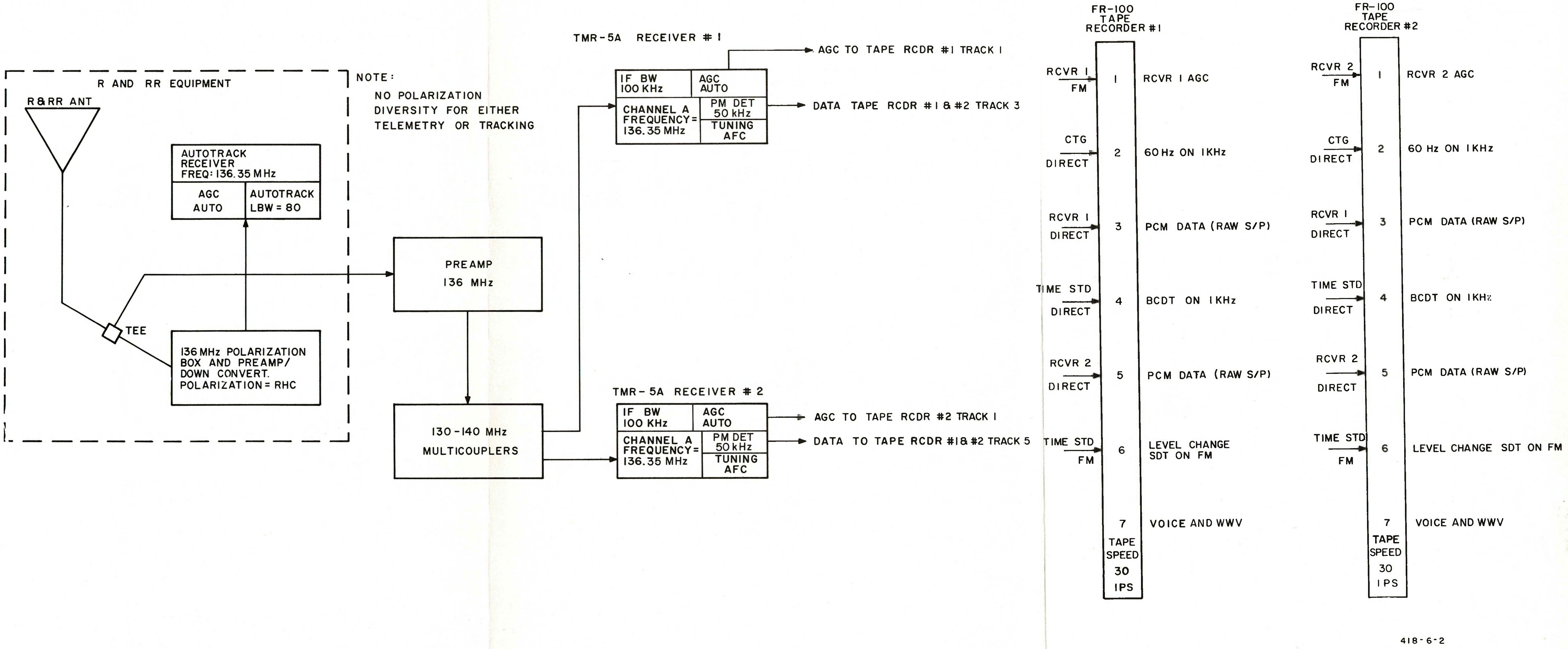


Figure 6-2. Carnarvon Telemetry Equipment Configuration

A.6 RECEIVED SIGNAL STRENGTH, MINITRACK INTERFEROMETER SYSTEM

Table 1 estimates the received signal strength using the Minitrack Interferometer System ambiguity antennas, and indicates the amount of signal above or below the threshold required for ambiguity resolution.

Calculations for the fine antennas are not presented, inasmuch as the ambiguity antennas represent the system constraint, and above-threshold performance using the ambiguity antennas ensures above-threshold performance of the system.

A.7 RECEIVED SIGNAL STRENGTH, TELEMETRY SYSTEMS

Tables 2 and 3 estimate the received signal strengths using the 9-yagi antenna system (19 db gain) and indicate the amount of signal above or below the threshold required for phase-lock and telemetry data, respectively.

When considering the use of other antenna systems, the following values should be added to the items indicated by an asterisk (*):

- 40-foot parabolic antenna system. . . . . + 0 db (32)
- 16-yagi antenna system. . . . . + 2 db (32)
- SATAN receiving antenna system. . . . . . + 3 db (32)
- 85-foot parabolic antenna system. . . . . + 7 db (71)

6.3.2.1 Antenna Characteristics

- Frequency band. . . . . 130 — 140 MHz
- Minimum gain (9-yagi) . . . . +19 db (use highest gain antenna available)
- Suggested polarization . . . . . . RHC *

6.3.2.2 Autotrack Equipment

- Frequency . . . . 136.35 MHz
- Mode . . . . closed loop
- Loop bandwidth . . . . 30 Hz
- AGC speed . . . . 30 ms

6.3.2.3 Telemetry Receiver

- Input frequency . . . . 136.350 MHz
- Type tuning . . . . STD
- IF bandwidth . . . . 100 kHz
- Gain control mode
  (with 215 demod) . . . . AGC
  (with 315 demod) . . . . Combined
- AGC speed . . . . 30 ms

6.3.2.4 Phase-lock Demodulator/Combiner or Diversity Demodulator

- Mode . . . . PM
- Bandwidth . . . . 50 kHz
- Calibrate switch . . . . operate
- Loop bandwidth . . . . 30 Hz
- AGC speed . . . . 30 ms

*The WRESAT may present unusual polarization difficulties because the spacecraft will have a tumbling, rather than a spinning motion. Therefore, there is no single receiving polarization which will work well at all times. If the AGC shows nulls greater than 10 to 12 db, operations may be improved by switching to a different type of polarization. For example, if right hand circular procedures 15 db nulls, try linear rather than left hand circular.

6.3.2.5 Data Recording Equipment

- FR-600 magnetic tape recorder
  - Speed . . . . 15 ips
  - Track assignments . . . . . . Refer to Table 6-1

Table 6-1
Tape Recorder Track Assignments

Track	Record Amplifier	Source	Signal
1	Direct	Summation amp	Multiplexed AGC's
2	Direct	Time STD	BCDT on 1 kHz and 60 Hz on 18.24 kHz
3	Direct	Div Combiner	Raw data
4	Direct	Time STD	10-kHz reference
5	Direct	Audio amp	WWV
6	Direct	Time STD	SDTC on 1 kHz
7	Direct	Audio amp	Voice

6.3.2.6 Quality Evaluation Equipment Set-up

- PFM Prepass Simulator and Sync Tone Filter
  - Range selector . . . . Range C
  - External reference . . . . . . Internal
  - Primary input . . . . FR-600 track 3 output
  - Secondary input . . . . Diversity combiner output
- Strip Chart Recorder
  - Speed . . . . 2.5 mm/sec maximum

    0.5 mm/sec minimum
  - Channel 6 . . . . Detected sync tone (from prepass simulator)
  - Channel 7 . . . . Channel B AGC
  - Channel 8 . . . . Channel A AGC

NOTE

The SDTC will not be readable but it may be recorded if the station desires to do so.

Detailed instructions converning the above equipment may be found in O&M Bulletin No. 91.

6.3.3 REAL-TIME DATA QUALITY EVALUATION

All stations listed in paragraph 6.2.1, except NEWFLD, will perform real-time quality evaluation on the received data. The equipment set-up is given in paragraph 6.3.2.6. A pass summary message, describing the quality of the received signals, will be transmitted by routine teletype to GPHY, GOPS, GNST, GTWL/J. Martin Code 531, and R. Serra Code 573.

The pass summary message will contain the maximum AGC, the magnitude of the variations in the amplitude of the detected sync tone (as recorded from the PFM prepass simulator) and other information necessary to evaluate the probable processability of the data. From this information it will be possible for GSFC to determine that the stations are operating satisfactorily, and will enable each station to evaluate their own performance. These unusual procedures are necessary because the transmitter lifetime is shorter than the time it would take for GSFC to receive data tapes and transmit comments to the stations.

●-●-●-●-●- SAMPLE FORMAT -●-●-●-●-●

REF WRESAT ORBIT XXX
ANT CODE X
AGC XXXXXXXX
CHAN A MAX XXX NULLS XX
CHAN B MAX XXX NULLS XX
TONE CALIB XX DIV
TONE DEV PLUS XX DIV MINUS XX DIV
REMARKS XXXX XXXX XXXX

●-●-●-●- END OF SAMPLE FORMAT -●-●-●-●

Explanation of sample format:

a. ORBIT — Enter the orbit (pass) number.

b. ANT CODE — Enter the antenna code letter per NETCON SOP 5A.

c. AGC — Identify the type of AGC reported, e. g., combined or receiver. The AGC calibration will be performed using a CW signal.

d. CHAN A — Enter the maximum AGC for this channel. This reading must be taken at the same time as the tone deviations readings (see item g). The magnitude of the AGC nulls during this period will be reported. The nulls will be read from the top of the "creast" (AGC peak) to the bottom of the "valley" (AGC Null). The one on two extreme values which do not appear to be part of a repeated pattern will be ignored. Readings will be reported as minus dbm, but only the numerical value will be included in the message.

e. CHAN B — The same type of data for channel B will be reported as for channel A. This reading must be taken at the same time as the tone deviations readings.

f. TONE CALIB — Enter the amplitude of the spikes in divisions, recorded during step during the second half of step 2.A.10 of O&M Bulletin No. 91.

g. TONE DEV — This reading should be taken while receiving a good signal and should be over a period of 100 to 200 pulses. Report the amplitude as plus or minus divisions, using the amplitude reported in item f as a reference. In counting the highest and lowest spikes, the one or two extreme values which are not part of a repeating pattern will be ignored.

h. REMARKS — Enter any comments which may be appropriate. These may include:

- If the input of the PFM prepass simulator is switched from primary to alternate the baseline will shift, but the variations in amplitude should remain the same; describe the results if this does not occur.
- Any noted interference
- The cause, in your judgment, of any unusual changes in the quality of the data during the pass

6.4 SHIPMENT OF MAGNETIC TAPE

All STADAN stations will forward the magnetic tape containing WRESAT telemetry data, in accordance with standard tape shipping instructions to:

NASA - Goddard Space Flight Center
Analog Data Accounting Office
Data Processing Branch
Code 564
Greenbelt, Maryland 20771
U. S. A.

There the tapes will be subjected to a quality assurance check prior to being forwarded to the WRE.

The strip chart recordings made utilizing the prepass simulator are to be included in the tape shipment.

6.5 WRE MOBILE VAN RECEIVER STATION

The Weapons Research Establishment (WRE) will maintain a mobile van for acquiring telemetry data from the spacecraft. The equipment parameters were obtained from their Technical Manual, ISD 123, dated May 1967, and are listed for general information purposes.

- Antenna — 22-db gain; V and H outlets; steerable in azimuth and elevation.
- Preamplifier — Two channels: gain 35 db; 3 db.
- Receiver — 136.000 to 136.999 MHz tunable in 1-kHz steps, selectable IF bandwidths including 100 kHz, selectable converted outputs including 62 kHz, AGC of various selectable speeds including 30-Hz, AM and FM detectors, additional equipments for providing IF band limiting to 40 kHz, and phase detection with various output bandwidths.

- Recorder — Two-track, direct record, response to 20 kHz, wow and flutter less than 0.2 percent p-p.
- Antenna — TACO 16-element crossed yagi, originally used for spacecraft telemetry in the STADAN.

The receiver is the 136-MHz telemetry receiver of the NASA Minitrack System. The 62-kHz converted output is passed through a 40-kHz filter — the 30-kHz IF will not accommodate sufficient sidebands and doppler — and then to an Interstate Electronics PL 107 tracking filter, which includes a correlated phase-detected output, band-limited to about 30 kHz.

The sub-carrier is recorded on one track of an instrumentation recorder at normal recording level. Another track is used for recording a WRE coded time.

SECTION 7
EXTERNAL AGENCY SUPPORT

SECTION 7

EXTERNAL AGENCY SUPPORT

7.1 INTRODUCTION

The following agencies are requested to support the WRESAT mission and will interface with NASA-GSFC.

- Weapons Research Establishment
- Smithsonian Astrophysical Observatory
- North American Air Defense Command

7.2 WEAPONS RESEARCH ESTABLISHMENT

During launch operations, the WRE will provide launch support and tracking coverage at the Woomera Range Center in accordance with mission requirements. Launch vehicle tracking, using C-band radar, will be provided from lift-off through 3rd-stage burn-out. If available, the final velocity vector at injection will be forwarded to GSFC. The Range Center will report launch countdown status and the significant events following lift-off to GSFC via SCAMA. If available, the latest spacecraft frequency as measured before lift-off will also be reported to GSFC. It is requested that the vehicle staging times be forwarded, as soon as possible, to OPSCON (GOPS) and SPOCC (GPHY).

A equipment van located at the range will provide spacecraft checkout operations prior to launch and perform postlaunch data acquisition operations. Magnetic tape recording of telemetry data will be basically the same as the STADAN stations. GSFC will teletype updated orbital predictions to the range.

7.3 SMITHSONIAN ASTROPHYSICAL OBSERVATORY

The Smithsonian Astrophysical Observatory (SAO) is requested to optically track the WRESAT whenever possible during the transmitting lifetime of the spacecraft. Tracking will be accomplished using the Baker-Nunn camera tracking system. Field-reduced observations are to be sent to GPUT by teletype in the 222 format as soon as possible after they are obtained.

7.4 NORTH AMERICAN AIR DEFENSE COMMAND

The North American Air Defense Command (NORAD) Space Defense Center (SDC) is requested to track the WRESAT spacecraft during the first 24 hours after launch. If requested, tracking data will be transmitted to GSFC via teletype. The items that will obtain orbit are as follows:

- WRESAT/third stage combination — The spacecraft dimensions are given in paragraph 4.5. The third stage motor is approximately 29 inches long and 24 inches in diameter. The third stage will stay with the spacecraft.

- Experiment covers — Two experiment covers will be ejected immediately on injection of the spacecraft into orbit. One cover, the nose tip, is 9 inches long and 5 inches in diameter and weighing 1-1/2 pounds, will be ejected with a velocity of approximately 5 feet per second. The other cover is kidney shaped, 6 inches by 4 inches and weighing 1 pound, will be ejected with a velocity of 15 feet per second.

SECTION 8

COMPUTING CENTER OPERATIONS

SECTION 8

COMPUTING CENTER OPERATIONS

8.1 RESPONSIBILITY

The GSFC Mission and Trajectory Analysis Division will be responsible for all orbital computations required for support of the WRESAT mission.

The WRE is responsible for all aspect computations that may be required.

8.2 ORBITAL PREDICTION REQUIREMENTS

Prelaunch predictions will be computed from the nominal trajectory data furnished by WRE. Postlaunch predictions will be based upon the orbit which best fits the tracking data received from the STADAN stations.

8.2.1 STATION PREDICTIONS

The Computation Division will furnish nominal station predictions for the stations listed in Table 8-1 at least 10 days before the scheduled launch date and covering the first 3 days following launch. If significant subsequent changes are made in the launch date, the launch window, or the nominal launch trajectory, the nominal predictions will be recomputed.

The predictions will be updated immediately following orbit determination. Due to the nature of planned orbit it may be necessary to update the predictions several times per week. The updated predictions will be sent to the stations as necessary to maintain a reasonable acquisition accuracy. Once the orbit is determined, predictions will be furnished to NETCON for a one week period for planning purposes. The final station scheduling times will have to be adjusted as a result of each update.

8.2.2 ORBITAL ELEMENTS AND EQUATOR CROSSINGS

In addition to the stations listed in Table 8-1 SPOCC (GPHY), SAO, NETCON, NORAD and WRE will receive nominal and updated orbital elements and equation crossings.

Table 8-1
Prediction Requirements

Location	Prime Vertical Meridian Crossings	AZ-EL	$\theta_1 - \theta_2$	ENV
WNKFLD	X	X	X	
NEWFLD	X	X		
ALASKA	X	X	X	X
ORORAL	X	X	X	X
SNTAGO	X	X	X	X
LIMAPU	X	X		
QUITOE	X	X	X	X
FTMYRS	X	X	X	
ROSMAN			X	X
JOBURG	X	X	X	X
MADGAR	X	X	X	X
KAUAIH		X		
OOMERA		X		
CARVON			X	

8.2.3 DISTRIBUTION OF PREDICTION PRINT-OUTS

Bound copies of nominal and postlaunch predictions will be distributed as shown in Table 8-2.

Table 8-2
Distribution of Prediction Print-outs

Recipient	Nominal Predictions		Postlaunch Predictions	
	World Map	Station Predictions	World Map	Station Predictions
NETCON/OPSCON	2	2	2	2
SPOCC	2	2	2	2
OCE	1	1	1	1

8.3 ORBIT DETERMINATION

Interferometer tracking data will be received on teletype tape by the Network Computation Section. The data will undergo editing, ambiguity resolution, and conversion to direction cosine data. Paper print-outs and BCD observation cards will be made containing the direction cosine data. The BCD observation cards will be forwarded to the Early Orbit Determination Group for orbital computation.

All radar, X-Y, optical and other tracking data received by the Communications Center will be forwarded to the Network Computation Section. The Network Computation Section will process the data and punch it out on BCD observation cards. The cards will then be forwarded to the Early Orbit Determination Group for use in orbital computations.

A revised estimate of the orbit, based on all available tracking data, will be computed as soon as possible after launch. Preliminary orbital information will be released when the OCE determines that an acceptable orbit solution has been achieved. It is estimated that a satisfactory solution will be obtained and verified and that updated predictions will be computed within ten hours after launch.

8.4 DEFINITIVE ORBITAL COMPUTATION

A ORB 3A output is required covering the spacecraft lifetime and will contain the following parameters.

- t - Universal time of spacecraft data
- h - Height of the spacecraft above the spheriod
- μ - Geodetic latitude of the spacecraft position
- λ - Longitude of the spacecraft position
- r - Radial distance of the spacecraft from the center of the earth
- α - Inertial right ascension of the spacecraft position
- α_V - Right ascension of the spacecraft velocity vector

- δ_v - Declination of the spacecraft velocity vector
- ϕ_G - Geomagnetic latitude of the spacecraft position
- R_o - A geomagnetic coordinate of the spacecraft position
- ν - True anomaly of the spacecraft position
- ϕ_p - The solar array angle
- The spacecraft-sun angle (The angle between the unit vector from the center of the earth to the spacecraft and the unit vector from the center of the earth to the sun)
- The spacecraft-moon angle (The angle between the unit vector from the center of the earth to the spacecraft and the unit vector from the center of the earth to the moon)
- The ascending node pass number
- B - The magnetic field strength
- The right ascension of the magnetic vector
- The declination of the magnetic vector

The following values are computed only at the Epoch Time.

- $\underline{r}$ - The inertial spacecraft position vector
- $\underline{r_s}$ - The inertial solar position vector
- e - The eccentricity of the spacecraft orbit
- a - The semi-major axis of the spacecraft orbit
- θ_v - The spacecraft velocity vector angle

The ORB 3A output will be available within two months following the end of the spacecraft lifetime, and will consist of one BCD tape and one printed copy.

SECTION 9

DATA PROCESSING

SECTION 9

DATA PROCESSING

9.1 RESPONSIBILITIES

Data processing for the WRESAT mission will be performed by the Australian Weapons Research Establishment. The GSFC Information Processing Division will evaluate the analog tapes recorded at the STADAN stations for data quality and proper recording techniques.

9.2 TAPE EVALUATION LOGGING PROCEDURES

A representative sample of the analog tapes is subjected to evaluation. The tapes selected for evaluation include the last tape received in a given shipment from each station. The evaluation process consists of the following operations:

- A check of each tape track for proper information on that track.
- A check for proper preparation of the magnetic tape log accompanying each tape.
- Strip chart recordings of the three time tracks, BCDT, SCDT, and WWV, are compared for consistency and accuracy.
- Observation of an oscilloscope display of the PFM data.
- Strip chart recordings of the AGC calibration curves are verified with the values specified by the voice track.

Reports summarizing the results of the tape evaluation are submitted weekly to the STADAN Operations Division (SOD) and the Operations Center Branch (OCB). However, if gross discrepancies are discovered during the evaluation process, pertinent personnel in the SOD and the OCB are notified immediately.

Upon receipt of the analog tapes at the analog data accounting office of the Data Processing Branch, a punched card is manually prepared for identification of each pass on each tape. The punched card reflects information contained in the analog tape log and in the appropriate STADAN Cumulative Telemetry Report as follows:

INFORMATION	CARD COLUMNS	CODE
Satellite	1-4	Assigned as needed
Station	5-7	FTM = FTMYRS QUI = QUITOE LIM = LIMAPU SNT = SNTAGO NFL = NEWFLD WNK = WNKFLD JOB = JOBURG SKA = ALASKA ROS = ROSMAN ACT = ORORAL MAD = MADGAR HAW = KAUAIH
Tape No.	9-12	Numeric
Date recorded	14-19	Year, month, day
Pass No.	21-24	Numeric
Intl. code	26-27	Numeric
Intl. code	29-30	Numeric
Intl. code	32	Alpha
Start time	34-39	Hr., Min., sec.
Stop time	41-46	Hr., min., sec.
Data quality	54	1-good; 2-questionable; 3-unusable
Tape quality	55	A-processable; B-limited C-questionable; D-useless
Date evaluated	57-61	Decade of year, month, day

Note: Columns not accounted for are always blank.

9.3 DISPOSITION OF TAPES

Following the evaluation and logging process described in paragraph 9.2, the analog tapes will be shipped to:

Director
Weapons Research Establishment
Box 1424 H GPO
Adelaide, South Australia
Attn: Mr. Bryan Rofe, Flight Projects Group

SECTION 10

NASA-GSFC COMMUNICATIONS CENTER OPERATIONS

SECTION 10

NASA-GSFC COMMUNICATIONS CENTER OPERATIONS

10.1 TELETYPE COMMUNICATIONS

Teletype communications and procedures for member stations of the NASCOM Network will be in accordance with NASCOP, Appendix B and D.

10.1.1 ADDRESSING TRAFFIC

Mission-oriented traffic will be addressed to GOPS. Quick-look messages will be addressed to both GOPS and GPHY.

10.2 VOICE COMMUNICATIONS

Voice communications facilities will be provided between GSFC and all STADAN stations except St. Johns, Newfoundland.

Voice switching and conferencing of the voice circuits required for STADAN operations will be accomplished at the GSFC SCAMA facility under the direction of NETCON or OPSCON.

10.3 NASCOM NETWORK SCHEDULING GROUP (NNSG)

The NNSG will schedule circuit utilization within the NASCOM Network to ensure the availability of circuits to meet mission requirements. In addition, the resources of the NASCOM Network that are not initially committed to the mission will be available for use in case of emergency.

APPENDIX A

WRESAT SIGNAL STRENGTH CALCULATIONS

APPENDIX A

SIGNAL STRENGTH CALCULATIONS

(WRESAT)

A.1 SPACECRAFT PARAMETERS

NOTE

The numbers in the right-hand margins of the following pages refer to the item numbers of the bibliography and indicate the sources of the data.

- Flight parameters

  - Apogee. . . . . 1300 kilometers (71,72)
  - Perigee . . . . 185 kilometers (71,72)
  - Inclination . . . . 75-85 degrees (72)
  - Period. . . . . 100 minutes (71)
  - Spin rate . . . . 120 rpm initially 30 rpm final (72)
  - Angular velocity (at perigee) . . . . 1.23×10^{-3} radians/sec. (71)

NOTE

The flight parameters presented above are approximate values suitable for use in performing signal strength calculations; however, their use in performing precise orbital computations is not recommended. Deviation of the above values from the precise values within the tolerances stated may cause an error no greater than ±1 db in the calculated signal strengths:

Apogee and perigee. . . . . ± 5 percent

Inclination . . . . ± 5 degrees

Period. . . . . ±10 percent

A.2 RF SYSTEMS PARAMETERS

- Carrier frequency. . . . . 136-137 MHz
- Carrier modulation
  - Type . . . . PAM/PFM/PM
  - Index. . . . . 1 radian (pk)
  - RF spectrum width. . . . . 60 kHz
  - Baseband . . . . 4.5 - 15 kHz
  - Baseband filter (2 RC sections). . . . 3 db at approx. 25 kHz
- Total transmitter power output . . . . . . 20 dbm (100 mw) minimum
21 dbm (125-mw) expected
- Radiating antenna characteristics
  - Type . . . . Turnstile
  - Polarization . . . . Circular
  - Maximum antenna gain (including passive element losses of 1 db). . . . . 1 db
  - Radiation pattern nulls. . . . . -3 db ± 3 db
- Maximum effective radiated power (ERP)
  - Total ERP (carrier + sidebands). . . . 22 dbm
  - Carrier ERP. . . . . 17 dbm
  - Total sideband ERP . . . . 21 dbm

A.3 SLANT RANGE CONSIDERATIONS

Of major interest in the calculation of expected signal strengths is the range over which the slant range may be expected to vary.

Calculations have been performed to estimate the maximum expected slant ranges corresponding to the earliest-acquisition look-angles of the steerable and Minitrack antennas, 10 degrees and 45 degrees respectively, with the spacecraft at apogee, and the minimum slant range, corresponding to an antenna look-angle of 90 degrees with the spacecraft at perigee.

The calculations result in the following:

- Maximum slant range, 10 degrees elevation. 3.32×10^3 kilometers
- Maximum slant range, 45 degrees elevation. 1.82×10^3 kilometers
- Minimum slant range. . . . . 185 kilometers

A.4 DOPPLER CONSIDERATIONS

For the following calculations, it was assumed that, over a short arc length, the path of a spacecraft in an elliptical orbit closely approximates that of a spacecraft in a circular orbit. The calculations below represent the worst-case Doppler and rate-of-change of Doppler, corresponding to the Doppler expected during an overhead pass. The results of the calculations are as follows:

- Maximum expected Doppler . . . . $\pm 3.29 \times 10^3$ Hz
- Maximum expected rate-of-change of Doppler. . . . . 138 Hz/sec.

A.5 SPECTRAL NOISE POWER DENSITY CONSIDERATIONS

It is estimated that a receiving antenna operating in the 130-150 MHz band will exhibit an antenna temperature of 1500 degrees kelvin $\pm$ 1200 degrees. This, when combined with the effects of losses between the feed and preamp and preamp noise figure will produce a system noise temperature of 1610 degrees kelvin which may be stated as a spectral noise density of -167 dbm/Hz, ± 3 db.

Given an equivalent noise bandwidth, the total noise power may be calculated using the following equation:

$$P_n = S_n + 10 \log (ENBW) \quad (72)$$

where:

P_n = total noise power (dbm)

S_n = spectral noise power density (dbm/Hz)

ENBW = equivalent noise bandwidth (Hz)

A.6 RECEIVED SIGNAL STRENGTH, MINITRACK INTERFEROMETER SYSTEM

Table 1 estimates the received signal strength using the Minitrack Interferometer System ambiguity antennas, and indicates the amount of signal above or below the threshold required for ambiguity resolution.

Calculations for the fine antennas are not presented, inasmuch as the ambiguity antennas represent the system constraint, and above-threshold performance using the ambiguity antennas ensures above-threshold performance of the system.

A.7 RECEIVED SIGNAL STRENGTH, TELEMETRY SYSTEMS

Tables 2 and 3 estimate the received signal strengths using the 9-yagi antenna system (19 db gain) and indicate the amount of signal above or below the threshold required for phase-lock and telemetry data, respectively.

When considering the use of other antenna systems, the following values should be added to the items indicated by an asterisk (*):

- 40-foot parabolic antenna system. . . . . + 0 db (32)
- 16-yagi antenna system. . . . . + 2 db (32)
- SATAN receiving antenna system. . . . . . + 3 db (32)
- 85-foot parabolic antenna system. . . . . + 7 db (71)

Table 1

Received Signal Strength, Minitrack Interferometer System
(Ambiguity Antennas)

Parameter	Mean Values 1820 km (Max. Range)	Mean Values 185 km (Min. Range)	3σ Deviation	Ref
Carrier ERP	+ 17 dbm	+ 17 dbm	± 0 db	71
Free-space attenuation	-141 dbm	-121 dbm	± 0 db	71
Receiving antenna gain	+ 3 db	+ 6 db	± 0 db	71
Passive element losses	- 1 db	- 1 db	± 0 db	71
Maximum signal level	-122 dbm	-102 dbm	± 0 db	71
Expected null depth (due to effects of cross-polarization and antenna pattern nulls)	- 7 db	- 7 db	± 4 db	71
Expected null level (due to effects of cross-polarization and antenna pattern nulls)	-129 dbm	-109 dbm	± 4 db	71
Signal required for ambiguity resolution	-135 db	-135 db	± 0 db	71
Optimum system signal margin	+ 6 dbm	+ 26 dbm	± 4 db	71
System operating margin	- 3 db	- 3 db	± 3 db	71
Signal margin	+ 3 db	+ 23 db	± 5 db	71

QUALIFICATIONS: Expected null depth value includes antenna pattern nulls of -3 db ± 3 db. Null depth values represent expected values; however under some circumstances, cross-polarization effects may result in nulls of approximately 20 db.

CONCLUSIONS: Possibility of marginal performance on some passes. Most passes will be good to apogee.

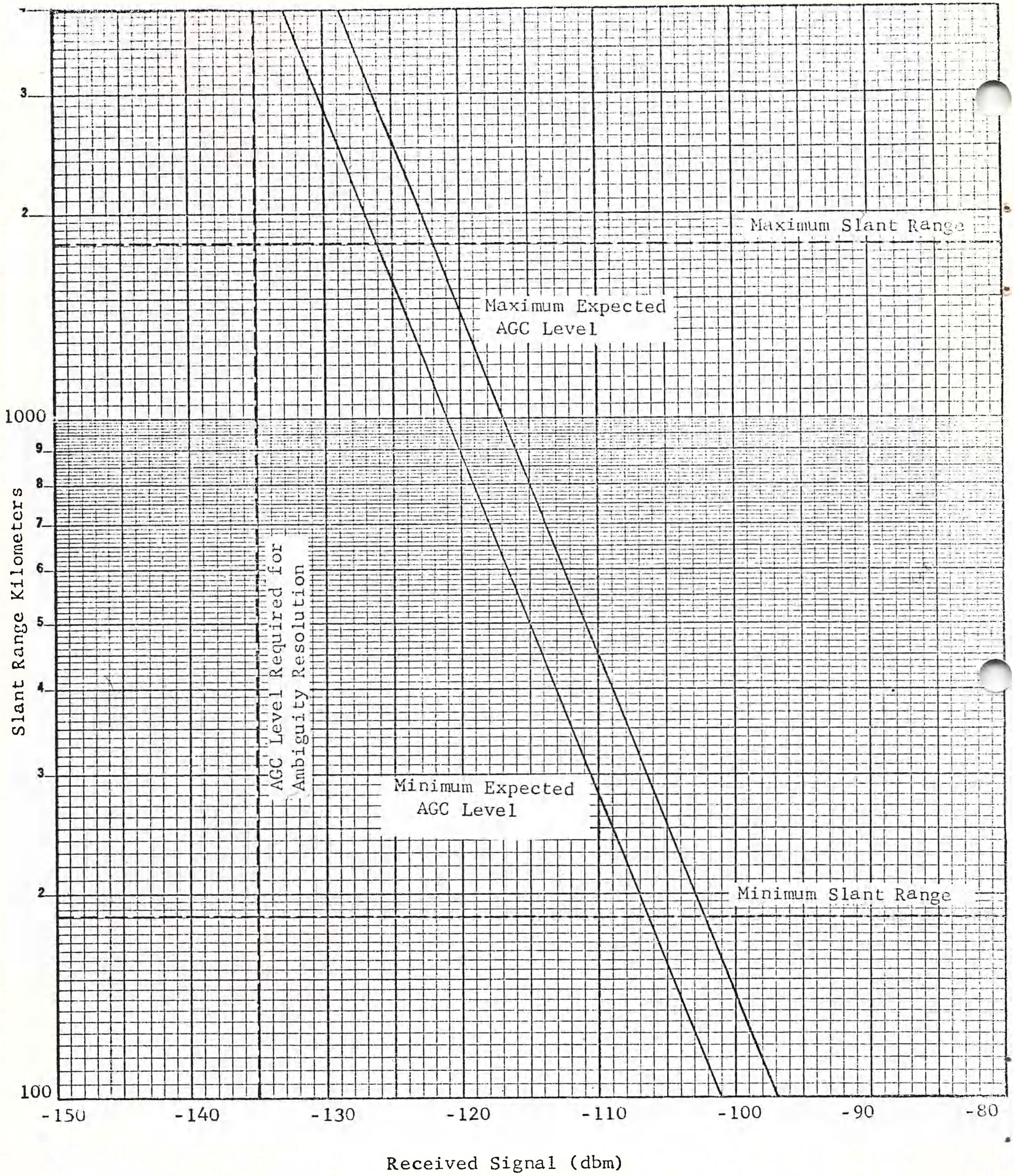


Figure 1. Received Signal Strength, Minitrack Interferometer System (Ambiguity Antenna)

Table 2

Received Signal Strength, 9-Yagi Antenna System
(Phase-Lock-Loop)

Parameter	Mean Values 3320 km (Max. Range)	185 km (Min. Range)	3 σ Deviation	Ref
Effective radiated carrier power	+ 17 dbm	+ 17 dbm	± 0 db	71
Free-space attenuation	-146 db	-121 db	± 0 db	71
Receiving antenna gain	+ 19 db	+ 19 db	± 0 db	32
Passive element losses	- 1 db	- 1 db	± 0 db	71
Maximum AGC level	-111 dbm	- 86 dbm	± 0 db	71
Expected null depth (includes cross-polarization effects and antenna ~~pattern nulls~~)	- 7 db	- 7 db	± 4 db	71
Expected null level (includes cross-polarization effects and antenna pattern nulls)	-118 dbm	- 93 dbm	± 4 db	71
Received noise power (300 Hz loop bandwidth)	-139 dbm	-139 dbm	± 3 db	71
Minimum received SNR	+ 21 db	+ 46 db	± 5 db	71
SNR required in loop for phase-lock	+ 6 db	+ 6 db	± 0 db	71
Signal margin, optimum system	+ 15 db	+ 40 db	± 5 db	71
System operating margin	- 3 db	- 3 db	± 3 db	71
Signal margin	+ 12 db	+ 37 db	± 6 db	71

QUALIFICATIONS: Null depth values shown represent expected values and include antenna pattern nulls of -3 db ± 3 db, cross-polarization effects may result in nulls of approximately 20 db under some circumstances.

CONCLUSIONS: Autotrack problems may be encountered due to the difficulty of tracking a cross-polarized signal. This will be especially true at apogee if tumbling causes significant cross-polarization.

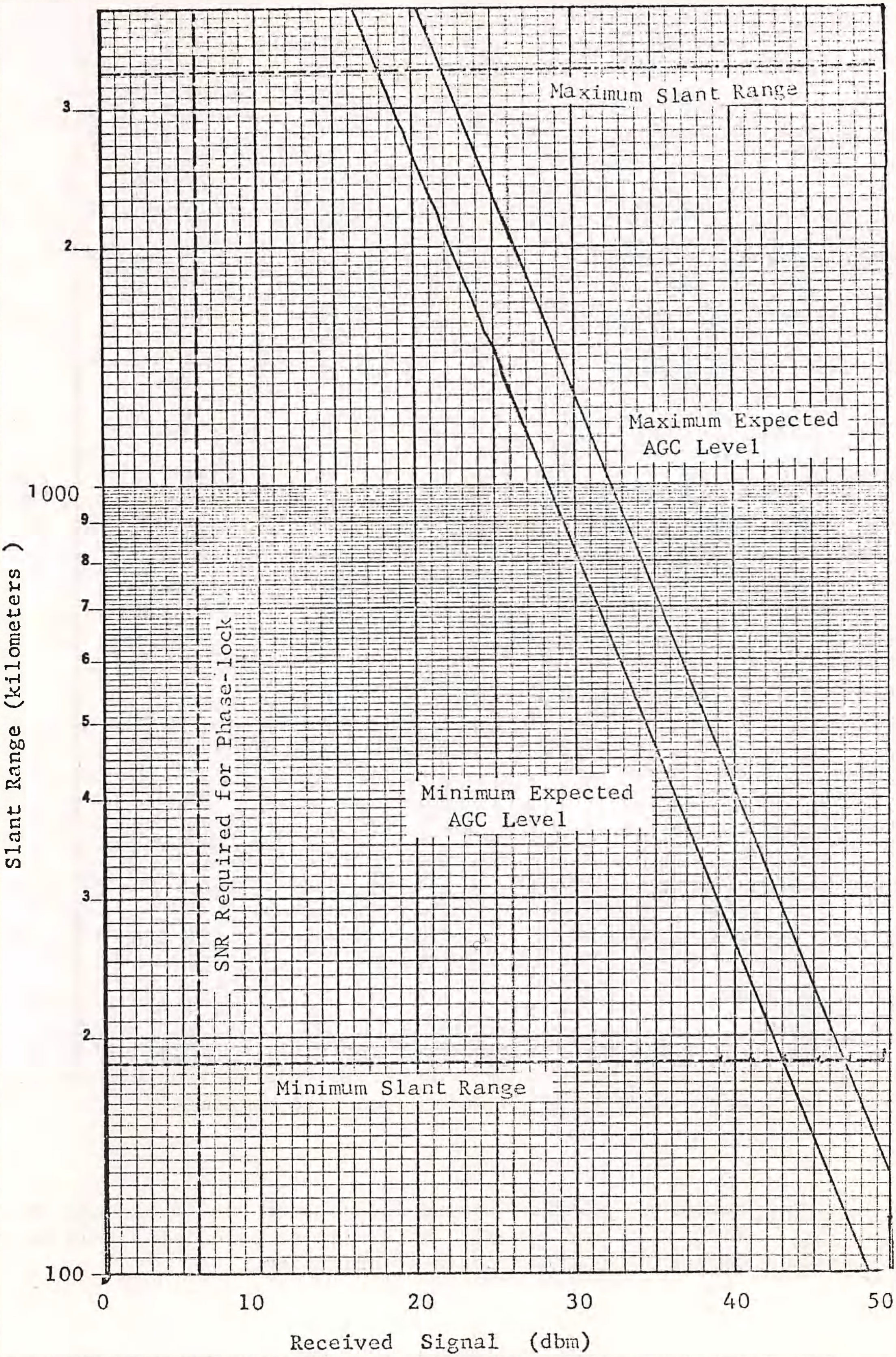


Figure 2. Received Signal Strength (Phase-lock-loop)

Table 3

Received Signal Strength, 9-Yagi Antenna System
(Diversity Polarization Telemetry Reception)

Parameter	Mean Values 3320 km (Max. Range)	Mean Values 165 km (Min. Range)	3 σ Deviation	Ref
Effective radiated sideband power	+ 21 dbm	+ 21 dbm	± 0 db	71
Free-space attenuation	-146 db	-121 db	± 0 db	71
Receiving antenna gain	+ 19 db	+ 19 db	± 0 db	32
Passive element losses	- 1 db	- 1 db	± 0 db	71
Maximum received signal level	-107 dbm	- 82 dbm	± 0 db	71
Expected null depth (due to antenna pattern nulls)	- 3 db	- 3 db	± 3 db	71
Expected null level (due to antenna pattern nulls).	-110 dbm	- 85 dbm	± 3 db	71
Received noise, 10 kHz bandwidth	-127 dbm	-127 dbm	± 3 db	71
Received SNR, optimum system	+ 17 db	+ 42 db	± 4 db	71
System operating margin	- 3 db	- 3 db	± 3 db	71
Received SNR, 10 kHz bandwidth	+ 14 db	+ 39 db	± 5 db	71
SNR required for good data	+ 12 db	+ 12 db	± 0 db	71
Signal margin, 10 kHz bandwidth	+ 2 db	+ 27 db	± 5 db	71

QUALIFICATIONS: Expected null depth values include polarization loss of 0 db.

CONCLUSIONS: No problems anticipated in the reception of telemetry data.

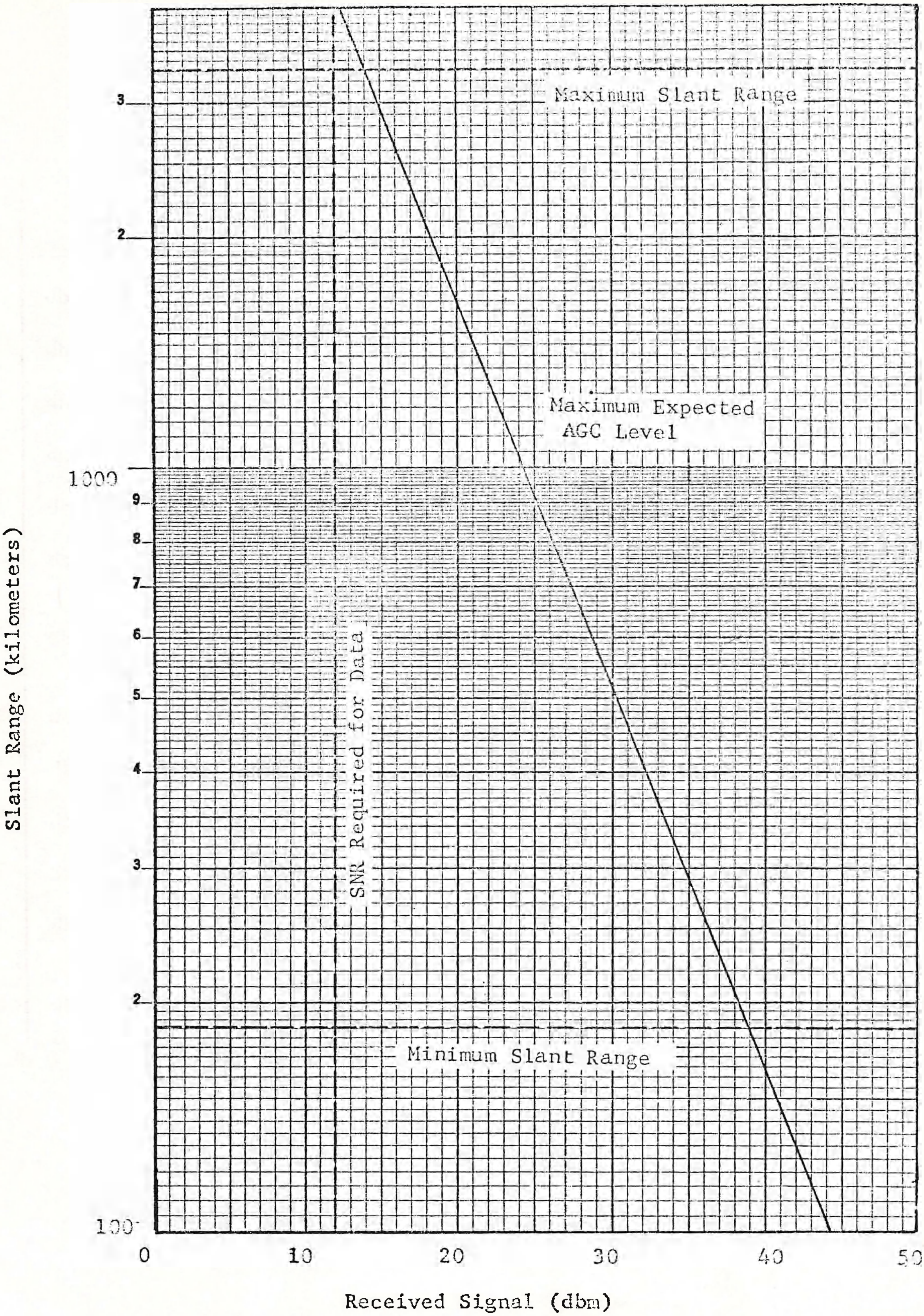


Figure 3. Received Signal Strength (Diversity Polarization Telemetry Reception)

APPENDIX B

WRESAT POTENTIAL FREQUENCY CONFLICTS

APPENDIX B

WRESAT POTENTIAL FREQUENCY CONFLICTS

B.1 INTRODUCTION

It is the purpose of this appendix to identify the spacecraft which are potential sources of radio-frequency interference to the WRESAT project.

The data presented in this appendix are obtained from records maintained by the Network Assurance Section and are periodically up-dated using the sources listed in the bibliography. As presented, the data represent the most current information available to the Network Assurance Section as of the date of this report, 17 October 1967.

B.2 POTENTIAL VHF TRACKING AND TELEMETRY FREQUENCY CONFLICTS

Table B-1 identifies the spacecraft which are potential sources of radio-frequency interference to the VHF tracking and telemetry frequency WRESAT. The following units of measurement are assumed for the data presented in these tables:

Frequency. MHz

Half-bandwidth (allotted and Doppler). . . . . kHz

Apogee . . . . kilometers

Perigee. kilometers

Inclination. . . . . degrees

Received signal strength . . . . dbm

The Mod/Mode column indicates the type of modulation and the mode of operation, as follows:

1 - normally on, not commandable off

2 - normally on, commandable off; STADAN supported

3 - normally off, commandable on; STADAN supported

4 - normally on, commandable off; not STADAN supported

5 - normally off, commandable on; not STADAN supported

6 - not radiating, not supported; still in orbit

In addition, the received signal strengths listed in Table B-1 are the signal strengths reported by the stations. In the cases where spacecraft have not been launched, the received signal strengths indicated have been calculated by the Network Assurance Section.

B.3 TENTATIVE LAUNCH SCHEDULE

Table B-2 lists the spacecraft keyed in prior tables as future launches, and gives the tentative launch dates for those spacecraft. The data in Table B-2 may change due to launch slippage, but represents the data available to the Network Assurance Section as of the date of this report, 17 October 1967.

Table B-1

Potential Tracking and Telemetry Frequency Conflicts, 136.350-MHz + 50-kHz

Code	Spacecraft	Freq.	½BW	Mod/Mode		Apogee	Perigee	Inc	Rcvd Sig Str
64762	INJUN-4	136.290	10	PCM/PM/AM	6	2490	531	81	-
X	INJUN-5	136.290	20	PCM/PM	2	3000	600	80	-080 to -127
67201	OSO-3	136.290	20	PCM/PM	3	562	535	33	-090 to -132
X	OSO-F	136.290	20	PCM/PM	3	550	550	33	-090 to -132
X	GEOS-B	136.320	5	CW	2	1480	1110	74	-102 to -120
X	TTS-A	136.320	7	PAM/FM/PM	2	·600	307	33	-082 to -121
64012	GG-1	136.320	10	FM/AM	6	933	911	70	-
X	GEOS-B	136.320	15	PM/FM	3	1430	1110	74	-102 to -120
66441	AE-B (X32)	136.320	20	PCM/PM	6	2650	265	65	-
X	RAE-A	136.350	15	PCM/PM	2	6000	6000	122	-110 to -126
X	RAE-B	136.350	15	PCM/PM	2	6000	6000	122	-110 to -126
651011	FR-1	136.350	20	FM/PM	6	760	747	76	-
X	WRESAT	136.350	35	PFM/PM	1	1300	185	80	-075 to -122
64511	IE-A (X20)	136.350	55	AM/FM	6	1020	870	80	-
X	OWL-B	136.380	5	CW	2	1110	1110	85	-112 to -122
67405	ERS-27	136.380	7	PAM/FM/PM	1	111000	8580	33	-120 to -164
65982	DME-A (X31)	136.380	20	PM/FM	3	2920	514	80	-090 to -108
X	ISIS-A	136.410	5	CW	2	3500	500	90	-087 to -152
65091	PEGASUS-1	136.410	20	FM/FM	3	709	495	32	-092 to -114
65391	PEGASUS-2	136.410	20	FM/FM	3	717	506	32	-091 to -120
65601	PEGASUS-3	136.410	20	FM/FM	3	512	491	29	-093 to -112

X Future launch; please see Table B-2

Table B-2

Tentative Launch Schedule

Spacecraft	Launch Date
INJUN-5	November 1967
WRESAT	4 December 1967
GEOS-B	12 December 1967
TTS-A	13 December 1967
RAE-A	15 February 1968
ISIS-A	September 1968
OSO-F	3Q68
OWL-B	3Q68
RAE-B	CY69

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