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Radio Science Handbook

Galileo Redshift Observations / USO Tests
Galileo Solar Wind Scintillation Experiment
Ulysses Solar Corona Experiment
Galileo Gravitational Wave Experiment

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1.0 Introduction

The Radio Science Handbook is an internal reference document prepared and used by the Radio Science Support Team (RSST) for planning, preparation, operations, and analysis of the activities listed on the cover page. It contains information, plans, strategies, and procedures to guide and assist the team members to achieve the goals identified for the activities being supported. It also contains descriptions of the various functions and roles, capabilities and facilities of the Radio Science Support Team.

This Handbook does not replace Flight Project or DSN documents and procedures. The Project Sequence of Events (and associated redlines) and the DSN's Network Operations Plan and Keyword File are intended to be the controlling documents for Radio Science activities.

Since the Voyager Neptune encounter operations plan, the following volumes of Radio Science Handbooks have been published by the RSST:

625-460 on February 1, 1990:
- Radio Science Operations Plan for the Ultrastable Oscillatory/Redshift Observations and Venus Range Fix Experiment

Volume 1 on 15 November 1990:
- Galileo Earth 1 Flyby/Mass Determination
- Ulysses First Opposition Test
- Galileo Redshift Observations/USO Tests

Volume 2 on 14 June 1991:
- Ulysses Solar Corona Experiment
- Galileo Redshift Observations/USO Tests

Volume 3 on 10 January 1992:
- Galileo Radio Scintillation Experiment
- Galileo Redshift Observations/USO Tests
- Ulysses Jupiter Encounter/IPTO Experiment
- Ulysses Gravitational Wave Experiment

Volume 4 on 22 January 1993:
- GLL/ULS/MO Joint Gravitational Wave Experiment
- Galileo Redshift Observations/USO Tests
- Mars Observer Cruise Tests

Volume 5 on 21 October 1994
- Galileo Redshift Observations/USO Tests
- Galileo Solar Wind Scintillation Experiment
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Experiments not addressed above will be included in future volumes of the Handbook.

1.1 Radio Science Master Schedule

The Radio Science Master Schedule, shown in Figures 1-1 and 1-2, is a schedule of the major Radio Science observation opportunities spanning the period from 1994 through 2009, and including Galileo, Ulysses, Mars Global Surveyor, and Cassini opportunities. The Master Schedule is used for reference during planning of future Radio Science activities and resource allocation within the support team. Also included are major events in development of the Deep Space Network (DSN) relevant to Radio Science.

1.2 The Radio Science Library

The following documents contain information relevant to the Radio Science activities of interest. These documents may be found in the Radio Science Library (264-325).

1.2.1 Project and DSN Interface Documents

Deep Space Network Operations Plan, Project Galileo, Document 870-7, Rev. C, August 15, 1990.

Deep Space Network/Flight Project Interface Design Handbook, Document 810-5, Rev. D, July 15 1988.

Deep Space Network Systems Requirements Detailed Interface Design, Document 820-13, Rev. A.

Radio Science Software and SPA Radio Science Software Specification Document, SSD1-DMO-5542-OP, Rev. B, Section 2, September 28, 1994.

DSS Subsystem Requirements, DSCC Radio Science Subsystem, Document 824-18, Rev. D, Section 2

DSN 34m Beam Waveguide Antenna Station System-Level Design Description Document, Document 831-7, July 1, 1994.

Galileo Science Requirements Document, PD 625-50, Rev D, Jan. 18, 1989.

Galileo Detailed Mission Requirements, Document 870-256, February 15, 1994. Supersedes Galileo SIRD, PD 625-501, Rev. A, May 1988.

Galileo Mission Operations System Functional Requirements, Radio Science System, No MOS-GLL-4-233A, Change 3, November 1, 1990.

Galileo Orbiter Functional Requirements Document, Telecommunications System, Document 625-205 GLL 3-300B May 9, 1989.

Ulysses Radio Science Requirements Document, ISPM-PI-2138, Issue 4, Updated for 1990 launch.

Ulysses SIRD, Document 628-6, Rev. A, June 12, 1990.

1.2.2 Recent Publications Relevant to the Science Experiments

Anderson, J.D., J.W. Armstrong, J.K. Campbell, F.B. Estabrook, T.P. Krisher, and E.L. Lau. "Gravitation and Celestial Mechanics Investigations with Galileo", *Space Science Reviews*, Vol. 60, pp. 591-610, May 1992.

Armstrong, J. W. "Spacecraft Gravitational Wave Experiments," *Gravitational Wave Data Analysis*, B. F. Schutz, ed., pp. 153-172, 1989.

Asmar, S. W., P. Eshe, D. Morabito. "Evaluation of Radio Science Instrument: A Preliminary Report on the USO Performance", JPL IOM 3394-90-061, August 10, 1990.

Asmar, S. W. and N. A. Renzetti. *The Deep Space Network as an Instrument for Radio Science Research*, JPL Publication 80-93, Rev. 1, April 15, 1993.

Bertotti, B., R. Ambrosini, S. W. Asmar, J. P. Brenkle, G. Comoretto, G. Giampieri, L. Iess, A. Messeri, H. D. Wahlquist. "The Gravitational Wave Experiment," *Astronomy and Astrophysics*, Suppl. Ser. 1, January 1992.

Berotti, B., "The Search for Gravitational Waves with ISPM," in *The International Solar Polar Mission - Its Scientific Investigation*, K. P. Wenzel, R. G. Mardsen and B. Battrick, eds., ESA SP-1050, 1983.

Bird, M.K., S. W. Asmar, J.P. Brenkle, P. Edenhofer, O. Funke, M. Patzold, and H. Volland. "Ulysses Radio Occultation Observations of the Io Plasma Torus During the Jupiter Encounter", *Science*, Vol. 257, pp. 1531-1535, September 11, 1992.

Bird, M. K., S. W. Asmar, J. P. Brenkle, P. Edenhofer, M. Patzold, and H. Volland. "The Coronal-Sounding Experiment," *Astronomy and Astrophyiscs*, Suppl. Ser. 1, January 1992.

Howard, H.T., V.R. Eshleman, D.P. Hinson, A.J. Kliore, G.F. Lindal, R. Woo, M.K. Bird, H. Volland, P. Edenhofer, M. Patzold, and H. Porsche. "Galileo Radio Science Investigations", *Space Science Review*, Vol. 60, pp. 565-590, May 1992.

Krisher, T. P., J. D. Anderson, J. K. Campbell. "Test of the Gravitational Redshift Effects at Saturn", *Physical Review Letters*, Vol. 64 No. 12, March 19, 1990.

Krisher, Timothy P., David D. Morabito, John D. Anderson. "The Galileo Solar Redshift Experiment", *Physical Review Letters* , 1993.

Thorne, K. S. "Gravitational Radiation," in *Three Hundred Years of Gravitation*, S. W. Hawking and W. Israel, eds., Cambridge University Press, 1987.

Tyler, G. Leonard, Georges Balmino, David P. Hinson, William L. Sjogren, David E. Smith, Richard Woo, Sami W. Asmar, Michael J. Connally, Carole L. Hamilton, and Richard A. Simpson. "Radio Science Investigations with Mars Observer", *Journal of Geophysical Research*, Vol. 97, No. E5, pp. 7759-7779, May 25, 1992.

Woo, R. "A Synoptic Study of Doppler Scintillation Transients in the Solar Wind," *Journal of Geophysical Research*, Vol. 93, No. A5, pp. 3919-3926, May 1, 1988.

Anticipated Radio Science Activities 1994 - 1997

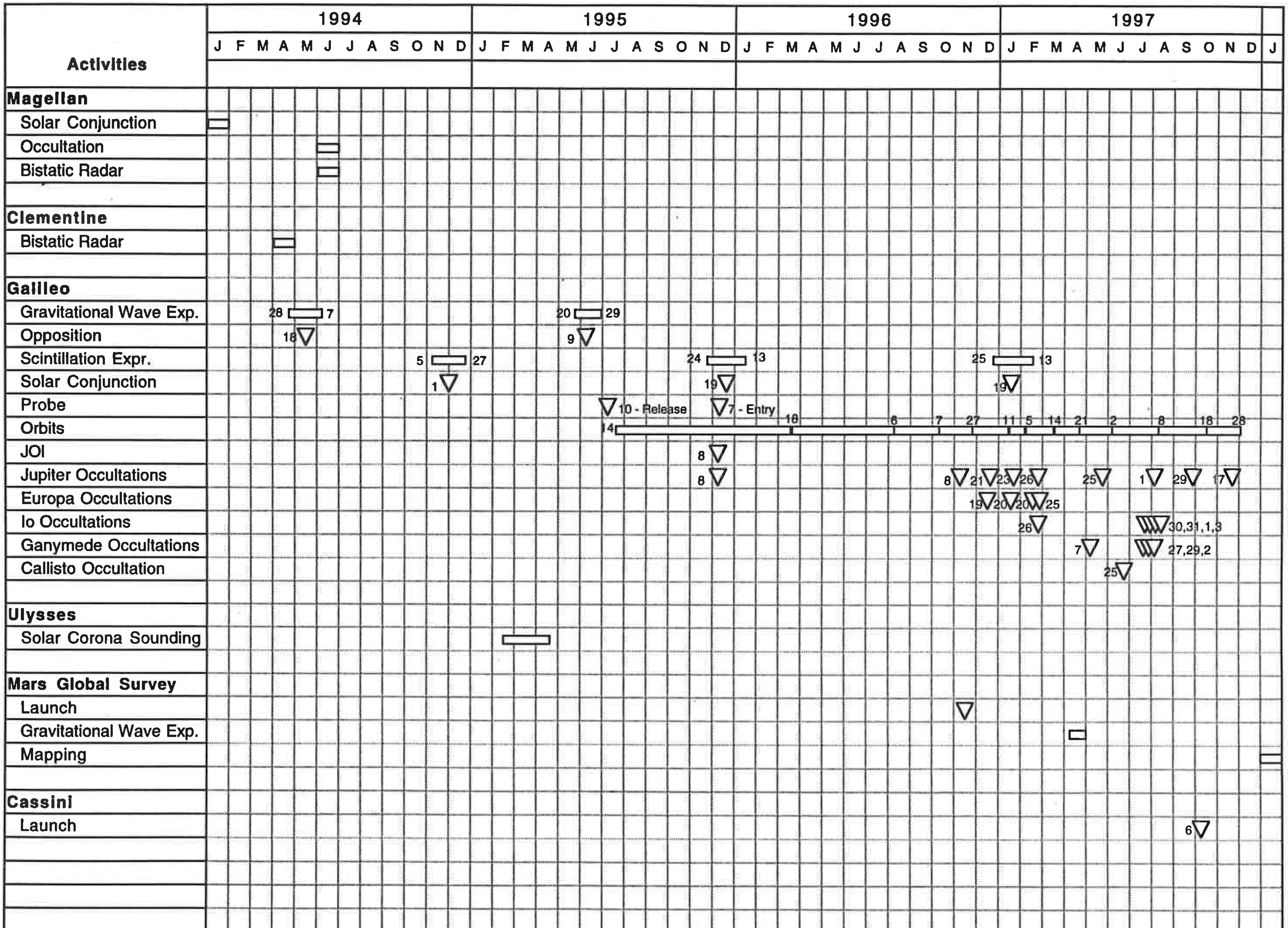


Figure 1-1. Radio Science Master Schedule 1994 - 1997

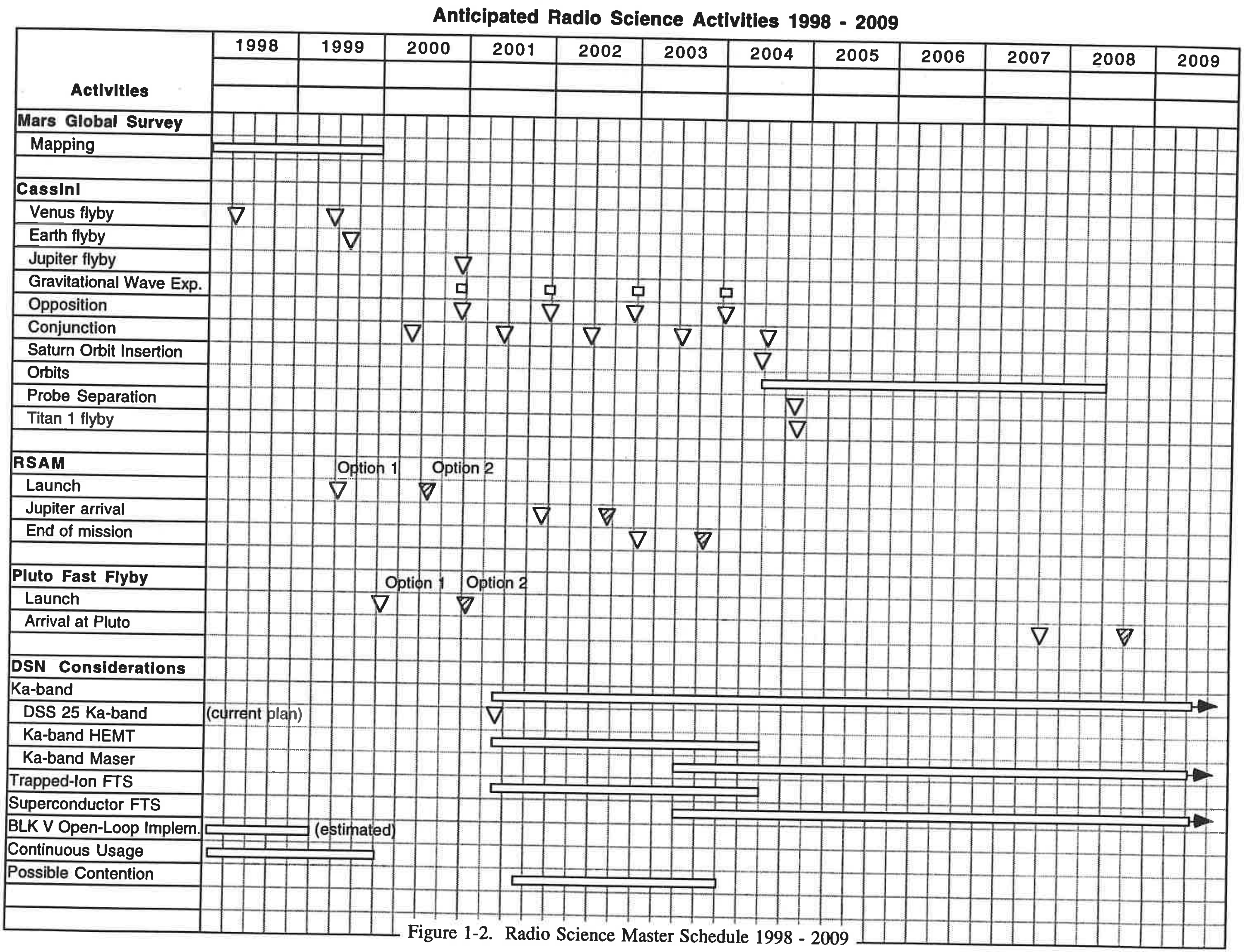


Figure 1-2. Radio Science Master Schedule 1998 - 2009

Section 2
Observation Description

2.0 Introduction

Radio Science investigators examine small changes in the phase, amplitude, and/or polarization of the radio signal propagating from a spacecraft to an Earth receiving station in order to study the atmospheric and ionospheric structure of planets and satellites, planetary gravitational fields, shapes, and masses, planetary rings, ephemerides of planets, solar plasma and magnetic fields, and aspects of the theory of general relativity like gravitational waves, gravitational redshift, etc.

Section 1 includes a list of recent journal publications relevant to these experiments.

The Radio Science experiments described below have been implemented, are in progress, or are planned for the near future for the Galileo and Ulysses projects. Mars Global Surveyor and Cassini Radio Science experiments will be described in future volumes of this document. Section 4 lists investigators involved in these experiments. **This section was prepared with assistance from Drs. J. Armstrong, M. Bird, T. Krisher, and R. Woo.**

For quick reference, Appendix A shows the exact schedule of tracking times for the experiments listed on the cover.

2.1 Galileo Redshift Observations & USO Tests

The Redshift Observations are performed to measure the frequency shift caused by the motion of the spacecraft as it moves in and out of the solar (or planetary) gravitational field. One of the four predicted effects of Einstein's theory of General Relativity is the change of a clock rate (an oscillator frequency) in a varying gravitational potential. The Galileo Ultra Stable Oscillator (USO) is the signal source for these observations and has sufficient inherent stability to allow detection of this phenomenon. The Galileo VEEGA trajectory provides a unique opportunity to detect the USO frequency shift as it flies through the changing solar and planetary gravitational fields.

The objectives of the Redshift Observations and USO tests are:

1. Make a direct scientific measurement of the redshift phenomenon described above.

2. Make engineering measurements of the USO frequency and frequency stability for calibration of the Radio Science instrument.

3. Exercise the operational aspects of the Radio Science system in the Project and at the Deep Space Network.

4. Train the Project (including the Radio Science Support Team) and the DSN in the operations required in preparation for the Jupiter Encounter.

5. Exercise the Radio Science software and analysis tools.

Prior to the observations, the orbiter will be commanded to use the USO as the frequency reference for the downlink radio signal for a period of about two hours. The frequency and frequency stability of the carrier will be estimated. When the data are received by the RSST, either in the form of tracking ATDFs and, for some passes, open-loop ODRs, they will then be processed to produce frequency residuals. From these, phase noise and frequency stability (Allan variance) can be determined.

2.2 *Galileo Solar Wind Scintillation Experiment*

Although the most interesting region of the solar wind is that surrounding the Sun, it has not yet been observed directly by spacecraft measurements. Until missions such as Solar Probe are flown, we must rely on remote sensing techniques with planetary spacecraft such as Galileo to probe the inner heliosphere. Radio scintillation and scattering measurements conducted during the Galileo superior conjunctions represent a powerful and essentially only tool for studying the complicated solar wind structure near the Sun.

The Galileo solar wind radio scintillation experiment is based on observations of radio scattering phenomena that arise from the propagation of radio waves through the turbulent plasma of the solar wind. These consist of Doppler and amplitude scintillations (fluctuations), as well as broadening of Galileo's monochromatic S-band signal (spectral broadening). Characteristics of these phenomena and the deduced solar wind structure are obtained from the processing of wideband DSP recordings of the Galileo radio signal. Successful DSP recordings are, therefore, important to the scintillation experiment.

Interplanetary disturbances, which are manifested as transients in the scintillation and spectral broadening measurements, are of particular interest in the Galileo experiment. Correlations with events observed on the Sun (e.g., flares) and at spacecraft located near 1 AU (e.g., Yohkoh) will be made. These correlative studies are clearly most effective if continuous radio scintillation data are available. For this reason, prolonged periods of near-continuous tracking of Galileo have been arranged. During the approximately ±1 month period surrounding superior conjunction, the Galileo radio signal will be probing the solar within about 0.3 AU of the Sun.

2.3 *Ulysses Solar Corona Experiment*

The Ulysses Solar Corona Experiment (SCE), conducted during the solar conjunctions, performs coronal-sounding measurements. The SCE utilizes dual frequency (S- and X-bands) Doppler and range data to determine the density, velocity, and turbulence spectrum of the Sun's atmosphere to distances well below 10 solar radii. Radio-sounding observations are sensitive to plasma parameters in the main acceleration regime of the solar wind.

The Doppler and ranging data will be used to drive the three dimensional distribution of the coronal electron density. The large scale structure can be inferred from the total electron content obtained from the dual frequency ranging. The dual-frequency Doppler is more sensitive to relative changes in the electron content. The dual-frequency Doppler data will also be used to characterize the level and spectral index of coronal turbulence. Another plasma parameter obtained from radio sounding is the velocity. The most reliable measurements of this type are obtained from cross correlation of radio scintillation using multiple signal ray paths. It is anticipated that the interplanetary vestiges of a coronal mass ejection will be occasionally detected as significant perturbation in the ranging and Doppler data.

2.4 Galileo Gravitational Wave Experiment

The Galileo Gravitational Wave Experiment is an effort to search for low-frequency gravitational waves generated by massive astrophysical systems. Gravitational waves--waves of space-time curvature--are transverse, carry energy and momentum, and propagate from their sources at the speed of light. The strength of the waves is characterized by the strain amplitude, h, which measures the fractional change in the separation of test masses and the fractional change at which separated clocks keep time. In a spacecraft gravitational wave experiment, the earth and a distant spacecraft act as separated test masses, with the transponded 2- or 3-way Doppler signal continuously measuring the relative dimensionless velocity $\Delta v/c$ between the Earth and the spacecraft. The metric perturbation due to the gravity wave, h, produces a signature in the Doppler time series that is of order h in $\Delta f/f_0$ and is replicated three times in the Doppler time series: once when the wave "shakes" the Earth, once when the wave shakes the spacecraft (suitably delayed by a one-way light time) and once when the initial shaking of the earth is transponded back to the earth a two-way light time later. This three pulse response is crucial in discrimination of gravitational waves from a noise background.

The Gravitational Wave Experiment will be most sensitive to waves having periods ~100-1000 seconds. Waves with these periods are generated by supermassive astrophysical systems undergoing violent dynamics. Searches will be made for gravitational waves of differing temporal character: bursts (e.g., produced during formation, collision, and coalescence of supermassive black holes), periodic waves (e.g., produced by black holes orbiting each other) and stochastic waves (e.g., produced at the Big Bang). Hybrids in this classification scheme (e.g. chirp waves from coalescing binaries) are also possible signals and the experiment will include processing for these signals.

During the gravitational wave experiment, care must be taken to maximize sensitivity. This leads to the following general requirements:

1. To the extent practical, observations should be done in the antisolar direction in order to minimize solar wind phase scintillation noise.

2. Tracking should be done with the highest radio frequencies possible, again to minimize solar wind scintillation noise.

3. Tracking should be done in the two- and three-way coherent modes.

4. Stations should be configured for maximum Doppler stability.

5. Tracking should be done during the highest elevation angles possible at each station.

6. Data should be taken using both the closed and open loop receivers with the Doppler sample rate set to be as large as is practical to minimize aliasing of thermal noise into the digital band.

7. Where practical, an independent assessment of station stability as well as the tropospheric and ionospheric noise should be done.

8. The spacecraft should be in quiet, minimum-dynamics modes.

9. Engineering telemetry from the spacecraft, logs of station and spacecraft events, etc. should be gathered to create a master file of "veto signals".

10. "Calibration signals" (electronically or mechanically introduced) should be injected to verify end-to-end sensitivity of the experiment prior to the beginning of the experiment.

Section 3
Instrument Description and Configuration

3.0 Introduction

This section describes the instrumentation used in support of the Radio Science activities. The Radio Science instrument is distributed between the spacecraft and the Ground Data System (GDS). The latter includes several subsystems at the Deep Space Communication Complexes (DSCCs) as well as several facilities at JPL used for Radio Science communications and data monitoring.

3.1 The Spacecraft

3.1.1 The Galileo Spacecraft

The Galileo spacecraft is shown in Figure 3-1. The Galileo telecommunications subsystem is shown in Figure 3-2. It handles three types of data: command, telemetry, and radiometric. The latter provides the capability to navigate the orbiter as well as to perform Radio Science observations. The subsystem is equipped with two redundant transponders with dual frequency (S- and X-bands) uplink and downlink capabilities. This means that the spacecraft can have the following combinations of uplink/downlink: S/S, X/X, S/X&S.

The subsystem may be operated in the coherent mode (i.e., the downlink signal is referenced to the uplink signal) or the non-coherent mode (i.e., an ultrastable oscillator (USO) onboard the spacecraft provides the downlink signal reference). In the absence of an uplink signal, the subsystem will switch to the one-way mode automatically. The spacecraft can also be commanded to a specific mode (TWNC ON or OFF) and/or to one of the following states: spacecraft modulated telemetry alone, ranging alone, spacecraft telemetry and ranging, or carrier alone. A tape recorder onboard the spacecraft will store data for playback at a later time during periods when no ground station coverage is available.

The HGA is aligned with the spin axis of the spacecraft and is pointed at the Earth by the attitude control system. Low Gain Antenna 1 (LGA-1) is located at the end of the HGA feed and is thus aligned with the spin axis. Low Gain antenna 2 (LGA-2) is located at the end of a boom as shown in Figure 3-1. When the signal is transmitted through LGA-2, a sinusoidal signature in the received Doppler is induced since the spacecraft is spinning with the antenna being located 3.58 meters off the spin axis. S-band on the HGA is linearly polarized whereas X-band is RCP; both LGA's transmit RCP.

The spacecraft was launched (10/89) with the HGA in the stowed position. The planned deployment date was April 1991; it was unsuccessful at that time and the Project has been attempting various maneuvers to open the antenna. On March 1, 1993, the Project will announce its plans for the planning of the remainder of the cruise and the orbital phases of the mission.

3.1.2 *The Ulysses Spacecraft*

The Ulysses spacecraft is shown in Figure 3-3. Figure 3-4 shows the radio frequency system of the Ulysses spacecraft. The system includes two S-band low gain antennas (LGA) for near-Earth communications and an S- and X-band high gain parabolic antenna (HGA) for deep space communications. The antennas are coupled to two redundant transponders, each housing a 5 W S-band power amplifier and an X-band exciter. The 20 W X-band output is produced by one of the two redundant TWTAs. The system has a considerable amount of cross-coupling. Each receiver may drive either, or both, modulators. Each X-band exciter may drive either of the two TWTAs. The output of the modulator is switched to drive either the S-band power amplifier or the X-band exciter, but not both. For modes where simultaneous S- and X-band downlinks are required, a chosen receiver drives the modulators of both transponders. One transponder then drives the S-band power amplifier and the other transponder drives the X-band exciter and a TWTA.

The transponders function in one of two modes: the coherent mode, in which the downlink signal is referenced to the uplink signal, and the non-coherent mode, where a free-running oscillator onboard the spacecraft provides the downlink signal reference. Commands to the spacecraft determine the selection of one of the following: spacecraft modulated telemetry alone, ranging alone, spacecraft telemetry and ranging, or carrier alone. Simultaneous ranging and commanding is not an operational mode of the Ulysses spacecraft. A tape recorder onboard the spacecraft will store telemetry data during periods when no ground station coverage is available for playback at a later time.

The HGA is aligned with the spin axis of the spacecraft and is pointed to Earth by control of the spin axis in inertial space. Typically, a daily attitude maneuver is performed. To perform this control, one reference is given by a sun-sensor while the other is given from CONSCAN processing of the uplink radio signal from Earth. For this reason, the S-band feed of the antenna is slightly offset from the spin axis. There is a minimum limit on the sun-probe-earth angle that can be tolerated thus forcing operational strategies for attitude control during conjunctions and oppositions.

For the Radio Science experiments, the radio system will be configured in the two-way coherent mode and both the S-band and X-band links will be activated simultaneously (thermal limitations on-board the spacecraft may operationally prevent activating dual links at certain times). In this configuration, both transponders receive the same S-band uplink signal which is referenced to a highly stable Hydrogen maser frequency standard at the DSS, and transmit coherent S-band and X-band downlink signals.

The dual frequency coherent link is used by the experimenters to measure the differential range and Doppler to determine the total electron content along the spacecraft to Earth line of sight. The data are also used to measure the rate of change of the total electron content in the interplanetary and ionospheric plasma to correct the Doppler for these effects.

3.2 *The Ground Data System*

3.2.1 *The Deep Space Network*

The Deep Space Communication Complexes (DSCCs) are an integral part of the Radio Science instrument, along with the other receiving stations and the spacecraft's Radio Frequency Subsystem. Their system performance directly determines the degree of success of the Radio Science investigations and their system calibration determines the degree of accuracy in the results of the experiments. The following paragraphs describe those functions performed by the individual subsystems of a DSCC. Figures 3-5 through 3-10 show the various systems relevant to the Radio Science activities.

3.2.1.1 *DSCC Monitor and Control Subsystem*

The DSCC Monitor and Control Subsystem (DMC) is part of the Monitor and Control System (MON) which also includes the ground communications Central Communications Terminal and the Network Operations Control Center (NOCC) Monitor and Control Subsystem. The DMC is the center of activity at a DSCC. The DMC receives and archives most of the information from the NOCC needed by the various DSCC subsystems during their operation. Control of most of the DSCC subsystems as well as the handling and displaying of any responses to control directives and configuration and status information received from each of the subsystems is done through the DMC. The effect of this is to centralize the control, display and archiving functions necessary to operate a DSCC. Communication between the various subsystems is done using a Local Area Network (LAN) hooked up to each subsystem via a Network Interface Unit (NIU).

The DMC operations are divided into two separate areas: the Complex Monitor and Control (CMC) and the Link Monitor and Control (LMC). The primary purpose of the CMC processor for Radio Science support is to receive and store all predict sets transmitted from NOCC such as Radio Science, antenna pointing, tracking, receiver, and uplink predict sets and then, at a later time, distribute them to the appropriate subsystems via the LAN. Those predict sets can be stored in the CMC for a maximum period of three days under normal conditions. The CMC also receives, processes and displays event/alarm messages and maintains an operator log and produces tape labels for the DSP. Assignment and configuration of the LMCs is done through the CMC and to a limited degree the CMC can perform some of the functions performed by a LMC. There is one on-line CMC, one backup CMC, and three LMCs at each DSCC. The backup CMC can function as an additional LMC if necessary.

The LMC processor provides the operator interface for monitor and control of a link which is a group of equipment required to support a spacecraft pass. For Radio Science, a link might include the DSCC Spectrum Processing Subsystem (DSP) (which, in turn, can control the SSI), or the Tracking Subsystem. The LMC also maintains an operator log which includes the operator directives and subsystem responses. One important Radio Science specific function which the LMC performs is receipt and transmission of the system temperature and signal level data from the PPM for display at the LMC console as well as placing this information in the Monitor 5-9 blocks. These blocks are recorded on magnetic tape as well as displayed in the

MCCC displays. The LMC is required to operate without interruption for the duration of the Radio Science data acquisition period.

The Station Communication Processor (SCP), which is part of the Digital Communications Subsystem, controls all data communication between the stations and JPL. The SCP receives all required data and status messages from the LMC/CMC and can record them to tape as well as transmit them to JPL via the data lines. The SCP also receives predicts and other data from JPL and passes them on to the CMC.

3.2.1.2 DSCC Antenna Mechanical Subsystem

The multi-mission Radio Science activities require support from the 70-m, the 34-m HEF, and the 34-m STD antenna subnets. The antenna at each DSCC will function as a large aperture collector which, by double reflection, causes the incoming RF energy to enter the feed horns. The large collecting surface of the antenna focuses the incoming energy onto a subreflector, which is adjustable in the axial and angular positions. These adjustments are made to optimize the channeling of energy from the primary reflector to the subreflector and then to the feedhorns. The 70-m and 34-m HEF antennas have "shaped" primary and secondary reflectors, whose forms are that of a modified paraboloid. This customization allows more uniform illumination of one reflector by the other. Conversely, the 34-m STD primary reflectors are classical paraboloids, while the subreflectors are similarly standard hyperboloids.

On the 70-m and 34-m STD antennas, the subreflector reflects the received energy from the antenna onto the dichroic plate, a device which reflects S-band energy to the S-band feedhorn and passes X-band energy through to the X-band feedhorn. In the 34-m HEF, there is one "common aperture feed", which accepts both frequencies, and therefore no plate. RF energy to be transmitted into space by the horns is focused by reflectors into narrow cylindrical beams, pointed with high precision (either to the dichroic plate or directly to the subreflector) by a series of drive motors and gear trains that can rotate the movable components and their support structures.

The different antennas can be pointed by several common means. Two pointing modes commonly used during a tracking pass are 1) CONSCAN on, or 2) CONSCAN off (blind pointing). With CONSCAN on, once the closed-loop receiver has acquired a signal from the spacecraft to provide feedback, the radio source is tracked by conically scanning around it. Pointing angle adjustments are computed from signal strength information supplied by the receiver. In this mode, the Antenna Pointing Assembly (APA) generates a circular scan pattern which is sent to the Antenna Control Subsystem (ACS). The ACS adds the scan pattern to the corrected pointing angle predicts. Software in the receiver-exciter controller computes the received signal level and sends it to the APA. The correlation of the scan position of the antenna with the received signal level variations allows the APA to compute offset changes which are sent to the ACS. Thus, within the capability of the closed-loop control system, the scan center is pointed precisely at the apparent direction of the spacecraft signal. An additional function of the APA is to provide antenna position angles and residuals, antenna control mode/status information and predict-correction parameters to the Station Communication Processor (SCP) via the LAN, which then sends this information to JPL via the GCF for antenna status monitoring.

However, during periods when excessive signal level dynamics or low received signal levels are expected (e.g., in an occultation experiment), CONSCAN cannot be used. Under these conditions, blind pointing (CONSCAN off) is used, and pointing angle adjustments rely on a predetermined Systematic Error Correction (SEC) model.

Independent of the CONSCAN state, subreflector motion in at least the z-axis may introduce phase variations in the received Radio Science data. For that reason, during certain experiments, the subreflector in the 70-m and 34-m HEFs may be frozen in the z-axis at an elevation angle selected to minimize the phase change and signal degradation. This can be done via operator OCIs from the LMC to the Subreflector Controller (SRC) which resides in the alidade room of the antennas. The SRC passes the commands to motors that drive the subreflector to the desired position. Unlike the two antennas mentioned above, the 34-m STD is not an Az-El pointed antenna, but a HA-DEC antenna. The same positioning of the subreflector of the 34-m STD does not create the same effect as for the 70-m and 34-m HEF.

Pointing angles for all three antenna types are computed by the NSS from an ephemeris provided by the Project and converted into antenna pointing predicts for each station. These predicts are received and archived by the CMC. Before each track, they are transferred to the APA, which transforms the direction cosines of the predicts into Az-El coordinates for the 70-m and 34-m HEF, and into HA-DEC coordinates for the 34-m STD. The LMC operator then downloads the antenna Az-El or HA-DEC (respectively) predict points to the antenna-mounted ACS computer along with a selected pointing SEC model. The pointing predicts consist of time-tagged Az-El or HA-DEC points at selected time intervals, and also include polynomial coefficients for interpolation between the points.

The ACS automatically interpolates the predict points, corrects the pointing predicts for refraction and subreflector position, and adds the proper systematic error correction and any manually entered antenna offsets. The ACS then sends angular position commands for each axis at the rate of once per second. In the 70-m and 34-m HEF, rate commands are generated from the position commands at the servo controller and are subsequently used to steer the antenna. In the 34-m STD, motors, not servos, are used to steer the antenna, so there is no feedback once the antenna has been told where to point.

When not using binary predicts (the routine mode for spacecraft tracking), the antennas can be pointed using planetary mode, a simpler mode which uses right ascension (RA) and declination (DEC) values. These change very slowly with respect to the celestial frame. Values are provided to the station in text form for manual entry. The ACS quadratically interpolates between three RA and DEC points which are on one-day centers. Other than predict and planetary, a third mode, sidereal, is available and is usually used to track radio sources fixed with respect to the celestial frame as in radio astronomy applications.

Regardless of the mode being used to track a spacecraft, a 70-m antenna has a special, high-accuracy pointing capability called Precision mode. A pointing control loop derives the main Az-El pointing servo drive error signals from a two-axis autocollimator mounted on the Intermediate Reference Structure. The autocollimator projects a light beam to a precision mirror mounted on the Master Equatorial drive system, a much smaller structure, independent of the main antenna, which is exactly positioned in HA and DEC with shaft encoders. The autocollimator detects elevation/cross-elevation errors between the two reference surfaces by measuring the angular displacement of the reflected light beam. This error is compensated for in the antenna servo by moving the antenna in the appropriate (Az-El) direction.

If not using the optical link Precision mode, a less accurate computer mode can be used where the servo utilizes the Az-El axis encoder readout for positioning, as done in the 34-m HEF.

From 1994 to 1996, four new 34-meter beam waveguide (BWG) antennas will be implemented in the DSN. These 34-meter beam waveguide antennas will use beam waveguides to channel the RF energy collected by the reflector dish to the feedhorn located in the pedestal of the antenna. Figures 3-9a and 3-9b show the34-m BWG block diagram and station respectively.

Three antennas (DSS 24, 25, and 26) will be implemented at Goldstone, Ca. The expected completion year for DSS 24 is 1994, and 1996 for DSS 25 and DSS 26. Initially, these antennas will be equipped with electronics to provide telemetry, tracking, and command services for deep space missions. Radio Science and VLBI functions will be implemented in the future.

These antenna will perform both uplink and downlink functions. In the uplink process, the amplified carrier signals modulated with command and ranging signals are sent to the spacecraft. The downlink process enables acquisition of signals from the spacecraft, which are then downconverted from RF to IF, and routed back to the SPC over a fiber-optic link. The signals are then demodulated in the receiver and decoded. The carrier frequencies and phase are measured in the receiver for Doppler tracking. Ranging modulation is demodulated in the receiver and correlated in the ranging processor to generate range delay for navigation use.

The components of the BWG structure are located in the pedestal room, and are therefore more accessible than those of non-beam waveguide antennas which are mounted inside the antenna dish. The BWG antenna also incorporates a new mechanism for subreflector positioning which uses a two-axis servomotor that allows movement in both horizontal and vertical directions.

The RS software currently in use cannot generate DSS 24 data blocks, however, the RS equipment is capable of receiving and recording BWG IF channels (S- and X-band only) if the receiver is manually connected to the BWG channels via the IF Distribution Assembly, and a suitable front end alias is provided to the software.

3.2.1.3 DSCC Antenna Microwave Subsystem

3.2.1.3.1 70-m Antennas

Each 70-m station has three feed cones installed on a structure at the center of the main reflector. The feeds are positioned 120 degrees apart on a circle. Selection of the feed is made by rotation of the subreflector. A dichroic mirror assembly, half on the S-band cone and half on the X-band cone, permit simultaneous use of the S- and X-band frequencies. The third cone is devoted to R&D and more specialized work.

The Antenna Microwave Subsystem (AMS) accepts the received S- and X- band signals at the feedhorn and transmits them through the polarizer plates to the orthomode transducer. The polarizer plates are adjusted so that the signals are directed to either of a set of redundant amplifiers for each frequency. For X-band, these amplifiers are Block IIA X-band Traveling Wave Masers (TWMs), and for S-band there are two Block IVA S-band TWMs.

3.2.1.3.2 34-m STD Antennas

These antennas have two feed horns, for S- and X-band energy, respectively. These horns are mounted on a cone which is fixed in relation to the subreflector. A dichroic plate mounted above the horns directs energy from the subreflector into the proper horn.

The AMS directs the received S- and X-band signals through the polarizer plates and on to amplification. There are two Block III S-band TWMs and two Block I X-band TWMs.

3.2.1.3.3 34-m HEF Antennas

Unlike the other antennas, the 34-m HEF uses a single feed horn for both X- and S-band. Simultaneous S- and X-band receive, as well as X-band transmit, is possible however, due to the presence of an S/X "combiner", which acts as a diplexer. As in the general case, the next component in the AMS on the X-band path is a polarizer, and then the orthomode transducer; for S-band, RCP or LCP is user selected through a switch, and not simultaneous, so neither device is present. X-band amplification can be selected from one of two Block II X-band TWMs or from a single X-band HEMT Low Noise Amplifier (LNA). S-band amplification is provided by one FET LNA.

3.2.1.3.4 34-m Beam Waveguide Antennas

The Antenna Microwave Subsystem (UWV) feedhorns transform free-space waves to guided waves and vice versa. The primary downlink function of the UWV provides low noise amplification via the TWM or cryogenically cooled HEMT at X-band and cryohemt at S-band. Each band has one output to the Block V Downconverter Assembly. For the S-band uplink, the amplified RF energy from the Exciter-Transmitter Subsystem ETX) is coupled into the UWV via a diplexer. The signal is then routed through the S-band feedhorn to the antenna.

3.2.1.4 DSCC Receiver-Exciter Subsystem

The Receiver-Exciter Subsystem is composed of three groups of equipment: the closed-loop receiver group, the open-loop receiver group, and the RF monitor group. This subsystem is controlled by the Receiver-Exciter Controller (REC) which communicates directly with the DMC for predicts and OCI reception and status reporting.

The exciter generates the S-band signal, (or X-band signal for 34-m HEF only), which is provided to the Transmitter Subsystem for the spacecraft uplink signal. It is tunable under the command of the Digitally Controlled Oscillator (DCO) which receives predicts from the Metric Data Assembly (MDA).

The diplexer in the signal paths between the transmitters and the feed horns for all three antennas (used for simultaneous transmission and reception) may be configured such that it is out of the received signal path (in listen-only or bypass mode) in order to improve the signal-to-noise ratio in the receiver system.

3.2.1.4.1 Closed-Loop Receivers

The Block IV receiver-exciter at the 70-m stations allows for two receiver channels, each capable of L-band, S-band or X-band reception, and an S-band exciter for generation of uplink signals through the low-power or high-power transmitter. The Block III receiver-exciter at the 34-m STD stations allows for two receiver channels, each capable of S-band or X-band reception and an exciter used to generate an uplink signal through the low-power transmitter. The receiver-exciter at the 34-m HEF stations allows for one channel only.

The closed-loop receivers provide the capability for rapid acquisition of a spacecraft signal and telemetry lockup. In order to accomplish acquisition within a short time, the receivers are predict driven to automatically search for, acquire, and track the downlink. Rapid acquisition precludes manual tuning even though the latter remains as a backup capability. The subsystem utilizes FFT analyzers for rapid acquisition. The predicts are NSS generated, transmitted to the CMC which sends them to the Receiver-Exciter Subsystem where two sets can be stored. The receiver starts acquisition at uplink time plus one round-trip-light-time or at operator specified times. In addition, the receivers can be operated from the LMC without a local operator attending them. The receivers send performance and status data, displays, and event messages to the LMC.

Either the exciter synthesizer signal or the SIM synthesizer signal is used as the reference for the Doppler extractor, depending on the spacecraft being tracked (and Project guidelines). The SIM synthesizer is not ramped; instead, it uses one constant frequency, the Track Synthesizer Frequency (TSF), which is an average frequency for the entire pass.

The closed-loop receiver AGC loop can be configured to one of three settings; narrow, medium or wide. It will be configured such that the expected amplitude changes are accommodated with minimum distortion. The loop bandwidth (2BLo) will be configured such that the expected phase changes can be accommodated while maintaining the best possible loop SNR.

3.2.1.4.2 Radio Science Open-Loop Receiver

The Radio Science Open-Loop Receiver (OLR) is a dedicated four channel, narrow-band receiver which provides amplified and downconverted video band signals to the DSCC Spectrum Processing Subsystem (DSP). The Radio Science open-loop receiving system and RIV are shown in figures 2a, 2b and 3 of appendix B.

The OLR utilizes a fixed first Local Oscillator (LO) frequency and a tunable second LO frequency to minimize phase noise and improve frequency stability. The OLR consists of an RF-to-IF downconverter located in the antenna, an IF selection switch (IVC), and a Radio Science

IF-VF downconverter (RIV) located in the SPC. The RF-IF in the 70-m antenna are equipped for four IF channels: XRCP, SRCP, XLCP, and SLCP. The 34-m HEF stations are equipped with a two-channel RF-IF: S-band and X-band. The IVC switches between IF sources, that is, from the 70-m or 34-m HEF stations.

The RIV contains the tunable second LO, a set of video bandpass filters, IF attenuators, and a controller (RIC). The LO tuning is done via DSP control of the POCA/PLO combination based on a predict set. The POCA is a Programmable Oscillator Control Assembly and the PLO is a Programmable Local Oscillator (commonly called the DANA synthesizer). The bandpass filters are selectable via the DSP. The RIC provides an interface between the DSP and the RIV. It is controlled from the LMC via the DSP. The RIC selects the filter and attenuator settings and provides monitor data to the DSP. The RIC could also be manually controlled from the front panel in case the electronic interface to the DSP is lost. Figures 2a and 2b show block diagrams of the open-loop receiver. Calibrations will be performed on the OLR and the DSP NBOC using estimates of the peak signal levels expected during the experiments as described in section 3.2.2.

3.2.1.4.3 Block V Receiver

The initial Block V implementation at Goldstone will contain two channels (S- and X-band) for carrier processing. Future expansion of the Block V will allow support of additional frequencies (Ka-band) at BWG stations and support for additional antennas of the BWG cluster. Large scale modifications of the Block V Receiver electronics will allow Radio Science and VLBI signal reception and processing within the Block V Receiver without additional RS or VLBI specific external equipment.

3.2.1.4.4 RF Monitor: SSI and PPM

The RF monitor group of the Receiver-Exciter Subsystem provides spectral measurements using the Spectral Signal Indicator (SSI), and measurements of the received channel system temperature and spacecraft signal level using the Precision Power Monitor (PPM).

The SSI provides a local display of the received signal spectrum at a dedicated terminal at the DSCC and routes these same data to the DSP which routes them to NOCC for remote display at JPL for real-time monitoring and RIV/DSP configuration verification. These displays are used to validate Radio Science System data at the DSS, NOCC, and Mission Support Areas. The SSI configuration is controlled by the DSP and a duplicate of the SSI spectrum appears on the LMC via the DSP. During real-time operations, the SSI data also serve as a quick look science data type for the Radio Science experiments.

The PPM measures system noise temperatures (SNT) using a Noise Adding Radiometer (NAR) and downlink signal levels using the Signal Level Estimator (SLE). The PPM accepts its input from the closed-loop receiver. SNT is measured by injecting known amounts of noise power into the signal path and comparing the total power with the noise injection "on" against the total power with the noise injection "off". That operation is based on the fact that receiver noise power is directly proportional to temperature, and thus measuring the relative increase in noise power due to the presence of a calibrated thermal noise source allows direct calculation of SNT.

Signal level is measured by calculating an FFT to estimate the SNR between the signal level and the receiver noise floor whose power is known from the SNT measurements.

There is one PPM controller at the SPC which is used to control all SNT measurements. The SNT integration time can be selected to represent the time required for a measurement of 30 K to have a 1-sigma uncertainty of 0.3 K or 1%.

3.2.1.5 DSCC Transmitter Subsystem

The Transmitter Subsystem accepts the S-band frequency exciter signal from the Block III or Block IV Receiver-Exciter Subsystem exciter and amplifies it to the required transmitted output level. The amplified signal is routed via the diplexer through the feedhorn to the antenna and then focused and beamed to the spacecraft.

The Transmitter Subsystem power capabilities range from 18 kW to 400 kW. Power levels above 18 kW are available only at 70-m stations.

3.2.1.6 DSCC Tracking Subsystem

The Tracking Subsystem's primary functions are to acquire and maintain the communications link with the spacecraft and to generate and format radiometric data containing Doppler and range. A block diagram of the DSN tracking system appears in Figures 3-7 and 3-8.

The DSCC Tracking Subsystem (DTK) receives the carrier signals and ranging spectra from the Receiver-Exciter Subsystem. The Doppler cycle counts are counted, formatted, and transmitted to JPL in real-time. Ranging data are also transmitted to JPL in real-time. Also contained in these blocks is the AGC information from the Receiver-Exciter Subsystem. The Radio Metric Data Conditioning Team (RMDCT) at JPL produces an ATDF tape which contains Doppler and ranging data.

In addition, the Tracking Subsystem receives from the CMC frequency predicts (used to compute frequency residuals and noise estimates), receiver tuning predicts (used to tune the closed-loop receivers), and uplink tuning predicts (used to tune the exciter). From the LMC, it receives configuration and control directives as well as configuration and status information on the transmitter, microwave and frequency and timing subsystems.

The Metric Data Assembly (MDA) controls all of the DTK functions supporting the uplink and downlink activities. The MDA receives uplink predicts and controls the uplink tuning by commanding the DCO. The MDA also controls the SRA. It formats the Doppler and range measurements and provides them to the GCF for transmission to NOCC.

The Sequential Ranging Assembly (SRA) measures the round trip light time (RTLT) of a radio signal traveling from a ground tracking station to a spacecraft and back. From the RTLT, phase, and Doppler data, the spacecraft range is measured. A coded signal is modulated on an S-band carrier and transmitted to the spacecraft where it is detected and transponded back to the station. As a result, the signal received at the tracking station is delayed by its round trip through space and shifted in frequency by the Doppler effect due to the relative motion between the spacecraft and the tracking station on Earth.

3.2.1.7 DSCC Spectrum Processing Subsystem (DSP)

The DSCC Spectrum Processing Subsystem (DSP) located at the SPC digitizes and records on magnetic tapes the narrowband output data from the RIV. It consists of a Narrow Band Occultation Converter (NBOC) containing four Analog-to-Digital Converters (ADCs), a ModComp CLASSIC computer processor called the Spectrum Processing Assembly (SPA) and two to six magnetic tape drives. The block diagram for the SPA-R hardware is shown in figure 3-6.

The DSP is operated through the LMC. Using the SPA-R software, the DSP allows for real-time frequency and time offsets (while in RUN mode) and, if necessary, snap tuning between the two frequency ranges transmitted by the spacecraft: coherent and noncoherent. The DSP receives Radio Science frequency predicts from the CMC, allows for multiple predict set archival (up to 60 sets) at the SPA and allows for manual predict generation and editing. It accepts configuration and control data from the LMC, provides display data to the LMC and transmits the signal spectra from the SSI as well as status information to NOCC and the Project Mission Support Area (MSA) via the GCF data lines. The DSP records the digitized narrowband samples and the supporting header information (i.e., time tags, POCA frequencies, etc.) on 9-track magnetic tapes in 6250 or 1600 bpi GCR format. The data format on the tape (called Original Data Record, ODR) is defined in document 820-13 module RSC-11-10A.

The Radio Science IF Switch (RIS) provides the DSP with the ability to select Prime, Cross, or Faraday Rotation configuration for the 34-meter and 70-mater antennas. In Prime mode, X-RCP, S-RCP, X-LCP, and S-LCP from the 70-meter antenna are selected as input signals to the RIV. In Cross mode, X-RCP and S-RCP from the 34-meter and X-LCP and S-LCP from the 70-meter antenna are selected as the input to the RIV. Faraday Rotation configurations the same as Prime configuration.

The RIC provides the DSP with the ability to control the IF to Video selection. The RIC can select the signal with the desired frequency (S-band or X-band)and polarization (Left or Right Circular). The signal is then directed to the DSP-R Signal Digitizer Assembly (RSSD) for analog signal processing.

The S-band and X-band signals from the spacecraft are mixed with the RF local oscillator frequency in the receiver to produce a Video Frequency (VF) signal. The VF signal is digitized by the RSSD. The digitized data are recorded on 8 mm tape and transmitted to SFOC. The RSSD performs a Fast Fourier Transform (FFT) on the IF signal so that a signal power spectrum can be displayed.

Through the DSP-RIC interface, the DSP controls the RIV's filter selection and attenuation levels. It also receives RIV performance monitoring via the RIC. In case of failure of the DSP-RIC interface, the RIV can be controlled manually from the front panel.

All the RIV and DSP control parameters and configuration directives are stored in the SPA in a macro-like file called an "experiment directive" table. A number of default directives exist in the DSP for the major Radio Science experiments. Operators can create their own table entries. The items controlled by the directive are shown in Section 3.2.2.

Items such as verification of the configuration of the prime open-loop recording subsystem, the selection of the required predict sets, and proper system performance prior to the recording periods will be checked in real-time at JPL via the NOCC displays using primarily the remote SSI display at NOCC and the NRV displays. Because of this, transmission of the DSP/SSI monitor information is enabled prior to the start of recording. The specific run time and tape recording times will be identified in the SOE.

The DSP can be used to duplicate ODRs. It also has the capability to play back a certain section of the recorded data after the conclusion of the recording periods.

Please note the following problem which was discovered during the Radio Science Phase 2B OPS software acceptance Testing:

When using a signal provided by the RIV, A/D samples generated with the RUN directive are invalid for the first several (to many) records, the number of which seems to depend on the configuration (rate, mode, resolution) used.

This problem DOES NOT occur when using 1) a synthesized signal source directly into the RSSD or 2) the RUN START STOP directive.

NOTE: When the DSP-R is in IDLE, there is no RIV signal present at the input to the RSSD. When the DSP-R is put into RUN mode, it appears that the RSSD begins sampling before a signal arrives at the RSSD.

1. Most of the time, the invalid A/D samples are of value 7F/80.
2. The invalid samples appear on both the buffer disk (hrvol) and ODRs.
3. This problem is seen at both SPC-10 and DTF-21.
4. This problem continues to occur after system is rebooted.
5. The number of invalid records varies depending on the configuration used.

EXAMPLES:

RATE	MODE	RESOL	FILTERS	ANT CNF	NBR RECS INVALID DATA
200	1	8	1	PRIME	6
200	1	8	1	CROSS	8
200	1	8	1	PRIME	8
200	1	12	1	CROSS	6 **
1000	1	8	2	PRIME	8
1250	1	16	3	PRIME	NONE
5000	1	8	3	PRIME	20
8000	2	12	3	PRIME	? **
8000	2	12	3	PRIME	NONE
12500	3	8	4	PRIME	? **
12500	3	8	4	PRIME	> 1000
50000	1	8	6	PRIME	> 200

** Some number of starting records are invalid but not strictly 7F/80. Difficult to tell when valid data starts but appears to range anywhere from 2 - 20 records.

3.2.1.8 DSCC Frequency and Timing Subsystem

The Frequency and Timing Subsystem (FTS) provides all frequency and timing references required by the other DSCC subsystems. It contain four frequency standards of which one is prime and the other three are backups. Selection of the prime standard is done via the CMC. Of these four standards, there are two Hydrogen masers followed by clean-up loops (CUL) and two Cesium standards. These four standards all feed the Coherent Reference Generator (CRG) which provides the frequency references used by the rest of the complex. It also provides the frequency reference to the Master Clock Assembly (MCA) which in turn provides time to the Time Insertion and Distribution assembly (TID) which provides UTC and SIM-time to the complex.

The monitoring capabilities of the DSCC FTS at JPL are limited to the MDA calculated Doppler pseudo-residuals, the Doppler noise, the SSI, and via the GPS. The GPS receivers receive a one-pulse-per-second pulse from the station's (Hydrogen maser referenced) FTS and a pulse from a GPS satellite at scheduled times. After compensating for the satellite signal delay, the timing offset is reported to JPL where a database is kept. The clock offsets reported in the JPL database between the clocks at the three DSN sites are given in microseconds, where each reading is a mean reading of measurements from several GPS satellites and the time tag associated with it is a mean time of the measurements. The clock offsets provided include those of SPC 10 relative to UTC(NIST), SPC 40 relative to SPC 10,...,etc.

3.2.2 *DSS Calibration and Configuration*

3.2.2.1 *Open-Loop Receiver Attenuation Calibration*

The open-loop receiver attenuator calibrations are performed to establish the output of the open-loop receivers at a level that will not saturate the input signal to the analog-to-digital converters. To achieve this goal, the calibration is done using a test signal generated by the exciter/translator that is set to the peak predicted signal level for the upcoming pass. Then the output level of the receiver's video band spectrum envelope is adjusted to the level determined by the third equation below (to 5 sigma). Note that the SNR in the second equation is in dB, and the SNR in the third equation is not. Use the fourth equation to compute changes in RMS voltage levels.

3.2.2.2 *Station Configuration*

The station configuration during the Radio Science activities is governed by Volume 2 of the Deep Space Network Operations Plan (NOP). This table, however, shows the recommended configuration of the DSCC Spectrum Processing Assembly (DSP) and open-loop system for the purpose of internal documentation by the Radio Science Support Team.

3.2.2.1. *Galileo USO Configuration:*

The Doppler sample rate is one per 10 seconds. The required frequency and timing reference is the Hydrogen maser. The DSP should be configured as shown in Table 3-1.

3.2.2.2.4 *Galileo Gravitational Wave Experiment Configuration*

The anticipated Doppler sample rate one per second. The required frequency and timing reference is the Hydrogen maser. During the experiment, Galileo will use the 70-m subnet (S-band). The DSP should be configured as shown in Table 3-1.

3.2.2.2.3 *Ulysses Solar Corona Experiment Configuration*

The Doppler sample rate is one per second. The required frequency and timing reference is the Hydrogen maser. The ranging parameters are shown in the NOP. The DSP should be configured as shown in Table 3-2.

3.2.2.2.4 *Galileo Gravitational Wave Experiment Configuration*

The anticipated Doppler sample rate one per second. The required frequency and timing reference is the Hydrogen maser. During the experiment, Galileo will use the 70-m subnet (S-band). The DSP should be configured as shown in Table 3-1.

Table 3-1: DSP Configuration for Galileo USO Test, Solar Wind Scintillation, and Gravitational Wave Experiments for 70-meter stations (DSS:14, 43,or 63)

Parameter	DIRECTIVE	Setting	Notes	*RSSD DIRECTIVE*	*RSSD Setting*
Filter number	DEFFL	1 1 1 1	82/100 Hz BW	DEFFL	*1 1 1 1*
Filter offset	RIVOF	-150	Hz	*RIVOF*	*-150*
NBOC mode	MODE	1		*N/A*	*N/A*
Sample rate	NBRAT	200	samp/sec	*SRATE*	*200 SR SR SR SR*
IVC switch	CFG	PRIME		*CFG*	*PRIME*
Chan. assign.	NBCHN		NBOC ch=RIV ch	*N/A*	*N/A*
		A=2	SRCP		
		B=2	SRCP		
		C=2	SRCP		
		D=2	SRCP		
Output to SSI	SSS	A		SDIN	*SR*
Bit resolution	NBRES	8		SDRES	*8*
Tape density, bpi	DENS	6250	458.3 min/tape	*N/A*	*N/A*

Table 3-2: DSP Configuration for Ulysses Solar Corona Experiment 34-meter STD stations (DSS:42, 61, or DSS-24 BWG)

Parameter	DIRECTIVE	Setting	Notes	*RSSD DIRECTIVE*	*RSSD Setting*
Filter number	DEFFL	2 2 2 2	500 Hz BW	*DSFFL*	*2 2 2 2*
Filter offset	RIVOF	-750	Hz	*RIVOF*	*-750*
NBOC mode	MODE	1		*N/A*	*N/A*
Sample rate	NBRAT	1000	samp/sec	*SRATE*	*1000 XR SR XR SR*
IVC switch	CFG	N/A		*CFG*	*N/A*
Chan. assign.	NBCHN		NBOC ch=RIV ch	*N/A*	*N/A*
		A=3	XRCP		
		B=4	SRCP		
		C=3	XRCP		
		D=4	SRCP		
Output to SSI	SSS	A		*SDIN*	*XR SR*
Bit resolution	NBRES	8		*SDRES*	*8*
Tape density, bpi	DENS	6250	458.3 min/tape	*N/A*	*N/A*

3.3 AMMOS and Other Facilities

3.3.1 AMMOS

AMMOS, the Advanced Multi-Mission Operations System, refers to the equipment, software and personnel that handle operations and data flow for flight projects. The AMMOS hardware and software used to support flight operations is called the Multi-mission Ground Data System (MGDS). Mars Observer, unlike Ulysses and Galileo, will use AMMOS exclusively for all telemetry, DSN monitor, radiometric, and, after May 1, 1993, radio science data delivery from the DSN. In addition, the Mars Observer Project delivers spacecraft commands to the DSN for transmission via AMMOS facilities. A block diagram of DSN->AMMOS data flow is shown as Figure 3-10.

Radio science data coming from the remote stations, including the new interface blocks RSC-11-11 (open loop samples) and RSC-11-12 (SSI and radio science monitor), is packaged with a DSN Standard Format Data Unit (SFDU) header (SFDUs are a type of standardized data identifier). It is then passed through the station gateway, the SCP (Station Comm Processor), over electronic links to the MGDS gateway, the CCP (Central Comm Processor), at JPL. The CCP routes data to the NOCC Gateway (NG) which supplies data to the NOCC and its monitor displays as well as to RODAN. The CCP also routes data to the SFOC Gateway (SG) which moves data onto AMMOS. Data passed to the SG is handed to the GIF which supplies an AMMOS SFDU header and routes it to the TIS which does some processing of the data. Examples of TIS processing are decommutation, where individual data types are extracted from data blocks, and channelization, where individual data types are identified and sorted by predetermined "channel" assignments (for example, USO Temperature is channel I-922). This data is then placed in the database for retrieval.

3.3.1.1 Roles of the AMMOS Subsystems

GIF: The interface between the DSN and AMMOS (i.e., the "front-end" gateway for data coming into AMMOS from each DSCC). GIF captures the telemetry and ground station monitor data, packages it in a standard format ("wrapping" it in an SFDU), and routes it to the TIS. It also routes command files back to the DSCCs.

TIS: Does the major processing (frame synchronization, decommutation, and extraction) of telemetry and monitor data, reading the telemetry stream, correcting obvious errors, and organizing the data for the remaining systems downstream.

CDB: Includes data base management software (CDB) and project-specific data storage facilities (Project Data Bases, PDBs). The CDB loader loads the data stream from the TIS into the PDB. Older data is archived off-line to make room for newer data coming in. The PDB also contains files (ancillary data, command files, etc.) in UNIX directories.

"Stream data" is frame- or packet-based and defined by a finite time interval. An example of stream data is real-time RSC-11-11 or MON 5-15 blocks. Spool files or spoolers are files created with a fixed size limit and are specially formatted for storing stream data for use by stream data tools. Specifically, the data may be retrieved from the files by choice of parameters, rather than having to accept the entire file.

"File data" (also called byte stream file data) is any data available in a (non-spooler) file with a filename. The data in this file may be repackaged stream data, which will no longer be available to stream tools and therefore no longer accessible by individual block parameters such as creation time. The other sort of file data is that which is provided originally in a file and never as a real-time stream. Files in this category include closed-loop ATDFs, weather data files, and various navigation files. File data may be any length.

The PDB catalog keeps track of both stream data and file data. Stream data is queried through the TDS, using various block parameters (time tag, spacecraft number, data type, etc.) to specify which particular data blocks are desired. File data is queried through WOTU interface from user workstations, where the file catalog entries indicate the contents of each file available. The user can determine the file needed after finding a catalog entry describing desired data.

TDS: The primary delivery mechanism for stream data to users. The Telemetry Output Tool from the AMMOS workstation enables users to build queries for the TDS which can time-merge a data stream taking data from the real-time broadcast stream, the near-real-time spoolers (the NERT cache), and/or the PDB.

CMD: Allows authorized users to send spacecraft commands and command sequences to the DSN and to monitor and control their radiation to the spacecraft. Also supports creation of command files.

Browser: Allows users to examine and summarize stream data records at their workstations. Displays or dumps (prints) records based on Browser templates. Filters can be used to select specific records; Browser can then write selected records to spoolers or byte stream files.

DMD: Allows users to read, analyze, and display telemetry and related data in a variety of formats. Processes real-time, near-real-time, and non-real-time channelized data and displays it graphically on-screen or produces a hard copy. Can output processed data to user programs or files.

3.3.1.2 Radio Science AMMOS Workstation

Radio Science has an AMMOS workstation located in the real-time area. This workstation, MMRS (Multi-Mission Radio Science), has all AMMOS tools for display and capture of data and can be used both to monitor the progress of on-going experiments and to retrieve data from previous experiments. The workstation will be used to support real-time Mars Global Surveyor operations just as RODAN is used to support other flight projects' activities. When fully operational, the AMMOS real-time data delivery system will allow Mars Global Surveyor data to be collected without the need for magnetic tape delivery from the station.

3.3.1.3 AMMOS versus RODAN

There are two main differences between the Mars Global Surveyor/AMMOS data system and the Multi-Mission Radio Science/RODAN data system. The first is the destination and the second is the data source.

Currently, radio science data goes through the SCP at the station to be transferred to JPL, and then on as described in Section 9.0. For radio science data, the DSP can route to either the SCP or the AMMOS system depending on operator selection. All data flows along the SCP to CCP path. The difference is that AMMOS-bound data will be routed from the CCP into the SG, while other data will be routed from the CCP into NG. From the NG, the data will be relayed to RODAN, through both an ethernet (prime interface) and a serial X.25 (backup) interface described in Section 5.1.5.

The data routed to AMMOS is sent directly to the project data base. Each AMMOS workstation may then access the data base and query data. RODAN receives its data from live ethernet and X.25 interfaces.

3.3.2 GROUND COMMUNICATIONS FACILITY

The Ground Communications Facility (GCF) provides the communication networks needed to support the communication requirements of the Radio Science System. These facilities exist at the DSCC and JPL and are briefly described in the following paragraphs.

3.3.2.1 GCF Data Subsystem

Presently, monitoring information from the DSN complexes is transported over Ground Communication Facility (GCF) data lines. The Radio Science Real-time Monitoring System (RMS) taps into these lines and feeds the data through an ethernet line to the RODAN. A X.25 serial line is used as a backup data line if problems occur with the primary ethernet line. See Section 5 for a discussion of the normal configuration of these lines.

The GCF data lines transmit Radio Science open-loop tuning predicts from the NOCC to the DSS (and CTA-21) and send Radio Science, Tracking and Monitor and Control Subsystems status and configuration data from the DSCC to the NOCC in real-time. After the completion of a Radio Science recording period, the data lines can be used to send Radio Science data from the DSCC to the NOCC.

3.3.2.2 GCF Data Records Subsystem

The GCF Data Records Generator (DRG) formats the incoming closed-loop data from the DSCC and provides them to the RMDCT team which converts the Doppler and range data into computer-compatible tapes called Archival Tracking Data Files (ATDF).

3.3.2.3 Voice Net Communications

The Ground Communications Facility voice nets provide both the means of controlling worldwide spacecraft tracking operations and for relaying information required to verify proper operation of the various ground and spacecraft subsystems. Section 6 contains a description of the voice nets as it is planned for Radio Science activities

3.3.2.4 RODAN Interface

Data lines from GCF to RODAN allow the RSST to capture and display Radio Science data from the GCF lines. See Section 9 for a more complete description.

3.3.3 Network Operations Control Center (NOCC)

The NOCC generates and transmits information to each DSCC prior to tracking support. It also receives, displays, logs and distributes data generated at the DSCC during tracking support.

3.3.3.1 NOCC Support Subsystem

The NOCC Support Subsystem (NSS) generates Radio Science, antenna pointing, tracking, receiver, and uplink predicts. The NSS also provides DSCC schedules and transmits a subset of the Project's SOE to be used at the stations during tracking support.

3.3.3.2 NOCC Display Subsystem

The NOCC Display Subsystem generates DTV graphic and alphanumeric status and configuration displays. The NOCC Display Subsystem provides these displays to the Network Operations Control Center and the Project's Mission Support Area. The specific subsystems involved are the NRV RTM which generates graphic displays of SSI data and alphanumeric displays of the DSP status and tuning information, the NTK RTM which generates alphanumeric displays of closed-loop data and the Video Assembly Processor (VAP) which generates graphic displays of selected data types.

The display subsystem at NOCC provides real-time visibility at JPL during real-time activities. The NRV remote SSI display, the NRV DSP status displays, the VAP Radio Science graphic displays, the NTK tracking alphanumeric displays and the NMP monitor alphanumeric displays are all expected to be used to support Radio Science experiments.

3.3.4 Mission Control Computer Center (MCCC)

The MCCC routes all NOCC displays utilized by Radio Science and the Real Time Display System (RTDS) via its distribution system.

The MCCC RTDS provides displays of the data contained in the Monitor 5-9 blocks. These data contain system temperature, AGC and signal level estimates as well as the receiver/exciter subsystem and antenna subsystem configuration information.

3.3.5 *Mission Support Area*

The Radio Science Multi-Mission Support Area contains the real-time control center for the Radio Science System. Voice lines and DTV display capability are provided to the Project's real-time operations personnel to aid in operations monitoring. Hard copies of displays may be requested from the NOCC.

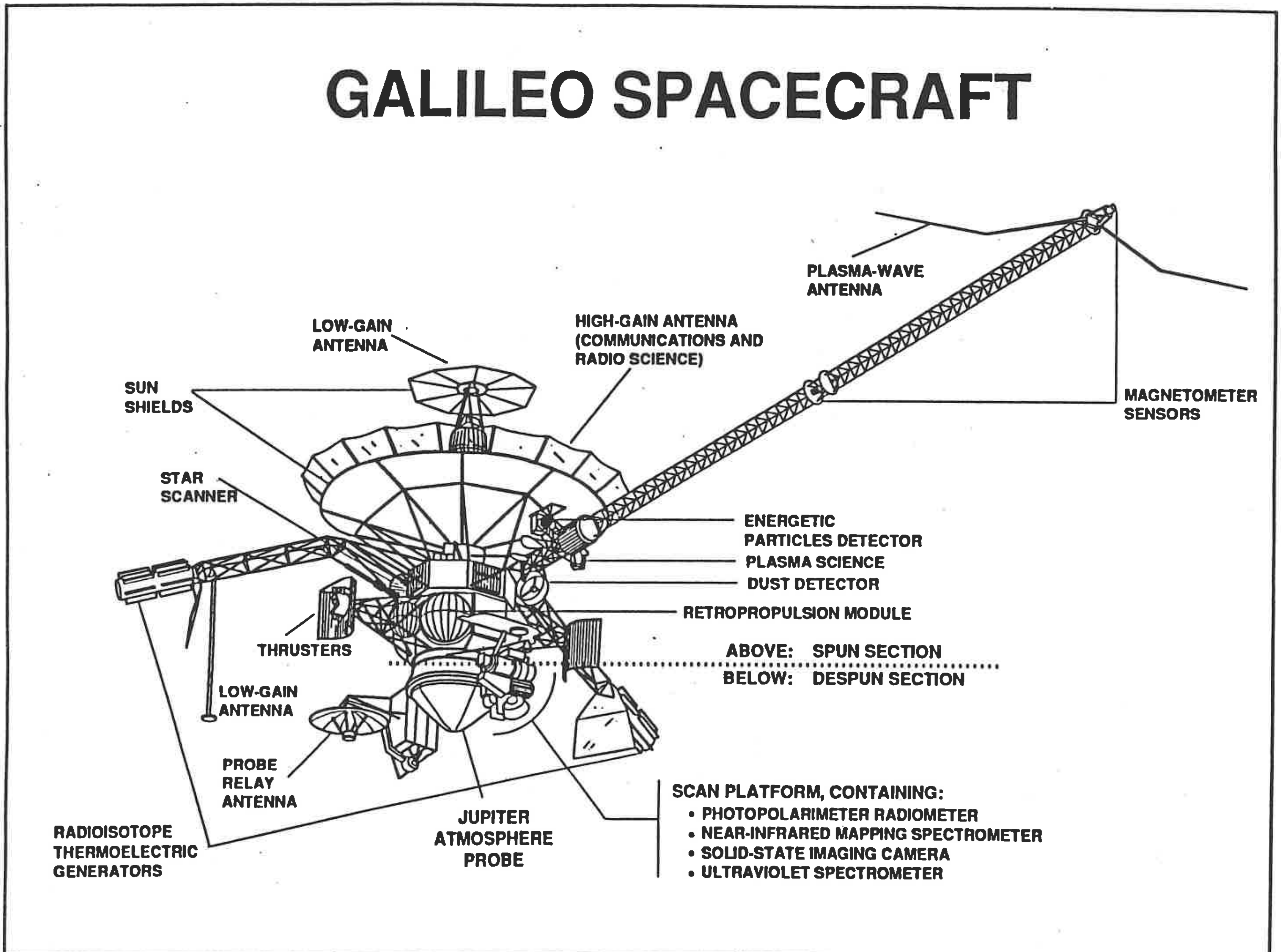


Figure 3-1. Galileo Spacecraft

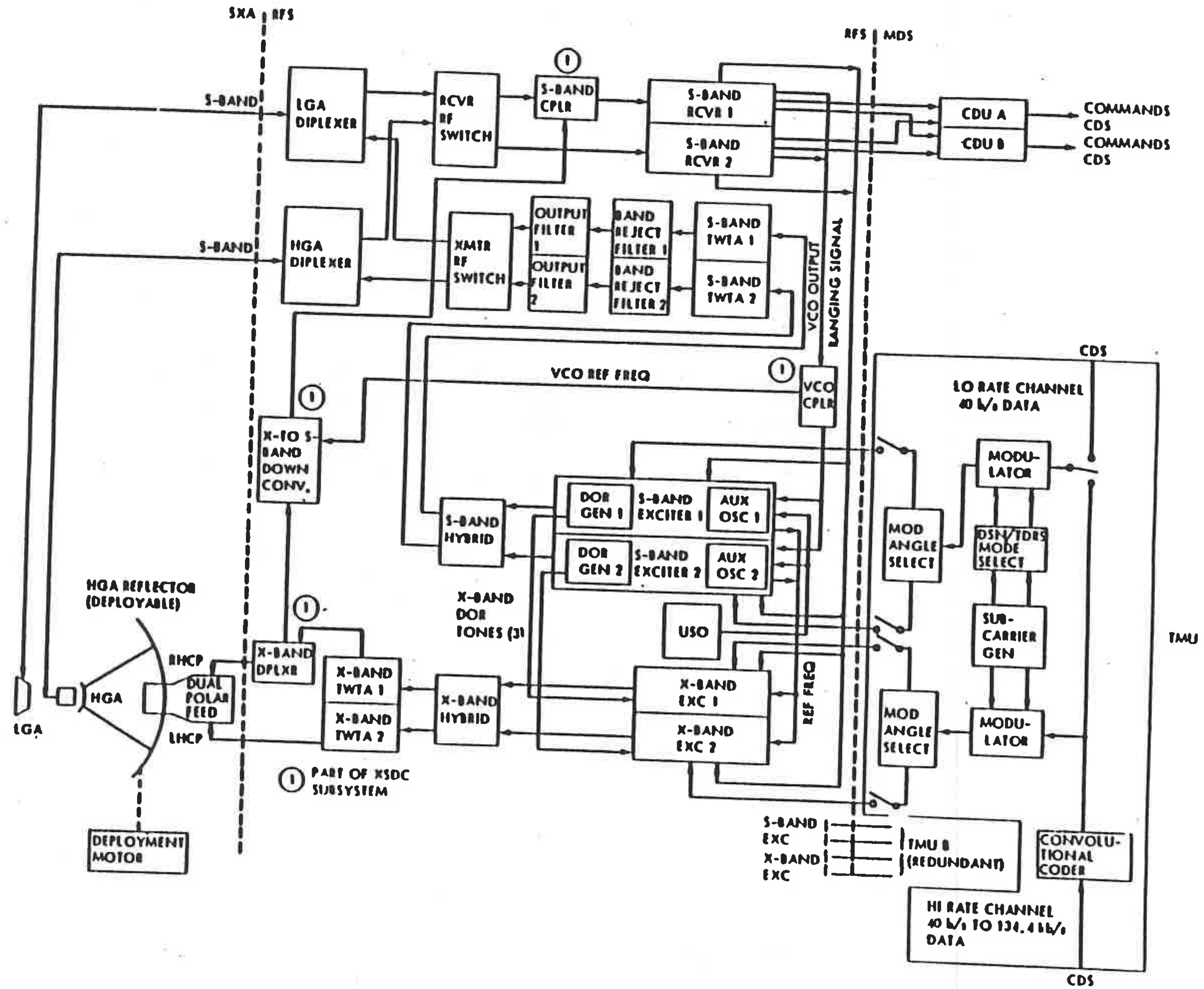


Figure 3-2. Galileo Orbiter Telecommunications System

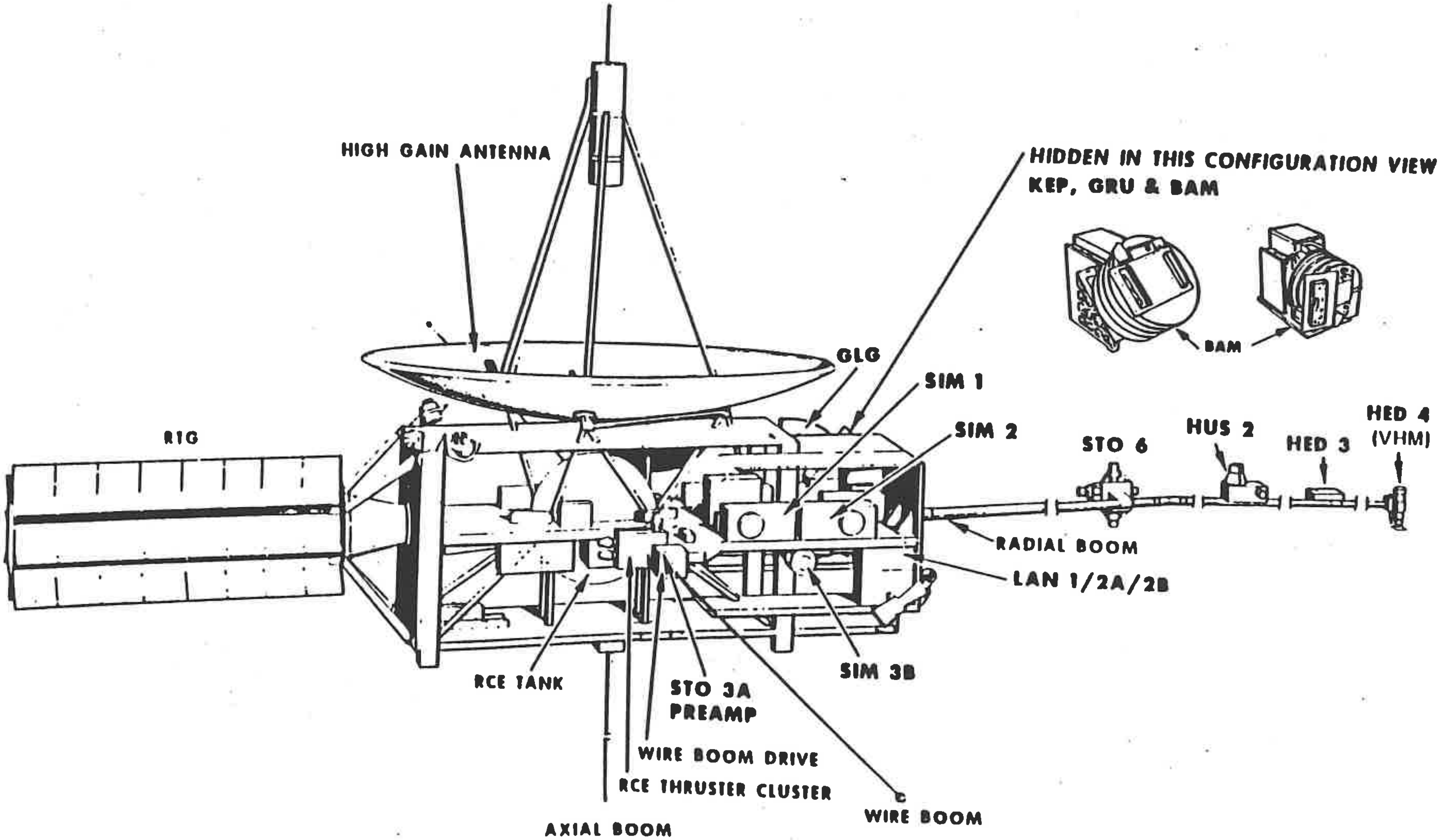


Figure 3-3. Ulysses Spacecraft

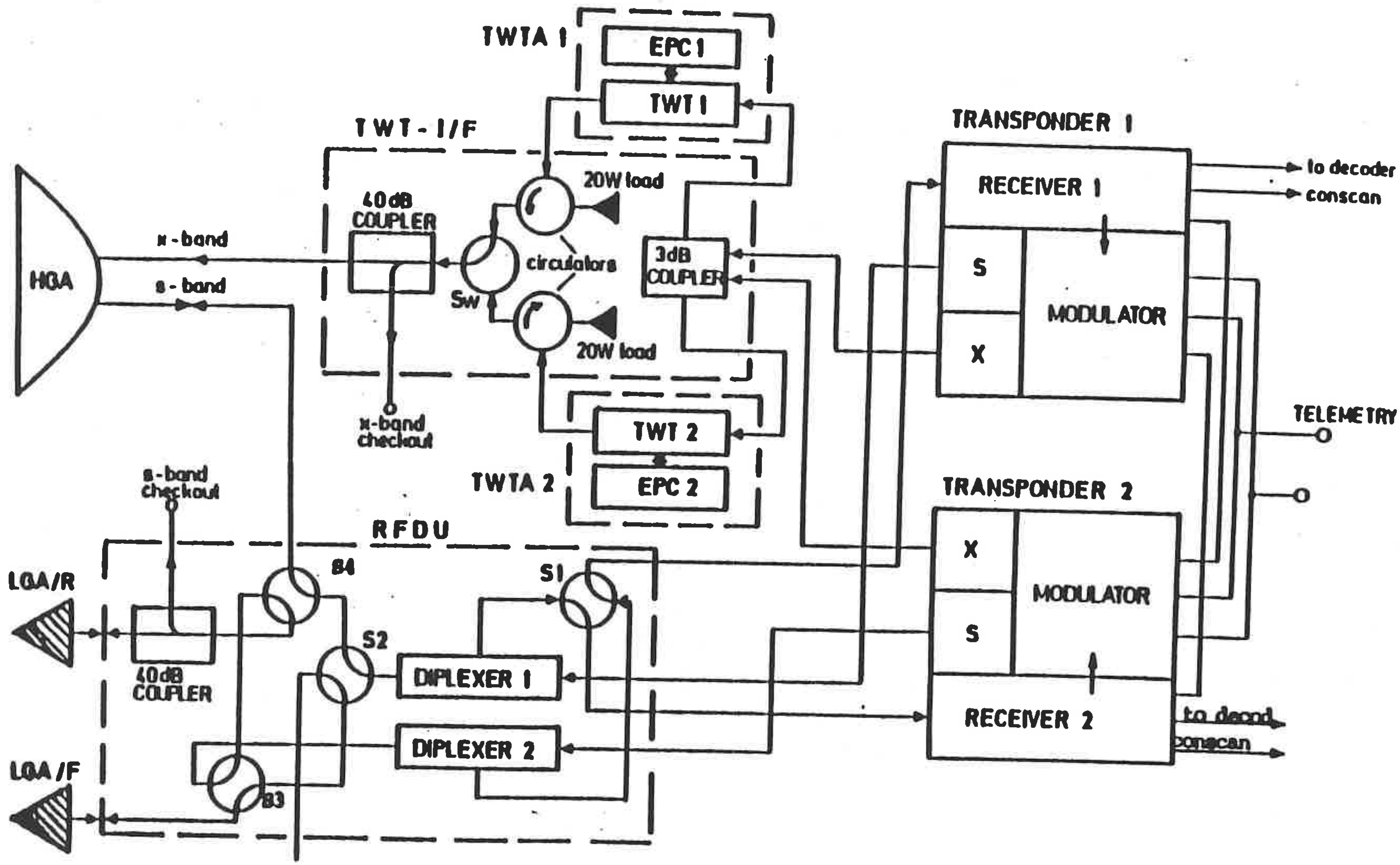


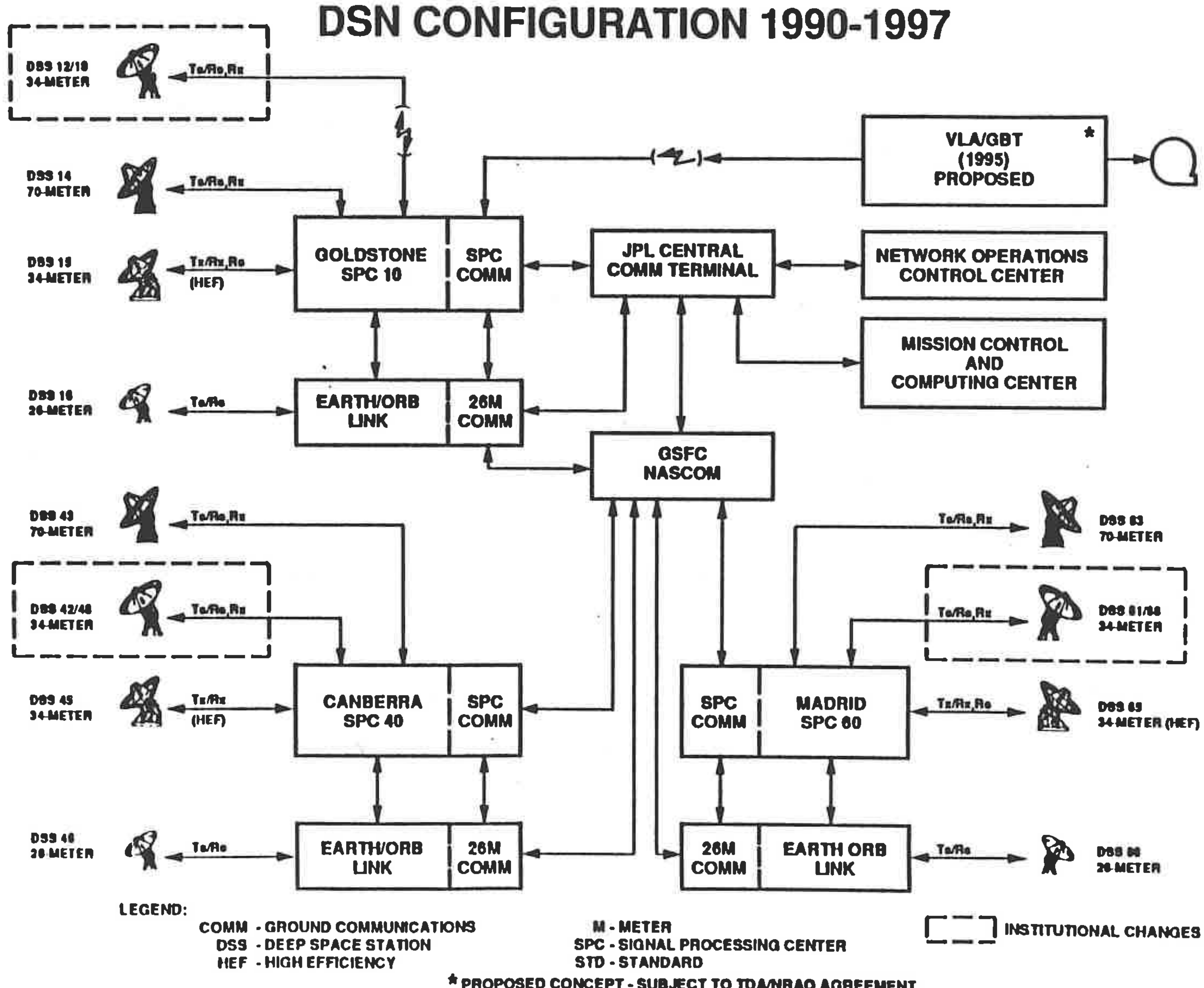
Figure 3-4. Ulysses Telecommunications System

TELECOMMUNICATIONS AND DATA ACQUISITION

GALILEO MOS DELTA DESIGN REVIEW

DSN INSTITUTIONAL CHANGES WITHIN THE MOS

JPL



6485-23767as

DJM-1
11-8-90

Figure 3-5. DSN Configuration 1990-1997

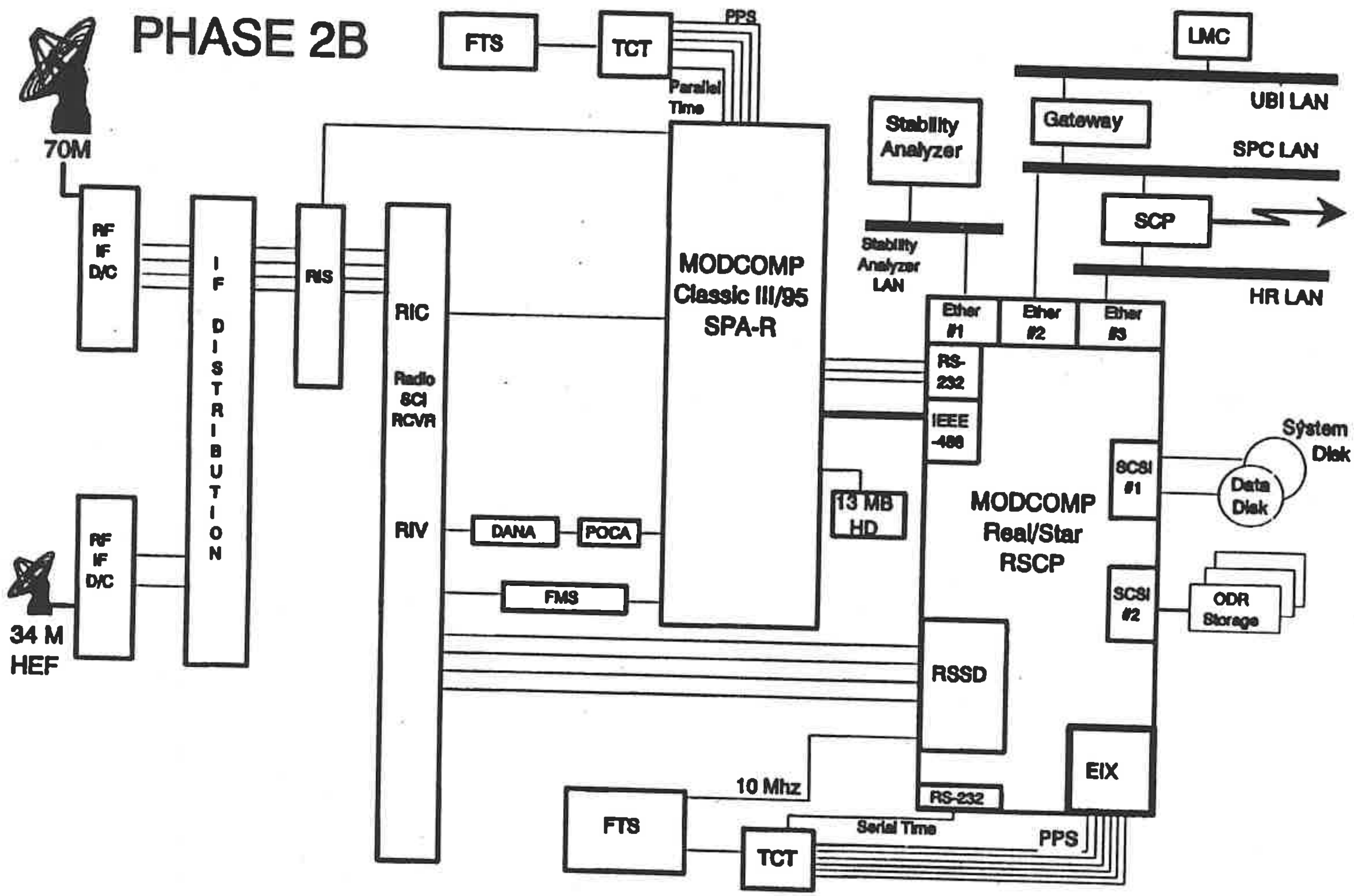


Figure 3-6. SPA-R and RSCP Hardware Block Diagram

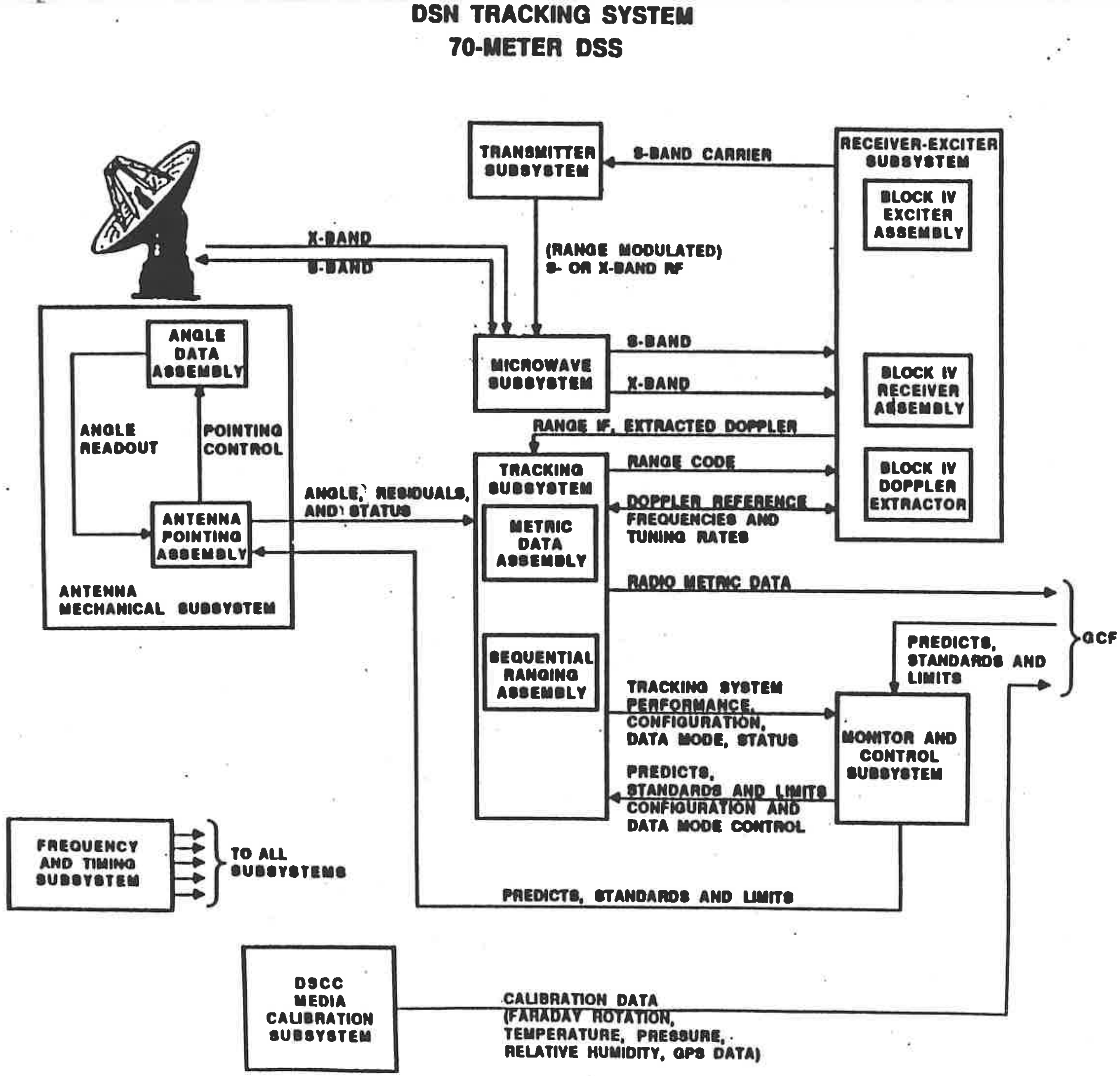


Figure 3-7. DSN Tracking System -- 70-Meter DSS

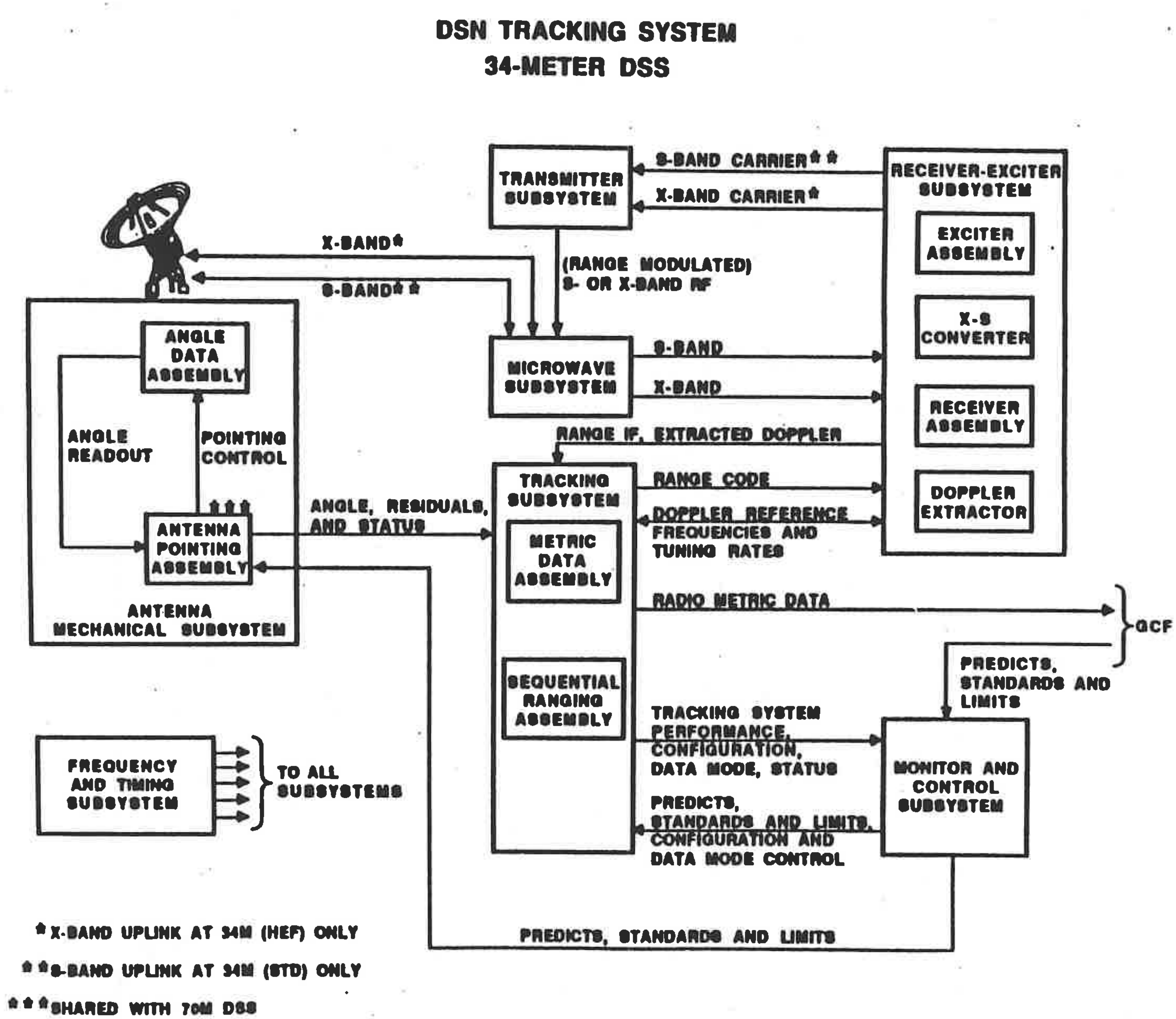


Figure 3-8. DSN Tracking System -- 34-Meter DSS

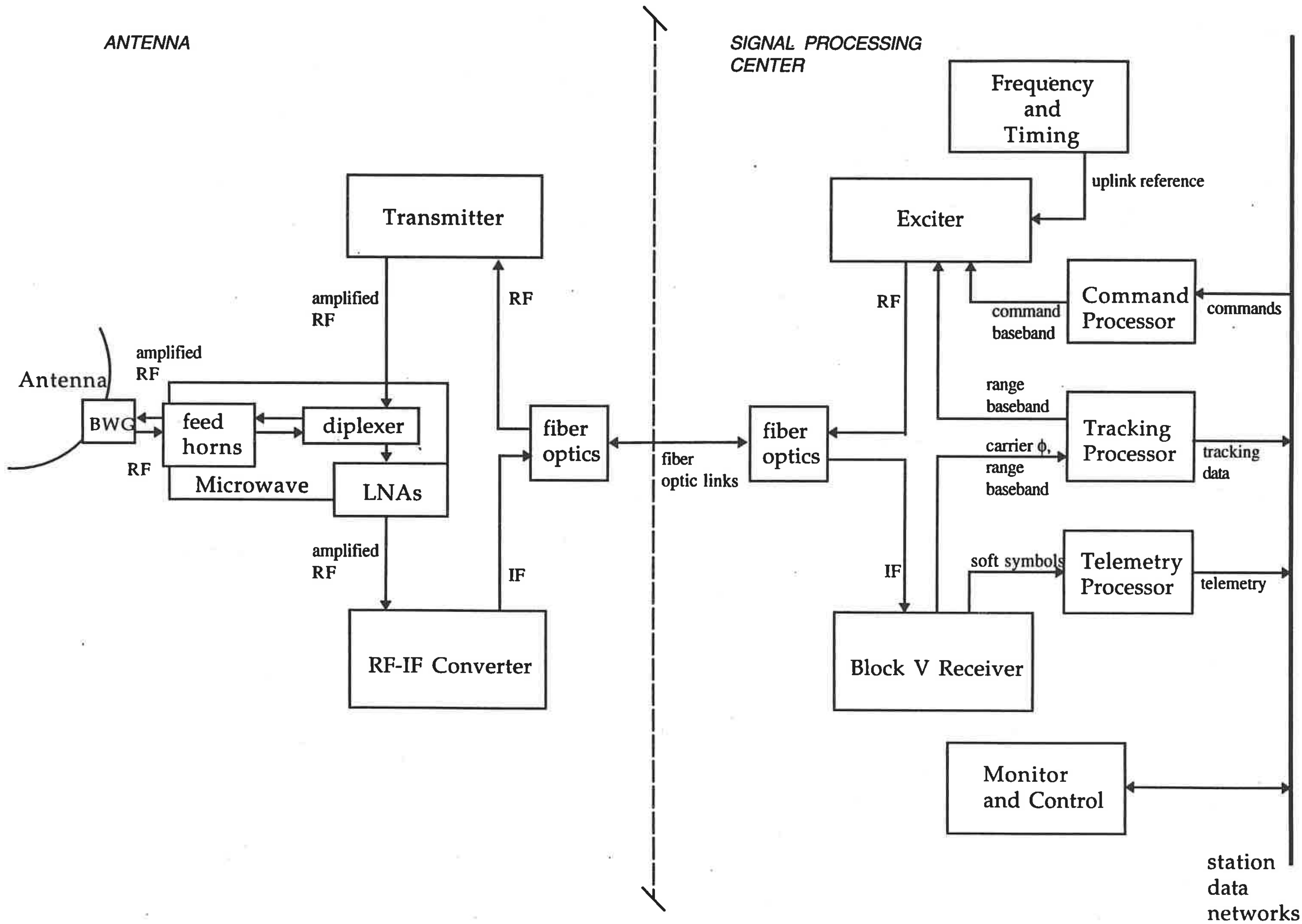


Figure 3-9a. 34-M Beam Waveguide Station Functional Block Diagram

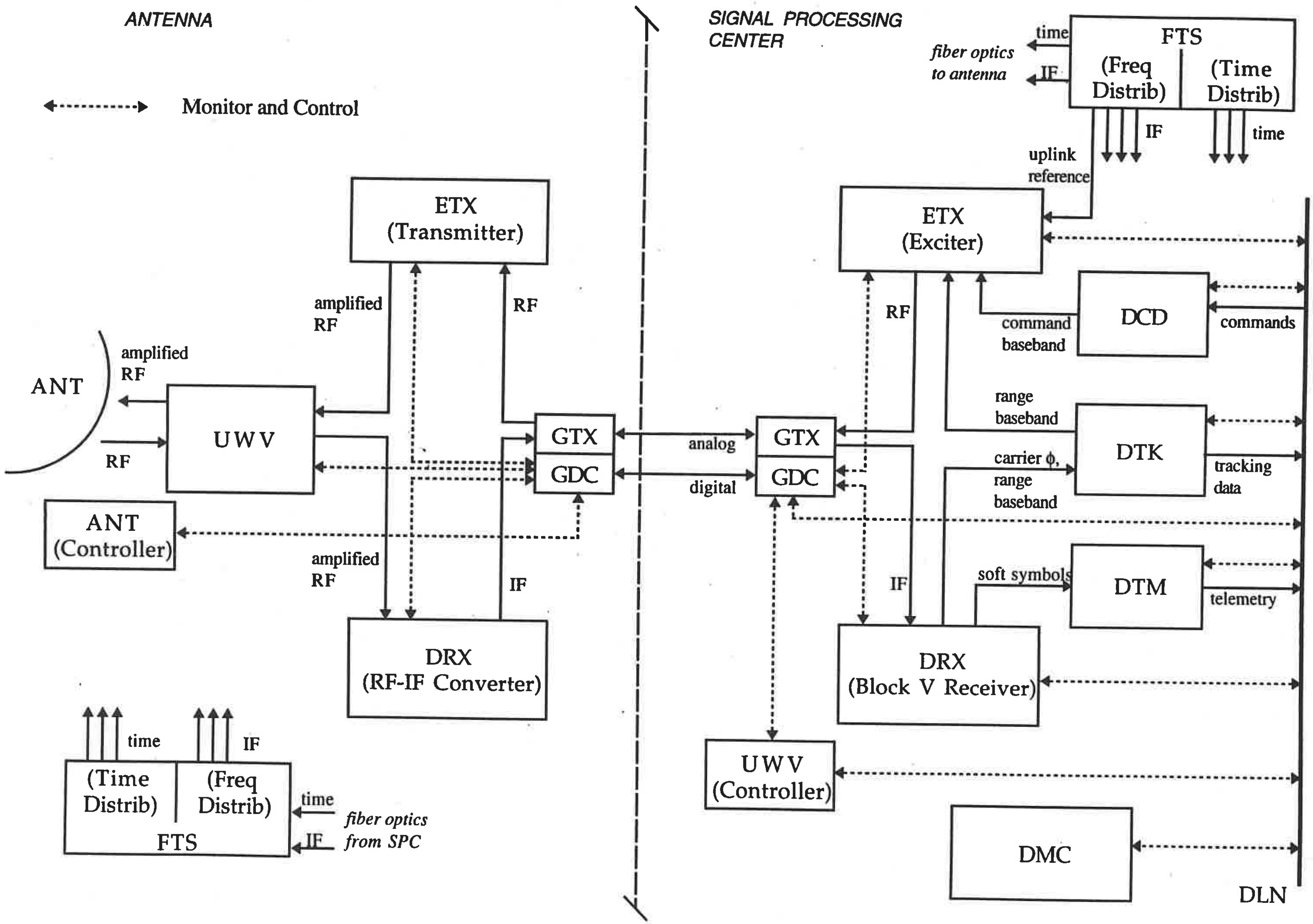
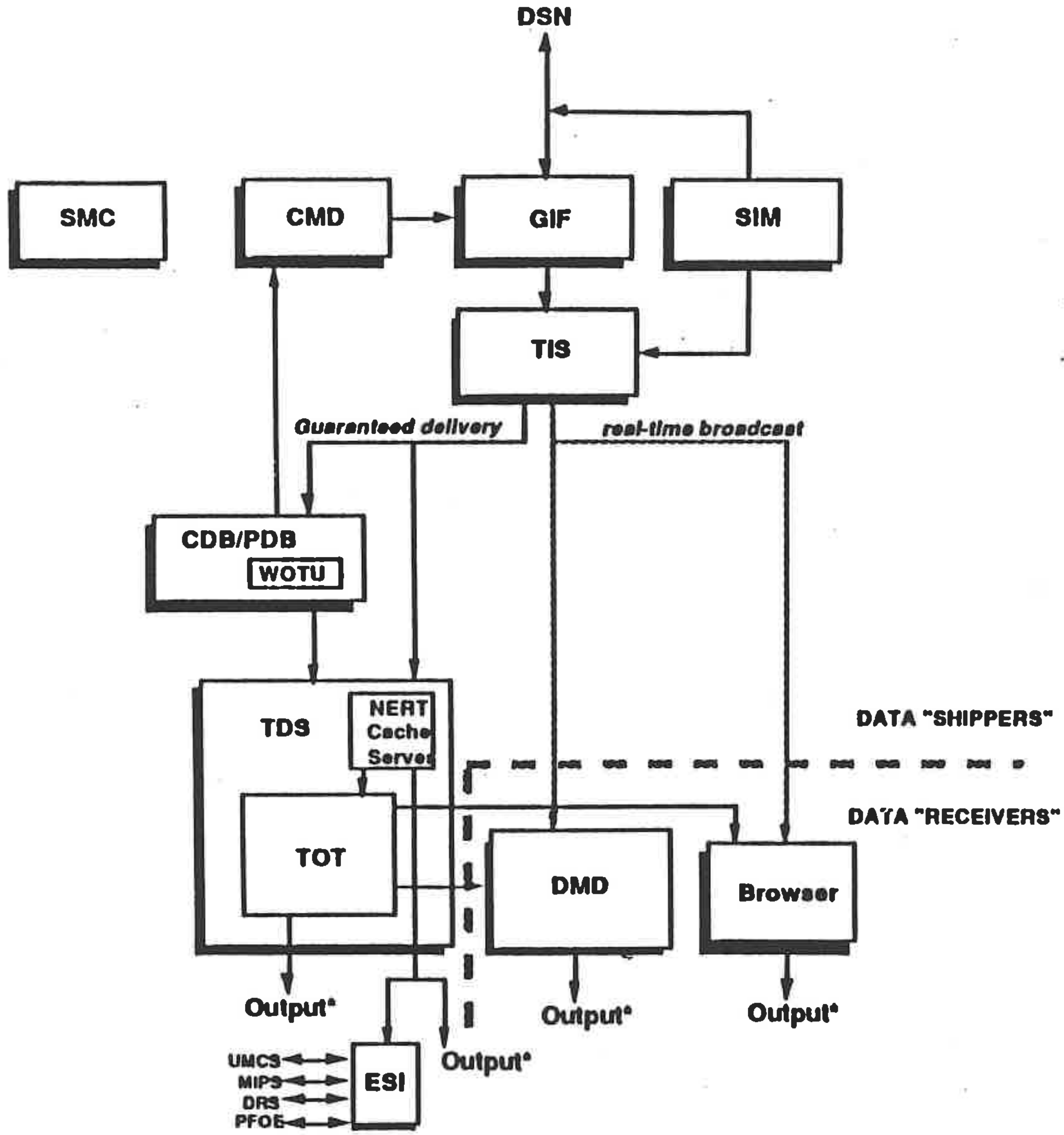


Figure 3-9b. 34-M Beam Waveguide Station

MGDS Subsystems



Legend:

CMD: Command Subsystem
CDB: Central Data Base
DMD: Data Monitor and Display Subsystem
DRS: Data Records System
ESI: External System Interface
GIF: Ground Comm. Facilities Interface
MIPS: Multimission Image Processing System
NERT: Near-real-time
PDB: Project Data Base
PFOE: Probe Flight Operations Equipment (Galileo)
SIM: Simulation Subsystem
SMC: System Monitor and Control Subsystem
TDS: Telemetry Delivery Subsystem
TOT: Telemetry Output Tool
UMCS: Ulysses Mission Control System
WOTU: Window on the Universe

* Output may be in the form of displays, printouts, bytestream files, spooler files, or UNIX pipes or virtual circuits to user programs.

Figure 3-10. MGDS Subsystems

Section 4
Team Organization and Responsibilities

4.0 Introduction

The Radio Science Support Team (RSST) provides coordination for all flight project activities supporting Radio Science experiments. The RSST operates as a single, comprehensive focal point for experiment-related Project functions and provides long range planning for experiment interfaces with multi-mission organizations. It serves as the operational interface between the Radio Science investigators and the other elements of the Flight Projects and the Deep Space Network. The RSST represents the interests of the investigators (especially ones not resident at JPL) at meetings relevant to the investigation. Specifically, the RSST:

1. Plans the implementation of the Radio Science experiments along with the investigators, defines the requirements on all aspects of the experiments, and resolves (or helps to resolve) intra- and inter-experiment conflicts.

2. Submits and integrates Radio Science requirements into the plans of the flight project, DSN, MOSO, and other multi-mission organizations.

3. Provides specifications for spacecraft and DSN equipment based on the experiment's needs for hardware, software and procedures, monitors the development of the equipment and participates in testing the hardware or the output product.

4. Reviews (and, when requested, participates in the negotiations leading to) the schedule of station tracking coverage.

5. Develops and integrates spacecraft and ground operation sequences for the acquisition of experiment data by interfacing with the mission design teams, sequence teams, spacecraft engineering teams, navigation teams, mission control teams, and other elements of the projects.

6. Coordinates with the mission control teams and the DSN the process of data acquisition by conducting real-time operations and collecting the data observables.

7. Logs, archives, and validates the data products in order to prepare the data observables for scientific analysis by the investigators.

The Radio Science Support Team is part of the Radio Science Systems Group of the Telecommunications Systems Section. The group currently supports Radio Science experiments on the Galileo, Ulysses, Mars Global Surveyor, and Cassini flight projects. The group has supported Radio Science experiments on Voyager, Magellan, Giotto, and Pioneer. Plans are underway to support various future missions.

Figure 4-1 shows the organization of the Radio Science Systems Group.

4.1 *RSST Individual Responsibilities*

4.1.1 *Science Coordinator/Experiment Representative*

The Science Coordinator/Experiment Representative (SC/ER) coordinates all the RSST tasks listed above, provides overall team direction, coordinates the team's resources, and ensures that schedules and staff plans are optimized to achieve the maximum return of quality data for the Radio Science experiments. The SC/ER develops the observation strategy, performs mission analysis trade-off studies, performs inter-experiment science integration, provides sequence inputs, and monitors the progression of the uplink process. She/He is the focal point for experiment requirements to the projects, keeps abreast of upcoming and on-going spacecraft activities which could affect the Radio Science investigations, and continually updates the rest of the Support Team on the status of the mission. During real-time operations, the SC/ER monitors the progress of the experiment and provides recommendations to the operations personnel to optimize its performance.

For some flight projects, if the Science Coordinator or Experiment Representative is also an investigator he/she may be called Investigation Scientist or Coordinating Scientist.

4.1.2 *Instrument Engineer*

The Radio Science Instrument Engineer's primary responsibilities are to develop, maintain, and interpret instrument (spacecraft and Ground Data System) requirements, monitor, and, when appropriate, participate in the planning, design, scheduling, and implementation of the instrument's components by interfacing with appropriate organizations (e.g., the DSN, Project spacecraft team). The Instrument Engineer performs instrument trade-off studies, designs the instrument operation configuration and verifies that all instrument and data interfaces (including GDS) satisfy team requirements. It is also the responsibility of the Instrument Engineer to test the data products during and after instrument implementation to ensure that the quality meets team requirements. He/she, along with the Software System Engineer, develops the software tools necessary for data validation and processing. The Instrument Engineer is the lead data analyst for the USO, telecommunication subsystem, and DSN systems stability. The Instrument Engineer also assists in Radio Science real-time operations.

4.1.3 *Operations Engineer*

The Radio Science Operations Engineer's primary responsibility is the verification of the proper conduct of pre-pass, real-time, and post-pass operations of the Radio Science data acquisition activities. Specifically, he/she verifies the presence and accuracy of the activity's Sequence Of Events (SOE) and predictions required by the station based on the information provided to him/her by the SC/ER. She/He handles communications regarding action or information required from the DSN station with the Project's Mission Controller (ACE), or Ground Controller (GC), via the appropriate voice nets. He/she coordinates with the RS System Administrator the availability of data displays needed for monitoring the activity, and insures that the Radio Science real-time support area and related facilities are equipped and staffed for real-time monitoring.

4.1.4 Software System Engineer

The Radio Science Software System Engineer's primary responsibilities include evaluation of existing Radio Science software, identifying software development tasks, and overseeing development, implementation, testing, documentation and delivery of software. He/she reports to the various projects on the software development status via periodic presentations.

The secondary responsibilities include using the Radio Science software for data analysis and validation, and assisting in Radio Science real-time operations.

4.1.5 System Administrator

The Radio Science System Administrator is responsible for the proper operation of the RSST computing equipment and peripherals. Her/His primary responsibility is the administration and upgrade of the RODAN computer facility (which includes the PRIME 4050 and several SUN workstations, all of which are further described in Section 5.0), its interfaces (e.g., RODAN-GCF) and the planning, implementation, and maintenance of future RSST computing facilities (including PC's, Mac's, and workstations).

Secondary responsibilities include the proper operation of the Real-time Monitoring System (RMS) (done in coordination with the RS Operations Engineer). The System Administrator also assists in Radio Science real-time operations.

4.1.6 Data Products Engineer

The Radio Science Data Products Engineer's primary responsibility is to request and receive, log, validate, archive, and distribute to Investigators the Radio Science data products (described in Section 6.0). She/He also maintains data interface agreements.

Secondary responsibilities include performing system back-ups and related tasks on the RODAN computer as well as assisting in Radio Science real-time operations.

4.1.7 Radio Science Analyst

The Radio Science Analyst conducts specialized scientific and engineering analysis needed for the planning, implementation, or data processing of Radio Science experiments. The Analyst also assists in Radio Science real-time operations.

4.2 RST Flight Project Interfaces

4.2.1 Galileo SEQ & Ulysses SOT

The Galileo Sequence Team (SEQ) is responsible for developing the command loads which incorporate both engineering and science activities for each sequence in the Mission. From the final product at the end of Sequence & Command Generation (S&CG), the Mission Control Team (MCT) generates the Galileo SFOS and ISOE.

The Ulysses Spacecraft Operations Team is responsible for coordinating the spacecraft configuration for all engineering and science activities which are eventually transferred to the Ulysses SEGs operator for generation of the Ulysses SFOS and ISOE products.

4.2.2 Galileo MCT & Ulysses SEGs Operators

The Galileo Mission Control Team (MCT) and the Ulysses SEGs Operators are the sources of the respective SFOSs and ISOEs. It is the responsibility of the Radio Science Team to insure that these products reflect the expected Radio Science data acquisition parameters and schedules.

4.2.3 Galileo & Ulysses ACEs

The Galileo ACE and Ulysses ACE are the primary interface for the Radio Science Team to affect real-time changes to SOE's and station configuration for the purpose of Radio Science data acquisition.

4.3 RST DSN Interfaces

4.3.1 Network Operations Project Engineer (NOPE)

The Galileo and Ulysses NOPEs are responsible for the overall operational support of the Deep Space Network for their respective flight projects. The NOPEs prepare and issue the Network Operations Plan which defines the configuration of all DSN systems for their respective flight projects including those relevant to Radio Science.

4.3.2 System Cognizant Operations Engineer (SCOE)

The SCOE is responsible for supporting Network Radio Science System testing, providing technical expertise on the DSN RS system, and providing technical advisory support as necessary to define system performance. He also provides backup to all those in the Radio Science Unit of the Network Advance Systems Group (NASG).

4.3.3 *Other NASG/Radio Science Unit Personnel*

There are three other positions within the Radio Science Unit of the Network Advanced Systems Group with responsibilities related to the Radio Science System. The *Radio Science Network Operations Analyst (NOA)* provides the technical interface between real-time operations and DSN system performance, monitors and reports DSN Radio Science systems and operations performance, investigates and resolves discrepancy reports, and acts as a backup to the RS Operations Specialist and to the RS Analyst. The *Radio Science Operations Specialist* performs operations function in support of all DSN Radio Science activities, represents DSN Operations in the development of Radio Science Operations Plans, and provides assistance and backup to the RS SCOE and the RS NOA. The *Radio Science Analyst* provides testing and data analysis support for Radio Science System test activities and assists the RS SCOE and the RS Operations Specialist.

4.3.4 *Comm Chief*

The Comm Chief is responsible for the configuration and operation of the GCF communications between all DSCC's and the NOCC. The Comm Chief is also responsible for ensuring that the proper data lines are connected to the RODAN computer at the request of the RSST.

4.3.5 *Ops Chief*

The Ops Chief is the DSN's lead person for all real-time DSN operations in support of flight projects.

4.3.6 *TrackCon*

The Track Controller is responsible for the real-time control of one or more stations supporting a Flight Project tracking pass. The TrackCon also serves as the real-time analyst for all incoming Tracking, VLBI, and Radio Science data and for all outgoing prediction data transfers for those stations and flight projects.

4.3.7 *DSN Radio Science Working Group*

The Radio Science Working Group oversees the implementation of DSN systems directly used for the acquisition of Radio Science data. It is headed by the DSN Radio Science System Engineer and has as members representatives of the Radio Science Teams for all Flight Projects as well as members of the organizations responsible for the design and implementation of hardware and software of DSN systems relevant to Radio Science.

Table 4-1. Key Radio Science Personnel

Radio Science Support Team

Sami Asmar	Ulysses Coordinating Scientist	3-0662
Jennifer Caetta	System Administrator	3-0665
Mick Connally	Mars Global Surveyor Exp. Rep.	3-1072
Randy Herrera	Galileo Science Coordinator	3-0664
Paula Eshe	Data Products Engineer	3-0663
Tony Horton	Operations Engineer	3-1142
Trish Priest	Assistant Galileo Sci. Coord.	3-0661
Phyllis Richardson	Gnd Inst Engr/Syst Engr	3-1073

Radio Science Operations area 3-0666

Deep Space Network

Pat Beyer	Galileo TDS Manager	4-0055
Dennis Enari	Ulysses TDS Manager	4-0074
Michelle Andrews	Asst Galileo NOPE	584-4425
Dave Recce	Deputy Galileo NOPE	584-4462
Roy Rose	Ulysses NOPE	584-4418
Byron Yetter	Galileo NOPE	584-4422
Ann Devereaux	Radio Science System Eng.	4-5376
Sal Abbate	R.S. Sys. Cog. Ops. Eng.	584-4461

Comm Chief 3-5800
Data Chief 3-7974
NATTRK 3-7810
Ops Chief 3-7990
Ops Con 3-7907
Support Chief 3-0505
Track Controller 3-5858
"The Cave" 3-1223, 3-1274, 3-1401, 3-1211

Flight Projects

Galileo ACE 3-5890
Ulysses ACE 3-0559

Table 4-2. Radio Science Investigators & Staff

Galileo

Propagation

Taylor Howard, Team Leader	Stanford Univ.
Von Eshleman	Stanford Univ. (retired)
Michael Flasar	Goddard SFC
Dave Hinson	Stanford Univ
Arvydas Kliore	JPL
Richard Woo	JPL
Michael Bird	Univ. Bonn, Germany
Peter Edenhofer	Univ. Bochum, Germany
Martin Pätzold	Univ. Koeln, Germany

Celestial Mechanics

John Anderson, Team Leader	JPL
Frank Estabrook	JPL
John Armstrong	JPL
James Campbell	JPL (on leave)
Timothy Krisher	JPL
Eunice Lau	JPL

Ulysses

Solar Corona

Michael Bird, Principal Investigator	Univ. Bonn, Germany
Peter Edenhofer	Univ. Bochum, Germany
Martin Pätzold	Univ. Koeln, Germany
Sami Asmar	JPL

Gravitational Waves

Bruno Bertotti, Principal Investgtr.	Univ. Pavia, Italy
Sami Asmar	JPL
Luciano Iess	CNR-IFSI, Italy
Hugo Wahlquist	JPL
Gianni Comoretto	Osser Astro Arcetri, Italy
Giacomo Giampieri	JPL (RRA)
Alfonso Messeri	CNR-IFSI, Italy
Roberto Ambrosini	Ist. Radioastro., Italy
Alberto Vecchio	Univ. Pavia, Italy

Table 4-2. Radio Science Investigators & Staff - cont'd

Giotto

Peter Edenhofer, Team Leader	Univ. Bochum, Germany
Michael Bird	Univ. Bonn, Germany
Martin Pätzold	Univ. Koeln, Germany
Herbert Porsche	DLR, Germany
Hans Volland	Univ. Bonn, Germany

Mars Global Surveyor

G. Leonard Tyler, Team Leader	Stanford Univ.
John Armstrong	JPL
Georges Balmino	CNES, France
F. Michael Flasar	GSFC
David Hinson	Stanford Univ.
Richard Simpson	Stanford Univ.
William Sjogren	JPL
David E. Smith	GSFC
Richard Woo	JPL

Cassini

Arvydas Kliore, Team Leader	JPL
Roberto Ambrosini	Ist. Radioastro., Italy
John D. Anderson	JPL
Bruno Bertotti	Univ. Pavia, Italy
Nicole Borderies	JPL
F. Michael Flasar	GSFC
Robert G. French	Wellesley Col.
Luciano Iess	CNR-IFSI, Italy
Essam A. Marouf	SJ State Univ.
Andrew F. Nagy	Univ. Michigan
Hugo Wahlquist	JPL

Huygens Doppler Wind Experiment

Michael Bird, Principal Investigator	Univ. Bonn, Germany

Table 4-2. Radio Science Investigators & Staff - cont'd

Magellan

Occultations	
Paul Steffes	Georgia Tech.
Jon Jenkins	NASA Ames
G. Leonard Tyler	Stanford Univ.
Venus Gravity Field	
William Sjogren	JPL
Solar Corona - Faraday Rotation	
Mike Bird	Univ. Bonn, Germany
Sami Asmar	JPL
Solar Wind Scintillation	
Richard Woo	JPL

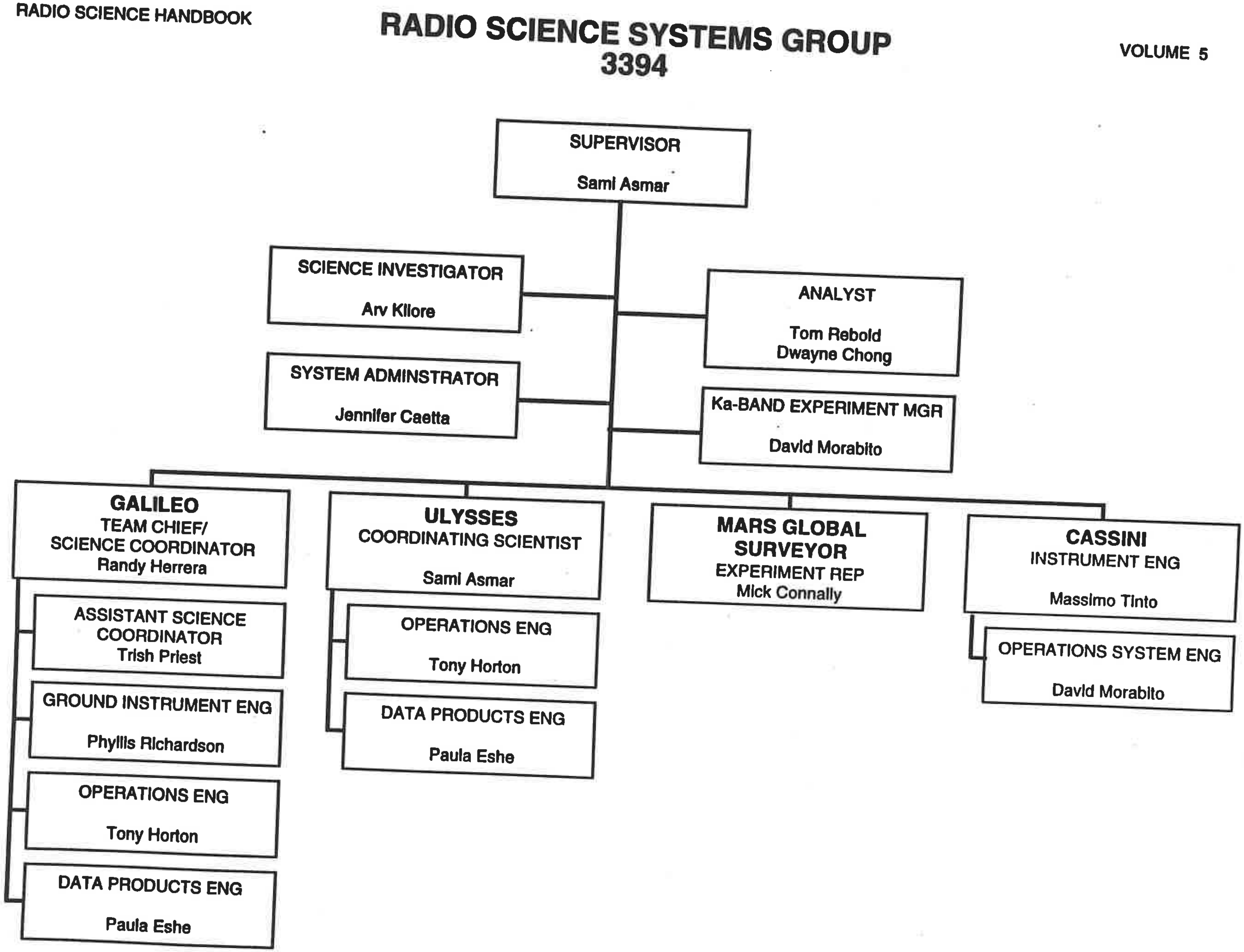


Figure 4-1. Radio Science Systems Group

Section 5
Operations

5.0 Introduction

This section deals with operations for Radio Science activities, which are broken up into three phases: pre-pass, real-time, and post-pass.

The following products are used by Radio Science Support Team (RSST) during operations and will be further explained in this Section: Integrated Sequence Of Events (ISOE), Space Flight Operation Schedule (SFOS), closed-loop receiver predictions and open-loop Radio Science predictions (should they be required).

The following key organizations are concerned with Radio Science operations and will be mentioned in the text: the Radio Science Team (RST) or Radio Science Support Team (RSST), the Mission Control Team (MCT), the Network Operations Control Team (NOCT), and the Deep Space Network (DSN) or Deep Space Station (DSS).

5.1 Pre-pass Phase

5.1.1 Network Operations Plan (NOP)

The NOP contains the parameters for configuring and calibrating the Radio Science System equipment at the DSN sites for each experiment. The experiments are listed in Volume II, Chapter 12, of the NOP. The details of each sub-section are negotiated with the Network Operations Planning Engineers (NOPEs) at the time of sequence (uplink) development, allowing sufficient time for the NOPEs to issue an update to the NOP.

Under normal circumstances, the ISOE (see below) will reference the appropriate NOP sub-section at the start of every pass containing a Radio Science observation. In contacting the TrackCon or the station over the VoiceNet, reference is made to the appropriate sub-section in the NOP (if not superseded by the ISOE or other TWX).

5.1.2 Predictions

The DSN's Network Support Subsystem (NSS) generates the predictions for frequency tuning (both open- and closed-loop receivers), and antenna pointing approximately one week in advance. The Network Operation Control Team (NOCT) transmits the predicts to the stations in binary form.

In the case of unique one-time activities (such as occultations and fly-bys), the Ops Engineer and/or the Investigator review the predict sets for accuracy.
Closed-loop receiver predicts are generated for all Radio Science activities. These include standard tracking predictions which are used by the Metric Data Assembly (MDA) to compute Doppler pseudo-residuals, and frequency tuning predictions which are used to tune the closed-loop receivers for initial signal acquisition.

Radio Science open-loop receiver predictions are required for those Galileo and Ulysses passes where the DSP has been scheduled for recording.

Antenna pointing predictions are generated for all passes.

5.1.3 Integrated Sequence of Events (ISOE) & Space Flight Operations Schedule (SFOS)

The ISOE is generated during the uplink development process. It is a second-by-second schedule of all events occurring both on the spacecraft and at the station. A related document is the DSN Keyword File. It is directly generated from the ISOE and contains coded time-stamped directives and notices for station personnel such as mod index changes and times, station configuration codes for calibration as well as pre- and post-calibration times, group activity start and stop times, and Doppler mode changes and times. The ISOE and its corresponding DSN Keyword File are the controlling products for any activity supported by the DSN; therefore, they contain all activities and information necessary to enable the station personnel to support each pass during a Radio Science experiment. The ISOE is used by all of the organizations responsible for real-time activities such as the Mission Control Team, the Network Operations Control Team, and the Radio Science Support Team.

Several copies of the ISOE are delivered to the RSST Real-Time Area in the week before activities are scheduled. One copy is highlighted by the Operations Engineer for RST activities; another copy is kept by the Data Production Engineer for inclusion in Passfolders.

RSST personnel preparing to monitor a pass verify that the ISOE corresponds to the expected activities or observation. Any discrepancies are discussed with the ACE (or Ops Eng immediately and noted in the logsheet.

The Mission Control Team (MCT) is responsible for supporting any correction or "redline" activities. The Operations Engineer verifies that all redlines have been included in the ISOE.

Another related product is the SFOS. It is a day-by-day synopsis of Project activities including spacecraft events, meetings, and reviews. This product is ONLY an overview of experiment activities. The ISOE remains the controlling document.

5.1.4 Multi-Mission Logsheet

Before the start of every pass, the RSST member on duty begins to fill out a Multi-Mission Logsheet (See Figures 5-1 & 5-2). The Operations Engineer provides a logsheet checklist. In this section, **bold** indicates a parameter that appears on the logsheet and *italics* indicate something that the user would write onto the logsheet.

Starting at the uppermost line, the **DSS**, **S/C ID**, **PASS** number (from the SFOS), **DOY**, **DATE**, and **SCHEDULED AOS** and **LOS** are entered by the RSST member on duty.

For three of the experiments covered by this volume of the Handbook, logsheets have been produced which already have the **SUPPORTING ACTIVITY** space filled in (See Figures 5-1 & 5-2).

During pre-cal, the station personnel use the VoiceNet to relay to the TrackCon which **MASER** and **RECEIVER** are supporting the pass (e.g., **MASER** *1*, **RECEIVER** *4*) as well as the **INITIAL ACQUISITION** conditions. The **WEATHER CONDITIONS** are also reported at this time. RSST personnel copy this information onto the logsheet into the appropriate place.

RTLT, **OWLT**, **SEP**, and **ANT MAX ELEVATION** (**ANGLE** and **TIME**) can be found in the SFOS.

The section under "MDA S & X-BAND" must be completed after the station has gone 2-way (if scheduled to do so). Data is obtained from the RMS displays of Doppler residuals. The **2-WAY DOPPLER TIME**, the time at which 2-way Doppler comes into lock, is reported by the station to the TrackCon over the VoiceNet.

The section under "SSI CFG" portion is completed from RMS displays.

If multiple channels are being recorded, the RSST member on duty requests from the TrackCon a "walk-thru" of the appropriate channels (i.e., cycle thru the ODAN channels of the SSI for 5 minutes each and make hard copies of each channel's display).

The **NBOC MODE**, **SAMPLE RATE**, and **FILTER OFFSET** are obtained from the RMS Text Page (under data type NRV).

The sections under "RIV Status" and "NBOC Status" are completed using NOCC Workstation displays (by the same names). Lines are drawn in the "NBOC Status" box to indicate the setup.

Finally, the **MIN RMS** and **MAX RMS** (root-mean-square) values of the DSP are obtained from the RMS (real-time monitoring system) Text Page and are compared against the NOCC Workstation values of **RMS CALC** found in the "NBOC Values" display.

For experiments where the open-loop system (DSP) is recording and the Spectral Signal Indicator (SSI) is being used, the portion of the logsheet dealing with the validation of the DSP is COMPLETELY filled out. Both receiver and ODAN modes can be exercised. Table 5-1 describes the different configurations of the SSI for the S- and X-band receiver channels as well as the output channels of the four A-to-Ds (ODAN mode).

5.1.5 Station Configuration & Calibration

Prior to every pass, station personnel perform equipment configuration and calibration. This includes important tasks such as setting the attenuators on the Radio Science IF-VF Converter (RIV), loading predict sets into the DSP, and building the link from the CMC. If possible, RSST personnel covering the pass in real-time are present for this activity and note important items in the logsheet.

5.1.6 *GCF-RODAN Interface and the Real-time Monitoring System (RMS)*

5.1.6.1 *GCF-RODAN Interface*

The RODAN/GCF interface was originally rigged to provide the RSST with visibility into DSP operations for the Voyager Uranus encounter in 1986. The interface provided valuable information and has been upgraded successively to use an ethernet connection between the Radio Science front end machine, *gamura*, a Sparc1, and the GCF machine using the UDP/IP protocol (In the near future, *gamura* will be upgraded to a Sparc5). There is a serial/X.25 interface standing by as a backup in case of network failure. The network connections back to the DSSs can be viewed on the end-to-end system diagram at the end of the Handbook.

For detailed procedures on setting up and running the GCF/RODAN interface, see Section 5.1.6.2.1.

5.1.6.2 *Real-time Monitoring System (RMS)*

The Radio Science Real-time Monitoring System (RMS) is one part of the Radio Science Operations and Data Analysis Network (RODAN) and displays real-time information necessary for monitoring the RS instrument and experiments which is sent from one or more DSN stations through the GCF. The real-time operations are based on two Sun workstations, which currently split the duties of data acquisition and display, each doing one of the functions. Each machine will be able to do both functions when they are upgraded to Sparc5s and can handle the CPU requirements of both tasks. *Gamura*, the front end, was described in Section 5.1.6.1. *Godzilla*, a Sun 4/330, is the display machine and will be upgraded to a Sparc5 after the display software has been upgraded to run on a more recent operating system version.

Gamura does some data filtering and processing and transfers the Radio Science data records using TCP/IP to *godzilla*. Before the interface can be started, two configuration files must be created or edited, one per machine. The files are basically identical except that the *gamura* file does not contain start and stop times.

The outline below shows the path of a Radio Science data record through the RMS:

1. Data record is received through either the X.25 or UDP interface on *gamura* and is passed to the filtering function.

2. The data record is checked against the operator-defined configuration file to determine if this data record is meant to be allowed through. If not, the data record is dropped. If so, it is passed to the header-stripping function.

3. The data record is checked to see if it has an SFDU or any other unwanted (for Radio Science purposes) headers. If so, the header is stripped; the remaining part of the data record is passed on to the sending function.

4. The data record is sent through TCP/IP to *godzilla*, and is stored in *godzilla's* shared memory according to record type.

5. When the operator brings up a display which is relevant to the data record's type, the data record is read in from shared memory into the main CPU space and displayed through a Sunview program. In future releases of the display software, the display will be X-windows based.

6. After the operator is done with the pass, he or she saves the data records comprising the shared memory database to disk and exits.

The present Radio Science Operations and Data Analysis Network (RODAN) is shown in Figure 5-3. This multi-mission computing facility is used to support Radio Science experiments.

5.1.6.2.1 Startup Procedures

This section outlines the procedures to start up the data acquisition portion of the RMS. Commands for the user to enter are presented in **bold** type; machine names are presented in *italics.*

If you intend only to run the display portion of the RMS, see Section 5.1.6.2.2.

Emergency procedures for starting up and shutting down the Sun workstations can be found next to *godzilla.*

Note: The data flow between *gamura* and *godzilla* is a TCP/IP socket. This requires a formal connection procedure, which needs the receiving end to be listening before the sending end is started. If at any point you believe that the steps below have all been completed, yet you have received error messages from either *godzilla* or *gamura*, then the connection has been attempted in the wrong order. The best thing to do at this point is to just start over again after killing off the old processes.

Because the ethernet link uses UDP protocol, it is up to the RSST user and the Comm Chief to determine that the ethernet link is indeed working, and if not, to switch the flow of data to the X.25 link.

1. Login as User *rms* on *godzilla*. Choose the ***New Display*** button from the ***Startup Menu*** window (Figure 5-4), which brings up the ***Main Selection Menu*** (Figure 5-5) and maybe the ***Data Base Utilities*** window (Figure 5-6); the ***Data Base Utilities*** window appears automatically only if the shared memory database was cleared before the last operator shut down the RMS. If the ***Data Base Utilities*** window does not automatically appear, choose the ***Data Base Utilities*** button from the ***Main Selection Menu.***

2. Choose the ***Get Live Data*** button from the ***Data Base Utilities*** window using the left mouse button (Button 1). If the database still contains data, the user will be prompted

to decide whether to continue using the old database or select a new one (Figure 5-7). If you wish to continue using the old database, skip to step 5. If not, you will be prompted to enter a configuration file name. If you have already prepared a configuration file, skip to step 4.

3. Using the right-hand button (Button 3) on the mouse, click on the background, open the ***Text Editor*** window (Figure 5-8) and load in a previously used configuration file. Edit this file until it describes which data types and time intervals you wish to use for the pass (or passes) being covered. Save the file, and quit the editor (See the System Administrator for details on running the Text Editor). A sample configuration file is given below:

```
94/045/23:30:00
94/046/04:00:00
77 DOP 14 S
77 ANG 14
77 M59 14
77 DOP 43 S
77 ANG 43
77 M59 43
77 SSI 40
77 NRV 40
```

4. Enter the configuration file name at the prompt in the ***Data Base Utilities*** window. At this point, *godzilla* will set up the receiving end of the connection to *gamura* (Figure 5-9).

5. Using Button 3 of the mouse again, click on the background and select ***Remote Login*** to *gamura* (Figure 5-10). Edit the configuration file for the filtering program on *gamura* using **pico**, an editor (See the System Administrator for details on **pico**). The configuration file looks identical to the sample configuration file above with the exception that there are no times or dates. Save the modified configuration file and exit the editor. Force the filtering program to accept the newly edited configuration file by running **modify_conf.file** (Figure 5-11). Additional configuration files can be added to the filtering program on *gamura* without restarting the program.

6. Enter the command **routertcp** at the *gamura* prompt (Figure 5-12). The default configuration is to use the UDP/IP interface to the GCF and to send the data to *godzilla* over the TCP/IP socket connection. If you do not wish to display data at all, but just to verify that data is coming in, you can use **routertcp -nd** (for No Display).

   If no data is flowing, attempt to query the GCF machine using **ping 137.228.10.24** from either *godzilla* or *gamura*. A positive response indicates that the machine on the other end is up and running and that the ethernet interface is working.

   If there is no response, start up the X.25 interface using the following procedure:

a. Call the Comm Chief (3-5800) and ask him to start the X.25 task to RODAN. The X.25 line is connected to the "RODAN4" modem at the GCF end.

b. Enter **syncstat hih0 1** on *gamura*, and wait until a series of "2"s pass through the "abort" column. After the "2"s return to "0"s, hit Control-C to stop the syncstat command.

c. Enter **ifconfig xpkt0** on *gamura*. You should see the following:

xpkt0: flags=51<UP,POINTOPOINT,RUNNING>

d. Enter **routertcp -if x25** at the prompt on *gamura*.

(For a complete listing of the options available with **routertcp**, use **routertcp -usage**).

At this point, data should be flowing from the GCF, through *gamura*, and be ready to be displayed (Figure 5-13).

7. Monitor the pass.

5.1.6.2.2 Using the RMS Display Software

The RMS Display Software is currently written in Sunview for use with Openwin 2. In future releases, it will be written in C/C++ on a Tcl/Tk X-based platform. The following sections describe some of the other options available to the user in the current version of the RMS Display Software.

5.1.6.2.2.1 "Load from Tape/Disk"

This option allows the user to access a previously saved database for perusal or examination. By clicking on this option with the left mouse button, the user first brings up a summary of the existing database (in virtual memory). The user is asked if the existing database should be deleted. After answering this, the user is given the option of creating a new database or adding to the existing database (in the case that it was not just deleted). The program next asks if the desired input is on disk or on tape. If the input is in a file on disk, the user is prompted for the name of the subdirectory containing the archived data. (Note: for each pass, the data is archived in several files according to data type. These files are put into a single subdirectory; so when loading input files from disk, you only need to name the subdirectory. Since the program must load all data types into the database, naming a single file will produce an error message.)

If the input was archived onto tape, the program assumes the presence of a tape drive at /dev/rst0. The user is prompted to install the tape in the tape drive, and the program reads the data both into shared memory and into a subdirectory (on disk) with the same name as the tape files. The data on tape is archived using **tar**, which organizes the entire data subdirectory into a single file before writing to tape.

5.1.6.2.2.2 "Save to Tape/Disk"

Data may be archived either to a subdirectory on disk or to tape. The user is asked to provide a name for the new subdirectory (Figure 5-14), and the data will automatically be archived into that directory. The user is then asked if the data should be backed up to tape (Figure 5-15). If this is chosen, the data is archived to tape using **tar**. The user uses the command **tar -tvf /dev/rst0** at the ***Data Base Utilities*** command line to examine the contents of the tape in the /dev/rst0 tape drive.

If the **tar** command fails at any point while archiving to tape, an error message is printed to the screen and the user is prompted to try again. However, if after two retries **tar** still fails, try re-inserting the tape and/or rewinding it using the command **mt -f /dev/rst0 rewind**.

5.1.6.2.2.3 "List Sub-Directories"

This command is essentially a macro for **ls -l | grep /**, with some other filtering done to make the output look cleaner. The output is a listing of all the subdirectories of the current working directory.

5.1.6.2.2.4 "Report About Present Data Base"

This option displays the status of the current database in virtual memory.

5.1.6.2.2.5 "Quit"

This option only destroys the ***Data Base Utilities*** window; it does not log the user out.

5.1.6.2.2.6 "Create a New Plot"

1. After a monitoring session has been setup using either live data or archived data to fill the database, the user selects the option ***Create a New Plot*** from the ***Main Selection Menu***.

2. When the ***Data Type Selection Menu*** appears, the user selects from among the various data types listed. This menu is automatically set according to what data types are available from the database.

3. After selecting a data type, the user selects a plot type (AGC, Doppler residuals, etc.) from the ***Plot Type*** menu.

4. After the plot is created and appears on the screen, the ***Main Selection Menu*** reappears. The user then chooses another plot by repeating steps 1-3.

5.1.6.2.3 Manipulating Workstation Displays Using The Mouse

To Resize A Plot: Position mouse at the corner or edge of the plot. Hold down the *control* key and the center mouse button simultaneously. Move the mouse to the desired new corner/side location, and release both the *control* key and the mouse button.

To Move a Plot: Position mouse at the border of the plot. Click and hold the center mouse button. Move the mouse to the desired location, and release the button.

To Bring a Plot Forward: Click the left mouse button on the edge of the plot.

To Change Start Time: Move mouse to the ***Start*** bar at the top of the display. Press the left mouse button to move the bar to the desired location. Release the left mouse button. To effect the change, click on ***Jump***.

To Change Time Span: Move mouse to the ***Span*** bar at the top of the display. Press the left mouse button to move the bar to the desired location, and release the button. To effect the change, click on ***Jump***.

To Display the Value for Data Point (X,Y): Click the right mouse button on the top black bar of the plot. Select ***Compute XY*** with the right mouse button. Point the mouse to the desired place on the plot and click the left mouse button: the coordinates will be displayed at the bottom of the graph.

To Modify the Graph (scale, plot type, etc): Click the right mouse button on the top black bar of the plot, and select the ***Modify Graph*** option by clicking the right mouse button again. The plot parameters window will appear. Click the left mouse button on the characteristic you wish to change. To change the value, delete the old value and enter in the new value. Note: to plot a continuous line, ***Plot Mode*** should be ***-1***, or the ascii value of the desired plot point symbol (e.g., *43* for + to plot discrete points. To implement the modifications, click on ***Accept Parameters*** with the left button.

To Make a Printout of the Plot: Click the right mouse button on the top black bar of the plot. Select ***Print*** with the right button. The plot will be resized to occupy the full monitor size while it is being spooled to the printer, then be restored to its original size.

5.2 Real-time Phase

5.2.1 VoiceNet Communication

A description of the voice nets is presented in Table 5-2. In order to ensure that voice communication during the Radio Science data acquisition period proceeds smoothly, all personnel using the VoiceNets must properly identify themselves prior to asking questions or making a request. This is simply a voice check to positively verify that your net is working. The call sign to be used by Radio Science personnel is "Galileo Radio Science" or "Ulysses Radio Science".

The proper way of contacting any other organization or individual on the VoiceNet is by identifying the recipient and then the sender. For instance, for an RSST member to call the Galileo TrackCon, the following would be spoken by the RSST member: "Galileo Track" [slight pause] "Galileo Radio Science".

In contacting the TrackCon or the station over the VoiceNet to clear any discrepancy, reference should be made to the appropriate sub-section in the NOP (if not superseded by the ISOE or other TWX).

5.2.2 Monitoring

The Real-time Monitoring System (RMS) is the main tool used by the RSST to monitor a pass. It displays plots of data vs. time (or frequency) covering the two broad categories of data in which the RST is interested: tracking (closed-loop) data and radio science (open-loop) data. The data received by the RMS are described in DSN document 820-13 (Modules TRK-2-15, MON-5-9, and RSC-11-11). RSST personnel use the RMS along with information via the VoiceNet to inspect the data quality.

The NOCC Workstation located in Building 230 is another valuable source of validation data. (Examples of displays produced by the NOCC Workstation can be seen at the end of this Chapter.)

Displays generated by both systems provide the RSST with an excellent window into the status and configuration of experiments being supported. Copies of all these plots and displays become products of the validation process and are added to the Passfolder. RSST personnel on duty are responsible for obtaining or creating those copies.

5.2.2.1 Tracking Data Monitoring

The MDA (Metric Data Assembly) which produces closed-loop Doppler is standard for all spacecraft tracks (w/ and w/o Radio Science). For Radio Science experiments, a higher Doppler sample rate is normally requested to obtain better resolution. Sample rates are part of the ISOE and NOP and are reported in real-time.

The SRA (Sequential Ranging Assembly) produces ranging data and is scheduled only when required. The Solar Corona Experiment, for instance, uses the SRA to measure electron content and is one example of an experiment which requires the SRA.

Before monitoring any RS pass, RSST personnel on duty determine the Doppler rate(s) for the pass and the status of any ranging requirement from the ISOE, NOP, and/or TWX. Appropriate actions via VoiceNet, phone, etc. are taken to insure that the tracking data is obtained. RSST personnel complete the appropriate areas of the logsheet based on the information obtained from all sources (RMS, NOCC Workstation, & VoiceNet).

See Section 3.0 of this Handbook for a more detailed description of this equipment.

5.2.2.2 Radio Science System Monitoring

The Radio Science System consists of various downconverters and the DSP (open-loop) recorder. Usage of the RSS is dependent upon the experiment requirements and will be scheduled on that basis. The DSP is configured according to the NOP that governs a specific experiment, and verified against the ISOE (recommended configurations appear in Chapter 12 of the NOP Volume II for Galileo).

The Spectral Signal Indicator (SSI) is a separate but related piece of equipment at the station that displays an FFT of the pre- or post-digitized signal from the DSP. The display is transmitted to the RMS and the NOCC Workstation and is used to help monitor (and thereby maintain) signal performance of the Radio Science System during periods of open-loop data recording.

Before monitoring any RS pass, RSST personnel on duty determine the configuration for the SSI and the DSP for the pass from the ISOE, NOP, and/or TWX. Appropriate actions via VoiceNet, phone, etc. are taken to insure that the RS data is obtained. RSST personnel complete the appropriate areas of the logsheet based on the information obtained from all sources (RMS, NOCC Workstation, & VoiceNet).

See Section 3.0 of this Handbook for a more detailed description of this equipment.

5.2.3 Sequence-Of-Events Confirmation

As stated previously, the Integrated Sequence Of Events (ISOE), its redlines, and its corresponding DSN Keyword file will be the controlling products for real-time operations during all Radio Science activities. It is important that all operations groups (RSST, MCT, NOCC and the participating DSCC) follow the same script. During the pass, the RSST personnel on duty individually confirm each item. Confirmation of each event provides visibility into the status of the ground data system at each station.

5.2.4 Failures & Emergencies

In case of unexpected equipment (hardware or software) or procedural failures, the TrackCon starts a Discrepancy Report (DR). A number is assigned and the NOCT (DSN) is responsible for tracking and closing all such DRs. If the failure was particularly serious, an Incident/Surprise/Anomaly (ISA) Report is also written by the RSST member who discovered the incident or by the Science Coordinator/Experiment Representative. These are tracked and closed by the specific flight project affected.

RSST personnel on-duty will note any DRs on the logsheet and briefly describe the failure, especially noting any loss of RS data. An ISA can be written by any member of a flight project. Copies of ISAs written by RSST personnel are kept as part of the logsheet.

In case of a spacecraft emergency, the RSST member on duty notes as much as possible on the logsheet without interfering with the Project's attempts to stabilize the situation. A voice-mail message to the rest of the RSST (especially the Science Coordinator/Experiment Representative) is appropriate. The RSST member who is covering the next pass is notified as soon as possible.

In case of facilities emergencies (power outages, air conditioning failures, computer crashes, etc.), the Support Chief (during regular hours), the Ops Chief (during swing or night shifts), or the System Administrators (Jennifer Caetta or Phyllis Richardson) are notified IMMEDIATELY (as appropriate). See Chapter 4 for a listing of phone and beeper numbers.

5.3 *Post-pass Phase*

5.3.1 *Post-Monitoring Period*

In most cases, monitoring of the entire pass is unnecessary. The most critical time period is the first hour or so of the pass (until the two-way signal is finally received on the ground in the case of two-way passes). This is the time period when problems can occur in configuration of the equipment and acquisition of the signal. The Operations Engineer in consultation with the Science Coordinator/Experiment Representative determine the level of support required for each pass and inform the RSST personnel.

Often, this might mean that the RMS is left running unattended for a major portion of a pass. If this is the case, the exiting RSST member "locks" the RMS screen. If the RMS is to be shut down, the procedures in Section 5.3.3 are followed.

When on-duty personnel are exiting, they inform the ACE that they are going off-shift and remind her/him of phone numbers to call regarding experiment outages and emergencies.

Following the recording period (EOT), timely delivery of the products should begin (See Section 6.0). It is not always necessary, but sometimes a good idea, to remind the TrackCon to remind the station personnel to **make a copy of the ODR** before mailing and hold the original at the station. The ODRs are mailed with the next consolidated shipment.

5.3.2 *RMS Takedown Procedures*

This section outlines the procedures to take down the data acquisition portion of the RMS at the end of the pass. Emergency procedures for starting up and shutting down the Sun workstations can be found next to *godzilla*.

1. After the pass finishes and the database has been saved (or deleted), type Cntl-C in the *gamura* window which was created in step 5 (Section 5.1.6.2.1) (Figure 5-16). Logout of *gamura* by entering **exit** at the *gamura* prompt. That window will disappear.

2. Move to the ***Data Base Utilities*** window and select ***Quit***. That window will disappear (Figure 5-17).

3. Move to the ***Startup Menu*** window and select ***Quit***. This will shut down OpenWin (Figure 5-18).

4. At the *godzilla* prompt, enter **exit**. This logs you out of *godzilla*.

Table 5-1. Station SSI Identification
(Valid only until RSSD is implemented)

Display	SSI Port	Signal Source
RCV1	1	Closed - Loop Receiver
RCV2	2	Closed - Loop Receiver
RCV3	3	Closed - Loop Receiver
RCV4	4	Closed - Loop Receiver
SRCP	5	S - band RCP from OLR
SLCP	6	S - band LCP from OLR
XRCP	7	X - band RCP from OLR
XLCP	8	X - band LCP from OLR
ODAN/B & D	9	S - band NBOC Output (RCP & LCP)
ODAN/A & C	9	X - band NBOC Output (RCP & LCP)
SP15	11	S - band from MMR
SP14	12	X - band from MMR

Table 5-2. VoiceNet Identification

INTER - 5: Standard Project operational net to NOCC for communication between Galileo ACE and Ops Chief.

INTER - 8: Standard Project operational net to NOCC for communication between Ulysses ACE and Ops Chief.

GDSCC - 1: Standard NOCC-to-DSN Complex control net (Goldstone) - **Listen Only For Us**

CDSCC - 1: Standard NOCC-to-DSN Complex control net (Canberra) -**Listen Only For Us**

MDSCC - 1: Standard NOCC-to-DSN Complex control net (Madrid) -**Listen Only For Us**

CMTRY: Commentary (and music)

RADIO SCIENCE OPERATIONS VALIDATION SHEET PAGE 1 OF OPERATOR (S) / /

DSS: S/C ID: PASS: DOY: DATE: SCHEDULED AOS: ____ DOY | TIME ____ LOS: ____ DOY | TIME ____

SUPPORTING ACTIVITY: GALILEO SCINTILLATION / GRAVITATIONAL WAVE EXPERIMENT

LIST DRs:

Station Configuration & Status:
S-BAND: MASER ____ RCVR: ____ . X-BAND: MASER ____ RCVR: ____ .

WEATHER CONDITIONS:

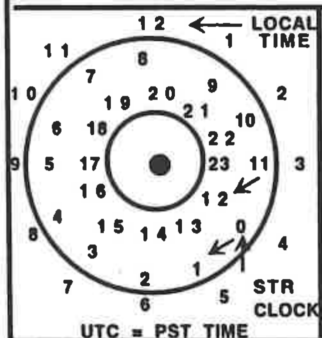
DSP RECORD TIME: ____ *STOP:* ____ *RTLT=HH:MM:SS:* ____

MDA RECORD TIME: ____ *STOP:* ____ *OWLT=HH:MM:SS:* ____

SEP° =

SAA° =

ANT MAX ELEVATION
ANGLE: *TIME:*



INITIAL ACQUITION

MON 5-9 S & X-BAND

I/L TIME: ____ /

AGC dB: ____ /

AGC/BW: ____ /

LOOP/BW: ____ /

SNT: ____ /

TXR ON/OFF TIME: /

MDA S & X-BAND

DOPP SAMP RATE: /

DOPP RESIDS: /

MDTR: /

2-WAY DOPPLER TIME:

SPACECRAFT & STATION INITITAL CONDITIONS (R-T COMMENTS) BELOW:

NBOC VALUES TEXT PAGE

VALIDATION TIME: ____

CHANNEL	A	B	C	D
(NOCC DISPLAY) RMS CALC:				
MAX: (RMS DISPY)				
MIN: (RMS DISPY)				

RIV STATUS

INPUT	ATTEN	FILTER
XRCP	____	____
SRCP	____	____
XLCP	____	____
SLCP	____	____

NBOC STATUS

JACK	CHANNEL
J1 ●	● A
J2 ●	● B
J3 ●	● C
J4 ●	● D

NBOC MODE = *FILTER OFFSET =*
SAMPLE RATE =
MIXED MODE PDX = YES / NO PREDICTS CODE =

SSI CFG

FULL BW: ____ HZ

CENTER FREQ: ____ HZ

ODAN CYCLE: A, B, C, D

SIGNAL PRESENCE: YES / NO

● / ●
SSI DISPLAY

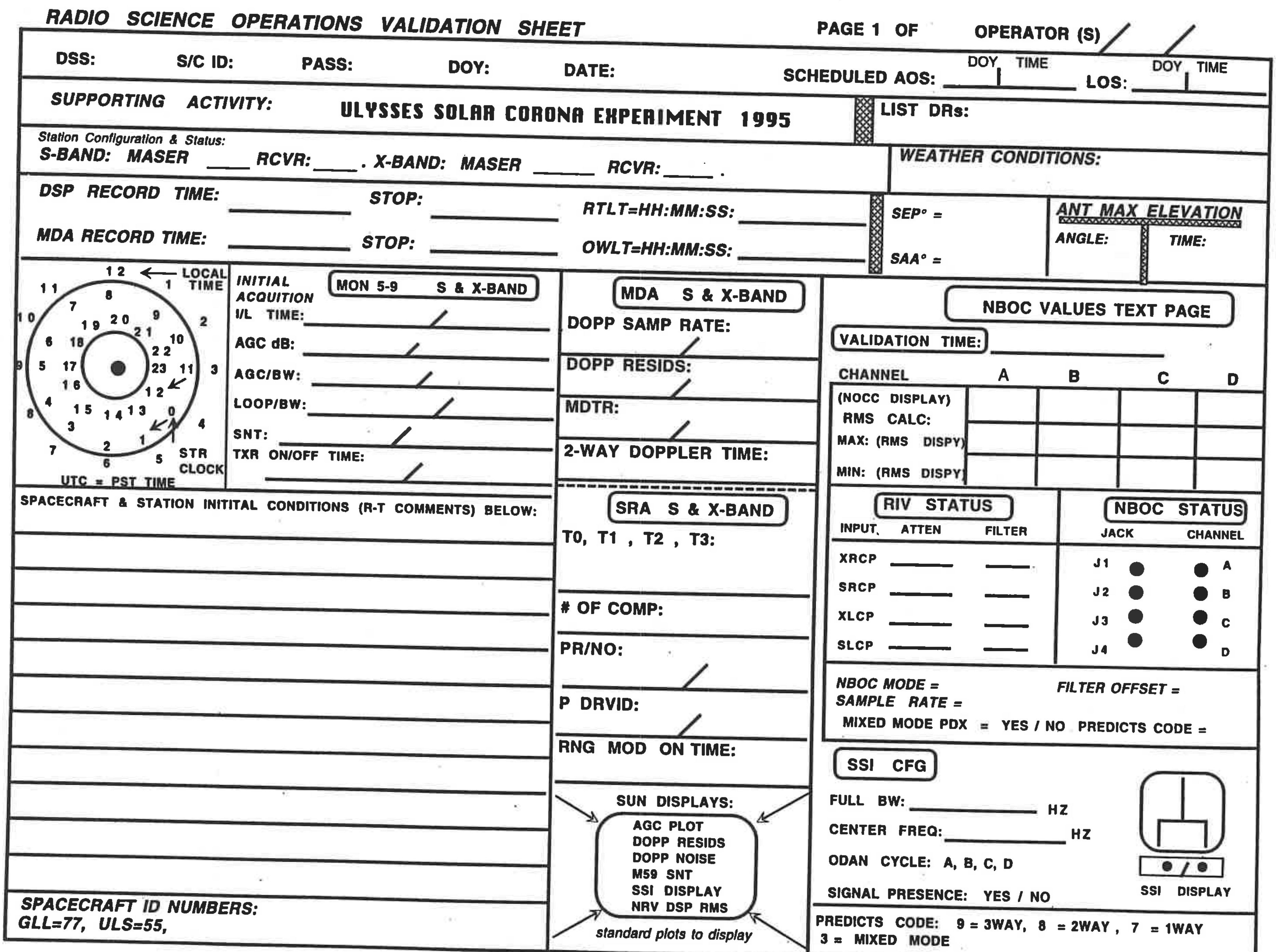
SUN DISPLAYS:
AGC PLOT
DOPP RESIDS
DOPP NOISE
M59 SNT
SSI DISPLAY
NRV DSP RMS
standard plots to display

S/C ID 'S GLL=77, ULS=55,

PREDICTS CODE: 9 = 3WAY, 8 = 2WAY , 7 = 1WAY
3 = MIXED MODE

RAH 10/10/94

Figure 5-1. Galileo Logsheet



RADIO SCIENCE OPERATIONS VALIDATION SHEET

PAGE 1 OF

OPERATOR (S)

DSS: S/C ID: PASS: DOY: DATE: SCHEDULED AOS: (DOY / TIME) LOS: (DOY / TIME)

SUPPORTING ACTIVITY: ULYSSES SOLAR CORONA EXPERIMENT 1995

LIST DRs:

Station Configuration & Status:
S-BAND: MASER ____ RCVR: ____ . X-BAND: MASER ____ RCVR: ____ .

WEATHER CONDITIONS:

DSP RECORD TIME: ____ STOP: ____ RTLT=HH:MM:SS: ____

MDA RECORD TIME: ____ STOP: ____ OWLT=HH:MM:SS: ____

SEP° =

SAA° =

ANT MAX ELEVATION
ANGLE: TIME:

LOCAL TIME
STR CLOCK
UTC = PST TIME

INITIAL ACQUITION

MON 5-9 S & X-BAND

I/L TIME:
AGC dB:
AGC/BW:
LOOP/BW:
SNT:
TXR ON/OFF TIME:

MDA S & X-BAND

DOPP SAMP RATE:
DOPP RESIDS:
MDTR:
2-WAY DOPPLER TIME:

NBOC VALUES TEXT PAGE

VALIDATION TIME:

CHANNEL	A	B	C	D
(NOCC DISPLAY) RMS CALC:				
MAX: (RMS DISPY)				
MIN: (RMS DISPY)				

SPACECRAFT & STATION INITITAL CONDITIONS (R-T COMMENTS) BELOW:

SRA S & X-BAND

T0, T1 , T2 , T3:
OF COMP:
PR/NO:
P DRVID:
RNG MOD ON TIME:

RIV STATUS

INPUT	ATTEN	FILTER
XRCP		
SRCP		
XLCP		
SLCP		

NBOC STATUS

JACK	CHANNEL
J1	A
J2	B
J3	C
J4	D

NBOC MODE =
SAMPLE RATE =
FILTER OFFSET =
MIXED MODE PDX = YES / NO PREDICTS CODE =

SUN DISPLAYS:
AGC PLOT
DOPP RESIDS
DOPP NOISE
M59 SNT
SSI DISPLAY
NRV DSP RMS
standard plots to display

SSI CFG

FULL BW: ____ HZ
CENTER FREQ: ____ HZ
ODAN CYCLE: A, B, C, D
SIGNAL PRESENCE: YES / NO

SSI DISPLAY

SPACECRAFT ID NUMBERS:
GLL=77, ULS=55,

PREDICTS CODE: 9 = 3WAY, 8 = 2WAY , 7 = 1WAY
3 = MIXED MODE

RAH 10/10/94

Figure 5-2. Ulysses Logsheet

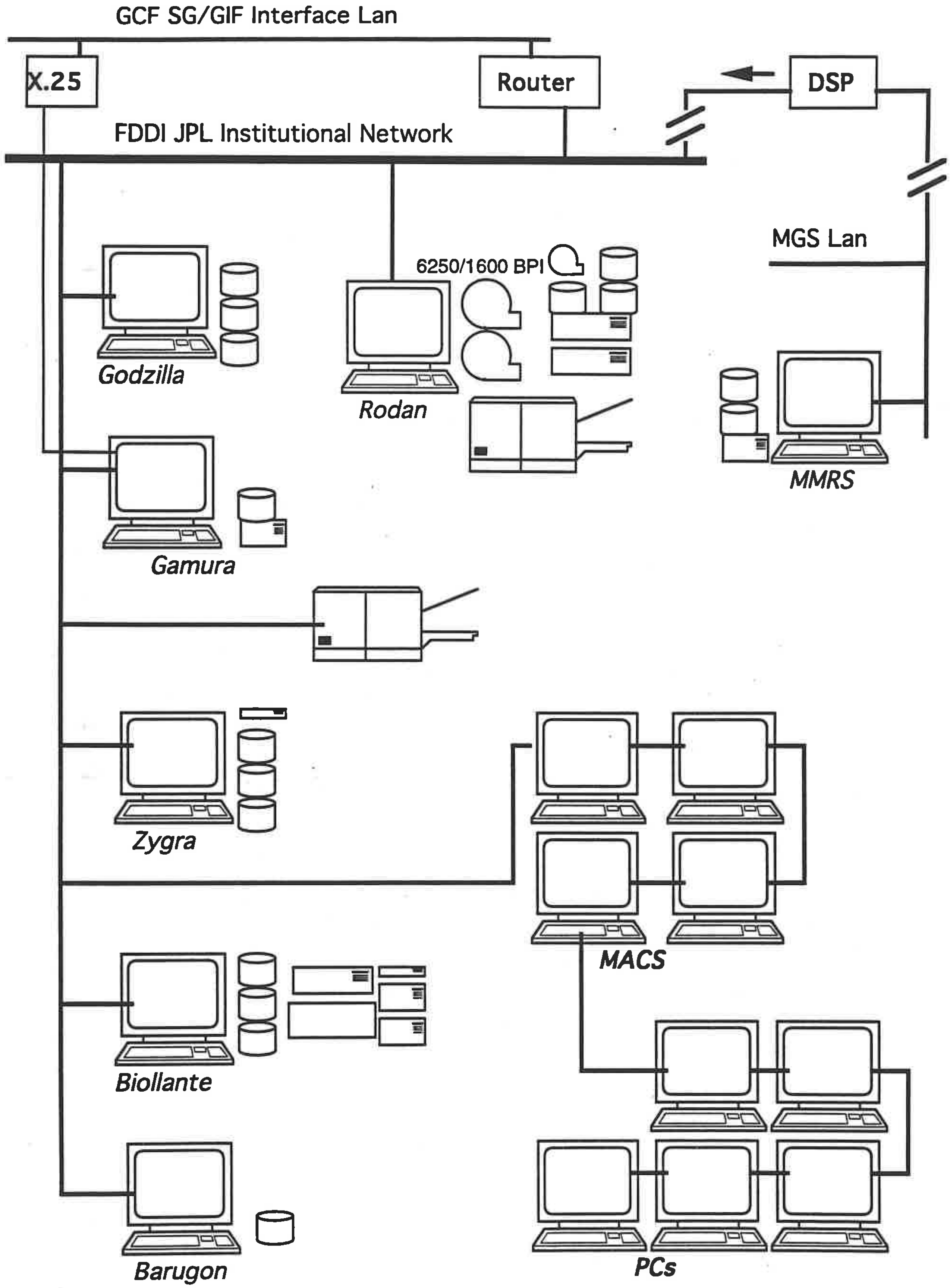


Figure 5-3. Radio Science Operations and Data Analysis Network (RODAN)

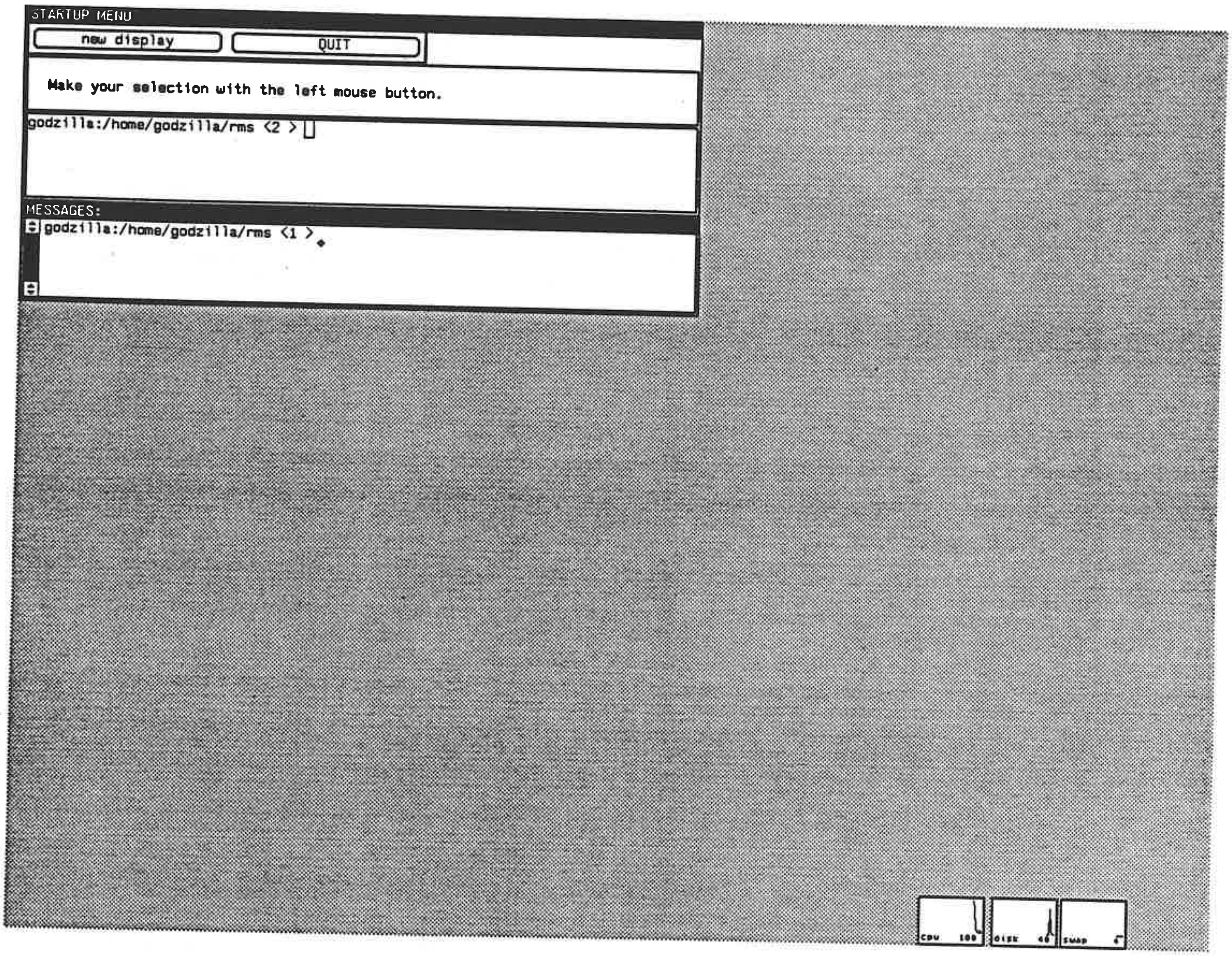


Figure 5-4. Startup Menu Window

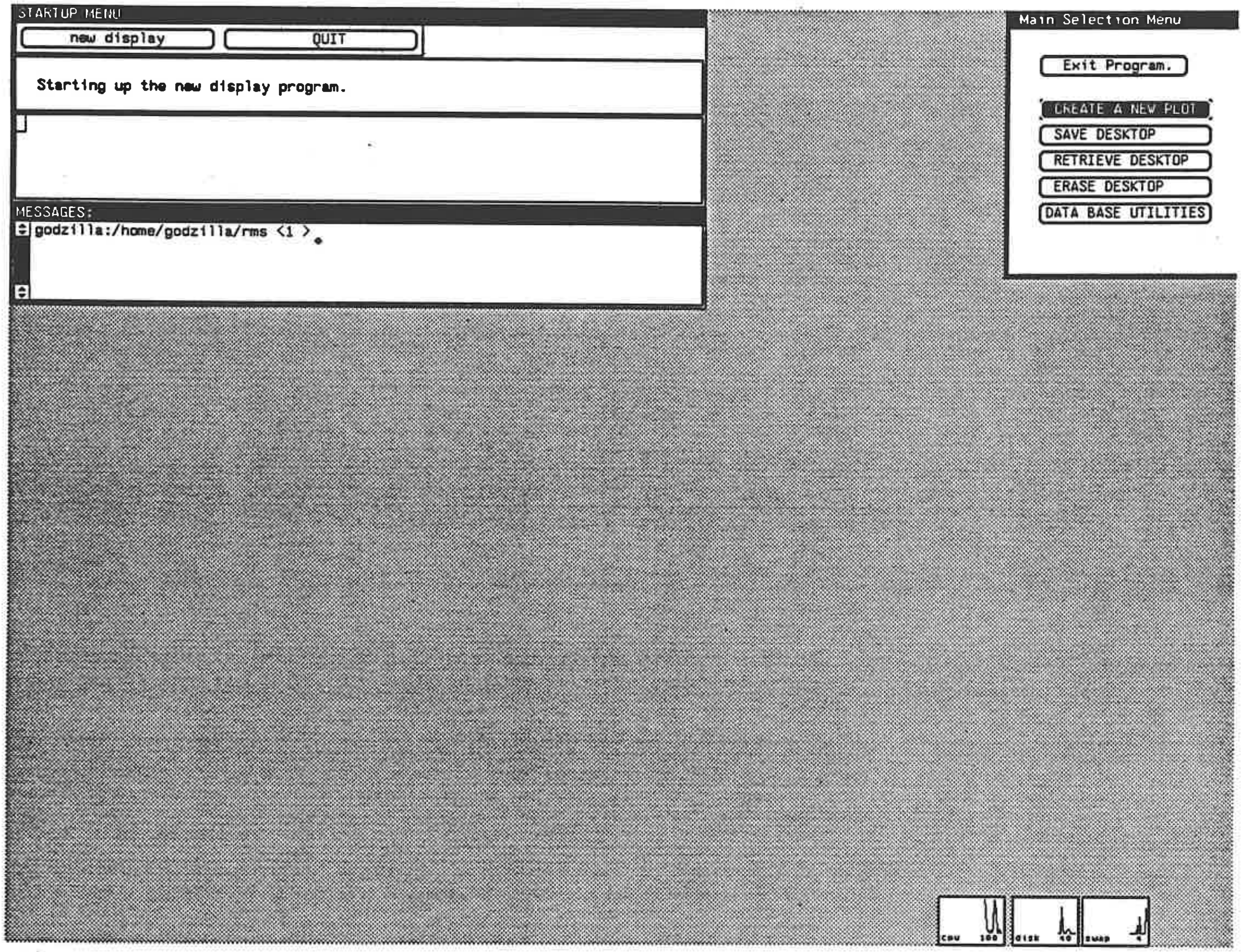


Figure 5-5. Main Selection Menu Window

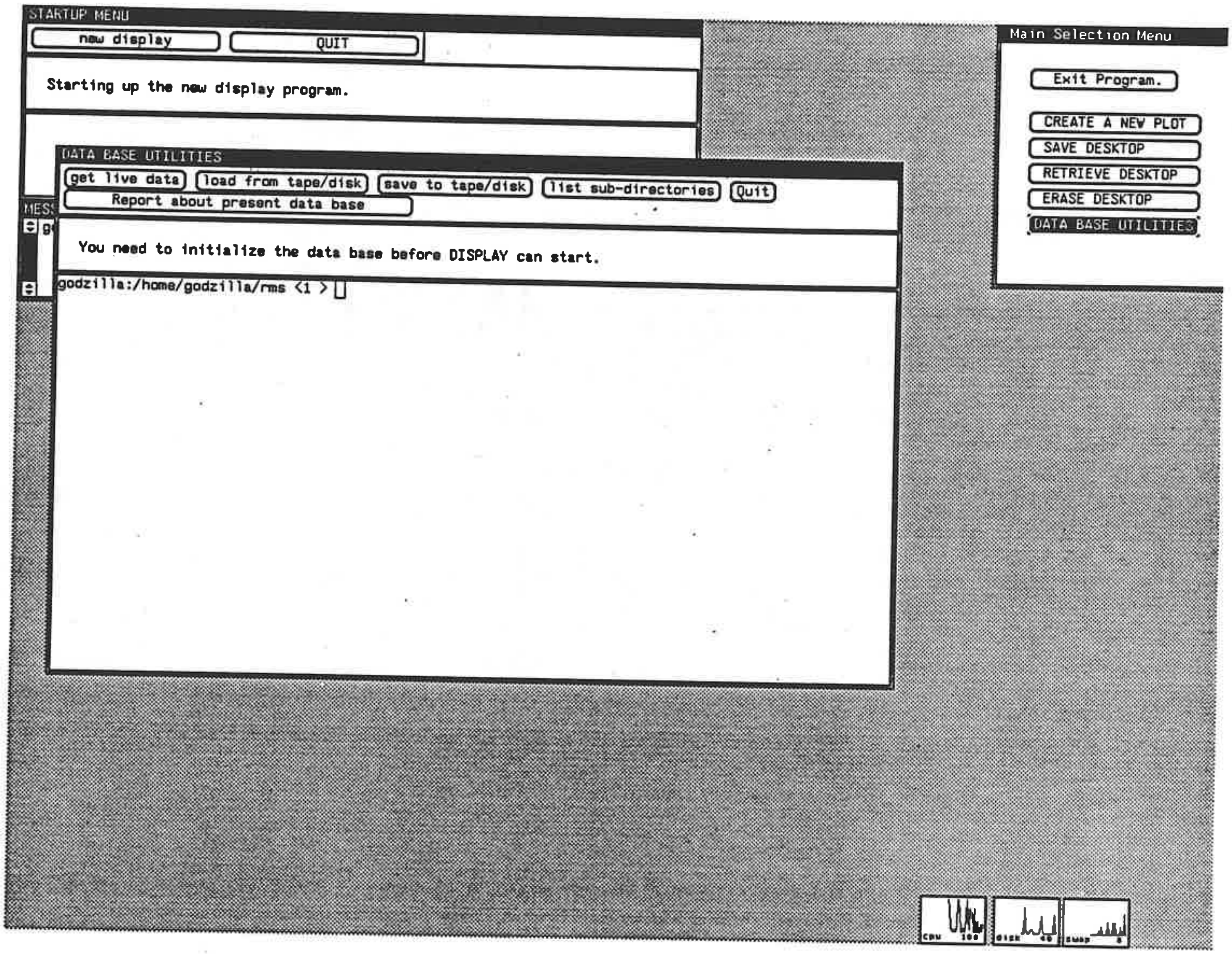


Figure 5-6. Data Base Utilities Window

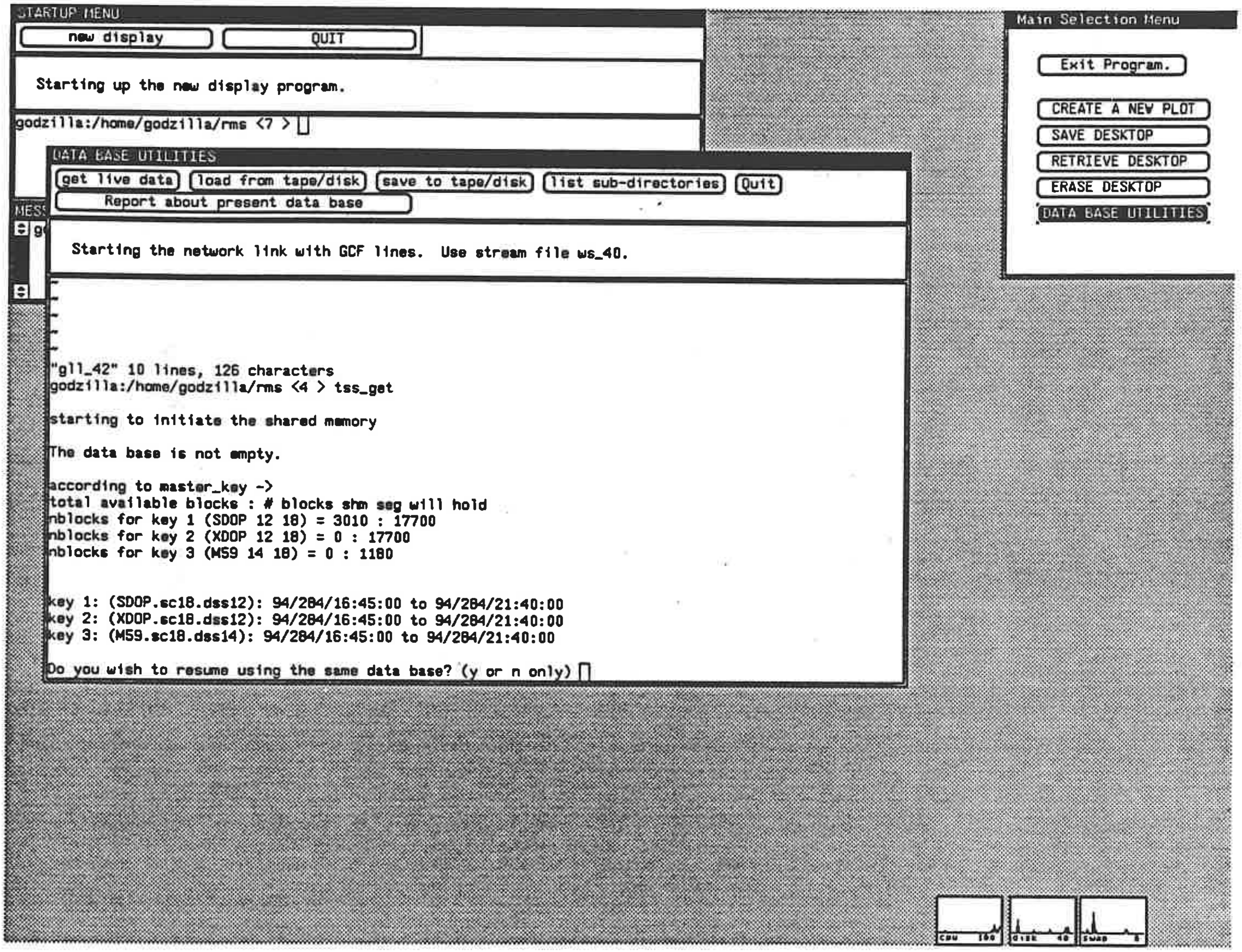


Figure 5-7. Old or New Data Base?

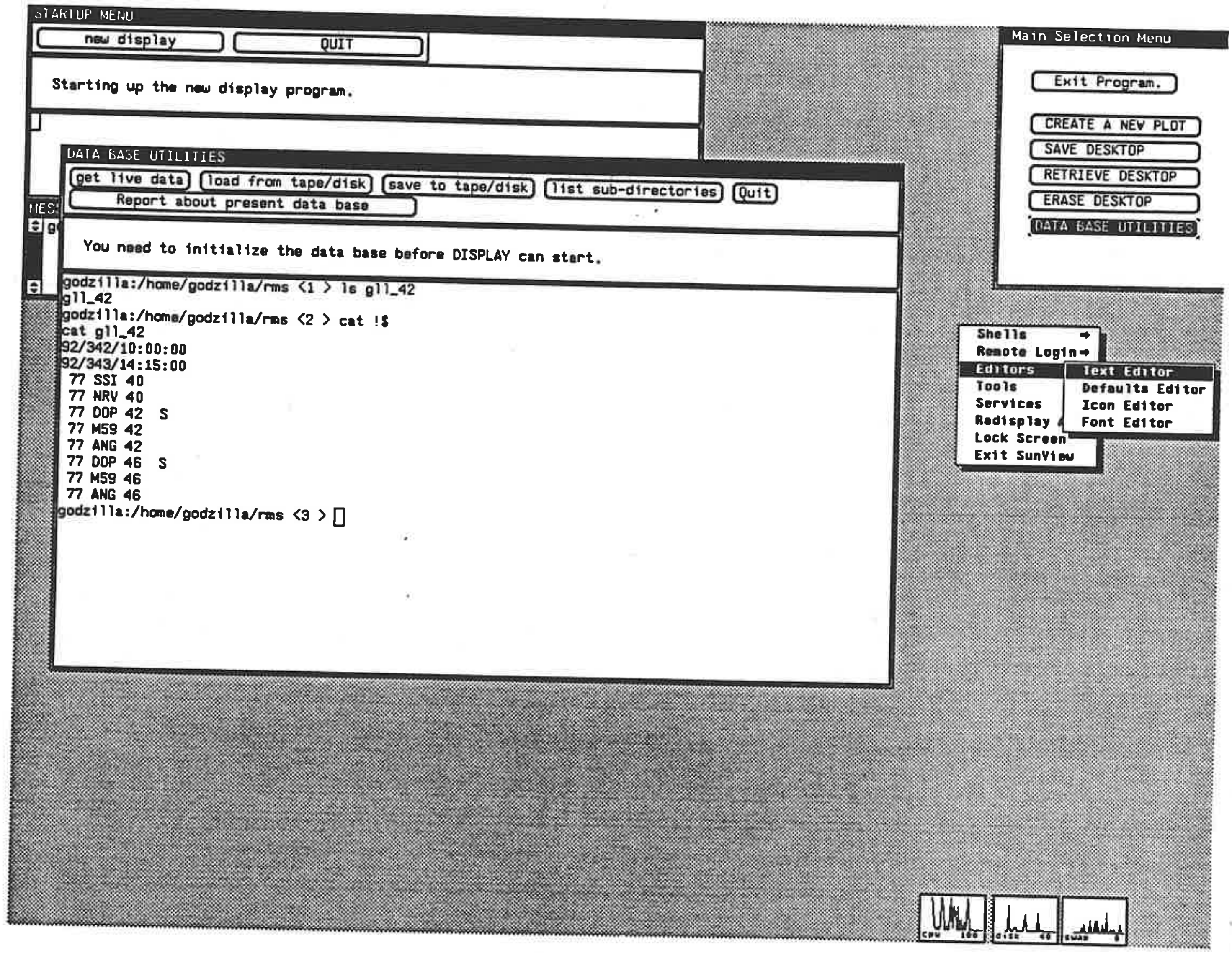


Figure 5-8. Text Editor Window

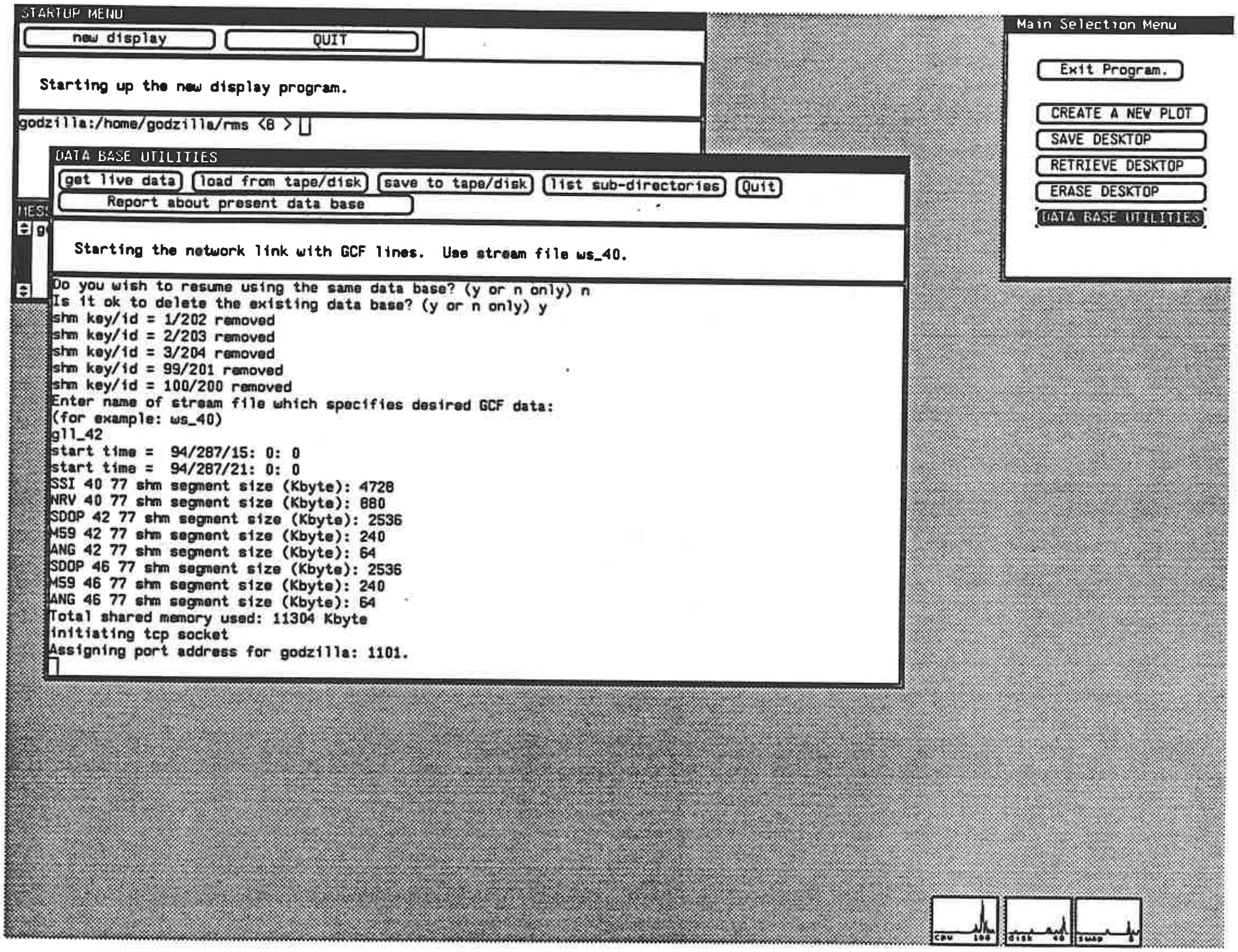


Figure 5-9. Configuration File

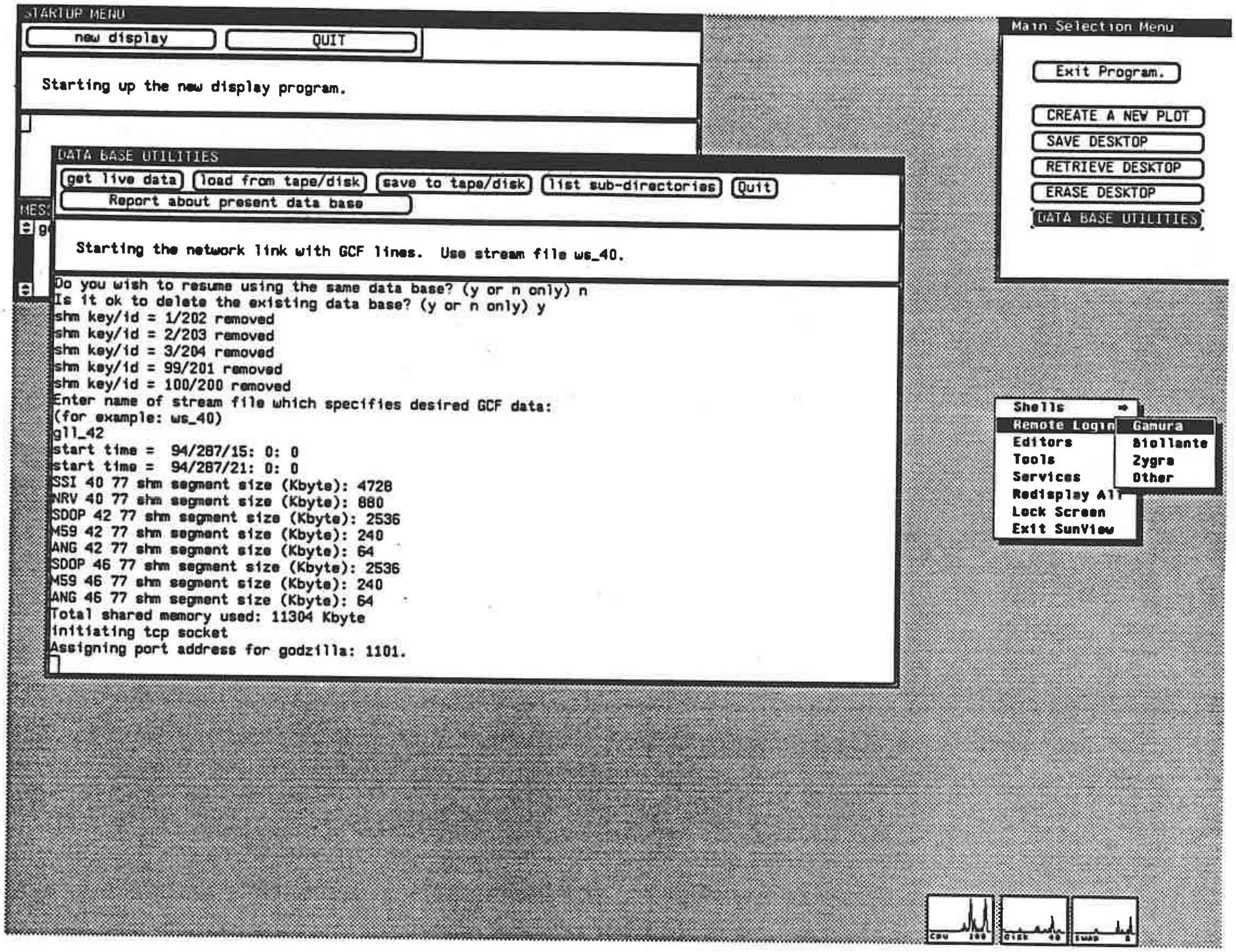


Figure 5-10. Remote Login to *gamura*

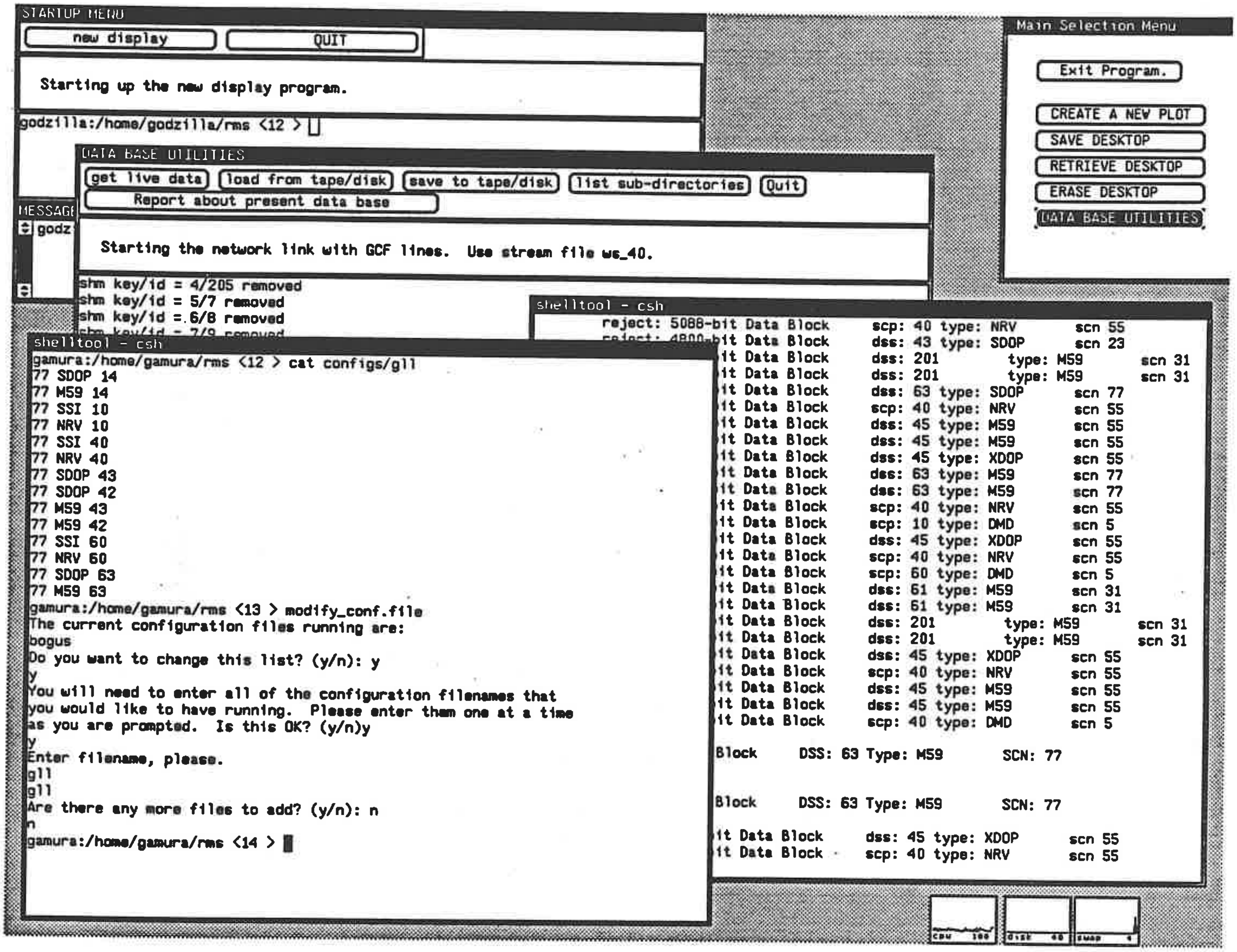


Figure 5-11. Modify-conf.file

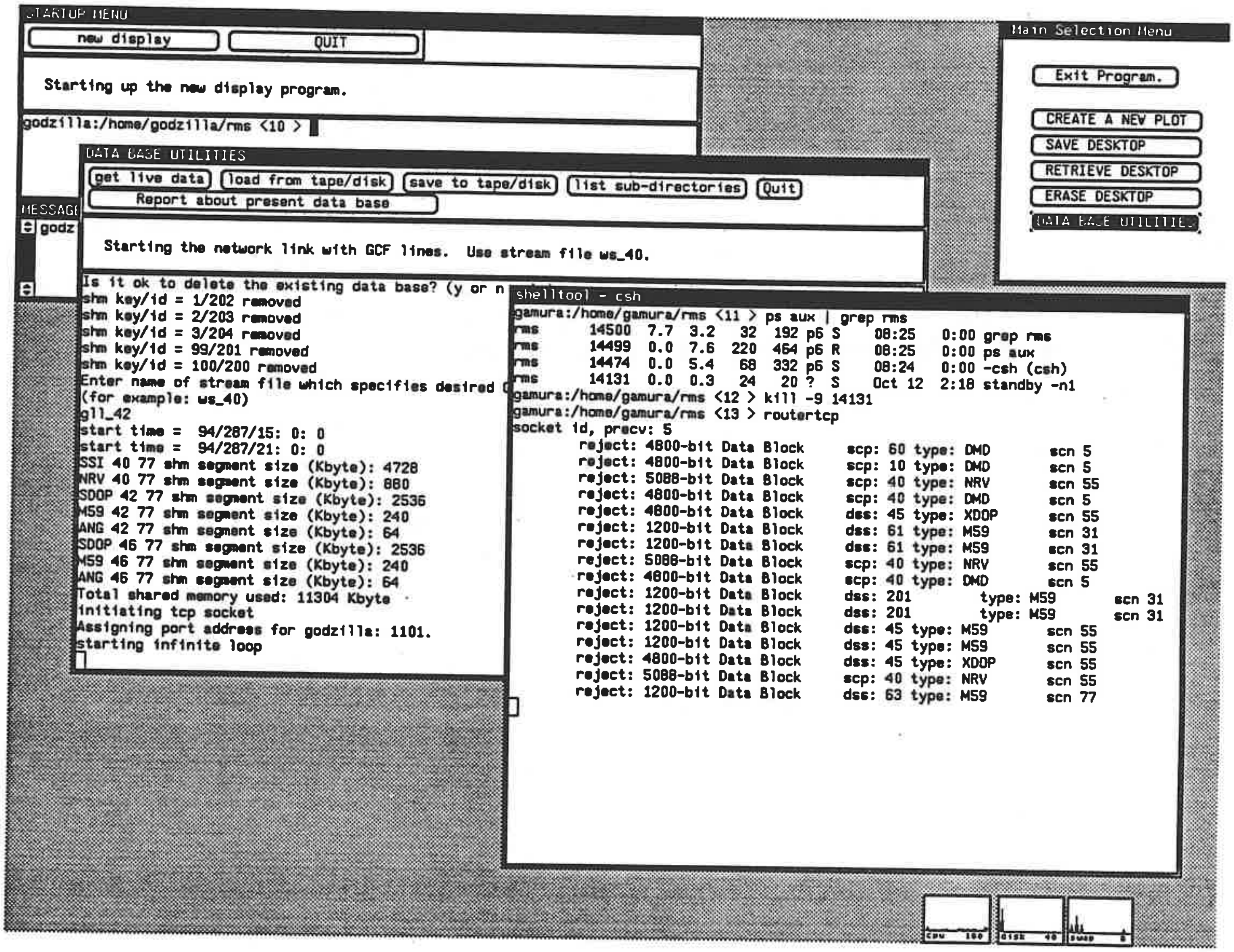


Figure 5-12. Routertcp

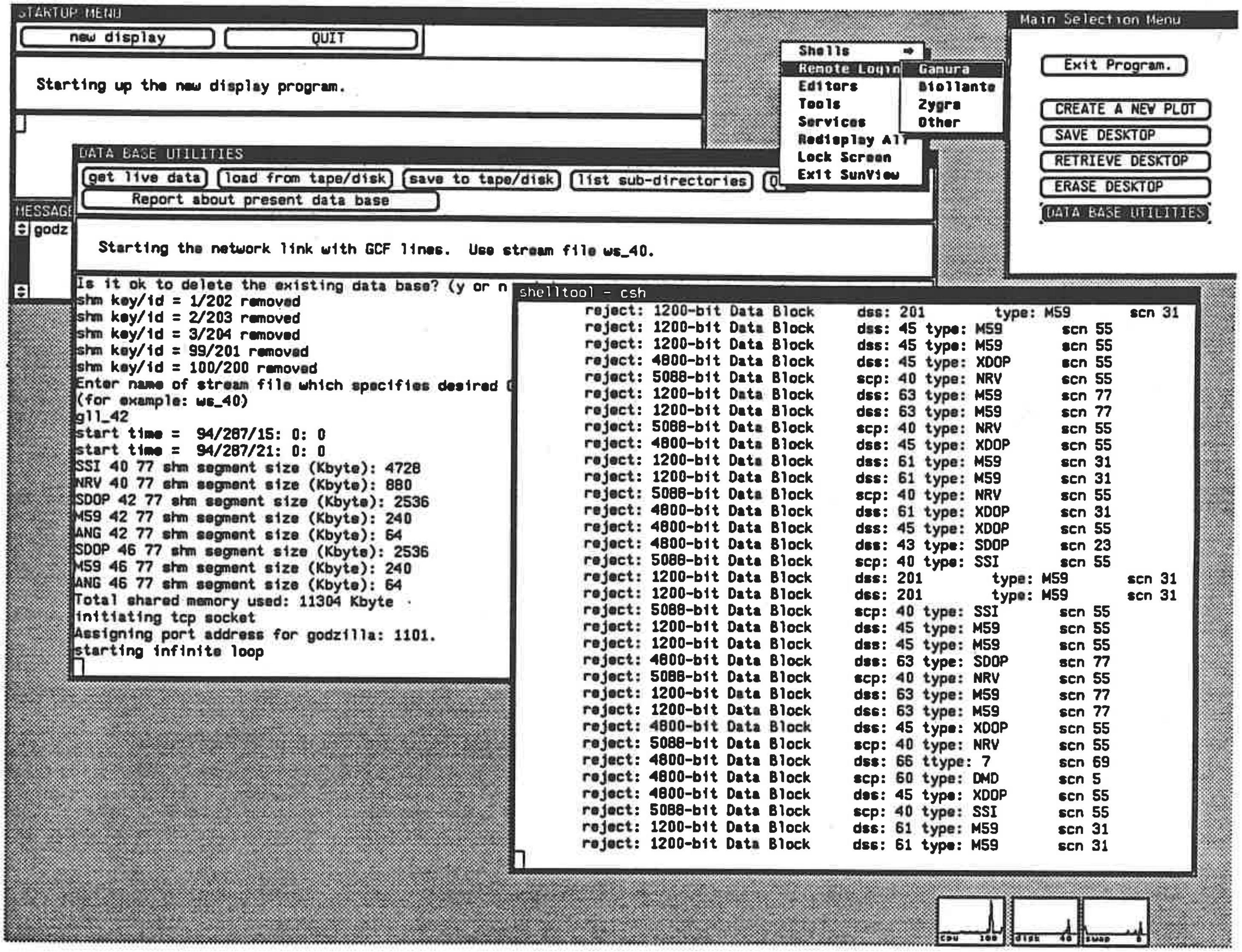


Figure 5-13. Data is Flowing

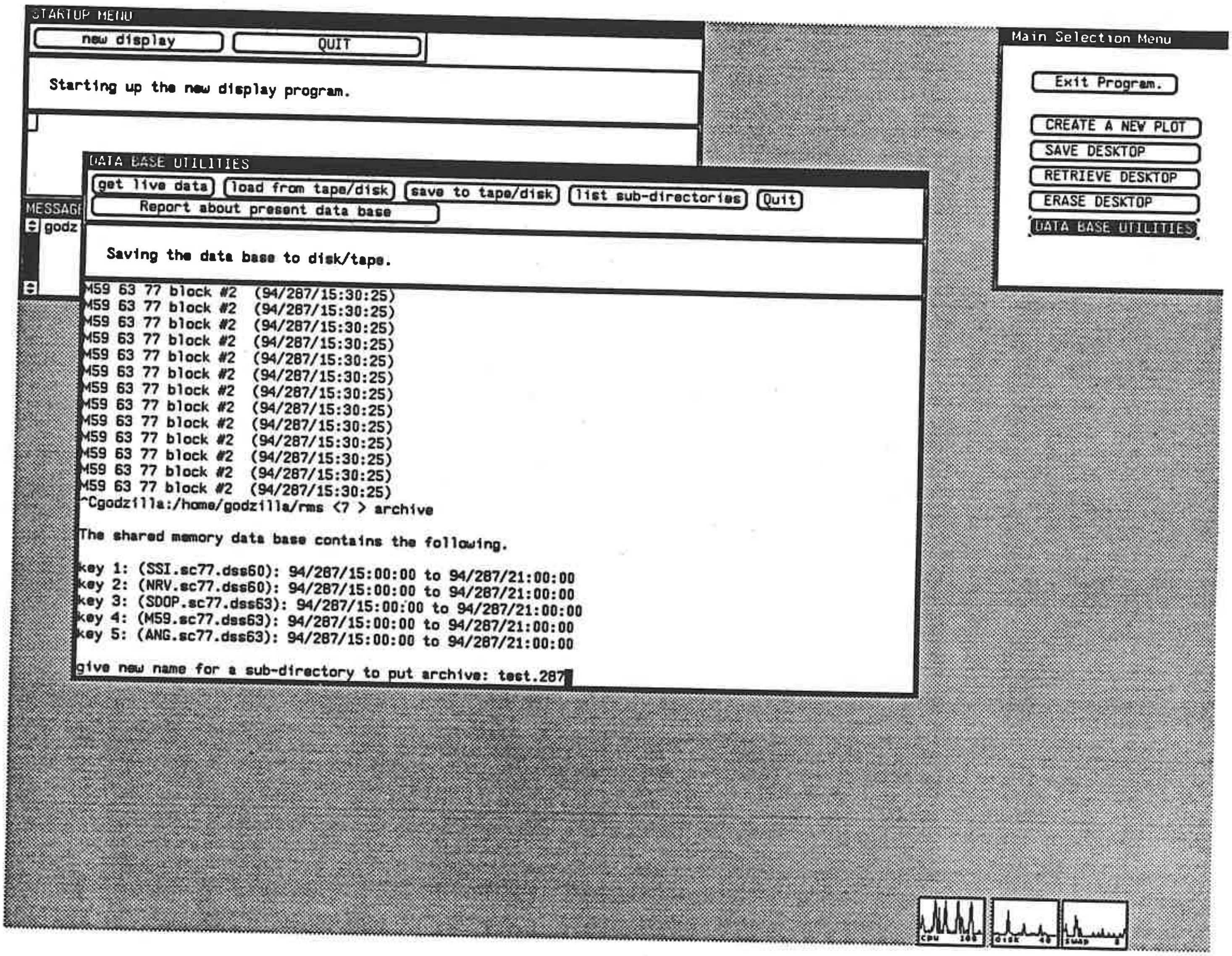


Figure 5-14. Subdirectory Name

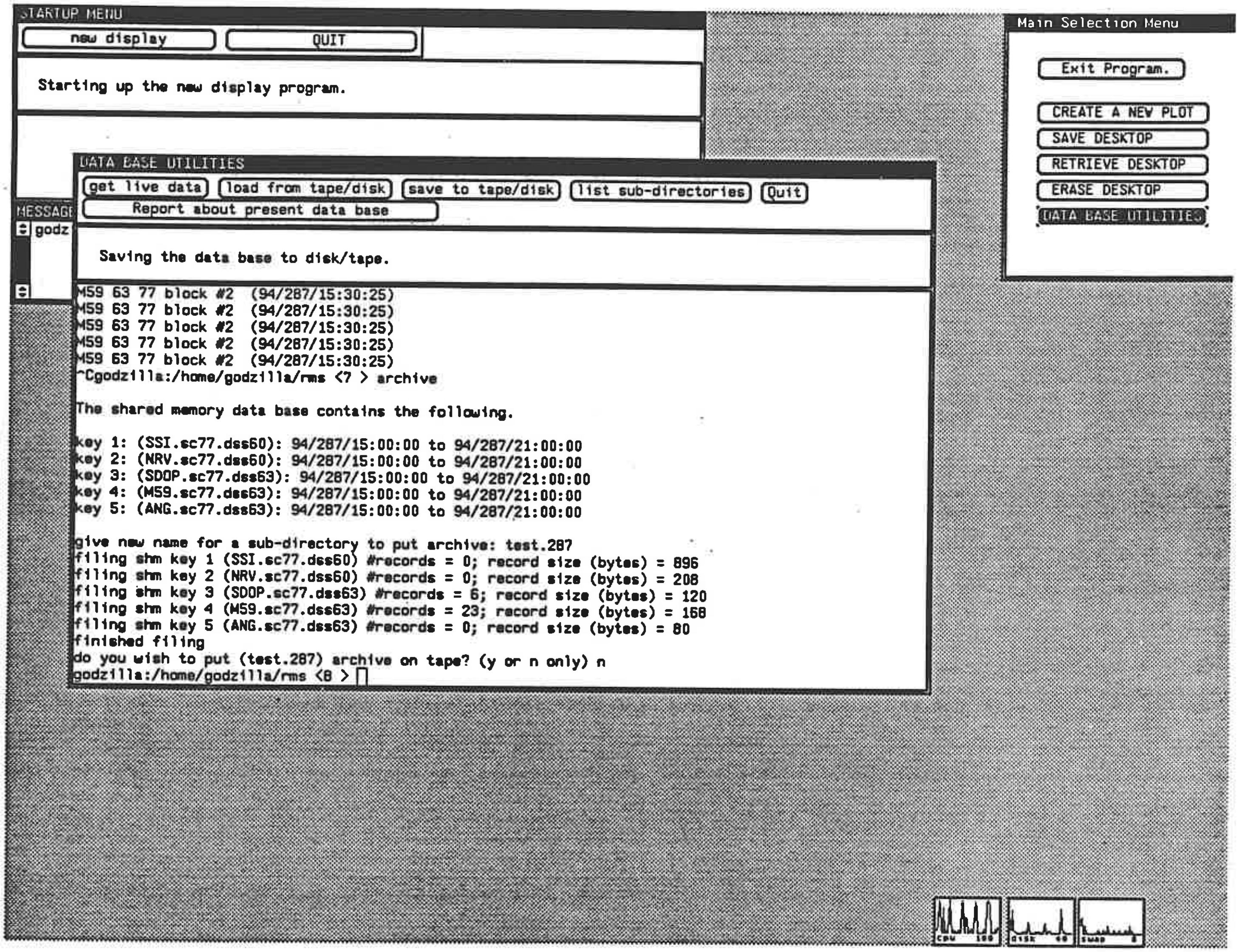


Figure 5-15. Backup to Tape

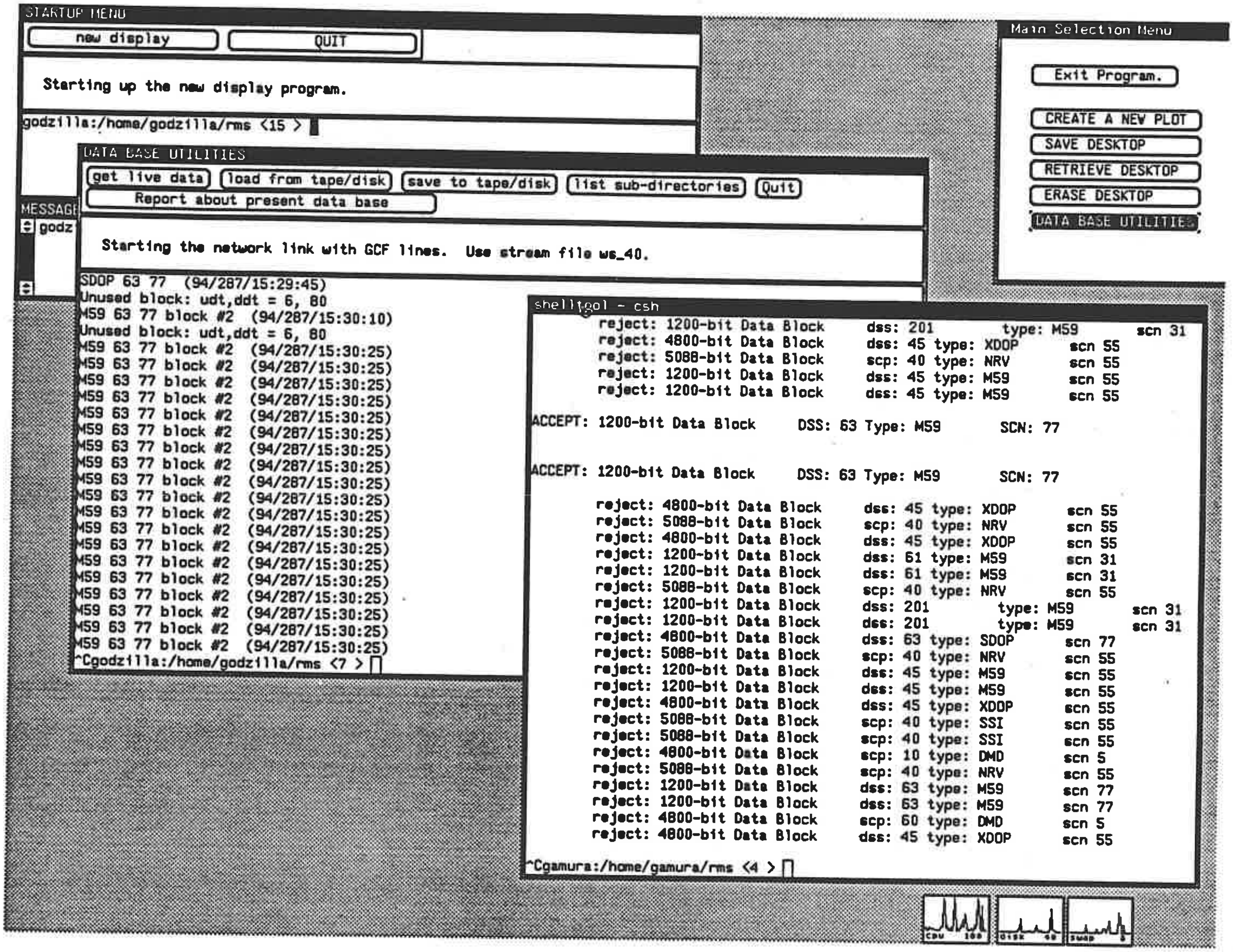


Figure 5-16. Logout of *gamura*

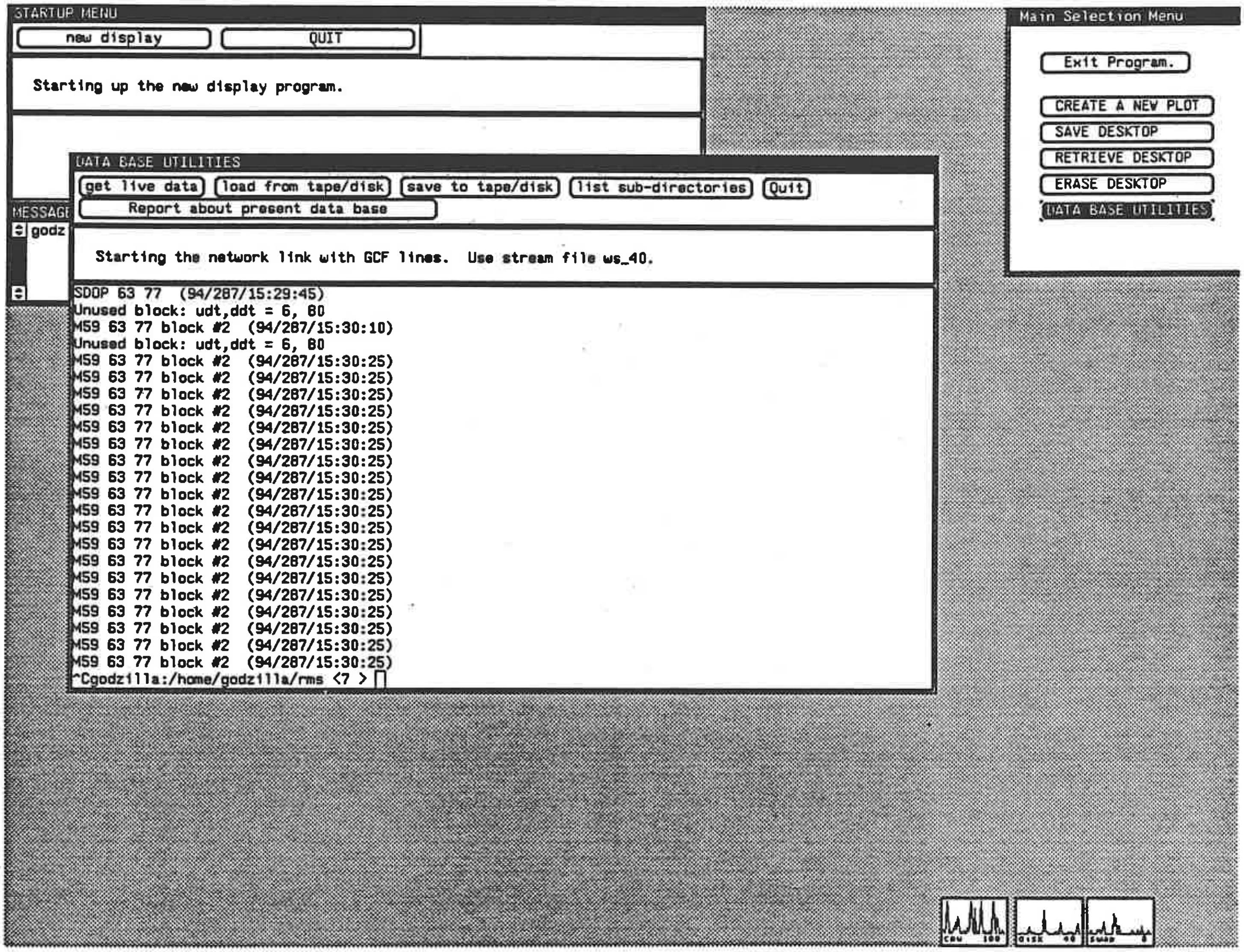


Figure 5-17. Quit Data Base Utilities

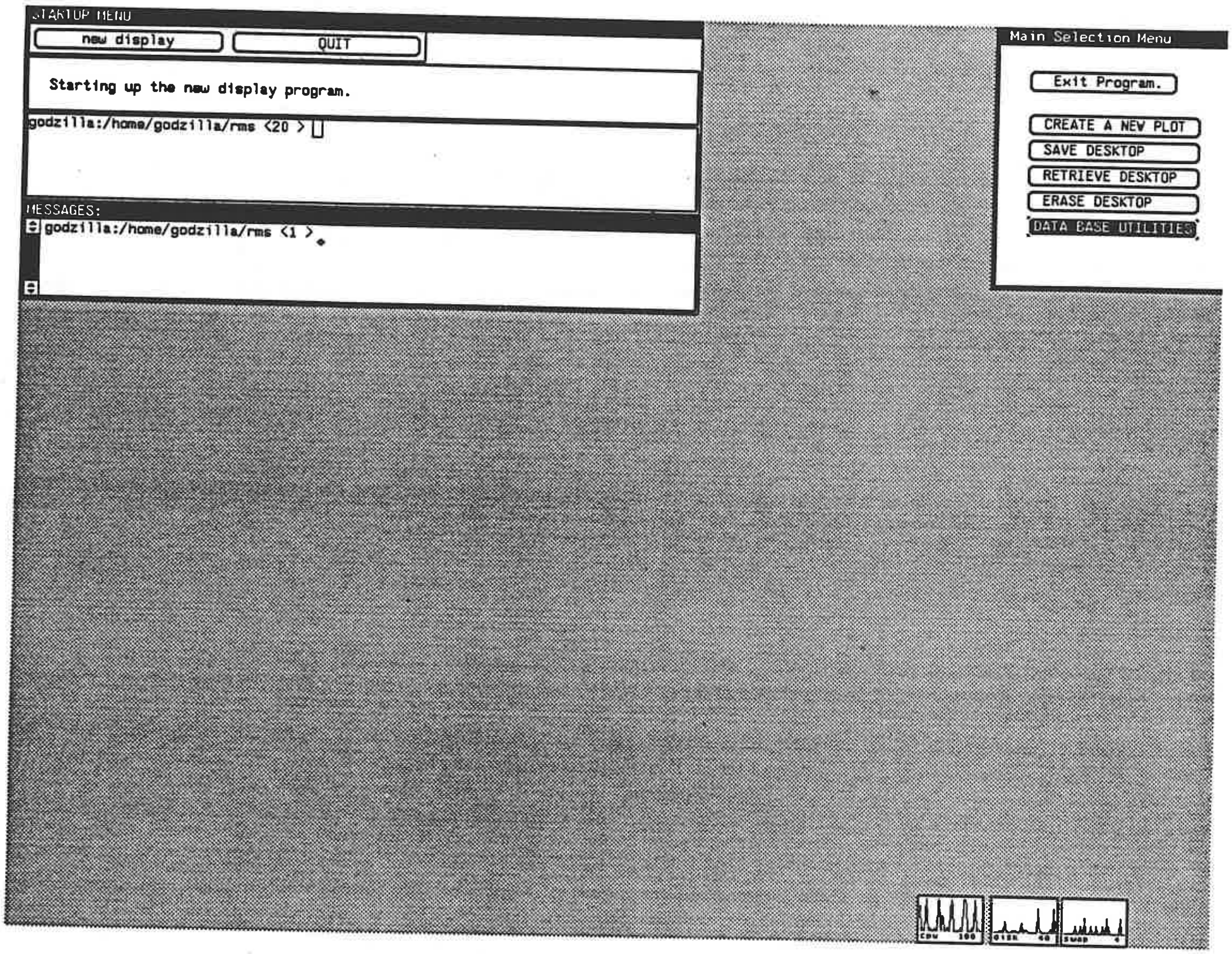


Figure 5-18. Quit Startup Menu

Section 6
Data Products

6.0 Introduction

Data handling operations for each Radio Science activity will begin upon completion of the Radio Science event. During this period, activities will consist of data product delivery (tapes, files, playback etc.) to the RSST, validation of data products, and the processing of the data. The RSST may require post-pass calibrations if problems arise during the pass. Section 6.1 specifies procedures and operation schedules for the delivery of data products. Section 6.2 describes special post-pass activities such as data calibration and playbacks. The processing and analysis of the data are discussed in Section 6.3.

6.1 Data Product Delivery

The Galileo USO test data product delivery strategy and schedules are given in Table 6-1. The Galileo Solar Wind Scintillation Experiment data product delivery strategy and schedules are given in Table 6-2. The Ulysses Solar Corona Experiment data product delivery strategy and schedules are given in Table 6-3. The Galileo Gravitational Wave Experiment data product delivery strategy and schedule are given in Table 6-4. These tables along with the following subsections describe each of the products as they relate to the specific activities. The format and interface agreement numbers for the data products are specified in Table 6-5 for Galileo, and Table 6-6 for Ulysses.

6.1.1 Open Loop Data

The open-loop data are recorded at the DSCC site on an 8mm helical scan tape or a 9-track 6250 bpi tape known as an ODR (Original Data Record). The tape contains up to 4 channels of digitized receiver data from the open loop receiver, as well as POCA (Programmable Oscillator Control Assembly), tuning, timing, configuration, and status information. When applicable, the ODR tape(s) will be logged and delivered to the RSST.

After each tape is written, the tape ID number, start and stop recording times, tape drive ID number, station ID, and pass number should be written onto the label.

Full duplication of all ODR tapes is required. The duplicates will be shipped to JPL while the original tapes will remain at the DSN complex until the duplicates are delivered to the RSST and have been validated. The tapes are to be shipped to JPL in the next available consolidated shipment. Once at JPL, the tape is to be delivered to the NDC (230-304A) to be logged, then delivered to the RSST (Attn: P. Eshe) where it will then be given an RSST tape ID.

Under special circumstances, the RSST may desire to process open-loop data immediately after a pass, rather than wait for the arrival of the open-loop ODRs. Arrangements should then be made for playback of the open-loop data after a pass. These IDRs (Intermediate Data Records) will be manufactured by the NDP and delivered to the RSST after completion of the playback.

6.1.2 Closed-Loop Tracking Data

Magnetic taes containing closed-loop tracking data in the form of an ATDF will be borrowed from the Radio Metric Data Conditioning Team (RMDCT) and copied. Arrangements are in progress to replace this process with electronic file transfer.

6.1.3 Spacecraft Trajectory Data (CRSPOSTA Files)

The Celestial Reference Set (CRSPOSTA) file contains spacecraft trajectory vectors for use in processing the Radio Science data. For each pass or set of passes, a CRSPOSTA file derived from the best available navigation solution will be required for Galileo and Ulysses.

The RSST will request the file from Project NAV via a request memo. GNAV will deliver the requested CRSPOSTA files into a permanently catalogued file on the UNISYS 1100B system. The RSST will transfer the file over to the PRIME computer using the Ethernet connection. In the event the Ethernet is down for an extended period of time, the RSST will initiate the proper tape movements to and from IPC in order to access the file.

For Galileo, the present SIS (210-12) specifies the NAVIO format as the CRS product to be delivered to the Orbiter Engineering Team (OET) and Radio Science. However, in practice, Radio Science receives the file in an ASCII format (CRSPOSTA), and OET receives it in a different data format.

The CRSPOSTA files residing on the UNISYS B system can be transferred to the PRIME using FTP as shown below;

1. Go to the directory on the PRIME in which you want the CRSPOSTA file(s) to be copied.

2. Type "FTP<cr>". Then, type "OPEN UNIB<cr>" at the FTP prompt (note if this doesn't work, then directly use the node number "OPEN 128.149.54.2").

3. Enter the login information.

4. Get the file by typing "GET" followed by the UNISYS file name, followed by the PRIME filename, for example;

   GET CRS.RS-89-349/CRS-D1 RS-89-349/CRS-D1

5. When the FTP prompt appears after successful transfer, go back to (4) for the next file transfer, or do a "BYE" to exit.

Note that sometimes the files residing on the UNISYS are not yet in ASCII format. In this case, you must directly log onto the UNISYS B system and perform the following steps prior to the file transfer:

```
@ASG,UP filename
@EMBED CRS.navelementname,filename
```

The @EMBED command will take the delivered NAV file (which is the element "navelementname" which was placed by NAV into the Radio Science permanently catalogued file "CRS") and recover the ASCII into the assigned file named "filename" which can then be transferred. For example:

```
@ASG,UP FILE1.
@EMBED CRS.RS-89-349/CRS-D1,FILE1.
```

The CRSPOSTA files from the Ulysses NAV team (UNAV) will be made available on the development VAX, *groucho*. UNAV will notify Radio Science via SPAN mail (or phone call) when these files are available and where they are located on GROUCHO. Since an account on GROUCHO is needed in order to use FTP, these files cannot be directly FTPed to RODAN. Therefore the following procedure must be used:

1. Log onto a VAX for which you have an account (e.g. JPLGP).

2. If you are using a VAX other than GROUCHO, transfer the file from GROUCHO to your VAX using the VAX COPY command as follows:

   ```
   COPY GROUCH::disk:[directory]filename  yourfilename
   ```

   where "disk" is name of the disk (e.g. USER$DISK2), "directory" is the directory name (e.g. TPM.ULYS.CRS), and "filename" is the name of the CRSPOSTA file residing on GROUCHO, and "yourfilename" is the name of the file into which the CRSPOSTA file is to be copied.

3. FTP the file from the VAX to the desired partition in RODAN.

6.1.4 NOCC Passfolder

The NOCC hard copy data will be requested by the RSST. The Passfolder includes the Controller's Log (Network Operations Log) and the Tracking System Pass Summary (NATTRK Log). Radio Science frequency predictions will be sent electronically to RSST.

6.1.5 Radiometric Tracking Calibration Data

Radiometric Tracking Calibration Data will be available on a permanently catalogued file residing on the UNISYS. These data include the changes induced in the various tracking data types based on media measurements.

6.1.6 Small Forces History File

A Small Forces History File (Attitude History File) is sometimes required in order to calibrate out the effects of the spacecraft spin. This file contains delta velocities which are induced by accelerations such as those due to Precession Maneuvers which occur between provided time tags. The file also contains the right ascension and declination of the spacecraft spin axis and the spacecraft rotation spin rate as inferred from the telemetry. This file is generated by Ulysses ESOC flight dynamics and is deliverable to the RSST from UNAV.

6.1.7 Timing And Polar Motion Files

This file contains estimates of the position of the Earth's rotation poles and universal time from astronomical observations. The information in this file allows for the earth's rotation to be accounted in the analysis of Doppler data.

6.1.8 SPICE Kernels

SPICE is a system for supplying scientist with necessary ancillary information for data analysis. The name "SPICE" comes from the five "kernels" in which this information is delivered. Each kernel is a file containing information which can then be manipulated using a series of software subroutines provided by JPL's Navigation and Ancillary Information Facility (NAIF), the "NAIF Toolkit". The five kernels are:

S Kernel This file provides information on the Spacecraft trajectory in inertial space and is provided by the spacecraft navigation teams.

P Kernel This file provides the ephemeris of the Planets and moons of the solar system and is also provided by the spacecraft navigation team.

I Kernel This file provides Instrument-specific information, such as pointing offsets. The science Team Leaders and Principal Investigators are responsible for this file.

C Kernel This file provides the spacecraft attitude in inertial Coordinates. The AACS analyst on the Spacecraft Team is responsible for the C kernel.

E Kernel The Event kernel provides a listing of spacecraft and ground events that might affect collected scientific data. The ISOE, as provided by the MCT, and notes provided by the Science Investigation Teams will comprise this kernel.

6.1.9 Navigation Information Files

This file contains information used to model solar radiation pressure such as the configuration and orientation of the spacecraft bus, the solar array, and the HGA.

TABLE 6-1. Data Product Delivery Strategy and Schedule -- Galileo USO Tests

PRODUCT	DELIVERY STRATEGY	DELIVERY SCHEDULE
ATDF(S)	Borrow original ATDF from RMDCT, make copy, and return original.	When ATDF is made.
ODR(S)	Only if open-loop data was acquired. The station will ship the ODR(s) to JPL NDC 230-304A (Attn. P. Eshe)	On next consolidated shipment.
CRSPOSTA FILE	A request memo is sent to J. Johanneson, GNAV. Will notify via forms delivered in mail, specifying file names and file locations.	Within a few days of request memo.
NOCC Passfolder	Request made to Patricia Nash (507-215). Passfolder then mailed to P. Eshe	Within one week.

TABLE 6-2. Data Product Delivery Strategy and Schedule -- Galileo Solar Wind Scintillation Experiment

PRODUCT	DELIVERY STRATEGY	DELIVERY SCHEDULE
ATDF(S)	Borrow original ATDF from RMDCT, make copy, and return original.	When ATDF is made.
ODR(S)	The station will ship the duplicate ODR(S) to JPL NDC (230-304A) (Attn. P. Eshe).	On weekly consolidated shipment.
Playback IDR(S)	To be generated only if specially requested.	Within one week
NOCC Passfolder	Request made to Patricia Nash (507-215). Passfolder then mailed to P. Eshe	Within one week

Table 6-3. Data Product Delivery Strategy and Schedule -- Ulysses Solar Corona Experiment

PRODUCT	DELIVERY STRATEGY	DELIVERY SCHEDULE
ATDF(s)	Borrow original ATDF from RMDCT, make copy, and return original.	When ATDF is made.
NOCC Passfolder	Request made to Patricia Nash (507-215). Passfolder then mailed to P. Eshe.	Within one week.
Radio. Trk. Calib. Data	Request memo sent to H. Royden, DSN TRK.	Within one week.
CRSPOSTA FILE	A request memo is sent to Tim McElrath, UNAV. Will place files on NAV VAX GROUCHO and notify via SPAN mail.	Within a few (TBD) days of request memo.
ODR	The station will ship the duplicate ODR(s) to JPL NDC (230-304A) (ATTN. P. Eshe)	On weekly consolidated shipment.

Table 6-4. Data Product Delivery Strategy and Schedule -- Galileo Gravitational Wave Experiment

PRODUCT	DELIVERY STRATEGY	DELIVERY SCHEDULE
ATDF(S)	Borrow original ATDF from RMDCT, make copy, and return original.	When ATDF is made.
ODR(S)	The station will ship the duplicate ODR(S) to JPL NDC (230-304A) (Attn. P. Eshe).	On weekly consolidated shipment.
Playback IDR(S)	To be generated only if specially requested.	Within one week
NOCC Passfolder	Request made to Patricia Nash (507-215). Passfolder then mailed to P. Eshe	Within one week

Table 6-5. Galileo Data Product Interface Agreements

DATA PRODUCT	SOURCE	USER	FORMAT #	IFA #
Archival Tracking Data File (ATDF)	DSN	RSS	SIS 1001-14	NAV-1
Original Data Record (ODR)	DSN	RSS	DSN 820-13 RSC 11-10A SIS 233-03	DSN-22
Playback Intermediate Data Record (IDR)	DSN	RSS	DSN 820-13 IDR-12-1A SIS 233-09	DSN-21
Spacecraft Trajectory Data (CRSPOSTA)	NAV	RSS	SIS 210-12	NAV-32
NOCC Passfolder	DSN	RSS	Paper	DSN-24

Table 6-6. Ulysses Data Product Interface Agreements

DATA PRODUCT	SOURCE	USER	FORMAT #	IFA #
Archival Tracking Data File (ATDF)	DSN/TRK	RSS	DSN 820-13 TRK 2-25	1tm
Original Data Record (ODR)	DSN/TRK	RSS	DSN 820-13 RSC 11-10A	1taa
Playback Intermediate Data Record (IDR)	DSN/TRK	RSS	DSN 820-13 IDR-12-1A	1taa
Radiometric Track Calibration Data	DSN/TRK	RSS	7sd	1tu
NOCC Passfolder Items	DSN	RSS	Hard copy	1tee
Small Forces History File	NAV	RSS	3sh	3tt
REGRES File	NAV	RSS	3sg	TBD
Spacecraft Trajectory Data (CRSPOSTA)	NAV	RSS	TBD	TBD
Spacecraft Range Delay	FLT	RSS	FR 3-500 APP. A NAV	7tb

6.2 Special Post-pass Activities

Currently, there are no requirements for post-pass calibrations for the Radio Science passes. However, it is important that any post-pass calibrations be performed with the same equipment used during the recording period. If any equipment had changed due to failures or if spare parts were used, then that information should be obtainable through the NOPE. Any post-test calibration tapes should be included in the shipment of all other tapes (ODRs).

Playback of open-loop data will not be required under normal circumstances. However, data playback may be requested through the NOPE of the appropriate project if special circumstances warrant it. If this is the case, then the appropriate GCF wideband line along with the DSP and an LMC may be scheduled for some period following the test. The playback request would normally specify adequate playback time to include the complete playback of the Radio Science data. IDRs containing the playback data will be generated on the DRG in NDPA and will be picked up by a RSST representative.

There are no requirements for any post-pass System Performance Tests (SPTs). However, one may be requested if deemed necessary during specific passes.

The DSP may be requested after the test for any specially requested tape duplication, data playback, and/or post-pass calibrations.

6.3 Data Validation and Processing

This section is primarily concerned with what is done with Radio Science data after it is delivered to the RSST.

The Radio Science software system is broken down into two subsystems: the Data Records Subsystem (DRS) and the Planning and Analysis Subsystem (PAS). The DRS is primarily concerned with data archiving and validation, while the PAS deals with experiment planning and data analysis.

At the present time, the Radio Science Team is moving away from using the Prime 4050 computer on which the Radio Science software system has historically been based. All program sets are being converted to run on Sun SparcStations, and will be upgraded to be more integrated, modular, and portable.

There are four program sets which run on the Prime which have been formally delivered to the Galileo Project (and some are also used by Ulysses):

> **RCLVAL (DRS)**: Formally delivered to the Galileo project in 1990, described in Section 6.3.1.4.

ROLVAL (DRS): Formally delivered to the Galileo project in March 1992, described in Section 6.3.1.5.

LMSPEC (PAS): Formally delivered to the Galileo project in 1984, used for evaluating imbtrack maneuvers for Galileo occultation events during the Jupiter orbital operations in 1995-1996. Not applicable in this version of the handbook.

STBLTY (PAS): First phase formally delivered to the Galileo project in November 1993, second phase to be delivered in December 1994. The first phase concentrated on performing stability analysis on cruise data, while the second phase will incorporate the added capability of performing stability analysis on Radio Science data acquired during Galileo planetary orbital operations.

6.3.1 Data Records Subsystem (DRS)

The RSST Data Records Subsystem (DRS) includes the software and procedures required to ensure that the data collected in support of Radio Science observations are usable by the Radio Science Investigators. The following subsections describe the RSST Data Records Subsystem.

6.3.1.1 Data Sources

The Radio Science data sources are the DSCC, the NOCC, the Multi-Mission Radio Metric Data Conditioning Team (MMNAV & RMDCT), the Galileo Navigation Team (GNAV), and the Ulysses Navigation Team (UNAV). The data types generated by each of these entities are described in detail in Section 6.1.

6.3.1.2 Closed-Loop Tracking Data Validation (RCLVAL)

Validation of the closed-loop tracking data for both Galileo and Ulysses employs (on the Prime computer) the program RCLVAL. The data validated includes Doppler pseudo-residuals and signal strengths (AGCs). RCLVAL is also used to flag when the data fell within or without specified tolerance limits, when data gaps occurred, and when the Doppler sample rate and "flagged" signal mode changed (including Doppler sample rate and mode values at those times). Plots of Doppler pseudo-residuals and AGCs can also be generated by the program and archived.

This program's functionality will be incorporated into the Radio Science Validation and Processing software (RSVP), which is currently being developed for Sun SparcStations, sometime around March 1995.

6.3.1.3 Open-Loop Data Validation (ROLVAL)

The ROLVAL software set is used to perform validation processing of open-loop data tapes (ODRs and/or playback IDRs) for Galileo and Ulysses. ROLVAL runs on the Prime 4050 computer and can read from 9-track and 4mm tapes. The software set can be divided into three basic programs:

ROLHDR: Produces plots and header dumps of POCA frequencies, time tags, rms voltage sample values, and min/max rms values. Also, this program flags changes in various header quantities as well as the times these changes occurred.

ROLFFT: Performs signal presence verification by producing plots of power spectral density according to specifications provided by the user.

ROLSMP: Produces plots of digitized sample values versus time, as well as histograms of sample values.

This program has already been incorporated into the Radio Science Validation and Processing software (RSVP). In the process of conversion, however, certain capabilities of ROLVAL which are no longer used were eliminated, such as flagging times when certain values were in and out of tolerance; if such capabilities are later required, they will be added to RSVP. Currently, the plots are generated from the RSVP output files by Matlab. A Tcl/Tk-based interface, called from within the RSVP functions, should be developed by March 1995.

6.3.1.6 Data Product Copying and Archiving

In addition to the validation programs described above, the DRS also employs utility programs to perform data product copying and archiving for all incoming data products (ODRs/IDRs, ATDFs, CRSPOSTA files, media calibration files, etc.).

6.3.2 Planning and Analysis Subsystem (PAS)

The Planning and Analysis Subsystem (PAS) is concerned primarily with experiment planning and analysis of Radio Science data. The following sections describe the software used to accomplish this analysis.

6.3.2.1 Stability Analysis Processing (STBLTY)

The ODRs/IDRs and/or ATDFs from selected Radio Science activities are processed using the program set STBLTY, which evaluates the frequency stability and phase noise of the signal received from the spacecraft, and estimates the frequency and frequency rate of the USO. The spacecraft trajectory from the CRSPOSTA files is used by the program set to estimate the "predicted" or "model" frequency which is then differenced from the observed frequency, which is extracted from the data. The frequency stability in terms of Allan deviation is then estimated from the resulting residuals.

STBLTY is currently being used both to measure the stability of Radio Science data, using the Galileo USO as the signal source, and to estimate the USO frequency. An output file of STBLTY containing summary records for the Gravitational Redshift experiments is periodically delivered to the Experimenter.

STBLTY has also been used to process Ulysses two-way Doppler residuals. In addition, it is expected to handle different open-loop data signal detection scenarios depending upon signal conditions.

STBLTY consists of several programs, each of which performs a specific task. Figure 6-1 is a block diagram illustrating the interconnection between the component programs making up the STBLTY program set as it relates to the processing of one-way (USO) data. Figure 6-2 is a block diagram for the corresponding two-way data processing case. Listed below are the descriptions of each program.

FILTER - is used to produce a filter file for input to the NBDECIM program, based on the desired filter specifications of the user. FILTER designs a linear phase finite impulse response (FIR) filter using the Remez Exchange Algorithm. The user provides the program with the desired filter center frequency, bandwidth, and decimation factor, and the program outputs the reversed ordered time series impulse response corresponding to the specified filter and decimation factor.

NBDECIM - reads the samples from an ODR or playback IDR, and then filters and decimates the data for each channel. The input time series is convolved with the appropriate impulse response time series output from FILTER in order to get the output filtered/decimated time series. The first N samples of each interval of input data are processed this way and the output series is written onto a file.

DETPHS - performs detection of the signal from the open-loop data file output from NBDECIM. It uses a least-squares algorithm to get estimated parameters. It is appropriate to use DETPHS on data where there are dynamic signal conditions such as occultation events.

PLLDEC - is a digital phase-locked-loop program which reads either ODRs or playback IDRs, and performs signal detection. It is operationally easier to use than NBDECIM/DETPHS. It is appropriate to use PLLDEC on data from events with strong and relatively static signal conditions.

GETTRAJ - reads an input file containing spacecraft centered trajectory EME50 vectors delivered from NAV, and outputs a file containing heliocentric position and velocity vectors of a specified earth-based DSN station and spacecraft.

OBSERVE - combines, displays, and edits all Radio Science data. Inputs include closed-loop tracking data from ATDFs, or open-loop data output from the digital filtering and detection programs (NBDECIM-DETPHS or PLLDEC). OBSERVE reconstructs the observed sky frequencies from the Doppler counts (from an input ATDF) or from the detected open-loop baseband frequencies and POCA tuning frequencies (from input files generated by the open-loop detection software which in turn use the ODR tapes as input).

RESIDUAL - computes frequency residuals from observed frequencies (OBSERVE output) and predicted frequencies (estimated from GETTRAJ output trajectory file).

STBLTY - reads in residuals computed from RESIDUAL and performs stability analysis. It computes Allan variance, phase noise, absolute frequency, and frequency drift rate. Writes summary information onto a database for one-way data.

FITUSO - allows one to fit and remove an aging model from the estimated spacecraft transmitted frequencies from a set of USO passes.

USOSMRY - displays parameters and statistics from the USO data base.

6.3.2.2 Stability Analysis Processing (RSVP)

The functionality of the STBLTY software set is currently being designed for use within the Radio Science Validation and Processing software (RSVP). This process involves streamlining the STBLTY set and re-engineering the entire processing approach. Figure 6-3 shows the black-box functional design of RSVP, which will include the STBLTY functionality by March 1995.

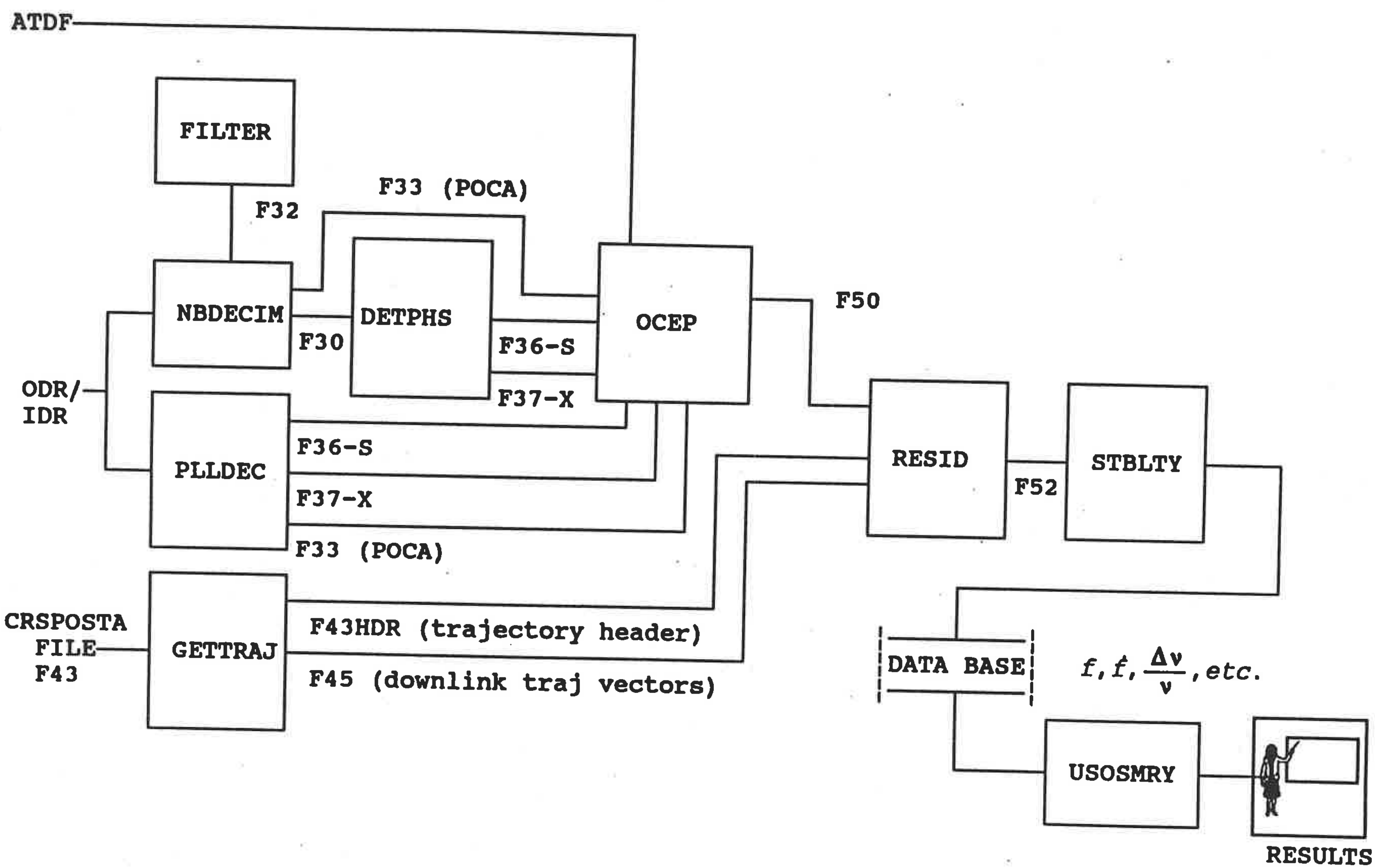


Figure 6-1. STBLTY Program Set for One-Way Data

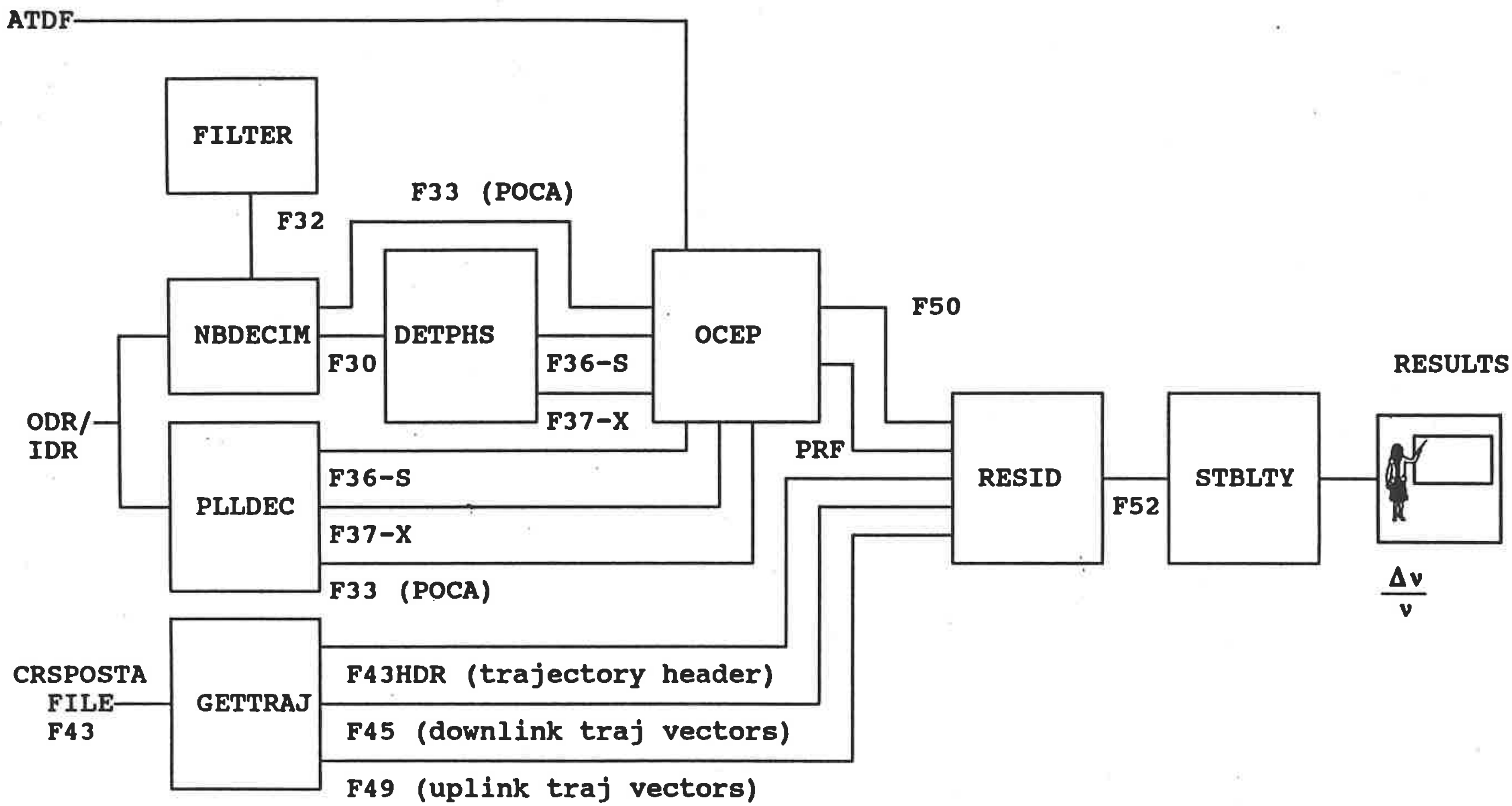


Figure 6-2. STBLTY Program Set for Two-Way Data

Appendix A
Schedule of Activities

GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VALID	OL VALID	SC SPIN	COMMENTS PAGE 1 LUD 10/04/94
EV-3	USO-ON	Mon.	16:34	4-Dec	5-Dec	339	00:34	00:45	14		Good	NA	GA0001	NA			NA	DLSP	USO Tuned ON 56 mins. early by real-time cmd.
																			1/sec Doppler taken near end of DSS 14 pass
	USO-Tst	Thur	13:30	7-Dec	7-Dec	341	21:30	23:28	14	51	Good	Good	GA0001	GAO0001		Good	Good	DLSP	Joe B. and Dave M. at DSS 14. Did not acquire
																			first 30 mins of OL data
	RFS TLC	Fri.	15:37	8-Dec.	8-Dec.	342	23:37	01:29	14		Good	NR	GA0002	NA		Good	NA	DLSP	1/sec. Doppler only, may have started late.
	USO Tst	Fri.	16:00	15 Dec	16-Dec	350	00:00	01:58	14	59	Good	Good	GA0003	GAO0002	YES	Good		DLSP	Good 1/sec Doppler + OL data. Luciano less
																			observed operations.
EV-4	RFS TLC	Thur.	13:02	21-Dec	21-Dec	355	21:02	22:55	14	70	Good	NR	GA0004			Good	NA	DLSP	1/sec. Doppler only- Started about 15 min late.
	USO Tst	Tue.	14:31	26-Dec	26-Dec	360	22:31	00:01	14	77	Good	Bad	GA0004	GAO0003-5		Good	NA	DLSP	No OL data acquired due to DSP problem.
																			DR F5493
	USO Tst	Tue.	09:05	2-Jan	2-Jan	2	17:05	18:59	14		Good	Good	GA0004	GAO0006		Good		DLSP	Good 1/sec Doppler + OL data. DSP Config. ?
X	RSF TLC	Thur.	11:02	4-Jan	4-Jan	4	19:02	20:55	14		Good	NR	GA0002	NA		Good	NA	ALSP	NIMS COVER DEPLOY
EV-5	USO Tst	Tue.	09:31	9-Jan	9-Jan	9	17:31	19:29	14	84	Good	NA	GA0002	NA	YES	Good	NA	DLSP	No, DSP Scheduled for this pass. Delta DOR
	USO Tst	Mon.	09:31	15-Jan	15-Jan	15	17:31	19:29	14	90	Good	?	GA0002	GAO0007-8	YES	Good		DLSP	SSI Red, No RT OL data displays. Possible wrong
																			Configuration. DR F5279.
X	RFS TLC	Tue.	12:19	16-Jan	16-Jan	16	20:19	22:11	14		None	NR	None	NA		NA	NA	ALSP	RFS Test aborted due to S/C anomaly.
																			X IN FIRST COLUM. FIRST S/C SAFING ANOMALY
X	USO Tst	Thur.	09:31	18-Jan	18-Jan	18	17:31	19:29	14		None	None	None	NA		NA	NA	ALSP	USO Test aborted.
X	USO Tst	Fri.	08:00	19-Jan	19-Jan	19	16:00	18:00	14		Good	NA	GA0002	NA		Good	NA	ALSP	DSS 14 Transmitter off to acquire 1-way data.
X	USO Tst	Fri.	08:01	26-Jan	26-Jan	26	16:01	17:59	14		None	None	None	NA		NA	NA	ALSP	USO Test aborted.
X	USO Tst	Sun	08:00	28-Jan	28-Jan	28	16:00	18:00	14		Good	NA	GA0002	NA		Good	NA	ALSP	DSS 14 Transmitter off.
X	USO Tst	Tue.	11:22	30-Jan	30-Jan	30	19:22	21:20	14		None	None	None	NA		NA	NA	ALSP	USO Test aborted.
X	USO Tst	Thur.	07:30	1-Feb	1-Feb	32	15:30	17:30	14	107	Good	NA	GA0008	NA	YES	Good	NA	ALSP	DSS 14 Transmitter off
X	USO Tst	Fri.	07:32	2-Feb	2-Feb	33	15:32	17:30	14		None	None	None	NA	YES	NA	NA	ALSP	USO Test aborted
	USO Tst	Sun.	07:30	4-Feb	4-Feb	35	17:30	19:30	14		None	NR	None	NA		NA	NA	DLSP	DSS 14 Transmitter off. Test aborted.
X	USO Tst	Tue.	02:45	6-Feb	6-Feb	37	10:45	12:45	63		Good	NA	GA0004	NA		Good	NA	DLSP	DSS 63 Transmitter off. No R/T Monitor.
EV-6	USO Tst	Mon.	09:32	5-Feb	5-Feb	36	17:32	19:30	14		None	NA	None	NA		NA	NA	DLSP	USO test was aborted.
X																			
	RFS TLC	Tue.	10:50	6-Feb	6-Feb	37	18:50	20:43	14		None	NR	None	NA		NA	NA	DLSP	RFS TLC Test was aborted.
	1-Way	Sat.	01:20	10-Feb	10-Feb	41	09:20	11:40	63	115	Good	NA	GA0004	NA	YES	Good	NA	DLSP	1/5 sec. One-way Doppler during Venus Encounter
																			Day.
	USO Tst	Mon.	19:00	12-Feb	13-Feb	44	03:00	05:20	43	118	Good	Good	GA0007	GAO0009		Good		DLSP	Late in pass. Low Elevation data
	USO Tst	Wed.	16:02	14-Feb	15-Feb	46	00:02	02:00	43	120	Good	Good	GA0005	N	YES	Good		DLSP	RST Demonstration. Woo and Estabrook observed
	USO Tst	Sun.	11:33	18-Feb	18-Feb	49	19:33	21:31	43	124	Good	Good	GA0007	N	YES	Good		DLSP	I/F lost with MDA/SRA required reload, no DR issued.
VE-1 -	CDU SNR	Wed	08:20	21-Feb	21-Feb	52	16:02	17:09	14		Bad	NR		NA		Bad	NA	DLSP	No RT Monitor. 1/60 sec Doppler
	RSF TLC	Wed.	13:57	21-Feb	21-Feb	52	21:57	23:51	43		Bad	NR		NA		Good	NA	DLSP	No RT Monitor
	RFS AGC	Thur.	12:08	22-Feb.	22-Feb.	53	20:08	21:39	14		Good	NR	GA0006	NA		Good	NA	DLSP	

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VALID	OL VALID	SC SPIN	COMMENTS PAGE 2 LUD10/04/94
	USO Tst	Sat.	18:03	24-Feb.	25-Feb.	56	02:03	03:32	43	130	Good	Good	GA0006	GAO0010	YES	Good		DLSP	
	USO Tst	Tue.	15:03	27-Feb	27-Feb	58	23:03	01:02	43	133	Good	Good	GA0006	GAO0011	YES	Good		DLSP	
	USO Tst	Thur.	16:03	1-Mar	2-Mar	61	00:03	02:32	43	135	Good	Good	GA0006	GAO0012	YES	Good		DLSP	Short Pre-cal.
	RFS TLC	SUN.	17:39	4-Mar	5-Mar	64	01:39	03:33	43	138	Good	NR	GA0006	NA	YES	Good	NA	DLSP	
	CDU SNR	Mon.	13:25	5-Mar	5-Mar	64	21:25	22:31	43	139	Good	NR	GA0006	NA	YES	Good	NA	DLSP	
	RFS AGC	Mon.	15:10	5-Mar	5-Mar	64	23:10	00:31	43		Good	NR		NA		Good	NA	DLSP	No RT Monitor.
	USO Tst	Thur.	18:04	8-Mar	9-Mar	68	02:04	03:48	43	142	Good	Good	GA0006	N	YES	Good		DLSP	
	USO Tst	Fri.	18:05	16-Mar	17-Mar	76	02:05	03:33	43	150	Good	Good	GA0007	N	YES	Good		DLSP	LGA -2 Switch 10/18/89 - 03/15/90
	USO Tst	Sun.	16:35	18-Mar	19-Mar	78	00:35	02:34	43	152	Good	Good	GA0007	N	YES	Good		DLSP	
	USO Tst	Sat.	11:05	24-Mar	24-Mar	83	19:05	21:04	43	158	Good	Good	GA0008	N	YES	Good		DLSP	
VE-2	USO Tst	Thur.	16:06	29-Mar	30-Mar	89	00:06	02:04	43	163	Good	Good	GA0007	N	YES	Good		DSLP	TSS Demonstration
	CDU SNR	Sun.	15:59	1-Apr	1-Apr	91	22:59	00:05	43	166	Bad	NR	GA0007	NA	YES	Good	NA	DLSP	Telecomm RT Monitor
	RFS TLC	Sun.	17:29	1-Apr	2-Apr	92	00:29	02:23	43	166	Marg	NR	GA0007	NA	YES	Good	NA	DLSP	Telecomm RT Monitor
	RFS AGC	Mon.	18:09	2-Apr	3-Apr	93	01:09	02:30	43	167	Good	NR	GA0007	NA		Good	NA	DLSP	No RT Monitor
	USO Tst	Sat.	15:06	7-Apr	7-Apr	97	22:06	00:05	43	172	Good	Good	GA0009	N	YES	Good		DLSP	
	USO Tst	Sat.	15:07	14-Apr	14-Apr	104	22:07	00:05	43	179	Good	?	GA0009	N	YES	Good		DLSP	
	USO Tst	Thur	17:37	19-Apr	20-Apr	110	00:37	02:36	43	184	Good	?	GA0010		YES			DLSP	Mis-placed Pass, found by Paula ,thanks !!!!
VE-3	USO Tst	Mon.	18:07	23-Apr	23-Apr	113	20:07	22:06	43	184	Good	NA	GA0010	NA	YES		NA	DLSP	
	USO Tst	Tue.	16:07	1-May	1-May	121	23:07	01:06	43	196	Good		GA0009	NA	YES	Good	NA	DLSP	
	USO Tst	Tue.	02:08	8-May	8-May	128	09:07	11:07	63	202	Good	?	GA0009	N	YES	Good		DLSP	No RT Monitor
	USO Tst	Wed.	16:17	16-May	16-May	136	23:17	01:17	43	211	Good	?	GA0009	GAO0013	YES	Good		DLSP	No RT Monitor
	USO Tst	Sat.	12:53	19-May	19-May	139	19:53	21:51	43	214	Good	NA	GA0009	NA	YES	Good	NA	DLSP	Post USO High Power Ranging Test.
	RFS TLC	Fri.	11:17	25-May	25-May	145	18:17	20:11	14	220	None	NR	NA	NA	YES	NA	NA	DLSP	MDA crashed. DRF7834 . Lost all Data.
	USO Tst	Tue.	12:08	29-May	29-May	149	19:08	21:06	43	224	Good		GA0009	GAO0014	YES	Good		DLSP	Predicts not loaded in DSP DR F7865
	CDU SNR	Thur.	10:43	31-May	31-May	151	17:43	18:49	43	226	Good	NR	GA0009	NA	YES	Good	NA	DLSP	Low Elevation
	RFS AGC	Fri.	14:12	1-Jun	1-Jun	152	21:12	22:34	43	227	Good	NR	GA0009	NA	YES	Good	NA	DLSP	
	USO Tst	Mon.	12:08	4-Jun	4-Jun	155	19:08	21:06	43	230	Good	NA	GA0009	NA	YES	Ugly	NA	DLSP	
VE-5	USO Tst	Mon	11:11	11-Jun	11-Jun	162	18:11	19:44	14	237	Good		GA0011		YES			DLSP	Low Elevation. No SSI Data DR F8002
	USO Tst	Thur	08:07	21-Jun	21-Jun	172	15:07	17:09	14	247	Good	?	GA0010	GAO0020	YES			DLSP	No SSI Displays
	USO Tst	Mon	09:07	25-Jun	25-Jun	176	16:07	18:09	14	251	Good	?	GA0010		YES			DLSP	No SSI displays DR F8135

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VAILD	OL VAILD	SC SPIN	COMMENTS PAGE 3 LUD 10/04/94
	USO Tst	Mon	11:07	2-Jul	2-Jul	183	18:07	20:09	43	258	Good	?	GA0010	GAO0015	YES			DLSP	No RT Monitor
	RFS TLC	Thurs.	14:51	5-Jul	5-Jul	186	21:51	23:45	43	261	Good	NR	GA0010	NA	YES		NA	DLSP	
	CDUSNR	Wed	13:11	11-Jul	11-Jul	192	20:11	22:17	43	267	Good	NR	GA0010	NA	YES		NA	DLSP	Italian GWE Demo.
	RFS AGC	Wed	16:26	11-Jul	12-Jul	192	23:26	00:47	43	267	Good	NR	GA0010	NA	YES		NA	DLSP	Low Elevation. GWE Demo.
	USO Tst	Thurs	07:37	12-Jul	12-Jul	193	14:37	16:38	14	268	Good	NA	GA0010	NA	YES		NA	DLSP	Italian GWE Demo.
	USO Tst	Mon	11:12	16-Jul	16-Jul	197	18:12	20:13	43	272	Good	NA	GA0010	NA	YES		NA	DLSP	DSP POCA red for support DRF8588.
	USO Tst	Wed.	14:06	25-Jul	25-Jul	206	21:06	23:08	43	281	Good	Good	GA0010	GAO0016	YES			DLSP	SSI not enabled and recording started late DRF8819
	USO Tst	Wed.	14:06	1-Aug	1-Aug	213	21:06	23:08	43	288	N/A	Good	GA0011	GAO0017	YES			DLSP	Stowed Antenna at 22:08z for High Winds DR F8899
	USO Tst	Thurs.	13:35	9-Aug	9-Aug	221	20:35	22:37	43	296	Marg		GA0011	GAO0018	YES			DLSP	
	USO Tst	Thurs.	11:05	16-Aug	16-Aug	228	18:05	20:07	43	303	Good		GA0011	GAO0019	YES			DLSP	
	USO Tst	Tue.	08:05	21-Aug	21-Aug	233	15:05	17:07	14	308	Good		GA0011		YES			DLSP	
	RFS TLC	Fri.	13:11	24-Aug	24-Aug	236	20:11	22:05	43	311	Marg		GA0011		YES			DLSP	
	RFS AGC	Mon.	11:41	27-Aug	27-Aug	239	18:41	20:02	43	314	Good		GA0011		YES			DLSP	
	USO Tst	Fri.	12:34	31-Aug	31-Aug	243	19:34	21:36	43	318	Good		GA0011		YES			DLSP	
	USO Tst	Thurs.	18:34	6-Sept.	7-Sep	250	01:34	03:36	63	324	Marg		GA0011		YES			DLSP	
	USO Tst	Mon.	12:04	10-Sept.	10-Sept.	253	19:04	21:05	43	328	Good		GA0011		YES			DLSP	
	USO Tst	Wed	12:18	19-Sept.	19-Sept.	262	19:18	21:20	43	337	Good		GA0012		YES			DLSP	
	USO TST	Mon.	15:30	24-Sept.	24-Sept.	268	00:30	03:40	63	342	Good		GA0012		YES			DLSP	
	USO Tst	Mon	11:47	01-Oct.	01-Oct.	274	18:47	20:49	43	349	Good		GA0012	GAO0021	YES			DLSP	
	USO Tst	Mon.	10:02	08-Oct.	08-Oct.	281	17:04	19:04	43	356	Good		GA0012		YES			DLSP	
	RSF AGC	Fri.	07:40	19-Oct.	19-Oct.	292	14:40	15:55	43	367	Good		GA0012					DLSP	
	RFS TLC	Fri.	09:30	19-Oct.	19-Oct.	292	16:30	18:24	43	367	Marg		GA0012					DLSP	
	USO Tst	Mon.	17:31	31-Oct.	31-Oct.	303	01:31	03:32	63	377	Good		GA0012					DLSP	
	USO Tst	Wed.	17:00	07-Nov.	07-Nov.	312	01:00	03:02	63	386								DLSP	
	USO Tst	Fri.	19:00	16-Nov.	16-Nov.	321	03:00	05:02	63	395			GA0016	GAO0022	YES			DLSP	
														GAO0023					
	USO Tst	Sun	17:00	25-Nov.	25-Nov.	330	01:00	03:01	63	404			GA0016	GAO0024	YES			DLSP	
																			LGA -1 Switch 3/15/90 - 12/08/90
	USO Tst	Mon.	01:54	10-Dec	10-Dec.	345	01:54	03:45	42	420			GA0016		YES			DLSP	
	USO Tst	Wed.	08:00	12-Dec	12-Dec.	346	08:00	11:00	63	421			None		YES			DLSP	
	USO Tst	Sun.	08:14	16-Dec.	16-Dec.	350	08:14	10:16	61	425			GA0016		YES			DLSP	

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO USO ACTIVITIES

LOAD 1991	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VAILD	OL VAILD	SC SPIN	COMMENTS PAGE 4 LUD10/04/94
	USO Tst	Thur.	07:30	3-Jan	3-Jan	4	07:30	09:32	63	444			GA0016		YES			DLSP	First USO Test for Year 1991
	USO Tst	Sun.	18:00	6-Jan	6-Jan	6	18:00	20:02	43	447			GA0016	GAO0044	YES			DLSP	
	CDU SNR	Wed.	16:58	9-Jan	9-Jan	9	16:58	17:49	43	450			GA0016		YES			DLSP	
	RFS AGC	Wed.	18:28	9-Jan	9-Jan	9	18:28	19:49	43	450			GA0016		YES			DLSP	
	RFS TLC	Thurs.	20:48	10-Jan	10-Jan	10	20:48	22:42	43	451			GA0016		YES			DLSP	
	USO Tst	Mon.	16:45	14-Jan	14-Jan	14	16:45	18:47	43	455			GA0017	GAO0045	YES			DLSP	
	USO Tst	Wed.	17:01	16-Jan	16-Jan	16	17:01	19:02	43	457			GA0017	GAO0046	YES			DLSP	
	USO Tst	Sat.	16:01	19-Jan	19-Jan	19	16:01	18:03	43	460			GA0017	GAO0047	YES			ALSP	
	USO Tst	Mon.	18:01	21-Jan	21-Jan	21	18:01	20:03	43	462			GA0017	GAO0048	YES			ALSP	
	USO Tst	Sat.	16:01	26-Jan	26-Jan	26	16:01	18:03	43	467			GA0017	GAO0049	YES			ALSP	
	USO Tst	Mon.	06:01	29-Jan	29-Jan	29	06:01	08:03	63	469			GA0017	GAO0050	YES			ALSP	
	USO Tst	Sat.	15:46	2-Feb	2-Feb	33	15:46	17:48	43	474			GA0017	GAO0051	YES			ALSP	LGA - 2 Switch 12/08/90 - 01/31/91
	USO Tst	Mon.	06:01	4-Feb	4-Feb	36	06:01	08:03	63	476			GA0017		YES			ALSP	
	USO Tst	Thurs.	06:01	7-Feb	7-Feb	39	06:01	08:03	63	479			GA0017		YES			ALSP	
	USO Tst	Tue.	15:02	12-Feb	12-Feb	43	15:02	17:03	43	484			GA0017	GAO0052	YES			ALSP	
	USO Tst	Mon	21:17	18-Feb	18-Feb	49	21:17	23:19	43	490			GA0017	GAO0053	YES			ALSP	
	USO Tst	Sun.	15:32	24-Feb	24-Feb	55	12:50	18:15	43	496			GA0018	GAO0054	YES			ALSP	
	RFS TLC	Thurs.	16:16	28-Feb	28-Feb	59	16:16	18:10	43	500			GA0018		YES			DLSP	
	USO Tst	Tue.	14:03	5-Mar	5-Mar	64	14:02	16:04	43	505			GA0018	GAO0055	YES			DLSP	
	RFS AGC	Wed.	22:31	6-Mar	6-Mar	65	22:31	23:53	43	506			GA0018		YES			DLSP	
	USO Tst	Thurs.	16:17	14-Mar	1'4-Mar	73	16:17	18:19	43	514			GA0018	GAO0056	YES			DLSP	
	USO Tst	Fri.	15:02	22-Mar	22-Mar	81	15:02	17:04	43	522			GA0018	GAO0057	YES			DLSP	
	USO Tst	Thurs.	13:02	28-Mar	28-Mar	87	13:02	15:04	43	528			GA0020		YES			ALSP	CDS Bus Reset A and Reset B 03/26/91 CDS Bus Reset A and Bus Reset B 03/26/91
	USO Tst	Wed.	16:02	3-Apr	3-Apr	93	16:02	18:04	43	534			GA0020		YES			ALSP	
	USO Tst	Tue.	16:00	9-Apr	9-Apr	99	16:00	18:00	43	540			GA0020		YES			DLSP	
	USO Tst	Fri.	13:45	19-Apr	19-Apr	109	13:45	15:30	43	550			GA0020		YES			ALSP	
	USO Tst	Sat.	00:00	27-Apr	28-Apr	118	00:00	02:00	63	558			GA0020		YES			ALSP	
	USO Tst	Mon	00:00	21-May	21-May	141	00:00	02:00	63	581			GA0021	GAO0058	YES			ALSP	

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VALD	OL VALD	SC SPIN	COMMENTS PAGE 5 LUD 10/04/94
	USO Tst	Mon	23:00	3-Jun	3-Jun	154	23:00	01:00	61	595			GA0021	GAO0059	YES			ALSP	
																			CDA BUS RESET A AND BUS RESET B 07/08/91
	USO	Mon		5-Aug	5-Aug	217	0645-1155		43									DLSP	USO WAS SWITCHED OFF FOR COLD TURN
																			#2. TWTA-1 LOW PWR AT 10BIT WAS
																			SELECTED
																			USO SWITCHED ON 228/013112
X	USO Tst	Wed	18:30	4-Sep	4-Sep	247	00:00	18:30	63	688			GA0029		YES			ALSP	
	HGA ANOMALY																		
X	USO Tst	Mon	21:15	16-Sep	16-Sep	259	21:15	23:15	14	701			GA0030	GAO0060	YES			DLSP	
X	USO Tst	Wed	00:45	2-Oct	2-Oct	275	00:45	02:45	43	716			GA0031	GAO0061	YES			DLSP	
X	USO Tst	Sat	15:00	19-Oct	19-Oct	292	15:00	17:00	63	733			GA0032		YES			DLSP	
X	USO Tst	Thur	03:30	14-Nov	14-Nov	318	03:30	05:30	43	759			GA0033		YES			DLSP	
X	USO Tst	Sat	20:15	30-Nov	30-Nov	334	20:15	22:14	14	776			GA0034		YES			DLSP	
																			FUTURE EVENTS
																			Cooling Turn #5 2/24/92-3/06/92
																			Cooling Turn #6 04/06/92- 04/17/92
1992																			
	USO Tst	Tue	03:25	10-Mar	10-Mar	70	03:25	05:25	43	876			GA0048		YES			DLSP	
	USO Tst	Wed	15:44	1-Apr	1-Apr	92	15:44	17:54	14	899			GA0049	GAO0062-64	YES			ALSP	Warming Turn #6 03/18/92-03/23/92
	USO Tst	Wed	19:32	22-Apr	22-Apr	113	19:32	21:42	43	920			GA0049		YES			ALSP	
	USO Tst	Thur	11:49	14-May	14-May	135	11:49	13:50	14	942			GA0051	GAO0065-68	YES				
	USO Tst	Wed	19:17	3-Jun	3-Jun	155	19:17	21:17	43	962			GA0051						
	USO Tst	Wed	20:45	24-Jun	24-Jun	176	20:45	22:44	43	963			GA0051	GAO0069	YES				
	USO Tst	Wed	03:12	15-Jul	15-Jul	198	03:12	05:12	63	1004			GA0053	GAO0070					
																			Warm / Cool Turns #7 07/20/92 - 07/31/92
	USO Tst	Sun	18:50	2-Aug	2-Aug	215	18:50	20:50	43	1022				GAO0071					
	USO Tst	Thur	03:35	26-Aug	26-Aug	240	03:35	05:35	63	1046	Good	Good		GAO0072					Channels 2 & 4 attu adjusted for 1 volt peak-to-peak
	USO Tst	Wed	06:30	17-Sep	17-Sep	262	01:30	08:30	63	1068	Good	Marginal		GAO0073-					DR # H2671 DSP halted 0130-0145z. reloaded
														GAO0076					DR # H2672 CH 4 indicates filter 0 instead of 1.
																			Sta unable to change 0145 - 0330z.
																			Warm/Cool Turns #8 0831/92- 0911/92
																			Warm / Cool Turns # 9 09/21/92 - 10/02/92
	USO Tst	Mon	04:30	5-Oct	5-Oct	279	23:30	01:30	63	1086	Good	Good	GA0058	GAO0077-78				DLSP	DR# H2882 18 min Tracking outage 2135Z To
																			2153Z. MDA Haulted no impact to USO Test.
																			DR# H2885 Ant went to brake due to pedestal brake.
																			being activiated from 0735Z to 0737Z. Also no
																			impact to the USO Test.
																			Cold Turn#10 & Spin-Up 10/19/92-10/23/92
	USO Tst	Wed	01:30	28-Oct	28-Oct	302	21:30	23:30	63				GA0060	NONE	YES				DSP RED DR#???
1993																			
	USO Tst	Fri	13:31	22-Jan	22-Jan	22	13:31	15:36	43	1196	GOOD	GOOD	GA0078	GAO0079	YES				
DSP	USO Tst	Mon	23:57	8-Feb	8-Feb	39	23:57	02:02	63	1214	GOOD	GOOD	GAO079	NO	YES				
DSP	USO Tst	Tue	02:33	2-Mar	2-Mar	61	02:33	04:38	63	1235	BAD	GOOD	GA0079	NO	YES				DR# H4873 SWAP DSP DUE TO CMC I/F PROBLEM.

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VAILD	OL VAILD	SC SPIN	COMMENTS PAGE 6 LUD 10/04/94
DSP	USO Tst	Mon	19:38	12-Apr	12-Apr	102	19:38	21:38	63	1277	GOOD	GOOD	GA0091	GA00080	YES				DR# H4830 SCP1 DROPOUTS DR# H4826 MON5-9 SNT PARAMETER PPM.
DSP	USO Tst	Mon	18:40	3-May	3-May	123	18:40	20:41	63	1298	GOOD	GOOD	GA0092	GA00081 GA00082	YES				
DSP	USO Tst	Mon	18:12	10_may	10-May	130	18:12	20:12	63	1305	GOOD	GOOD	GA0092	GA00083	YES				
DSP	USO Tst	Mon	16:29	24-May	24-May	144	16:29	18:30	63	1319	GOOD	GOOD	GA0092	GA00084	YES				
DSP	USO Tst	Mon	19:56	7-Jun	7-Jun	158	19:56	21:57	63	1333	GOOD	GOOD	GA0093	NO	YES				DR# H6638 STA UNABLE TO CONFIRM DSP-R RECORDING
DSP	USO Tst	Thur	16:42	8-Jul	8-Jul	189	16:42	18:42	63	1364	GOOD	GOOD	GA0095	?	YES				DR# H7167 PPM RED
DSP	USO Tst	Mon	21:29	19-Jul	19-Jul	200	21:29	23:29	14	1375	GOOD	GOOD							CANCELLED
DSP	USO Tst	Tue	22:07	3-Aug	3-Aug	215	22:07	00:17	14	1389	GOOD	GOOD	GAO097	GA00085	YES				DR# H8081 APA-1 "NO WATCHDOG". DR# H7631 COMM OUTAGE
NDSP	USO Tst	Wed	22:29	18-Aug	18-Aug	230	22:29	00:29	14	1403	GOOD	GOOD	GAO099	NO	YES				NO DSP SCHEDULED
NDSP	USO Tst	Sun	14:29	21-Aug	21-Aug	234	14:29	16:29	63	1408	GOOD	GOOD	GAO099	NO	YES				SUPPORT CANCELLED DUE TO MARS OBSERVER EMERGENCY
NDSP	USO Tst	Tue	19:30	13-Sep	13-Sep	256	11:30	13:30	63	1430	GOOD	GOOD	GAO100	NO	YES				NO DSP TAPE RECEIVED
DSP	USO Tst	Mon	01:15	27-Sep	27-Sep	270	21:15	23:15	43	1445	GOOD	GOOD	GA0101		NO				NO DSP TAPE RECEIVED
DSP	USO Tst	Tue	06:04	5-Oct	5-Oct	283	14:04	16:05	63	1457			GA0106	GA00086	NO				
DSP	USO Tst	Mon	12:37	13-Dec	13-Dec	352	20:37	22:37	43	1527			GA0124	GA00087	NO				
1994																			
DSP	USO Tst	Tue	12:51	4-Jan	4-Jan	4	20:51	22:50	43	1544			GA0125	GA00088	NO				
DSP	USO Tst	Tue	09:33	1-Feb	1-Feb	32	17:33	19:35	43	1572			GA0125	GA00089	NO				
DSP	USO Tst	Sat	10:02	12-Feb	12-Feb	43	18:02	20:04	43	1583			GAO125	GA00090	NO				
DSP	USO Tst	Mon	09:59	28-Feb	28-Feb	59	17:59	20:00	43	1599			GAO126	GA00091	NO				
DSP	USO Tst	Mon	12:30	14-Mar	14-Mar	73	20:30	22:31	43	1613			GAO127	GA00092	NO				
DSP	USO Tst	Mon	12:29	28-Mar	28-Mar	87	20:29	22:30	43	1627			GAO127	GA00093	NO				
DSP	USO Tst	Mon	10:59	25-Apr	25-Apr	115	18:59	21:00	43	1655			GAO129	GA00094	NO				
DSP	USO Tst	Mon	05:00	20-Jun	20-Jun	171	04:00	06:00	14	1711			GAO155	GA00095	NO				
DSP	USO Tst	Sun	00:32	3-Jul	3-Jul	184	07:32	09:32	43	1724			GAO155	GA00096					
DSP	USO Tst	Mon	02:00	18-Jul	18-Jul	199	09:00	11:00	43	1739			GAO156	GA00097					
DSP	USO Tst	Tue	02:00	2-Aug	2-Aug	214	09:00	11:00	43				GAO157	GA00098					
DSP	USO Tst	Sun	02:00	14-Aug	14-Aug	226	09:00	11:00	43				GAO158	GA00099					
DSP	USO Tst	Mon	08:00	12-Sep	12-Sep	255	15:00	17:00	63	1795			GAO161						DR # J4418 MOD 3 MASER FAILED NO LCP RECORD
DSP	USO Tst	Tue	06:00	27-Sep	27-Sep	270	13:00	15:00	63										
DSP	USO Tst	Tue	06:45	11-Oct	11-Oct	284	13:45	15:45	63										

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

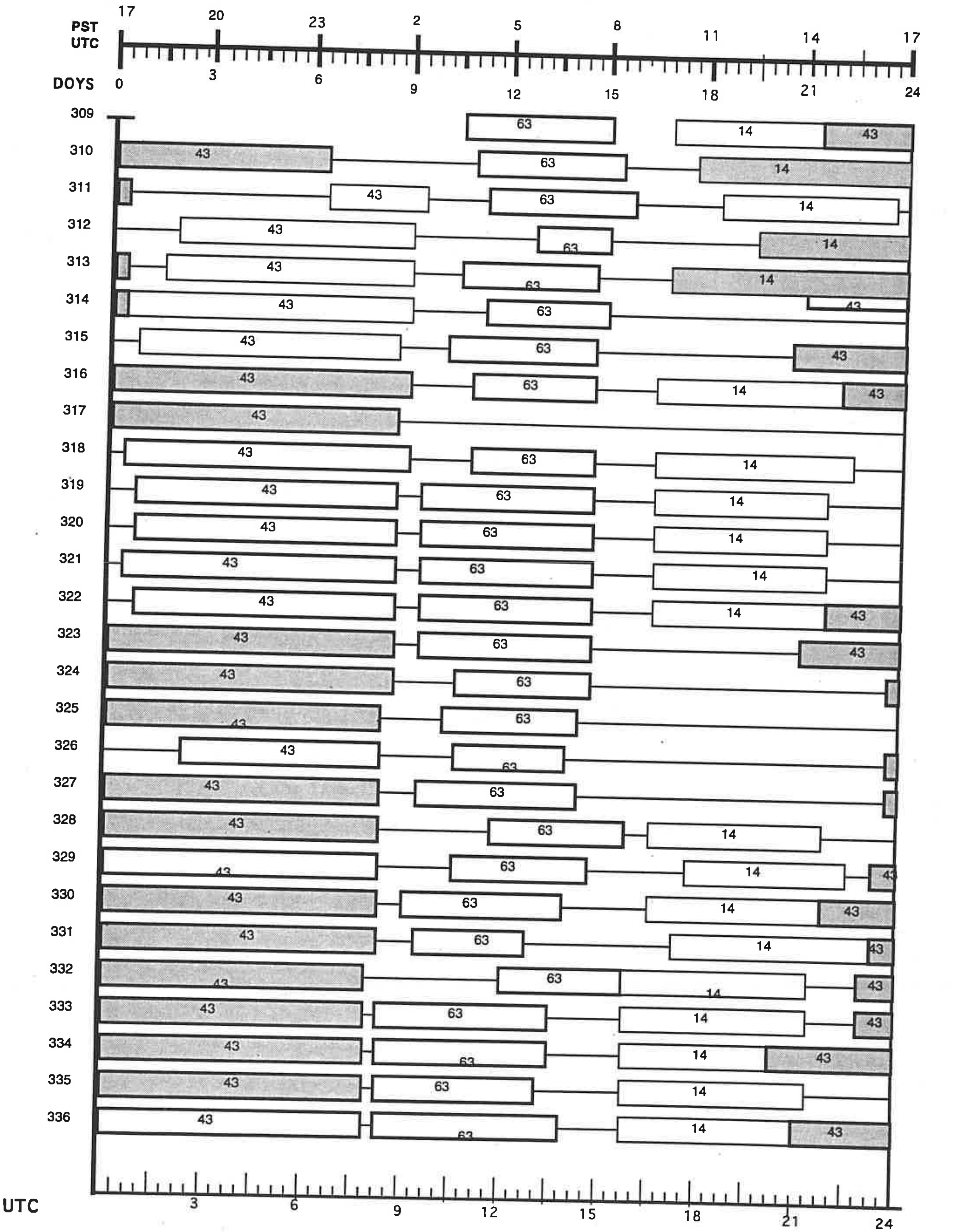
GALILEO USO ACTIVITIES

LOAD	EVENT	PST DOW	PST BEGIN	PST DATE	UTC DATE	UTC DOY	UTC BEGIN	UTC END	DSS	PASS #	CL DOPP	OL DATA	ATDF	OL ODR	P-FLD	CL VAILD	OL VAILD	SC SPIN	COMMENTS PAGE 7 LUD 10/04/94
DSP	USO Tst	Tue	21:48	Oct-25	Oct-25	298	21:48	23:48	14										
1995																			
DSP	USO Tst	Tue	00:49	Jan-10	Jan-10	10	00:49	02:49	43										
DSP	USO Tst	Thur	00:48	Jan-26	Jan-26	26	00:48	02:48	43										

NA- NOT AVAILABLE NR- NOT REQUIRED N- NEED ODRs D= DSP SCHED N =DSP NOT SCHED - = DSP NOT APPL

GALILEO SOLAR WIND SCINTILLATION EXPERIMENT 94

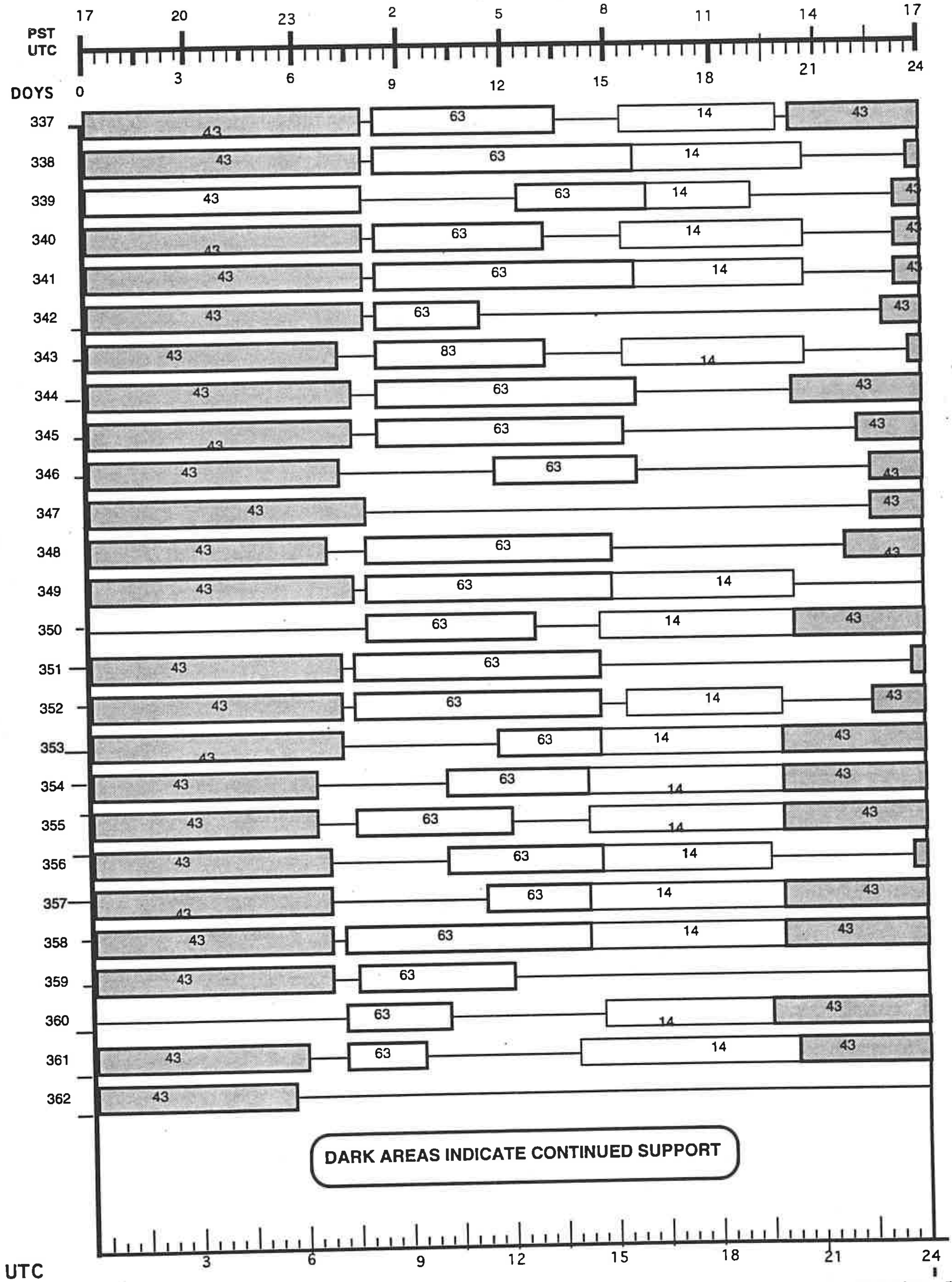
STATION ALLOCATION



10/10/94 RAH

GALILEO SOLAR WIND SCINTILLATION EXPERIMENT 94

STATION ALLOCATION



10/10/94 RAH

Galileo Solar Wind Scintillation Experiment '94

DOY	DSS	BOT (UTC)	EOT (UTC)	Config.	Comments (time in UTC)
309	63	10:35	15:05	6486	
309	14	17:00	21:15	0481	
309	43	21:15	6:15	0481	309/23:38 TWNC on
310	63	11:00	15:10	6486	
310	14	**17:45**	0:30	**0481**	**Bold indicates a change from original station allocation.**
311	43	6:15	9:25	0481	
311	63	11:45	15:45	6486	
311	14	18:15	23:45	0481	
312	43	1:45	9:00	0481	312/07:25-20:26 TWNC off
312	63	12:05	15:00	6486	
312	14	**19:15**	0:30	**0481**	
313	43	1:15	8:50	0481	
313	63	10:55	14:55	6486	
313	14	17:05	**0:15**	0481	FSR
313	43	21:00	9:05	0481	FSR 20:11-23:36 (scet)
314	63	10:55	14:55	6486	
314	14				FSR BLK V 16:41-23:56(scet)
314	43	0:45	8:50	0481	FSR
315	63	10:50	14:50	6486	
315	14				No GLL Track
315	43	20:50	9:00	0481	
316	63	10:30	14:50	6486	
316	14	**16:45**	22:00	**0481**	
316	43	21:45	8:45	0481	
317	63				No GLL Track
317	14				No GLL Track
318	43	0:20	9:00	0481	
318	63	10:45	14:45	6486	
318	14	16:35	22:35	0481	
319	43	0:50	8:50	0481	319/07:14-18:55 TWNC off
319	63	**9:00**	**14:35**	6486	
319	14	16:45	21:45	0481	
320	43	0:45	8:50	0481	
320	63	9:15	**14:30**	6486	
320	14				FSR BLK V 15:41-23:41(scet)
321	43	**0:30**	8:45	0481	FSR
321	63	9:15	**14:25**	6486	
321	14	16:30	21:45	0481	
322	43	0:45	8:45	0481	
322	63	9:15	**14:25**	6486	
322	14	**16:30**	21:45	**0481**	
322	43	21:35	8:40	0481	
323	63	9:10	**14:20**	6486	
323	14				BLK V 15:56-20:31(scet)
323	43	21:00	8:05	0481	
324	63	10:40	**14:15**	6486	
324	14				FSR BLK V 15:41-22:56(scet)
325	43	**23:45**	8:35	0481	FSR

Galileo Solar Wind Scintillation Experiment '94

DOY	DSS	BOT (UTC)	EOT (UTC)	Config.	Comments (time in UTC)
325	63	10:10	14:10	6486	
325	14				BLK V 18:26-21:56(scet)
326	43	**0:20**	8:15	0481	326/06:44-327/03:04 TWNC off
326	63	10:35	13:50	6486	
326	14				FSR BLK V 18:11-22:56(scet)
327	43	**23:45**	8:15	0481	FSR
327	63	9:55	14:05	6486	
327	14				
327	43	23:50	8:05	0481	
328	63	11:55	15:55	6486	
328	14	**16:15**	21:35	**0481**	
329	43	0:05	8:05	0481	
329	63	10:35	14:40	6486	
329	14	**17:50**	22:35	**0481**	
329	43	23:10	8:20	0481	
330	63	9:00	13:50	6486	
330	14	**16:30**	21:45	**0481**	
330	43	21:25	8:15	0481	
331	63	9:10	13:50	6486	
331	14	**17:15**	23:30	**0481**	
331	43	23:15	8:00	0481	
332	63	12:20	16:00	6486	
332	14	**15:40**	21:20	**0481**	
332	43	23:00	8:00	0481	333/07:50-18:45 TWNC off
333	63	8:15	13:35	6486	
333	14	**15:35**	21:15	**0481**	
333	43	23:20	7:45	0481	
334	63	8:15	13:35	6486	
334	14	**15:35**	20:05	**0481**	
334	43	19:50	7:55	0481	
335	63	8:10	13:15	6486	
335	14	**15:35**	21:25	**0481**	
336	43	0:00	8:00	0481	
336	63	8:10	16:00	0481	
336	14	**15:30**	21:05	**0481**	
336	43	20:50	7:50	0481	
337	63	8:05	13:25	6486	
337	14	**15:25**	19:40	**0481**	
337	43	20:00	7:45	0481	
338	63	8:30	15:45	6486	
338	14	**15:25**	20:45	**0481**	
338	43	23:45	7:45	0481	
339	63	12:30	15:55	6486	
339	14	**15:20**	19:05	**0481**	
339	43	23:15	7:20	0481	340/07:10-16:30 TWNC off
340	63	8:30	13:15	6486	
340	14	**15:20**	20:55	**0481**	
340	43	23:15	7:30	6481	
341	63	8:20	15:45	6486	
341	14	**15:15**	20:45	**0481**	
341	43	23:15	8:00	0481	

Galileo Solar Wind Scintillation Experiment '94

DOY	DSS	BOT (UTC)	EOT (UTC)	Config.	Comments (time in UTC)
342	63	8:15	**11:20**	6486	Compr.4 Blk-V (13:05)
342	14				FSR BLK V 14:10-22:10(scet)
342	43	**23:00**	7:10	0481	FSR
343	63	8:10	12:55	6486	
343	14	**15:10**	20:40	**0481**	
343	43	23:55	7:35	0481	
344	63	8:10	15:35	6486	
344	14				BLK V 14:30-19:45(scet)
344	43	20:20	7:30	0481	
345	63	8:20	15:25	6486	
345	14				BLK V 14:35-18:40(scet)
345	43	22:15	7:25	0481	
346	63	11:45	15:30	6486	
346	14				BLK V 14:25-19:35(scet)
346	43	22:45	7:45	0481	
347	63				Delete Compr. 4 BlkV 347/05:55-23:26 TWNC off
347	14				FSR BLK V 14:10-22:10(scet)
347	43	**22:45**	6:45	0481	FSR
348	63	8:00	15:00	6486	
348	14				BLK V 14:20-19:30(scet)
348	43	22:35	7:35	0481	
349	63	7:55	14:55	6486	
349	14	**14:50**	20:15	**0481**	
349	43				
350	63	7:50	12:30	6486	
350	14	**14:45**	20:10	**0481**	
350	43	19:50	7:25	0481	
351	63	7:45	14:45	6486	
351	14				Blk V 13:55-19:10(scet)
351	43	23:55	7:20	0481	FSR deleted
352	63	7:45	14:45	6486	
352	14	**15:20**	20:00	**0481**	
352	43	22:15	7:15	0481	
353	63	11:40	14:40	6486	
353	14	**14:35**	20:15	**0481**	
353	43	20:00	6:20	0481	354/05:40-17:11 TWNC off
354	63	10:20	14:35	6486	
354	14	**14:35**	19:55	**0481**	
354	43	19:40	6:20	0481	
355	63	7:35	12:00	6486	
355	14	**14:35**	20:25	**0481**	
355	43	20:15	6:55	0481	
356	63	10:15	14:35	6486	
356	14	**14:30**	19:50	**0481**	
356	43	23:55	6:50	0481	
357	63	11:30	14:30	6486	
357	14	**14:30**	19:45	**0481**	
357	43	19:30	6:45	0481	

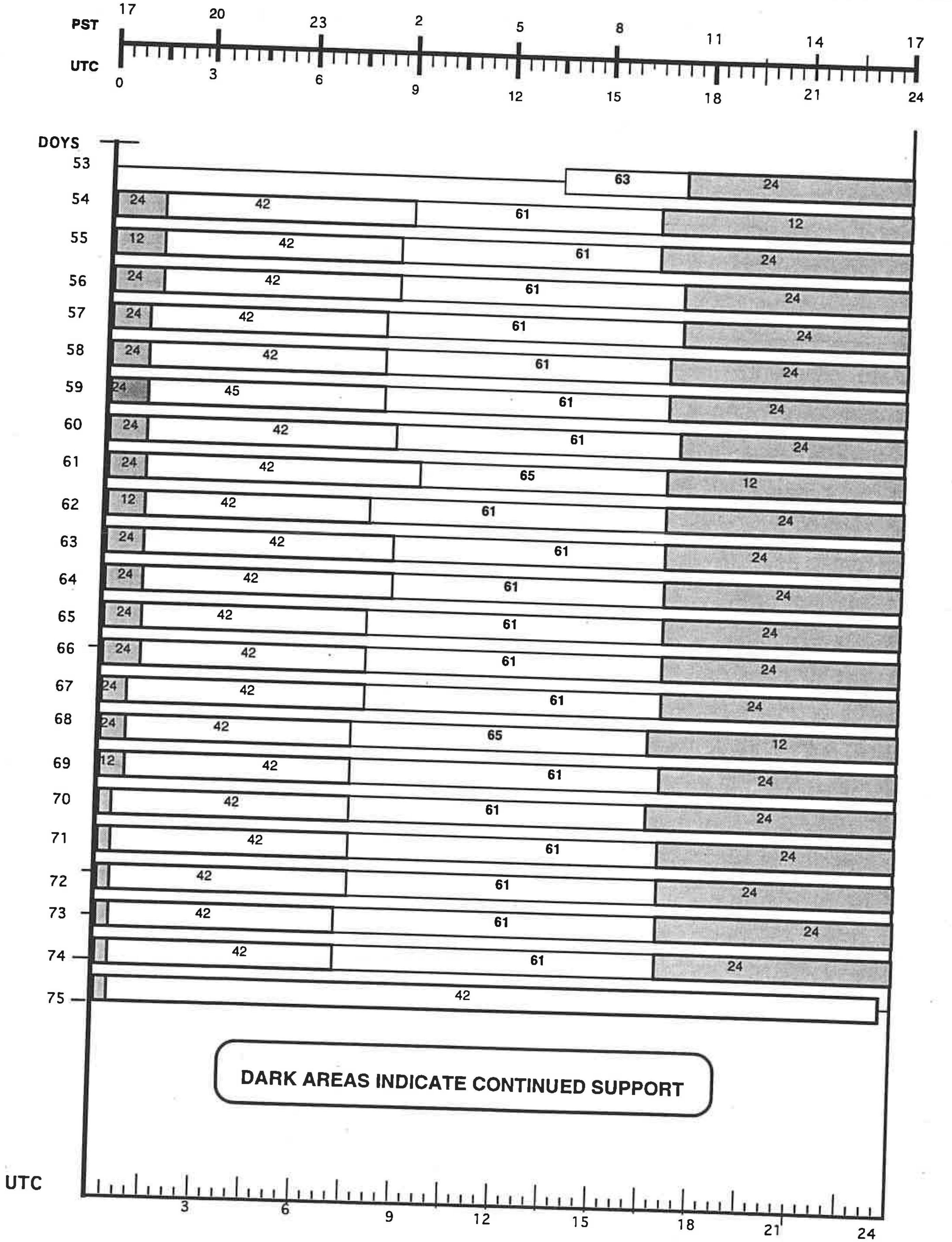
Galileo Solar Wind Scintillation Experiment '94

DOY	DSS	BOT (UTC)	EOT (UTC)	Config.	Comments (time in UTC)
358	63	7:25	14:25	6486	
358	14	**14:20**	19:40	**0481**	
358	43	19:25	6:40	0481	
359	63	7:25	12:00	6486	
359	14				
359	43				
360	63	7:00	10:15	486	
360	14	**14:15**	19:35	**0481**	
360	43	19:20	5:50	0481	
361	63	7:10	**9:20**	6486	Compr. 4 BlkV (14:20)
361	14	**14:15**	**22:00**	**0481**	FSR
361	43	**18:30**	5:45	0481	FSR
					362/19:29 TWNC off

ULYSSES SOLAR CORONA EXPERIMENT 95

STATION ALLOCATION

10/11/94 RAH



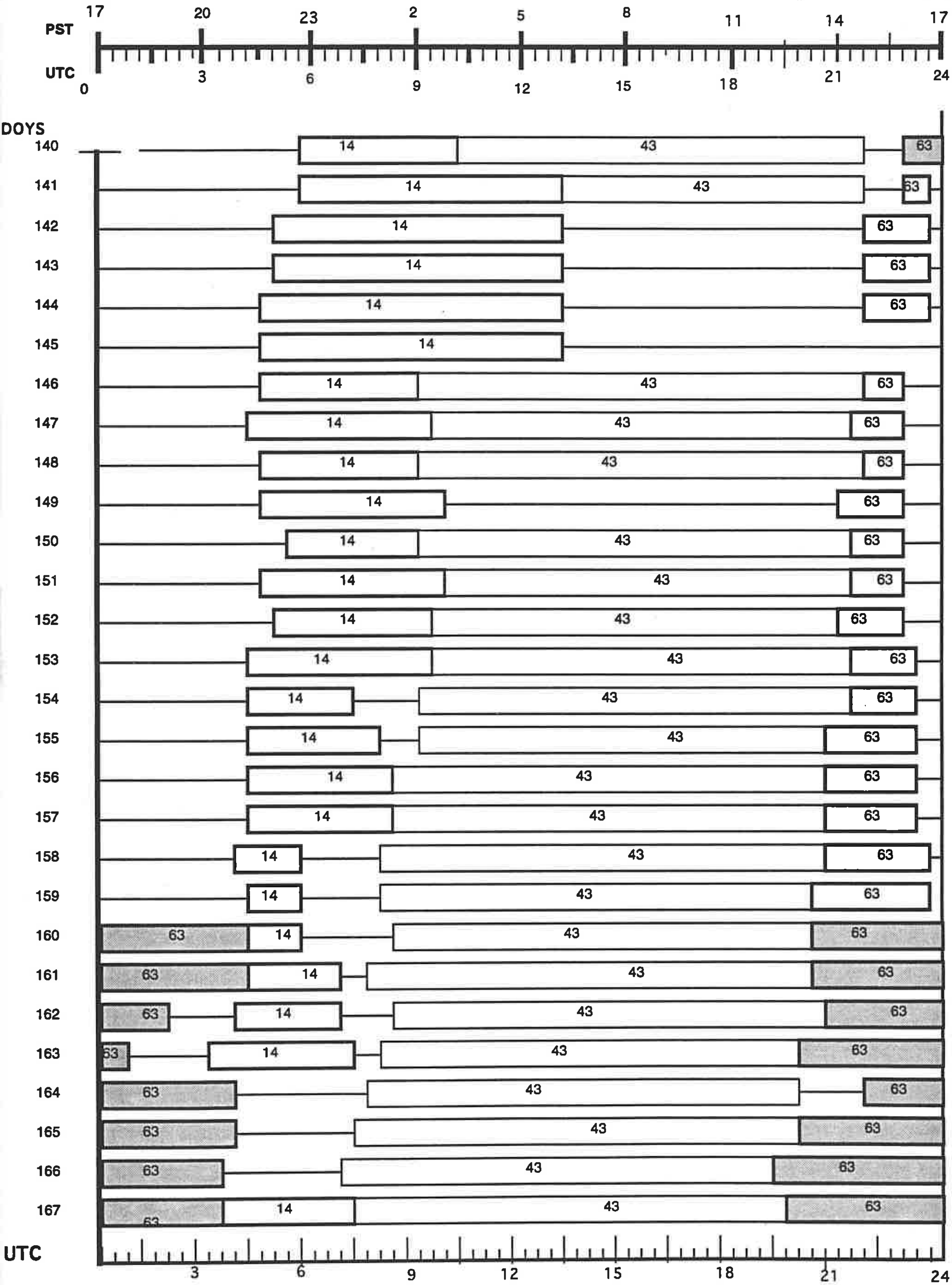
DOY	DSS	DOW	BOT	BOT L	EOT	EOT L	CONFIGURATION	COMMENTS	RSST SUPPORT 8-23-94
54	42	FRI	0000Z	4PM	0850Z	12:50 AM	300I		PRE-CAL IS 2HOURS.THE CFG CODE IS
54	61	SAT	0820Z	12:20 AM	1700Z	9:00 AM	300I		BEING CHANGED SHOULD READ WHEN DONE
54	12	SAT	1630Z	8:30 AM	0030Z	4:30PM	300I		540K FOE DSP SUPPORT.
54	42	SAT	0000Z	4:00 PM	0845Z	12:45 AM	300I		
55	61	SUN	0815Z	12:15 AM	1700Z	9:00 AM	300I		
55	24	SUN	1630Z	8:30 AM	0030Z	4:30 PM	300I		
55	42	SUN	0000Z	4:00 PM	0840Z	12:40 AM	300I		
56	61	MON	0810Z	12:10 AM	1700Z	9:00 AM	300I		
56	24	MON	1630Z	8:30 AM	0030Z	4:30 PM	300I		
56	42	MON	0000Z	4:00 PM	0830Z	12:30 AM	300I		
57	61	TUE	0805Z	12:05 AM	1700Z	9:00 AM	300I		
57	24	TUE	1630Z	8:30 AM	0030Z	4:30 PM	300I		
57	42	TUE	0015Z	4:15 PM	0830Z	12:30 AM	300I		
58	61	WED	0800Z	MIDNIGHT	1615Z	8:15 AM	300I		
58	24	WED	1545Z	7:45 AM	2345Z	3:45 PM	300I		
58	42	WED	2315Z	3:15 PM	0825Z	12:25 AM	300I		
59	61	THUR	0755Z	11:55 PM	1615Z	8:15 AM	300I		
59	24	THUR	1545Z	7:45 AM	2345Z	3:45 PM	300I		
59	42	THUR	2315Z	3:15 PM	0825Z	12:45 AM	300I		
60	61	FRI	0815Z	12:15 AM	1615Z	8:15 AM	300I		
60	24	FRI	1545Z	7:45 AM	2345Z	3:45 PM	300I		
60	42	FRI	2315Z	3:15 PM	0820Z	12:20 AM	300I		
61	61	SAT	0735Z	11:35 PM	1630Z	8:30 AM	300I		
61	12	SAT	1600Z	8:00 AM	0000Z	4:00 PM	300I		
61	42	SAT	2330Z	3:30 PM	0820Z	12:20 AM	300I		
62	61	SUN	0730Z	11:30 PM	1630Z	8:30 AM	300I		
62	24	SUN	1530Z	7:30 AM	0000Z	4:00 PM	300I		
62	42	SUN	2330Z	3:30 PM	0815Z	12:15 AM	300I		
63	61	MON	0725Z	11:25 PM	1630Z	8:30 AM	300I		
63	24	MON	1600Z	8:00 AM	0000Z	4:00 PM	300I		
63	42	MON	2330Z	3:30 PM	0810Z	12:10 AM	300I		
64	61	TUE	0720Z	11:20 PM	1630Z	8:30 AM	300I		
64	24	TUE	1530Z	7:30 AM	0000Z	4:00 PM	300I		
64	45	TUE	0000Z	4:00 PM	0615Z	10:15 PM	300I		
65	42	TUE	0600Z	10:00 PM	0800Z	MIDNIGHT	300I		
65	61	WED	0715Z	11:15 PM	1510Z	7:10 AM	300I		
65	24	WED	1440Z	6:40 AM	2040Z	12:40 PM	300I		
65	42	WED	2010Z	12:10 PM	0740Z	11:40 PM	300I		
66	61	THUR	0720Z	11:20 PM	1510Z	7:10 AM	300I		
66	24	THUR	1440Z	6:40 AM	2045Z	12:45 PM	300I		

DOY	DSS	DOW	BOT	BOT L	EOT	EOT L	CONFIGURATION	COMMENTS	RSST SUPPORT
66	42	THUR	2015Z	12:15 PM	0740Z	11:40 PM	3001		
67	61	FRI	0715Z	11:15 PM	1455Z	6:55 AM	3001		
67	24	FRI	1435Z	6:35 AM	2050Z	12:50 PM	3001		
67	42	FRI	2020Z	12:20 PM	0735Z	11:35 PM	3001		
68	61	SAT	0715Z	11:15 PM	1500Z	7:00 AM	3001		
68	12	SAT	1430Z	6:30 AM	2055Z	12:55 PM	3001		
68	42	SAT	2025Z	12:25 PM	0735Z	11:35 PM	3001		
69	61	SUN	0710Z	11:10 PM	1500Z	7:00 AM	3001		
69	24	SUN	1430Z	6:30 AM	2100Z	1:00 PM	3001		
69	42	SUN	2030Z	12:30 PM	0730Z	11:30 PM	3001		
70	61	MON	0710Z	11:10 PM	1500Z	7:00 AM	3001		
70	24	MON	1430Z	6:30 AM	2100Z	1:00 PM	3001		
70	42	MON	2030Z	12:30 PM	0730Z	11:30 PM	3001		
71	61	TUE	0710Z	11:10 PM	1500Z	7:00 AM	3001		
71	24	TUE	1430Z	6:30 AM	2100Z	1:00 PM	3001		
71	42	TUE	2030Z	12:30 PM	2345Z	3:45PM	3001		
71	45	TUE	2315Z	3:15 PM	0730Z	11:30 PM	3001		
72	61	TUE	0645Z	10:45 PM	1530Z	7:30 AM	3001		
72	24	WED	1500Z	7:00 AM	2330Z	3:30 PM	3001		
72	42	WED	2300Z	3:00 PM	0710Z	11:10 PM	3001		
73	61	WED	0640Z	10:40 PM	1500Z	7:00 AM	3001		
73	24	WED	1430Z	6:30 AM	2300Z	3:00 PM	3001		
73	42	WED	2230Z	2:30 PM	0705Z	11:05 PM	3001		
74	61	WED	0635Z	10:35 PM	1505Z	7:05 AM	3001		
74	24	THUR	1435Z	6:35 AM	2305Z	3:05 PM	3001		
74	42	THUR	2235Z	2:35 PM	0700Z	11:00 PM	3001		

GALILEO GRAVITATIONAL WAVE EXPERIMENT 95

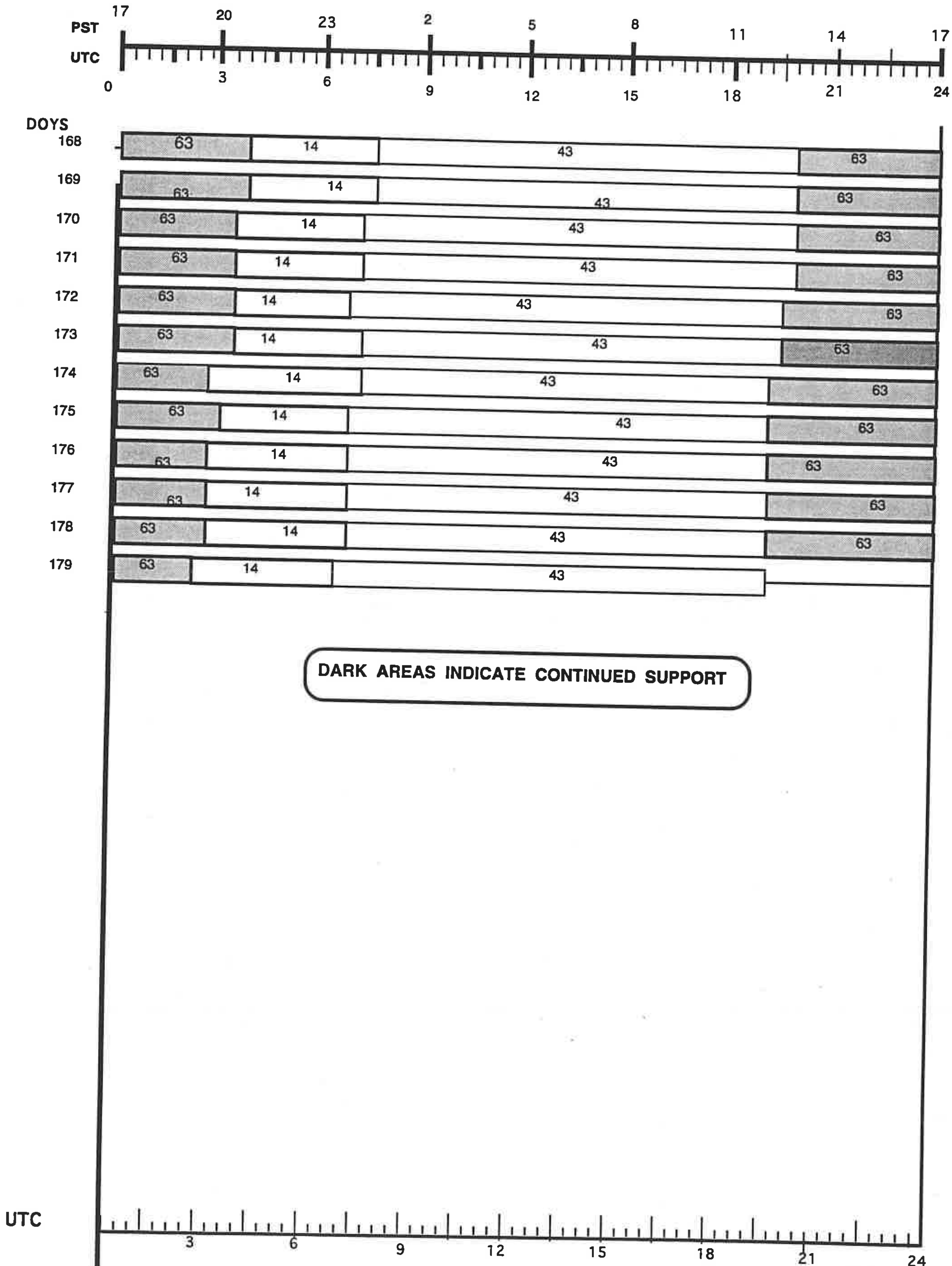
STATION ALLOCATION

10/10/94 RAH



GALILEO GRAVITATIONAL WAVE EXPERIMENT 95

STATION ALLOCATION



10/10/94 RAH

DOY	DOW	DSS	AOS	EOT	CFG	COMMENTS
140	SAT	14	0550Z	1000Z	6481	GRAVITY WAVE MAY 20 - JUNE 28 1995
140	SUN	43	0940Z	2150Z	6481	
140		63	2240Z	2350Z	6481	
141		14	0550Z	1245Z	6481	
141	MON	43	1225Z	2150Z	6481	
141		63	2230Z	2335Z	6481	
142		14	0500Z	1315Z	6481	
142	TUE	63	2150Z	2330Z	6481	
143		14	0500Z	1315Z	6481	
143	WED	63	2140Z	2320Z	6481	
144		14	0450Z	1300Z	6481	
144	THUR	63	**2300Z**	**2310Z**	6481	
145		14	0445Z	1300Z	6481	
146		14	0445Z	0900Z	6481	
146	FRI	43	0840Z	2140Z	6481	
146		63	2125Z	2245Z	6481	
147		14	0435Z	0910Z	6481	
147	SAT	43	0835Z	2135Z	6481	
147		63	2120Z	2245Z	6481	
148		14	0440Z	0850Z	6481	
148	SUN	43	0830Z	2240Z	6481	
148		63	2115Z	2235Z	6481	
149		14	0445Z	0945Z	6481	
149	MON	63	2110Z	2245Z	6481	
150		14	0440Z	0850Z	6481	
150	TUE	43	0830Z	2120Z	6481	
150		63	2105Z	2215Z	6481	
151		14	0420Z	0930Z	6481	
151	WED	43	0910Z	2115Z	6481	
151		63	2105Z	2255Z	6481	
152		14	0420Z	0915Z	6481	
152	THUR	43	0855Z	2105Z	6481	
152		63	2055Z	2300Z	6481	
153		14	0425Z	0820Z	6481	
153	FRI	43	0800Z	2105Z	6481	
153		63	2050Z	2310Z	6481	
154		14	0420Z	0715Z	6481	
154	SAT	43	0845Z	2110Z	6481	
154		63	2050Z	2315Z	6481	
155		14	0420Z	0745Z	6481	
155	SUN	43	0900Z	2055Z	6481	
155		63	2040Z	2315Z	6481	
156		14	0410Z	0830Z	6481	
156	MON	43	0810Z	2050Z	6481	
156		63	2040Z	2325Z	6481	
157		14	0410Z	0830Z	6481	
157	TUE	43	0810Z	2055Z	6481	
157		63	2035Z	2330Z	6481	
158		14	0405Z	0605Z	6481	
158	WED	43	0805Z	2040Z	6481	
158		63	2025Z	2345Z	6481	
159		14	0405Z	0605Z	6481	
159	THUR	43	0810Z	2035Z	6481	
159		63	2020Z	0405Z	6481	
160		14	0345Z	0645Z	6481	
160	FRI	43	0815Z	2030Z	6481	

DOY	DOW	DSS	AOS	EOT	CFG	COMMENTS
160		63	2020Z	0225Z	6481	
161		14	0345Z	0645Z	6481	
161	SAT	43	0810Z	2030Z	6481	
161		63	2320Z	0350Z	6481	
162		14	0330Z	0730Z	6481	
162	SUN	43	0810Z	2025Z	6481	
162		63	2015Z	0055Z	6481	
163		14	0325Z	0725Z	6481	
163	MON	43	0705Z	2020Z	6481	
163		63	2015Z	0350Z	6481	
164	TUE	43	0725Z	2015Z	6481	
164		63	2145Z	0350Z	6481	
165	WED	43	0720Z	2010Z	6481	
165		63	2000Z	0345Z	6481	
166	THUR	43	0725Z	2000Z	6481	
166		63	1950Z	0340Z	6481	
167		14	0320Z	0735Z	6481	
167	FRI	43	0715Z	2000Z	6481	
167		63	1950Z	0335Z	6481	
168		14	0315Z	0725Z	6481	
168	SAT	43	0705Z	1955Z	6481	
168		63	1945Z	0330Z	6481	
169		14	0310Z	0720Z	6481	
169	SUN	43	0700Z	1950Z	6481	
169		63	1940Z	0320Z	6481	
170		14	0300Z	0715Z	6481	
170		43	0655Z	1945Z	6481	
170	MON	63	1935Z	0325Z	6481	
171		14	0305Z	0710Z	6481	
171		43	0650Z	1940Z	6481	
171	TUE	63	1930Z	0315Z	6481	
172		14	0255Z	0705Z	6481	
172		43	0645Z	1935Z	6481	
172	WED	63	1925Z	0310Z	6481	
173		14	0250Z	0705Z	6481	
173		43	0645Z	1930Z	6481	
173	THUR	63	1945Z	0310Z	6481	
174		14	0250Z	0700Z	6481	
174		43	0640Z	1925Z	6481	
174	FRI	63	1915Z	0305Z	6481	
175		14	0245Z	0655Z	6481	
175		43	0635Z	1920Z	6481	
175	SAT	63	1910Z	0250Z	6481	
176		14	0240Z	0650Z	6481	
176		43	0630Z	1920Z	6481	
176	SUN	63	1910Z	0250Z	6481	
177		14	0215Z	0630Z	6481	
177		43	0610Z	1915Z	6481	
177	MON	63	1900Z	0250Z	6481	
178		14	0210Z	0630Z	6481	
178		43	0610Z	1910Z	6481	
178	TUE	63	1850Z	0225Z	6481	
179		14	0205Z	0620Z	6481	
179		43	0600Z	1905Z	6481	

Appendix B
DSN Radio Science Open-Loop System

DSN RADIO SCIENCE OPEN-LOOP SYSTEM

Note: This appendix was taken, as is, from *Document 810-5, REV. D; VOL. I, DSN/ FLIGHT PROJECT INTERFACE DESIGN, module RS-10,* which was prepared by Ann Devereaux but has not been released at the time of this punlication. Permission was obtained from Robert Sniffin, Document 810-5 Custodian.

A. PURPOSE

This module presents the capabilities of the Radio Science System (RSS) for supporting various radio science experiments.

B. SCOPE

This module outlines the RSS system functions, architecture, and data interfaces. System performance characteristics, and operational configurations are also covered. Though radio science experiments can include Deep Space Communications Complex (DSCC) uplink support and closed-loop receiver tracking, this module is restricted to a description of the RSS open-loop recording capability, which is used solely for radio science support. Details of closed-loop Doppler tracking can be found in TRK-20. Details of the Exciter-Transmitter functions can be found in the TCI modules, and in CMD-10.

C. LOCATION OF MATERIAL

D. GENERAL INFORMATION

The the DSN Radio Science System supports radio science experiments, which use spacecraft radio frequency signals to remotely probe features of the solar system . By measuring perturbations of the radio frequency wave as it travels between the spacecraft and the ground stations, characteristics of obstacles or media in the path may be studied. Targets for radio science experiments include planets, planetary atmospheres, and rings. Non-planetary subjects include gravitational radiation and solar plasma. Details of DSN RSS applications may be found in JPL Pub. 80-93, "The Deep Space Network as an Instrument for Radio Science Research".

Observables for radio science experiments are the frequency, phase, and amplitude of the communication signal's carrier. The DSN RSS has been designed to enable accurate retrieval of this information.

D.1. System Functions

The functions of the Radio Science System can be summarized as follows:

1. Generation and transmission of an uplink carrier signal to the spacecraft with a pure spectrum, including low phase noise, and stable frequency.

2. Acquisition, downconversion, digitization, and recording of the downlink carrier with minimal distortion to its frequency, phase and amplitude characteristics.

D.2. System Architecture

The Radio Science capability of the DSN encompasses several subsystems. For any experiment, common subsystems include Microwave (UWV), Antenna (ANT), Frequency and Timing (FTS), DSCC Monitor and Control (DMC). The Ground Communications Facility (GCF) and the Network Operations Control Center (NOCC) are used to monitor experiments as they are being conducted. Some experiments require two-way tracking, and so the Exciter (RCV/EXC) and Transmitter (TXR) subsystems are used. These subsystems may all be used in conjunction with the Radio Science open-loop receivers. In addition, experiments may use closed-loop Doppler and ranging. The Radio Science System is pictured in Figure 1.

The Open-Loop Receiver Subsystem is pictured in Figure 2. There are two kinds of open-loop receivers, the Radio Science IF-VF Downconverter (RIV) used by the 70M and 34HEF subnet, and the Multimission Receiver (MMR) used by the 34STD subnet. Antennas supported by the RIV have a VLBI-Radio Science Downconverter (VRD) to perform the RF-IF downconversion; those supported by the MMR use the MMR Downconverter. As shown in the diagram, each DSCC is supported by one open-loop receiving string, which consists of a RIV and MMR receiver and a DSCC Spectrum Processor (DSP) data handler. Two variations on this architecture are the inclusion of a second RIV/DSP string at DSCC-40, and the absence of an MMR (and therefore open-loop tracking capability for DSS-12) at DSCC-10. A summary of the complexes and their capabilities is in Table 1.

D.3. System Description

The basic requirement for the Radio Science open-loop receiving system is to record all the information which is contained in a specified bandwidth. To accomplish this, the bandpass of interest, centered around some radio frequency, is shifted to video band (near baseband) for digital sampling. A maximum of four RF channels may be accepted by the Radio Science open-loop system for processing. These RF channels are drawn from the set XRCP, SRCP, XLCP, and SLCP, corresponding to the two possible polarizations of both S- and X-band signals.

D.3.1 Downconversion

D.3.1.1 RIV Downconversion

The downconversion in the RIV is carried out in steps, as shown in Figure 3. The initial RF-IF downconversion occurs in the VRD, which is located in the antenna. The IF signals are transmitted to the Signal Processing Center (SPC) via rigid coaxial cable.

The RIV is located in the SPC, in the Dual Cabinet Assembly (DCA). The DCA contains the RIV and the RIV Controller (RIC).

The RIV performs several stages of downconversion, the first of which is done via a programmable local oscillator. The DANA synthesizer is driven by the Programmable Oscillator Controller Assembly (POCA), which uses predicts to determine a best carrier frequency. The DANA output is scaled to the incoming IF channels, and mixes both S-derived and X-derived signals down to 50 MHz plus a characteristic offset determined by frequency band and bandwidth selected. Along with mixing, the RIV dictates a bandwidth for recording through one of six crystal filters, selected by operator command. A listing of four filters currently installed comprises Table 2a; a listing of all filters available for ready installation is Table 2b. The RIV also contains an attenuator, which is set by station operators based on the average predicted signal strength for a tracking pass. The attenuator prevents a signal from either saturating or underdriving the analog to digital converters (A/Ds) which will do the bandpass digitization.

After the signal has been digitized within the VF bandwidth, it is possible to reconstruct the original RF frequency received at the antenna though use of the formulas in Table 4. The RIV formulas reverse the specific downconversion (multiplication and addition) steps in the RIV receiver.

D.3.1.2 MMR Downconversion

The MMR receivers were the predecessors to the RIVs. In this older design, the first local oscillator (LO) has a programmable frequency output, and not the second LO as in the RIV. Consequently, it is during the RF to IF downconversion that the signal is centered within a passband. For the MMR system, both the RF-IF and IF-VF converters are referred to as the "MMR".

The RF-IF MMR, located in the antenna, receives the same POCA/DANA frequency information as the RIV, though scaled to S and X RF rather than IF. The two channels of the RF-IF MMR are then sent by hard-line cable to the IF-VF MMR, located in the SPC. As with the RIV, the IF-VF MMR has several stages of fixed-frequency downconverters, attenuators, and a set of crystal filters for anti-aliasing. Table 2c lists the MMR filters installed at SPC 40 and 60. Filters are selected through the MMR Controller (MRC).

After the signal has been digitized within in the VF bandwidth, it is possible to reconstruct the original RF frequency received at the antenna though use of the formulas in Table 4. The two sets of MMR formulas reverse the specific downconversion (multiplication and addition) steps in the MMR receivers for Australia and Spain, respectively.

D.3.2 Sampling and Recording

The outputs of the MMR or RIV are within kilohertz of DC. This offset from DC is that which was included in the POCA/DANA tuning for a particular filter configuration. The offset/filter relationships are listed in Table 2a,b,c. This offset, along with the filter bandwidth, is important in the selection of the sampling frequency to be used when the VF signal is sent to the Radio Science Signal Digitizer (RSSD). The RSSD has four input channels, which may be assigned to any combination of four RIV channels (including redundant assignments) from any one antenna. Inside the RSSD, a selected pair of inputs may be sampled at a rate independent of that chosen for the other pair. The RSSD can digitize the data as 8-, 12-, or 16-bit samples. Sampling frequencies for the different sample sizes are available from a discrete set, which is listed in Table 3. Sampling frequencies commonly associated with certain filters are indicated in Table 2a.

Once sampled and digitized, the bandpass of interest is represented as a time-series of voltages. Frequency domain reconstruction of these samples will produce a noise bandwidth of 1/2 the sampling frequency, with a representation of the carrier signal located at some position relative to the center of this bandwidth. The absolute value of this center frequency is determined by the DANA frequency which was being used at the time of the observation. Reconstruction of the true received RF frequency (the "sky frequency") requires undoing, mathematically, the various stages of downconversion in the RS receiver string. Formulas for frequency reconstruction are given in Table 5.

The RSSD is part of a larger assembly called the Radio Science Communication Processor (RSCP). The RSCP serves as both data formatter and data distributor, for both outside users and various storage media. The RSCP normally provides data in two formats, real-time data blocks (per 820-13/RSC-11-11B) and 8mm (Exabyte) tape compilations (per 820-13/RSC-11-13). Table 3 provides a complete list of RS data interfaces. The RSCP and an associated assembly, the Spectrum Processing Assembly-Radio Science (SPA-R), together comprise the DSCC Spectrum Processor-Radio Science (DSP-R) Subsystem. The SPA-R is a master controller, connecting the RSCP, RIC or MRC, and POCA. A future evolution of the system will have the SPA-R and RSCP combined. Status information available from the DSP includes configuration data such as filter selection and channel assignment, monitor data such as A/D voltage levels and POCA frequencies, and real-time FFT spectral images of the incoming signal. The FFT display is called the Spectrum Signal Indicator (SSI). Since the open-loop receivers have by definition no automatic mechanism for locating a signal, the SSI display is the only way to tell if a signal is indeed in the bandpass being recorded.

D.4 SYSTEM INTERFACES

D.4.1 System Inputs

The RS open-loop receiving system requires predicted values for spacecraft downlink frequency for the tuning of the POCA/DANA over the course of a tracking pass. Predict files are generated by NOCC Support Subsystem and transmitted to the station electronically.

D.4.2 System Outputs

Table 6 lists the software interfaces which govern data produced by the RSS.

(i) Advanced Multimission Operations System (AMMOS) Users

The DSP, through the RSCP, routes SFDU-formatted data blocks (RSC-11-12, RSC-11-11B, etc.) to the Station Communications Processor (SCP) to be transmitted to the Ground Communications Facility (GCF) at JPL. The GCF will then route the data in real-time to AMMOS workstations, as well as archiving it in the on-line Project Database (PDB) for later retrieval. In addition, 8mm (Exabyte) ODR tapes (RSC-11-13) are created at the station; these are available at user request.

Monitor data from other systems (MON-5-15, TRK-2-15, etc.) can also be accessed through AMMOS workstations from both real-time broadcast and the PDB.

Closed-loop Doppler information, packaged as Archival Tracking Data Files (ATDFs) or Orbital Tracking Data Files (OTDFs), are available as files from the PDB, or as 9-track tapes.

(ii) Other Users

All monitor data is sent in real-time, in SFDU-formatted blocks, from the station to JPL. The GCF routes the data to the NOCC Gateway (NG). Monitor data of interest (RSC-11-12, MON-5-9, etc.) is sent through serial interface to RODAN, which is the RS-specific monitoring and analysis system.

Open-loop carrier samples (RSC-11-13) are recorded on 8mm ODR tapes at the DSCC sites and shipped to JPL. Data can also be played back at the end of the pass; in that case, an IDR tape will be available from the GCF Data Record and Generator Assembly (GDR).

Closed-loop Doppler information is packaged as ATDFs on 9-track tapes.

D.4.3 Radio Science Stability Analyzer

The Radio Science Stability Analyzer (RSA) is part of the FTS Subsystem. The purpose of this assembly is to provide real-time analysis of the performance of the RS System. The RSA can accept either VF input, directly from the RIV, or digital samples from the DSP-R. The RSA has the capability to process four channels at a time, to a maximum sampling rate of 100KHz. The performance characteristics generated by the RSA include plots of frequency residuals and Allan variance.

The RSA cannot perform analysis on data from actual tracking passes, as it does not have the capability of removing spacecraft Doppler signatures. Therefore, the RSA can be used only with a Test Transmitter or Test Translator as signal source.

D.5 SYSTEM PERFORMANCE

Performance metrics of the system are presented in this section.

D.5.1 Frequency Stability

Long-term frequency stability tests are conducted with the exciter/transmitter subsystems and the RS open-loop subsystem. An uplink signal generated by the exciter is translated at the antenna by the Test Translator to a downlink frequency. The downlink signal is then passed through the RF-IF downconverter present at the antenna, and into the RS receiver chain. In doing this test, contributions from the FTS and ANT cannot be measured. FTS noise is cancelled out, due to the fact that the test path is essentially zero light time, and the same FTS signals therefore reach each component of the uplink and downlink simultaneously. ANT noise is also excluded in this test, as the test signal is not actually transmitted and received with the antenna dish. Estimated FTS and ANT values, based on test data, can be factored in to measured stability. Though this test method only measures two-way stability of the system, two-way tests have so far met the more stringent one-way requirements, and are the only tests performed. Frequency stability is quoted as the Allan variation over a specified integration time. Table 6 has two-way measured system performance as well as estimated system performance (including FTS and ANT) for the 34 HEF and 70M subnets.

D.5.2 Phase Stability (Spectral Purity)

Phase stability testing characterizes stability over very short integration times; that is, spurious signals very close to the carrier. The phase noise region is defined to be frequencies within 100kHz of the carrier. Both amplitude and phase variations appear as phase noise. Phase noise is quoted in dB relative to the carrier, in a 1 Hz band a specified distance from the carrier: dBc-Hz at 10 Hz, for example. Table 7 contains sets of phase noise levels, at specified frequencies, for the 34 HEF and 70M subnets.

D.5.3 Amplitude Stability

Amplitude stability testing measures the amplitude variation produced by the open-loop receiving system on a constant amplitude test signal input. Amplitude stability is specified in terms of peak-to-peak amplitude variation over a specifed period of time. Table 8 contains amplitude stability of the 70M and 34HEF subnets.

	DSCC-10			DSCC-40			DSCC-60		
Antenna	34S	34H	70M	34S	34H	70M	34S	34H	70M
DSS number	12	15	14	42	45	43	61	65	63
Uplink	S	X	S	S	X	S	S	X	S
Downlink	S&X	SorX	S&X	S&X	SorX	S&X	S&X	SorX	S&X
Fiber Optic FTS	N	Y	Y	N	Y	Y	N	Y	Y
RS Channels	0	2	4	2	2	4	2	2	4
RIV	0	--- 1 ---		0	--- 2 ---		0	--- 1 ---	
MMR	0	0	0	1	0	0	1	0	0
DSP	---- 1 ----			---- 2 ----			---- 1 ----		

Table 1: DSN Equipment and Capabilities

Filter Select		X-band	S-band	Typical Usage
1	bandwidth (Hz)	82	82	
	offset (Hz)	-550	-150	
	sampling rate (per sec)	200	200	Gravity Wave
2	bandwidth	415	415	
	offset	-2750	-750	
	sampling rate	1K	1K	Solar Conjunctions
3	bandwidth	2K	2K	
	offset	-13750	-3750	Mars Observer Occultations
	sampling rate	5K	5K	
4	bandwidth	6250	1700	
	offset	+3750	+1023	Pioneer Venus Occultations
	sampling rate	15K	5K	
5	bandwidth	45K	45K	
	offset	-275K	-75K	
	sampling rate	50K	50K	Sideband Analysis
6	bandwidth	20K	20K	
	offset	-137500	-37500	
	sampling rate	50K	50K	Bistatic Radar

Table 2a: RIV Filter Selections (As Installed)

Filter Designation	Band	Bandwidth (Hz)	Offset (Hz)
1	X	82	-550
2	S	82	-150
3	X	415	-2750
4	S	415	-750
5	X	2000	-13750
6	S	2000	-3750
9	X	7000	-55770
10	S	7000	-15210
11	X	3500	-27500
12	S	3500	-7500
15	X	20K	-137500
16	S	20K	-37500
17	X	45K	-275000
18	S	45K	-75000
19	X	6250	+3750
20	S	1700	+1023
21	S	8540	-15000
22	S	4500	-7500

Table 2b: Available RIV Filters (Installed and Spare)

Filter Select		X-BAND	S-BAND
1	bandwidth (Hz)	100	100
	offset (Hz)	-550	-150
2	bandwidth	500	500
	offset	-2750	-750
3	bandwidth	1K	1K
	offset	-5500	-1500
4	bandwidth	3K	818
	offset	+1500	+409
5	bandwidth	7500	2045
	offset	+3750	+1023
6	bandwidth	15K	4091
	offset	+7500	+2045
7	bandwidth	30K	8182
	offset	+15K	+4091

Table 2c: MMR Filter Selections

8-bit Samples (Samples per second)

200, 250, 400, 500, 1k, 1250, 2k, 2.5k, 3125, 4k,5k,6250,10k,12.5k,15625, 20k,25k,31250, 50k

12-bit Samples (Samples per second)

200, 1k, 1250, 2k, 5k, 10k

16-bit Samples (Samples per second)

1250

Table 3: Available Sampling Rates for Differently Sized Samples

RIV Receivers (70 M and 34 HEF)

$$F_{S\text{-band Sky}} = 3 \times (F_{Syn} + (790\times10^6)/11) + 1950\times10^6 - (Offset_S + (F_{Recorded} - 1/4\ F_{SampRate}))$$

$$F_{X\text{-band Sky}} = 11 \times (F_{Syn} - 10\times10^6) + 8050\times10^6 - (Offset_X + (F_{Recorded} - 1/4\ F_{SampRate}))$$

MMR Receivers (34 M STD)
DSS 42 (Australia)

$$F_{S\text{-band Sky}} = 3 \times (3/2\ F_{Syn} + 600\times10^6) + 300\times10^6 - (Offset_S + (F_{Recorded} - 1/4\ F_{SampRate}))$$

$$F_{X\text{-band Sky}} = 11 \times ((3/2 \times F_{Syn} + 600\times10^6) + (100\times10^6 \times 8/11)) + 300\times10^6 - (Offset_X + (F_{Recorded} - 1/4\ F_{SampRate}))$$

DSS 61 (Spain)

$$F_{S\text{-band Sky}} = 48 \times F_{Syn} + 300\times10^6 - (Offset_S + (F_{Recorded} - 1/4\ F_{SampRate}))$$

$$F_{X\text{-band Sky}} = 11 \times ((16 \times F_{Syn}) + (100\times10^6 \times 8/11)) + 300\times10^6 - (Offset_X + (F_{Recorded} - 1/4\ F_{SampRate}))$$

LEGEND:

$F_{S\text{-band Sky}}$	S-Band frequency received at antenna (RF signal)
$F_{X\text{-band Sky}}$	X-Band frequency received at antenna (RF signal)
F_{Syn}	Synthesizer frequency reported for a given second
$Offset_S$	S-band filter offset
$Offset_X$	X-band filter offset
$F_{SampRate}$	Digital sampling rate
$F_{Recorded}$	Carrier frequency as recorded in the digitized spectrum

Table 4: Received RF Frequency Reconstruction Formulas

DATATYPE	INTERFACE
Open-Loop Samples	
- Real-time	820-13, RSC-11-11B
- IDR (ODR playback)	820-13, RSC-11-4A
- ODR	820-13, RSC-11-13
DSP/ RS Receiver Monitor/ Spectral Monitor (SSI)	820-13, RSC-11-12
Meteorological Data	820-13, TRK-2-24
Delay in Earth Ionosphere	820-13, TRK-2-23
Tracking System Monitor (Antenna Pointing Angles/Subreflector Position/Noise Temperature, etc.)	820-13, MON-5-15 (AMMOS) 820-13, MON-5-9 (other)
Closed-Loop (Doppler and Ranging) Configuration Monitor and Data	820-13, TRK-2-15

Table 5: Software Interfaces for Radio Science Data Types

34 Meter HEF Subnet

INTEGRATION TIME	FTS	ANT	DSCC-10 STATIC Test		DSCC-40 DYNAMIC Test	
			meas	estim	meas	estim
1 sec	2.0e-13	0.5e-13	5.5e-14	2.9e-13	1.2e-13	3.1e-13
10 sec	4.0e-14	1.0e-14	9.7e-15	5.9e-14	2.7e-14	6.4e-14
100 sec	8.0e-15	N/A	1.6e-15	N/A	1.9e-15	N/A
1000 sec	1.5e-15	1.0e-15	1.3e-15	2.9e-15	5.8e-16	2.6e-15
3600 sec	N/A	N/A	2.5e-15	N/A	9.3e-16	N/A
5000 sec	N/A	N/A	6.4e-16	N/A	1.3e-15	N/A

70 Meter Subnet

INTEGRATION TIME	FTS	ANT	DSCC-40 STATIC Test		DSCC-40 DYNAMIC Test	
			meas	estim	meas	estim
1 sec	2.0e-13	0.5e-13	4.3e-13	5.1e-13	3.7e-13	4.7e-13
10 sec	4.0e-14	1.0e-14	7.0e-14	9.1e-14	1.0e-13	1.2e-13
100 sec	8.0e-15	N/A	N/A	N/A	1.3e-14	N/A
1000 sec	1.5e-15	1.0e-15	1.8e-15	3.1e-15	2.2e-15	3.4e-15
3600 sec	N/A	N/A	N/A	N/A	2.1e-15	N/A
5000 sec	N/A	N/A	N/A	N/A	2.8e-15	N/A

Notes

N/A: not available
"Dynamic" test involves ramped uplink;
"static" test uses constant frequency
FTS and ANT contributions are 1-way
Measured values are those specifically registered in test
Estimated values are the root-sum-squared combination of 2 FTS, 2 ANT, and measured values, producing estimated total system performance in 2-way mode
See text (Section 5.1) for further description of test procedures

Table 6: RS System Frequency Stability With 34HEF and 70M Subnets

34 Meter HEF Subnet	DSCC-60
Offset from Carrier	Noise, dBc
1 Hz	-54.07
10 Hz	-60.17
100 Hz	-74.0

70 Meter Subnet	DSCC-40
Offset from Carrier	Noise, dBc
1 Hz	-54.07
10 Hz	-60.17
100 Hz	-74.0

Table 7: RS System Phase Noise With 34HEF and 70M Subnets

34 Meter HEF Subnet

Averaging Time	X-band variation	S-band variation
20 Min	TBD	TBD
4 Hr	TBD	TBD

70 Meter Subnet

Averaging Time	X-band variation	S-band variation
20 Min	TBD	0.06 dB
4 Hr	TBD	0.30 dB

Table 8: RS System Amplitude Variation With 34HEF and 70M Subnets

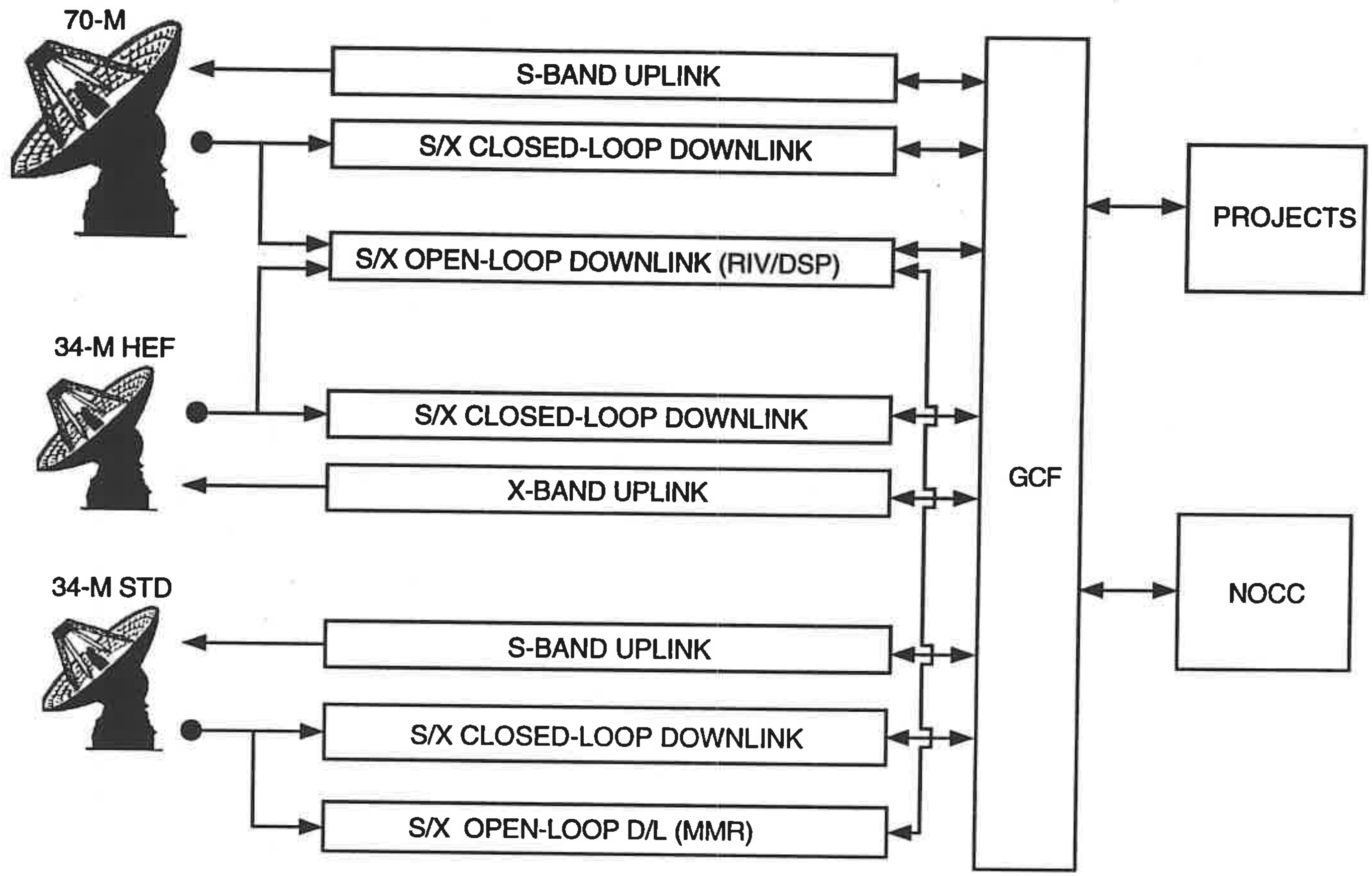


Figure 1 : Radio Science System

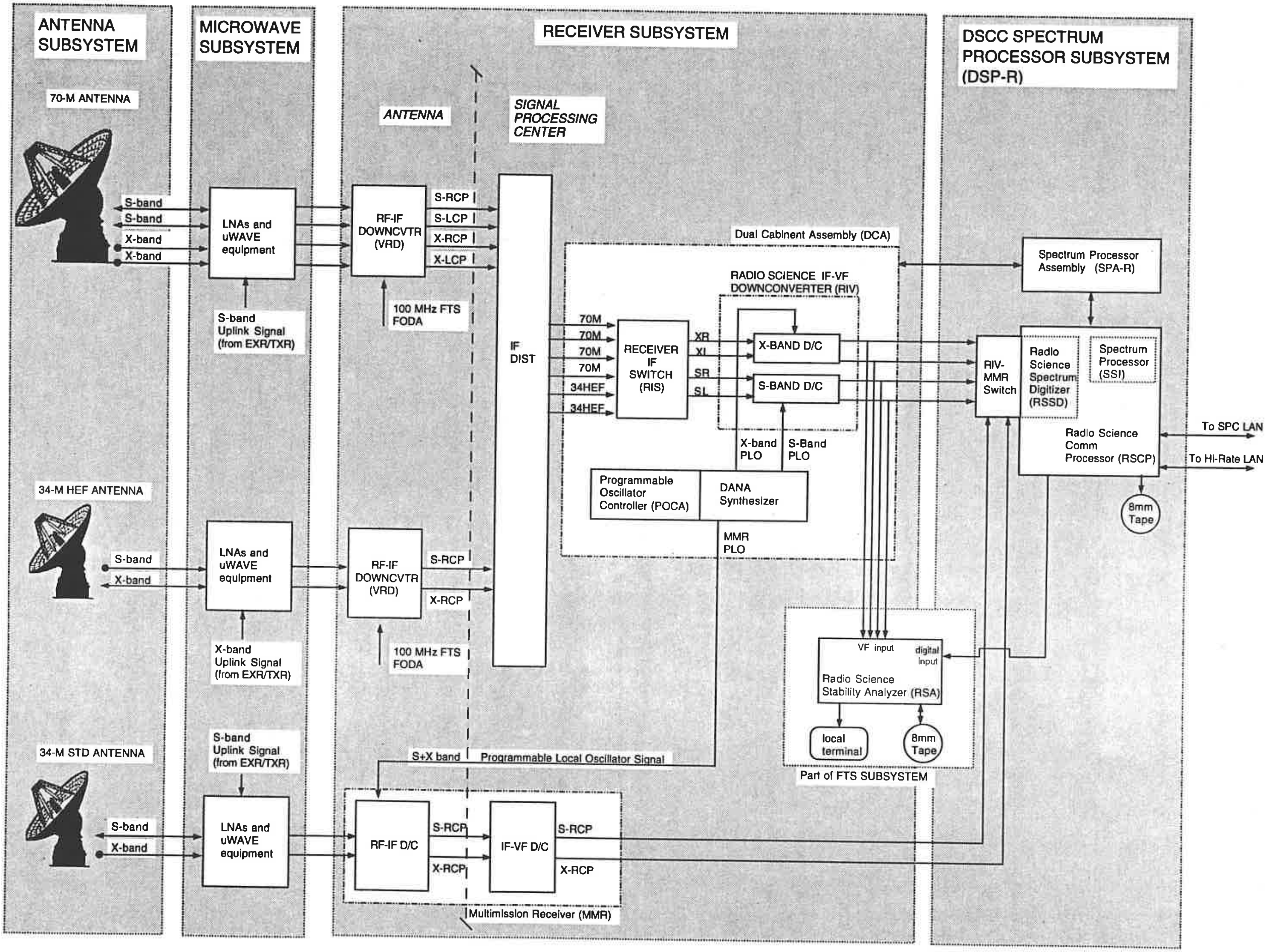


FIGURE 2a : RADIO SCIENCE OPEN-LOOP RECEIVING SYSTEM

asd 1/15/94

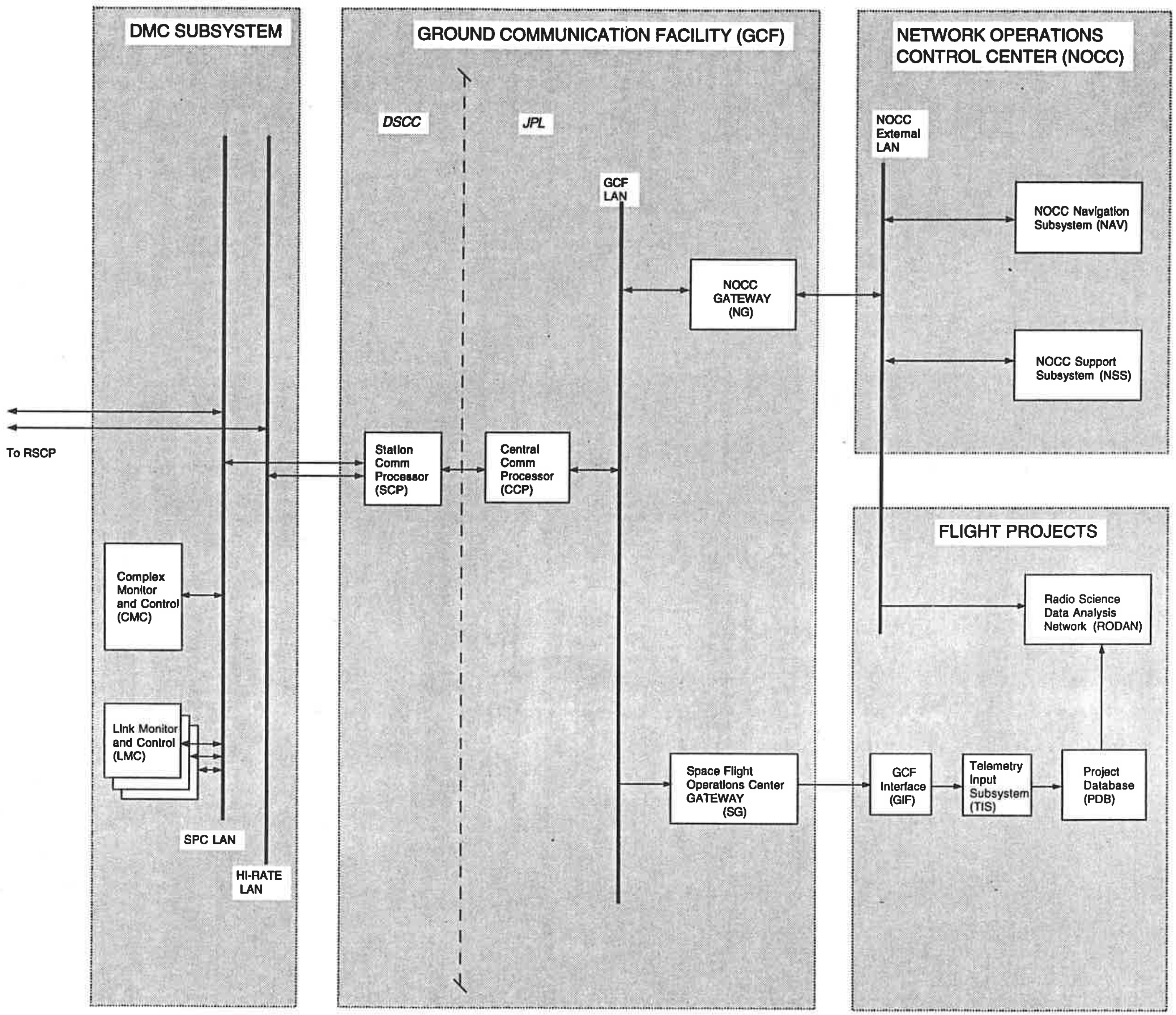


FIGURE 2b : RADIO SCIENCE OPEN-LOOP RECEIVING SYSTEM

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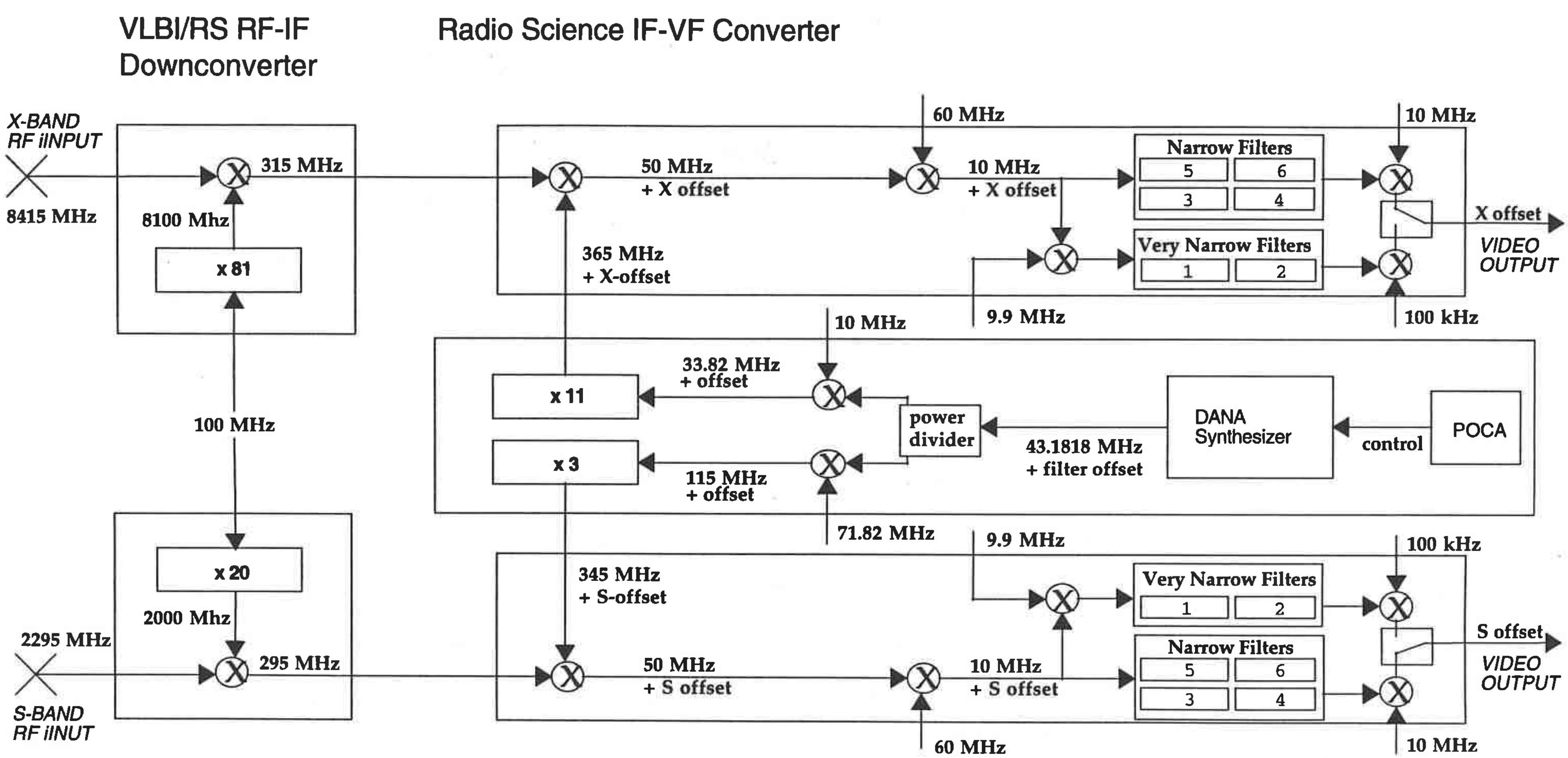

Figure 3: Downlink Frequency Conversion in the Radio Science Open Loop Receiver (RIV)

asd 1/15/94

Acronyms

AMMOS	Advanced Multimission Operations System (JPL real-time data system)
ANT	Antenna Subsystem
ATDF	Archival Tracking Data Files
DC	Direct Current (frequency of 0 Hertz)
DSCC	Deep Space Communication Complex
DSN	Deep Space Network
DSP	Deep Space Communications Complex Spectrum Processor
DSS	Deep Space Station
FFT	Fast Fourier Transform
FTS	Frequency and Timing Subsystem
GCF	Ground Communications Facility
IDR	Intermediate Data Record
IF	Intermediate Frequency (around 300 MHz)
MMR	Multimission Receiver
ODR	Original Data Record
OTDF	Orbital Tracking Data File
POCA	Programmable Oscillator Controller Assembly
PDB	Project Data Base
RIV	Radio Science IF-VF Converter
RF	Radio Frequency (approximately 2-10 gigahertz)
RODAN	Radio Science Data Analysis Network
RSA	Radio Science Stability Analyzer
RSCP	Radio Science Communications Processor
RSS	Radio Science System
SLCP	S-band Left Circularly Polarized
SPC	Station Processing Center
SSI	Spectrum Signal Indicator
SRCP	S-band Right Circularly Polarized
TBD	To Be Determined
XLCP	X-band Left Circularly Polarized
XRCP	X-band Right Circularly Polarized
VF	Video Frequency (approximately 0-150 kilohertz)

Appendix C
Abbreviations and Acronyms

A/D	Analog-to-Digital Converter
ACE	Galileo/Ulysses/MO Mission Controller
ADC	Analog-to-Digital Converter
AGC	Automatic Gain Control signal level
AMMOS	Advanced Multi-Mission Operations System
AMS	Antenna Microwave System
AOS	Acquisition Of Signal at a DSS
APA	Antenna Pointing Assembly
APC	Advanced Personal Computer (NEC Computer)
ARA	Area Routing Assembly
ARD	Antenna Reference Distribution
ASAP	Standard Radio Science Time Requirement
ATDF	Archival Tracking Data File (closed-loop data tape)
ATR	All The Rest
AUX OSC	Auxiliary oscillator in a spacecraft
BLK III	Closed-loop receiver (design phase III)
BLK IV	Closed-loop receiver (design phase IV)
BLK V	Receiver (design phase V)
BOA	Beginning of Activity
BOT	Beginning of Track
BPI	Bits Per Inch
BPF	Band Pass Filter
BWG	Beam Waveguide
C/A	Closest Approach
CBM	Cured By Magic (see DR)
CCP	Central Communications Processor
CCR	Closed Cycle Refrigerator (for the maser)
CCS	Computer Command Subsystem
CDB	Central Database
CDU	Command Detector Unit
CEP	Critical Events Period
CMC	Complex Monitor and Control
COH	Coherent downlink
CONSCAN	Conical Scanning of a Radio source used to accurately point the antenna
CPL	Command Procedure Language (for PRIME computer)
CRG	Coherent Reference Generator
CRS	CTA-21 Radio Science Subsystem
CRS	Celestial Reference Set (Spacecraft Trajectory Vectors)
CRSPOSTA	CRS ASCII Format
CUL	Clean Up Loop
D/A	Digital-to-Analog Converter
DAC	Digital-to-Analog Converter

DAS	Data Acquisition System
dBc	Decibel relative to carrier
dBc/Hz	dBc per Hertz, magnitude relative to carrier spectral density
DC	Direct Current (frequency equals zero)
DCO	Digitally Controlled Oscillator
DDP	Digital Display Processor
DL	Predicted one-way downlink frequency
DMC	DSCC Monitor and Control
DMT	Data Management Team
DOY	Day Of Year (UTC)
DR	Discrepency Report (see CBM)
DRA	Digital Recording Assembly
DRG	Data Records Generator
DRS	Radio Science Software Data Records Subsystem
DSCC	Deep Space Communications Complex
DSN	Deep Space Network
DSP	DSCC Spectrum Processor
DSS	Deep Space Station
DTK	DSCC Tracking Subsystem
DTR	Digital Tape Recorder (spacecraft)
DTV	Digitial TV monitoring display device
EOA	End of Activity
EOT	End of Track
ER	Experiment Representative
ERT	Earth Received Time
ETX	Exciter-Transmitter Subsystem
FDS	Flight Data System
FFT	Fast Fourier Transform
FPS	Floating Point Systems (maker of the Array Processor used by the RSST)
FRO	Frequency Offset
FTP	File Transfer Protocol
FTS	Frequency and Timing Subsystem
GC	Ulysses Ground Controller (Ulysses ACE)
GCF	Ground Communications Facility
GCR	Group Coded Recording
GDS	Ground Data System
GLL	Galileo Project
GNAV	Galileo Navigation Team
GPS	Global Positioning System
GSD	Great Science Data!
GWE	Gravitational Wave Experiment (Ulysses)

HB	Radio Science HandBook
HGA	High-Gain Antenna (spacecraft)
IA	Interface Agreement
ICD	Interface Control Document
IDR	Intermediate Data Records tape (playback tape)
IF	Intermediate Frequency
IMOP	Integrated Mission Operations Profile (Galileo)
IMOP	What I do after I spill something.
IOM	InterOffice Memorandum
IPC	Information Processing Center (JPL computer facility)
IPS	Inches Per Second
ISOE	Integrated Sequence of Events
IVC	IF Selection Switch
JPL	Jet Propulsion Laboratory
L(f)	Single sideband phase noise spectral density as a function of offset frequency (f) from carrier
LAN	Local Area Network
LCP	Left-handed Circularly Polarized
LGA	Low Gain Antenna (Spacecraft)
LMC	Link Monitor and Control
LNA	Low Noise Amplifier
LO	Local Oscillator
LOS	Loss Of Signal at a DSS
LPF	Low Pass Filter
MCA	Master Clock Assembly
MCCC	Mission Control Computer Center
MCT	Mission Control Team
MDA	Metric Data Assembly
MGC	Manual Gain Control
MGDS	Mission Ground Data System
MI	Modulation Index
MISD	Mission Director's Voice Net
MMR	Multi-Mission Receiver (at 34-m STD stations)
MMRS	Multi-Mission Radio Science (MGS SUN SPARCStation)
MONIDR	Monitor Intermediate Data Record
MOU	Memorandum of Understanding
MSA	Mission Support Area
MTS	MCCC Telemetry Subsystem
NAR	Noise Adding Radiometer
NATTRK	Network Analysis Team Tracking Analyst
NAV	Project Navigation Team

NB	Narrow-Band
NBOC	Narrow-Band Occultation Converter
NCOH	Non-Coherent downlink
NDC	Network Data Center
NDPA	Network Data Processing Area
NDPT	Network Data Processing Team
NDS	Network Display Subsystem
NERT	Near Real-time
NG	NOCC Gateway
NIST	National Institute of Standards and Technology
NIU	Network Interface Unit
NMP	Network Monitor Processor display system
NOA	Network Operations Analyst
NOCC	Network Operations Control Center
NOCG	Network Operations Control Group
NOCT	Network Operations Control Team
NOP	Network Operations Plan
NOPE	Network Operations Project Engineer
NOSG	Network Operations Scheduling Group
NRV	NOCC Radio Science/VLBI Display Subsystem
NRZ	Non-Return to Zero
NSP	NASA Support Plan
NSS	NOCC Support Subsystem
NTK	Network Tracking Display System
OCI	Operator Control Input
OD	Orbit Determination by the Project's Navigation Team
ODF	Orbit Data File
ODR	Original Data Record
OEA	Operations Engineering Analysis
OIA	Operational Interface Agreement
O/L	Open-Loop
OLR	Open-Loop Receiver
OOPS	Technical term used by RSST for errors in HB
OPCH	DSN Operations Chief
ORT	Operational Readiness Test
OVT	Operational Verification Test
OWLT	One-Way Light Time
PAS	Radio Science Software Planning and Analysis Subsystem
PBNBIDR	Playback Narrow Band Intermediate Data Records
PC	Personal Computer
PDB	Project Data Base
PE	Phase Encoded
PIDR	Parkes Intermediate Data Record
PLL	Phase-Lock Loop

PLO	Programmed Local Oscillator
POCA	Programmable Oscillator Control Assembly
PPM	Precision Power Monitor
PRA	Planetary Ranging Assembly
RASM	Remote Access Sensing Mailbox
RAYPATH	DSN program used to generate light-time file modeling atmospheric effects and used as an input for the generation of predictions
RCP	Right-handed Circularly Polarized
REC	Receiver-Exciter Controller
RF	Radio Frequency
RFS	Radio Frequency Subsystem (spacecraft)
RIC	RIV Controller
RIS	Radio Science IF Switch
RIV	Radio Science IF-VF Converter Assembly
RMDCT	Radio Metric Data Conditioning Team
RMS	Real-time Monitoring System (formally TSS)
RODAN	Radio Occultation Data Analysis Computer Facility
ROLS	Radio Occultation Limbtrack Systems
ROVER	Wide-band backup recording system (obsolete)
RSWG	Radio Science Working Group
RSS	Radio Science System
RSSD	DSP-R Signal Digitizer Assembly
RSST	Radio Science Support Team (Not Galileo Remote Sensing Science Teams; SSI, NIMS PPR and UVS)
RSSS	Radio Science Support System (alias RODAN)
RST	Radio Science Team (Investigators and RSST)
RSVP	Radio Science Validation and Processing Software
RTDS	Real-Time Display System
RTLT	Round-Trip Light-Time
RTM	Real-Time Monitor (supplies data to NOCC graphics/display systems)
SCE	Solar Corona Experiment (Ulysses)
SCET	SpaceCraft Event Time
SCOE	System Cognizant Operations Engineer
SCP	Station Communications Processor
SCT	SpaceCraft Team
SDT	Science Data Team
SEF	Sequence of Events File
SEG1	Sequence of Events Generation program (generates SFOS, ISOE and DSN keyword file)
SEL	Station Event List
SEP	Sun-Earth Probe Angle
SEQGEN	SEQuence of events GENeration program (generates SEFs)

SFDU	Standard Format Data Unit
SFOC	Space Flight Operations Center
SFOS	Space Flight Operations Schedule
SG	SFOC Gateway
SIRD	Support Instrumentation Requirements Documents
SIS	Software Interface Specification
SLE	Signal Level Estimator
SNR	Signal-to-Noise Ratio
SNT	System Noise Temperature
SOE	Sequence of Events
SOM	Software Operations Manual
SOP	Standard Operations Procedures
SPA	Spectrum Processor Assembly
SPC	Signal Processing Center
SPD	S-band Polarization Diversity (microwave subsystem)
SPE	Static Phase Error
SPR	System Performance Record
SPT	System Performance Test
SRA	Sequential Ranging Assembly
SRD	Science Requirements Document
SSA	Solid State Amplifier (spacecraft S-band downlink)
SSB	Single Sideband
SSI	Spectral Signal Indicator (not Solid-State Imaging!)
SSS	SSI Input Channel Selection (DSP OCI)
TBD	To Be Determined, since we don't know the answer
TBS	To Be Subjected to further scrutiny
TCG	Time Code Generator
TCM	Trajectory Correction Maneuver
TCT	Time Code Translator
TID	Time Insertion and Distribution
TLC	Tracking Loop Capacitor
TMO	Time Offset (OCI)
TMU	Telemetry Modulation Unit
TSF	Track Synthesizer Frequency
TSS	Test Support System (now called RMS)
TWM	Traveling Wave Maser
TWNC	Two-Way Non-Coherent switch (spacecraft)
TWNC	Too Wishy-washy, Nebulous and Confusing
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier (spacecraft)
TWX	Teletype message
TXR	DSS transmitter

ULS	Ulysses Project
UNAV	Ulysses Navigation Team
USO	Ultra-Stable Oscillator
UTC	Universal Time, Coordinated
VAP	Video Assembly Processor
VCO	Voltage Controlled Oscillator
VEEGA	Venus-Earth-Earth-Gravity-Assist
VF	Video Frequency
VTR	Video Tape Recorder
XA	Doppler-compensated ground-transmitter DCO frequency for spacecraft receiver's best-lock frequency
XRO	X-band receiver only (microwave subsystem) determination experiment

Appendix D
The Radio Science Directory

The Radio Science Directory

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