# Viking Mission Support

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*This article describes the Network Operations Plan for Viking 1975 and includes some DSN support requirements unique to Viking which have resulted in unusual attention to Deep Space Station hardware failure mode configurations. Also discussed are samples of the single point failure strategies incorporated in the Viking 1975 Deep Space Station telemetry hardware configurations. The rationale for the implementation of 100-kW transmitter capability at DSSs 43 and 63 is also given.*

## I. Network Operations Plan for Viking

The publication of the Network Operations Plan for Viking 1975 (Ref. 1) constitutes a further milestone marking the initial point at which the DSN operations personnel in general became directly involved with the Viking Project. This document interprets all the Project requirements levied on the Deep Space Network to support the Viking 1975 mission. It specifies the required human and technical interfaces and the manner in which the DSN capabilities, described in the DSN Preparation Plan for Viking 1975 Project (Ref. 2), will be employed by Network Operations to support Viking pre-launch and flight operations activities. Finally, this constitutes the prime reference regarding the Viking DSN training, testing, configurations, procedures, and operations, for all personnel in the DSN Operations Office.

## II. Unique Viking Requirements

In previous missions, during the limited critical and/or extremely high-activity periods, the requirement for hardware failure backup has been met at the Deep Space Stations by scheduling a second station in parallel and/or the use of complete parallel strings of equipment readied in a "standby" state.

The Viking 1975 mission is unique in this respect in that: (1) the critical/high-activity periods will extend for up to 5 months continuously, (2) three DSSs at each location will be required for 2 months, 7 days per week (no backup stations) (see Fig. 1), and (3) the 5-month period requires the simultaneous use of six telemetry hardware strings out of a total station complement of six strings (no backup strings) at each 64-m-antenna DSS.

Another unique characteristic of the Viking mission is that, during the planetary operations phase, four spacecraft will be within the beamwidth of a single DSS antenna, and the 64-m subnet will be required to track up to three spacecraft simultaneously and to provide one uplink and process six telemetry subcarriers. As practically all of the Deep Space Station equipment will be in use during three-spacecraft operations, the configurations defined in the Network Operations Plan have been designed to include new extensive "cross-switching" capabilities. These greatly increase the flexibility over current configurations and provide optimum use of the equipment for data processing in the case of an equipment failure. Also, the conjoint 26-m-antenna stations provide uplink and backup telemetry hardware, accessible from their conjoint 64-m-antenna stations. (DSSs 11 and 14 have the same capability, using a microwave link.)

## III. Deep Space Station Telemetry Requirements for Viking

The 64-m-antenna DSS Viking 1975 telemetry configurations are required to be capable of processing the types of data shown in Tables 1 and 2 from two Orbiters and one Lander simultaneously.

## IV. Configuration Rationale

Because of the difference in capabilities between the 26-m co-located, 26-m conjoint, and 64-m DSSs and also the difference between the hardware strings inside the DSSs, some configuration rules or guidelines became evident when the Viking configurations were formulated. Samples of some basic rules are:

(1) *Rule:* The 64-m-antenna DSS should be regarded as prime telemetry receiver for all three spacecraft.
*Reason:* Greater antenna gain of 64-m DSS.

(2) *Rule:* The 64-m-antenna DSS should be configured to provide the prime Orbiter uplink and receive that spacecraft telemetry on the Block IV receiver/exciter.
*Reason:* The Block III and Block IV receiver/exciter subsystems are separate subsystems with no coherent, common reference, and the X-band receiver (Block IV only) must be coherent with the S-band uplink, which is being multiplied in the spacecraft to provide the S-band and X-band downlinks.

(3) *Rule:* Only one Orbiter should be scheduled to provide X-band ranging for a complete station pass.
*Reason:* To switch from one Orbiter to the other would involve a double station uplink transfer of the two Orbiters between the 26-m, Block III and 64-m Block IV exciters, causing approximately 60 min loss of command, metric, and ranging data on each transfer.

As these rules emerged with the development of the detailed configurations, it became apparent that certain spacecraft/ground receiver configurations had logically evolved. These will vary with the single Orbiter, Orbiter and Lander, Orbiter and Orbiter, or Orbiter, Lander, and Orbiter situations encountered during the mission. The Network Operations Plan for Viking contains a total capabilities configuration, standard configurations for each of the spacecraft combinations, plus approximately 50 alternate backup configurations to cover specific failures. Each configuration is designated by a code number. The samples used here to illustrate the concept are for the Orbiter/Lander/Orbiter situation.

## V. 64-m-Antenna Telemetry Configurations for Viking

The DSS 14 Viking 1975 hardware capabilities are shown in Fig. 2. The Orbiter/Lander/Orbiter standard configuration is presented in Fig. 3.

## VI. Failure Strategy and Configurations

The single point failure recovery is presented in the Network Operations Plan for Viking in the form of tables, listing the reconfiguration to be applied in the case of failure of each receiver, subcarrier demodulator assembly (SDA), symbol synchronizer assembly (SSA), block decoder assembly (BDA), data decoder assembly (DDA), and telemetry and command processor (TCP).

Experience has shown that an assembly failure rarely occurs during real-time tracking, but quite often is discovered during the pre-track calibrations. The tables referred to have a column labeled "Resultant Constraint," which indicates what data, if any, are changed (e.g., lower bit rate) or lost (e.g., X-band doppler and ranging deleted) when the reconfiguration is complete. There is no listing of amount of data lost during the reconfiguration resulting from real-time re-initialization or reloading of the software. The example shown in Fig. 4 would be applicable in the event of failure of Receiver No. 1, which is listed under Code 31. In this case, the receiver is replaced by Receiver No. 4, which is normally receiving the X-band signal, so that the X-band data are "given up" in favor of the S-band telemetry.

The second example, as shown in Fig. 5, would be applicable in the event of failure of SDA 3, which is listed under Code 36. In this case, SDA 3 is replaced by SDA 7 (in the 26-m conjoint DSS). During planetary operations, the conjoint 26-m DSS (or DSS 11 at Goldstone) would normally be scheduled to support in parallel to supply the second uplink. At DSSs 43 and 63, the receiver output (subcarrier plus data) is hardwired to the SDA at DSS 42 or 61, and the SDA output is hardwired back to the 64-m SSA. At DSS 14/11, these functions are carried out via a microwave link.

## VII. Rationale for Implementation of 100-kW Transmitter Capability at DSSs 43 and 63

The DSN response to the Viking requirement for 100-kW transmit capability at the overseas DSSs (Ref. 3, p. 2300.2) is given in the NASA Support Plan (Ref. 4, p. 430.1) as follows; ". . . at DSSs 43 and 63, 100 kw transmitter will provide dual links at 10 kw each." At the time this was written, the requirement and its response were principally oriented toward the need for simultaneous commanding from a single station to two spacecraft (Orbiter/Orbiter or Orbiter/Lander).

Early in 1973, the Tracking and Data System met with the Project and indicated that the dual-carrier, single-transmitter mode of operation presented technical problems which were not fully understood and recommended that the "dual-carrier" mode be considered as a "mission enhancement" feature only in all future mission planning. The prime mission mode was to be based on the use of two subnets, with the simultaneous command requirement being met with two stations, i.e., a 64-m and a 26-m DSS at each longitude. This decision is reported in Ref. 5.

In preparing the FY'74/75 budget, it was proposed that the "mission enhancement" feature of Viking support be dropped by deferring the 100-kW transmitters to a post-Viking era.

Evaluation of the consequent impact on the Viking mission planning and flight support showed that, irrespective of the dual-carrier requirement, there remained a need for a 100-kW transmit capability at DSSs 43 and 63, as well as the 400-kW transmit capability at DSS 14, to avoid unacceptable risks and/or constraints to Viking Lander operations (Mission B particularly) due to any of the following causes:

(1) Worst-case telecommunications performance

(2) Adverse landing slopes (20 deg)

(3) Random Lander orientation

(4) High-gain antenna or computer malfunction

(5) Southerly landing sites (30°S)

(6) Need for real-time retargeting of landing site

(7) Late launch in the secondary mission

The dominant factor influencing all of the foregoing effects is the most recent Lander low-gain antenna patterns measured on a ⅜-scale model. These patterns show severe distortion due to adjacent hardware on the Lander structure, which results in large negative gain over substantial portions of the antenna field of view. Most of the conditions described above could result in Earth look vectors which lie in these negative gain areas, and hence require a high-power transmit capability to compensate for the antenna gain deficiencies.

Typical low-gain antenna radiation patterns discussed above were analyzed at gain levels of $-3$ and $-10$ dB. These are the levels required to support the command link for 20- and 100-kW transmitters. This analysis is summarized in Fig. 6, which shows the Lander cone and clock angle regions where the low-gain antenna coverage is adequate to support the command link.

The history of the look vector to Earth as seen from the Lander for a 30°S latitude landing site is also shown in Fig. 6. The dashed line represents the nominal Earth track as seen from the Lander early in the mission. Time ticks are located on the nominal track to provide a relative time reference. The envelope about the nominal track considers a $\pm$20-deg adverse surface slope, $+20$ deg uncertainty in he landed azimuth of Lander leg 1, and the worst case relative Earth/Mars geometry over the 90-day landed mission.

The shaded areas within the Earth track envelope represent those areas where the Lander antenna gain is not sufficient to support the command link with a 100-kW transmitter. The area which lies between the shaded contour and the upper contour line is that Lander cone/clock angle region where command capability exists with a 100-kW transmitter but not with 20 kW. Command capability exists with a 20-kW transmitter for the Lander cone/clock angle region above the second contour.

Obviously, the opportunity to command the Lander over the low-gain antenna is severly limited for the 30°S latitude landing site. Only one half of the total daily Earth view period is available for Lander command with a 20-kW transmitter.

The command link performance for this same set of conditons (30°S latitude) is given in Fig. 7 for no-slope conditions and in Fig. 8 for 20-deg slope conditions.

In Fig. 7, the performance is shown for the time of day when Earth has risen to a 15-deg elevation angle above the local horizon. No adverse slope is considered. At this time of day, the Lander cone angle of the look vector to Earth is 105 deg, or conversely, the aspect angle of Earth as seen from the Lander antenna boresight is 75 deg.

The curve labeled "nominal" was generated from the free space Lander gain pattern at an aspect angle of 75 deg. This curve shows a margin of approximately 3 dB above that required with 20 kW of transmitter power. The best and worst curves were developed from the installed ⅜-scale model antenna pattern data as follows: The curve labeled "best" was derived from the highest Lander gain found on the installed patterns at an aspect angle of 75 deg. Because of the uncertainty in the landed Lander azimuth orientation and the desire to place no further constraint on the time of day at which a command session can occur, the entire Lander clock angle region (0–360 deg) was considered.

The curve labeled "worst" was derived as explained above, except that the lowest Lander gain at an aspect angle of 75 deg over the total clock angle region was considered.

Figure 8 reflects the same conditions as defined for Fig. 7, except that a 20-deg adverse surface slope was considered. The nominal, best, and worst curves consider Lander antenna gain at an aspect angle of 95 deg.

The curves shown in Figs. 7 and 8 indicate that the 20-kW capability is inadequate to meet the required command link margins under the worst-case conditions considered.

These data were presented in overview by the Martin Marietta Corporation (MMC) at the Viking Lander Critical Design Review in Denver on September 18–20 and in detail to the Viking Telecommunications Working Group at MMC in Denver on September 21. Both these organizations, as well as the Viking Project Manager, agreed that the 100-kW transmit capability at the overseas stations was a necessary element in the DSN support planned for the Viking mission. Accordingly, the current revision to the Viking Support Instrumentation Requirements Document, dated September 17, 1973, deletes the dual-carrier requirement, but restates the requirements for the 100-kW capability at DSSs 43 and 63 for the purposes described above. Implementation of this capability has since been reinstated and is proceeding toward an operational date of January 1, 1976.

## References


1. Network Operations Plan for Viking 75 Project, JPL Document 614-21, Nov. 1, 1973 (JPL internal document).
2. Deep Space Network, Preparation Plan for Viking 75 Project, JPL Document 614-20, Rev. A, Nov. 15, 1973 (JPL internal document).
3. Support Instrumentation Requirements Document (SIRD) for Viking, July 1, 1971 (JPL internal document).
4. NASA Support Plan (NSP) for Viking, Rev. 0, May 1, 1972 (JPL internal document).
5. Mudgway, D. J., and Johnston, D., "Viking Mission Support," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XVII, p. 9, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1973.

**Table 1. Viking Orbiter (VO) channel assignments**

| TLM channel | Designator | Description | Bit rate | Subcarrier frequency, kHz |
|---|---|---|---|---|
| Low | B | Uncoded engineering data | $8\frac{1}{3}$ or $33\frac{1}{3}$ bits/s | 24.0 |
| High | C | Coded (32, 6) science data | 1, 2, 4, 8, or 16 kbits/s | 240.0 |
| | A | Uncoded science data | 1, 2, or 4 kbits/s | 240.0 |

**Table 2. Viking Lander (VL) channel assignments (for VL/DSN S-band direct link)[a]**

| TLM channel | Designator | Description | Bit rate, bits/s | Subcarrier frequency, kHz |
|---|---|---|---|---|
| Low | B | Uncoded engineering data | $8\frac{1}{3}$ | 12.0 |
| High | A | Coded (32, 6) science data | 250, 500, and 1000 | 72.0 |

[a]The VL/VO UHF link at 4 or 16 kbits/s will not be received by the DSSs.

Relay "feedthrough" data (VL to VO) during preseparation and landing will be received at the DSSs via the VO subcarrier and are regarded as VO data by the DSN.

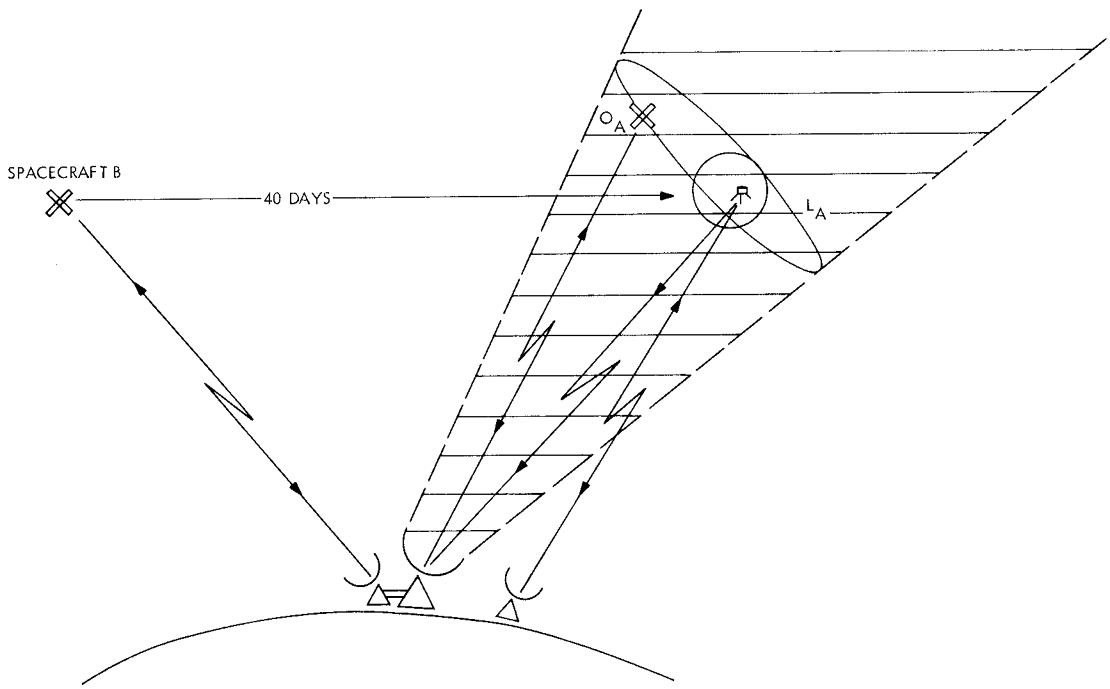



Fig. 1. Three-station requirement

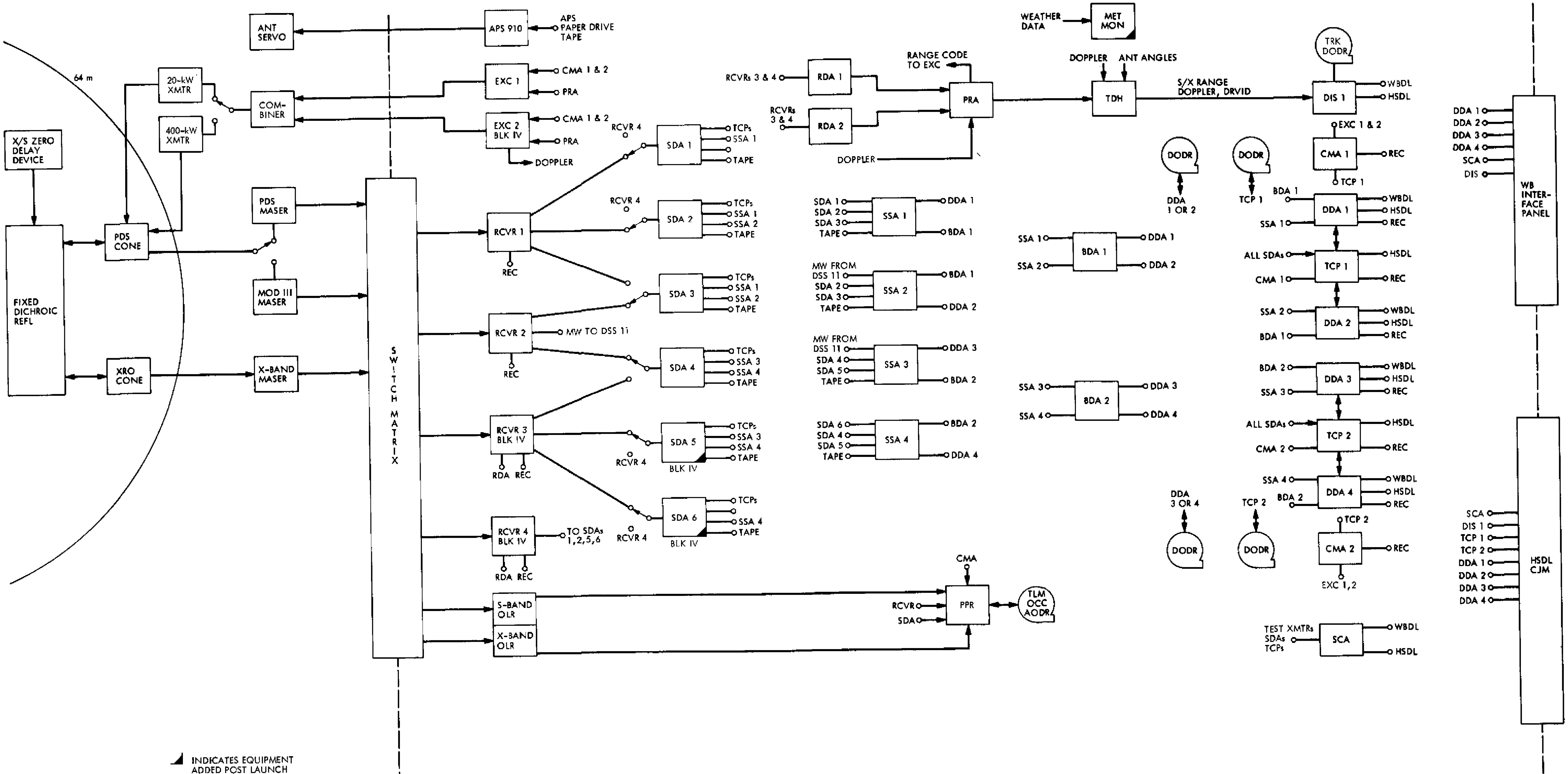
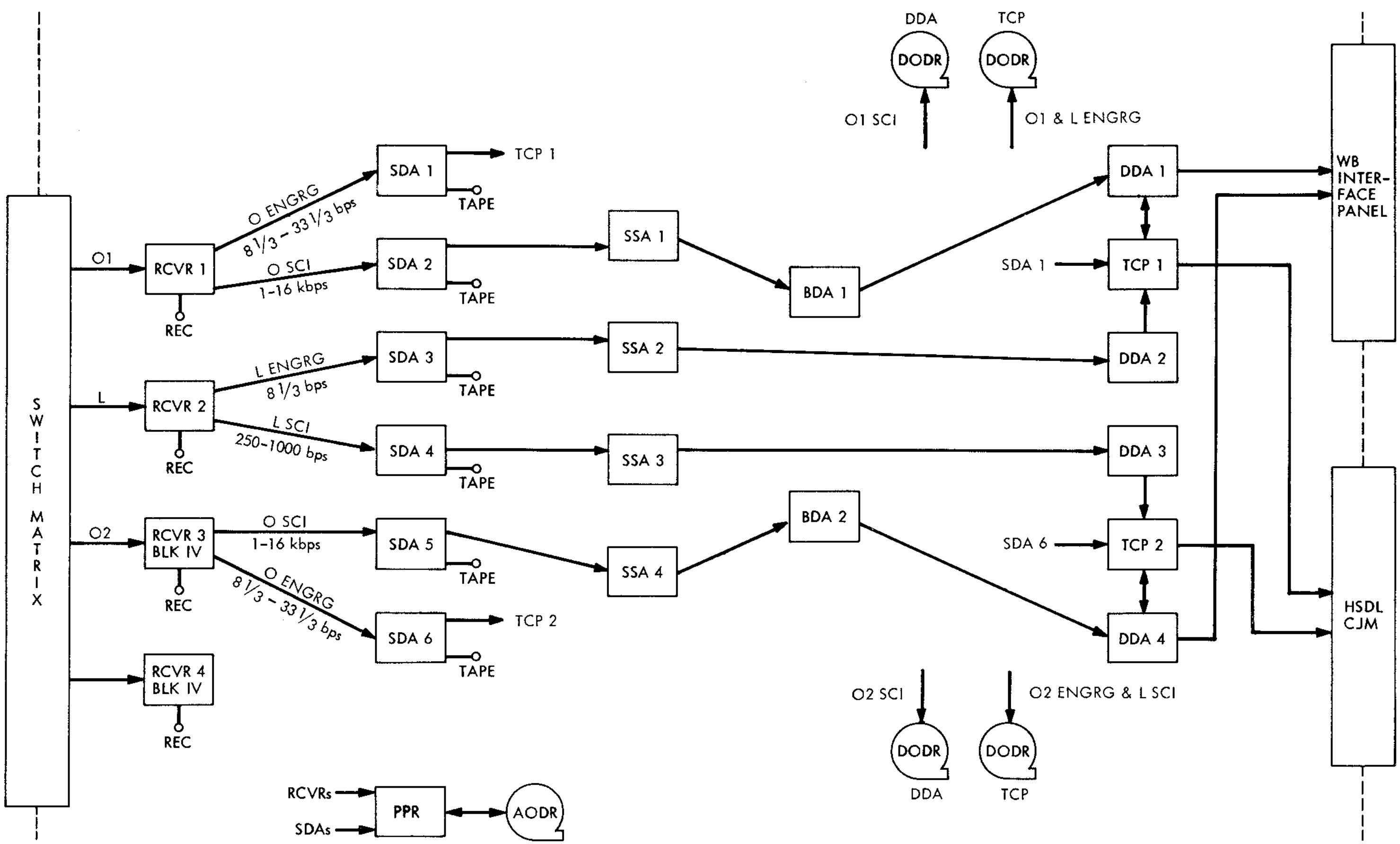
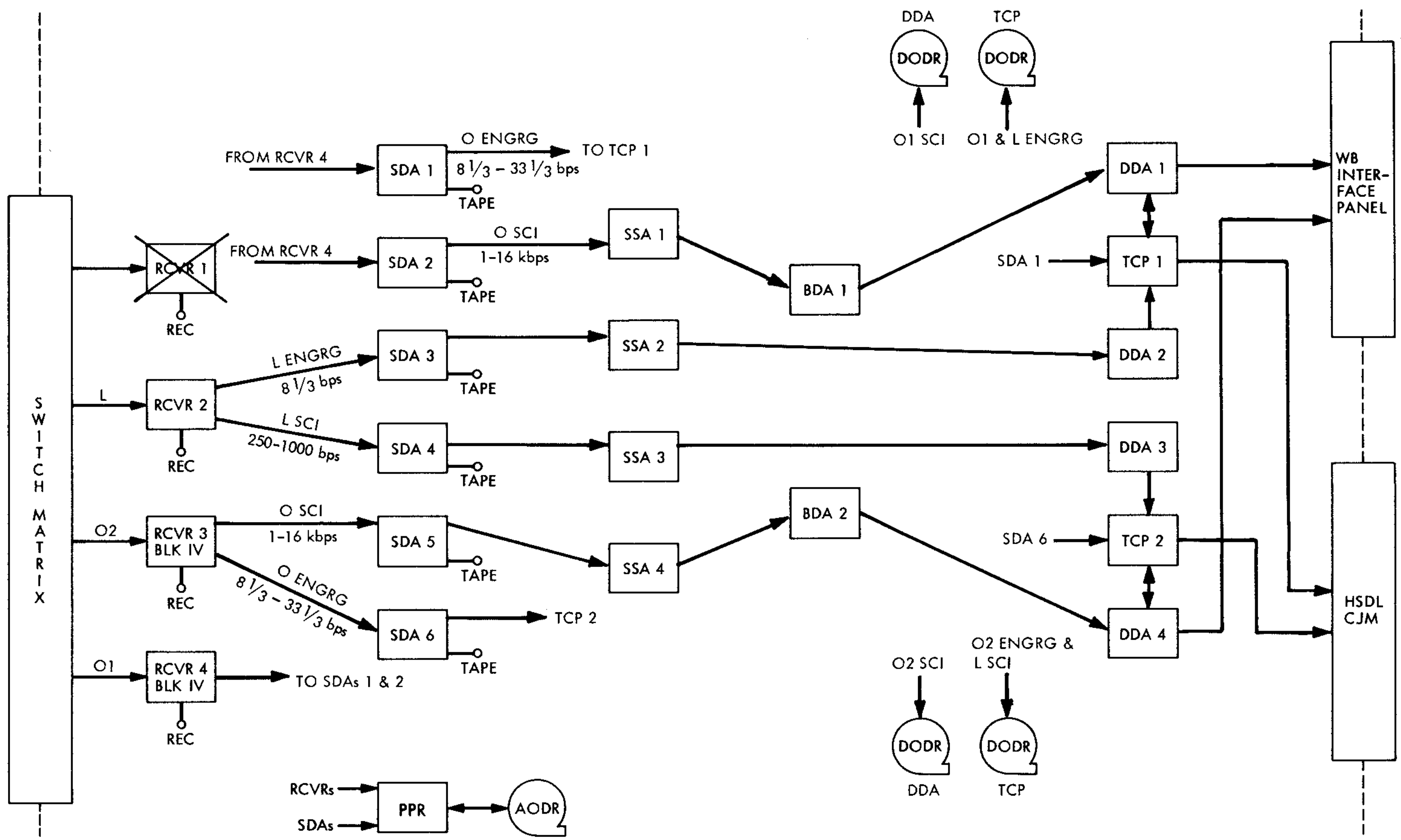



Fig. 2. DSS 14 Viking hardware capabilities



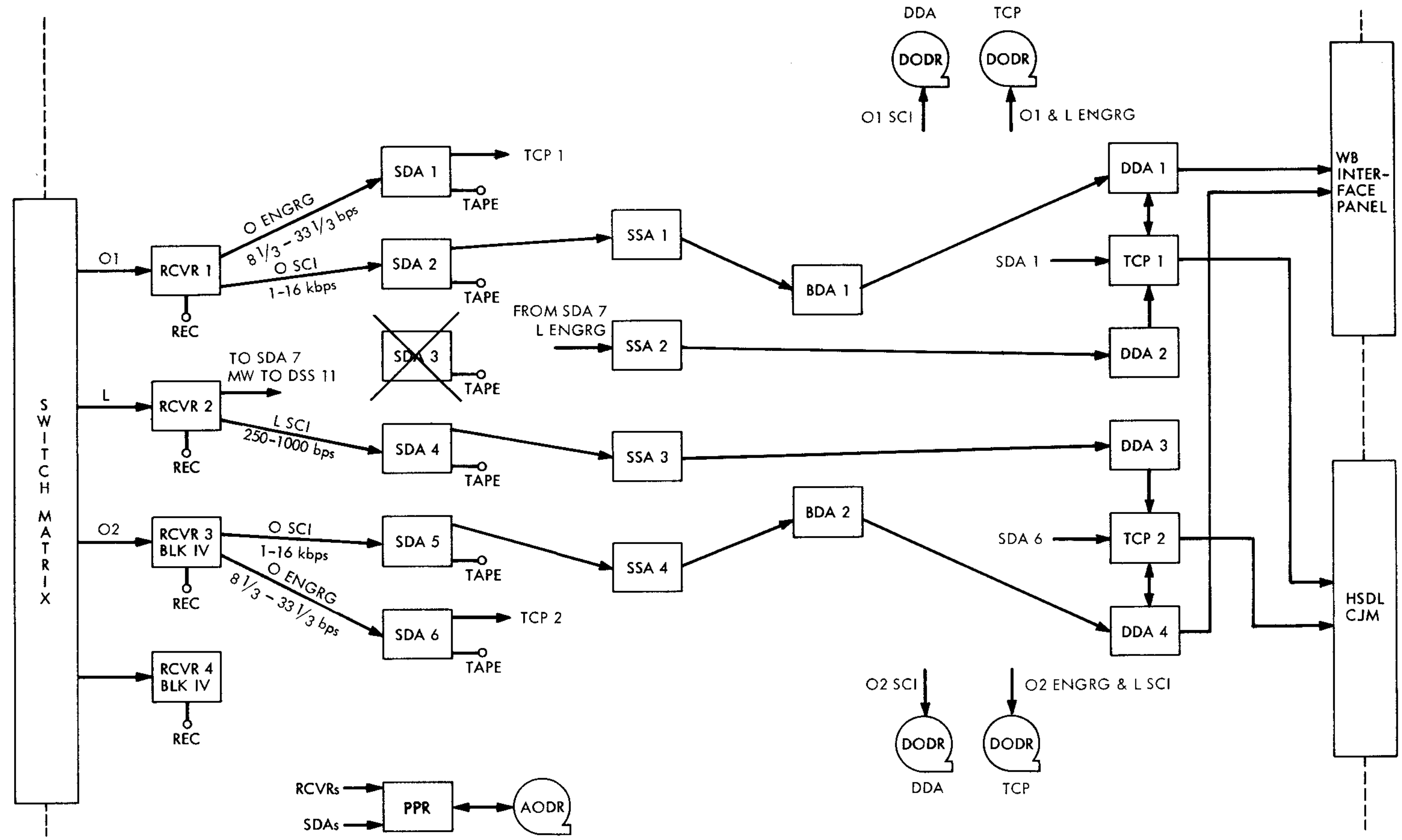

| CODE | SPACECRAFT | RECEIVER | DATA TYPE | SDA | SSA | BDA | DDA | TCP |
|---|---|---|---|---|---|---|---|---|
| 30 | ORBITER 1 | 1 | ENGINEERING | 1 | 0 | 0 | 0 | 1 |
| | | | SCIENCE | 2 | 1 | 1 | 1 | |
| | LANDER | 2 | ENGINEERING | 3 | 2 | 0 | 2 | |
| | | | SCIENCE | 4 | 3 | 0 | 3 | 2 |
| | ORBITER 2 | 3 | SCIENCE | 5 | 4 | 2 | 4 | |
| | | | ENGINEERING | 6 | 0 | 0 | 0 | |

**Fig. 3. Standard planetary configuration, Orbiter/Lander/Orbiter, Code 30**




| CONFIG-URATION CODE | FAILED ASSEMBLY | SPACECRAFT AND DATA TYPE | REPLACED BY | RECON-FIGURE | RE-INITIALIZE TCP FOR CONFIGUR-ATION | RESULTANT CONSTRAINT |
|---|---|---|---|---|---|---|
| 31 | RCVR 1 | ORBITER 1 ENGIN-EERING AND SCIENCE | RCVR 4 | SDA 1 FOR RCVR 4<br>SDA 2 FOR RCVR 4 | TC1/4, 1, 0, 0, 0, 0S<br>1<br>TC3/4, 2, 1, 2, 1, 1S | X-BAND LOST |

Fig. 4. Failure strategy configuration, Orbiter/Lander/Orbiter, Code 31




| CONFIG-URATION CODE | FAILED ASSEMBLY | SPACECRAFT AND DATA TYPE | REPLACED BY | RECON-FIGURE | RE-INITIALIZE TCP FOR CONFIGUR-ATION | RESULTANT CONSTRAINT |
|---|---|---|---|---|---|---|
| 36 | SDA 3 | LANDER ENGIN-EERING | SDA 7 | SDA 7 FOR RCVR 2 | TC2/2, 7, 2, 1, 0, 2S 1 | 26 m DSS LOSES ONE SDA |
| | NOTE: SDAs 7 AND 8 ARE LOCATED AT CONJOINT 26-m STA-TIONS FOR DSSs 43/63 AND AT A DSS 11 FOR DSS 14. | | | | | |

**Fig. 5. Failure strategy configuration, Orbiter/Lander/Orbiter, Code 36**

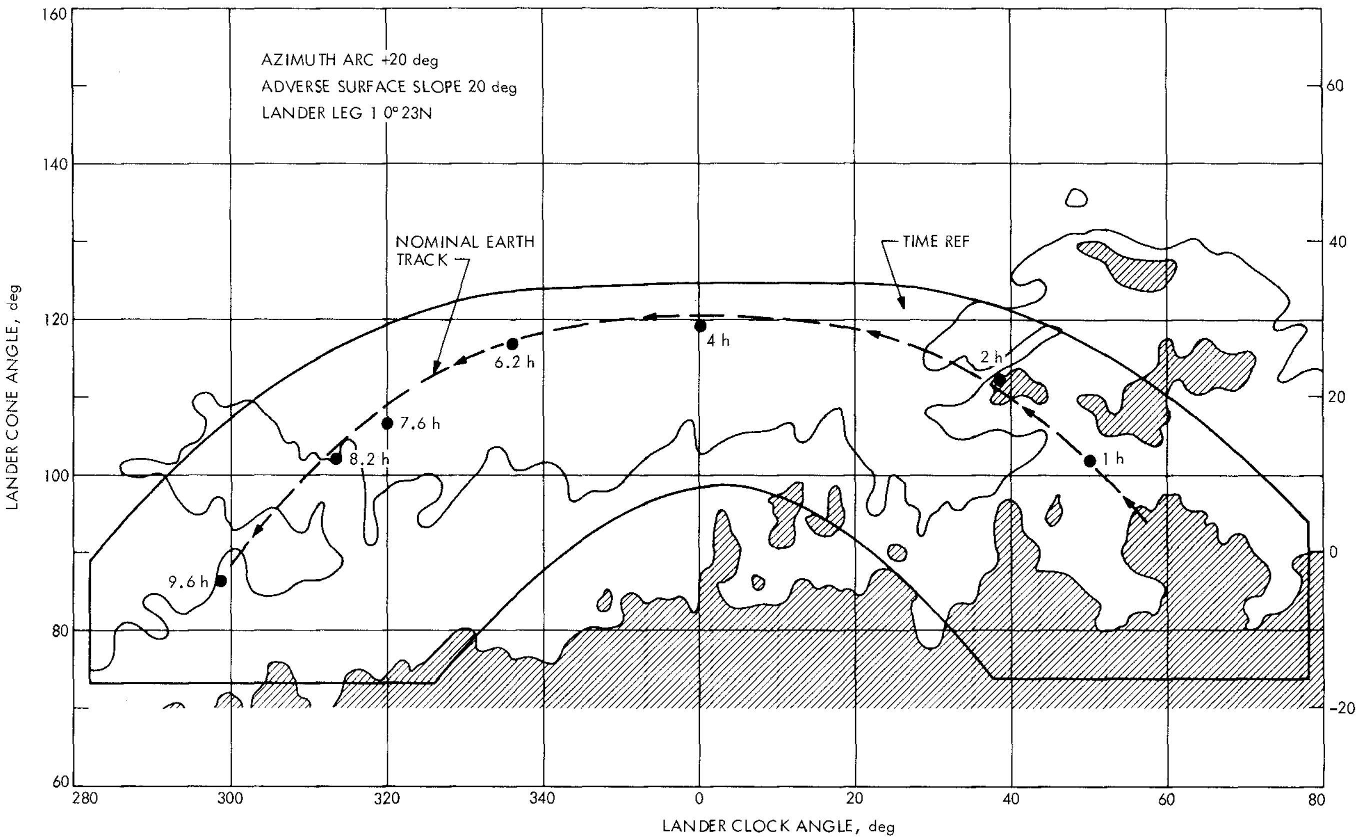



Fig. 6. Earth track envelope (30°S latitude)

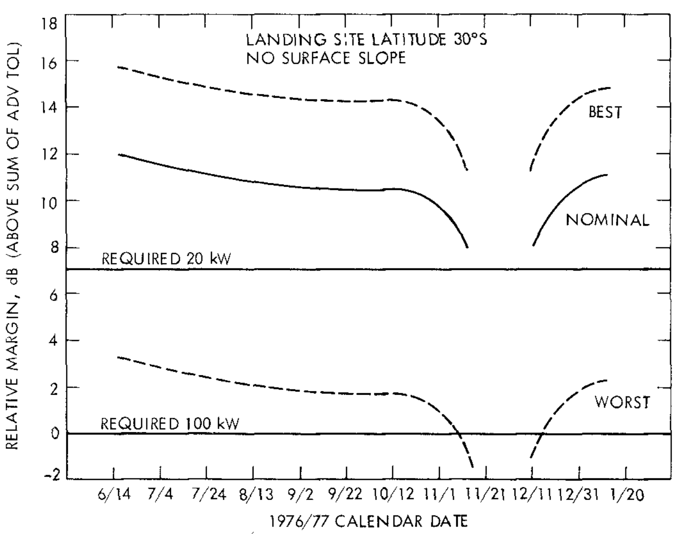



Fig. 7. Viking Lander command margin (Earth elevation = 15 deg, cone angle = 105 deg)

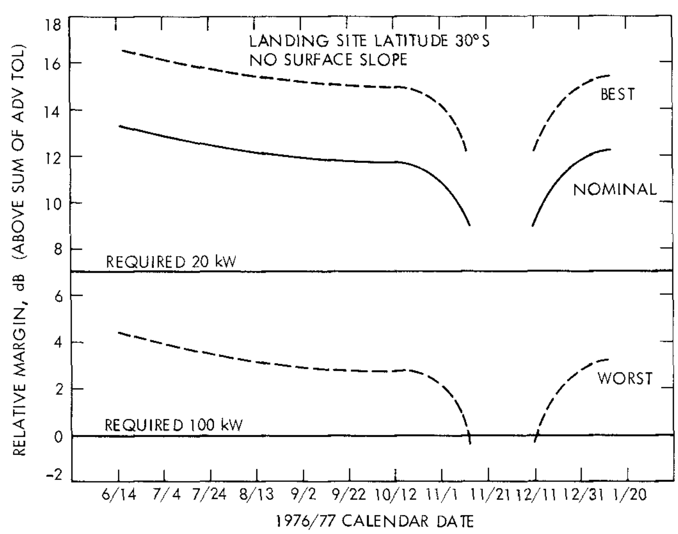



Fig. 8. Viking Lander command margin (Earth elevation = 25 deg, cone angle = 115 deg)