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

Extended Mission Operations December 1976 to May 1978

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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 launch operations in 1975. Cruise-phase activities for both spacecraft from launch through Mars orbit insertion and the landing of Viking 1 are described in the second volume. The third volume discusses the support provided for the Mars orbit insertion and landing of Viking 2 and the landed operations of both spacecraft until the end of the Prime Mission on November 15, 1976. This volume, the fourth, describes the Extended Mission support activities beginning in November 1976 and continuing through May 1978.

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

ACKNOWLEDGMENTS

In the course of preparing this fourth volume of the series, the author has relied upon the many separate articles published in the DSN Progress Reports to provide the reader with engineering and operations details of the TDS support for the Viking Extended Mission.

Throughout the Extended Mission, T. H. Howe and D. W. Johnston provided regular contributions. F. H. J. Taylor and A. L. Berman have published articles of special interest; other such articles are contained in the DSN Progress Reports.

As in the previous volumes, editorial support was provided by the TDA and DSN Documentation groups of JPL. The contribution of all of these people to the material content of this volume is gratefully acknowledged.

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ABSTRACT

This document describes and evaluates the support provided by the Deep Space Network to the Viking Extended Mission from December 1976 through May 1978.

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

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

I. INTRODUCTION

A. EXTENDED MISSION

As the planet Mars and the four attendant Viking spacecraft emerged from behind the Sun in November 1976, the Earth-to-spacecraft telecommunications links began to return to normal, mission operations activitity increased, and the Viking Extended Mission, as this new phase of the project was called, began.

The Viking Extended Mission (VEM) continued to place heavy demands on the Deep Space Network (DSN) for tracking support, not only because of the continuation of the original science experiments, but because of greatly increased emphasis on Radio Science.

Occultation, solar corona, intra-station long baseline interferometry, bistatic radar, precision differenced ranging, gravity waves and gravity field experiments were all added features of the VEM in which the Network played a dominant and demanding part.

Further complexity to Network support effort was caused by the Mark III Data Subsystem reconfiguration program, in which all of the Network stations were progressively modified. In this program the obsolete telemetry and command processing computers and their software were replaced by new MODCOMP minicomputers and new software. This had to be accomplished without impact to the tracking support for Viking. The program involved not only modifying, but requalifying all Deep Space Stations prior to resumption of Viking flight operations.

Two Voyager launches took place in August and September 1977; Viking operations became subject to new additional scheduling constraints as Voyager (now in its prime mission) demanded a major share of Network resources.

To the great credit of the Viking Project, all four spacecraft (two Orbiters and two Landers) remained active, with some minor exceptions, throughout the VEM. The presence of four active spacecraft at the planet afforded the Project scientists with enormous scope for innovative experiments. However, at times, these experiments created nearly impossible operational demands. Station operations crews were often required to reconfigure the stations several times during a single pass to complete multiple spacecraft acquisitions.

Following a one-month transition period, project management of the Viking Mission passed from Langley Research Center to Jet Propulsion Laboratory, concurrently with the end of the Viking Extended Mission on May 31, 1978.

Beginning on June 1, Viking operations were conducted under the terms of a new Support Instrumentation Requirements Document and NASA Support Plan for the Viking Continuation Mission.

B. BACKGROUND INFORMATION

The first three volumes of JPL Technical Memorandum 33-783 describe the previous Tracking and Data System Support for the Viking 1975 Mission to Mars:

Volume I Prelaunch Planning, Implementation, and Testing, by D. J. Mudgway and M. R. Traxler, dated January 15, 1977

Volume II Launch Through Landing of Viking 7, by D. J. Mudgway and M. R. Traxler, dated March 15, 1977

Volume III Planetary Operations, by D. J. Mudgway, dated September 1, 1977

II. VIKING EXTENDED MISSION OPERATIONS

A. NOVEMBER-DECEMBER 1976 (Ref. 1)

At the start of the Viking Extended Mission operations (November 16, 1976), the Sun-Earth-Probe (SEP) angle was approximately 2.8 degrees from the center of the solar disc. The degradation of the RF link due to the Sun was such that the Viking Orbiters were switched to a single subcarrier mode transmitting engineering telemetry only. The bit error rate (BER) was estimated at 23 in 4687 bits, or 5 x 10^{-3}.

At this time, the 64-meter diameter Deep Space Stations were using 100 kW of uplink power on a daily basis to decrease the noise on the two-way doppler and ranging. The degradation of the RF links gradually increased as the SEP angle decreased, until the closed-loop receivers were out of lock more than 50% of the time. A summary of the events during the degradation and recovery of the RF links through the 1976 solar conjunction period is given in Table 1.

B. JANUARY-FEBRUARY 1977 (Ref. 2)

Several maneuvers were carried out which concluded with Viking Orbiter 1 in a 23.5-hour orbit and a periapsis altitude of 300 km. This orbit caused the spacecraft to 'walk" around Mars progressively every 25 days. The low-periapsis-altitude pictures were the closest ever taken but, although some clear areas were observed, most of the pictures were degraded due to the presence of dust clouds in the southern hemisphere and the carbon dioxide polar hood in the northern hemisphere.

Viking Lander 1, at 22 degrees north of the equator, was experiencing temperatures of about 178 K (-140°F) on the surface of Mars.

Orbiter 2 was in a synchronous orbit over Lander 2, with a periapsis altitude of 800 km. Lander 2, high in the northern hemisphere (48 degrees north), which was then in Mars winter, experienced outside temperatures of about 150 K (-190°F).

Table 1. Summary of solar conjunction effects on telecommunications links in 1976

Nov. 16	DSS 61, bit error rate about 5 x 10^{-3}. The SEP was about 2.8 deg, and decreasing 0.3 deg/day.
Nov. 18	DSS 61, bit error rate about 10^{-2}.
Nov. 22	X-band practically out of lock all the time, especially in two-way (when uplink at S-band is perturbed by Sun). SEP about 1 deg.
Nov. 23	DSS 14 could not lock closed-loop S-band receiver (about 50% out of lock) and could not lock telemetry on today's pass, beginning about 15:00 GMT (Day 76/328).
Nov. 25	Minimum SEP occurred today (Day 76/330/00:00 approximately).
Nov. 26	DSS 14 locked telemetry data (8-1/3 b/s single subcarrier) on today's pass, beginning about 15:00 GMT (Day 76/331). Station also locked X-band downlink.
Dec. 1	DSS 61 was first 26-meter downlink since minimum SEP. SNR about 2.5 dB, BER not available, but data were readable.
Dec. 2	DSS 61 BER about 10^{-2}, data quality described as "very poor."
Dec. 8	First 33-1/3 b/s single subcarrier (obtained at both DSS 42 and DSS 43, with even DSS 42 SNR above threshold. SNR about 7.5 dB at DSS 43, BER not available).
Dec. 13	SEP 5 deg today. First 2-kb/s dual subcarrier (DSS 43).
Dec. 14	First 4-kb/s playback, DSS 14, SNR 5 dB (above threshold).
Dec. 17	First 8-kb/s playback, DSS 43, SNR 4 dB (above Visual Imaging Subsystem (VIS) threshold).

With minor exceptions, the four spacecraft were functioning normally. Both Orbiters were experiencing daily occultations; the radio signals were regularly interrupted as the spacecraft passed behind Mars.

C. MARCH-APRIL 1977 (Ref. 3)

As of April 30, 1977, all four Viking spacecraft continued to perform their assigned tasks. Lander 2 was sent a final set of commands on April 14 for automatic survival mode. The spacecraft would operate in this mode for the next 6 months to provide information about Martian weather and quakes, and to provide soil analysis and photos. The data would be relayed to Earth via Orbiter 2 every week and and a half. The temperature at the Lander 2 location reached the frost point of carbon dioxide, but no frost was seen in the Lander 2 photos. Lander 1 remained actively controlled from the Earth; data were received by both direct and relay links.

Both Viking Orbiters continued photographic, temperature, and water-vapor mapping of the Mars surface. Every two weeks Orbiter 1 came within photo range of Phobos. A close encounter with Phobos was to occur during the last part of May 1977.

D. MAY-JUNE 1977 (Ref. 4)

During May and June 1977 all four Viking spacecraft continued to perform as planned with the two Landers in their low activity automatic survival mode and the two Orbiters continuing their photographic, weather, and water mapping missions.

A major dust storm covered a large part of the entire planet through June 1977. Excellent pictures of the cloud formations were obtained by the Orbiters, but the Lander's pictures quickly deteriorated to the point where the Sun was practically obscured.

On May 27, 1977, Orbiter 1 passed within 100 km of Phobos and obtained some spectacular pictures of the Martian moon.

The only Orbiter spacecraft performance change noted during May and June was the degradation of 2-5 dB in the performance of the Orbiter 1 Radio Frequency System and/or the Command Detector Unit.

E. JULY-AUGUST 1977 (Ref. 5)

Throughout August 1977, all four Viking spacecraft continued to perform as planned. The Orbiters' X-band transmitter and relay subsystems were "on" continuously, with relays being performed routinely. All Orbiter subsystems continued to perform well and no performance degradation was evident during this period.

Lander 1's surface sampler scoop was programmed to roll a Mars rock, and a subrock soil sample was taken. The scoop was also used to scratch a rock in an attempt to obtain rock chips for chemical analysis.

The temperatures at the Lander 2 location started an upward trend, accompanied by lower atmospheric pressures. However, Lander 2 continued in a dormant state, with no direct links taking place.

F. SEPTEMBER-OCTOBER 1977 (Ref. 6)

The communications link between the spacecraft and the Deep Space Stations continued to improve during September. This was a result of the combination of decreasing communications range to Earth and a decreasing Earth cone angle for the Orbiter low-gain antennas. The links were predicted to continue to improve until mid-January 1978. These improved links made possible the reception of 33-1/3 b/s single-subcarrier telemetry data from the Orbiter low-gain antenna by a 64-meter station. The 26-meter diameter Deep Space Stations processed dual-subcarrier 2-kb/s telemetry data routinely during the period. Beginning in October, it was possible to receive 8-1/3 b/s single-subcarrier telemetry data at these stations.

However, two spacecraft problems occurred during September and October. The first occurred on September 19 on Orbiter 2 during a planned switch from Processor B to Processor A. An anomaly caused the Orbiter to switch to the low-gain antenna and single-subcarrier mode at a data rate of 8-1/3 b/s.

Following unsuccessful attempts to improve the signal level, a spacecraft "emergency" was declared by the Viking Project Manager. Since DSS 14 would not have the spacecraft in view for some 10 hours later, DSS 43 was contacted and requested to support. At that time, the station was still in the process of conducting system performance tests as part of its data subsystems upgrade. The personnel responded to the emergency and were able to obtain lock in less than one hour. Following analysis of telemetry downlink indications, it was confirmed that a safing sequence had occurred. Commands were then transmitted to reestablish normal links.

The cause of the anomaly was determined to be a timing offset between Processor A and Processor B on the Viking Orbiter.

The second problem occurred over DSS 14 on October 6, 1977, during a Lander 2 direct link. Downlink lock was lost approximately 14 minutes prior to the scheduled time of end of link. Attempts by DSS 14 and DSS 43, which was supporting a demonstration pass, to lock to the downlink were unsuccessful. An attempt to obtain lock the following day was also unsuccessful.

The apparent cause of the anomaly was a fault in the low-voltage power supply for the traveling wave tube amplifier (TWTA). About one year previously, the other TWTA failed to come on during a scheduled direct link and no attempt had been made to use it since that time. Lander 2 continued to operate with an uplink capability only, and the Lander-to-Orbiter relay links were used to return all science data.

G. NOVEMBER-DECEMBER 1977 (Ref. 7)

The two Viking Orbiters continued to make detailed photo maps of Mars during November and December 1977 and to measure the temperature and water vapor content of the Martian atmosphere. The Orbiters also continued to act as relay stations for Viking Lander data transmission to Earth.

Spring equinox occurred in the northern hemisphere of Mars during early November. The frost seen earlier in Lander photos disappeared, and the polar hood clouds started to break up. A record wind gust of 122 km/h was recorded by Lander 2. The Landers continued to take soil samples for analysis.

The Earth-received signal level continued to increase by about 0.5 dB per week because of the decreasing distance between Mars and Earth. In December, the telecommunications links had improved to a point 10 dB stronger than the levels recorded one year earlier. The Orbiter signal levels are compared in Table 2.

The Viking Project declared a spacecraft emergency on November 1 when Orbiter 2 indicated a leaking yaw-axis attitude control jet. The leak was stopped by sending commands to perform a yaw turn and clear the leaky valve; then the Reaction Control Assembly (RCA) was commanded off.

Orbiter 1 showed a small roll axis gas leak on November 18, which was monitored for several days until performance returned to normal. It was thought that the gas leak was caused by a particle that had become lodged in a gas valve and subsequently cleared itself.

On November 25, Orbiter 1 again developed an anomaly in the stability of the yaw-axis control system. Analysis showed that the anomaly was not caused by a microleak but was due to a strong and variable gravity gradient torque experienced near periapsis. Using a computer model, the effect was later confirmed.

During this period, there were several non-propulsive maneuvers on both Orbiters for the purpose of the Visual Imaging and Bistatic Radar experiments.

The two Viking Orbiters continued to make detailed photo maps of Mars during this reporting period. Viking scientists received close-up photos of surface feature details never before seen, as the planet slowly moved toward an alignment with the Earth and Sun.

As well as making detailed photographs of Mars, the Viking Orbiters also continued to check Martian cloud patterns, temperatures, and water

Table 2. Viking Orbiter signal levels for 64-m DSS and high-gain antenna

Link configuration (high-gain antenna)	Dec. 1976	Dec. 1977
S-band uplink, 20 kW	-109 dBm	-99 dBm
S-band downlink	-143 dBm	-133 dBm
X-band downlink	-153 dBm	-143 dBm

vapor in the atmosphere. The Viking Landers continued their investigation into the composition of the Martian soil. Both Landers pushed rocks aside and picked up subrock soil samples for chemical analysis.

Photo mapping of the Mars surface by the Viking Landers also continued during this reporting period. Photographs of the Mars surface under one of Lander 1's descent rocket motors were taken using mirrors on the scoop mechanism.

H. JANUARY-MAY 1978 (Ref. 8)

On January 19, 1978, the signal received from the Viking spacecraft reached its maximum signal level as the Earth-Mars distance reached a minimum of 99.7 million kilometers with a one-way lighttime of 5 minutes and 26 seconds.

On February 8, the Viking Orbiter 2 spacecraft developed a major gas leak in the roll axis stabilization system. Despite vigorous corrective activity, the leak continued for more than two days. During this time, the leak was variable, ranging from 100 grams per day up to as much as 680 grams (1.5 lb) per day. During the two days, a total of about 900 grams (2 lb) of attitude control gas was lost. Prior to the leak, Orbiter 2 was using between 22 and 36 grams of gas per day for normal operations. During the remaining weeks in February, the Orbiter 2 spacecraft continued to experience an intermittent gas leak. By late March the gas supply had been severely depleted, and the spacecraft was commanded into a roll drift mode of operation to conserve gas. Meanwhile, scientists set about preparing science sequences to make the most use out of the remaining life of the spacecraft.

III. NETWORK OPERATIONS

A. TRACKING COVERAGE

The enormous amounts of DSN tracking coverage provided to the two Orbiters and Landers are a measure of the intensity of activity which characterized the Viking Extended Mission. The DSN support for calendar year 1977 is given in Table 3. The monthly totals are given in the references.

Table 4 shows the Viking Extended Mission tracking support for January through April 1978. Noticeable during this period is the reduction of overall 64-meter station support (DSSs 14, 43, 63) from January to February. This will be a continuing trend as other deep space projects, such as the Voyager mission to Jupiter and Saturn, require the 64-meter network. The increase in 64-meter activity in April resulted from additional support require. to cover the Orbiter 2 gas leak problem.

Table 3. Number of tracks and tracking time in hours for the Viking Extended Mission during 1977

DSS	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total tracks / Total hours
11	23[a] / 135[b]	22 / 142	10 / 100	17 / 118	38 / 228	40 / 289	44 / 343	42 / 343	26 / 210	40 / 408	35 / 310	43 / 320	379 / 2925
12	4 / 135	1 / 6	- / -	24 / 176	17 / 119	1 / 4	1 / 1	1 / 7	- / -	- / -	- / -	- / -	49 / 324
14	52 / 341	59 / 392	[illegible] / [illegible]	20 / 176	- / -	- / -	10 / 46	16 / 126	28 / 363	43 / 329	41 / 358	45 / 254	364 / 2753
42	21 / 247	25 / 226	58 / 453	17 / 138	17 / 162	14 / 112	10 / 69	- / -	- / -	14 / 100	18 / 116	20 / 126	214 / 1749
43	68 / 721	62 / 627	- / -	63 / 603	60 / 521	57 / 486	31 / 238	- / -	1 / 01	24 / 141	36 / 214	48 / 196	450 / 3748
44	- / -	- / -	7 / 7	1 / 4	- / -	- / -	16 / 99	26 / 166	6 / 22	12 / 51	- / -	- / -	68 / 349
61	35 / 261	29 / 227	12 / 72	40 / 317	54 / 461	51 / 475	37 / 337	35 / 332	38 / 345	22 / 203	- / -	- / -	353 / 3020
62	- / -	2 / 7	4 / 22	9 / 55	3 / 14	2 / 7	- / -	- / -	- / -	3 / 23	5 / 28	9 / 36	37 / 192
63	38 / 327	28 / 202	66 / 525	15 / 78	23 / 186	15 / 136	40 / 399	64 / 590	57 / 590	15 / 136	- / -	- / -	361 / 3169
Total track	241	228	207	206	212	180	189	184	156	173	135	164	2275
Total hours	2043	1829	1547	1665	1691	1509	1511	1554	1531	1391	1026	[illegible]	18229

[a]Number of tracks; represents the summation of all Viking spacecraft tracked.
[b]Track time in hours; represents scheduled station support.

Table 4. Number of tracks and tracking time in hours for the Viking Extended Mission during January through April 1978

DSS	Jan	Feb	Mar	Apr
11	8[a] 72[b]	- -	19 167	- -
12	- -	4 13	5 22	1 8
14	40 319	25 218	37 272	47 365
42	22 166	23 76	30 201	30 192
43	57 294	14 207	15 68	27 163
44	- -	11 51	6 43	- -
61	10 88	38 243	25 281	15 159
62	6 27	2 25	3 22	3 29
63	13 101	21 181	30 293	42 440
Total track	156	138	170	165
Total hours	1067	1014	1369	1356

[a]Number of tracks; represents the summation of all Viking spacecraft tracked.
[b]Track time in hours; represents scheduled station support.

B. COMMAND ACTIVITY

The number of commands sent to the four Viking spacecraft in 1977 is also a measure of the mission operations activity and is given in Table 5. The command activity in 1978 is given in Table 6. The monthly totals are given in the references.

C. INTERMEDIATE DATA RECORD PRODUCTION

The amount of data delivered to the Project on the Intermediate Data Record (IDR) and the delivery time from the end of the station pass provide a measure of the DSN data product performance. The amount of data on an IDR is expressed as a percentage of the number of data blocks expected to be written on the IDR. The number of data blocks expected is computed from the block rate (number of blocks per second) and data times, as well as start and stop Block Serial Numbers. The number actually written is a straightforward block count as the IDR is written. Both the number expected and the number written are found on the IDR File Summary, a product of the merge function delivered with the tape to the Project.

The percentage of data on telemetry IDRs delivered during the Viking Extended Mission is given in Fig. 1. Throughout the Extended Mission the content of the telemetry IDRs was well above the committed mission level of 99.5%.

IDR production time is defined as the time between loss of signal (LOS) at a Deep Space Station and delivery of a completed IDR. The processes involved are generally a DSS recall, and always a merge function. Once the merge of the Network Data Log (NDL) and recall tape is complete, an IDR is ready to be delivered to the Project. IDR tapes are picked up at the Network Data Processing Terminal, and are delivered to the flight project data library. The production times for VEM telemetry IDRs are also given in Fig. 1.

The committed maximum delivery time was 24 hours, and DSN performance met that requirement. However, the introduction of tracking IDRs in May 1978, and the testing that preceded that new capability (together with a change in contractor staffing), severely impacted the delivery performance in the last 3 or 4 months of the VEM. Another significant factor in IDR production times was an increase in work load in the Network Data Processing area, where the IDRs are produced. The increase in work load due to increased activity by Pioneer and the addition of tracking IDRs is shown in Table 7.

The overall Viking IDR statistics for all DSN stations that supported the mission from April 23, 1976, when IDR deliveries to the Viking Prime Mission first started, through the end of the Extended Mission on May 31, 1978 are shown in Table 8.

The monthly levels of IDR production activity during the Viking Extended Mission are shown in Fig. 2 for all projects combined and for Viking alone.

Table 5. Number of commands transmitted in Viking Extended Mission during 1977

	Number of commands												
DSS	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	1977 Total
11	1521	1394	1027	117	811	0	1	795	2028	3687	3064	4746	19191
12	0	0	0	1314	721	0	0	0	0	0	0	0	2035
14	769	1404	1206	274	0	0	74	108	2704	2108	1134	1589	11370
42	2072	953	1778	8	1886	1619	0	0	0	18	1250	0	9589
43	919	2523	0	2094	1447	972	1190	0	0	456	656	491	10748
44	0	0	2	1	0	0	0	5	19	2	0	0	29
61	605	1116	1328	1925	1922	3838	4257	5589	5256	1371	0	0	27207
62	0	0	1	1991	0	496	0	0	0	0	14	5	2507
63	795	472	2039	381	657	383	2579	2318	1610	847	0	0	12099
Total	6681	7862	7381	8105	7462	7308	8101	8815	11617	8489	6118	6831	94770

Table 6. Number of commands transmitted in Viking Extended Mission during January through April 1978

DSS	Number of commands			
	Jan	Feb	Mar	Apr
11	1947	0	119	0
12	0	1	1	374
14	4565	1079	1326	3032
42	1447	1305	261	1079
43	1593	1732	124	275
44	0	255	3	0
61	992	3548	1073	1503
62	1	1006	461	73
63	895	128	2597	4005
Total	11440	9054	5965	10341

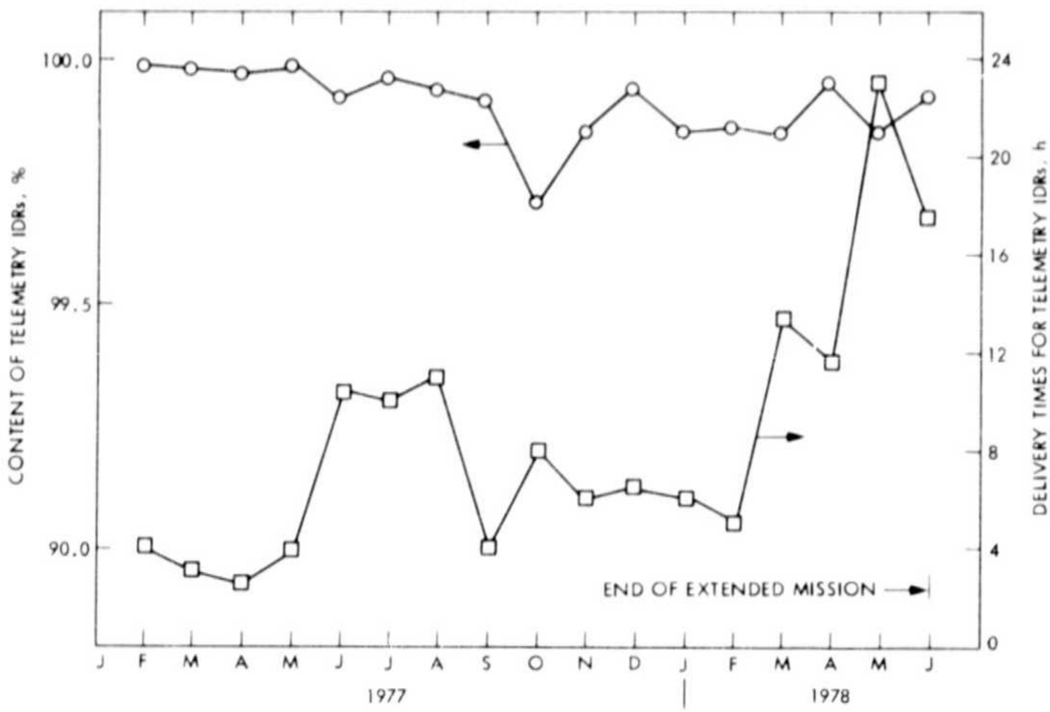

Figure 1. Viking Extended Mission telemetry IDR performance

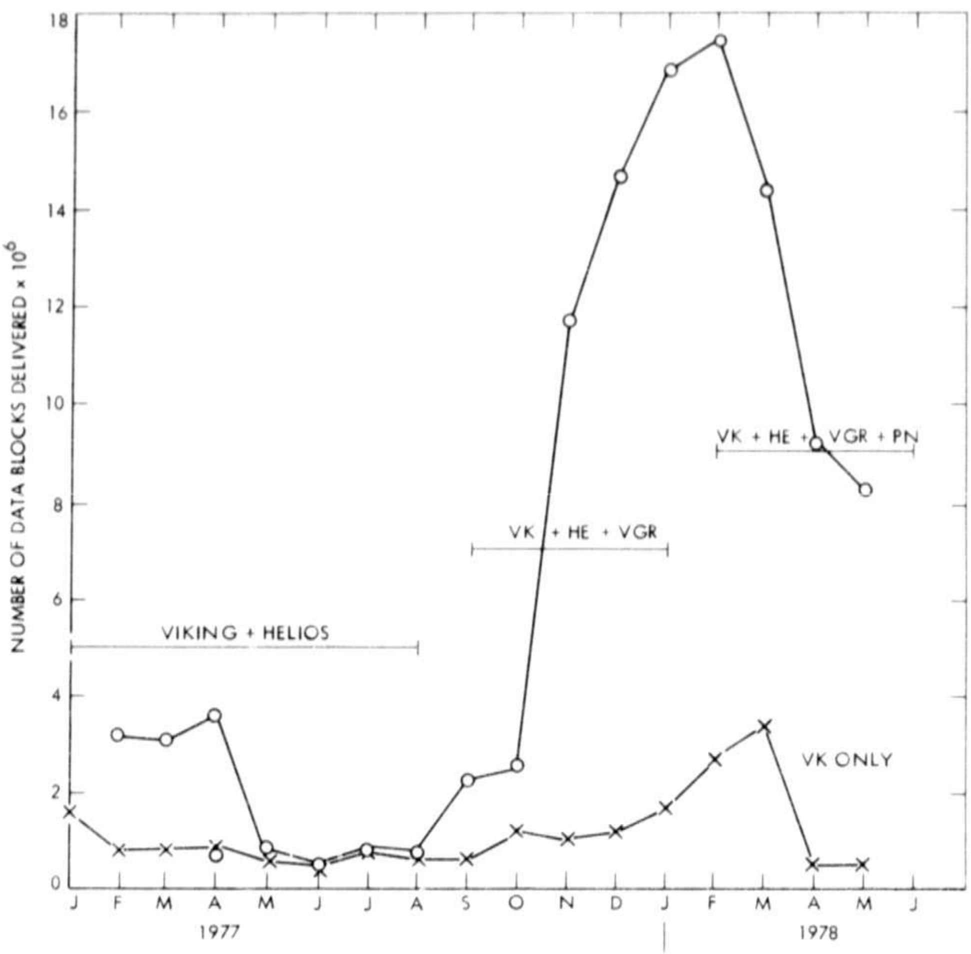

Figure 2. Monthly IDR production during the Viking Extended Mission

Table 7. Total number of telemetry IDRs delivered to all flight projects in 1978

Month	Number of telemetry IDRs
January	516
February	698
March	664
April	713
May	857
June	1035
July	1044

Table 8. Viking IDR statistics, April 23, 1976 through May 31, 1978

DSS	Total number of blocks delivered	Number of blocks missed after recall	Percent of blocks on IDR
11	644,220	2,869	99.557
14	18,050,990	8,041	99.955
42	297,237	185	99.938
43	26,781,936	44,115	99.835
44	173,397	463	99.734
61	578,750	485	99.916
62	50,833	80	99.843
63	22,975,742	18,268	99.921
Totals :	69,553,105	74,506	99.893

IV. NETWORK RECONFIGURATION

A. ANTENNA REWORK

Tests during 1976 had indicated that the ball and socket assemblies on the DSS 63 and DSS 43 antennas required rework to improve lubrication on the bearing surfaces. The rework at DSS 63, which consisted of removing the three assemblies and fitting new ball and socket assemblies, was started on November 15, 1976, and successfully completed on December 14, 1976. A similar rework was carried out at DSS 43 during March 1977.

B. IMPLEMENTATION OF MDS RECONFIGURATION

Following the completion of the Viking Prime Mission on November 15, 1976, and the period of solar conjunction which continued through mid-January 1977, the Deep Space Network embarked on a major reconfiguration effort. This was called the Mark III-DSN Data Subsystem (MDS) implementation task and involved all stations of the Network during 1977. It was carefully phased with the principal Flight Project support activity, and the launch of the new Voyager Mission, as shown in the schedule in Fig. 3.

As the Viking Extended Mission increased in tempo following the solar conjunction period, important relativity experiments were conducted with DSSs 14, 42, and 63 (Refs. 1 and 2) while the MDS implementation activity got under way with DSSs 12, 44, and 62. As each of these stations was withdrawn in turn from Viking Extended Mission support, the MDS reconfiguration was accomplished, and the station was returned to operational support following an appropriate period of testing and crew retraining.

It was planned to take advantage of the DSS 14 downtime for the MDS reconfiguration to carry out a number of rather long overdue modifications and upgrades in the following areas:

(1) Relocation of microwave tricone equipment, and modifications to the XRO feed cone.

(2) Rehabilitation and upgrade of the main electrical power system.

(3) Modification and improvements to the hydrostatic pump equipment.

(4) Improvements to the water cooling and treatment plant.

(5) Transmitter crowbar modifications, and maser bypass.

Together with the MDS related tasks, this represented a substantial effort, and a special manager was assigned for the Project to coordinate and manage the resources necessary to accomplish this job on schedule. Some 87 individual modification kits were provided to the station and installed during the months of April and May.

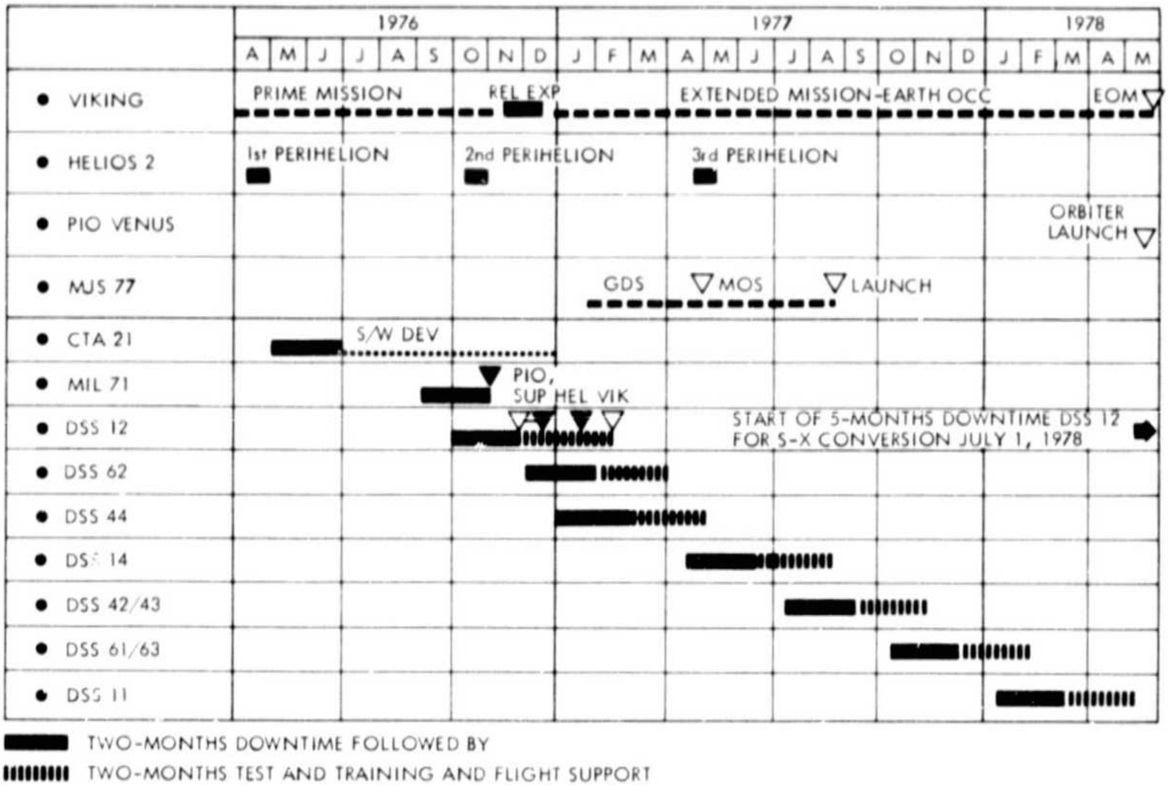

Figure 3. Mark III-DSN Data Subsystem implementation schedule

The test schedule which followed the implementation phase is shown in Fig. 4. This allowed completion of the reconfiguration by June 15, at which point the Viking Extended Mission Ground Data System schedule became effective, as shown in Fig. 5.

The DSN planned to continue the MDS reconfiguration around the Network as shown in the schedules in Figs. 3 and 5, with DSS 42/43 and DSS 61/63 following in order after DSS 14. The Viking Extended Mission operations had been integrated with the Ground Data System schedule of Fig. 5, in such a way as to minimize the impact to the mission data return as a result of the reconfiguration described above.

By mid-July, DSSs 12, 14, and 62 had completed system performance testing in the new configuration and resumed operational support. Stations 42 and 43 were released from tracking support on July 15, and began their 2-1/2 months of reconfiguration and re-test. The testing phase at DSS 42/43 was completed on October 16, 1977, and these stations were placed under Viking configuration control on October 18, 1977, to begin its implementation phase. The testing phase was scheduled to begin on January 1, 1978. DSS 11 was to begin the MDS upgrade on January 15, 1978.

By January 31, 1978, DSS 61/63 was again operational and heavily involved in Viking support, and by mid-March 1978 work on the last station, DSS 11, had been completed. It became operational on April 26, 1978 following a successful series of demonstration tracks on a live Viking spacecraft.

The accomplishment of this major reconfiguration throughout the entire Network, in the midst of a heavy and demanding tracking support schedule that included two major launches (Voyagers 1 and 2), presented a complicated and exacting task. That it was carried out on schedule, without any significant problems and without impacting the on-going Flight Project support, is a credit to all the personnel involved. References 1 through 8 describe the details of this activity.

V. TELECOMMUNICATIONS LINK PERFORMANCE

In Ref. 3, the DSN to Viking Orbiter telecommunication link effects during the 1976 Superior Conjunction are described by F. H. J. Taylor.

The minimum Sun-Earth-Probe (SEP) angle of 0.25 degree occurred on November 25, 1976. For two successive days, closed-loop receiver lock on the downlink signals could not be maintained at the 64-meter DSS. Following this period, as the SEP gradually increased, the S-band and X-band telecommunication links with all spacecraft gradually returned to normal.

For the followng year, throughout 1977, the Earth-Mars range gradually decreased, and data rates were increased to take advantage of the improved signal to noise ratios. As a consequence, data volume during the Extended Mission exceeded that of the Prime Mission.

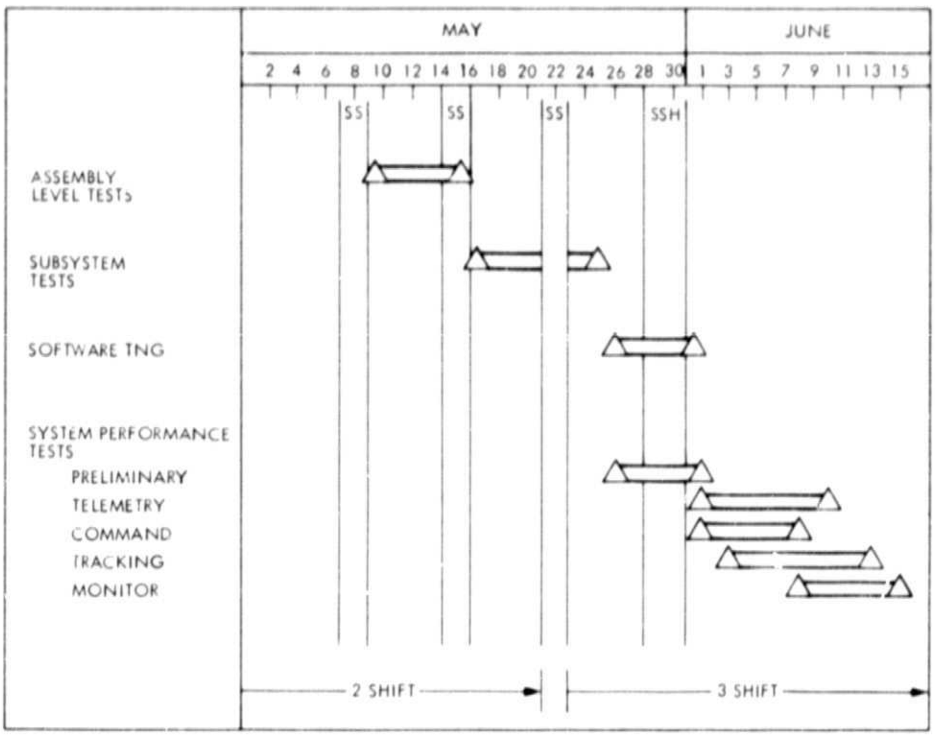

Figure 4. DSS 14 downtime project; test schedule

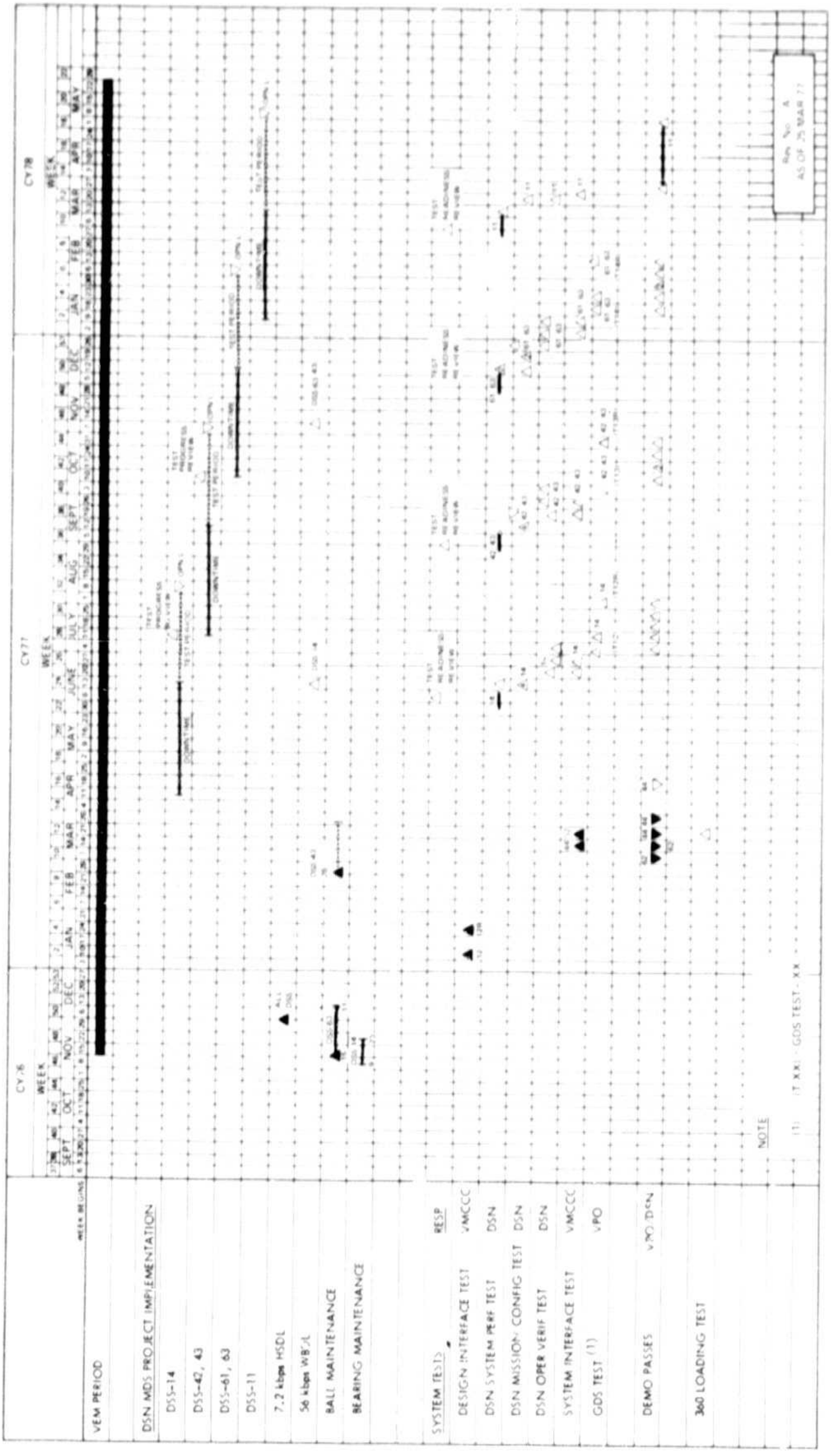

Figure 5. Viking Extended Mission Ground Data System schedule

The performance of the links and the strategies employed to take full advantage of the link capabilities are described in detail in Ref. 9.

VI. RADIO SCIENCE SUPPORT

At the outset, it was recognized that the Viking Extended Mission would be heavily emphasizing Radio Science experiments because of the very unique opportunities provided by two active Landers and two active Orbiters. The Radio Science experiments supported were:

(1) General relativity experiment

(2) Solar corona experiments

(3) Generation of near-simultaneous Orbiter-Lander range data by the Deep Space Stations

(4) Occultations

(5) Very long baseline interferometry

(6) Solar wind experiments

(7) Gravity waves

(8) Gravity fields

(9) Bistatic radar

Many of these experiments were carried out several times per week on the average throughout 1977, and the data were delivered to the Radio Science Team. All of the open-loop occultation data were digitized at CTA 21 before delivery to the Project.

Network support for these experiments was characterized by extremely complex operational procedures, for which there was often meager documentation, little opportunity for crew training, and competing Project requirements for Telemetry and Command support.

Radio science activities and experimentation continued during January, February, March, and April 1978. These activities included near-simultaneous Lander/Orbiter ranging, Orbiter 1 and 2 Earth occultation, bistatic radar, and gravity wave experiments.

The purpose of the experiments and the configuration and procedures employed by the Network are described in Refs. 10 through 13.

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