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Volume III

Tracking and Data System Support for the Viking 1975 Mission to Mars

Planetary Operations

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16. Abstract

This document describes and evaluates the support provided by the Deep Space Network to the 1975 Viking Mission from the first landing on Mars July 1976 to the end of the Prime Mission on November 15, 1976.

Tracking and data acquisition support required the continuous operation of a worldwide network of tracking stations with 64-meter and 26-meter diameter antennas, together with a global communications system for the transfer of commands, telemetry, and radio metric data between the stations and the Network Operations Control Center in Pasadena, California.

Performance of the deep-space communications links between Earth and Mars, and innovative new management techniques for operations and data handling are included.

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PREFACE

This report describes Tracking and Data System support of the Viking 1975 Mission to Mars in four volumes corresponding to the four major phases of the Project.

The first volume presents organization, planning, implementation, and test activities from inception of the Project in 1969 to the 1975 launch operations. Cruise-phase activities for both spacecraft from launch through Mars orbit insertion and the landing of Viking 1 are described in the second volume. This volume, the third, discusses the support provided for the Mars orbit insertion and landing of Viking 2 and the landed operations of both spacecraft until the end of the Prime Mission, November 15, 1976. The Extended Mission Support activities are described in the fourth volume.

The Tracking and Data System activities described in this report were managed and/or carried out by the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, under Contract No. NAS7-100, sponsored by the National Aeronautics and Space Administration.

N.A. Renzetti
Tracking and Data System Manager

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In the course of preparing this report, the author drew freely upon published data from many sources both within and without the various organizations that comprise the Deep Space Network.

In particular, material for Section II, Mission Events, was drawn from the Mission Status Bulletins published by the Viking Public Affairs Support Office. The performance of the Network Systems was edited from the monthly Network Analysis Reports issued by the Operations Analysis Group, and the Network's bimonthly Progress Reports furnished data for the tracking station performance.

The data describing link performance were drawn from the excellent summaries prepared by F. H. Taylor, and published in the Orbiter Performance Analysis Group's monthly reports. The Lander Performance Analysis Group's daily reports formed the basis for the comments on the direct link from the stations to the Landers. To the authors of these documents, an expression of deep appreciation is tendered.

In addition, a great deal of unpublished material was provided in the form of discussions and conversations with individuals in many areas throughout the Deep Space Network and the Viking Flight Team. The discussions on Radio Science with J. P. Brenkle, on Intermediate Data Record Production with J. Goodwin and J. Swindlehurst, on Operations Support with D. W. Johnston, on Tracking Analysis with A. Berman, and on Operations Reliability with K. W. Graham were particularly helpful, and are gratefully acknowledged.

Finally, this report and the two volumes that preceded it were assembled into an intelligible ensemble of facts, figures, and observations through the skilled efforts of Billie J. Weir in typing the manuscript through many revisions, and Bill Barton in editing the material into a form suitable for submitting for publication.

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ABSTRACT

This document describes and evaluates the support provided by the Deep Space Network to the 1975 Viking Mission from the first landing on Mars in July 1976 to the end of the Prime Mission on November 15, 1976.

Tracking and data acquisition support required the continuous operation of a worldwide network of tracking stations with 64-meter and 26-meter diameter antennas, together with a global communications system for the transfer of commands, telemetry, and radio metric data between the stations and the Network Operations Control Center in Pasadena, California.

Performance of the deep-space communications links between Earth and Mars, and innovative new management techniques for operations and data handling are included.

I. INTRODUCTION

The touchdown of Viking Lander I on the surface of Mars on July 20, 1976, signalled the beginning of the Deep Space Network's most complex mission operation. A few weeks later, Lander 2 touched down on the opposite side of the planet, and the Network was called on to support four independent spacecraft (two orbiters and two landers) encompassed within a single antenna beamwidth.

From Lander 2 touchdown (September 3, 1976) until the conclusion of the Prime Mission on November 15, 1976, the Network had to establish and maintain reliable telecommunication links to all four spacecraft. Communication simultaneously with three spacecraft was required for the purposes of navigation, telemetry, and command. The Network was also required to deliver to the Mission Control Directorate at Pasadena totally gap-free magnetic tape records of all data received at nine tracking stations around the Earth within 24 hours of the real-time arrival of these data at the stations. Intense efforts and a high degree of expertise by Network personnel in carrying out these assignments made a major contribution to the over-all success of the Viking Mission.

All commitments to the Viking Project, which were on a scale never previously required of the Network by any deep space mission, were met. In achieving this, the Deep Space Network was ably assisted, throughout the mission, by the NASA Communications Network and its worldwide common carriers.

On several occasions, the Network was able to effect a speedy recovery from potentially disastrous situations and was called upon to assist the Mission in recovery when the spacecraft themselves were in jeopardy.

The details of this performance and the actions necessary to achieve and maintain it through the end of the Prime Mission are covered in this volume of the Viking Tracking and Data System final report.

II. MISSION EVENTS

A. LANDING OPERATIONS

Viking 1 Lander touchdown on the surface of Mars was announced by the Viking Flight Team in Pasadena, California, at 5:12 a.m. (Pacific Daylight Time), Tuesday, July 20, 1976. The announcement climaxed a long night of anxiety that preceeded the culmination of a complex planning and support effort. (Touchdown was officially registered at 202/11:43:06 Greenwich Mean Time, spacecraft time.)

The landing on Mars had been within 17 seconds of the predicted time and with the terminal velocity of 249.97 centimeters (8.2 feet) per second, well within the predicted 243.84 centimeters (8 feet) per second plus or minus 91.44 centimeters (3 feet) per second.

In his congratulatory telephone call, President Gerald R. Ford reminded the flight team that it was on July 20 (1969) that man had first set foot on the Moon. Dr. James C. Fletcher, Administrator, National Aeronautics and Space Administration, told press representatives, "We've gained one more important objective in exploration of our solar system, with the hope and vision of more to come." James S. Martin, Jr., Viking Project Manager, expressed his appreciation to the entire flight team and to the "10,000 people across the country who deserve a part of the credit given to me." A. Thomas Young, Mission Director, reported there were no problems during descent, and the entry science data were successfully acquired.

The first pictures received from Viking Lander 1 are shown in Figs. 1 and 2. In these pictures, the Lander appeared to be in nearly nominal attitude, positioned in a stable level-landed configuration. The most distant horizon visible in Fig. 2 was estimated to be 3 or 4 kilometers away with a low ridge near the right margin apparently covered with rock debris and thought to be the rampart of an old crater. By July 27, both Orbiter 1 and Lander 1 continued to function well. The location of Lander 1 was placed at coordinates 22.46 degrees north and 48.01 degrees west, which was 30 kilometers west and 4 kilometers north of the target itself.

Several problems had appeared during the first few days following the July 20th landing. The surface sampler had not extended to its proper position because of a retaining pin, which did not release properly, but this was cleared a few days later. The Lander relay transmitter operated correctly in the 30-watt mode the first day, and then unexpectedly transmitted in the 1-watt mode for the next two relay links. A few days later the transmitter had corrected itself, and was operating in the 30-watt mode again. The seismometer remained uncaged, and despite intensive efforts to release the seismometer, it could not be activated. The Lander's No. 1 receiver, which was to be used as a low-gain backup for the primary high-gain receiver No. 2, had failed to lockup properly with the Deep Space Network transmission since the first day, when it did so with difficulty. Its sensitivity appeared to be degraded by approximately 10 dB, and efforts were in hand to analyze the problem with the hope of using the Network's 100-kilowatt transmitters to lock up the receiver. One possibility being explored was that

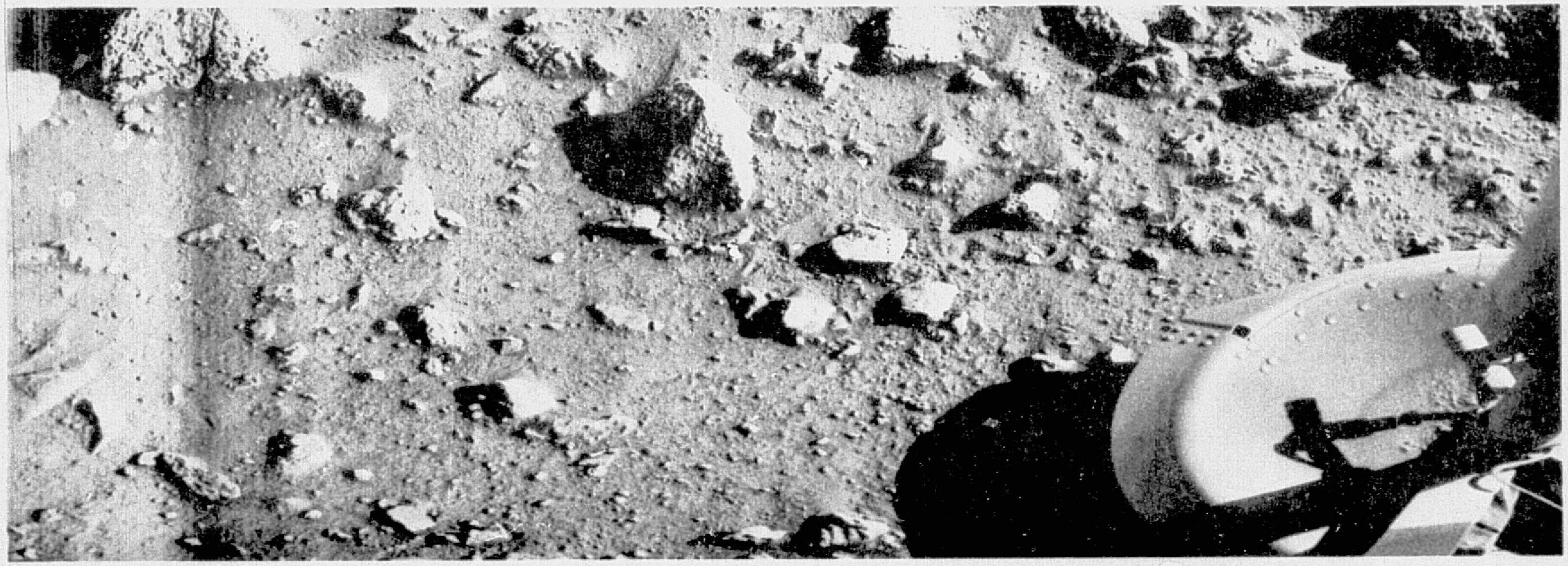


Fig. 1. First image sequence of Mars from Lander 1

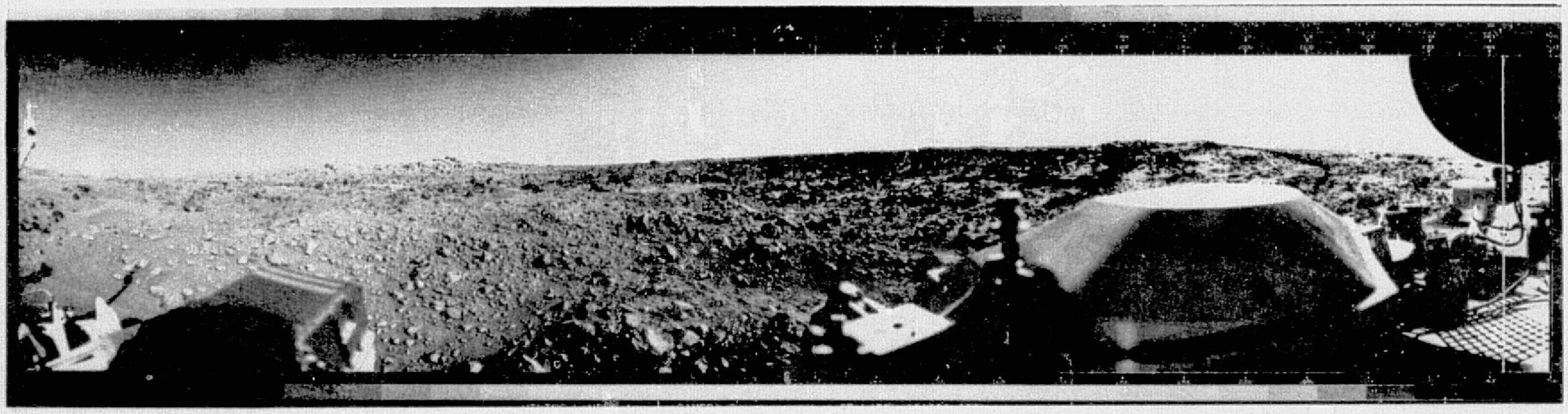


Fig. 2. First panoramic view of Mars from Lander 1

the receiver had experienced a frequency change because of some unknown defect in a component and efforts were in hand to determine the correct frequency for that receiver.

At 6:19 p.m. (Pacific Daylight Time), July 27, with Viking 2 spacecraft near its Mars Orbit insertion point, an approach midcourse maneuver was performed to refine the spacecraft approach trajectory. At that time, the Viking 2 landing was scheduled for September 4, at a landing site in the B latitude region, which lies between 40 degrees and 50 degrees north.

The first Mars soil samples from Lander 1 were acquired on July 28 to begin the internal analysis. The first sample fed the biology distributor, the next two samples went to the organic molecular analysis processor, and the last to the organic chemistry instrument.

By August 7, Viking 2 had successfully completed a maneuver and engine burn to insert the spacecraft into an almost perfect orbit, being only 0.2-hour greater tnan the desired orbit period of 27.4 hours, and a periapsis altitude only 19 kilometers greater than 1,500 kilometers desired. The Viking 2 orbit parameters were such that the periapsis would "walk" around the planet at the rate of 40 degrees per day at the latitude band of between 40 and 50 degrees north selected for the Lander. The full 360-degree walk was to take nine days and would permit a good examination of the specific landing site in the region known as Utopia.

By August 13, Viking Orbiter 1 had been in orbit around Mars for 55 days, and Lander 1 had been on the surface for 24 days.

By then, the engineering team had been able to resolve a problem with the surface sampler that had occurred on August 3 during a second soil acquisition. The ultrahigh frequency relay transmitter had maintained its 30-watt transmission mode since early in the landed mission when for a few days it transmitted in the 1-watt mode. Receiver No. 1, which served only as a backup for the main receiver, was still considered a problem although the receiver had been locked up successfully on one or two occasions, and engineers were confident the receiver would be useful should it be needed.

Striking pictures of the Mars landscape had been obtained by Viking Lander 1, and these are shown in Figs. 3, 4, and 5. Viking Orbiter 1 continued to carry out the site photo-mapping of the region associated with the preselected landing site option for Lander 2.

Analysis by the Lander 1 biology instrument of the soil sampler was within the realm of a biological response. However, other possible causes of the response were being considered and tested as the experiment continued, so the data could not be accepted as biological until other explanations were excluded, or until the results of other experiments were fully evaluated.

By August 20, Orbiter 1 had supplied the picture data needed to complete a comprehensive reconnaissance of the Sydonia region in which the preselected B-1 site for Viking 2 was located. Meanwhile, Viking 2 provided similar coverage of the Alba Paterra region in which the Viking 2 backup site B-2 was targetted,

Fig. 3. Surface material eroded by Lander 1 engine exhaust

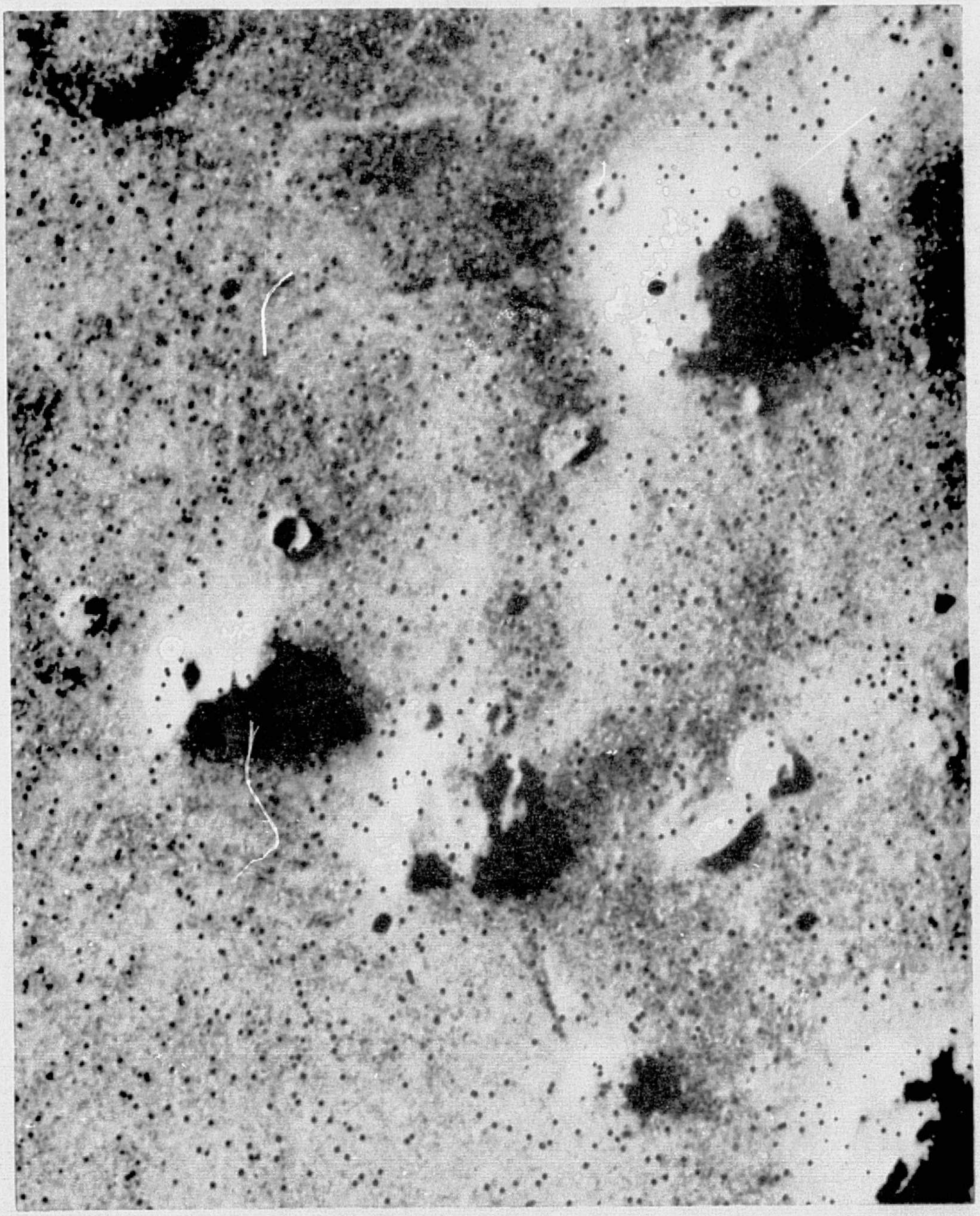


Fig. 4. Eroded mesa as seen from Orbiter 1

Fig. 5. Lander 1, Camera 2, views Mars terrain

and a broad new area known as Utopia (B-3), which was believed, at that time, to be the most promising. A tentative landing time line had been developed for the landing of Viking 2 as follows:

Saturday 8/21: select preliminary site coordinates

Wednesday 8/25: Mars orbit trim No. 3, 11 a.m. (Pacific Daylight Time)

Friday 8/27: final orbit trim

Sunday 8/29: vertical pictures of site

Monday 8/30: finalized site coordinates

Tuesday 8/31: weather observation of site

Wednesday 9/01: weather observation of site

Thursday 9/02: Lander preseparation check-out approximately at 7 a.m. (Pacific Daylight Time)

Friday 9/03: Landing 2 p.m. to 6 p.m. (Pacific Daylight Time)

Utopia is a large broad plain located to the north and on the opposite side of the planet from Viking 1 landing site in Chryse. Lander 2 had been targetted well to the north of Viking 1, at 47.9 degrees north and 225.8 degrees west.

A Mars orbit trim maneuver was successfully completed at 10:48 a.m. (Pacific Daylight Time), Wednesday, August 25, to halt Viking 2's westward walk around the planet, and to initiate a slower drift of the spacecraft's periapsis back to the East towards the precise coordinates of the landing site.

At 1:46 p.m., August 27, the final trim needed to synchronize the periapsis point of the landing site was conducted and the final preparation for the September 3 landing begin. Meanwhile, the Viking 1 Orbiter began a process of broadening its photographic coverage of other areas of interest such as the canyon region, the volcanoes, the highlands, and the channel region to the northwest of Chryse, where Lander 1 was in operation on the surface.

Lander communication links continued to perform well. It appeared that the lockup capability of the backup receiver No. 1 was temperature-dependent and that it could be locked up for its link with Earth when the environmental conditions were satisfactory.

Reflecting at least as much precision as the Viking 1 landing, the Viking 2 landing took place safely in the Utopia Planitia on September 3. The landing occurred at 3:58:20 p.m. (Pacific Daylight Time). During the landing, a problem with the Orbiter's attitude control system caused the high-rate data relay stream to Earth to be interrupted before the deorbit burn had been completed. The rest of the landing sequence was conducted in the "blind," except for low-rate engineering to provide data during the automatic descent sequence. Shortly after the Lander capsule separated from the Orbiter, a power failure occurred that caused a loss of the Orbiter prime Inertial Reference Unit and Attitude Control System. Almost immediately, the backup Inertial Reference Unit and Attitude Control System regained control of the Orbiter and stabilized its attitude, but, during the few moments it was without attitude control, the Orbiter's attitude changed enough for the high-gain antenna to point away from Earth. Immediately, commands were prepared and transmitted to the Orbiter to reactivate the Orbiter computers and switch the spacecraft system from the high-gain mode to the low-gain mode; this established a nominal engineering low-rate engineering data link with Earth so that the problem could be evaluated and the orientation of the antenna determined.

The Viking Lander continued its descent through the Martian atmosphere, and, on touchdown, switched its relay rate to the 16 kilobits mode to provide the high-rate, ultrahigh frequency relay channel to the Orbiter. The indication of the data relay rate changeover on the Lander was received, although the Sol 0 (Martian day) picture could not be immediately acquired as originally planned. Later that evening, the Orbiter was commanded back to celestial reference and the high-rate data link reestablished.

The first mission data received on Sunday morning was a playback of the two Mars day (SOL) 0 pictures recorded on the Orbiter's tape recorder. Then followed the first Lander direct link to Earth followed by a Lander relay link from the Orbiter. The direct link provided a diagnostic check of the Lander's condition and the relay provided the first color picture of the Utopia site. It also indicated that the Viking 2 seismometer had successfully uncaged and was operating normally.

The second picture following the Viking 2 landing was a 310-degree panorama around the Lander including the bottom half of the Lander high-gain antenna. An obvious blemish visible on the high-gain antenna was thought, at first, to be damage to the antenna. However, the subsequent direct-link communication parameter appeared nominal, and it was subsequently established that the blemish resulted from a small amount of Martian dirt thrown up on to the antenna surface during landing sequence. The first two pictures taken by Viking 2 Lander at the Utopia sight are shown in Figs. 6 and 7. Mars' famous rock, "Big Joe," is shown in Fig. 8.

B. VIKING 1 PLANETARY OPERATIONS

As of October 29, 1976, the Viking 1 Orbiter had been in orbit about Mars for 132 days and the Lander had been on the surface for 101 days.

Viking Lander 1 continued to operate in the reduced mission. The latest sampling of Lander 1 weather data from Chryse showed only minor variations from the data acquired piror to the reduced mission at that site. Wind velocities were somewhat higher. Atmospheric pressure had leveled off at 6.85 millibars.

The labeled release and gas exchange experiments were in their long incubation modes. The labeled release experiment, after a third injection of nutrient,

Fig. 6. First picture taken by Lander 2 at Utopia site

Fig. 7. Second picture taken by Lander 2 at Utopia site

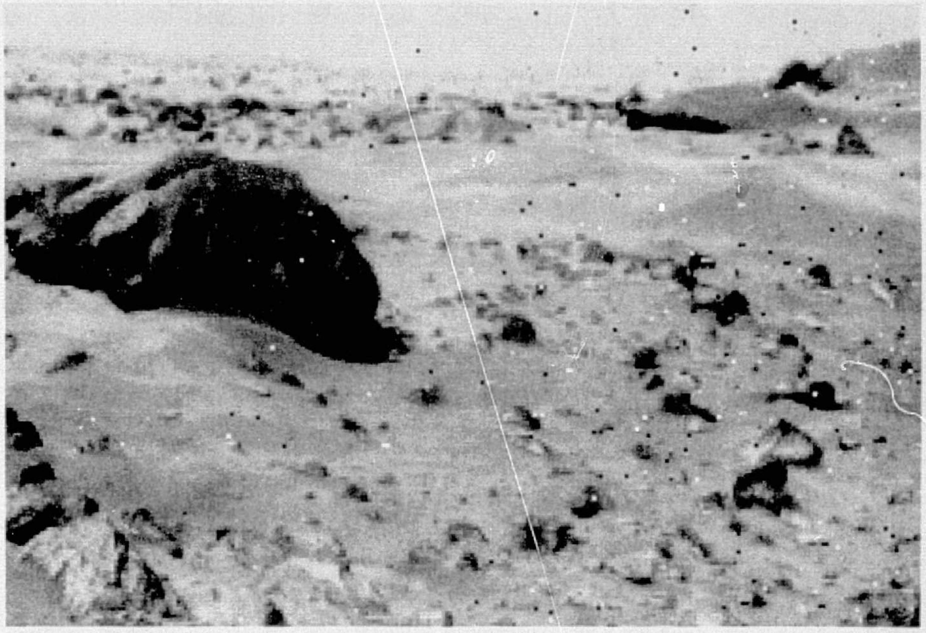


Fig. 8. "Big Joe," one of the most photographed of Mars' rocks

showed an immediate increase in count rate followed by a count-rate falloff of up to 30 percent. After such spurts of activity, the count rates evolved slowly in an apparent linear fashion instead of the hoped for exponential rise that would fit the response produce of a biological model.

Viking Orbiter 1 had ended its walk. The relay communications link between Earth and Lander 2 through Orbiter 1 had been tested and was found to be excellent, thus permitting Orbiter 2 to begin its walk.

C. VIKING 2 PLANETARY OPERATIONS

As of October 29, 1976, Orbiter 2 had been in orbit about Mars for 83 days and the Lander had been on the surface for 56 days. Both the Orbiter and Lander were performing well after weathering noncritical but troublesome problems.

On October 13, the direct downlink from Lander 2 was not received. The following relay link included enough engineering data to isolate the problem to the electronics that are peculiar to the Direct Communications System. The relay downlink was not affected and continued to perform well.

Switch to the redundant traveling wave tube amplifier was made early in November to allow the Lander 2 Direct Communication System to participate in the preconjunction radio science activities.

Orbiter 2 experienced occasional problems with the thermal mapper mirror and an isolated tape recorder incident.

Conjunction, the period of time when Mars is behind the Sun, was rapidly approaching and would signal the end of the Viking Prime Mission. It would, however, afford an opportunity for the Orbiters and Landers to perform some of the most important radio science experiments ever carried out. Among other things, radio science experiments were to precisely determine planetary size and mass and atmospheric characteristics, and provide new data about the Sun and the solar wind. One of the most interesting studies to be carried out was the test of Einstein's Theory of Relativity.

On November 16, 1976, the Viking Prime Mission ended. Interest and activity gradually moved to the events surrounding the then rapidly approaching solar conjunction; preparation also began for resuming operations in the Viking Extended Mission about the middle of December.

III. NETWORK OPERATIONS

A. TRACKING STATION OPERATIONS

1. Tracking Support

a. Lander 1. The first Lander direct link took place during the Deep Space Station 43 (Australia) view period on July 21, 1976, approximately 18 hours after the landing, during the Martian morning.

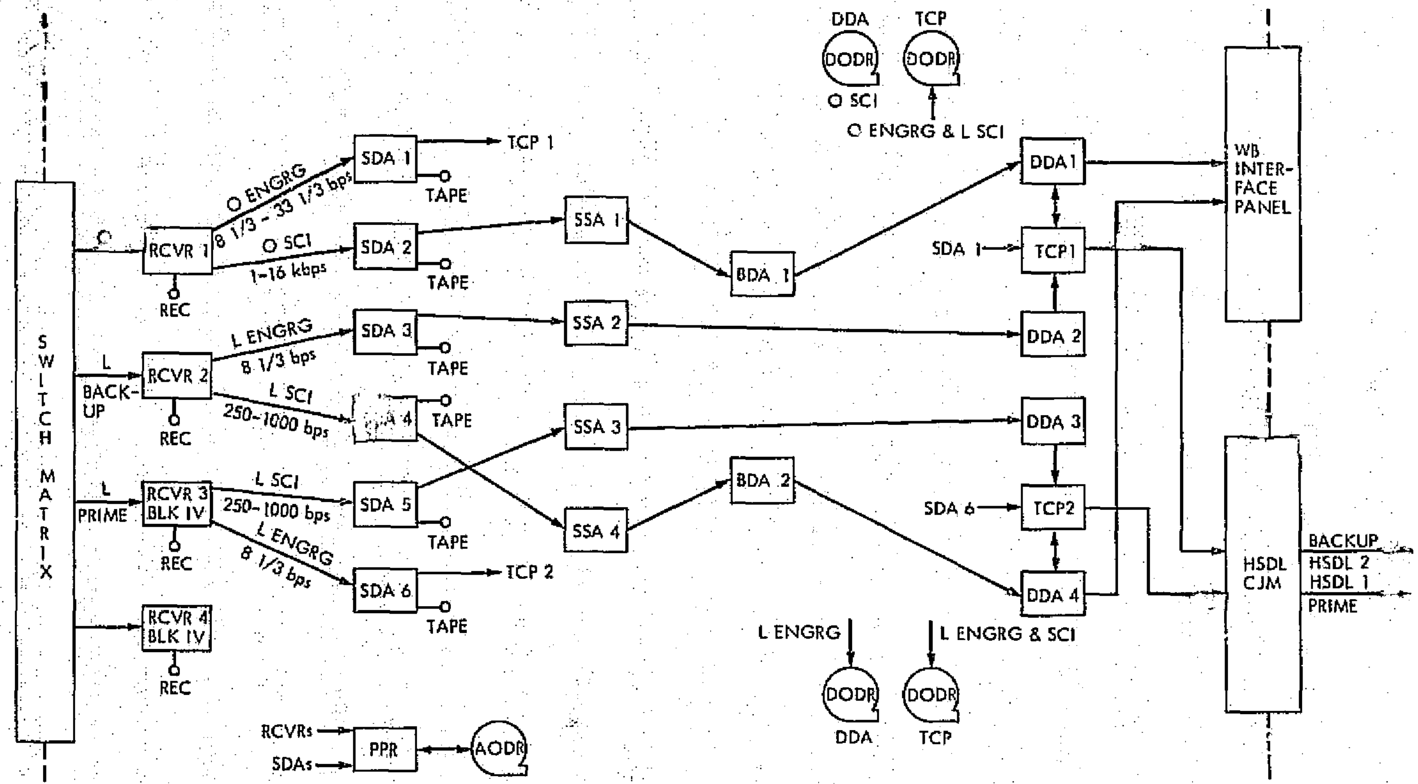
For the Lander direct-link support, a special telemetry and command configuration had been devised. This configuration (Code 61) provided for redundant Lander telemetry processing channels. Redundant command capability was provided by the use of two separate high-speed data lines connected to separate Command Modulator Assemblies. The Code 61 configuration is shown in Fig. 9. The figure shows prime Lander engineering and science data provided by Telemetry and Command Processor 2, channels 1 and 2.

Backup processing was provided by Telemetry and Command Processor 2, channel 3, and Telemetry and Command Processor 1, channel 2. From this configuration, Lander data were supplied via three different transmission paths over two high-speed data lines and one wideband data line. The configuration minimized the possibility that a single-point failure would cause a loss of data.

Lander direct-link support began with the beginning of the uplink acquisition sweep. A transmitter power output level of 20 kilowatts was used. The sweep was designed to take into account the uncertainties of the Lander best lock receiver frequencies and widened to insure the acquisition of both lander receivers. A total frequency range at S-band of 135,648 Hz was swept at a rate of 43.2 Hz per second. The duration of the sweep lasted 52.5 minutes. Table 1 shows the uplink/downlink sweep and ranging parameters used during the first direct link. Since the spacecraft transmitter was not turned on until the uplink acquisition sweep had been completed, the sweep was completed in the blind without benefit of downlink lock.

Command modulation was then turned on, but commanding was delayed until the results of the commands could be verified by the downlink telemetry. Commands were selected that would not alter any spacecraft parameter but would allow the Lander Team to verify command capability.

At approximately 2 hours and 10 minutes following the start of the uplink acquisition sweep, Station 43 obtained lock on the downlink. A special downlink acquisition sweep for the Block IV receiver had been devised that guaranteed lock in either the one-way or two-way tracking mode. The sweep covered a range of 105,600 Hz at S-band, and was swept at a rate of 4800 Hz per second. Lock was obtained on the Block IV receiver in the two-way tracking mode. Following downlink acquisition it was discovered that uplink lock on spacecraft Receiver 1 had not been attained. Several minutes following downlink lock, Receiver 1 was observed to go into lock. The commands sent earlier were observed to be received and processed by both spacecraft receivers through monitoring of the



AODR ANALOG ORIGINAL DATA RECORD
BDA BLOCK DECODER ASSEMBLY
BLK BLOCK
CJM COMMUNICATIONS JUNCTION MODULE
DDA DATA DECODER ASSEMBLY
DODR DIGITAL ORIGINAL DATA RECORD
ENGRG ENGINEERING
HSDL HIGH-SPEED DATA LINE
L LANDER

O ORBITER
PPR PRE- AND POST DETECTION RECORDING SUBSYSTEM
RCVR RECEIVER ASSEMBLY
REC RECORDING SUBSYSTEM
SCI SCIENCE
SDA SUBCARRIER DEMODULATOR ASSEMBLY
SSA SYMBOL SYNCHRONIZER ASSEMBLY
TCP TELEMETRY AND COMMAND PROCESSOR
WB WIDEBAND JUNCTION MODULE ASSEMBLY

CODE	SPACECRAFT	RECEIVER	DATA TYPE	SDA	SSA	BDA	DDA	TCP
61	ORBITER	1	ENGRG	1	0	0	0	1
			SCI	2	1	1	1	
	BACKUP LANDER	2	ENGRG	3	2	0	2	
			SCI	4	4	2	4	2
	PRIME LANDER	3	SCI	5	3	0	3	
			ENGRG	6	2	0	0	

Fig. 9. Standard planetary configuration, Orbiter-Orbiter-Lander, Code 61

Table 1. Lander 1 initial acquisition: Station 43, Sol 1[a,b]

Parameter	Value
Uplink acquisition sweep	
Transmitter on	05:10:00 Universal Time, Coordinated
Transmitter power	20 kW
Frequency	44022494.0 Hz
Start tuning (time 0)	05:10:40 Universal Time, Coordinated
Tune to	44020604.0 Hz
Tuning rate (rate 0)	-0.9000 Hz/s
Time (time 1)	05:45:40 Universal Time, Coordinated
Tune to track synthesizer frequency	44021540.0 Hz
Tuning rate (rate 1)	+0.9000 Hz/s
Stop tuning (time 2)	06:03:00 Universal Time, Coordinated
Command modulation on	06:03:29 Universal Time, Coordinated
Range modulation on	07:20:20 Universal Time, Coordinated
Sweep duration	52 min 20 s
Downlink acquisition sweep	
Start sweep	07:10:00 Universal Time, Coordinated
Sweep upper limit	44753046.55 Hz
Sweep lower limit	44751846.55 Hz
Sweep rate	100 Hz/s
Ranging parameters	
Enter acquisition directive	07:20:40 Universal Time, Coordinated
T1	38 s
T2	9 s
T3	0 s
Round trip light time	38 min 5 s
Components	15

[a]Receiver voltage-controlled oscillator = 23.8625 MHz. Bias receiver frequencies according to actual measurements.

[b]Receiver to be swept in acquisition mode with acquisition trigger at zero-beat enabled.

command segment count. Ranging data were successfully obtained during the last 10 minutes of the downlink pass. At approximately 1 hour after the downlink acquisition took place, loss of lock was observed. No anomalies, except the initial failure to lock spacecraft Receiver 1, occurred during the first direct link.

The station workload during the months of August through November 15, is depicted in Table 2. It shows the number of Viking passes provided, the number of hours of tracking time, and the number of commands transmitted.

Table 2. Deep Space Station support summary for Viking orbital and lander operations

Deep Space Station	Number of tracks[a]	Hours tracked	Number of commands transmitted
		August	
11	30	229:35	2
12	6	42:55	0
14	69	494:34	2,248
42	27	242:53	1,440
43	69	571:21	3,094
44	7	56:55	0
61	31	305:24	3,511
62	9	83:45	438
63	62	541:52	2,318
Total (monthly)	310	2569:14	13,051
		September	
11	29	216:14	1,430
12	6	45:21	6
14	72	487:59	1,205
42	35	315:42	1,532
43	68	578:06	2,685
44	11	91:29	4
61	29	261:13	1,078
62	7	59:37	332
63	83	557:52	438
Total (monthly)	340	2613:33	8,660
		October	
11	32	212:43	1,515
12	0	0:0	0
14	77	413:57	1,292
42	32	351:08	2,776
43	85	787:16	2,967
44	1	4:51	0
61	31	251:52	2,676
62	5	35:36	319
63	79	590:02	1,524
Total (monthly)	342	2647:25	13,069

Table 2. (Contd)

Deep Space Station	Number of tracks[a]	Hours tracked	Number of commands transmitted
	November 1 - 15		
11	18	103:36	339
12	0	0	0
14	30	167:18	403
42	11	113:43	444
43	36	327:16	1,963
44	0	0	0
61	17	133:49	0
62	2	15:40	0
63	24	181:01	143
Total (monthly)	138	1042:23	3,292
Report total	1130	8872:35	38,072

[a]The number of tracks includes the number of passes, each of which includes one, two, or three spacecraft simultaneously.

The more significant events of the mission that engaged special attention from the Network are given in Table 3.

b. Separation and Landing of Lander 2. Because of an attitude control anomaly shortly after separation, Orbiter 2 switched from the high-gain to the low-gain antenna while still in the high-rate telemetry mode, causing the loss of all telemetry data except for some relay-link signal level readings. These indicated that the descent was proceeding normally until the Lander's 4-kbps descent data changed to 16 kbps on touchdown. However, some of the high-rate data were available in real time since the Orbiter remained on the low-gain antenna. The data were recorded by the Orbiter and replayed several hours later when the problem had been corrected.

Reports from Station 14 at Goldstone indicated that the X-band signal level started to decrease at 19:46.27 and went out of lock at 19:47.02. About one minute later the S-band signal level started to decrease rapidly and at 19:47.52 (Greenwich Mean Time) all three S-band receivers were out of lock. Two minutes later the station recovered the S-band signal at a steady level of -169 dBm, which was consistent with low-rate data on the low-gain antenna.

Immediate corrective action required the station to transmit three commands to verify the low-gain antenna, switch to cruise mode, and select 8-1/3 bps telemetry data rate. The spacecraft responded with low-rate telemetry, indicating that the Attitude Control System had switched to inertial reference because of a failed 400-Hz inverter unit. As a result, the spacecraft had rolled off the celestial reference, Vega, by an unknown amount creating a severe high-gain antenna pointing error.

Table 3. Significant Viking Mission events supported by the Deep Space Network

Event	Day/time	Station
Lander 1 touchdown	202/12:12:07	43
Lander 1 direct link established	203/0700 – 0830	43
Orbiter 2 Mars orbit insertion	220/12:33:42	63
Orbiter 2 Mars orbit trim No. 1		
Mars orbit trim No. 2		
Mars orbit trim No. 3	238/18:26:02	14
Orbiter 2-Lander 2 separation	247/19:38:59	14
Lander 2 touchdown	247/22:58:20	14
Lander 2 direct link established	249/01:30:00	43

Further commands were sent to ensure the recording of the immediate post-landed data. By this time Station 43 in Canberra had acquired the spacecraft and, using the contingency plan originally developed for Mars orbit insertion, commanded a 360-degree roll to obtain a star map and an X-band strip chart recording at signal level.

The roll attitude indicated by the star map was consistent with signal level peak obtained from the strip chart, both of which confirmed that the spacecraft had rolled 22 degrees off Vega and that the high-gain antenna was in good condition.

Following this determination, more commands rolled the spacecraft back 22 degrees while still an inertial reference, and selected the high-gain antenna. As expected, the signal level returned to normal, and playback of the postlanded pictures was initiated from the Orbiter tape recorder.

All sequences were executed as planned, and the first pictures from Lander 2 of the Mars surface were received in the early morning of September 4, approximately 9 hours later than originally scheduled.

With two spacecraft in orbit and two spacecraft landed, all returning extremely large amounts of data daily, the Viking Mission now entered a period of exceptionally high activity, with the Deep Space Network being utilized to near 100-percent capability continuously. The loss of data due to Network hardware failures was insignificant. This was made possible, to a large degree, by utilizing 64-meter Station "failure-mode" configurations that were designed to optimize the data processing capabilities at a station in the event of a single-point failure in any telemetry stream.

c. <u>Planetary Operations Activities</u>. Deep Space Network Operations support of Viking planetary operations continued through October and November with the official end of the prime and start of the extended mission occurring on November 15. The actual support of radio science started on a regular basis with solar corona and Earth occultation experiments beginning on October 3 and 6, respectively. High-power transmitter (usually at 100 kilowatts) support for the relativity experiment began on November 3; this support was terminated on November 7. These conditions were established primarily because of the link degradation during the superior conjunction period, and remained in effect through the end of this reporting period. Because of the nature of the radio science organization and requirements, and the degradation of all data types during superior connunction, an extra effort was required in short-range planning and control of the required support. This effort was expended mainly in the production and coordination of special procedures and in the generation of the sequence of events to be used by the Network Operations Control Team and supporting Deep Space Stations. Added tracking by Station 43 was required also, affecting support of other projects and station activities.

Other support during the period included additional Receiver 1 tests of Lander 1 using Station 63. The special procedures required were implemented without problems during the tracks from October 9 through 12. A special alternating ranging test was successfully supported by DSSs 61 and 63 on October 17 with Orbiter 2. The purpose of the test was to develop the procedures to be used for the Mariner Jupiter-Saturn (Voyager) Project ranging support requirements.

The 64-meter stations, Network Data Processing Area, and the Ground Communications Facility were released from Viking modified configuration control (soft freeze) on November 15. All Network facilities remained in standard configuration control throughout the period except for Stations 12 and 63. Station 12 was released on October 3 for Mark III Data System reconfiguration. Station 63 was released on 15 November for antenna bearing corrective maintenance.

Three significant problems occurred during the period that required action by the Network Operations Control Team. Station 14 was unable to process high-rate telemetry through October 22 to 27 because of Block Decoding Assembly failures requiring special coordination of data recovery procedures. Data recovery involved shipping the analog recordings to Compatibility Test Area 21 for digitization and subsequent Intermediate Data Record production. Time was not available for this effort at Station 14 because of tracking and station internal requirements. On November 16, the second problem occurred when Station 14 tracking support was cancelled to extend the hydrostatic bearing maintenance work in progress. Using Station 11, Viking support requirements were successfully negotiated in real time. The third problem was that on October 29; radio frequency interference caused loss of data at Stations 11 and 14 for 45 minutes.

d. Occultation and Solar Corona Support. On October 1 Lander 1 was continuing to send data via the daily direct S-band link; Lander 2 was sending science data via both the relay link and direct link; Orbiter 1 was synchronized over Lander 2 and acted as a relay station; and Orbiter 2 had just begun an orbital walk for observations of the Martian northern polar cap.

Highlights of DSN support and Viking activities during October and November were:

October 2: The first "grazing" Earth occultation for Orbiter 1 occurred with no degradation observed on the downlink.

October 3: Stations 14 and 43 began taking data for the Solar Corona Experiment.

October 4: "Grazing" Earth occultations continued for Orbiter 1 with no degradation observed on the downlink.

October 5: The first "hard" Earth occultation occurred during Station 43's pass on this date. No effects of superior conjunction on automatic gain control or signal-to-noise ratio had been observed.

October 7: The third Earth occultation occurred. Orbiter X-band downlink signal level increased by 3 dB when the uplink transmitter was turned off.

October 11: Following Earth occultation exit, Orbiter 1 was found to be transmitting in the cruise mode at a data rate of 33.333 bps. The attitude control electronics had switched to the backup system. The Command Computer Subsystem had erroneously responded to a loss of Sun signal during Solar occultation and issued a "sun loss routine."

Orbiter 2's infrared thermal mapper was commanded on. It had been turned off earlier due to a mirror-stepping problem.

October 15: Orbiter 1 Earth occultations occurred during Station 63 view period.

October 17: An alternating range experiment was tried during Station 61/63 view period for the Mariner Jupiter-Saturn 77 (Voyager) Project.

A special Radio Science Coordination Voice Network for Stations 14 and 43 was introduced for the purpose of technical information exchange between the radio science advisors and the stations. Superior conjunction effects had not yet been observed on the downlinks. Some noise had been observed on the uplink.

October 21: A high-gain antenna calibration for Orbiter took place during the Station 14 pass. The station's Digital Instrumentation Subsystem program halted during this test causing two data points to be lost. Automatic gain control levels were reported by voice during the outage.

October 26: Effects of solar conjunction were now being seen in uplink and downlink. Variations were seen in uplink signal level and downlink signal-to-noise ratios.

October 29: Severe radio frequency interference at Station 14 caused loss of 8-kbps data for half an hour. A message was sent to all network stations requesting system noise temperatures be included in the posttrack reports for the purpose of determining solar conjunction effects on station parameters. The data were to be taken between November 4 and December 17, 1976.

November 4: A message was sent to all network stations advising them of a requirement to use high-power transmitters during the time frame of November 3 to December 13, 1976. Power levels to be used were:

100 kilowatts at Station 14

50 kilowatts at Stations 43 and 63

20 kilowatts at Stations 11, 42, and 61

Use of higher power levels decreased noise on two-way doppler and ranging.

November 6: Solar conjunction effects continued to be seen. Effects were:

Up to 10-dB fluctuation on uplink signal levels

Up to 20-dB degradation on engineering signal-to-noise ratios.

Both 26- and 64-meter stations indicated the same signal-to-noise ratio.

Downlink was degraded by 2 dB.

November 10: Two-kbps data being received on this date showed signal-to-noise ratio of 6 dB, but there was extremely high bit error rate. The Sun-Earth-Probe angle on this date was 4.5 degrees. This was the last attempt for Orbiter high-rate data.

November 15: This was the last day of the Viking Prime Mission. Engineering data were still being received at a signal-to-noise ratio of 3 dB at 26-meter stations and 5 dB at 64-meter stations. Bit error rates for 26-meter stations were estimated to be 23 in 4687 bits or 5×10^{-3}.

Table 4 lists the Viking support activities during the reporting period.

e. Viking Computer-Aided Countdown Program. Another factor that contributed significantly to the level of station support provided to the Viking Mission was the computer-aided countdown technique. The computer-aided countdown program was developed by personnel of the Madrid Deep Space Station (62) within its "Network Engineering Program," with the assistance of the Network System Support Group. Work on the program began in March 1975; however, because of a heavy workload associated with preparations for Viking launch and tracking support, it was not completed until March 1976. During that month, the program was evaluated and software acceptance testing was performed.

The program effectively combined tasks previously performed by several separate test software programs, and shortened the time required to support station precalibrations.

Table 4. Viking support activities

Period	Deep Space Station	Number of tracks	Track time	Number of commands
September	11	29	216:14	1430
	12	6	45:21	6
	14	72	487:59	1205
	42	35	315:42	1532
	43	68	578:06	2685
	44	11	91:29	4
	61	29	261:13	1078
	62	7	59:37	332
	63	83	557:52	438
		340	2613:33	8660
October	11	32	212:43	1515
	12	0	0:0	0
	14	77	413:57	1292
	42	32	351:08	2776
	43	85	787:16	2967
	44	1	4:51	0
	61	31	251:52	2676
	62	5	35:36	319
	63	79	590:02	1524
		342	2647:25	13069
November 1-15	11	18	103:36	339
	12	0	0	0
	14	30	167:18	403
	42	11	113:43	444
	43	36	327:16	1963
	44	0	0	0
	61	17	133:49	0
	62	2	15:40	0
	63	24	181:01	143
		138	1042:23	3292

The program provided for a centralized verification of station performance in four important areas:

(1) Telemetry System performance.

(2) Command System performance.

(3) Doppler performance.

(4) Planetary Ranging Assembly countdown performance.

Written for a typical 64-meter station, the program had the ability to test and verify six telemetry channels, two command processors, the Block III S-band receiver and the Block IV, S- and X-band doppler receiver.

For 26-meter stations, the program was capable of testing four telemetry channels, two command processors, and the Block III S-band doppler receiver.

The software was designed with the flexibility of accommodating all possible Viking telemetry rates, Orbiter and/or Lander command, and any combination of Block III, Block IV, S-band, or X-band doppler processors.

The computer-aided countdown was first used by the Network in April 1976. The months of April and May were designated as a trial and training period. During this period, the three levels of computer-aided countdowns were exercised, while personnel became familiar with the program and developed procedures for optimizing its use. Table 5 defines the computer-aided countdown level by station, and identifies the options of each. Beginning on June 1, 1976, the level 1 countdowns were committed at all Network stations supporting Viking, and were continued throughout the Viking prime mission.

Table 6 identifies the results of the level 1 computer-aided countdowns during the two months of continuous use during the Prime Mission.

Starting with the Viking extended mission, the level 2 computer aided countdowns were to become the prime countdown level, with the option of using level 1 for passes in which a critical event was scheduled.

2. Link Performance for August and September 1976

a. Orbiter 1. Link performance for August of Orbiter 1 is shown in Figs. 10 and 11. The large step downward for the uplink signal level, which began at the end of June, appears in Fig. 10 to have stabilized. Both Stations 11 (Goldstone) and 61 (Spain) show the downward trend to reach a value of almost -4 dB through August.

Almost all downlink tracking for Orbiter 1 (as well as Orbiter 2) in August was with the 64-meter stations. On the average, there is almost no trend in downlink signal level during the month. Station 14 went from a mean value of -0.6 dB to -0.1 dB from July to August. That station has a standard deviation in August of 0.6 dB, with extremes of -1.6 dB and +1.0 dB, while Station 63 is down to -1.0 dB in August from -0.5 dB in July for the mean downlink residual.

Table 5. Computer-aided countdown levels

Station	Level	Time to execute, hours	Options
14, 43, 63	1	6	2 hours of full Deep Space Station testing followed by a built-in 2.5-hour hold (or rectification), then 1.5 hours of retest and data transfer test
	2	3	2 hours of full Deep Space Station testing followed by a 1-hour retest and data transfer test
42, 61	1	4.5	1.5 hours of full Deep Space Station testing followed by a 2-hour built-in hold, then a 1-hour retest and data transfer test
	2	2.5	1.5 hours of full Deep Space Station testing followed by a 1-hour retest and data transfer test
11, 12, 44, 62	1	3	1.5 hours of full Deep Space Station testing followed by a 0.5-hour built-in hold, then a 1-hour retest and data transfer test
	2	2.5	1.5 hours of full Deep Space Station testing followed by a 1-hour retest and data transfer test
	3	1.5	1 hour of full Deep Space Station testing followed by 0.5 hour of data transfer test

Table 6. Computer-aided countdown utilization for Viking Prime Mission

Performance	Station 14, passes	Station 43, passes	Station 63, passes	Total, passes
64-m computer-aided countdown scheduled for 6-channel support	50	36	57	143
Station green after full Deep Space Station testing	38	30	50	118
Equipment anomalies corrected during built-in hold	8	3	6	17
Equipment anomalies corrected during testing and built-in hold	2	3	2	7
DSS unable to support 6 channels at the end of the computer-aided countdown due to equipment anomalies	2	0	2	4

Conclusions:

1. Deep Space Stations were red for 6 channel support prior to the built-in hold 17.5% of the passes
2. Deep Space Stations were red for 6 channel support prior to AOS 2.8% of the passes

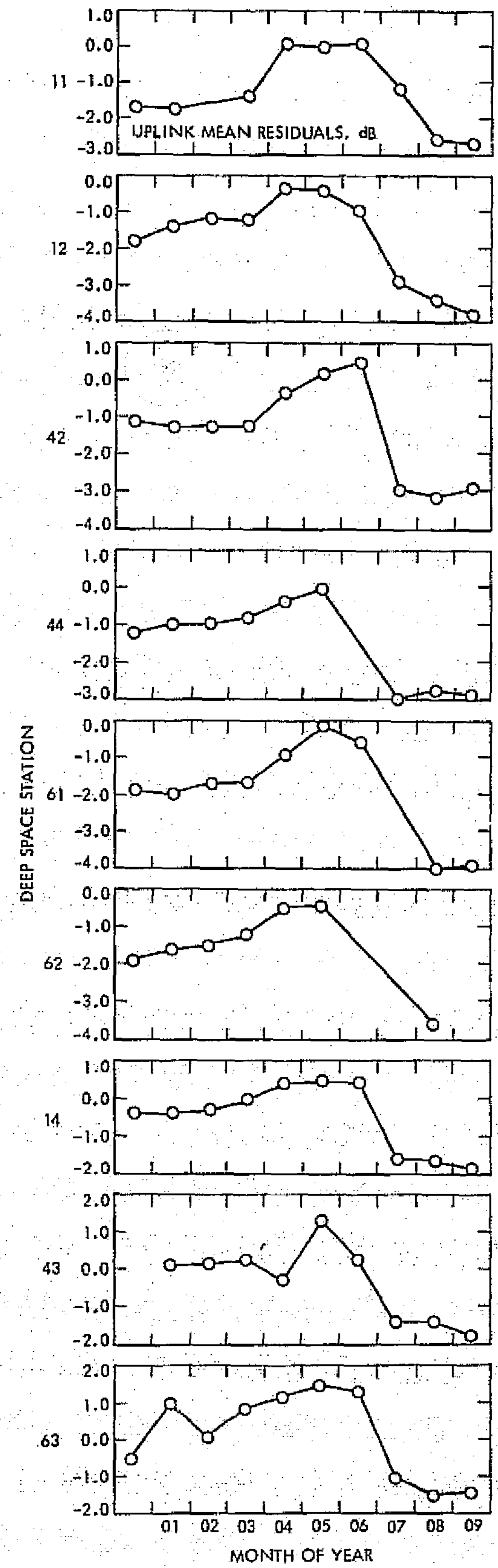


Fig. 10. S-band uplink signal level residuals for Viking Orbiter 1

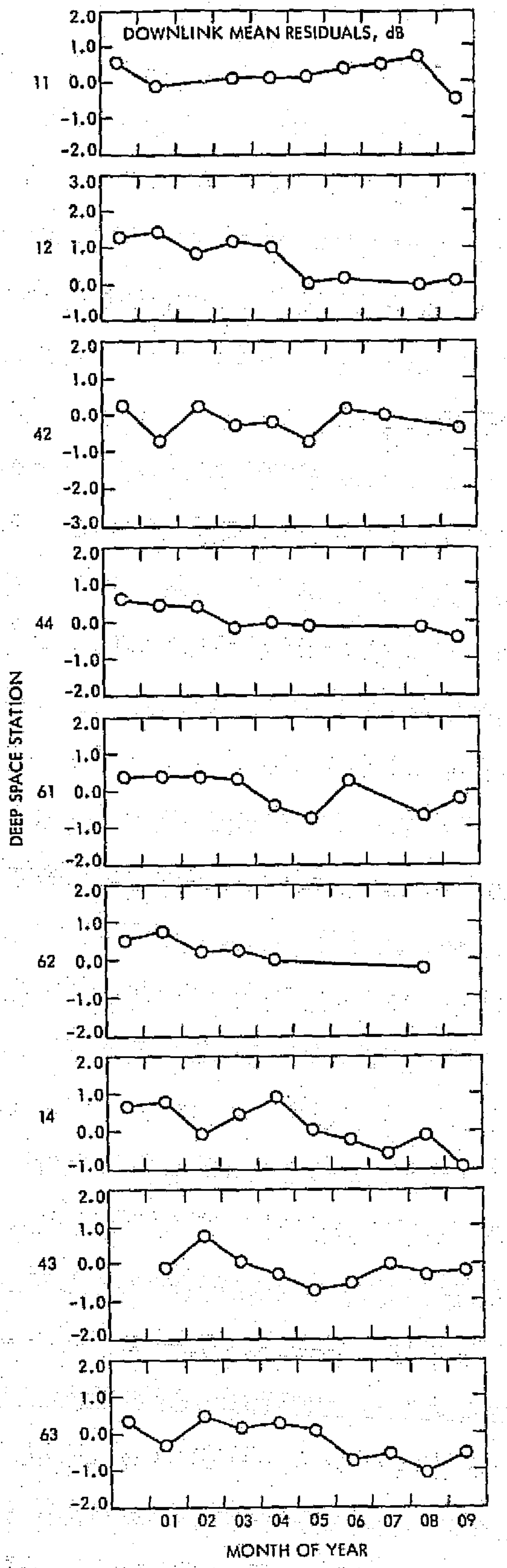


Fig. 11. S-band downlink signal level residuals for Viking Orbiter 1

High-rate signal-to-noise ratio performance remains outstanding. In August, both 2 kbps and 4 kbps had 0 dB residuals, and 8 kbps had -0.2 dB mean residual. The latter is down from the 0.0 dB mean residual in July, but not a significant amount. Of interest to users of the data are the extremes, particularly the negative extreme. For 4 kbps, the lowest residual observed was -0.6 dB, and for 8 kbps, the lowest was -0.8 dB. On several days, Station 63 operated with Maser 2, which elevated the system noise temperature. With the predicts corrected for the known system noise temperature, the residuals for these passes remained normal.

b. Orbiter 2. The August data for Orbiter 2 are summarized in Figs. 12 and 13. The performance during August remained very stable for all the S-band links.

Orbiter 2 was busy with site certification activities for the September landing of Viking 2. Accordingly, Orbiter 2 had most of the 64-meter uplinks during August. At these 64-meter stations, the uplink residuals were little changed from July.

Downlink performance for Orbiter 2 was uniformly good, with the greatest negative downlink residual being the -0.5 dB at Station 63 and the greatest positive one being +0.6 dB at Station 11 at Goldstone.

The low-rate signal-to-noise ratio performance for Orbiter 2 shows the same characteristic as mentioned for the Orbiter 1, that is, one dB difference between the 33-1/3 bps residual and the 8-1/3 bps residual.

The high-rate signal-to-noise ratios were excellent. The crucial 8-kbps rate, used for playback of site-certification Visual Imaging Subsystem, had a mean value of +0.3 dB in August, little changed from the July value of +0.4 dB, and a standard deviation unchanged at 0.3 dB. The 4 kbps, used for infrared data playback and soon to be used for relay data playback on Orbiter 2, also had a mean residual of +0.3 dB, and a standard deviation of 0.4 dB. The 2 kbps, appearing mainly in the Flight Data System real-time high-rate mode (but also in September for the Viking Lander Capsule checkout) consistently has a large positive residual.

c. Orbiters 1 and 2 X-band Downlink Signal Level. Figures 14 and 15 show the Orbiter 1 and Orbiter 2 X-band downlink residual points respectively.

Looking at Fig. 14, the Orbiter 1 mean value is 0.7 dB for August and there is a large amount of scatter, as evidenced by the 1.7-dB standard deviation. Figure 15 shows a similar situation for Orbiter 2. The mean value is +1.2 dB, and the standard deivation is 1.4 dB. The range of data (extremes) for Orbiter 1 is from -2.1 to +3.8 dB; for Orbiter 2 it is -3.3 dB to +4.1 dB. This large scatter was observed previously and reported in Volume II of this report.

d. Lost High-Rate Data. Perhaps the most significant "new" problem to surface during August in the telecommunications area was the recognition that a certain amount of the high-rate "science" data were being lost somewhere between source and users. On Days 76/233 and 76/234 (August 20 and 21), it was reported

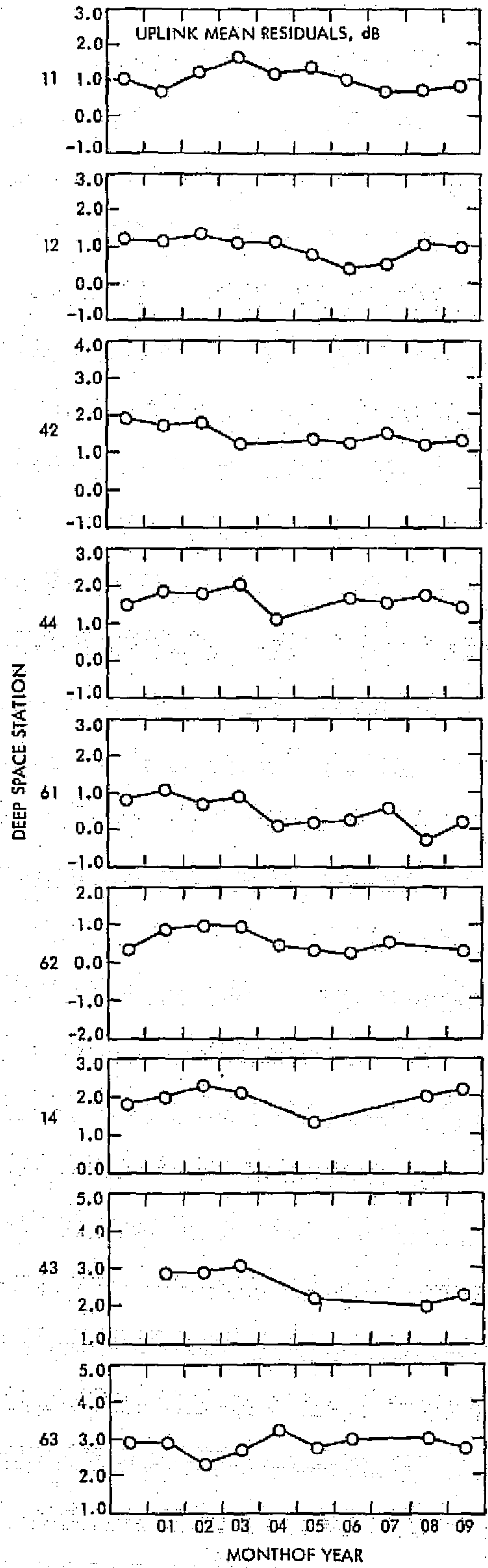


Fig. 12. S-band uplink signal level residuals for Viking Orbiter 2

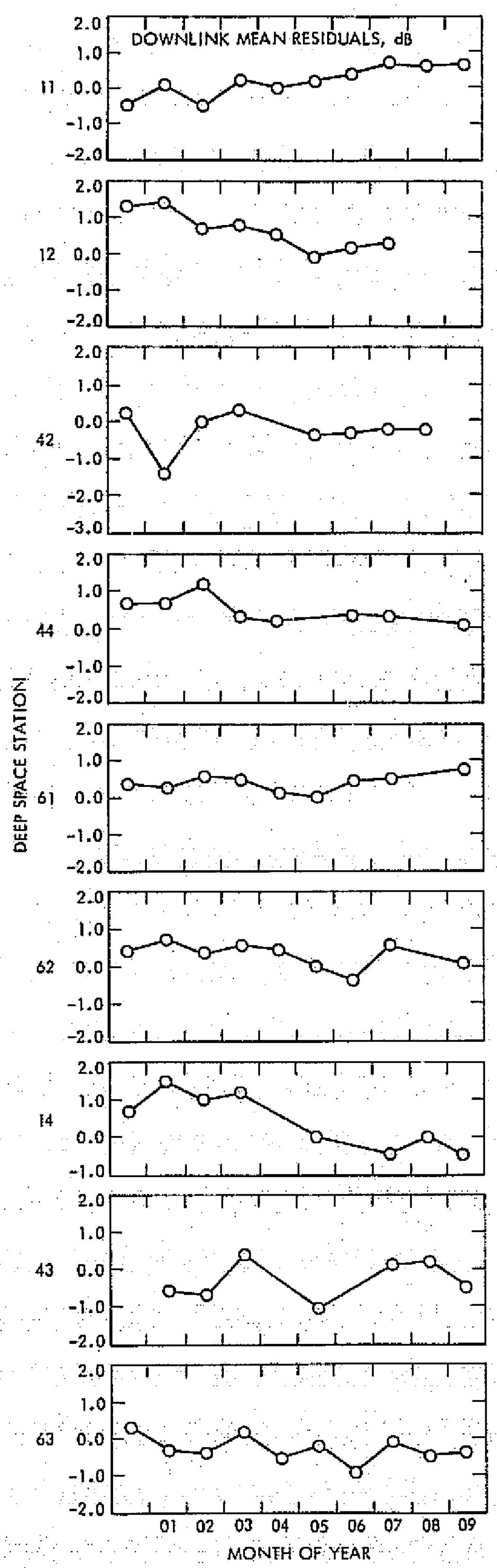


Fig. 13. S-band downlink signal level residuals for Viking Orbiter 2

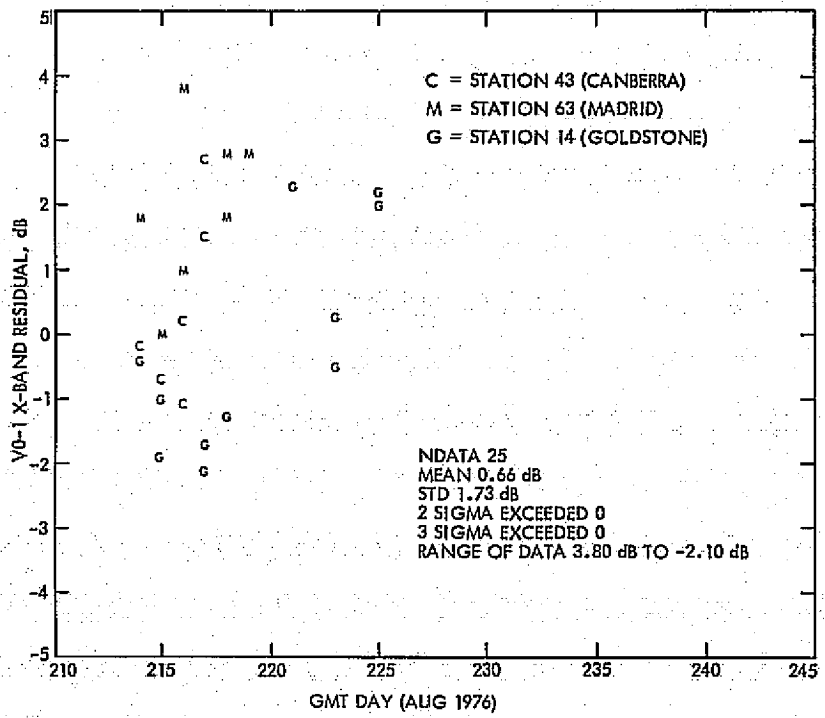


Fig. 14. X-band downlink signal level residuals for Viking Orbiter 1 during August 1976

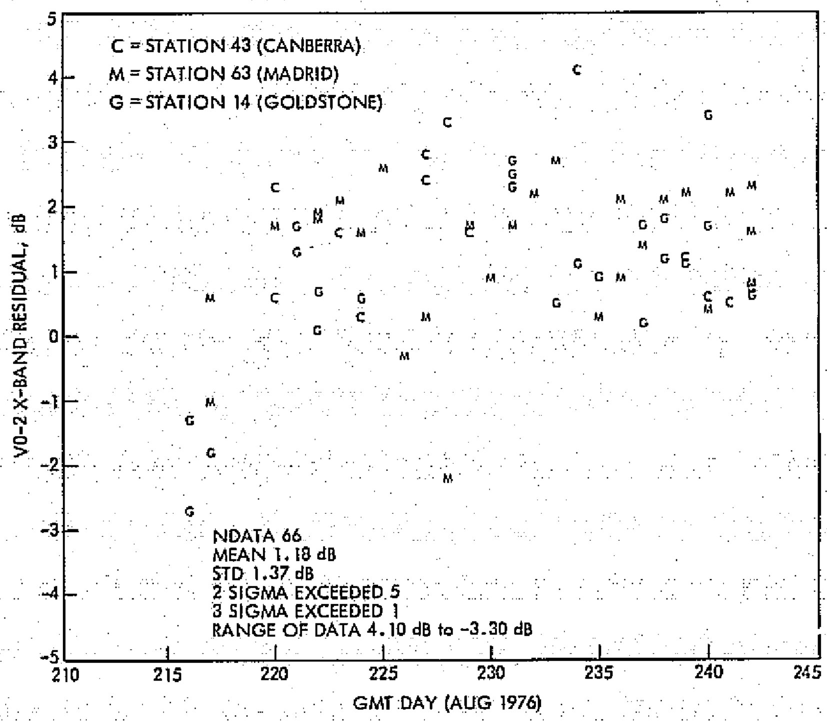


Fig. 15. X-band downlink signal level residuals for Viking Orbiter 2 during August 1976

that the Subcarrier Demodulator Assembly at Station 43 was slow to lock up on the 4-kbps infrared data stream after a period of single-subcarrier operation on Orbiter 2.

A message was sent to Station 43 requesting further information. This message pointed out that the Day 76/234 problem occurred with Station 43 using two parallel processing channels (i.e., different receivers and Subcarrier Demodulator Assemblies), and both were slow to lock up. The Analog Original Data Record tape for the Day 76/233 pass was returned from Australia, and played back at Compatibility Test Area 21. It was found (a) the speed-lock signal on the tape was faulty, therefore the Test Area 21 Subcarrier Demodulator Assembly could not lock up on the receiver base-band output on the tape, although this was not a problem related to the original subcarrier Demodulator Assembly slow lockup; and (b) examination of the signal spectrum confirmed that the high-rate subcarrier was present beginning at the time it should have been, but the signal levels on the tape were too low to determine if there was proper modulation of the subcarrier.

There have been other occurrences of slow or no lockup of Network equipment. These have occurred on at least one Lander 1 direct link, as well as with both Orbiters 1 and 2 high-rate links, with both Visual Imaging Subsystem and infrared data, and at several stations. As it does not appear to be a problem confined to a single Orbiter, the Network investigated further.

e. Orbiter 1 Link Performance for September. All uplink signal level residuals for Orbiter 1 remained stable during August and September as shown in Fig. 10.

None of these had changed significantly since the "uplink anomaly" first occurred at the end of June.

Downlink performance for S-band is summarized in Fig. 11, and all residuals are smaller than 1 dB from predicted values. Figure 11 shows that little overall trend for the past three months. The 26-meter network was used sparingly for downlink, and all the values included in the figure represent the cruise mode, when the station was being used primarily for its uplink.

For Orbiter 1, 33-1/3 bps engineering signal-to-noise ratio was usually very close to predict, whether or not the high-rate channel was ON. The high-rate signal-to-noise ratio continued its excellent performance. Almost all Visual Imaging Subsystem data were returned at 8 kbps. The 8 kbps signal-to-noise ratio mean residual was -0.3 dB in September.

Residuals for the uplink and downlink signal level, low and high-rate signal-to-noise ratio, X-band signal level, and doppler noise, for the month of September data are shown in Fig. 16. A significant increase in doppler noise at the end of the month is apparent. This trend, which is also present in the Orbiter 2 data (Fig. 17), is attributed to solar activity at the onset of the Viking superior conjunction.

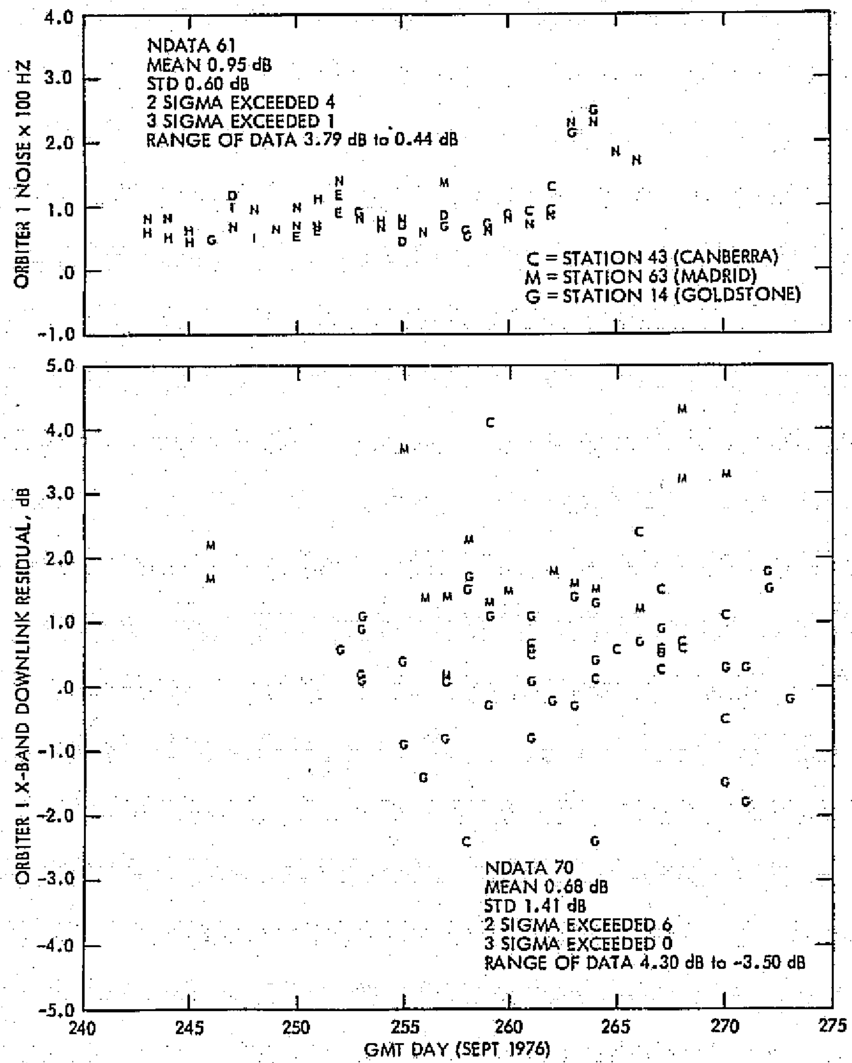


Fig. 16. Orbiter 1 doppler noise and X-band downlink signal level residuals during September 1976

f. Orbiter 2 Link Performance. Orbiter 2 uplink quantities (Fig. 12), like those for Orbiter 1, do not show any particular trends during September.

It is interesting to note that the Station 14 value is 4.1 dB higher than that for Orbiter 1; the Station 43 value is 4.1 dB higher, and the Station 63 value is 4.1 dB higher. Again, comparing the 26-meter Orbiter 2 values with the Orbiter 1 values, the Station 11 value was 4.2 dB higher for Orbiter 1; the Station 42 value was 4.3 dB higher, and the Station 61 value was 4.1 dB higher. Again, the consistency of station performance, between Orbiter 1 and Orbiter 2, is remarkable, although there is station-to-station difference on a single orbiter.

S-band downlink (Fig. 13) was close to the predicted value, as on Orbiter 1. Over the 64-meter network, the mean residuals were -0.5 dB for Station 14; -0.5 dB for Station 43, and -0.4 dB for Station 63.

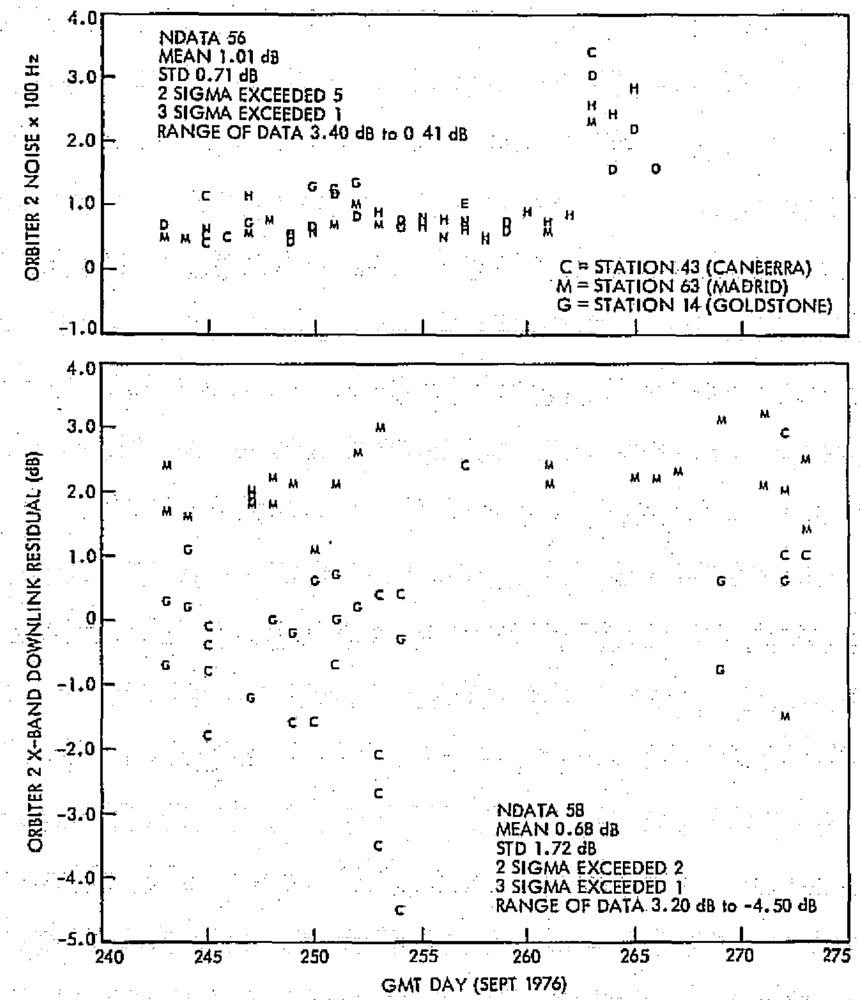


Fig. 17. Orbiter 2 doppler noise and X-band downlink signal level residuals during September 1976

Except for the doppler noise, none of the link quantities showed any overall trend during the month. The X-band signal level showed a very large amount of scatter, as has been the experience on the Viking mission. Orbiter 2 data ranged from +3.2 to -4.5 dB, relative to predicts, for the X-band.

g. Earth Occultations. The Viking Radio Science Team generated requirements for the communications links during Earth occultations:

(1) S-band and X-band carriers are to be ON during the time the beam is within 1000 km of the surface of Mars.

(2) The cruise mode is to be ON during the time the beam is within 1000 km of the surface.

(3) The ranging channel is to be OFF during the time the beam is within 1000 km of the surface.

(4) To preclude disruption of the incoming downlink signal, no transmitter tuning is permitted until after the Earth received time of the exit occultation signal at 1000 km.

3. Link Performance for October and November

Link performance for Orbiters 1 and 2 remained normal during the reporting period of October 7 to November 15 except for the onset of effects of superior conjunction.

Because of the onset of superior conjunction effects, no attempt was made this time to quantify the link performance in terms of "mean residuals" or maximum/minimum values. An assessment of the various links is that the Orbiter telecommunications performance did not change, nor had the Network station performance.

Qualitative link performance is given in Figs. 18 through 20 for Orbiter 1 and in Figs. 21 through 23 for Orbiter 2.

In each of the figures, the small characters are keys, to the identity of the station involved. These follow (same keys for all figures):

Key	Station	Key	Station	Key	Station
M	63	C	43	G	14
N	61	D	42	H	11
O	62	E	44	I	12

Some statistical data are included with each of the figures. Residuals are defined as the difference between the predicted value and the observed value. All the residuals are in dB.

There are no obvious trends contained anywhere in the data, except for the last three weeks. These points, beginning with Day 300 (approximately), constitute times that are within 30 days of the minimum Sun-Earth-Probe angle of superior conjunction. Of the various link quantities, the first to indicate degradation is the low-rate signal-to-noise ratio; the last is the high-rate signal-to-noise ratio or the X-band downlink. The others fall in between.

4. Superior Conjunction

a. <u>Predictions</u>. The variations of the Sun-Earth-Probe angle for the Viking mission has been known for several years. Experience from previous missions indicates that no severe effects on S-band telecommunications occur until the Sun-Earth-Probe angle becomes less than five degrees. Figure 24 shows the change in the predicted Sun-Earth-Probe angle, starting on November 1.

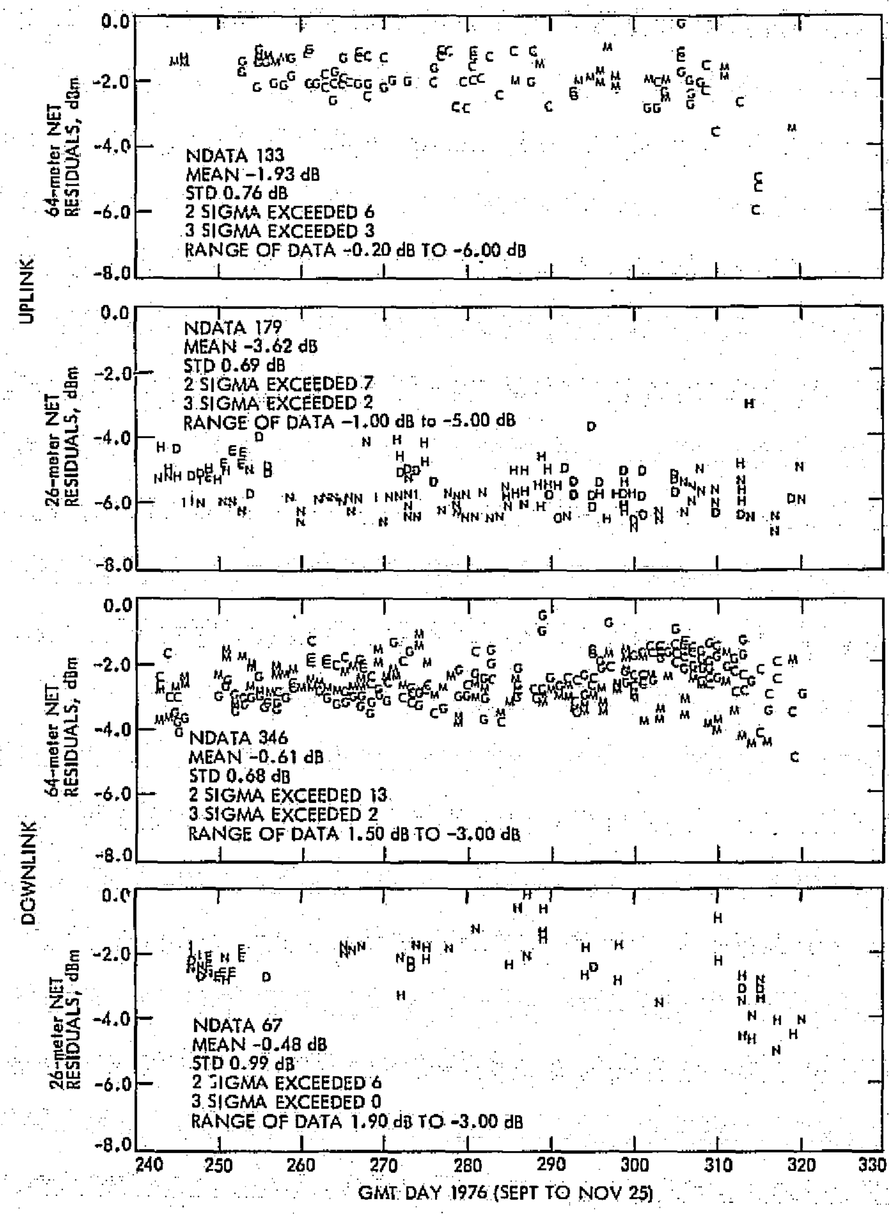


Fig. 18. Orbiter I uplink and S-band downlink signal level residuals

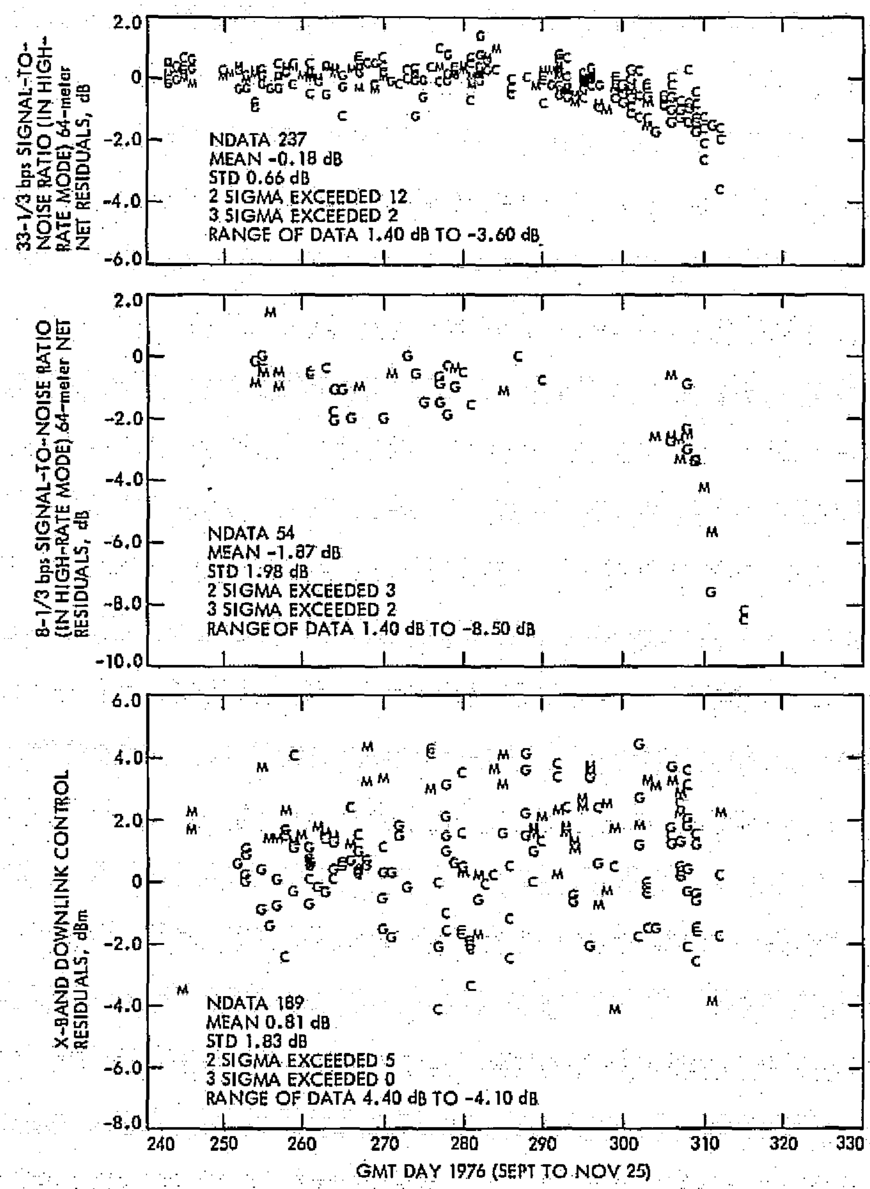


Fig. 19. Orbiter 1 low-rate telemetry and X-band downlink signal level residuals

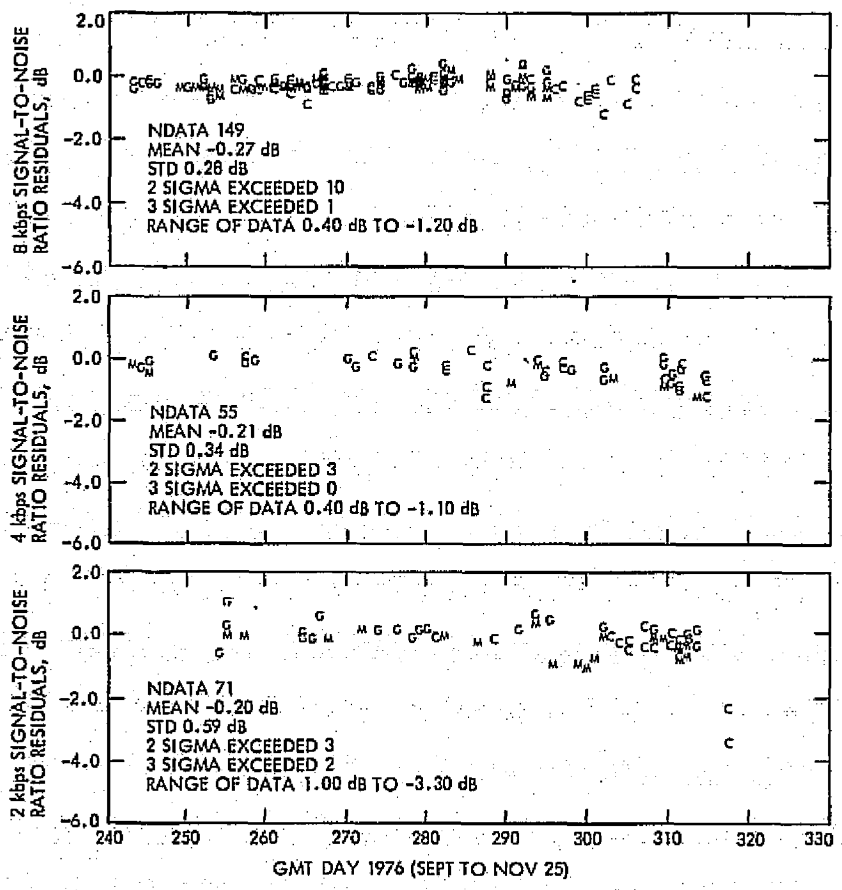


Fig. 20. Orbiter 1 high-rate signal-to-noise ratio residuals

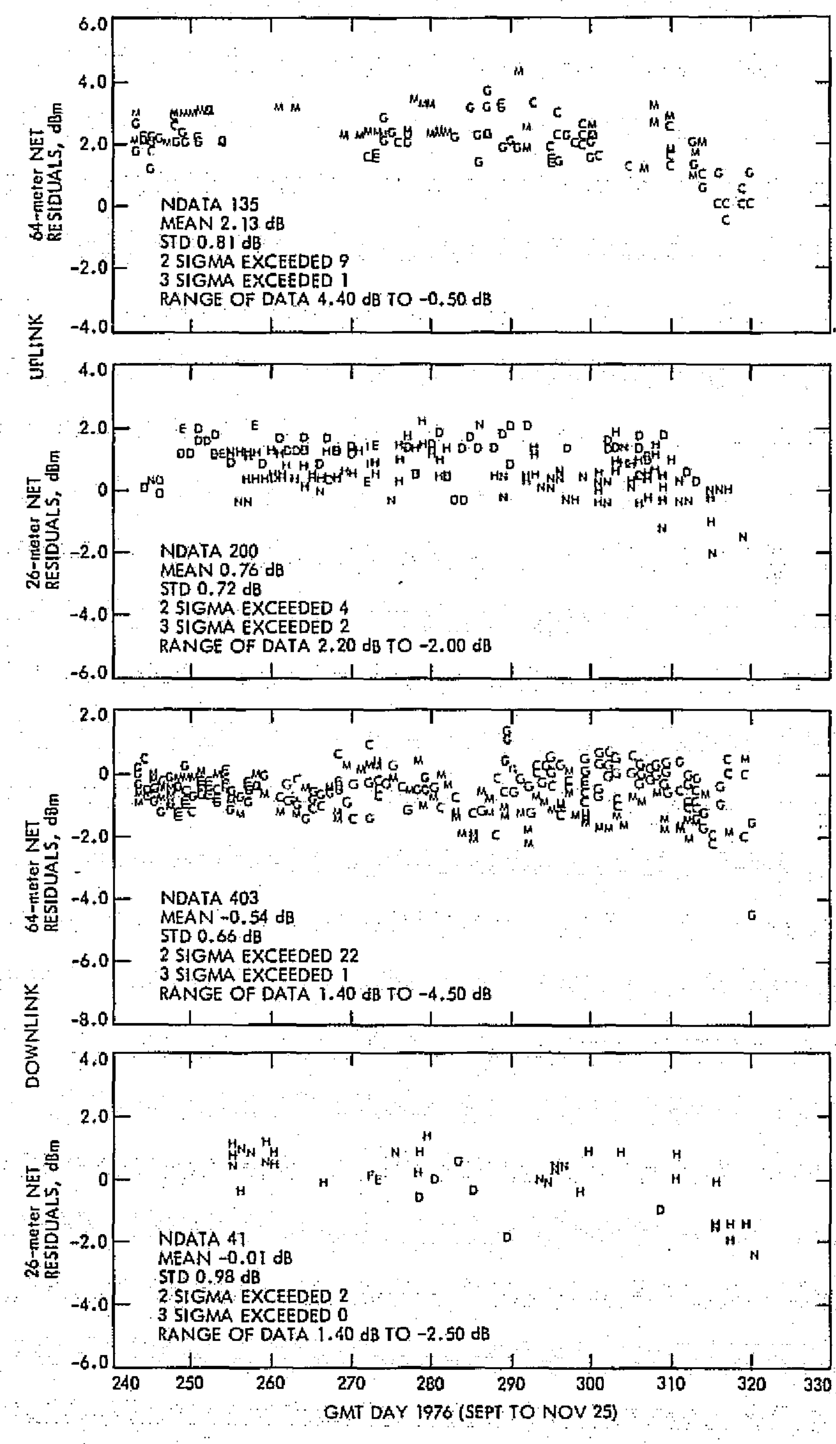


Fig. 21. Orbiter 2 uplink and S-band downlink signal level residuals

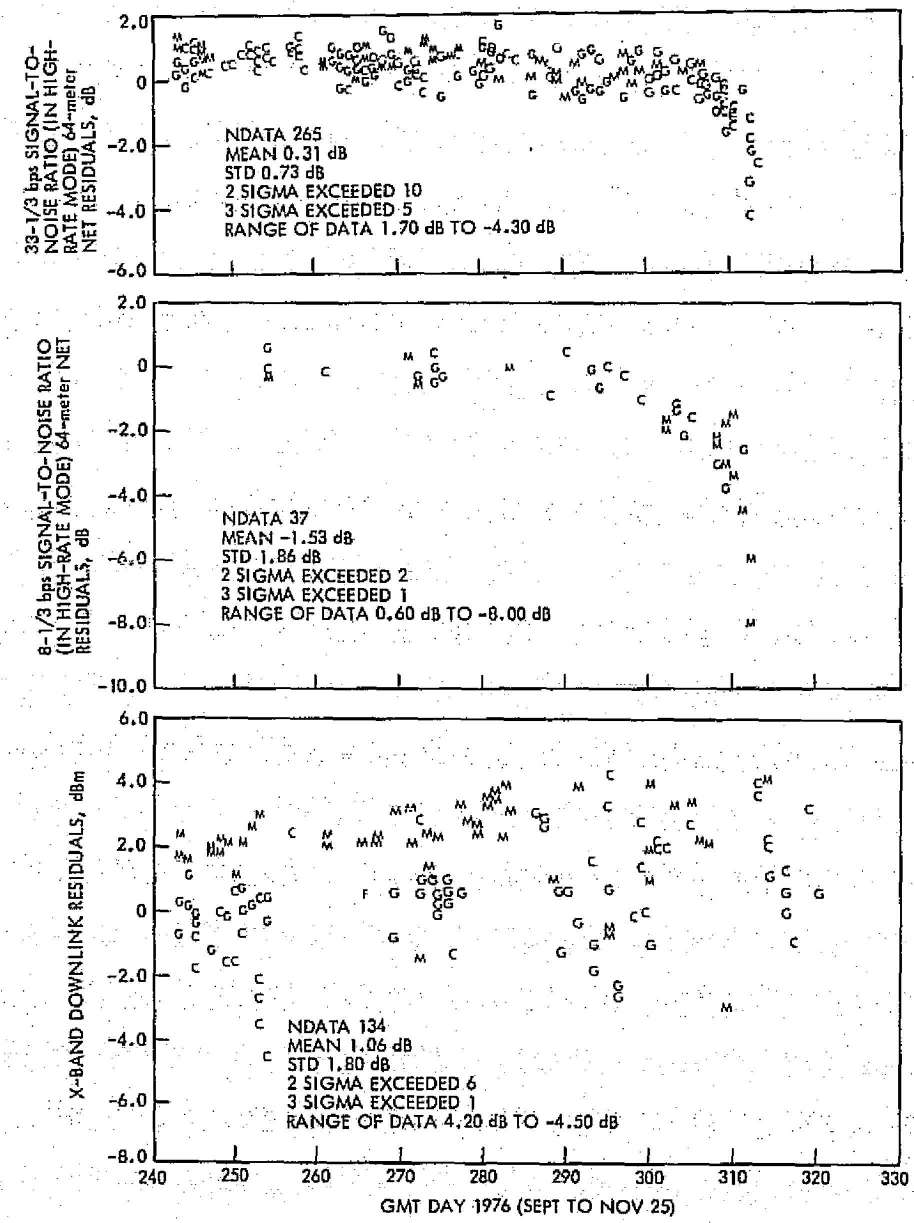


Fig. 22. Orbiter 2 low-rate signal-to-noise ratio and X-band downlink signal level residuals

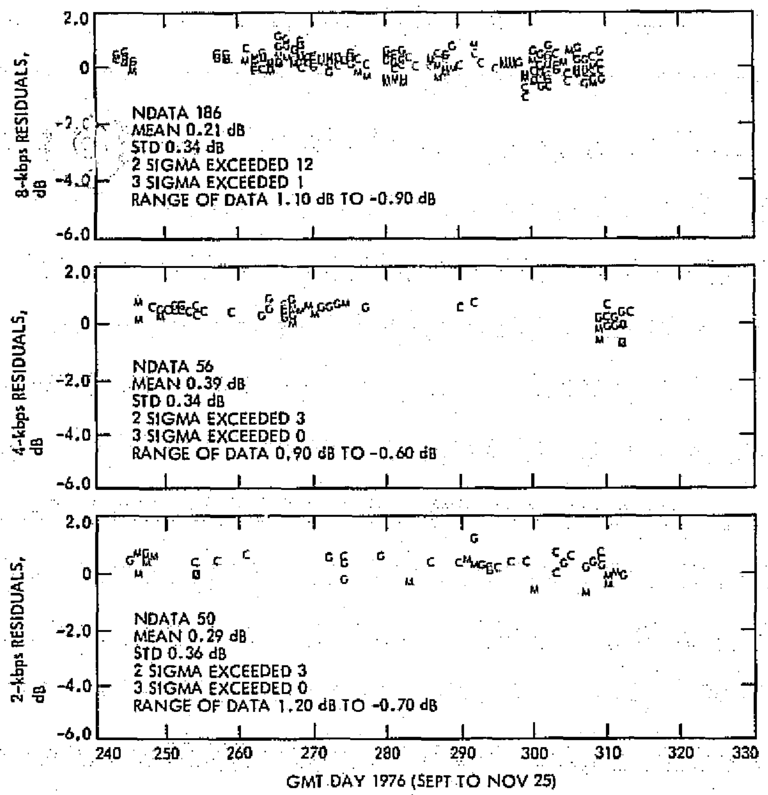


Fig. 23. Orbiter 2 high-rate signal-to-noise ratio residuals

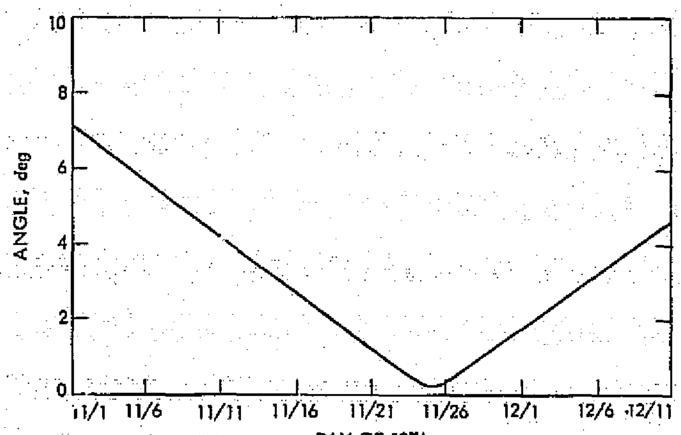


Fig. 24. Mars-Earth-Sun angles

Figure 25 shows predicted degradation in the S-band downlink signal level and low-rate channel signal-to-noise ratio. These are shown as a function of calendar date at the top and days from closest approach (November 25) at the bottom. Also shown is the amount of variation expected over any given station pass. Note that there are no explicit predictions for effects on the command uplink and none for effects on the high-rate channel. This is because data on these links was not available during the Mariner Mars 1971 and Mariner Venus/Mercury 1973 missions. It is assumed that the command uplink and the high-rate signal-to-noise ratio downlink degradations follow a curve similar to that for the low-rate telemetry.

Superior conjunction effects can be categorized as (a) noise temperature increases, and (b) spectral spreading. Figures 26 and 27, taken from a report on the Helios superior conjunction, show the Deep Space Network-predicted system noise temperature at 26-meter and at 64-meter stations, respectively, together with the actual observed data added. It is interesting to note that at 26-meter stations, the actual system noise temperature was as much as 10 dB higher than predicted! At 64-meter stations, pass-average temperature was sometimes 3 dB higher than predicted. This is believed to be caused by the "quadripod effect", wherein the four-legged support structure of the antenna feed "squints" sidelobes into the Sun.

The Helios data suggest that noise temperature effects do not become severe until the Sun-Earth-Probe angle becomes less than 4 degrees. Viking dates are superimposed at the bottom of Figs. 26 and 27. The critical time for noise temperature effects was November 12.

Figures 28 and 29 show a potentially far more damaging effect, spectral spreading. Figure 28 shows the excess signal-to-noise degradation observed on Helios at 26-meter stations. Excess signal-to-noise degradation is that which is over and above the amount caused by system noise temperature increases (which can be measured). As in previous figures, the Viking dates are superimposed on the bottom. This superimposition is based on equal Sun-Earth-Probe angles. Figure 29 shows the excess signal-to-noise ratio degradation at 64-meter stations. Each dot represents one complete pass, so these are pass-average values. In a sense, then, they are equivalent to the "nominal" values shown in Fig. 27. They are also significantly more severe than Fig. 25, particularly for Sun-Earth-Probes, smaller than [illegible] degrees. The Fig. 27 predicts are superimposed on Fig. 29.

Figure 30 summarizes the prediction information used in planning changes to date rate on the incoming side of superior conjunction. The spots on the figure are pass-average Helios degradation (downlink signal-to-noise ratio), as a function of Sun-Earth-Probe angle. Viking dates are superimposed. The solid curve is a "worst case" prediction that was used on Viking for planning (a) Lander playback capability, (b) infrared science playback capability, and (c) uplink command capability. The middle dotted curve was the one used for planning Visual Imaging Subsystem playback capability and for predicting the dropout of low-rate 8-1/3 bps cruise data. The top dotted curves were not used; they were "nominal" Viking predicts based on the old Mariner Mars 1971 data.

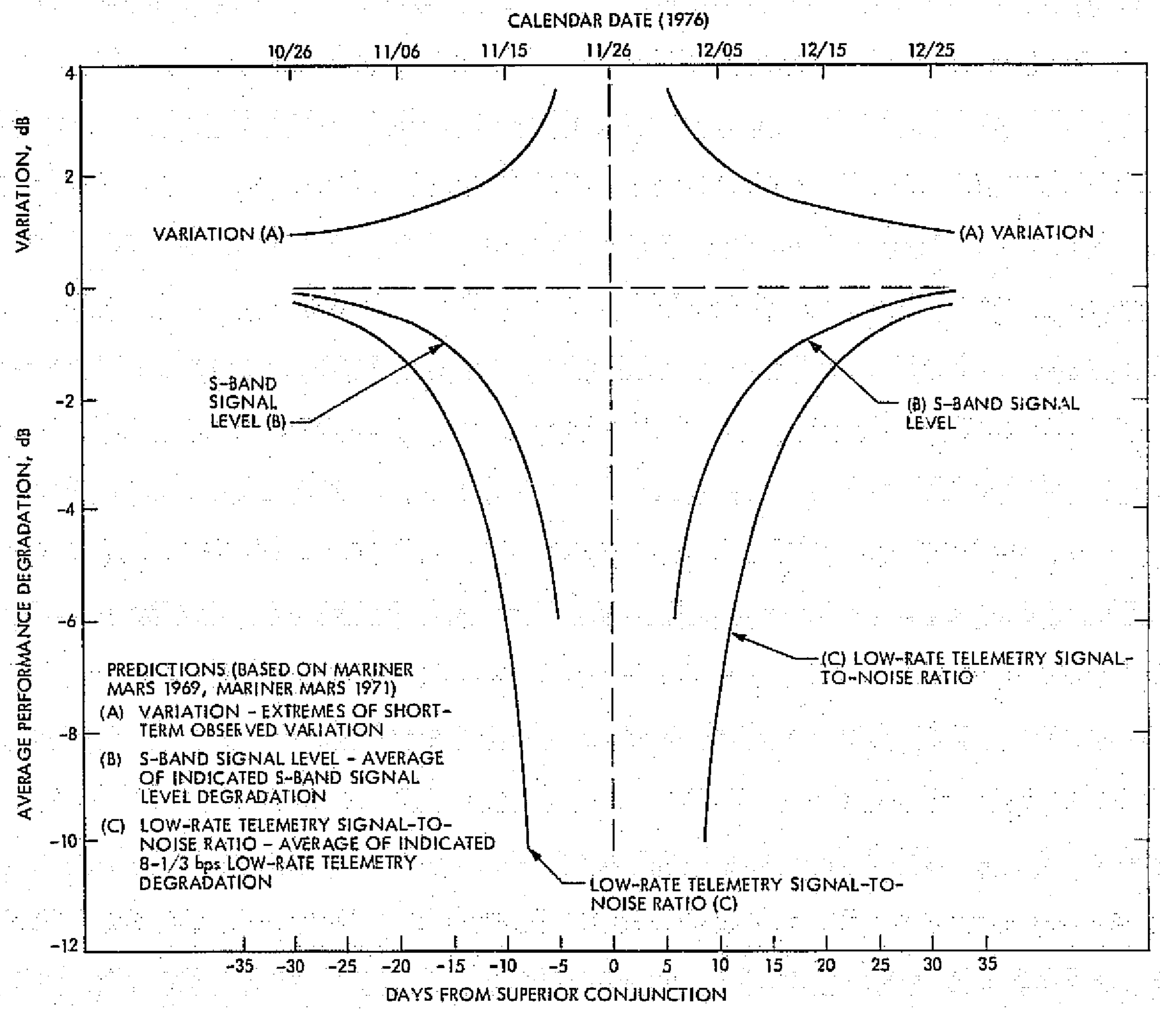


Fig. 25. Predicted degradation of radio frequency links

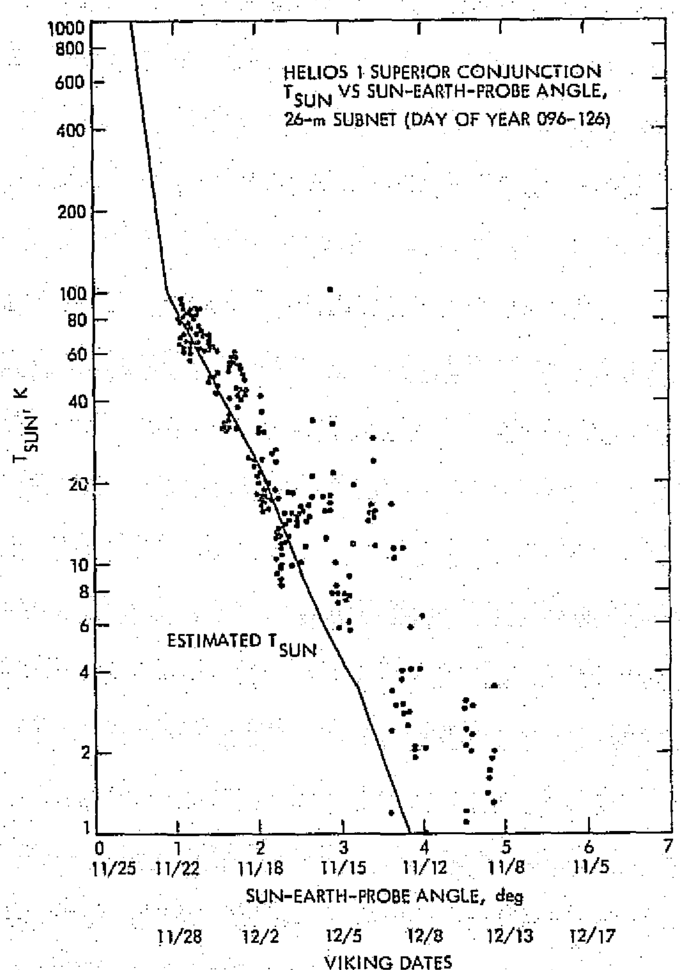


Fig. 26. System noise temperature as function of Sun-Earth-Probe angles

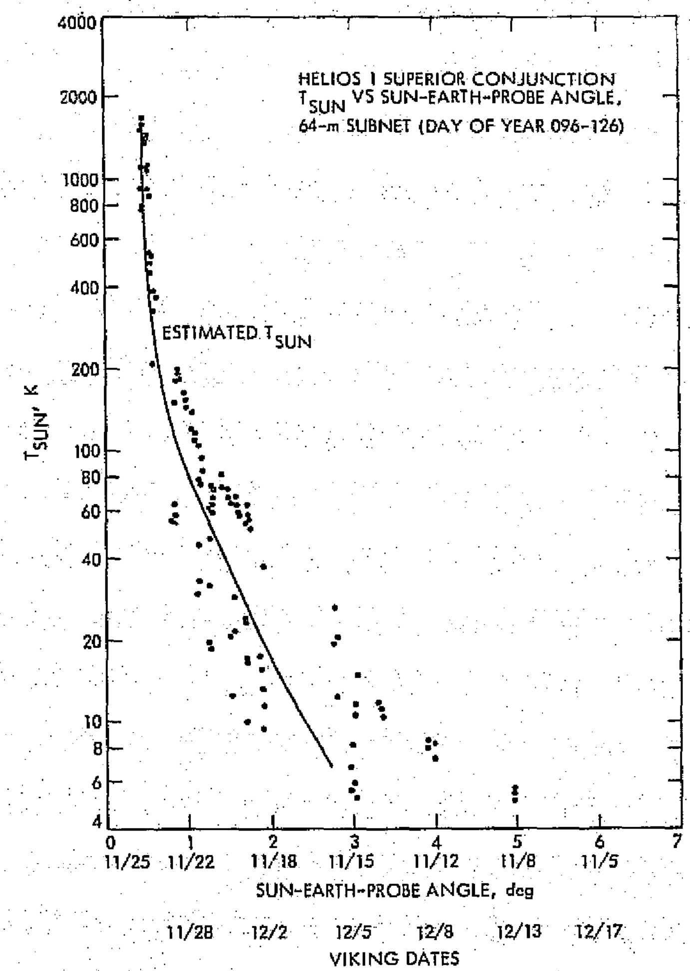


Fig. 27. System noise temperature (64-meter) as function of Sun-Earth-Probe angle

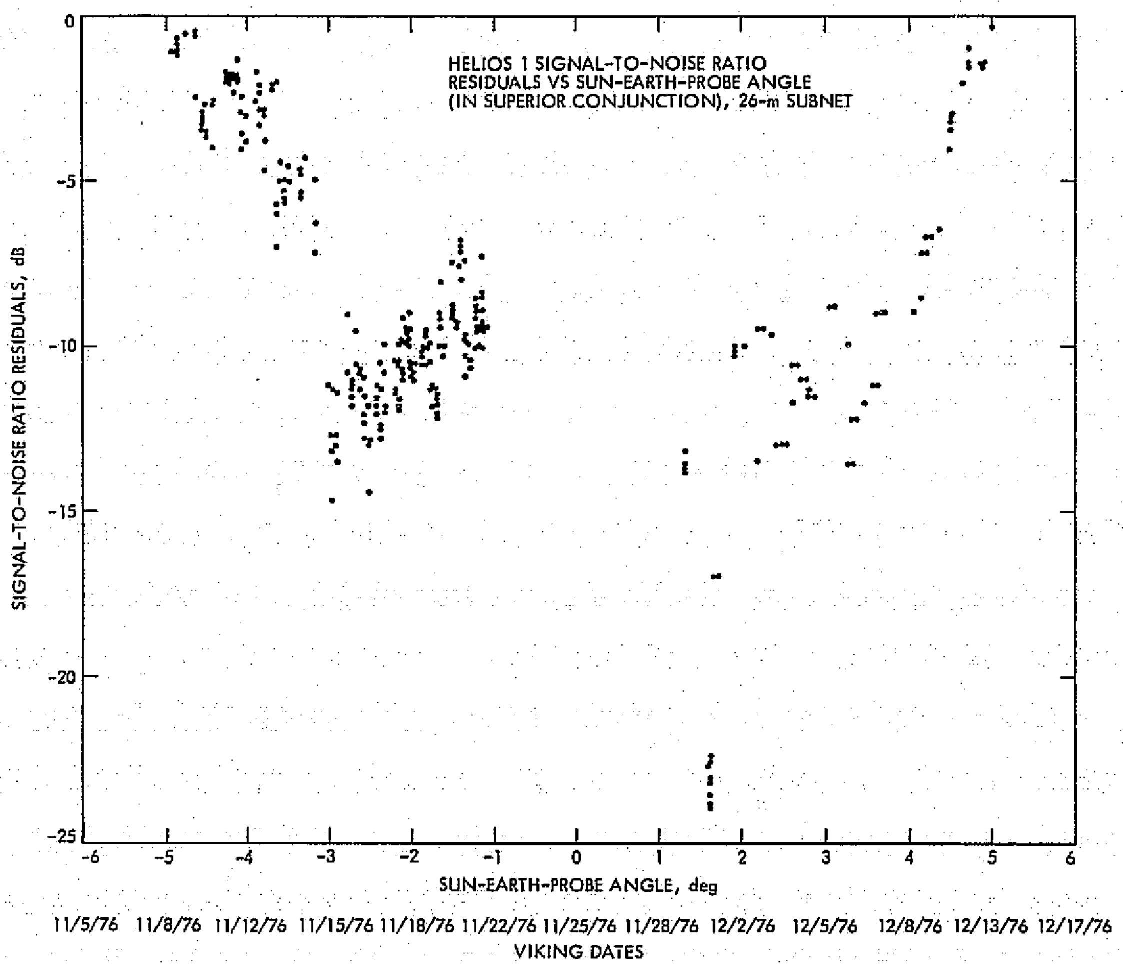


Fig. 28. Excess signal-to-noise ratio degradation (26-meter) as function of Sun-Earth-Probe angle

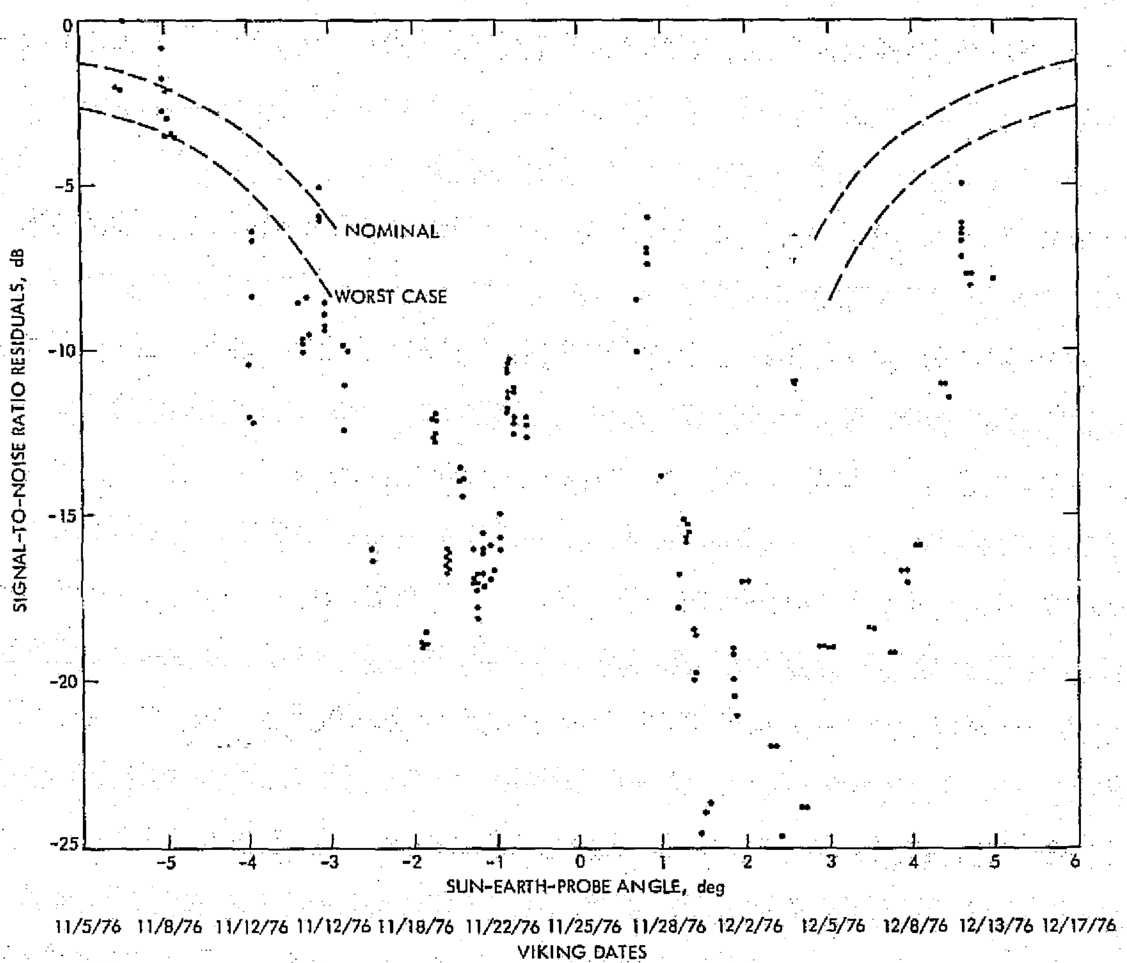


Fig. 29. Excess signal-to-noise ratio degradation (64-meter) as function of Sun-Earth-Probe angle

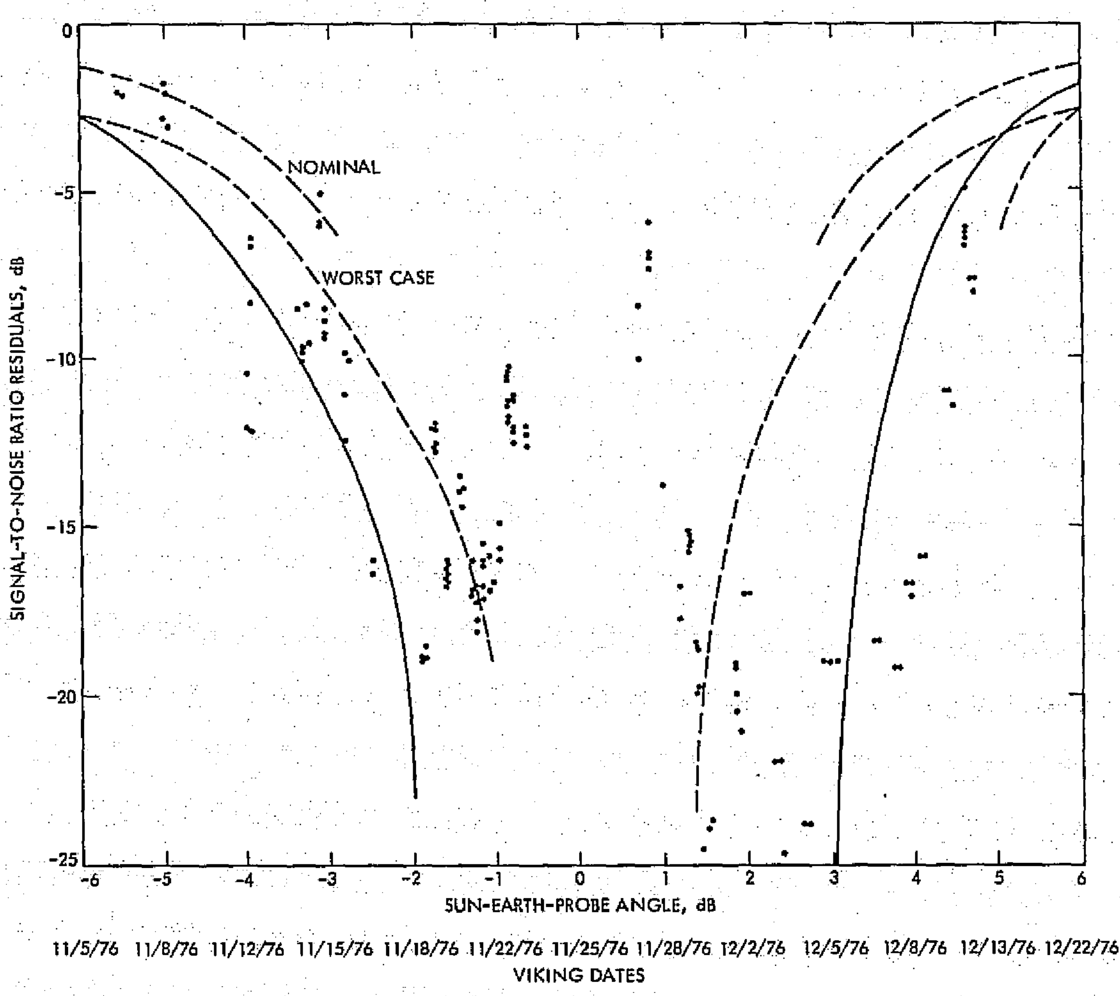


Fig. 30. All-purpose superior conjunction predicts

The Viking telecommunications analyst developed a program to compute the time and magnitude of the Network antenna "quadripod effect." Figure 31 visualizes the quadripod, and Figs. 32 and 33 (respectively) show the predicted system noise temperature increase resulting from the antenna pattern distortion caused by the presence of the quadripod. Figure 32 is for dates prior to November 25, and Fig. 33 for dates after that time. Note that temperature increases of thousands of degrees Kelvin are possible within a day or so of November 25, compared to the normal temperature of the 64-meter receiving system of about 20 degrees K. (As of November 22, temperatures up to 400 degrees K had been seen.)

Additional physical factors affecting communication link performance include the "sunspot number" and the "solar radio frequency flux." The solar activity is generally defined as "quiet" during the Viking superior conjunction period.

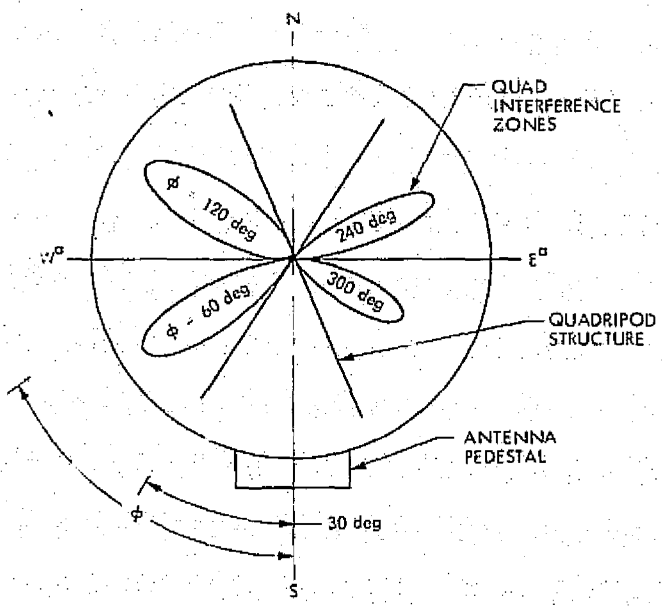
b. Superior Conjunction Observed Effects. The Viking superior conjunction occurred on November 25, 1976, with a minimum Sun-Earth-Probe angle of about 0.25 degrees. As of November 22, the Sun-Earth-Probe angle was slightly less than one degree, and significant effects had already occurred on all Orbiter links with the Network. However, radio metric data of good quality were still being obtained, and the low-rate 8-1/3 bps cruise data were still being received at an acceptable bit error rate.

An interesting look at how superior conjunction was affecting the link quantities that are familiar to Orbiter Telecom Performance Analysis Group appears in Fig. 34 through 41.

Figure 34 shows typical uplink signal level, downlink signal level, and low-rate signal-to-noise ratio during an earlier portion of the mission when these quantities were not disturbed by the Sun. Both high-gain and low-gain antenna operations are on this plot, which was taken during the Orbiter 1 Mission Orbit Trim No. 9. The uplink signal level happens to be going between three adjacent data numbers at a level of about -135 dBm prior to the maneuver, and between two adjacent data numbers following it. These were typical. The downlink signal level hardly varies at all, and the low-rate signal-to-noise ratio is steady as a function of time, and confined to a small portion of the plot.

Figures 35, 36 and 37 are taken about two weeks prior to the minimum Sun-Earth-Probe angle at a time that this angle was slightly larger than 4 degrees. This was the last Orbiter 1 pass in which high-rate data were present, at 2 kbps. The top plot of Fig. 35 shows the uplink signal level prior to a period of one-way. The signal level, although at -120 dBm, which is more than 15 dB higher than that in Fig. 38, scatters about 7 dB peak-to-peak.

The top two plots of Fig. 36 show the S-band downlink signal level from two different receivers at the station. Thus, the "glitching" that occurs on receiver No. 3 is an artifact, the automatic gain control from receiver No. 4 is closer to the truth. The automatic gain control is well-behaved. The bottom plot of Fig. 34 shows the low-rate channel signal-to-noise ratio (8-1/3 bps), and the bottom plot of Fig. 35 shows the high-rate channel signal-to-noise ratio (2 kbps). The scale of the low-rate signal-to-noise ratio is compressed by a



[a]REVERSE EAST-WEST FOR SOUTHERN HEMISPHERE

Fig. 31. "Quadripod" geometry reflector coordinate system (looking toward dish at horizon) defining azimuthal angle (courtesy of Viking Radioscience Team)

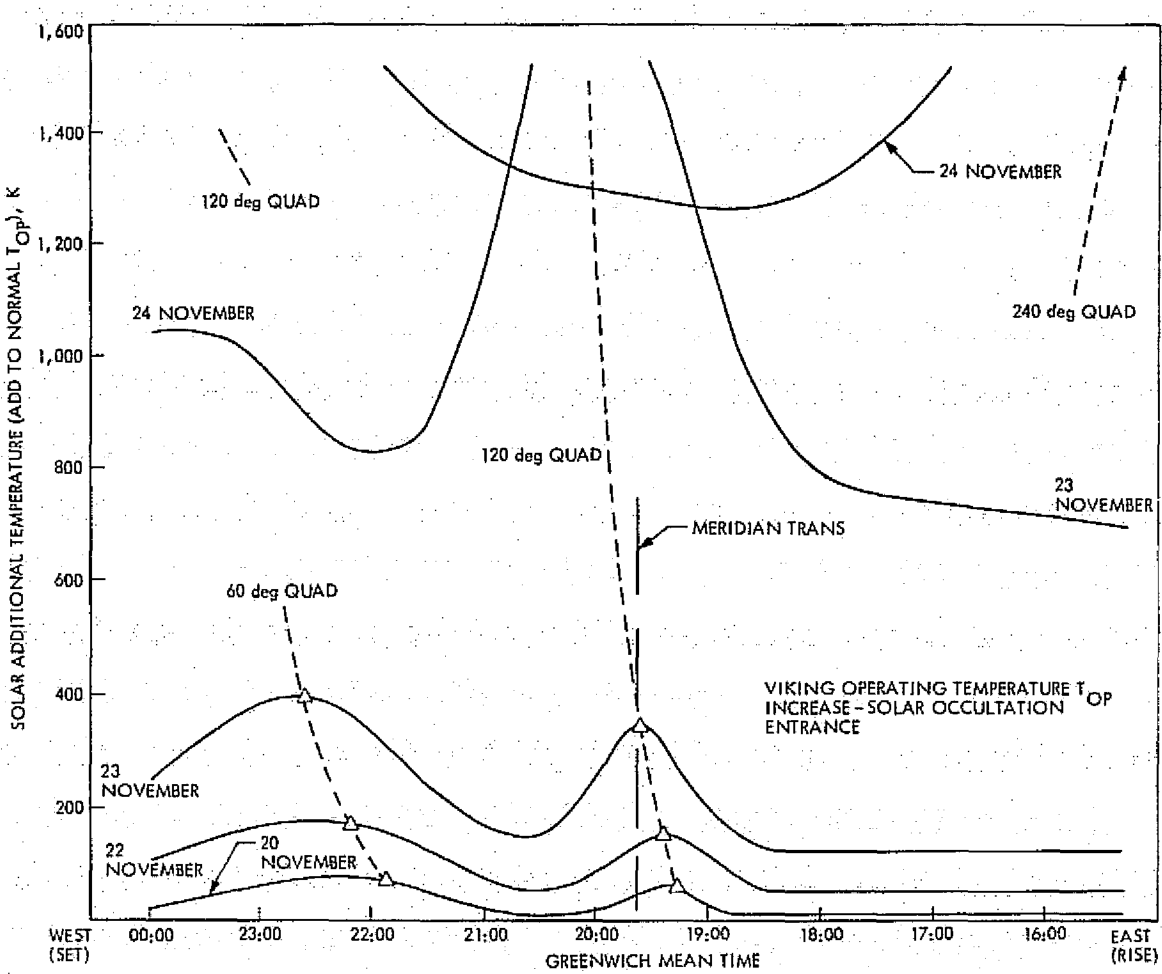


Fig. 32. Predicted system noise temperature increases for "Quadripod" (prior to November 25)

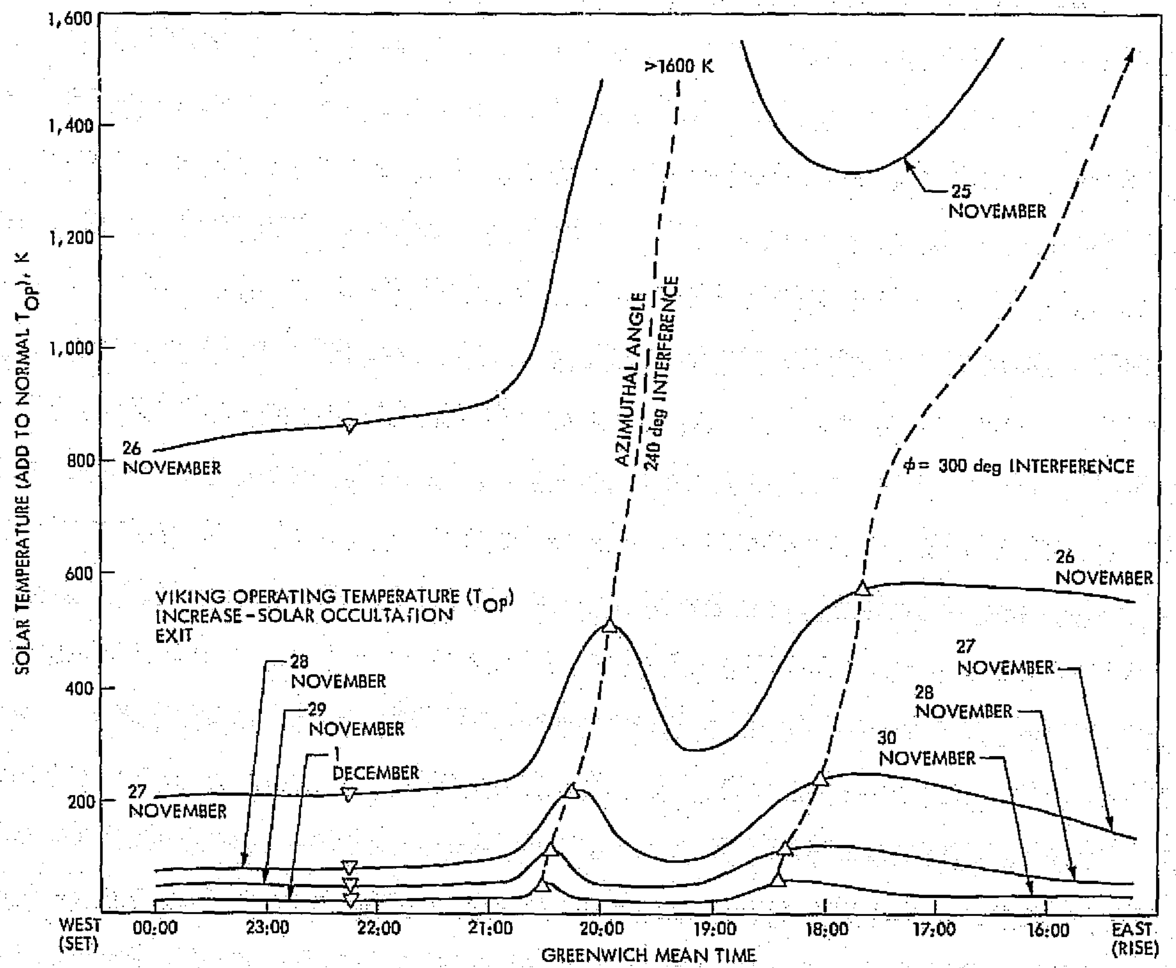


Fig. 33. Predicted maximum "Quadripod" system noise temperatures (after November 25) (courtesy of Viking Radioscience Team)

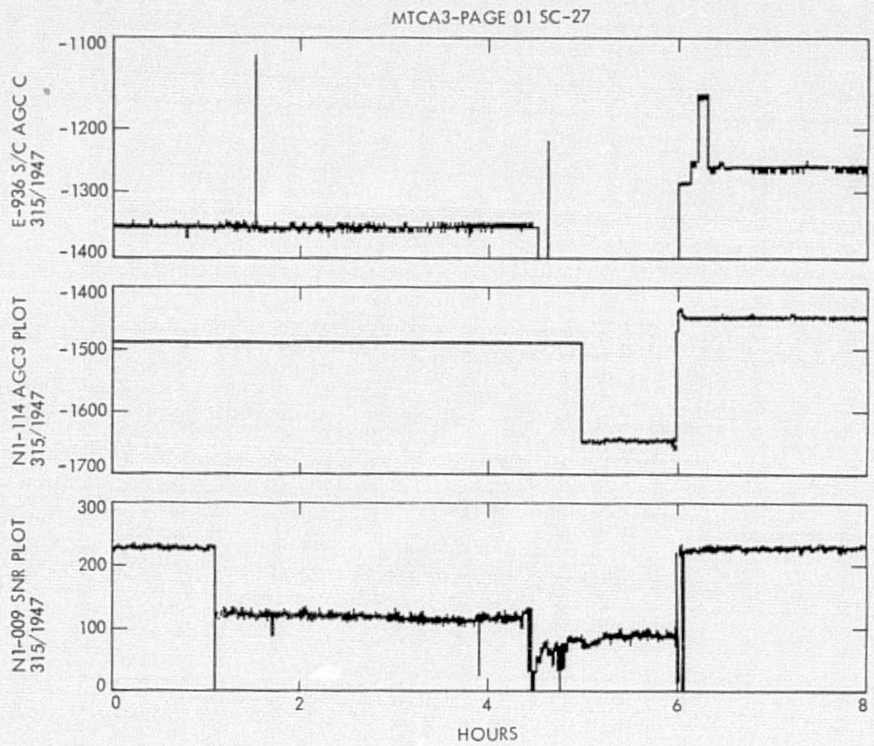


Fig. 34. Sample of telecommunications digital television plot prior to superior conjunction

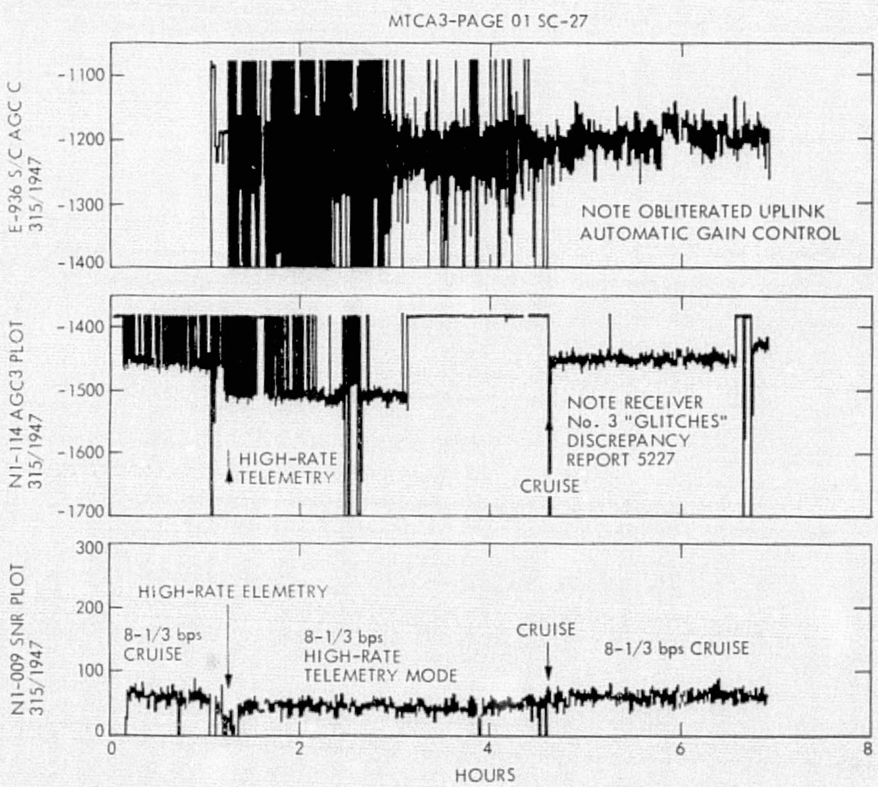


Fig. 35. Orbiter 1 pass 450 (November 11)

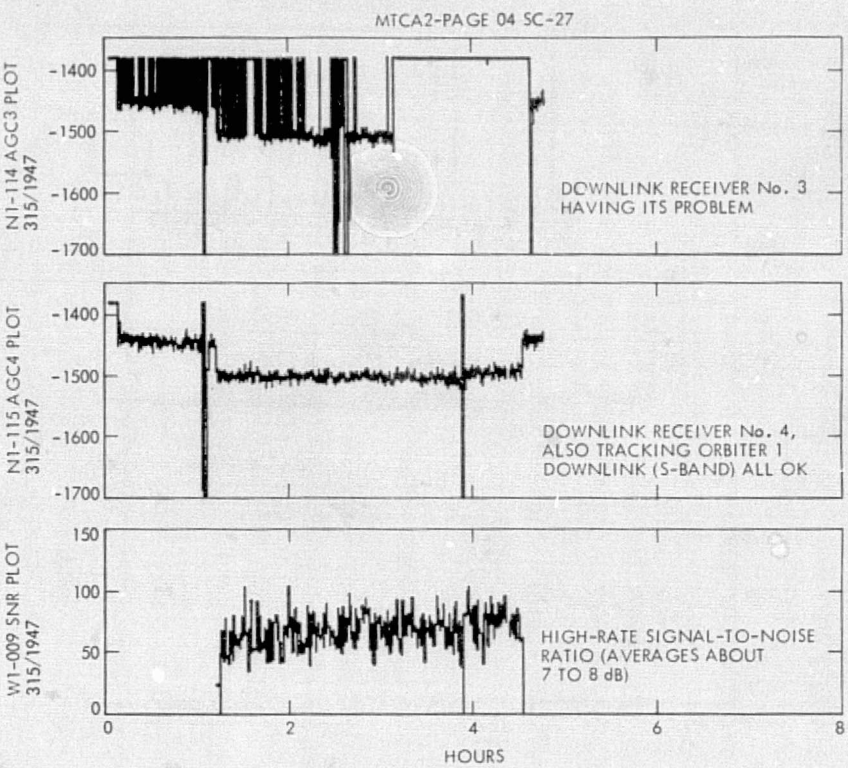


Fig. 36. Downlink quantities - Station 14 pass on November 11

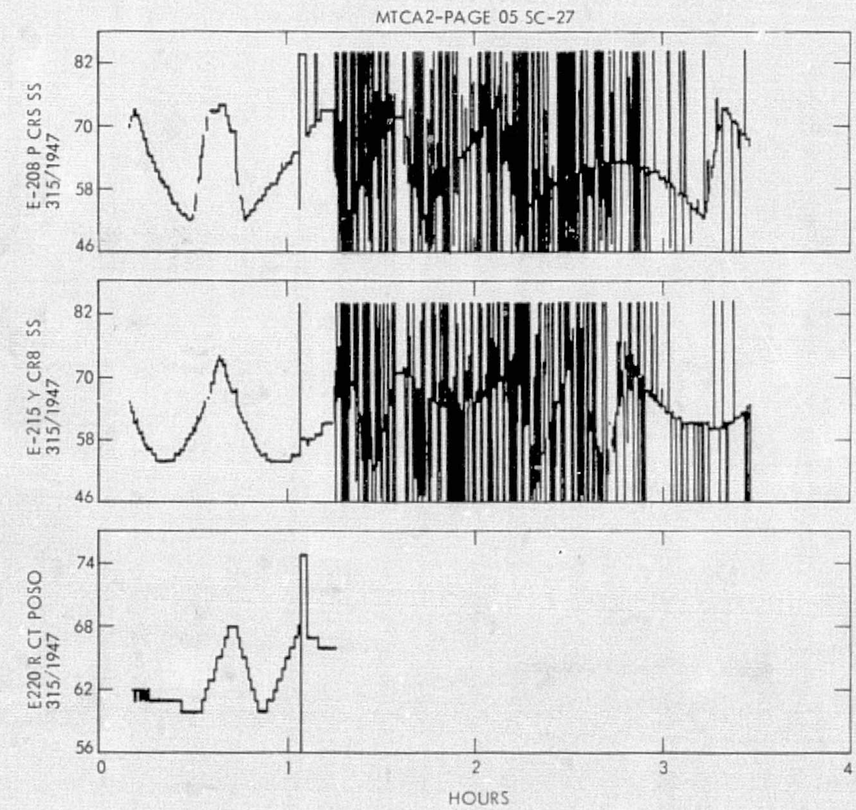


Fig. 37. Effect of bit error rate on 2 kbps high-rate

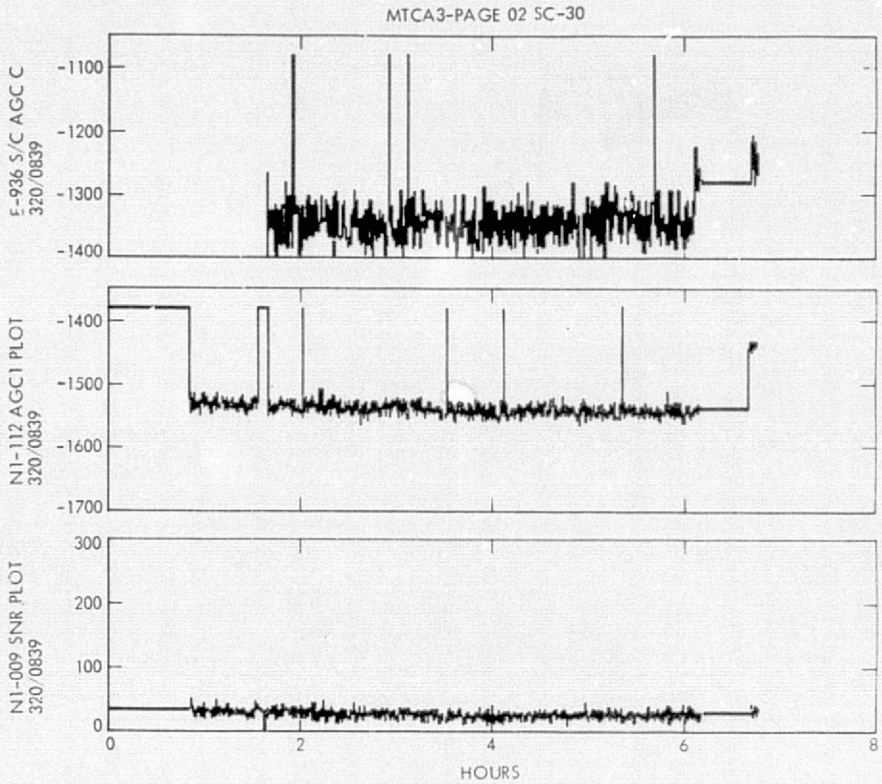


Fig. 38. Orbiter 1 pass 455, November 15, 1976, Station 61 (Sun-Earth-Probe angle = 3.0 deg)

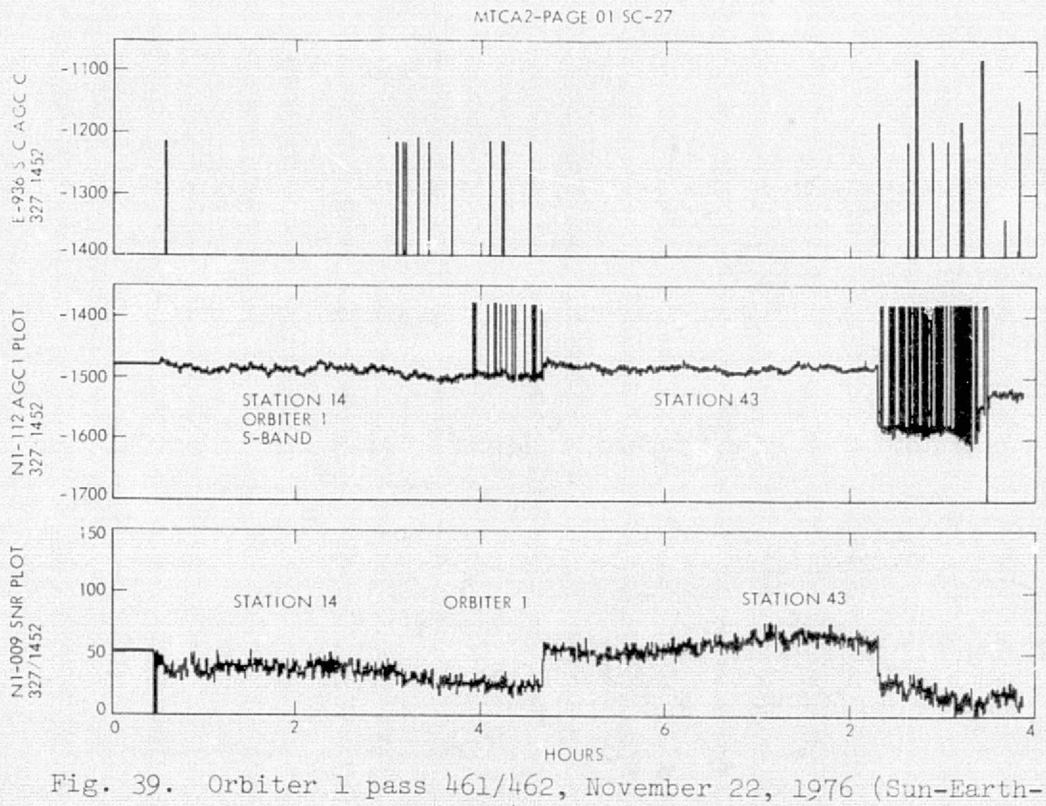


Fig. 39. Orbiter 1 pass 461/462, November 22, 1976 (Sun-Earth-Probe angle - 1 deg)

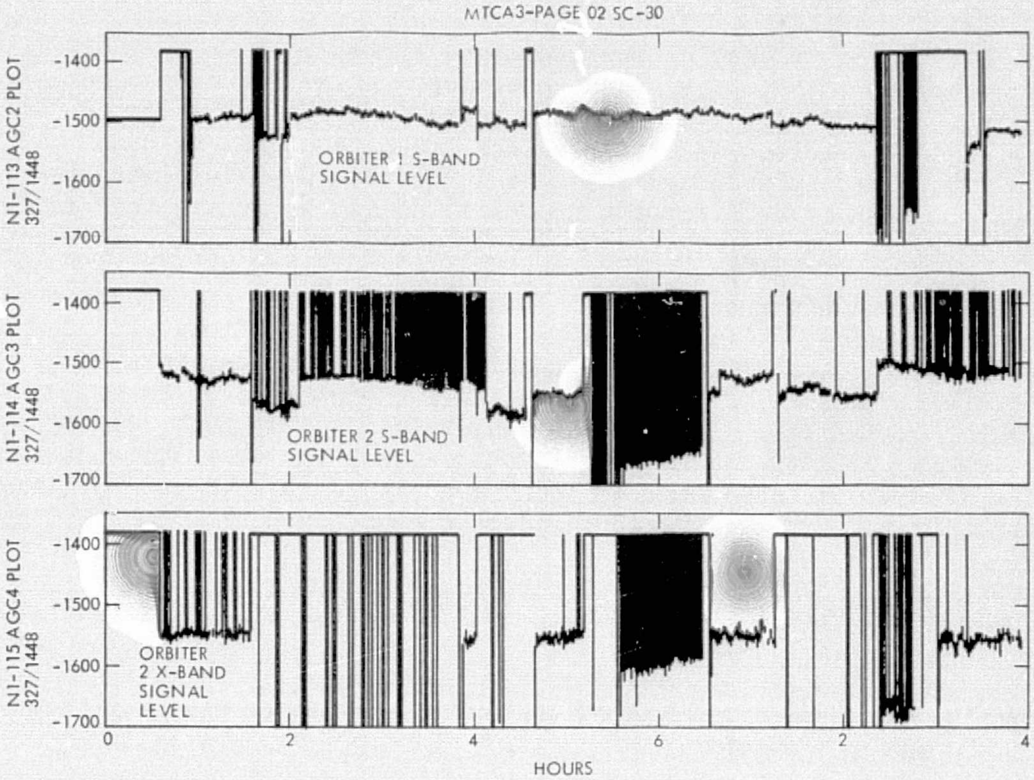


Fig. 40. Orbiters 1 and 2 passes 461/462 — 441/442, November 22, 1976 (Sun-Earth-Probe angle = 1 deg)

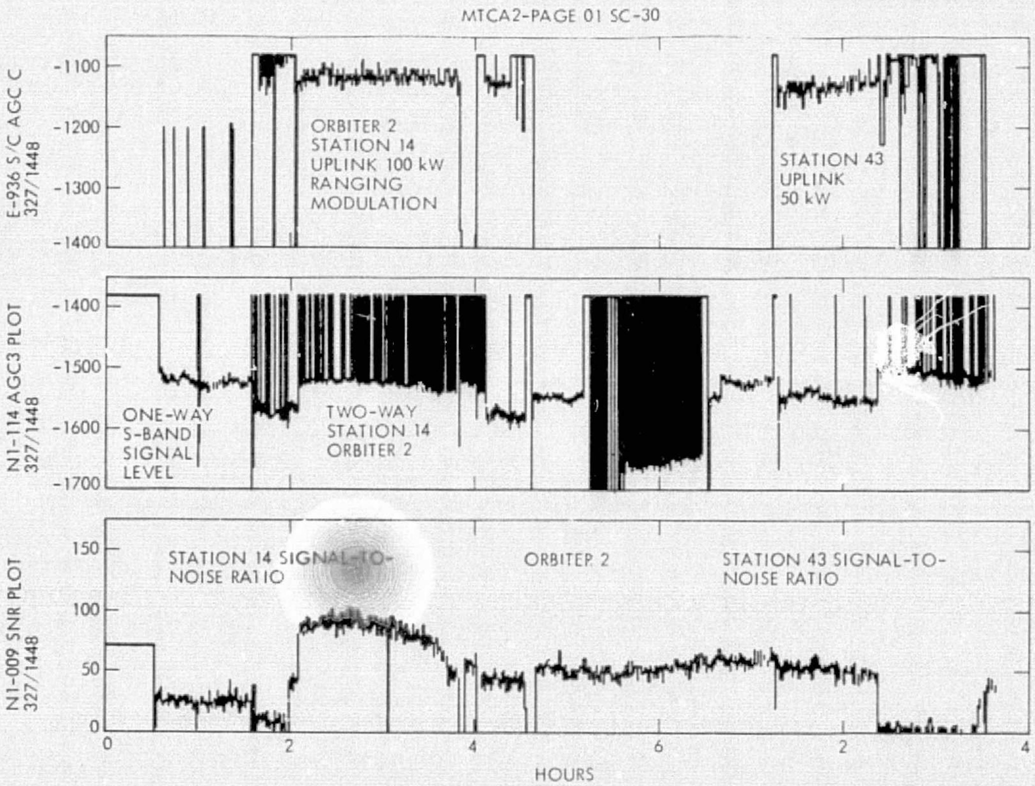


Fig. 41. Orbiter 2 pass 441/442, November 22, 1976 (Sun-Earth-Probe angle = 1 deg)

factor of 2 compared to that of the high-rate signal-to-noise ratio. It is immediately apparent that there is more scatter in the low-rate signal-to-noise ratio than in that of Fig. 34. And also there is more scatter in the indicated high-rate signal-to-noise ratio than in the low-rate signal-to-noise ratio. It is also a fact (but astonishing) that the indicated low-rate signal-to-noise ratio does not seem to be different in magnitude in the cruise mode than in the high-rate mode.

The link conditions continued to degrade even after the Orbiters were placed in cruise mode. Figure 38 shows the telecommunications plot for Orbiter 1 on November 15, 10 days prior to minimum Sun-Earth-Probe angle, when the Sun-Earth-Probe angle was three degrees. The uplink signal level is now scattering about 10 dB peak-to-peak. This is the maximum value that has been observed through November 22. The downlink signal level and the low-rate signal-to-noise ratio do not show much more scatter than is normal away from conjunction. This is probably due to the heavy "weighting" that exists in the Network software. The "residuals" are interesting.

(1) Uplink signal level mean residual, because of conjunction effects, is not more than 1 dB, through November 22, although the scatter about the average value can be very large. This scatter is asserted to be due to the lack of filtering in the spacecraft in the Radio Frequency System.

(2) S-band downlink signal level mean residual also shows little average degradation, at least until Sun-Earth-Probe angle approaches 1 degree. This is in comparison with the signal-to-noise ratio.

(3) The low-rate signal-to-noise ratio, which would be predicted to be 20 dB at a 26-meter station and 30 dB at a 64-meter station (neglecting "saturation" effects due to internal noise in the station equipment), has come down to the 2-dB range at 26-meter stations and the 2- to 7-dB range at 64-meter stations.

Figure 39 shows the Orbiter 1 and 2 link data during the November 22 Station 14 and 43 passes, when the Sun-Earth-Probe angle was less than one degree. During these passes, Orbiter 1 was one-way continuously, and Orbiter 2 had uplinks from both Station 14, at 100 kilowatts, and Station 43, at 50 kilowatts. Only ranging modulation was on the uplink.

All the "spikes" in the Orbiter 1 uplink are the result of bit errors in the most significant bit of the uplink telemetry word. Orbiter 1 S-band downlink was being monitored by the station receiver No. 1 (middle plot in Fig. 39). Note the variation. The vertical spikes represent periods of difficulty when the receiver was glitching out of lock. The Orbiter 1 low-rate signal-to-noise ratio shows long secular trends, and quite a difference between Station 14 and Station 43. Away from conjunction, the signal-to-noise ratio would remain within 1 to 2 dB, throughout.

A summary of the solar effects seen at various Sun-Earth-Probe angles is given in the "Notable Events" portion of this report, at about one-degree intervals of Sun-Earth-Probe.

c. Solar Conjunction Summary of Observations to Date (November 23, 7:50 am). Sun-Earth-Probe angle about 0.7 degrees.

Station 14 tracking. The average performance, through yesterday, both Orbiters 1 and 2:

(1) Uplink signal level — with 50 kilowatts from Station 43 and 100 kilowatts from Station 14, ranging modulation only — the average uplink signal level is degraded perhaps 1 dB at the most. The scatter is presently less than seen a little earlier, being 5 dB peak-to-peak. Absolute level is -111 dBm at Station 14.

(2) The two-way S-band downlink signal level may be degraded as much as 5 to 10 dB, in some passes, whereas the one-way is affected not more than 5 dB.

(3) X-band downlink signal level is partically out of receiver lock two-way, at 1-degree Sun-Earth-Probe angle, with signal level reading about -170 to -175 dBm. The predicted level is -153 dBm, neglecting solar effects. The one-way signal level is about -155 dBm, fairly stable. The stations are now adjusting loop bandwidth and other parameters, to optimize the S-band and the X-band tracking. Some of the variations reported are probably due to the changing configurations.

(4) Low-rate signal-to-noise ratio has been affected at Sun-Earth-Probe angles smaller than 2 degrees, by the one-way or two-way difference. It varies considerably over long periods during a single pass also, perhaps due to quadripod effects. The value is as low as 2 to 3 dB at 64-meter stations sometimes, and as high as 7 or 8 dB.

(5) Bit error rate during the Station 14 pass on November 22 was quite variable, going from a low of 6×10^{-3} up to about 4×10^{-2}. This is consistent with the variability noted in the signal-to-noise ratio. The bit error rate is significantly higher at 1 degree Sun-Earth-Probe angle than it was at 2 degrees.

5. Antenna Maintenance

In mid-August, 1976, a potentially serious problem with the hydrostatic bearing became evident at Station 14 at Goldstone. The problem lay in the difficulty of maintaining a satisfactory oil film height between the hydrostatic bearing and the pad. The area of concern lay between azimuth 128 degrees and 140 degrees, which had a history of deterioration since the antenna was built. The previous history predicted a failure condition arising about every 3 months, although the film height had been stable for several months at that time. Nevertheless, the last maintenance had been carried out in June, using a skimming technique that could no longer be used for further maintenance. Further delay in correcting the problem could only increase the chance of catastrophic failure.

A new technique, which required an 18-hour down time on seven successive days had been developed. It also entailed some risk of no success on the first few attempts since the method had never been used before. A failed attempt would have required a two-week period to recover and return the antenna to operations.

Coming as it did at such a critical time in the mission, just prior to the second landing, the situation and issues involved were of concern to the Network and to the Project.

Accordingly, a plan was put into effect that required daily measurement and reporting of the oil film height against an established set of safety criteria. In this way, some warning of a deteriorating situation would become visible, permitting a reevaluation of the risk involved in continuing operations. It was also decided that a firm work plan for refurbishment would be scheduled for November 15, or sooner, if the bearing showed any signs of deterioration prior to that time.

This plan worked very well. The oil film height remained in a stable condition through November 5, at which time, the operational usage of Station 14 was such that the work was started and carried out on alternate week days to a successful completion on November 19, 1976.

A cross-sectional diagram of the hydrostatic bearing, ball and socket, pad and grout is given in Fig. 42.

A further incipient problem had been known for some considerable time in the ball and socket joint (see Fig. 42) on the antennas at Stations 43 and 63. An inspection carried out in late 1975 had revealed that the joint which permitted the pad to rotate as it followed the contours of the number was "frozen" because of a lack of proper lubrication. Prolonged attempts to force grease into the joint under high pressure were unsuccessful, so a spare unit was shipped to Canberra in January 1976. Prior to installation, this unit was found to be defective and was returned to the United States. New units were ordered for both Station 63 and 43 since the Station 14 units were satisfactory. Installation was then postponed to the period November 15 through December 15 when the stations were not expected to be required because of solar conjunction.

Fortunately, the ball and sockets gave no trouble during the Mission, and eventually the Madrid station replacement was made in November and December of 1976. Since the Canberra station was required to support the Viking Relativity Experiment during solar conjunction, the ball and socket replacement was deferred until March 1977. No deleterious effects appeared.

B. NETWORK OPERATIONS CONTROL CENTER

1. Performance

The performance of the Network Data Processing Terminal showed a steady improvement in the data percentage and delivery times of telemetry Intermediate Data Records during the last three months of the Mission.

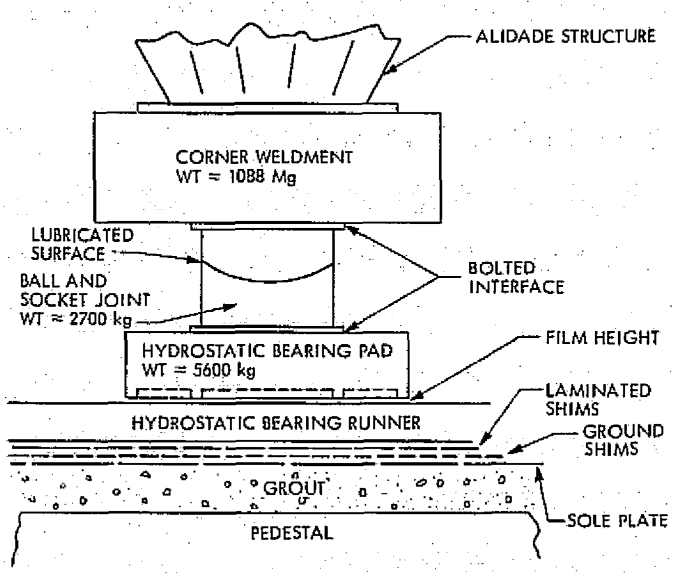


Fig. 42. Hydrostatic Bearing and Ball Joint Assembly

Table 7 shows the statistics covering the quantity, quality, and delivery times achieved during the period encompassing July 20 through October 20, 1976. There were 573 Intermediate Data Records delivered with an additional 79 Remake/ Supplemental Intermediate Data Records requests completed. An average of 99.991 percent of the required telemetry data was recovered and delivered within seven hours from scheduled loss-of-signal at the 64-meter stations. Of this total, 36 Intermediate Data Records were late (6.3 percent of the total) in their entirety. Approximately 30 more were delivered partly completed. Of special significance is the drastic decrease in the average delivery time between the first and second month. In both of these time periods, Intermediate Data Records were normally delivered within 15 minutes of generation. (The third period reflects a tendency to wait for the completion of all Intermediate Data Records from one station, prior to pickup.) Additionally, there were periods where the Network Operations Control Area was not manned for pickup during midnight shifts. The improvement in time was the result of systems enhancements and the learning curve within the Network Data Processing Terminal.

A slight improvement in the data quantity (99.983 percent to 99.995 percent) delivered can be attributed to the same improvements. Because of the current state of the hardware and software systems, only more recall time could provide any increase in the percentage of data delivered. Any further increase would appear to require further system enhancement or require a trade-off in percentage delivered versus delivery times.

Table 8 shows the number of tapes written during the accomplishment of the Intermediate Data Record task. However, the ratio of number of Network Data Logs to number of passes during the first period is indicative of the number of tape-read errors and processor problems encountered during that period.

Table 7. Intermediate Data Record quality summary

Time period, day/h	No. of passes	No. of remakes	Average data content,[a] %	Average delivery time	No. of deliveries exceeding 24h[b]
202/1500Z 233/1500Z	160	42	99.983	10 h 27 m	17
233/1500Z 264/1500Z	192	10	99.996	4 h 52 s	6
264/1500Z	221	27	99.995	6 h 20 s	13
202/1500Z 264/1500Z	573	79	99.991	7:00	36

[a]487 of the records delivered had only two or less data blocks missing.

[b]Average late delivery time was 36 h.

Table 8. Data records support summary

Period	Passes	Remakes and supplements	Network data logs	Recalls	Intermediate data records	Tapes	Average number of data records per pass
20 July 20 August	160	42	476	359	476	1311	2.975
20 August 20 September	192	10	369	325	405	1099	2.109
20 September 20 October 294/1500Z	221	27	393	440	480	1313	2.172
Total for 3-month period	573	74	1238	1124	1361	3723	2.375

The ratio of Intermediate Data Record to number of passes was also high during this period. The Major problem was the number of halts and read errors experienced that resulted in generation of fragmented Intermediate Data Records. Many of the Records were pieced together from several passes through the data, resulting in an inefficient use of tapes and time.

One of the major factors impacting Intermediate Data Record generation was the limited amount of time available for data recall. With only two wide-band lines available, and three stations (64-meter) engaged in around-the-clock support, there was little time available for extended recalls.

Under normal conditions, with the Data Records Processor and Automatic Recall System interface working, there is sufficient time to meet all requirements and insure a high percentage Intermediate Data Records. However, 6.3 percent of all Intermediate Data Records (36) have been one or more days late because of recall and/or playback problems. This resulted from hardware malfunctions at either end, high numbers of unrecallable gaps, systems interface problems, or tape-read problems encountered after the station has been released.

2. Intermediate Data Record Production

There are several areas where problems can impact the production of Intermediate Data Records within Viking Intermediate Data Record system support requirements. These are logging (Network Data Logs), recall (to include gap editing), and merge.

a. Logging Function. The Network Log Processor provides the interface between the Network Data Processing Terminal and the rest of the Network. All incoming and outgoing traffic is routed through it. As the data are received by the Network Log Processor, they are logged on one of four Network Data Log tapes as shown in Fig. 43. Because the Network Log Processor doesn't validate what it writes, improperly written data blocks or records are not detected until the Network Data Log is used in the merge process.

b. Recall Function. The recall function of the Data Records Processor interfaces with the Automatic Telemetry Recall System program in the station Telemetry Command Processor. Edited gap lists are received from the Network Support Controller (Sigma V) and stored on the Data Records Processor disc files as shown in Fig. 43. Typical problems are:

(1) No response or improper response from the Telemetry and Command Processor.

(2) Telemetry and Command Processor acknowledged, tape positioned, but no data are received.

(3) Blocks rejected due to time range error. Data received are outside the time range of the active recall request. Either the data contain a timing anomaly, or the Telemetry and Command Processor's high-speed

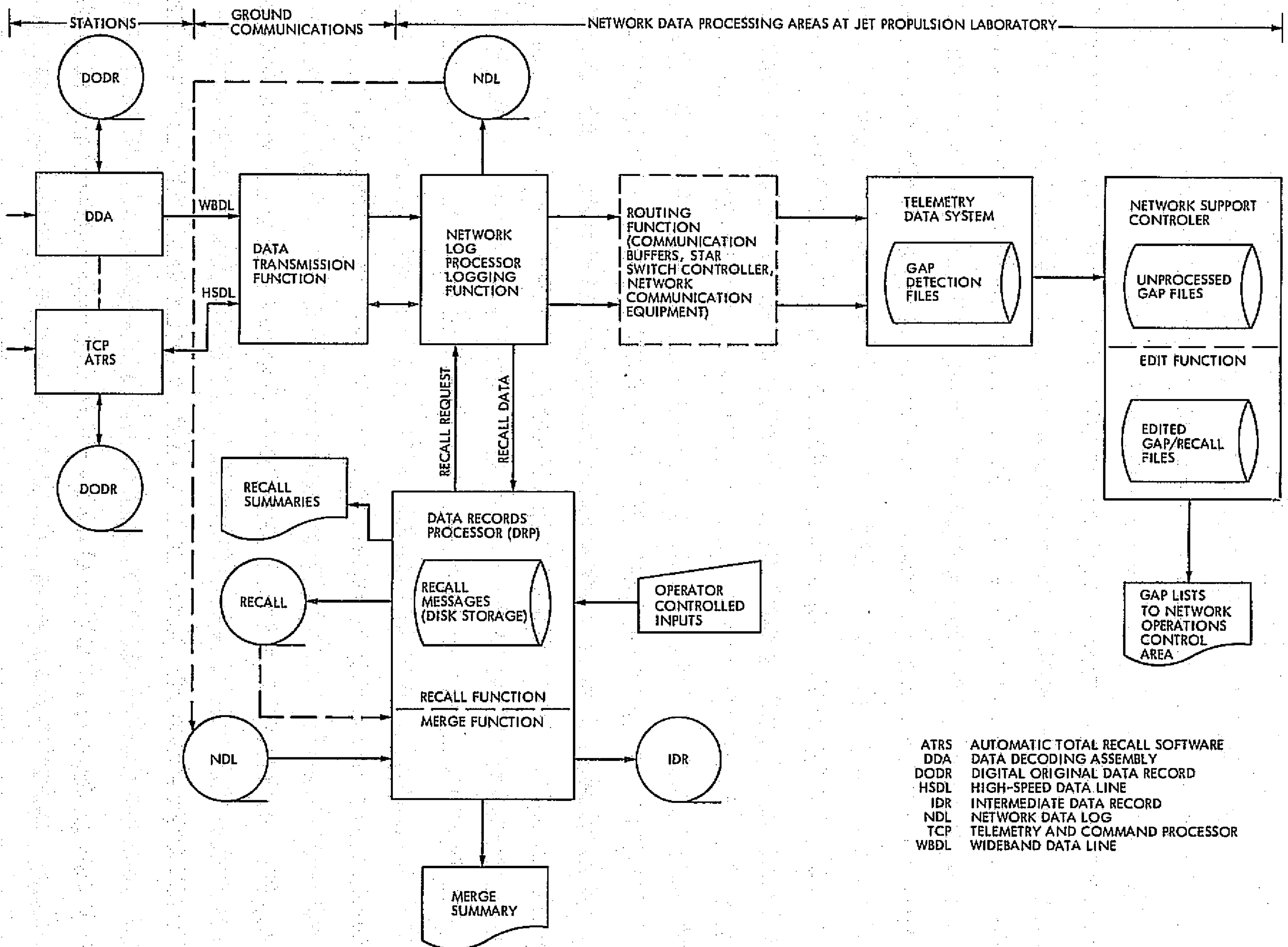


Fig. 43. Data flow for Intermediate Data Record production

status block is received prior to the last block of wideband data transmitted. The latter problem is a result of different routing of the high-speed and wideband data streams.

(4) Systems failure in the Real Time Telemetry Processor, the support controller or the Data Record Processor software, requires a reload of the system resulting in deletion of the edited gap list files.

(5) Delays in producing edited gap lists because of excessive gaps and slow printer rate.

c. Merge Function. The Merge Processor is the first place the validity of the Network Data Log and recall tapes are checked. Until the merge summary prints out, or the system alarms over a read error, there is no way of insuring that the data are recoverable.

Anomalies that continued to hinder the merge process are as follows:

(1) System will not read because of apparent parity error.

(2) Merge Program terminates on "terminal read error."

(3) Incorrect indication of end of data on recall tapes.

(4) System halts: this still occurs on a random basis and only a system recovery/reload can restore operations.

(5) Data block time tag error.

By the end of the mission, there were several improvements being considered for addition to the existing system. In the order of their potential for improving Intermediate Data Record production, they were:

(1) New magnetic tape controller (hardware) and handler software.

(2) Merge Program revision to allow reading Network Data Log's past "terminal" error records.

(3) Recall processor patch to allow data to be logged to the recall tape after the status block is received.

C. NETWORK SYSTEM PERFORMANCE

The performance of the Network Command, Telemetry, Tracking, and Monitor Systems in support of the Viking Mission from July 20 through the end of Mission on November 15, 1976, is given in the following paragraphs.

1. Command System

The performance of the Network Command System in supporting planetary operations with Viking Landers 1 and 2, and Viking Orbiters 1 and 2 is given in Table 9 in terms of the monthly number of commands transmitted by spacecraft. The cumulative total for the entire mission is also included. The loss of command capability due to either ground communication outages or station failures is presented in Table 10 for each spacecraft on a monthly basis. The cumulative totals for the entire mission are included along with the number of aborted commands experienced.

A better appreciation of the remarkable reliability of the Network Command System support for Viking is obtained from the following summarized facts:

Number of spacecraft	4
Number of stations	9
Number of days of operation	360
Number of commands transmitted	73,795
Number of commands aborted	3
Percentage of time Command System in operation	97.2

As the complexity of the mission increased with the arrival of the second Lander for a total of four spacecraft, the demands on the Command System likewise increased. With increased utilization, the number of anomalies likewise increased significantly in August as the monthly summary shows in Table 11. There were no significant failures or anomalies for Lander 1 in September 1976, and there were no significant anomalies for Landers 1 or 2 during October or November. In September some improvement was noted as the system matured and personnel settled down to high-activity operations. The improvement continued through October and had become negligible as the mission ended in November.

Table 9. Number of commands transmitted during August through November 1976

Month	Orbiter 1 (Spacecraft No. 27)	Lander 1 (Spacecraft No. 26)	Orbiter 2 (Spacecraft No. 30)	Lander 2 (Spacecraft No. 29)
August	4,706	3,364	4,321	660
September	4,745	20	2,578	2,374
October	5,024	526	4,921	2,598
November	1,108	218	1,812	154
Cumulative Total for Mission	29,668	11,922	19,828	12,377

Table 10. Command capability lost due to ground communications or station failures as a percentage of scheduled tracking time

	Lander 1		Orbiter 1		Lander 2		Orbiter 2		
Month	GC	DSS	GC	DSS	GC	DSS	GC	DSS	Aborts
August	0.0	0.0	0.8	1.8	0.0	0.65	0.78	0.33	None
September	0.0	0.0	0.9	0.39	0.0	0.37	0.9	0.85	None
October	0.0	0.0	1.94	0.11	0.0	0.0	0.46	0.32	None
November	0.0	3.66	0.2	0.98	0.12	0.62	0.3	0.42	2
Cumulative total for Mission	0.00	0.9	0.22	0.8	0.01	0.13	0.22	0.53	3

GC ground communications
DSS Deep Space Station

Table 11. Significant command anomalies by pass in August through November 1976

Station	Pass	Subsystem	Spacecraft	Comments
43	349	Antenna	Orbiter 1	Workman inadvertantly hit stop button on the antenna. Outage time was 1[illegible] minutes
61	360	Transmitter	Orbiter 1	Lost transmitter due to a burned out high-voltage fan. Command was impacted by 5[illegible] minutes
14	361	Transmitter	Orbiter 1	Two-way transfer between Station 11 and 14 impacted commanding for 1 hour due to poor predicts generated by Network Operations Control Area
14	364	Command Modulator Assembly 1	Orbiter 1	Intermittant subcarrier frequency alarms. Command System was degraded 40 minutes
61	370	Exciter	Orbiter 1	A bit verify alarm was received due to marginal confirmation phase detector. Outage time 30 minutes
61	371	A antenna	Orbiter 1	Photo reader on the Antenna Pointing Subsystem failed, impacting command for 1 hour 9 minutes
61	375	Transmitter	Orbiter 1	Operator forgot to turn the transmitter off after command test was performed. Therefore, at time the transmitter was supposed to go on, it was turned off. Outage time was 39 minutes
14	364/ 2[illegible]	Command Modulator Assembly 1	Lander 1	Received subcarrier frequency warning and abort alarms. The system was degraded for 40 minutes
43	370/ 32	Command Modulator Assembly 2	Lander 1	Station received data quality symbol period, watchdog timer, and configuration word check alarms. Outage time was 1 hour 37 minutes
43	371/ 34	Antenna	Lander 1	The emergency stop button at the antenna was inadvertantly pressed. Commanding was impacted by 1 hour 31 minutes
43	378/ 41	Command Modulator Assembly 2	Lander 1	Symbol period warning and abort alarms were received. Outage time was 3 minutes
14	335	Telemetry and Command Processor 2	Viking 2	A reload on Telemetry and Command Processor/Command Modulator Assembly Beta was performed due to a memory parity error. Outage time 12 minutes
6[illegible]	336	Telemetry and Command Processor 2	Viking 2	Operator inadvertantly took the system down. Outage time 56 minutes
63	342	Telemetry and Command Processor 2	Viking 2	Unable to get response for Telemetry and Command Processor/Command Modulator Assembly Beta while checking Command system. Outage time was 18 minutes
11	342	Low-power transmitter	Viking 2	Heat exchanger purification loop sight glass broke. Command capability was lost for 1 hour 11 minutes
11	343	Command Modulator Assembly 1	Viking 2	Received subcarrier frequency alarms. Switched to Command Modulator Assembly 2. Outage time was 6 minutes
14	350	Command Modulator Assembly 1	Viking 2	Subcarrier frequency warning and abort alarms were received. Outage time was 3 minutes
11	379	Command Modulator Assembly 2	Orbiter 1	Station received data quality warning alarms degrading the Command System for 1 hour
12	382	Frequency and Timing Subsystem	Orbiter 1	Intermittent symbol period alarms on both Telemetry and Command Processor/Command Modulator Assembly. A bent pin in one of the cables was found and corrected. The system was degraded for 43 minutes
61	383	Low-power transmitter	Orbiter 1	Lost the transmitter due to low magnet flow undercurrent. Outage time was 15 minutes
14	390	64-m antenna	Orbiter 1	Antenna went to brake due to low-voltage distribution, which tripped the circuit breakers. Command was impacted for 32 minutes
43	401	Block IV exciter assembly	Orbiter 1	Command was impacted by 22 minutes due to operator error while tuning
43	407	64-m antenna	Orbiter 1	The counter-torque motor on number 4 gear reduced flange seal burst. Command outage was 4 hours and 11 minutes
14	361	Command Modulator Assembly 2	Orbiter 2	Subcarrier frequency warning and abort limit were received. Command system was degraded for 2 hours and 56 minutes

Table 11. (Contd)

Station	Pass	Subsystem	Spacecraft	Comments
11	381	Commercial power	Orbiter 2	Power glitch caused a loss of the prime Telemetry and Command Processor/ Command Modulator Assembly impacting command for 20 minutes
11	382	Commercial power	Orbiter 2	Commercial power to the transmitter was momentarily lost causing 24 minutes command outage
43	369/ SOL 7	Block IV Exciter Assembly	Lander 2	Programmed Oscillator Control Assembly exciter continued to tune beyond the desired frequency. The impact to command was 29 minutes
42	410	Frequency and Timing Subsystem	Orbiter 1	Received symbol period abort and warning limit alarms from all 3 Command Modulator Assemblies in conjoint station
11	430	Power	Orbiter 1	Both Telemetry and Command Processors were taken down due to a power failure
14	439	Block IV Exciter Assembly	Orbiter 1	Wrong exciter frequency selected for transmitter turn-on; operator error
42	440	Block III Exciter Assembly	Orbiter 1	Uplink transfer not successful
43	390	Frequency and Timing Subsystem	Orbiter 2	Received symbol period abort and warning alarms
14	399	Block IV Exciter Assembly	Orbiter 2	Maser lost helium
14	400	Command Modulator Assembly 2	Orbiter 2	Received subcarrier alarms from Command Modulator Assembly B which was prime
61	407	Low-rate transmitter	Orbiter 2	400-Hz motor generator which was high transmitter failed. Transmitter arc detector failure
42	411	26-m antenna	Orbiter 2	Antenna drove off point faulty Filbrick Amplifier
61	413	Block III exciter assembly	Orbiter 2	Maser Failure
61	419	26-m antenna	Orbiter 2	Late acquisition of signal due to antenna failure, going to emergency brake
14	426	Block IV exciter assembly	Orbiter 2	Two command aborts due to exciter frequency alarms
11	431	CMA	Orbiter 2	Checksum error causes high-speed data line blocks to be rejected by real-time monitor

2. Telemetry System

a. Operational Support. The Deep Space Network Telemetry System probably saw the peak of its activity with the heavy support of the Viking Project during the month of August. The Mission Orbiter Insertion of Viking 2 on August 7 and preparations for the successful landing on September 3, in addition to the required Viking 1 support, created considerable activity throughout the system.

Selection and certification of a landing site and the necessary orbit trim maneuvers constituted most of the Viking 2 activity. Orbiter 1 was transmitting imagery data and results from science experiments during this period.

The Viking project was supported by all stations.

(1) Lander 1 was supported by only the 64-meter network for a total of 26 tracks.

(2) Orbiter 1 was supported by both the 26-meter and the 64-meter networks. The 26-meter network was used for 69 tracks and the 64-meter network for 86 tracks.

(3) Orbiter 2 was supported by both the networks. The 26-meter network was used for 36 tracks and the 64-meter network for 90 tracks.

Because of the critical phases of the Viking Project operations, much of the Deep Space Network was under configuration freeze. Also, the analysis personnel were busy with Lander 1 direct link, Orbiter 2 Mars Orbit Insertion, and preparation for the Lander 2 landing. Therefore little new system information became available during August.

Support of the Network telemetry system validation and Intermediate Data Record generation by the Block III Network Data Processing Area/Network Data Processing Terminal system continued during August.

A test to confirm ability of the above system to produce Intermediate Data Records was tested in the form of an Intermediate Data Record Production Verification Test conducted during August. This three-hour test consisted of a playback of a 36-minute segment of a Viking Digital Original Data Record from Compatibility Test Area 21 to the Network Operations Control Center, followed by recall and merge of three deliberately-introduced data gaps. Already hampered by facility scheduling problems and by lack of actual telemetry data on the Digital Original Data Record, the test revealed two anomalous results in the Network Support Computer: disappearance of gap from the unedited gap list, and failure of a gap to be deleted upon command. Nonetheless, the test was considered to have fulfilled its objectives according to the final report, having demonstrated that the other components in the data recall process were capable of producing an Intermediate Data Record in a timely manner.

In September and October, Lander 1 was supported by the 64-meter network exclusively at a predominant rate of 500 bps coded. Lander 2, also exclusively by the 64-meter net, had support at a predominant rate of 250 bps coded. Orbiters 1 and 2 were supported by both the 26- and 64-meter nets at Stations 11, 14, 42, 61, 62, and 63. The predominant low rate was 33.3 bps uncoded and the high rate was 8000 bps coded.

With the start of the Mars/Viking solar conjunction period, degradation on low-rate uncoded bit signal-to-noise ratio began to be observed. This effect, due to solar corona effects, continued until 25 November 1976, when the Sun-Earth-Probe angle reached its minimum value, ~0.263 degrees. There was data collection for a study of Viking superior conjunction telemetry performance. October hourly S-band and X-band signal-to-noise ratio readings were requested of the Stations, for analysis by the Network Operations Analysis Group.

A problem was discovered with the X-band downlink signal level at Station 43. Degradation by approximately 1 to 3 dB occurred whenever the S-band transmitter was turned on. This degradation was found to be a result of the uplink S-band fourth harmonic producing some saturation towards the higher end of the X-band maser band pass. Engineering Change Order 75.236, already installed at Station 14, and scheduled for installation at Stations 43 and 63 in the near future, were expected to solve the problem.

Lander 1 was tracked by Stations 11, 14 and 43 during November at predominant rates of 8-1/3 bps at Stations 11 and 14, and 8-1/3 and 500 bps at Station 43, while Lander 2 was supported exclusively by Station 14 at a predominant rate of 8-1/3 bps uncoded.

Orbiter 1 was supported by both the 26-meter and 64-meter networks at Stations 11, 14, 42, 43, 61 and 63. Predominant rates were 8-1/3 bps at the 26-meter sites and 8-1/3 and 4k bps at the 64-meter sites. Orbiter 2 was supported at the same sites with an additional site being Station 62. Predominant rates were also identical with the exception of 8k bps at the 64-meter stations.

For the entire month of November, Viking/Mars was in superior conjunction. The minimum Sun-Earth-Probe angle reached its minimum value of ~0.263 degrees on November 25 (the spacecraft also was occulted for a short time by the south polar region of the Sun). Solar corona effects caused severe degradation of telemetry performance especially on low-rate uncoded data; no high-rate data transmission occurred after November 7. Data collection of hourly S- and X-band system noise temperature readings were gathered from the 64-meter stations, as were system noise temperature elevation profiles. These data were analyzed to provide better understanding of solar corona effects, small Sun-Earth-Probe angles/high system noise temperature, and elevation effects on telemetry performance.

b. Discrepancy Reports. During August, September, October, and November, 120 Discrepancy Reports were opened on the telemetry subsystems. Tables 12 and 13 show how they were distributed.

The Telemetry and Command Processor Assembly accrued most of the Discrepancy Reports with approximately 25 precent. The microwave and digital subsystems also contributed significantly to the number of Discrepancy Reports with the balance divided between the Receiver-Exciter Subsystem and the Subcarrier Demodulator Assembly. There were no major outages as the anomalies were quite random in occurrence.

Table 12. Distribution of Telemetry System Discrepancy Reports by subsystem for August through November 1976

Subsystem	August	September	October	November	Total
Antenna Microwave Subsystem	9	2	8	5	24
Receiver-Exciter Subsystem	2	–	7	–	9
Subcarrier Demodulator Assembly	6	2	1	2	11
Symbol Synchronizer Assembly	1	–	3	2	6
Block Decoder Assembly	–	1	1	–	2
Data Decoder Assembly	6	5	4	5	20
Telemetry & Command Processor Assembly	3	4	14	7	28
Analog Instrumentation Subsystem/Pre & Post Detection Recording Subsystem	1	–	–	–	1
Telemetry & Command Processor Assembly/Recording Subsystem	2	2	2	1	7
Data Decoder Assembly/Recording Subsystem	7	1	3	1	12
Totals	37	17	43	23	120

Table 13. Distribution of Telemetry System Discrepancy Reports by category for August through November 1976

Category	August	September	October	November	Total
Hardware	24	14	19	15	72
Software	2	4	3	–	9
Procedural	4	–	4	–	10
Documentation	2	–	5	–	7
Unknown	7	8	12	6	33
Total	39	26	43	23	131

Eighteen percent of the Discrepancy Reports were written against procedures or documentation.

Nineteen Discrepancy Reports were opened against Network Operations Control Center performance during August. Twelve of these (63 percent) cited particular hardware or software failures. Of these only five (26 percent) were attributable to known causes. Five of the Discrepancy Reports (26 percent) were determined to have been caused by procedural errors, while two (11 percent) were found to have resulted from a series of assorted anomalies that caused late Intermediate Data Record delivery.

c. System Performance. Telecommunications performance of each tracking station is evaluated in terms of the differences between actual performance and predicted performance. These differences are termed residuals. Residuals are calculated from the downlink carrier power and the telemetry signal-to-noise ratio.

The use of the residuals is twofold:

(1) Whenever the hourly residual reading exceeds 1 dB, the Deep Space Station is alerted to impending problems. If the residuals exceed 1.5 dB, a Discrepancy Report is written to initiate concentrated investigative action.

(2) The residuals are averaged over a long-term interval to provide trend analysis information.

The spacecraft-dependent residuals are found in Tables 14 and 15, and are an indication of how well the performance of the telemetry data stream can be predicted and controlled. The severe degradation due to solar corona effects is apparent in the November data.

d. Data Accountability. Considerable effort is made by the Network to ensure that all data blocks recoverable from the Digital Original Data Record are included on all Viking Intermediate Data Records. Furthermore, during critical periods, the Analog Original Data Record may be played back to produce supplemental Digital Original Data Records and Intermediate Data Records to ensure inclusion of all data. Intermediate Data Records are delivered to the Viking Project library within 24 hours of loss of signal.

Table 16 shows the percentage of Digital Original Data Record data and the timeliness of Intermediate Data Record delivery during the months of August, September, October, and November 1976.

The percentage of data on Intermediate Data Record is computed by subtracting the first Block Serial Number from the last and dividing by the number of received blocks as printed on the Intermediate Data Record file summary produced by the Data Records Processor. The mean value of the result is given in Table 16 for each 64-meter station and for all 64-meter stations together. During September, 99.73 percent of all Intermediate Data Records delivered contained a minimum of 99.96 percent of all data recoverable from the Station Digital Original Data Records. In October this figure fell to 99.922 percent, while in November

Table 14. Residuals for downlink signal level and signal-to-noise ratio for 26-meter stations

Parameter	August		September		October		November	
	Orbiter 1	Orbiter 2	Orbiter 1	Orbiter 2	Orbiter 1	Orbiter 2	Orbiter 1	Orbiter 2
Signal level observations	68	36	32	49	39	46	22	25
Mean, dB	-0.6	-0.2	-0.2	-0.1	-0.1	0.0	-1.7	-1.1
Sigma, dB	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.2
Signal/noise observations	7	24	2.0	9.0	5.0	5.0	21	12
Mean, dB	-0.5	0.3	-1.0	0.0	1.2	-0.4	-14.2	-14.9
Sigma, dB	0.3	0.5	-	0.2	0.1	0.5	2.2	2.0

Table 15. Residuals for downlink signal level and signal-to-noise ratio for 64-meter stations

Parameter	August				September				October				November			
	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Orbiter 1	Lander 1	Orbiter 2	Lander 2
Signal level observations	86	26	90	—	76	24	87	25	88	30	79	12	43	10	63	7
Mean, dB	-0.2	-0.2	0	—	-0.2	-0.3	-0.2	-0.2	-0.1	-0.2	-0.4	-1.4	-0.4	-2.7	-1.1	-2.6
Sigma, dB	0.7	0.6	0.5		0.6	0.8	0.6	0.6	0.7	0.5	0.5	0.8	1.2	5.6	1.0	3.5
Low rate signal/noise observations	86	4	51		61.0	22	65.0	61	74	31	58	11	23 6 10	2 6	33 5 14	70
Mean, dB	-0.8	-1.0	-0.3		-0.5	-0.3	-0.1	-0.3	-0.7	-1.6	-0.6	-0.5	+15.9 -2.5 -1.6	-10.6 -7.7	-19.5 -2.8 -1.6	16.6
Sigma, dB	0.3	—	0.3	—	0.4	0.5	0.3	0.4	0.4	1.5	0.4	0.6	9.6 1.2 0.6	0.4 2.7	4.3 1.8 1.0	3
High-rate signal/noise observations	96	25	52	—	69	25	68	69	74	31	51	10	17	4	19	—
Mean, dB	-0.5	0.1	0	—	-0.1	-0.2	-0.1	-0.1	-0.3	-0.2	-0.2	-0.3	-0.6	-0.4	-0.3	—
Sigma, dB	0.3	0.2	0.2	—	0.4	0.3	0.3	0.4	0.6	0.3	0.3	0.3	0.4	0.4	0.2	—

Table 16. Telemetry Intermediate Data Record statistics for August through November 1976

Parameter	DSS 14				DSS 43				DSS 63				All stations			
	Aug.	Sept.	Oct.	Nov.	Aug.	Sept.	Oct.	Nov.	Aug.	Sept.	Oct.	Nov.	Aug.	Sept.	Oct.	Nov.
Percentage of Digital Original Data Record data included on Intermediate Data Record	99.92	99.99	99.99	99.99	100	99.99	99.99	99.95	99.9	99.99	99.99	99.99	99.9	99.99	99.99	99.97
Mean delivery time, h	11.2	3.3	4.8	6.28	15	4.4	8.9	5.58	13.6	3.6	6.1	3.26	13.3	3.8	6.6	5.12
Number of records	56	64	75	11	59	63	73	25	63	75	72	13	178	202	220	49

it decreased again to 99.462 percent of all data recoverable from the Digital Original Data Records. The average delivery times for Intermediate Data Records were 3.8 hours in September, 6.6 hours in October, and 5.12 hours in November.

3. Tracking System

a. Radio Metric Data Quality. The primary navigational data type generated by the Deep Space Network is doppler data. These data are continuously monitored by the Network Analysis Team, tracking in near real-time via use of the Network Operations Control Center pseudo-residual program. Doppler data residuals (actual-predicted) produced during August-November 1976 period by the pseudo-residual program consistently indicated a high level of accuracy in the polynomial coefficient tapes (the frequency independent observables) supplied to the Network Operations Control Team by the Viking Project Flight Pat Analysis Group. Additionally, the Network Analysis Team, Tracking, computes a pass-average doppler noise value for each Viking pass tracked. Doppler noise is the primary tool used in detecting tracking system malfunctions. When a spacecraft is not affected by solar plasma (Sun-Earth-Probe angles less than 50 degrees), and is at adequate signal levels, pass average 60-second sample rate, two-way doppler noise data are nominally expected to be 0.003 Hz $\pm$0.002 Hz.

For spacecraft in solar conjunction phases, as were the Viking spacecraft during the August to October 1976 period, the Network Operations Analysis Group, Tracking, has developed a Solar Plasma Doppler Noise Model - "ISEDB." During the August-November period, the Viking Sun-Earth-Probe angle declined from 36 degrees to 3 degrees. Figure 44 presents the ISEDB Model and the pass-average doppler noise for Vikings 1 and 2 during this period. Examination of this figure shows the observed doppler noise to be centered compactly about the ISEDB Model, and, hence, indicates generation of the highest (possible under conditions of solar conjunction) quality doppler data for Viking navigation. The cyclical variations of the observed doppler noise about the mean model (particularly evident after day of year 250) are due to routine fluctuations in solar activity. Starting in late September, weekly tabulations of observed Viking doppler noise, as compared to the ISEDB Model, were made availble by Network Orbiter Analysis Group Track to the Viking project, as a "quick look" indicator of signal path integrated electron density.

b. Viking Spacecraft Frequencies. During each one-way tracking period, the Network Tracking Analysis Team reestimates the spacecraft auxiliary oscillator frequency, and during each subsequent uplink acquisition a similar reestimation of the spacecraft best-lock frequency is performed. The data for Vikings 1 and 2 during the August-November period are presented in Figs. 45 through 48.

Spacecraft frequency data gathered by the Network in this fashion have proven quite effective and reliable in the past, and it is routinely reflected in the tracking predictions supplied to the Deep Space Stations and the Network Operations Control Center for both spacecraft acqusitions and radio metric data validation. Additionally, the data assume paramount importance during critical phases of the mission, when complicated mission strategies demand rapid and precise uplink and downlink acquisitions. The relative paucity of Viking 2

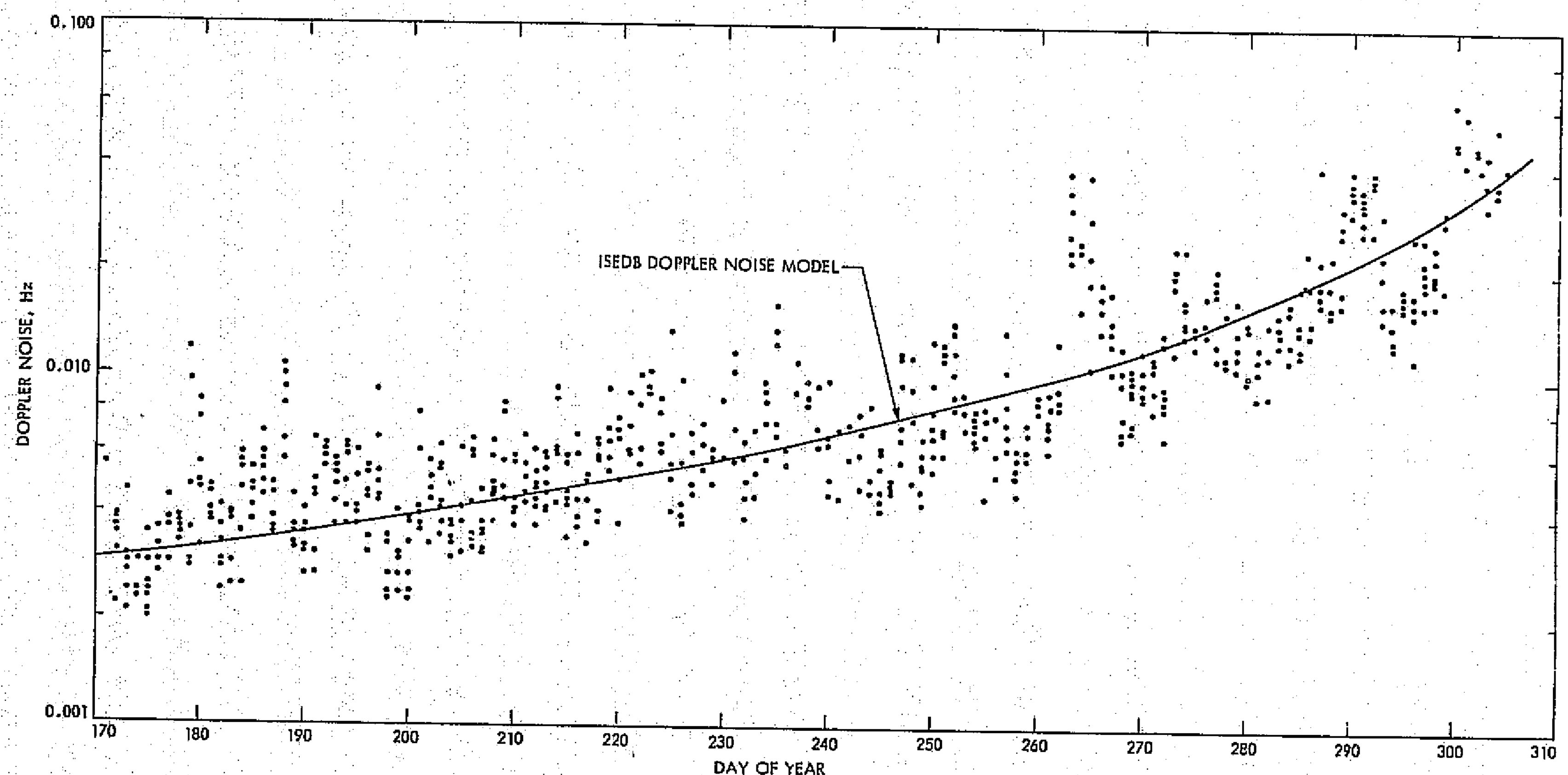


Fig. 44. Vikings 1 and 2 composite doppler noise versus day of year

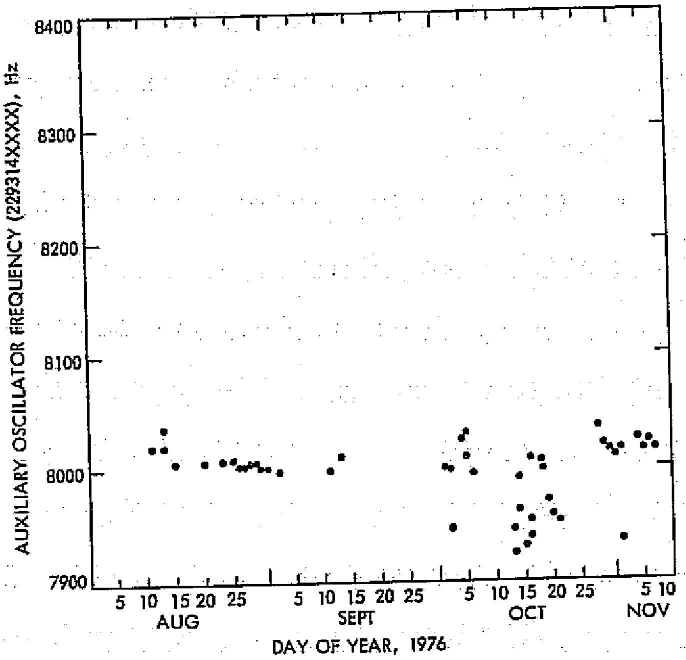


Fig. 45. Viking 1 spacecraft auxiliary oscillator frequency

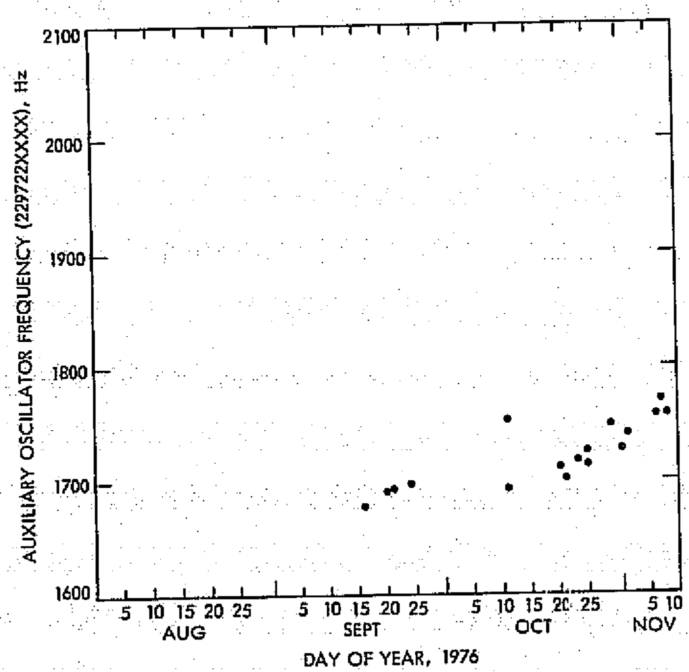


Fig. 46. Viking 2 spacecraft auxiliary oscillator frequency

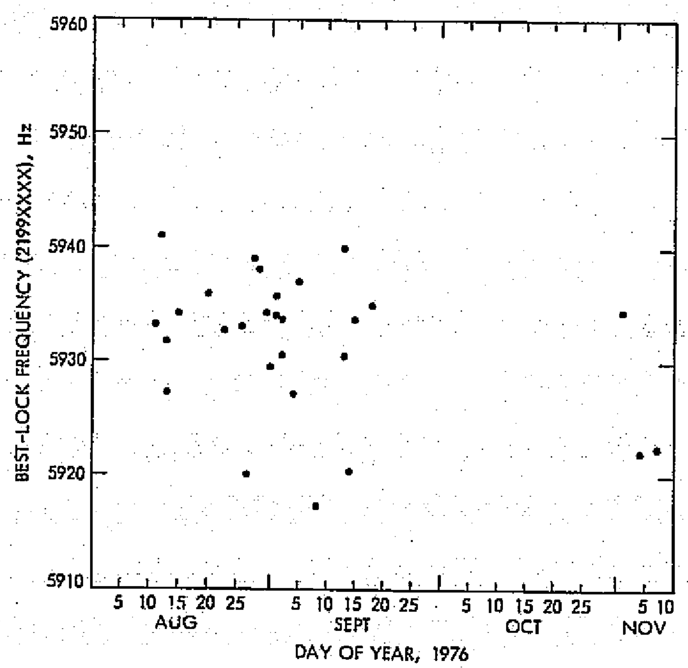


Fig. 47. Viking 1 spacecraft best-lock frequency

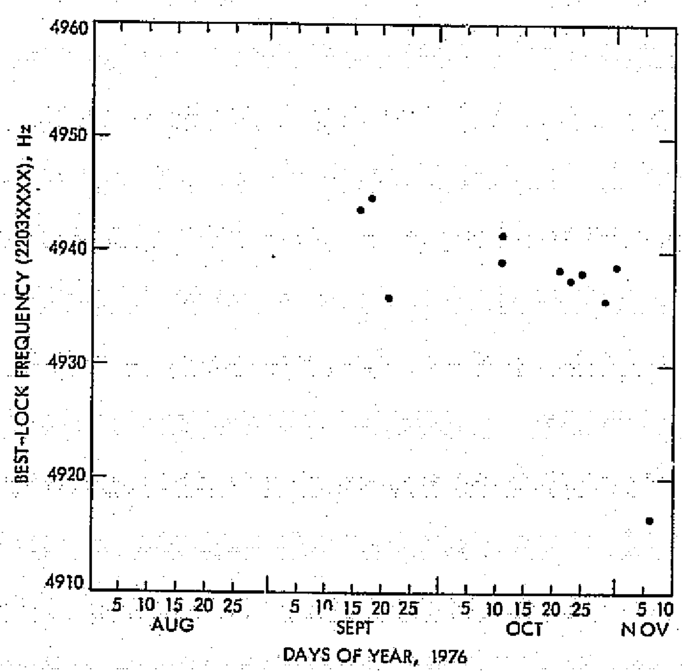


Fig. 48. Viking 2 spacecraft best-lock frequency

frequency measurements (as compared to earlier periods in the mission) is due to the continuous two-way tracking schedule for Viking 2 during August and the first half of September in support of Viking 2 mission Orbit Insertion and the subsequent Viking 2 landing.

c. Mission Support and Analysis. In August and September of 1976, most of the support in the Network tracking analysis area was devoted to Lander acquisition procedure development and design of new ranging parameters for the MU II ranging equipment at Station 14 and the Planetary Ranging Assembly operational ranging system at the 26-meter and 64-meter stations.

An example of the sets of ranging parameters, as developed by the Network Analysis Tracking Group, used during this period is given here.

For all Planetary Ranging Assembly equipped stations:

(1) T_1 = 419 (26-meter), 59 (64-meter).

(2) T_2 = 19 (26-meter), 5 (64-meter).

(3) T_3 = 300 (26-meter), 120 (64-meter).

(4) Number of components = 15.

(5) Carrier suppression = 9 dB.

(6) T_0 (1) = RNG MOD ON + RTLT + 5 min.

(7) Subsequent T_0:

(a) At 64-meter stations, T_0s are spaced 60 minutes apart. Last T_0 no later than START TUNE FOR TRANSFER - 15 minutes. If the spacecraft ranging channel is commanded off during the track, the last T_0 should be at or before time of transmit of this command + round trip light time - 15 minutes.

(b) At 26-meter stations, T_0s are spaced 90 minutes apart. Last T_0 no later than START TUNE FOR TRANSFER - 30 minutes. If the spacecraft ranging channel is commanded off during the track, the last T_0 should be at or before the time of transmit of this command + round trip light time - 30 minutes.

(8) Collect at least 3 postrange acquisition differenced range versus integrated doppler points before reinitialization for the next T_0.

(9) Doppler sample rate = 60 seconds.

For Station 14, with MU II equipment:

(1) T_1 = 240.

(2) T_2 = 240.

(3) $T_3 = 240$.

(4) $T_C = 60$.

(5) $C_1 = 4$.

(6) $C_2 = 13$.

(7) $C_N = 3$.

(8) Carrier suppression = 9 dB.

(9) TX (1) = RNG MOD ON + 1 min.

(10) Subsequent acquisitions are pipelined.

(11) Doppler sample rate = 60 seconds.

To prepare for problems with the daily critical Lander acquisitions, a set of emergency guidelines were produced and issued to the Operations Control Team and the stations. These guidelines are given here to illustrate the complexity of the daily routine of Orbiter and Lander acquisitions.

If the uplink is interrupted:

(1) During the acquisition sweep: Snap to the start tuning frequency (according to the acquisition message) and redo the entire acquisition sweep. Since the sweep takes approximately 24 minutes, there will be sufficient time to complete the acquisition sweep before the downlink is turned on.

(2) After completion of the uplink sweep and:

(a) Interruption is for less than 20 minutes: At this time, it is safe to assume that the spacecraft receiver had been acquired and is drifting to its rest frequency. Thus, the recommended recovery action during this time period would be snap to TSF + 100 Hz (voltage-controlled oscillator), sweep to TSF - 100 Hz (voltage-controlled oscillator) and return to TSF using a tuning rate of 0.900 Hz/second (digitally-controlled oscillator).

(b) Interruption is for more than twenty minutes: Follow the recovery procedure outlined in Item 1. Be aware that in this case it is highly likely that the station will see tuning effects in the downlink. Caution should be exercised to insure that receiver lock is achieved on the carrier.

(3) During a special ramping test:

The most conservative procedure is to immediately seek the advice of the Lander Performance Analysis Group Telecommunications Analyst.

To facilitate the daily program of Orbiter receiver frequency ramp instructions, a new program was written for use with the Hewlett-Packard 0810 calculator. This program accepted inputs representing exciter frequency, receiver frequency, and doppler frequency, and produced receiver tuning frequencies and rates of either S- or X-band.

With the approach of Viking occultations, the basic procedures, requirements and strategies for occultation support were reviewed and special recommendations were made to the Network Operations Control Team. Three areas requiring special attention were:

(1) Selection of Synthesizer Local Oscillator (SYNLO) frequencies:

The equation for this Block IV open-loop receiver ("SYNLO") frequency is as follows:

$$\text{SYNLO (S-band)} = \frac{1}{48}\left\{48\,\frac{240}{221}\,TSF_R - D + \text{Bias} - 50 \times 10^6 + \text{AUDIO}\right\}$$

where TSF_R = received track synthesizer frequency (~44 MHz)

D = Unbiased S-band doppler

The Audio bandwidth used would be:

$$496 \le \text{AUDIO} \le 4959$$

The basic plan was to set AUDIO (at the time of occultation) approximately 500 to 1000 Hz from the AUDIO limit that allows the major (or entire) portion of the pre- and post-occultation data to be in the AUDIO bandwidth.

Since the Doppler rates are negative during the occultation period, the enter occultation SYNLO would be selected near the beginning of the AUDIO bandwidth (496 Hz), and the exit occultation SYNLO would be selected near the end of the AUDIO bandwidth (4959 Hz). Specifically, the SYNLO frequencies would be selected as follows:

(a) Grazing trajectories:

SYNLO selected for a time t such that:

$$t = \frac{T_{en} + 1000\text{ km} + T_{ex} + 1000\text{ km}}{2}$$

and with AUDIO set to the center of bandwidth:

AUDIO = 2727 Hz

(b) Enter occultation:

SYNLO selected for a time, $t = T_{en}$

and with an AUDIO = 1000 Hz

This allows a safety margin of 504 Hz for PREDIK errors.

(c) Exit occultation:

SYNLO selected for a time, $t = T_{ex}$

and with an AUDIO = 4000 Hz

This allows a safety margin of 959 Hz for combined PREDIK and auxiliary oscillator frequency (one-way) errors.

(2) Logging and distribution of operational occulation data:

Figure 49 is the form in use to serve both to transmit the occultation prediction parameters from Network Operations Analysis Group to the Network Operations Control Team and as the operational occultation log. Responsibilities in connection with the form are as follows:

(a) Network Operations Analysis Group Track: The entire form, with the exception of A.2., A.3., B.2., B.3., and C.

(b) Controller: A.2., A.3., B.2., B.3., C.

(c) Network Operations Project Engineer: Distribution of completed form to Radio Science Team.

(3) Closed-loop receiver reacquisitions at exit occultation: The stations were to use the acquisition mode of the Block IV receiver as follows:

(a) Start sweep 5 minutes prior to expected acquisition of signal.

(b) Sweep ±1000 Hz (S-band) about D1 at T_{ex}.

(c) Sweep rate 2000 Hz/second (S-band).

(d) Radio frequency bandwidth 10 Hz.

VIKING OCCULTATION EXPERIMENT

OCCULTED SPACECRAFT

S/C: 27 PASS: 435 DOY: 301

TRANSMIT DSS: 62 RECEIVE DSS: 63/62

A. ENTER OCCULTATION

1. EXPECTED LOS:	13:58:16	GMT
2. ACTUAL LOS (S-BAND):	13:58:20	GMT
3. ACTUAL LOS (X-BAND):	13:58:20	GMT
4. TSF:	43991900	HZ
5. SYNLO:	N/A	HZ

B. EXIT OCCULTATION

1. EXPECTED AOS:	16:03:13	GMT
2. ACTUAL AOS (S-BAND):	16:02:53	GMT
3. ACTUAL AOS (X-BAND):	16:03:16	GMT
4. TSF:	43991900.	HZ
5. SYNLO:	N/A	HZ

C. REMARKS (Frequency Deviations, Etc.):

NON-OCCULTED SPACECRAFT

S/C: 30 PASS: 415 DOY: 301

TRANSMIT DSS: 61 RECEIVE DSS: 61/63

POST OCCULTATION RECEIVER ACQUISITION:

S-BAND: SWEEP DI ± 1000 HZ AT 1000 HZ/SEC (S-BAND)

X-BAND: SWEEP DI ± 850 HZ AT 425 HZ/SEC (X-BAND)

RECEIVERS SHOULD BE IN ACQ MODE WITH AT' ENABLED AND 10 HZ RF BANDWIDTH.

NOAG TRACK Wachley CONTROLLER ________ NOPE ________

Fig. 49. Viking occultation experiment sheet

As the Prime Mission approached its conclusion in November, the emphasis shifted from navigation requirements to radio science requirements, and new guidelines for ranging parameters were necessary.

(a) Stations 43 and 63:

T_1 = 89

T_2 = 4

T_3 = 70

Number of components = 15

Carrier suppression = 2.3 dB

T_0 = RNG MOD ON + RTL + 10 seconds (rounded "up" to coincide with a doppler sample).

Doppler Sample Rate = 10 seconds

Differenced range versus integrated doppler collected until loss of the spacecraft's ranging channel.

(b) DSS 14 (using the MU II type of ranging):

T_1 = 30

T_2 = 15

T_3 = 20

T_C = 15

C_1 = 4

C_2 = 13

C_N = 2

TX = RNG MOD ON + 10 seconds

Carrier suppression = 2.3 dB

Doppler sample rate = 1 second

In September, a new technique for interstation range validation was explored and developed. This technique used the predicted range (corrected by the doppler pseudo residual) to transform a range acquisition from one station to another. The transformed range was then used to validate range acquisiton at the second station. By mid-October, the use of this technique resulted in agreement between stations on the order of 10 to 20 meters.

Until the development of the "pseudo-differenced range versus integrated doppler" algorithm, it was difficult if not impossible, to validate range data in near-real-time. Using this technique, range was routinely validated by NAT/Track and the Project was warned of bad or questionable range data. However, this technique could only be used to determine consistency between several range acquisitions taken during a single station pass.

During October a new algorithm (differential range validation) was developed which, using predicted range and doppler pseudo-residuals, could validate single acquisitions between separate stations. This algorithm afforded a great improvement in the Network's ability to validate many data in near-real time.

As a part of the effort to obtain accurate and reliable range data, an organization known as the ranging accuracy team had been established sometime earlier. Considerable effort was expended to collect, analyze, and publish extensive data relating to the station range delay calibration. As a result of this, previously unknown frequency dependencies were uncovered, zero delay devices were improved and much more reliable ranging data were provided to the Viking Project.

4. Monitor System

Formerly, the Monitor Analysis Group was responsible for investigating and reporting anomalies that occurred with the Monitor System. This consisted basically of the Digital Instrumentation System computer, Station Monitor and Control Assembly, Monitor/Tracking Data Handling Digital Original Data Records recorders, and all other peripheral Digital Instrumentation System components, and the Network Control System Real-Time Monitor and associated format displays.

In addition, the Group was responsible for a wider range of common system and interface problems, which included: station Frequency and Timing System; power; all site communication equipment including high-speed, wideband, and voice; Ground Communications Facility circuits and terminal equipment between each site and the Space Flight Operations Facility Building and its communications equipment; and all Network Control System Network Data Processing Area common equipment including communications, timing, power, and the various computers i.e., Log Processor Subsystems, Star Switch Controller, Communications Equipment Subsystem, and NASCOM Assembly.

In September 1976, the scope of this Group's activities was reviewed in interest of economizing in manpower. A decision was made to cover the performance of the hardware and software formerly defined as the Monitor System in either the Tracking, Telemetry, or Command Systems, as appropriate. Consequently, no further unique Monitor System performance data were accumulated, and regular monthly performance reporting was discontinued.

IV. PLANETARY CONFIGURATIONS

A. INTRODUCTION

With the advent of full planetary operations on July 20, 1976, following the successful landing of Viking Lander 1, the entire resources of the Deep Space Network were called upon to support the mission. These resources included three 64-meter stations, six 26-meter stations, Deep Space Network and NASA Communications ground communications, and the Network Operations Control Center.

The basis for these extensive requirements lay in the simultaneous support of two Orbiters and either one of two Landers. The capabilities required of the various elements of the Network encompassed telemetry, command, and tracking support, error-free data transmission services from Madrid, Spain, Canberra, Australia, and Goldstone, California, as well as Network control and monitoring and gap-free data record production.

B. DEEP SPACE STATIONS

The configuration of each of these elements of the Network as they were used to support Viking planetary operations is described in the following paragraphs.

1. 64-meter Stations

The three 64-meter Deep Space Stations at Goldstone, California (14), Robledo, Spain (63), and Tidbinbilla, Australia (43) were configured for Viking Planetary Operations as shown in Fig. 50.

Two Block II receivers and two Block IV receivers provided a redundant capability for three radio frequency carriers from two Orbiters and a Lander. Block III receivers were capable only of S-band reception while Block IV receivers could receive either S- or X-band. Two open-loop receivers were provided for radio science occultation and solar corona experiments.

Six subcarrier demodulations were connected by an extremely flexible switch matrix to associated Block Decoders, Symbol Synchronizers, and Data Decoders, which, together with the Telemetry and Command Processor, provided the capability required to handle six simultaneous data streams, i.e., two subcarrier data streams per spacecraft. The data rate capabilities are given in Table 17.

Interfaces from the Data Decoder Assembly and Telemetry and Command Processor to the ground communication subsystems provided the transmission of low-rate (33-1/3 bps), medium-rate (2 kbps), or high-rate (16 kbps) data to the Network Operations Control Center via NASA Communications and Network ground communication links.

Table 17. Telemetry data rate capabilities for Viking

Deep Space Station	Telemetry channel combination	Lander (A or B)		Orbiter A		Orbiter B	
		Uncoded	Coded	Uncoded	Coded	Uncoded	Coded
64-meter	1	8	1000	33	-	33	-
	2	8	1000	33	-	33, 16,000	-
	3	8	1000	33	-	33	16,000
	4	8	1000	33, 16,000	-	33, 16,000	-
	5	8	1000	33, 16,000	-	33	16,000
	6	8	1000	33	16,000	33	16,000
	Note: Only the maximum bit rate (bps) required on each channel is shown.						
26-meter	7	-	-	33	2000		
	8	-	-			33	2000

Note: Maximum capability at any single complex is six streams on the 64-meter DSS simultaneously with the two streams on any 26-meter DSS (including conjoint stations).

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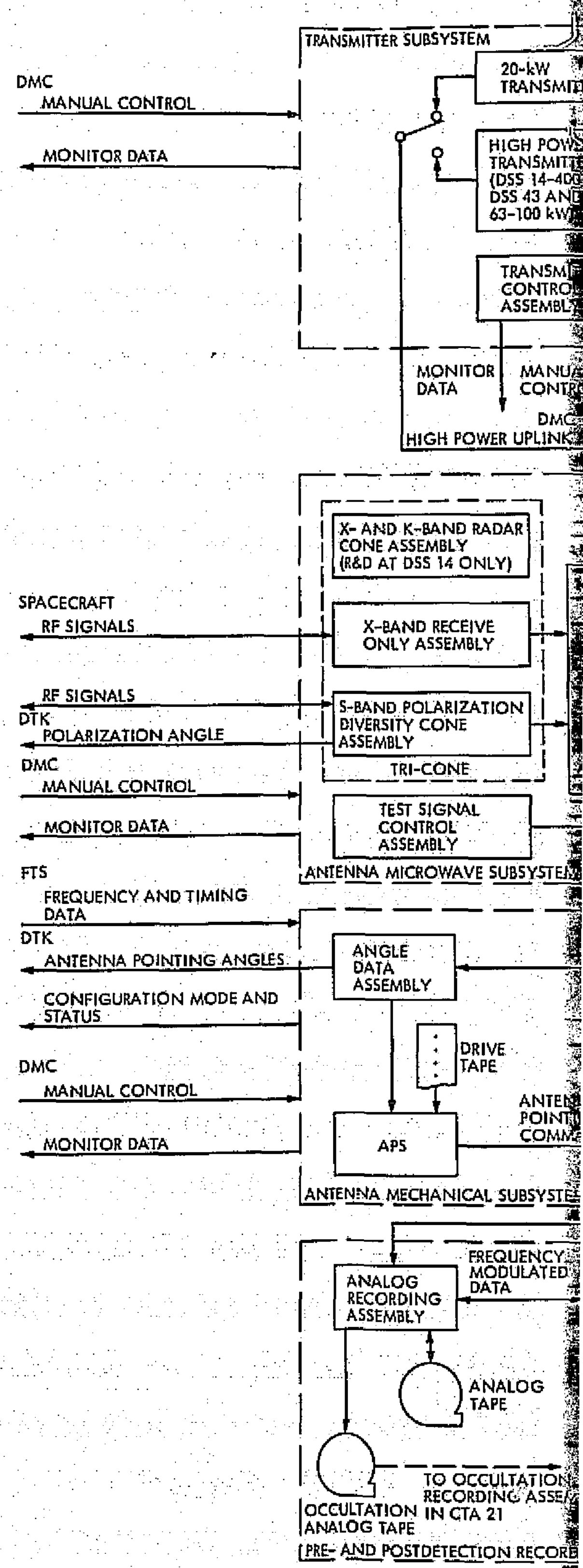

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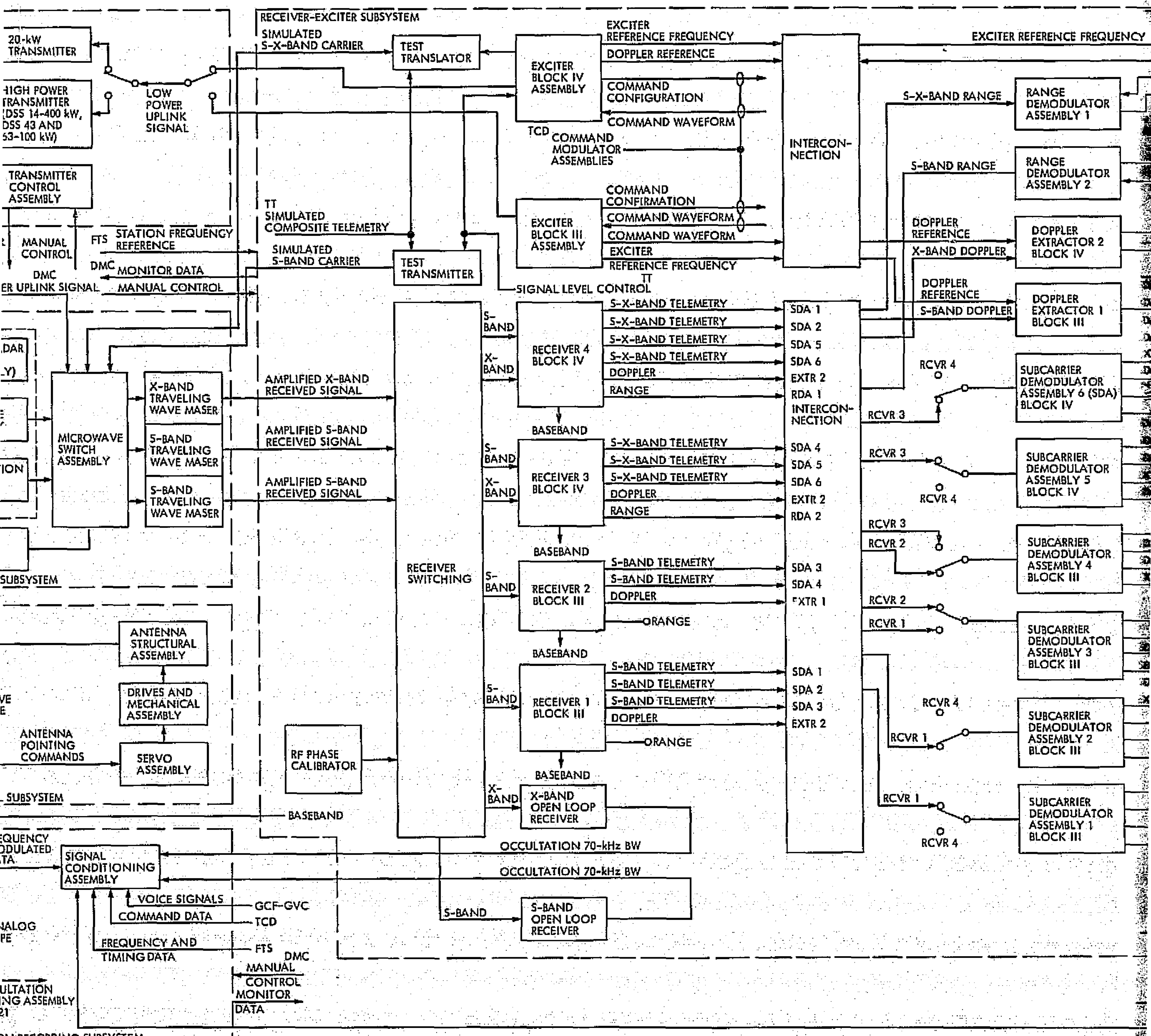

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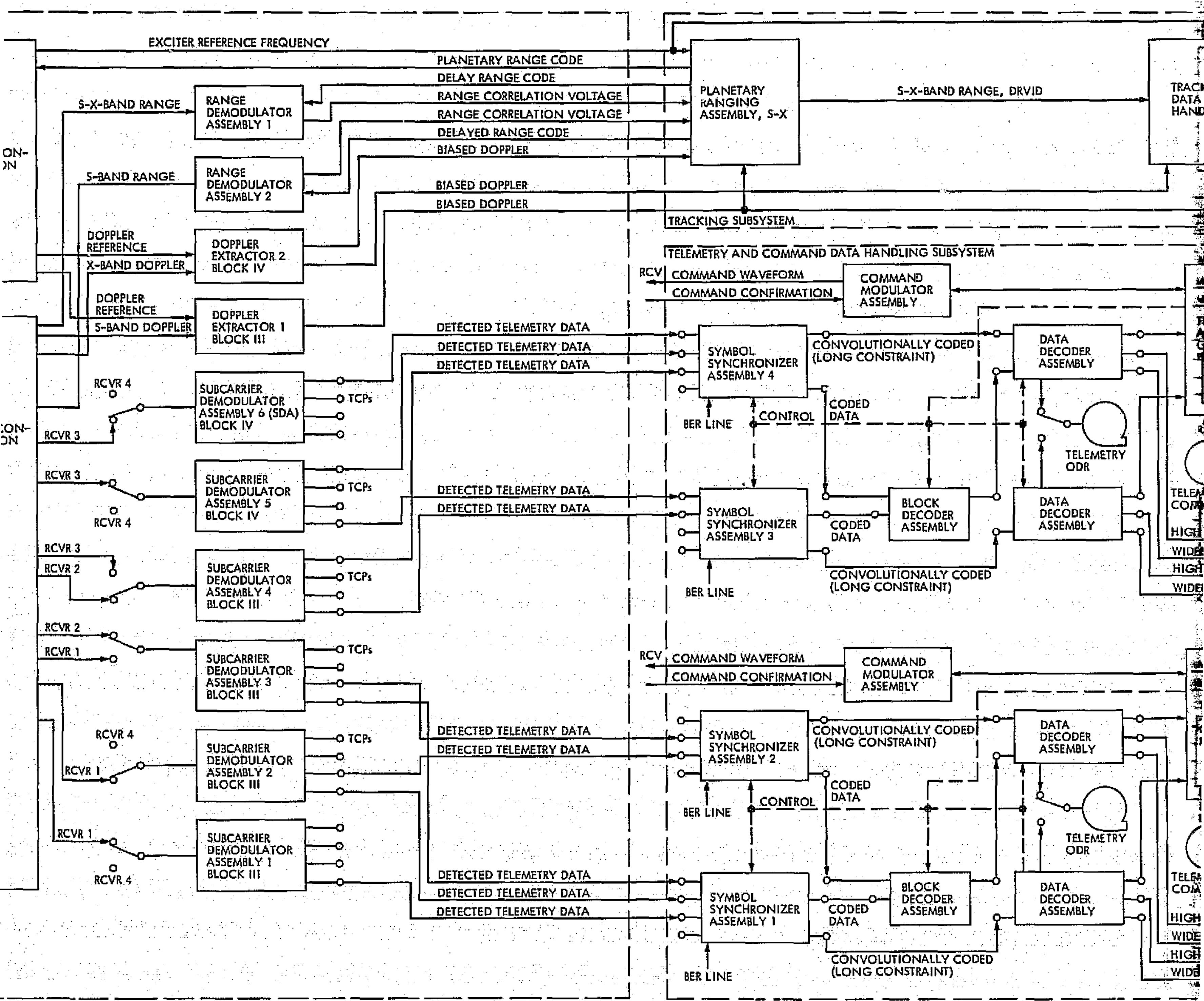
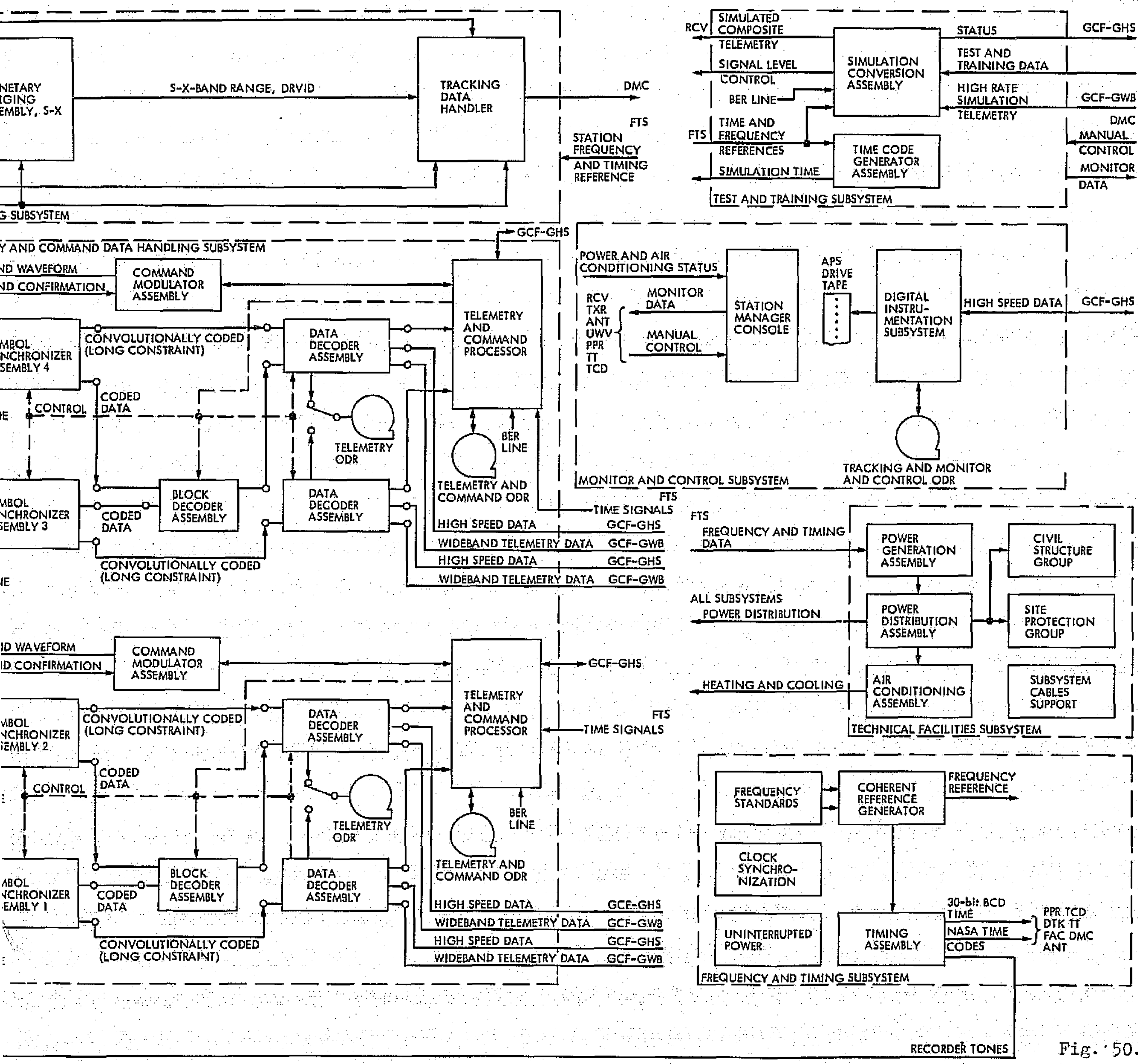
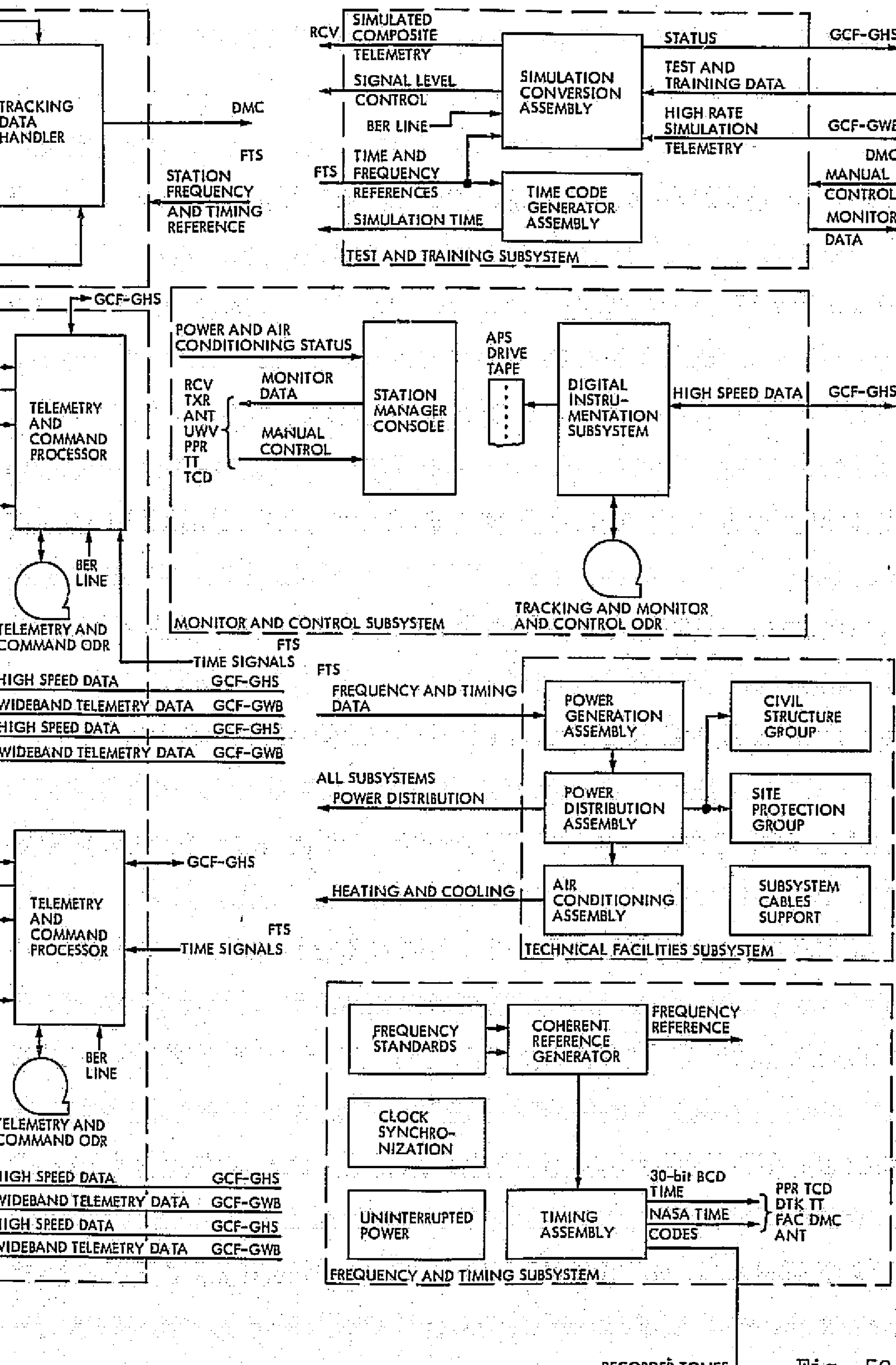




NETARY
IGING
EMBLY, S-X
S-X-BAND RANGE, DRVID
TRACKING DATA HANDLER
DMC
FTS
STATION FREQUENCY AND TIMING REFERENCE
G SUBSYSTEM
RCV
SIMULATED COMPOSITE TELEMETRY
SIGNAL LEVEL CONTROL
BER LINE
SIMULATION CONVERSION ASSEMBLY
STATUS
GCF-GHS
TEST AND TRAINING DATA
HIGH RATE SIMULATION TELEMETRY
GCF-GWB
DMC
MANUAL CONTROL
MONITOR DATA
FTS
TIME AND FREQUENCY REFERENCES
SIMULATION TIME
TIME CODE GENERATOR ASSEMBLY
TEST AND TRAINING SUBSYSTEM
Y AND COMMAND DATA HANDLING SUBSYSTEM
GCF-GHS
ND WAVEFORM
ND CONFIRMATION
COMMAND MODULATOR ASSEMBLY
TELEMETRY AND COMMAND PROCESSOR
MBOL
NCHRONIZER
SEMBLY 4
CONVOLUTIONALLY CODED (LONG CONSTRAINT)
DATA DECODER ASSEMBLY
CODED DATA
CONTROL
TELEMETRY ODR
BER LINE
TELEMETRY AND COMMAND ODR
MBOL
NCHRONIZER
SEMBLY 3
CODED DATA
BLOCK DECODER ASSEMBLY
DATA DECODER ASSEMBLY
CONVOLUTIONALLY CODED (LONG CONSTRAINT)
FTS
TIME SIGNALS
HIGH SPEED DATA GCF-GHS
WIDEBAND TELEMETRY DATA GCF-GWB
HIGH SPEED DATA GCF-GHS
WIDEBAND TELEMETRY DATA GCF-GWB
POWER AND AIR CONDITIONING STATUS
RCV
TXR
ANT
UWV
PPR
TT
TCD
MONITOR DATA
MANUAL CONTROL
STATION MANAGER CONSOLE
APS DRIVE TAPE
DIGITAL INSTRU-MENTATION SUBSYSTEM
HIGH SPEED DATA
GCF-GHS
TRACKING AND MONITOR AND CONTROL ODR
MONITOR AND CONTROL SUBSYSTEM
FTS
FREQUENCY AND TIMING DATA
POWER GENERATION ASSEMBLY
CIVIL STRUCTURE GROUP
ALL SUBSYSTEMS POWER DISTRIBUTION
POWER DISTRIBUTION ASSEMBLY
SITE PROTECTION GROUP
HEATING AND COOLING
AIR CONDITIONING ASSEMBLY
SUBSYSTEM CABLES SUPPORT
TECHNICAL FACILITIES SUBSYSTEM
ND WAVEFORM
ND CONFIRMATION
COMMAND MODULATOR ASSEMBLY
GCF-GHS
TELEMETRY AND COMMAND PROCESSOR
FTS
TIME SIGNALS
MBOL
NCHRONIZER
EMBLY 2
CONVOLUTIONALLY CODED (LONG CONSTRAINT)
DATA DECODER ASSEMBLY
CODED DATA
CONTROL
TELEMETRY ODR
BER LINE
TELEMETRY AND COMMAND ODR
MBOL
NCHRONIZER
EMBLY 1
CODED DATA
BLOCK DECODER ASSEMBLY
DATA DECODER ASSEMBLY
CONVOLUTIONALLY CODED (LONG CONSTRAINT)
HIGH SPEED DATA GCF-GHS
WIDEBAND TELEMETRY DATA GCF-GWB
HIGH SPEED DATA GCF-GHS
WIDEBAND TELEMETRY DATA GCF-GWB
FREQUENCY STANDARDS
COHERENT REFERENCE GENERATOR
FREQUENCY REFERENCE
CLOCK SYNCHRO-NIZATION
30-bit BCD TIME
NASA TIME CODES
PPR TCD
DTK TT
FAC DMC
ANT
UNINTERRUPTED POWER
TIMING ASSEMBLY
FREQUENCY AND TIMING SUBSYSTEM
RECORDER TONES

Fig. 50. De
f
6



ANT	ANTENNA MECHANICAL SUBSYSTEM
APS	ANTENNA POINTING SUBSYSTEM
BCD	BINARY-CODED DECIMAL
BER	BIT ERROR RATE
BW	BANDWIDTH
CTA	COMPATIBILITY TEST AREA, JPL, PASADENA, CALIFORNIA
DIS	DIGITAL INSTRUMENTATION SUBSYSTEM
DMC	MONITOR AND CONTROL SUBSYSTEM
DRIVID	DIFFERENCED RANGE VERSUS INTEGRATED DOPPLER
DSS	DEEP SPACE STATION
DTK	DEEP SPACE STATION TRACKING SUBSYSTEM
EXTR	EXCITER ASSEMBLY
FAC	TECHNICAL FACILITIES SUBSYSTEM
FTS	FREQUENCY AND TIMING SUBSYSTEM
GCF	GROUND COMMUNICATIONS FACILITY
GHS	GROUND COMMUNICATIONS FACILITY HIGH-SPEED DATA SUBSYSTEM
GVC	GROUND COMMUNICATIONS FACILITY VOICE SUBSYSTEM
GWB	GROUND COMMUNICATIONS FACILITY WIDEBAND SUBSYSTEM
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ODR	ORIGINAL DATA RECORD
PPR	PRE- AND POSTDETECTION RECORDING SUBSYSTEM
R&D	RESEARCH AND DEVELOPMENT
RCV	RECEIVER-EXCITER SUBSYSTEM
RCVR	RECEIVER ASSEMBLY
RDA	RANGE DEMODULATOR ASSEMBLY
RF	RADIO FREQUENCY
SDA	SUBCARRIER DEMODULATOR ASSEMBLY
SMC	STATION MANAGER CONSOLE
TCD	TELEMETRY AND COMMAND DATA HANDLING SUBSYSTEM
TCP	TELEMETRY AND COMMAND PROCESSOR
TT	TEST AND TRAINING SUBSYSTEM
TXR	TRANSMITTER SUBSYSTEM
UWV	ANTENNA MICROWAVE SUBSYSTEM

Fig. 50. Deep Space Network Mark III-75 functional network design, 64-meter stations

Two Command Modulation Assemblies and dual transmitter exciters afforded redundant paths to either a 20-kW or 100-kW S-band transmitter for command purposes, one uplink at a time.

Radio metric data were generated by the station's tracking subsystem, which consisted of two doppler counters and two Range Demodulation Assemblies. This, together with the Planetary Ranging Assembly, provided S- or X-band ranging simultaneously with S- or X-band doppler.

Early in the Mission, the Planetary Ranging Assembly had been replaced by the so-called MU-III ranging machine to give better ranging performance at small Sun-Earth-Probe angles for Helios. The Planetary Ranging Assembly was, however, retained for backup purposes. Later, as the Viking mission approached its solar conjunction phase, the MU II machine would become prime for Viking radio science purposes.

Digital data records were made by pairs of 9-track high-diversity tape recorders attached to the Data Decoder Assemblies and Analog Data Records of baseband, and detected data were made by FR1400 analog recorders. Two high-performance Honeywell machines were available for baseband playback at the stations when necessary.

Rubidium frequency standards were the basis for all station tracking and frequency references. Interstation time synchronization to 20 microseconds was accomplished by means of an X-band moonbounce link from the Madrid and Canberra stations to the master clock at Goldstone.

To the maximum extent possible, this configuration was designed to permit the flexibility in switching and interchange of assemblies in the telemetry, command, and tracking subsystems. This approach was necessary to affect to some degree the lack of redundancy when the stations were called upon to support planetary operations for three spacecraft (two Orbiters and one Lander) simultaneously. The alternate configurations permitted by this approach were each separately defined and coded in the Network Operations Plan and used by the stations as directed by the Station Controllers at the Network Operations Control Center.

2. 26-meter stations

The Network is comprised of six 26-meter stations (in addition to the three 64-meter stations) geographically located as follows:

Space Station	Location
11	Pioneer, Goldstone, California
12	Echo, Goldstone, California
42[a]	Tidbinbilla, Canberra, Australia
44	Honeysuckle Creek, Canberra, Australia
61[a]	Robledo, Madrid, Spain
62	Madrid, Spain

[a]These are "conjoint" stations that share the same control room and same equipment (such as ranging) as the 64-meter station at the same location.

The basic configuration for all 26-meter stations is shown in Fig. 51.

Two Block II receivers provide a capability for receiving two S-band downlink carriers if necessary. Generally, they were used but for only one carrier with a backup receiver since the two subcarrier demodulations that followed could accommodate only one low-rate (33 1/3 bps) and one medium-rate (2000 bps) data channel. Block decoding at 2000 bps or less was accomplished in the Data Decoders feeding the symbol synchronizers.

Two telemetry and command processors (XDS 920 computers) performed the necessary telemetry formatting and outputting functions to the single high-speed communications line. Either one or two command channels, each consisting of one Telemetry and Command Processor and a Command Modulation Assembly, was capable of driving the single Block III exciter and 20-kW transmitter.

At Station 11, only S-band ranging was available using the standard Planetary Ranging Assembly. At the conjoint stations (42 and 61), the ranging capability (using the Planetary Ranging Assembly and Range Demodulation Assembly) was shared with the 64-meter station, so that either (but not both) stations could provide ranging support. The remaining stations (12, 62, and 44) did not have a ranging capability. However, all stations could provide S-band doppler using their Block III doppler extractors outputting to high-speed data lines through the Tracking Data Handler. Angle data and differenced range versus integrated doppler completed the radio metric data types generated at these stations.

Digital data were recorded at the output of the Telemetry and Command Processor. Baseband and detected analog records were made at the input and output of the Subcarrier Demodulator Assembly. At the conjoint stations, a single crew was used to operate both stations from the one control room. To reduce the

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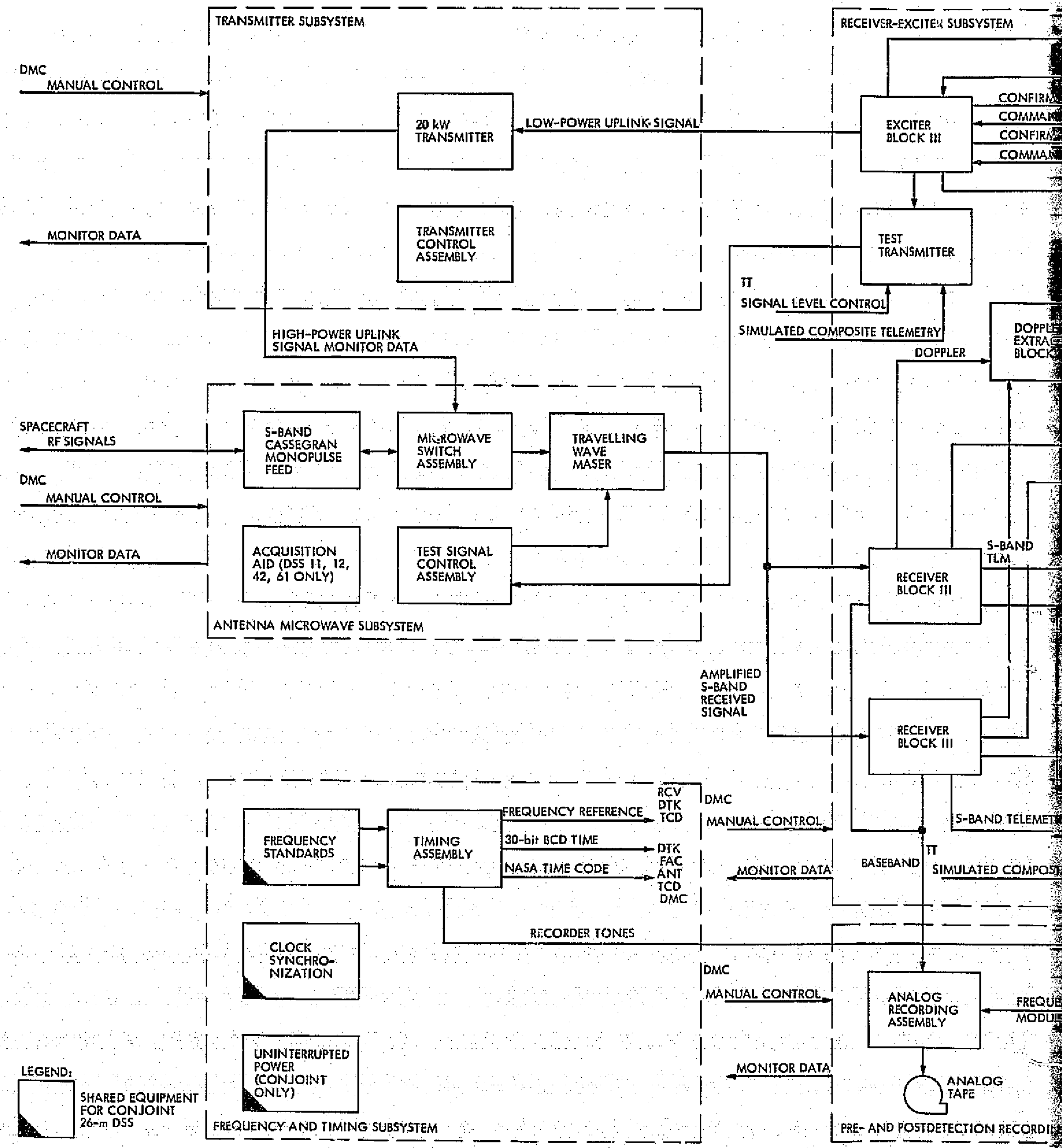

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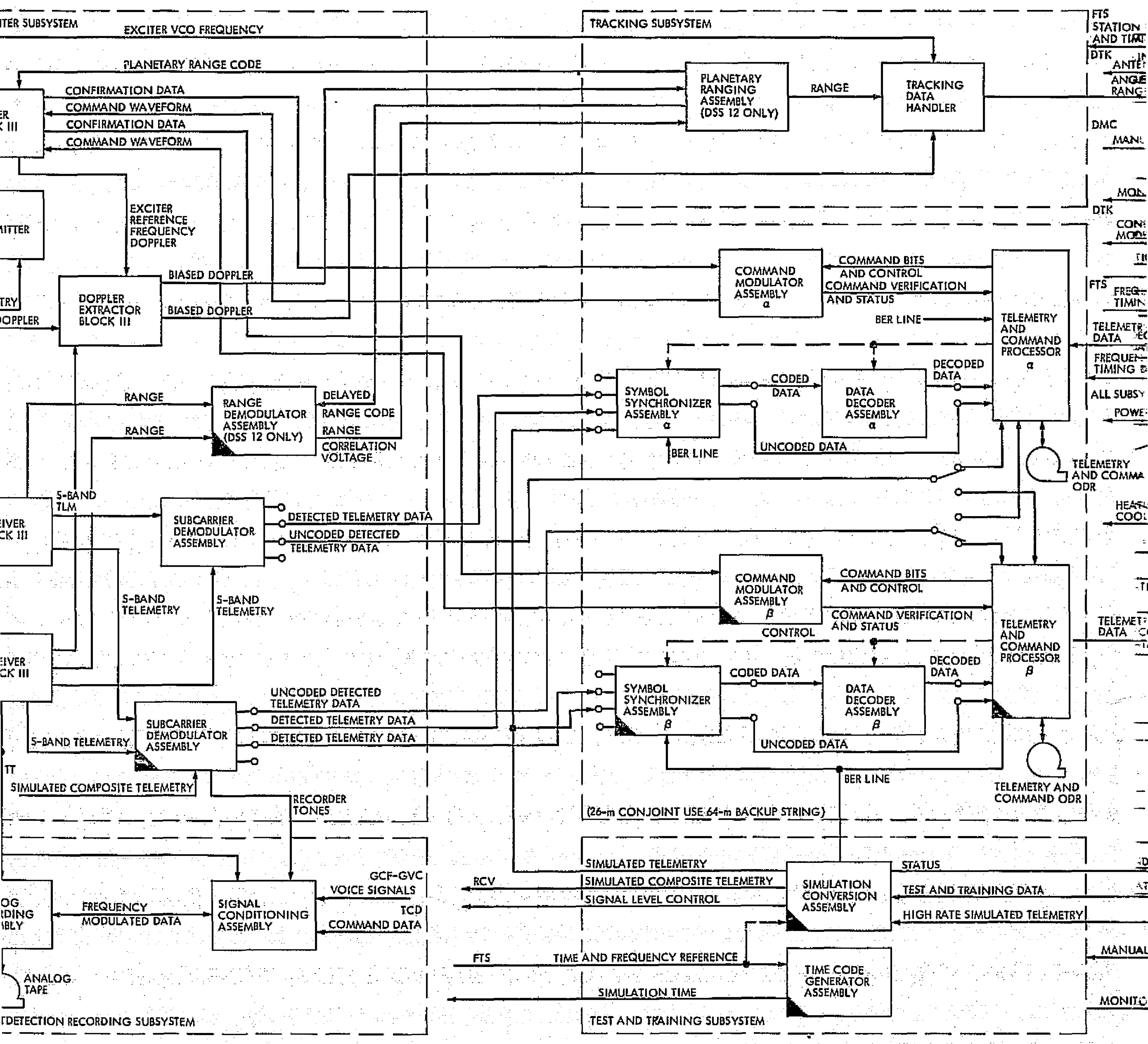

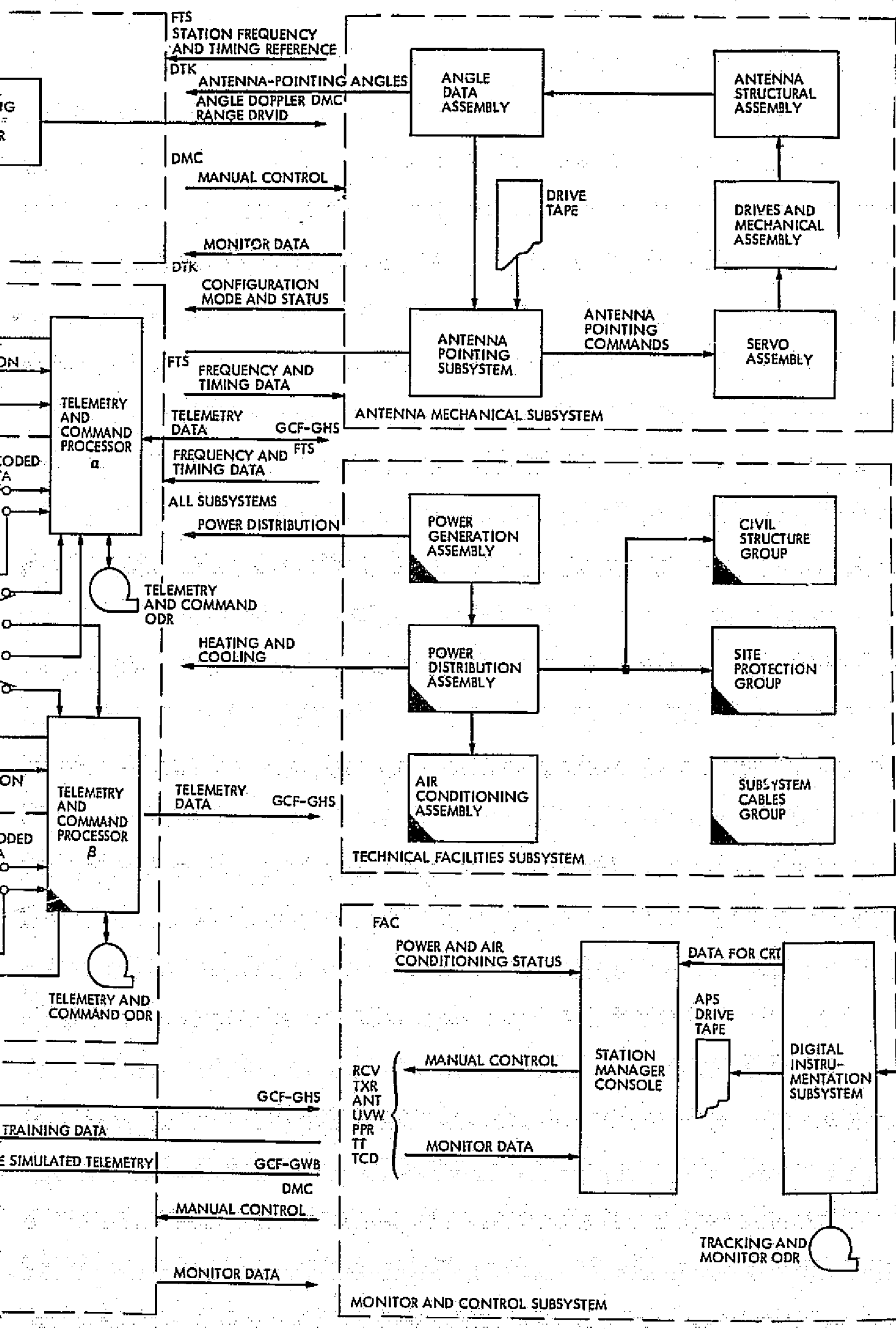

ANT	ANTENNA MECHANICAL SUBSYSTEM
APS	ANTENNA POINTING SUBSYSTEM
BCD	BINARY-CODED DECIMAL
BER	BIT ERROR RATE
CRT	CATHODE RAY TUBE
DMC	MONITOR AND CONTROL SUBSYSTEM
DSS	DEEP SPACE STATION
DTK	NETWORK TRACKING SUBSYSTEM
FAC	TECHNICAL FACILITIES SUBSYSTEM
FTS	FREQUENCY AND TIMING SUBSYSTEM
GCF	GROUND COMMUNICATIONS FACILITY
GHS	HIGH-SPEED DATA SUBSYSTEM
GVC	GROUND COMMUNICATIONS FACILITY VOICE SUBSYSTEM
GWB	WIDEBAND DATA SUBSYSTEM
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ODR	ORIGINAL DATA RECORD
PPR	PRE- AND POSTDETECTION RECORDING SUBSYSTEM
RCV	RECEIVER-EXCITER SUBSYSTEM
RF	RADIO FREQUENCY
TCD	TELEMETRY AND COMMAND DATA HANDLING SUBSYSTEM
TCG	TIME CODE GENERATOR ASSEMBLY
TLM	TELEMETRY
TT	TEST AND TRAINING SUBSYSTEM
TXR	TRANSMITTER SUBSYSTEM
UWV	ANTENNA MICROWAVE SUBSYSTEM
VCO	VOLTAGE-CONTROLLED OSCILLATOR

Fig. 51. Deep Space Network Mark III-75 functional network design, 26-meter stations

demands upon these crews during operations, the station monitor and control functions were exercised from a newly developed Station Monitor and Control Assembly known as SMC II B. This assembly provided remote control of some functions such as receiver timing and, by bringing other monitoring functions to a single console, permitted the station to be operated during the peak activity periods with fewer operators than otherwise would have been required.

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V. RADIO SCIENCE

A. GENERAL

A very important part of the Deep Space Network support for the Viking Prime Mission was concerned with the radio science experiments. This activity increased considerably during the latter part of the Viking Prime Mission, and, in many cases, continued into the Viking Extended Mission. The specific experiments that were carried out follow:

(1) Orbiter-quasar very long baseline interferometry.

(2) Earth occultation.

(3) Solar corona.

(4) General relativity.

(5) Orbiter S- and X-band doppler and ranging.

(6) Lander ranging.

Each of these experiments was designed to provide scientific data on specific areas of the solar system, and the questions concerning the deep space environment. Following is a brief description of each experiment, and the status at the end of the prime mission.

B. OCCULTATION EXPERIMENT

Toward the end of the prime mission, the orbit of Orbiter 1 passed behind Mars as viewed from Earth. Thus, in early October, the Orbiter's signal was gradually cutoff, or occulted by the atmosphere and later by the surface of Mars. The variations in the signal on entry and exit from occultation are used to determine Martian atmospheric and ionospheric properties. In addition, occultation measurements produce precise radii of Mars at the occultation points.

Earth occultations with Orbiter I started on October 6, 1976, over the Canberra station, "walked" into the Madrid station, and ended over the Goldstone station. There were 27 pairs of occultations. Only about 75 percent of the occultations provided useful data because of conflicting requirements of other objectives of the mission, or insufficient occultation receiving equipment at the Madrid station, which had not been scheduled for occultation support in the original planning for Radio Science.

The configuration used for occultation observations at Stations 14 (Goldstone) and 43 (Australia) consisted of the standard closed-loop system and also the open-loop system, which is the most important. The open-loop system consists of two open-loop receivers and two dedicated open-loop FR 1400 analog recorders. The open-loop system is shown in Fig. 52.

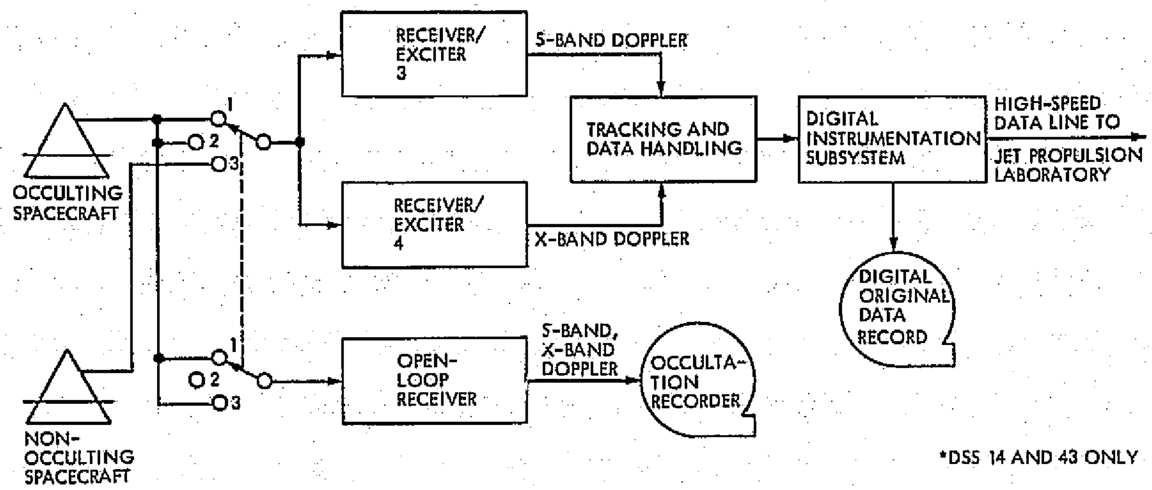


Fig. 52. Occultation configuration

The pattern of occultations for first phase involving Orbiter 1 only is shown in Fig. 53. This phase ran from October 1 to November 1. The next phase, involving Orbiter 2 was to begin on January 16, 1977, over Stations 63 and 14.

The analog data recorded during these occultation passes were forwarded to Compatibility Test Area 21 for analog-to-digital conversion using the configuration shown in Fig. 54.

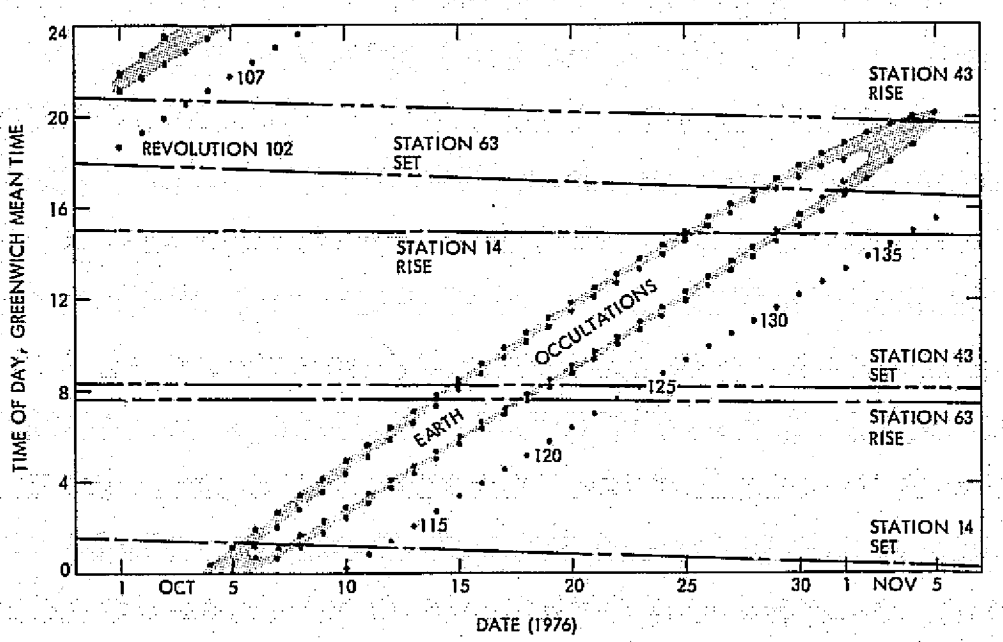


Fig. 53. Orbiter 1 Earth occultations

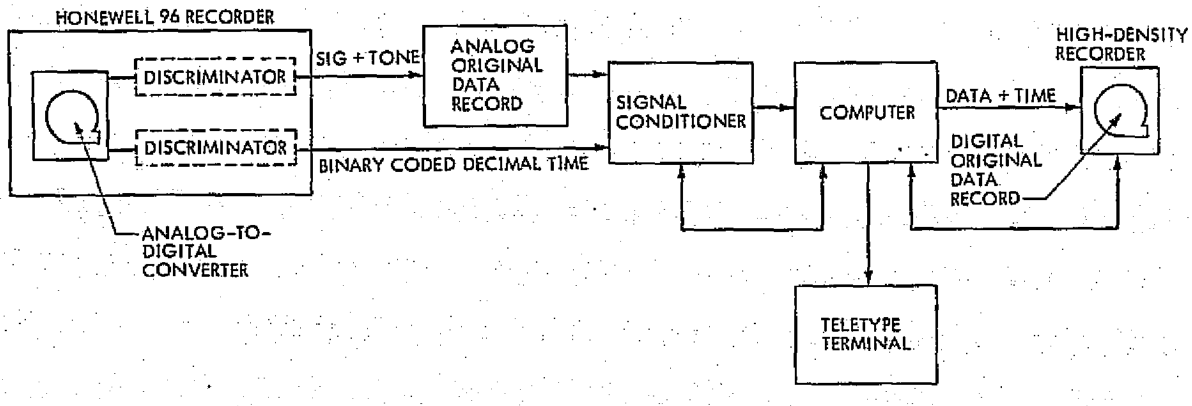


Fig. 54. Analog-to-digital conversion configuration at Compatibility Test Area 21

Each analog occultation tape contained recordings of both S- and X-band data from receivers operated in both the open-loop and closed-loop modes. The closed-loop receiver data can consist of up to 16 parameters that are digitized in pairs. A single occultation could result in analog tapes containing 22 minutes of entry and exit data from the open-loop receivers and 22 minutes of closed-loop receiver data. Digitization of all analog data by the Compatibility Test Area would require approximately 12 to 15 hours.

However, typical requirements during the Prime Mission have been on the order of four hours digitization time for each occultation. In addition to the occultation data conversion support, Compatibility Test Area 21 provides a backup capability for analog-to-digital conversion of Viking telemetry data. During the Prime Mission, a combined total of 38 occultation and telemetry analog tapes, resulting in 63 digital tapes, were processed by Compatibility Test Area 21.

C. GENERAL RELATIVITY EXPERIMENT

In September, the Viking Project approved the General Relativity Time-Delay Experiment proposed by the Radio Science Team.

General relativity predicts that radio waves will be slowed as they pass near the Sun by an amount that increases logarithmically to a maximum of about 250 microseconds (equivalent to approximately 38 km in one-way range) for rays that graze the solar limb on an Earth-Mars round trip. With the Viking Spacecraft, it was possible to test this prediction to an accuracy of 0.1 percent. The best prior test of any non-null prediction of general relativity had an accuracy of 1 percent. Thus the Viking experiment could yield a tenfold improvement in the testing of general relativity.

Two things made Viking unique for this test of general relativity: (1) the existence of the Lander(s) that enabled a determination of the precise position of the target in the solar system and, hence, to separate the direct relativistic effect from the total range; and (2) the existance of both S-band and X-band (downlink only) on the Orbiters that allowed separation of the effects of the plasma of the solar corona from the direct relativistic effect. (The dual-frequency capability also existed with Mariner 10, but its orbit was only poorly known; the orbit of Mariner 9 was also not known well enough, and, in addition, dual-frequency capability was not available).

The achievement of a 0.1-percent accuracy in the Viking general relativity experiment depended entirely upon the near simultaneity of the S- and X-band tracking of an orbiter and the S-band tracking of a lander.

The period of time covered by the simultaneous Lander and Orbiter ranging extended from November 3 through December 9. In addition, near-simultaneous Lander and Orbiter ranging before and after this time period was to be used as an essential part of the general relativity experiment data base, to solve for planetary ephemerides errors and as part of the Radio Science Lander location and Martian pole location experiments.

Experience during the Viking prime mission had shown that the ranging system — the planning, sequencing, data acquisition and processing — required continuous technical expertise to ensure good usable data. Due to various reasons, only about 25 percent of the near-simultaneous Lander and Orbiter ranging passes that were scheduled actually acquired good near-simultaneous Orbiter and Lander ranging. As a consequence of this poor record, the Real-Time Radio Science Ranging Team was organized and started into operation near the end of October.

By the end of the mission, there had been four attempts to acquire simultaneous Lander and Orbiter ranging from Station 14 and Station 43. The first pass with Lander 1 on November 3 experienced a ranging equipment failure that was corrected in time for a successful pass the next day. The two passes with Lander 2 on November 8 and 9 were successful. The Real-Time Ranging Team was able to monitor and correct many operational errors that would have resulted in lost ranging data. It appeared that the General Relativity Experiment should be able to achieve its objectives although solar corona effects were to become more severe with the approach of solar conjunction on November 25.

D. SOLAR CORONA EXPERIMENT

As Mars and Earth neared superior conjunction on November 25, radio signals from Viking spacecraft passed close to the Sun and were gradually affected by the influence of the solar corona. Signal variations, using dual-frequency downlinks, provided new information on regions close to the Sun.

Eight days of intensive solar corona data were acquired from October 3 through 10 to check the solar corona data acquisition process and also get useful solar corona data at a Sun-Earth-Probe angle of about 15 degrees. These data were acquired from Stations 14 and 43 using Orbiter 1, Orbiter 2, and Lander 2. Data were acquired in two modes: a multiple-spacecraft, single-station mode, and a single-spacecraft, dual-station mode. Both closed-loop data (4 streams of

10 per second data for a couple of hours) and open-loop data were acquired. The open-loop receivers at DSS 14 were operated in two modes: a mode to collect dual S-band data from two orbiters using synthesizer local oscillator predictions, and a mode to collect S- and X-band data from one orbiter using programmed local oscillator predictions. This week of successful operations provided the experience and data needed to design the solar corona passes during the solar conjunction period.

Open-loop analog recordings at the radio frequency carrier spectra from Orbiter 1 and Orbiter 2 were first delivered to the Radio Science Team on October 3, 1976. These tapes were first checked at Compatibility Test Area 21 for format, content, and data quality, and exhibited many defects at first. Daily air shipment of tapes from Goldstone was instigated so that the tapes could be examined at the Jet Propulsion Laboratory, and corrective instruction fed back to the station prior to the following pass. By October 8, the data quality had improved such that daily checks were no longer necessary, and provision of analog solar corona data became a routine procedure.

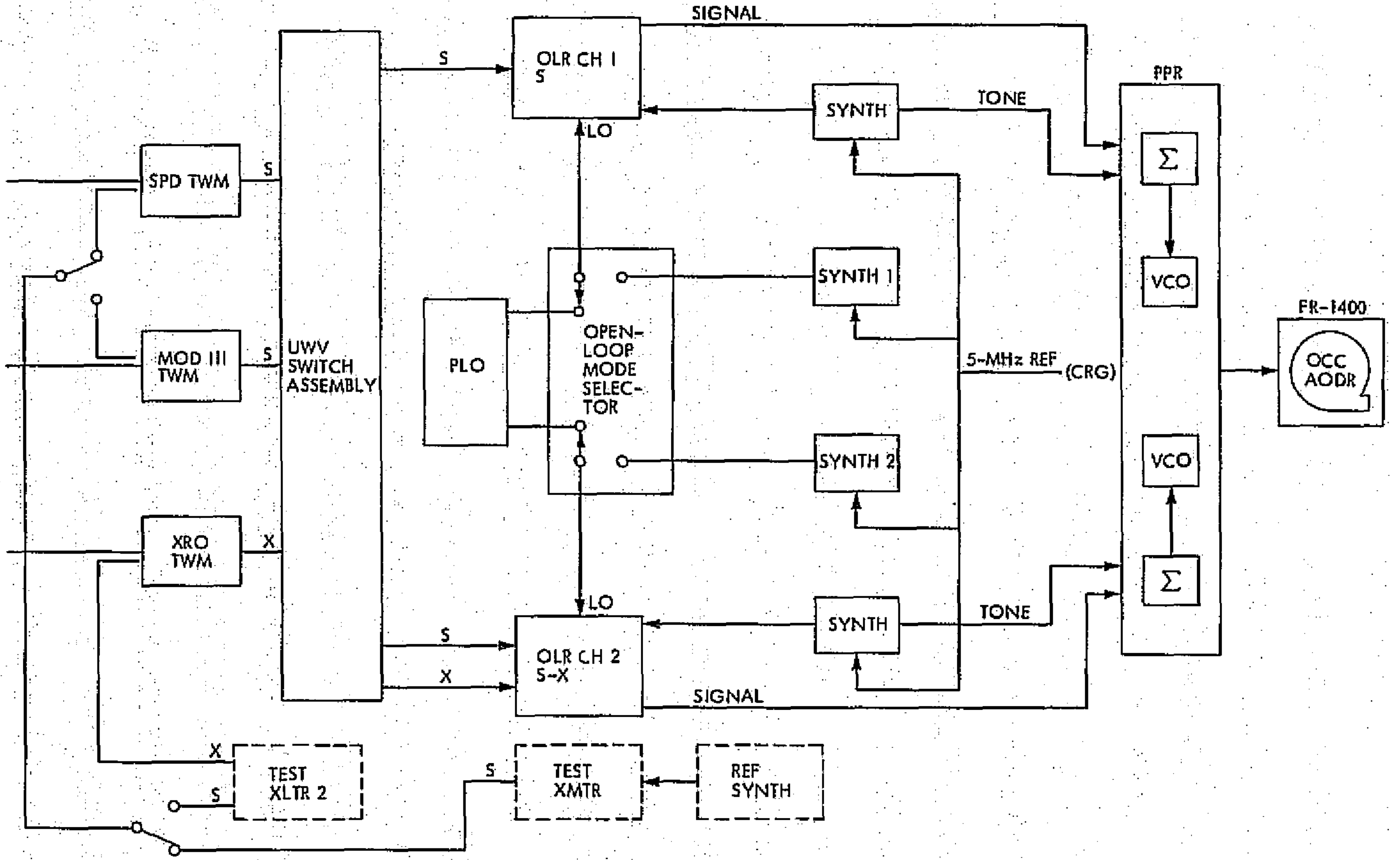
The configurations at Stations 14 and 43 differed somewhat in that Station 14 used a programmed local oscillator at certain times, as described above, in addition to the synthesizer. These differences in configurations are shown for comparison in Fig. 55 and 56.

Fortunately for the solar corona experiment, there were extensive periods of one-way tracking of the "second" Orbiter during the general relativity experiment. Since one-way S- and X-band data are not corrupted by the uplink solar corona scintillations, these data provided additional observations of great value to the solar corona experimenters.

E. ORBITER-QUASAR VERY LONG BASELINE INTERFEROMETRY

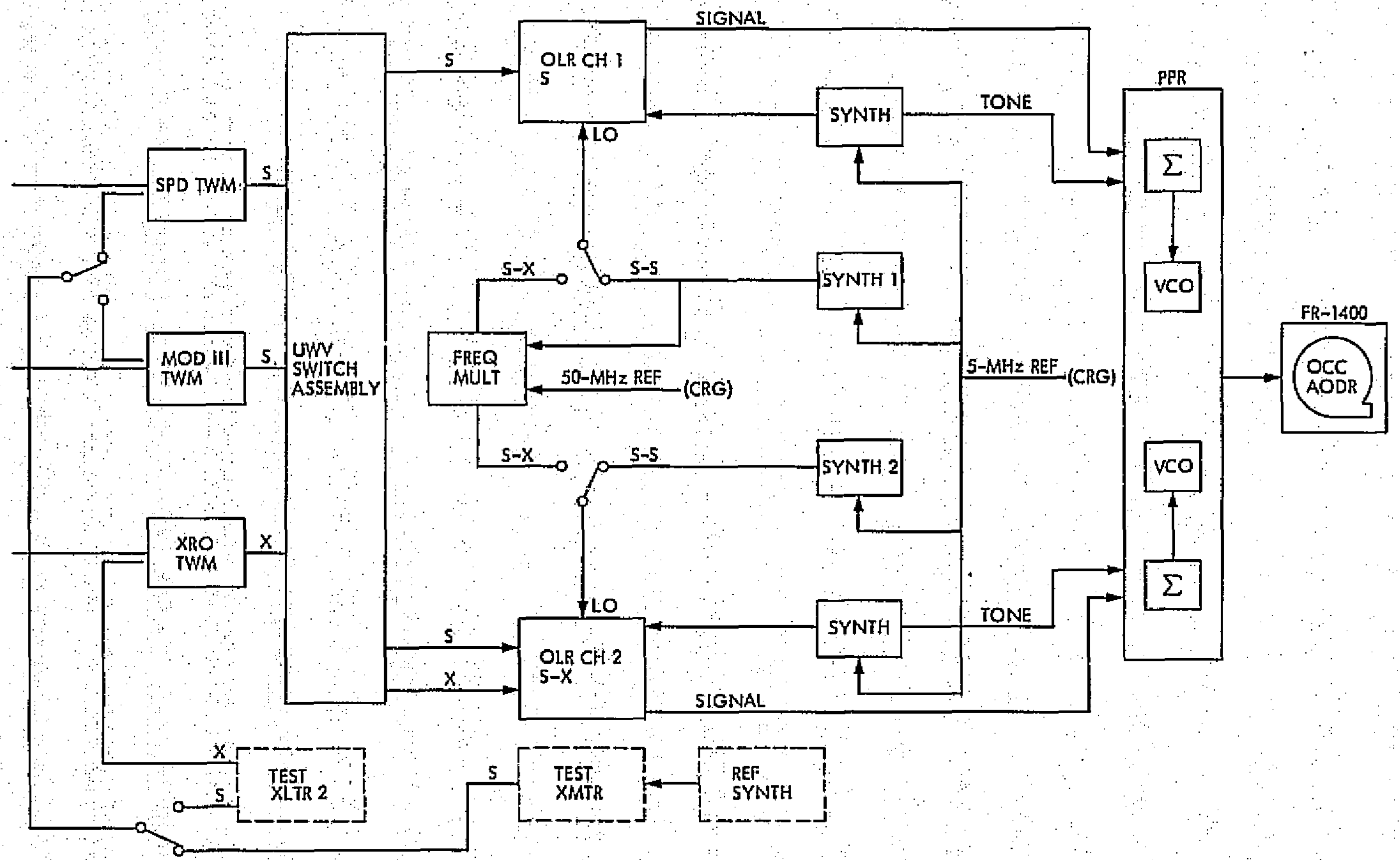
A total of six Orbiter-quasar very long baseline interferometry passes of data were acquired between Stations 14 and 42 after Viking arrived at Mars. These passes were:

Date	Orbiter	Quasar
July 14	1	OL 064.5
July 15	1	OL 064.5
August 19	1	P1148-00
September 22/23	2	3C 279
September 23/24	2	3C 279



AODR	ANALOG ORIGINAL DATA RECORD	S	S-BAND
CH	CHANNEL	SPD	S-BAND POLARIZATION DIVERSITY
CRG	COHERENT REFERENCE GENERATOR ASSEMBLY	SYNTH	SYNTHESIZER
LO	LOCAL OSCILLATOR	TWM	TRAVELING-WAVE MASER
OCC	OCCULTATION	UWV	ANTENNA MICROWAVE SYSTEM
OLR	OPEN-LOOP RECEIVER ASSEMBLY	VCO	VOLTAGE-CONTROLLED OSCILLATOR
PLO	PROGRAMMED LOCAL OSCILLATOR	X	X-BAND
PPR	PRE- AND POSTDETECTION RECORDING SUBSYSTEM	XLTR	TRANSLATOR
REF	REFERENCE	XRO	X-BAND RECEIVE ONLY

Fig. 55. Simplified Open-Loop System block diagram, Station 14



CH CHANNEL
CRG COHERENT REFERENCE GENERATOR ASSEMBLY
FREQ MULT FREQUENCY MULTIPLIER
LO LOCAL OSCILLATOR
OCC OCCULTATION
OLR OPEN-LOOP RECEIVER ASSEMBLY
PPR PRE- AND POSTDETECTION RECORDING SUBSYSTEM
REF REFERENCE
S S-BAND
SPD S-BAND POLARIZATION DIVERSITY
SYNTH SYNTHESIZER
TWM TRAVELING-WAVE MASER
UWV ANTENNA MICROWAVE SYSTEM
VCO VOLTAGE-CONTROLLED OSCILLATOR
X X-BAND
XLTR TRANSLATOR
XMTR TRANSMITTER
XRO X-BAND RECEIVE ONLY

Fig. 56. Simplified Open-Loop System block diagram, Station 43

During a very long baseline interferometry experiment, radio signals from a spacecraft and quasar were alternately recorded at two Deep Space Stations. The experiment yielded precise measurements of angular separation of the two sources. The results shows precise location of the spacecraft and that of Mars and Earth as well. By performing such experiments over a period of years, exact orbits can be determined and the general theory of relativity can be tested.

By the end of October, the data from the first two passes had been processed through the California Institute of Technology very long baseline interferometry correlator and appeared to be of good quality. Processing of the remaining data was in progress.

At Stations 14 and 42 special equipment was required to perform these functions. This equipment is listed here and its configuration is depicted in Fig. 57.

(1) Very long baseline interferometry S-band receiver.

(2) Hydrogen maser.

(3) Viking frequency converters.

(4) Mark II recorder system.

(5) Very long baseline interferometry frequency synthesizer.

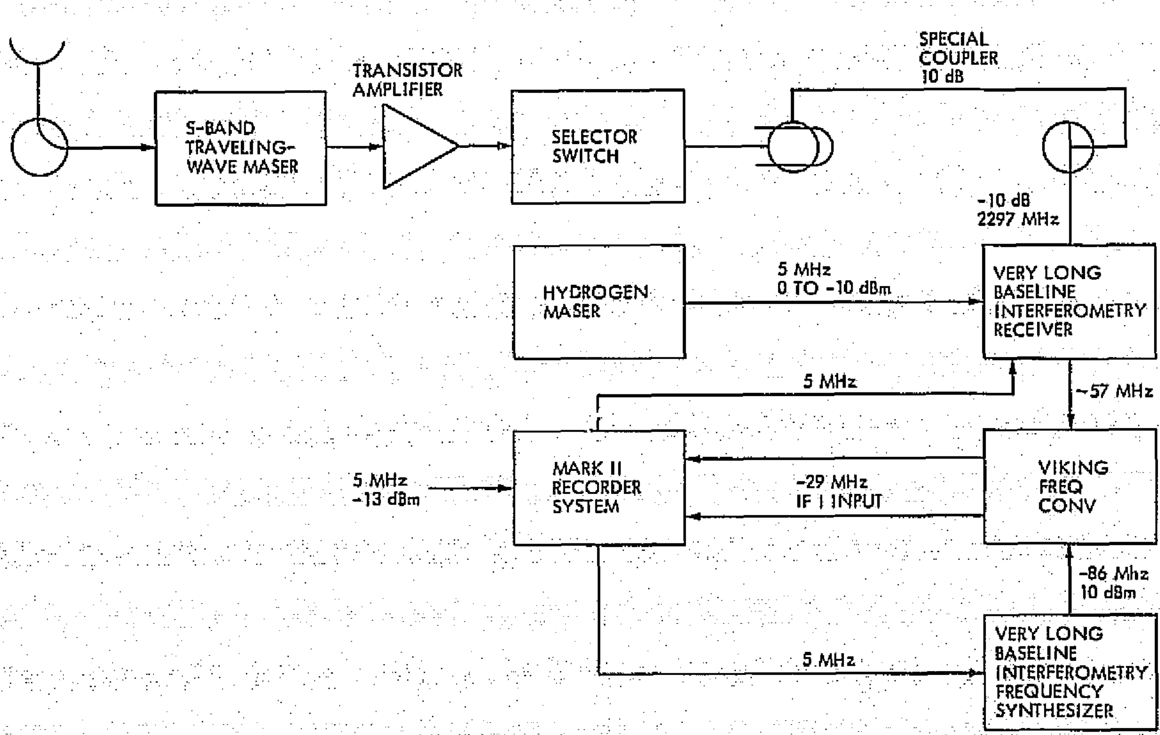


Fig. 57. Very long baseline interferometry configuration for Stations 14, 42, and 43

Continued acquisition of the Orbiter-quasar very long baseline interferometry data type during the Viking Extended Mission depends upon the resources available to plan, acquire, process, and analyze this data type.

F. LANDER RANGING

By acquiring Lander doppler and ranging data along with near-simultaneous ranging from the Lander and Orbiter, much knowledge may be gained concerning Martian polar properties and Lander position. Specifically, these data will be used for Viking Lander Location, and Martian Pole Location and Dynamics Experiments.

Near-simultaneous Lander and Orbiter ranging had been requested for the Radio Science Lander Location and Martian Pole Location and Dynamics Experiments. The technique of near-simultaneous ranging from the Lander and Orbiter from the same Deep Space Network station (shown in Fig. 58) eliminates the effects of differential charged particle and differential station location errors for stations located on different continents.

The power of the Lander doppler and ranging data had been demonstrated during the mission by the use of small amounts of data to solve for very accurate Lander locations and Mars pole dynamics. Lander and near-simultaneous orbiter ranging yields knowledge about changes in the Martian spin rate, and Martian pole precession and nutations — important results for understanding Martian dynamics and internal structure.

In addition, Lander and near-simultaneous Orbit ranging is to be used for another test of general relativity — a dynamic test as contrasted to the time-delay test discussed earlier. This dynamic test of general relativity will require Lander and Orbiter ranging over the lifetime of the Landers and Orbiters, and will be carried out during the Viking Extended Mission.

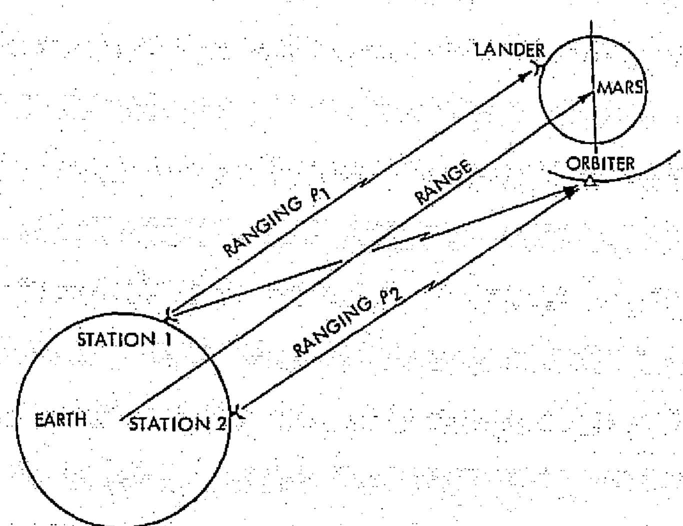


Fig. 58. Technique for near-simultaneous Lander-Orbiter ranging

G. ORBITER S- AND X-BAND DOPPLER AND RANGING

Since November 1975 when the X-band transponders on both the Orbiters were turned on, several hundred S- and X-band doppler and ranging passes of excellent data had been acquired during cruise and planetary operations. These data were extremely useful in evaluating the new X-band system performance, monitoring solar flares and solar corona noise, and for the charged particle calibration of doppler and ranging data. Four data types, i.e., S- and X-band doppler and ranging, have been compared and yield the same charged particle results. Namely, S- and X-band differential doppler, S-band and X-band differenced range versus integrated doppler, and S- and X-band range yielded the same change of total electron content during recent high solar corona activity passes. These data afforded the first practical demonstration of validity of the dual frequency calibration of charged particle effects in the interplanetary medium.

VI. RELIABILITY AND DISCREPANCIES

A. OPERATIONAL RELIABILITY

Data on the operational reliability of the Network for Viking support continued to be compiled by the Viking Ground Data System Support Office through the end of October 1976. This represented a total of one year's accumulation of data relative to Viking support throughout the Network, after which the work was discontinued. With the permission of the Chief of the Viking Ground Data Support Office, their data are reproduced in Table 18 below, since they afford a closely-bounded overall statement of how the Network actually performed throughout the mission from a reliability point of view.

Table 18. Operational reliability for Viking support from August 1975 through August 1976

Operational performance parameter	Deep Space Stations								
	11	12	14	42	43	44	61	62	63
Total support time, hours	1895	1729	1436	2274	1649	1429	2469	1941	2404
Number of failures	24	29	61	26	45	17	17	22	52
Mean recovery time, minutes	72	31	40	58	48	92	80	36	50
Mean time between failures, hours	79	60	24	87	37	84	145	88	46

The probabilistic data for up time and recovery time for each of the stations based on approximately one year of data are given in Figs. 59 through 67. In collecting these data, a system failure was defined as having occurred in real time system when either the real time recording of the data stream was not accomplished, the real time transmission of the data stream was not accomplished, or the real time display of the data in the mission support area was not accomplished. Failure of a single use input/output device was not considered a system failure.

Recovery is defined to be the recovery of the system capabilities. This is not necessarily the same as recovering to the same state of processing as when the system failure occurred.

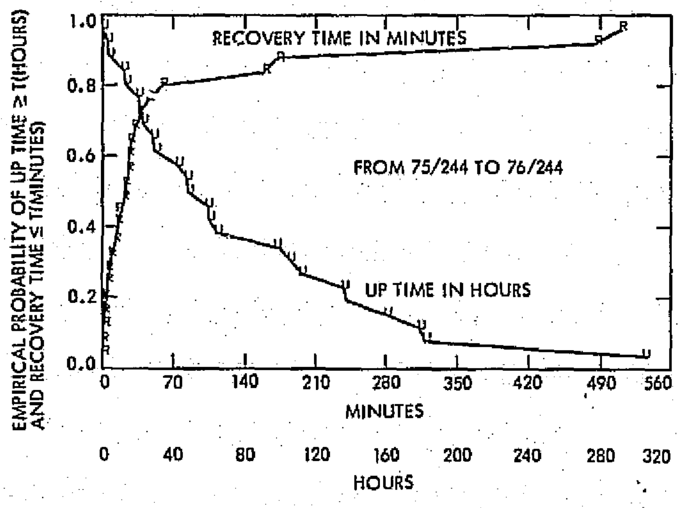


Fig. 59. Probabilistic data for uptime and recovery time at Station 11

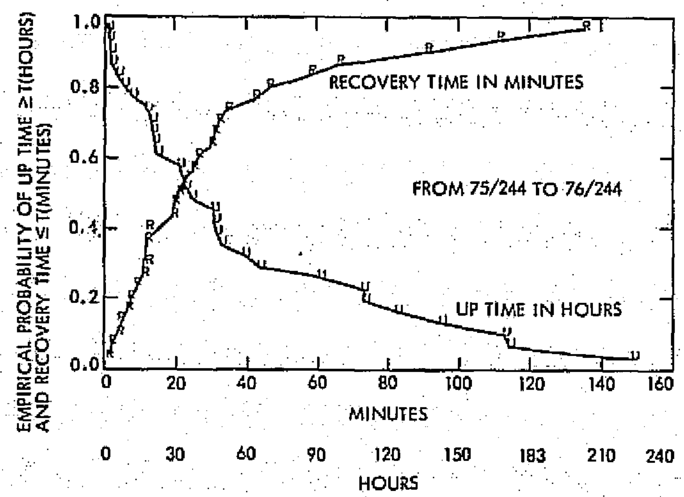


Fig. 60. Probabilistic data for uptime and recovery time at Station 12

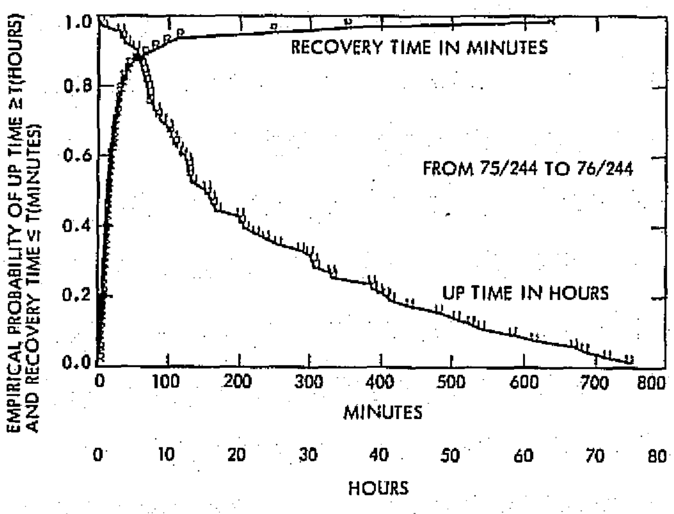


Fig. 61. Probabilistic data for uptime and recovery time at Station 14

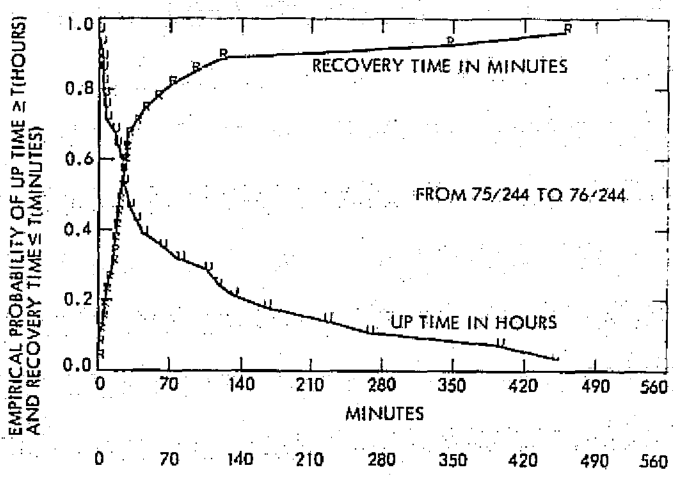


Fig. 62. Probabilistic data for uptime and recovery time at Station 42

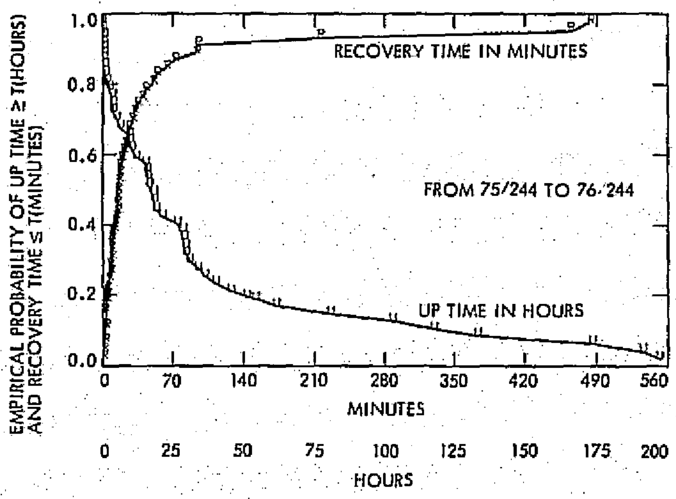


Fig. 63. Probabilistic data for uptime and recovery time at Station 43

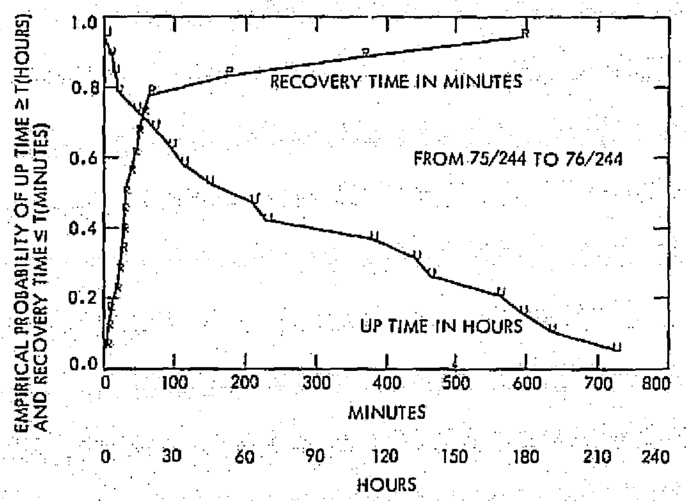


Fig. 64. Probabilistic data for uptime and recovery time at Station 44

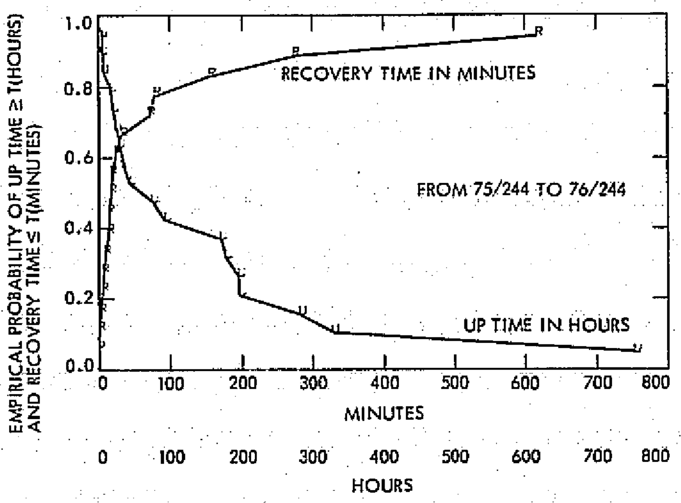


Fig. 65. Probabilistic data for uptime and recovery time at Station 61

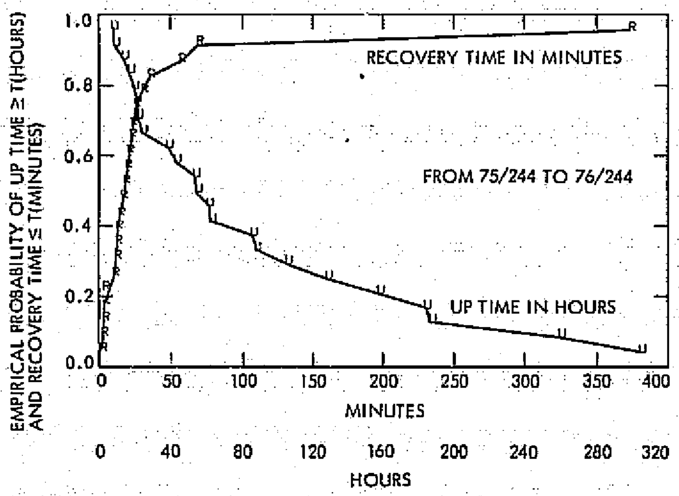


Fig. 66. Probabilistic data for uptime and recovery time at Station 62

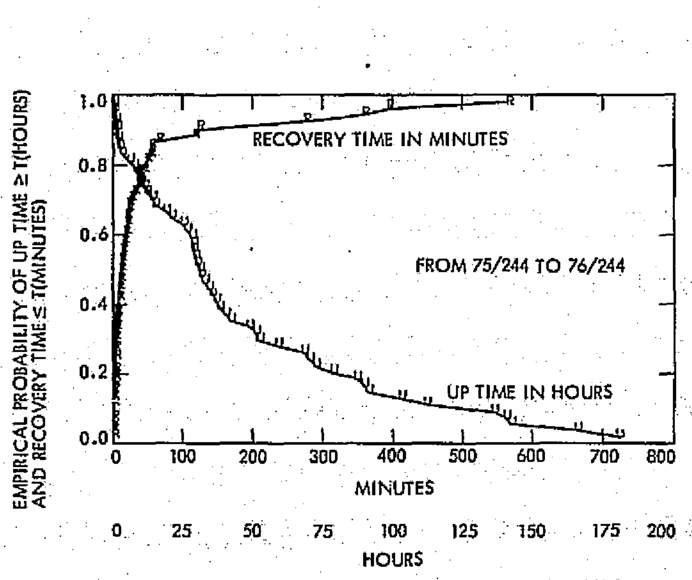


Fig. 67. Probabilistic data for uptime and recovery time at Station 63

B. DISCREPANCY REPORTS

The status of Viking hardware- and software-related discrepancies on September 1, as a necessary condition for Network readiness to support the second landing, is given in Table 19.

Of the total 27 reports outstanding at that time, only one was considered significant to Viking Lander operations. This anomaly concerned the slow lock up of the subcarrier demodulator at Station 43 for data rates of 4 kbps, and was under intensive investigation at the time.

The status of Viking-related Discrepancy Reports being carried by the Network's reporting system at the end of the Prime Mission is given in Table 20. The minimal number of discrepancies remaining active reflects the maturity of the Network. This is a result of the efficient and expedient attention that eventually evolved within the organization for identifying, analyzing, and closing out the anomalies.

Table 19. Viking Discrepancy Report status as of September 1, 1976

System \ Station	11	12	14	42	43	44	61	62	63	Network Data Processing Area	Control Area Network Operations	Totals
Tracking					1							1
Monitor										2	0	2
Telemetry	2		3		4				3	3	0	15
Command		1			1					1	0	3
Totals	2	1	3	0	6	0	0	0	3	6	0	21

Table 20. Viking Discrepancy Report status at end of Prime Mission

Discrepancy Reports \ Stations	11	12	14	42	43	44	61	62	63	Network Data Processing Area	Network Operations Control Area	Ground Communications	Network
Number outstanding on 11/1/76	0	0	8	0	5	0	0	0	0	7	1	0	0
Number closed out from launch through 11/1/76	67	54	233	55	143	23	41	30	168	222	122	50	33

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APPENDIX A

CHRONOLOGY OF EVENTS (1976)

July 4	Deep Space Network support for both Viking 1 and Viking 2 continues at satisfactory level. Network Operations Control Center delivering high quality Intermediate Data Records well within time limit.
July 6	Engine generator failure at Station 43 led to reevaluation of engine generator configurations throughout the Network to eliminate single part of failure mode.
July 7	Viking Lander 1 site strategy changes in light of new data from Arecibo. Expect landing about July 20.
July 8	Potential strike threat involving Australian stations appears to have been averted.
July 11	Australian general strike did not impact stations or communications during Viking pass.
July 20	Network gives perfect performance in support of Viking 1 landing.
July 21	Viking Lander 1 direct link established by Station 43.
July 22	Intensive effort with help from Division 33 to solve persistent Telemetry and Command Processor Assembly/Digital Instrumentation Subsystem problems at Station 14 related to the 2400 (Greenwich Mean Time) rollover problem.
July 24	Extensive investigation by Jet Propulsion Laboratory Division 33 engineers of Data Decoder Assembly timing problem present at Station 14 during 2400 hours (Greenwich Mean Time) rollover sequence. Data Decoder Assembly multiplex switch is suspected as cause. Investigations at Compatibility Test Area 21.
July 26	Forgings for new ball and socket assemblies for Station 43 arrived at Jet Propulsion Laboratory for machining and testing.
July 27	Special Data Decoder Assembly trouble shooting effort at Station 14 was terminated after several tracks without problems verified that problem had been corrected.
July 30	Network Operations Control Center Network Log Processor delayed delivery of 24 out of 41 Intermediate Data Records over the past few days. Division 33 help required to correct the problems.

August 1	Network Operations Control Center experienced Magnetic Tape Controller problems that caused Intermediate Data Record backlog.
August 3	No significant anomalies remaining in Network Operations Control Center identified as potential threat to continued Intermediate Data Record production for Viking.
August 6	Spare 100-kW klystron now received at Station 63 after repairs at Varian.
August 7	Mars Orbit Insertion for Orbiter 2 results in three spacecraft in antenna beamwidth simultaneously. All 64-meter station capabilities now saturated.
August 9	Network continues to support Lander 1 on surface of Mars and Orbiters 1 and 2 in orbit.
August 10	Block III Network Control System equipment in Network Operations Control Center experienced failure of Communication Equipment Subsystem resulting in Intermediate Data Record Backlogs.
August 11	Block I Network Control System equipment finally released, and removal from Network Operations Control Center begins.
August 12	Occultation Demonstration Test over Station 14.
August 14	Mission Orbit Trim No. 2 for Viking 2 over Station 43.
August 15	Two of three concave sections of the ball and socket assemblies for Stations 43 and 63 failed the heat treatment process — possible schedule impact.
August 18	Developed plan to perform special corrective maintenance to a segment (135 degrees) of Station 14 azimuth bearing in event that film height falls below 0.003 inches. Coordinated plan with Viking Mission Operations to minimize impact to mission.
	First full year of Viking Flight Operations has been completed.
	Two successful demonstration tests of communication circuit from Tidbinbilla to Jet Propulsion Laboratory via Ororal Valley and the ATS satellite.
August 19	Analog baseband playback being exercised regularly on weekly basis at all 64-meter stations.
	Orbiter 1/Lander 1/quasar very long baseline over Stations 41 and 42.

August 20	Six simultaneous data streams in regular operational use at 64-meter stations. Routine production of high quality Intermediate Data Records in progress.
	100-kW transmitter used extensively to support Lander 1 receiver anomaly investigation.
	Orbiter 1/Quasar Very Long Baseline Interferometry Experiment supported by Stations 14 and 42.
August 22	Nine potential anomalies identified in Network Operations Control Center require correction to ensure maintaining pressure for Intermediate Data Record production.
	Orbiter 1/Quasar Very Long Baseline Interferometry Experiment supported by Stations 14 and 42.
August 25	Mars Orbit Trim No. 3 for Viking 2 supported by Station 63.
August 26	Repair of cracks in antenna ball and socket assemblies for Stations 43 and 63 will cause delays such that air shipment may be necessary to meet original November schedule.
	Problems being experienced in digitizing occultation tapes from Station 14 at Compatibility Test Area 21.
	Work progressing in Network Operations Control Center using Mars Orbit Determination camp field service engineers.
August 27	Mars orbit trim No. 4 for Viking 2 supported by Station 14.
September 2	Station 14 antenna hydrostatic bearing condition remains stable.
September 3	Separation and touchdown for Lander 2, Friday, September 3, 1558 (Pacific Daylight Time).
September 4	First Lander 2 direct link over Station 43.
September 9	Orbiter 2 starts "walk" around planet at 40 degrees per day. All Lander 1 data returns via direct link at 1 kbps.
September 1	All the Network systems reporting green status for separation and touchdown of Lander 2; to be covered by Station 14 with Station 11 as backup.
September 2	Last Lander 1 relay link occurs on Sol 43.
September 3	Viking Radio Science Team requests extensive support for radio science during the solar occultation period, November 15 through December 15. This will impact the critical antenna maintenance rework planned during that period.

Excellent performance by all elements of Deep Space Network characterizes the leading of Viking 2 on Friday, September 3. Events were complicated by an orbiter attitude control anomaly following separation.

September 4 — First Lander 2 direct link successfully established by Station 43.

September 6 — Compatibility Test Area 21 used to support orbiter attitude control tests using Orbiter 3 at some impact to Metric Data Assembly software checkout.

September 8 — Final testing of open-loop receiver at Station 14 completed in preparation for live spacecraft occultation configuration test. Progress continues on analog baseband playback at Station 14.

September 9 — Critical antenna maintenance schedule during period November 15 through December 15, reexamined to defer Station 43 ball and socket work to December or January.

September 10 — Very long baseline interferometry procedures and sequences provided to Stations 14 and 42 for Orbiter quasar very long baseline interferometry passes on September 22, 23, and 24.

September 11 — Mars Orbit Trim No. 7 for Orbiter 1 performed over Station 14.

September 12 — Viking relativity experiment during conjunction period November 15 through December 15, now fully supported by Project with Station 43 downtime for ball and socket replacement starting between February 25 and March 10. Viking prime mission support continues with no outages or significant anomalies reported.

September 14 — Viking occultation recording test conducted successfully at Station 14, with similar test at Station 43 scheduled for September 22.

September 15 — Backup Network communications equipment implemented into the Block III Network Control System configuration and being used in support of Network Operations Control Center operations.

September 16 — Station 14 hydrostatic bearing being closely monitored due to an abnormally low film-height condition at 123 degree azimuth. Shimming to correct this condition may adversely affect the existing critical area around 135 degree azimuth. Corrective maintenance being deferred for approximately 10 days to avoid current Viking high-priority activities.

September 16 — Total commands transmitted to all Viking spacecraft now exceed 50,000.

September 17	Negotiated firm dates for Station 43 antenna repair to commence on February 28, 1977, and for Station 14 bearing repairs to start November 15, or sooner if possible.
September 20	Viking prime mission support continues to involve all elements of the Network and performance continues to exceed all expectations under prolonged maximum loading conditions.
	Station 14 hydrostatic bearing film height condition at 123-degree azimuth remains stable at greater than 0.004 inches.
September 22	Orbiter 1 Occultation Demonstration Test conducted at Station 43 discloses some procedural problems and doppler slips in the Radio Metric Data System. Quasar Orbiter very long baseline interferometry sequences conducted with Stations 14 and 42 on September 23.
September 23	Departure date of ship to deliver ball and socket joints to Station 63 is delayed 10 days, with latest arrival in Spain scheduled for November 15.
September 24	Viking 1 orbital walk ends with execution of Mars Orbit Trim No. 9 over Station 63.
September 28	Serious antenna outage at Station 42 averted by prompt action of station engineers in correcting three concurrent azimuth drive problems. Network continues to maintain high level of support of Viking prime mission with no significant problems reported and excellent intermediate Data Record deliveries.
September 30	Successful Occultation Demonstration Test performed at Station 43 in preparation for Viking occultation in early September.
October 8	First successful playback of baseband data from FR2000 analog receivers into Block IV. Subcarrier Demodulator Assembly accomplished at Station 14.
October 13	Viking Lander 2 loses downlink communications on traveling wave tube amplifier No. 1. Diagnosis in progress.
October 25	Both Block Decoder Assemblies red at Station 14, causing serious loss of high-rate data.
November 1	Block Decoder Assembly problem corrected at Station 14.
November 2	Occurrence of radio frequency interference at Goldstone of unknown origin causes loss of 50 minutes of 8-kbps high-rate data.
November 5	Station 14 begins critical bearing maintenance on alternate days.

November 4	Reliable occultation and solar corona data being delivered to Viking Radio Science Team.
November 11	Solar effects begin to degrade Viking telecommunication links with onset of solar conjunction.
November 12	Network Operations continued to maintain its high level of support with no significant problems or anomalies.
November 15	Viking Prime Mission ends.

Postscript:

As the Prime Mission ends, it is timely to recognize the contribution of many people in the development, engineering, technical support, documentation, network analysis, and secretarial areas without whose efforts the front-line operations teams could not have met the demands of the mission in the outstanding way that they did.

The Deep Space Network Manager recognizes and commends all these people for their help in various ways during the eight eventful years that the Network has been involved in the Viking Project.

APPENDIX B

IN RETROSPECT

November 15, 1976, marked the end of the Viking Prime Mission and, what was for the Deep Space Network, the conclusion of the largest, most complex, and most demanding mission ever supported.

It was the largest mission in terms of its demands upon the resources of the Network, the most complex in terms of operational sequences, scheduling, and numbers of spacecraft, and the most demanding in terms of a continuous, sustained high level of performance throughout the Network for long periods of time. That the Network was able to meet this challenge and provide the required level of support contributed in a major way to the success of the Viking mission.

However, this measure of success was not achieved easily or without cost, nor was it by any means perfect.

This closing section affords an opportunity to examine, in retrospect, the adequacy of the management, planning, implementation, and test processes that preceded the mission, the quality of support provided during the mission, and the efficiency of the Deep Space Network working relationships with elements of the Project both before and during the mission.

The greatest single deficiency in the Network planning and implementation activity in the years preceding launch was the failure to achieve many of its original schedules, except for those associated with the Telemetry and Command Processor software. Viewed in the harsh unforgiving light of the Project's own rigorous scheduling and review techniques, the Network's performance in meeting the original schedules and achieving milestones on time was poor indeed. Eventually, as built-in slack time eroded, and tension in the mission environment increased, confrontations between Project Management and top level Laboratory Management took place on what were relatively minor items of implementation. The reasons for the Network's poor schedule performance, relative to Viking, can be attributed to several factors:

(1) The impact of the earlier Mariner Venus-Mercury implementation, the Pioneer 10 and 11 launches, the Helios 1 and 2 launches, and the continuation of these missions into extended phases.

(2) A gross underestimation of the engineering resources needed to deliver hardware, software, and documentation to the stations in time to allow for implementation and adequate testing at the subsystem and system level, prior to the start of operational crew testing and training. It can be claimed, and with justification, that the limited engineering manpower available was a reflection of the diminished budget and manpower constraints of that period.

(3) As a result of (2) above, the stations were in many cases forced into declaring an operational status with inadequate training and procedures, and immature hardware and software configurations. As was to

be expected, numerous problems and anomalies surfaced only as the systems matured in the operational environment to which they were connected, causing repercussions throughout the Mission Operation's organizations, overloading the limited resources available to immediately work on the problems, and eroding the credibility of the Network, as seen by Project Management.

(4) Unforeseen hardware and software problems. This applied particularly to the new dual-frequency S/X-band receiver, and a new system for automatically recalling previously recorded telemetry data from the stations to the Network Control Center. The former was a new development with a greater-than-usual incidence of complex radio frequency problems, while the latter problems were created by the constraints of earlier software programs being required to perform a greatly increased new task.

(5) A rather loose organizational discipline between the development and operations organizations relative to responsibility for delivery of fully-checked and documented Engineering Change Order Kits to the stations.

(6) A belated recognition of the magnitude of the Network reconfiguration task for Viking, and the need for an improved engineering change management structure to direct the multiple interlocking tasks in a coherent manner.

(7) The specialization of particular individuals in certain initial tasks so that continuation of the work became critically dependent on these particular individuals. Thus, resignations, sickness, vacations, pregnancies, and the working week of particular individuals could have a major effect on a high-level schedule. This was particularly true in the development of the automatic telemetry recall system and Network Operations Control Center software.

However, most of the areas of weakness were the outcome of a relatively short-term peak load on an on-going organization whose resources were constrained by manpower limitations to a rather lower average level of effort. As a result of the Viking experience, some of these deficiencies, particularly those related to engineering change management and new implementation, have been corrected for future missions. But there still remains much scope for improvement in the remaining areas of weakness, as the Network continues to evolve to meet the demands of future missions.

Another factor stemmed from the difference between the Management approach adopted by Jet Propulsion Laboratory Flight Projects to which the Deep Space Network was accustomed, and the management approach used by the Langley Research Center for the Viking Project.

Although in the real world one does not expect perfect harmony, the working relationships between the Network managed by JPL and the Project managed by LRC were not always conducive to greatest efficiency in the utilization of the overtaxed Network resources. Individual idiosyncrasies surfaced early in the life of the project, and to a certain extent, persisted to its conclusion, coloring working relationships between individuals and between working groups across the Project-Network interfaces.

The Project, under pressure to meet its own launch schedules and cost ceilings, was understandably intolerant of the Network's own internal problems of manpower cost and schedules, and could do little to help, except by escalating the deficiencies to top management levels.

The Viking Project was forced, because of its widespread geographic disposition, to place a great deal of reliance on documentation, frequent status reviews, and regular progress reporting for its management of such a vast Project. Wisely, the Project Office set up an organization at Langely Research Center to properly manage the huge volume of paperwork that resulted. The Network was unused to this management technique, with one individual as the recipient of the resulting avalanche of written material. The paperwork soon became an impossible bottleneck, demanding attention that should have been spent on tasks more directly related to the Network implementation and test activity.

Without a formalized status reporting system giving resolution to the assembly or test level on a weekly, and in some cases, daily basis, the DSN was unable to match the three-level, weekly and monthly status and progress exhibits demanded by the Project scheduling office.

Certainly, the introduction of the Engineering Change Management System did much to improve this situation, but, in the end, the Project itself had to assist with planning, updating, and rescheduling the vast number of tests of various kinds that were simultaneously in progress throughout the entire world-wide network.

However negative the foregoing observations may appear in retrospect, the Network's performance, once into the actual mission, was nothing short of amazing.

Although problems with hardware, software, and operations personnel cannot be denied, solutions or workarounds to these problems were rapidly found, and back-up, redundant channels, or tape recordings were brought into action, without significant loss of any data, and without jeopardizing a single critical spacecraft sequence, or sending one improper command — proof that the Network functioned as a complete entity throughout its planning, implementation, and operational phases.

It is hoped that these observations, made as the Viking Prime Mission draws to a close, will afford some insight into the less-obvious aspects of the Deep Space Network support for Viking that may be of interest to future planners of large scale mission support.

APPENDIX C

NASA OBJECTIVES FOR THE VIKING PROJECT

S-815-75-01/02

NASA OBJECTIVES FOR THE VIKING PROJECT

OBJECTIVES

The purpose of the Viking missions is to significantly advance the knowledge of the planet Mars by means of observations from Martian orbit and direct measurements in the atmosphere and on the surface during the 1975 opportunity. Particular emphasis will be placed on obtaining biological, chemical, and environmental data relevant to the existence of life on the planet at this time, at some time in the past, or the possibility of life existing at a future date.

R. S. Kraemer
Robert S. Kraemer
Director, Planetary Programs

Date: 7-31-75

Noel W. Hinners
Noel W. Hinners
Associate Administrator for Space Science

Date: July 31, 1975

ASSESSMENT OF THE VIKING 75 MISSION

Based upon the results of the Viking 75 Mission with respect to the approved pre-launch mission objectives, the primary mission is adjudged a success.

A. T. Young
A. Thomas Young, Director
Lunar and Planetary Programs

Date: 1/3/77

Noel W. Hinners
Noel W. Hinners
Associate Administrator for Space Science

Date: 1/5/77

12/27/76

APPENDIX D

ASSESSMENT OF PRIMARY MISSION

Post Landing
Mission Operation Report
Report No. S-815-75-01/02

MEMORANDUM

January 6, 1977

TO: A/Administrator

FROM: S/Associate Administrator for Space Science

SUBJECT: Viking 75 Mission, Assessment of Primary Mission

Two Viking spacecraft were launched with Titan/III Centaur launch vehicles on August 20 and September 9, 1975, from the Air Force Eastern Test Range, Pad 41. Both launches occurred within their nominal launch windows. After launch, the spacecraft identifiers were changed from A and B to 1 and 2.

The spacecraft arrived at Mars and were successfully inserted into orbit on June 19 and August 7, 1976. The Viking 1 Lander successfully landed at 22.5°N latitude by 48.0°W longitude on July 20, 1976. The Viking 2 Lander descended safely on September 3, 1976, at 47.9°N latitude by 225.9°W longitude.

All the Viking scientific instruments, except for the seismometer on Lander 1, which failed to uncage, operated satisfactorily and continue to send data back to Earth. With the exception of the seismometer failure, it has been possible to work around the few anomalies that occurred by using alternate operating modes designed into the system.

Details of mission plans and operations have been reported in the Prelaunch Mission Operation Report (August 1, 1975), Post Launch Mission Operation Reports #1 and #2 (August 28, 1975 and September 16, 1975), Pre-Orbit Insertion and Landing Mission Operation Report (June 9, 1976) and the daily Viking Status Reports issued from pre-encounter through the primary mission.

Based upon the results of the Viking 75 Mission, the primary mission is adjudged as successful.

Noel W. Hinners

Noel W. Hinners

APPENDIX E

PRELIMINARY SCIENTIFIC RESULTS

S-815-75-01/02

PRELIMINARY SCIENTIFIC RESULTS

The Viking Project objectives were to significantly advance the knowledge of the planet Mars by means of observations from Martian orbit and by direct measurements in the atmosphere and on the surface during the 1975 opportunity. Particular emphasis was placed on obtaining biological, chemical, and environmental data relevant to the existence of life on the planet at this time, at some time in the past, or the possibility of life existing at a future data.

Preliminary scientific results for the primary mission have been reported in:

Viking 1 Early Results	NASA SP-408
Science Vol. 193	27 August 1976
Science Vol. 194	1 October 1976
Science Vol. 194	17 December 1976

These results are summarized in the following brief statements.

Orbiter imaging shows the Mars surface to be much more heterogeneous than anticipated. Some of the surface features are very ancient while others appear to be of recent origin. Crater frequency and size distribution is being used as a basis for estimating the sequence in the formation of these features. The major volcanic piles are comparatively young although no present activity has been observed.

Water is more abundant than was suggested by earlier data. The residual polar caps are composed of water ice. Unique lobate crater ejecta and large areas of surface slumping also suggest subsurface water or permafrost. Atmospheric water vapor shows distinct diurnal and seasonal cycling.

Nitrogen, argon, krypton, and xenon were detected in the atmosphere and the isotope ratios for carbon, oxygen, nitrogen, and argon were established. The isotope ratios are in some cases significantly different from those observed on Earth. These observations will continue to be the subject of study and discussion relative to the evolutionary history of Mars.

The landing sites are surprisingly similar although they appeared to be quite different in character at the limit of orbiter image resolution. While there are a few notable differences in the two sites, they are generally rock strewn landscapes with fine wind-blown material interspersed. At site 1 there are drifts of fines that show evidence of stratification, suggesting cyclic episodes of deposition and erosion. At site 2 a small depression crosses the near field of view. This may be a part of the large scale polygonal fracture pattern covering much of the northern hemisphere at the latitude of the landing site.

12/27/76

Elemental analysis of the surface fines show a high concentration of silicon, iron, magnesium, calcium, aluminium and sulfur in that order of relative abundance. The high Ca/K ratio, together with the elemental abundances, indicate the material to be basaltic rather than granitic in origin. This indication is supported by the Radio Science observation that the surface dielectric constant at the landing sites is consistent with that for pumic or tuff.

Rocks in the fields of view show a wide diversity of size, color and texture. However, attempts to obtain a sample of small rocks or coarse gravel for elemental analysis were unsuccessful during the nominal mission. This is due to an apparent characteristic of the sample sites where pebble-like features are really clods of adhesive surface material.

The Biology experiments have not unambiguously demonstrated the presence or absence of living organisms in the Mars surface samples. What appear to be positive indications have been received from two of the three experiments. The third experiment shows a high reactivity of the surface material when exposed to moisture. The chemistry of the soil is not understood and the response appears to be significantly different than tests with Earth and lunar soils. Experiment parameters will be modified during the Viking Extended Mission in an attempt to better understand this unique chemistry and to determine with more confidence the presence or absence of biological activity. Earth based tests are also underway to help understand the biology experiment data.

No organic compounds were identified in the surface samples acquired. The organic analysis data did reveal the presence of a hydrated mineral, stable at 200°C, but which released water equivalent to about 1% of the sample at 350° and 500°C. A somewhat higher water concentration was measured in a sample from beneath a rock.

The Physical and Magnetic Properties investigations show the surface to have good bearing strength. The fine surface has a cohesiveness of approximately 10^3 dynes/cm^2 and contains 3 to 7% of magnetic particles.

Meteorological observations show the weather to be mild during the northern summer and highly predictable from day-to-day. Temperatures range from a low of 187°K just before sunup to 242°K in mid-afternoon. The mean vector wind has been from the south at 2.4m/sec with steady state variations from near zero at midnight to 8-9 m/sec in midday. Atmospheric pressure on Mars shows a predictable semidiurnal harmonic. There was a small but steady drop in pressure from the time of landing to late in the primary mission. This drop was estimated to be the result of south polar deposition of CO_2 from the atmosphere. A similar conclusion was drawn from the infrared thermal mapper data taken from orbit. Thus Mars is expected to have a semiannual pressure cycle as the deposition and evaporation of CO_2 shifts from pole to pole with the seasons.

While a large volume of Radio Science data remains to be analyzed and interpreted, early results include an improved knowledge of Mars ephemeris, rotation and shape. Occultation measurements, together with other atmospheric and meteorological observations will make possible modeling of the dynamics of the Martian atmosphere. Analysis and interpretation of the Relativity, Solar Corona, and VLBI data should increase our knowledge of the Solar system and the universe.

NASA — JPL — Coml., L.A., Calif.