NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Technical Memorandum 33-783

Volume II

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

Launch Through Landing of Viking I

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Tracking and Data System Support for the Viking 1975 Mission to Mars

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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 this, the second, volume. The third volume discusses the support provided for the landed operations of Viking 1 and the landing and subsequent planetary operations for Viking 2. The end of the Viking Prime Mission is planned for November 15, 1976, and operations extending beyond that point are covered in the fourth volume of this series.

The Tracking and Data System activities discussed 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.

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Tracking and Data System
Manager

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Outside the Deep Space Network, but within the Viking Flight Team, appreciation is also expressed to the Orbiter Performance Analysis Group for making available much of the DSN-Orbiter telecommunications performance analysis data used in this report.

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ABSTRACT

The Viking 1975 mission to Mars depended on NASA's Deep Space Network and Spaceflight Tracking and Data Network, together with the NASA Communications Network and support from stations of the Air Force Eastern Test Range, to provide its tracking and data acquisition support. This document describes the Tracking and Data System support for the Viking Mars mission from launch in August and September 1975 through the cruise phase to the landing of the first Lander on the surface of Mars in July 1975.

Beginning with tracking coverage of the launch phase, the report describes the deep space operations during the long cruise phase that occupied approximately 11 months, the implementation of a vast worldwide network of tracking stations and global communications systems, and the performance of the personnel, hardware, and software involved in this vast undertaking.

Some of the unique problems inherent in the deployment and management of a worldwide tracking and data acquisition network to support the two Viking Orbiters and two Viking Landers simultaneously over 320 million kilometers (200 million miles) of deep space are highlighted.

I. COUNTDOWN AND LAUNCH

A. INTRODUCTION

The initial planning of tracking and data acquisition support for the Viking Project commenced as early as September 1968 and increased in scope and complexity as the Project itself developed from the conceptual stage to a firm design for the mission. As the mission and spacecraft designs evolved, the demands on the Tracking and Data System increased, with tradeoffs being made where necessary to keep within the constraints of schedules and resources.

During this period, the Tracking and Data System supported the tracking demands of Helios 1, Pioneers 10 and 11, Mariner 9 (Mars), and Mariner 10 (Venus/Mercury). A major new three-phase implementation in the Network Operations Control Center was also started and completed up to the second phase by the time of the Viking launches in August and September 1975.

This workload, along with the rescheduling of the Viking launch itself from 1973 to the 1975 opportunity, inevitably made an impact on the final Viking implementation schedules. This situation forced some innovations to the existing engineering change management procedures and to the design and execution of the resulting requalification tests of the tracking stations at system and subsystem levels.

As the size and complexity of Viking support in both the near-Earth and deep space phases continued to increase, the demands for well-trained crews to operate and maintain the vast complex of hardware and software became pressing. Again, innovative approaches to personnel training and qualification in the exacting timeliness called for by the Viking launches and following cruise operations were required.

Prior to launch, both Viking Orbiters and Landers were required to pass a comprehensive family of radio frequency and data system compatibility tests to ensure that these interfaces would be compatible with the deep space stations which later were to track the spacecraft throughout the mission.

Finally, all near-Earth supporting stations and facilities---encompassing the Air Force Eastern Test Range, Spaceflight Tracking and Data Network, NASA Communications, and Kennedy Space Center---together with the worldwide complex of stations of the Deep Space Network, were brought together with the Mission Control Center at the Jet Propulsion Laboratory in a progressive series of tests. These were to verify that all Earth-based elements of the Viking Project were ready to support the commitment of both spacecraft to launch.

The history of this effort up to the events surrounding the actual launches themselves is given in Volume I of this series. This document, Volume II, commences with the launch of Vikings A and B, continues through the long cruise of both spacecraft to the planet Mars, and concludes with the landing of Viking 1.

The history continues in Volume III with a description of the Tracking and Data System support for Viking mission operations with the Landers on the surface of Mars and the Orbiters in orbit about Mars.

B. MISSION A ACTIVITY

1. First Attempt, August 11, 1975

Viking A spacecraft was initially scheduled for launch at 20:59 (GMT) on August 11, 1975. At that time, the tracking ship Vanguard was prepared to cover the launch on a best-obtainable basis while enroute from support of the Apollo-Soyuz Test Project. One Advanced Range Instrumentation Aircraft was deployed to Ascension Island and two aircraft were deployed to Cape Town, South Africa.

The countdown started 9 hours prior to scheduled launch time with the establishment of voice and data circuits to all near-Earth stations. The validation of stations proceeded in accordance with the published sequence of events with only minor difficulties. The data line to the Vanguard was lost; the Ascension radar experienced a power supply problem; and the second Ascension radar had a transmitter outage of approximately 13 minutes duration.

At T minus 150 minutes, a problem occurred on the Titan solid rocket booster stage when a thrust vector control valve did not respond properly during checkout. The launch had to be scrubbed for that day because the valve checkout involved unloading and purging the N_2O_4 tanks on the solid booster. However, after the valve was replaced and checked out, the launch was rescheduled for August 14.

Later, this new date had to be changed because of another problem. While preparing to charge the Orbiter batteries on August 13, it was discovered that the batteries had fallen from their normal charge of 37 volts down to 9 volts. This drainage had occurred because a motorized rotary switch aboard the Orbiter had turned "ON" inadvertently, some time after the launch postponement on August 11. The entire Viking A spacecraft was removed from the launch vehicle, and the Viking B spacecraft was substituted. Orbiter Precount, Lander Prelaunch and Cruise Update, and Orbiter Flight Data Subsystem Update tests were then performed in preparation for a launch on August 20.

However, the delay from the original launch date enabled the ship Vanguard to reach a more favorable test support position prior to launch.

2. Second (Final) Attempt, August 20, 1975

The countdown was conducted in accordance with the published sequence of events for a liftoff at the beginning of the launch "window" at 21:22 (GMT) on August 20. The actual launch was accomplished at 21:22:00.155 (GMT).

During the countdown, the Antigua radar failed its antenna slew checks. As a result, metric data were expected to be adequate for near-Earth purposes, but inadequate for range safety purposes. A 104-degree launch azimuth cutoff, for range safety purposes, was therefore imposed. (The impact of this cutoff was that the duration of the launch "window" was reduced from 71 minutes to 49 minutes.)

Post-launch investigation revealed that the azimuth angle encoder was loose, and that a module which provides reference voltage in the digital-to-analog converter was defective. (These defects were correlated prior to the Viking B launch.)

All range instrumentation aircraft were airborne on time, and the validation of stations providing real-time telemetry data was performed successfully except for aircraft 2. (Post-launch examination revealed the problem to be a connector, which was repaired prior to the Viking B launch.) The problem affected only the real-time retransmission capability of spacecraft telemetry data. It was decided "in-count" that this problem would not result in a "hold "or" scrub," and launch occurred as scheduled.

Fortunately, no abnormal launch pad damage occurred at launch. Two checkout antennas were blown off their mounts at the launch pad, however, and had to be replaced before the Viking B launch.

During the time period August 11 through 20, 1975, supporting stations of the Deep Space Network remained in their Viking configuration and performed operational verification tests to assure that all systems were maintaining their "green" status.

Following the launch, downlink signals from the Viking 1 spacecraft were acquired by the prime Australian station (Station 42) at 22:10:05 (GMT) and by the backup Australian station (Station 44) at 22:11:38 (GMT). The downlink signal levels received by the stations were in close agreement with the predicted nominal values.

At 22:26:15 (GMT) the prime Australian station transmitted the first commands to the spacecraft to begin its Canopus acquisition sequence at 27:42:04 (GMT). These commands were repeated at 22:44:50 and 22:45:20 (GMT) for verification. A successful acquisition of Canopus by the spacecraft was made, and the spacecraft entered its cruise mode, which would continue until August 27. At that time, the first midcourse maneuver was scheduled to take place and target the Mars landing for July 4, 1976.

C. MISSION B ACTIVITY

The Viking B launch date had been rescheduled to September 3, as a result of the Viking A launch date change. But, during routine spacecraft checks on September 2, a degradation of 3 dB in the uplink signal level was detected when the receiver was switched to the high-gain antenna. In order to investigate this anomaly, the spacecraft was demated from the launch vehicle and the shroud removed. The problem was cleared after a complete set of new hardware (cables, joints, etc.) was installed between the high-gain antenna and the diplexer. The spacecraft was then rechecked and remated to the launch vehicle. The revised launch date was now September 9, and all systems were "green."

The countdown was conducted in accordance with the published sequence of events for a liftoff at the beginning of the launch "window" at 18:39 (GMT) on September 9.

Early in the countdown, the Antigua radar experienced a problem with the high-rate slew checkout, but the low-rate slew checkout was satisfactory. It was determined that the radar tracking data would be acceptable.

While range aircraft 1 was preparing to take off at Ascension Island, it experienced a damaged wing when jet blast from aircraft 3 blew a loading ramp into the first aircraft. Because the first aircraft was now unable to support the launch, the third aircraft took the first aircraft's test support position and identification.

All stations supporting the near-Earth phase remained "green" throughout the remainder of the countdown. Launch occurred without any unscheduled holds at 18:38:59.960 (GMT) on September 9.

Severe fire damage to the launch pad and to the Aerospace Ground Equipment building was experienced. The damage was sufficient to cause a delay in the Helios B launch, from early December 1975 to mid-January 1976.

Following liftoff, initial acquisition of the spacecraft at Station 42 in Australia was accomplished at 19:27:26 (GMT), exactly in accordance with predictions.

On September 19, 1975, as planned, the Deep Space Network provided support for the first midcourse maneuver of Viking 2, which targeted the spacecraft to arrive at Mars on August 7, 1976.

II. NEAR-EARTH SUPPORT

A. MISSION A NEAR-EARTH LAUNCH SUPPORT

1. General Summary

The Mission A flightpath was nominal and on time throughout the near-Earth phase of the mission, although the vehicle passed through the African protective line about 10 seconds late. Table 1 provides nominal versus actual reported MARK event information.

Overlapping coverage, combined with conservatively planned quality data intervals, resulted in ground telemetry systems performance that exceeded the required coverage intervals. The acquisition of quality telemetry data by all Advanced Range Instrumental Aircraft began later than planned. Only aircraft 1 retransmitted spacecraft telemetry data in real time. Aircraft 2 was unable to retransmit in real time because of a connector problem, and the third aircraft was directed not to attempt real-time retransmission since it was providing essentially the same coverage as the first. The later than nominal acquisition of signal by aircraft 1 resulted in only a short gap in the "in-sync" data processed in real time by the Mission Test Computer at the Jet Propulsion Laboratory.

All stations of the Spaceflight Tracking and Data Network, including the ship Vanguard, provided excellent telemetry support, with a number of stations exceeding the amount planned. Decommutator lock on certain links at certain stations was less than scheduled for the usual reasons of low elevation pass and/or poor aspect angles. Telemetry data from all stations were generally excellent and adequately covered the flight.

Performance by Air Force Eastern Test Range radars was successful in that each radar provided support for at least 95 percent of its planned interval.

The Bermuda radar of the Spaceflight Tracking and Data Network exceeded its planned data interval. The tracking ship Vanguard experienced beacon lobing because of poor aspect angles, resulting in loss of data for a short period prior to loss of signal approximately 7 minutes earlier than predicted. However, sufficient data were received by the Real-Time Computer System at Cape Canaveral to enable timely computations of orbital parameters.

NASA Communications Network support (voice, data, and teletype circuits) was excellent throughout the near-Earth phase of the mission.

The Real-Time Computing System provided timely computations of orbital parameters, inter-net predicts for acquisition by the Deep Space Network, and mapping to planetary encounter.

Telemetry data recorded at the tracking stations were returned to the Kennedy Space Center within the specified 36 hours after launch. Aircraft 2 picked up the Johannesburg station data and delivered them

Table 1. Nominal versus actual MARK events for Viking A (launched August 20, 1975)

Mark	Event	Time (actual), GMT	Elapsed time, seconds	
			Actual	Nominal
1	Forward bearing release	21:23:40.1	100.1	100
2	Titan stage 1 ignition	21:23:50.5	110.5	111
3	Titan stage 0 jettison	21:24:01.8	121.8	122
4	Titan stage 1 cutoff	21:26:19.5	259.5	256
5	Titan stage 1 separation	21:26:20.2	260.2	257
6	Titan stage 2 ignition	21:26:20.2	260.2	257
7	Shroud jettison	21:26:32.1	272.1	268
8	Titan stage 2 cutoff	21:29:47.7	467.7	460
9	Titan/Centaur separation	21:29:54.4	474.4	466
10	Centaur MES 1	21:30:05.8	485.8	476
11	Centaur MECO 1	21:32:11.4	611.4	603
12	Centaur MES 2	21·47:31.5	1531.51	1523
13	Centaur MECO 2	21:52:46.8	1846.8	1842

Table 1 (contd)

Mark	Event	Time (actual), GMT	Elapsed time, seconds	
			Actual	Nominal
14	Spacecraft separation	21:56:27.2	2067.2	2062
15	Spacecraft solar panel deploy	21:58:42	2202.0	2182
16	Start Centaur retroburn	22:10:41.4	2921.4	2917
17	End Centaur retroburn	22:14:51.8	3171.8	3167
18	Bioshield jettison	23:28:50	7610.0	7602

First motion---(reference data to this time) 21:22:00.632 (GMT)
Flight azimuth---96.57 degrees
MES = main engine start
MECO = main engine cutoff

to Ascension Island. The Johannesburg, Ascension, and all aircraft telemetry data were airlifted to Patrick Air Force Base. The Bermuda station data were returned by expedited air-freight shipment. The Antigua, Grand Turk, and Grand Bahama Island data were returned by an aircraft chartered by the Military Airlift Command.

The overall near-Earth support for Viking A was considered excellent.

2. Launch Vehicle Telemetry Support

Launch vehicle telemetry support was provided during the launch on August 20, 1975, by three separate radio links. Titan telemetry was transmitted at 2287.5 MHz and the Centaur transmitted telemetry at 2202.5 and 2208.5 MHz. Near-Earth support was provided on all three links for both the receive and record modes as well as some real-time transmissions to Building AE and the Central Instrumentation Facility for performance evaluation. The Titan telemetry coverage, shown in Fig. 1, met or exceeded requirements with only minor problems from all supporting stations.

Coverage for the Centaur telemetry (2202.5 and 2208.5 MHz) links is shown in Figs. 2 through 5, respectively. All requirements were met or exceeded.

In summary, the launch vehicle telemetry data via all three radio links were generally excellent, with slight degradation at some sites because of the low elevation angles of the vehicle. No major problems were noted.

3. Spacecraft Telemetry Suppport

Spacecraft telemetry support was provided on two separate radio links. The spacecraft telemetry was extracted from the Centaur 2202.5-MHz link from launch until spacecraft separation. The 2293.1-MHz link was utilized as spacecraft telemetry from spacecraft separation until two-way acquisition by the Deep Space Network.

The spacecraft telemetry coverage and requirements are shown in Figs. 6 and 7. All recording requirements were met or exceeded. Times of acquisition of signal and loss of signal are shown in the figures as reported by individual stations.

Table 2 shows the actual spacecraft telemetry coverage as determined at the Merritt Island station, which received all near-Earth spacecraft data in real time. In addition, the planned coverage versus the actual coverage is shown in this table. Actual coverage was 98 percent of that planned. As the real-time spacecraft telemetry data were received at Merritt Island, data from selected stations were processed, formatted, and transmitted to the control center at the Jet Propulsion Laboratory.

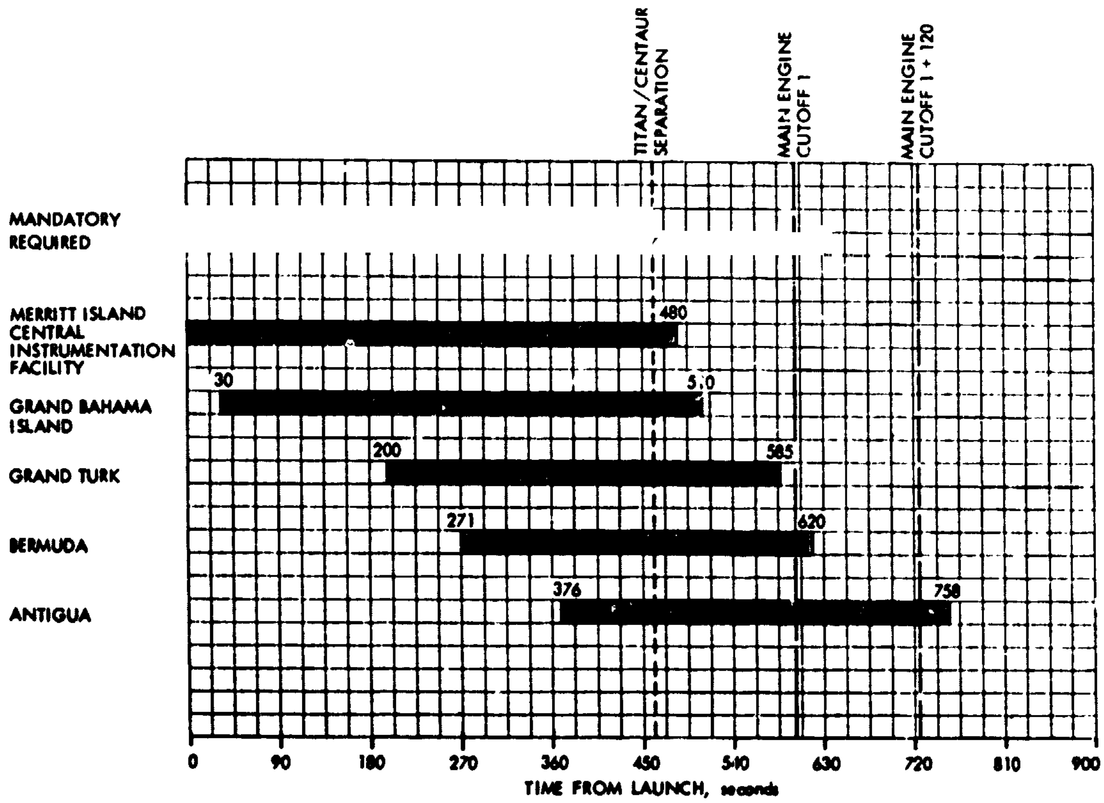


Fig. 1. Viking A Titan telemetry coverage (2287.5-MHz link)

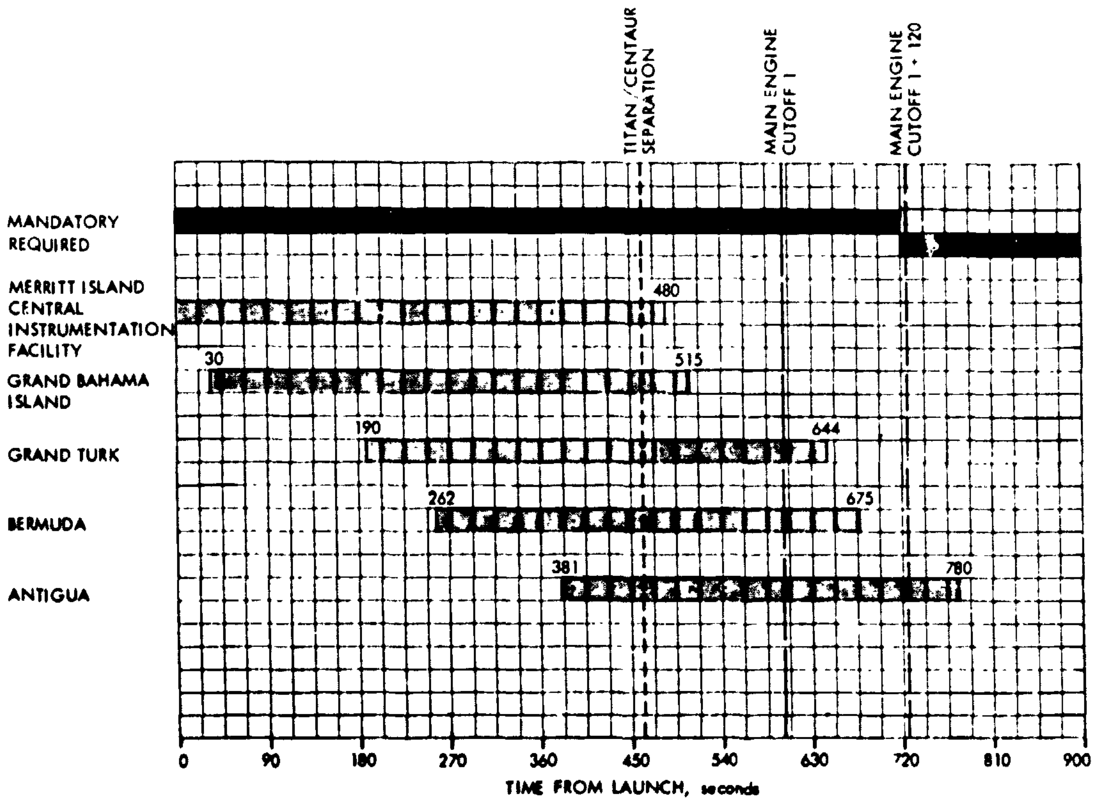


Fig. 2. Viking A uprange Centaur telemetry coverage (2202.5-MHz link)

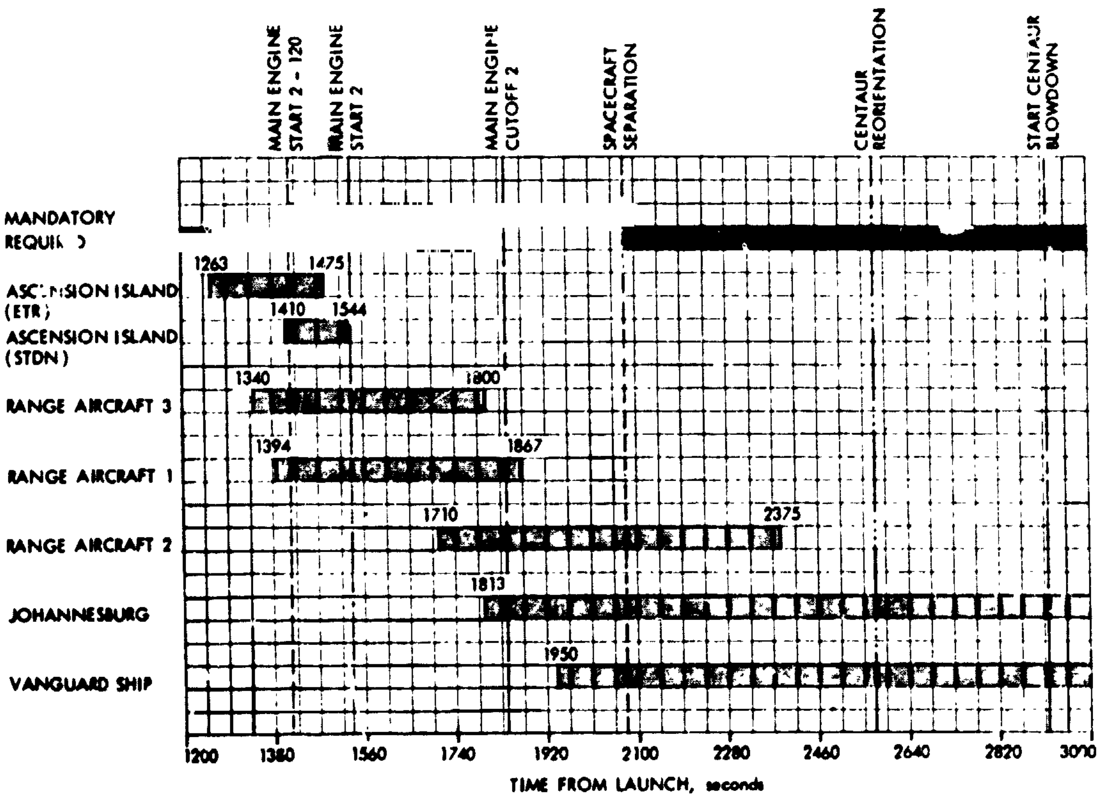


Fig. 3. Viking A downrange Centaur telemetry coverage (2202.5-MHz link)

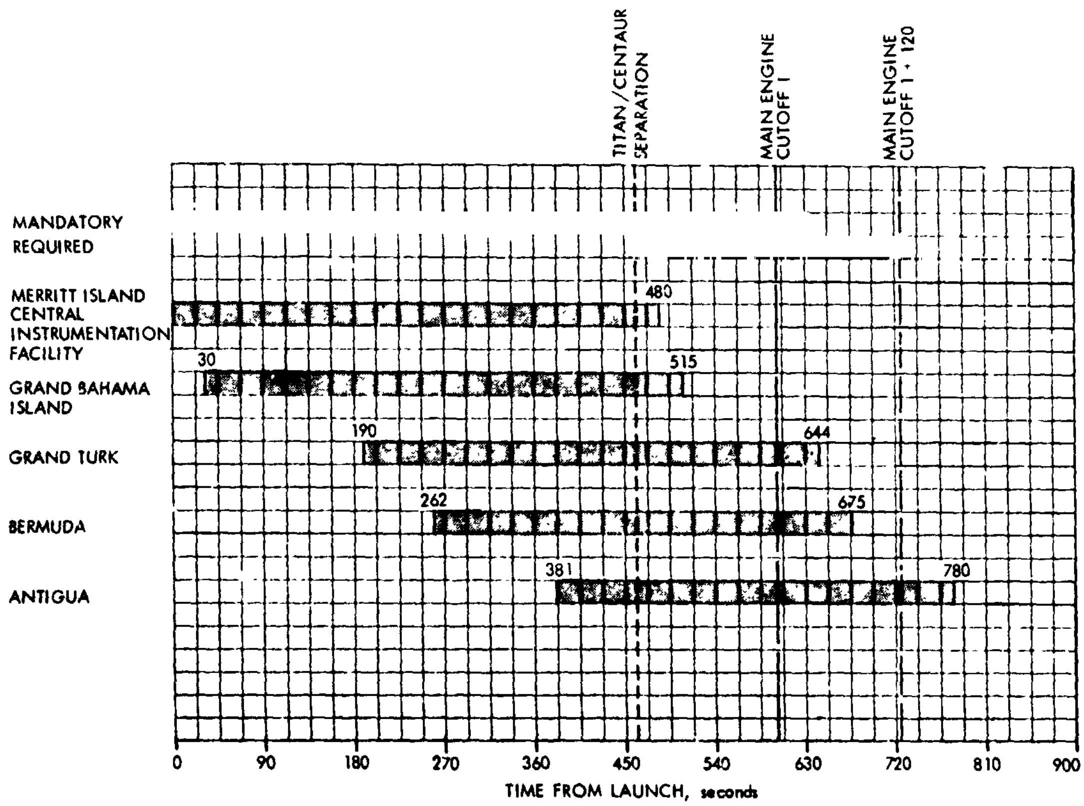


Fig. 4. Viking A uprange Centaur telemetry coverage (2208.5-MHz link)

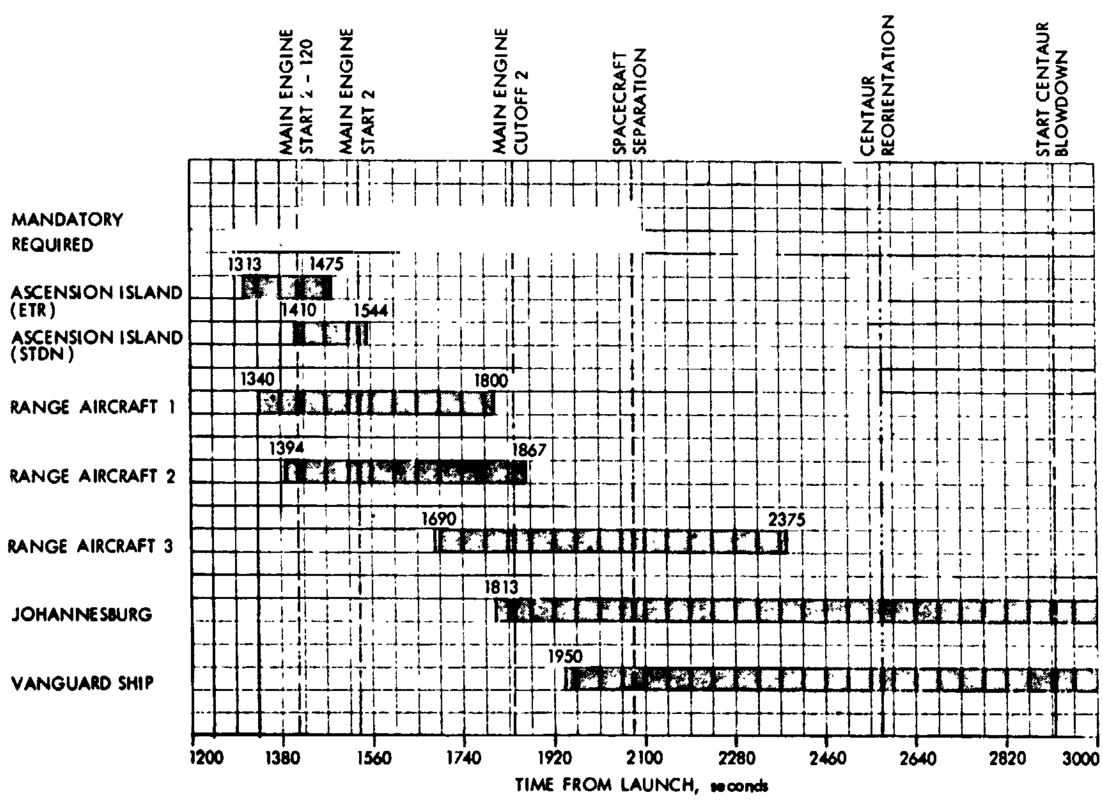


Fig. 5. Viking A downrange Centaur telemetry coverage (2208.5-MHz link)

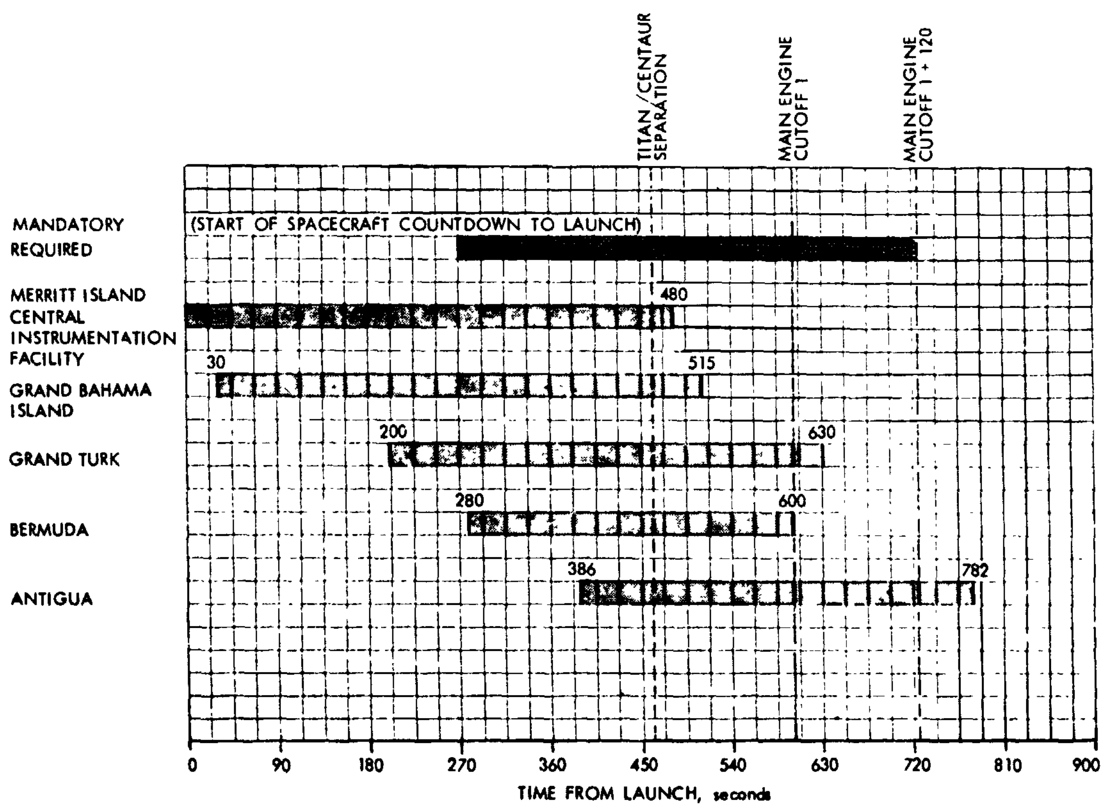


Fig. 6. Viking A uprange spacecraft telemetry coverage (2293.1-MHz link)

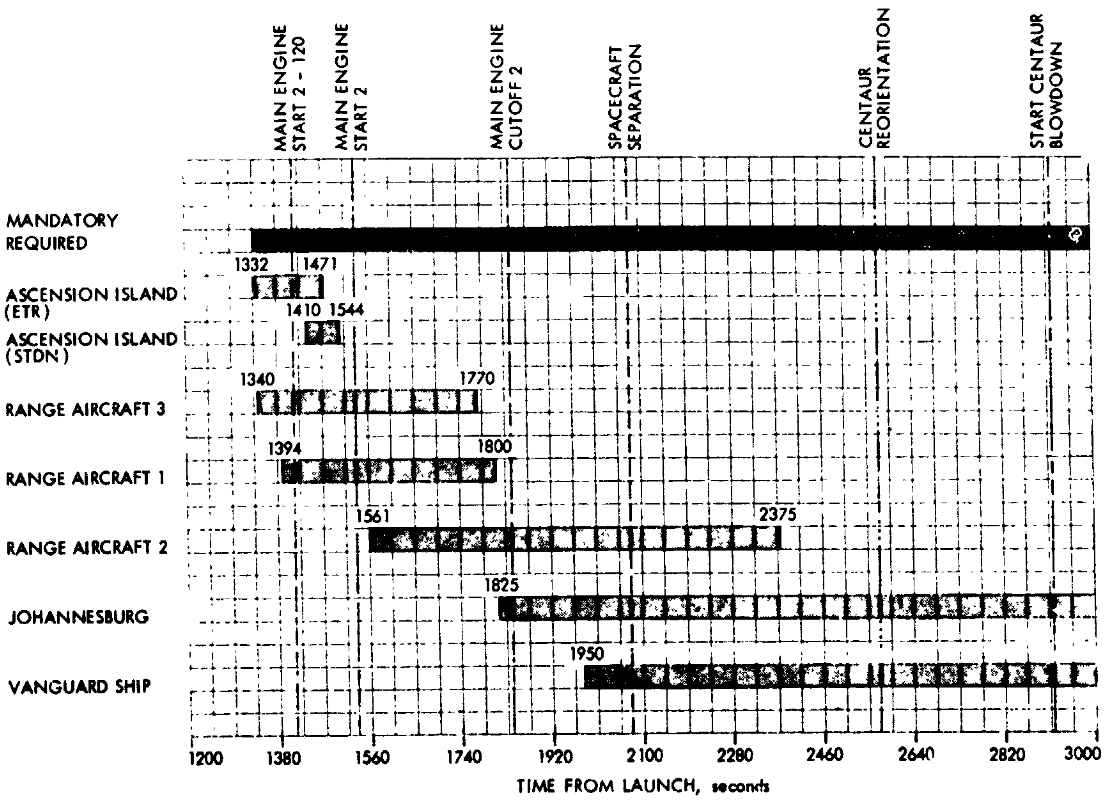


Fig. 7. Viking A downrange spacecraft telemetry coverage (2293.1-MHz link)

Table 2. Spacecraft telemetry delivered to Merritt Island Station 71 for Viking A

Station	Planned coverage, seconds		Actual coverage, seconds		Data outages, seconds
	Acquisition of signal	Loss of signal	Acquisition of signal	Loss of signal	
Merritt Island launch area	0	450	0	473	13
Grand Bahama Island	75	490	76	493	21
Grand Turk	250	593	251	634	6
Bermuda	310	632	311	674	0
Antigua	445	726	446	782	0
Ascension Island (ETR)	1309	1500	1333	1474	20
Ascension Island (STDN)	1339	1530	1440	1548	7
Range aircraft	1485	1895	1514	1851	7
Johannesburg (STDN)	1850	3600	1853	3167	46
Vanguard ship	1965	7200	1965	4862	0
Guam (STDN)	3300	7200	3301	4860	6

$$\text{Percentage of planned coverage} = \frac{\text{data received - data lost}}{\text{data planned}}$$

$$= \frac{4309 - 126}{4277} = 98\%$$

ETR = Eastern Test Range

STDN = Spaceflight Tracking and Data Network

In summary, the spacecraft telemetry coverage during the near-Earth phase met nearly all requirements. Aircraft 2 did not transmit spacecraft data in real time because of a problem in a patchboard, but aircraft 1 coverage exceeded that planned for aircraft 1 and provided most of the data for aircraft 2. Therefore, very little data were lost. As shown in Tables 2 and 3, the percentage of quality data received at the Mission Control Center exceeded 95 percent of that which was planned.

4. Metric Data Support

Nine metric data radars supported the Viking A launch. These were the Air Force radars at Cape Canaveral, Patrick Air Force Base, Merritt Island, Grand Bahama Island, Antigua, and two at Ascension and the Goddard radars at Bermuda, together with the ship Vanguard. All stations met or exceeded their planned tracking intervals except Vanguard, which had problems acquiring and holding track because of poor aspect angles. The loss of these data did not adversely affect computations of the transfer and Centaur post-deflection orbit by the Real-Time Computing System.

The actual metric data coverage provided on Viking A is given in Figs. 8 and 9. All radars transmitted high speed and/or teletype metric data to the Real-Time Computing System.

The Antigua metric data were used to provide orbital elements on the Centaur parking orbit, and Vanguard data were used to compute orbital elements on the transfer orbit to Mars and the Centaur post-deflection orbit. Metric data from Station 42 at Canberra were also used to compute orbital elements on the Viking spacecraft orbit. The orbital elements computed by the Real-Time Computer System for Viking A are given in Table 4.

Besides providing orbital elements on the parking orbit, transfer orbit, and spacecraft orbit, the computing system also provided computations of I-matrix, inter-net predicts, and Mars B-plane mapping. The B-plane mapping was provided for the transfer, spacecraft, and Centaur post-deflection orbits. These Mars B-plane mapping parameters are provided in Table 5.

The Real-Time Computer System also provided four sets of inter-net predicts to deep space stations at Canberra, Honeysuckle, and Madrid. The first set of predicts was sent in the minus count at T minus 45 minutes and was based on nominal data computed from polynomial coefficients. The second set was based on actual parking orbit data plus a nominal Centaur second burn. The third set was based on the actual transfer orbit obtained from Vanguard data, and the last set was based on the actual spacecraft orbit computed from Canberra data.

The overall metric data and computing support for Viking A met or exceeded the planned amounts.

Table 3. Viking A spacecraft data received at the Mission Control Center from near-Earth stations

Station	Planned: Acquisition of signal	Planned: Loss of signal	Planned: Coverage, seconds	Actual: In sync	Actual: Out of sync	Actual: Coverage, seconds	Actual: Outage, min:s
	(Launch plus min:s)			h:min:s			
Merritt Island launch area	T-0	7:30		18:39:00	18:44:20		00:40
Grand Bahama Island	1:15	8:10					
Grand Turk	-	-					
Bermuda	5:10	10:35		18:44:20	18:46:25		00:14
Antigua	7:30	12:00 12:00	720	18:46:39	18:51:55	775	00:54
Ascension Island (ETR)	21:55	25:30		19:01:33	19:02:00		00:38
Ascension Island (STDN)	21:55	25:30		19:02:20	19:05:01		00:20 00:34
Range Aircraft 1	24:45	29:45		19:06:55	19:07:56		01:54 00:20
Range Aircraft 3	26:15	31:15		No data			01:00
Range Aircraft 2	28:00	32:40		19:08:56	19:09:23		01:55
Johannesburg (STDN)	32:10	44:45		19:11:18	19:13:00		
Vanguard ship	33:55	⟶		19:13:00	19:13:54		
Station 42 acquisition of signal	48:40	Planned 53:14 Planned 30:59	2579	19:32:14	30:21	2151	06:41

$$\frac{\text{Actual} = 2151\ \text{s}}{\text{Planned} = 2579\ \text{s}} = 83.4\%\ \text{overall}$$

ETR = Eastern Test Range
STDN = Spaceflight Tracking and Data Network

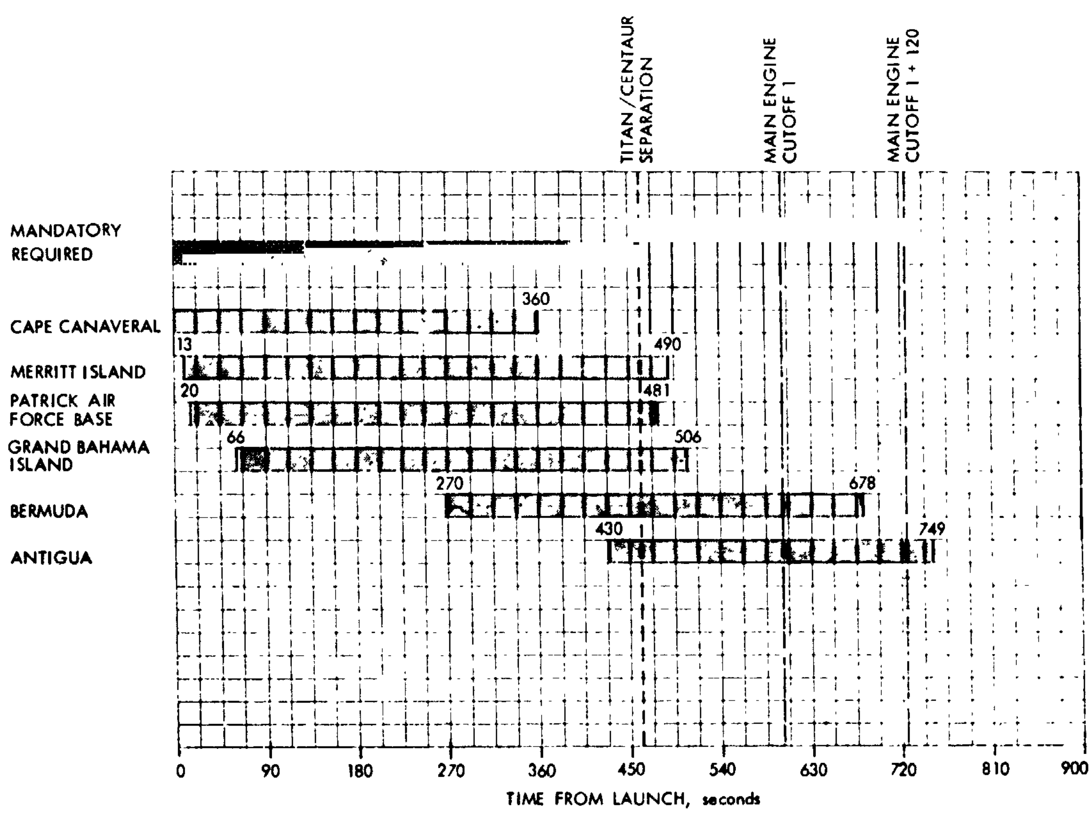


Fig. 8. Viking A uprange metric data coverage (5765.0-MHz link)

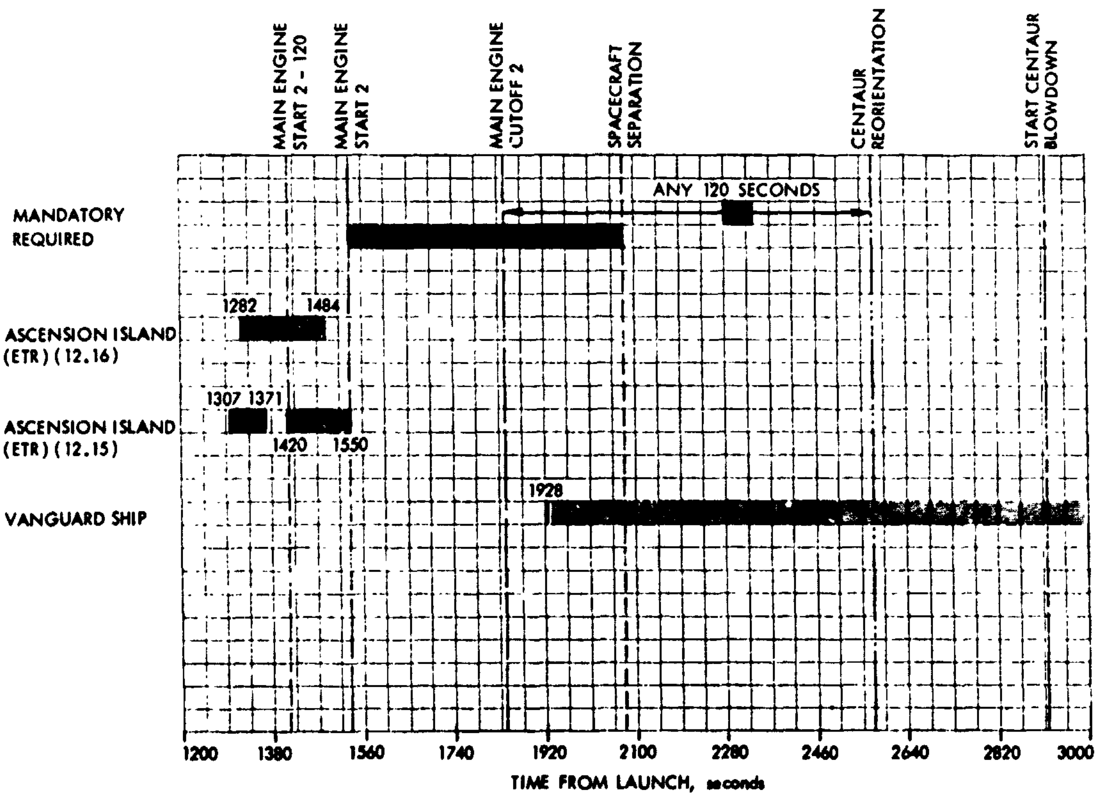


Fig. 9. Viking A downrange metric data coverage (5765.0-MHz link)

Table 4. Orbital elements for Viking A from Real-Time Computer System at the Air Force Eastern Test Range

Parameter[a]	Parking orbit	Parking orbit + nominal Centaur second burn	Transfer orbit Vanguard	Post-deflection	Spacecraft data
Epoch time	0612	1844	1844	3419	1844
Radius	06543.6277	06686.3748	06671.9592	15706.5209	6681.3542
Latitude	023.4308	-015.9035	-015.9898	-026.9969	-015.9826
Longitude	302.5450	018.9380	018.8767	095.2010	018.9839
Velocity	07.3894	11.4261	11.4424	07.8877	11.4326
Path angle	00.0469	08.5136	08.5209	60.4842	08.4209
Azimuth angle	108.9603	115.7212	115.6584	076.0485	115.7023
Inclination	029.1852	029.1265	029.1243	029.0173	029.1535
Eccentricity	00.0007	01.3475	01.3485	01.3220	01.3484
Vis viva energy	-60.9138	21.0960	21.2030	20.1996	21.1545

[a]Epoch time is in seconds from launch. The next six parameters are Earth-fixed sphericals in kilometers, degrees, and kilometers per second. Inclination is in degrees; eccentricity is nondimensional; and vis viva energy is in km^2/s^2.

Table 5. Viking mission A computed Mars B-plane mapping parameters from Real-Time Computer System at the Air Force Eastern Test Range

Parameters	Transfer orbit	Spacecraft orbit	Centaur post-deflection orbit
Time of closest approach, mo/day/yr h:min:s	06/17/76 03:01:45	06/21/76 16:59:58.7	07/03/76 00:23:25.4
B-vector, km	630602.46	486076.69	571252.07
Partial vector in Mars equatorial plane B · TC, km	-123149.97	200179.60	483534.13
Partial vector perpendicular to Mars equatorial plane B · RC, km	618460.63	-442943.20	-304177.04

5. Communications Support

Project communications requirements for the near-Earth phase of the Viking A mission were for voice, data, and teletype channels within and between the elements of the supporting stations.

Near-Earth communications included elements of NASA Communications Network, Spaceflight Tracking and Data Network, Kennedy Space Center, and Jet Propulsion Laboratory in order to provide all required support. All available resources were used to provide the project with a very high percentage of error-free real-time data.

A description of near-Earth communications is given in Volume I of this report on pages 85-99.

6. Problems and Corrective Action

Only two significant problems impacted the near-Earth support for Mission A. These problems were with real-time retransmission of the spacecraft data from aircraft 2, and the ship Vanguard radar not tracking the entire metric data interval committed.

Range Instrumentation Aircraft 2 received and recorded its assigned data span; however, because of instrumentation problems, it did not retransmit the spacecraft data in real time as tasked. In post-launch investigations, the patchboard demultiplexer was removed, bench checked, and replaced. Further on-board checkout revealed the problem to be in a connector to the patchboard. The corrective action taken was to repair the connector. Further corrective action will improve on-board troubleshooting for future operations.

This is but one example of the susceptibility of telemetry aircraft to unique operational problems. It is such that backup aircraft appear justified in support of telemetry data requirements which are truly "mandatory."

Vanguard radar lost track at approximately "point of closest approach" for a period of 4 minutes, and, after reacquisition, experienced intermittent losses of data totaling 3.4 minutes, until "loss of signal." The cause was attributed to beacon lobing, resulting from poor aspect angles and a weak signal. No corrective action is planned, except to continue to make the site personnel aware of possible weak signal conditions as was indicated for this mission. The Vanguard radar did gather enough metric data to allow computation of the Centaur transfer orbit and Centaur post-deflection orbit. This was the ship's primary metric data task.

Other sites (Bermuda, Ascension, and Johannesburg) also had some degraded telemetry data because of low station elevation angles during the tracking periods. These degraded telemetry data were predicted, however, and were of no serious consequence.

The Antigua radar data were slightly degraded by the presence of an azimuth bias of about 0.0254 mm (2 mils) and erratic angle data bits. Post-test investigation revealed that the azimuth encoder was loose and that a module which provides reference voltage in the digital-to-analog converter was defective. These items were corrected before Viking B launch. This problem did not have a major impact because the Antigua data were of sufficient quality for the Air Force Eastern Test Range Computing System to compute a good set of parking orbit parameters.

B. MISSION B NEAR-EARTH LAUNCH SUPPORT

1. General Summary

The trajectory was nominal and the events were on time throughout the near-Earth phase of the mission, although the vehicle passed through the African protective line about 7 seconds late. Table 6 provides the nominal versus actual MARK events for the Viking B launch.

Ground telemetry stations of the Air Force Eastern Test Range exceeded their respective intervals by a wide margin.

Both aircraft experienced telemetry acquisition problems and did not obtain the planned coverages; however, the requirements to receive and record and to report in real time the occurrences of Centaur second engine start and cutoff times were satisfied.

All stations of the Spaceflight Tracking and Data Network, including the tracking ship Vanguard, provided telemetry support exceeding 100 percent of that planned. Acquisition data inaccuracies caused the Johannesburg station difficulty in acquiring the Centaur 2202.5-MHz link.

Telemetry data from all stations except from the aircraft were generally excellent and adequately covered the flight.

Radar performance by stations of the Air Force Eastern Test Range was successful in that all radars (except Patrick Air Force Base) supported for at least 95 percent of their planned interval. The Patrick radar was redundant to other mainland radars.

The Bermuda radar exceeded its scheduled data interval. Acquisition data inaccuracies caused the Vanguard radar difficulties in acquiring the Centaur beacon (acquired initially on a side lobe). Sufficient data were received by the Real-Time Computer System to enable timely computations of orbital parameters.

NASA communications support (voice, data, and teletype circuits) was excellent throughout the near-Earth phase of the mission.

Computations of orbital parameters, inter-net predicts for Deep Space Network acquisition, and Mars mapping to planetary encounter were accomplished on time.

2. Launch Vehicle Telemetry Support

Launch vehicle telemetry support was provided during the launch of Viking B on three separate radio links. Titan telemetry was transmitted at 2287.5 MHz, and Centaur telemetry was transmitted at 2202.5 and 2208.5 MHz. Near-Earth support was provided on all three links. Both the receive and record mode and real-time transmission mode to Building AE and Central Instrumentation Facility were exercised. Launch vehicle performance by analysis of the data from the three radio links was carried out in Building AE.

Titan telemetry support coverage is shown in Fig. 10. All requirements were met or exceeded.

Centaur telemetry support coverage is shown in Figs. 11, 12, 13, and 14. All requirements were met or exceeded.

In summary, telemetry data support from all stations except the aircraft was generally excellent and met or exceeded the requirements.

3. Spacecraft Telemetry Support

Spacecraft telemetry support was provided during the launch of Viking B on two separate radio links. The spacecraft telemetry was extracted from the Centaur 2202.5-MHz link from launch to spacecraft separation. The spacecraft 2297.3-MHz link was utilized from spacecraft separation until acquisition by the Deep Space Network.

The spacecraft telemetry requirements and coverage are shown in Figs. 15 and 16. Acquisition of signal and loss of signal shown in the figure are at times reported by the individual stations.

Table 7 shows the actual spacecraft telemetry coverage as determined by Merritt Island Station 71 as it received all near-Earth data in real time. In addition, the planned coverage versus the actual coverage is shown.

As the spacecraft data were received in real time at Merritt Island Station 71, data from selected stations were processed, formatted, and transmitted to the Mission Control Center at the Jet Propulsion Laboratory. Table 8 shows the actual data coverage.

In summary, station support met or exceeded requirements except for Ascension and the aircraft. Both Ascension stations had minor problems because of low elevation aspect angles. The aircraft coverage, as shown in Table 7, leaves much to be desired.

Table 6. Nominal versus actual MARK events for Viking B (launched September 9, 1975)

Mark	Event	Time (actual), GMT	Elapsed time, seconds	
			Actual	Nominal
0	Liftoff	18:38:59.960	0.0	0
1	Forward bearing release	18:40:40.0	100.0	100
2	Titan Stage 1 ignition	18:40:52.0	112.0	111
3	Titan Stage 0 jettison	18:41:02.95	123.0	122
4	Titan Stage 1 cutoff	18:43:21.0	261.0	256
5	Titan Stage 1 separation	18:43:21.65	261.7	257
6	Titan Stage 2 ignition	18:43:21.85	261.9	257
7	Shroud jettison	18:43:33.35	273.4	268
8	Titan Stage 2 cutoff	18:46:50.0	470.0	460
9	Titan/Centaur separation	18:46:53.25	473.3	466
10	Centaur MES 1	18:47:05.1	485.1	476
11	Centaur MECO 1	18:49:13.2	613.2	609
12	Centaur MES 2	19:07:27.0	1707.0	1702
13	Centaur MECO 2	19:12:27.8	2007.8	2005

Table 6 (contd)

Mark	Event	Time (actual), GMT	Elapsed time, seconds	
			Actual	Nominal
14	Spacecraft separation	19:16:07.8	2227.8	2225
15	Spacecraft solar panel deploy	19:18:23.0	2363.0	2345
16	Start Centaur retro	19:30:22.8	3082.8	3080
17	End Centaur retro	19:34:33	3333.0	3330
18	Bioshield jettison	20:47:00	7680.0	7602

First motion---(reference data to this time) 18:38:59.960 (GMT)
Flight azimuth---96.51 degrees
MES = main engine start
MECO = main engine cutoff

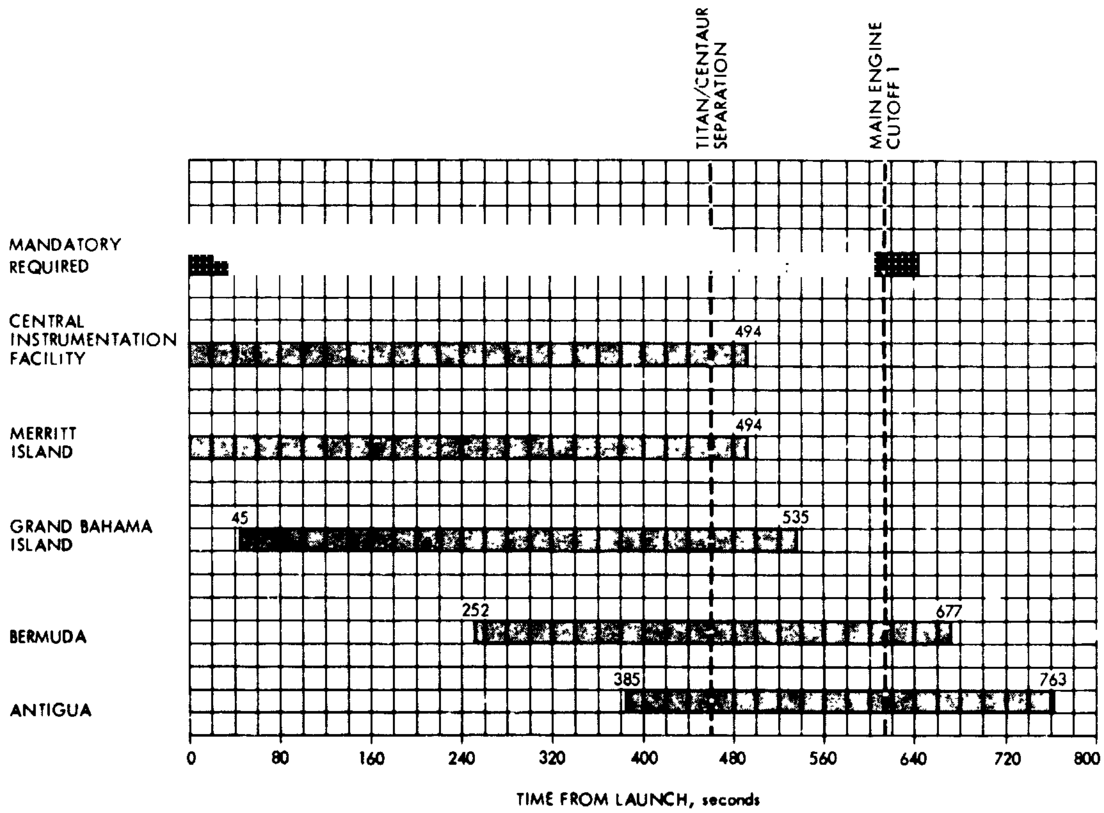


Fig. 10. Viking B Titan telemetry coverage (2287.5-MHz link)

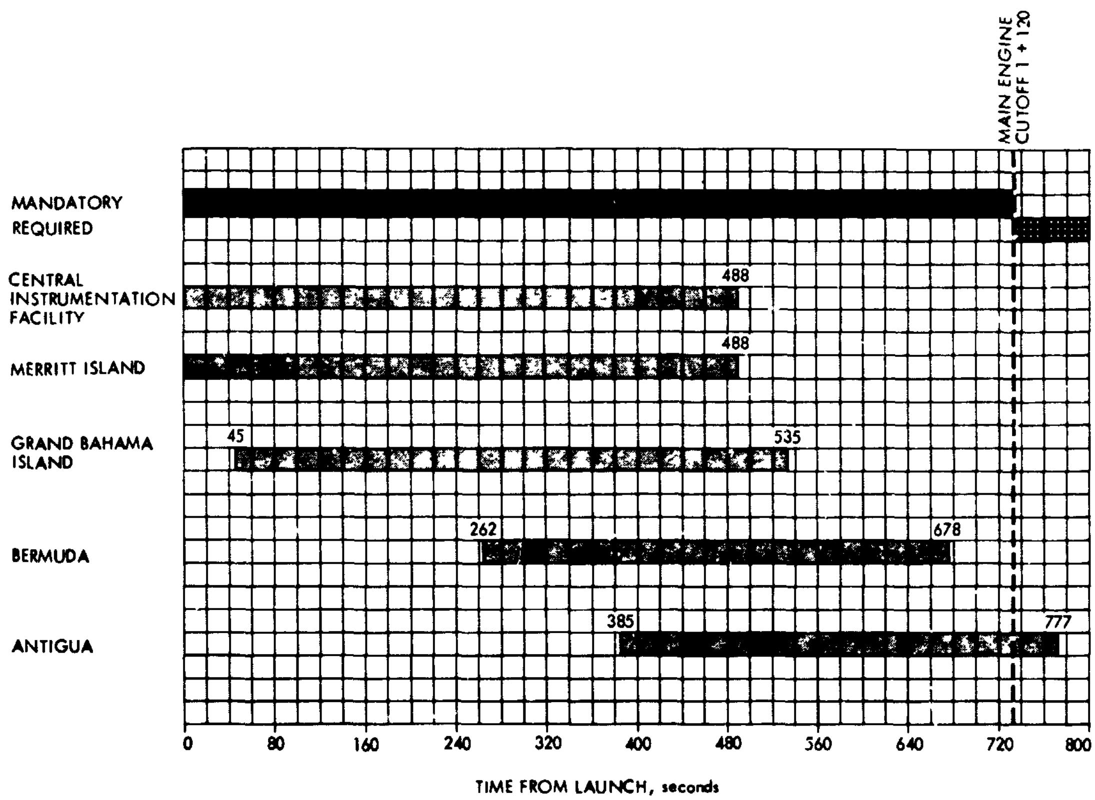


Fig. 11. Viking B uprange Centaur telemetry coverage (2202.5-MHz link)

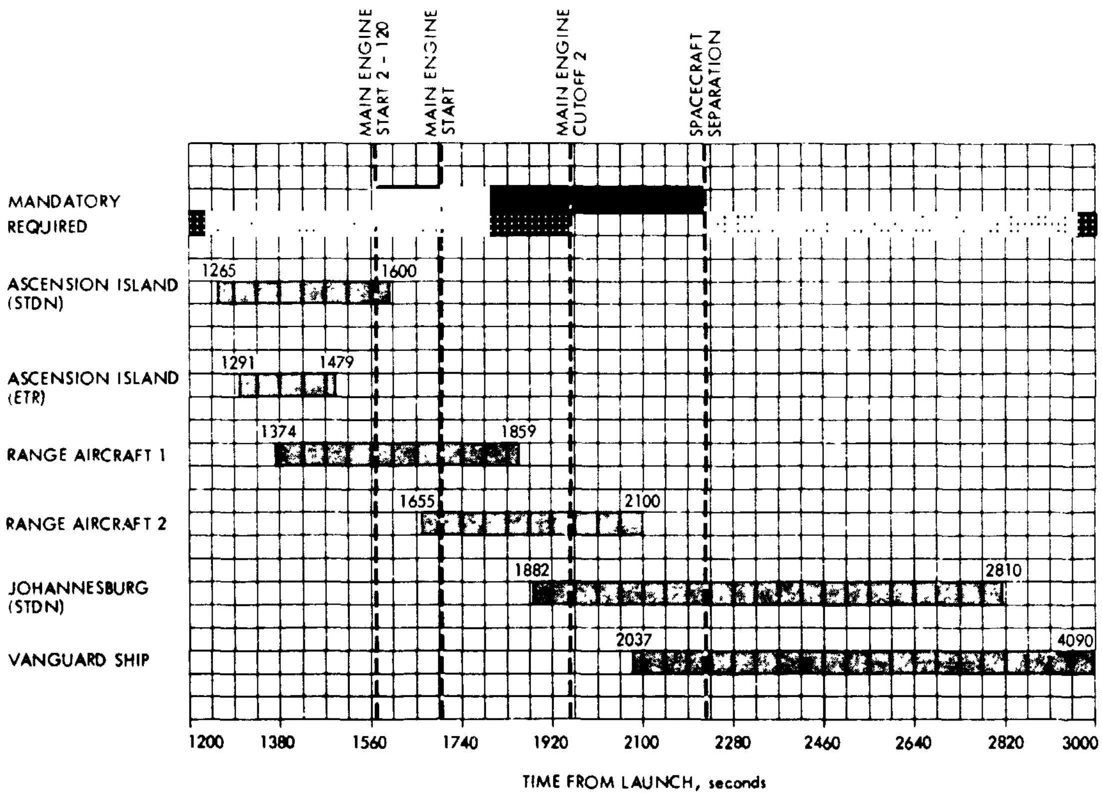


Fig. 12. Viking B downrange Centaur telemetry coverage (2202.5-MHz link)

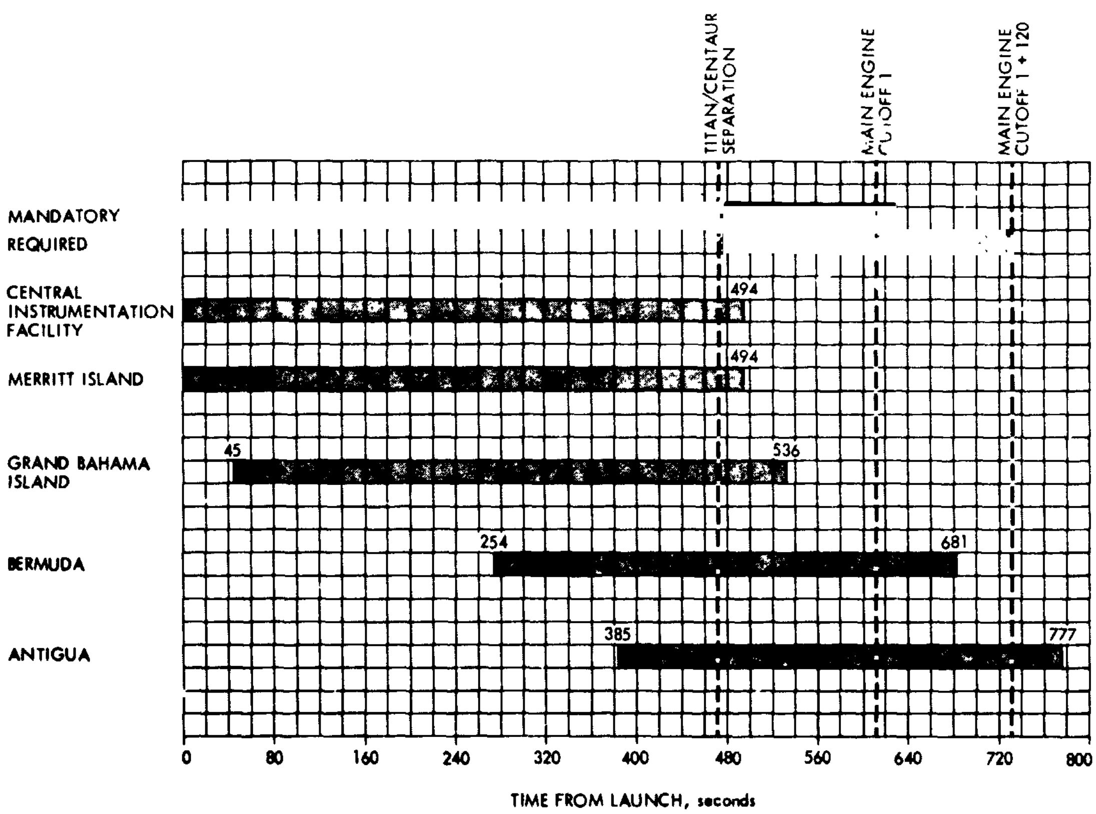


Fig. 13. Viking B uprange Centaur telemetry coverage (2208.5-MHz link)

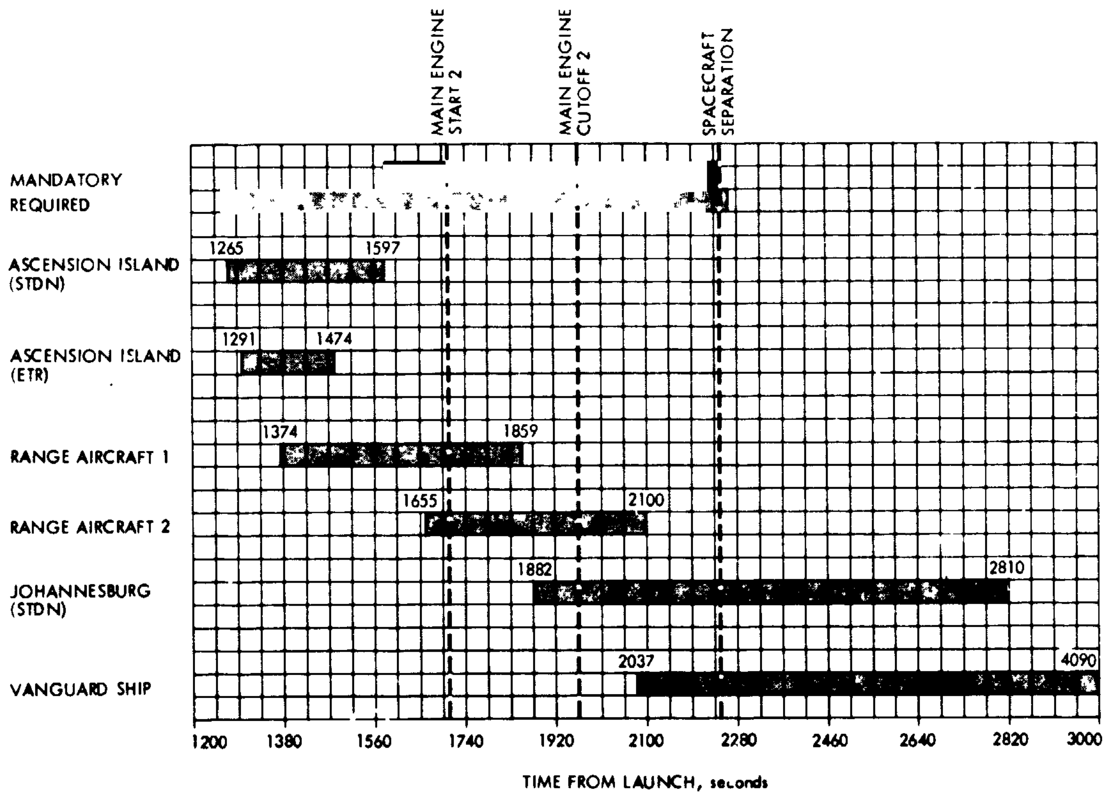


Fig. 14. Viking B downrange Centaur telemetry coverage (2208.5-MHz link)

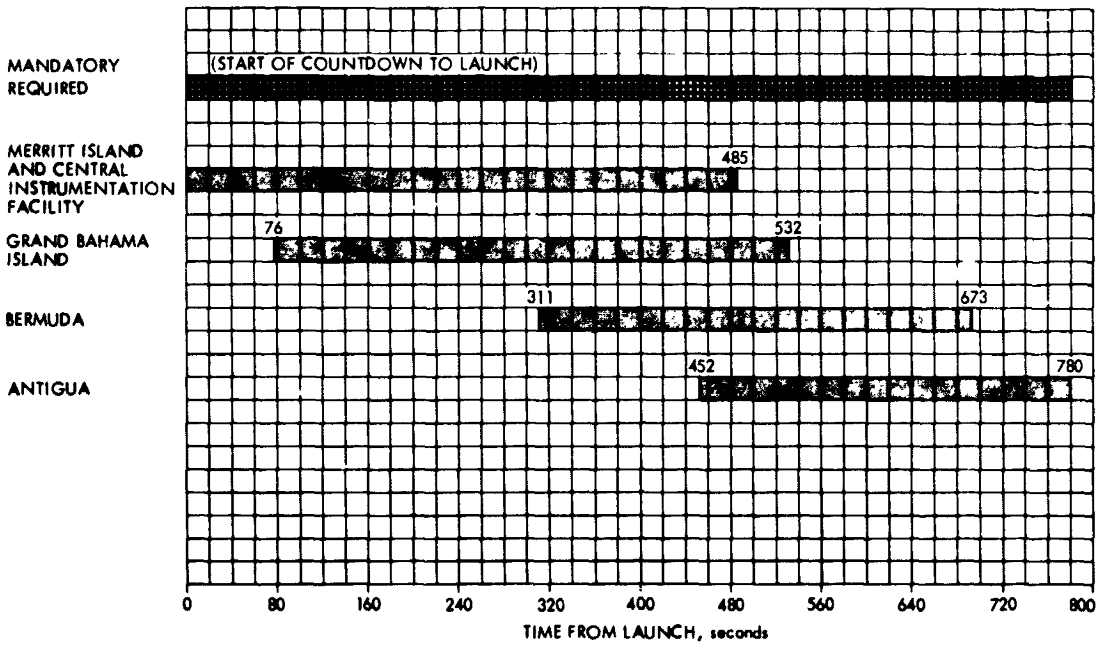


Fig. 15. Viking B uprange spacecraft telemetry coverage to Merritt Island Station 71 (2297.3-MHz link)

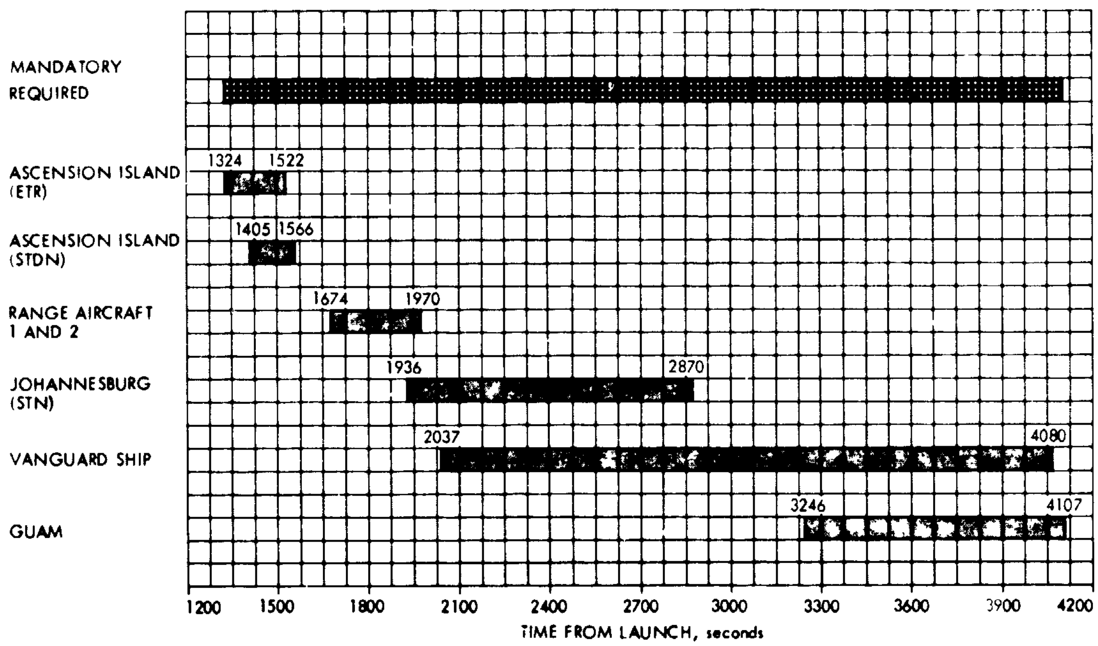


Fig. 16. Viking B downrange spacecraft telemetry coverage to Merritt Island Station 71 (2297.3-MHz link)

Table 7. Spacecraft telemetry delivered to Merritt Island Station 71 for Viking B

Station	Planned coverage, seconds		Actual coverage, seconds		Data outages, seconds
	Acquisition of signal	Loss of signal	Acquisition of signal	Loss of signal	
Merritt Island launch area	0	450	0	485	14
Grand Bahama Island	75	490	76	532	47
Bermuda	310	635	311	673	0
Antigua	450	720	452	780	0
Ascension Island (ETR)	1315	1530	1324	1520	67
Ascension Island (STDN)	1315	1530	1405	1566	14
Range aircraft	1485	1960	1674	1970	176
Johannesburg (STDN)	1930	2645	1936	2870	0
Vanguard ship	2035	7200	2037	4080[a]	13
Guam (STDN)	3245	b	3246	4107	---

[a]Released from support.

[b]Until released from support.

$$\text{Percent of planned coverage} = \frac{\text{data received} - \text{data lost}}{\text{data planned}}$$

$$= \frac{3455 - 331}{3512} = 88.95\%$$

ETR = Eastern Test Range

STDN = Spaceflight Tracking and Data Network

Table 8. Viking B spacecraft data received at the Mission Control Center from near-Earth stations

Station	Planned			Actual			
	Acquisition of signal	Loss of signal	Coverage, seconds	In sync	Out of sync	Coverage, seconds	Outage, min:s
	(Launch plus min:s)			h:min:s			
Merritt Island launch area		7:30		21:22:00	21:23:56		00:20
Grand Bahama Island	1:15	8:10		21:24:16	21:26:10		
				(Outage on Mission Test Computer A only)			00:00
Grand Turk	3:15	9:50		21:26:17	21:27:24		
Bermuda	3:50	10:40		21:27:44	21:28:22		00:20
				(Outage on Mission Test Computer B only)			00:00
Antigua	7:30	12:00	720	21:28:58	21:34:54	754	00:40
	(Planned 10:10 outage between Antigua and Ascension)						
Ascension Island (ETR)	22:10	25:30		21:44:53	21:45:20		00:13
Ascension Island (STDN)	22:10	25:30		21:45:33	21:47:07		00:13
Range Aircraft 3	23:50	28:45		21:47:34			00:27
Range Aircraft 1	24:45	27:25			21:52:43		00:14
Johannesburg (NASA)	30:50	---		21:52:57	21:54:44		00:07
Vanguard ship	32:45	---		21:54:51	21:58:10		
Johannesburg (NASA)			1900	21:58:10	22:15:50	1857	01.14
Station 42	49:00			22:15:54			

$\frac{\text{Actual} = 2510 \text{ s}}{\text{Planned} = 2620 \text{ s}} = 95.8\%$ overall

ETR = Eastern Test Range
NASA = National Aeronautics and Space Administration
STDN = Spaceflight Tracking and Data Network

4. Metric Data Support

Nine metric data radars supported the Viking B launch. These radars were the Air Force radars at Cape Canaveral, Patrick Air Force Base, Merritt Island, Grand Bahama Island, Antigua, and two at Ascension, and the Spaceflight Tracking and Data Network radars at Bermuda and the tracking ship Vanguard. All stations met or exceeded their planned tracking intervals except those at Patrick and the tracking ship Vanguard.

The Patrick data loss was attributed to an equipment malfunction. The ship Vanguard's late acquisition of data resulted from inaccurate acquisition pointing data provided by the Goddard Space Flight Center for the mission. Poor aspect angles were attributed to the loss of data later during the tracking pass. The loss of these data did not adversely affect the computations of the transfer orbit and Centaur post-deflection orbit. Actual metric data coverage provided on Viking B is given in Figs. 17 and 18. All radars transmitted metric data to the Real-Time Computer System in real time via teletype or high-speed data line.

Antigua metric data were used to provide orbital elements on the Centaur parking orbit; Vanguard data were used to compute orbital elements on the transfer orbit to Mars and the Centaur post-deflection orbit. Data from the deep space station at Canberra were also used to compute orbital elements on the Viking spacecraft orbit. (See Table 9.)

Besides providing orbital elements on the parking orbit, transfer orbit, and spacecraft orbit, the Real-Time Computer System also provided computations of I-matrix, inter-net predicts, and Mars B-plane mapping. The B-plane mapping was provided for the transfer, spacecraft, and Centaur post-deflection orbits. These Mars B-plane mapping parameters are provided in Table 10.

Four sets of inter-net predicts were also provided to deep space stations at Canberra, Honeysuckle, and Madrid. The first set of predicts was sent in the minus count at T minus 45 minutes and was based on nominal data computed from polynomial coefficients. The second set was based on actual parking orbit data plus a nominal Centaur second burn. The third set was based on the actual transfer orbit obtained from Vanguard data, and the last set was based on the actual spacecraft orbit computed from Canberra data.

The overall metric data and computing support for Viking B was very good.

5. Communications Support

Project communications requirements for the near-Earth phase of the Viking B mission were for voice, data, and teletype channels within and between the elements of the supporting stations.

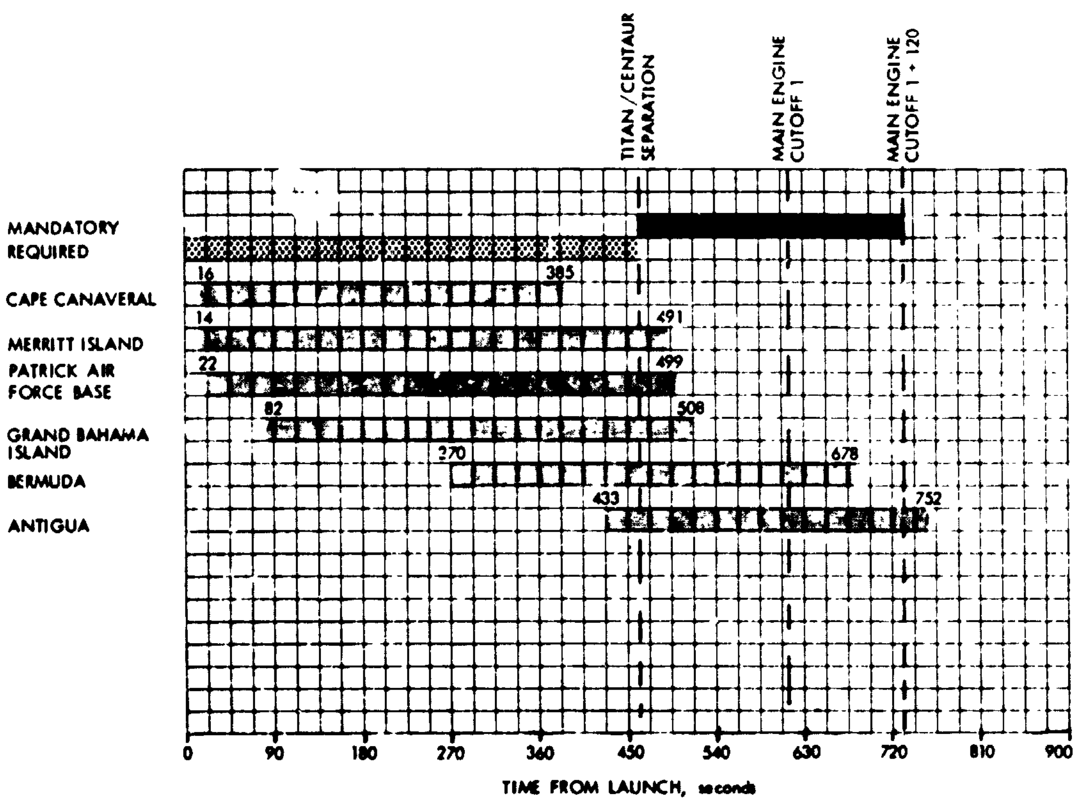


Fig. 17. Viking B uprange metric data coverage (5765.0-MHz link)

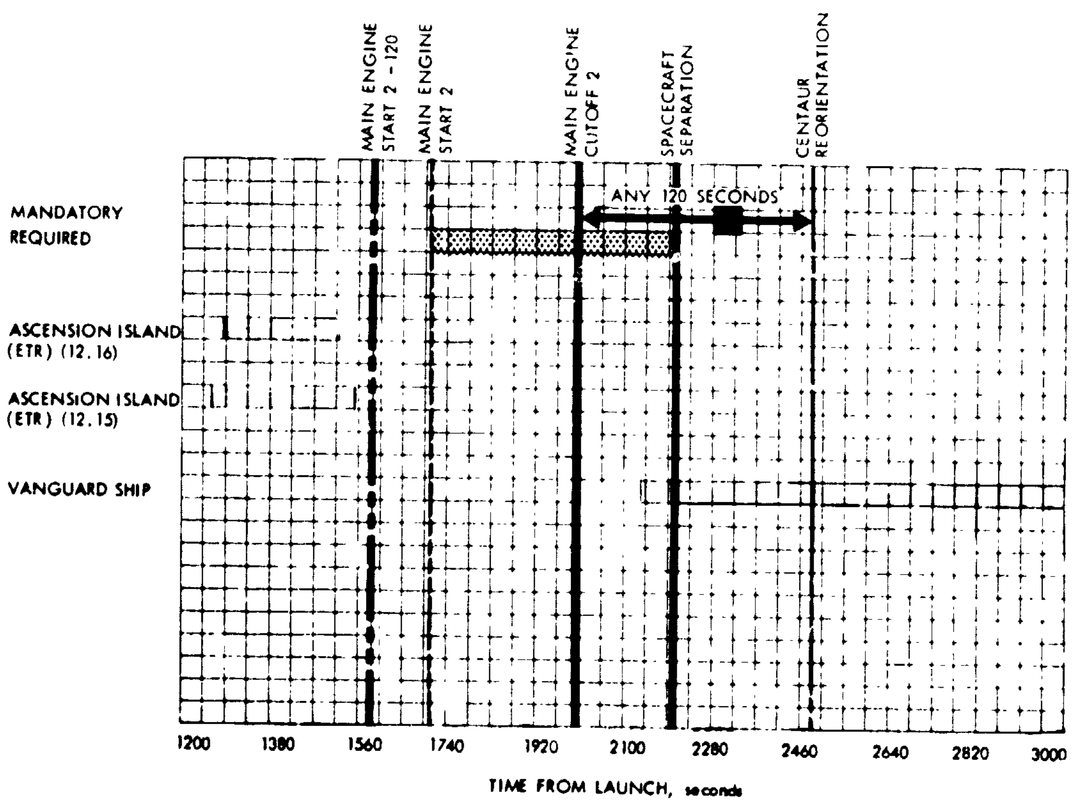


Fig. 18. Viking B downrange metric data coverage (5765.0-MHz link)

Table 9. Orbital elements for Viking B from Real-Time Computer System at the Air Force Eastern Test Range

Parameter*	Parking orbit	Transfer orbit	Transfer orbit Vanguard	Post-deflection	Spacecraft data
Epoch time	0612	2007	2007	3480	2007
Radius	06544.0346	06661.4196	06657.0366	14485.0157	06659.6252
Latitude	23.5182	-20.1242	-20.0804	-24.7783	-020.0413
Longitude	302.3875	028.5448	28.5007	105.4496	028.5945
Velocity	07.3880	11.1850	11.1933	07.7877	11.1888
Path angle	00.0062	07.8182	07.8138	56.7191	07.7621
Azimuth angle	108.8816	112.5130	112.4606	70.6686	112.3940
Inclination	029.2104	029.2200	029.1561	029.1283	029.0845
Eccentricity	00.0003	01.2463	01.2481	01.2276	01.2475
Vis viva energy	-60.9287	14.9757	15.0912	14.2665	15.0435

*Epoch time is in seconds from launch. The next six parameters are Earth-fixed spherical in kilometers, degrees, and kilometers per second. Inclination is in degrees; eccentricity is in degrees; and vis viva energy is in km^2/s^2.

Table 10. Viking mission B computed Mars B-plane mapping parameters from Real-Time Computer System at the Air Force Eastern Test Range

Parameters	Transfer orbit	Spacecraft orbit	Centaur post-deflection orbit
Time of closest approach, mo/day/yr h:min:s	08/08/76 00:47:56.1	08/09/76 16:35:39.2	08/08/76 00:47:56.1
B-vector, km	208983.80	713059.93	208983.80
Partial vector in Mars equatorial plane B · TC, km	192235.28	618632.17	192235.28
Partial vector perpendicular to Mars equatorial plane B · RC, km	-81974.528	-354610.69	-81974.528

Near-Earth communications included elements of NASA Communications Network, Air Force Eastern Test Range, Kennedy Space Center, and Jet Propulsion Laboratory in order to provide all required support. All available resources of this network were used to provide the project with a very high percentage of error-free real-time data from all supporting elements of the near-Earth tracking and data system.

A description of near-Earth communications is given in Volume I of this report on pages 85-99.

6. Problems and Corrective Action

Range aircraft 1 experienced wing damage while preparing for takeoff from Ascension for its assigned test support position when the jet blast from aircraft 3 blew a loading platform into the wing. The aircraft was grounded, and aircraft 3 was assigned to take its place and identification.

Corrective action to increase awareness by both flight and ground crews in operating these unique resources has been implemented.

Aircraft 1 acquired good quality data, about 190 seconds late, on the launch vehicle telemetry links. A total of 159 seconds of data was obtained after acquisition, representing only 36.7 percent of the committed data. The launch vehicle telemetry signal appeared to be weak and fluctuating. Intermittent data were also obtained on the spacecraft link. This could have been caused by unfavorable antenna aspect angles, equipment problems, or improper pointing data. Unfortunately, an accurate evaluation of aircraft antenna performance is not possible because it has not been modified to provide a function recording of the necessary information.

Aircraft 2 also acquired late, and much of its committed launch vehicle telemetry was not provided.

Aircraft 2 was approximately 69 kilometers (37 nautical miles) short of its assigned position throughout the data run due to a navigational error. This would have a negligible effect upon data coverage. The antenna was manually tracked for most of the test. Attempts to place the antenna in autotrack made it drive off target. The reason for this could not be determined, except that both aircraft reported a very weak signal, and Ascension recordings also indicated fluctuations which could hinder aircraft tracking efforts. This aircraft also has not been modified to provide antenna position recordings which could verify antenna performance during this interval. The antenna vertical gyro was found to drift in azimuth and elevation so a switch was made to the gyro simulator for the data recording interval.

It has been recommended that the modifications to the aircraft be given priority to make this important evaluation tool available for upcoming missions.

The overall aircraft performance is another example of the susceptibility of telemetry aircraft to unique operational problems that justifies backup telemetry aircraft in support of truly "mandatory" data requirements.

Johannesburg had difficulty acquiring autotrack on the main beam of the Centaur 2202.5-MHz link. Autotrack was obtained after the station switched from the nominal inter-net predict acquisition data to the acquisition aid antenna. Autotrack occurred 1.3 minutes later than the predicted time.

Post-test analysis indicated that the inter-net predicts generated by Goddard from powered flight tapes provided General Dynamics Convair were inaccurate.

Although the Viking B launch was nominal, the acquisition information sent to Johannesburg was based on the Viking A vis viva energy (referred to as C3), because the Project decided not to recompute detailed launch trajectories for Viking B. This decision was based on costs because a very large number of launch trajectories would otherwise have had to be recomputed for each launch time of each launch window. Use of the Viking A information in lieu of the Viking B information for generating the data sent to Johannesburg was responsible for the inaccuracies in the predicts and the subsequent acquisition problem experienced by the station.

Steps have been taken to provide a more accurate and manageable set of powered flight tapes to Goddard on future unmanned missions.

The ship Vanguard also had difficulty acquiring with its radar. It initially acquired on a side lobe using the inter-range vector data. The Vanguard radar acquired the main lobe when the antenna acquisition source was designated.

Post-test analysis showed that the inter-range vector was off by 0.85 degree in elevation, which was enough to put the radar on the first side lobe. The reason for this was that the wrong set of polynomial coefficients was taken off the polynomial coefficient magnetic tape. The tape contained two sets of polynomials for launch date September 9, 1975, and arrival on August 7, 1976 -- one for Viking A and one for Viking B. The Viking A set came first on the tape and was mistakenly used. It is planned to have future dual-mission polynomial coefficients on separate magnetic tapes.

Even though the first 1.8 minutes of the expected Vanguard radar metric data were lost and the Vanguard had several later dropouts because of poor aspect angles and long range, the major data needed to compute both "Centaur transfer orbit" and "Centaur post-deflection orbit" orbital elements were provided.

The radar at Patrick Air Force Base experienced low signal from launch, and when the parametric amplifiers were turned on at T plus 124 seconds to improve the signal-to-noise ratio, an oscillation in elevation angle was observed. This condition was improved by re-initiation at

T plus 201 seconds, but did not return to normal until automatic frequency control was selected at T plus 289 seconds.

Post-flight investigation could not identify any specific equipment or component defects that would have positively caused the problem. However, receiver local oscillators were replaced, and no further manifestation of the anomaly was observed. Signal levels in subsequent tests also were restored to expected values.

III. INITIAL ACQUISITION SUPPORT

A. GENERAL

The initial acquisition of Viking 1 spacecraft by the Deep Space Network occurred at 22:09:56 (GMT), August 20, 1975, at Station 42 in Canberra, Australia. Launch had been at 21:22:00 that day from Cape Canaveral, Florida, at a launch azimuth of 96.57 degrees into a trans-Mars, heliocentric orbit. Orbital injection occurred over South Africa, giving Australian stations first view of the spacecraft.

Under similar conditions on September 9, Viking 2 spacecraft (launched at 18:38:59) was also successfully acquired by Station 42 at 19:27:26. Again, initial acquisition success was attributed to careful implementation of the initial acquisition strategy and intensive testing and training of the station and operations personnel.

The initial acquisition strategy jointly worked out by the Deep Space Network and Viking flight teams employed safeguards necessary to the initial acquisition configuration plans. To ensure that the spacecraft receivers locked to the ground transmitter signal, the low-gain, wide-beam acquisition antenna was used for the uplink, and, to avoid ground receiver saturation, when receiving downlink on the high-gain, narrow-beam tracking antenna, the maser had to be bypassed. Further complications were introduced, since the Project desired to make a Canopus star map prior to Canopus star lock. This dictated that uplink transmitter power from the high-gain antenna was required to ensure continuous uplink and downlink lock during the 720-degree roll, during which nulls greater than 40 dB were anticipated.

A reconfiguration of the ground transmitter from the acquisition antenna to the tracking antenna was therefore necessary, and it was agreed that the station should be reconfigured at launch plus 1 hour 36 minutes. But since telemetry was critical at that time, the reconfiguration had to be accomplished without loss of telemetry, which meant that Station 42 could not simply turn off its transmitter and reconfigure, as this would result in dropping two-way lock and the loss of 1 minute of telemetry data.

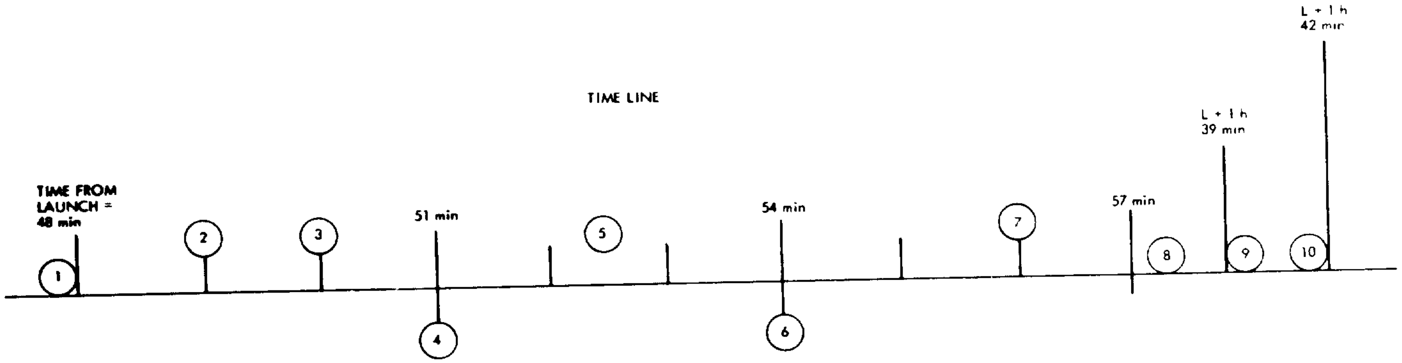
The plan to accomplish the station uplink and downlink reconfiguration required the transfer of uplink to Station 44 (the backup station), while Station 42 reconfigured its transmitter and maser, followed by the transfer of the uplink back to Station 42. This unusual transfer permitted the reconfiguration to be accomplished and ensured that the valuable bioshield telemetry data would not be interrupted.

The initial acquisition, initial conditions at Stations 42 and 44, and the strategy are illustrated as a function of time in Figs. 19 and 20.

STATION 42/44 S-BAND CASSEGRAIN MONOPULSE (TRACKING) ANTENNA DOWNLINK GAIN (BEAMWIDTH)	53.3 dB (0.33°)
STATION 42/44 S-BAND CASSEGRAIN MONOPULSE (TRACKING) ANTENNA UPLINK GAIN (BEAMWIDTH)	51.8 dB (0.36°)
STATION 42 S-BAND ACQUISITION ANTENNA DOWNLINK GAIN (BEAMWIDTH)	21.7 dB (16°)
STATION 42 S-BAND ACQUISITION ANTENNA UPLINK GAIN (BEAMWIDTH)	18.9 dB (17°)
STATION 44 S-BAND ACQUISITION ANTENNA DOWNLINK GAIN (BEAMWIDTH)	20.8 dB (5°)

STATION 42	STATION 44
RECEIVER 5 - S-BAND CASSEGRAIN MONOPULSE (TRACKING) ANTENNA (MASER BYPASS)	RECEIVER 1 - S-BAND CASSEGRAIN MONOPULSE (TRACKING) ANTENNA (MASER BYPASS)
RECEIVER 6 - S-BAND ACQUISITION ANTENNA (MASER 2)	RECEIVER 2 - S-BAND ACQUISITION ANTENNA (MASER 2)
TRANSMITTER (10 kW) - S-BAND ACQUISITION ANTENNA	TRANSMITTER (1 kW) - S-BAND CASSEGRAIN MONOPULSE (TRACKING) ANTENNA
TRACKING MODE ANTENNA POINTING SYSTEM TAPE	TRACKING MODE ANTENNA POINTING SYSTEM TAPE

Fig. 19. Initial acquisition strategy (initial conditions)



(1) STATION 42 RECEIVER 6 ONE-WAY TELEMETRY TO LINE 1/s
STATION 44 RECEIVER 2 ONE-WAY TELEMETRY TO LINE 1/10 s

(2) START SIDE BAND SEARCH STATION 42 RECEIVER 5/STATION 44 RECEIVER 1

(3) CONFIRM MAIN CARRIER/MAIN BEAM

(4) STATION 42 TRANSMITTER ON - START TUNING SWEEP

(5) STATION 42 COMPLETE TRANSMITTER SWEEP - CONFIRM TWO-WAY LOCK ON MAIN CARRIER
STATION 44 - CONFIRM REACQUISITION THREE-WAY

(6) STATION 42 CONFIRM TRACKING RATES AND GO AUTOTRACK. TELEMETRY DATA FROM RECEIVER 5 OR 6 AT PROJECT DISCRETION

(7) STATION 42 COMMAND MODULATION ON - REPORT 'GREEN' FOR COMMAND

(8) STATION 42 HOLD TRANSMITTING ON S-BAND ACQUISITION ANTENNA, RECEIVER 5 ON S-BAND CASSEGRAIN MONOPULSE IN AUTOTRACK MODE

(9) STATION 42 TRANSFER UPLINK TO STATION 44 - STATION 44 TRANSMITTER ON AT 1 kW ON S-BAND CASSEGRAIN MONOPULSE (STATION 42 RECONFIGURE TRANSMITTER TO S-BAND CASSEGRAIN MONOPULSE/S-BAND CASSEGRAIN MONOPULSE TO MASER)

(10) STATION 44 TRANSFER UPLINK BACK TO STATION 42 - STATION 42 TRANSMITTER ON AT 10-kW S-BAND CASSEGRAIN MONOPULSE (STATION 44 RECONFIGURE S-BAND CASSEGRAIN MONOPULSE TO MASER)

Fig. 20. Initial acquisition strategy (timeline)

Prelaunch tracking operations planning and analysis and other acquisition activities are described in greater detail in Refs. 1 and 2.

Initial acquisition planning for Viking 2 was similar to Viking 1 in both trajectory followed and the acquisition procedures employed and in characteristics of its radio frequency subsystem.

B. POST-FLIGHT ANALYSIS OF VIKING 1 LAUNCH PHASE

Using a new predict generation program based on inputs from the Viking Flight Path Analysis Group at launch minus 4 hours 25 minutes, the stations were sent the predicts necessary for generating an antenna drive tape well ahead of schedule. Additionally, since the Orbiter Performance Analysis Group made no last minute changes to the Viking Orbiter transmit and receive frequencies, it was not necessary to generate any additional sets of frequency predicts.

All remaining possible predict generation throughput time problems were alleviated when the launch occurred within a fraction of a second of the expected time.

Only one set of predicts had to be generated between launch and spacecraft rise at the Australia stations. This set gave the station predicts with a Greenwich Mean Time field, since all previous text predicts were generated in time from launch. Thus, while the new generation scheme had been carefully planned to handle any launch situation, the optimum situation (i.e., nominal countdown and launch) occurred, alleviating the problem of getting actual liftoff predicts to Station 42 prior to spacecraft rise.

During the early portion of the Station 42 launch pass, the radio metric data, when differenced with preflight nominal predicts by the Network Control System pseudoresidual program, produced the following residuals:

Parameter	Residual
Hour angle:	~ -0.07 degree
Two-way doppler:	~ 10 Hz at S-band
Exciter frequency:	~ -0.3 Hz at voltage-controlled oscillator frequency

The predicted 3-sigma uncertainties for these parameters were:

Hour angle:	~ 0.002 degree
Two-way doppler:	~ 10 Hz at S-band
Exciter frequency:	~ 55 Hz at voltage-controlled oscillator frequency

Except for hour angle, all residuals were generally within the 3-sigma uncertainties. While it substantially exceeded the 3-sigma uncertainty, the hour angle residual caused no impact on the acquisition of the downlink and no degradation of the received signal level. Additionally, from a historical perspective, this was perhaps the smallest early launch pass hour angle residual yet achieved. The two-way doppler residuals (shown in Fig. 21) started quite large (approximately -70 Hz), but gradually decreased to approximately the 3-sigma value of 10 Hz as the spacecraft's apparent motion approached sidereal rate.

Considering the many possible sources of error, both in frequency and in trajectory, the miniscule difference between the measured and predicted best lock frequencies of the exciter frequency indicates that the reference frequency supplied by the Orbiter Performance and Analysis Group was highly accurate. Additionally, since the difference between predicted and measured best lock frequencies was smaller than the supplied 3-sigma uncertainty by more than two orders of magnitude, one must consider that perhaps the 3-sigma frequency uncertainty calculations were overly pessimistic.

The Viking 1 one-way downlink was acquired by Station 42 at 22:10:05, 33 seconds before the predicted 22:10:38 spacecraft rise time. Subsequent stereographic plots of the spacecraft trajectory indicated a possible 1.5-degree hour angle error in the horizon mask used in the predicts software. Considering the rate of change of hour angle that occurred during this period (approximately 0.04 degree per second), this error would seem to account for the discrepancy in the rise time.

The downlink acquisition is depicted in Fig. 22. As can be seen in this plot, the receiver appears to have been drifting in the region around a one-way doppler frequency of 1047000 Hz prior to expected acquisition time. The signal was apparently detected at 22:09:51 with receivers reported in lock at 22:10:05, though both monitor and tracking data indicate possible continuous receiver lock as early as 22:09:53.

Australian Station 42 was instructed (by means of the acquisition message shown in Fig. 23) to perform the following uplink acquisition sweep:

Transmitter on:	22:13:40
Start sweep:	22:14:00
Starting frequency:	21.996130 MHz
Sweep rate:	3 Hz/s (voltage-controlled oscillator frequency)
End sweep:	22:15:30
Ending frequency:	21.996400 MHz (voltage-controlled oscillator frequency)
Sweep duration:	90 seconds

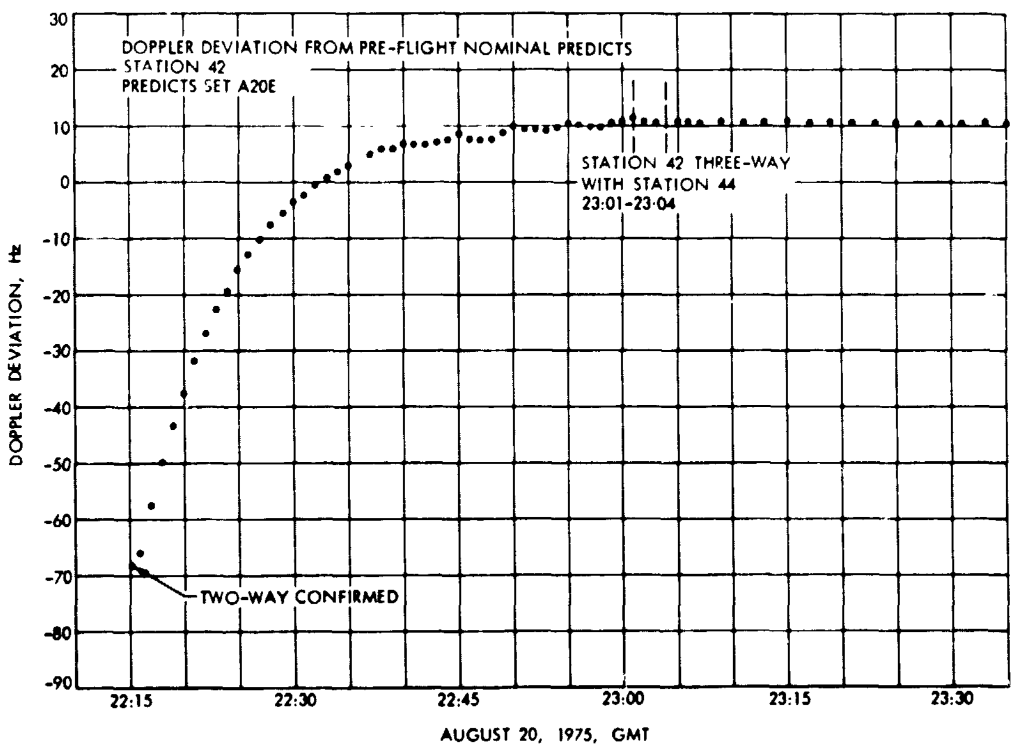


Fig. 21. Two-way doppler residuals for Viking 1

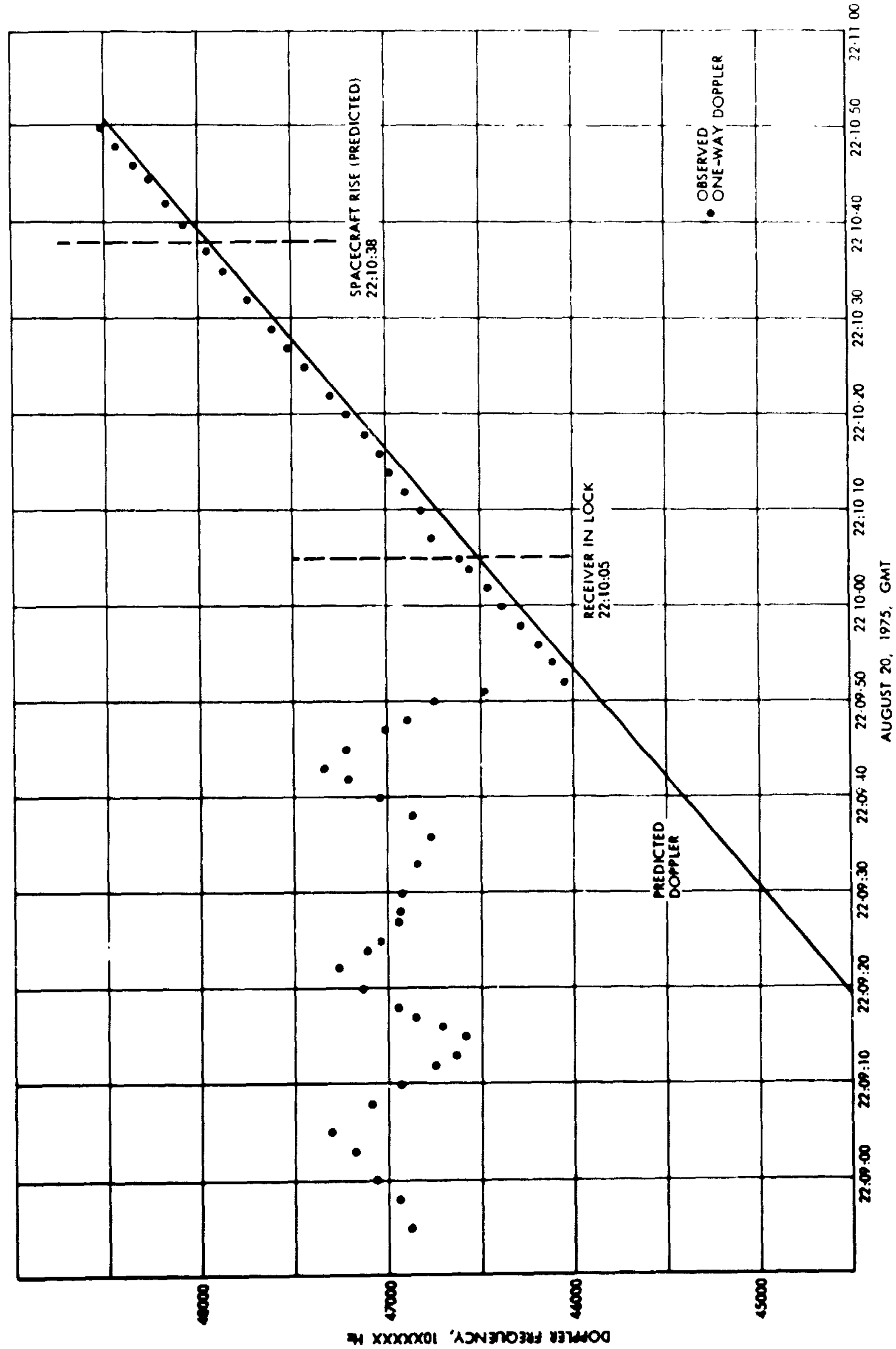


Fig. 22. Initial downlink acquisition at Station 42 for Viking 1

VIKING INITIAL ACQUISITION STATION 42 VERSION 3

A	PREDICTS		
1	TEXT	A20E	IS PRIME
2	DRIVE TAPE	A20D	IS PRIME
3.	HA/X BIAS	NONE	DEG
4	DEC/Y BIAS	NONE	DEG
5.	APS TIME BIAS	NONE	GMT
B.	INITIAL UPLINK ACQUISITION SWEEP		
6.	TXR ON	22:13:40	GMT
7.	TXR POWER	10	KW
8.	FREQUENCY	21.996130	MHZ
9.	START TUNING	22:14:00	GMT
10.	TUNING RATE	180	HZ/MIN(VCO)
11.	TRACK SYN FREQ	21.996400	MHZ
12.	CMD MOD ON	NONE	GMT
C.	CONTINGENCY SWEEP: EXECUTE ONLY IF DIRECTED		
13	START TUNING	22:19:00	GMT
14.	TUNING RATE	180	HZ/MIN(VCO)
15.	SWEEP DOWN TO	21.996160	MHZ
16.	SWEEP UP TO	21 996510	MHZ
17.	SWEEP DOWN TO TSF	21.996400	MHZ
18.	CMD MOD ON	NONE	GMT

SPECIAL INSTRUCTIONS: NONE

Fig. 23. Station 42 acquisition message for Viking 1

A comparison of the instructed sweep and the sweep as actually performed can be seen in Fig. 24. The uplink sweep began approximately 8 seconds later than planned. The switch to the two-way, coherent mode occurred at 22:14:49, within 5 seconds of the expected time. After an extensive search that included momentarily (~4 seconds) locking onto the telemetry subcarrier (see Table 11), the two-way downlink was acquired at 22:15:19. Even after the late start, the station was able to complete the uplink sweep within 1 second of the planned 22:15:30 time. The tuning rate averaged a commendable 3.[illegible] Hz/s.

In adherence to the angle drive strategy, the antenna at Station 42 was initially computer-driven using the preflight nominal predicts, generated at launch minus 2 hours. The drive mode was successfully changed to autotrack at 22:15:40, 9 seconds after completion of the uplink acquisition sweep.

In preparation for an uplink transfer from Station 42 to Station 44, the drive mode was changed to computer mode at 23:00:00. At 23:07:50, after maser 1 had been switched into the antenna microwave subsystem and the uplink transferred back to Station 42, autotracking was resumed at that station.

Commencing at 01:10:02, Station 42 began the acquisition of ranging data via the Planetary Ranging Assembly. It was soon apparent to the Network Operations Analysis Group that the Planetary Ranging Assembly data were incorrect, and a malfunction was suspected.

The malfunction, which resulted in a -0.9-second error in the range acquisition time, was identified several days later as an incorrect adjustment of an isolation amplifier in the Frequency and Timing Subsystem, which supplies 1-pulse-per-second timing to the ranging system. At that time, it was found that the receiver coder in the Ranging Logic Assembly was being synchronized onto the trailing edge of the one-per-second pulses rather than the leading edge as it should properly have been.

C. POST-FLIGHT ANALYSIS OF VIKING 2 LAUNCH PHASE

The new predicts system functioned smoothly and efficiently during the Viking 2 launch phase. Because the Viking Flight Path Analysis Group was able to deliver the first predicts at launch minus 2 hours 30 minutes, Australian acquisition Stations 42 and 44 had more than enough time to generate a drive tape well before launch. During the launch countdown, changes made by the Orbiter Performance Analysis Group to the predicted frequencies were small enough to make the generation of additional planned frequency predicts unnecessary.

As was the case in the Viking 1 launch, the remaining throughput time problems and concerns were allayed when launch occurred within a fraction of a second of the expected time. This left only one predict set to be generated between launch and spacecraft rise; this set updated the frequencies and gave the stations text predicts with a Greenwich Mean Time field (all previous predicts had been generated in time from launch).

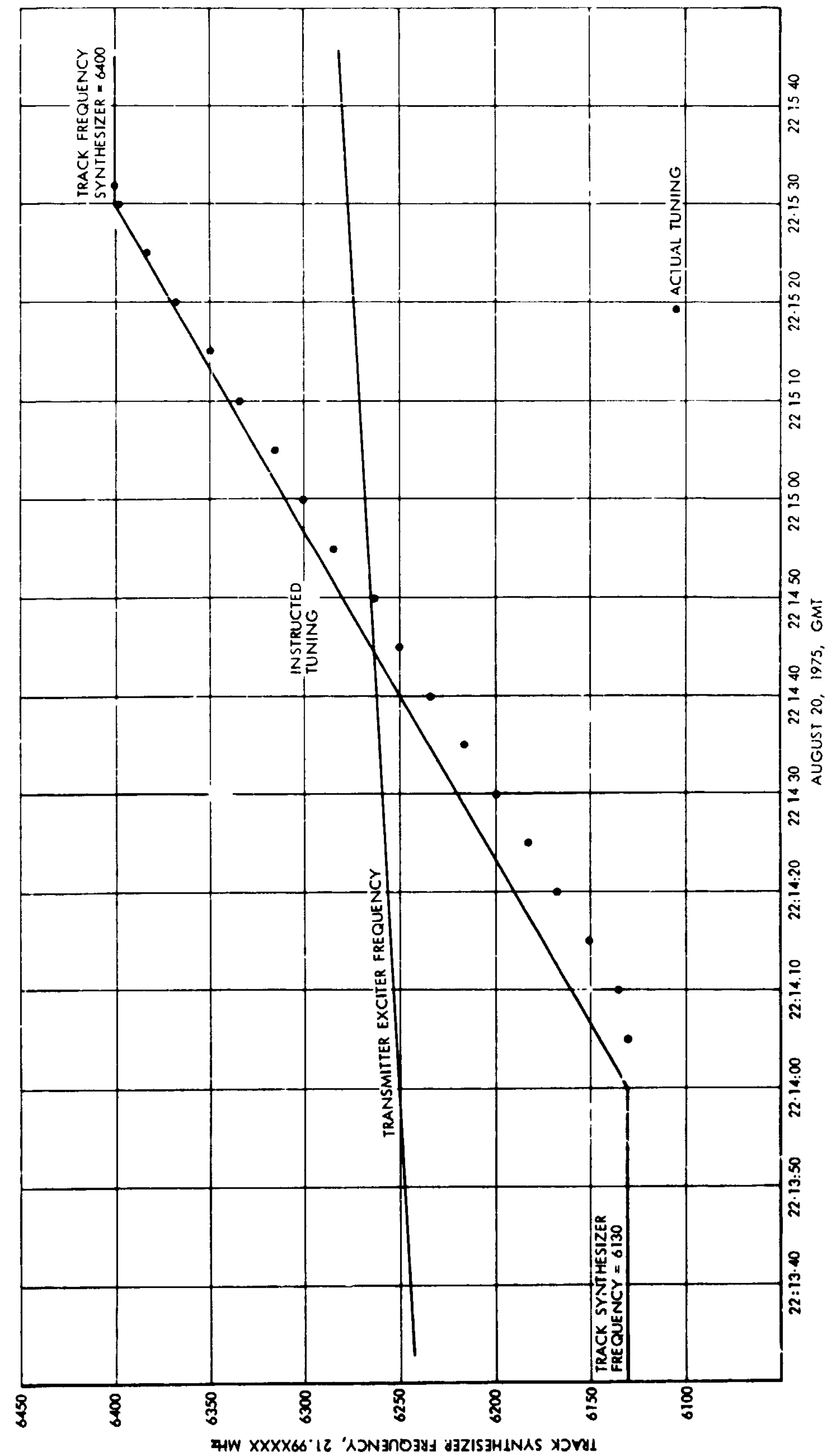


Fig. 24. Comparison of actual and instructed tuning at Station 42 for Viking 1

Table 11. Doppler residuals for Viking 1

GMT	Residual	Comments
22:13:30	34.416	Final one-way residual
22:14:00	-9420.715	Tuning---one-way doppler flagged two-way
22:14:10	-9163.489	Tuning
22:14:20	-6156.806	Tuning
22:14:30	-3037.731	Tuning
22:14:40	222.214	Tuning
22:14:49	-2280.683	Receiver out of lock---switch to coherent mode
22:15:00	-24066.756	Receiver locked on telemetry subcarrier
22:15:02	-24065.680	Receiver locked on telemetry subcarrier
22:15:19	-68.254	Receiver locked on carrier---good two-way
22:16:00	-66.052	Good two-way residual
22:18:00	-50.027	Good two-way residual
22:20:00	-37.420	Good two-way residual

During the early portion of the Station 42 launch pass, the radio metric data, when differenced with the preflight nominal predicts by the Network Operations Control Center pseudoresidual program, yielded the following residuals:

Hour angle: ~ -0.07 degree

Two-way doppler: ~ -29 Hz at S-band

Exciter frequency: ~ 14 Hz (voltage-controlled oscillator frequency)

These can be compared to the 3-sigma uncertainties supplied by the Viking Project:

Hour angle: ~ 0.002 degree

Two-way doppler: ~ 10 Hz at S-band

Exciter frequency: ~ 55 Hz (voltage-controlled oscillator frequency; total frequency/trajectory uncertainty)

The residuals, in general, exceeded the 3-sigma uncertainties (which must be considered miniscule when compared to previous mission trajectory uncertainties). The hour angle residual had no impact on the acquisition of the downlink and no degradation of received signal level even though it substantially exceeded the 3-sigma uncertainty. Additionally, the magnitude of this angle residual is nearly equal to the hour angle residual of the Viking 1 launch, which places it amongst the smallest early launch pass angle residuals yet achieved.

The two-way doppler residuals (shown in Fig. 25) started quite large (approximately -300 Hz).

The difference between the measured and predicted best lock frequencies, for the exciter voltage-controlled oscillator, fell well within the total trajectory/frequency 3-sigma uncertainty. Though larger than the residual for the Viking 1 launch (~-0.3 Hz), the magnitude of this residual fell easily within the boundaries of the prescribed uplink sweep and caused no problem in the uplink acquisition.

Acquisition of the Viking 2 one-way downlink at Station 42 was reported at 19:27:01, 25 seconds prior to the expected spacecraft rise time of 19:27:26. This again indicated a possible error in the Station 42 horizon mask used in the prediction software.

The downlink acquisition is illustrated in Fig. 26. As can be seen, it appears that the receiver was being tuned through the region near the predicted one-way doppler prior to the expected spacecraft rise time. The signal was apparently detected at approximately 19:26:41 with receiver 5, connected to the S-band Cassegrain monopulse reported in lock at 19:27:01. Both monitor and tracking data indicate, however, that receiver 6, connected to the S-band acquisition antenna, may have sustained lock from as early as 19:26:41.

Station 42 was instructed to perform the following uplink acquisition sweep designed according to the specifications previously described:

Transmitter on:	19:30:40
Start sweep:	19:31:00
Starting frequency:	22.035090 MHz (voltage-controlled oscillator frequency)
Sweep rate:	180 Hz/min (voltage-controlled oscillator frequency)
End sweep:	19:32:30
Ending frequency:	22.035360 MHz (voltage-controlled oscillator frequency)
Sweep duration:	90 seconds

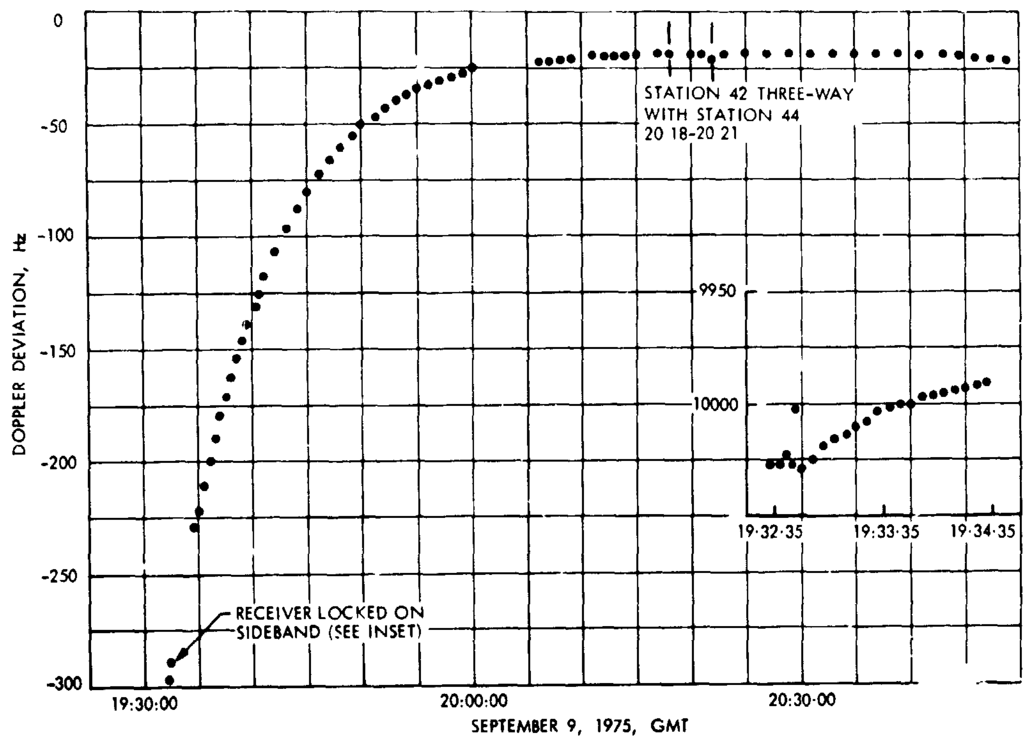


Fig. 25. Two-way doppler residuals for Viking 2

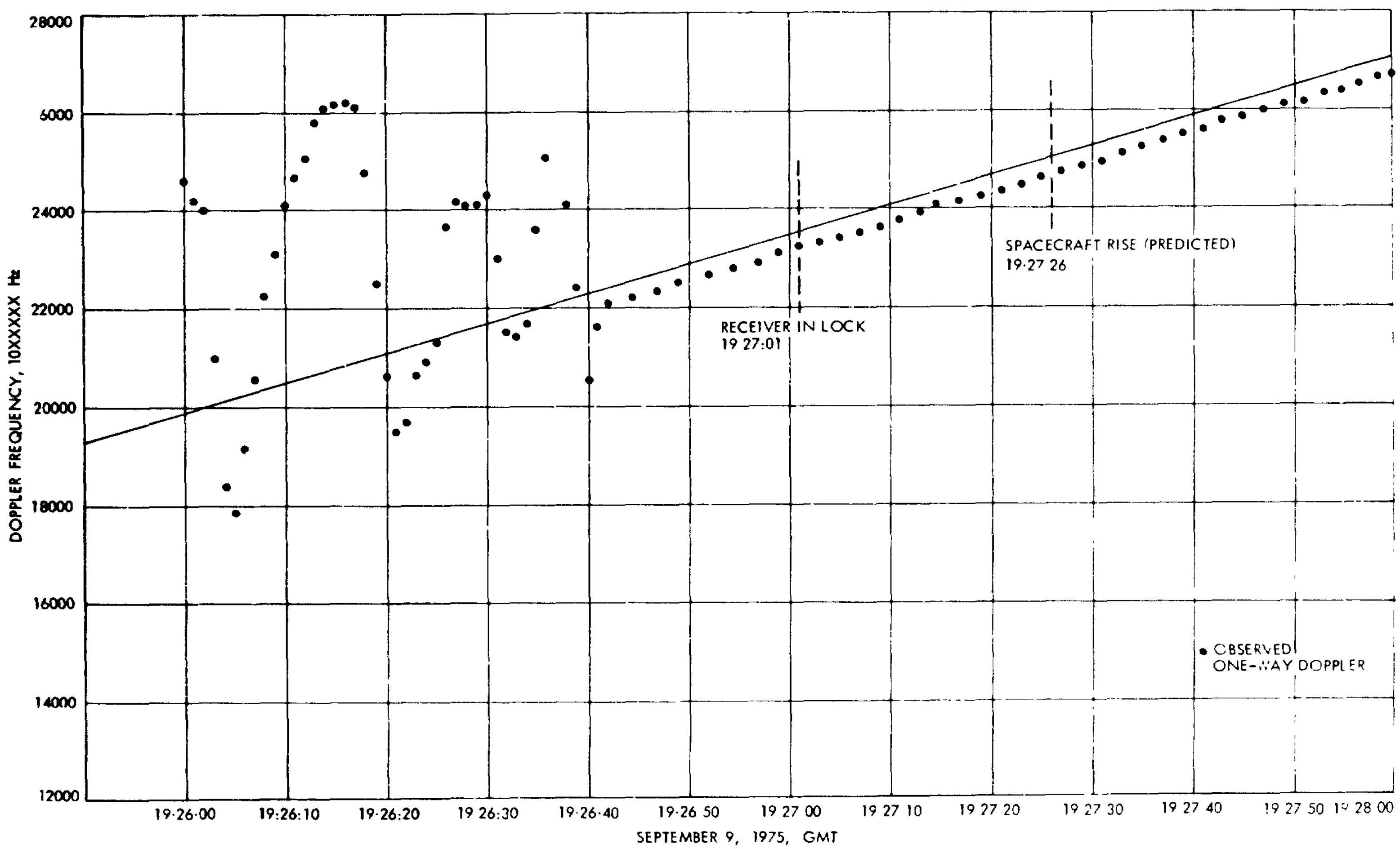


Fig. 26. Station 42 acquisition of Viking 2 downlink

A comparison of the instructed sweep with the actual uplink acquisition sweep is depicted in Fig. 27. As is shown, the sweep began approximately 7 seconds later than planned. At 19:32:02, the switch to the two-way coherent mode occurred. The two-way downlink was very quickly acquired by Station 42 with the receiver back in lock at 19:32:12. However, as the receiver was being locked to the downlink, tuning slowed and almost stopped for several seconds. The tuning rate for the remainder of the sweep was somewhat slower than during the initial portion of the sweep, causing the ramp to take only 15 seconds longer than originally planned.

When the doppler extractor was switched from the S-band acquisition antenna receiver to the S-band Cassegrain monopulse antenna receiver, it was found that the receiver was in lock on a sideband located approximately 10 kHz from the main carrier (see Table 12). Receiver lock on the sideband was broken approximately 2 minutes later, and the carrier reacquired at 19:34:44.

In following the angle strategy, the antenna at Station 42 was initially computer-driven by using the preflight nominal predicts generated at launch minus 2 hours. The drive mode was changed to autotrack at 19:35:51 following completion of the uplink acquisition. As was the case during the Viking 1 initial pass, it was necessary to transfer the uplink to Station 44 in order to allow Station 42 to switch maser 1 into the antenna microwave subsystem. In preparation for this reconfiguration, the drive mode at Station 42 was changed back to computer mode at 20:17:00. Autotracking was resumed 5 minutes later, following the uplink transfer back to that station.

After the failure of maser 1 at 23:11:16, Station 42 returned to computer drive for the remainder of the pass. The acquisition of range data at that station began at 22:25:02 and continued with generally good results through the acquisition of seven range points.

Since it was designated to serve as a backup, Station 44 in Australia played a somewhat passive role in the Viking 2 launch phase operations. Its availability, however, allowed some unique (for a launch phase) configurations to be used at Station 42.

Following this plan, the backup station acquired the one-way Viking 2 downlink at 19:29:18 (as was the case with Station 42, this time was considerably earlier than the predicted spacecraft rise time). The acquisition is shown in Fig. 28. Autotracking of the spacecraft began at 19:33:38, after completion of the Station 42 uplink acquisition sweep and confirmation of good three-way downlink. The uplink was handed over to Station 44 by means of a track synthesizer frequency transfer (which does not require tuning of the uplink) from 20:18:02 to 20:21:02. Telemetry and tracking data continued uninterrupted during this period. The backup station was reconfigured to normal cruise configuration at 20:27:40 and continued tracking in the three-way mode until spacecraft set at 00:28:20.

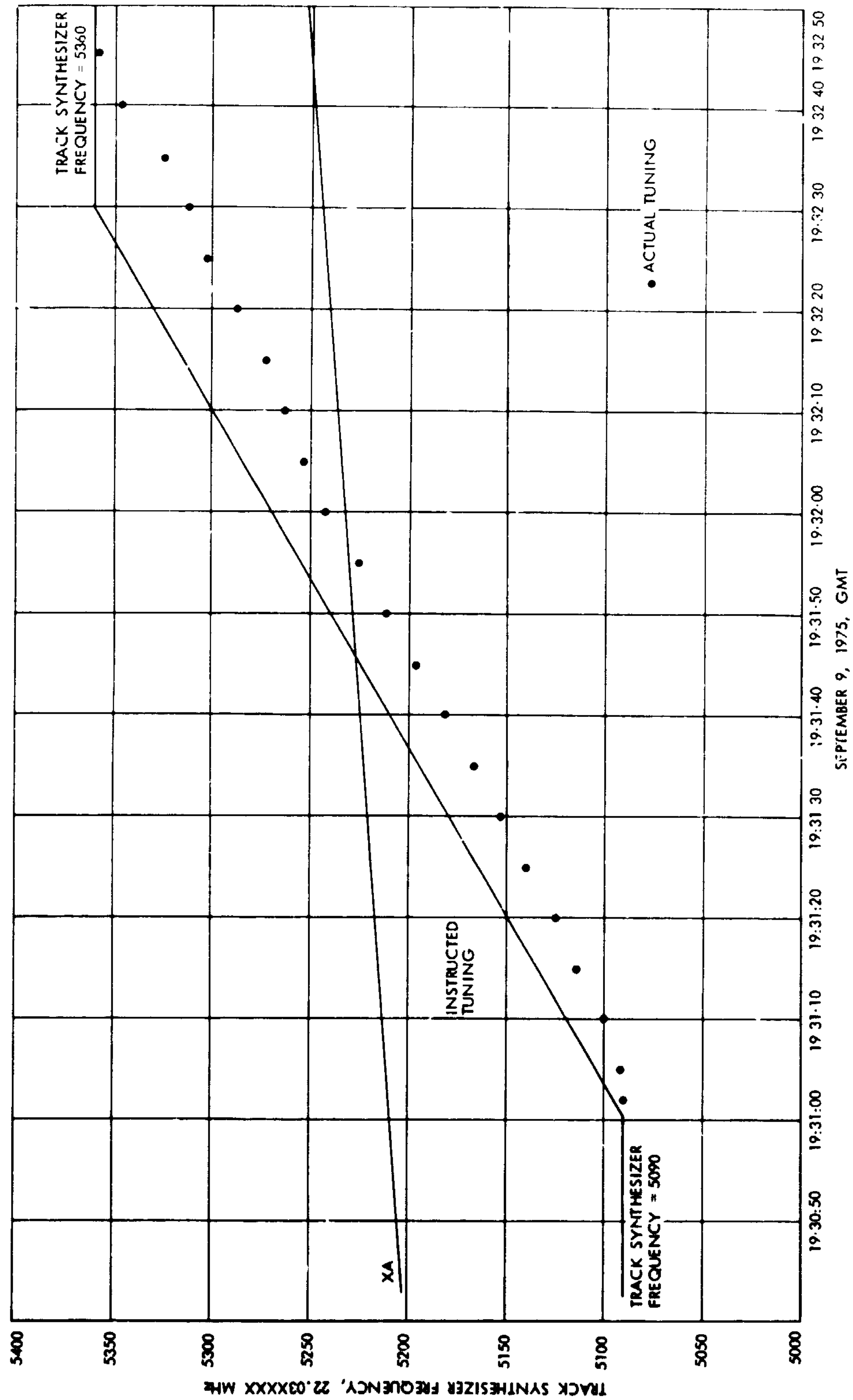


Fig. 27. Comparison of instructed sweep with actual uplink acquisition for Viking 2

Table 12. Doppler residuals for Viking 2

GMT	Residual	Comments
19:30:30	-275.331	Final good one-way residual
19:31:00	-15029.743	Tuning---one-way doppler flagged two-way
19:31:20	-12163.310	Tuning
19:31:40	-7095.466	Tuning
19:32:02	-1650.137	Receiver out of lock---switch to coherent mode
19:32:12	-298.039	Good two-way residual
19:32:20	-291.406	Good two-way residual
19:32:30	-286.623	Good two-way residual
19:32:34	-10026.788	Switch doppler extractor---SCM RCVR on sideband
19:33:00	-10019.764	RCVR on sideband
19:33:30	-10007.272	RCVR on sideband
19:34:00	-9993.609	RCVR on sideband
19:34:36	-11827.154	Receiver out of lock
19:34:44	-228.606	Receiver in lock on carrier
19:35:00	-203.622	Good two-way residual

SCM = S-band Cassegrain monopulse

RCVR = Station Receiver Assembly

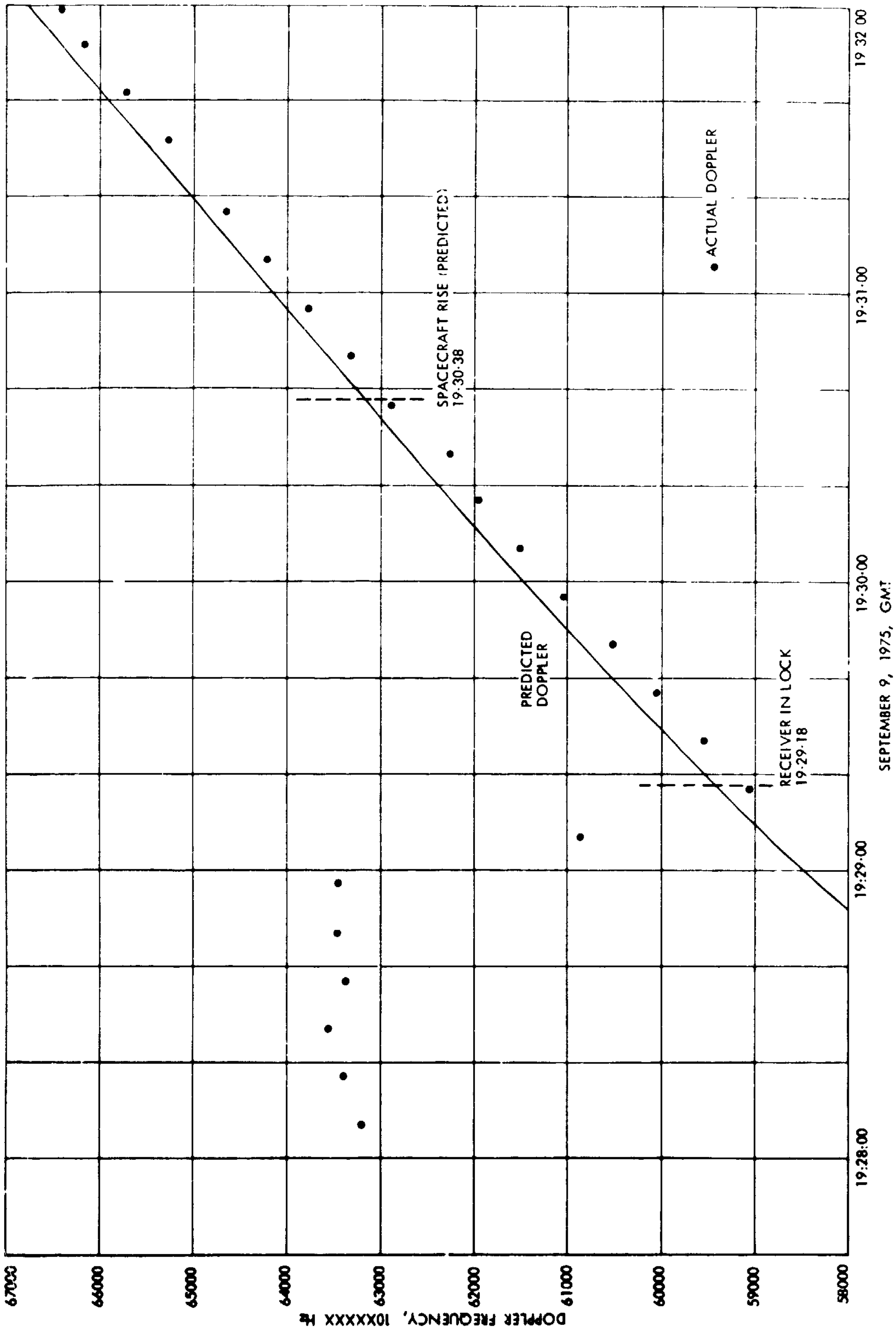


Fig. 28. Station 44 acquisition of Viking 2 downlink

IV. DEEP SPACE NETWORK SUPPORT

A. CRUISE SUPPORT (SEPTEMBER THROUGH DECEMBER 1975)

Following the successful launches of Viking 1 on August 20, 1975, and Viking 2 on September 9, 1975, the Deep Space Network faced dual tasks of considerable magnitude in its support for Viking. First, the demands for cruise support of both Viking spacecraft were immediate and severe for that part of the organization responsible for mission operations. Second, the full planetary configuration required to support Viking planetary operations had not yet been completed, and a significant amount of implementation, testing, and training remained to be accomplished prior to the February 2, 1976, deadline for the start of full planetary flight operations training.

The span of both of these activities covered the early cruise months of late August, September, October, November, and December 1975, and began essentially following the completion of the two-way initial acquisition sequences described in Section III.

The following narrative describes this activity against the background of the on-going dual spacecraft Viking mission, in terms of Network operations, planetary configuration development, and what was to become a dominating new requirement, X-band Mars radar.

1. Mission Events

On August 27, with Viking 1 operating perfectly, the Orbiter maneuver engine was fired to change spacecraft direction and velocity in order to bring it within the desired target area for insertion into Mars orbit. Later in the flight, smaller corrections would be made to refine the trajectory even further.

The original aiming points were purposely biased a considerable distance from Mars to avoid any possibility of having a spacecraft impact the surface should either Viking be inoperable after separation from the launch vehicle. This was done in compliance wih an international "planetary quarantine" agreement, wherein a spacecraft out of control must not possibly land on another planet and contaminate it with Earth organisms (see Fig. 29).

Meanwhile, at Cape Kennedy, the Viking 2 spacecraft was undergoing precountdown checks when the receiver sensitivity of the S-Band Radio Subsystem on the Orbiter suddenly degraded. Efforts to isolate the problem, and work around it, were not successful, and a decision was made to recycle the spacecraft back to the assembly building for detailed troubleshooting. The Titan booster was defueled on August 31, and the Viking 2 spacecraft was demated the following day. In the assembly area, all Orbiter radio frequency coaxial hardwares were removed and replaced with new ones; all changes were verified and preparations for launch were restarted.

Viking 2 was launched at 18:38 (GMT) on September 9, and the trajectory correction maneuver was successfully performed on September 19. Viking 1 would arrive at Mars on June 19, 1976, only one day later than originally planned. Viking 2 would arrive on August 7, 1976,

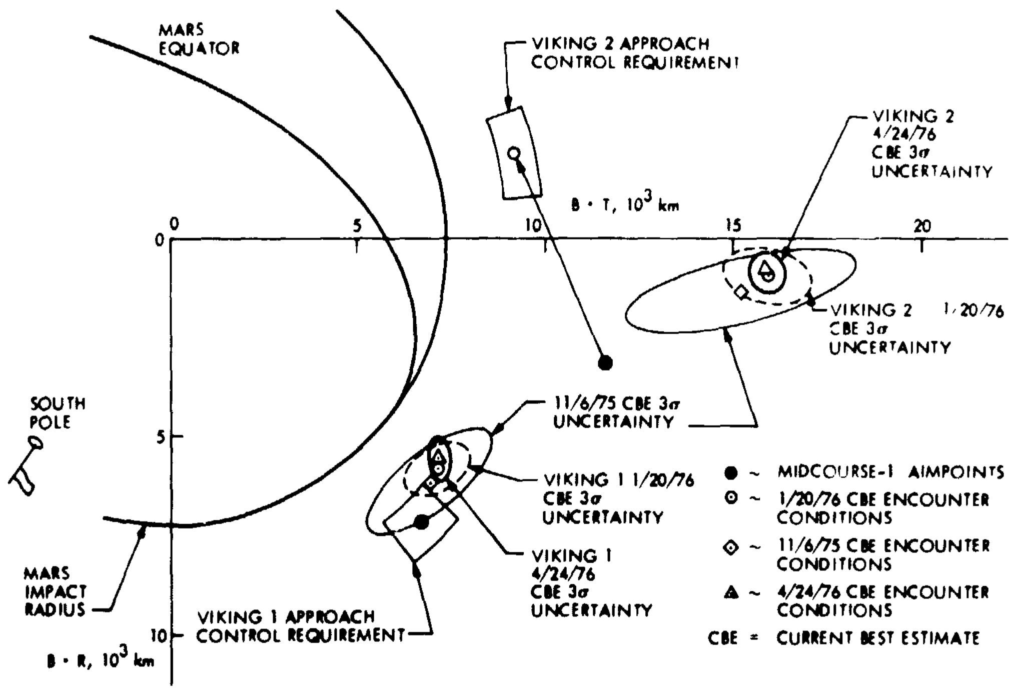


Fig. 29. Viking 1 and 2 encounter aim points

the exact day planned several years earlier. The time lost previously was offset by introducing minute corrections to the trajectory aiming point, launch vehicle burn durations, and injection velocities while the spacecraft was still near the Earth.

Viking operations had now settled down to a comfortable routine, with both spacecraft operating in a normal fashion. The first activity after trajectory correction maneuvers was the start of checkout of the Orbiter science instruments and calibration of the Canopus star tracker. Both pairs of TV cameras checked out "green," as did the Mars atmospheric water detector and the infrared thermal mapper. In fact, some test television pictures were successfully played back. Other activities on the Orbiter included gyro drift calibrations, some signal-to-noise ratio tests, and radio subsystem threshold tests.

The Landers remained essentially quiescent, except for some science instrument venting sequences and routine tape recorder maintenance activity. On October 19, the Viking Lander 1 batteries were given a full charge as part of their conditioning for future operations. Viking Lander 2 battery A conditioning was scheduled to start on October 31, but the charger did not turn on after the command was transmitted to the spacecraft. After several days of detailed analysis, it was decided to attempt to charge battery B, using the backup charger aboard. On November 5, at 18:00 (GMT), the charge command was sent to the spacecraft. Approximately 90 seconds later, telemetry confirmed that the charger was activated and battery B was receiving a charge. As of November 7, two of the four batteries were fully charged, and the third battery was being brought up to its full rated power.

Subsystem checkouts on both Orbiters and Landers were performed on a regular basis, all with satisfactory results. A Viking Lander 1 cruise checkout, on November 13, showed all subsystems normal; a similar checkout was subsequently performed on the Viking Lander 2, on November 21, with all readings normal. A series of tape recorder maintenance sequences and gas chromatograph mass spectrometer oven bakeouts were planned throughout the cruise period for both Landers; these were performed without any problems during this period.

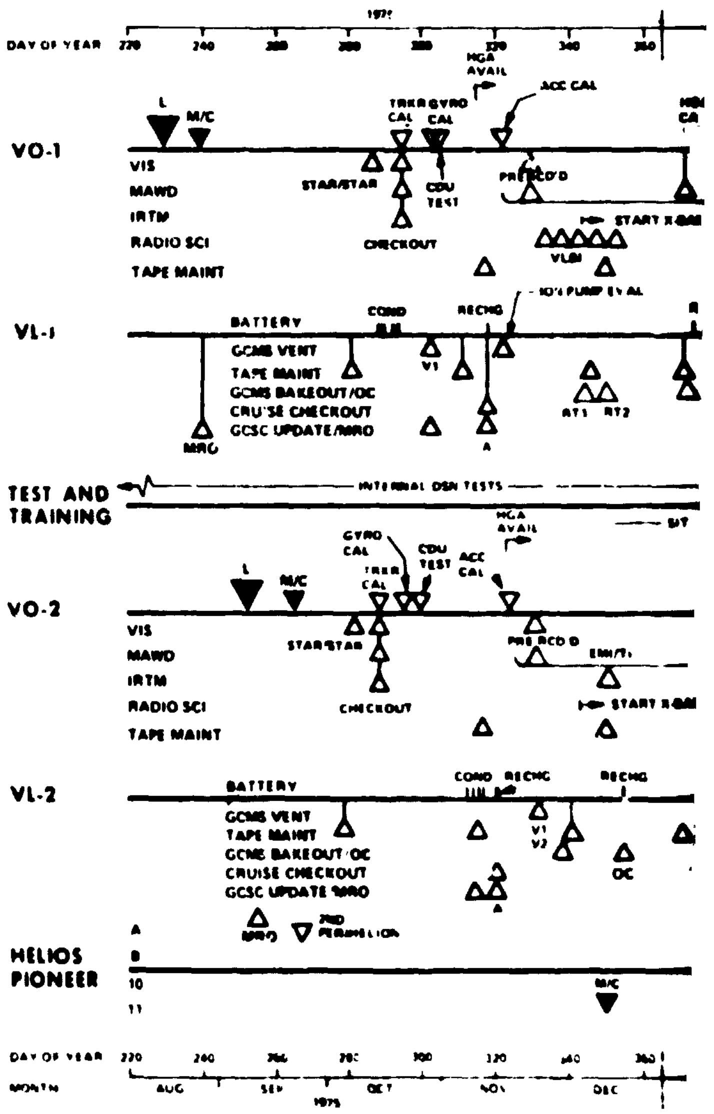
Routine Orbiter activities included Mars atmospheric water detector calibrations, accelerometer calibrations, and playback of prerecorded video frames at various data transmission rates. On November 12, the Viking Orbiter 1 high-gain antenna was put into operation for the first time, and Viking Orbiter 2 followed suit on November 18. It was not possible to use these high-gain antennas before this time because of the thermal constraint imposed on the antenna actuators. If used earlier in the mission, the spacecraft-to-Earth pointing angles of the antenna would have exposed the actuators to direct sunlight, and would have caused them to overheat. For safety, the mission plan delayed their use until each spacecraft was farther away from the Sun, thus reducing the heating problem.

Both Viking Orbiter high-gain antennas were repositioned on a daily basis to keep the narrow radio beams aimed directly at Earth. Even though the distances to the two Vikings were many millions of kilometers, the relative movement of Earth, as seen from the spacecraft, was great enough to necessitate these antenna "updates" once a day. As the distance increased, the changes became less frequent.

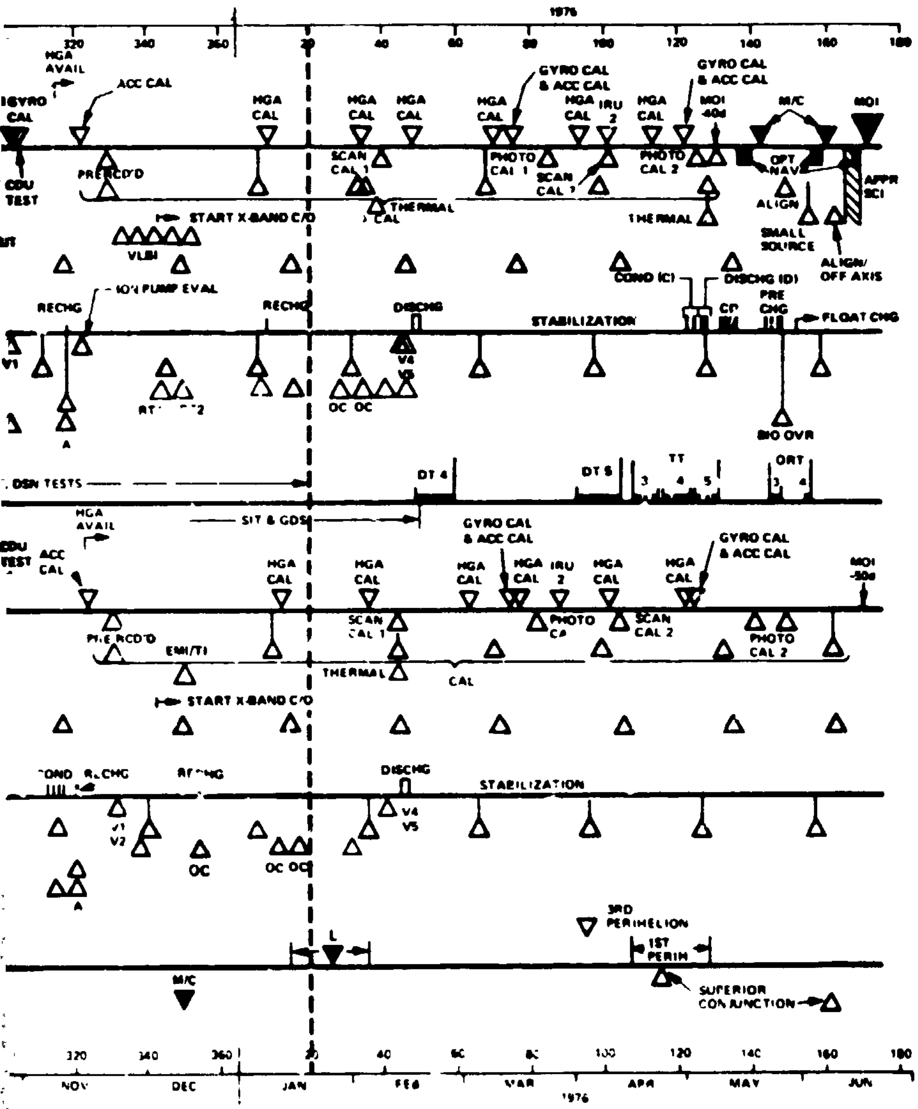
No major activities were scheduled during the Christmas and New Year holiday periods, aside from high-gain antenna position updates and continuous tracking and monitoring. No anomalies or problems occurred, and Viking Mission Control reported at the end of 1975 that both spacecraft were in condition "green.

The Viking mission profile strategy during cruise is shown in Fig. 30 for both spacecraft (Viking Orbiters 1 and 2, and Viking Landers 1 and 2). Pertinent events for Helios and Pioneer are also shown, since both of these flight projects influenced Network support for Viking to some extent. The initial occurrence of events of significance to Network support during this period was as follows:

	Initial occurrence			
Event	Spacecraft 1		Spacecraft 2	
	Station	Day	Station	Day
33-1/3-bps telemetry	42	232	42	252
Station/station handover	42/44	232		
Ranging at S-band	42	233	42	253
Command transmission	42	233	42	252
64-m station tracks Viking	43	233	43	253
1-kbps uncoded telemetry (Lander memory readout)	43	233	43	253
2-kbps coded telemetry (Orbiter Computer Command Subsystem readout)	42	233	42	253
Midcourse maneuver	14	239	14	262
Use of Orbiter high-gain antenna	63	315	62	322
4- and 16-kbps telemetry (Lander checkout data)	14	317	14	325
Spacecraft X-band transmitter turned ON		325		325
X-band range and doppler received	14	339		
X-band telemetry experiment			14	342
Very long baseline interferometry test			11/14/42/43	355



FOLDOUT FRAME



ACC	ACCELEROMETER
APPR SCI	APPROACH SCIENCE
CAL	CALIBRATION
CDU	COMMAND DISTRIBUTION UNIT
COND or CD	CONDITIONING
C O	CHECKOUT
DT	DEMONSTRATION TEST
GCMS	GAS CHROMATOGRAPH MASS SPECTROMETER
GCSC	GUIDANCE CONTROL AND SEQUENCING COMPUTER
HGA	HIGH GAIN ANTENNA
IRTM	INFRARED THERMAL MAPPER
IRU	INERTIAL REFERENCE UNIT
L	LAUNCH
MAWD	MARS ATMOSPHERE WATER DETECTOR
M C	MIDCOURSE
MOI	MARS ORBIT INSERTION
MRO	MEMORY READOUT
OC	OVEN CONDITIONING
OPT NAV	OPTICAL NAVIGATION
ORT	OPERATIONAL READINESS TEST
TT	TRAINING TEST
VIS	VIDEO IMAGING SUBSYSTEM
VLBI	VERY LONG BASELINE INTERFEROMETRY

Fig. 30. Viking mission profile strategy during cruise

FOLDOUT FRAME 2

2. Network Operations

a. Telemetry System. The performance of the Network Telemetry System in support of Viking is analyzed on a month-by-month basis in terms of downlink signal level and signal-to-noise ratio. The expected values for these parameters are compared continuously with actual values observed during the mission, and the "residual" value is calculated. Provided the residuals remain within specified limits, the telemetry system is considered to be performing correctly. Out-of-limits anomalies are investigated, and remedial action is taken where necessary.

Telemetry performance for the months of August, September, and December for Vikings 1 and 2 is given in Tables 13 and 14 in terms of the residuals for signal level and signal-to-noise ratio for 64- and 26-meter stations, respectively.

Due to the demands of the Viking mission overwhelming Network resources available for analysis in this area, data are not available for October and November. However, daily status records indicate that the mean value for signal level differentials did not exceed 0.5 dB during this period.

b. Tracking System. The Network Tracking System participation in the successful launches of Vikings 1 and 2 on August 20 and September 9, respectively, and the initial acquisition sequences that followed are described in Section III. After the initial acquisitions, the Tracking System provided radio metric data of high quality for support of the Viking navigation function. This support is reported here under three headings: (1) Radio Metric Data Quality, (2) Viking Spacecraft Frequencies, and (3) Tracking Prediction System Enhancement for Orbital Operations.

(1) Radio Metric Data Quality. The primary navigational data type generated by the Network is doppler data. These data are continuously monitored by the Network Analysis Team for tracking, in near-real time using the Network Operations Control Center Pseudoresidual Program. Doppler data residuals (actual minus predicted) produced during the August-December 1975 period by the pseudoresidual program consistently indicated a high level of accuracy in the polynomial coefficient tapes (the frequency-independent observable produced by the Viking Project for use with the Network Prediction Program). Figure 31 is a diagram of tracking data flow supplied to the Network Operations Control Team by the Viking Project Flight Path Analysis Group. Additionally, a value for pass average doppler noise is computed 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 at Sun-Earth-probe angles less than 45 degrees and is at adequate signal levels, the average value for two-way doppler noise at a sample rate of 60 samples per second is nominally expected to be 0.003 Hz $\pm$ 0.002 Hz.

Table 13. 64-meter station residuals for downlink signal level and signal-to-noise ratio for Vikings 1 and 2 during August, September, December 1975[a]

Parameter	August		September		December	
	Viking 1	Viking 2	Viking 1	Viking 2	Viking 1	Viking 2
Signal level						
Observations	19	N/A[b]	20	4	18	10
Mean, dB	-0.6	---	-0.3	0.0	+0.2	+0.2
Sigma, dB	1.2	---	0.6	0.0	0.5	0.5
Signal/noise ratio						
Observations	c	N/A	20	N/A	c	c
Mean, dB	---	---	-0.7	---	---	---
Sigma, dB	---	---	1.1	---	---	---

[a] Data not available for October and November.

[b] Not applicable, since spacecraft not tracked.

[c] Signal-to-noise ratio estimator saturated.

Table 14. 26-meter station residuals for downlink signal level and signal-to-noise ratio for Vikings 1 and 2 during August, September, December 1975[a]

	August		September		December	
Parameter	Viking 1	Viking 2	Viking 1	Viking 2	Viking 1	Viking 2
Signal level						
Observations	12	N/A[b]	63	58	68	75
Mean, dB	-0.5		-10.4		-0.2	-0.1
Sigma, dB	1.4		0.7		0.4	0.5
Signal/noise ratio						
Observations	6	N/A	63	c	c	c
Mean, dB	0.2		-0.2	---	---	---
Sigma, dB	1.0		0.7	---	---	---

[a]Data not available for October and November.

[b]Not applicable, since spacecraft not launched.

[c]Signal-to-noise ratio estimator saturated.

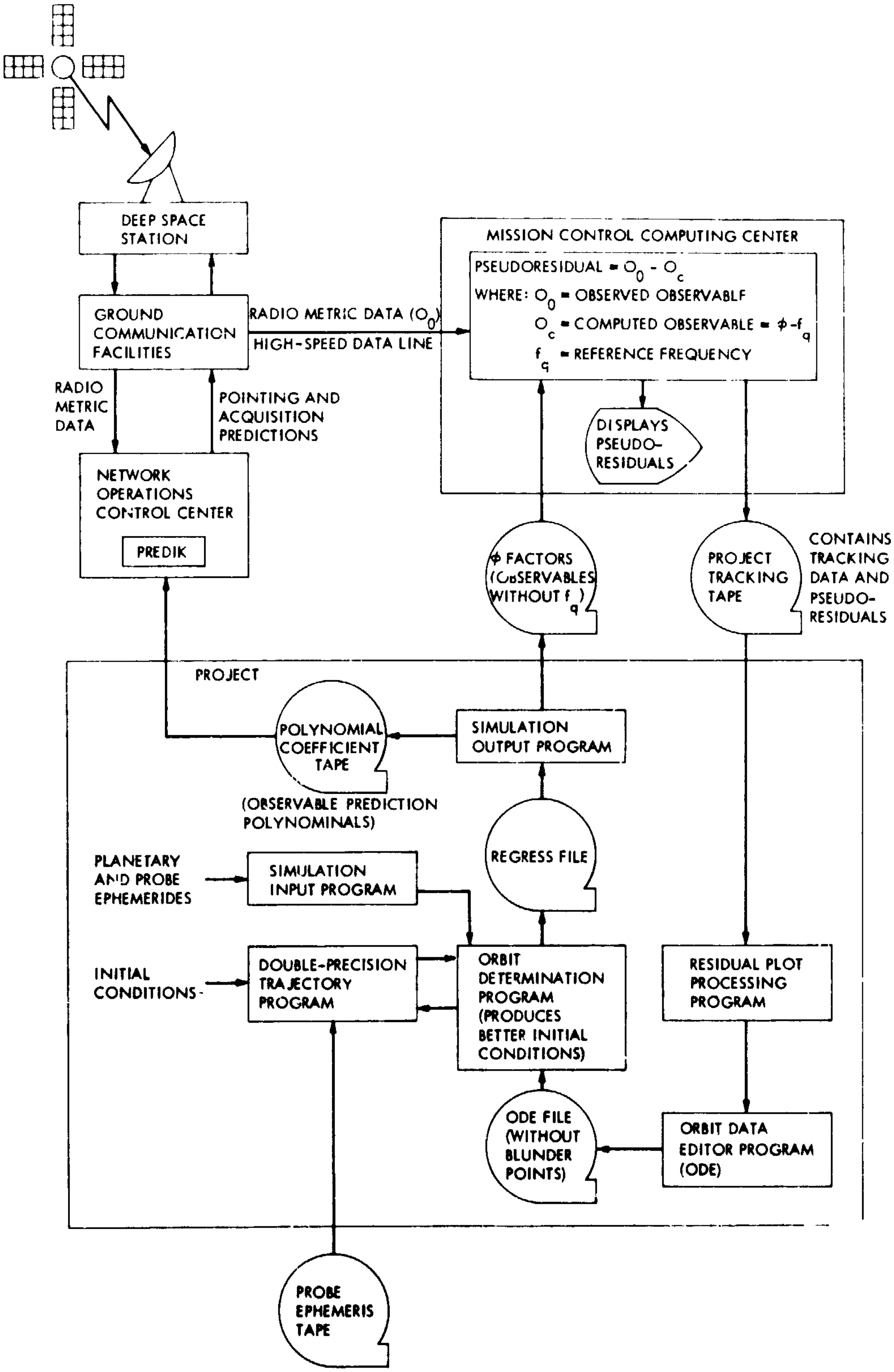


Fig. 31. Tracking data flow diagram

Figures 32 and 33 present "pass average" doppler noise for Vikings 1 and 2 for the August-December period. Examination of these figures indicates generation of nominal, high-quality doppler data for Viking navigation.

(2) Viking Spacecraft Frequencies. During each one-way tracking period, the Network Analysis Team re-estimates the spacecraft auxiliary oscillator frequency, and during each subsequent uplink acquisition a similar re-estimation of the spacecraft best lock frequency is performed. These data for Vikings 1 and 2 during the August-December 1975 period are presented in Figs. 34 through 37.

Spacecraft frequency data gathered by the Network in this fashion has 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 acquisitions and radio metric data validation. Additionally, these data assume paramount importance during mission critical phases, when complicated mission strategies demand rapid and precise uplink and downlink acquisitions.

(3) Tracking Prediction System Enhancement for Orbital Operations. In early 1975, a study (Ref. 3) was performed to investigate difficulties associated with X-band tracking during the Viking orbital phase. During the course of this study, it became apparent that extensive quantities of receiver frequency and receiver frequency rate prediction data would be required. To meet this need, the Network Operations Analyst for tracking proposed an additional capability to the prediction system to produce receiver-level predicts. During December 1975, two new formats (and the associated algorithms) were designed, which were almost completely symmetrical to the current doppler predict formats, but which replaced each doppler field with the corresponding open- or closed-loop receiver frequency. In addition, a receiver frequency rate field was added. At the same time, it was decided to move the responsibility for tropospheric correction of the observables from the Flight Path Analysis Group (polynomial coefficient tapes) to the Network Operations Control Team, which was expected to substantially reduce computer run time in the production of polynomial coefficient tapes by the Flight Path Analysis Group. This work was completed subsequent to December 1975, and the software program was transferred to Operations as "PREDIK Version 5."

(4) Midcourse Maneuvers. The near-Earth midcourse corrections necessary to put the Viking spacecraft on the proper Mars intercept trajectories were programmed to occur over Station 14 as follows (time GMT):

(a) Viking 1 (August 27, 1975):

Burn start---18:30:00.0
Burn stop---18:30:12.1
Change in velocity (line of sight)---44.3 Hz (two-way)

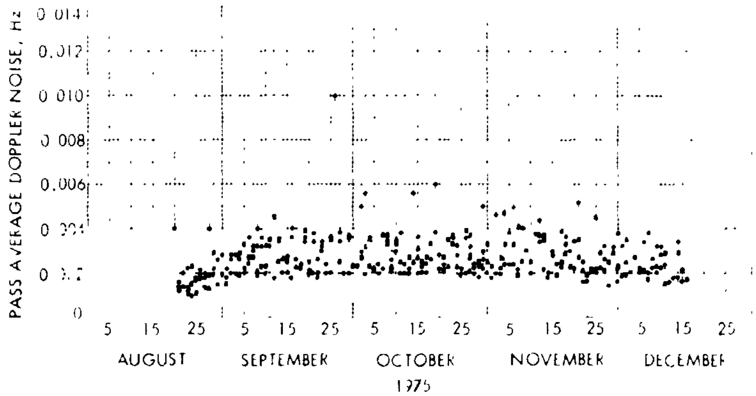


Fig. 32. Viking 1 doppler noise composite for all stations through December 1975

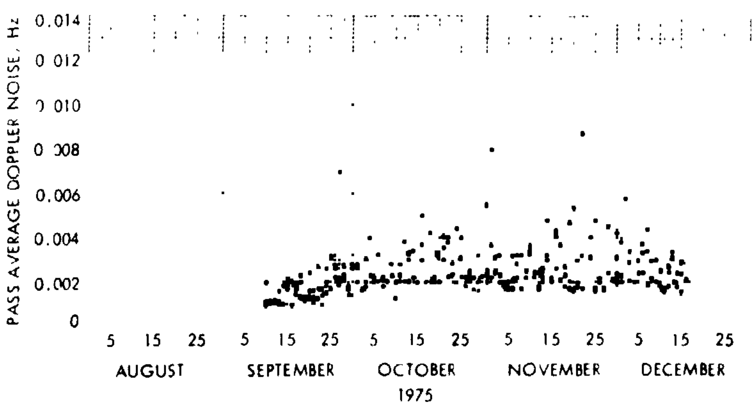


Fig. 33. Viking 2 doppler noise composite for all stations through December 1975

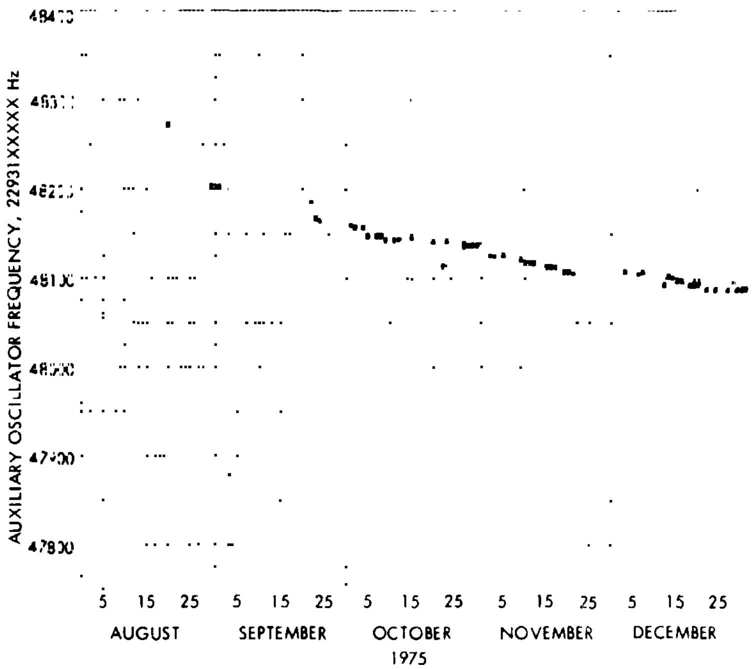


Fig. 34. Viking 1 auxiliary oscillator frequency through December 1975

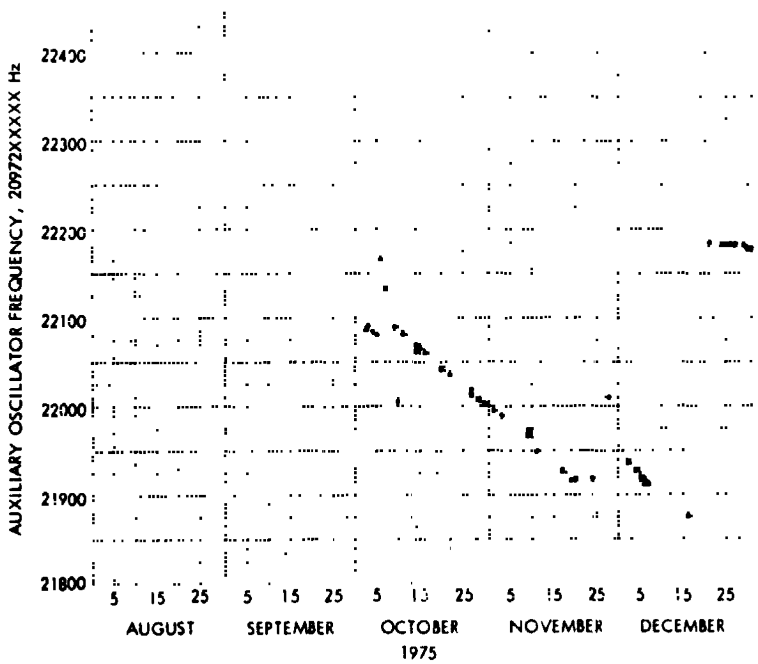


Fig. 35. Viking 2 auxiliary oscillator frequency through December 1975

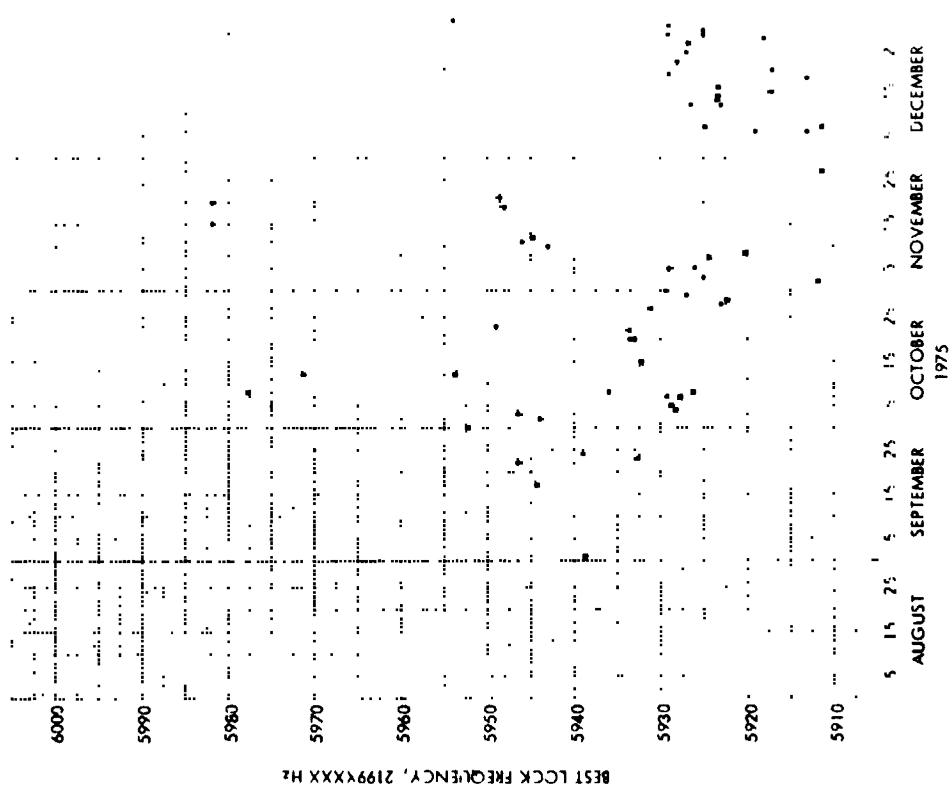


Fig. 36. Viking 1 channel 9 best lock frequency through December 1975

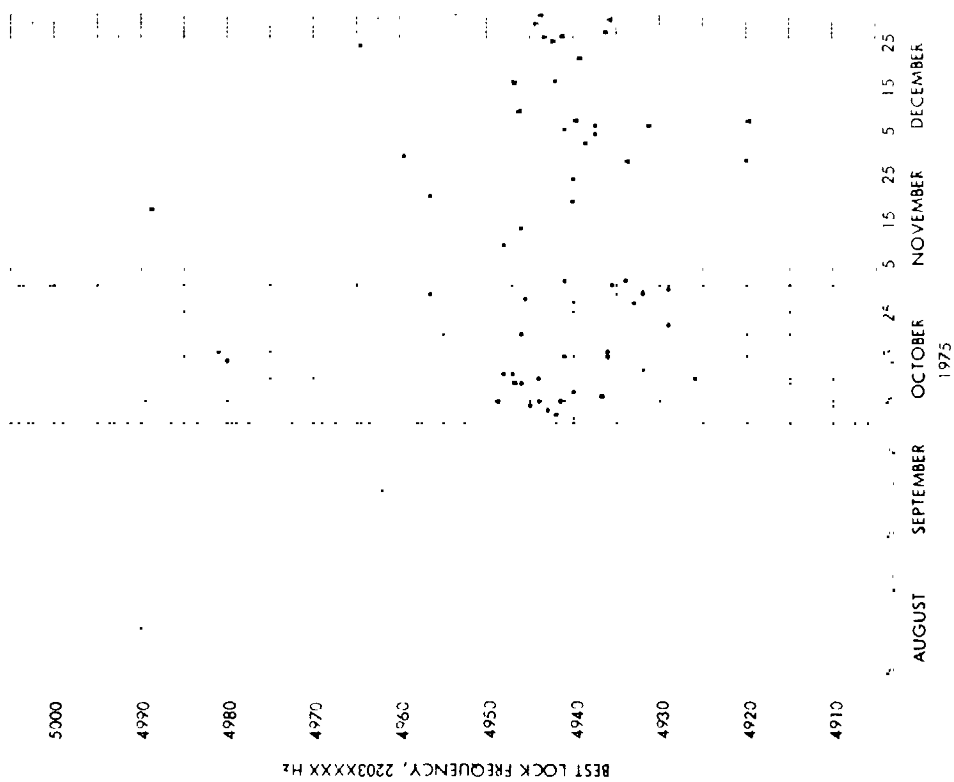


Fig. 37. Channel 20 best lock frequency through December 1975

(b) Viking 2 (September 19, 1975):

Burn start---16:30:00.0
Burn stop---16:30:20.9
Change in velocity (line of sight)---108.9 Hz (two-way)

Both maneuvers were quite nominal in times of execution and achievement of desired velocity change; for instance, burn errors in both cases were held to less than 2 Hz. Support by the Network during the midcourse maneuvers was both nominal and routine. Figure 38 displays two-way doppler residuals during the Viking 1 maneuver, and Fig. 39 displays two-way doppler residuals during the Viking 2 maneuver. (Figures were produced by Mission Control and Computing Center Pseudoresidual Program.)

Upon completion of the midcourse maneuver, the spacecraft was commanded to return to its original attitude orientation with the Sun and Canopus and enter into its cruise mode.

c. Command System. The Viking command activity for each month is shown in Table 15 for each of the two Orbiters and two Landers. Since the Orbiters and Landers were still in the mated configuration, commands addressed to the Landers were transmitted on the corresponding Orbiter carrier frequency.

One abort was experienced in November at Station 61. A configuration word check error caused a command message to abort. This problem was attributed to low relative humidity (35 percent) in the control room at the time, creating an equipment hazard due to static electricity. This condition was corrected, and there were no recurrences of the problem.

Command capability was also lost because of high-speed data line outages or failures at the deep space stations. These periods of loss are shown in Table 16 as a percentage of the total scheduled track time for the month. The cumulative total for the mission through the end of December due to all outages is given in the last row of Table 17.

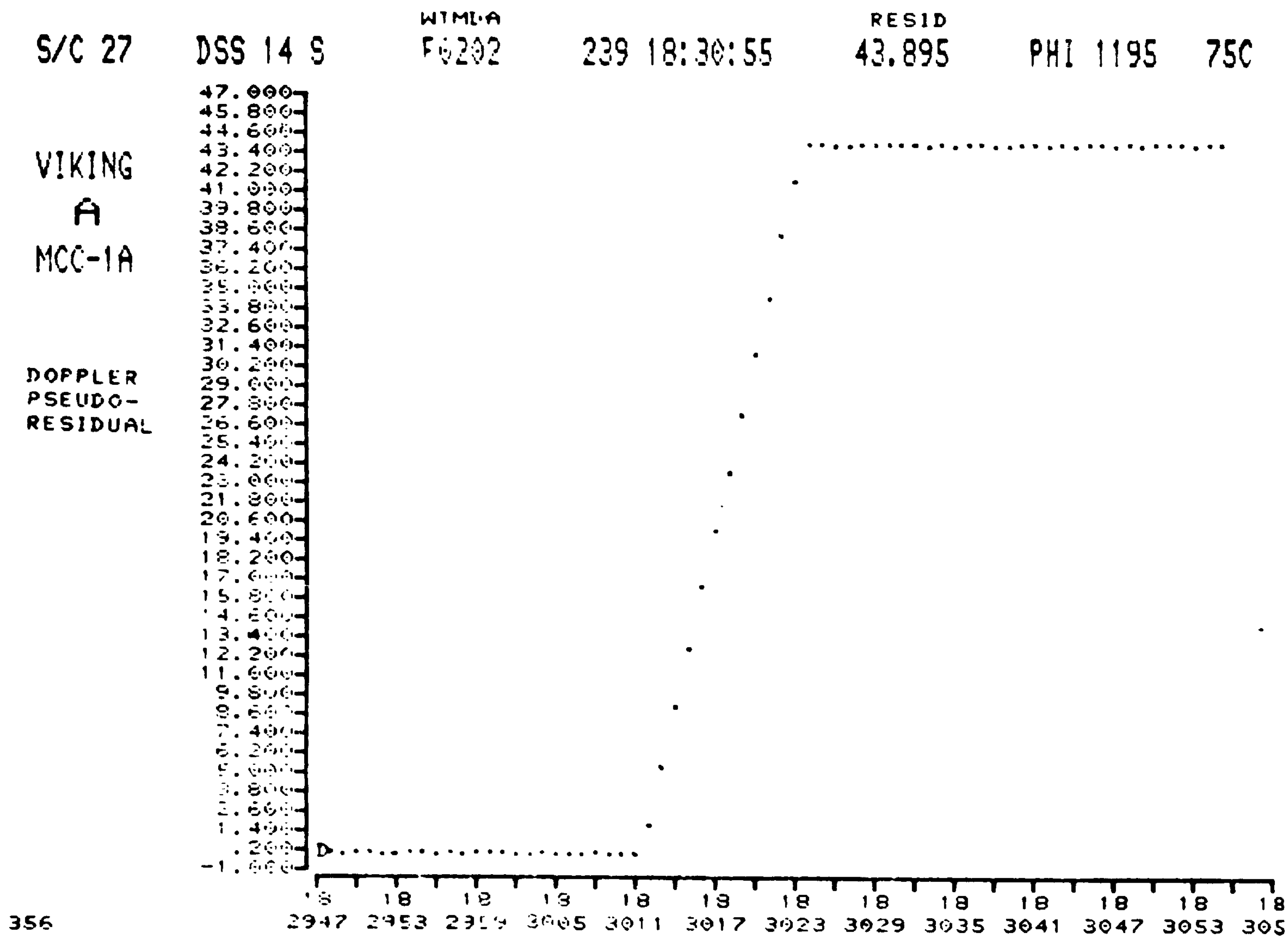


Fig. 35. Two-way doppler residuals during Viking 1 midcourse maneuver on August 27, 1975

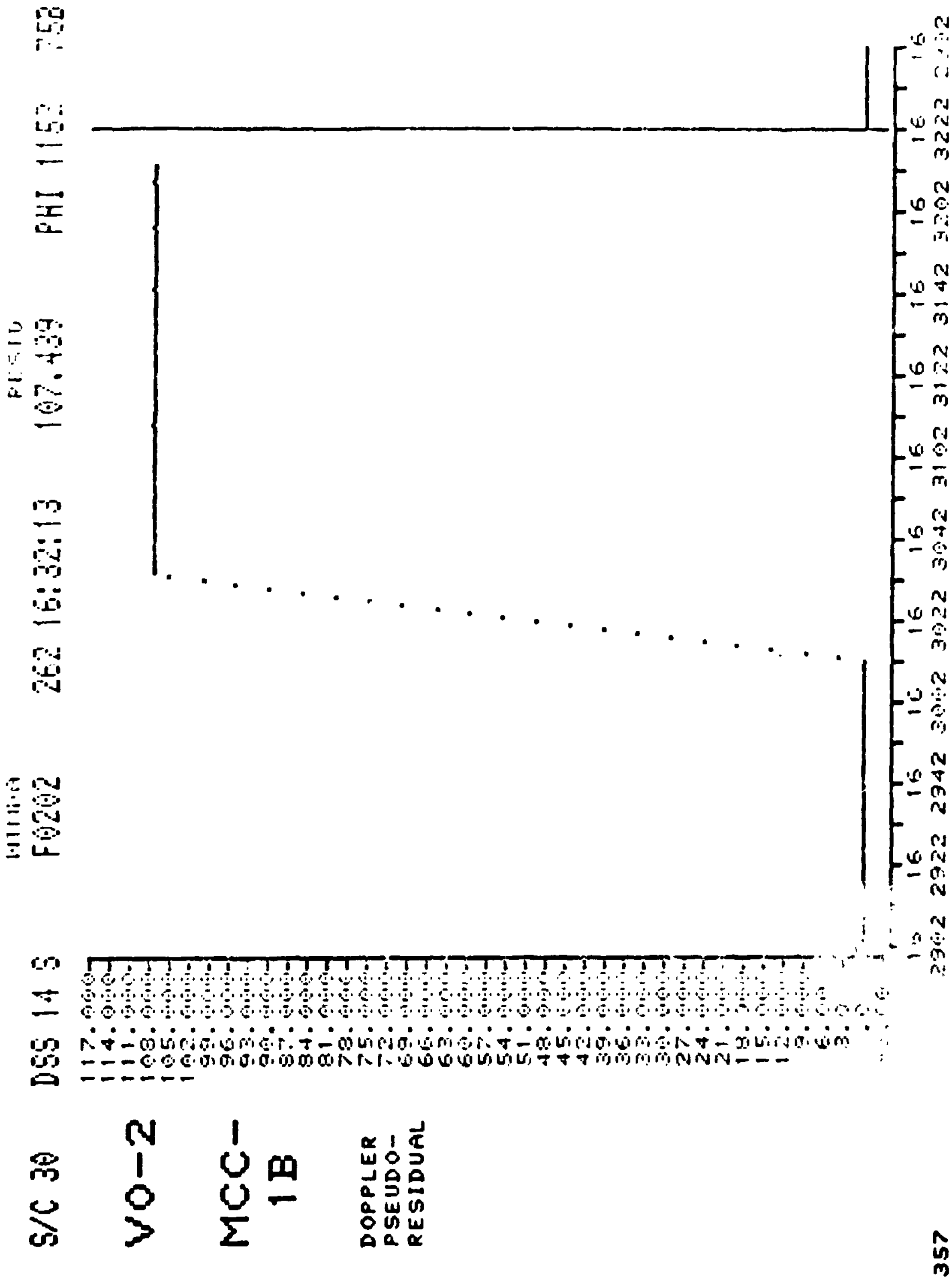


Fig. 39. Two-way ...ler residuals during Viking 2 midcourse maneuver on September 19, 1975

Table 15. Number of commands transmitted by month during 1975

Month	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Abort	Comments
August	334	58	0	0	0	
September	69	0	370	58	0	
October	508	344	498	189	0	
November	425	206	439	446	1	Configuration word check error at Station 61
December	165	256	552	340	0	

Table 16. Command capability loss due to communications or station failures during 1975 as percentage of scheduled track time

Month	Viking 1		Viking 2	
	HSDL[a]	Stations	HSDL[a]	Stations
August	0.07	0.16		
September	0.17	0.51	0.16	0.19
October	0.06	0.25	0.12	1.59
November	0.04	1.95	0.09	0.66
December	0.05	0.39	0.03	0.21
Cumulative total for mission	0.702		0.560	

[a]HSDL = high-speed data lines

Table 17. Station tracking support for Viking spacecraft, August through December 1975

Month	Station									Network Total
	11	12	14	42	43	44	61	62	63	
August	6	1	4	2	10	1	3	1	7	35
September	26	23	2	28	5	22	22	12	18	158
October	31	20	9	37	7	19	39	15	8	185
November	11	27	15	31	30	3	34	28	1	180
December	30	4	16	28	2	32	21	29	12	174
Total tracks	104	75	46	126	54	77	119	85	46	732
Total hours	739	493	378	1084	441	606	944	766	429	5880

d. Monitor System. The Network Monitor System continued to function with few major anomalies in support of both Viking spacecraft since launch. The tracking hours provided to Vikings 1 and 2 by each station from launch through December 1975 are given in Table 17.

Some anomalies, however, did occur from time to time, and these were investigated and closed out appropriately. The incidence of anomalies on a monthly basis is shown in Table 18. Each anomaly listed therein was identified by a Discrepancy Report and in most cases by a Viking Incident, Surprise, and Anomaly Report (VISA). The anomalies listed therein include those contributed by the Network Operations Control Center, as well as those attributed to station problems.

3. Planetary Configuration Development

a. Implementation. Implementation of the planetary configuration for Viking throughout the Network had been slowed somewhat in August by the application of configuration control for Viking 1. However, immediately following the launch, this activity resumed, only to be suspended again in September for the Viking 2 launch.

After several months of operation, it had become apparent that the existing Change Management Schedule could not be updated and published fast enough to provide the Network Manager with the daily visibility needed to maintain control of the extremely dynamic reconfiguration situation by then developing in the Network.

While the number of changes needed prior to launch was substantial, the number of engineering changes required to complete the planetary configuration was enormous (over 400). This, combined with the now critical demands for station time because of the tracking demands of Vikings 1 and 2 and the approaching Helios B launch, made it necessary to revise the engineering change management system to provide a response much closer to real time than had hitherto been possible.

Table 18. Incidence of anomalies in Network Monitor System during Viking tracks

Spacecraft	August	September	October	November	December
Viking 1	1	0	10	6	8
Viking 2	Not applicable	0	5	4	3

The Engineering Change Order status reporting system was re-designed to a new format, a sample extract of which is shown in Fig. 40 for Station 14 at Goldstone. Printouts of status for all stations and all changes were then available at any terminal at any time. Data were updated either by engineers at the Jet Propulsion Laboratory or by the deep space stations at least twice per week and were, therefore, never more than a few days old when presented to the user.

Each engineering change is presented by number and title, together with all its associated subsystems. The category of change indicated the phase of the mission for which the change was required and was related to the "Network Due" date, allowing for the time required to carry out the requisite testing after completion of installation.

The facility status was added by the stations to indicate the status of the installation in progress at each station in accordance with a prearranged code.

Significant steps in the life of each engineering change were also indicated as follows:

MFGC	Manufacturing complete
COER	Received by Cognizant Operations Engineer
COES	Shipped to station by Cognizant Operations Engineer
FACR	Received by the facility (station)

Each milestone date was given by day (D) or by week (W) and shown complete by a # sign or rescheduled by an * sign. Using these data, a Change Management Team headed by the Network Manager met twice weekly to review progress, resolve conflicts, and reschedule changes where necessary, and to ensure that slack time was minimized.

By September 4, a daily "RED" list of delinquent Engineering Change Orders was being issued to identify critical work requiring immediate attention.

Corresponding schedules for operations and configurations testing to daily resolution were now required to interact with this detailed change monitoring process. By October, the Network implementation and test schedules were in direct conflict with Viking flight support for station time, and a special meeting was convened on October 2 by the Operations Support Coordination Office to consider the problem. The outcome of this meeting was the formation of a joint Deep Space Network-Viking Project scheduling group in which flight support, implementation, and test tradeoffs were made before the integrated Viking schedule was submitted to the scheduling board for final allocation of time among all flight projects.

As this joint Viking scheduling team gained experience, it became most effective in resolving these problems at its weekly meetings, and its planetary development and test schedule became the bedsheet for all Viking scheduling thereafter. The planetary development schedule for December 1975 is shown in Fig. 41.

```
14      PROJECT  :  VIK

ECO... SUB.  CAT . TITLE...................... FS CPLDAT SLK DSNDUE TST CHGDAT

74.043 13.0  G T/M UPS BATTERY BACKUP          G  760514  -9 760315   7 760421
MFGC: D750415*    COER: W750416 #   COES: W750423 #   FACR: W750718*

74.043 29.0  G T/M UPS BATTERY BACKUP          G  760514  -9 760315   7 760421
MFGC: D750602*    COER: W750602 #   COES:         #   FACR: W750703*

74.043 39.3  G T/M UPS BATTERY BACKUP          G  760514  -9 760315   7 760421
MFGC: D750415*    COER: W750416 #   COES: W750423 #   FACR: W750430*

74.117 37.0B F T/M XRO FEED AND TWM            H  760531 -33 751015   4 760421
MFGC. D741119*    COER: W741119 #   COES: W741126 #   FACR: W741203*

74.134 29.0  G T/M MET. MON. DATA              E #760430  -9 760301   9 760409
MFGC: D750515*    COER: W750515 #   COES: W750522 #   FACR: W750529*

74.134 39.0  G T/M MET. MON. DATA              E #760430  -9 760301   9 760409
MFGC: D760122 #   COER: W760122 #   COES: D751013*    FACR: D751017*

74.134 39.6  G T/M MET. MON. DATA              E #760430  -9 760301   9 760409
MFGC: D750207*    COER: D750209*    COES: D750214*    FACR: D750224*

74.261 29.0  F T/M FTS PULSE ISOLATION         H #760430 -20 751215  -5 760421
MFGC: D750218*    COER: D750220*    COES: D750224*    FACR: D750228*

74.261 38.0  F T/M FTS PULSE ISOLATION         H #760430 -20 751215  -5 760421
MFGC: D750612*    COER: W750612 #   COES: D750620*    FACR: W750627*

74.261 39.6R F T/M FTS PULSE ISOLATION         H #760430 -20 751215  -5 760421
MFGC: W750701*    COER: W750701 #   COES: W750708 #   FACR: W750729*

74.265 38.4  G T/M CRG STATUS PANEL            G #760430 -20 751215  20 760421
MFGC: D751015*    COER: W751015 #   COES: D751105*    FACR: W751124*
```

Fig. 40. Engineering Change Order Status

		RESPONSIBILITY	1975												
			NOVEMBER				DECEMBER					JANUARY			
		DAY/WEEK	3/45	10/46	17/47	24/48	1/49	8/50	15/51	22/52	29/1	5/2	12/3	19/4	26/
PROJECT MILESTONES	HELIOS												15 ▽ HELIOS B LAUNCH		
	PIONEER								15-16 ▽ PIONEER 11 TCM						P R A
	VIKING													21 ▽ 22 ▽ PMOSR/TRR	
DSS 14	MCT		21 1/8 F 1/13 F	57 3/8 A 2/13 F 1/7 A	8 1/8 E	8 1/8 E 1/14 ◆	14 ◆ 1/14	48 ◆ 3/8 2/10	29 2/8 2/10 ◆ 1/10 R ◆ 1/13	24 3/8	38 1/12 1/13 1/13 R	28 2/8 1/12	24 3/8	38 1/8 2/10 1/10 R	
	OVT		10 1/10 E	10 1/10 E	10 1/10 E	20 2/10 E									
	IMPLEMENTATION				28 1/12 E 1/16 E	10 1/4 E 1/6 E	6 1/4 ◆ 1/5 ◆ 1/6 E 1/8 ◆	0 1/4 ◆ 1/6 ◆ 1/8 ◆ 1/9 ◆	6 1/6 1/8 ◆ 1/10 R ◆	8 2/4 1/5 ◆ 2/8 ◆		24 3/8	10 1/10		20 1/8 1/1
	DEVELOPMENT			43 1/6 E 1/8 E 1/9 E 2/10 E									21 1/5 1/6 1/10		
	MARS RADAR			XKR CONE	16 2/8 E	30 1/7 E 1/8 E 1/15 E	63 4/8 E 1/9 E 1/10 E 1/12 E	64 4/10E 2/12E 14 ▽	OPERATIONAL DEMONSTRATION 20 ▽	24 ▽ 27 ▽ 28 ▽ 2-12 HR TRAIN PERIODS	30 ▽ 1st OBSERVATION C SITES	5 ▽	11 ▽ 15 ▽ 17 ▽ 2nd OBSERVATION C SITES	23 ▽	
	PROJECT TESTS		SIT	11 ▼	17 ◆ ▽ R		GDS 5 ▼ 5.1	12 ◆ ▽ 5.1R	16 ▽ 5.31			9 ▽ 5.31R			

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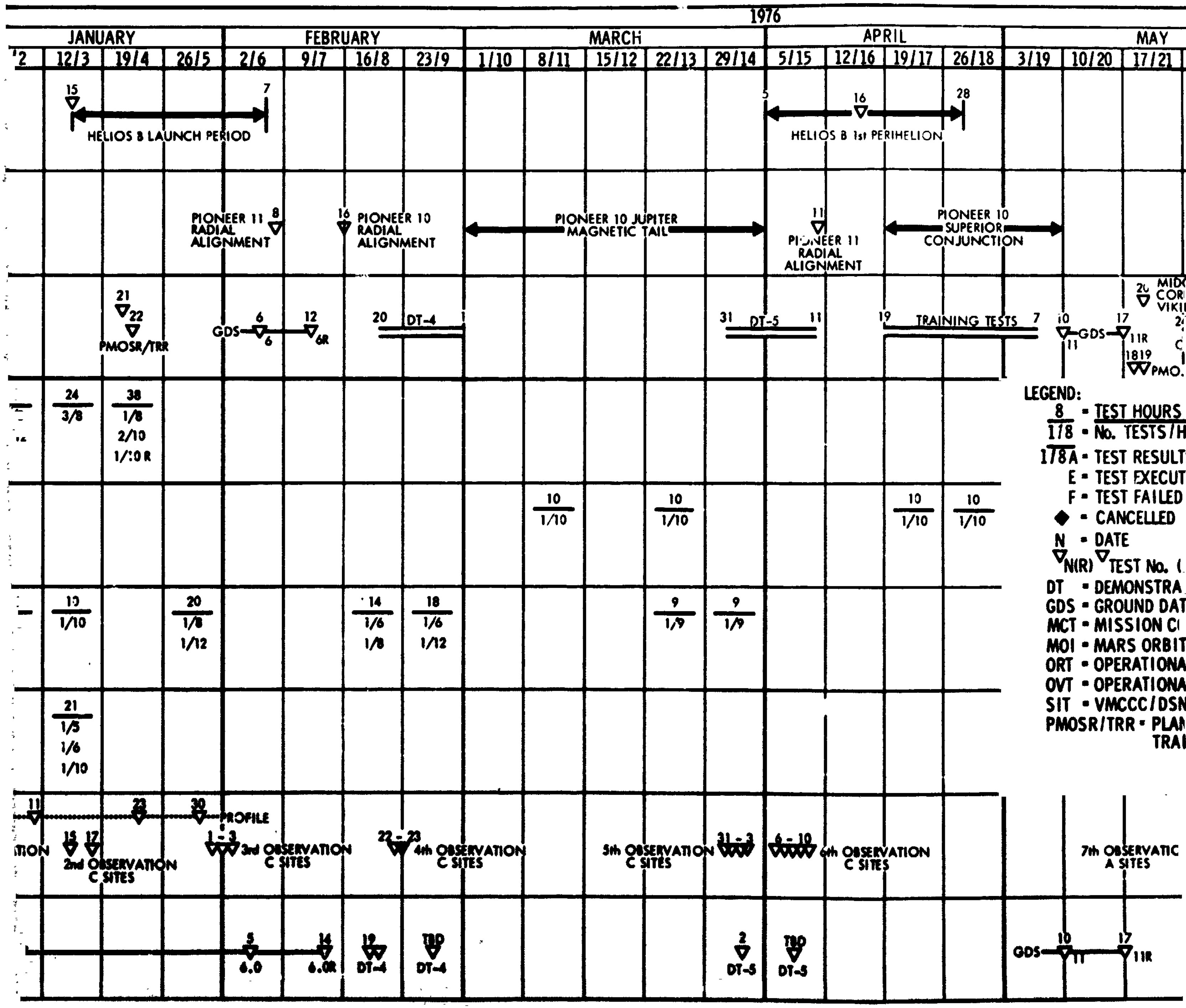

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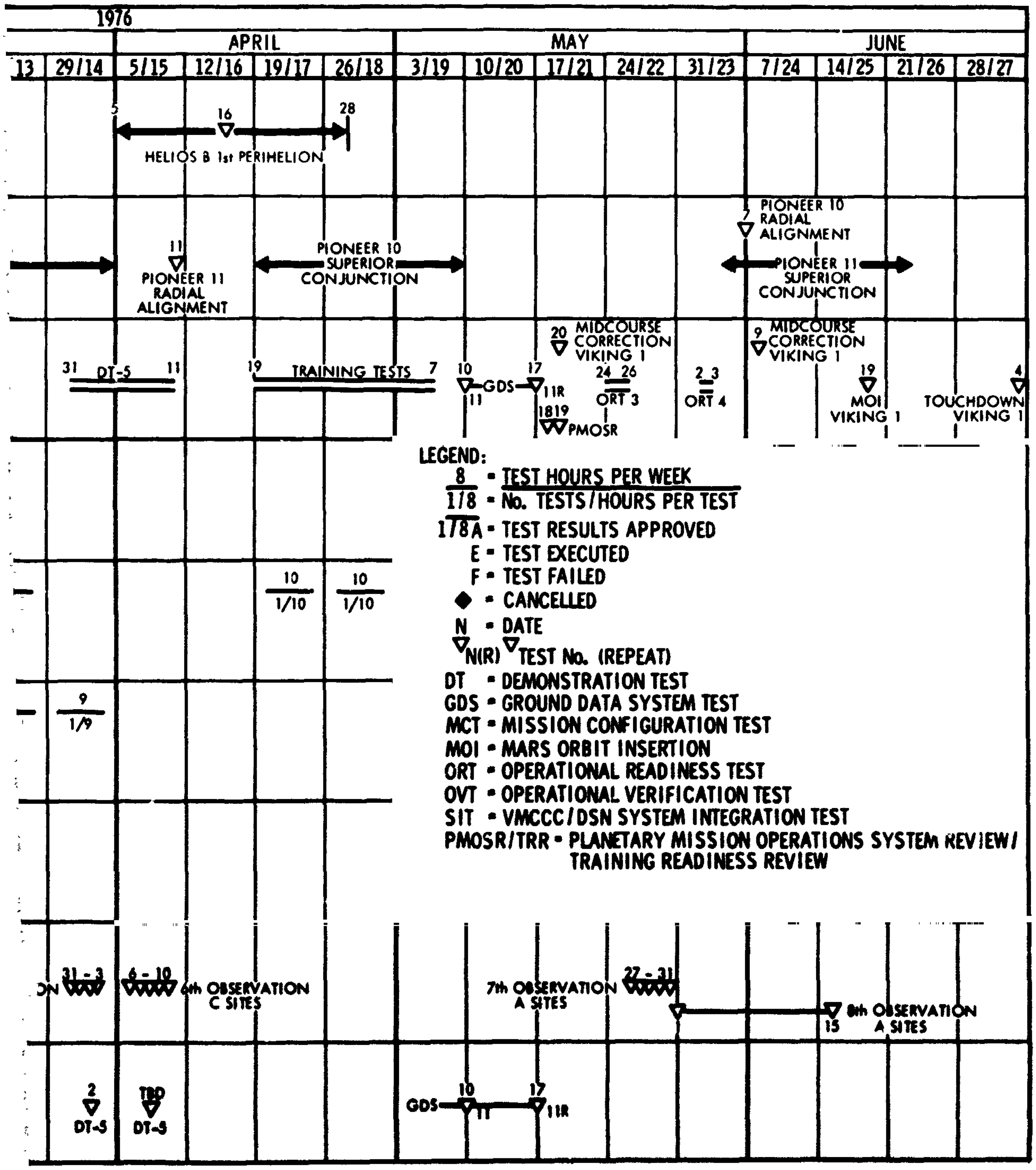

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		RESPONSIBILITY	1975							
			NOVEMBER				DECEMBER			
		DAY/WEEK	3/45	10/46	17/47	24/48	1/49	8/50	15/51	22/52
DSS 43	MCT		63 3/5 E 1/8 E 4/10 E	18 1/8 A 1/10 E	20 2/10 E	10 1/10 E	26 2/13 E 1/13 R◆	16 1/3 E 1/13 E	50 5/10	26 2/8 1/10
	OVT			10 1/10 E	10 1/10 E	20 2/10 E	20 2/10E	20 2/10E	10 1/10 1/10 ◆	
	IMPLEMENTATION		1[illegible] 1/[illegible] E	64 2/12 E 1/40 E	1[illegible] 1/10 E		0 1/4 ◆ 1/6 *◆	6 2/4◆ 1/6 *E	8 2/4	0 1/8 ◆ 1/1[illegible]◆ 1/12◆
	DEVELOPMENT			CONSCAN ······	········	8 1/8 E	8 1/8 E	8◆ 1/8	········	8◆ 1/8
	PROJECT TESTS									
DSS 63	MCT		34 2/10 E 1/14 E	37 1/5 A 1/9 E 1/10 E 1/13 A	9 1/9 A 2/13 ◆	13 1/13 E 1/13 R◆	13 1/13 E	25 2/6 1/13 E 1/13 R◆	20 1/10 1/10 R 1/10◆	26 2/8 1/10
	OVT				30 3/10 E	10 1/10 E	10 1/10	10 1/10E 2/10◆	20 2/10	
	IMPLEMENTATION			9 1/9 E	8 1/8 E	6 ◆ 1/6 *	4 ◆ 1/4	4 1/4E 1/4 ◆ 1/6 *◆	8 2/4 1/12 ◆	6 1/6 1/8 1/[illegible]
	DEVELOPMENT			4 1/4 E	4 1/4 E	4 ◆ 1/4	4 ◆ 1/4	4 ◆ 1/4	4 ◆ 1/4	4 1/4
	PROJECT TESTS									

FOLDOUT FRAME

1975																		1976	
DECEMBER					JANUARY				FEBRUARY				MARCH						
1/49	8/50	15/51	22/52	29/1	5/2	12/3	19/4	26/5	2/6	9/7	16/8	23/9	1/10	8/11	15/12	22/13	29/14	5/15	12/
26 2/13 E 1/13 R◆	16 1/3 E 1/13 E	50 5/10	26 2/8 1/10	12 1/12	13 1/13	13 1/13	36 2/8 1/10 1/10 R	24 3/8											
20 2/10E	20 2/10E	10 1/10 1/10◆		10 1/10	10 1/10									10 1/10	10 1/10				
0 1/4◆ 1/6 *◆	6 2/4◆ 1/6 * E	8 2/4	0 1/8◆ 1/10◆ 1/12◆	12◆ 1/12	8◆ 1/8	10 1/8◆ 1/10	8◆ 1/8	12 1/12	5 1/5	21 1/5 2/8	26 3/4 1/6 1/8	29 1/4 1/5 1/8 1/12	28 1/4 2/12	24 1/4 1/8 1/12	27 1/3 3/8	29 1/5 3/8	25 2/8, * 1/9	25 2/8, * 1/9	1: 1, 1/
						← STATION MONITOR CONSOLE IIA 160 HOURS →													
8 1/8 E	8◆ 1/8		8◆ 1/8	16 2/8	8 1/8			8 1/8											
				SIT ▽ 3		13 ▽ R ◆ 17 ▽ 5.32	22 ▽ 5.32	26 ▽ 5.32R GDS	6 ▽ 6.0	12 ▽ 6.0R	TO BE DETERMINED ▽ DT-4	TO BE DETERMINED ▽ DT-4					2 ▽ DT-5	TO BE DETERMINED ▽ DT-5	
13 1/13 E	25 2/6 1/13 E 1/13 R◆	20 1/10 1/10 R 1/10◆	26 2/8 1/10	12 1/12	13 1/13	21 1/8 1/13	30 2/10 1/10 R												
10 1/10	10 1/10E 2/10◆	20 2/10		10 1/10	10 1/10 1/10◆									10 1/10		10 1/10			
4◆ 1/4	4 1/4E 1/4◆ 1/6 *◆	8 2/4 1/12◆	6 1/6 * 1/8◆ 1/12◆	12◆ 1/12	8◆ 1/8	8◆ 1/8	8◆ 1/8	12 1/12	5 1/5	21 1/5 2/8	26 3/4 1/6 1/8	29 1/4 1/5 1/8 1/12	28 1/4 2/12	24 1/4 1/8 1/12	27 1/3 3/8	29 1/5 3/8	25 2/8, * 1/9	25 2/8, * 1/9	1/ 1
						← STATION MONITOR CONSOLE IIA 160 HOURS →													
4◆ 1/4	4◆ 1/4	4◆ 1/4	4◆ 1/4	8◆ 1/8	4 1/4														
					SIT ▽ 7		19 ▽ 24 ▽ GDS 5.32	30 ▽ 5.32R	6 ▽ 6.0	12 ▽ 6.0R	19 ▽▽ DT-4	TO BE DETERMINED ▽ DT-4					2 ▽ DT-5	TO BE DETERMIN ▽ DT-5	

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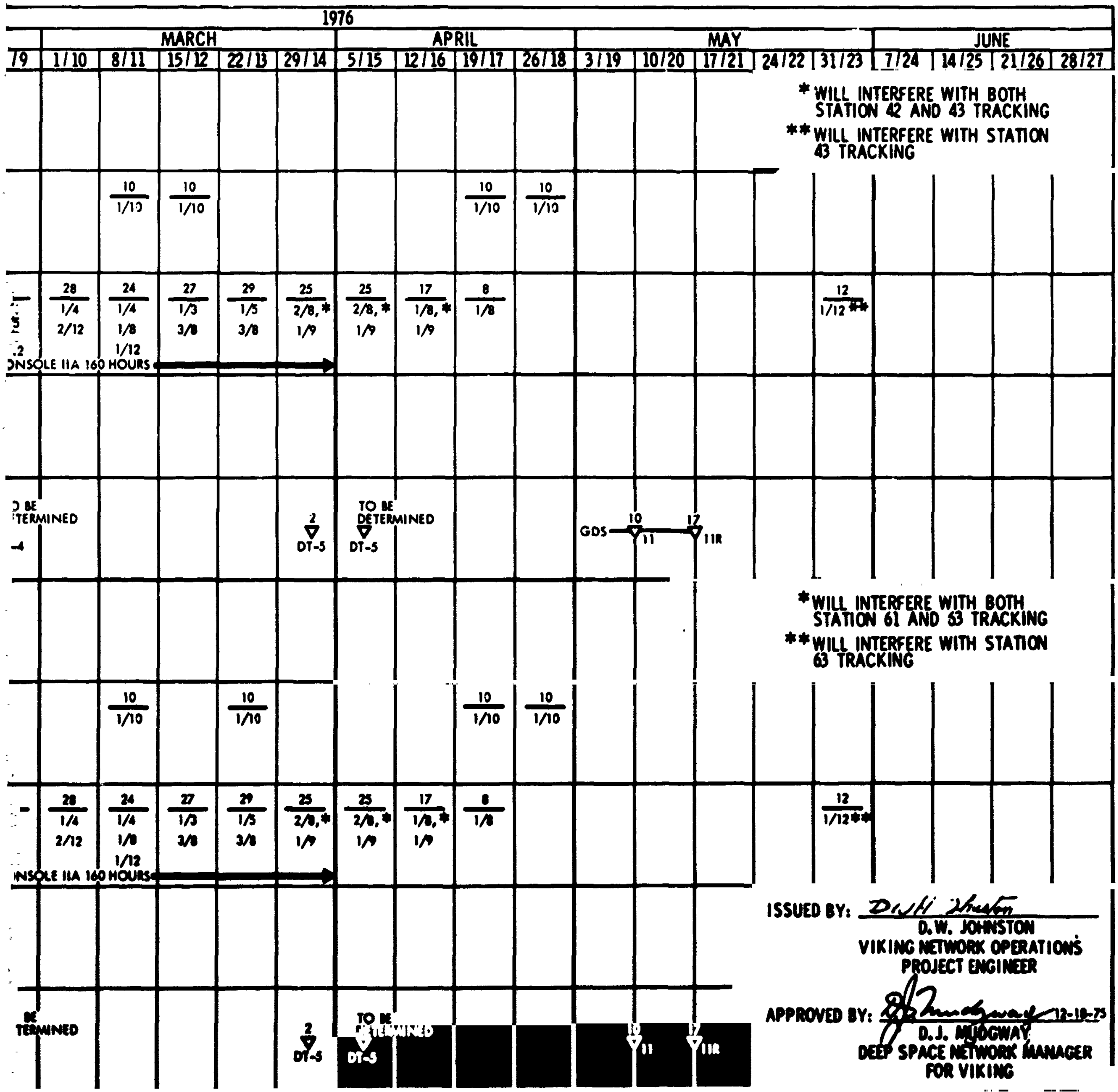

Fig. 41. Planetary development schedule as of December 1975

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As the implementation schedule for the Engineering Change Orders continued to arouse concern, the Viking Project requested a re-evaluation of the amount of work remaining to be accomplished to meet the original commitments. This was carried out as a joint Deep Space Network-Viking effort in late October, and a preliminary version of a new Tracking and Data System level 4 schedule, containing only "essential" Viking items, was issued in November. Figure 42 is a Tracking and Data System level 4 schedule, December 23, 1975.

By that time, the high-power transmitter installations at Stations 43 in Australia and 63 in Spain had been completed, as had the Block IV receiver installations. Implementation of the rest of the planetary configuration was nearing completion, and mission configuration testing was well advanced.

The first system integration test with Station 14 at Goldstone and the Mission Control and Computing Center had been run successfully, thereby verifying the overall design of the planetary network configuration.

The main items of concern at this time (November 1975) were the Station Monitor and Control Assemblies, completion of the Network Operations Control Center, and analog recording capability for data rates above the existing 2-kbps limit.

In early September, the status of the Intermediate Data Record capability and the operations capability in the Network Operations control Center was reviewed with Network and Viking personnel. Hardware and software problems had resulted in delays of up to two months in the original completion dates. As a result, the control center facilities were rescheduled for full operational readiness to February 1, 1976, with the Intermediate Data Record capability to be available on February 5, 1976. These dates were then phased into the Ground Data System test program.

During all of the preceding test activity with the Goldstone station, the Ampex FR 1400 analog tape machines had consistently failed to give acceptable results on replay at data rates above about 2 kbps. Engineers were requested to investigate alternative means of providing an analog playback capability up to 16 kbps, as was now being firmly required by the Project.

On October 9, the results of playback tests with Ampex FR 2000 recorders showed degradation of 0.2 to 0.8 dB at all bit rates. Indications were that three FR 2000 machines could be made available to meet the analog record and playback requirements. Two machines were to be transferred from Compatibility Test Area 21 (to be replaced later with Honeywell 96 machines), and one was to be borrowed from the laboratory loan pool. One machine would go to each of Stations 14, 43, and 63. On November 6, the decision to implement this plan was made, and the effort appeared as line item 8 on the December 23 schedule. See Fig. 42.

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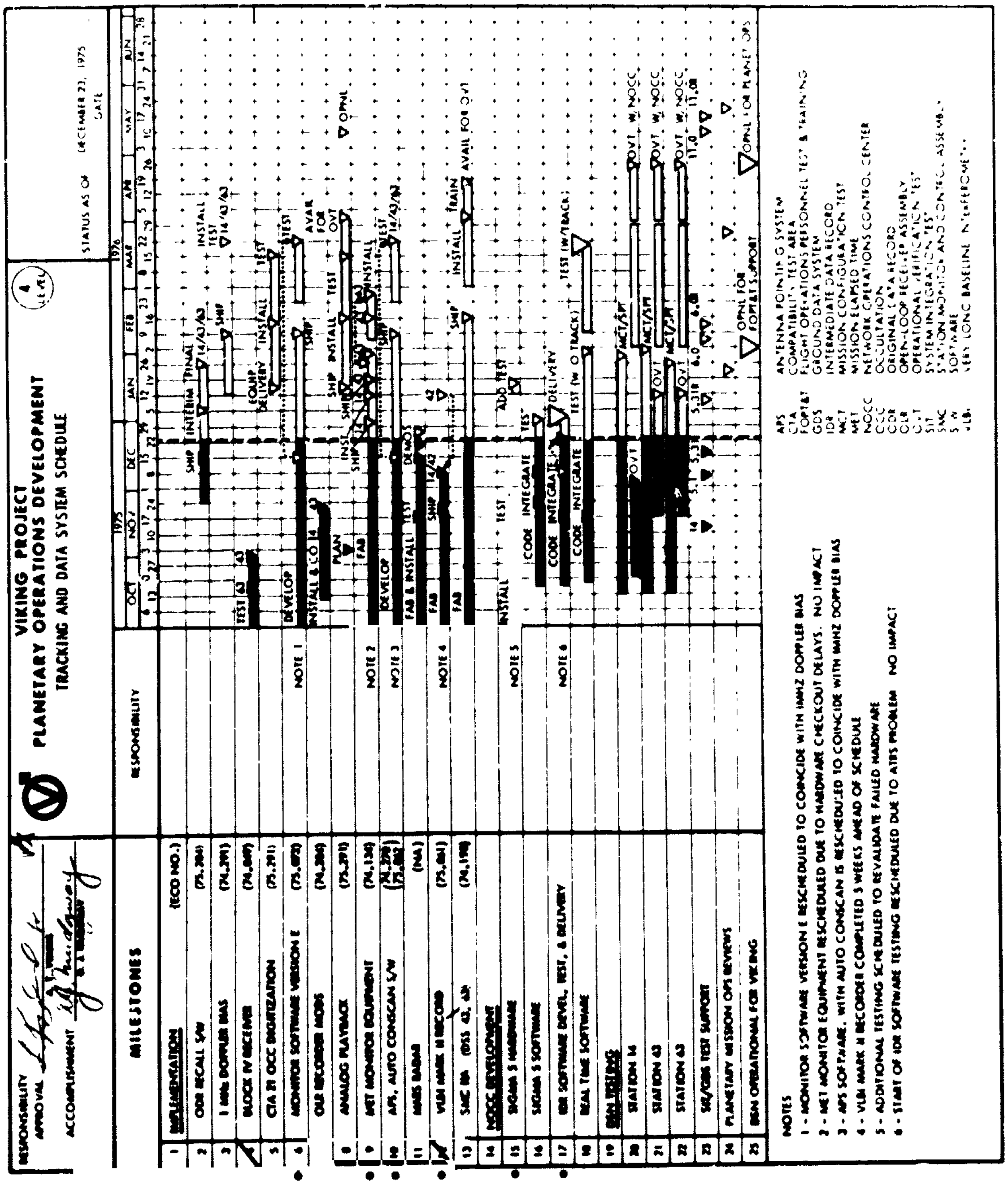


Fig. 42. Tracking and Data System level 4 schedule as of December 1975

On Wednesday, November 5, an in-depth review on the status of the Station Monitor and Control Assemblies was held. From this review, two things became apparent:

(1) The 64-meter stations, particularly Stations 43 and 63, were critically dependent on the timely arrival of the Station Monitor and Control Assemblies for their crew training and ultimate support of Viking planetary operations.

(2) There was a significant uncertainty in the availability of operational units to the stations in time to support the start of planetary operations on May 1, 1976, recognizing that the time preceding this date was needed for installation, test, and training.

Nevertheless, the Station Monitor and Control Assembly schedule was added to the December 23 schedule (Fig. 42) as line item 13.

However, by the end of November, confidence in being able to meet the required schedule had diminished further, and with the assemblies now having a direct bearing on planetary readiness, a backup plan was initiated. The backup plan involved supplementing Station 43 and 63 crews with personnel from other stations if the date of readiness for the Station Monitor and Control Assemblies could not be met. This plan was first presented to the Viking Project at the Network status review on November 26. With the emphasis on planetary readiness increasing and progress on monitor and control assemblies lagging, this backup plan soon attracted much greater attention from Network and Project management, and, by January 1976, had become the prime plan.

Augmentation of station staffing had replaced Station Monitor and Control Assemblies as the prime requirement for planetary operational readiness.

Throughout the Network, implementation and test activity continued to make good progress through the month of December, with two exceptions: automatic telemetry recall software and version E of the monitor software. Both were required to be operational at the 64-meter stations by January 1, and both had problems.

The recall software was required to work at the stations in conjunction with the Network Operations Control Center at the Jet Propulsion Laboratory to produce the Intermediate Data Records for tests on January 5. On December 15, after intensive software trouble shooting efforts at Compatibility Test Area 21, a program containing several known anomalies was shipped to the stations, while work continued throughout the Christmas vacation period to identify and correct these anomalies.

However, despite the best efforts of software engineers, the anomalies in version E of the monitor software could not be adequately cleared and verified, and a backup plan using the existing version D was put into effect.

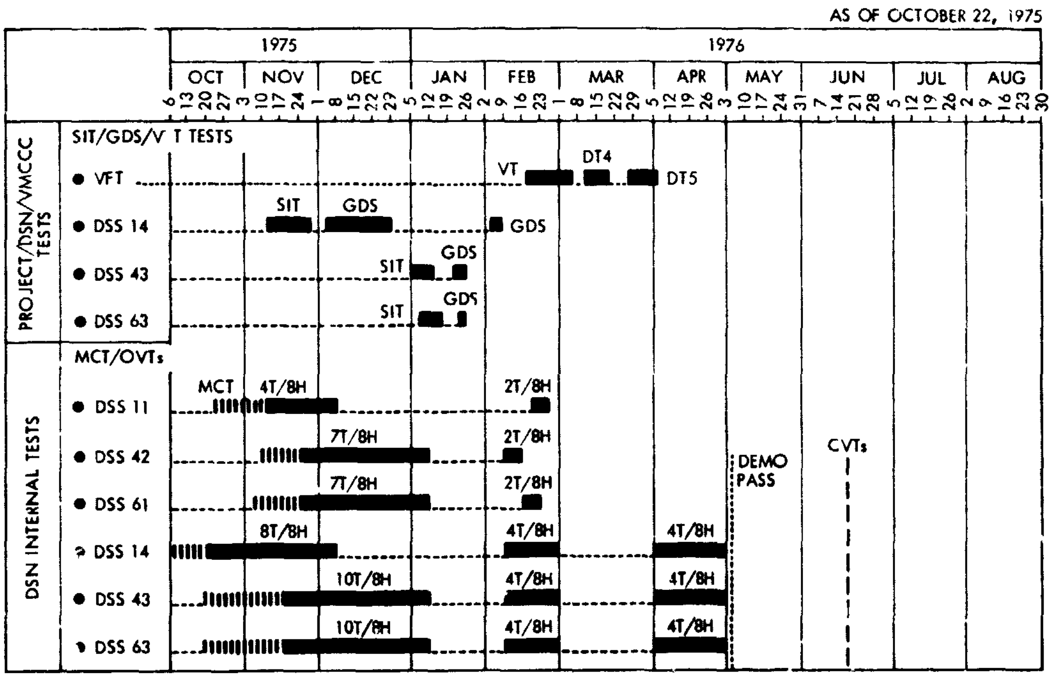
b. Planetary Testing and Training. In order to prepare for Viking landed planetary operations, the program of planetary test and training shown in Fig. 43 was begun in October 1975. This test series comprised Mission Configuration Tests and Operational Verification Tests. Of primary concern was the training of the 64-meter subnet (Stations 14, 43, and 63) and the conjoint 26-meter subnet (Stations 11, 61, and 42). Later, a further series of tests would be conducted in order to check the Network Operations Control Center, which was to be available in February 1976. These tests would be conducted primarily for the training of the Network Operations Control Team. During May 1976, a short series of Operational Verification Tests were to be conducted with the 64-meter stations for operational checkout of the new Station Monitor and Control Assemblies. Upon completion of this final test phase, the Network would be considered qualified to support Viking planetary operations.

(1) Configuration and Performance Tests. Mission Configuration Tests and System Performance Tests conducted with Station 14 were begun in October, and required 96 hours of testing, concluding approximately November 1, 1975. The test series at Stations 43 and 63 was begun in mid-October and would require 233 hours; these were scheduled to be completed by December 1, 1975. The 26-meter subnet required 1[illegible] hours of testing to be concluded by mid-November. All stations were to perform an additional 20 hours of Monitor and Control Assembly testing during February 1976.

(2) Operations Verification Tests. Viking planetary testing was begun October 21, 1975, by an Operational Verification Test conducted with the Goldstone stations. The first phase of the planetary testing comprised eight tests with the Goldstone complex---the first four involving only Station 14 and the remaining four involving both Stations 14 and 11, the conjoint 26-meter station. In November, a similar testing program commenced with the overseas stations in Spain and Australia. Ten tests were scheduled for each of the overseas facilities. These were to be divided, as was the series with the Goldstone stations, so that the first five would be with the 64-meter stations and the remaining five with both the 64-meter and the respective 26-meter conjoint stations.

The purpose of the first half of the tests was to train personnel at the 64-meter stations for planetary operations involving the processing of telemetry data from three spacecraft (two orbiters and one lander, six simultaneous data streams); commanding of orbiters and landers individually (no dual commanding was planned at that time); and tracking of the spacecraft, while processing doppler and radio metric data of only one spacecraft at any one time.

The second half of the tests involved both the 64-meter and the respective 26-meter conjoint stations, and was primarily concerned with practicing the Viking planetary failure strategies. This involved rerouting of telemetry data through the 26-meter conjoint station. Familiarity with these backup configurations was essential because



CVT = CONFIGURATION VERIFICATION TEST
DSN = DEEP SPACE NETWORK
DSS = DEEP SPACE STATION
DT = DEMONSTRATION TEST
GDS = GROUND DATA SYSTEM TESTS
MCT = MISSION CONFIGURATION TESTS
NT x NH = TESTS x HOURS EACH
OVT = OPERATIONAL VERIFICATION TESTS
SIT = VMCCC/DSN SYSTEM INTEGRATION TESTS
VFT = VIKING FLIGHT TEAM
VMCCC = VIKING MISSION CONTROL AND COMPUTING CENTER
VT = VERIFICATION TEST

Fig. 43. Viking planetary test and training schedule as of October 1975

no redundant equipment is available at the station as all of a 64-meter station's equipment is on line during full planetary operations.

Upon completion of this first phase of testing, the Network would be prepared to support the scheduled Viking flight-team training tests.

(3) Viking Mission Tests. Soon after the planetary testing began, Network support was required for other Viking Mission test programs.

The first system integration test was scheduled for November 12 with the Goldstone 64-meter station. Time was also scheduled for retests, if required, later in November. Following the tests with Station 14, these same tests were to be conducted in Australia with Station 43 on January 5, 1976, with a retest scheduled for January 13, and in Spain with Station 63 on January 8 with a retest scheduled for January 16. At completion of these tests, the Network and Mission Control Center was prepared to support the Viking Project planetary testing effort.

The first Viking Ground Data System test involving a deep space station was scheduled for December 6, 1975, with stations at Goldstone, California. This was test 5.1 and was to be a combined station test involving the 64-meter station and the 26-meter conjoint station, to be followed by test 5.31, scheduled for December 16 with a possible retest on December 29.

The overseas stations in Australia and in Spain were scheduled to begin their Ground Data System testing in January 1976. Test 5.32 was scheduled first with the Australian stations on January 21 with a possible retest on January 29. Test 5.32 was scheduled with the Spanish stations on January 24 with a possible retest on February 1 followed by a combined station test. Test 6.0 would be an 18-hour test involving Stations 14 and 11 at Goldstone and Stations 43 and 42 in Australia, and was to conclude the planetary series of Ground Data System tests.

Following these tests, the flight operations personnel test and training exercises were to be conducted. These would involve substantial Network support and were scheduled in late February and late March 1976. Detailed discussions of these are found in Section IV-B.

4. Mars Radar

In contrast to the 1971 and 1973 Mars radar opportunities conducted at S-band frequencies, it was desired to conduct the 1975 observations at X-band frequencies. This was due in part to the availability of an experimental high-power (400-kW) X-band transmitter at Station 14, and in part to the greatly increased emphasis placed on the Mars landing C-site characteristics.

During August, hardware problems had precluded any radar data being obtained, and only one of four X-band transmitting klystrons remained serviceable. Attempts to obtain data in September were equally unsuccessful, and it was determined that a complete overhaul of the microwave system and protective circuitry was needed to ensure readiness for the important C-site observation opportunities in late December.

Because of the impact of this work on the ongoing planetary implementation and testing and mission support at Station 14, as well as the need for station downtime to remove and later re-install the X-band cone, a meeting with Network and Project management was called on September 15, 1975. At this meeting, the Project agreed to fund the repair of two of the faulty klystrons then with the vendor, subject to the Network reactivating the X-band radar capability on the schedule shown in Fig. 44. This then became line item 11 on the Tracking and Data System schedule (see Fig. 42).

Removal of the X-band cone for disassembly and cleaning of the feed and waveguides was scheduled for October 14, 1975. Technical problems delayed this until October 21, and two-shift operation was initiated to complete the work by the November 17 milestone date. A new klystron received at the Jet Propulsion Laboratory on October 21 was found to be faulty and was returned to the vendor. Two more repaired klystrons were scheduled for acceptance testing on October 29 and November 26.

By December 11, the cone and waveguide had been re-installed, together with two repaired klystrons, each of which had been run up to the 100-kW power level. Additional testing had been delayed because of the problems with the high-voltage power supply and the high-speed protective circuits.

On December 16, a demonstration test was conducted successfully in accordance with the schedule, and full Mars radar passes were made on December 27, 28, and 30. Because of problems still remaining in the transmitter klystrons, these passes were conducted at a power level of 165 kW, which was adequate at that time because of the shorter Earth-Mars range. Good data were obtained on two of these passes.

As the Earth-Mars range increased, however, the power level was soon to become inadequate, and the full 400-kW power level became a necessity for observations early in 1976.

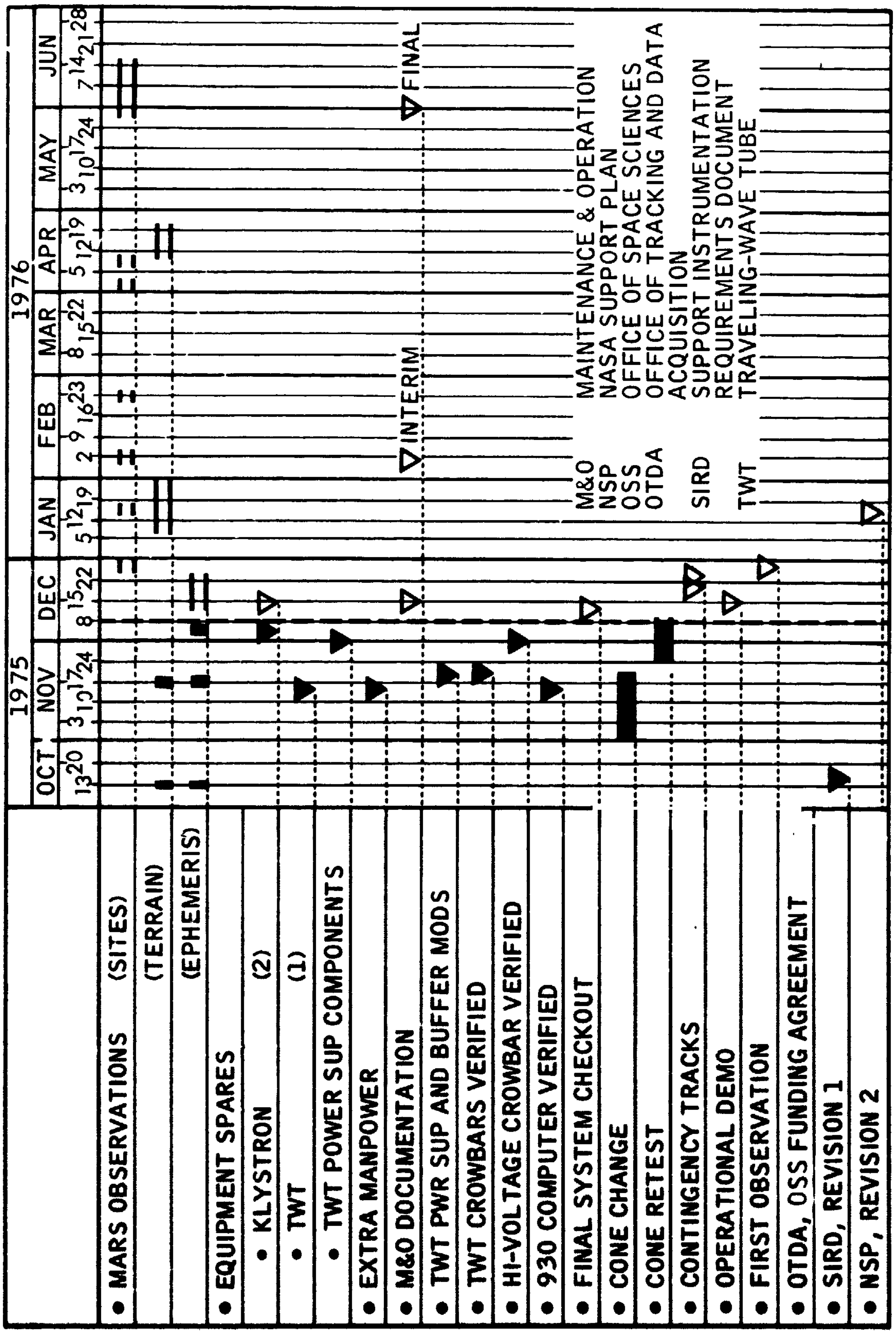


Fig. 44. Mars radar activation schedule as of December 1975

5. Radio Science

Several times during the Viking missions, Mars, as viewed from the Earth, passes within a few line-of-sight degrees of a quasar, an intense extragalactic radio source. At such times, the radio signals from an orbiter and the quasar were recorded alternately, but simultaneously, at two tracking stations in a very long baseline interferometry experiment. This yielded a precise measurement of the angular separation of the two sources. With suitable data analysis, the results gave the precise location of the spacecraft, and thus Mars and Earth, with respect to the fixed, inertial frame defined by the very distant quasar. By making such observations over a period of years, in various spacecraft missions, the precise orbits of Mars and Earth with respect to the inertial frame could be determined. An application of such information is to determine the relativistic advance of the perihelion of Mars, thus providing a test of the theory of general relativity, with consequent implications on development of the fundamental laws of physics.

As part of the Viking very long baseline interferometry experiment, demonstration passes were conducted between Goldstone Station 14 and Canberra Station 42 in December 1975. In these experiments, the radio transmissions from the Viking 1 spacecraft and a quasar were received alternately by each of the two receiving stations during a period of mutual overlap. A simplified block diagram of the station receiving equipment is given in Fig. 45. The digitized data from the received radio spectrum were returned to the National Radio Astronomy Observatory for correlation and reduction of the data. The observations during December were carried out with Viking 1 as follows:

Time (UTC)	Date	Quasar Source
09:32 to 12:35	December 2	P0422 + 00
08:19 to 12:22	December 5	P0422 + 00
08:0[illegible] to 11:30	December 9	P0422 + 00
09:05 to 12:05	December 14	P0422 + 00
08:42 to 11:42	December 21	3C120

All experiments were supported successfully by the stations, and the data from the passes on December 5, 14, and 21 were processed at the National Radio Astronomy Observatory. The data from passes on December 2 and 9 were of very poor quality because of the digital tape recorder problems. These problems had been corrected and further observations scheduled for the first part of 1976.

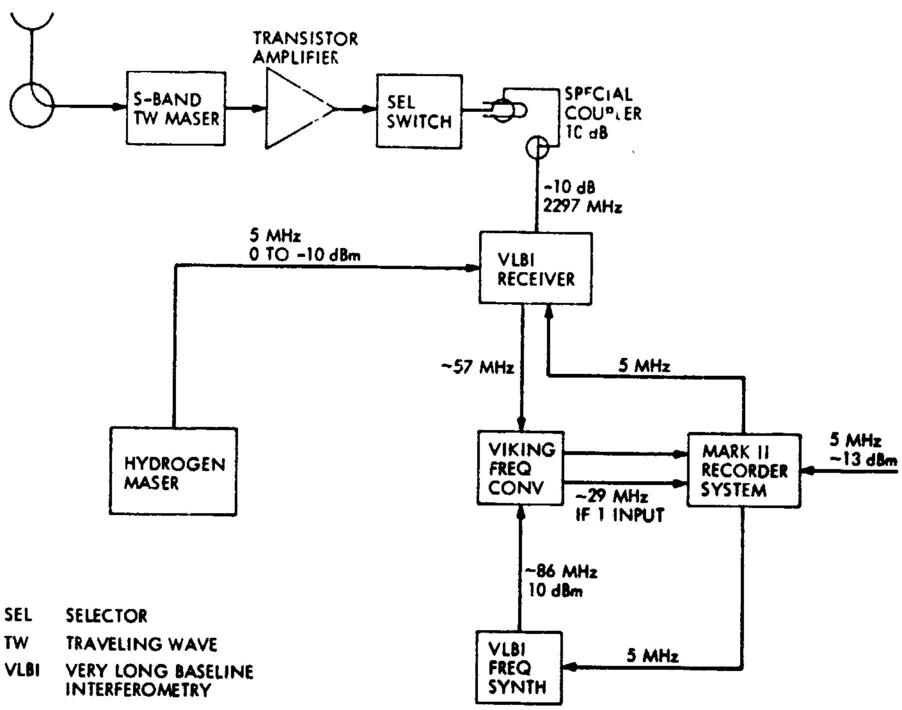


Fig. 45. Receiving station configuration for very long baseline interferometry experiments

6. Operational Reliability

Immediately following the launches, the Viking Project began accumulating gross operational data on Network performance during scheduled Viking tracks. These data were gathered from the station pass summaries and the weekly Network discrepancy reports as part of an overall Project study of the operational reliability of the entire Ground Data System.

The data covering Day of Year 233 through Day of Year 365 (August through December 31, 1975) are reproduced in Table 19 and includes all failures.

On the basis of these data, it appears that the 26-meter stations (11, 12, 42, 44, 61, 62) achieved a significantly higher value for mean time between failures than the 64-meter stations (14, 43, 63). This result is to be expected in view of the much greater complexity of the 64-meter stations. Differences between like stations are noticeable, but, during the period covered in the data implementation, testing, training, and other disturbing factors were in progress at some stations more than at other stations. It is not, therefore, considered meaningful to draw any conclusions regarding relative performance.

Additional data accumulated as the mission progressed are reported in subsequent sections of this report.

Table 19. Operational reliability for Viking support from August through December 31, 1975

Operational Performance	Station								
	11	12	14	42	43	44	62	62	63
Total support time, hours	720	480	371	1044	422	583	916	766	416
Number of failures	12	8	16	15	17	8	11	14	7
Mean recovery time, minutes	105	22	55	77	64	140	87	46	96
Mean time between failures, hours	60	60	23	70	25	73	83	55	59

B. CRUISE SUPPORT (JANUARY THROUGH APRIL 1976)

1. Mission Events

As 1976 opened, both Viking spacecraft continued to operate normally and remained in excellent condition. Viking 1 reached the halfway point of its cruise to Mars on January 19, 1976. In flight 152 days since launch on August 20, 1975, it then had 152 days to go until Mars orbit insertion on June 19, 1976. At this point, Viking 1 was slightly more than 152 million kilometers (89 million miles) from Earth and 24 million kilometers (15 million miles) from Mars. Viking 2 was 4.8 million kilometers (3 million miles) behind Viking 1.

Viking Orbiter subsystem testing and housekeeping activities were conducted without incident. These included high-gain antenna position updates, atmospheric water detector wavelength calibrations, and science scan platform slews.

A new item added to the checkout sequence was the opening and adjusting of solar energy controllers on the Orbiters. As the Viking spacecraft traveled farther away from the Sun, less solar energy penetrated through the white thermal shroud over the rocket motor propellant tanks, allowing internal temperatures to drop. If this condition had been permitted to continue, the propellants would have become too cold to provide full-rated thrust during the crucial orbit insertion burn.

On command, the louvers were opened, allowing sunlight to enter the Orbiter bus. Sunlight striking the curved reflector inside the solar energy controller was turned 90 degrees and diffused over the bottom of the tanks to maintain proper propellant temperatures during the cruise period. In early 1976, the louvers were opened about one-third of their total travel and were adjusted on a weekly basis as temperature data were received and analyzed by Viking Flight Team members.

Viking Lander subsystem operations also continued on a regular basis. These included tape recorder maintenance sequences, relay communication equipment checkouts, and meteorology instrument checkouts.

The Gas Chromatograph Mass Spectrometer instruments continued to function well during cruise testing. These instruments were designed to test the Martian atmosphere and surface material for organic compounds. An analysis of engineering data indicated that one of the three small ovens associated with this instrument on each spacecraft was not heating properly. However, loss of one oven on each instrument did not seriously affect the operation of the instrument.

On February 20, Viking Flight Team members started an intensive test and training exercise, called Demonstration Test 4, in preparation for the planetary operations that were to begin in June. The overall objective of the test was to demonstrate the Viking Flight Team's capability to execute the flight operations associated with the Viking 1 Orbiter and Lander during the period from separation minus 58 hours to completion of the eighth day on Mars (Sol 8).

Detailed objectives of the test were to:

(1) Demonstrate the capability to perform the sequences necessary to initiate separation, landing, and landed operations with Viking Lander 1 as prescribed by Primary Mission Design.

(2) Demonstrate the capability to respond to the information gained from data.

(3) Demonstrate the capability to perform the functions inherent in the Planetary Mission Operations strategy.

(4) Demonstrate the capability of the Flight Team to sustain the continuous level of activity required to operate the Orbiter and Lander concurrently.

(5) Produce the Flight Plan products required during this portion of the mission.

The test started on February 20, 58 hours before separation, and ran through Sol 8, ending on March 2.

The spacecraft positions by the end of March were: Viking 1---188.69 million kilometers (117.26 million miles) from Earth and 18.98 million kilometers (11.8 million miles) from Mars; Viking 2---182.76 million kilometers (113.57 million miles) from Earth and 25.37 million kilometers (15.76 million miles) from Mars. Viking 1 was on a 675.90 million-kilometer (420 million miles) heliocentric intercept trajectory, while Viking 2 was on a 712.91 million-kilometer (443 million miles) heliocentric Mars-intercept trajectory (Fig. 46).

An inertial reference unit calibration for Viking 1 Orbiter was carried out during March 22-23, while the same calibration was carried out for Viking 2 Orbiter on both March 26 and 27. The Viking 2 Orbiter television cameras were subjected to an extensive calibration exercise on March 16, followed by a duplicate exercise for Viking 1 Orbiter on March 23, 25, and 26. A total of 116 pictures were acquired by each Orbiter using the planet Jupiter as a target. Some of these pictures were transmitted to Earth the same day in each case, with the balance being received over the following days. This was a quiet period for the Landers.

In early April the X-band radar at Goldstone performed measurements to provide additional data to refine the information about the Viking alternate landing sites. These sites are a group of site locations which provide alternates to the preselected sites for contingency missions.

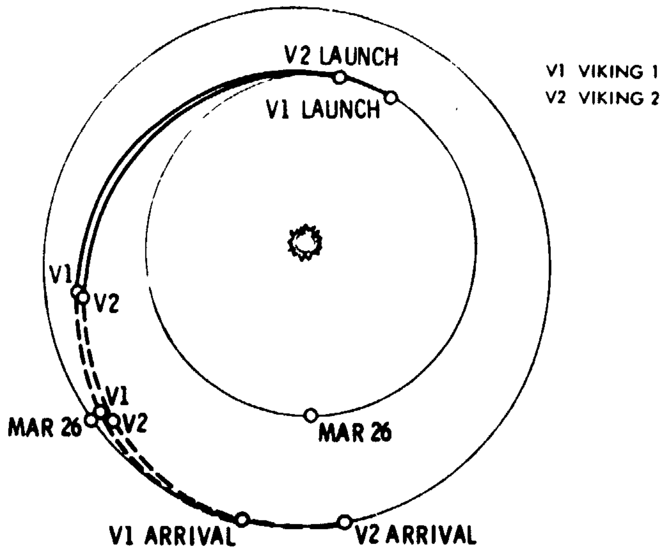


Fig. 46. Status of Vikings 1 (V1) and 2 (V2) showing true heliocentric orbits around Sun (March 1976)

The doppler radar procedure used measures radar reflectivity from the surface of Mars, and analysis of these data was to yield a variety of information concerning the average roughness and density of the Martian surface.

These data are important to the selection of the landing sites, since there must be enough atmosphere to slow the descending Lander before its parachute is deployed and terminal phase rockets are ignited. The surface must also be smooth enough and of sufficient strength to result in a successful landing.

Later in April, Demonstration Test 7 got under way on schedule to provide a major simulated demonstration of landed operations covering Mars days Sol 8 through 11. During this period, routine monitoring of both spacecraft continued with the activity being rather quiet.

By the week of April 16, the infrared thermal mapper and Mars atmospheric water detector had each been calibrated, and spacecraft tape recorder maintenance and meterology checkout had been completed on Viking Lander 2. The water detector calibrations were made using simulated conditions that would be experienced during a normal orbit of Mars.

At the end of April, the Viking spacecraft continued to operate as expected during their long flights to Mars. Round-trip communications time between Earth and the spacecraft had increased to nearly 26 minutes for Viking 1 and 25 minutes for Viking 2. Although spacecraft activity during the final week of April was light, the Viking Flight Team was busy with Demonstration Test 4 rehearsing for the landing of Viking. While Viking Orbiter 2 and Viking Lander 2 remained quiet, a high-gain antenna calibration on Orbiter 1 and tape recorder maintenance, meteorology checkout, and battery charging on Lander 1 were accomplished.

Media preparations for covering the Viking orbiter operations were quickening. Major plans for television coverage were well advanced and reflected an international interest in the Viking mission. Commercial networks in the United States had also made preparations for their coverage of the Viking mission.

At the end of April, Viking 1 was 234 million kilometers (146 million miles) from Earth and less than 13 million kilometers (8 million miles) from Mars, 57 days from its insertion into Mars orbit on June 19. Its speed relative to Earth was 11,000 kilometers per hour (69,000 miles per hour) and 9087 kilometers per hour (5647 miles per hour) relative to Mars. Viking 1 had flown 576 million kilometers (358 million miles) of its 676 million-kilometer (420 million mile) heliocentric Mars intercept trajectory. Viking 2 at this time was 228.8 million kilometers (142.2 million miles) from Earth and 21.4 million kilometers (13.3 million miles) from Mars, 106 days from its orbit insertion on August 27. Its speed was more than 111,000 kilometers per hour (69,101 miles per hour) relative to Earth and 6561 kilometers per hour (4077 miles per hour) relative to Mars. Viking 2 had flown 526.7 million kilometers (327.3 million miles) of its 712 million-kilometer (443 million mile) heliocentric trajectory enroute to the planet.

2. Network Operations

Viking spacecraft activities during the early months of 1976 required a very high level of support from the Deep Space Network. The level of activity and complexity of this support approached that anticipated during planetary operations and generally exceeded that of the planetary test exercises as well. A summary of the major cruise support activities during this period is provided in the following paragraphs.

a. Significant Mission Events. The significant Viking cruise activities that had been supported by the Network are listed in Table 20. Many of the spacecraft activities required the transmission of large numbers of commands and/or processing of multiple telemetry streams, including the highest Viking data rate (16.2 kbps) by the stations. These activities also imposed a workload on the Network Operations Control Center and Ground Communications Facility far beyond that which would be expected in a normal "quiet cruise."

b. Station Support. The extent of support provided by the deep space stations in terms of the total number of passes, tracking hours, and commands transmitted is shown in Table 21. The only major outage to occur at a station after January 1 was an antenna servo pump motor failure at the Honeysuckle Creek station (Station 44). As a result, the station tracking schedule was adjusted to meet the Viking Project requirement of no gaps to exceed 3 hours and minimal impact on operations.

c. Network Operations Control Center. Implementation of the Network Operations Control Center continued throughout this period. Because a number of unexpected problems caused delays in subsystem delivery schedules, a major effort was concentrated on meeting the Network commitment to the Viking Project for Intermediate Data Record production, which required the completion of an operable telemetry subsystem in the Control Center. This requirement was met, and Intermediate Data Records were produced to support Viking operations after March 1. Training of operations personnel to perform the functions involved in the routine generation of these records during the prime mission planetary operations was conducted continuously throughout this period.

d. Discrepancy Reports. Failures and anomalies in the Network configuration for Viking are documented and tracked by the Discrepancy Report System. The discrepancies reported during the first quarter of 1976 are given in Table 22. The station dependent number is unusually high because of continued development of new capabilities being demonstrated for the first time in support of the Viking Project. Although actually investigated, the remaining open discrepancy reports were of no immediate impact to operations.

e. Command System. The Viking command activity is shown for each month in Table 23 for each of the two Orbiters and two Landers. Since the Orbiters and Landers remain in the initial condition throughout the entire cruise period, commands addressed to the Landers are transmitted in the Viking Orbiter radio frequency carriers.

Table 20. Significant Viking activities supported by the Deep Space Network from January through April 1976

Date	Spacecraft	Activity
Jan 5	Orbiter 1	Mars Atmospheric Water Detector (MAWD) calibration
Jan 5	Lander 2	Tape recorder maintenance
Jan 6	Orbiter 1	High-gain antenna (HGA) calibration (utilizing Mars Station 14 X-band capability)
Jan 7	Lander 1	Tape recorder maintenance
Jan 7	Orbiter 1	MAWD calibration
Jan 8	Lander 1	Gas Chromatograph Mass Spectrometer (GCMS) bakeout
Jan 13	Lander 2	GCMS oven characteristics sequence
Jan 14	Lander 1	GCMS bakeout
Jan 14	Orbiter 2	X-band telemetry experiment
Jan 15	Lander 2	Tape recorder maintenance
Jan 16	Lander 1	Tape recorder maintenance
Jan 16 & 17		X-band telemetry experiment
Jan 20	Lander 2	GCMS oven characteristics sequence
Jan 28	Lander 1	GCMS oven characteristics sequence
Jan 31	Lander 2	GCMS bakeout
Feb 2	Lander 1	GCMS oven characteristics sequence
Feb 3	Lander 2	Tape recorder maintenance
Feb 4	Lander 1	MAWD calibration
Feb 6	Lander 2	GCMS vents
Feb 7	Lander 1	GCMS bakeout
Feb 9	Lander 1	Infrared Thermal Mapper (IRTM) calibration

Table 20 (contd)

Date	Spacecraft	Activity
Feb 9	Orbiter 1	Video Imaging Subsystem (VIS) scan calibration
Feb 10	Lander 2	Power conditioning sequence (battery charge/discharge)
Feb 11	Orbiter 2	MAWD calibration
Feb 11	Lander 2	Tape recorder maintenance
Feb 12 & 13	Lander 1	GCMS bakeout
Feb 13	Orbiter 2	IRTM calibration and VIS scan calibration
Feb 15	Orbiter 2	VIS scan calibration playback
Feb 17	Lander 1	GCMS vents close and atmospheric analysis
Feb 18	Orbiter 1	Tape recorder maintenance and HGA calibration
Feb 19	Lander 1	Power conditioning sequence
Mar 8	Orbiter 1	MAWD calibration
Mar 8	Orbiter 2	Tape recorder maintenance
Mar 10	Lander 1	Tape recorder maintenance
Mar 10	Orbiter 1	HGA calibration
Mar 11	Orbiter 2	MAWD calibration
Mar 11	Lander 2	Tape recorder maintenance
Mar 15	Orbiter 2	Accelerometer and gyro calibration
Mar 16	Orbiter 2	Photo calibration
Mar 16	Orbiter 1	Tape recorder maintenance
Mar 18	Orbiter 1	Accelerometer and gyro calibration

Table 20 (contd)

Date	Spacecraft	Activity
Mar 22	Lander 1	Inertial reference unit (IRU) calibration
Mar 23	Orbiter 1	Photo calibration
Mar 22 - 24	Orbiters 1 & 2	Playback of photo calibration data
Mar 26	Lander 2	IRU calibration
Mar 27	Orbiter 1	HGA calibration
Apr 11	Orbiter 1	Onboard computer software update
Apr 12	Orbiter 1	Scan calibration
Apr 14	Orbiter 2	Onboard computer software update
Apr 15	Orbiter 2	Scan calibration
Apr 16	Orbiter 2	VIS picture playback
Apr 16	Lander 2	Tape recorder maintenance
Apr 17	Orbiter 1	VIS playback
Apr 17	Lander 1	Battery charge and tape recorder maintenance
Apr 18	Orbiter 2	Very long baseline interferometer (VLBI) with quasar source

Table 21. Station support of Viking cruise operations from January through March 1976

Month	Station	Number of passes	Time tracked, h:min	Commands transmitted
January	11	10	71:30	100
	12	25	211:26	245
	14	15	112:29	324
	42	8	35:55	0
	43	24	150:09	21
	44	27	183:36	20
	61	14	107:55	191
	62	36	309:29	345
	63	12	117:55	0
Monthly total:		171	1300:24	1246
February	11	2	04:54	0
	12	32	278:52	564
	14	11	99:38	15
	42	31	139:33	21
	43	17	124:05	59
	44	11	48:25	13
	61	4	37:51	0
	62	32	290:13	624
	63	24	219:47	556
Monthly total:		164	1243:18	1852

Table 21 (contd)

Month	Station	Number of passes	Time tracked, h:min	Commands transmitted
March	11	15	71:16	17
	12	24	171:31	302
	14	17	124:23	0
	42	17	62:33	0
	43	20	101:23	0
	44	26	131:04	197
	61	7	67:03	0
	62	31	276:30	259
	63	32	298:21	338
Monthly total		189	1304:04	1113
Report total		524	3847:46	4211

Table 22. Distribution of Viking discrepancy reports from January through March 1976

Resolution type	Station 11	12	14	42	43	44	61	62	63	MIL[a] 71	Network	GCF[b]	NDPA[c]	NOCA[d]	Total
Facility dependent	21	24	106	29	64	19	24	24	53	16	5	24	20	28	457
Facility independent	4	5	8	7	3	0	0	3	3	1	2	6	5	12	59
Other or unavoidable	2	2	2	0	1	0	0	1	0	1	9	4	1	2	25
Total discrepancy reports closed	27	31	116	36	68	19	24	28	56	18	16	34	26	42	541
Total discrepancy reports generated	29	33	128	38	75	19	26	29	81	18	17	34	41	46	614
Discrepancy reports open as of March 31, 1976	2	2	12	2	7	0	2	1	25	0	1	0	15	4	73

[a]Merritt Island
[b]Ground Communications Facility
[c]Network Data Processing Area
[d]Network Operations Control Area

Table 23. Number of commands transmitted by month from January through April 1976

Month	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Aborts
January	251	377	239	379	0
February	552	533	441	346	0
March	505	35	538	35	0
April	550	1803	517	36	0
Cumulative total for mission	3359	3612	3594	1829	0

Loss of command capability due to high-speed data line outages or failures at the deep space stations are shown in Table 24 as a percentage of the total scheduled track time for the month. The cumulative total for the mission through the end of April due to all outages is given in the last line of the table.

f. Telemetry System. The performance of the Network Telemetry System in support of Viking is analyzed on a month-by-month basis in terms of direct signal level and signal-to-noise ratio. The expected values of these parameters are compared continuously with actual values observed during the time interval, and a residual value is evaluated. Provided the residuals remain within specified limits, the Telemetry System is considered to be performing correctly. Out-of-limits anomalies are investigated and remedial action taken where necessary.

Telemetry performance for the months of January, February, March, and April 1976 for Vikings 1 and 2 are given in Table 25 in terms of residuals for signal level and signal-to-noise ratios for 26- and 64-meter stations, respectively.

The number of occasions on which an anomalous residual occurred in either signal level or signal-to-noise ratio during Viking tracks for the reporting period is given in Table 26 for both spacecraft.

Table 24. Command capability loss due to high-speed data line or station failures from January through April 1976 as a percentage of scheduled track time

Month	Viking 1		Viking 2	
	Line failure, percent	Station failure, percent	Line failure, percent	Station failure, percent
January	0.03	0.37	0.07	0.21
February	0.00	0.66	0.17	1.53
March	0.13	0.57	0.14	0.35
April	0.11	0.36	0.13	0.35
Cumulative total for mission	0.629		0.601	

g. Tracking System

(1) Radio Metric Data Quality. The primary navigational data type generated by the Network are doppler data. These data are continuously monitored by the Network Analysis Team in near real time using a pseudoresidual program. Doppler data residuals (actual minus predicted) produced during the period January-April 1976 by this program consistently indicated a high level of accuracy in the polynomial coefficients (the frequency independent observables) supplied to the Network Operations Control Team by the Viking Project Flight Path Analysis Group. Additionally, the Network Analysis Team 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 45 degrees) and is at adequate signal levels, two-way doppler noise data are nominally expected to be 0.003 ± 0.002 Hz, for a 60-second sample rate averaged over a pass.

Figures 47 and 48 present pass average doppler noise for Vikings 1 and 2 for the January-April 1976 period. Examination of these figures indicates generation of nominal, high quality doppler data for Viking navigation.

Table 25. Residuals for S-band downlink signal level and signal-to-noise ratio for Vikings 1 and 2 from January through April 1976

Parameter	January		February		March		April	
	Viking 1	Viking 2	Viking 1	Viking 2	Viking 1	Viking 2	Viking 1	Viking 2
26-meter stations								
Signal Level								
Observations	58	51	50	58	61	59	75	78
Mean, dB	+0.1	+0.2	+0.2	+0.3	+0.1	+0.3	-0.3	0.0
Sigma, dB	0.6	0.5	0.4	0.5	0.5	0.4	0.5	0.5
Signal/noise ratio								
Observations	*	*	4	2	22	23	*	*
Mean, dB	---	---	-0.8	-0.1	-0.6	-0.3		
Sigma, dB	---	---	0.6	---	0.6	0.4		
64-meter stations								
Signal Level								
Observations	23	26	25	14	27	27	13	11
Mean, dB	-0.1	-0.2	-0.2	-0.1	0.1	0.3	0.1	-0.3
Sigma, dB	0.6	0.6	0.8	0.7	0.5	0.5	0.6	0.4
Signal/noise ratio								
Observations	*	*	6	1	4	*	6	*
Mean, dB			-0.8	-0.1	-1.1		-0.5	
Sigma, dB			0.4	---	0		0.4	

*Signal-to-noise ratio estimator saturated.

Table 26. Number of anomalous residuals in signal level or signal-to-noise ratio during Viking tracks from January through April 1976

Spacecraft	January	February	March	April
Viking 1	5	8	4	4
Viking 2	7	4	2	3

(2) Viking Spacecraft Frequencies. During each one-way tracking period, the Network Analysis Team re-estimates the spacecraft auxiliary oscillator frequency and during each subsequent uplink acquisition a similar re-estimation of the spacecraft best lock frequency is performed. These data for Vikings 1 and 2 during the January-April period are presented as follows:

Viking 1 spacecraft auxiliary oscillator frequency	Fig. 49
Viking 2 spacecraft auxiliary oscillator frequency	Fig. 50
Viking 1 spacecraft best lock frequency	Fig. 51
Viking 2 spacecraft best lock frequency	Fig. 52

Spacecraft frequency data gathered by the Network in this fashion have proven quite effective and reliable in the past, and the reliability is routinely reflected in the tracking predictions supplied to the deep space stations and the Network Operations Control Center for both spacecraft acquisitions and radio metric data validation. Additionally, these data assume paramount importance during mission critical phases, when complicated mission strategies demand rapid and precise uplink and downlink acquisitions.

(3) Development of a Viking 1 Mars Orbit Insertion Strategy. During April 1976, a series of meetings were convened between representatives of the Orbiter Performance Analysis Group, the Viking Project Flight Path Analysis Group, and the Network. As a result of these meetings, the key features of the Viking 1 Mars orbit insertion were formulated as follows:

(a) The ground transmitter would be maintained "ON" throughout the critical Mars orbit insertion period.

(b) Uplink ramping would be performed during the preburn period of low uplink signal level.

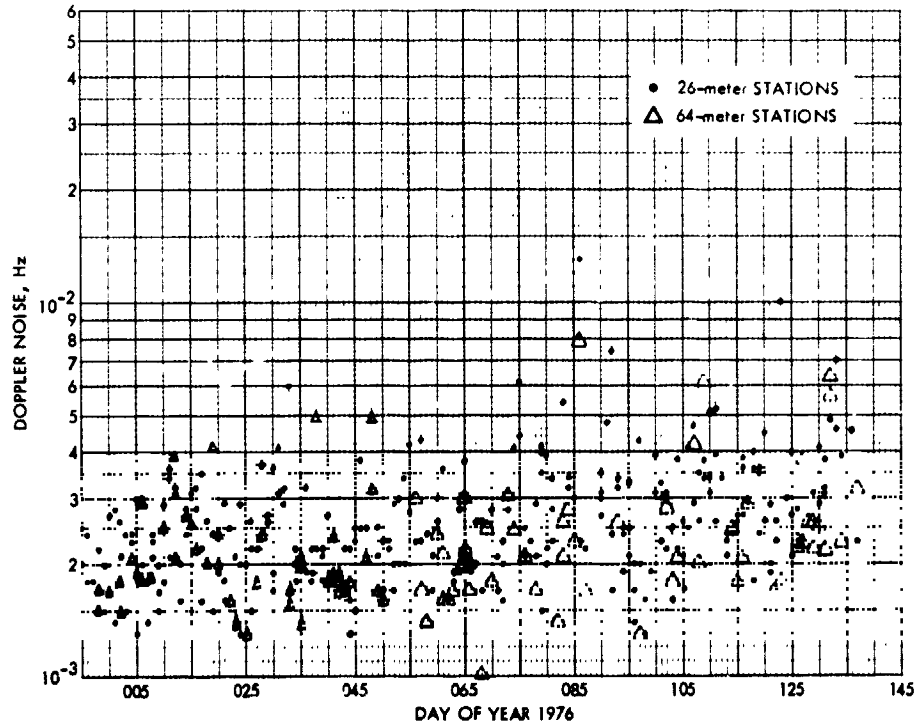


Fig. 47. Viking 1 composite doppler noise versus day of year for all stations from January through April 1976

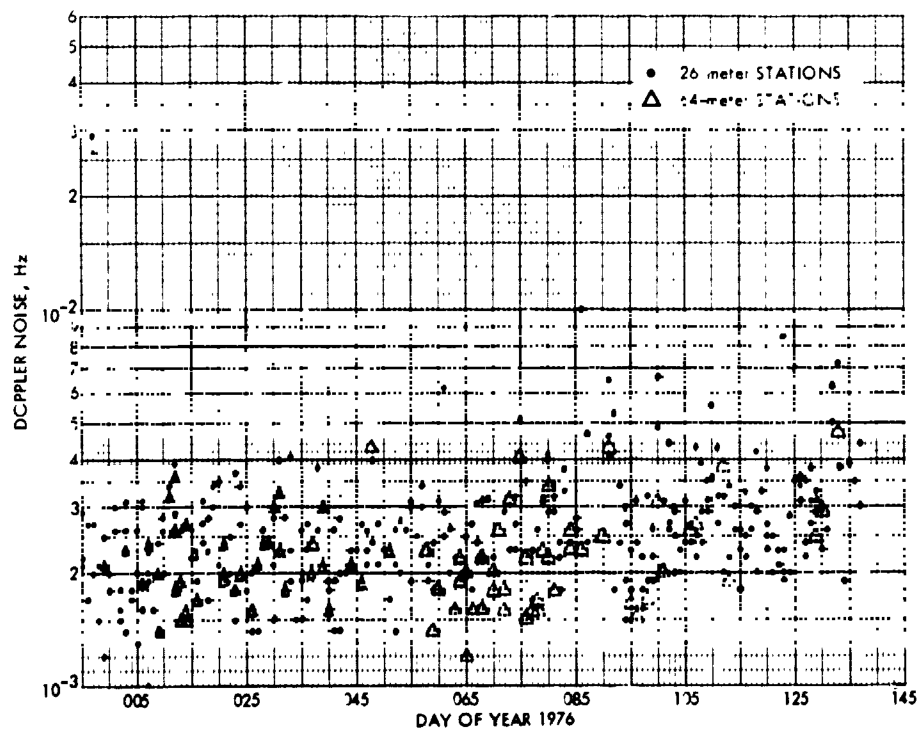


Fig. 48. Viking 2 composite doppler noise versus day of year for all stations from January through April 1976

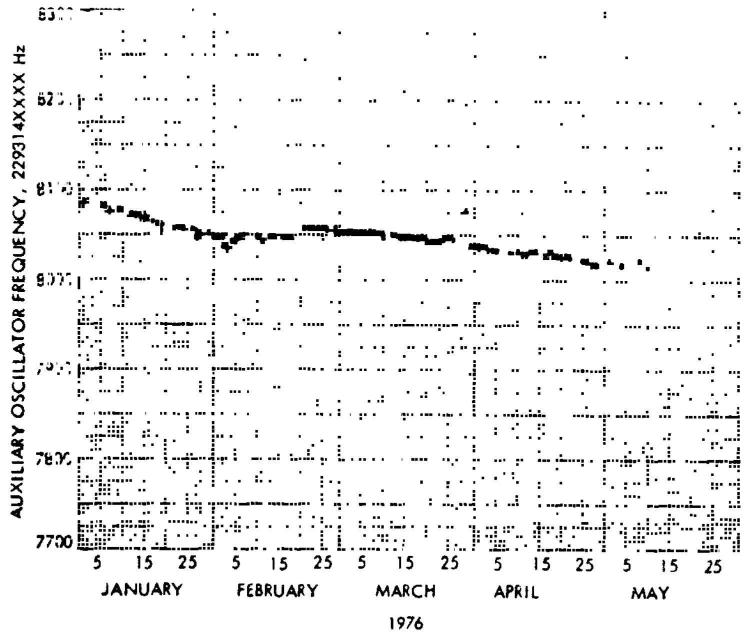


Fig. 49. Viking 1 auxiliary oscillator frequency from January through April 1976

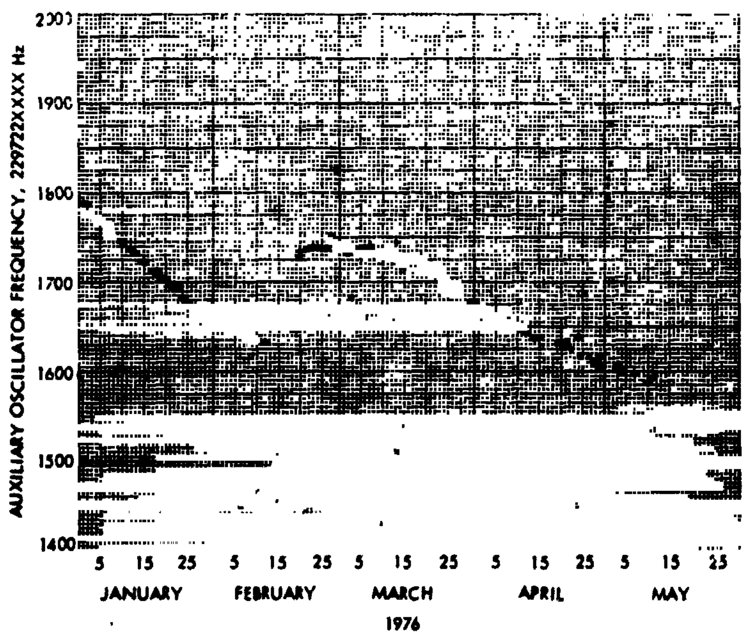


Fig. 50. Viking 2 auxiliary oscillator frequency from January through April 1976

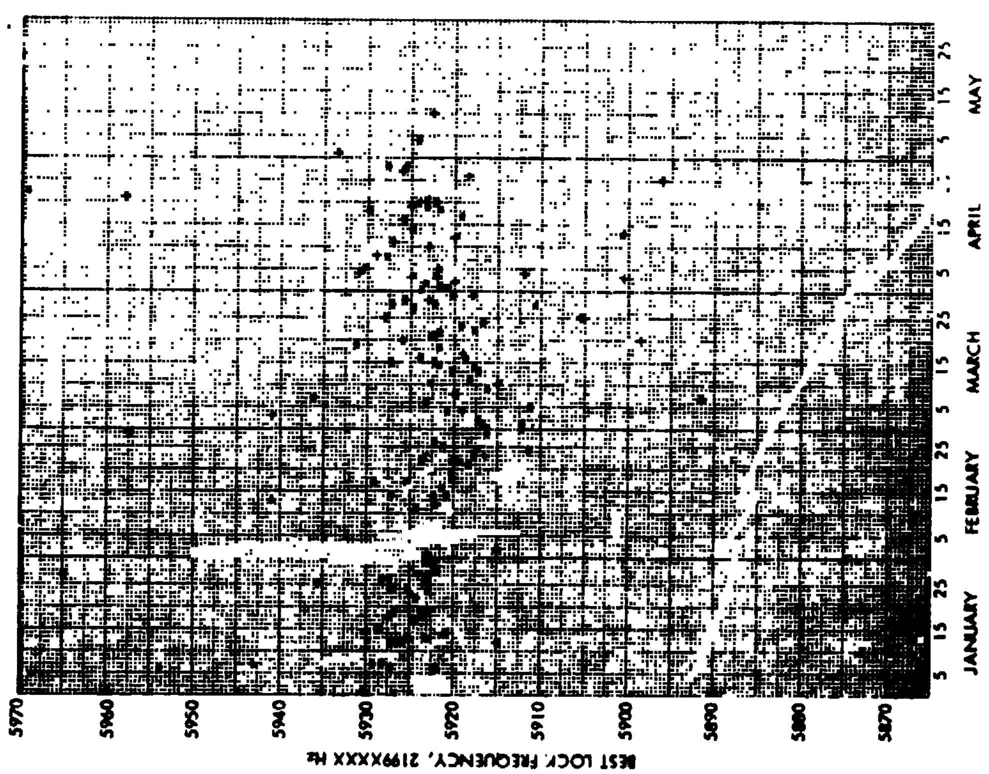


Fig. 51. Viking 1 channel 9 best lock frequency from January through April 1976

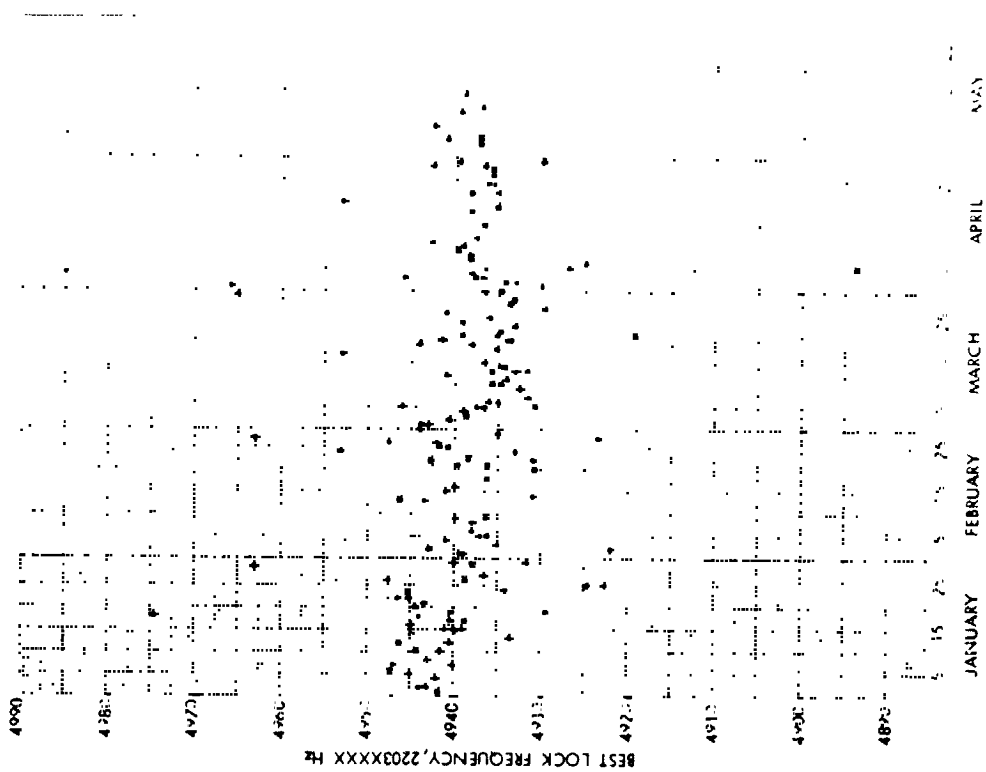


Fig. 52. Viking 2 channel 20 best lock frequency from January through April 1976

(c) An "insurance sweep" would be performed immediately after the uplink ramping (in item (b) above) to ensure an uplink in the contingency of the uplink being lost during the ramping period.

(d) The reacquisition of the uplink during the post-burn period would be delayed (by approximately 10 minutes from the earliest opportunity) so that the Flight Path Analysis Group could clearly gauge in near real time the end of the Mars orbit insertion burn and the beginning of the post-burn roll turn in the doppler data. Earlier uplink tuning would disrupt the doppler ground reference frequency.

Using the above guidelines and, additionally, working with the Lander Performance Analysis Group and Viking Radio Science, the TRACK Network Operations Analyst prepared the "Deep Space Network Tracking Operations Plan for the Viking 1 Planetary Phase," which contained the following major topics:

(a) Mars Orbit Insertion Operations

(b) Lander Operations

(c) Special X-band Tracking Operations

(d) Special Predict Requirements

The report was initially issued on May 10, 1976, as a module of the Tracking Operations Analysis Manual and was subsequently incorporated into the Viking Network Operations Plan.

(4) <u>Solar Plasma Modeling for the Viking Solar Conjunction Period.</u> In March 1976, the TRACK Network Operations Analyst concluded work on a year-long project to study solar plasma effects during the Pioneer and Helios 1975 solar conjunctions. The central concluding thesis of this research was that solar corruption of doppler data (i.e., increased doppler phase jitter) is directly proportional to the total columnar electron density along the signal path and, hence, can be easily modeled as a simple function of the Earth-Sun-spacecraft geometry (the detailed findings were published by A. L. Berman and J. A. Wackley in Ref. 3. The major impact of this work on tracking operations during the upcoming Viking solar conjunction period (starting in July 1976) is that the (solar-induced) doppler noise model will allow deep space station tracking system malfunctions to be differentiated from solar plasma effects and, hence, more rapidly diagnosed and corrected. In support of this effort, the Network Analysis Team for tracking (the unit in charge of near real-time tracking system performance validation) was to be supplied with doppler noise predictions during the Viking solar conjunction period. There also existed the possibility that the Viking Radio Science Team might be able to use the solar noise model to deduce scientific information (from the observed Viking doppler data noise) about solar corona electron densities.

h. Monitor System. The Network Monitor System continued to support DSN operations of Viking Mission Operations during the period January through April 1976. The number of station tracking hours provided to Vikings 1 and 2 for each station throughout this period is given in Table 27.

The incidence of anomalies identified by a discrepancy report is given in Table 28. The anomalies listed therein include those awarded to the Network Operations Control Center.

3. Planetary Configuration Development

a. Engineering Change Management---January Through April 1976. By January 1976, Network implementation of the planetary configuration for Viking had progressed to the point where 13 key items remained outstanding:

(1) Ampex FR 2000 recorders to provide high-rate analog playback at all 64-meter stations.

(2) Dedicated FR 1400 recorders to Stations 14 and 43 to allow recording of Viking telemetry data simultaneously with occultation data.

(3) G. E. Terminets to replace A. B. Dick printers for higher speed and better reliability.

(4) Command backup printer to provide a second hard copy of all commands transmitted in case of printer failure.

(5) Autotrack Conscan to provide more accurate pointing of antenna for reception of X-band signals.

(6) Autotrack detectors and recorders to more accurately align radio frequency boresight and verify antenna pointing.

(7) ±1-MHz doppler bias to replace existing 5-MHz bias for better doppler resolution and offset of high doppler frequencies.

(8) Phase II version of monitor software to accommodate both Block II and Block III receivers.

(9) Original Data Record recall software to provide Network Operations Control Center with capability for recall of Digital Original Data Records directly from the deep space stations.

(10) Operational capability for Network Operations Control Center to generate Intermediate Data Records from a Network Data Log and a gap list in conjunction with the Original Data Record recall software.

Table 27. Station support for Viking spacecraft from January through April 1976

Month	Station									Network Total
	11	12	14	42	43	44	61	62	63	
January	10	26	15	8	27	27	14	36	13	176
February	2	31	11	31	16	11	4	32	23	161
March	15	24	16	17	20	26	6	31	32	187
April	25	33	1	31	0	29	35	7	24	185
Total tracks	52	114	43	87	63	93	59	106	92	709
Total hours	357	974	345	470	469	648	473	952	843	5531

Table 28. Incidence of anomalies (discrepancy reports) in Network Monitor System during Viking tracks

Area	January	February	March	April
Other[a]	13	13	8	5
NDPA[b]/NOCA[a] only	Not operational	Not operational	Not operational	15

[a]Other includes:

Digital Instrumentation Subsystem (DIS)

Tracking Data Handling Subsystem (TDH)

Station Monitor and Control (SMC)

Frequency and Timing Subsystem (FTS)

Facility Power (FAC); FAC = Technical Facilities Subsystem

Communications (COM)

[b]NDPA includes the Network Data Processing Area.

[c]NOCA includes the Network Operations Control Area.

(11) Network Control System tracking subs, ·em to accommodate the ±1-MHz doppler bias change.

(12) Mars radar X-band transmitter power increased to 400 kW.

(13) Augument additional technical staff, in lieu of the Station Monitor and Control Consoles, at Stations 43 and 63 to handle Viking planetary operations.

By March 16, all 13 work items on the level 4 schedule (Fig. 53) had progressed to completion as shown.

From this point until all the items were finally accomplished on March 8, weekly meetings to review progress were held with top-level management from both the Project and the Jet Propulsion Laboratory. These meetings were supported by lower-level engineering and operations meetings held three times per week to monitor progress and expedite the resolution of the multitude of problems that occurred from week to week.

At this stage of implementation, even the computerized change management and reporting system was not fast enough for essentially real-time reporting. Because by then the number of changes was substantially smaller, a daily teletype message reporting system was put into effect to serve the needs of the particular situation as it existed at that time.

When Viking implementation was completed on March 15, the intensified high-level meetings were discontinued, and the balance of the Viking-related (but not essential) engineering changes were monitored and reported by the regular weekly status reporting system.

b. Implementation. The first complete Intermediate Data Record was delivered to the Project on January 10 as a product of Ground Data System Test 6.0 conducted the previous day. Subsequently, a data format design anomaly was discovered in the delivered tape. This was eventually corrected by a minor modification to the mission operations software in the Mission Control Center.

A firm plan for augmentation of the station staffing for planetary operations was put into effect with milestone dates as shown on the level 4 schedule (Fig. 44). The plan called for 10 additional personnel, and the restructuring of the existing operations and maintenance crews at the 64-meter Spanish station. If necessary, overtime was to be used, and additional staff were to be released from the conjoint station when version B of the Station Monitor and Control unit arrived.

The antenna pointing software and the telemetry recall software continued to cause problems with unexpected anomalies throughout January and February. A great deal of time and engineering effort were expended on qualifying both of these changes at Compatibility Test Area 21 and the Goldstone station to isolate the problems. Both anomalies were eventually cleared in March.

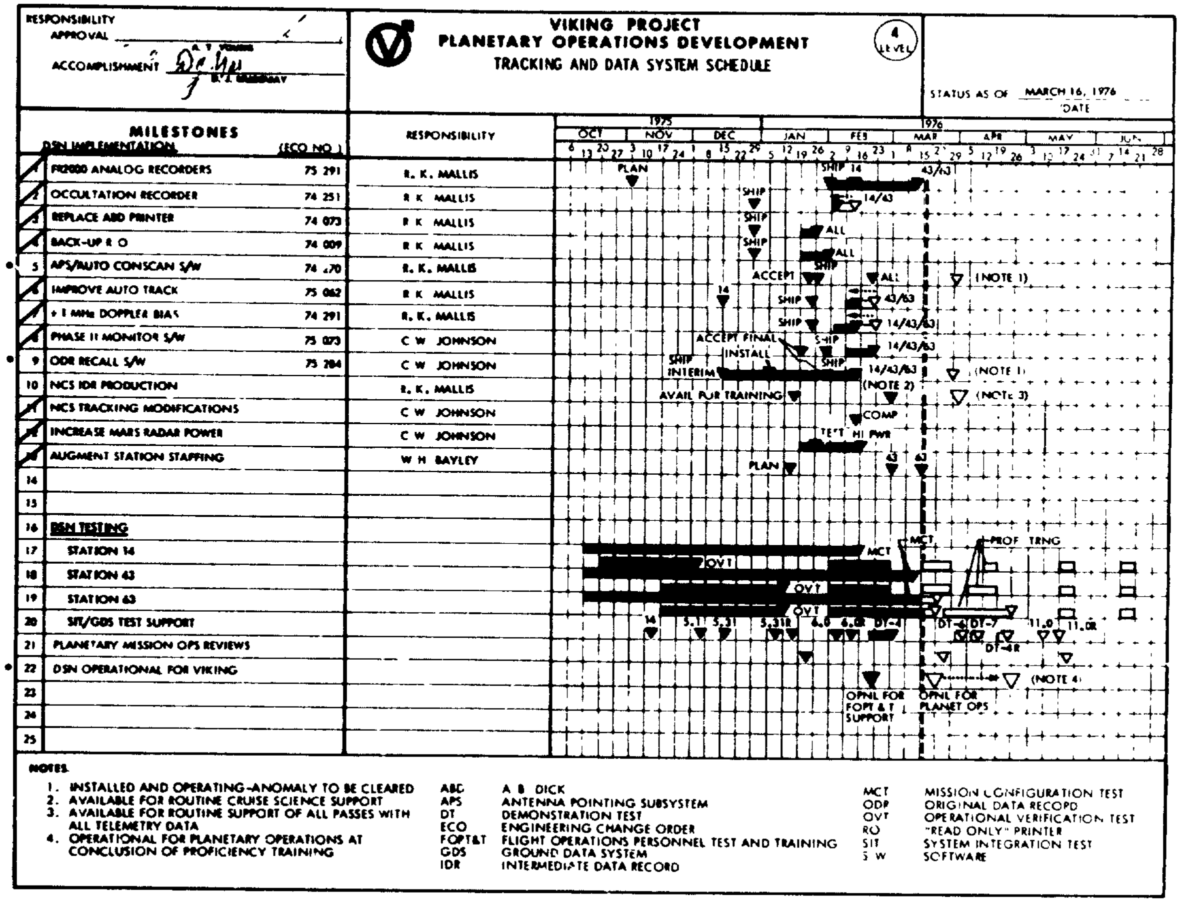


Fig. 53. Viking Project planetary operations development: Tracking and Data System schedule level 4 as of March 1976

The 400-kW klystron in the high-power transmitter at Goldstone developed a short circuit in its filament assembly in mid-February. The high-power transmitter was required by the Project for use in the event of a malfunction or mishap during landing that might preclude commanding the Viking Lander with the standard 20-kW transmitter because of adverse antenna look angles. A study by the Project eventually satisfied the communications team that the advantages of the 400 kW as compared to the 100 kW were slight, and the following Network recommendation was adopted:

(1) Install one of two existing spare 100-kW tubes for use during the mission if the need arises.

(2) Repair the 400-kW tube and hold as backup for some unforeseen contingency.

The 100-kW installation was made on March 22.

The three Ampex FR 2000 analog machines, which had been rapidly assembled and checked out to meet the sudden new requirements for replay of Analog Original Data Records in October, were shipped on schedule and installed in the stations at Goldstone, Madrid, and Canberra. Goldstone was first on line with good results from a replay of some questionable Orbiter video data at 16 kbps in early March. Following checkout and calibration by the Ampex factory representative and a short period of crew training, the machines at Stations 43 and 63 came on line the week of March 8 as scheduled.

At the end of February, Demonstration Test 4 was supported by Stations 11, 14, 43, 63 over a three-day continuous period. This test afforded the first opportunity to demonstrate the new Intermediate Data Record and recall capability under operational conditions over an extended period of time. Satisfactory records were produced for all passes with an average delivery time of 12.8 hours, well within the 24-hour time limit allotted. By March 1, the Control Center was delivering records on a regular basis for cruise science activity, and it was anticipated that by April 1, with three partly trained crews, this could be expanded to include all Viking mission activity on an operational basis.

Early in March, the Network Operations Control Center began delivering Intermediate Data Records to the Project during Viking Demonstration Test 4. During this period, the Network Operations Control Center operations crews were supported heavily by engineering development personnel.

The Network Operations Control Center was then turned over to the operations staff for more routine operational production of Intermediate Data Records. Troubles became immediately apparent both at the stations and in the Network Operations Control Center. As a consequence, the Network was not ready to support routine operations with the Intermediate Data Records on April 1 as previously committed, and a special task team was established on March 29 to identify and correct the problems.

A deadline for accomplishment of this task was set by the Viking Project for April 26.

Turning first to the station end of the system, four areas of improvement were identified as follows:

(1) Use of highest quality certified tape on 9-track high density digital tape machines.

(2) More rigorous attention to tape recorder alignment and calibration.

(3) Record and playback on the same machines to minimize skew problems.

(4) Use of the new version of the Intermediate Data Record recall software, which provided, among other things, the ability to continue the operating in the "search" mode in the presence of a large number of tape read errors.

With these measures in effect at the stations, an immediate improvement in Intermediate Data Record quality was noted, although reliability in the Network Operations Control Center hardware and software continued to remain poor.

Some statistics of Intermediate Data Record production in the first two weeks following this work is given in Table 29.

At this point, the attention of the task team turned to the Network Operations Control Center itself, particularly the Network Data Processing Terminal and the Network Data Processing Area shown in Figure 54. Specific issues considered essential to completion of an operational capability by April 26 were:

(1) Correct the Intermediate Data Record summary statement of the number of data blocks expected and missed in real time.

(2) Correct the signal level and signal-to-noise ratio statements on the Intermediate Data Record summary.

(3) Provide a correct statement of the recall codes which give the reasons for blocks missed and the type of recall procedures initiated.

(4) Correct several errors in the gap detection logic which gave erroneous number of gaps or garbled messages when particular numbers of gaps were accumulated.

In addition to this work on the software running in the Data Records Processor, it was decided to provide an extra computer and magnetic tape unit in the Network Data Processing Terminal to perform the function of merging the recalled data with the real-time data. This additional "merge" capability permitted the recall and merge activities

Table 29. Intermediate Data Record statistics

Date (April 1976)	Pass	Station	Bit rate, kbps	Blocks received in real time	Blocks missed in real time	Blocks missing after recall	Percent delivered
8	DT-7	43	8/2	23393	Not Available	3	99.9
			8	16160		9	99.9
	DT-7	43	0.250	1118		0	100
			0.250	529		0	100
11	DT-7	43	2/8	23010		6	99.9
			2/8	6923		0	100
			0.250	274		0	100
12	237	63	2	10628		47	99.6
			8	23650		109	99.6
			2	3628		2	None
11	236	63	2	22184		82	99.6
14	219	63	2	9981	101	0	100
15	220	63	2	8716	10	0	100
			2	4798	7	0	100
			8	23755	30	1	99.99
			2	13941	1	0	100
16	221	63	0.5	6714	34	34	99.496
			8	73343	850	92	99.875
17	241	14	8	80895	2	2	99.998
	252	63	8	38092	2034	13	99.96
			0.5	8132	30	30	99.63

Table 29 (contd)

Date (April 1976)	Pass	Station	Bit rate, kbps	Blocks received in real time	Blocks missed in real time	Blocks missing after recall	Percent delivered
20	DT-4R	63	16	19021	91	21	99.89
21	DT-4R	14	8	47775	3250	13	99.98

DT = Demonstration Test.

Blocks received in real time = number of wideband blocks received on Network data log in real time as data are delivered to the Mission Control and Computing Center.
Blocks missing after recall = number of blocks not available after one recall operation from Digital Original Data Record at station.

Blocks recalled = number of blocks recalled from station Digital Original Data Record by Network Operations Control Center recall process working in conjunction with Automatic Total Recall System recall software at station.

Percent delivered = percentage of total blocks on Digital Original Data Record which were delivered on Intermediate Data Record.

to be carried out simultaneously, a capability considered necessary to meet the operational requirements of delivering the Intermediate Data Record within 24 hours after the end of each pass.

The software and hardware additions described above involved two weeks of intensive implementation and testing. Daily status meetings were held to resolve problems and re-allocate priorities and resources. By April 21, all work was completed and had passed through acceptance testing. From this point on, the Network Operations Control Center became subject to the standard Network discrepancy reporting system and all subsequent failures or anomalies would be accounted for in that system.

The following day, April 22, the Network Operations organization was briefed on the capabilities then available in the Network Operations Control Center. It was these capabilities, enhanced to some limited extent as time permitted, that the Network Operations Control Team would use to support Viking planetary operations.

With this capability delivered for operational support, the implementation task for Viking could be considered complete.

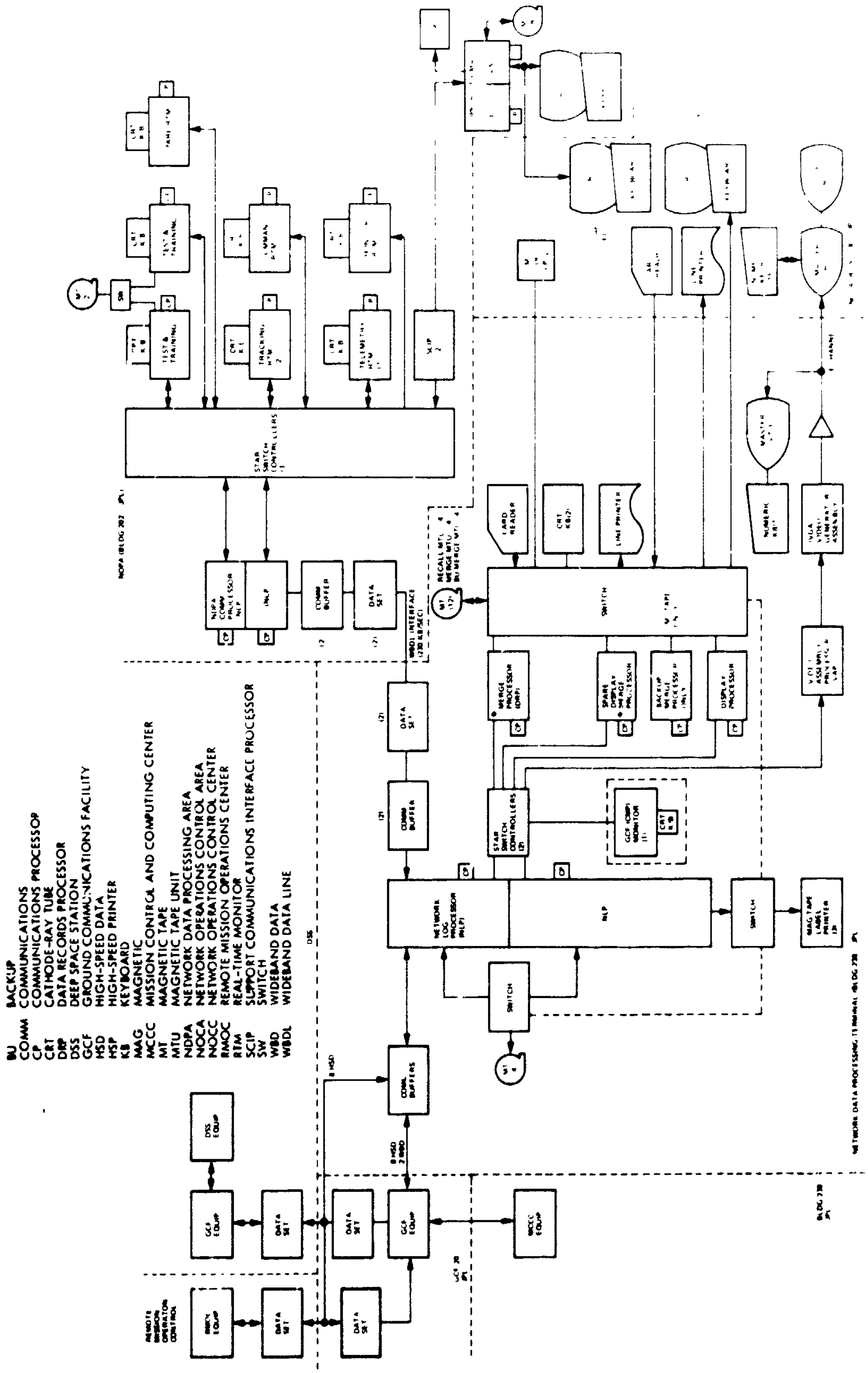


Fig. 54. Network Operations Control Center block diagram, 1976-1977

A number of known problems remained, and some unknown problems were to be expected as the Network configuration for Viking matured with operational use.

Improvements always would be desired or become necessary as the operations teams accumulated experience in the mission environment. These facts were recognized in committing the Network to operational support. To the extent that the exigencies of the Viking mission permitted, these issues were resolved as they arose during the progress of the mission.

c. Test and Training. The test and training program for Viking planetary operations necessarily reflected the changes made in January to the implementation schedule, and was the product of the joint Network/ Viking scheduling group described earlier. A schedule was developed which showed not only Operational Test and Configuration Tests, but the time required for implementation, development, Mars radar experiments, Network operations training, and other significant flight project activities.

The planetary development schedule for February 1976 is shown in Fig. 55. The complexity of the scheduling task is evident from the study of this figure. The schedule was updated and issued monthly with completed milestones as shown. The correlation between line items on the level 4 implementation schedule and milestones on the planetary development schedule is given in the legend on the latter.

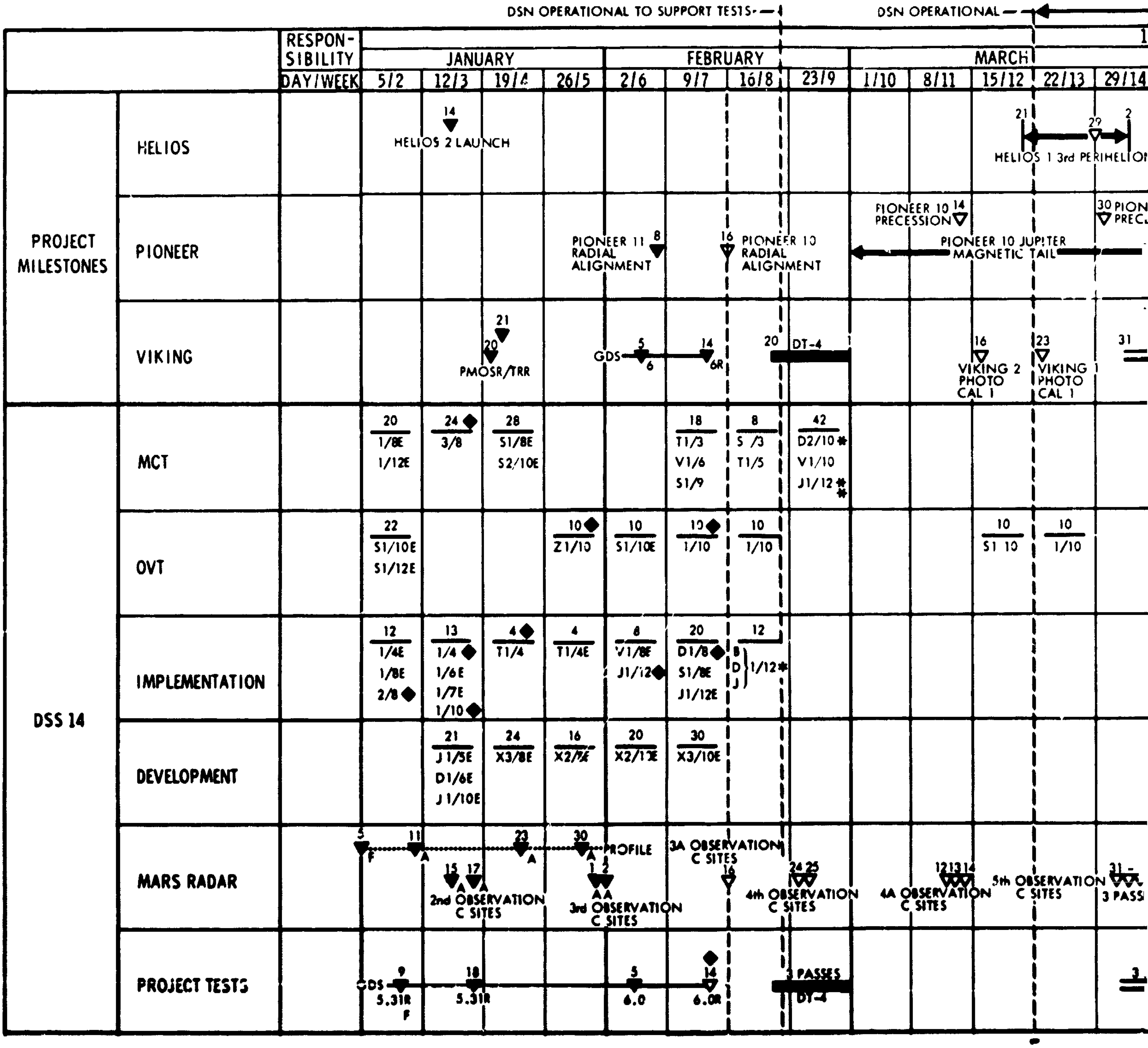
(1) Ground Data System Tests. Tests supported during the months of January, February, March, and April were:

(a) Test 5.31. This test with Goldstone Stations 11 and 14 was run on January 9, and problems were experienced with generation of Digital Original Data Records, and recalls to the Network Operations Center for generating Intermediate Data Records. It was repeated on January 19 with Station 14 only, and most of the objectives were accomplished, including generation of Intermediate Data Records, and demonstration of analog-to-digital data record conversion.

(b) Test 5.32. The test with Australian Station 43 was run on January 22. Despite hardware and operator problems, all test items were completed except for two Intermediate Data Record recall outages. The planetary configuration was demonstrated and no re-run was required.

The test with Spanish Station 63, run on January 24, was characterized by wideband communication circuit problems, both during the test and during the recall sequences. A need for better briefing of the station on test requirements was apparent. System recall problems prevented full data record requirements being met, but a re-run was not required as the telemetry configuration had been demonstrated.

(c) Test 6.0. This test involving all three 64-meter stations was run on February 4, 5, and 6. The first 12 hours of the test with Stations 43/63 were satisfactory. During the last 4 hours of the Madrid pass and most of the Goldstone pass, the Viking simulation system and



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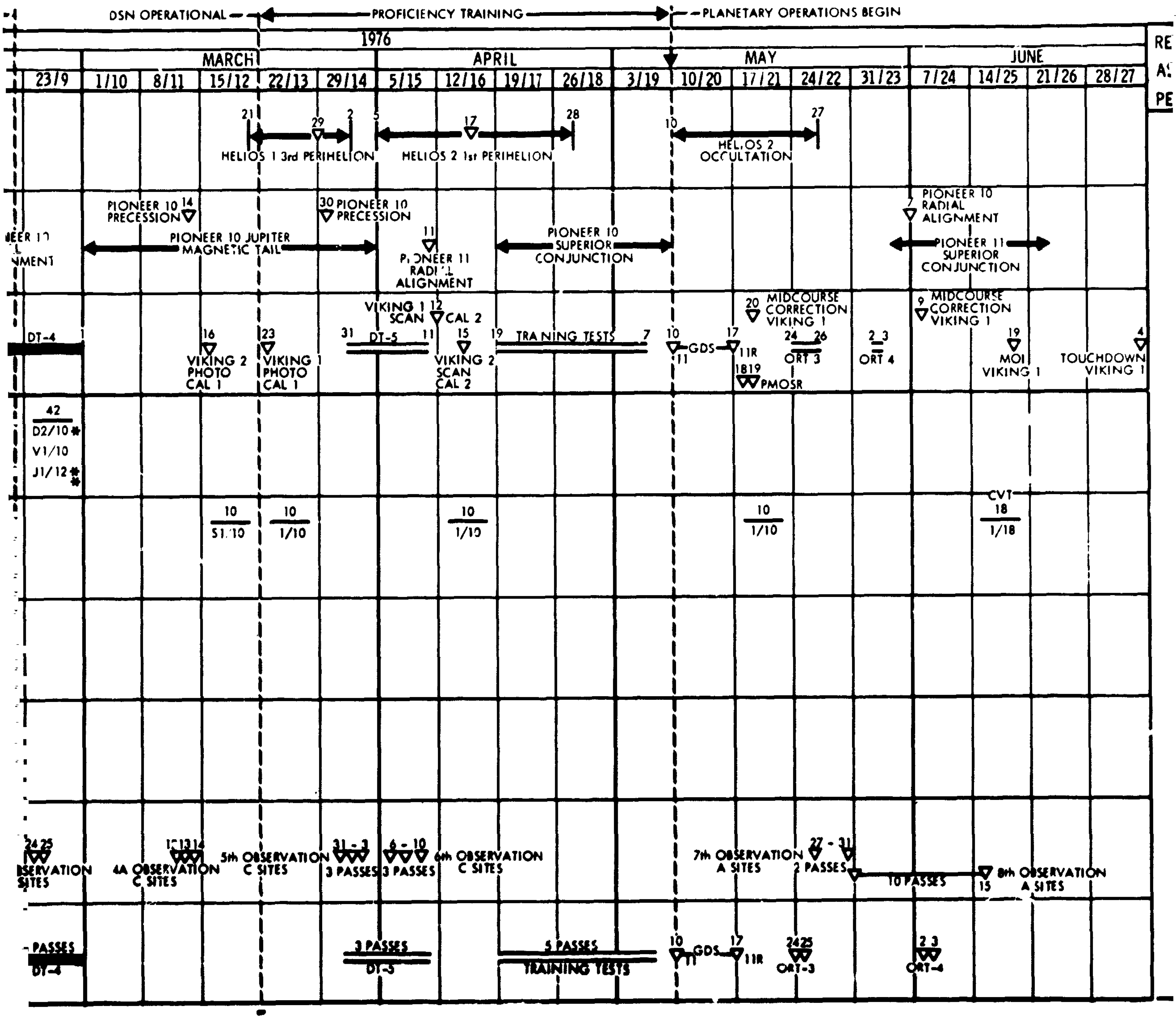

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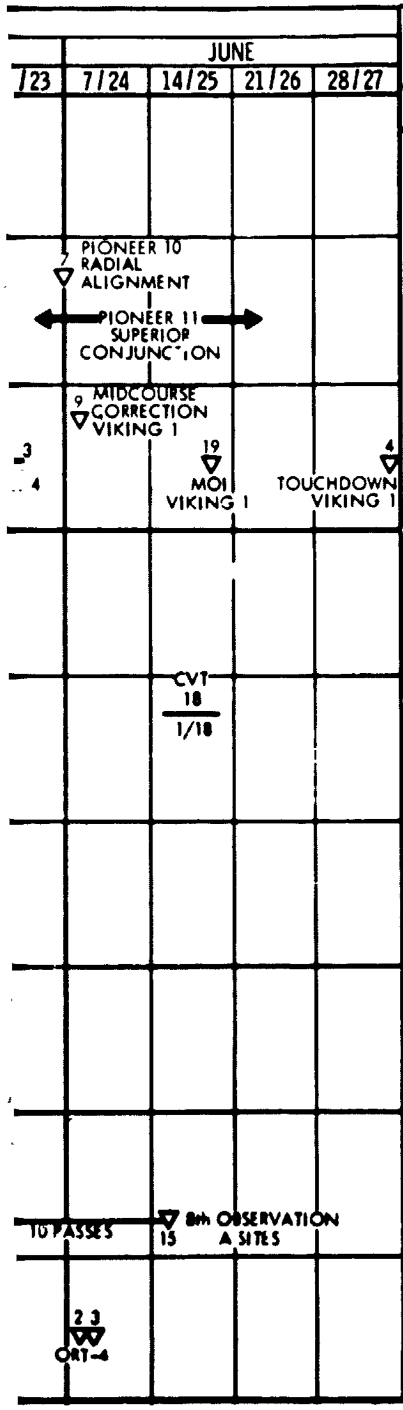

REVISION No: 7

AS OF: 16 FEBRUARY 1976 PACIFIC STANDARD TIME

PERIOD: 5 JANUARY 1976 TO 4 JULY 1976

LEGEND:

8	-	TEST HOURS PER WEEK	
1/8	-	No. TESTS/HOURS PER TEST	
1/8A	-	TESTS RESULTS APPROVED	
E	-	TEST EXECUTED	
F	-	TEST FAILED	
◆	-	CANCELLED	ENGINEERING CHANGE ORDER NUMBER
8 / B1/8	-	1 MEGA HERTZ DOPPLER BIAS	74.291
C	-	A. B. DICK PRINTER	74.073
D	-	DIGITAL INSTRUMENTATION SUBSYSTEM MONITOR	75.073
G	-	DOPPLER STABILITY	
H	-	RANGING STABILITY	
J	-	ANTENNA POINTING SUBSYSTEM/AUTO CONICAL SCANNING	75.062, 74.270
L	-	BACKUP R. O. (TELETYPE)	74.009
S	-	AUTOMATIC TOTAL RECALL SUBSYSTEM III	75.284
T	-	OPEN LOOP RECEIVER/RECORDER	74.251
V	-	FR 2000 RECORDERS	75.291
X	-	X-BAND RADAR	
Z	-	COMBINED OVT WITH CONJOINT DSS 11, 42 OR 61	
N.	-	DATE	
▽N(R)		▽TEST No. (REPEAT)	
TRK	-	TRACKING	
PROD	-	PRODUCTION	
MODS	-	MODIFICATION	
TT	-	TRAINING TESTS	
DT	-	DEMONSTRATION TEST	
MOI	-	MARS ORBIT INSERTION	
GDS	-	GROUND DATA SYSTEM TEST	
NCS	-	NETWORK CONTROL SYSTEM	
IDR	-	INTERMEDIATE DATA RECORD	
ORT	-	OPERATIONAL READINESS TEST	
MCT	-	MISSION CONFIGURATION TEST	
OVT	-	OPERATIONAL VERIFICATION TEST	
CVT	-	CONFIGURATION VERIFICATION TEST	
SIT	-	VMCCC/DSN SYSTEM INTEGRATION TEST	
NOCC	-	NETWORK OPERATIONS CONTROL CENTER	
PMOSR/TRR	-	PLANETARY MISSION OPERATIONS SYSTEM REVIEW/ TRAINING READINESS REVIEW	
*	-	1 DEMO PASS REQUIRED UPON COMPLETION OF MCT	
**	-	3 DEMO PASSES REQUIRED UPON COMPLETION OF MCT	

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DSN OPERATIONAL TO SUPPORT TESTS

		RESPONSIBILITY	JANUARY				FEBRUARY			
		DAY/WEEK	5/2	12/3	19/4	26/5	2/6	9/7	16/8	23/9
DSS 43	MCT		1? 1/10E	13 1/13E	26 G1/8F S1/8 G1/10F 1/10R ◆			8 ◆ T1/8	17 T1/? S1/12	32 J1/12 D2/10
	OVT		10 1/10E	10 ◆ S1/10	10 S1/10E			10 ◆ 1/10	10 1/10	
	IMPLEMENTATION		8 ◆ 1/8	18 ◆ 1/8 1/10	4 L1/4E 1/8 ◆		12 T1/4F V1/8E	20 S1/8E J1/12F	30 D1/7 J1/11 B1/12 *	
	DEVELOPMENT		8 ······ CONSCAN J1/8E			8 J1/8E				
	PROJECT TESTS		SIT	13 R 17 ◆ 5.32	22 5.32 — GDS	1 ◆ 5.32R	5 6.0	14 ◆ 6.0R		2 PASSES DT-4
DSS 63	MCT		14 1/12 ◆ 1/14E	13 1/13E 1/13 ◆	19 S1/9E H1/10RE 2/10 ◆				17 S1/7 S1/10	35 D1/10 D1/12 J1/13
	OVT		10 1/10E 1/10 ◆	10 S1/10E		10 Z1/10E		10 ◆ 1/10	10 1/10	
	IMPLEMENTATION		8 ◆ 1/8	8 ◆ 1/8	4 L1/4E 1/8 ◆		8 V1/8E	20 S1/8E J1/12E	12 B, D, J 1/12 *	
	PROJECT TESTS		7 — SIT	19 R	24 5.32 — GDS	30 ◆ 5.32R	5 6.0	14 6.0R		3 PASSES DT-4
NOCC	NCS IDR PROD									
	NCS TRAK MODS							4 1/4E		

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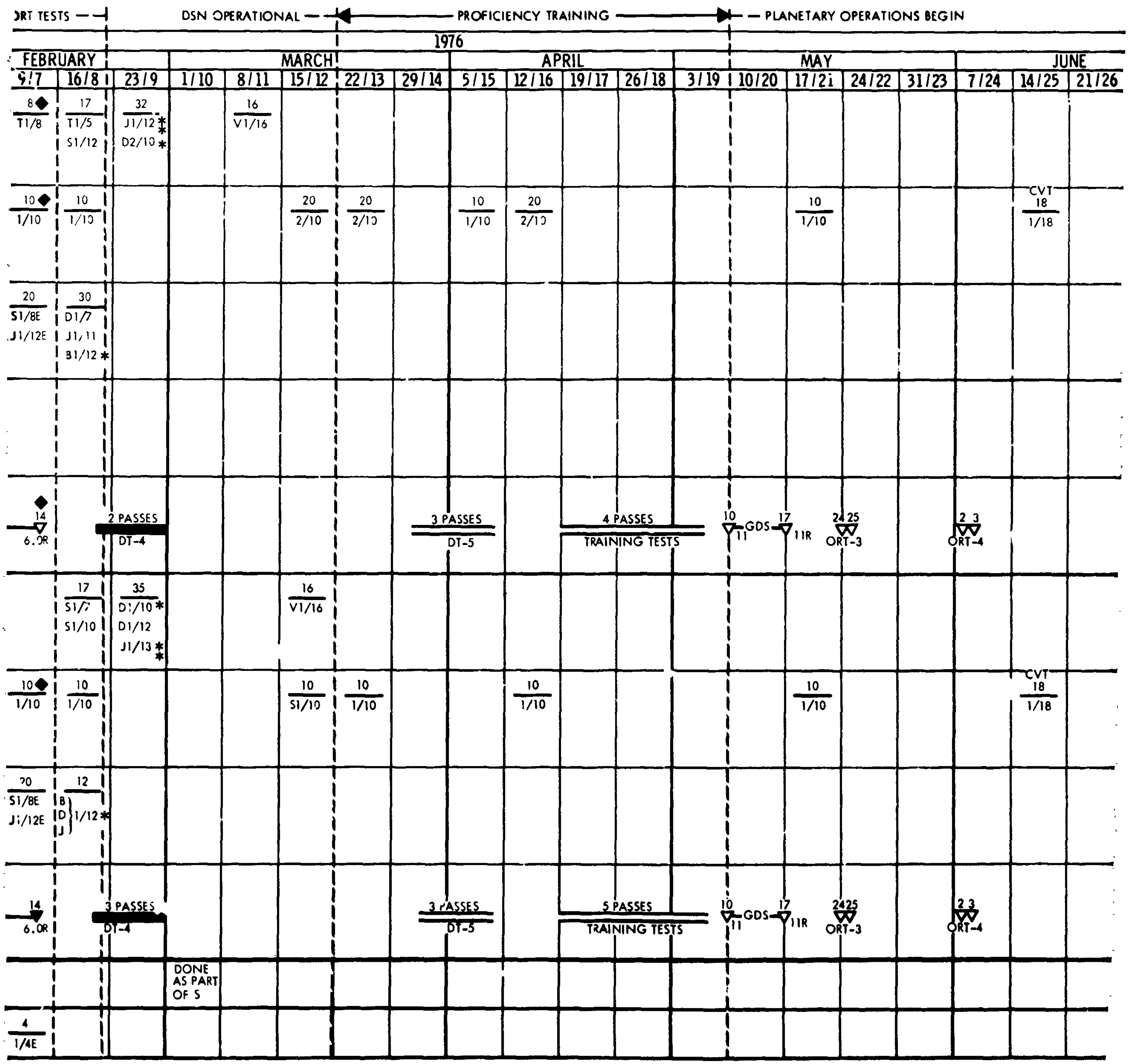

Fig. 55. Network planetary

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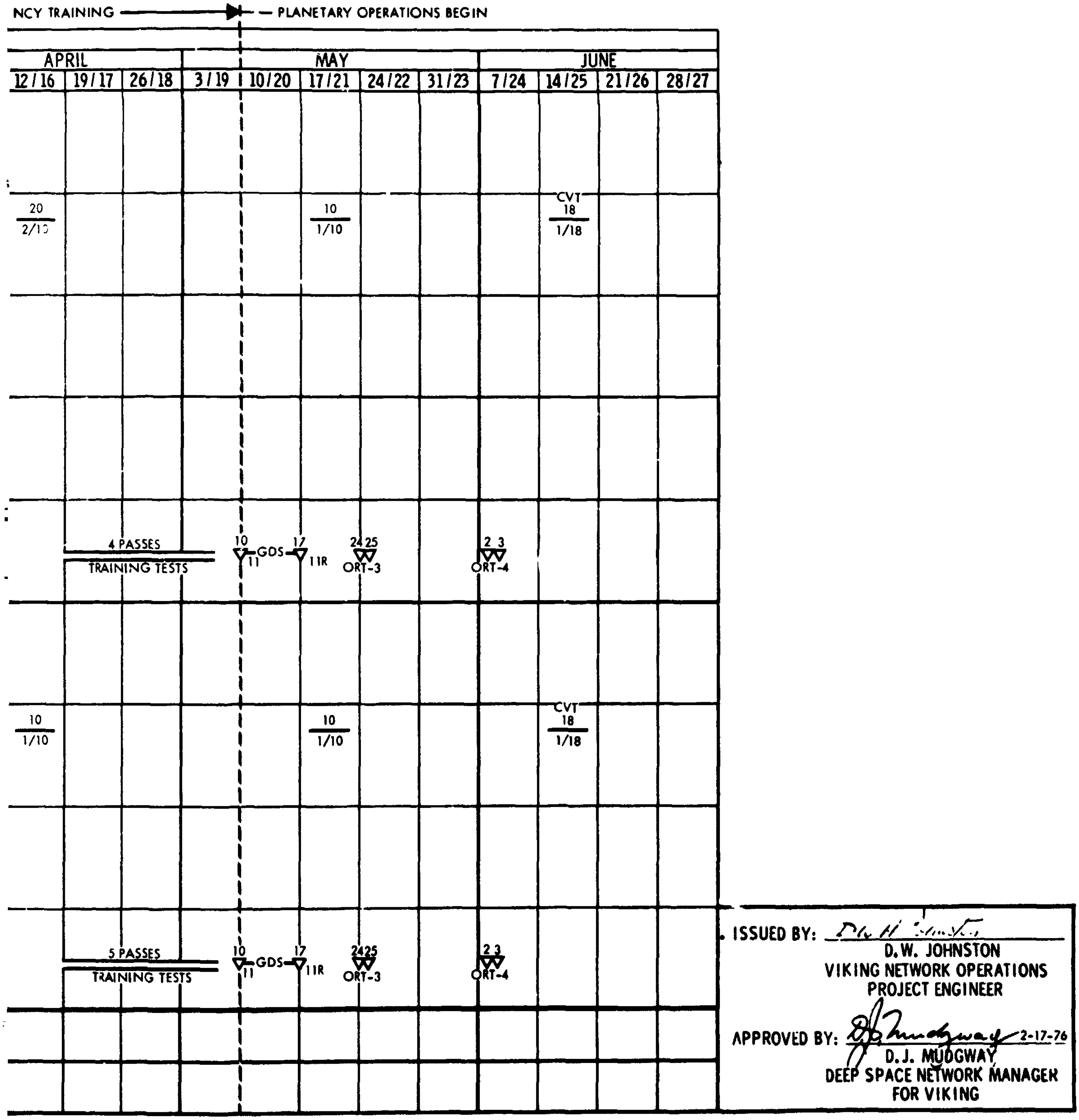


Fig. 55. Network planetary development schedule as of February 1976

FOLDOUT FRAME 3

Viking spacecraft mathematical models overloaded the Mission Control Center computers when 12 simultaneous telemetry data teams were being processed. Very little useful testing resulted. At Goldstone, problems were encountered with the Signal Conditioning Assembly/Simulation interface and a re-run of the last 10 hours of the test was required. The re-run of Test 6.0 was scheduled for February 14, with Madrid Station 63 only and resulted in all objectives being met. Data recalls were accomplished and Intermediate Data Records delivered. However, a day-of-year (188-189) toggling problem occurred during recall of the 8-kbps spacecraft data and was deferred for investigation. No further re-runs were required.

(d) Demonstration Test 4.0. The purpose of the test was to demonstrate the ability of the Viking Flight Team, including the Network to execute flight operations associated with the Viking 1 Orbiter and Lander during the period from Orbiter-Lander separation minus 58 hours to completion of landed operations on the eighth Mars day (Sol 8). The Network participated in a long loop mode for the first three days (February 20, 21, and 22). Apart from a day-of-year toggling problem at Station 63, which was discovered during Original Digital Data Record recall on the second day, no problems of significance were encountered by the Network.

All Intermediate Data Records were delivered on all passes within an average time of 12.8 hours, well within the 24 hours allotted to this function.

Special attention was paid to preparation, and real-time monitoring, of all communication circuits during this test by the Jet Propulsion Laboratory, stations, and NASA Communications personnel. As a result, communication circuit performance was excellent, the only failure being an 18-minute outage on the high-speed circuits in Australia. This was also the first usage of the 48-kbps wideband circuit between the Goddard Space Flight Center and the Jet Propulsion Laboratory, which produced a 99.99 percent throughput for the two days of its use.

(e) Additional Viking Testing. System integration tests were carried out during this period with the Australian and Spanish stations only, since all Goldstone stations had completed their system integration testing with the Mission Control Center in November 1975. The first integration test with the Australian station experienced a number of delays and had to be re-run. Objectives were met on the second attempt. All test objectives set for the integration test with the Spanish stations were accomplished and no retest was necessary.

In addition to the Ground Data System Tests and Integration Tests, an intense program of operational verification testing was also carried out during this period. The Operational Verification Tests were designed to examine the following capabilities in an operational test:

(1) Joint failure mode configurations for both 64- and 26-meter stations.

(2) The automatic total recall system for replaying Original Data Records.

(3) Production of Intermediate Data Records.

(4) Critical Viking command procedures.

(5) A new configuration for wideband data transmission lines.

(6) A new 64-meter configuration employing dual high-speed data lines to provide full redundancy for Viking Lander operations.

Tests to exercise the joint failure mode configurations were completed with all stations in late January 1976.

Because of numerous hardware and software problems, in the complex system for automatic data recall and Intermediate Data Record production, the operator training on this system could not start until about mid-February. During March, an Operational Verification Test for each of the nine tracking stations, together with the Network Operations Control Center, exercised the recall functions by the use of planned data outages. In addition to exercising the new recall software programs, these tests also exercised the 16-kbps analog recall capability using the new Ampex FR 2000 analog recorders at the 64-meter stations.

Later in March, Intermediate Data Records were also produced from some live spacecraft passes. This activity was supported by operations personnel who were in training, but with assistance and advice from the engineering development personnel. However, these live passes involving some 80 Intermediate Data Records were not successful because of hardware and software problems, combined with inadequate training under actual operational conditions. It was this serious deficiency in demonstrable capability to produce Intermediate Data Records that led to the formation of the task team described earlier. As a result, the date for a fully operational system was slipped to April 26 to enable the hardware and software and procedural improvements to be made.

New and improved command procedures were also exercised by every shift at every station during this period to remove two constraints in the command system which had previously been handled by means of procedural "work arounds." These constraints limited the number of manual commands that could be sent to the Viking spacecraft in case of a computer or transmission line failure. These procedures gave the stations the capability to manually recover from an anomalous condition in the station computers and to substantially increase the number of contiguous commands that could be transmitted manually under these conditions.

(6) New Wideband Data Lines. To meet the Viking flight support requirements from the Australian and Spanish stations, a new wideband data channel was activated between the Jet Propulsion Laboratory and the Goddard Space Flight Center in February 1976, using the new RCA domestic satellite. This new wideband service operated at 56 kbps and provided dual 27.6-kbps wideband channels. When first activated, difficulties

were experienced by NASA Communications and the commercial carriers in getting this new capability to meet its specifications. By mid-February these problems were resolved, and Operational Verification Tests were conducted between the overseas stations and the Jet Propulsion Laboratory to verify the proficiency of the station and communication crews in handling this new capability.

(7) Redundant Configuration. To provide full redundancy for the direct Viking Lander data streams during the first 20 Mars days, a new station configuration had been developed. The configuration provided for two data channels to be assigned to Viking engineering and science while the remaining four provided prime and backup channels for Lander engineering and science. Because this was a new configuration that had been requested on the basis of experience obtained during the various mission operations tests conducted in the past few months, it was necessary to exercise station crews in the implementation of this configuration. These tests were carried out in late February and provided a precursor to the Project's demonstration test, which followed at the end of February.

4. Mars Radar

As the Earth-Mars range increased in the first months of 1976, efforts were renewed to increase the Mars radar transmitter to its full 400-kW rated power output. While this work was in progress, Mars radar data-gathering passes continued at all available opportunities as follows:

January:	5, 11, 15, 17, 23, 30
February:	1, 2, 3, 14, 24, 25
March:	12, 13, 14, 30, 31
April:	1, 5, 7, 9, 12, 13

While not all of these passes resulted in good data, they provided multiple opportunities to observe all the C-sites, and the requirements of the Project were satisfied.

In December 1975, the transmitter had been run up to the 300-kW level, and additional testing had been delayed because of failures in the traveling-wave tube power supply, need for minor redesign in the crow bar protective circuits, and a high-voltage transformer rectifier problem. In January, this had been corrected, and the power level increased to 300 kW. A body current problem was then discovered in one of the klystrons, and, after further investigation and testing, the 400-kW level was reported available on February 16. From that time on, all Mars radar tracks were conducted at full-power output.

Late in March a calibration of the Mars ephemeris was carried out in order to verify the C-site altitude data received up to that time. The area of Syrtis Major was used for this purpose because data from earlier observations were available for comparison. The calibration enabled the drift in the ephemeris predictions to be corrected, which resulted in valid altitude data being obtained.

By the end of April, the level of the signal returns from the planet had fallen to less than one-eightieth of their value during the closest approach observations in December 1975. As a consequence, the range gated spectrum technique used up to this point produced data that were too noisy for practical use. The use of continuous spectrum observations from this point on resulted in data with less noise, but also with less surface resolutions than those obtained by the range gated spectrum measurements used earlier.

However, the Mars radar observations continued to provide the Project with useful information relative to the "C" landing sites, and the observations were continued through the succeeding months.

5. Radio Science

In early October 1976, the orientation of the orbit of Orbiter 1 with respect to Mars and the Earth was such that the Orbiter would pass behind the planet, as viewed from the Earth, during a portion of its orbit. The spacecraft signals would be gradually cut off, or occulted, by the surface of Mars. In the occultation experiment, the variations in the signal properties (frequency, phase, and amplitude) as the spacecraft enters or emerges from occultation could be used to infer atmospheric and ionospheric properties, as listed earlier. On Orbiter 1, occultations would continue until early December, and the occultation points, or locations where the target rays graze the surface at occultation, would be distributed at various locations on the planet so that the atmospheric and ionospheric properties would be determined globally. By measurement of the exact time of signal cutoff or re-establishment, occultation measurements could also produce precise radii of the planet at the occultation points. There would be no occultations of Orbiter 2 during the Viking primary mission, but such occultations would start in January 1977.

An occultation open-loop system demonstration test was supported at Station 14 at Goldstone on March 16, 1976 during Viking 1 pass 210. System calibration and recording of spacecraft S/X-band signals was accomplished by the station with minor adjustments made to accommodate actual signal conditions.

Two analog recordings of two- and one-way signal spectrums were produced on the occultation recorders at 152.4 centimeters (60 inches) per second covering a period of 30 minutes. Monitoring of recorded data at random intervals indicated no significant degradation of baseband signal-to-noise margins during the recording process. Actual signal levels during the test were -135 dBm for S-band and -143 dBm for X-band.

The occultation test tapes were sent by the station through normal means to Compatibility Test Area 21 for digitizing and further analysis.

6. Operational Reliability

In Section IV-A of this report, Network operational reliability data accumulated by the Viking Project, as part of its overall study of Ground Data System reliability, were given. The previous data covered the period from launch through December 31, 1975, and with certain qualifications tended to show that the mean time between failures for the 26-meter stations was somewhat higher than that for the 64-meter stations.

In Table 30 the data are extended out to Day of Year 122 (April 30, 1976).

Table 30. Operational reliability for Viking support from August 1975 through April 30, 1976

Operational performance	Station								
	11	12	14	42	43	44	61	62	63
Total support time, hours	1036	1373	708	1442	770	1155	1392	1699	1243
Number of failures	15	20	31	17	32	15	13	22	30
Mean recovery time, minutes	90	27	53	75	84	99	95	36	72
Mean time between failures, hours	69	69	23	85	24	77	107	77	41

Again, these data generally reflect a larger value for mean time between failures for the 26-meter stations as compared to the 64-meter stations. Also apparent is a dramatic improvement in the mean time between failures for Cebreros Station 62, reflecting a large increase in the tracking hours with a comparatively small increase in the number of failures.

Up to this point in the mission, and recognizing the limited data accumulated, the state of continuous change prevailing at some of the stations as the planetary configuration was completed, and the varying levels of operator proficiency, it can only be concluded that:

(a) The mean time between failures for the 26-meter stations appears to be higher than for the 64-meter stations.

(b) Values observed for the 26-meter stations range between 69 and 107 hours.

(c) Values observed for the 64-meter stations range between 23 and 40 hours.

Additional data accumulated as the mission progressed are reported in subsequent sections of this report.

C. CRUISE SUPPORT (MAY THROUGH JULY 1976)

1. Mission Events

Spacecraft activity was light during the early weeks of May as the Flight Team involved itself in Training Test 3, a simulation of the preseparation through landing phase. A Ground Data System test was scheduled to begin on May 9, and was to be followed by the last of the training tests. Rescheduled from an earlier time frame, Training Test 4 was a simulation of the orbit insertion events with a malfunction problem introduced as part of the training program. By mid-May all testing activities had been completed with the exception of the final Operational Readiness Test scheduled for early June as a final full-dress rehearsal for the Viking 1 Mars orbit insertion.

During this period, both Viking spacecraft continued to operate well and to perform as expected on their flights to Mars. Round-trip communication time between Earth and the spacecraft had increased to 28 minutes and 18 seconds for Viking 1 and 27 minutes and 38 seconds for Viking 2 by the first week in May.

On May 1, photo calibrations were conducted on Viking 1. Camera A was used to record the photo sequence using Mars as the calibration target. The planet offered little more than a partial disk of light at this great distance--11.2 million kilometers (7 million miles)--but the slight amount of lightening at the left side of the terminator was identified as the fringe of the south polar hood. Figure 56 shows the planet as it appeared in this photo sequence.

An occultation demonstration was conducted on May 12, using spacecraft data to test ground equipment and software peculiar to the requirements of a Mars occultation experiment. This kind of experiment would occur as the spacecraft approached the limb and went behind the planet or as it emerged from behind the planet, and provided an opportunity to conduct radio science investigations of the Mars atmosphere and ionosphere.

The one remaining test exercise prior to Viking 1 Mars orbit insertion, the Operational Readiness Test, was conducted on June 2 and 3. Appropriately, the Operational Readiness Test was the last full-dress simulation of the Viking 1 orbit insertion activity. The latest spacecraft data were used as a baseline for the exercise to make it as similar as possible to the actual Viking 1 Mars orbit insertion events.

Fig. 56 Mars as photographed by Viking 1 from distance of 11.2 million kilometers (7 million miles)

Viking 2 continued to perform as expected, and by June 14 was 5.2 million kilometers (3.3 million miles) from Mars and 53 days away from its orbit insertion scheduled for August 7.

At that time, Viking 1 was within 1.6 million kilometers (730,000 miles) of Mars. Approach observations had begun, when the spacecraft gave indications of a minute leak in the helium pressurization system for the oxidizer and fuel tanks of the Orbiter propulsion system. With the Viking 1 spacecraft only five days away from orbit insertion on June 19 and under careful monitoring, orbit insertion activities were replanned. Because the leak was first detected as the propulsion system was being prepared for the final course correction maneuver on June 9, the engine burn was delayed to the following morning. The maneuver called for a longer burn than originally planned since it was believed that the leak might be caused by a tiny particle trapped in the regulator valve, and this particle might be flushed out by the increased helium flow during a longer engine burn. However, the maneuver did not resolve the leak problem although the leak rate was somewhat reduced.

An additional single course correction maneuver prior to orbit insertion was then planned for June 15. The objectives were essentially the same as the first approach maneuver. Because of these additional maneuvers, the orbit insertion of Viking 1 was re-designed for an initial Mars orbit period of 42.6 hours instead of the originally planned 24.6 hours. While the orbital statistics were being redefined with consideration for the factors of site certification and orbit synchronization, considerable activity on approach photography was underway. In these pictures, Mars appeared to be growing rapidly as Viking 1 closed to the orbit insertion point. Surface features were becoming visible with increasing detail, and, in the high contrast version shown in Fig. 57, the details of the 4000-kilometer (2500-mile) long Martian grand canyon, Valles Marineris, could be seen southeast of the middle volcanoes.

Engine ignition for the Mars orbit insertion burn occurred on schedule at 3:38 p.m., Pacific Daylight Time (PDT). Engine shutdown was confirmed at 4:16 p.m. (PDT), and it was quickly noted that the burn had ended 10 seconds earlier than predicted. The spacecraft was then "unwound" through a reversal of the pre-Mars orbit insertion roll-yaw-roll maneuvers (Fig. 58). The high-gain antenna was again repositioned, and Viking Mars orbit insertion was essentially concluded at 5:23 p.m. (PDT).

The accuracy of the orbit insertion burn was extremely important to the planning and accuracy of the Mars orbit to which the spacecraft was to be trimmed after only one full revolution. The nominal insertion orbit would have been 1500 kilometers at its periapsis (low point) and 50,600 kilometers at its apoapsis (high point). The spacecraft revolution period on this orbit was designed to be 42.6 hours. Orbital geometry for insertion and mission orbits is illustrated in Fig. 59.

After close analysis of the radio metric data following orbit insertion, it was determined that the orbital period was only 12 minutes short of the planned period of 42.4 hours, well within the 99 percent

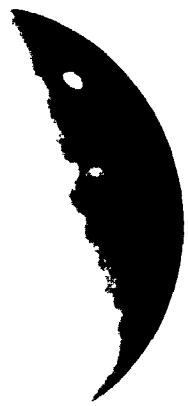


Fig. 57. Mars surface features become more visible near orbit insertion

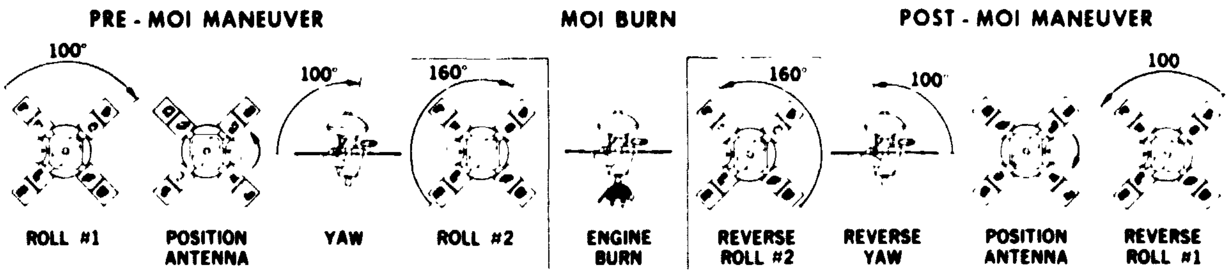
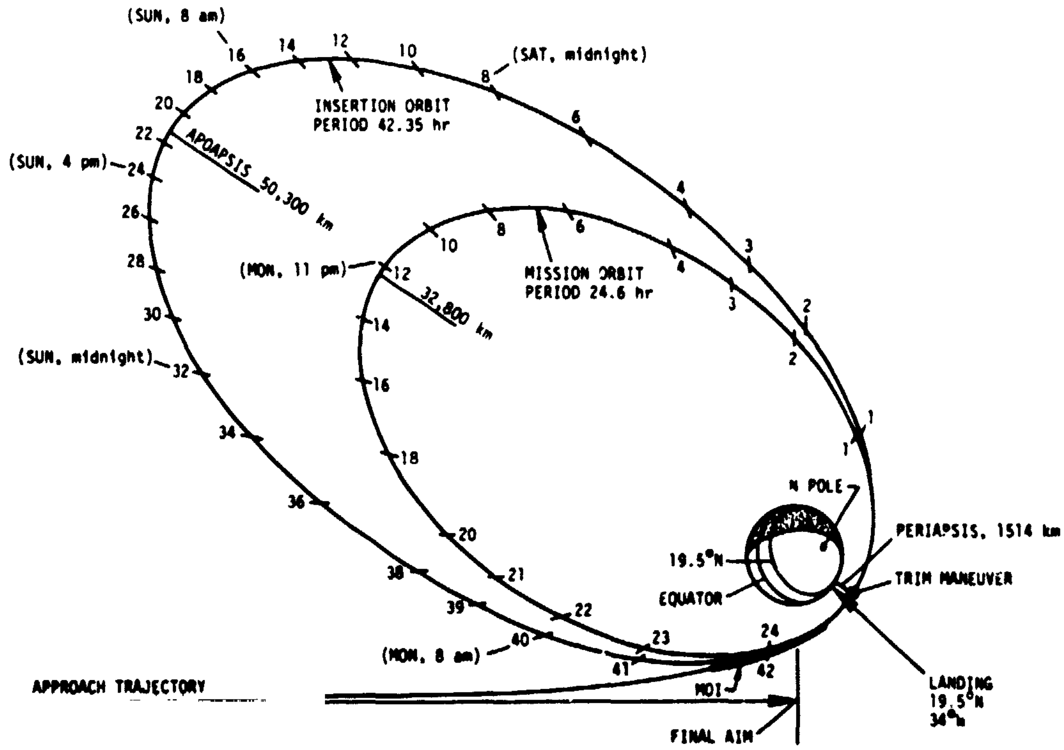


Fig. 58. Roll-yaw-roll maneuver pre- and post-mission orbit insertion (MOI)



NOTE: TIMES INDICATED FOR MISSION EVENTS HAVE BEEN TRANSLATED TO EARTH-RECEIVED TIMES (PDT) – REAL TIME FOR THE EVENTS IS 18 MINUTES EARLIER AT MARS, REQUIRING THAT AMOUNT OF TIME FOR TRANSMISSION TO EARTH AT THE SPEED OF LIGHT. TICK MARKS INDICATE SPACECRAFT FLIGHT HOURS WITH PERIAPSIS AS ZERO POINT.

Fig. 59. Orbital geometry for insertion and mission orbits

tolerance allowed. The periapsis, which was initially predicted to be 1511 kilometers, was only 3 kilometers higher at 1514 kilometers.

The orbital trim maneuver was successfully performed at 10:44 a.m. (PDT), June 21. It required an 80-meter-per-second burn lasting 132 seconds, and consumed a third of the remaining 212 kilograms (425 pounds) of propellant. During this maneuver, the apoapsis was reduced from its insertion orbit altitude of 50,300 kilometers (31,255 miles) to the mission altitude of 32,800 kilometers (20,381 miles), with the periapsis remaining unchanged at 1514 kilometers (941 miles). Once the trim was completed, Viking 1 was in a 24.6-hour (length of Martian day) orbit that would pass the spacecraft over the Viking 1 prime landing site in Chryse. The landing site would then be viewed on each subsequent revolution near its lowest altitude. The first landing site certification pictures were taken on June 22 for transmission back to Earth late that afternoon.

With the completion of orbit insertion and trim, the cruise period for Viking 1 had been passed. In the following days, the critical decisions on selection of the actual landing site, using the Goldstone radar data and site certification pictures, were to be made to set the stage for the actual landing on July 4.

Dramatic surprises were discovered in the first pictures (Figs. 60 and 61) taken during the site certification activities in late June. A photo of the crater Yuty (Fig. 60) in the region known as Chryse showed clear evidence of fluvial action on the planet surface. Yuty is 18.7 kilometers (11 miles) across, and the ejecta flows produced by the impact of the meteorite are layers of broken rock and other debris. The leading edge forms a ridge as on the flows of great avalanches on Earth. Wind erosion has worn the area down, and water erosion may have been responsible for some of the features. Viking 1 was at a range of 1925 kilometers (1196 miles) when this picture was taken.

The cause of the river-like channel features in Chryse seems all but fully answered by the pictures (Fig. 61) taken during Viking 1's first two high-resolution passes over the region.

The current flow appears to have been northerly and quite strong enough to erode grooves and layers from the large island-like and crater features resisting in its path. Along the edge of the main channels, smaller eddy channels can also be seen--again suggesting a strong fluvial current. Figure 61 contains six frames acquired during the P4 reconnaissance of the A-1 landing site area.

Photos of the original A-1 site had led to a growing concern about the unexpected variety of terrain features in the preselected A-1 landing site and prompted the decision to delay the landing of Viking 1 for further evaluation and study of possible landing sites. The site certification team chose to broaden its knowledge by examining other possible sites in order to better understand Martian geological shaping processes and their surface dispersion and to determine the relative safety of those sites in comparison to site A-1. This expanded study necessitated a landing delay of at least a week and possibly

Fig. 60. Mars crater Yuty shown from distance of 1925 kilometer• (1196 miles)

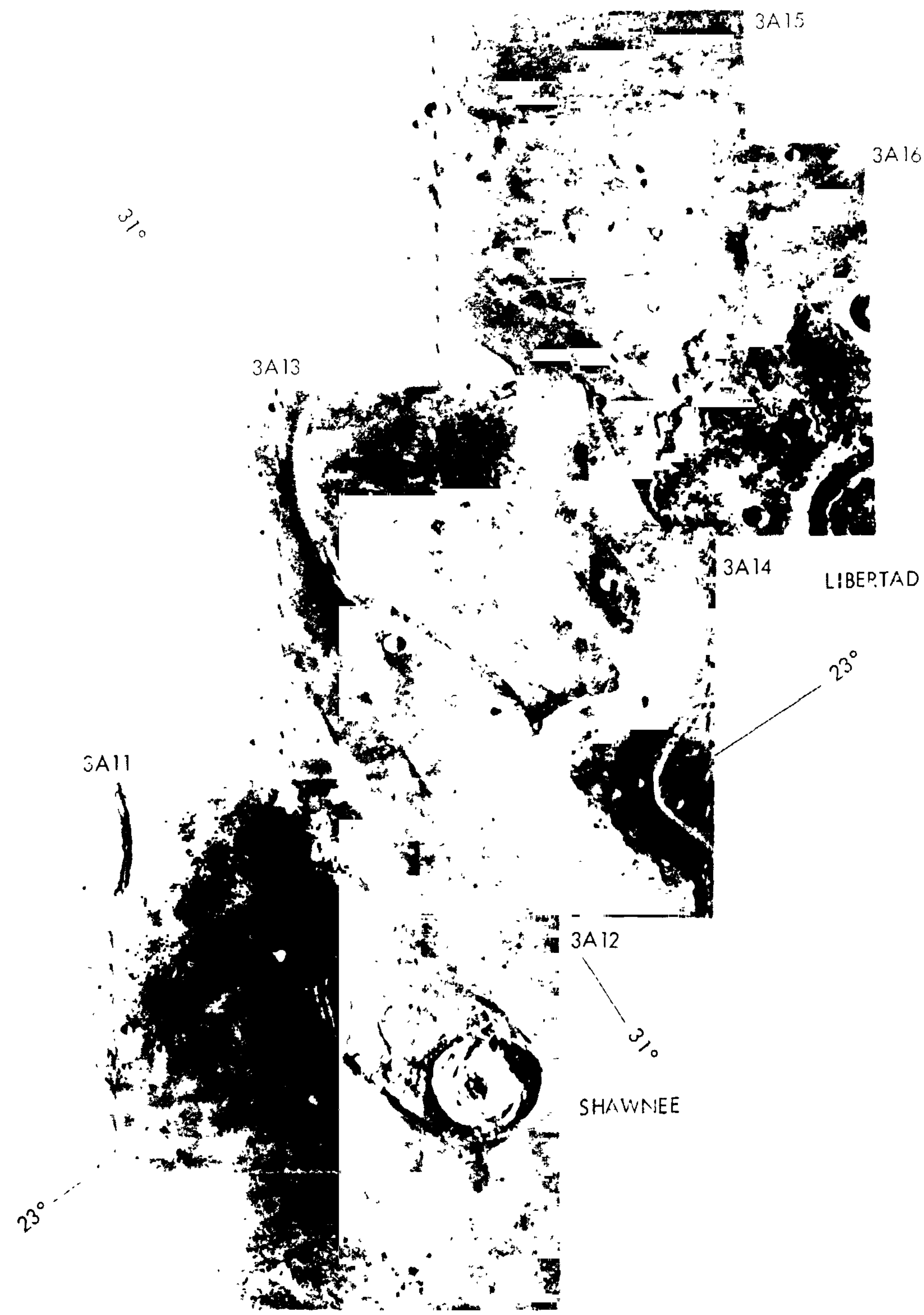


Fig. 61. Photos taken in first two high-resolution passes by Viking over Chryse region of Mars

as much as two and a half weeks beyond July 4. Meanwhile, spacecraft 1 and spacecraft 2 both continued to perform perfectly.

The initial part of the decision included a plan to look carefully at an area adjacent to the A-1 site and closer to the central basin of Chryse. This area may have contained sediments deposited from the highlands through the channels shown in Fig. 61.

Evaluation of the A-1 site continued with observations of the Chryse Basin on June 27 and 29. Both sequences returned pictures to Earth for further study. In addition to the reconnaissance of the Chryse Basin adjacent to the A-1 site, observations were being made of the B-1 site, the primary landing site for Viking 2, and C-1, an alternate candidate for the Viking 2 spacecraft and the subject of the Goldstone radar studies earlier in the year.

By July 1, preparations were being made to move the Viking spacecraft into a new orbit synchronized for a new site northwest of A-1. However, radar data acquired from Arecibo during the scan of the A-1 northwest area on July 4 and 5 indicated that there was roughness adjacent to, if not actually in, the A-1 northwest target landing ellipse. The same radar observations showed the western part of Chryse Planitia to be smooth over a large area. Hence, the decision was made to plan the trim maneuver and possible landing for that region. Should the orbiter photo data prove it to be unsatisfactory, the A-1 northwest area would again become a strong and likely candidate for the actual landing.

A trim maneuver was to be performed on Thursday, July 8, to rotate the spacecraft's orbital path to a point approximately 23 degrees north latitude and 51 degrees west longitude, at which point another engine burn would synchronize the spacecraft orbit with the selected landing point once again. The Viking timeline, on which all mission activities were based with the option to return to the original A-1 northwest area, is given below:

July 8	Begin orbital trim maneuver to 51°W; burn completed 5:58 p.m. (PDT)
July 9	Reconnaissance, 46°-50°W
July 11	Reconnaissance, 50°-56°W
July 14	Far west vs northwest decision, far west option
July 16	Trim maneuver, sync at 51°W
July 20	Land approximately 5:00 a.m. (PDT)
or	
July 14	Far west vs northwest decision, northwest option

July 16 Begin orbital trim maneuver to 44°W

July 22 Land approximately 12:00 noon (PDT)

Meanwhile, Viking 2 continued to approach the planet and had begun to take optical navigation photos of Mars against its star background in order to precisely plot the spacecraft's approach to the planet. Mars orbit insertion for Viking 2 was still planned for August 7, with the landing on September 4.

Following the decision to move the spacecraft west to observe, and possibly land at, a site beyond the A-1 northwest reconnaissance region, the engine was burned and the spacecraft started towards the new orbit at a rate of 2 degrees per day.

The western area of Chryse was photographed during Periapsides 20 and 22. An area was found in the eastern sector of the Periapsis 20 photo coverage which accommodated the 99 percent landing ellipse with a minimum of hazard associations. This site, though near the channel depositional area, was free of fluvial features and appeared much like lunar mare terrain. Because the site was near the central basin, the possibility of finding water was still greater. The landing site at 22.4 degrees north, 47.5 degrees west, with an elevation 2.5 kilometers below the mean Mars surface level is photo-mapped in Fig. 62.

Once the decision to land had been made, the necessary planning rapidly followed.

The flight plan summary covering separation, descent, touchdown, and the first direct link is shown in Figs. 63 and 64 as it was used during the actual events on Day 202, Tuesday, July 20, and Day 203, Wednesday, July 21. The critical decision to go "for separation" was made at approximately 10:30 p.m. (PDT) on Monday night, July 19, and the format documentation of that most significant event is shown in Fig. 65. That decision was based on the Separation Go Reports from the various Directorates. The Mission Control Directorate Report, describing the Viking Mission Control and Computing Center and Deep Space Network status for the Ground Data System, is shown in Fig. 66. Reports from the Spacecraft Performance and Flight Path Analysis Directorate and from the Science and Mission Planning Directorate were equally favorable, and the Project Manager signed the release for the separation event.

The sequence of events that followed separation is shown pictorially in Fig. 67, beginning at Lander separation and de-orbit and ending with terminal descent and touchdown. The Viking 1 timeline for these events is shown in terms of Pacific Daylight Time for Pasadena, California, in Table 31.

Once the separation and descent sequences had been initiated, all events occurred precisely as planned and touchdown was reported at approximately 5:12 a.m. (PDT), Tuesday, July 20, close to the target landing site, 22.4 degrees north latitude, 47.5 degrees west longitude. The entry and landing sequences were virtually perfect, and the accuracy of the event was so precise that the landing occurred within +17 seconds

Fig. 62. Photomapping march across Chryse landing site

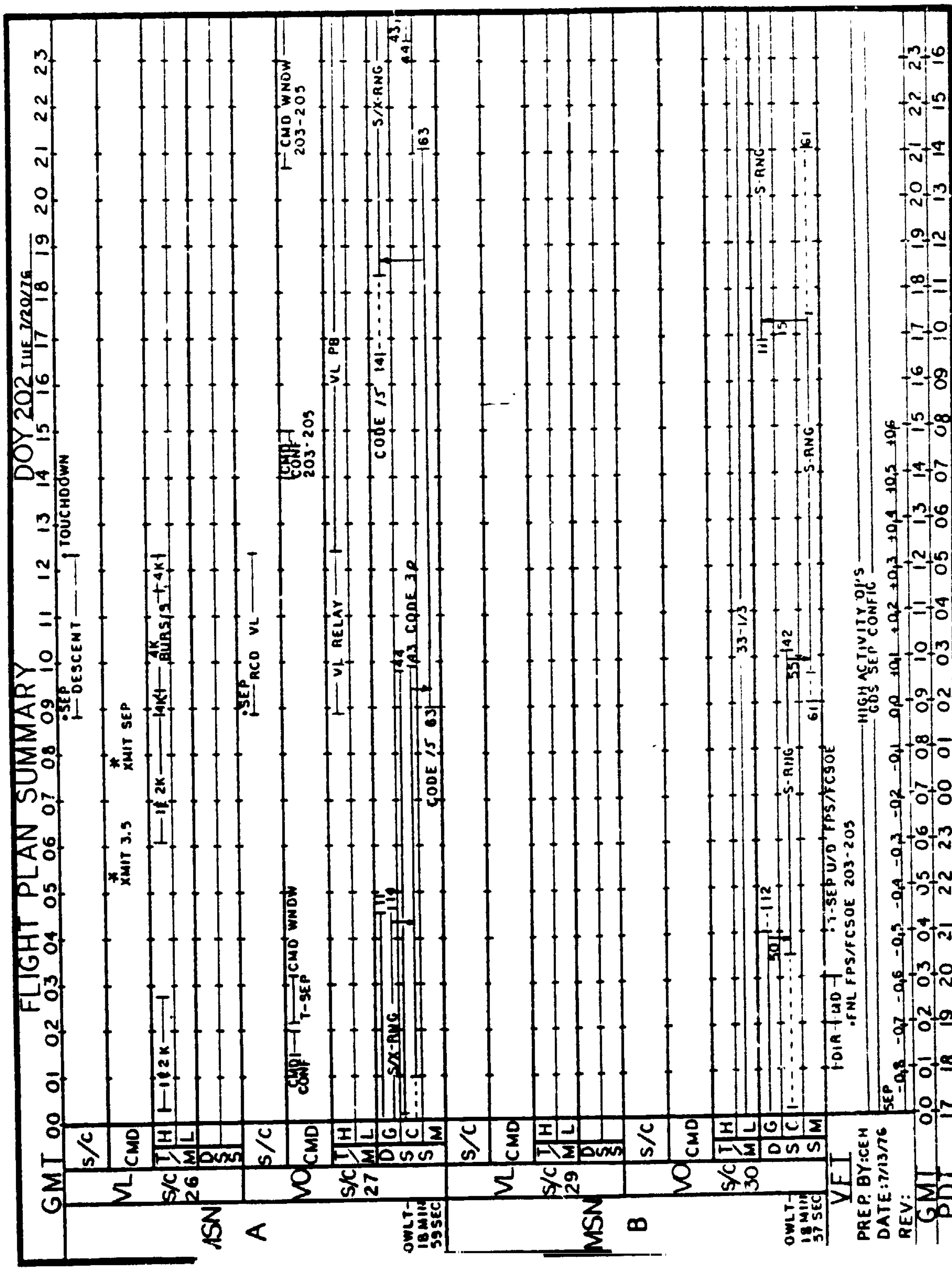


Fig. 63. Flight plan summary for July 20, 1976

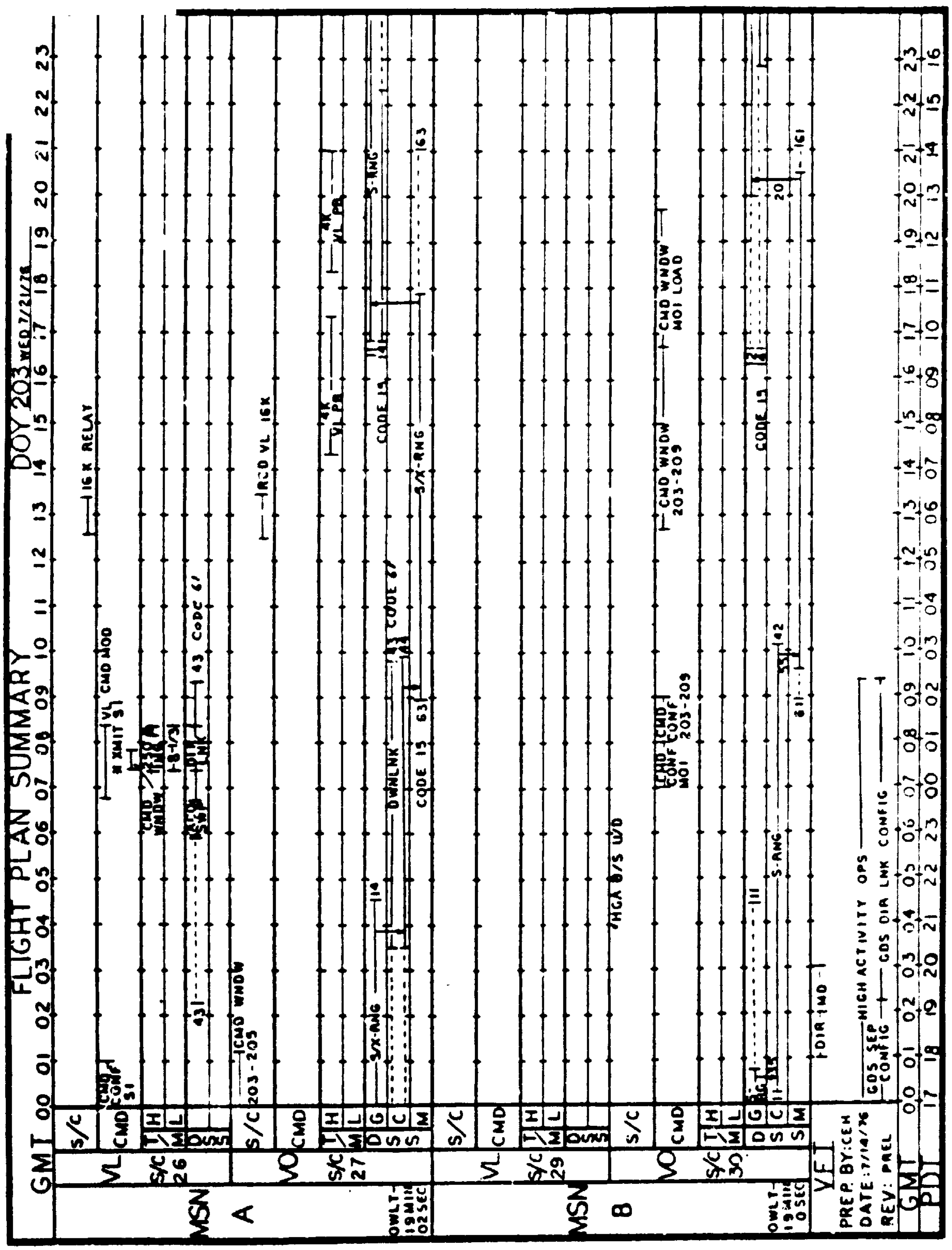
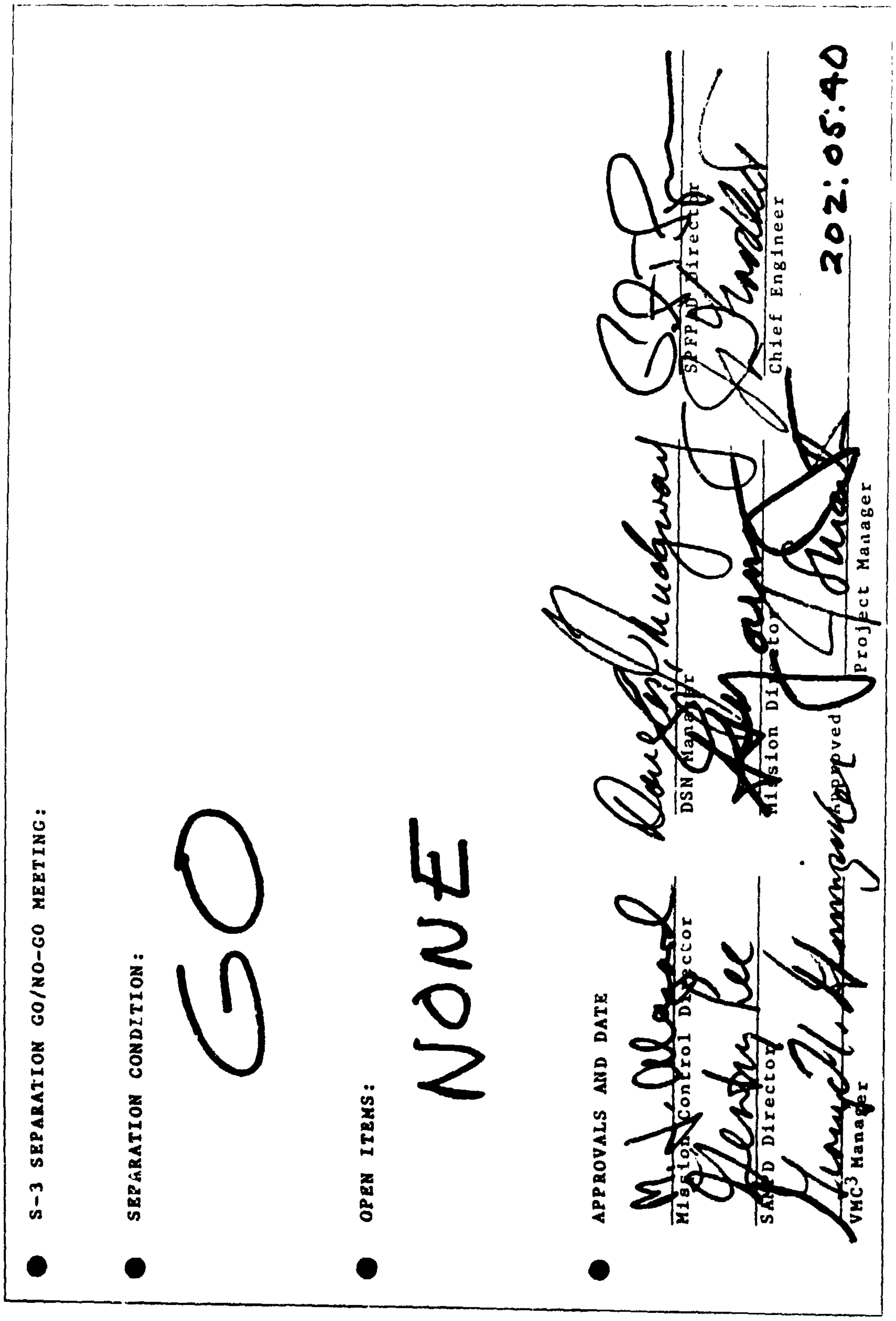


Fig. 64. Flight plan summary for July 21, 1976



- S-3 SEPARATION GO/NO-GO MEETING:
- SEPARATION CONDITION:

  GO

- OPEN ITEMS:

  NONE

- APPROVALS AND DATE

Mission Control Director	DSN Manager
SA[illegible]D Director	SFPP[illegible]D Director
Mission Director	Chief Engineer
VMC^3 Manager	
Approved	Project Manager

202:05:40

Fig. 65. Copy of separation "GO" decision

MISSION CONTROL DIRECTORATE
SEPARATION GO/NO GO REPORT
(S-2 HOURS)

1. VMCCC

a. Capable of receiving, processing and displaying VL data on DTV and/or printers from S-3 hours to Touchdown.

[X] MTCF [X] MCCF [X] GPCF

b. VMCCC Problems existing at S-3 hours:

NONE

1108A has 4 out of 5 Fastran equivalents. This is no impact to Separation.

2. DSN

a. The DSN has capability to receive, record, process, and output VL data to JPL from S-3 hours to touchdown from the 64 meter station (s) at:

[ ] DSS 14 [X] DSS 43 SEP-3HRS. TO SEP +1 HR. [X] DSS 63 SEP +10MIN. TO TD + 9HRS.

b. Configuration is code 2 at 43, 15 at 63.

c. The DSN has capability to uplink commands to the VO and VL from S-3 hours to transmission of the "Go" Command from the stations at:

[ ] DSS 11	[ ] DSS 42	[ ] DSS 61
[ ] DSS 12	[X] DSS 43 Prime	[ ] DSS 62
[ ] DSS 14	[X] DSS 44 Backup	[ ] DSS 63

d. DSN problems existing at S-3 hours:

NONE

DSS-14 is testing and working TCP & intermittent halt.
Goddard has verified extra security arrangement.

3. The Mission Control Director has reviewed the System Status and based upon the Ground Data System condition at S-3 hours recommends separation:

[X] GO [ ] NO GO

M. J. Alazard 20:05:05:00
M. J. Alazard
Mission Control Director

Fig. 66. Copy of Mission Control Directorate Separation GO/NO GO Report (separation minus 2 hours)

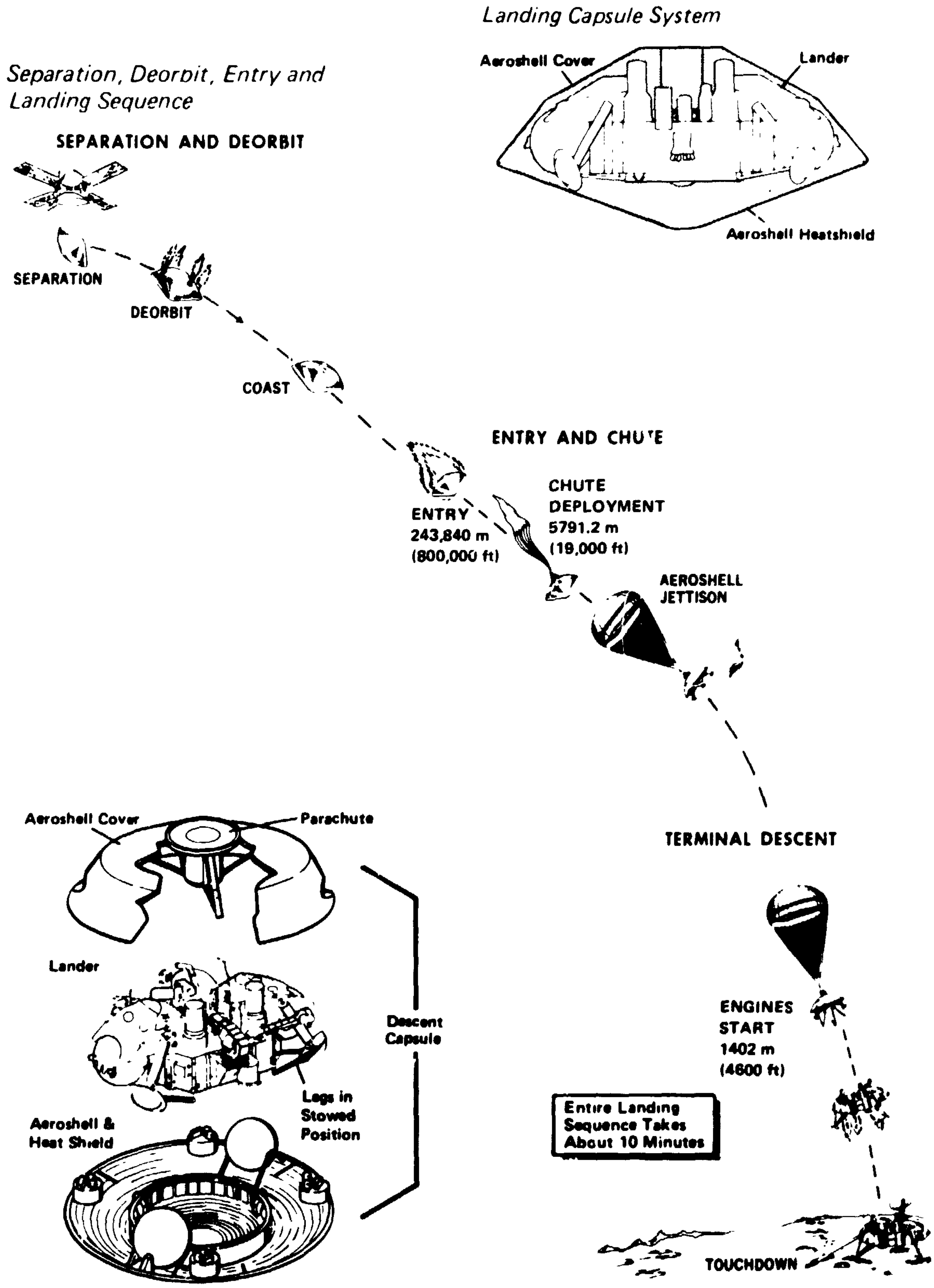


Fig. 67. Sequence of events following Lander-Orbiter separation of Viking 1

Table 31. Viking 1 timeline--separation through landing, July 20, 1976

Pacific Daylight Time	Event
01:51:15	Separation
01:58:16	Initiate Lander de-orbit burn
02:20:32	Lander de-orbit burn complete
04:54:03	Orient Lander for entry (20-degree angle of attack)
04:57:08	Initiate pitch program to maintain entry angle
05:03:08	Entry altitude (244 kilometers or 806,490 feet above mean surface level of Mars); radar altimeter 1 power on
05:10:06.5	6 kilometers (19,376 feet) above terrain; deploy parachute
05:10:13.5	Separate aeroshell; open terminal roll control valve
05:10:13.5	Initiate terminal roll control
05:10:16.5	Terminal descent landing radar power on
05:10:16.5	Initiate roll maneuver
05:10:25.5	Deploy Lander legs
05:11:06.9	1462 meters (4797 feet) above terrain; open terminal engine feed valve
05:11:08.8	Separate parachute
05:11:09.4	Initiate terminal engine on
05:11:39.3	41.7 meters (137 feet) above terrain; initiate radar altimeter termination
05:11:43	16.7 meters (55 feet) above terrain
05:11:49.8	TOUCHDOWN
05:46:56	Downlink begins

Table 31 (contd)

Pacific Daylight Time	Event
05:47:52	First picture image begins (on television monitors)
06:08:20	First picture image ends
06:10:38	Second picture image begins
06:46:10	Second picture image ends
06:46:10	Downlink ends

of the predicted time (202/11:52:50), and the terminal velocity predicted to be 2.49 meters (8.3 feet) per second ±9.1 centimeters (0.3 foot) per second was actually reported as 2.46 meters (8.2 feet) per second.

Following congratulations to the Flight Team from the Viking Project Manager, J. S. Martin, Jr., and the National Aeronautics and Space Administration Administrator, James C. Fletcher, President Gerald Ford personally congratulated the Project Manager and the Flight Team and declared July 20, 1976, as "Space Exploration Day."

The Lander appeared to be in a nearly nominal attitude, positioned in a stable, level-landed configuration. The first two pictures received from Viking Lander 1 on the surface of Mars are shown in Fig. 68. The upper picture shows the top of a Lander leg, indicating very little penetration of the foot pad into the Martian surface and some light-colored roughly faceted and deeply pitted rocks in the foreground. The lower picture is a panorama covering approximately 300 degrees of the Mars surface. The quality of these pictures astonished the Flight Team, hundreds of guests, and the national television audience that saw them a short time later.

As the Viking Flight Team now turned its attention to the initiation of full planetary operation for Viking Lander 1 and Viking Orbiter 1, Spacecraft 2 continued to rapidly approach the planet, and to demand attention for a decision on its landing site and the parameters for its Mars orbit insertion. Viking 2 was then 4,472,300 kilometers (2,780,000 miles) from Mars and in excellent condition. Its final approach maneuver was scheduled for July 28 and its Mars orbit insertion for August 7.

Fig. 68. First two photos received from Lander 1

2. Network Operations

a. Station Support. The tempo of activity at the tracking stations increased as Viking 1 began to activate its approach science instruments in April and May and its optical navigation sequences in June. Viking 2 activity also began to increase from the low-level engineering data gathering that had prevailed during the long cruise period.

Data rates increased to 8 kbps for Viking Orbiter 1 and to the maximum of 16 kbps for Viking Orbiter 2. Increased emphasis also was being placed on the production of complete Intermediate Data Records, which necessitated a great deal of time being spent in post-pass playbacks. Computer-assisted countdowns were introduced as a routine procedure; this resulted in reduction of prepass countdowns from 8 to 3 hours for cruise support.

Economies were made in station maintenance time wherever possible to satisfy demands for more time for tracking and for post-pass recall of data lost during real-time transmission.

Anomalies and failures continued at the normal level with problems being predominately in the telemetry and command data processing area.

Two training tests took place, both simulating the Mars orbit insertion for Viking Orbiter 1. Training Test 4 occurred on May 10-11, and Operational Readiness Test 3 took place on June 2-3. Significant progress in uplink procedures (commanding, transmitter and receiver tuning) was evident from Training Test 4 to Operational Readiness Test 3. Apart from one or two unfortunate occurrences, operator experience and confidence in handling complex mission sequences increased markedly in June and July and culminated in a perfect performance throughout the Network in the most critical sequences of all, namely, separation, descent, landing. and Viking Lander acquisition. Although similar events for Viking 2 still lay ahead, the performance of all station personnel during these critical Viking 1 sequences completely confirmed the Station Director's confidence in his station staff and their training. This was particularly noteworthy because of the decision in January 1976 to cancel plans to provide all 64-meter stations with Station Monitor Consoles, which resulted in the need for additional staff on short notice to fully man the stations.

The station workload is reflected in the prevailing level of spacecraft activity as depicted in the list of significant Viking events given in Tables 32 and 33. Station support summaries of Viking operations during the period April through July are given in Table 34.

The approach midcourse maneuver of Viking 1 was performed in two steps because of the spacecraft pressurant leak problem. The original maneuver was delayed one day to June 10 with a second maneuver performed on June 15. Madrid Station 63 successfully supported both maneuvers.

Table 32. Significant Viking activities supported by Deep Space Network

Date	Spacecraft	Activity
Mar 26	Lander 2	Inertial reference unit calibration
Mar 27	Orbiter 1	High-gain antenna calibration
Apr 11	Orbiter 1	Computer program update
Apr 12	Orbiter 1	Scan calibration 2
Apr 14	Orbiter 2	Computer program update
Apr 15	Orbiter 2	Scan calibration 2
Apr 16	Orbiter 2	Visual imaging playback and Lander 2 maintenance
Apr 17	Orbiter 1	Visual imaging playback
Apr 17	Lander 1	Battery charge and tape recorder main-enance
Apr 18	Orbiter 2	Very long baseline interferometry with Orbiter 2 and quasar source
Apr 20-21	Orbiter 2	Demonstration Test 4
Apr 23-24	Lander 1	Initial command load update
Apr 23-26	Lander 1	Battery conditioning sequence
Apr 26-29	Lander 1	Training Test 5
May 1-2	Orbiter 1	Photo calibration and playback sequences
May 3	Orbiter 1	Training Test 3
May 3	Orbiter 2	Quasar/Orbiter very long baseline inter-ferometry experiment
May 5-7	Orbiter 1	Command load update and battery condi-tioning sequence
May 8	Orbiter 1	Infrared Thermal Mapper playback
May 8, 9, and 11	Orbiter 1	Photo calibration playback

Table 32 (contd)

Date	Spacecraft	Activity
May 12	Orbiter 2	Mars Atmospheric Water Detector calibration
May 13-14	Lander 1	Battery conditioning sequence
May 15-18	Lander 2	Battery conditioning sequence
May 17-20	Orbiter 1	Optical Navigation Sequence 1
May 19-20	Lander 1	Battery conditioning sequence
May 21	Lander 1	Battery conditioning
May 21-22	Orbiter 2	16-kbps playback
May 23-26	Lander 2	Battery conditioning
May 24-25	Orbiter 2	16-kbps playback
May 25	Orbiter 1	Gyro and accelerometer calibration
July 18	Orbiter 1	Station 63 transmits Orbiter preseparation command load and Lander descent update
July 19	Lander 1	Station 43 receives Lander preseparation checkout
July 19	Lander 1	Station 14 transmits preseparation checkout update
June 1-2	Viking 1	8-kbps high-rate playback
June 2-3	Viking 1	Operational Readiness Test 3 for Mars orbital insertion
June 3-6	Orbiter 1	Optical navigation sequences
June 4	Lander 2	Initial command load update
June 10	Viking 1	Approach midcourse maneuver
June 10, 11 and 13	Orbiter 1	Optical navigation sequences
June 10	Lander 2	Initial command load update

Table 32 (contd)

Date	Spacecraft	Activity
June 10-13	Lander 2	Battery conditioning sequence
June 14	Orbiter 1	Visual Imaging Subsystem and Infrared Thermal Mapper alignment test playback
June 15	Viking 1	Second approach midcourse maneuver (required because of the continued gas regulator leakage problem)
June 16	Viking 1	Viking 1 approach science start
June 19	Viking 1	Mars orbit insertion
June 21	Viking 1	First Mars orbit trim
June 21	Viking 1	Site certification sequence start
July 8	Orbiter 1	Mars orbit trim
July 9-15	Orbiter 1	Site certification photo sequence
July 13	Orbiter 1	Mars orbit trim
July 15	Orbiter 2	Optical navigation sequence start
July 18-19	Lander 1	Preseparation checkout
July 18	Viking 2	Optical navigation sequence completion
July 18	Orbiter 1	Station 63 transmits Orbiter preseparation command load and Lander descent update
July 19	Lander 1	Station receives Viking Lander preseparation checkout data
July 19	Lander 1	Station 14 transmits preseparation checkout update
July 20	Orbiter 1/ Lander 1	Station 43 transmits separation command
July 20	Lander 1	Touchdown and start of landed operations

Table 33. Sequence of Network events for Viking 1 landing

GMT	Station	Event
July 20:		
00:05	43	Acquisition of Orbiter signal
03:25	14/43	Transfer from Station 14 to 43
04:35	14	Loss of Orbiter signal
04:50	43	Transmission of separation minus 3.5 hours update
05:21	43	Start receiving 1- and 2-kbps Lander check-out data
07:47:15	43	Transmit Lander separation Go command
08:51:15	43	Lander separation from Orbiter
08:51:15	43	Start receiving 4-kbps Lander descent data
09:00	63	Acquisition of Orbiter signal; start receiving 4-kbps Lander descent data
09:20	43/63	Transfer from Station 43 to 63
09:50	43	Loss of Orbiter signal
12:11:49	63	Lander touchdown: end receiving 4-kbps Lander Descent Data
12:59	63	Start receiving 4-kbps playback of critical Lander data
16:40	14	Acquisition of Orbiter signal (Orbiter)
19:00	63/14	Transfer from Station 63 to 14
21:05	63	Loss of Orbiter signal
July 21:		
01:07	14	End of receiving 4-kbps playback of critical Lander data

Table 34. Summary of station support for Viking operations from April through July

Month	Station	Number of passes	Hours tracked	Commands transmitted
April	11	33	223:39	392
	12	33	236:42	588
	14	1	03:38	20
	42	32	164:03	0
	43	0	0	0
	44	29	194:04	9
	61	33	241:07	45
	62	7	69:43	0
	63	23	208:53	2206
April total:		191	1346:49	3260
May	11	29	277:40	753
	12	25	176:47	490
	14	11	61:37	15
	42	30	214:12	9
	43	24	184:32	574
	44	9	62:27	447
	61	32	281:24	233
	62	4	36:44	28
	63	28	287:55	6274
May total		192	1583:18	8823

Table 34 (contd)

Month	Station	Number of passes	Hours tracked	Commands transmitted
June	11	25	194:24	413
	12	15	103:00	0
	14	18	165:50	504
	42	22	167:36	15
	43	28	220:53	3410
	44	11	89:56	43
	61	25	232:05	399
	62	9	93:11	32
	63	29	320:43	619
June total:		182	1589:18	5435
July	11	29	239:10	358
	12	7	52:27	216
	14	40	336:03	1827
	42	26	205:29	183
	43	49	349:03	1641
	44	11	76:28	0
	61	26	260:20	1354
	62	7	58:53	92
	63	43	362:14	2276
July total:		238	1940:07	7947
Four-month total:		803	6459:32	25465

The Viking 1 Mars orbit insertion was successfully supported on June 19 by Goldstone Station 14 with Station 11 as backup. A Mars orbit trim maneuver was performed on June 21 over Madrid Station 63. This put the Viking 1 Orbiter in the proper orbit over the prime landing site. The first site certification pictures were taken on June 22 and, for the next several weeks, high-rate telemetry data were received periodically by the 64-meter network in support of this activity. The Viking 1 landing was delayed from the July 4 scheduled date to July 20 because landing site requirements necessitated additional trim maneuvers and additional site certification photos. The successful landing was covered by Madrid Station 63 with the initial surface pictures played back via the Orbiter relay link shortly after touchdown, as reported here earlier.

b. Network Operations Control Center. Implementation of the Viking configuration in the Network Operations Control Center was concluded on April 26, 1976, and all resources were assigned to accomplishment of selected enhancement features of the existing systems. The enhancement effort was completed on June 1, and the capabilities existing at that time were put under configuration control for the remainder of the prime Viking mission. These capabilities were considered to be the minimum required to meet the Network commitment to Viking planetary operations. System maturity and operator experience would contribute to increased proficiency in the operation of the Control Center on a continuous basis. Training in the production of Intermediate Data Records was considered to be complete.

The production of Intermediate Data Records and their delivery within 24 hours after the end of each tracking pass continued to strain the resources of the Network Operations Control Center. However, as operator training and experience increased and the hardware and software gained maturity under operational conditions, it became possible to maintain a higher standard of performance with continuous high-data content on each record delivered.

Typical daily performance is shown in Table 35, which contains the data record production statistics for July 1, 1976. The "Percentage of data delivered," given in the table, refers to the number of data blocks on an Intermediate Data Record as a percentage of the number estimated to be available on the digital data records made during the pass at the tracking station. This percentage reflects the completeness of the data delivered to the Project from which the final Experimenter Data Records are compiled. The real-time data, which was subject to gaps due to outages or "bits" on the worldwide communication circuits, were used for mission control and real-time decision working purposes only.

The Viking Project deemed it necessary to have all of the data available at the stations delivered to its data library without any gaps within 24 hours after the end of each pass. Thus, the achievement of "100 percent Intermediate Data Record data content" became a major Network goal in support of this Project.

Table 35. Intermediate Data Record statistics for Viking Orbiter 1 on July 1, 1976

Station	Bit rate, kbps	Blocks on Intermediate Data Record	Blocks missed in real time	Blocks missed after recall	Delivered within 24 hours	Percentage of data delivered on Intermediate Data Record
63	2, 8	22,295	40	3	Yes	99.987
14	8	38,677	0	0	Yes	100
43	8	124,699	123	0	Yes	100
Accumulated totals since April 23, 1976						
63		2,390,397		395		99.983
14		1,357,683		325		99.976
43		2.361,142		587		99.975
Network		6,117.750		1321		99.978

As the second Viking spacecraft continued to approach Mar , the daily activity began to include far encounter picture data to be used for optical navigation. As a consequence, the Network Operations Control Center began to receive demands for Intermediate Data Records from two spacecraft, Viking Orbiter 1 and Viking Orbiter 2, at data rates between 2 and 8 kbps. This demand provided a further increase in operational loading, and, by the time of the Viking 1 landing decision of July 19, the Intermediate Data Record statistics had achieved the performance shown in Table 36.

By July 1976, the system had matured significantly, and the Network was generating Intermediate Data Records for the Viking Project with close to 100 percent of the digital data on them. During standard operations, 100 percent of the data blocks that are recoverable from the Digital Original Data Record should be contained on an Intermediate Data Record. During Project-defined critical periods, supplemental digital records may be generated from analog records to assure that 100 percent of the data blocks on the digital record is delivered on an Intermediate Data Record. The Intermediate Data Records are expected to be delivered to the Viking Project Library within 24 hours after the end of each station pass.

Statistics on percentage of data on an Intermediate Data Record and delivery times are given in Tables 37 and 38 for July.

The percentage of data is obtained by dividing the number of blocks received by the number of data blocks expected. The number expected is computed by subtracting the first data block number from the last, and adding the number of completed counting cycles. This gives a count of the number of blocks written on the Intermediate Data Record tape. The Data Records Processor computes these values following the merging process. Table 38 gives the quantity of data delivered on all Intermediate Data Records generated during July.

During July, 97.9 percent of all records delivered to the Project contained a minimum of 99.8 percent of all data recoverable from the digital records.

Intermediate Data Records are required to be delivered to the Viking Project Library within 24 hours after the end of each station pass. The tapes are picked up by Network Information Control personnel and delivered to the Viking Project Library.

c. Discrepancy Reports. The status of Viking-related discrepancy reports on July 19, the day on which the Deep Space Network reported "go" condition for Viking 1 Lander separation, is given in Table 39. Of the 107 discrepancy reports outstanding, only 25 were considered significant to the subsequent surface operations. All of these were related to timing problems being experienced at that time in the telemetry and command processor at Station 14 at Goldstone. As a consequence, a special task team was dispatched to the station; the problem was determined to be caused by noise entering the processor from some recently added software test interfaces.

Table 36. Intermediate Data Record statistics on July 19, 1976

Date (July 1976)	Orbiter	Station	Bit rate, kbps	Blocks on Intermediate Data Record	Blocks missed in real time	Blocks missed after recall	Delivered within 24 hours	Percent of blocks on Intermediate Data Record
16	1	63	2,4,8	120,994	469	435	No	99.642
17	2	14	8	66,359	157	134	No	99.798
17	1	14	8	62,118	37	37	No	99.940
17	1	43	2,8	67,562	46	9	Yes	99.987
17	2	63	8	36,940	251	2	Yes	99.995
17	1	63	2,8	57,431	285	10	No	99.983
18	1	14	8	88,143	643	12	Yes	99.986
Accumulated totals since April 23, 1976								
		14		2,388,380		535		99.978
		43		2,974.891		710		99.975
		63		3,683,076		1024		99.972
		61		8,528		13		99.845
		Network		9,054,825		2282		99.975

Table 37. Delivery times for Intermediate Data Record during July 1976 (hours after loss of signal)

Parameter	Station			
	14	43	63	All
Mean, hours	16.0	22.1	13.2	17.2
Data limits:				
Low	1	0.5	1	1
High	91	173.2	[illegible]	173.2
Number of records	28	36	31	95

Table 38. Quantity of data on Intermediate Data Records during July 1976

Parameter	Station			
	14	43	63	All
Mean, %	99.9	99.8	99.9	99.9
Standard deviation	0.05	0.37	0.05	0.23
Number of records	28	36	31	95

The Viking Incident Surprise and Anomaly Reporting System was carrying only 23 of the 107 total at this time, and none of these included the telemetry-related problems discussed above.

Table 39. Viking discrepancy report summary as of July 19, 1976[a]

Subsystem	Station								NDPA[b]	NOCA[c]	Totals
	11	12	14	43	44	61	62	63			
Monitor	3		6	2	1				26	1	39
Telemetry	1		15	3				7	30	7	63
Tracking			1	1				1	1		4
Command			1								1
Totals	4	0	23	6	1	0	0	8	57	3	107[d]

[a]23 of the total discrepancy reports also carry Viking Incident Surprise and Anomaly Reports.

[b]Network Data Processing Area.

[c]Network Operations Control Area.

[d]25 classed as significant, 82 classed as not significant.

d. Command System. The performance of the Network Command System in supporting Vikings 1 and 2 is given in Table 40 in terms of the number of commands transmitted. The loss of command capability due to ground communications line outages or station equipment outages is given in Table 41.

Table 40. Number of commands transmitted from May through July 1976

Month	Orbiter 1	Lander 1	Orbiter 2	Lander 2	Aborts
May	1467	2999	463	3894	0
June	4250	134	250	868	1
July	5009	1049	1889	0	0
Cumulative total for mission	14085	7794	6196	6591	2

Table 41. Command capability lost due to communication line or station failures from May through August 1976 as a percentage of scheduled tracking time

Month	Viking 1		Viking 2	
	Line Failure, percent	Station Failure, percent	Line Failure, percent	Station Failure, percent
May	0.12	2.22	0.13	0.71
June	0.24	0.20	0.65	0.32
July	0.22	1.25	0.32	0.7
Cumulative total for mission	0.71%		0.56%	

A more detailed appreciation of the daily performance of the system can be obtained from the monthly list of significant problems and anomalies which follows:

Station	Pass	Orbiter	Description
63	263	1	Two-way transfer was missed due to incorrect configuration of the transmitter. Command transmission was delayed 52 minutes. Telemetry and Command Processor A was unable to lock on high-rate data. A reload cleared the problem. Impact on commanding was 41 minutes.
44	269	1	Because of an operator error, commands intended for the Lander were not received by the spacecraft.
63	269	1	Command Modulator Assembly B had symbol period, subcarrier frequency, and data quality alarms. A swap was made to second unit. Performed a validation and proceeded commanding. Outage time was 20 minutes.
42	270	1	Telemetry Command Processor B received symbol rate alarms. A reload was attempted with no success. Unit A was validated in real time and declared "green" for commanding. Outage time was 42 minutes.
14	270	1	Command capability was lost for 4 minutes. Telemetry Command Processor A halted, switched to the B string.
43	274	1	Operator error caused the Frequency Timing Subsystem to glitch. All computers were reloaded followed by command validations of both Telemetry Command Processors. Outage time was 45 minutes.
42	278	1	Command capability was lost due to beam and body over-currents on the transmitter. The station tracked one-way for the remainder of the pass. Command outage time was 28 minutes.
63	280	1	A blown fuse in the antenna power supply, located at the servo rack, caused a 36-minute command outage. Reacquisition of the uplink was performed.
42	280	1	Station received a configuration word check fail. A re-initialization and reload failed to clear the alarm. Command Modulator Assembly

Station	Pass	Orbiter	Description
			A was then declared "red." Command capability was lost for 4 hours and 45 minutes, as no backup was available due to Viking 2 commitment.
42	281	1	Body over-current alarm caused the transmitter to trip off. Reacquired the spacecraft with outage time of 15 miutes.
11	240	2	Command validation was performed due to a halt of Telemetry Command Processor B. Outage time was 49 minutes.
12	250	2	The station had a degraded command system during the pass. Transmitter power had very large fluctuations. Degraded time was 3 hours and 55 minutes.
42	254	2	Transmitter beam and body over-current alarms caused a 29-minute command outage.
14	256	2	Exciter frequency alarm was received and cleared after 2 seconds. Some time later, a bit verify alarm was observed, clearing 1 second later. Commanding was delayed 27 minutes.

On the night of May 17, a significant procedural error occurred in the transmission of commands intended for Lander 1 that did not reach the spacecraft. The close out of Discrepancy Report 4379, which described the incident, is given below as an illustration of the mistakes that can occur when nonstandard procedures are adopted to force additional capability out of an already fully loaded system.

Investigation revealed that the Beta command system had been incorrectly configured during pretrack countdown, resulting in a subcarrier frequency of 512.0 Hz instead of 385.0 Hz. Configuration words and idle sequence patterns were also set incorrectly. During command initialization, the station operator typed instruction CINT/VKO, 26, 310& vice CINT/VKL, 26, 310$. This is allowable by the current software programs, as no internal check is made to compare parameter 1 (project) with parameter 2 (spacecraft I.D.). The end result, however, was that, while the system was initialized for Lander 1, all data loaded into the configuration/ standards and limits table were taken from the Orbiter software module. Under normal circumstances, the command analysts would have transmitted a configuration/standards and limits table during validation of the system. Had this been done, the nonstandard configuration would have been overlaid.

Because of a Viking test, which required control of the Network simulation system through the command system at the Network Operations Control Center, a special tape was used that consisted predominantly of simulation control messages and a limited number of command blocks. The needed command table was not present on this tape and, therefore, was not available for transmission. The command analyst attempted to validate the system by recalling the configuration/standards and limits from the station and making a visual verification. It was at this point that the incorrect configuration went undetected.

To avoid future occurrences of this kind, all command tapes containing simulation control messages were removed from the Network Operations Control Center tape library. Check lists were provided for each spacecraft that had to be filled out by the command analyst in the event that it became necessary to validate a station command configuration by recalling standards and limits from the station.

Command system anomalies for the month of June 1976, which directly impacted Viking 1 or Viking 2, were as follows:

Station	Pass	Viking	Anomaly
14	295	1	Reload on Telemetry and Command Processor. 24-bit counter alarm. Outage time 3 minutes.
14	296	1	Subcarrier frequency warning and abort alarms cleared immediately.
43	297	1	Data quality warning alarm. Station switched to backup Command Modulation Assembly.
14	306	1	Exciter frequency alarms cleared two seconds later.
14	309	1	Exciter frequency, bit verify, and data quality alarms. Outage time 51 minutes.
14	312	1	Telemetry and Command Processor stopped. Lost access to teletype input/output device. Outage time 7 minutes.
14	312	1	Station procedural. Outage time 26 minutes.
14	315	1	Telemetry and Command Processor stopped. Lost access to teletype input/output device. Outage time 7 minutes.
42	267	2	Body current alarm tripped transmitter off, which aborted a command. Outage time 43 minutes.
11	269	2	Station lost commercial power. Outage time 22 minutes.

Station	Pass	Viking	Anomaly
44/ NDPA*	271	2	Data quality alarms. Station procedural. Outage time 33 minutes.
12	281	2	100-ampere circuit breakers tripped transmitter off. Outage time 18 minutes.
11	288	2	Transmitter beam and body current alarms. Outage time 43 minutes.

Most of the above anomalies were also closed out in June. At the end of the month, six discrepancy reports remained open against the command system, all of which were related to problems in the Network Data Processing Area.

During the month of July, 13 anomalies occurred in the command system as follows:

Station	Pass	Spacecraft	Anomaly
63	317	Orbiter 1	Antenna drove off point. Outage time 4 minutes.
14	319	Orbiter 1	Telemetry and Command Processor halted at radio day. Outage time 18 minutes.
14	319	Orbiter 1	Momentary commercial power outage. Outage time 16 minutes.
14	326	Orbiter 1	Telemetry and Command Processor halted after trying to restart TM-4. Outage time 19 minutes.
14	328	Orbiter 1	Bit verify alarm received. Outage time 33 minutes.
14	329	Orbiter 1	Telemetry and Command Processor halted at radio day. Outage time 18 minutes.
63	336	Orbiter 1	Received symbol rate errors. Degraded outage time 8 hours 47 minutes.
14	338	Orbiter 1	Lost commercial power. Outage time 41 minutes.

*Network Data Processing Area

Station	Pass	Spacecraft	Anomaly
12	340	Orbiter 1	Symbol warning and symbol abort alarms received, causing an expired command to appear. Outage time 42 minutes.
11	299	Viking 2	Unable to turn ranging modulation and command modulation off at Station Monitor Control-76. Outage time 8 minutes.
11	311	Viking 2	Antenna Pointing System computer stopped processing. Outage time 2 minutes.
11	316	Viking 2	Antenna drove off point. Outage time 22 minutes.
61	320	Viking 2	Bit verify forced command system IDLE sequence to calibrate 2. Outage time 3 minutes.

All of these 13 anomalies were recorded as discrepancies and were properly closed out by month's end. In addition, all of the discrepancy reports outstanding from the previous month were closed out.

Therefore, by the end of July, the Network Command System had reached maturity under the heaviest Viking loads experienced to this point in the mission, and was used continuously by the Viking flight controllers with an extremely high degree of confidence in conducting mission operations with both Orbiters and Lander 1.

e. Telemetry System. The performance of the Telemetry System in support of Vikings 1 and 2 is analyzed each month in terms of signal level and signal-to-noise ratio. The predicted value for these parameters is compared with the actual measured value and the difference or "residual" evaluated as a measure of telemetry performance. These data for May, June, and July 1976 are given in Table 42. The data includes S- and X-band data for both Viking Orbiters, even though the X-band channel is used for downlink ranging data only. However, the most reliable indicator of true telemetry performance is the signal-to-noise ratio residual. These data for both the high-rate and low-rate data channels are also included in Table 42.

Table 42. Residuals for downlink signal level and signal-to-noise ratio from May through July 1976

Month (1976)	Signal level observations	Mean, dB	Sigma, dB	Signal/noise observations	Mean, dB	Sigma, dB
26-meter stations						
May						
Viking 1	50	0	0.5	53	-0.4	0.4
Viking 2	75	-0.1	0.6	75	0.1	0.4
June						
Viking 1	27	0	0.6	23	-0.2	0.3
Viking 2	81	0	0.6	82	0.3	0.3
July						
Viking 1	--	--	--	--	--	--
Viking 2	19	-0.4	0.5	13	-0.4	0.5
64-meter stations						
May						
Viking 1	42[a]	-0.2	0.6	18[c]	-0.6	0.3
	24[b]	0.3	2.3	17[d]	-0.2	0.4
Viking 2	18	-0.2	0.6	11	0	0.4
	12	2.1	0.6	10	0.1	0.6
June						
Viking 1	67	0.2	0.5	44	-0.4	0.6
	68	1.0	1.1	64	-0.2	0.6
Viking 2	8	-0.5	0.7	5	-0.1	0.4
	NA[e]	NA	NA	5	0.4	0.5
July						
Viking 1	6	1.0	0.2	8	-0.7	0.5
	0	0	0	8	0.9	0.9
Viking 2	87	-0.1	0.5	65	-0.7	0.4
	59	0.07	1.9	65	-0.5	0.5

[a]S-band.
[b]X-band.
[c]Low-rate data 8-1/3 bps or 33-1/3 bps.
[d]High-rate data 250 bps through 16 kbps.
[e]Not available.

Anomalous conditions in downlink signal level or signal-to-noise ratio residuals are based on specified standards and limits for these parameters, which represent the best observed performance over an extended period of time. The standards and limits adopted for the Viking missions are:

Viking 1:	Downlink signal level	+1.5 dB -1.0 dB
	Downlink signal-to-noise ratio	+1.2 dB -1.6 dB
Viking 2:	Downlink signal level	+1.6 dB -1.2 dB
	Downlink signal-to-noise ratio	+1.5 dB -1.5 dB

Any circumstances which give rise to an anomalous residual within the definitions given above are subject to a discrepancy report and resulting investigative and close-out action.

During July, 36 discrepancy reports were opened against the Telemetry System distributed among the assemblies on a percentage basis shown in Table 43.

Table 43. Distribution of discrepancy reports against the Telemetry System during July 1976

Assembly	Percent of Total
Microwave	16.7
Receiver	5.6
Subcarrier Demodulator	8.3
Symbol Synchronizer	0
Block Decoder	5.6
Data Decoder	25.0
Telemetry and Command Processor	19.4
Analog Instrumentation and Recording	0
Digital Data Recording, 7 Track	0
Digital Data Recording, 9 Track	19.4

These data reflect the real-time experience of the operations teams which experienced the most trouble from the Telemetry and Command Processor, Data Decoder, and 9-track High-Density Tape Recorders used for making the Digital Original Data Records at data rates in excess of 2 kbps.

f. Tracking System

(1) Radio Metric Data Quality. The primary navigational data type generated by the Network is doppler data. These data are continuously monitored in the Network Operations Control Center where doppler data residuals (actual minus predicted) are produced. During the May-July 1976 period, the pseudoresidual program consistently indicated a high level of accuracy in the polynomial coefficients (the frequency-independent observables) supplied to the Network Operations Control Team by the Viking Project Flight Path Analysis Group. Additionally, the Network Analysis team 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 ± 0.002 Hz.

Figures 69 and 70 present "pass average" doppler noise for Vikings 1 and 2 for the May-July 1976 period. Examination of the figures indicates generation of nominal, high-quality doppler data for Viking navigation. Additionally, an increasing trend in the noise data is clearly seen in both figures, the trend being gradual in the beginning of the period (May and June) but accelerating towards the end of the period (July). As expected, this is the effect of entry into the solar conjunction phase, and by August 1 the Viking Sun-Earth-probe angle had reached approximately 37 degress. At this Sun-Earth-probe angle, the expected pass average doppler noise is 0.005 Hz versus a nominal value of 0.003 Hz. Inspection of Figs. 69 and 70 indicates the observed Viking 1 and 2 "pass average" doppler noise to be centered very close to 0.005 Hz as August 1 is reached.

(2) Viking Spacecraft Frequencies. During each one-way tracking period, the Network Analysis Team re-estimates the spacecraft auxiliary oscillator frequency, and during each subsequent uplink acquisition a similar re-estimation of the spacecraft best lock frequency is performed. The data for Vikings 1 and 2 during the May-July period are presented as follows:

Viking 1 spacecraft auxiliary oscillator frequency	Fig. 71
Viking 2 spacecraft auxiliary oscillator frequency	Fig. 72
Viking 1 spacecraft best lock frequency	Fig. 73
Viking 2 spacecraft best lock frequency	Fig. 74

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 acquisitions

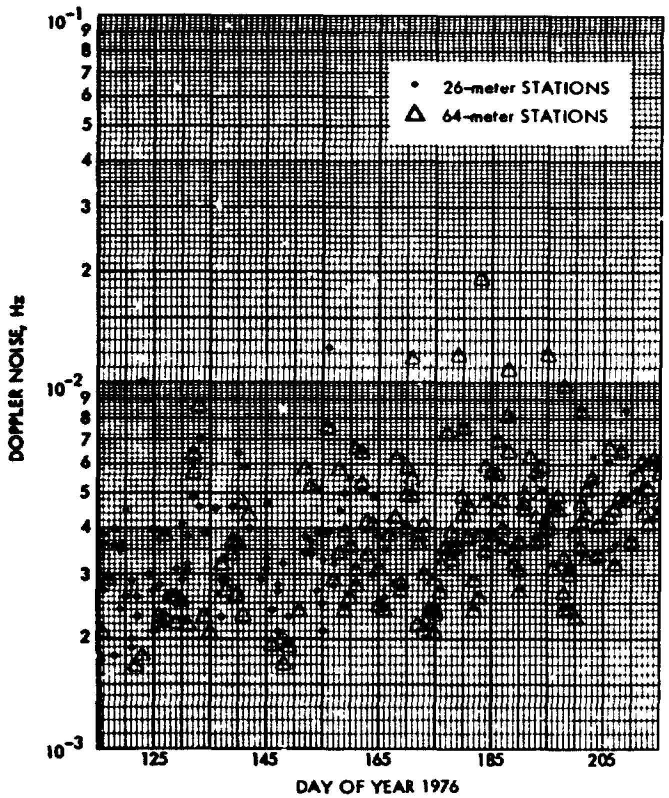


Fig. 69. Viking 1 composite doppler noise versus day of year

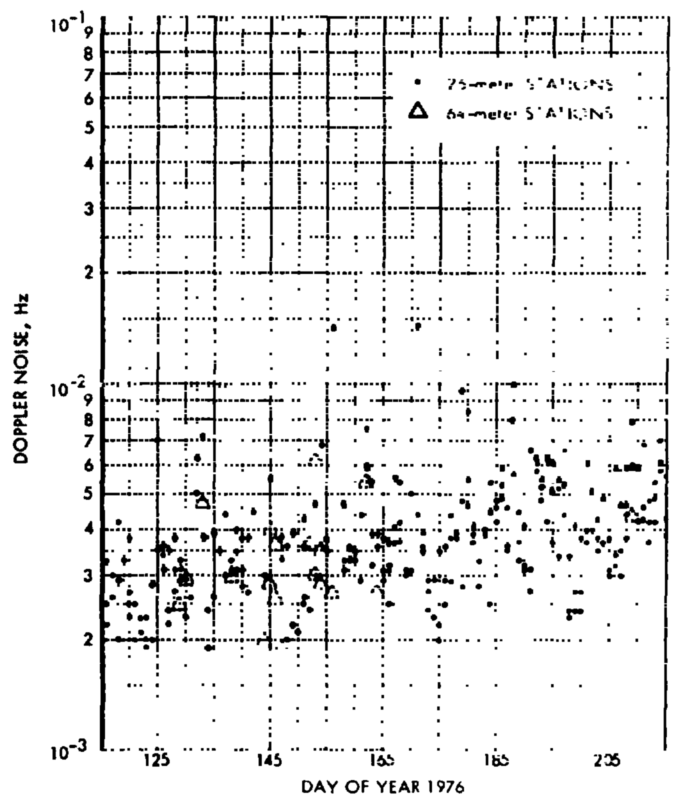


Fig. 70. Viking 2 composite doppler noise versus day of year

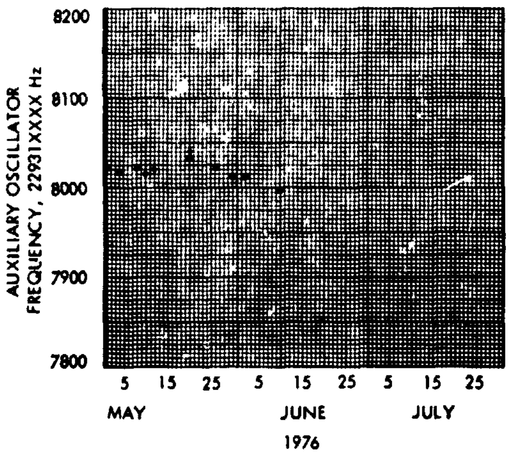


Fig. 71. Viking 1 spacecraft auxiliary oscillator frequency

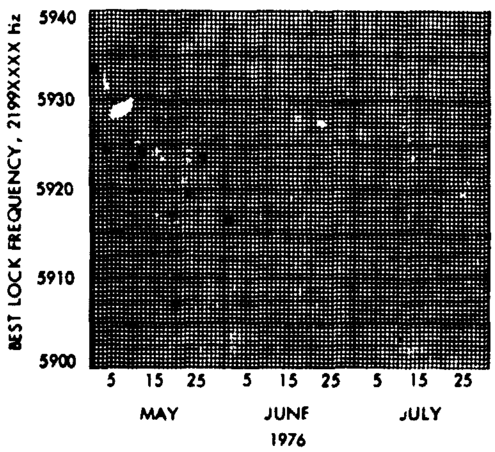


Fig. 73. Viking 1 spacecraft best lock frequency

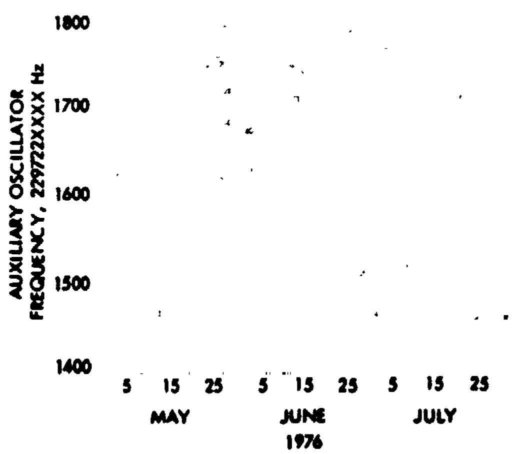


Fig. 72. Viking 2 spacecraft auxiliary oscillator frequency

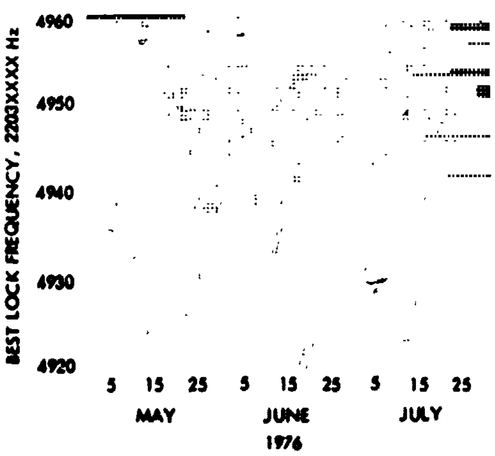


Fig. 74. Viking 2 spacecraft best lock frequency

and radio metric data validation. Additionally, the data assume paramount importance during mission critical phases, when complicated mission strategies demand rapid and precise uplink and downlink acquisitions. The relative paucity of frequency measurements (as compared to earlier periods in the mission) is due to the fact that both Vikings were being tracked continuously in the two-way mode, and frequency measurements were only possible when two-way transfers were unsuccessful.

(3) Motor Burn Strategy. One June 19, 1976, at 22:30:35 GMT, the Viking 1 spacecraft executed a 38-minute motor burn which placed the spacecraft in a highly elliptical synchronous orbit about the Planet Mars.

In order to properly align the Viking 1 spacecraft for Mars orbit insertion motor burn, the spacecraft went through a sequence of three turns: a roll turn, a yaw turn, followed by a second roll turn. Following the burn, the spacecraft went through the same turns in reverse order to restore it to its original orientation. Because the combination of the resulting geometric orientation (unfavorable cone and clock angles) and the use of the low-gain antennas could have caused the loss of both the uplink and downlink signals during portions of these maneuvers, strategies were designed to minimize the resulting data outages and to provide continuous two-way doppler through the burn period to the maximum extent possible. The effect of the burn and subsequent periapsis passage on the transmitter exciter frequency tuning is shown in Fig. 75. The changes in two-way doppler at Goldstone Station 14 resulting from the exciter tuning strategy are given in Fig. 76.

The preburn uplink strategy was designed to acquire the spacecraft receiver at the earliest possible time by ramping the uplink frequency to closely approximate the change in frequency due to doppler as seen by the spacecraft receiver. In this way the spacecraft receiver would see a constant frequency close to its best lock frequency and could, therefore, be expected to acquire as soon as the signal level rose above threshold. An "insurance sweep" executed at the time of the switch to the high-gain antenna was to ensure reacquisition in the case of a premature drop in signal level.

Figure 77 illustrates this tuning strategy along with a nominal timeline. The procedure for a nominal burn, start time 23:03:08 Greenwich Mean Time, was:

(a) Tuning sweep

Start time:	21:27:00 GMT
Frequency rate:	+0.0275 Hz/s
Start frequency:	43993800 Hz

(b) Insurance sweep

Start time:	21:57:00 GMT
End time:	21:59:35 GMT
Lower frequency limit:	43993750 Hz

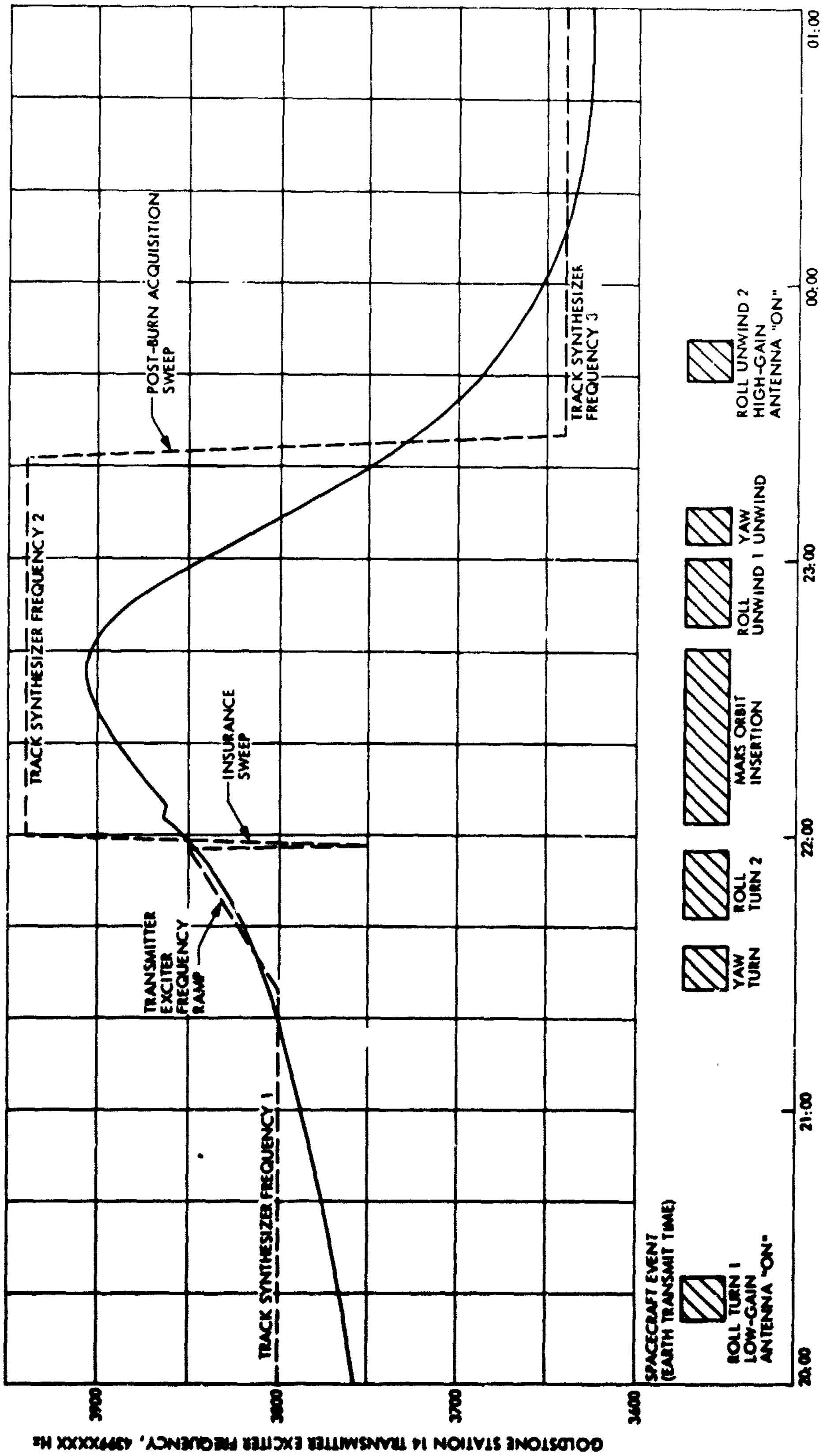


Fig. 75. Effect of burn and subsequent periapsis passage on transmitter exciter frequency tuning for Viking 1

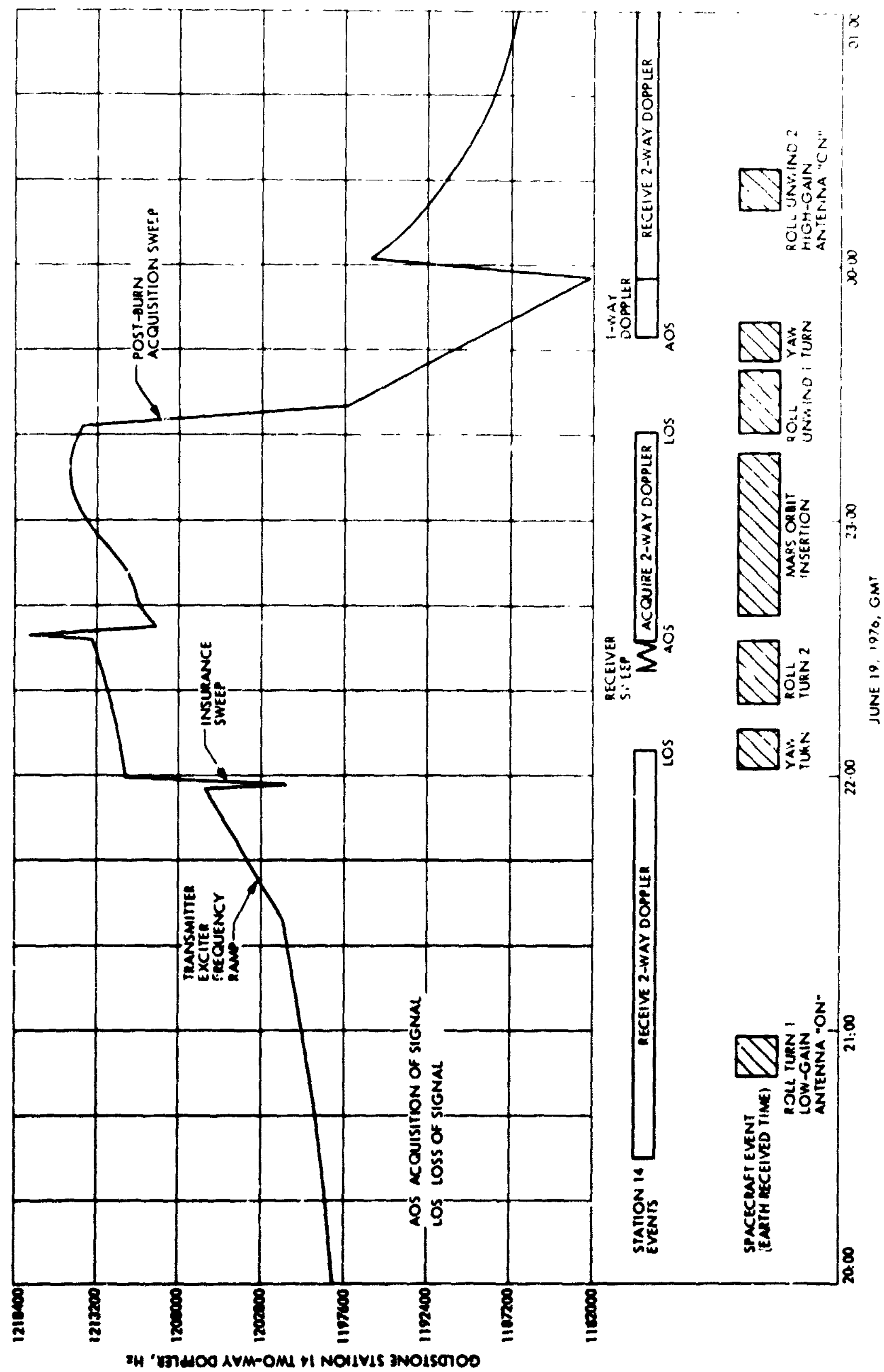


Fig. 76. Effect of Mars orbit insertion and transmitter exciter frequency tuning on two-way doppler at Station 14

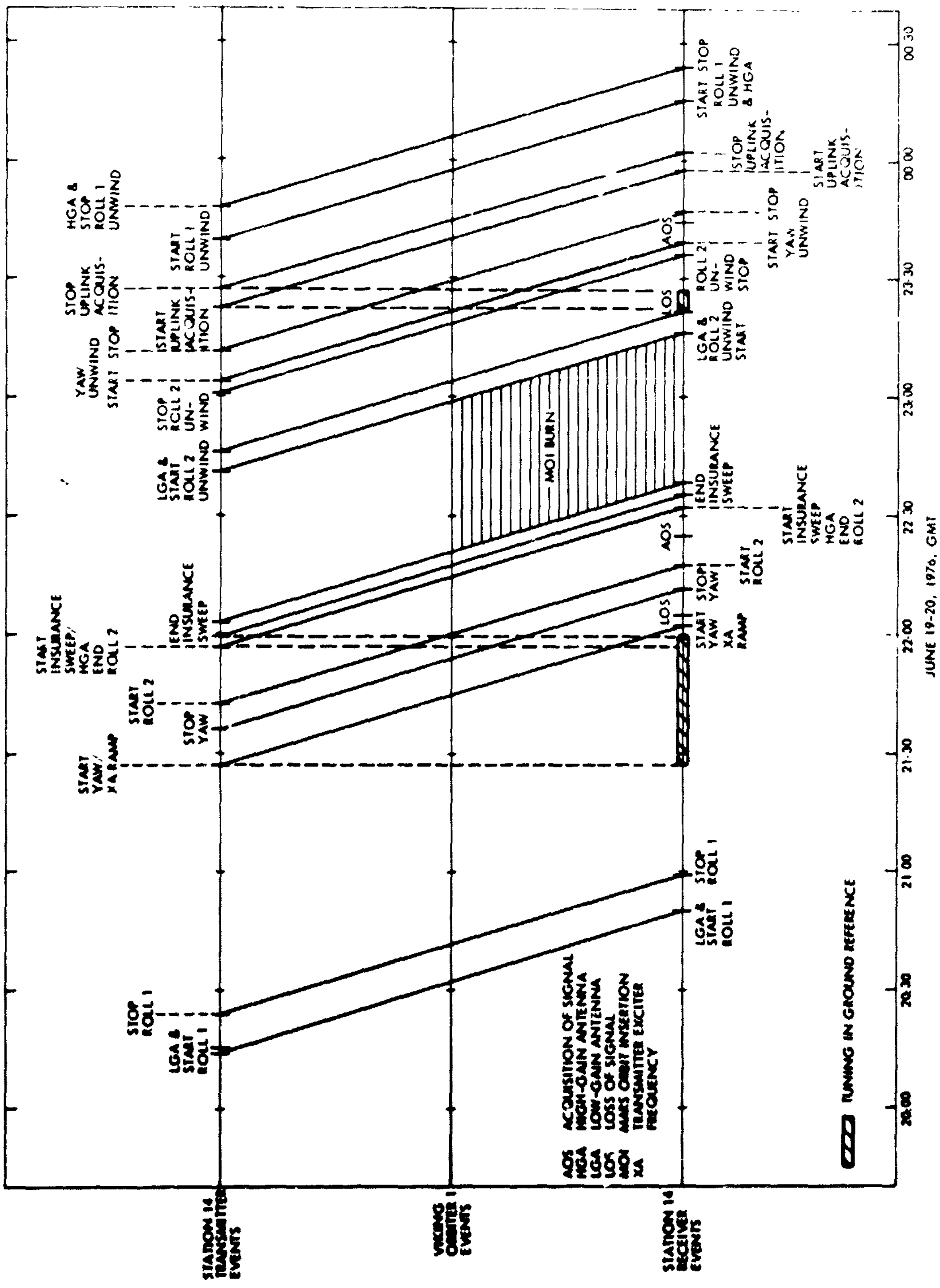


Fig. 77. Viking 1 mission orbit insertion tuning strategy for June 19, 1975

g. Monitor System. Viking 1 was tracked a total of 111 times in July compared to 95 times in June, while Viking 2 passes totaled 116 in July and 91 in June. Viking Lander 1 made its successful landing on July 20 and was tracked on 10 occasions during the remainder of July. Table 44 shows station support from May through July.

Intermittent erroneous "receiver out-of-lock" indications occurred in the digital instrumentation system at Station 14 during May, June, and July. By far the most serious problems, however, occurred in the Network Data Processing Area of the Operations Control Center. Delivery of Intermediate Data Records was seriously delayed and the generation of predicts and real-time system performance monitoring was impacted.

Since most of these problems were of a system design nature, the engineering development organization was called in to assist with identification and correction of these problems.

Table 45 shows the incidence of anomalies/failures in the Monitor System from May through July 1976.

h. Telecommunications. All S-band link performance remained normal through May, with no significant trends developing. Viking 1 downlink signal strength through May 1976 is shown in Fig. 78. The mean values for the uplink residuals for the 26-meter stations were in the range of -0.6 to +0.1 dB for Orbiter 1 and in the range of +0.2 to +1.3 dB for Orbiter 2. For these stations, the mean value of the downlink residuals were in the range of -0.8 to +0.1 dB for Orbiter 1 and in the range of -0.4 to +0.2 dB for Orbiter 2.

The signal-to-noise ratio of the 33-1/3-bps low-rate engineering data at 26-meter stations had a 0.0-dB mean residual for Orbiter 1 and a 0.8-dB mean value for Orbiter 2. The signal-to-noise ratio of the 8-kbps high-rate science data at 64-meter stations had a +0.3-dB mean residual for Orbiter 1 and high-rate 16-kbps signal-to-noise ratio had a +0.9 dB mean residual for Orbiter 2.

The residuals for the X-band downlink signal level for May are shown in Fig. 79. The data show that a large positive residual of 2 to 3 dB on the X-band signal level for both spacecraft exists at all 64-meter stations.

In June, a great deal of attention was paid to the analysis and monitoring of the 8-kbps playback and the 2-kbps real-time portions of a lengthy series of optical navigation picture-taking sequences.

Closer to Mars, two approach midcourse maneuvers served as prelude to the Mars orbit insertion on June 19. Both the approach midcourses and nonpropulsive maneuvers in orbit utilized the low-gain antennas as the sole means of communications with Earth. For the Mars orbit insertion, the low-gain antenna was used during the maneuver turns, and then the high-gain antenna was again used (after articulation) in the motor burn attitude. Telecommunications link performance was very close to the nominal predicted value throughout all these maneuvers.

Table 44. Station support for Viking Orbiters 1 and 2 and Viking Lander 1 from May through July 1976

	Station								
Month	11	12	14	42	43	44	61	62	63
May	29	25	10	30	25	9	32	4	27
June	28	15	19	23	28	10	26	8	29
July	28	8	37	28	44	11	30	8	43
Total tracks	85	48	66	81	97*	30	88	20	99*
Total hours	652	310	528	610	705*	221	821	167	913*

*Includes Viking Lander 1 tracks.

Table 45. Incidence of anomalies/failures in Monitor System during Viking tracks from May through July 1976

Area	May	June	July
Other[a]	7	11	17
NDPA[b]/NOCA[c] only	42	25	15

[a]Other includes:
- Digital Instrumentation Subsystem (DIS)
- Tracking Data Handling Subsystem (TDH)
- Station Monitor and Control (SMC)
- Frequency and Timing Subsystem (FTS)
- Facility Power (FAC)
- Communications (COM)

[b]NDPA includes the Network Data Processing Area.

[c]NOCA includes the Network Operations Control Area.

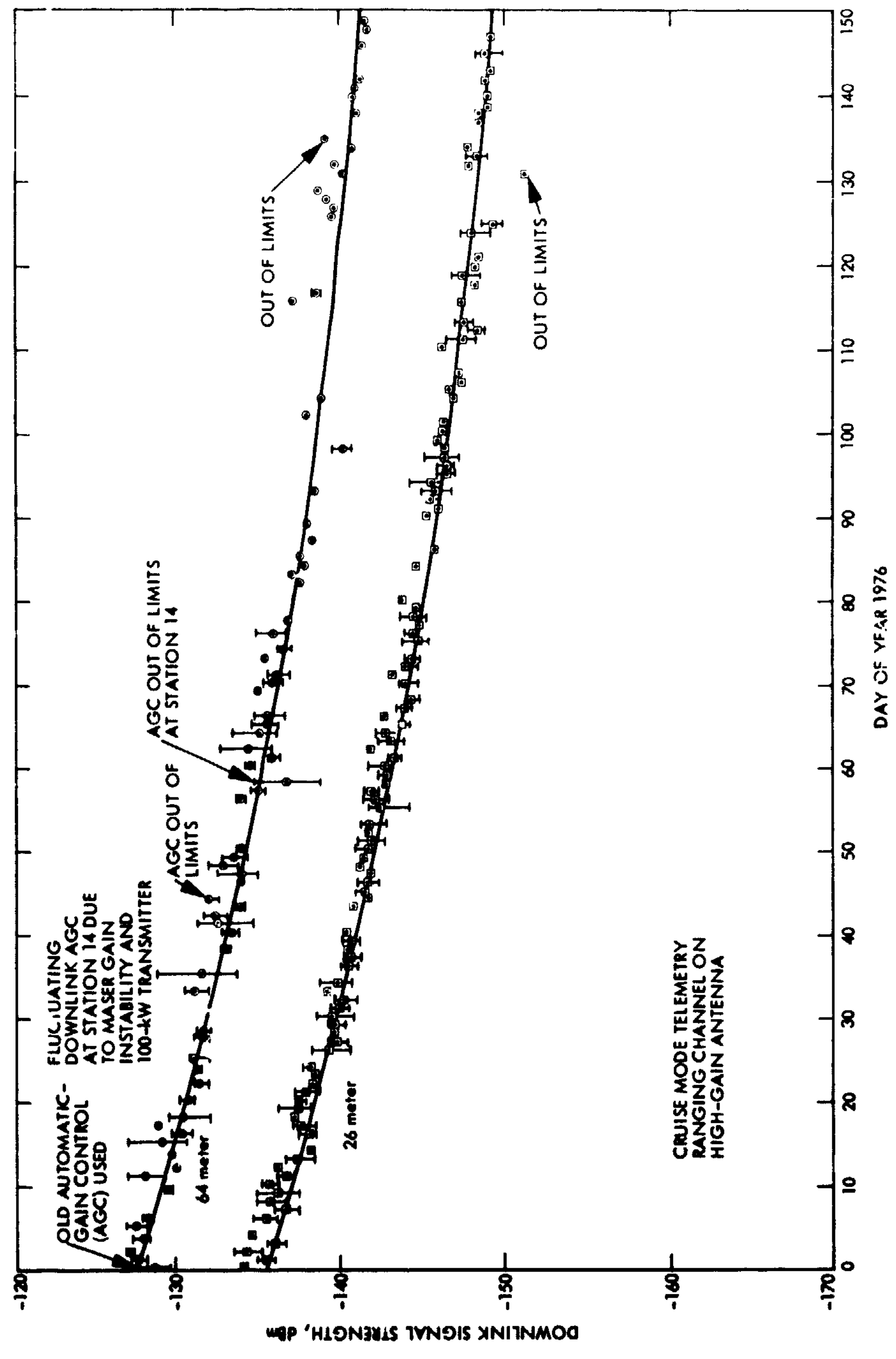


Fig. 78. Viking 1 downlink signal level at 26- and 64-meter stations through May 1976

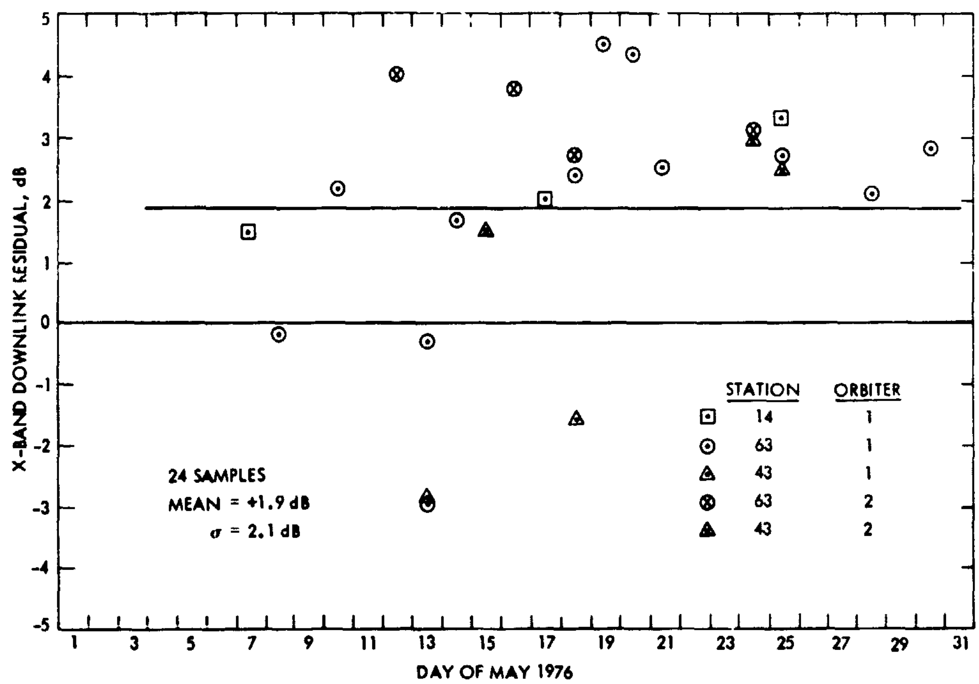


Fig. 79. Viking Orbiter 1 X-band downlink signal level residuals for May 1976

Throughout the month of June, the S-band link performance of all these 64-meter stations was normal, and no major tracking problems occurred. X-band support was provided using the new Conscan equipment for improved antenna pointing.

In the 26-meter subnet, the uplink signal level mean residual was -0.4 dB for Orbiter 1 and +0.7 dB for Orbiter 2, compared to -0.2 dB for Orbiter 1 and +0.7 dB for Orbiter 2 in May. The 26-meter downlink signal level mean residual was +0.2 dB for Orbiter 1 and was +0.3 dB for Orbiter 2. Comparable May figures were -0.3 dB for Orbiter 1 and 0.0 dB for Orbiter 2. None of these numbers represents any significant trend.

Figure 80 shows the values for S-band downlink signal level at 26- and 64-meter stations for the month of June, as a continuation of the previous plot for May for Orbiter 1. Figure 81 displays uplink and downlink residuals through June and affords a good measure of the stability and accuracy of the stations' performance when taken in combination with the performance of the spacecraft itself.

Similar plots for Orbiter 2 are given in Figs. 82 and 83.

The X-band performance data for both Orbiters 1 and 2 are given in Fig. 84 for all three 64-meter stations. The residual values appear to continue at about 2.0 dB. Efforts to discover the cause for this residual had not been successful, but investigations continued.

On June 30, 1976, during the "Revolution 10" nonpropulsive maneuver, the uplink signal level suddenly changed by -1.8 dB. Subsequently, the uplink signal level residuals on 64-meter stations averaged -2.5 dB, with no further trend developing. Careful investigation by Orbiter and Deep Space Network telecommunications analysts eliminated the Ground Data System (including the tracking stations) as possible causes, and left the question of some spacecraft-related anomaly in the flight radio system or its telemetry for further investigation. Meanwhile, the Orbiter 1 telecommunications link continued to operate quite satisfactorily.

Through July, telecommunications performance remained close to predictions, as the number of spacecraft to be tracked by the Network increased from two to three with the separation of the first Lander from its Orbiter.

Almost all Orbiter 1 tracking during July was from the 64-meter net, and there were very little 26-meter data available for downlink analysis.

The uplink and downlink signal level residuals for the period January through July 1976 are displayed graphically in Fig. 85.

At Madrid Station 63, the average uplink signal level was -1.0 dB below predicts in July. In June, it was +1.4 dB, and thus the change from June (average) to July (average) was -2.4 dB. Similarly, at Canberra Station 43, the average July uplink signal level was -1.4 dB below predicts;

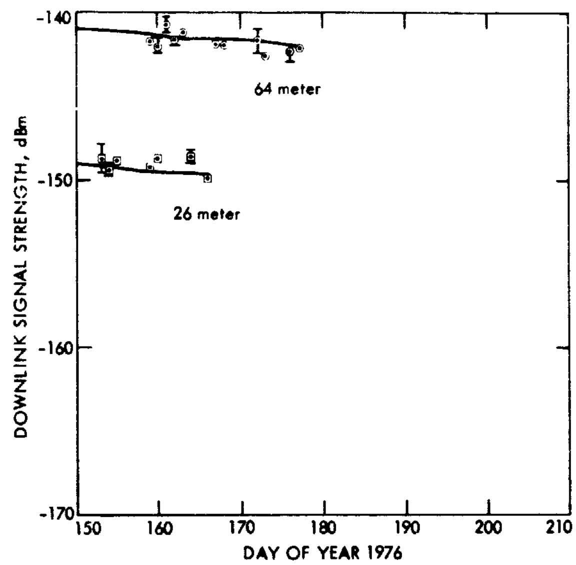


Fig. 80. Viking Orbiter 1 downlink signal level at 26- and 64-meter stations through June 1976

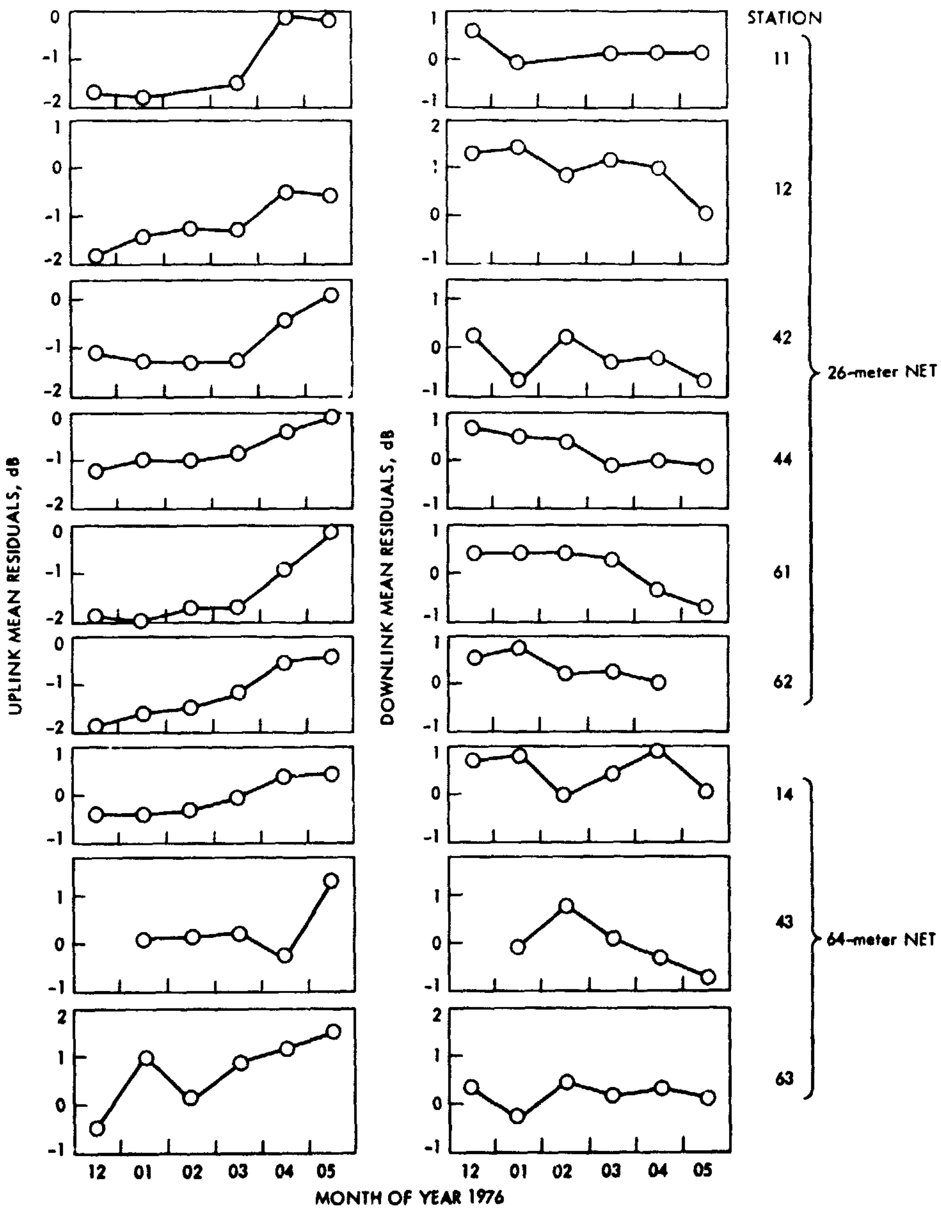


Fig. 81. Viking Orbiter 1 uplink and downlink signal level residuals through June 1976

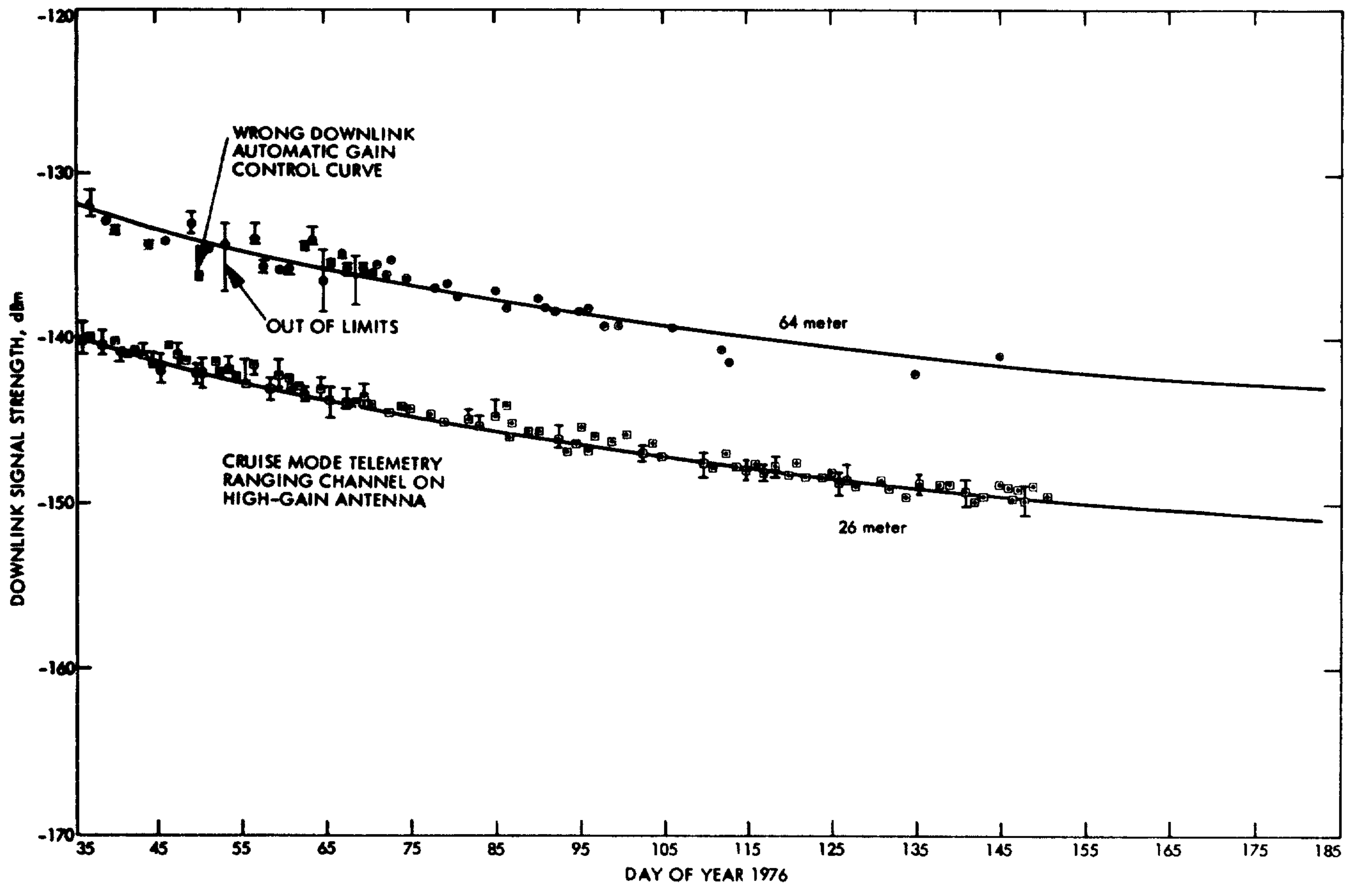


Fig. 82. Viking Orbiter 2 downlink signal level at 26- and 64-meter stations through June 1976

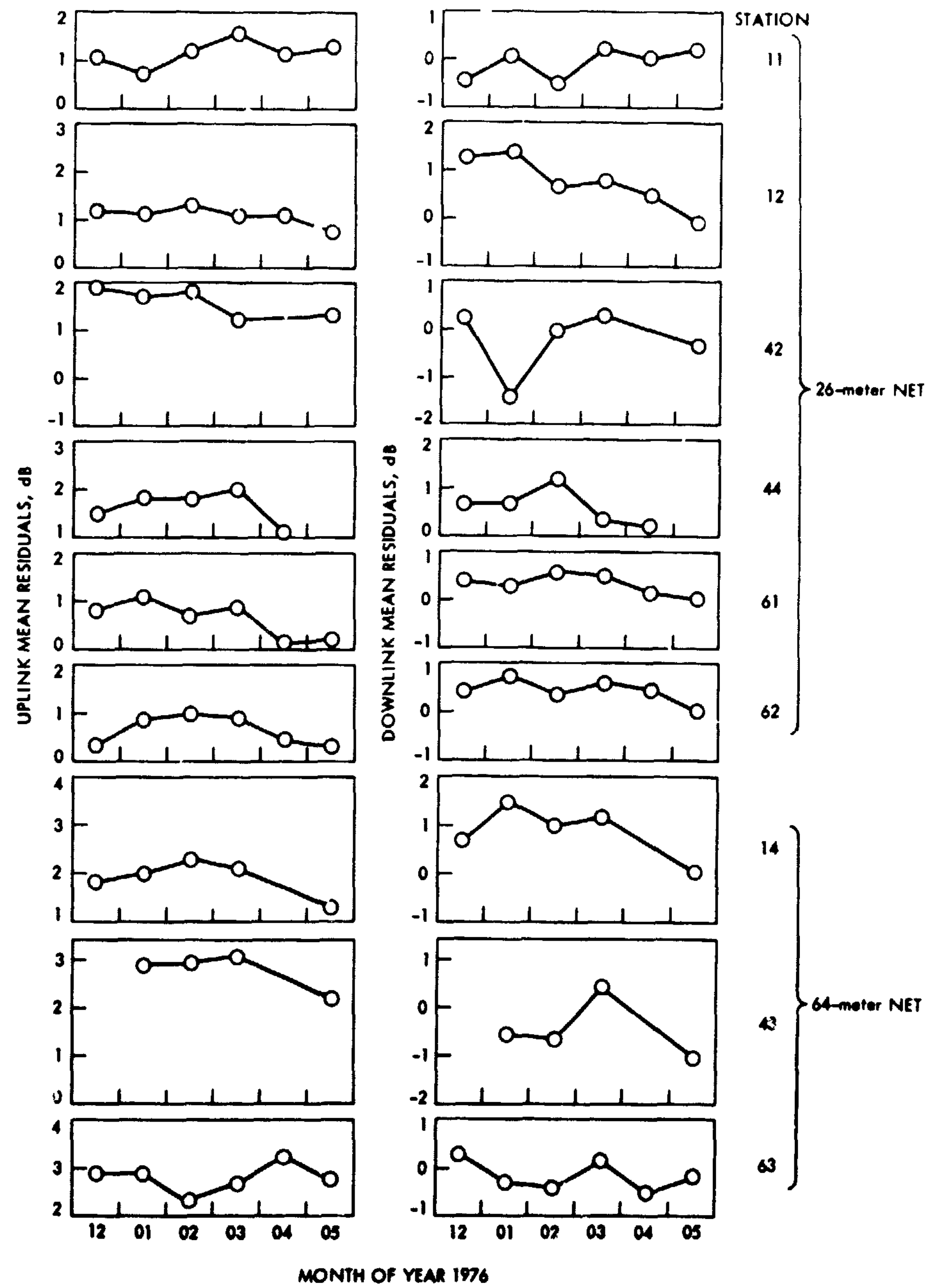


Fig. 83. Viking Orbiter 2 uplink and downlink signal level residuals

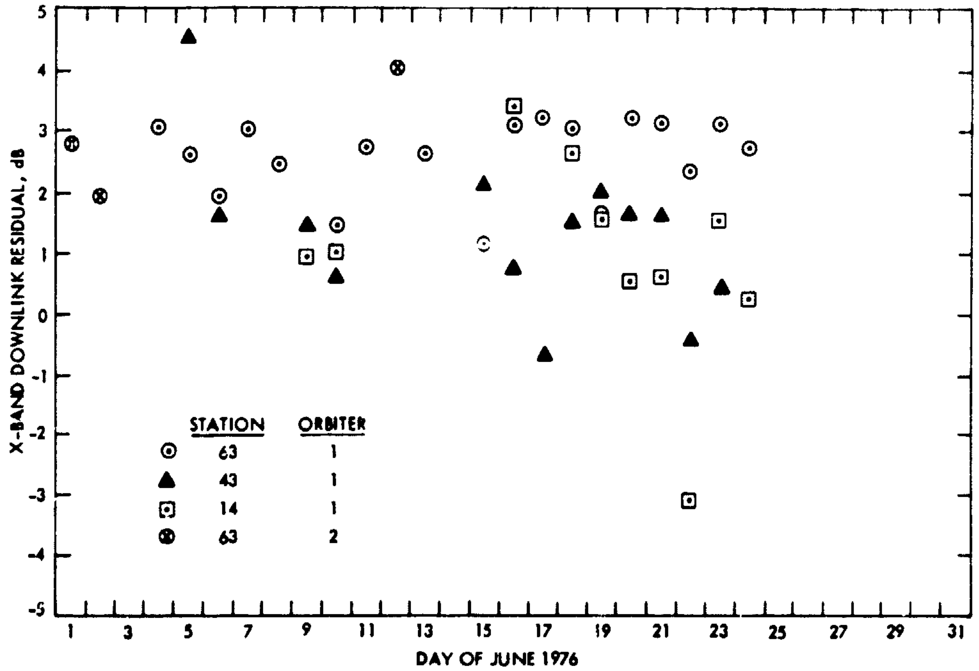


Fig. 84. Viking Orbiter 1 and 2 X-band downlink signal level residuals for June 1976

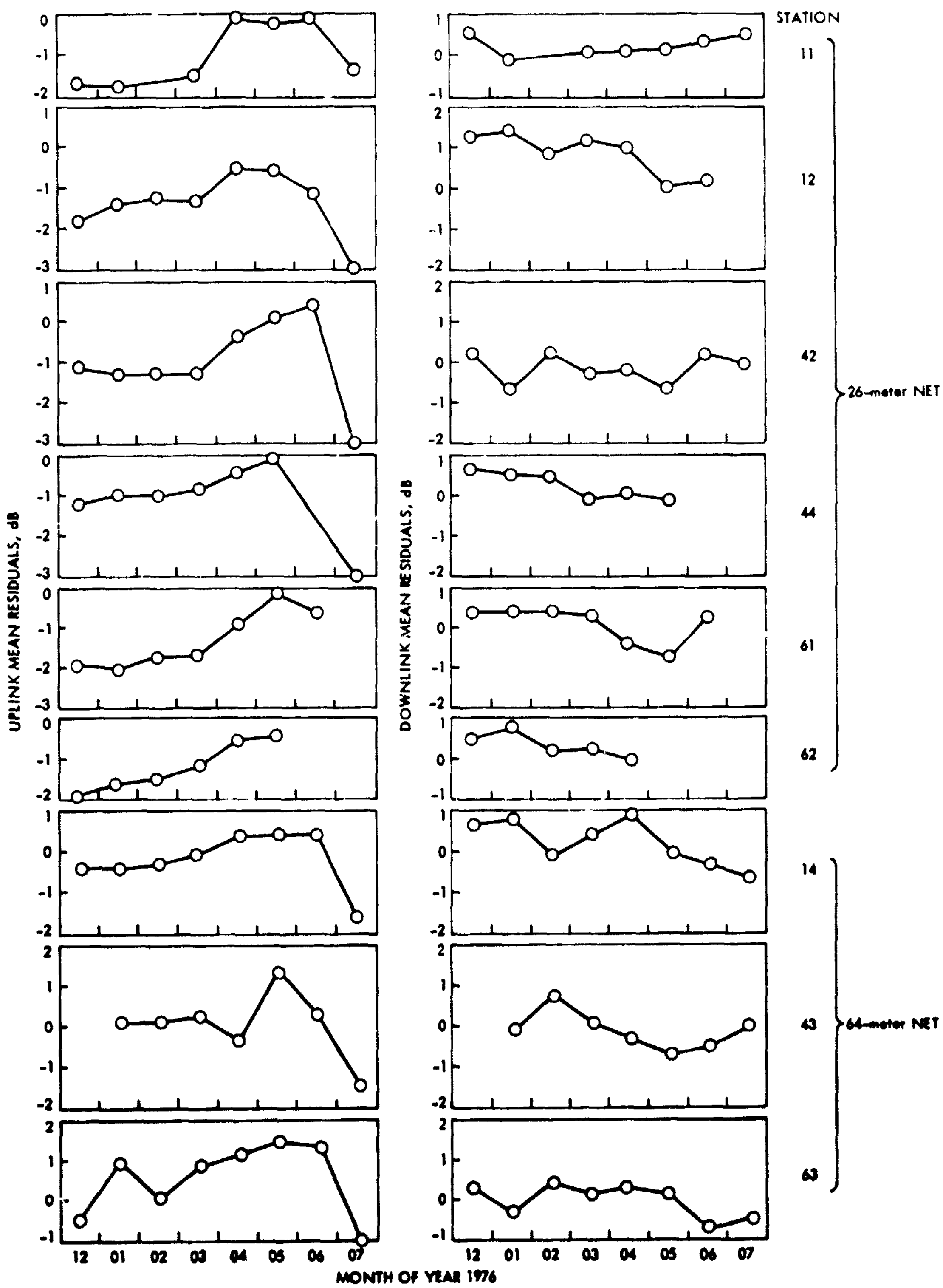


Fig. 85. Viking Orbiter 1 uplink and downlink signal level residuals from December 1975 through July 1976

in June it had been +0.3 dB above predicts, with a change from June to July of -1.7 dB. Finally, at Goldstone Station 14, the uplink signal level in July averaged -1.6 dB below predict, compared to a +0.4-dB residual in June, for a June-to-July change of -2.0 dB.

For downlink signal level, there were no significant trends. At Station 63, the July average residual was -0.5 dB, compared to -0.7 dB in June. At Station 43, the July average residual was 0.0 dB, up from -0.5 dB in June. Station 14 had a July average residual of -0.6 dB, which was down from the June average of -0.2 dB.

Because there was very little 64-meter cracking of Orbiter 2 in July, no 64-meter uplink signal level residuals were obtained during the month. A small amount of downlink signal level information, and some signal-to-noise ratio data, was obtained. Figure 86 summarizes the data for Orbiter 2.

For uplink signal level, the three 26-meter stations with most data were 61 in Spain, 42 in Australia, and 11 at Goldstone. No particular trends from June are evident. Station 61 had a mean uplink signal level residual of +0.6 dB in July and +0.3 dB in June; Station 42 had a mean uplink signal level residual of +0.6 dB in July and +0.3 dB in June; Station 42 had a mean uplink signal level residual of +1.5 dB in July and +1.2 dB in June; and, finally, Station 11 had a mean residual of +0.7 dB in July with +0.1 dB in June.

The downlink signal level at the 26-meter stations (which would all be cruise telemetry mode) and at the 64-meter stations also shows no significant trend.

The X-band downlink residuals for Orbiter 1 are shown in Fig. 87, and those for Orbiter 2 in Fig. 88. There is still a tremendous amount of scatter, compared to the S-band links, but a mean residual of 0.00 dB is not an unreasonable estimate.

i. Prelanding Operations for Viking 1. In July, the years of planning, testing, and training that had been expended in support of the Viking Project culminated in the successful landing of Viking 1 on July 20. Preceding the more obvious events of the actual landing sequence, however, was an enormous background of detailed planning, which ensured a smooth transition through the sequence, and provided well understood and validated alternative actions, for use in the event that trouble had occurred. This aspect of the prelanding operations is described below.

(1) Preseparation Checkout. Network support of activities associated with the landing of Viking Lander 1 began on July 18, 1976 with Madrid Station 63 supporting the "separation minus 39 hours" command update. The prime purpose of this command load was to prepare the

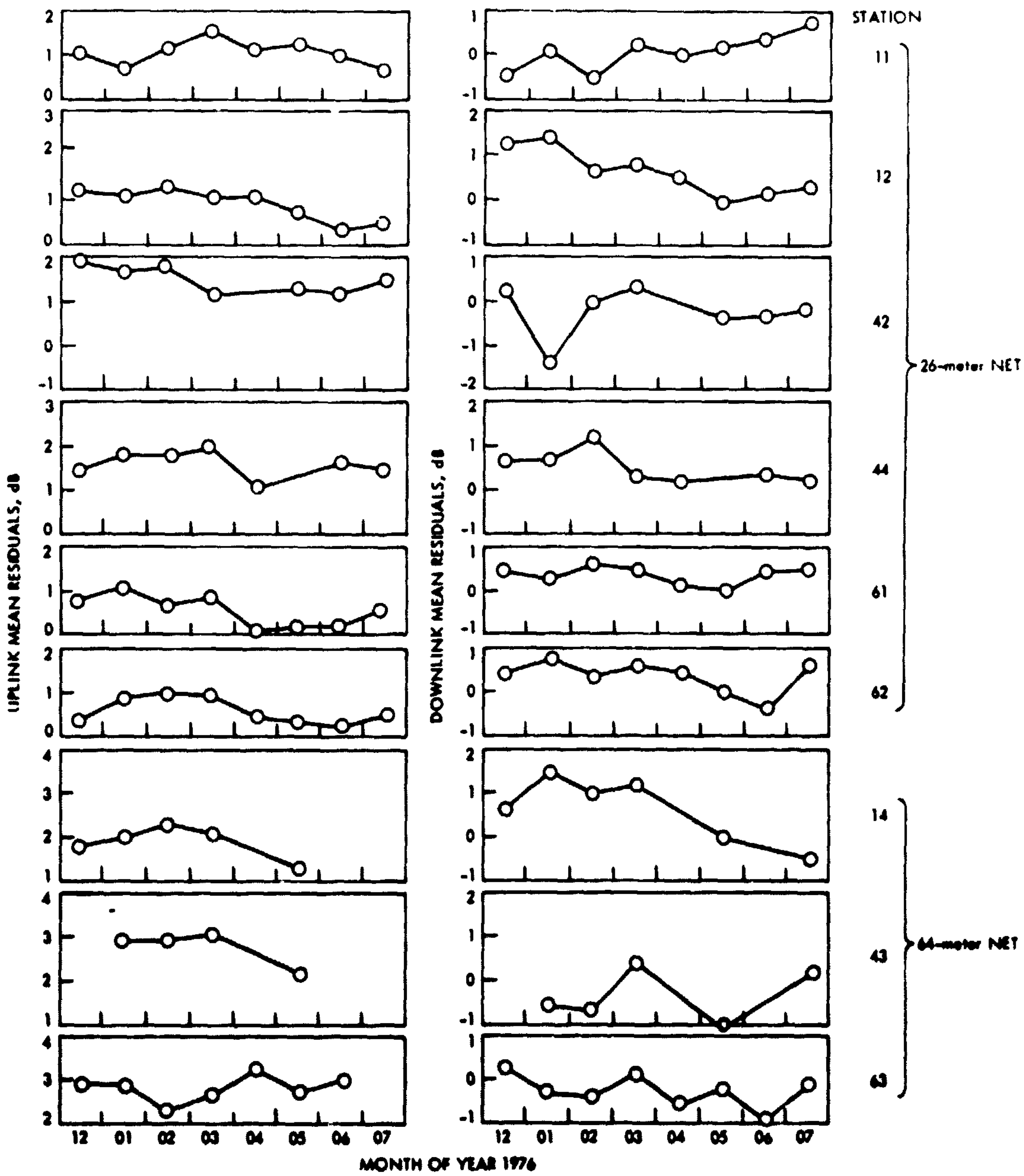


Fig. 86. Viking Orbiter 2 uplink and downlink signal level residuals from December 1975 through July 1976

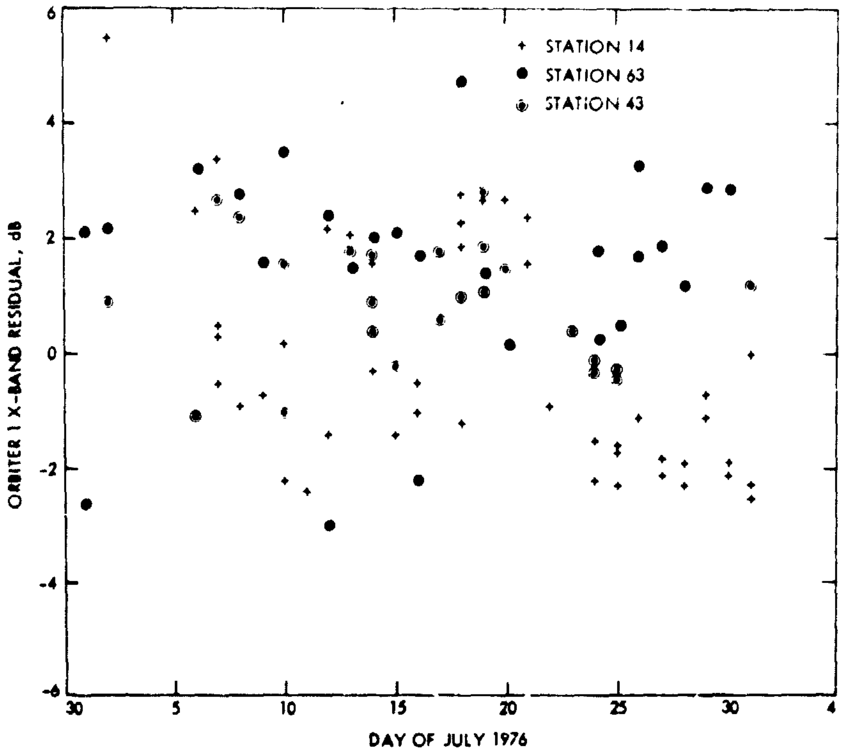


Fig. 87. Viking Orbiter 1 X-band downlink signal level residuals for July 1976

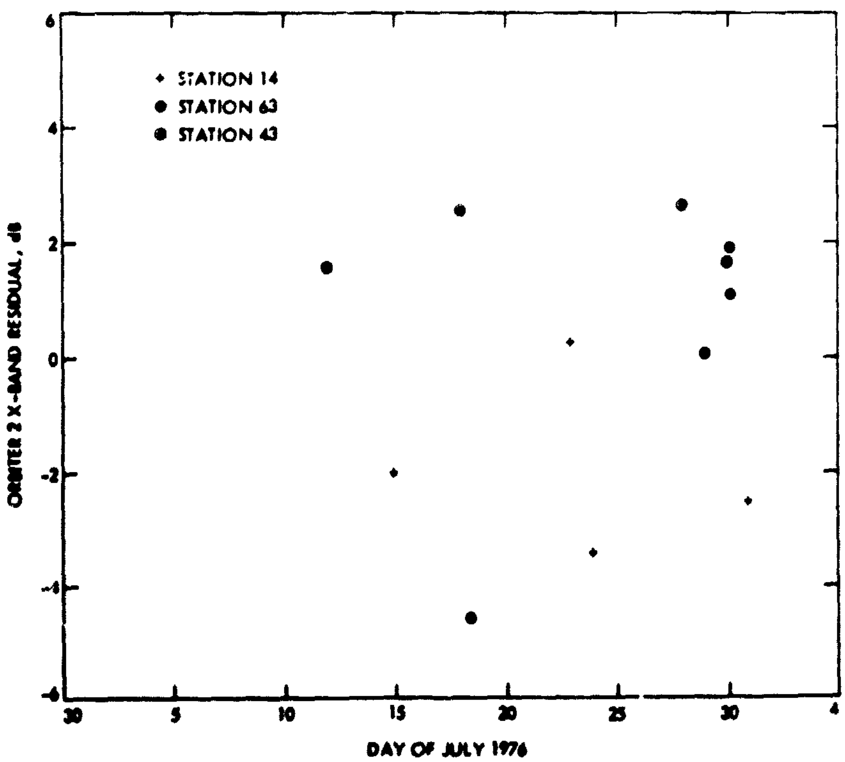


Fig. 88. Viking Orbiter 2 X-band downlink signal level residuals for July 1976

mated Lander for the preseparation checkout. Station 63 was configured to the standard Orbiter/Orbiter configuration with one Command Modulator Assembly initialized for Orbiter 1 and the other initialized for Lander 1 and mated Lander commanding. The command load was successfully transmitted without incident.

The preseparation checkout occurred over Canberra Station 43 on July 19, 1976. A unique telemetry configuration was utilized during this pass in order to provide redundant data channels all the way from the station to the Mission Control Center. During the major portion of preseparation checkout, medium-rate data at 1 or 2 kbps was to be received. Redundant data streams were provided for these data rates by specifying configuration code 24, as shown in Fig. 89. In this configuration, one Telemetry and Command Processor outputs medium-rate data to the high-speed data line, and the other Telemetry and Command Processor outputs medium-rate data to the wideband data line, thus providing dual transmission paths to the Mission Control Center.

Following the completion of the 1- and 2-kbps data sequences, the spacecraft data rate changed to high rate at 4 kbps. At this data rate, the processing capability of the high-speed data channel was exceeded, and a new configuration was enabled, which maintained redundant processing channels at the station, but permitted both data streams to be transmitted via the wideband data channel to the Mission Control Center, where dual data processing strings completed the total redundancy concept for this critical portion of the mission.

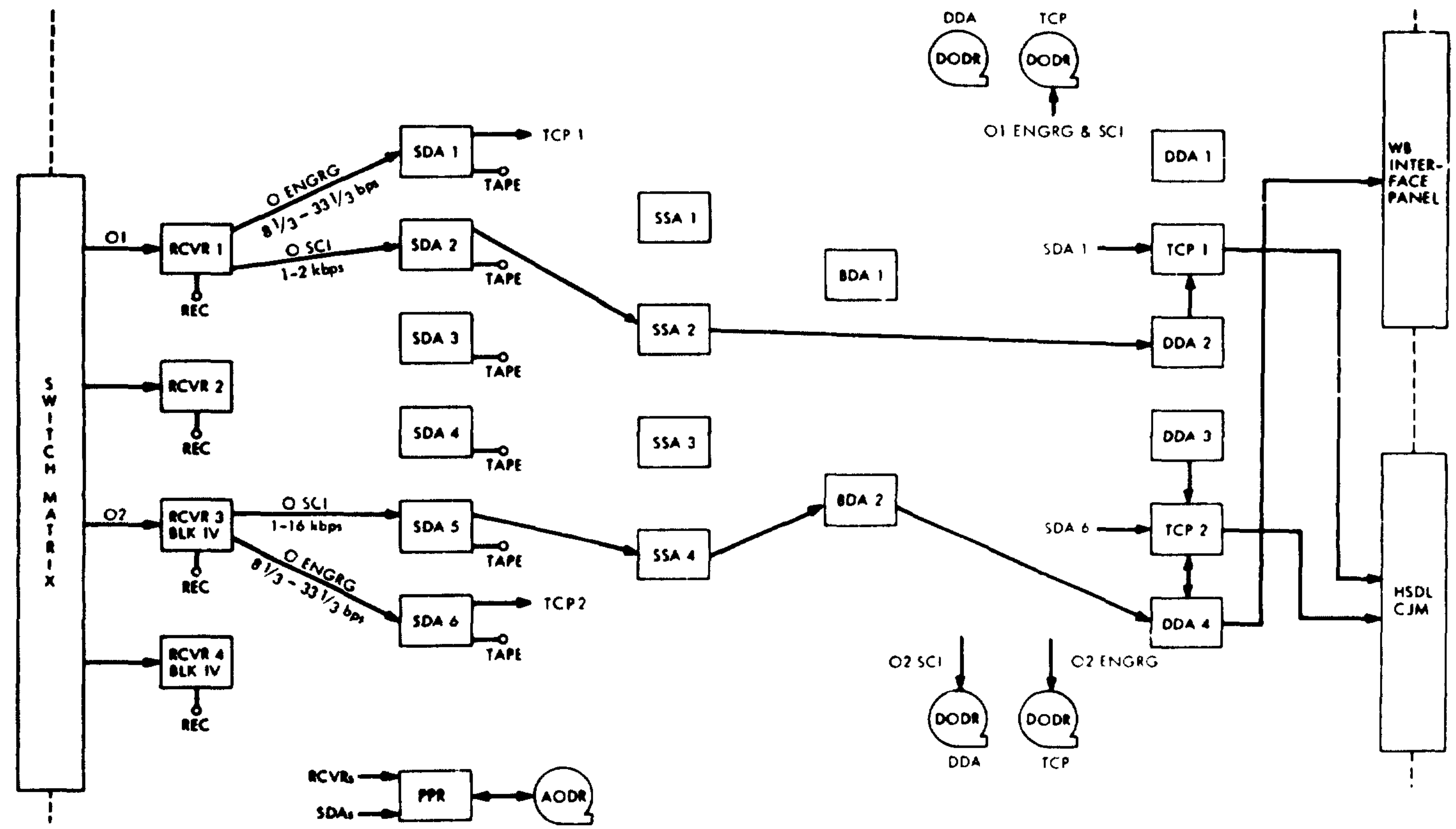
Stations 62 and 44 provided backup command capability during the preseparation phase.

(2) Separation, Descent, and Landing. This phase of the landing activity was divided into two major events. The first event was the transmission of the separation "GO" command followed by the second event of separation, descent, and landing.

The Lander's Guidance Control and Sequencing computer software was designed such that before executing the separation sequence, the "GO/NO-GO" flag was tested. If the flag had not been set to "GO" by ground command, the program would have defaulted to "NO-GO," and separation would have been inhibited. The transmission of the "GO" command was left until 45 minutes prior to separation, to allow consideration of the latest relevant data and to give the Flight Team an opportunity to respond successfully to any anomalies discovered prior to separation. A "NO-GO" decision could have resulted in a separation delay of from 1 to 8 days or more, depending on the cause of the "NO-GO."

The telemetry configuration used by Station 43 on the previous day for preseparation checkout (code 24) was used again for this pass.

Due to the importance of the "GO" command, special precautions were taken to ensure that the command would be successfully transmitted. Station 43 configured its two Command Modulator Assemblies for mated Lander commanding. The two Telemetry and Command Processor command stacks were then loaded with "GO" commands. The prime Telemetry and



AODR	ANALOG ORIGINAL DATA RECORD	PPR	PRE- AND POSTDETECTION RECORDING SUBSYSTEM
BDA	BLOCK DECODER ASSEMBLY	RCVR	RECEIVER ASSEMBLY
BLK	BLOCK	REC	RECORDING SUBSYSTEM
CJM	COMMUNICATIONS JUNCTION MODULE	SCI	SCIENCE
DDA	DATA DECODER ASSEMBLY	SDA	SUBCARRIER DEMODULATOR ASSEMBLY
DODR	DIGITAL ORIGINAL DATA RECORD	SSA	SYMBOL SYNCHRONIZER ASSEMBLY
ENGRG	ENGINEERING	TCP	TELEMETRY AND COMMAND PROCESSOR
HSDL	HIGH-SPEED DATA LINE	WB	WIDEBAND

Fig. 89. Station configuration (code 24) to provide redundant data channels for Viking 1 preseparation checkout

Command Processor contained timed commands to be transmitted at separation minus 45 minutes, while the backup Telemetry and Command Processor contained the identical commands, but untimed. The backup processor was to be used in the event problems developed in the prime string.

In addition to the commands loaded into the processor stacks, duplicate commands were also loaded into the manual buffer of each processor. These commands were to be transmitted if problems developed which would prevent transmission of the commands residing in the command stack.

A backup command capability was also provided by Station 44. At this station, the "GO" commands were loaded into the stack and manual buffer in the same way commands had been loaded in the backup string at Station 43.

Station 44 was to have been used following a failure at Station 43. The exciter frequency at Station 44 was chosen so that, in the event of a transmitter or antenna failure at Station 43, it would only be necessary to turn on the transmitter at Station 44 and tune to a new reference frequency, and thus capture the spacecraft receiver as it drifted toward its rest frequency. Command transmission could then be continued with only a slight delay.

The "GO" command was successfully transmitted by Station 43 on July 20, 1976, using the prime transmission path.

The telemetry configuration chosen for support of the separation, descent, and touchdown events was the standard two Orbiter configuration (code 15). In this configuration, both Telemetry and Command Processor strings were initialized for Orbiter 1, giving two redundant processing channels for engineering and science data. Since no commanding was anticipated during the descent phase, no special configurations or procedures were required. Station 63 was the prime station for support of separation, descent, and touchdown.

A special procedure was used during the descent phase for telemetry processing at Station 63. As the spacecraft began its descent and passed through the atmosphere of Mars, the 4000-bps data were transmitted in bursts of short duration. Between these data bursts were blocks of invalid data. In order to ensure that each of the 4000-bps bursts was processed at the station, the stations were instructed to initialize the two high-rate processing channels at the beginning of the burst data and to remain initialized even though the data appeared as noise between bursts. Testing during compatibility and operational tests, both prior to launch and during cruise, had proven this to be a feasible plan.

Throughout the separation, descent, and touchdown sequences, the stations, ground communications, Network Control Center, and the operations control teams all functioned smoothly, with no anomalies, and no loss of data. This flawless performance was considered to be attributable, in no small measure, to the tremendous amount of time and effort that had been devoted to testing all elements of the Network individually and collectively, and to the thoroughness of the operations personnel training programs.

3. Planetary Configuration Development

a. Implementation. Following the achievement of operational status in the Network Operations Control Center in late April 1976, a number of desirable but not essential features of the system still remained incomplete. In addition, operational usage of the facility soon revealed deficiencies that required attention in order to meet the increasing demands of the Viking mission as orbit insertion activity for Viking 1 approached. Using the task team that had been established to complete the initial phase of operational readiness, an accelerated work plan was initiated to cover the "enhancement items" for completion by June 1. The plan encompassed the following major items of software and hardware:

(1) Software

(a) Modify the data records processor software to allow recall to be restarted just prior to an error received during a recall sequence.

(b) Install an updated magnetic tape handler program to increase the reliability of the recall merge process and reduce the size of data gaps.

(c) Correct the Network communications equipment to simultaneously route data to two Network telemetry monitors.

(d) Provide ability to synchronize on inverted telemetry data.

(e) Complete the Block III Network command subsystem to permit the stations to be configured for "commanding" from the Network Operations Control Center.

(f) Develop simplified algorithms to reduce the problems created by time regressions during the recall-merge process.

(2) Hardware

(a) Replace the existing "borrowed" magnetic tape assembly with permanent 4-drive units in the Network Data Processing Area.

(b) Convert four megadata display/keyboard terminals for use in the Network Operations Control Center to provide additional capability.

(c) Improve air conditioning facilities for electronic rack cooling and Network data processing terminal.

(d) Upgrade star switch controllers for overwrite protection.

With the upgrade of the star switch controllers, the time regression problems appeared to be corrected and all work was completed by June 1. The enhanced system now provided much improved edit, display, and format facilities, and was considered capable of supporting planetary operations with adequate margin for failures and anomalies.

b. Planetary Preparation Tests. The Network planetary preparation test effort continued at an accelerated pace during the months of May and June 1976. The Operations Planning Group conducted 19 Operational Verification Tests and Ground Data System tests and participated in four additional Project tests during the period beginning May 1, 1976, and ending on June 18, 1976. The basic objectives of Operational Verification Tests and Ground Data System tests are described in Volume I of this document. The tests supported were as follows:

(1) Network Tests. One test was conducted with Station 43 during the first week of May for the primary purpose of further increasing station operator proficiency. The test configuration (Code 30) used the Telemetry System to process six telemetry data streams from three Viking spacecraft (two Orbiters and one Lander simultaneously).

Two tests were conducted with Station 12 and one with Station 61 in May and June. These tests were designed to exercise the Automatic Total Recall Subsystem. Test objectives included recall of data from seven- and nine-track Digital Original Data Records in the automatic and manual modes, in addition to the conversion of analog data records to digital data records.

Five tests were completed with 64-meter stations during May and June, using Code 61/15 configuration. These tests were designed to simulate the configurations and procedures which would be used for the Lander direct S-band link telemetry and command. The Code 61 configuration used two telemetry processing channels for Orbiter data and the remaining four for Lander direct link data. The Code 15 configuration was used following the termination of the Lander direct link, using a second telemetry processor as a backup for Orbiter data.

At the request of the Viking Project, an additional test was completed with each of the 64-meter stations to demonstrate the ability of the stations to decommutate and display selected engineering data words at the site. Four engineering measurements were displayed at the stations and values compared in real time with the values being displayed in the Viking Project operations area. This program ran in any one of three computers at the stations and was to be used in the event of an emergency when the Project had lost the capability to process and display Orbiter engineering data. Key parameters would be selected with the values displayed at the stations being relayed to Project operations by voice.

A special configuration was tested at Station 14 on two occasions wherein Orbiter science data at data rates of 2 kbps and lower were routed through two telemetry strings for transmission over a wideband data line and high-speed data line simultaneously. This provided two diversely routed transmission paths, and, in the event of a failure of the prime high-speed data line, the data would continue to be transmitted to the Mission Control Center on the wideband data line. It was used at Station 14 during Mars orbit insertion of the first Viking Orbiter.

Configuration verification tests were conducted with Stations 14, 43, and 63 in preparation for orbit insertion of Orbiter 1. These were engineering tests to verify that the configurations defined by the Network Operations Plan could be complied with and functionally checked. Following the successful completion of these tests, the stations were placed under Viking configuration "freeze," which prohibited any changes being made to the stations during the "freeze" period.

(2) Viking Project Tests. The objective of Training Test 3 was to verify that the Viking Flight Team could detect and properly respond to selected spacecraft and Ground Data System failures or anomalous conditions that might occur during the 52-hour time period preceding Orbiter-Lander separation. Stations 43 and 63 supported this test using Configuration Code 15 with both telemetry processors initialized for Orbiter 1.

The primary purpose of Ground Data System Test 11.0 was to test those capabilities, configurations, software, and procedures not previously tested. The test was conducted with Stations 14, 43, and 63 and included the following activities:

(a) Configuration Codes 61, 1, 15.

(b) Real-time playback of analog data records and conversion to digital data records was demonstrated.

(c) Automatic Total Recall Subsystem III software was used for automatic recall and production of Intermediate Data Records.

(d) Manual command procedures were exercised and tracking data for S- and X-band at all Viking-required sample rates and modes were delivered to the Mission Control Center.

Several failures occurred during this test which prevented the successful completion of all test objectives. Stations 43 and 63 were, therefore, scheduled for a retest. For the most part, items retested were those associated with the nonreal-time portion of the original test, such as analog-to-digital conversion and use of the ATRS III program for recall of digital data. The retest was, however, successful, and the Ground Data System was certified as ready to support for planetary operations.

An additional test was requested by the Mission Control Director in order to give the Directorate personnel an opportunity to exercise procedures associated with the preseparation checkout and separation phases of the Viking mission. The test was supported by Stations 14 and 63.

The objective of the final Operational Readiness Test 3 was to demonstrate to the Viking Mission Director the final readiness of all elements of the Viking Flight Operations System to support Mars orbit insertion of the Viking 1 mission. Where possible, the same personnel, hardware, software, configurations, etc., which were used to support this test, were to be used in support of the actual mission event. The 64-meter subnet was used to support this test with Station 14 performing the orbit insertion command load update and Station 63 supporting the simulated Mars orbit insertion.

With the successful completion of Operational Readiness Test 3, the Project test effort for planetary operations was concluded.

4. Mars Radar

During May and June, the X-band Mars radar facility at Goldstone continued to support an intensified program of observations. The early observations continued previous coverage of the Viking C-sites, and, in June, the view periods began to cover the prime landing A-sites. Results of observations made on the following days are shown in Table 46.

During the period of these observations, the received signal level decreased significantly due to the increasing Earth-Mars range. Typical C-1 site data taken around April 10, 1976, are compared with typical A-1 site data taken two months later on June 11, 1976. (See Figs. 90 and 91.)

The importance of the A-1 site observations was enhanced by the additional radar coverage provided by the S-band radar at the Cornell Radio Astronomy Observatory at Arecibo, Puerto Rico. The overlapping areas of coverage for prime A-1 and A-2 landing sites are shown in Figs. 92 and 93.

With these observations, the X-band radar support for the 1976 opportunity was concluded. A total of 527 hours of active radar support had been provided since the beginning of the year when continuous observations at full power began. The radar data were intensively analyzed by the Viking Landing Site Selection Group in its landing site selection processes. At the time the radar observations concluded on June 15, the Viking Project had decided to await the first of the site certification pictures from Orbiter 1 to correlate with the Goldstone and Arecibo radar data before making the final decision on the actual landing site.

5. Radio Science

During the months of May and June, three occultation demonstration passes were carried out with Stations 14 (Goldstone) and 43 (Australia). The first two tests on May 12 and 15 produced good data, which were pro-

Table 46. Goldstone X-band Mars radar observations

Observation date		Site	Data quality
May	10	Terrain calibration	Partial pass given to Helios
	12	Terrain calibration	Good data
	14	Terrain calibration	Good data
	19	Terrain calibration	Good data
	26	Terrain calibration	Good data
	29	A-1	Good data
	30	A-1	
	31	A-1	Good data
June	1	A-1	No pass
	2	A-1	No pass due to Operational Readiness Test 3
	3	A-1	Good data
	4	A-1	Good data
	5	A-1	Good data
	6	A-1	Good data
	7	A-1	Good data
	8	A-1	Bad data due to transmitter problem
	9	A-1	No pass due to midcourse maneuvers
	10	A-1	No pass due to optical nonsupport
	11	A-1 & A-2	Good data
	12	A-2	Good data

Table 46 (contd)

Observation date	Site	Data quality
13	A-2	Partial pass---good data
14	A-2	Partial pass---good data
15	A-2	No data due to transmitter failure

cessed through the entire system and provided a satisfactory demonstration of end-to-end operation. The third test on May 31, utilizing both Stations 14 and 43 simultaneously, was a failure because of procedural and predict problems. Corrective action was taken, and further tests were scheduled.

The very long baseline interferometry tests using the Viking spacecraft and a quasar (PO 735+17) had experienced tape recorder problems on five successive passes on April 18, 24, and 28, and May 3 and 7. After several unsuccessful attempts to correct the problem at the stations, it was decided that specialist help was needed, and late in June an engineer was sent to the site to investigate the problems.

The 1976 program for very long baseline interferometry observations called for four passes, subject to mission operations schedules, between the following dates: July 8-20, August 14-28, September 1-5, September 9-23, and October 5-16.

The first of the very long baseline interferometry experiments was scheduled for July 13 and 14, using Station 14 at Goldstone and Station 42 in Canberra, Australia. The scheduled times for the experiments were July 13-14, 23:25-04:50 Universal Time Code, and July 14-15, 23:25-04:50 Universal Time Code.

The purpose of these Viking/quasar experiments was to determine the position of Mars relative to the quasar reference frame.

The configuration and operational instructions for these experiments were contained in the Network Operations Plan and used the configuration given in Fig. 45 of this report.

Each experiment began by observing a calibrator source (0J287) for 10 minutes, the position of 0J287 being right ascension 08 degrees 53 minutes 28.0 seconds, and declination +20 degrees 11 minutes 51 seconds. The remainder of the experiment was to be spent moving the antennas back and forth between Viking Orbiter 1 and the natural radio source 0L064.5, the position of the natural radio source being right ascension

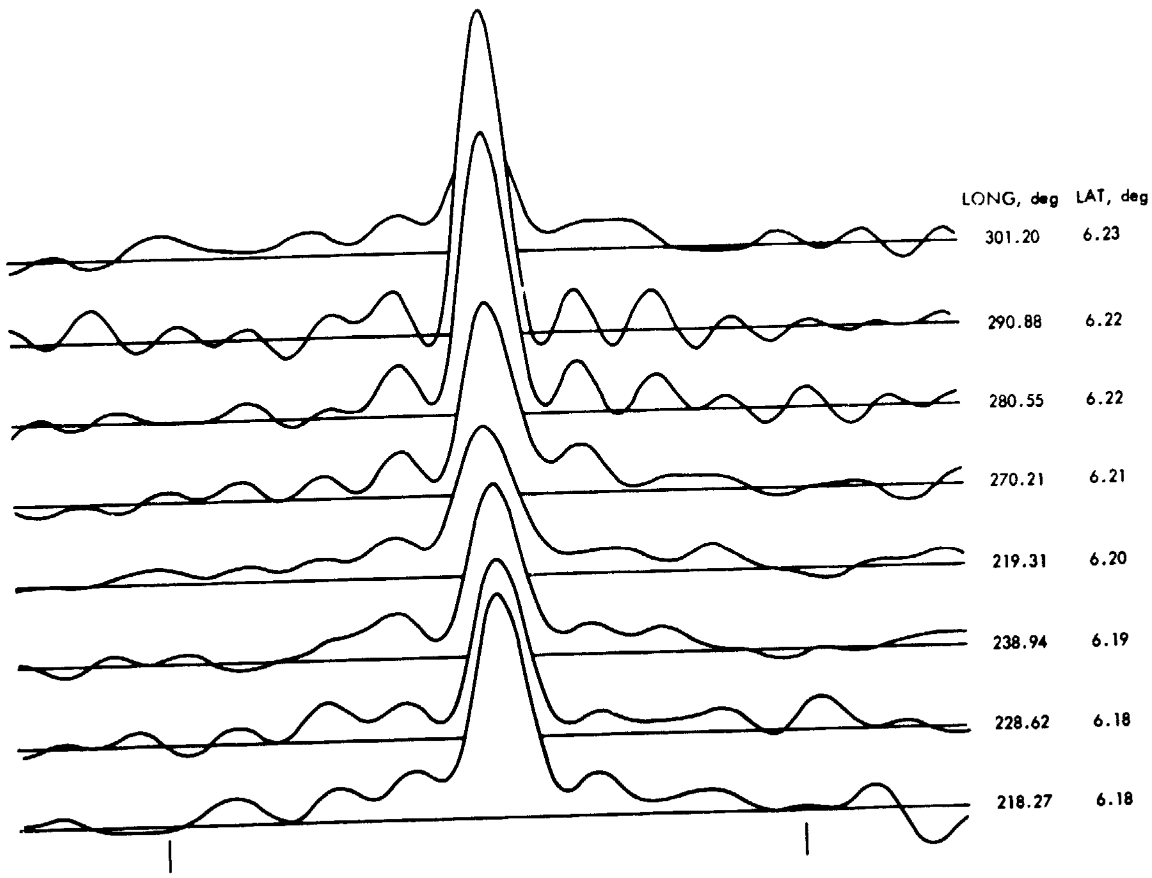


Fig. 90. X-band radar spectra from Viking C-site observation on April 10, 1976

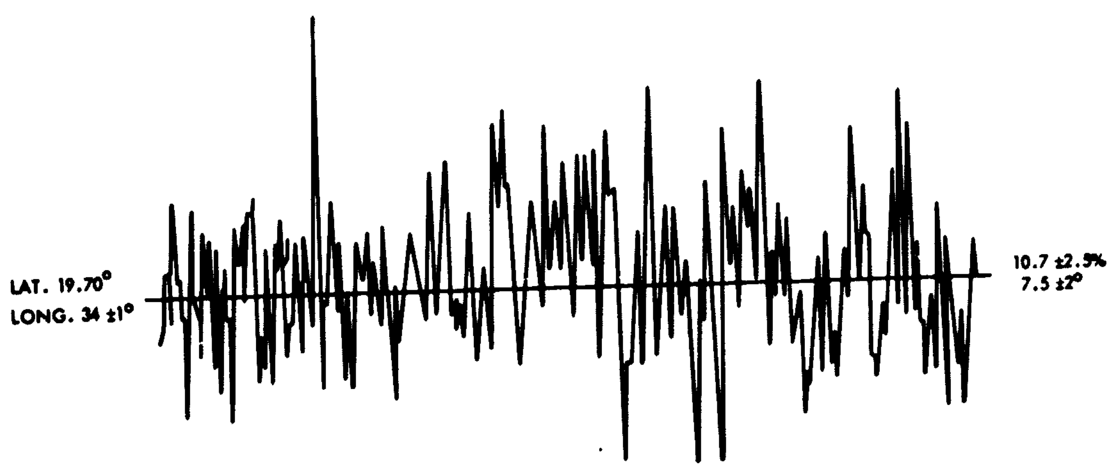


Fig. 91. X-band radar spectra from Viking A-site observation on June 11, 1976

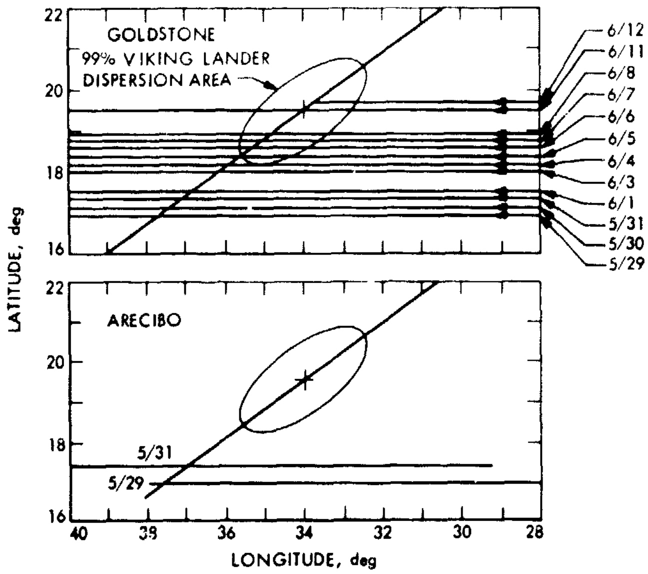


Fig. 92. Site A-1 radar observations during May-June 1976

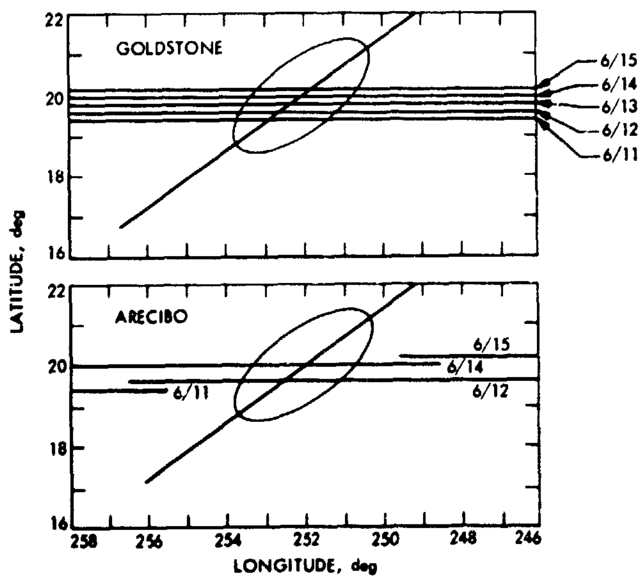


Fig. 93. Site A-2 radar observations during June 1976

10 degrees 40 minutes 04 seconds, and declination +06 degrees 17 minutes 35 seconds.

This involved cycling the antenna between Viking 1 and the natural radio source with a cycle time of 5 minutes. Since rapid move times were essential, the antennas were driven manually; to avoid the necessity of continually loading source positions into the pointing system, the position of the natural source OL064.5 was permanently loaded into the antenna pointing system, while the position of Viking Orbiter 1 was treated as an hour angle and declination offset. The positions of Viking 1 to the natural radio source are given below:

Universal Time Code	Declination, degrees	Hour angle, degrees
01:30	4.377	2.868
02:00	4.372	2.856
02:30	4.367	2.844
03:00	4.362	2.833
03:30	4.357	2.821
04:00	4.353	2.809
04:30	4.348	2.798

On this occasion, briefing of station personnel by the experimenters had been accomplished well beforehand, and the experiments were carried out successfully.

6. Operational Reliability

Data on the operational reliability of the Network continued to be accumulated from August 1975 through July 1976. These data are shown in Table 47.

The trend in reliability for the deep space stations in the month of July 1976 showed no significant differences from the averages apparent in these data over the past eight months.

The lower reliability of the 64-meter stations reflects the greater complexity of these stations compared to the 26-meter networks. As a group, the Spanish stations show a somewhat higher value for "mean time between failures" than the Australian or American groups of stations.

Table 47. Operational reliability for Viking support from August 1975 through July 1976

Operational Performance	Station								
	11	12	14	42	43	44	61	62	63
Total support time, hours	1096	1095	1221	2044	1463	1376	2192	1865	2161
Number of failures	23	30	52	25	45	17	14	22	48
Mean recovery time, minutes	90.2	30.3	44.7	59.7	63.4	91.5	88.7	35.8	50
Mean time between failures, hours	73.8	56.5	23.5	81.7	32.5	81.0	156.6	84.8	45

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APPENDIX

VIKING TRACKING AND DATA SYSTEM CHRONOLOGY OF EVENTS

(July 1975 - July 1976)

July 1975	Merritt Island Station 71, having completed all compatibility tests, provides prelaunch support. Block IV Receiver-Exciter for Stations 43 (Australia) and 63 (Spain) installed; checkout of continuing antenna noise abatement expected to be completed by July 23. At Station 63, checkout of high-power transmitter installation continues toward completion by mid-August. Operational Verification Tests now complete and crews trained at all stations. Additional Project requirements for analog recording during planetary operations have been received. All elements reported ready to launch at Near-Earth Readiness Review on July 1. Deep Space Network Readiness Review held on July 9. At Mission Operations Readiness Review on July 11, Deep Space Network reported ready to support launch and cruise.
August 1975	All stations fully operational ready to support launch on August 9 except for completion of noise abatement work at Station 43 (Australia). This work completed at 08:00 (GMT) August 11. Deep Space Network supports initial launch attempt with no failures on August 11. Configuration control at Stations 43 and 63 delays planetary reconfigurations. Revision 2 of the NASA Support Plan corresponding to Support Instrumentation Requirements Document Revisions F, G, and H sent to headquarters for signoff.
September 1975	Merritt Island Station 71 provides backup support during Viking B radio system investigation. Viking B successfully launched on September 9, and Deep Space Network supporting two spacecraft. Implementation of remaining reconfiguration resumes at Stations 43 and 63. First X-band Mars radar attempts not successful because of technical problems with the research and development equipment. Revision 2 of the Viking NASA Support Plan published.
October 1975	Network continues support of Vikings 1 and 2 without significant anomalies or outages. Some delays experienced by planetary implementation in equipment, installation, and difficulties in scheduling station time. Network Control System Block III rescheduled for full operational readiness by February 1, 1976, with Intermediate Data Record capability on February 5. Both Network and Project providing additional funding for X-band Mars radar transmitter. New work plans developed

for radar readiness for first opportunity in early December.

November 1975 — Network continues support of Vikings 1 and 2 with no significant anomalies or outages. The high-power transmitter at Station 43 completed on schedule. First system integration test with Goldstone Station 14 and Mission Control Center completed successfully. Station scheduling for test and implementation coordinated with Project mission requirements for more effective allocation of station time. X-band radar cone removed from Station 14 antenna for rework. Problems continue with delivery of X-band klystrons from Varian. All four klystrons are presently at Varian for rework.

December 1975 — X-band capability for doppler and ranging demonstrated by Network. X-band telemetry experiment carried out at Station 14. Two Viking very long baseline interferometry experiments conducted with Stations 14 and 42. Implementation and testing of the planetary configuration at all 64-meter stations is in final stages. Block III Network Control System continues on schedule toward operational readiness on February 1, with software problems being resolved in Compatibility Test Area 21. X-band radar cone replaced on Station 14 antenna. X-band transmitter with two Varian-repaired klystrons under test. Mars radar demonstration test run on December 16. Network-Project coordination for station scheduling time continues. Mars radar experiments on December 27, 28, and 30.

January 1976 — Mars radar experiments conducted on January 6, 11, 15, and 17 using the 165-kW level. Ground Data System Test 5.31 rerun with Stations 11 and 14 conducted at Goldstone. Network status review on January 9. Mandatory list of 13 work items developed. Removal of the Station Monitor Console IIA items from the Viking schedule justified by adding a staff augmentation plan for Stations 43 and 63. Further very long baseline interferometry experiments at Stations 14 and 42. Planetary mission operations status review held on January 21.

February 1976 — Ground Data System Test 6.0 supported and provided overseas 64-meter stations with first planetary operations. Demonstration Test 4 supported by Stations 11, 14, 43, and 63. Satisfactory Intermediate Data Records delivered on all passes.

March 1976 — Network support for cruise operations continues. X-band Mars radar transmitter power now at 400 kW. Network delivers Intermediate Data Records for all Viking cruise science activity. Additional Network

Operations Control Center crews are in training. Viking Project becomes concerned about the large number of incomplete cruise science Intermediate Data Records delivered over the past few weeks. Task team established to investigate problems experienced recently with Viking records. Prime suspect is inadequate quality of tape being used at the stations to make high-rate digital records. Investigations continue at high tempo.

April 1976 — Demonstration Test 7 and a rerun of Demonstration Test 4 conducted for training of operational crews in orbit and landing procedures. Successful delivery of data records with better than 99.5 percent data return reported for Demonstration Test 7, and flight operations indicate station-related problems now cleared. Intense effort to respond to Viking demands for Network Operations Control Center by April 26. Evidence that success now completely dependent upon continuing high level of effort by one or two key individuals. Continuation of intense effort results in completion of all hardware and software by noon on April 22. This followed by in-depth briefing to all operations personnel on capabilities available for planetary support. Viking Project informed on April 26 that implementation now complete. Some improvements to be incorporated between April 26 and June 1. High-quality data records now regularly delivered to the Flight Project. As of this date, implementation for Viking is considered complete.

May 1976 — Network Operations Control Center now regularly delivering Viking Intermediate Data Records with data content in excess of 99.97 percent; many instances of 100 percent now appearing. Attention concentrating on reliability and correction of known anomalies. Cruise operations and Training Test covering separation and landing supported. Work on Gravity Waves experiment is suspended, pending further direction. Compatibility Test Area 21 supports rerun of orbit insertion command load tests with Viking Orbiter 3. Ground Data System Test 11.0 supported with all 64-meter stations. Viking planetary operations begin on Monday, May 10. Configuration control in effect. 200-kW S-band klystron shipped to Arecibo on loan for Arecibo radar spare. Deep Space Network Manager at NASA Headquarters for final Viking Planetary Operations Readiness Review. Negotiations completed with Varian to expedite the repair of the failed 100-kW klystron delivery now estimated at 45 days after receipt of order. Delivery expected about July 20.

June 1976

All enhancement work items for the Network Operations Control Center completed. Final Viking Operations Readiness Tests supported satisfactorily. Goldstone technicians informed Aeronutronic Ford of intention to strike at midnight on June 15. The Maintenance and Operations Contractor proceeds to implement a contingency plan to maintain critical services at Goldstone in the event of strike action. Occultation demonstration tests conducted in early June failed due to operational problems. Tests to be rescheduled. Mars radar observations continuing daily of prime A-site. Severe overheating problem due to hot weather noted in the X-band radar cone. Negotiations with Viking Project regarding 100 percent requirement for Digital Original Data Record data on the Viking Intermediate Data Records. Mars radar observations of the prime A-site completed on June 15; no further passes scheduled. Goldstone technicians adopt second Company offer and strike action averted on June 17. Viking 1 second approach midcourse correction maneuver supported satisfactorily by Network. Spacecraft propulsion pressurization problems still persist. Mars orbit insertion for Viking 1 accomplished on June 19 without incident.

July 1976

Evaluation of A-1 prime landing site photos prompts decision to defer landing from July 4 to later date to permit better understanding of surface conditions at A-1 and other possible sites. Arecibo radar data give best agreement with visual imaging data at site approximately 44.7°W, 22.5°N. Decision made to land at that site on July 20. Successful very long baseline interferometry experiment conducted with Stations 14/42 on July 14 and 15. Spare 10-kW klystron shipped from Spain now on site at Station 43 in good condition. Network support for both Viking missions continues without significant anomalies, except for 6-hour interruption to Station 63 wideband circuit on June 28. Probable cause was amplifier failure at Madrid Intelsat Terminal. Network Operations Control Center delivering high-quality data records within time limit required, but some backlogging is becoming evident. Engine generator failure at Station 43 in Australia during week of July 5 led to a re-evaluation of generator configurations throughout the Network to eliminate single point failure modes. Network and facility regulations related to energy conservation are waived to permit stations to utilize backup power generating equipment to maximize reliability during critical Viking phases. To relieve a potential data records backlog, software to permit direct transfer of data to Intermediate Data Records from tapes shipped in from stations is delivered to Operations Control Center during week of July 12. Configuration freeze for Viking applied on

July 17 for the stations, Control Center, and all communications circuits including NASA Communications. Expected duration through Sol 20, August 10, 1976. Impact of 24-hour strike threat at Australian stations is averted by personnel cooperation and use of skeleton crews to cover Australian internal communications circuits. On July 18, Viking Flight Team (including Network) work-day moves to Mars time, 16:00-24:00 daily. NASCOM special coverage in effect at all switch centers and satellite terminals. July 19, 10:30 p.m., Deep Space Network reports "green" for Viking 1 Orbiter-Lander separation. Canberra Station 43 transmits the separation "GO" command during Pass 336. Separation, descent, and landing sequences for Viking 1 carried out perfectly. Viking Lander 1 touchdown reported at 202/11:43:06 GMT, spacecraft time. One-way light time 19 minutes 0.1 second. Deviation from predicted touchdown time +17 seconds. Contrary to expectations, Madrid Station 63 retains lock throughout descent on the 4-kbps uncoded, direct feedthrough, burst mode data. Madrid Station 63 receives first Lander relay pictures of the Mars surface from Orbiter 1 at 4 kbps. Viking 2 commences playback of high-rate optical navigation data.

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