Viking Mission Support

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This article discusses the capabilities of the DSN as a significant factor in the radio frequency and data management design and the engineering requirements of the two orbiters and two landers for the Viking missions. Also described is the DSN involvement in the extremely complex lander acquisition sequence in which trade-offs are made between the total lander "on" period of 2 h and competing factors of round-trip light time and telemetry and command lock-up times.

I. Vehicle Descriptions

The *Viking* 1975 mission to Mars uses two spacecraft, each consisting of an orbiter and a lander, launched up to 10 days apart and arriving at the planet up to 30 days apart about a year later. On arrival, each spacecraft is placed in orbit, and the scientific instruments on board are used to obtain data to aid in the selection of a suitable landing site.

The lander is then separated from the spacecraft and injected into a suitable landing trajectory from which the complex landing sequence depicted in Fig. 1 can be carried out. Each orbiter will then act as a relay station between either of the landers and earth, receiving data from each lander on a UHF relay circuit, recording and retransmitting the same data on an S-band link to the DSSs. A lower rate, direct S-band link from the landers to the DSS can also be used during orbital operations when desired. However, each lander can support this latter link only for 2 h in each 24-h period.

The stringent requirements for planetary quarantine which apply to the landers preclude the replacement of lander elements, such as the radio system, after the lander capsule has been sealed prior to launch. This does not apply to the orbiter, however, and a spare orbiter radio system is kept available in case either orbiter should develop a fault in this area.

II. Frequency Selection

From the foregoing brief summary of the *Viking* 1975 mission, it is apparent that frequency assignments for S-band communications with the DSN must satisfy the following basic requirements:

(1) Two 2-way channels, one for each of the two orbiters, both to be operated simultaneously from any one DSS.

(2) One 2-way channel, to be shared between the two landers. Each lander uses it only during the daily 2-h period during which it is in direct contact with earth.

(3) One 2-way channel, to be assigned to the spare orbiter radio system. This could be used on either orbiter as required.

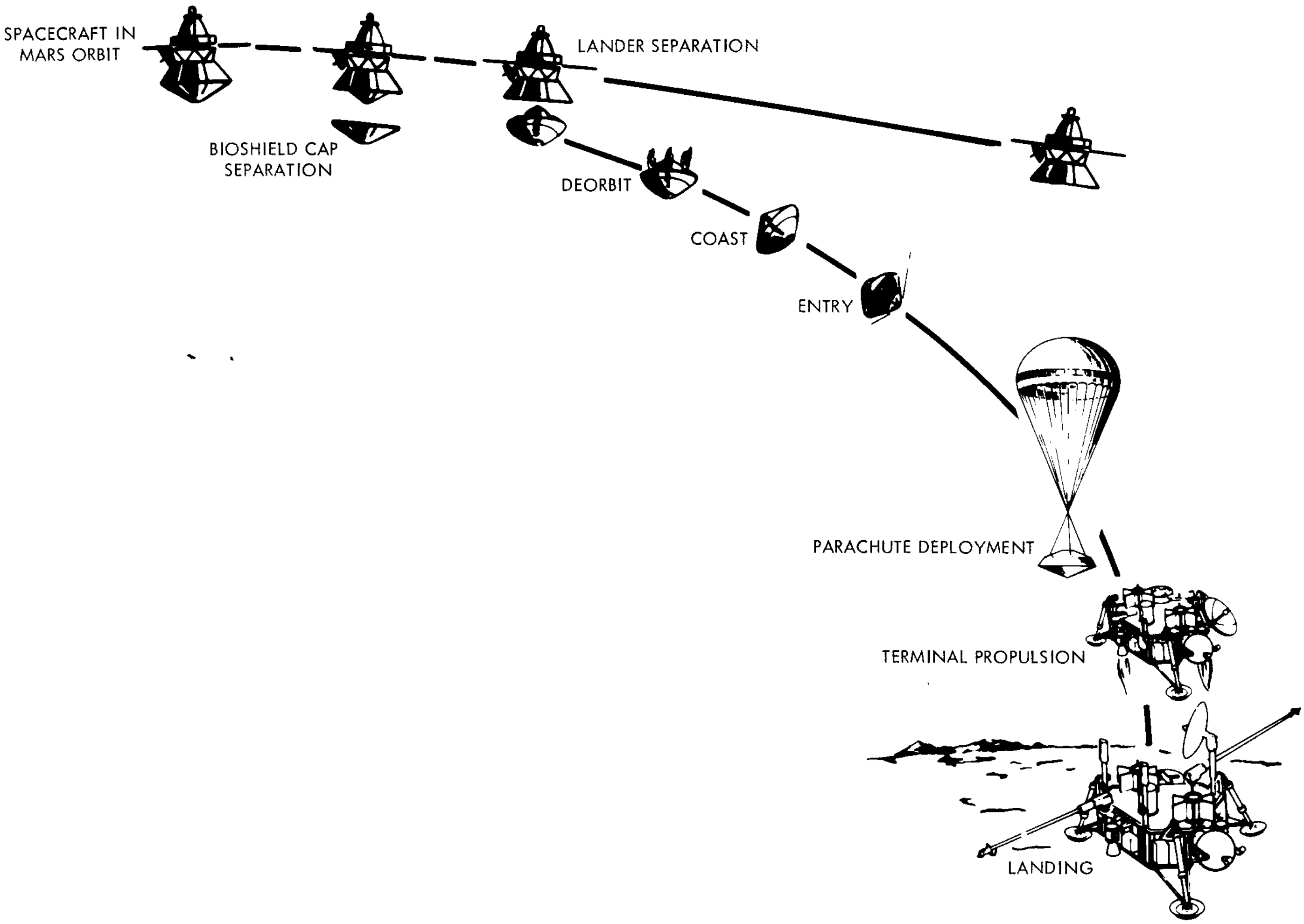

Fig. 1. Typical *Viking* landing sequence

In making these four frequency assignments, many other factors were also involved. These included the capability of the DSSs to support simultaneous multiple up and down links, bandwidth requirements for ranging, command, and telemetry, doppler offsets, and existing channels already assigned to current flight projects.

The 64-m-antenna DSSs will have the capability to support two simultaneous uplinks and four simultaneous downlinks. However, the high-power Klystron amplifiers used for transmitting the uplink are known to produce intermodulation products under certain conditions of nonlinear operation. Therefore, it was necessary to select frequencies for which these undesirable products would be minimized, and would not appear in the band pass of adjoining receive channels. In the case of the channels selected, there are no first-degree intermodulation products of order less than 700 lying within the chosen receive band.

Excluding the doppler effects, the RF bandwidths required on each channel are:

Ranging	3.6 MHz
Telemetry (high rate)	4.1 MHz
Command	4.0 kHz

Therefore, to prevent spectral components falling outside the designated space bands, the lowest uplink transmit frequency must be at least 1.8 MHz from the lower transmit band edge (2110 MHz) and the highest downlink receive frequency must be 2.05 MHz from the higher band edge (2300 MHz). Therefore, the frequencies chosen must lie between channels 9 and 21.

The frequency offset due to two-way doppler effects can become appreciable in missions of this type, and must also be taken into consideration in assigning frequencies to avoid interference between adjacent channels. A two-way doppler plot for a typical *Viking* trajectory is shown in Fig. 2 for the period from launch to encounter. A cyclic variation of ± 8.0 kHz due to earth rotation is superimposed on the steady-state offset throughout the mission.

It can be seen from these plots that, during the cruise periods of the mission, the two-way doppler offset may exceed 300 kHz. Furthermore, the specified tuning range of a DSIF receiver is 9 parts in 10^5 (which is equivalent to about 207 kHz), and the bandwidth of adjacent deep space frequency channels is approximately ± 185 kHz.

To all of these effects must be added an uncertainty in the actual orbiter or lander carrier frequency of $\pm 3 \times 10^{-5}$.

Finally, although the space band contains some 29 channels spaced approximately 270 kHz apart, these are not all available to a new flight project. Channels 14, 17, and 23 are assigned to *Mariner* Mars 1971, channels 15 and 21 to the Helios Project, and channels 6 and 7 to *Pioneer*.

The DSN has taken all these factors into consideration in making the tentative frequency assignments in Table 1.

Table 1. Tentative frequency assignments for *Viking* spacecraft

Channel	Frequency, MHz	Recommended use
10A	2293.518519	Orbiter 1
10B	2111.948303	
13A	2294.629630	Orbiter spare
13B	2112.971451	
16A	2295.740741	Landers 1 and 2
16B	2113.994599	
19A	2296.851852	Orbiter 2
19B	2115.017747	

III. Orbital Doppler

Typical one-way doppler frequency shift due to orbital motion for the orbiter is shown in Fig. 3, as a function of time from periapsis. The corresponding doppler rates are shown in Fig. 4.

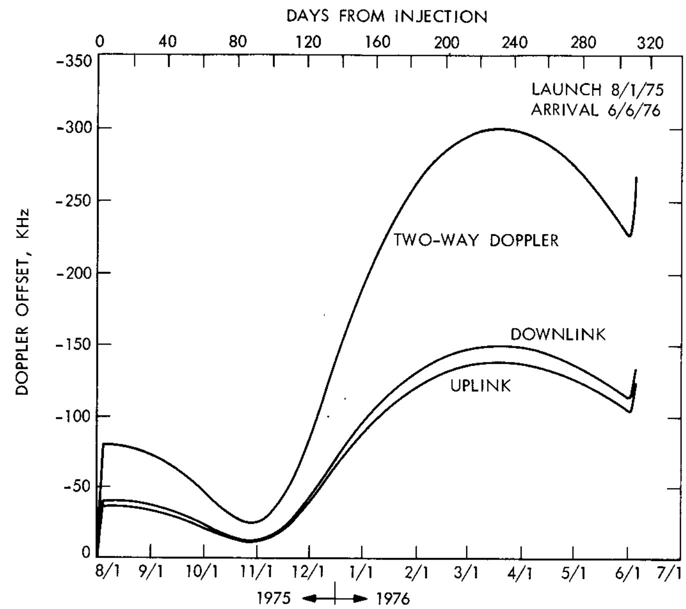

Fig. 2. Doppler offset for typical *Viking* trajectory

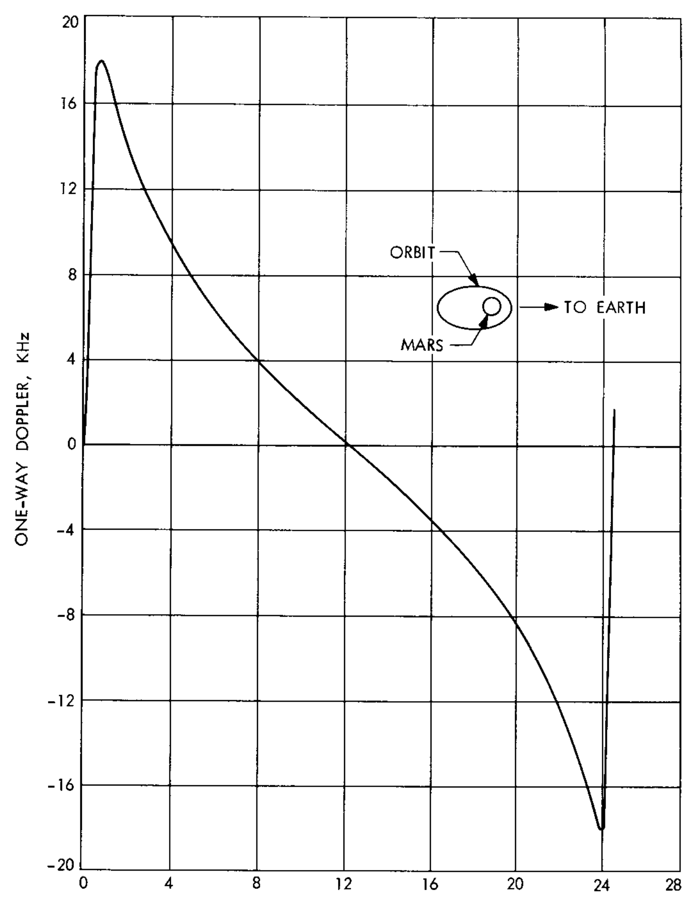

Fig. 3. Typical *Viking* orbiter one-way doppler shift (look angle parallel to line of apsides)

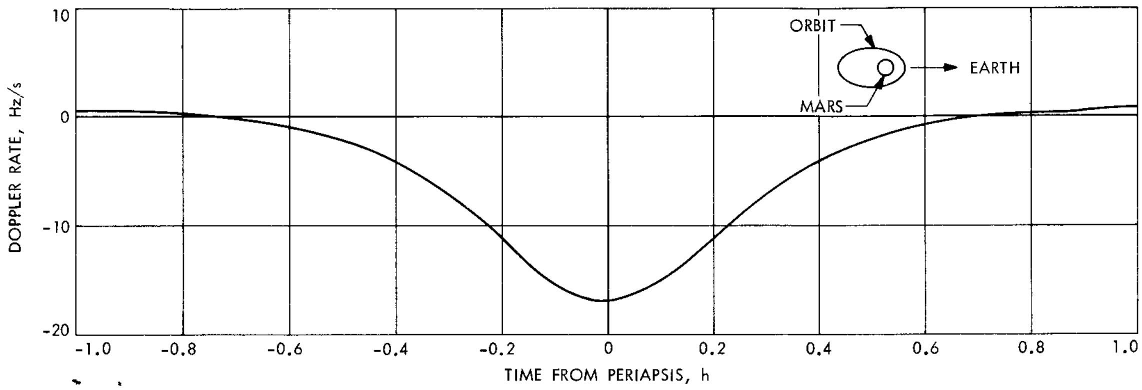

Fig. 4. Typical *Viking* orbiter one-way doppler rate (look angle parallel to line of apsides)

In order to continuously maintain a coherent two-way link with the DSS, the orbiter transponder must be able to accommodate doppler excursions of about -40 kHz peak-to-peak and doppler rates of about 20 Hz/s, while the ground receiver at the DSS must accommodate approximately twice these amounts. In both the uplink and downlink doppler, an additional allowance must be made for an earth–Mars separation rate equivalent to about -70 kHz at the beginning of orbital operations, changing to about $+20$ kHz at the end of the mission.

Although the ground receiver can accommodate a tuning range of 207 kHz at S-band, with RF tracking rates in excess of 50 Hz/s, it is imperative that the ability of the *Viking* orbiter to track under these conditions be carefully examined, and a determination made as to the need for a programmed local oscillator on the DSS ground transmitter.

The doppler offset seen by the *Viking* lander due to Mars rotation will exceed ± 1.7 kHz, together with ± 3.28 kHz due to earth rotation and the effect due to earth–Mars separation. In this case, the rate of change of doppler is much lower and unlikely to exceed the lander RF loop capability.

The capabilities of orbiter, lander, and DSS to track the orbital doppler are dependent on the signal-to-noise ratio and allowable phase error. Careful analysis of the trade-offs must be made to ensure the required capability of the telecommunication link during orbital operations.

IV. Lander Acquisition

As mentioned previously, each lander is constrained by power and thermal considerations to a daily "on" period of about 2 h. With an earth–Mars round-trip light time of 40 min, it becomes apparent that a carefully planned lander acquisition sequence is necessary if the maximum time for ground commanding and telemetry data transmission is to be realized.

The lander transmitter is turned on at a specified time each day by a beacon signal from the orbiter passing overhead, and is turned off at the expiration of the 2-h transmitting period. The lander receiver is turned on about 1 h prior to the transmitter.

The lander acquisition procedure takes advantage of this information to turn on the ground transmitter about 1 h prior to the expected lander on period, sweeping the ground carrier right across the lander receiver passband and returning to the expected best lock frequency of the lander receiver.

Thus, when the orbiter beacon activates the lander transmitter, it should come *on* in the two-way coherent mode.

On reaching earth, the DSS receiver, subcarrier demodulator, and bit synchronizer must be locked up, after which a final adjustment to the telemetered static phase error (SPE) can be made prior to starting any command sequences.

Estimates for the time required to accomplish these functions vary from 1 to 5 min, although it is expected that the time will diminish as proficiency improves and uncertainties in the lander carrier and subcarrier frequencies are reduced. The sequence of events described above is shown in Fig. 5.

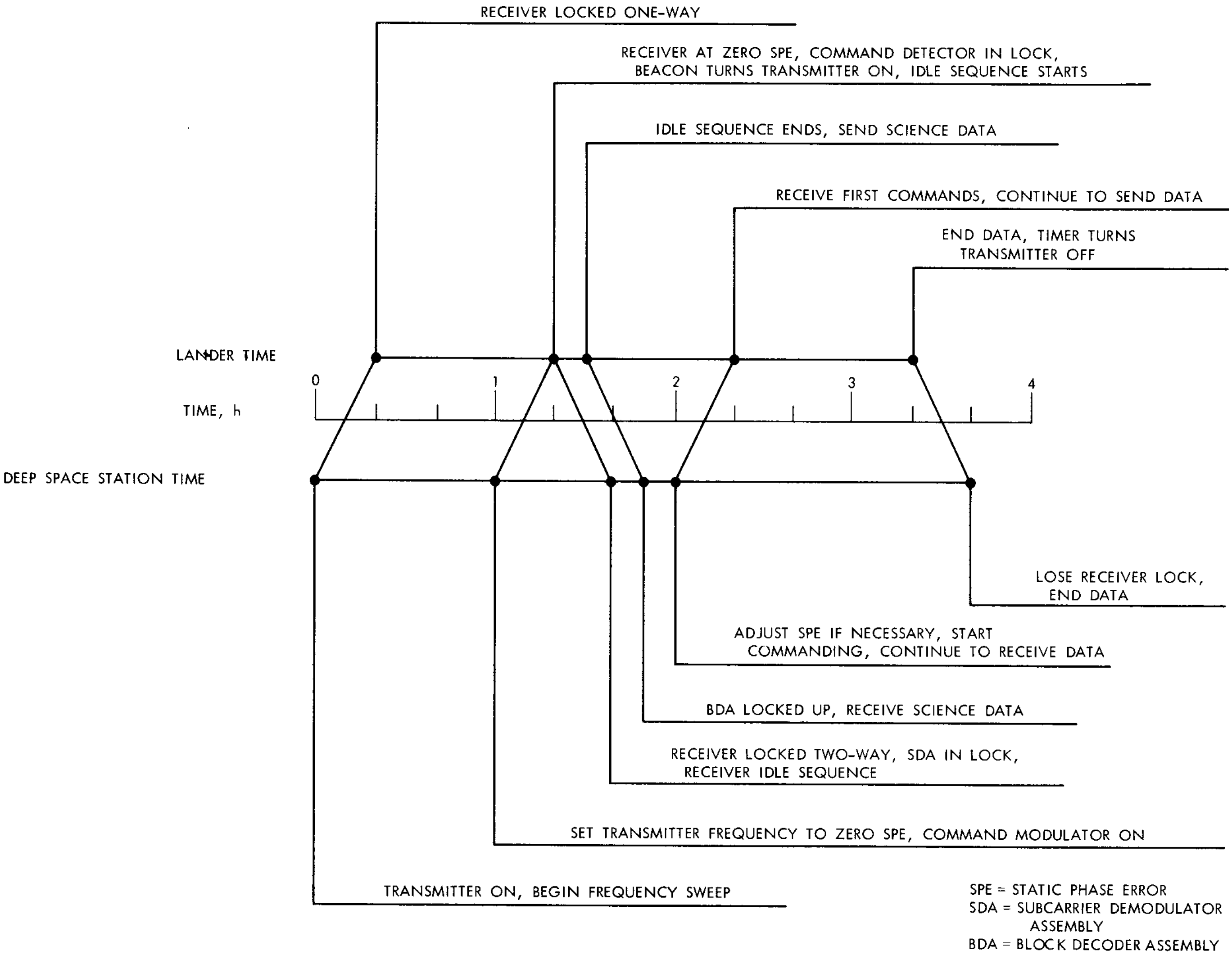

Fig. 5. Typical lander-DSS acquisition sequence

In order to avoid loss of valuable science data during these lock-up activities, it has been proposed that the lander might transmit a few minutes of idle-sequence bit prior to sending the first science data.

A procedure such as this would permit early lock-up of the DSS telemetry equipment in preparation for the arrival of the science data at the conclusion of the idle sequence.