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FAILURE REPORT FOR DSIF AND TELECOMMUNICATIONS

OPERATIONS FOR RANGER 3

March 9, 1962

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Introduction

This memorandum adds further information to that in the previously issued "RA-III Preliminary Flight Performance Report and Failure Analysis, Submitted by Spacecraft Data Analysis Team, Edited by A. E. Dickinson" (Re-Order No. 62-30).

In general, DSIF and telecommunications performance was acceptable in Ranger 3 with both significant successes and failures. The principal successes were the early and independent acquisition by South Africa, the in-tolerance performance of the high-gain communications link, and the successful operation of the parametric and maser receivers. The significant failures concern the substandard performance of the low-gain communication system, the malfunction of the engineering telemetry decommutator and teletype encoder at Johannesburg, and the two-way doppler errors at Goldstone. There were also several minor failures which did not result in significant performance degradation. The remainder of this memorandum discusses the failures in more detail.

1. Pointing Information

Ranger 3 was launched 203011Z, 26 January, on an azimuth of 97.8 degrees. The actual launch time was transmitted as soon as it was known. Pointing information, based upon the actual launch time and assuming a nominal powered flight, was generated by the JPL computer and transmitted to DSIF-1 and -5. The AMR tracking stations failed to provide any tracking data owing to various equipment malfunctions and operational errors. The AMR computer, therefore, could not provide any pointing information. (It is significant that although the AMR computer is capable of computing and transmitting DSIF pointing information, it cannot perform this function without tracking data from the AMR tracking stations.) DSIF-1 and -5 were instructed to use the nominal prediction. DSIF-1 acquired the transponder signal at 2055Z, approximately five minutes prior to the expected horizon time. DSIF-5 acquired the transponder signal at approximately 2056Z with the new acquisition aid and acquired the signal with the main antenna at 2057Z, approximately 3 minutes prior to the expected horizon time. In retrospect, it would seem that this earlier than-expected acquisition should have been an immediate clue that the flight was nonstandard. We will investigate the utility of time of acquisition at the DSIF station for an early clue to nonstandard vehicle performance. We will also investigate the dependence of initial azimuth angle at the first DSIF station on injection errors. It is anticipated that the deviations of the initial azimuth angle will be very small under normal (3 sigma) conditions, permitting a simpler, more reliable, and more nearly independent acquisition technique for the station. From past experience, the principal effect of injection error is to change the time at which the probe first appears, with only a second order effect on the initial azimuth angle.

II. Parametric Amplifier Problem at Johannesburg

Parametric amplifier performance at Johannesburg was substandard during the first part of the South African track. The degraded performance was caused by a combination of insufficient time to check the system completely before launch, a subsystem problem involving the combined connections of the parametric amplifier and the acquisition aid into the receiver, and nonfunctioning compensation circuitry. The result was that the parametric amplifier had to be retuned during the first pass over the station, losing approximately 20 minutes tracking time at South Africa. However, the Woomera station was tracking at that particular time so that no telemetry was lost. This failure should not recur in the future.

III. Engineering Telemetry Decommutator and Teletype Encoder

The engineering telemetry decommutator and teletype encoder, installed in Johannesburg, did not function properly during Ranger 3 and is still not functioning properly. The engineering telemetry decommutator has had seven modifications to date in order for the teletype encoder to be compatible with the decommutator. At present, the primary difficulty is in the high-speed punch circuitry and/or the high-speed punch. These problems will be cleared up before Ranger 4. Checkout time at JPL and Johannesburg was insufficient because of the late delivery of the teletype encoder.

Our experience with teletype circuits and equipment is still quite limited and it would be expecting too much to anticipate that highly reliable teletype transmission will be with us in the near future. System operation in the DOC should therefore not count on reliable teletype until experience has justified the confidence. At the present time, teletype should be assumed to be unreliable.

IV. Test Transponder Problem at Goldstone

During the Ranger 3 operation, an insufficient number of spares for the test transponders were available at Goldstone. When the power supply failed to one of the test transponders, there were no spare parts available at the station to repair this and, consequently, they had to be shipped to Goldstone to make the repair. The spares are presently limited because there are always two or three test transponders in the process of being modified at Motorola. This situation should be expected to clear gradually. However, no data was lost because of this particular failure.

V. Two-Way Doppler Errors at Goldstone

When the doppler data recorded at DSIF-3 during the Ranger 3 operation on 27 January were reduced, it was discovered that an error existed during approximately four hours of the tracking period. The computer accepted these data because the data flag was "good". Following is the sequence of events from the station log:

100000 - RTC-4 midcourse maneuver initiated
101322 - Signal level at -148 dbm and varying
101400 - Signal level dropped to -154 dbm
101555 - Receivers reported loss-of-lock
101950 - Signal reacquired at -153 dbm
113700 - RTC-3 initiated
114030 - Signal level at -112 dbm

The station log indicates that all loops were locked during the entire period that the doppler was incorrect.

Two possibilities were immediately investigated: (1) the spacecraft transponder may have acquired a sideband of the ground transmitter, which was being modulated during the time of reacquisition. Analysis of the doppler data shows that this could not have been the case. However, inasmuch as this situation may occur during future operations, the following acquisition procedure is being initiated whenever any loss of lock occurs during two-way doppler mode:

a. Remove transmitter modulation

b. Acquire one-way lock

c. Acquire two-way lock

d. Reapply transmitter modulation

(2) Another possibility is that one of the loops associated with the doppler data was or had dropped out-of-lock. These loops are being investigated to establish that their design assures a reasonable margin of safety under the dynamic ranges encountered. In addition, the feasibility of providing reliable visual indication to the operator of individual loop conditions, which will provide him with a more definite indication of loop-lock than is presently available, is under investigation. Simultaneously, the interlocked information from all the loops will be added to the data condition format of the data system, and the "lock-unlock" condition will be recorded by the instrumentation system. All of this will provide useful information for analyzing purposes if difficulty should again be experienced. Detailed information of this type is not presently available to aid in localizing or correlating the problem. Goldstone first, and subsequently Woomera and Johannesburg, will be supplied the necessary instrumentation to indicate the in-lock or out-of-lock condition of the pertinent loops in the doppler system. STET information will be sent to each station just prior to the station pass so that the station manager can monitor the performance of the doppler loops.

VI. Substandard Performance of the Low-Gain Telecommunications Subsystem

The signal strength received on the ground from the transponder via the omnidirectional antenna was observed during the majority of the flight to be between 12 and 15 decibels below design. The instant of failure has been pinpointed by spacecraft telemetry and ground signal strength to be the time of squib firing to unlatch the solar panels. The characteristic failure performance is an immediate drop in signal strength of 6 or 7 decibels followed by a slow degradation over a period of a few minutes to a final value of 12 to 15 db below design. Telemetry and signal strength records also show that this particular performance occurred every time that the omnidirectional system was turned on thereafter during the flight, specifically during the midcourse antenna mode switching. The characteristic performance of this failure has been duplicated in ground tests by abruptly introducing a severe mismatch between the final power amplifier cavity and the omnidirectional antenna. Alternatively, the failure can be produced by inserting the mismatch while the transmitter is off and in turning the transmitter on (the midcourse antenna mode switch case). This failure performance would not be expected had there been a permanent failure in the components of the cavity or any preceding circuit in the transmitter chain. Unfortunately, the precise physical mechanism which produces the mismatch has not yet been determined. The coaxial cable from the power amplifier cavity to the omnidirectional antenna passes within about one foot of the squib, leading to a suggestion that a squib explosion may have damaged that coaxial line; however, we are told that such squib explosions are highly unlikely based on ground tests to date. Shock measurements made on the spacecraft and caused by the squib firing have indicated shocks of approximately 8 g, a shock level which is quite insufficient to produce damage to a normal coaxial line. Indeed, this level of shock is encountered by putting the coaxial line down on a laboratory bench. Conceivably, the coaxial line could have had an intermittent connection which this low-level shock managed to dislodge, but this type of failure should have been expected to have occurred in the many ground tests before launch, had it existed.

There is therefore no present guarantee that the same failure will not recur on Ranger 4. Strictly speaking, there is a remote possibility of a similar failure in the high-gain antenna channel, based on the fact that the Ranger 3 failure is not yet completely understood.

VII. Spacecraft Telemetry Subsystem

The measurement of the pressure in the attitude control nitrogen tank was out of range during the flight up through terminal maneuver. Prior to the flight, the tank was charged to a pressure higher than the design range. After the spacecraft used enough gas to bring the pressure into the measurement range, the measurement appeared normal. The measurement range for Ranger 4 and subsequent vehicles is being investigated.

During the video transmission period, the received data was quite noisy, however, the received subcarrier frequencies indicated normal operation of the telemetry subsystem. There was no spectrum shift as previously reported.

Real time operation of the telemetry decommutators was not entirely satisfactory in that synchronization was poor at higher signal-to-noise ratios than was desired. Part of this problem was recognized before the flight, but further investigation is in progress.

VIII. Spacecraft Command Subsystem

For the duration of the flight up to battery exhaustion, 16 "real-time" and 6 "stored" commands were sent to the spacecraft. All data to date indicate that these commands were received and decoded correctly by the command subsystem.

After battery exhaustion and subsequent reacquisition of the Sun, attempts to send real-time commands were generally unsuccessful. Telemetered data during this period indicate that the main power voltage was below the regulator threshold. Since it is known that the command system will not work when the supply voltages are reduced below 75% of the normal values, the low supply voltage is the probable cause.

The question conceivably could be raised as to whether or not the tolerance of the command system to a low supply voltage should be increased. However, this is probably not practical for Ranger 4.

IX. Loss of Midcourse Maneuver Telemetry

Telemetry was lost during the midcourse maneuver primarily because the attitude of the spacecraft was such that telemetry transmission had to be sent through a null-region of the omnidirectional antenna. Contributing to the loss was the substandard performance of the telecommunications channel through the omnidirectional antenna. The attitude vector for the maneuver was far off standard (where telemetry would have been received easily) because the trajectory itself was far off standard. Assuming a successful injection on Ranger 4, this particular loss of telemetry should not recur provided the telecommunications channel through the omnidirectional antenna is at least as good as on Ranger 3.

The problem of nulls in the omnidirectional pattern was recognized in the Ranger design; however, normal midcourse maneuvers were not expected to produce serious trouble. In Mariner design, the midcourse maneuver can occur over a wider attitude angle and, consequently, another solution was adopted. The Mariner solution was to use more than one radiating element, to select polarizations carefully, and to provide for changing the polarization in the DSIF station receiving antenna. Decreases in signal strength of more than 5 or 6 decibels (rather than the 20-decibel loss in the Ranger case) were anticipated from Mariner A. A similar solution is conceivable for Rangers, but not in time for Ranger 4. The need for a change would have to be determined from a system study.