

# Tracking Operations During the Viking 2 Launch Phase

J. A. Wackley  
Network Operations Office

*Viking 2 launch phase operational procedures, and in particular the DSN initial acquisition procedures, were very intensively considered and conservatively designed to accommodate even the most unfavorable of launch possibilities. These procedures were successfully implemented and strongly contributed to the highly successful launch of Viking 2.*

## I. Introduction

The Viking 2 spacecraft was launched from the Air Force Eastern Test Range (AFETR) at 18:38:59.96 Greenwich Mean Time (GMT) on 9 September, 1975, at a launch azimuth of 96.507 degrees. Like its sister spacecraft, Viking 1, the mission of Viking 2 is to study the planet Mars via direct measurements in its atmosphere, on its surface, and in orbit around it. After being placed in a parking orbit by the combination Titan III-E/Centaur D-1T launch vehicle, Viking 2 was injected into a trans-Mars, heliocentric transfer orbit over southern Africa. The resulting near-Earth portion of the orbit was such that, within the Deep Space Network (DSN), the Australian complex of tracking stations was first to view the spacecraft. The Deep Space Station (DSS) selected to perform the initial acquisition was DSS 42, with DSS 44 serving as a backup.

In the following sections, the prelaunch tracking operations planning will be reviewed and an analysis of

the subsequent launch phase tracking operations at DSS 42 and DSS 44 will be presented.

## II. Review of the Viking Acquisition Strategy

Since Viking 2 was similar to Viking 1 in both the trajectory it was to follow and in the characteristics of its radio frequency subsystem, it was not necessary to make any major revisions to the acquisition plan used during the Viking 1 launch (described in detail in Reference 1). The main points of this plan were:

- (1) Antenna to be driven in computer mode until after confirmation of two-way. In order to accomplish this, tracking predictions based within two seconds of the actual liftoff time were needed by the stations. Thus, with this necessity in mind, the new Polynomial Coefficient Tape-Network Operations Control Center Prediction software (PCT-PREDIK) prediction generation system was carefully exercised

in prelaunch testing and an elaborate PCT generation plan was developed (see Reference 1). By the day of launch, the throughput time of the system had been reduced from approximately 41 minutes to less than 30 minutes.

- (2) Uplink acquisition to commence at approximately rise plus three minutes in order to collect as much two-way doppler data as possible before the interruption in data to be caused by the uplink transfer to DSS 44.
- (3) Uplink acquisition sweep to encompass  $XA \pm 110$  Hz by use of the voltage-controlled oscillator (VCO). The extent of the sweep was chosen based upon the combination of the trajectory uncertainties and the spacecraft receiver uncertainties provided by the Orbiter Performance Analysis Group (OPAG) these being (at VCO level):

$$3\sigma \text{ XA TRAJECTORY} \sim .05 \text{ Hz}$$

$$3\sigma \text{ XA S/C RECEIVER} \sim 15 \text{ Hz}$$

$$3\sigma \text{ XA S/C "RANDOM WALK"} \sim 7.5 \text{ Hz}$$

$$3\sigma \text{ XA S/C VCO TEMPERATURE} \sim 5.6^\circ\text{C}$$

and

$$\partial XA / \partial T \sim 9 \text{ Hz}/^\circ\text{C}$$

which when combined give a total  $3\sigma$  uncertainty of approximately 53 Hz. Thus the sweep was designed to encompass approximately twice the  $3\sigma$  values about the XA. Figure 1 details the XA frequency versus time.

- (4) Uplink tuning rate to be 3 Hz/sec (VCO). This rate was considered to be close to the limit of the accurate manual tuning capability and when received at the spacecraft would result in an effective tuning rate of about 280 Hz/sec, approximately the geometric mean of the allowable tuning rates.

Additionally, the open window launch trajectory for 9 September resulted in maximum angular and frequency rates of:

$$d/dt \{ HA \} \cong .06 \text{ degree/second}$$

$$d/dt \{ D2 \} \cong 119 \text{ Hz/second (S-band)}$$

$$d/dt \{ XA \} \cong .6 \text{ Hz/second (VCO)}$$

where

HA = Local (station) hour angle

D2 = Two-way doppler frequency

XA = Spacecraft receiver best lock with doppler accounted for

While these rates are higher than those encountered during the Viking 1 launch, they are much lower than those encountered in previous parking orbit ascent trajectories. Figure 2 is a stereographic illustration of the launch pass over DSS 42. The Elevation Angle versus time is shown in Figure 3, which also serves as a time line for the important tracking events at DSS 42.

### III. Postflight Analysis of the Viking 2 Launch Phase

#### A. Tracking Predictions

1. **The PCT-PREDIK Prediction Generation System.** The PCT-PREDIK System functioned smoothly and efficiently during the Viking 2 launch phase. Because the Viking Flight Path Analysis Group (FPAG) was able to deliver the first PCT at launch minus two hours 30 minutes, Stations 42 and 44 had more than enough time to generate a drive tape well before launch using predicts set B09D. During the launch countdown, changes made to the predicted frequency were small enough (XMTREF was changed by 3 Hz) that it was decided not to generate the planned frequency update predicts (predicts set B09F).

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 predicts set to be generated between launch and spacecraft rise; this set updated the frequencies and gave the stations text predicts with a GMT time field (all previous text predicts had been generated in time from launch (TFL)).

2. **Prediction accuracy.** During the early portion of the DSS 42 launch pass, the radiometric data, when differenced with the preflight nominal predicts set B09E by the Network Operations Control Center (NOCC) pseudoresidual program yielded the following residuals:

$$\Delta HA \sim -.07 \text{ degree}$$

$$\Delta D2 \sim -29 \text{ Hz (S-band)}$$

$$\Delta XA \sim 14 \text{ Hz (VCO)}$$

These can be compared to the  $3\sigma$  uncertainties supplied by the Viking project:

$$\Delta HA \sim .002 \text{ degree}$$

$$\Delta D2 \sim 10 \text{ Hz (S-band)}$$

$$\Delta XA \sim 55 \text{ Hz (VCO; total frequency/trajectory uncertainty)}$$

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 caused 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 among the smallest early launch pass angle residuals yet achieved.

The two way doppler residuals shown in Figure 4 started quite large (approximately -300 Hz), but gradually decreased to approximately -29 Hz (or three times the expected  $3\sigma$  value) as the apparent motion of the spacecraft approached sidereal rate.

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

#### **B. One-Way Acquisition at DSS 42**

Acquisition of the Viking 2 one-way downlink at DSS 42 was reported at 19:27:01 GMT, 25 seconds prior to the expected spacecraft rise time of 19:27:26 GMT. This again indicates a possible error in the DSS 42 horizon mask used in the prediction software. (This problem was first noted during the Viking 1 launch. See Reference 1, Section VI-B.)

The downlink acquisition is illustrated in Figure 5. 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 GMT with Receiver 5 (connected to the S-band Cassegrain Monopulse (SCM) Antenna) reported in lock at 19:27:01 GMT. Both monitor and tracking data indicate, however, that Receiver 6 (connected to the S-Band Acquisition Aid (SAA) Antenna) may have sustained lock from as early as 19:26:41 GMT.

#### **C. Two-Way Acquisition at DSS 42**

DSS 42 was instructed to perform the following uplink acquisition sweep designed according to the specifications described in Section II:

TRANSMITTER ON: 19:30:40 GMT  
START SWEEP: 19:31:00 GMT  
STARTING FREQUENCY: 22.035090 MHz (VCO)  
SWEEP RATE: 180 Hz/min (VCO)

END SWEEP: 19:32:30 GMT

ENDING FREQUENCY: 22.035360 MHz (VCO)

SWEEP DURATION: 90 seconds

A comparison of the instructed sweep with the actual uplink acquisition sweep is depicted in Figure 6. As is shown, the sweep began approximately seven seconds later than planned. At 19:32:02 GMT, the switch to the two-way coherent mode occurred. The two-way downlink was very quickly acquired by DSS 42 with the receiver back in lock at 19:32:12 GMT. 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 fifteen seconds longer than originally planned.

When the doppler extractor was switched from the SAA antenna receiver to the SCM antenna receiver, it was found that that receiver was in lock on a sideband located approximately 10 kHz from the main carrier (see Table 1). Receiver lock on the sideband was broken approximately two minutes later and the carrier reacquired at 19:34:44 GMT.

#### **D. Angle Tracking**

In following the angle strategy reviewed in Section II, the antenna at DSS 42 was initially computer-driven using the preflight nominal predicts set B09D, generated at launch minus two hours. The drive mode was changed to autotrack at 19:35:51 GMT following completion of the uplink acquisition.

As was the case during the Viking 1 initial pass, it was necessary to transfer the uplink to DSS 44 in order to allow DSS 42 to switch maser No. 1 into the antenna microwave subsystem. In preparation for this reconfiguration, the drive mode at DSS 42 was changed back to computer mode at 20:17:00 GMT. Autotracking was resumed five minutes later, following the uplink transfer back to DSS 42. After the failure of maser No. 1 at 23:11:16 GMT, DSS 42 returned to computer drive for the remainder of the pass.

#### **E. Ranging**

The acquisition of range data at DSS 42 began at 22:25:02 GMT and continued with generally good results through the acquisition of seven range points. Using the Pseudo-Differenced Range Versus Integrated Doppler (DRVID) technique the range points were evaluated with the following results:

Acquisitions	Pseudo-DRVID (RU)
1/2	4
2/3	-11
3/4	376836
4/5	*
5/6	-1
6/7	352235

\*Unable to compare due to erroneous reset of doppler counter.

As can be seen, two acquisitions, numbers four and seven of the seven completed, resulted in erroneous range points. Acquisition number four was started at 23:10:02 GMT and completed two minutes later, during which time maser No. 1 failed causing the acquisition to be erroneous. The seventh and final acquisition began at 00:15:02 GMT. During this acquisition the antenna drove approximately two degrees off point causing a bad acquisition.

The pseudo-DRVID computed for the remaining five points indicates that they were of good quality and usable for orbit determination.

#### F. Launch Pass Activities at DSS 44

Since it was designated to serve as a backup station, DSS 44 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 DSS 42.

In prelaunch planning sessions, the acquisition planning group was presented with the following constraints and requirements (among others):

- (1) The downlink signal level at spacecraft rise was expected to be strong enough ( $\sim -80$  dBm for the SCM antenna) to cause saturation of the maser.
- (2) A planned roll turn (at launch plus 150 minutes) of the spacecraft to execute a sky map could cause unfavorable antenna angles. This would result in the possible loss of two-way lock if the S-band Acquisition Aid antenna was transmitting.

(3) Bioshield separation needed to be observed in the attitude control system telemetry.

(4) Two-way doppler and telemetry needed to be continued without major interruption.

To resolve these difficulties, it was decided that both stations would be configured in the maser by-pass mode (i.e., the maser would be completely out of the antenna microwave system) during the period of high signal level and that the S-band Cassegrain Monopulse (SCM) antenna would be used for transmission during the roll turn. Thus, an uplink transfer would be effected between DSS 42 and DSS 44 at approximately launch plus 100 minutes in order to provide continuous telemetry and alleviate the need to reacquire the uplink while DSS 42 reconfigured the maser and transmitter. When it again had the uplink, DSS 42 would be configured for normal cruise support (i.e., maser in, SCM antenna transmitting) without loss of data to the Viking project.

Following this plan, DSS 44 acquired the one-way Viking 2 downlink at 19:29:18 GMT (as was the case with DSS 42, this time was considerably earlier than the predicted spacecraft rise time). The acquisition is shown in Figure 7. Autotracking of the spacecraft began at 19:33:38 GMT, after completion of the DSS 42 uplink acquisition sweep and confirmation of good three-way downlink.

The uplink was handed over to DSS 44 by means of a tracking synthesizer frequency (TSF) transfer (which does not require tuning of the uplink) from 20:18:02 to 20:21:02 GMT. Telemetry and tracking data continued uninterrupted during this period.

DSS 44 was reconfigured to normal cruise configuration at 20:27:40 GMT and continued tracking in the three-way mode until spacecraft set at 00:28:20 GMT.

#### IV. Summary

The acquisition strategy used during the Viking 1 launch was again successfully implemented during the Viking 2 launch. This strategy had been carefully planned to accommodate even the most unfavorable launch possibilities. The culmination of this careful planning and extensive training was the successful acquisition of Viking 2 and completion of the Viking launch phase.

## Acknowledgement

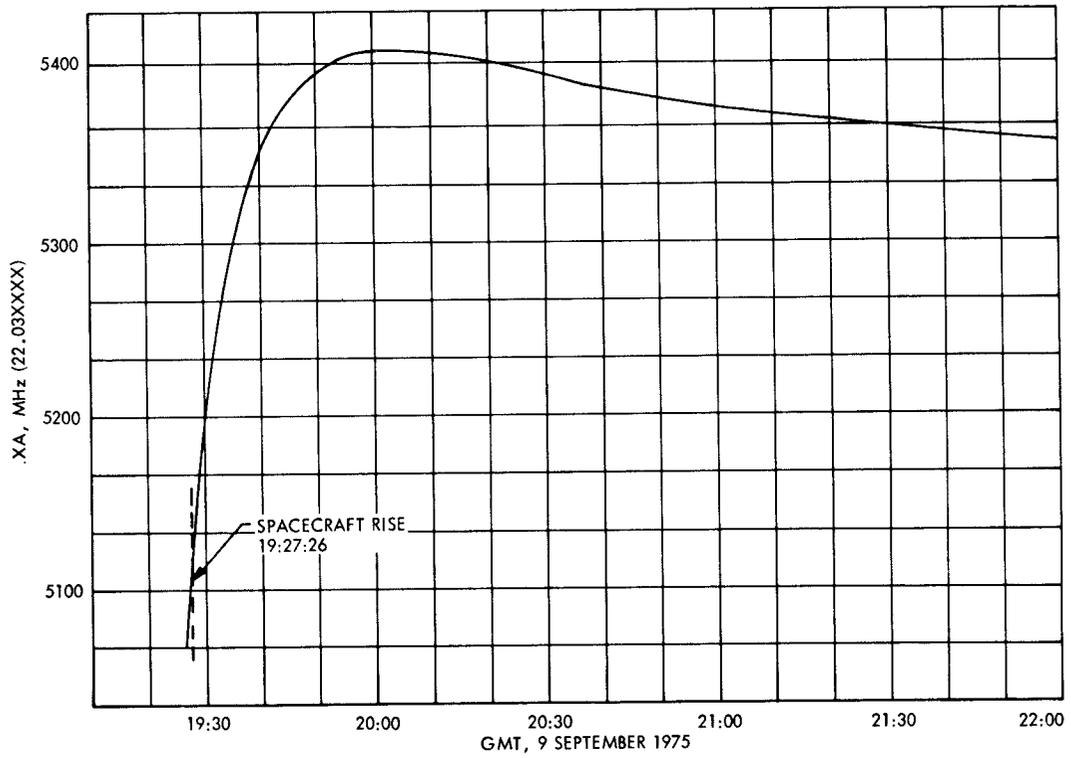
The author wishes to acknowledge C. Linthurst and C. Darling for the fine graphical illustrations.

## Reference

1. Berman, A. L. and Wackley, J. A., 'Tracking Operations During the Viking 1 Launch Phase', in *The Deep Space Network Progress Report 42-30*, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1975.

**Table 1. Doppler residuals**

GMT	Residuals	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	Receiver on sideband
19:33:30	-10007.272	Receiver on sideband
19:34:00	-9993.609	Receiver 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



**Fig. 1. Best lock frequency at DSS 42, Viking 2 launch, September 9, 1975**

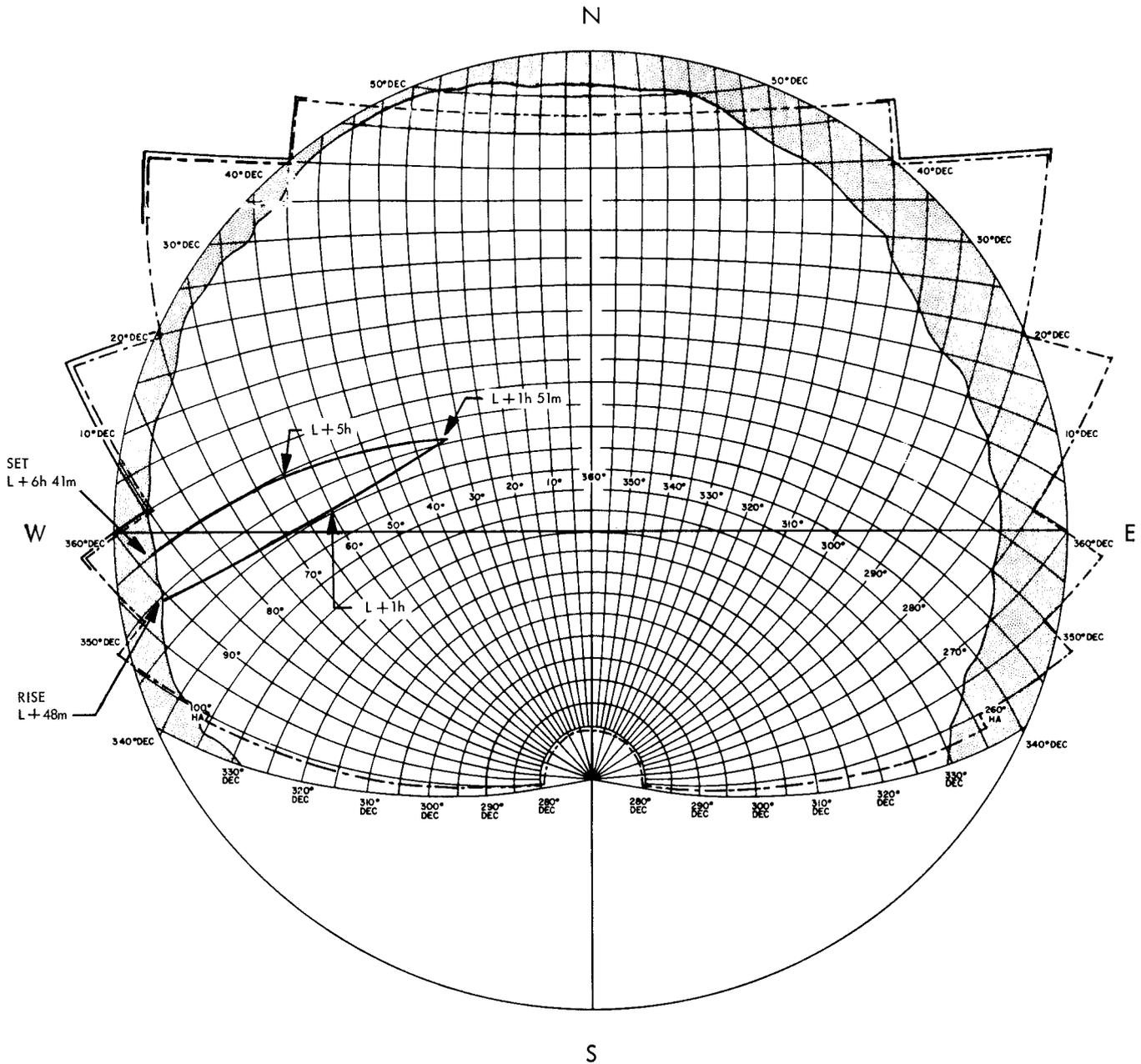
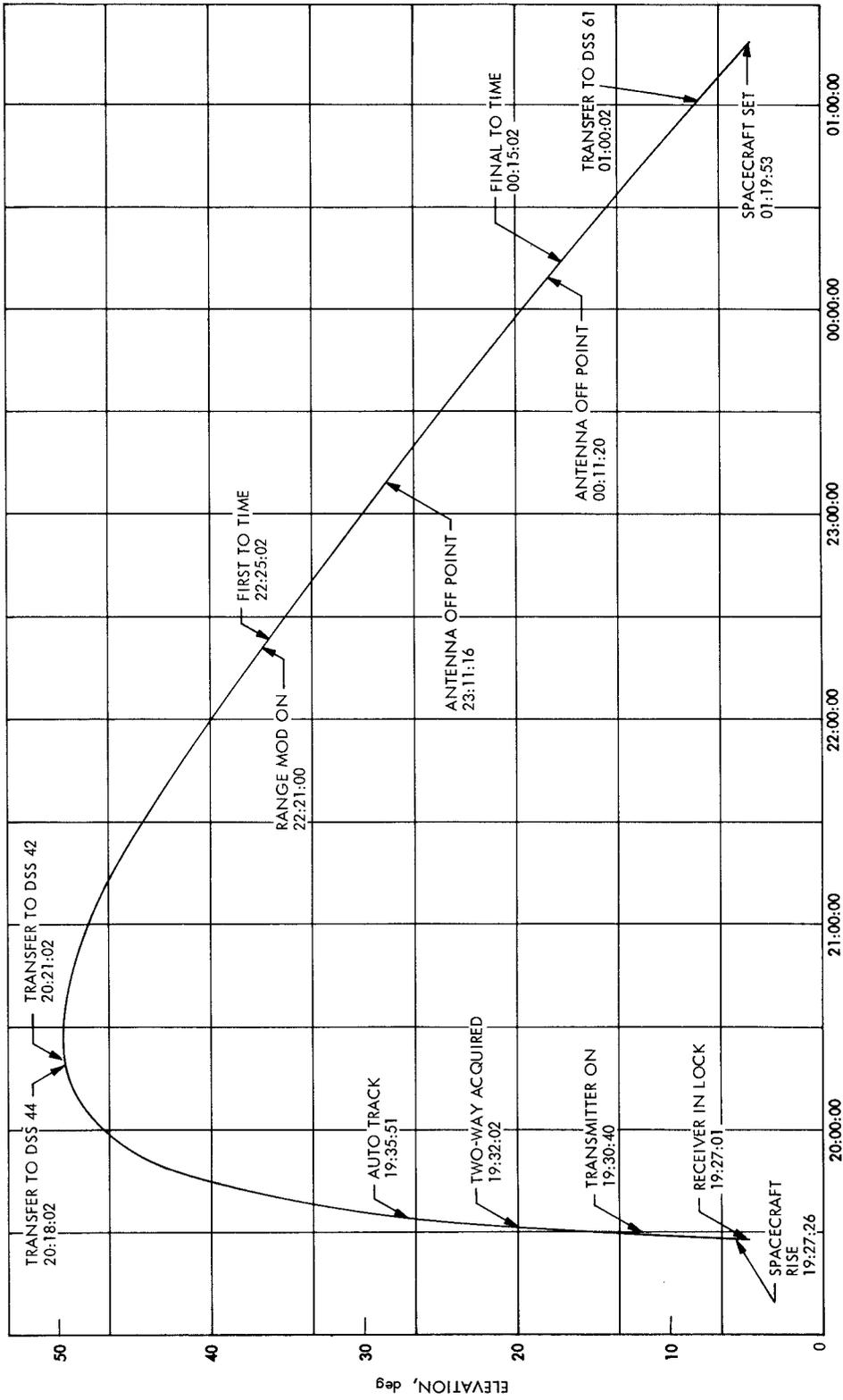


Fig. 2. DSS 42 Viking 2 launch, September 9, 1975



GMT, 9 SEPTEMBER 1975

Fig. 3. Elevation at DSS 42, Viking 2 launch, September 9, 1975

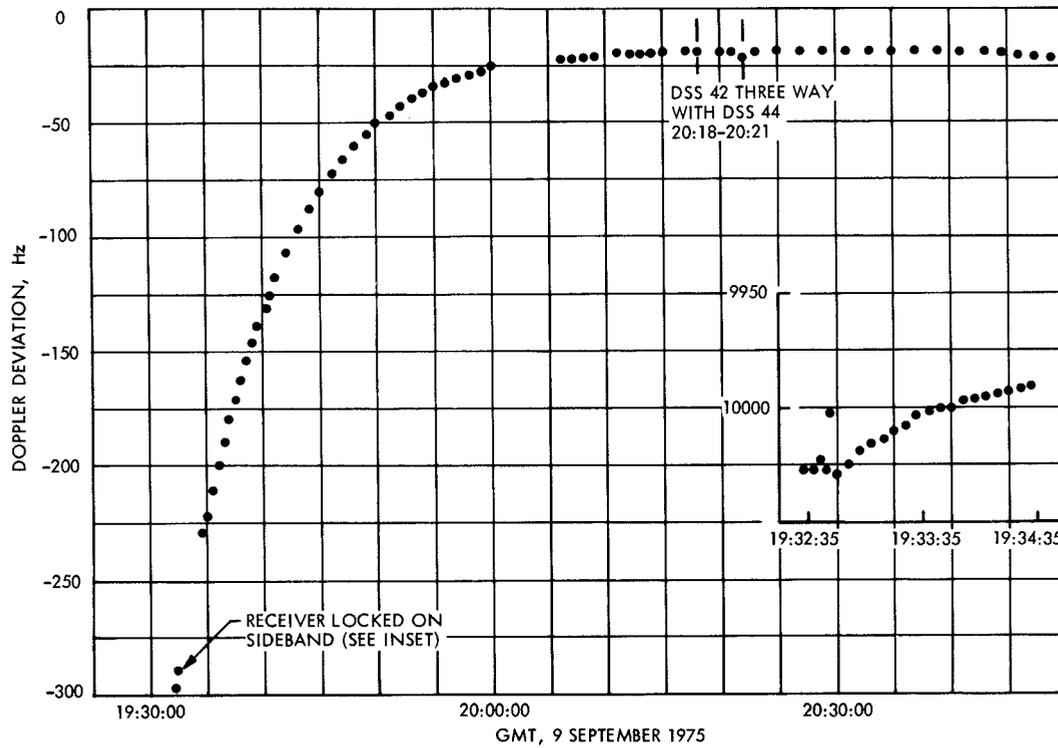


Fig. 4. Doppler deviation from preflight nominal predicts, DSS 42, predicts set B09E

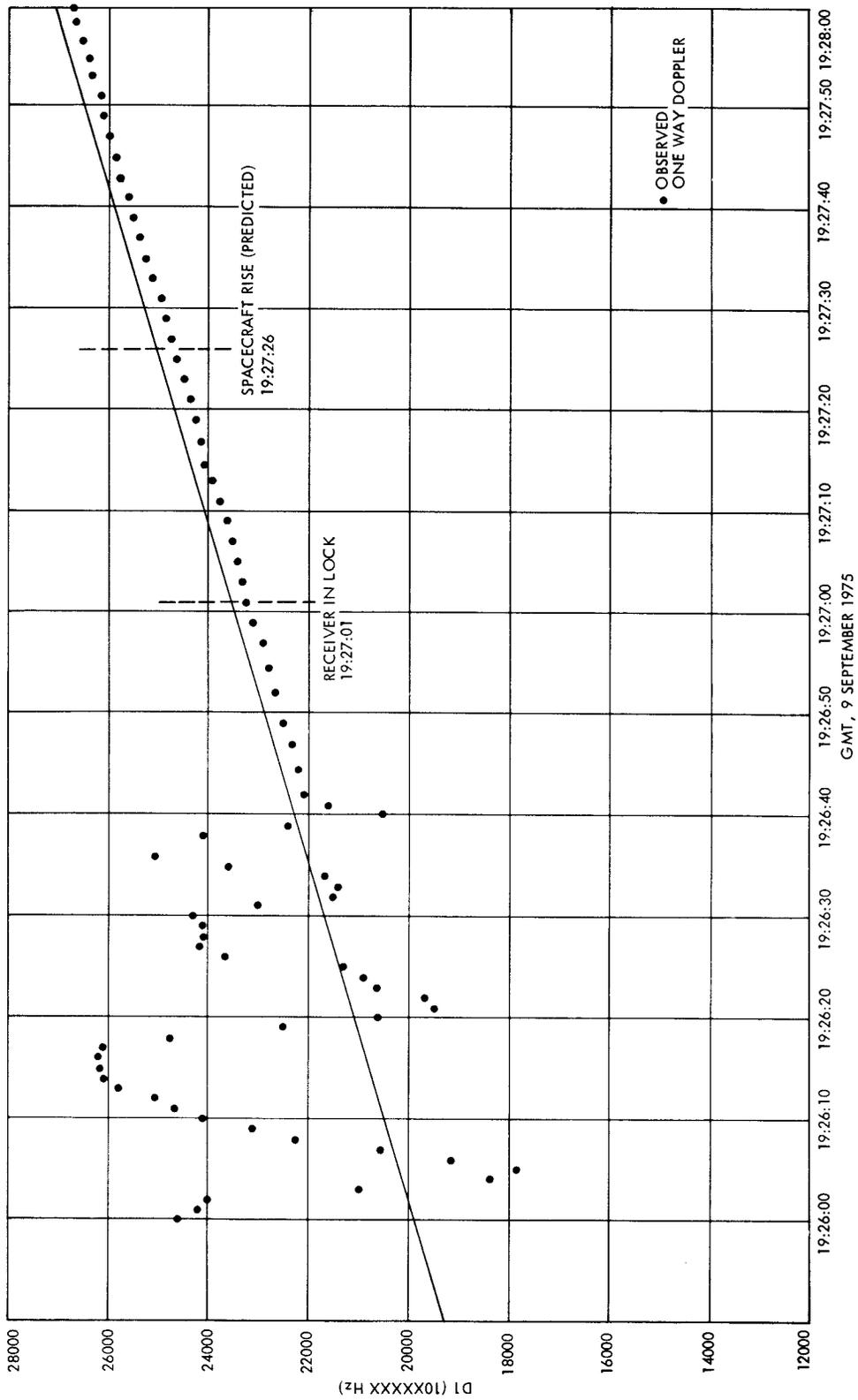


Fig. 5. Initial downlink acquisition at DSS 42, Viking 2 launch

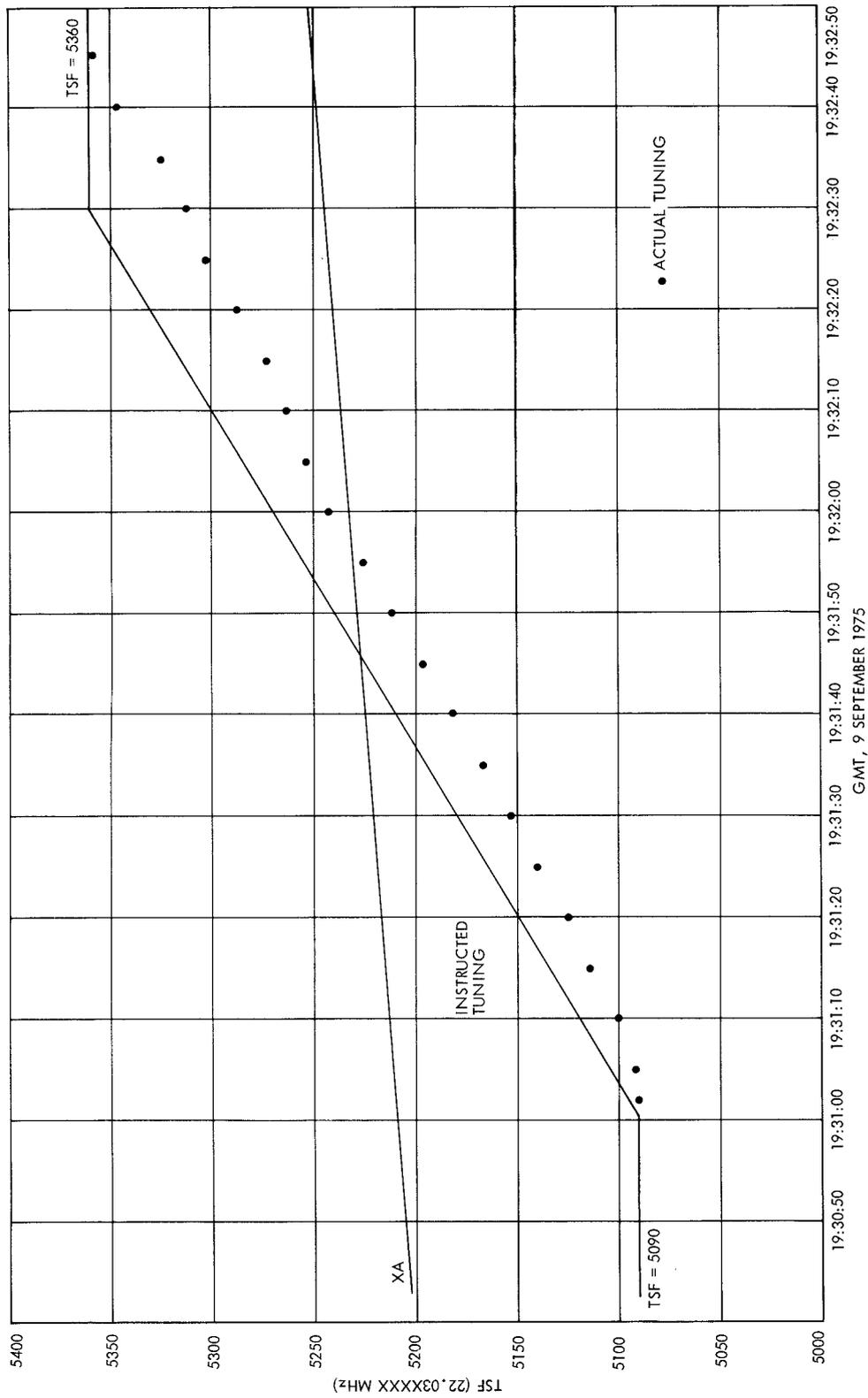


Fig. 6. Comparison of actual tuning to instructed tuning at DSS 42, Viking 2 launch

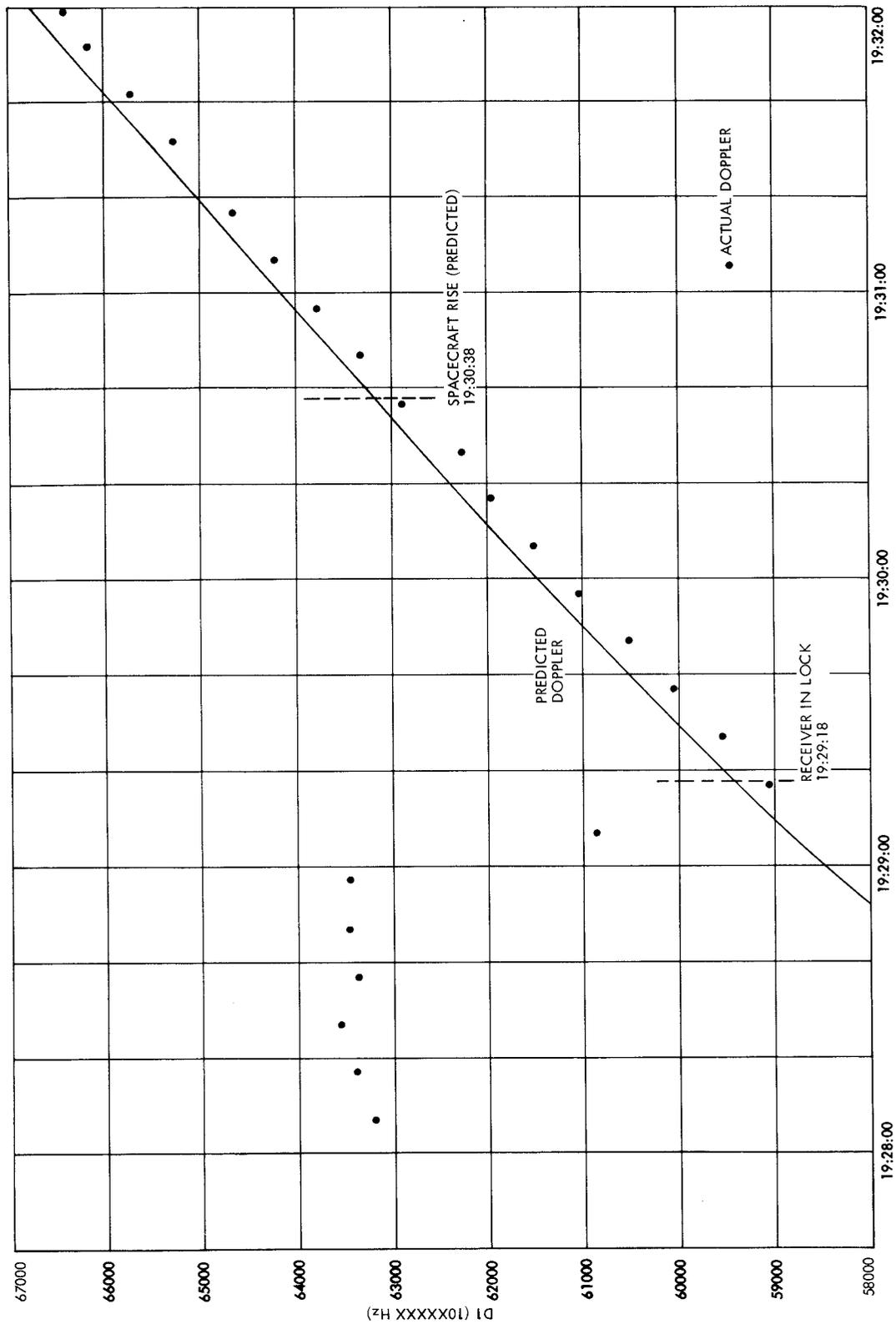


Fig. 7. Initial downlink acquisition at DSS 44, Viking 2 launch