JET PROPULSION LABORATORY *California Institute of Technology* • *4800 Oak Grove Drive, Pasadena, California*

Recipients of Jet Propulsion Laboratory
Technical Report No. 32-345

November 7, 1962

SUBJECT: Errata for Technical Report No. 32-345

Gentlemen:

It is requested that the following changes be made in your copy of Jet Propulsion Laboratory Technical Report No. 32-345, entitled "The *Ranger 4* Flight Path and Its Determination From Tracking Data," by T. W. Hamilton et al., dated September 15, 1962:

1. On page 7 (Fig. 9, under call-out, LOCATION OF LUNAR IMPACT), change θ to equal 231.4 instead of 277.1.

2. On page 32 (upper half of Table 9, under column heading, Standard deviation), change the last three items to read

   $\dot{X}$ 0.648 m/sec instead of X 0.648 m/sec

   $\dot{Y}$ 1.242 m/sec instead of Y 1.242 m/sec

   $\dot{Z}$ 2.225 m/sec instead of Z 2.225 m/sec

3. On page 33 (Fig. 30), change abscissa to read

$$\frac{\Delta\, GM_E}{GM_E \text{ (NOMINAL)}} \times 10^5 \text{ instead of } \frac{\Delta\, GM_E}{\Delta GM_E \text{ (NOMINAL)}} \times 10^5$$

4. On page 33 (last line of text), change the bias to be 6900-m instead of 6000-yd.

Very truly yours,

JET PROPULSION LABORATORY

I. E. Newlan, *Manager*
Technical Information Section

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The Ranger 4 *Flight Path And Its Determination From Tracking Data*

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ABSTRACT

This Report describes the current best estimate of the *Ranger 4* spacecraft flight path and the way in which it was determined. A comparison with independent information sources confirms the accuracy of the orbit based on the Deep Space Instrumentation Facility (DSIF) tracking of the spacecraft transponder for 10½ hr. The miss parameter, as determined by the transponder tracking, is believed to be within 30 km of the correct value. This error is well within the bounds expected and testifies to the accuracy potential of Earth-based tracking.

I. INTRODUCTION

This Report describes the current best estimate of the *Ranger 4* spacecraft flight path and the way in which it was determined. A comparison with independent information sources confirms the accuracy of the orbit based on the Deep Space Instrumentation Facility (DSIF) tracking of the spacecraft transponder for 10½ hr. The miss parameter, as determined by the transponder tracking, is believed to be within 30 km of the correct value. This error is well within the bounds expected and testifies to the accuracy potential of Earth-based tracking.

Section II describes the DSIF transponder orbit in terms of its trajectory parameters near the Earth, in trans-lunar flight, and near the Moon. Symbols used and definitions of key trajectory quantities are given.

Section III summarizes the key events in the tracking of the *Ranger 4* mission and gives a general description of the DSIF stations and tracking modes.

Section IV describes the DSIF transponder orbit determination and compares that orbit with information obtained by the Atlantic Missile Range (AMR) tracking of the *C*-band transponder in the *Agena* booster stage.

While the spacecraft batteries were depleted at 10½ hr after launch, the radio beacon carried within the *Ranger 4* spacecraft's payload, the "rough landing" capsule, continued to operate on its own power supply. The weak signals emitted from the tumbling capsule were tracked at the DSIF stations throughout the mission. Valuable data were taken at both Goldstone stations in the several hours prior to lunar impact. Both the doppler shift records and time of signal loss at the Goldstone stations confirm the accuracy of the previously determined orbit. The results are presented in this Report, Section V.

Section VI gives a functional description of the in-flight determination of the flight path together with the techniques used in editing and weighting the tracking data.

II. TRAJECTORY DESCRIPTION

The *Ranger 4* trajectory was made up of a pre-injection and a post-injection phase. The pre-injection phase consisted of all powered flight and coast periods from launch to injection (burnout of the last booster stage). The post-injection phase consisted of the coast period from injection to lunar impact.

The trajectory characteristics of the pre-injection phase were obtained from observed flight data in combination with nominal flight conditions (Ref. 1). The trajectory characteristics during the post-injection phase corresponded to the DSIF transponder orbit (Section IV-B). The miss parameter **B** was used to measure the miss distance for the lunar trajectory. The miss parameter **B** is defined in Appendix A.

A. Pre-injection Phase

Using the *Atlas D/Agena B* boosters, the *Ranger 4* spacecraft was launched from the Atlantic Missile Range on April 23, 1962 at 20 hr, 50 min, 15 sec (20:50:15) Greenwich Mean Time (GMT). The fact that the *Ranger 4* spacecraft impacted the Moon without the aid of a midcourse maneuver demonstrated the adequacy of the performance obtained from the *Atlas* and *Agena* boost vehicles. The sequence of events from launch through injection is shown in Fig. 1.

After rising vertically for a short period, the *Atlas* booster rolled to a launch azimuth of 100.4 deg (east of north), as determined by the launch time, and performed a programmed pitch-down maneuver until the booster engines were cut off and jettisoned. During the subsequent *Atlas* sustainer and vernier stages, adjustments in vehicle attitude and engine cutoff times were commanded as required by the ground guidance computer to adjust the altitude and velocity at *Atlas* vernier engine cutoff. The protective shroud covering the *Ranger 4* spacecraft was ejected during the *Atlas* vernier stage.

After the *Atlas/Agena* separation, there was a short coast period prior to the first *Agena* ignition. The *Agena B/Ranger 4* spacecraft was nearly horizontal throughout the first *Agena* burn. The attitude was maintained by horizon scanner instrumentation and gyros within the *Agena* booster. At a preset value of sensed velocity increase the *Agena* engine was cut off.

The *Agena B/Ranger 4* spacecraft continued coasting in a circular parking orbit for 254 sec at an altitude of 185 km and a space-fixed velocity of 7.800 km/sec. The parking orbit was terminated by a stored command determined by the ground guidance computer and transmitted to the *Agena* during the *Atlas* vernier stage.

The second *Agena* ignition, which terminated the parking orbit, initiated the final increase in velocity prior to injection. During the second *Agena* burn (as was the case for the first *Agena* burn), the vehicle's horizontal attitude and engine cutoff were controlled by the horizon scanner instrumentation and the preset value of sensed velocity increase, respectively. The second *Agena* cutoff concluded all powered flight for the *Ranger 4* spacecraft and represented the injection time.

B. Post-injection Phase

Prior to injection, the *Agena/Ranger 4* spacecraft traveled in a southeasterly direction over the Atlantic Ocean. Injection occurred in the mid-Atlantic Ocean. Following injection, the *Agena* and *Ranger 4* separated with the spacecraft continuing on its course over the South Africa continent. The *Agena* booster then, in turn, performed a programmed yaw maneuver and ignited its retro-rocket. The retro-rocket impulse was designed to eliminate interference with the spacecraft operation and reduce the chance of lunar impact by the *Agena* booster.

At injection, the spacecraft was traveling 10.958 km/sec in geocentric space-fixed coordinates at a geocentric radius of 6,567.8 km. The spacecraft geocentric distance (Fig. 2) increased while the space-fixed velocity (Fig. 3) was decreasing. This, in effect, reduced the geocentric angular rate of the spacecraft in inertial coordinates until at 1.5 hr after injection the angular rate of the Earth exceeded that of the spacecraft. This caused the Earth track of the spacecraft to reverse its direction from increasing to decreasing Earth longitude (positive easterly). The subsequent Earth track of the spacecraft was similar to that of the Sun except with a greater change in latitude. These characteristics are illustrated in Fig. 4, which shows the Earth track of the spacecraft from launch to 25 hr past injection.

For the *Ranger 4* trajectory, injection occurred at 2.89 deg past perigee of the geocentric conic with a flight time from injection to lunar impact of 63.76 hr. During the first 40 hr past injection, the spacecraft was for the most part under the influence of the Earth's gravitational field

EVENT
1. LIFTOFF
2. *ATLAS* BOOSTER ENGINE CUTOFF
3. *ATLAS* SUSTAINER ENGINE CUTOFF
4. *ATLAS* VERNIER ENGINE CUTOFF
5. SPACECRAFT SHROUD EJECTION
6. *ATLAS* *AGENA*-B SEPARATION
7. *AGENA*-B FIRST IGNITION
8. *AGENA*-B FIRST CUTOFF
9. *AGENA*-B SECOND IGNITION
10. *AGENA*-B SECOND CUTOFF
11. SPACECRAFT SEPARATION
12. INITIATE *AGENA* YAW MANEUVER
13. COMPLETE *AGENA* YAW MANEUVER
14. IGNITE *AGENA* RETRO-ROCKET

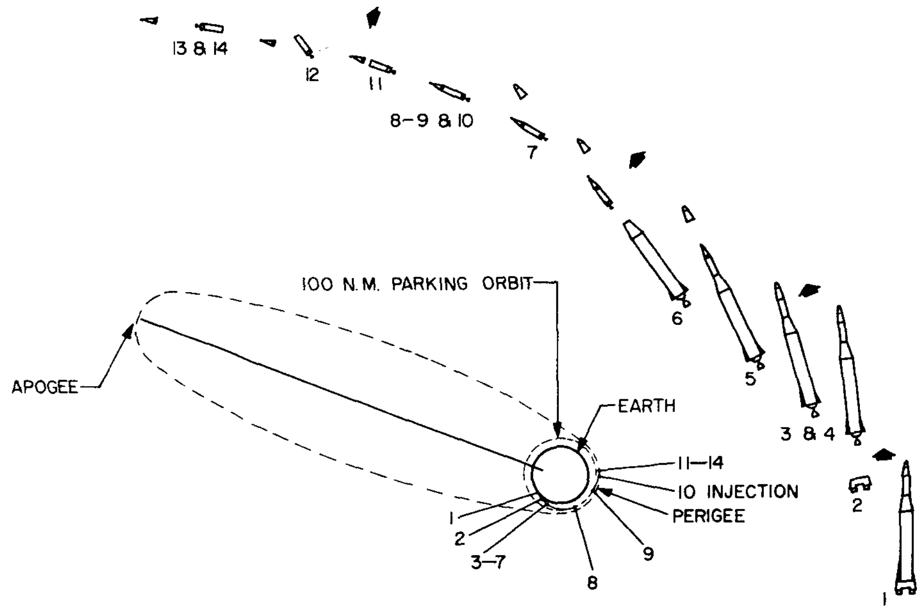

Fig. 1. Sequence of events

and essentially remained in an elliptical geocentric orbit. The trajectory during this period can be described by an ellipse having a perigee and apogee distance of 6,564 and 606,407 km, respectively, an eccentricity of 0.978, and an inclination of 29.70 deg to the Earth's equator.

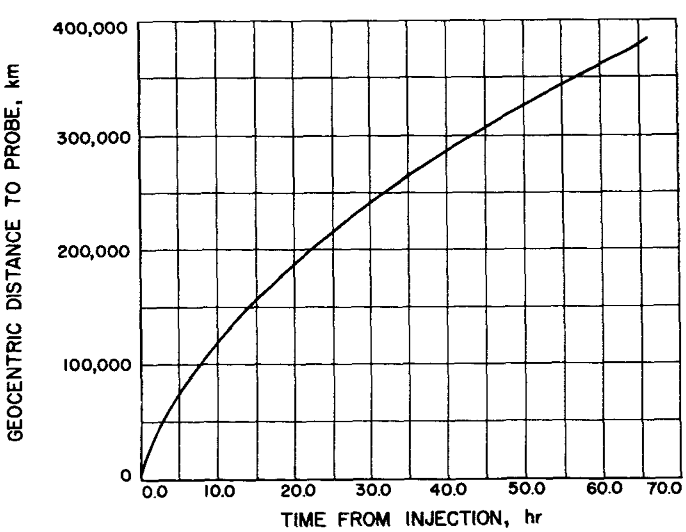

Fig. 2. Geocentric distance to probe vs time from injection

As the spacecraft approached the Moon's gravitational field, a transition was made from the Earth to the Moon as the predominant force affecting the spacecraft's flight. After this transition, the trajectory can be described by a Moon-centered hyperbola. The hyperbola is inclined 13.5 deg to the lunar equator with the spacecraft approaching the Moon's surface in retrograde motion. Lunar impact occurred at 57.53 deg before perigee of the selenocentric

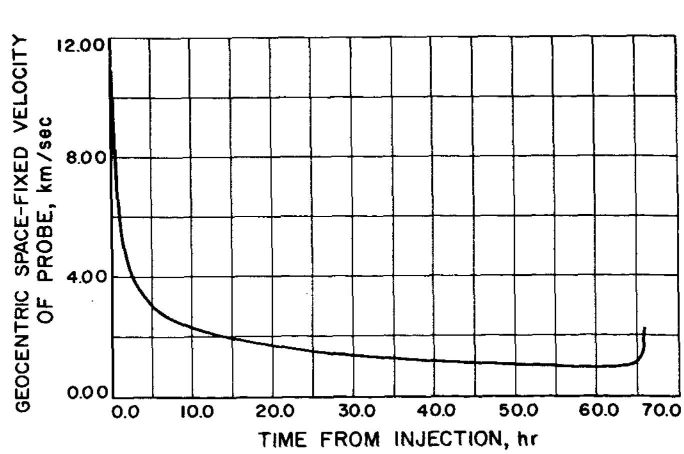

Fig. 3. Geocentric space-fixed inertial velocity of probe vs time from injection

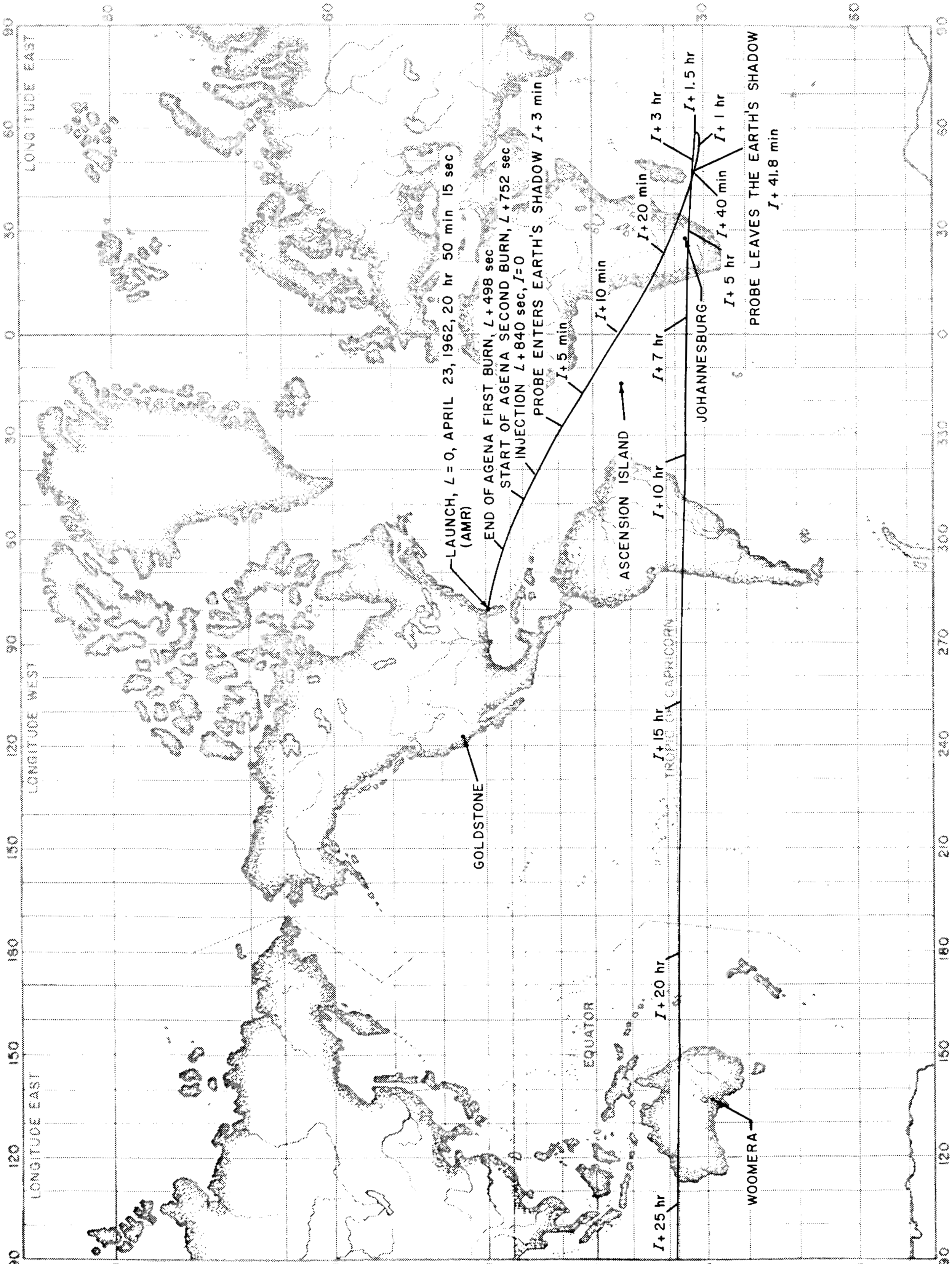

Fig. 4. Earth-track *Ranger 4* trajectory

(Moon-centered) hyperbola. The hyperbola perigee distance was 1,271 km (467 km below the Moon's surface) and the eccentricity was 1.380.

A general sketch of the *Ranger 4* trajectory from injection to lunar impact is shown in Fig. 5. The inertial Earth-centered coordinates used are referenced to the Earth's equator and the vernal equinox direction. In addition, the position of the Moon during the *Ranger 4* flight and the direction to the Sun are noted. This sketch illustrates how the initially elliptical path of the trajectory was altered as the spacecraft encountered the influence of the Moon's gravitational field.

The probe was in direct sunlight except for a brief period following injection. At 3 min past injection, the spacecraft entered the Earth's shadow and emerged 38.8 min later. The relative position along the trajectory at which these events occurred is shown in Fig. 4. The angular relations between Earth, Sun, and spacecraft from injection to lunar impact are graphically illustrated in Fig. 6, 7, and 8.

The portion of the *Ranger 4* trajectory when the spacecraft encountered the Moon is shown in Fig. 9. As the spacecraft approached the Moon's surface, it was occulted by the Moon 70 sec before lunar impact at an altitude of 529 km. The actual impact could not be observed from Earth. Lunar impact occurred on April 26, 1962 at 12:50:00 GMT. The spacecraft impacted the Moon's surface at a velocity of 2.669 km/sec. The impact location was 121.3 deg from the Moon-Earth line at a selenocentric south latitude and east longitude of 12.0 and 231.4 deg, respectively. The spacecraft arrived at the

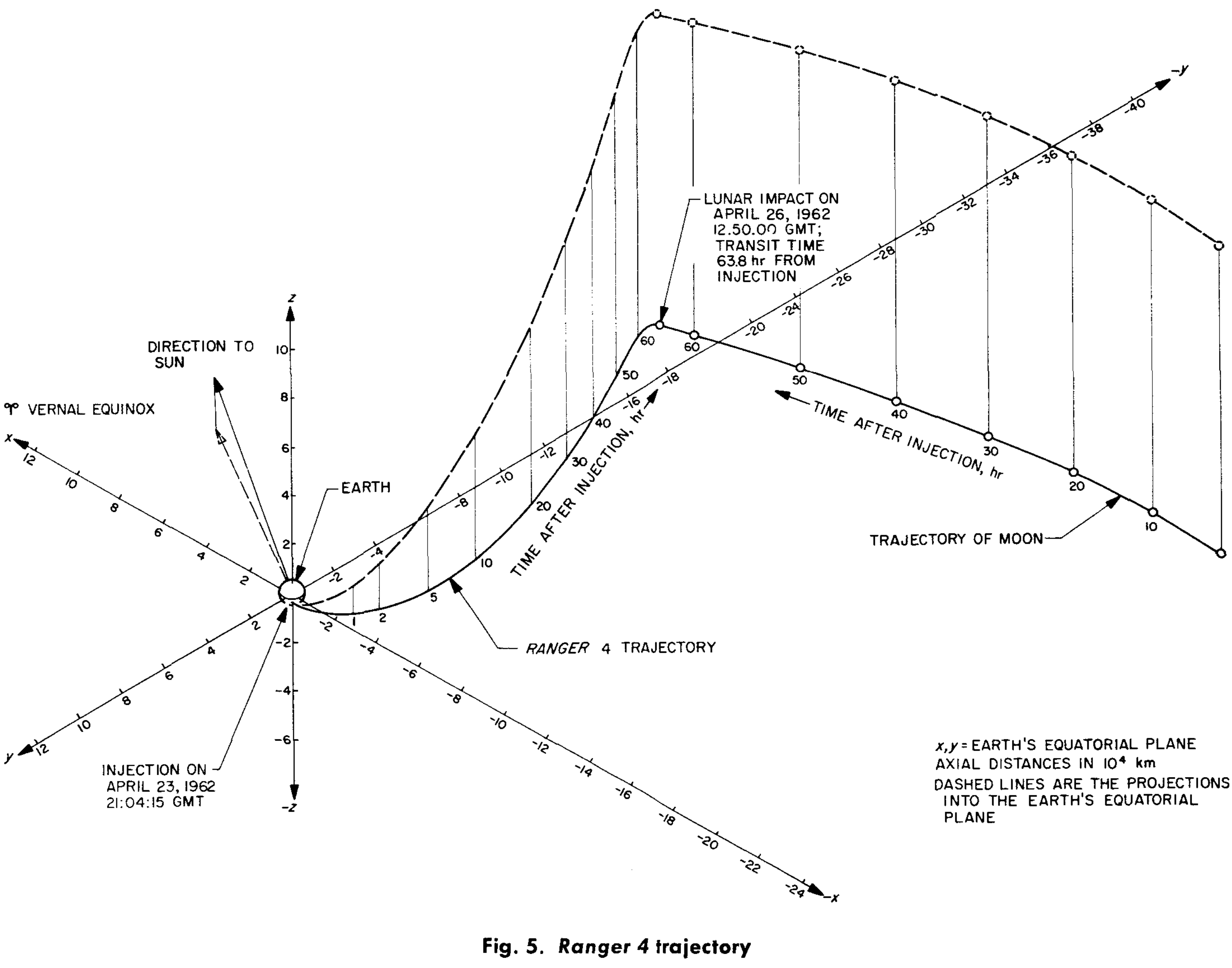

Fig. 5. *Ranger 4* trajectory

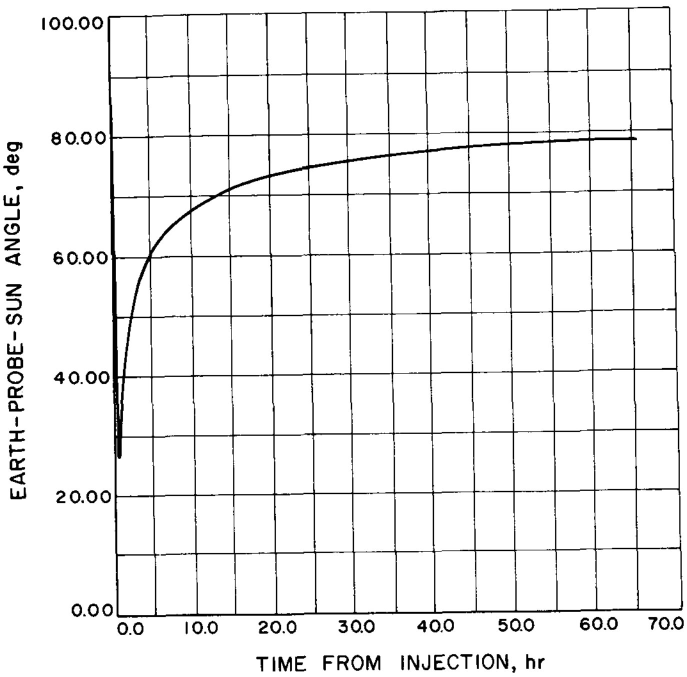

Fig. 6. Earth-probe-Sun angle vs time from injection

Moon's surface in the forenoon of the lunar day. The relative position of the impact location to the Sun's terminator, sub-solar point, and sub-terrestrial point is shown in Fig. 9. The variation in the spacecraft's altitude and velocity relative to the Moon's surface during the last two hr prior to impact is shown in Fig. 10 and 11, respectively.

A detailed study of the *Ranger 4* trajectory can be made by examination of the trajectory printout presented in Appendix B. In this printout the trajectory parameters are listed at selected times from the epoch of the DSIF transponder orbit to lunar impact. The printouts were obtained from the initial conditions corresponding to the DSIF transponder orbit using the Space Trajectory Program described in Ref. 2.

Trajectory printouts provided in Appendix C (a) and (b) demonstrate the closeness of the actual conditions to nominal flight conditions at injection and lunar impact. Printout in Appendix C (a) is the nominal flight trajectory. Trajectory printout in Appendix C (b) is just the

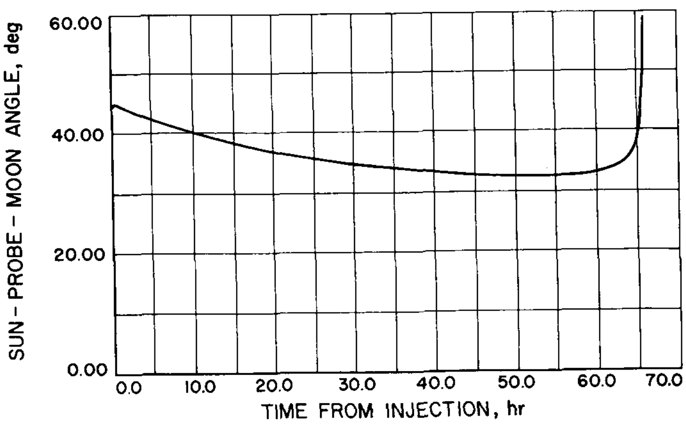

Fig. 7. Sun-probe-Moon angle vs time from injection

DSIF transponder orbit extrapolated back a few seconds for comparison at the nominal injection time (Ref. 3). Table D-1 (Appendix D) is a key to the trajectory printout. Table D-2 contains the definitions of the printed quantities. Constants and conversion factors used in all *Ranger 4* trajectory computations are listed in Table D-3.

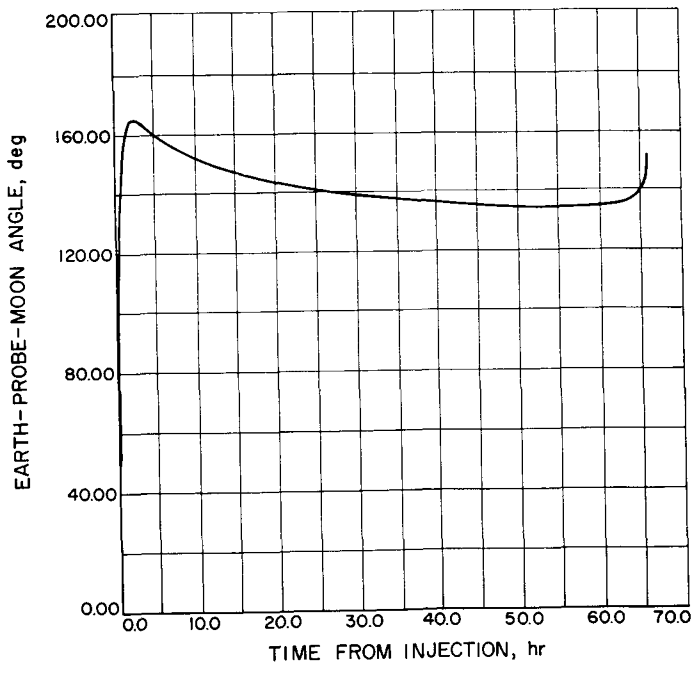

Fig. 8. Earth-probe-Moon angle vs time from injection

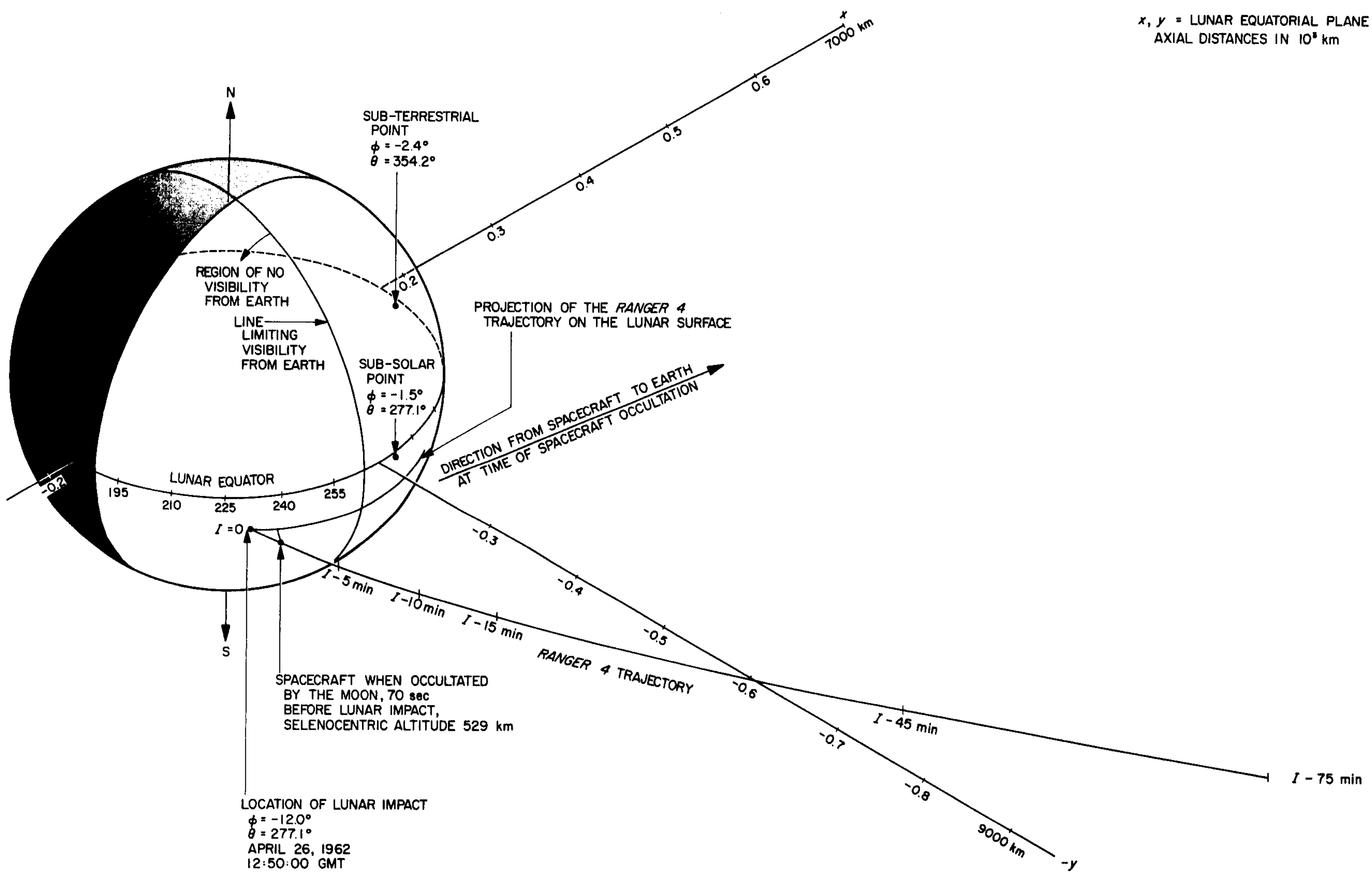

Fig. 9. Lunar encounter *Ranger 4* trajectory

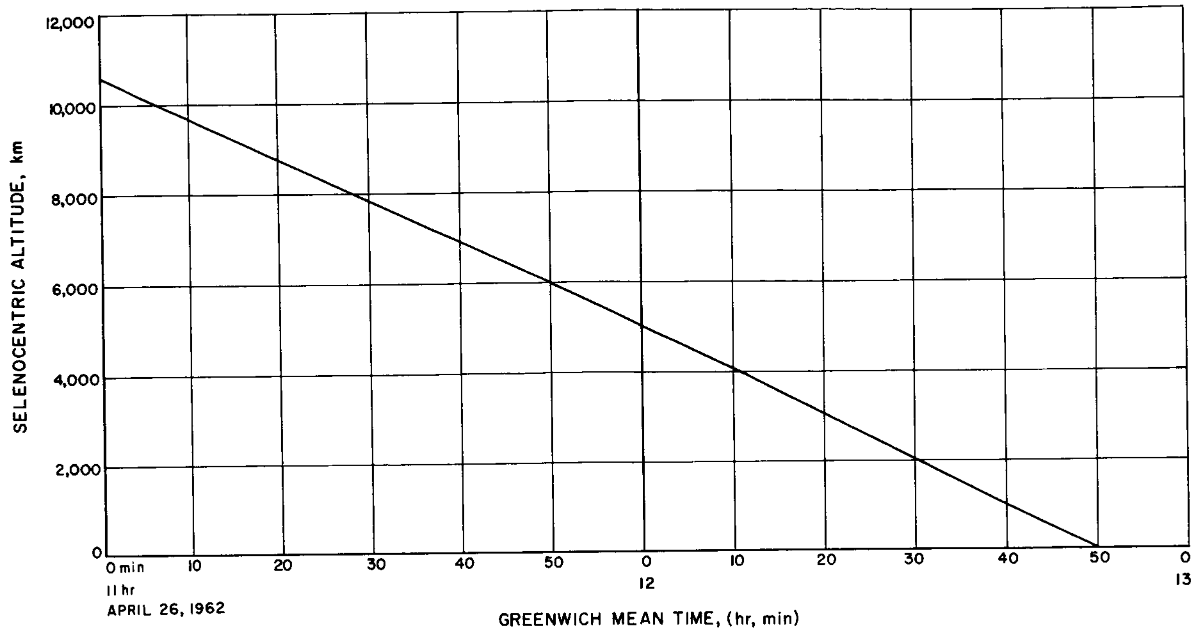

Fig. 10. Selenocentric altitude of probe vs GMT during lunar descent (last 2 hr)

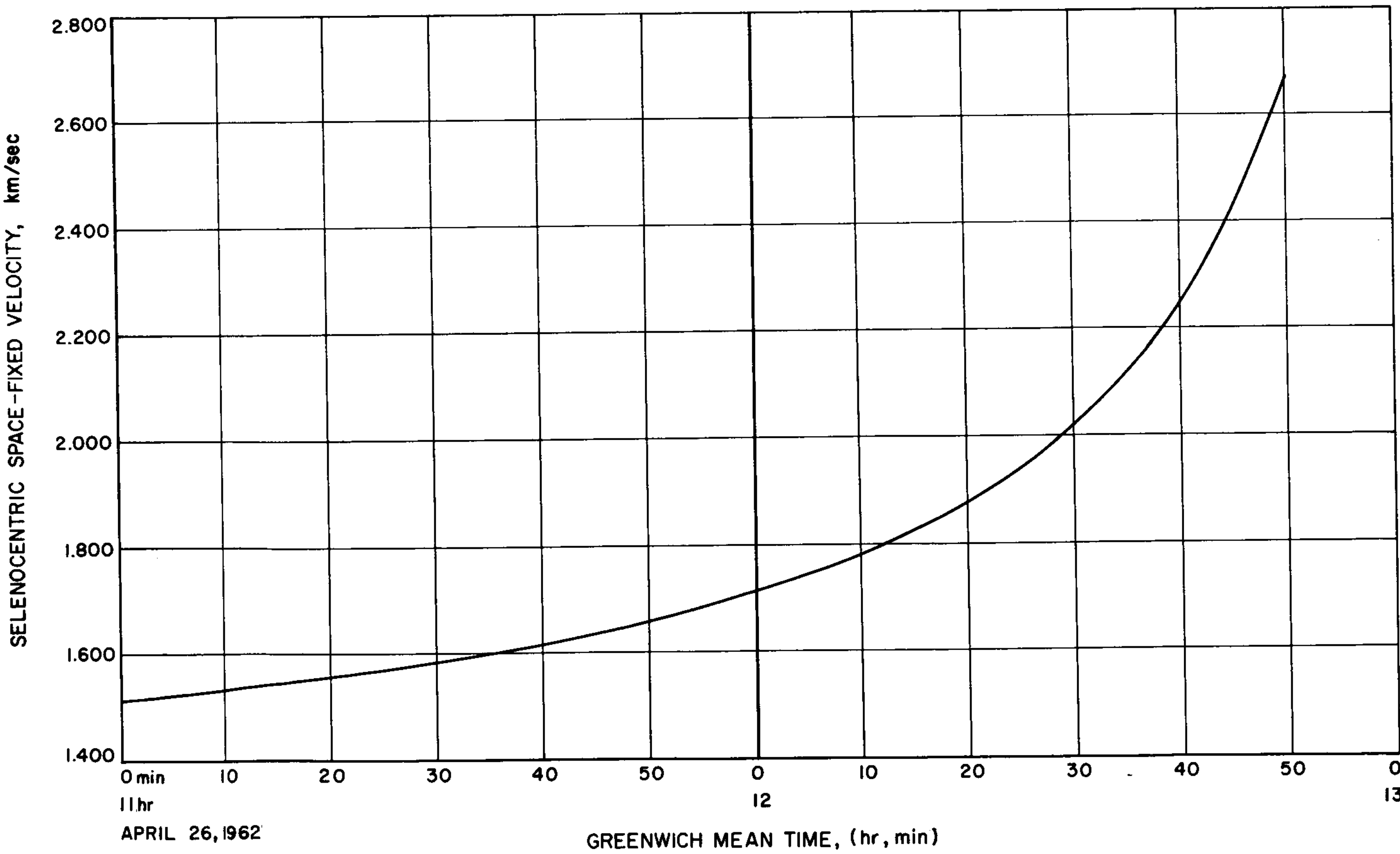

Fig. 11. Selenocentric space-fixed velocity of probe vs GMT during lunar descent (last 2 hr)

III. THE TRACKING SEQUENCE OF EVENTS

A. Introduction

This Section summarizes the key events in the tracking of the *Ranger 4* and the *Agena* stage. Part B describes the DSIF post-injection tracking of the *Ranger 4* transponder and the payload "rough landing" capsule beacon. Part C summarizes the AMR post parking-orbit tracking of the *Agena* C-band transponder by the Twin Falls Victory Ship and the Ascension Island FPS-16 Tracking Station.

To help interpret the results of the analysis of the tracking data given in Sections IV and V, Table 1 summarizes the key events of the launch to lunar impact sequence. When comparing the *Agena* orbit with the spacecraft orbit, it is important to note that all DSIF tracking after I_2 occurs *after* event 5 (Fig. 1) whereas some *Agena* C-band transponder tracking occurs under the following conditions:

1. Before I_2, when the *Agena* rocket motor is thrusting.
2. Between I_2 and event 5, when the spacecraft and *Agena* are still mechanically attached (the path of the combination differs from the final spacecraft orbit due to the imparting of about 0.3 m/sec relative velocity at mechanical separation).

Table 1. Review of key event times

Event	Date	GMT[a]	Remarks
Atlas liftoff, L	April 23	20:50:15	
Agena stage parking orbit injection, I_1		20:58:33	$L + 498^s$
Agena stage translunar orbit injection, I_2		21:04:15	$L + 840^s$
Reference epoch for orbit determination, E		21:04:19	$I_2 + 4^s$
Mechanical separation of *Agena* and spacecraft		21:06:53	$L + 998^s, I_2 + 158^s$
Ignite *Agena* retromotor[c]		21:13:23	$L + 1388^s$
Burnout of *Agena* retromotor		21:13:43	$L + 1408^s$
Loss of spacecraft transponder due to battery depletion	April 24	07:22	$L + 10^h 32^m$
Loss of capsule beacon signal due to occultation by Moon	April 26	12:47:46[b]	$L + 63^h 57^m 31^s$

[a]Universal time at event.
[b]Corrected by −1.25 sec to account for signal travel time to Stations 2, 3.
[c]The purpose of the retro-maneuver is to bias the *Agena* stage off of a nominal lunar impact trajectory. The resultant probability of the *Agena* stage impacting is thus significantly lowered.

3. Between event 5 and 6, when the *Agena* orbit is slightly changed by the mechanical separation velocity.
4. Between event 6 and 7, when the *Agena* orbit is being changed by the retro-rocket thrust.
5. After event 7, when the *Agena* orbit has undergone significant change from its orbit prior to event 6.

In using the *Agena* C-band transponder data it is quite important to employ only the data corresponding to the desired *Agena* orbit.

B. DSIF Tracking of Ranger 4 Transponder and Payload Beacon

1. General Information

The detailed characteristics of the Deep Space Systems employed in the *Ranger 4* mission are given in Ref. 4. The names and locations of the stations used are summarized in Table 2. Stations 2, 3, 4, 5 use 85-ft diameter antennas whereas Station 1 (The Mobile Tracking Station) has a 10-ft diameter Az-El mounted antenna.

Table 3 indicates the nominal periods of visibility of the spacecraft to the participating DSIF stations during the course of the mission. Note that the view periods are labeled according to the *day* of "rise" and that the "set" times are often on the next day. Note that the signals may be received from the spacecraft somewhat before "rise" and somewhat after "set" times.

The DSIF tracking modes are defined as follows:[1]

GM-1. Ground receiver tracks the *transponder* signal in the 2-way doppler mode. The transmitting station (designated by an integer q) receives the return signal and compares it with the current transmitter signal to generate 2-way doppler. At the present time this doppler is much more accurate than that taken in any other mode.

GM-2. Ground receiver tracks the *transponder* signal in the 1-way doppler mode. The spacecraft return signal is obtained from a crystal reference in

[1]Reference 6 plus Section IV of this Report. Times measured from "rise" refer to rise time at the receiving station listed.

Table 2. Deep space station locations[a]

Station	Location	Geodetic latitude	Astronomic longitude
2, 3	Goldstone, California, U.S.A.	35.4°N	116.8°W
1, 5	Johannesburg, South Africa	25.9°S	27.7°E
4	Woomera, Australia	31.4°S	136.9°E

[a] Ref. 5. Locations are approximate.

Table 3. Nominal view periods at DSIF stations[a]

Date of rise	Station	Rise GMT	Set GMT	View period
April 23	1, 5	21:13:45	09:04:33[b]	$11^h\ 51^m$
	4	22:03:16	00:53:58[b]	$2^h\ 51^m$
April 24	2, 3	08:28:45	16:58:54	$8^h\ 30^m$
	4	13:22:51	02:26:19[b]	$13^h\ 03^m$
	1, 5	21:01:54	09:38:22[b]	$12^h\ 37^m$
April 25	2, 3	08:42:25	17:31:54	$8^h\ 49^m$
	4	13:49:29	02:36:52[b]	$12^h\ 47^m$
	1, 5	21:19:05	09:45:31[b]	$12^h\ 26^m$
April 26	2, 3	08:44:08	12:47:46[c]	$4^h\ 04^m$

[a] Based on 5-deg elevation angle and post-flight transponder-determined orbit. Universal time at spacecraft.
[b] Set occurs on the next day after rise.
[c] Loss of capsule beacon signal due to occultation by Moon.

the spacecraft ($q = 0$). The accuracy of the doppler data obtained is limited by unknown small changes in the spacecraft crystal frequency. This doppler is termed 1-way because the doppler shift occurs only on the spacecraft-to-ground transit rather than in both directions as in GM-1.

GM-3. Ground receiver tracks the *transponder* signal in the 3-way doppler mode. One DSIF station is in GM-1 and another station is "listening in" on the return signal. The accuracy of doppler generated in GM-3 is being determined on the *Ranger* series of flights but is limited primarily by variations in the reference frequency of the transmitting station. Improvements are anticipated in the stability of the transmitter reference oscillators which will make 3-way doppler a primary data type in the future.

GM-4. Ground receiver tracks the *capsule beacon* signal in the 1-way doppler mode. The doppler limitations of GM-2 are present and the value of angle tracking is degraded because of the lower, and varying, signal level of the capsule beacon.

The only doppler data used to determine the *Ranger 4* spacecraft orbit based on transponder data was 2-way (GM-1), whereas angular data was used when the stations were in either GM-1, GM-2, or GM-3. Angular data from Station 1 (Table 2) was rejected because carefully calibrated, more accurate, data was available from Station 5.

2. Transponder Tracking

Table 4 summarizes the transmitter number q versus time during the mission, as well as the acquisition times on the first pass. The most critical times are initial acquisition in GM-2 and initial times in GM-1, in reverse order. After that, delays of under 10 min in transferring transmitting responsibilities from station-to-station have minor effect on the accuracy to which the spacecraft orbit can be determined.

The information in Table 4 is somewhat compressed in that the time of transition from $q = 0$ to $q \neq 0$ is *chosen* to be the time when the first valid 2-way doppler was received at the transmitting station; the transition from $q \neq 0$ to $q = 0$ is chosen to be the time of the last valid 2-way doppler point in that interval. Thus, Table 4 is more aptly a list of time intervals in which 2-way doppler was taken.

Table 4. Transmitter number and acquisition times[a]

Transmitter, q	Time interval	Receiving station, i	Acquisition time (GMT on April 23, 24	Remarks
0	Launch to t_1 = 21:29:31			
		1	21:13	Rise − 1^m
		5	21:15	Rise + 1^m
1	t_1 to t_2 = 23:05:21			
		1	21:29:31	Rise + 16^m
		4	22:23	Rise + 20^m
0	t_2 to t_3 = 23:16:51			$t_3 - t_2 = 6^m$
5	t_3 to t_4 = 23:35:51			
		5	23:16:51	
0	t_4 to t_5 = 23:40:11			$t_5 - t_4 = 4^m$
1	t_5 to t_6 = 23:40:11			$t_6 - t_5 = 26^m$
		1	23:40:11	
0	t_6 to t_7 = 00:09:51			$t_7 - t_6 = 4^m$
5	t_7 to t_8 = 07:20:51			$t_8 - t_7 = 7^h\ 11^m$
		5	00:09:51	
0	t_8 on			

[a] Reference 6 plus Section IV of this Report. Times measured from "rise" refer to rise time at the receiving station listed.

The shifting of the transmitting assignment from Station 1 to 5 and back to 1 and then back to 5 represents a successful execution of the preflight plan. After 96 min of good 2-way doppler from previously flight-tested Station 1, about 30 min were allowed to try to obtain good 2-way doppler from Station 5 where no 2-way doppler had been available previously, and then the transmitting job was handed back to Station 1 while Station 5 data quality was evaluated. Within 53 min after the *first* good 2-way doppler point was received from Station 5, the data quality had been determined to be excellent and Station 5 was allowed to re-establish 2-way lock.

As an example of the interpretation of Table 4, consider the first time $q = 1$ appears in the left-hand column. From t_1 to t_2 Station 1 was transmitting; Station 1 achieved 2-way lock (GM-1) at the time indicated to the right of "1" in the *receiving* station column. Station 4 achieved lock on the signal in GM-3 at the time indicated to the right of "4" in the receiving station column. The time from t_2 to t_3 was spent in transferring the transmitting assignment to Station 5.

3. Capsule Beacon Tracking

At 10 hr and 32 min after launch the spacecraft transponder signal was lost due to depletion of the spacecraft's batteries. For the remainder of the mission all DSIF stations tracked the capsule beacon, except for short periods of time during which unsuccessful searches were made for the transponder signal. Table 5 summarizes the periods of beacon tracking for the DSIFs.

C. AMR Tracking

1. Introduction

After burnout of the final stage, two AMR stations tracked the *Agena* Stage C-band transponder. The first data near final stage cutoff came from the Twin Falls Victory (TFV) ship. Shortly after the TFV lost the transponder the Ascension Island FPS-16 tracker acquired the transponder and tracked through the sequence of events described in Section III-A. Figure 12 illustrates the elevation angles at the two stations for the first 10 min after the reference epoch E (injection time + 4 sec).

2. TFV Tracking

The TFV ship began tracking during the final burn and sent data to Jet Propulsion Laboratory (JPL) covering the interval from 21:03:19 GMT ($E - 60$ sec) to 21:08:16 GMT ($E + 237$ sec). The ship was reported "on station" at 326° 45′ east longitude, 13° 35′ north latitude

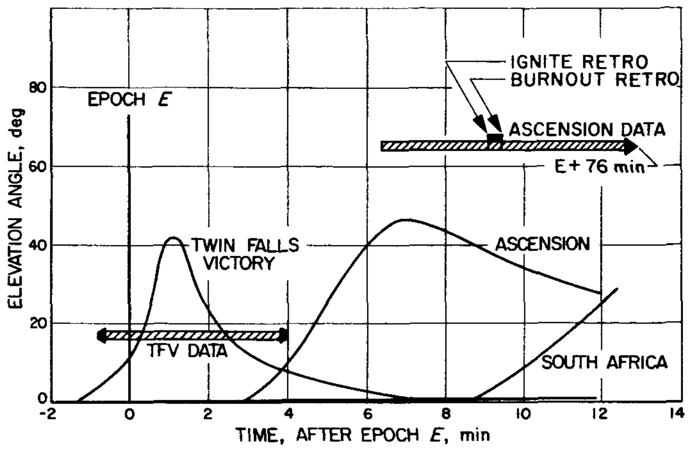

Fig. 12. AMR stations view periods and data spans

(astronomic) during the tracking interval. At E the probe's elevation was 12 deg at an azimuth of 280 deg east of north, at a range of 745 km. At closest approach to the ship the vehicle range and elevation were 332 km and 42 deg respectively. The azimuth angle to the vehicle when it was at the ship's horizon was 125 deg east. A total of 78 data sets (time-azimuth-elevation range), after E, was received at JPL. The data received were already corrected for ship's pitch and roll by means of an inertial reference and an onboard digital computer. The data were sampled every 3 sec and transmitted over Milgo 165 digital-radio teletype equipment at a rate of 1 sample per 6 sec.

3. Ascension Island Station Tracking

The Ascension Island tracker (7.9° south latitude, 14.4° west longitude) sent real-time data to JPL covering from 21:14:18 GMT ($E + 9^m 59^s$) to 21:29:12 GMT ($E + 24^m 53^s$). Since these data were taken after the *Agena* retrorocket maneuver had begun (Table 1), it will not be

Table 5. Summary of capsule beacon tracking

Date	Station	Acquisition GMT	End of track GMT
April 24	2	08:32	17:03
	3	09:04	17:40
	4	13:52	01:58
	5	21:40	09:25
April 25	2	08:47	17:30
	4	14:23	02:13
	5	21:40	09:32
April 26	2	8:46	12:47
	3	8:33	12:47

discussed here. In non-real time, data covering the interval 21:10:42 GMT ($E + 6^m\ 23^s$) to 22:21:00 GMT ($E + 76^m\ 41^s$) were received at JPL. About 90 sec of this data was obtained prior to *Agena* retro-ignition. During this 90-sec interval the elevation angle varied between 43 and 46 deg. The azimuth and range at the first and last point where 26° E, 1235 km and 71° E, 1648 km, respectively. The data sets were sampled every 6 sec and contained the same measurement types as the TFV ship. Transmission was over the Milgo 165 equipment.

IV. FLIGHT PATH DETERMINATION USING TRANSPONDER TRACKING

A. Introduction

The real-time determination of the parking orbit is the responsibility of the AMR. Their pre-injection tracking of the *Agena* vehicle *C*-band transponder is important in establishing the parking orbit and detecting non-standard flight conditions. The AMR supplies JPL with parking orbit elements and initial acquisition information for transmittal to the DSIF stations and for preliminary estimation of the spacecraft injection conditions. The primary post-injection tracking of the spacecraft is done by the DSIF.

The pitfalls in utilizing AMR post-injection tracking of the *Agena* transponder were described in Section III-A. The primary functions of the AMR post-injection *tracking* coverage are: (1) evaluation of the *Agena* performance, (2) detection of non-standard flight path, and (3) assistance in improving the convergence of the Orbit Determination Program (ODP) when very limited amounts of DSIF data are available.

Our long-range objective is to utilize AMR post-injection tracking along with the DSIF tracking data to determine the spacecraft orbit. We are currently testing the consistency of the two data sources and determining the best ways to use this information. In Part B of this Section we describe the results of the flight path analysis of the *Ranger 4* spacecraft as derived from the 10.5 hr of DSIF tracking of the spacecraft transponder. Part C describes the preliminary results of our investigation of the compatibility of the AMR Ascension Island and Twin Falls Victory Ship tracking data with the DSIF tracking results. The results of the comparison are very encouraging and suggest the lines along which our procedures must be modified to utilize the AMR data in the spacecraft orbit determination.

B. Flight Path Determination Using DSIF Tracking of the Spacecraft Transponder

1. Summary of Data Taken

The complete sequence of tracking events and ground tracking modes is described in Section III. Section VI-C discusses the estimation method used. Table 6 summarizes the data points used in the orbit determination.

Angle tracking data was used whenever the ground stations were in GM-1, GM-2, or GM-3 and the "data condition" code indicated good data. Only 2-way doppler data (GM-1) were used; the reasons were discussed in Section III-B1. Table 6 provides a gross picture of the performance of the data taking and handling system; Column 3 gives the total number of data points taken at each station during the life of the spacecraft transponder. The editing of the data, described in Section VI-B1, allowed the number of points (and percentage of total) listed in Column 4 to be used in the final orbit determination. Of particular interest is the number and percentage of data sets rejected for bad format or as "blunder

Table 6. Summary of data used in orbit determination

Station	Data types	Points received / % of received	Points used / % of received	Bad format rejection / % of received	Blunder points / % of received	Bad data condition / % of received	Rejection limits on blunder points
1 Mobile tracker	2-way doppler	881	703	39	2	137	3 cps
		100	79.8	4.4	0.2	15.6	
4 Woomera	Hour angle, declination	87	35	15	2	35	0.15 deg
		100	40.2	17.2	2.3	40.2	
5 Johannesburg	2-way doppler	428	377	0.14[a]	11	26[a]	1.5 cps
		100	88.0	3.3	2.6	6.1	
	Hour angle, declination	960	719	29	53	159	0.15 deg
		100	74.9	3.0	5.5	16.6	

[a]Doppler and angles are given on each data message and the entire message is rejected for any format errors or bad condition; thus, the 2-way doppler rejects of columns 5 and 7 are a sub-set of the angle rejects listed below them.

points." As discussed in Section VI-C, no attempt is made to unscramble data messages containing any format errors. "Blunder" points can create significant problems in converging on an orbit when very little data is available and hence are important in influencing the time required to establish our first estimate of the orbit. The number and percentage of the points omitted because of "bad data condition" are listed in Column 7. When the tracking station operators or automatic detectors recognized that the data being transmitted would not be usable, the data condition codeword reflected these situations. This situation occurred when re-tuning the ground transmitter to maximize the signal received at the spacecraft, when commands were being sent, and during the acquisition phase.

2. Weighting of the Data

The data weights were assigned in accordance with the policy described in Section VI-C. The weighting assigned to the data depends upon the sampling interval and, for doppler, the counting time and the range to the spacecraft. During the flight, the effective noise due to variation of the transmitter reference frequency was calculated from regular recordings of the transmitter frequency. The noise in the doppler due to this variation never became a dominant factor because the oscillator performance exceeded specifications and because transponder tracking ended prematurely. Table 7 summarizes the sample and counting intervals and weights used.

3. Discussion of Residuals

Once the data points and weights are fixed, the set of initial conditions which minimizes the weighted sum of the residuals squared is found by an iterative method. The physical constants described in Ref. 7 were used in the trajectory calculation. Subsequently the influence of variation of GM-Earth on the resultant estimator was examined (Section IV-B4 below).

The differences between the vector of all observations and the calculated values based on the converged solution is called the vector of residuals. Figures 13 through 29 are the residual plots, by station, vs time for the data types used in the final orbit. The detailed analysis of the residuals will be published in another report. The Station 1 doppler residuals have a parabolic form due to the rounding of the data. Note that the oscillations in the Station 5 doppler data are due to the regular tumbling of the spacecraft which caused a variation in the equivalent phase center. The tumbling effect can also be seen in the angle data since there was a wide variation in return signal strength due to relative nulls in the antenna pattern.

4. Statistics of Data and Orbit Estimates

a. Tracking data statistics. The root-mean-squared noise (RMS) and mean of the residuals for each station is given in Table 8 for each data type used. Note that the RMS noise and weights of Table 7 differ significantly in most cases. The difference in angle weighting is due to the presence of low-frequency mechanical deflection of the DSIF antennas.

b. Statistics of orbit estimate; data noise. The accuracy of the orbit obtained depends on the statistics of the tracking noise and on the statistics of all error sources which influence the orbital estimate. The tracking noise statistics are represented by the "equivalent or worse" white noise method described in Section VI-C. The *Ranger 4* ODP does not "solve for" nor directly include the effects of deviations in physical constants such as GM-Earth and station locations. Table 9 gives the covariance matrix describing the uncertainty in the space-fixed Cartesian coordinates at the reference epoch E,

Table 7. Summary of weights, sample, and count times

Station	Data type	E to $E + 80$ min			$E + 80$ min on		
		Sample spacing, sec	Count time, sec	Weight, cps[a] or deg	Sample spacing, sec	Count time	Weight, cps[a] or deg
1	2-way doppler	10	1[b]	0.7	10	1	0.7
4	Hour angle, declination	60		0.18	60		0.18
5	2-way doppler				60	50	0.20
	HA, declination	10		0.45	60		0.18

[a] E is reference epoch used for orbit determination (Table 6). 1 cps $= c/2f = 0.156$ m/sec where the transmitting frequency f is 96×10^7 cps.
[b] Station 1 doppler is counted $\pm 1/2$ sec centered about the message time. All other stations time tag the data at the end of the counting interval.

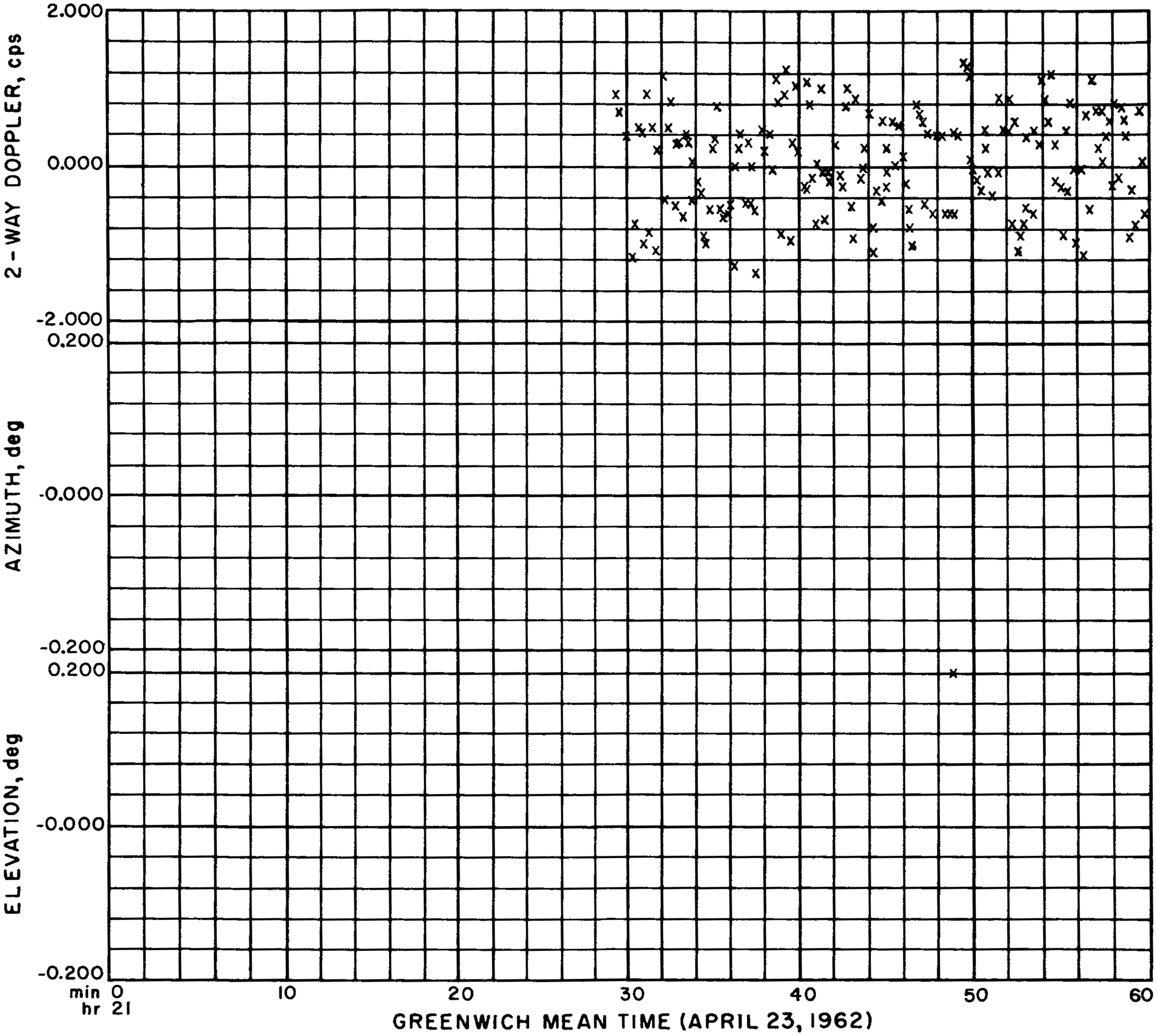

Fig. 13. Station 1 residuals (from 21:00 GMT April 23, 1962)

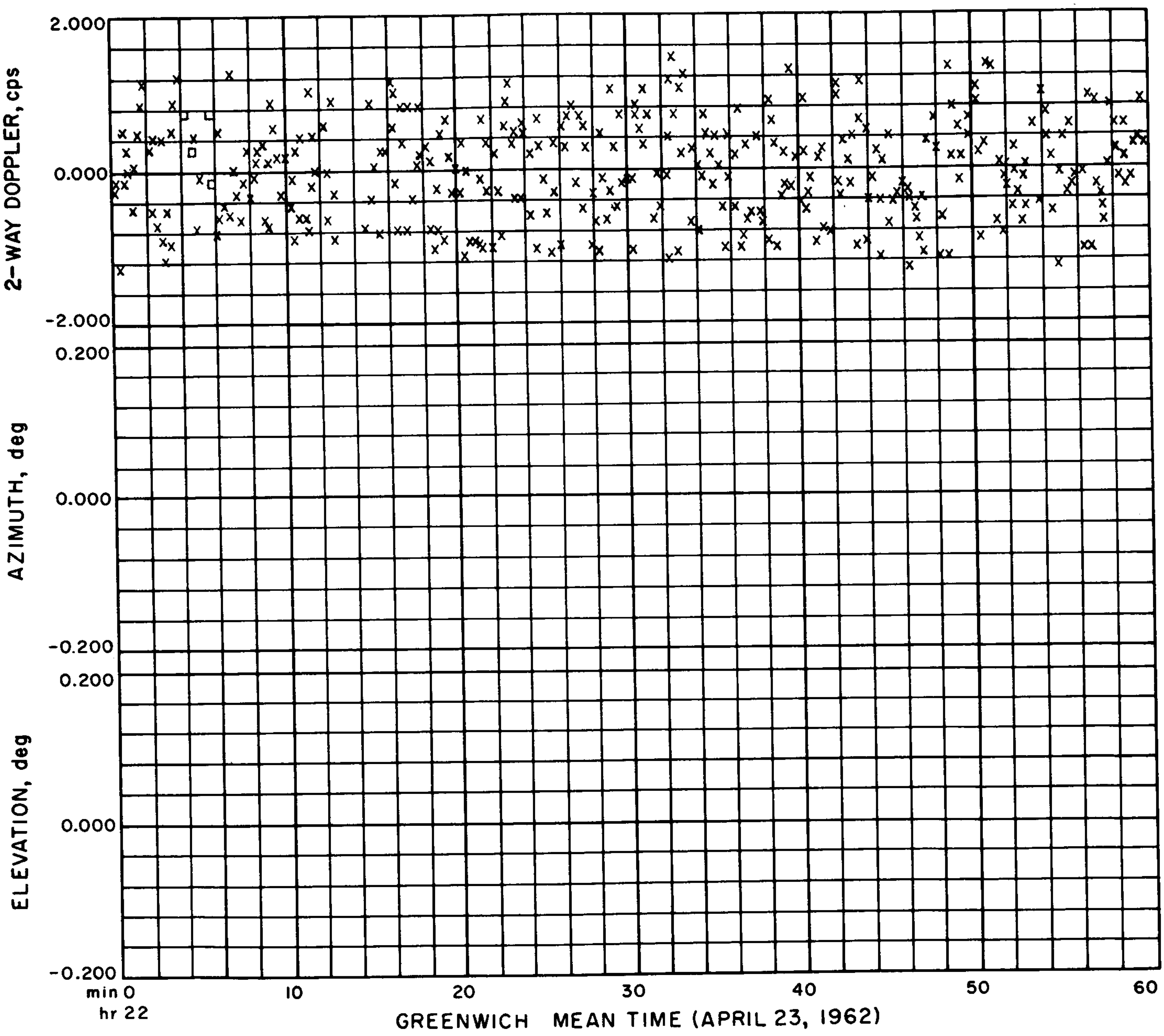

Fig. 14. Station 1 residuals (from 22:00 GMT April 23, 1962)

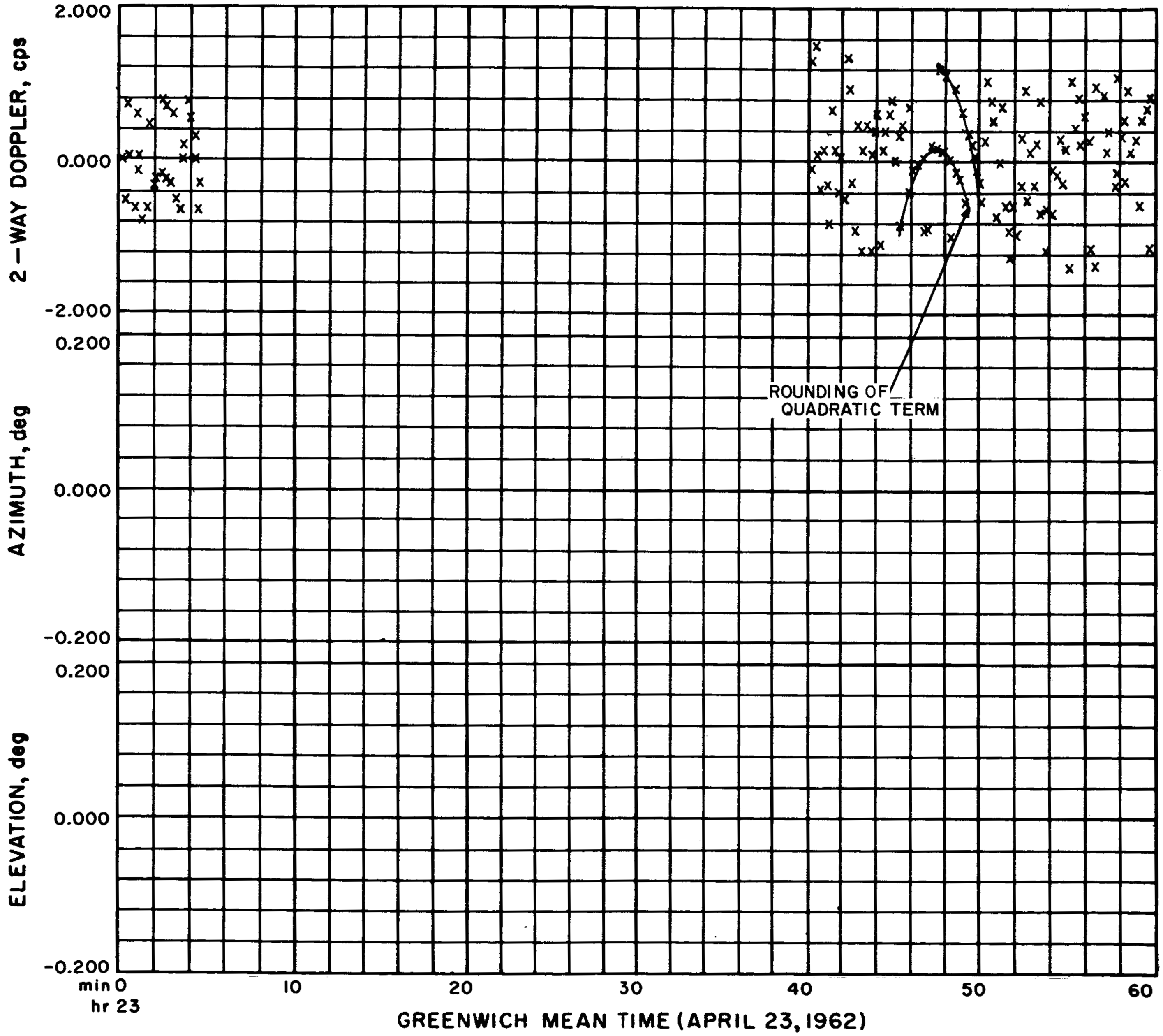

Fig. 15. Station 1 residuals (from 23:00 GMT April 23, 1962)

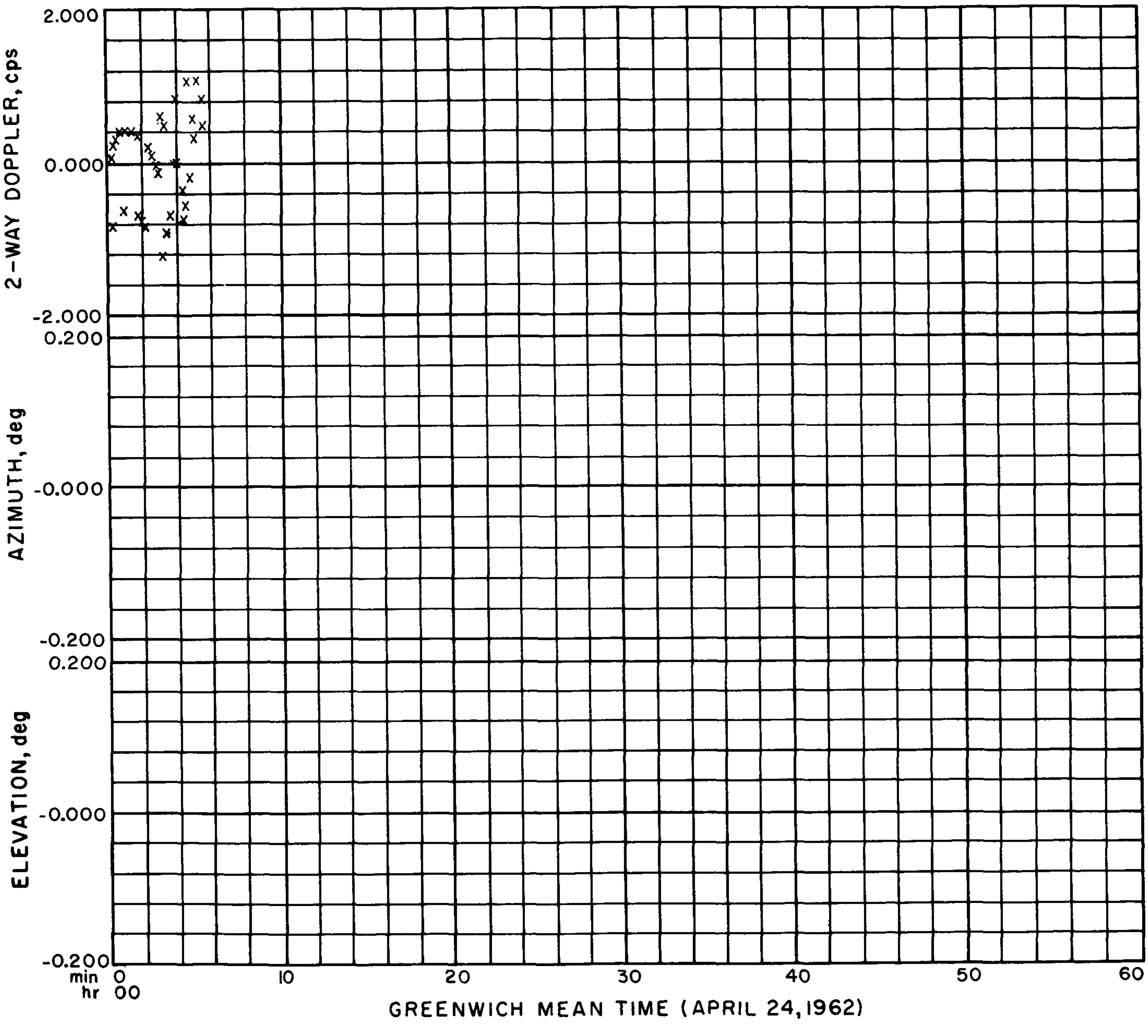

Fig. 16. Station 1 residuals (from 00:00 GMT April 24, 1962)

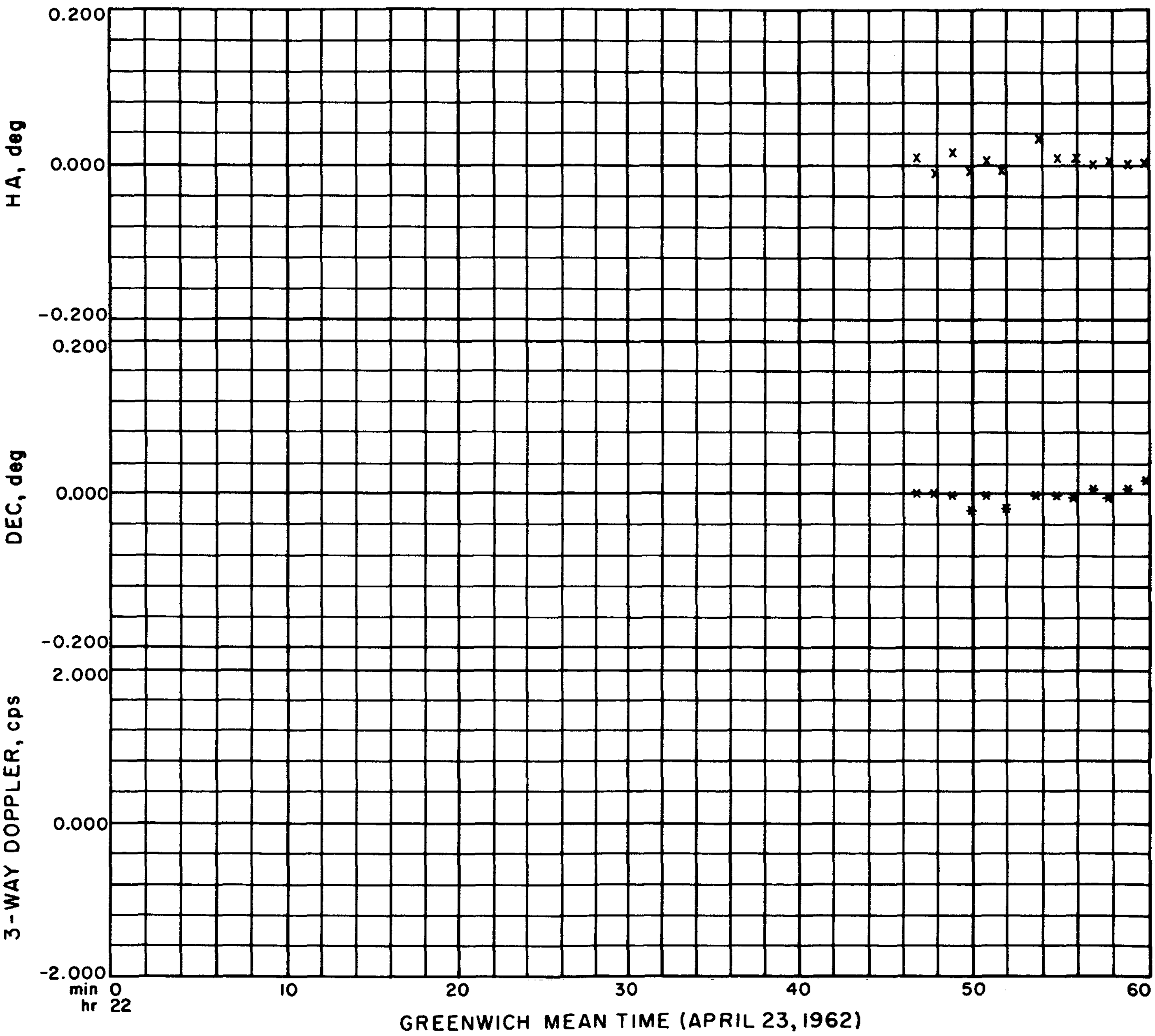

Fig. 17. Station 4 residuals (from 22:00 GMT April 23, 1962)

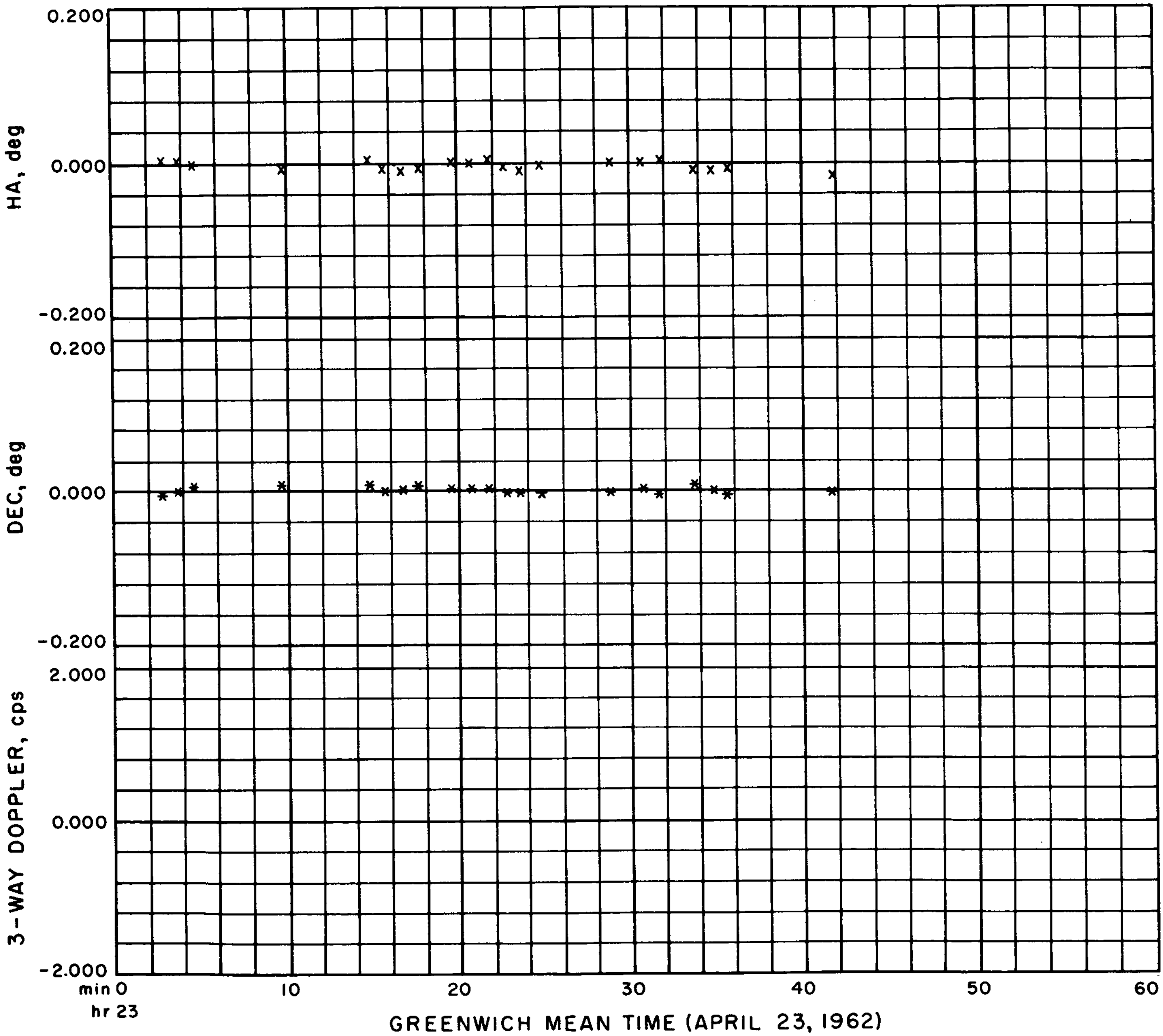

Fig. 18. Station 4 residuals (from 23:00 GMT April 23, 1962)

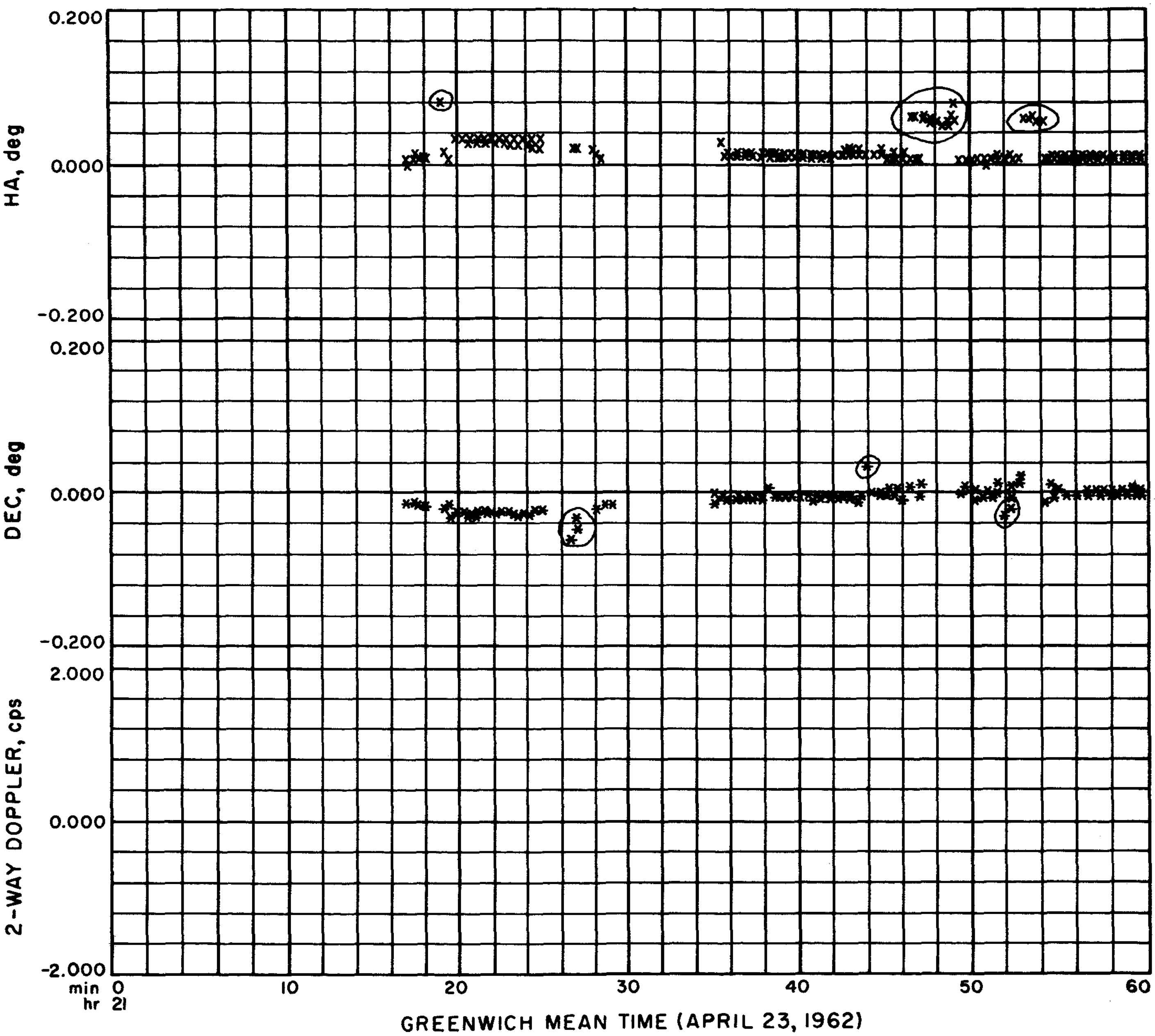

Fig. 19. Station 5 residuals (from 21:00 GMT April 23, 1962)

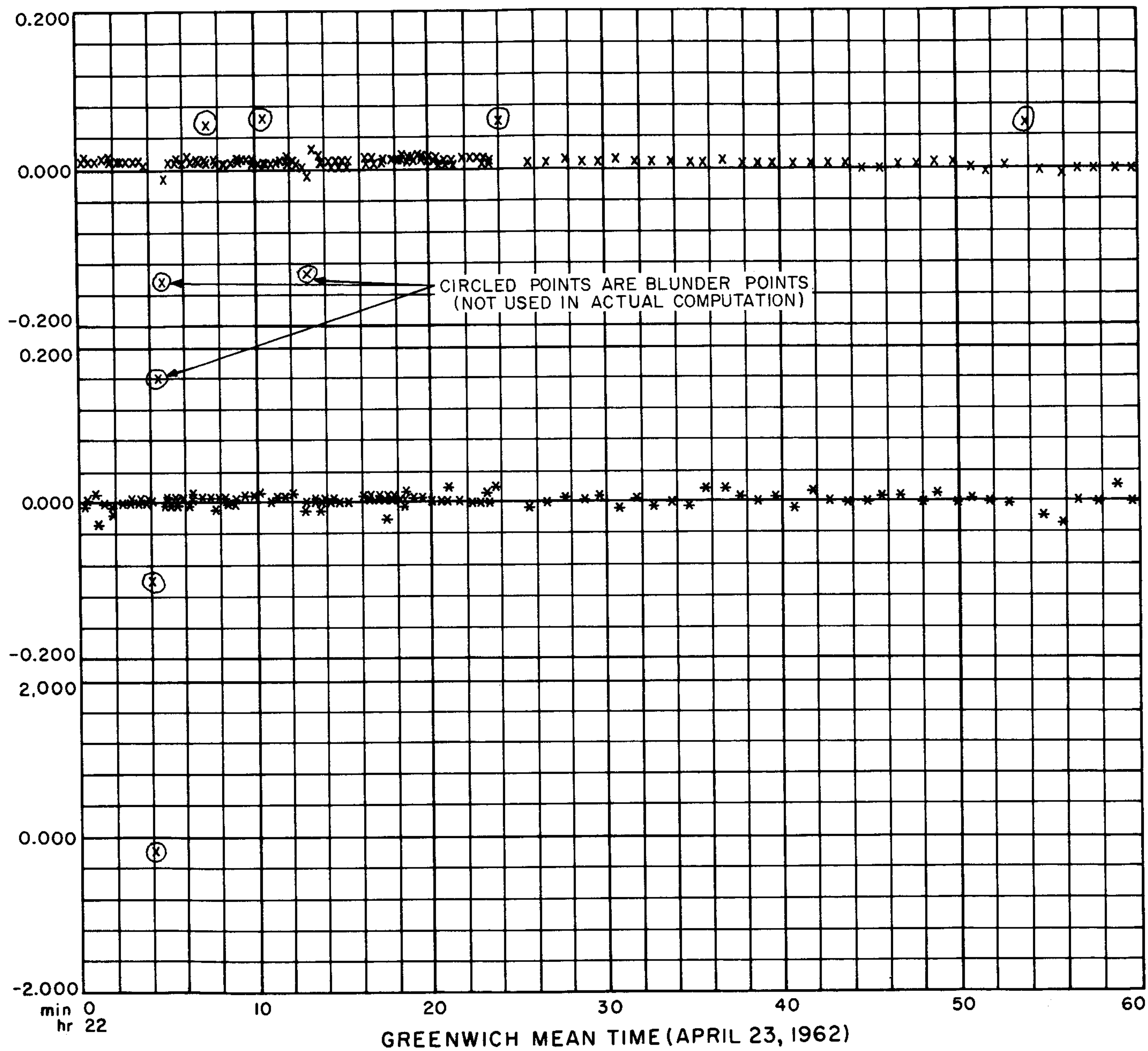

Fig. 20. Station 5 residuals (from 22:00 GMT April 23, 1962)

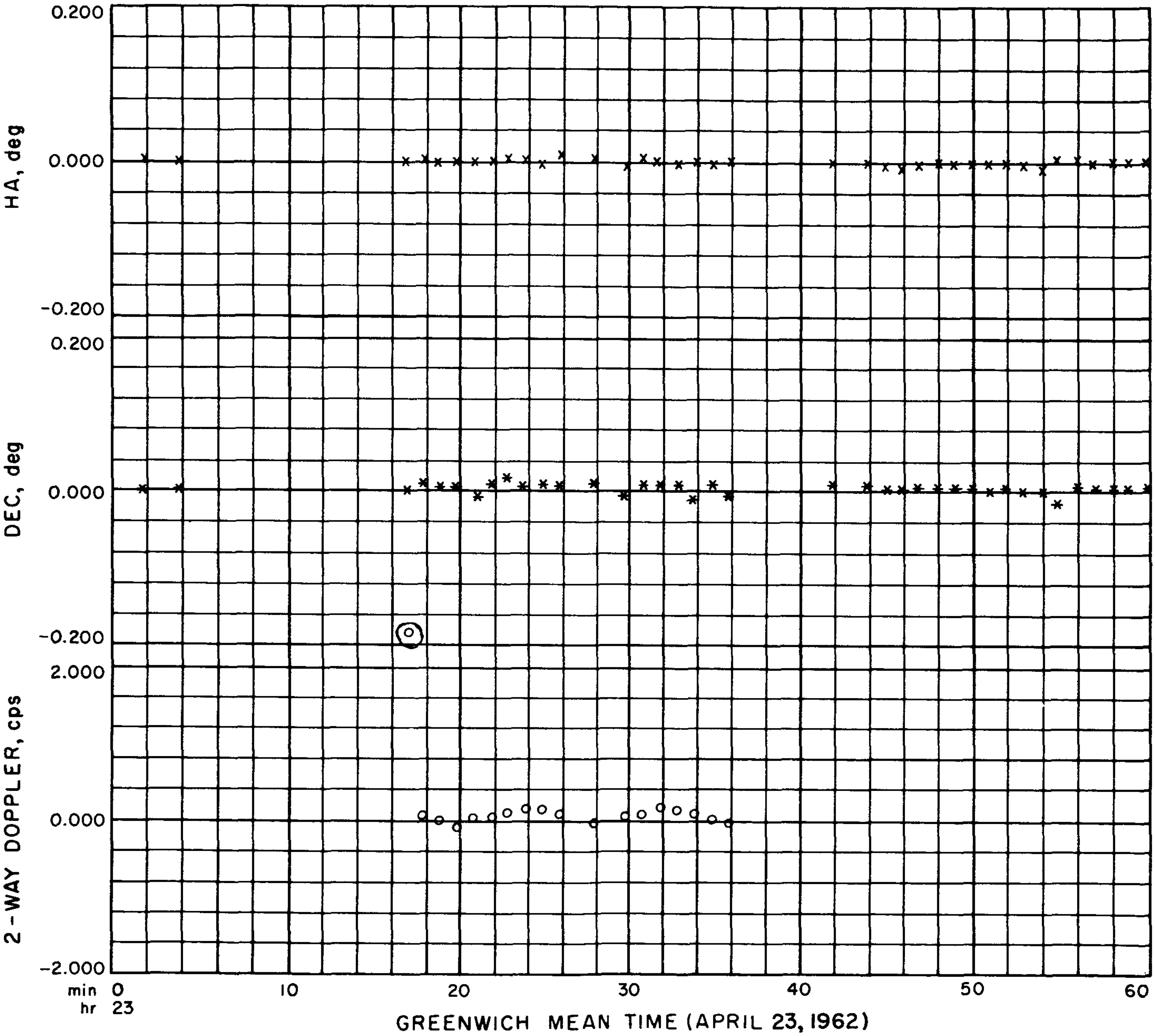

Fig. 21. Station 5 residuals (from 23:00 GMT April 23, 1962)

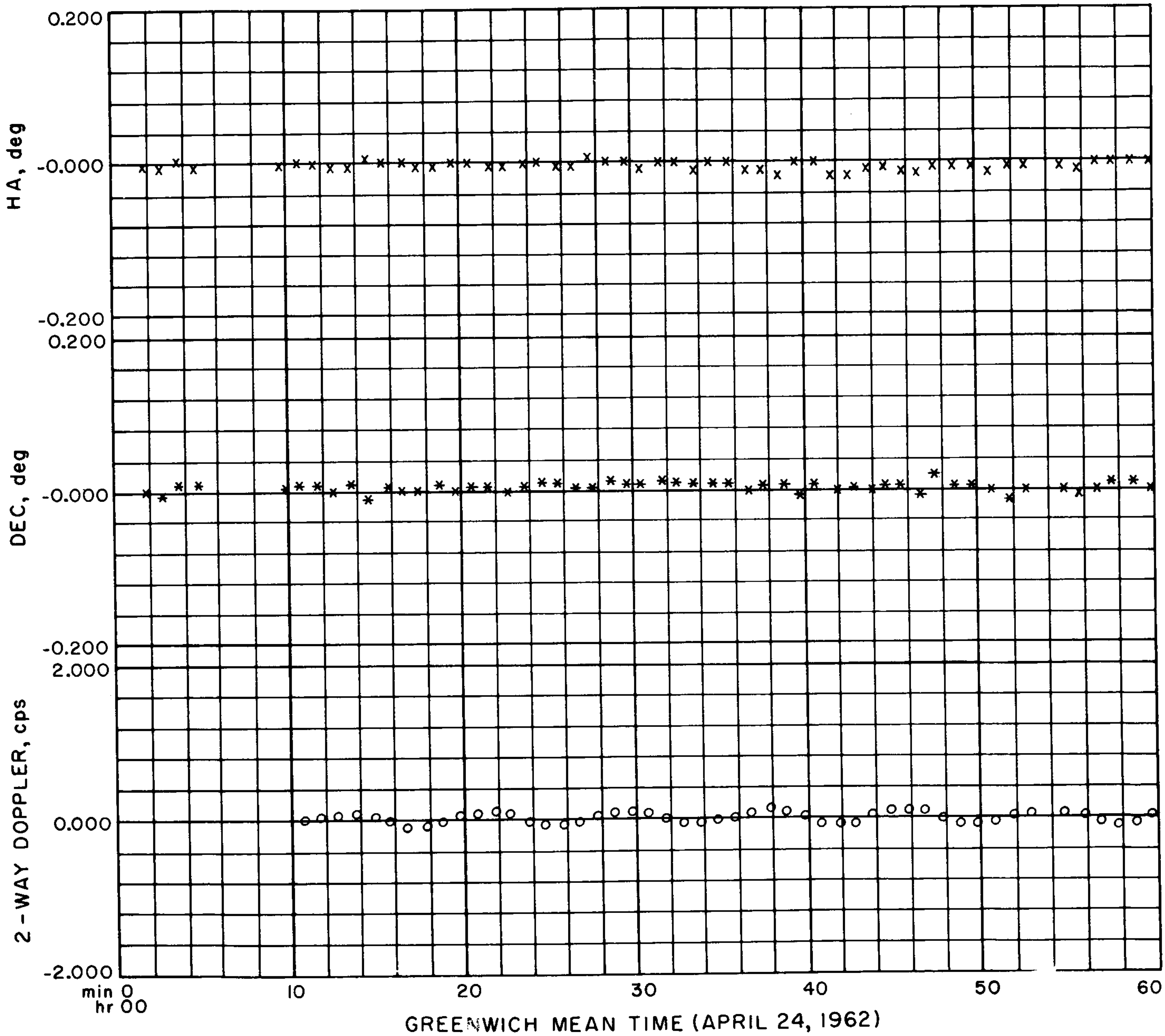

Fig. 22. Station 5 residuals (from 00:00 GMT April 24, 1962)

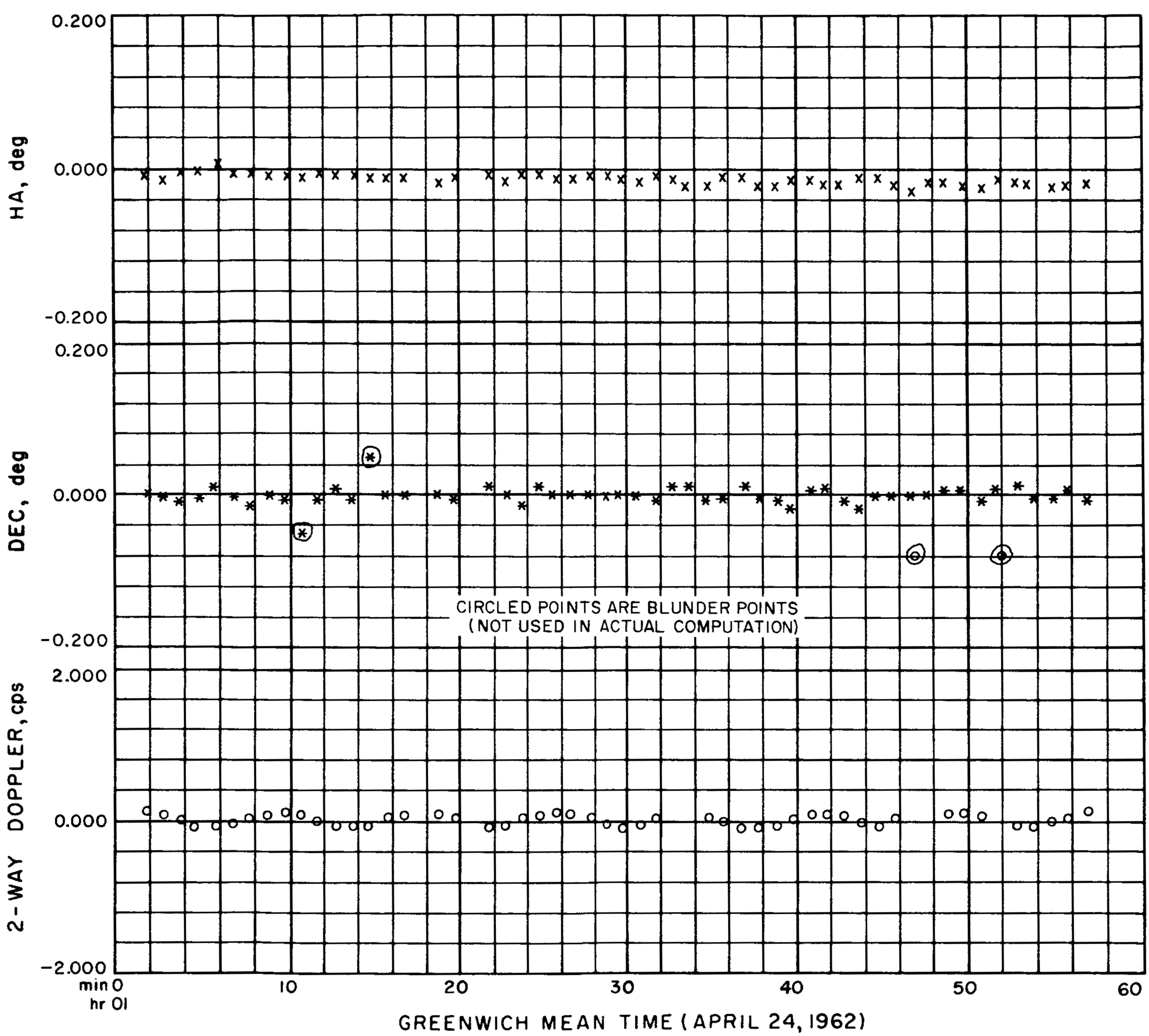

Fig. 23. Station 5 residuals (from 01:00 GMT April 24, 1962)

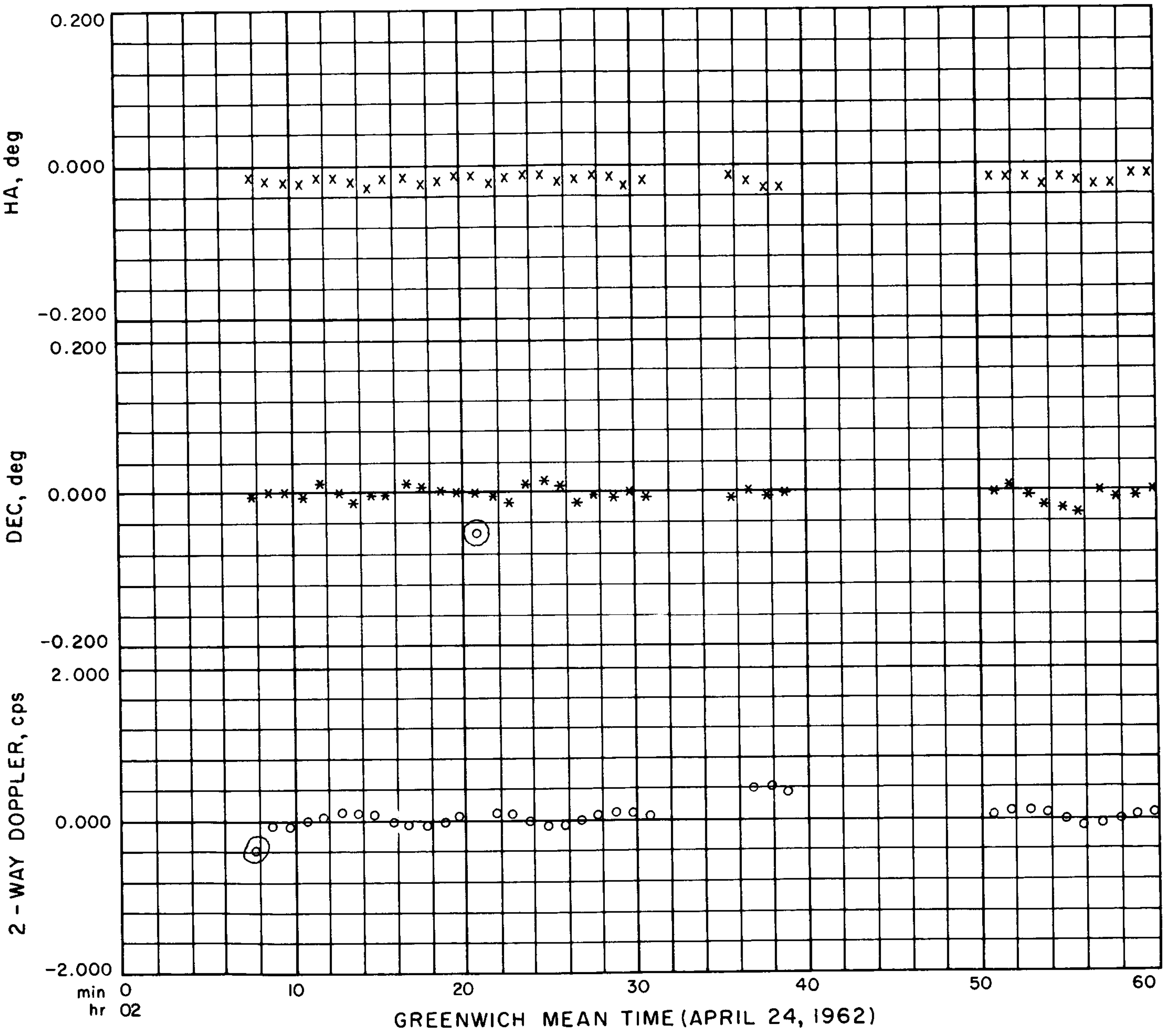

Fig. 24. Station 5 residuals (from 02:00 GMT April 24, 1962)

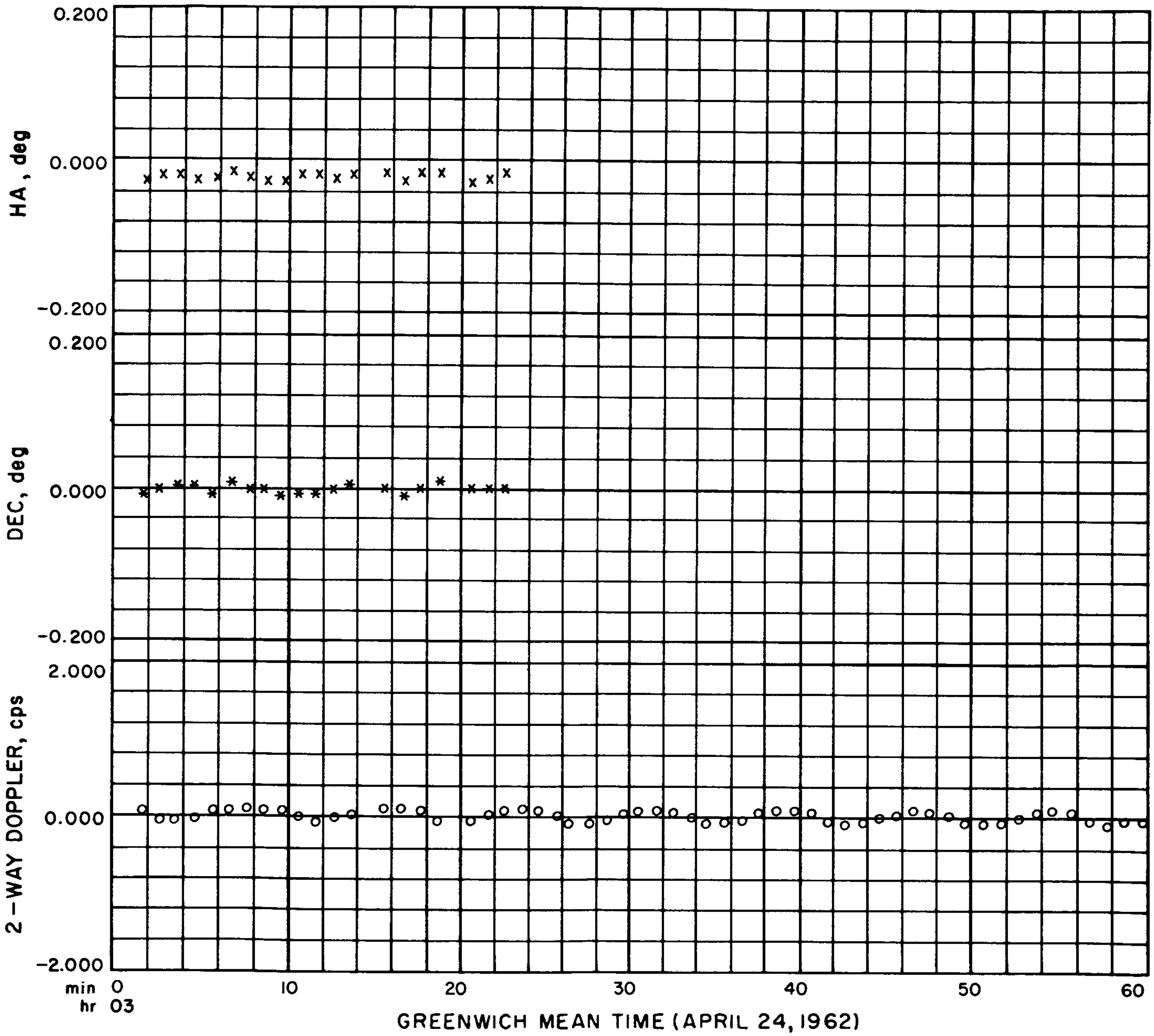

Fig. 25. Station 5 residuals (from 03:00 GMT April 24, 1962)

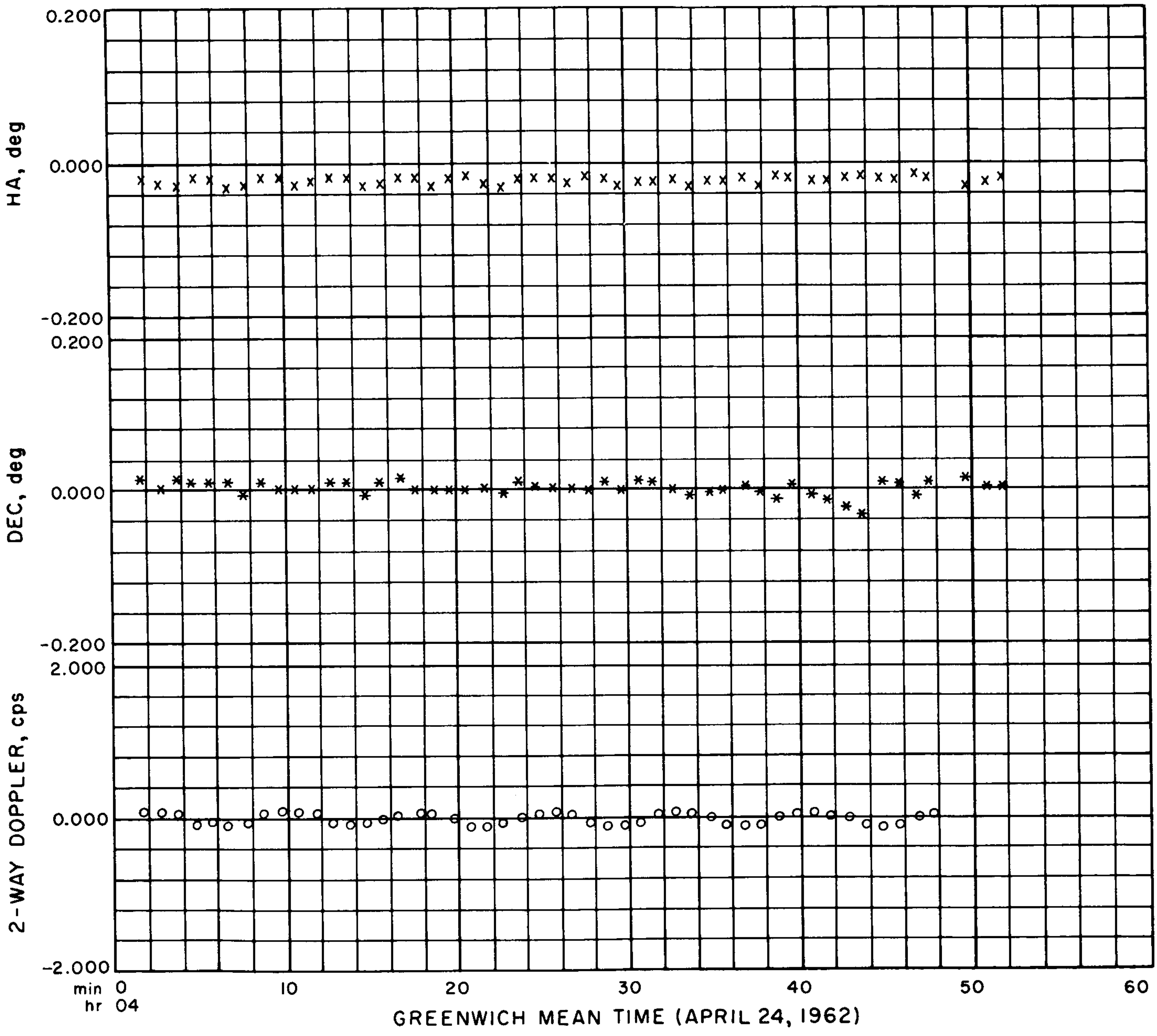

Fig. 26. Station 5 residuals (from 04:00 GMT April 24, 1962)

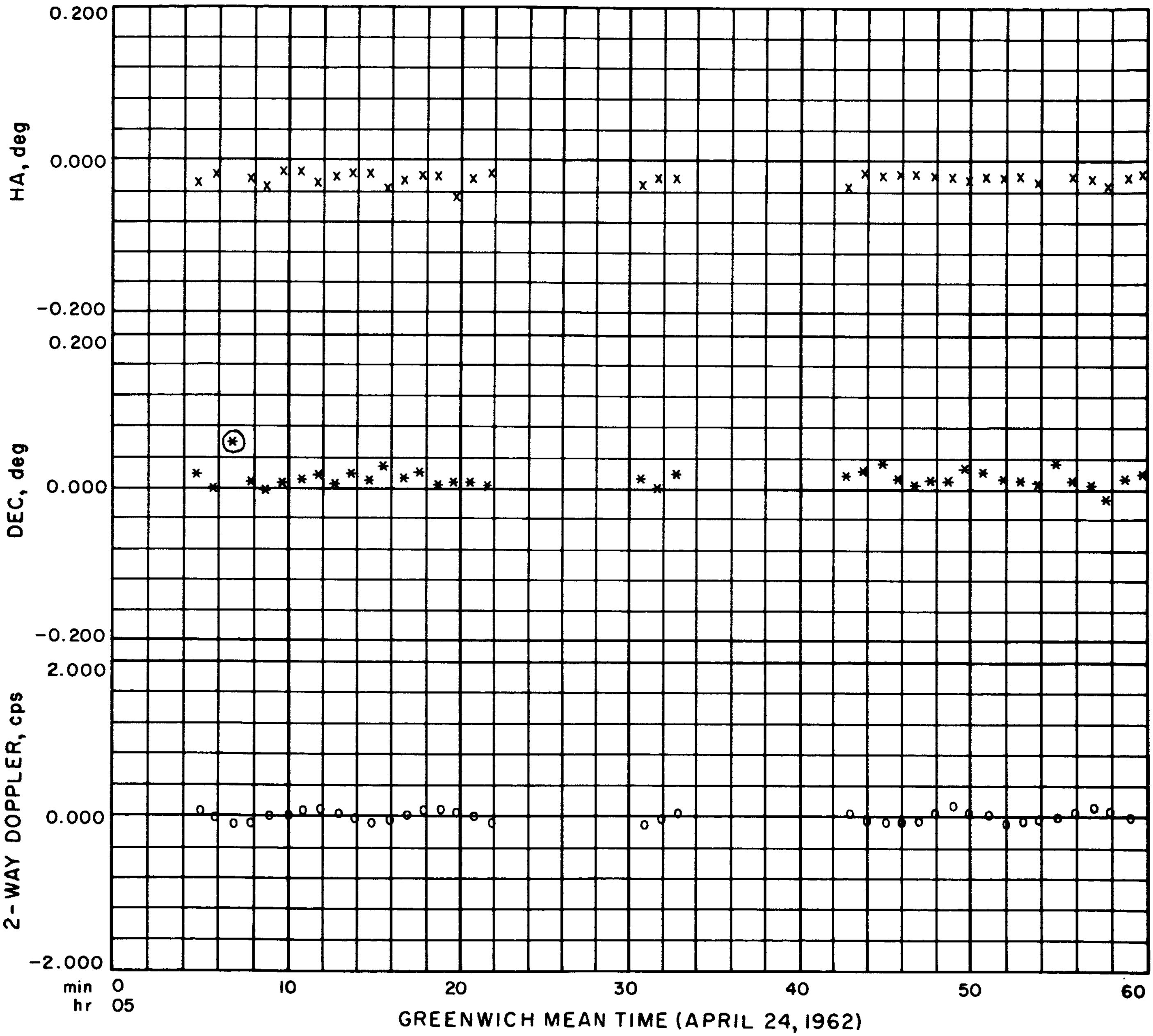

Fig. 27. Station 5 residuals (from 05:00 GMT April 24, 1962)

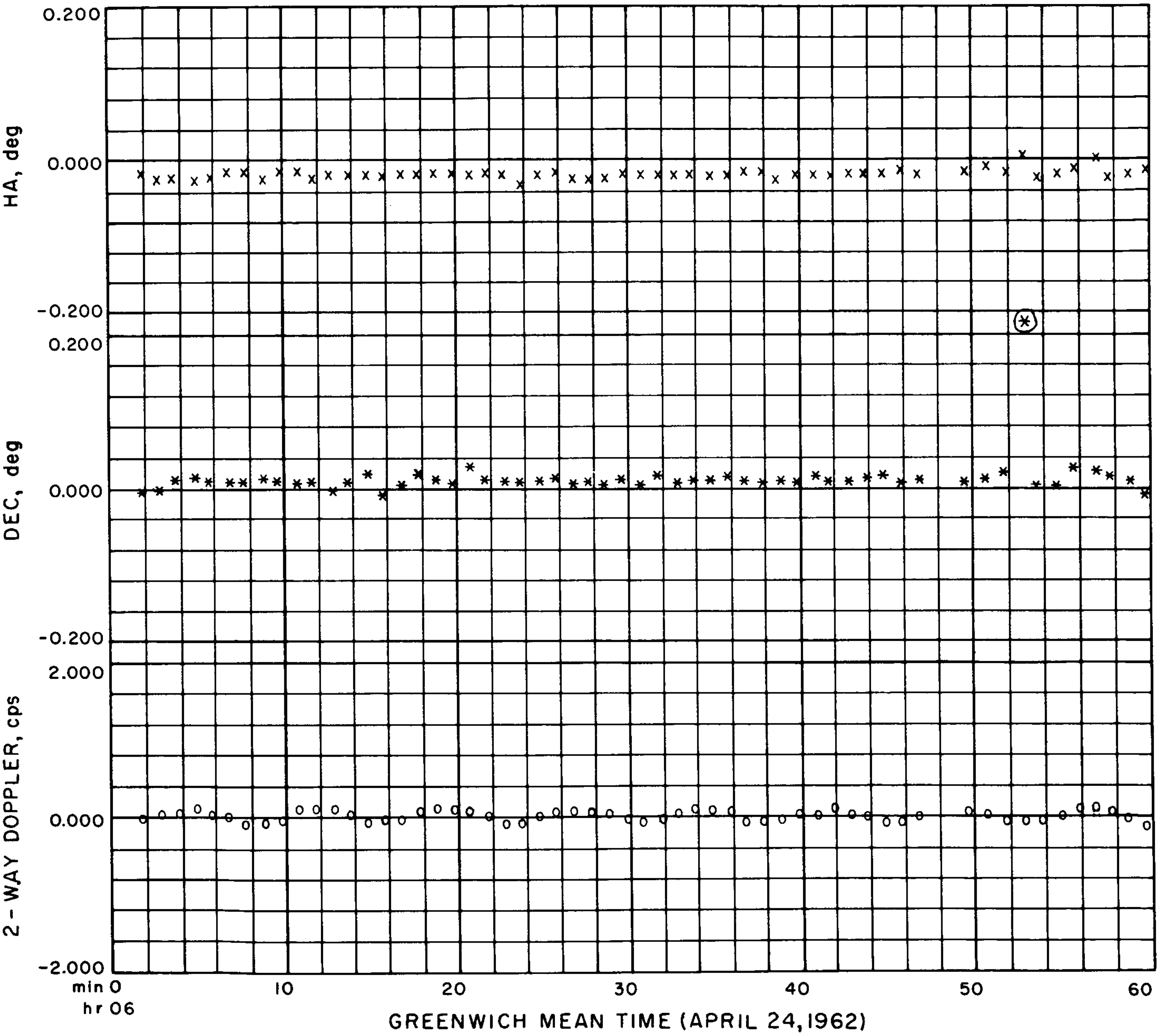

Fig. 28. Station 5 residuals (from 06:00 GMT April 24, 1962)

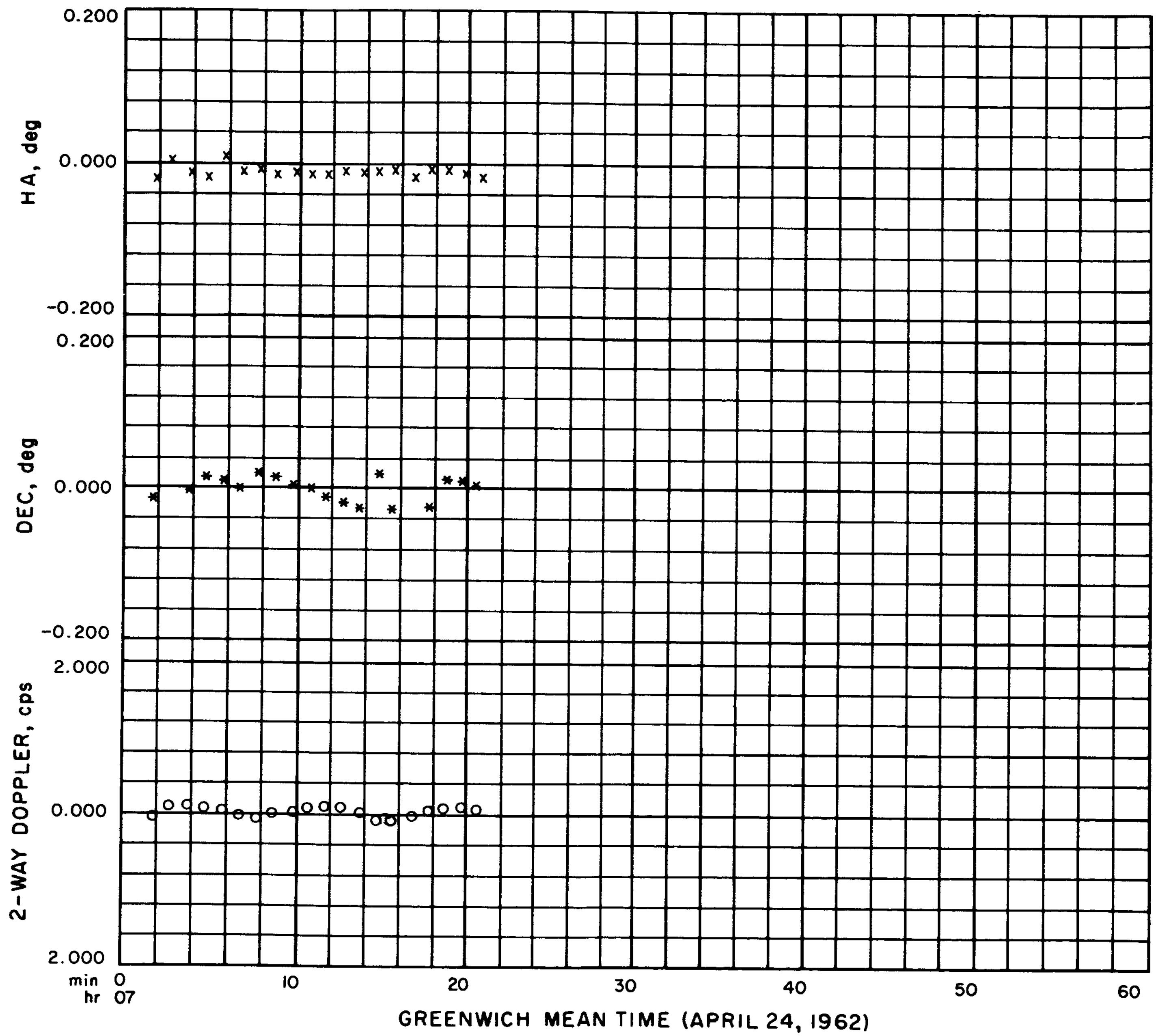

Fig. 29. Station 5 residuals (from 07:00 GMT April 24, 1962)

considering only the noise on the tracking data. The covariance matrix is given in terms of its normalized correlation matrix and standard deviations of the coordinates. The coordinates at E are given in Section II. The lower part of Table 9 gives the corresponding quantities in Earth-fixed spherical (defined in Section IV-C 1) coordinates.

The covariance of errors in knowledge of the coordinates at E may be "mapped" to the target region using the miss parameter **B** (Appendix A) and T_L, the linearized time-of-flight, as measures of target error. T_L may be considered to represent the flight time to a vertical impact (the influence of **B** on the parameter T_L is thus removed). Table 10 represents the standard deviations and correlation matrix in the $\mathbf{B \cdot R}$, $\mathbf{B \cdot T}$, T_L system. The

Table 8. Tracking noise statistics

Station	Data types	No. of Points	RMS	Mean[a]
1	2-way doppler, cps	703	0.639	−0.005
4	Hour angle, deg	35	0.009	−0.001
	Declination, deg	35	0.007	−0.002
5	2-way doppler, cps	377	0.078	−0.002
	Hour angle, deg	719	0.020	−0.002
	Declination, deg	719	0.012	−0.002

[a]Antenna angle biases were calibrated out.

axes of the 1-sigma dispersion ellipse are found by evaluating the eigen-values of the 2×2 covariance matrix of $\mathbf{B \cdot R}$, $\mathbf{B \cdot T}$ uncertainties. The results are: major semi-axis = 22.9 km, minor semi-axis = 14.6 km, and orientation of major axis = 149.6 deg CCW from the R axis. The standard deviation of actual flight time to the estimated impact point is 18.8 sec. It was determined by using Table 10 data plus the relationships

$$\frac{\partial T_I}{\partial \mathbf{B \cdot T}} = 0.656 \text{ sec/km and } \frac{\partial T_I}{\partial \mathbf{B \cdot R}} \simeq 0$$

c. Statistics of orbit estimate; physical constants. The only error source which could significantly degrade the target accuracies indicated in Section IV-B4b, above, appears to be GM-Earth. A systematic investigation utilizing the technique first suggested in Ref. 4 was carried out to determine the sensitivity of our target parameters to changes in the assumed GM-Earth as well as to form an independent estimate of that quantity from our tracking data.

Figure 30 shows the variation of the weighted sum of residuals squared (on second and third iterations) as a function of the *fractional* variation in GM from its nominal value. The minimum is at -0.7×10^{-5} and the standard deviation of this estimate is 3.2×10^{-5}. A wide range

Table 9. Statistics of knowledge of injection conditions ignoring physical constant errors

Space-fixed Cartesian Coordinates at Epoch E

Standard deviation	Correlation coefficients						
		X	Y	Z	$\dot{X}$	$\dot{Y}$	$\dot{Z}$
X 0.290 km	X	1	0.384	−0.106	−0.378	0.144	0.057
Y 0.384	Y		1	−0.941	0.701	0.940	−0.874
Z 0.676	Z			1	−0.868	−0.983	0.973
$\dot{X}$ 0.648 m/sec	$\dot{X}$		Symmetrical		1	0.854	−0.941
$\dot{Y}$ 1.242	$\dot{Y}$					1	−0.979
$\dot{Z}$ 2.225	$\dot{Z}$						1

Earth-fixed Spherical Coordinates at Epoch E

Standard deviation	Correlation coefficients						
		r	ϕ	λ	v	γ	σ
r 0.135 km	r	1	−0.682	0.031	−0.974	0.724	0.768
ϕ 0.0063°	ϕ		1	0.614	0.518	−0.784	−0.971
λ 0.0035°	λ			1	−0.177	−0.054	−0.466
v 0.0943 m/sec	v				1	−0.585	−0.606
γ 0.0015°	γ			Symmetrical		1	0.867
σ 0.0136°	σ						1

Table 10. Statistics of knowledge of target error ignoring physical constant errors

Standard deviation		Correlation coefficients		
		B • R	B • T	T_L
B • R 21.0 km	B • R	1	−0.375	0.697
B • T 17.0 km	B • T		1	0.273
T_L 18.5 sec	T_L	Symmetrical		1

of opinions as to the accuracy of our current knowledge of GM is available. The most pessimistic figures are around 1×10^{-5}. Thus, while our answer is encouragingly close to the adopted value, it affords no new information. We shall continue to assume the adopted values of Ref. 7 with an uncertainty of 0.5 part in 10^5.

The degradation of the orbit estimate due to a 0.5×10^{-5} fractional error in GM-Earth is described in Table 11. The change in the converged target coordinates estimate per 10^{-5} fractional change in GM is listed as obtained from the previously described computer runs.

Previous studies of the effect of station location errors indicate that less than a 15-km target error results from station location errors of 10^{-3} deg in latitude and longitude and 37 m in altitude.

We conclude that our estimate of the orbit should be accurate about a 22-km 1-sigma circle in the **B** plane and about 33 sec in linearized time-of-flight after allowing for uncertainties in the physical constants. Due to the favorable correlation between T_L and **B** • T errors (Tables 10 and 11) the 1-sigma impact time uncertainty is only 26 sec.

We plan to re-evaluate the *Ranger 4* flight data using a more sophisticated orbit determination program which has just been completed. Here, the uncertainties in physical constants and station locations will be handled in a rigorous fashion in order to obtain a better estimate of the orbit and its uncertainties.

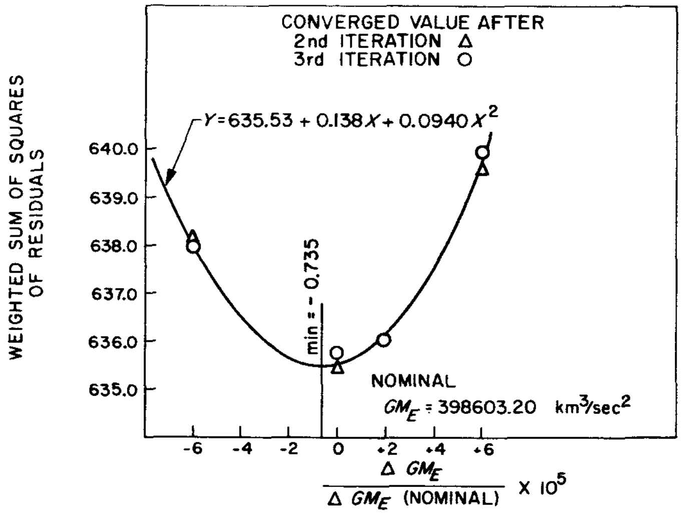

Fig. 30. Solving for GM_E using *Ranger 4* data

C. Comparison of AMR and DSIF Tracking Results

1. Introduction

Section III has described the sequence of events necessary to understanding the use of AMR tracking data as well as a summary of the AMR tracking data available for comparison with the DSIF tracking results. Part IV-C2, below, summarizes our analysis of the TFV ship tracking results. First, we computed the orbital elements (see glossary of terms that follows) based on TFV data alone. Comparison with the DSIF orbital elements suggested that the ship's location required adjustment. The TFV orbital elements with adjusted ship's location showed good agreement with the DSIF-determined elements.

In Part IV-C3, below, we have applied the same approach to the analysis of the Ascension Island data. The initial disagreement of orbital elements derived solely from Ascension data led to a comparison of Ascension observation with those calculated on the basis of the DSIF-only orbit. The assumption of a 6000-yd bias in

Table 11. Variation in estimate of impact conditions with changes in GM of the Earth[a]

Fractional change in GM_E	Δ B • T, km	Δ B • R, km	Δ Lat, deg	Δ Long, deg	Δ Impact time, sec	Δ T_L, sec
$+2 \times 10^{-5}$	−55.7	−0.4	0.39	−2.25	−70	−108
$+6 \times 10^{-5}$	−167.4	−0.8	1.26	−7.13	−206	−325
-6×10^{-5}	+169.2	0.0	−1.04	6.32	+222	+326

[a]Estimated change in impact conditions per 0.5×10^{-5} change in GM_E: ΔB • T = −14.0, ΔB • R = −0.03, Δ Impact time = −17.9, ΔT_L = −27.1.

the Ascension range data puts all residuals and orbital elements within the range of expected variation.

We consider that the problems encountered are not serious and can be eliminated in the future so that our goal of using AMR data in assisting the determination of the spacecraft orbit in real time is not far off. Modifications in operational and computational procedures at JPL are indicated in order to make proper utilization of the potential of the AMR tracking data.

GLOSSARY OF TERMS

The two sets of orbital parameters used are Earth-fixed spherical coordinates and a set of Keplerian orbital elements. All elements are referred to true (instantaneous) equator and equinox of date.

Earth-fixed spherical coordinates

r_o Earth center to probe distance, km

ϕ_o geocentric latitude, deg

λ_o longitude, east, deg

v_o speed in Earth-rotating framework, km/sec

γ_o path angle of velocity, above local (geocentric) horizon, deg

σ_o azimuth angle of velocity, east of north, deg

Keplerian orbital elements

a semi-major axis, km

e eccentricity

i inclination angle, deg

Ω right ascension of ascending node, deg

ω argument of perigee, deg

$\omega + \nu$ sum of ω and true anomaly at epoch E

2. Twin Falls Victory Ship Tracking Results

The TFV data available (Fig. 12) brackets the time of mechanical spring-separation of the *Agena* stage from the spacecraft. Since the relative separation velocity is only about 0.3 m/sec, the *Agena* orbit and the post-separation *Ranger 4* spacecraft orbit were treated as one. As discussed in the Introduction, we first determined an orbit using TFV data only. The weighting standard deviations used were 30 m in range and 0.3 deg in azimuth and elevation (by comparison with the RMS residuals it can be seen that we assumed correlated errors were present in both the range and angle data). Table 12 lists the Earth-fixed spherical orbital elements at the reference epoch E as well as the RMS error of the residuals.

Table 12 lists the corresponding orbital elements for the DSIF orbit found in Section IV-B. In interpreting the differences it is important to note that the ship's position estimate cannot normally be trusted to better than ±2 nautical mi (±0.034 deg). To illustrate the effect of ship's location on the orbit estimate, the latitude and longitude of the ship were varied by 0.1 deg in turn, with the following results:

Change in orbit estimate	Change in ship's location	
	0.1 deg latitude	0.1 deg longitude
δr_o, km	−0.0055	0
$\delta \phi_o$, deg	0.0993	0
$\delta \lambda_o$, deg	−0.0030	0.100
δv_o, km/sec	−0.00002	0
$\delta \gamma_o$, deg	0.0006	0
$\delta \sigma_o$, deg	0.0132	0

Utilizing the above information, we made an approximate adjustment of the ship's location to better match the orbital elements; the latitude was changed by about 0.10 deg and the longitude by about 0.02 deg. Table 13 summarizes the results analogous to Table 12 with the ship's location adjusted. In columns 5 and 6 we have listed the expected 1-σ errors in each orbital element due to the data noise and a ±2 nautical mi error in ship's location.

The residuals for the adjusted orbit are shown in Fig. 31. Note that the RMS of the residuals are essentially the same for both the adjusted and unadjusted orbits. This is because changes in ship's location can be so well compensated for by errors in the orbit parameters ϕ_o, λ_o, as illustrated previously.

The only discrepancy between these two orbits which appears significant is the 1.7-m/sec difference in speed. We believe that this difference is accounted for by the ship's speed of 5 knots (2.6 m/sec) during the tracking

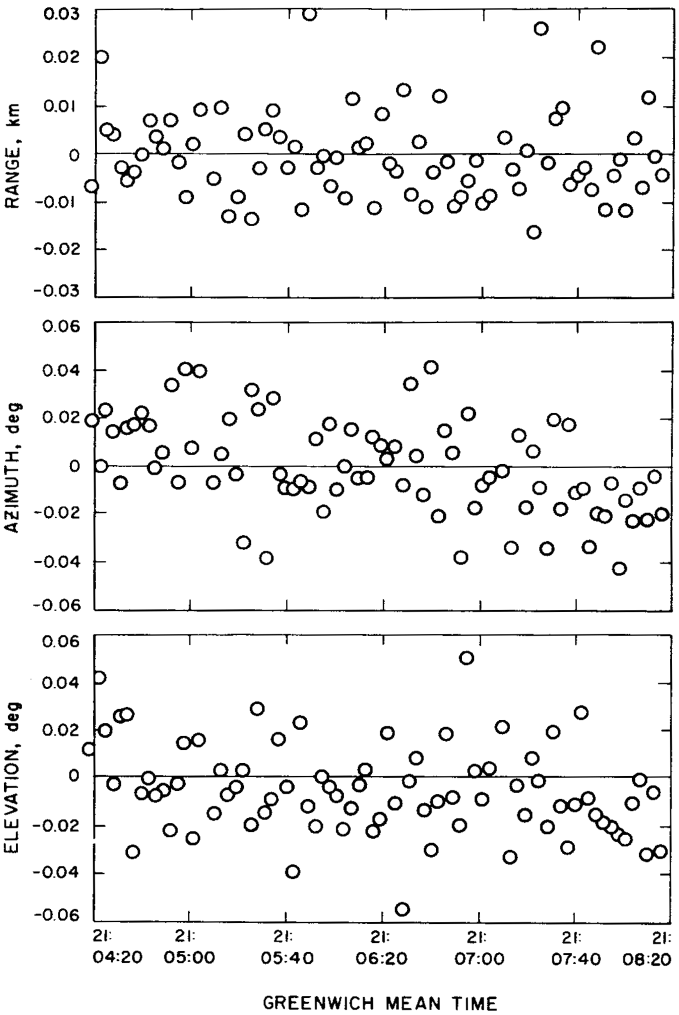

Fig. 31. TFV (adjusted) residuals

period. In the future, proper arrangements will be made for considering the effect of ship's velocity.

3. Ascension Transponder Tracking Results

The Ascension data were placed in the Orbit Determination Program and an orbit was found for the *Agena* vehicle (pre-retro) using these weights: azimuths and elevation angles 0.02 deg, range 30 m. The resulting orbit is given in Table 14 where comparison is made with the DSIF orbit. Two coordinate systems are shown, Earth-fixed sphericals and Keplerian orbital elements, in order to emphasize separate features. Note how conspicuous is the excessive semi-major axis and r_0 associated with the Ascension orbit.

The residuals of this orbit are shown in Fig. 32 indicating errors of a systematic nature.

In order to detect possible errors, we calculated the Ascension Island observations based on the DSIF orbit. The residuals are shown in Fig. 33. It appears that the Ascension data had range readings which were 5.5 km too high.

A second Ascension orbit was then computed, the same as before except 6900 m were subtracted from the Ascension range data. This range adjustment was chosen after several tries. The results are shown in Table 15. Residuals of this orbit are shown in Fig. 34. The fit to the equations of motion is better and the discrepancies between DSIF and the range-adjusted orbit are smaller. It should be noted that if a timing discrepancy existed between Ascension and the DSIF, and this were the only error, then comparison of orbital elements would show discrepancies only in two of the elements, Ω and $(\omega + \nu)$. Such does not appear to be the case.

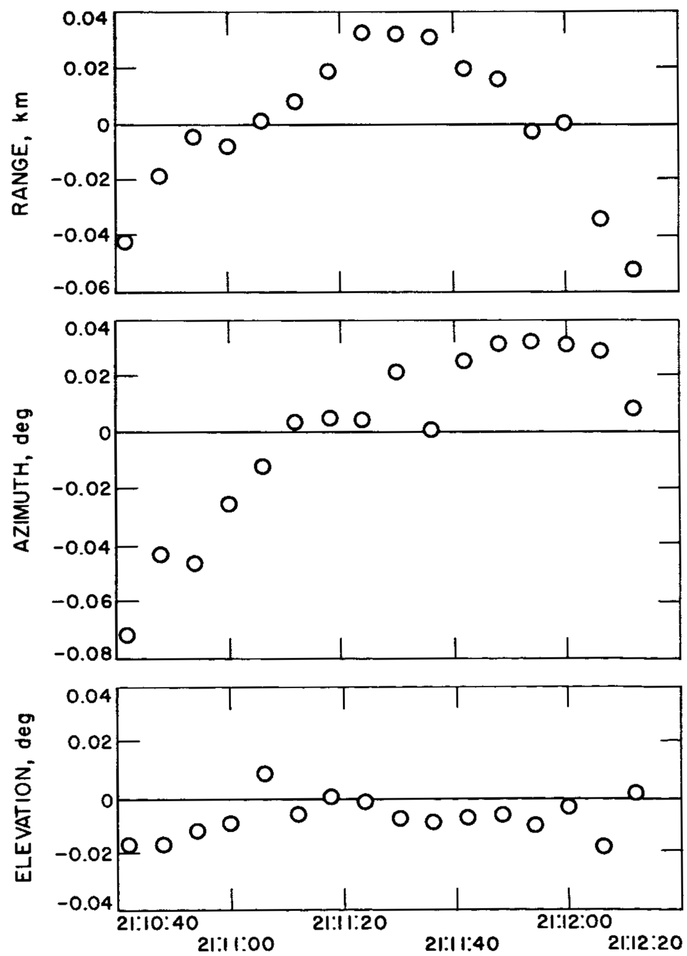

Fig. 32. Original Ascension Island orbit residuals

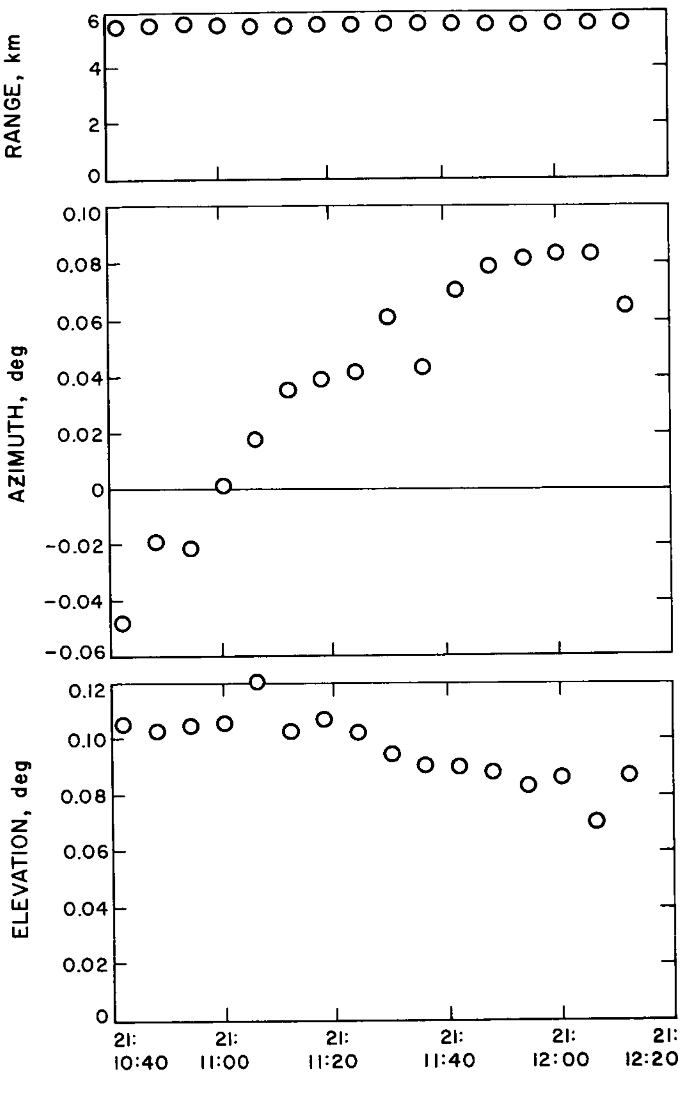

Fig. 33. Original Ascension Island residuals based on DSIF orbit

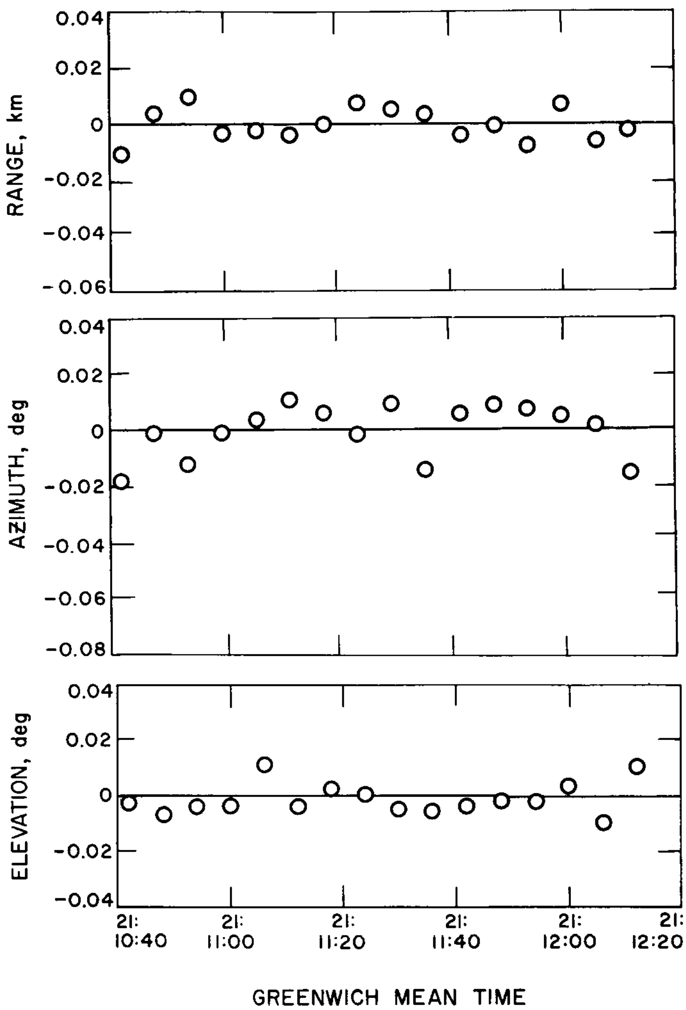

Fig. 34. Revised Ascension Island orbit (range bias removed) residuals

Table 12. Ship's orbit based on unadjusted location

Earth-fixed spherical coordinates at epoch E (E = April 23, 1962 21:04:19 GMT)

Coordinates	r_o, km	ϕ_o, deg	λ_o, deg	v_o, km/sec	γ_o, deg	σ_o, deg
Ship's orbit (unadjusted)	6568.7855	14.4806	320.2411	10.5416	1.6847	117.3531
DSIF	6568.8833	14.5741	320.2590	10.5433	1.6688	117.2733
Difference	−0.0978	−0.0935	−0.0179	−0.0017	0.0159	0.0798
1-σ ship's orbit errors[a]	0.290	0.0044	0.0013	0.0003	0.013	0.034

Data type	No. of points	RMS	Ship's (estimated) position
AZ	78	0.0194 deg	(From Section III-C)
EL	78	0.0188 deg	13.4948°N latitude (geocentric)
Range	78	0.0895 km	326.7500°E longitude

[a] Based on theoretical errors due to the data noise implied by the weighting sigmas used. Errors in ship's location and velocity are not considered.

Table 13. Ship's orbit based on adjusted location[a]

Earth-fixed spherical coordinates at epoch E (E = April 23, 1962 21:04:19 GMT)

Coordinates	r_o, km	ϕ_o, deg	λ_o, deg	v_o, km/sec	γ_o, deg	σ_o, deg
Ship's orbit (adjusted)	6568.7814	14.5735	320.2563	10.54155	1.6852	117.3408
DSIF	6568.8833	14.5741	320.2590	10.54329	1.6688	117.2773
Difference	−0.0109	−0.0006	−0.0027	−0.00174	0.0164	0.0635
1-σ ship orbit errors[a]	0.290	0.044	0.0013	0.00027	0.013	0.034
1-σ ship orbit errors, location errors[b]	0.002	0.035	0.035	0.00001	0.0002	0.005

Data type	No. of points	RMS	Ship's (adjusted) position
AZ	78	0.0194 deg	13.5884°N latitude (geocentric)
EL	78	0.0196 deg	326.7680°E longitude
Range	78	0.00897 km	

[a] Theoretical noise due to data noise implied by the weighting sigmas used.
[b] Theoretical noise due to uncorrelated 2 nautical mi latitude and longitude errors.

Table 14. Comparison of original Ascension orbit with DSIF orbit

Earth-fixed spherical coordinates at epoch E (E = April 23, 1962 21:04:19 GMT)

Coordinates	r_o, km	ϕ_o, deg	λ_o, deg	v_o, km/sec	γ_o, deg	σ_o, deg
Ascension (original)	6581.141	14.6300	320.2565	10.5579	1.5080	117.3326
DSIF	6568.883	14.5740	320.2590	10.5433	1.6688	117.2773
Difference	12.258	0.0560	−0.0025	0.0146	−0.1608	0.0553
1-σ Ascension orbit errors[a]	1.32	0.013	0.004	0.015	0.018	0.017
Keplerian orbital elements at epoch *E*						
Coordinates	a, km	e	i, deg	Ω, deg	ω, deg	$(\omega + \nu)$, deg
Ascension (original)	537,275	0.987759	29.7699	334.9101	146.5029	149.4230
DSIF	306,500	0.978588	29.6988	334.8797	146.2298	149.4764
Difference	230,775	0.009171	0.0711	0.0304	0.2731	−0.0534

Data type	No. of points	RMS
AZ	16	0.031 deg
EL	16	0.0098 deg
Range	16	0.025 km

[a] Theoretical error expected from data errors consistent with the weights assumed.

Table 15. Comparison of adjusted Ascension orbit with DSIF orbit

Earth-fixed spherical coordinates at epoch E (E = April 23, 1962 21:04:19 GMT)

Coordinates	r_o, km	ϕ_o, deg	λ_o, deg	v_o, km/sec	γ_o, deg	σ_o, deg
Ascension (adjusted)	6569.574	14.5643	320.2552	10.5427	1.6652	117.3006
DSIF	6568.883	14.5740	320.2590	10.5433	1.6688	117.2773
Difference	−0.691	−0.0097	−0.0038	−0.0006	−0.0036	0.0233
1-σ Ascension orbit errors[a]	1.32	0.013	0.004	0.015	0.018	0.017
Keplerian orbital elements at epoch E						
Coordinates	**a, km**	**e**	**i, deg**	**Ω, deg**	**ω, deg**	**$(\omega + \nu)$, deg**
Ascension (adjusted)	306,277	0.978567	29.0134	334.8381	146.2739	149.5135
DSIF	306,500	0.978588	29.6988	334.8797	146.2298	149.4764
Difference	223	−0.000021	0.0146	−0.0417	0.0442	0.0372

Data type	No. of points	RMS
AZ	16	0.0097 deg
EL	16	0.0057 deg
Range	16	0.0061 km

[a] Theoretical error expected from data errors consistent with the weights assumed.

V. CONFIRMATION OF THE DSIF TRANSPONDER-BASED ORBIT ACCURACY BY TRACKING THE CAPSULE BEACON NEAR LUNAR IMPACT

A. Introduction

Our analysis of the doppler-shift data received from the capsule beacon just prior to impact has confirmed that the orbit determined using the DSIF transponder data is consistent with these observations. As indicated in Section III-B1, the pass of April 26 at the two Goldstone Deep Space Stations began about 4 hr and 4 min before the time the spacecraft was occulted by the Moon's leading edge. Figures 35 and 36 show the actual doppler values recorded at Stations 2 and 3 during the last hour before impact with the Moon. In subsequent comparisons, the discrete data points are not shown.

In Part B of this Section we review the data-taking system and the formulae relating the observations with the spacecraft orbit, capsule transmitter frequency, and ground station bias oscillator frequency. Estimates are made of the necessary quantities and the actual observations are compared to the values derived from the DSIF transponder orbit described in Section IV-B. We show that the expected variations in the capsule doppler data due to errors in our orbit estimate (Section IV-B4) bracket the actual observations, indicating consistency of these two information sources.

In Part C of this Section the records at Station 2 and 3 which define the time-of-signal loss are shown and discussed. Again the deviation in the actual loss time from that predicted is well within the expected bounds. Plots

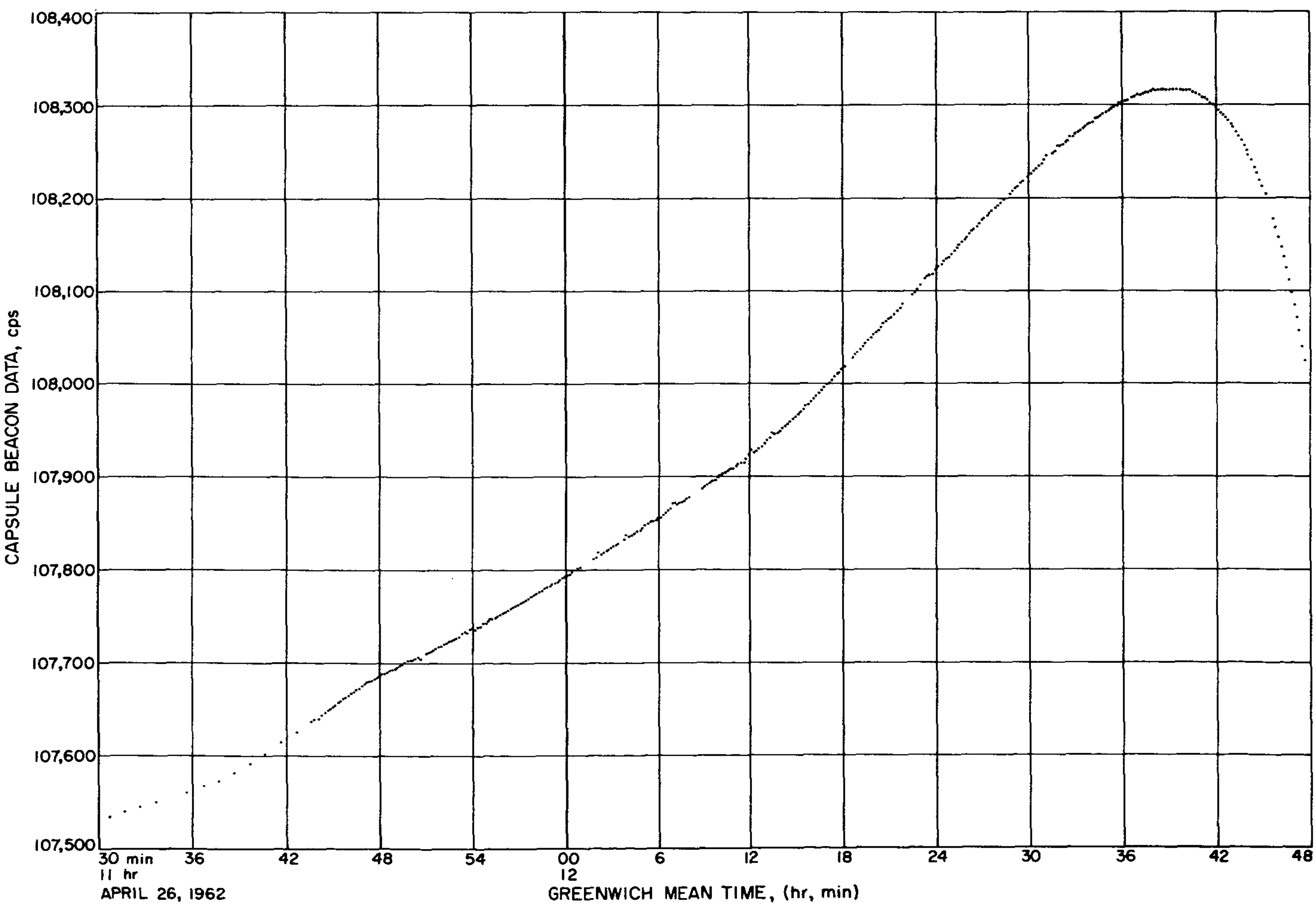

Fig. 35. Actual recorded data from DSIF 2

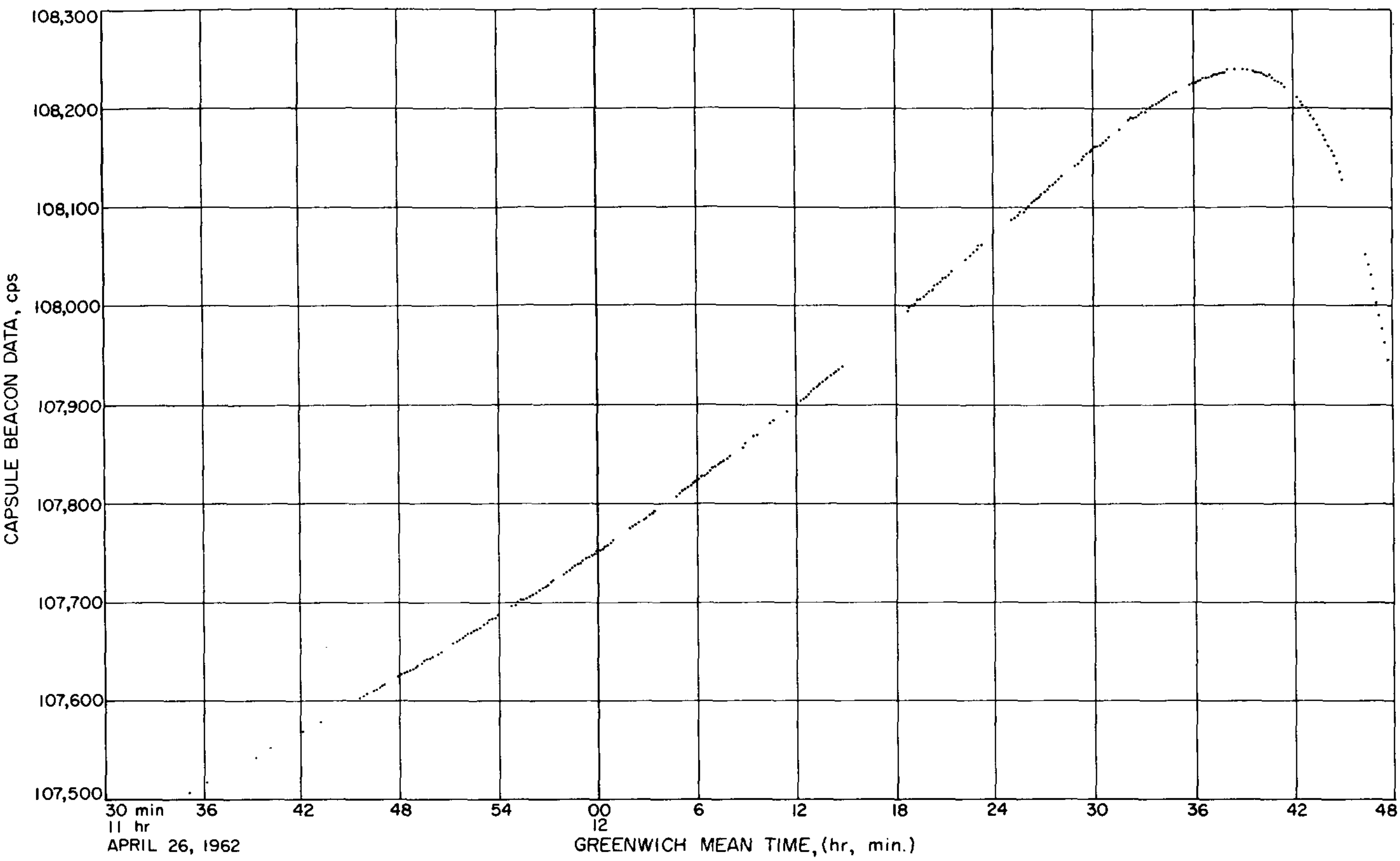

Fig. 36. Actual recorded data from DSIF 3

are presented which indicate the sensitivity of the time-of-signal loss to deviation in coordinates near impact.

B. Data System

1. Recordings

The frequency recorded at the tracking station in GM-4 (Section III-B1) is f_{cb} and is a function of the beacon crystal frequency and the bias oscillator frequency at the receiving station. Recordings of f_{cb} were made throughout the entire mission as described in Section III-B3. The formula used in the orbit determination program to calculate f_{cb} at the ith receiving station is given in Fig. 37. Thus,

$$f'_{cb_i} = 930.15 \times 10^6 + (f_0 + D_o \Delta_{t_i} - 0.455 \times 10^6)$$
$$- (f_t + D_t \Delta t_i)\left(1 - \frac{\dot{r}_i}{c} + \text{higher order terms}\right)$$

where

f'_{cb_i} = calculated capsule beacon frequency in cps

f_0 = bias oscillator frequency in cps

f_{t_0} = capsule crystal frequency at a reference time in cps

D_0 = bias oscillator drift rate in cps/min

D_t = capsule crystal drift rate in cps/min

$\dot{r}_i$ = range rate

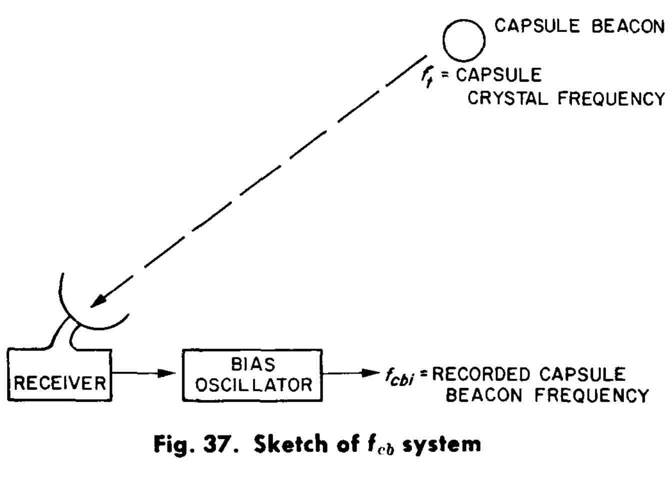

Fig. 37. Sketch of f_{cb} system

c = velocity of light

Δt_i = difference in min between reference time and recording time f_{cb}.

Since the capsule crystal-derived frequency is not precisely known, and varies significantly with temperature and other factors, a value of the crystal frequency as a function of time was obtained by studying residuals at different stations. By using the relationship $f_t = f_{t_0} + D_t \Delta t_i$, calculated values of f'_{cb_i} were generated. These values showed close agreement to actual data taken at Stations 3 and 5 where bias oscillators were steady. The value for drift rate ($D_t = +1.54$ cps/min) in f_t corresponds to a temperature change of $-5.3°$ F/day. Thus, having now estimated f_t with data prior to the last two hours before impact, we must now include the bias oscillator drift into the final calculation.

Periodically, values of the bias oscillators at the various DSIF stations were automatically recorded. Other times the values were observed, noted as steady or unsteady, and manually recorded. Figure 38 shows the oscillator recordings at Stations 2 and 3 during the final pass. Note that Station 2 recordings were oscillating quite widely and were sparse in the last half hour before impact. Station 3's lack of recordings prior to 11^h20^m was due to visual observation of a steady oscillator. When it did start to drift, the operator switched to automatic recording and then at 11^h55^m to manual recordings. The recordings have been represented by the three lines indicated in Fig. 38. Since the Orbit Determination Program (ODP) can use but one drift constant D_0, the solid line represents the drift D_0 used for the calculated values. Note that the solid line passes through all the automatic recorded values and deviates from the manual recordings. Therefore, to bring the manual recordings (dash lines) into the evaluation, the actual data cards were reconstructed to simulate the difference between recorded oscillator frequency and the values used in the ODP calculations.

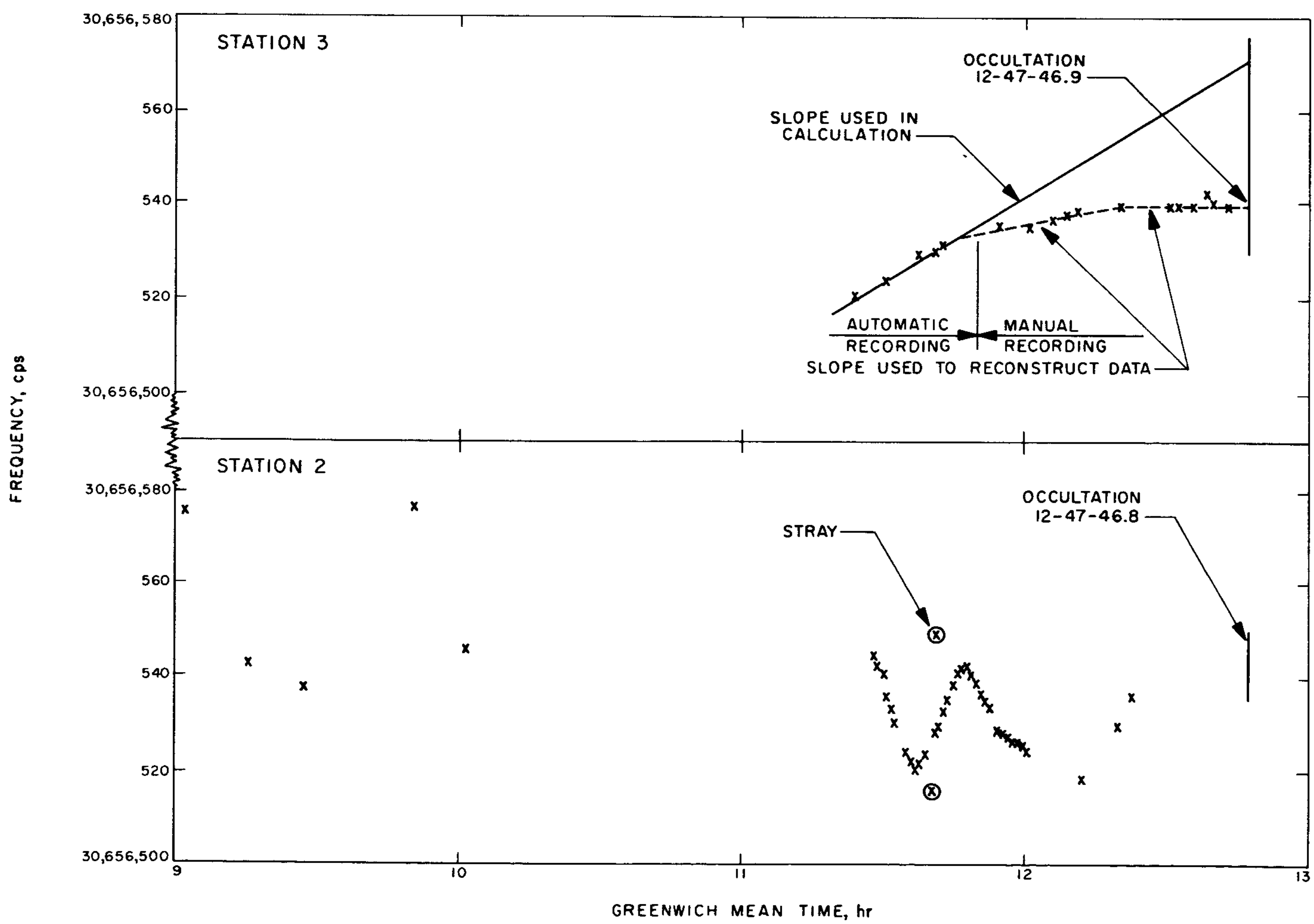

Fig. 38. Bias oscillator frequency vs time (*Ranger 4* third pass)

Residuals were generated [f_{cb_i} (observed) − f'_{cb_i} (calculated) on both the original data and the reconstructed data using the converged transponder orbit injection conditions and the previously estimated values of f_t, D_t, and D_0 (Fig. 39). The Station 2 residuals were in agreement with Station 3 residuals between 11:30 and 12:00 GMT where bias oscillator recordings were available. Since adequate recordings were not available after this time, we shall concentrate on the Station 3 doppler information. In most of the discussion that follows we have chosen the solid line (Fig. 38) as the representation of the bias oscillator frequency. Figure 40 shows the effect of the different assumptions on the calculated values f'_{cb_i}. The agreement in both cases is discussed in the following paragraphs. The manual recordings are considered to be questionable since they were derived from a counter in a non-standard patch condition.

2. Discussion of Results

In order to interpret the accuracy of the transponder determined orbit using either of the two curves in Fig. 40, it is necessary to describe the expected variation of the observable doppler during the last hour of flight. We will use the parameters **B • T**, **B • R**, and T_L described in Section IV-B4 to describe the expected variations. Table 16 gives the correlation matrix and standard deviations associated with our estimate of total accuracy (Section IV-B4c).

Table 16. Statistics of knowledge of target errors including physical constant errors

Standard deviation		Correlation coefficients			
			B • R	**B • T**	T_L
B • R	21.0 km	**B • R**	1	−0.290	0.391
B • T	22.0 km	**B • T**		1	0.646
T_L	32.8 sec	T_L	Symmetrical		1

We have perturbed these parameters in turn by their 1-sigma uncertainty. Changes of ±20 km in **B • R** caused no significant change in the doppler curves. Variation of T_L, the linearized flight time, causes a shift of the time axis equal to the negative of T_L. The resulting doppler curves for ±33 sec variation in T_L are shown in Fig. 41. Figure 42 depicts the effect of ±20 km variation in **B • T** while holding T_L, **B • R** constant. One additional variation was made to determine the change in the doppler curve caused by a ±0.2% variation in the GM of the Moon (Fig. 43). It should be noted that this effect is nearly identical with an error in ΔT_L.

Figures 41–43 are based upon the extrapolation of the automatic recordings of the bias oscillator. Also plotted is the curve representing the individual data

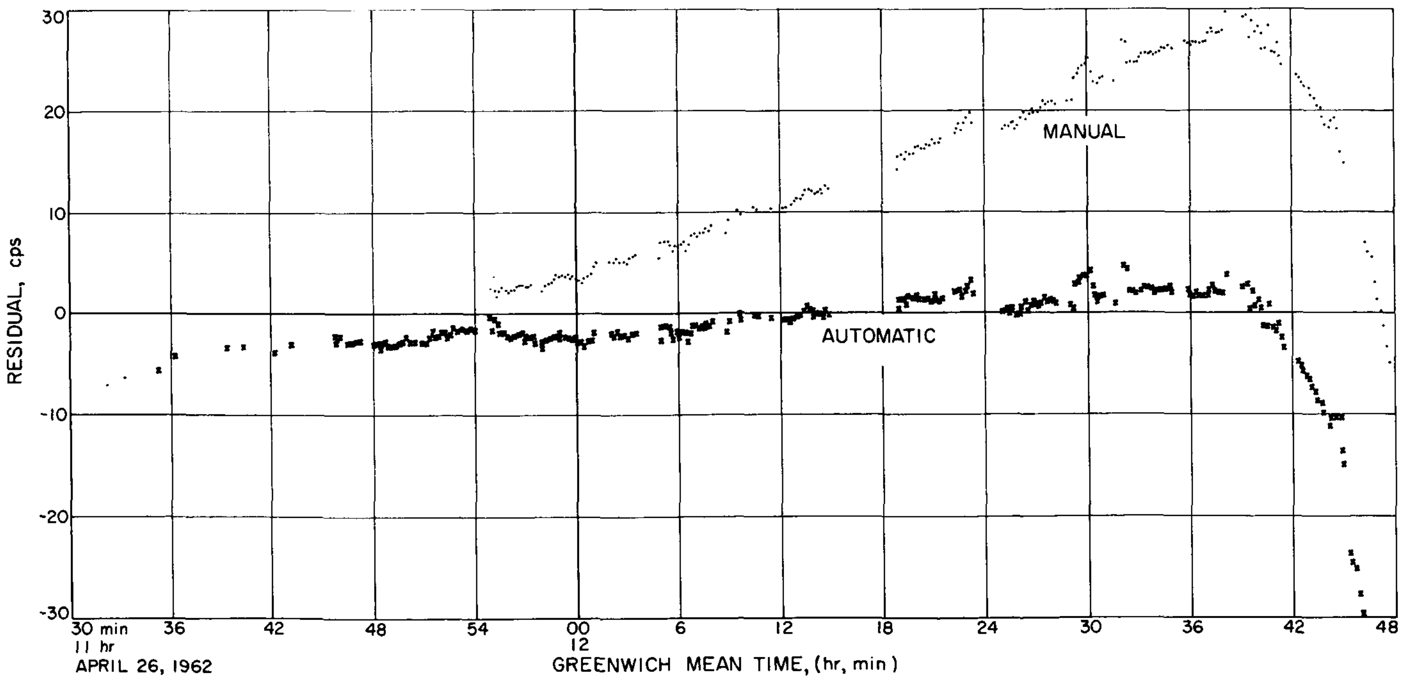

Fig. 39. Residuals on reconstructed data using manual recordings vs residuals on extrapolated automatic recordings (Station 3)

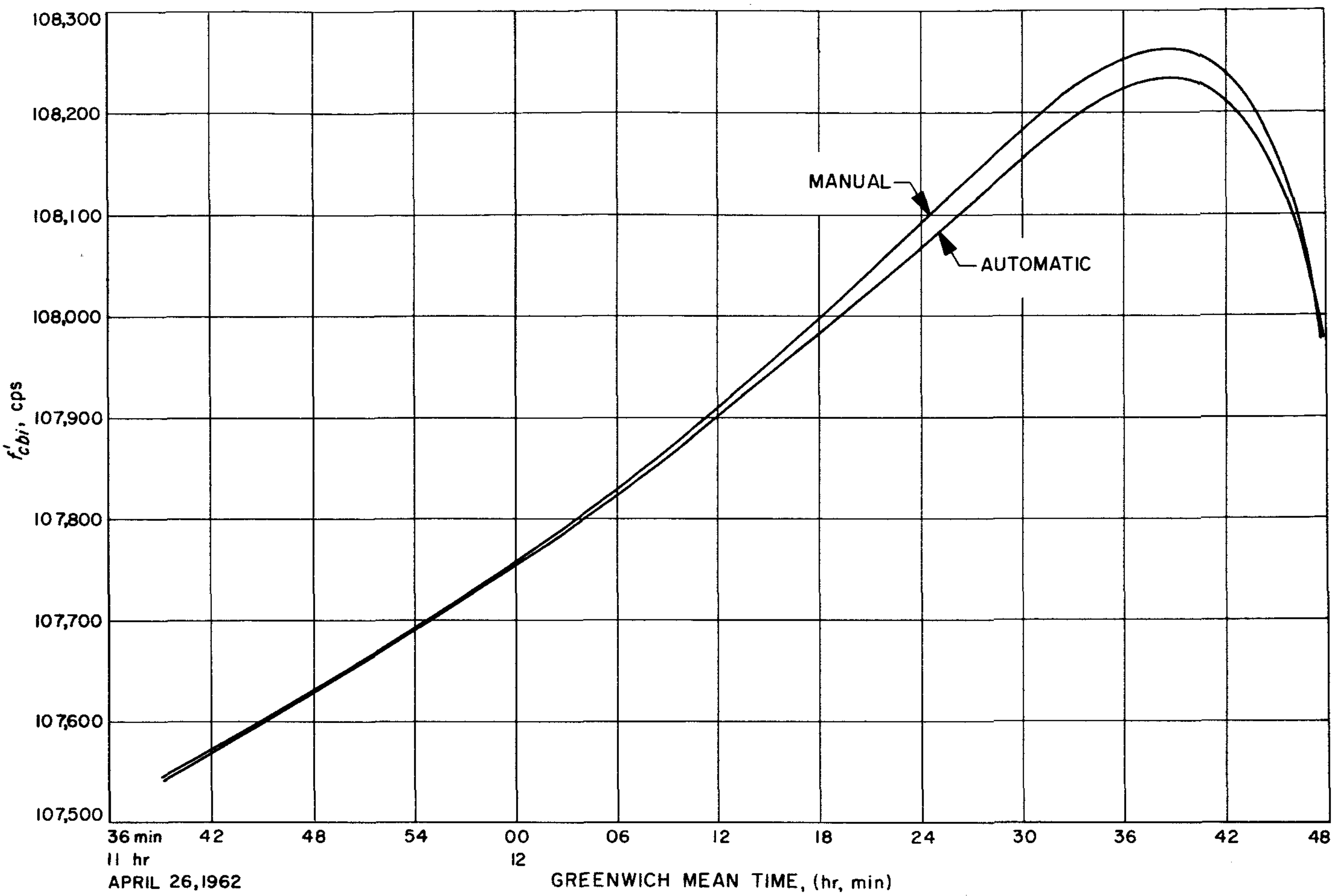

Fig. 40. Calculated beacon data—manual recordings vs automatic recordings of bias oscillator at Station 3

points taken at Station 3. It appears evident that these observations are consistent with their expected variation based on the uncertainties in the transponder orbit. No more careful comparison can be made at this time until our computing programs have added flexibility.

Referring to Fig. 40, the assumption that the manual recordings give the correct bias oscillator frequency leads to a moderately different doppler curve. Since the offset of the beacon transmitter frequency f_{T_0} is uncertain to ± 20 cycles, the calculated doppler frequency curves have a constant offset uncertainty of ± 20 cycles. This is due to lack of complete calibrations of the bias oscillator frequency in the region where the slope was evaluated. Considering this additional factor, it appears that either of the two doppler curves in Fig. 40 is reasonably consistent with the predicted values.

Figures 44, 45, and 46 show some of the residual plots for Stations 2, 3, and 5. Figure 44 shows the wide oscillations due to the (uncompensated) effect of the bias oscillator frequency variations evident in Fig. 38. Figure 45 shows the residuals at Station 5 (South Africa) during an interval where the bias oscillator was reported steady. It can be seen that the slope chosen to represent the capsule crystal frequency fits the observations well; the bias is due to fixed offset in a reference oscillator. Figure 46 shows the Station 3 residuals during the final pass. Note that they are stable for the first two hours and then start drifting off as indicated by the bias oscillator log (Fig. 38).

C. *Verification by Time of Signal Loss*

1. Observational Records

The primary evidence of occultation of the capsule by the Moon is the loss of received signal at the ground station. Various functions related to the received signal are recorded by the DSIF on magnetic tape and independently on direct-write oscillographs.

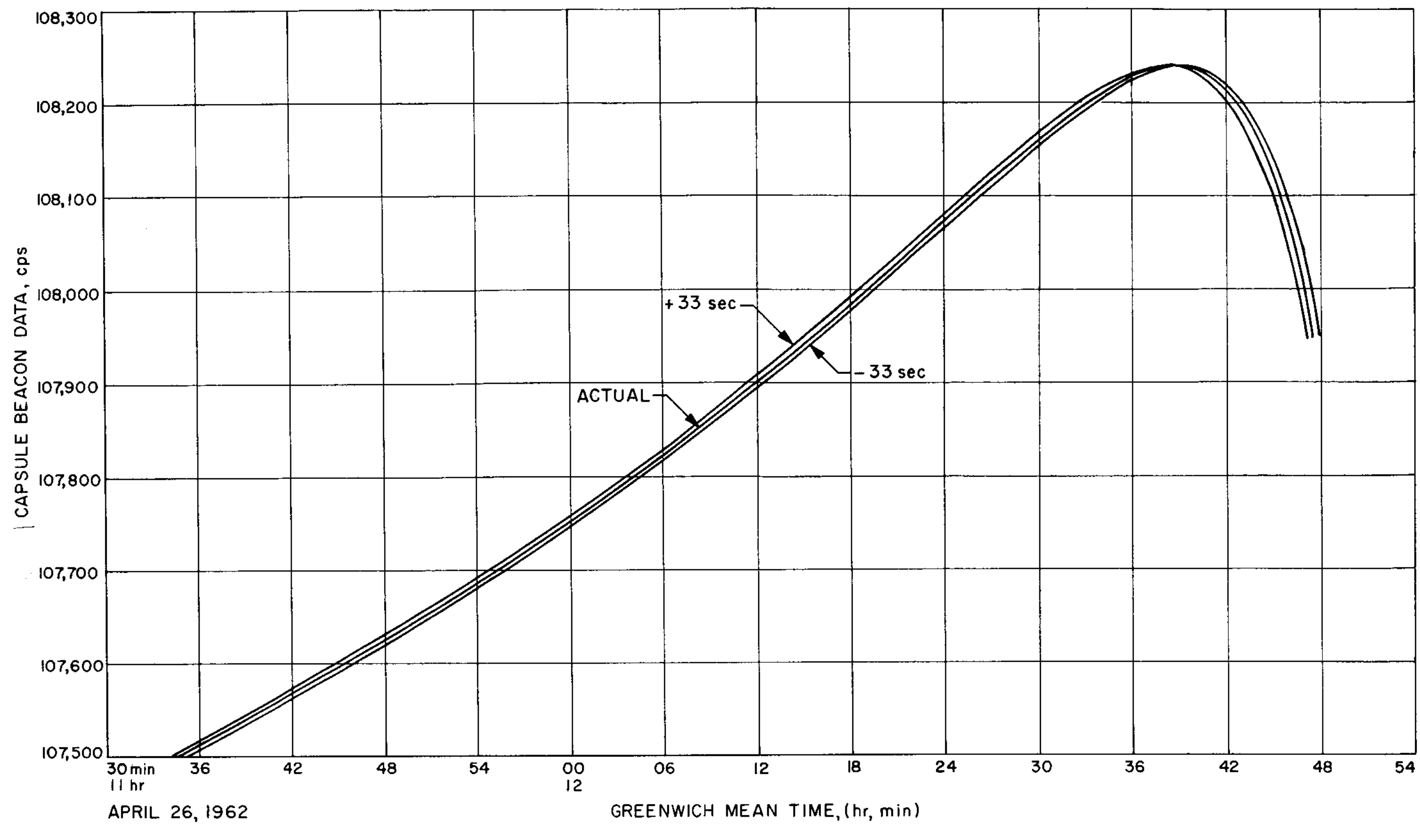

Fig. 41. Actual data vs perturbations in T_L

Figure 47 is a recording of the receiver functions recorded on magnetic tape at DSIF-2 for the last few seconds prior to occultation. Figure 48 is a reproduction of the DSIF-3 direct-write oscillograph record for the same time. It is included to illustrate both types of records from which occultation time was determined.

In Figure 47, the trace labeled *signal strength* is the one of critical interest. At the time noted by the arrow 124747, the signal started to decay. The rate of decay is characteristic of the 10-sec time constant of the receiver.

The time associated with the event is determined from a binary-coded-decimal (BCD) time code which records days, hours, and minutes, and from a 1-pps time code. Both the BCD code and the 1-pps code are derived from the station secondary standard which is synchronized to WWV. In Fig. 48, the BCD code may be seen at the top of the trace. In the case of Fig. 47, which is a playback of the magnetic tape, the mechanization of the playback recorder precludes the recording of the BCD code, so that only the 1-pps code appears at the top of the trace.

In Fig. 48, the channel labeled Acquisition Relay is an event channel which marks loss of receiver lock, i.e., loss of signal. The time shown on the figure is the time of change of state of this relay. It is consistent with the time of signal tail-off as shown on Fig. 47. The rate of tail-off is lower at Station 3 since the AGC time constant is longer, i.e., 300 sec.

The conclusion is that, neglecting signal time-of-flight, the capsule signal was occulted by the Moon at 124747. The accuracy to which this time can be determined is approximately ± 0.3 sec/RMS.

2. Discussion of Results

The actual and predicted times of signal loss are:

Actual	$12^h47^m46^s$ GMT	April 26, 1962
Predicted	$12^h48^m10^s$ GMT	April 26, 1962

when corrected for light-time. The error of -24 sec is consistent with the expected 1-sigma variation of 26 sec described in Section IV-B4c. The confirmation given by the time the capsule beacon signal was lost significantly enhances our confidence in the accuracy of the DSIF transponder determined orbit.

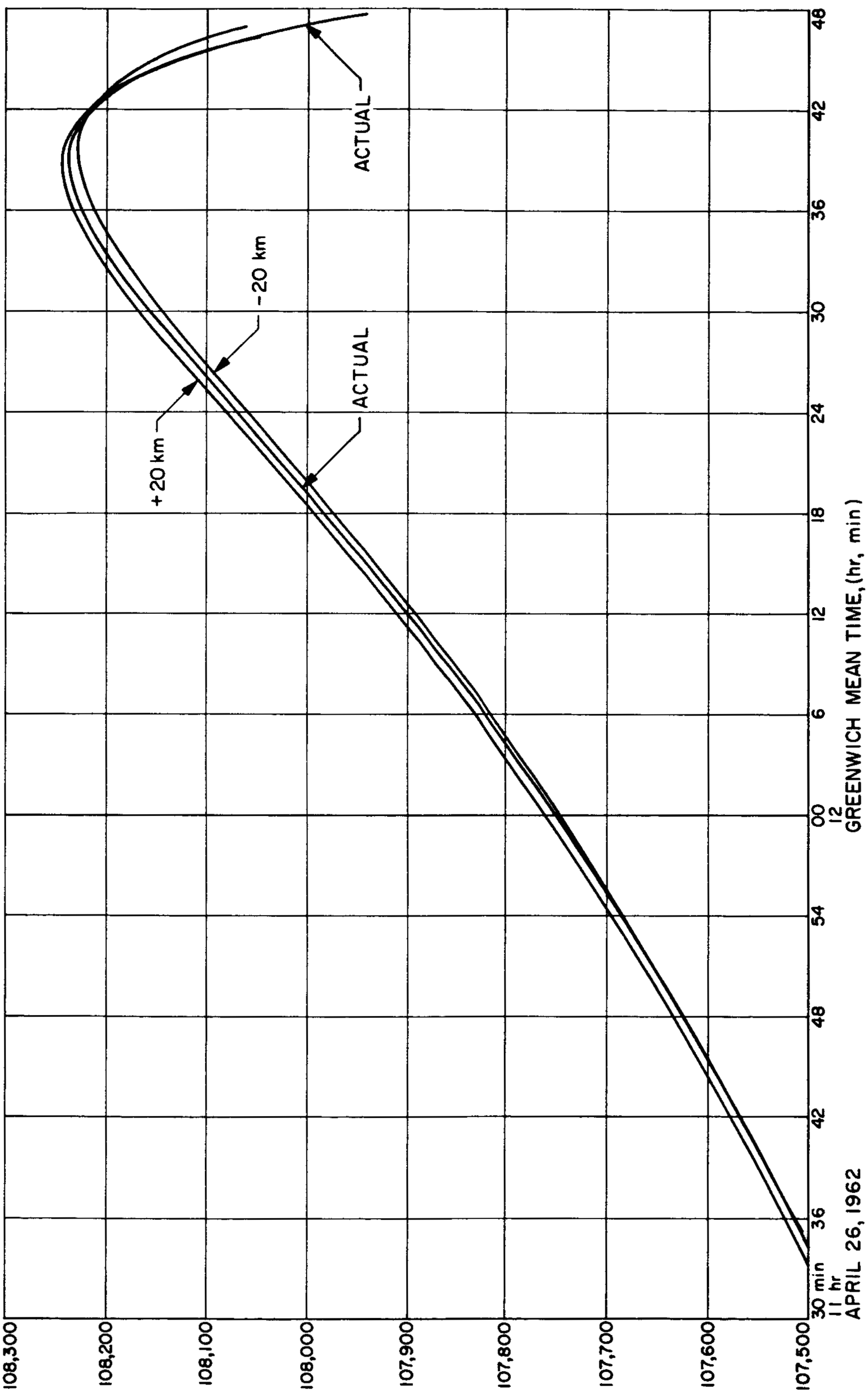

Fig. 42. Actual data vs perturbations in B · T

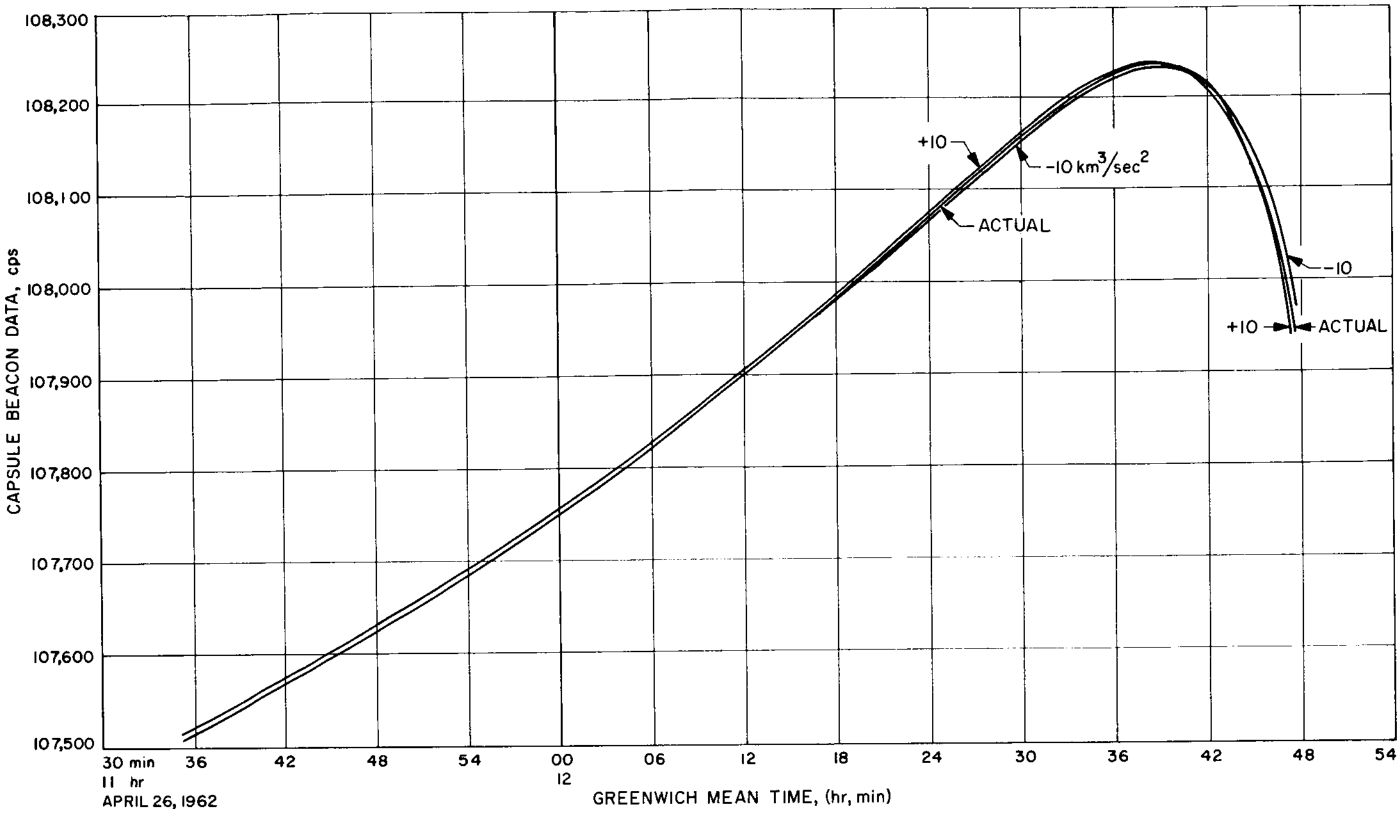

Fig. 43. Actual data vs perturbations in Moon's GM

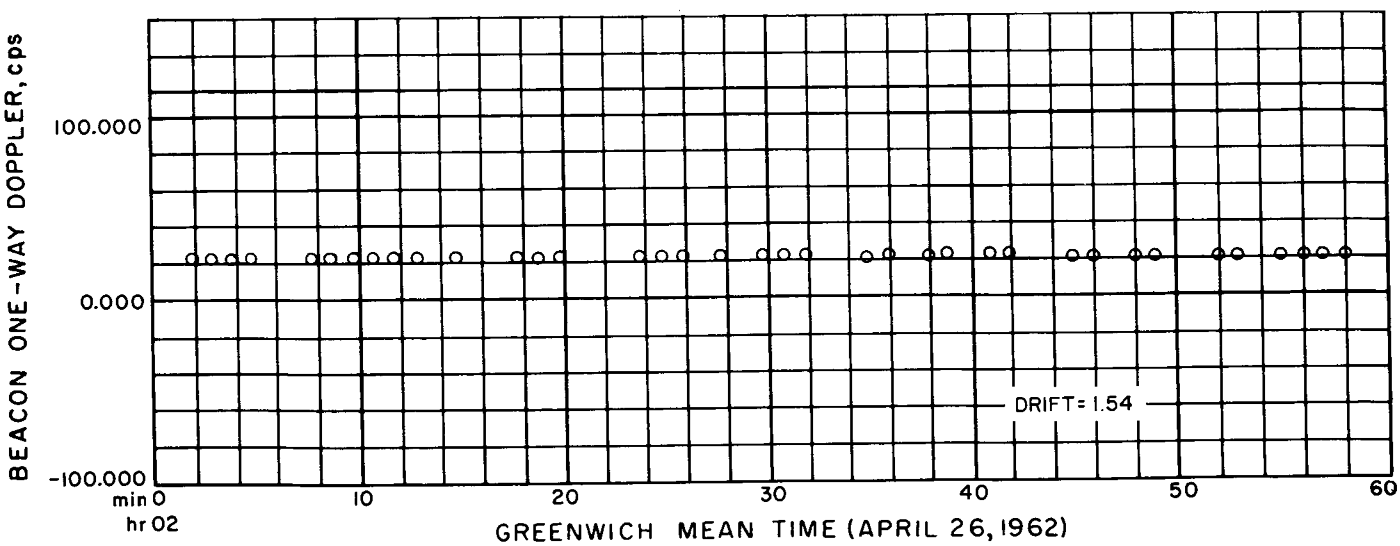

Fig. 45. Station 5 residuals (from 02:00 GMT April 26, 1962)

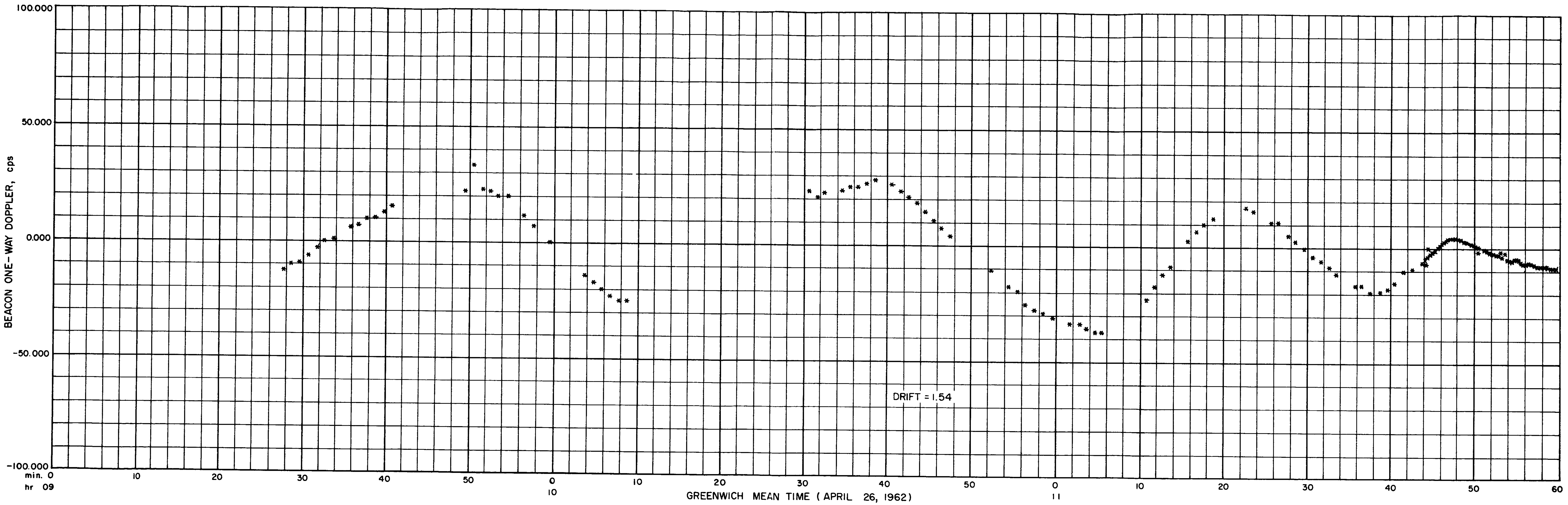

Fig. 44. Station 2 residuals (from 09:00 GMT April 26, 1962)

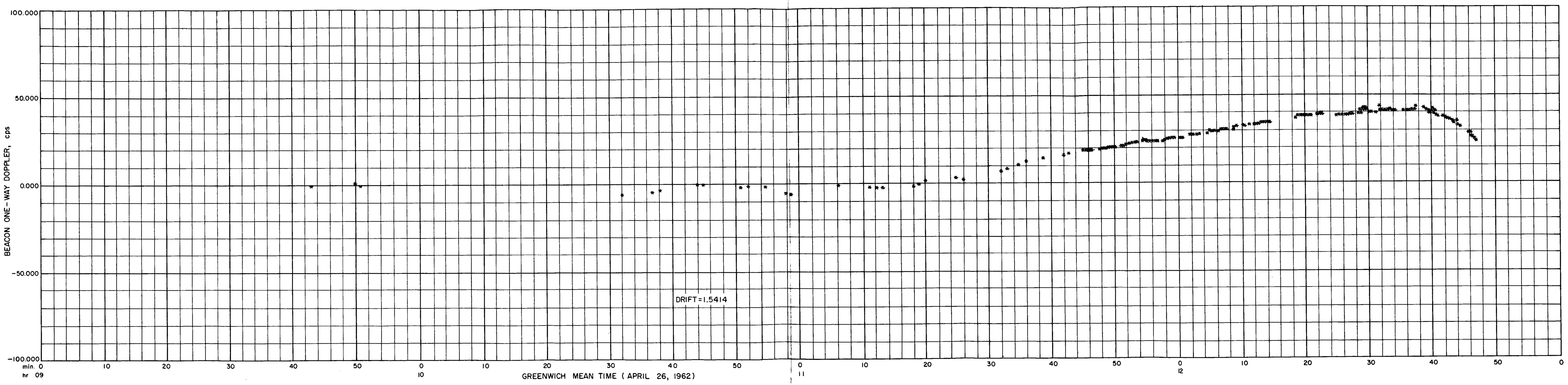

Fig. 46. Station 3 residuals (from 09:00 GMT April 26, 1962)

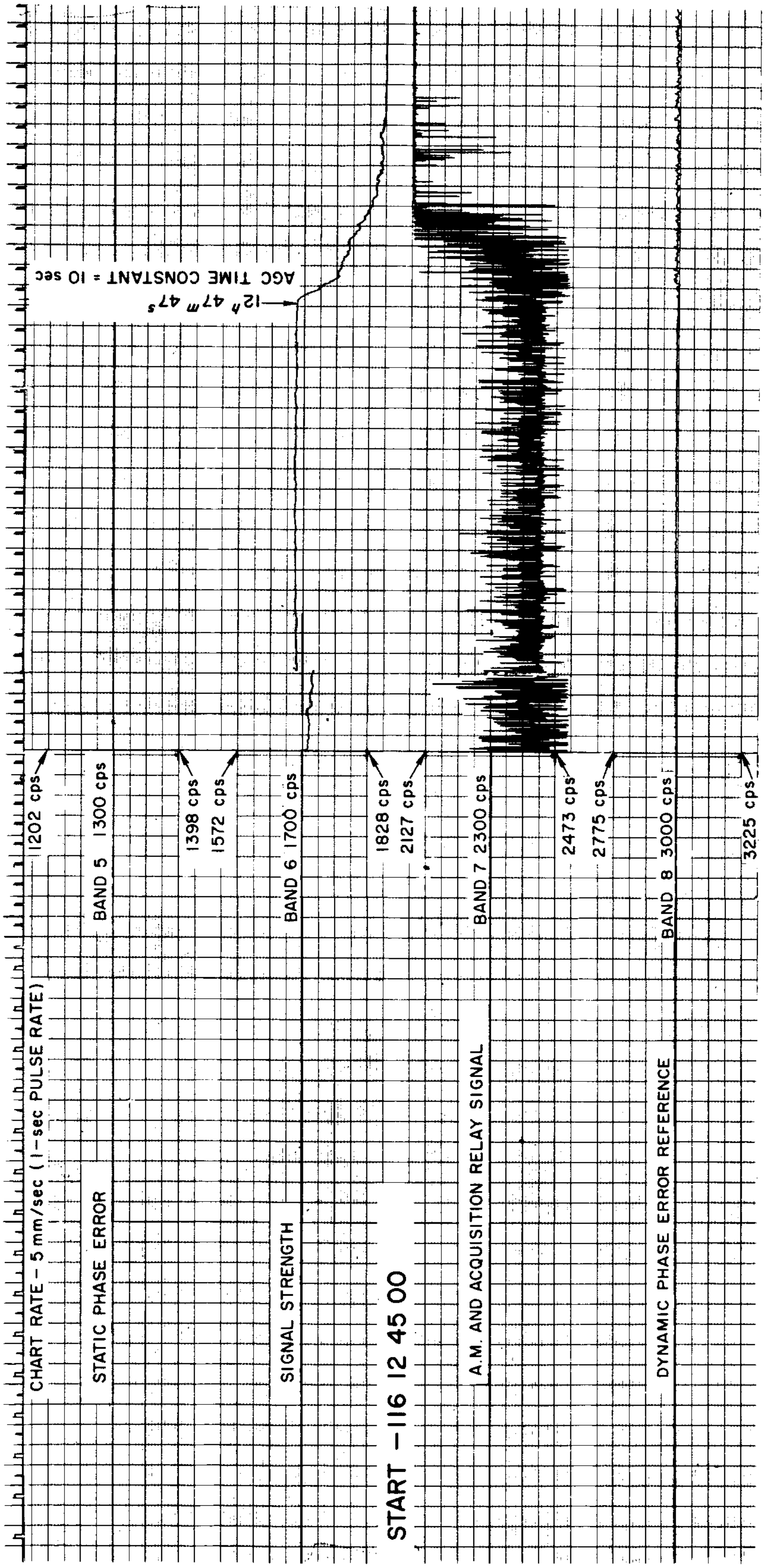

Fig. 47. *Ranger 4 Pioneer* DSIF 2 receiver functions

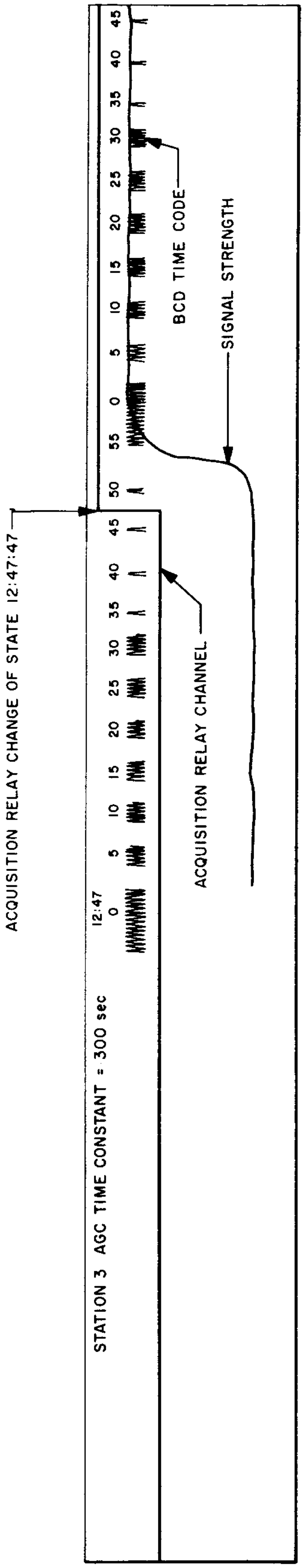

Fig. 48. Oscillograph recording of receiver functions (*Ranger 4* echo DSIF 3)

VI. FLIGHT PATH ANALYSIS OPERATION AND POLICIES

A. Introduction

The Flight Path Analysis (FPA) group is the part of the Spaceflight Operations team which performs the real-time radio guidance calculations as well as the post-flight determination of the spacecraft orbit. The functions performed are depicted in Fig. 49. It should be noted that the functions are sometimes carried on simultaneously in a single digital computer program.

B. Operational Description

1. Data Editing, Analysis, and Evaluation

Editing, analysis, and evaluation of the tracking data is accomplished in several ways.

a. Teletype (TTY) printed display of incoming data are visually scanned in real time to detect any systematic errors.

b. Station reports, both printed and verbal, are analyzed to detect any abnormalities. In addition, critical information on oscillator drift statistics, frequency changes, and changes in transmitter assignment is evaluated.

c. Newly received TTY data is periodically entered, in batches, into a large digital computer program called the Tracking Data Editing Program (TDEP). The TDEP checks the format, data condition code, data range, station, and time sequence against the input master format and control cards. All data are listed along with the reason for rejection of any data point. The new data which have not been rejected are added to the TDEP's Master Data Tape which contains all accepted data.

d. Once the orbit is reasonably well known, the deviations of the values of new observations from their predicted values (the residuals) are tested to determine whether they are within selected *rejection limits*. In this way *"blunder points"* are easily detected *before* they influence the estimate of the orbit.

e. The residuals and rejected data points are analyzed to determine the validity of the noise models and to locate any systematic error source. On the basis of the information gained from the evaluation of the incoming station reports and tracking data, corrective action is recommended to the Tracking Director.

2. Orbit Determination

The tracking data placed on the TDEP's master data tape is the basis for forming an Orbit Determination Program (ODP) data tape. Control of the information placed on the ODP data tape is exercised through input to the TDEP. The ODP and TDEP are linked in such a way that the ODP can call the TDEP to add new data to the ODP tape. The most important ODP inputs are the edited tracking data, the data weights, and rejection limits.

The policies used in editing the data, and in selecting weights and rejection limits, are described in Section VI-C. During the flight, new data points are continually being added to the ODP tape, weights are revised, and residuals from selected converged orbits are plotted and printed. The converged ODP output provides an estimate of the initial conditions and physical constants (parameters, in general) describing the flight path as well as a statistical description of the uncertainties in the parameter vector. The estimated covariance of the parameter vector is then *mapped* to other regions useful for interpretation of results. Typically, the properties of the "error ellipse" in the impact parameter plane (B-plane) are computed as well as other quantities useful in considering maneuver alternatives.

3. Trajectory Information

At all times of a typical mission trajectory, information is essential to the analysis of spacecraft performance and scientific data, to assist in tracking station acquisition, for antenna pointing, and for general information. As suggested in Fig. 1, the basis for forming these trajectory estimates varies with the amount of information available and is continually updated.

4. Maneuver Alternatives

Since the examination of the midcourse and terminal maneuver alternatives was not necessary on this flight, this function will not be discussed at length. As suggested in Fig. 49, the trajectory estimate(s), information on expected spacecraft performance and current status, statistics of current and future knowledge of the flight path, spacecraft restraints, and mission objectives dependent on the flight path are input into a digital computer program which is designed to examine the detailed results of following the available alternative maneuvers (trajectory corrections). Commands necessary to implement any of

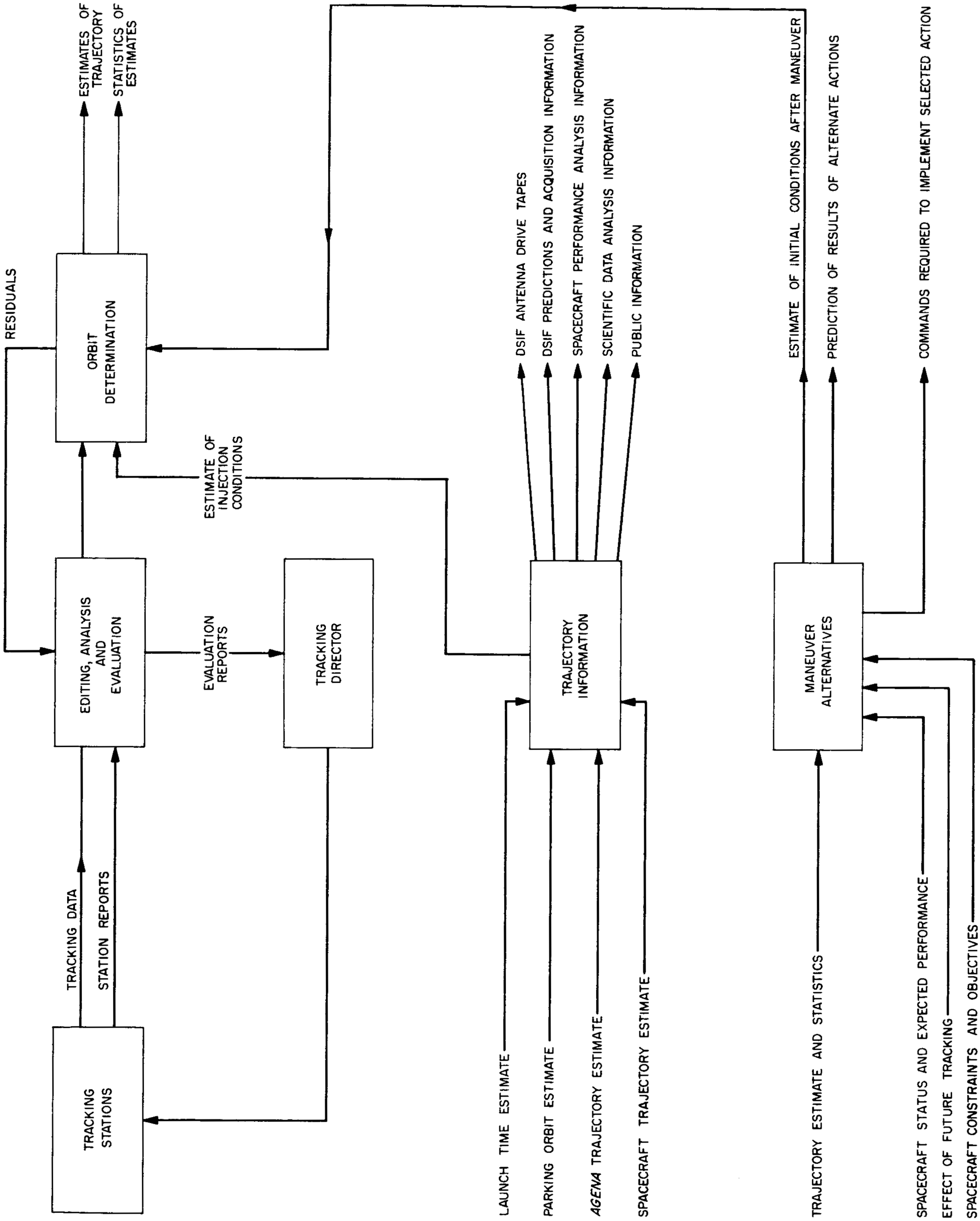

Fig. 49. FPA functions

the various alternate maneuvers are also computed and checked.

C. *In-flight Policies*

The JPL *Ranger* Orbit Determination Program (ODP) is designed to find the set of initial conditions at injection epoch which causes the weighted sum of squares of the residuals (observed minus computed) to be *minimized*. We call our method *modified*-least-squares (MLS) to call attention to the method used in obtaining the weights. In the usual least squares (LS) method, the individual data points are weighted inversely proportional to their expected (or measured) variances in forming the weighted sum of the squared residuals. In MLS, the independent weighting values are determined by the expected (or measured) *effective variances*[2]. In arriving at the effective variance for each data type at each station (vs time), consideration is given to the effective correlation width of all recognized error sources, the sampling rates, range to the spacecraft, counting time, and elevation angle. The ODP-calculated covariance matrix of injection errors will always give a conservative estimate of the accuracy when *effective variances* ("equivalent-or-worse uncorrelated noise") are used. In editing the data, our policy is that it is better to reject a data set with questionable format than to attempt the real-time correction of the error. An analogous policy is used in weighting the data; there is a maximum weight which can be assigned to any data point independent of whether it appears that the data may be dramatically better in a particular time interval. By sacrificing our possibility of extracting the maximum possible information during the flight we reduce the sensitivity to "blunder points" or small "hidden" errors whose effect may be very significant. Section IV-B summarizes our experience on *Ranger 4* in terms of the fraction of the received data which was rejected for various reasons.

[2] This approach was first used at JPL by A. R. M. Noton in August, 1959 in a JPL internal Technical Memorandum 312-522, *Effect of Correlated Data in Orbit Determination from Radio Tracking Data*. Further discussion was given by A. R. M. Noton, E. Cutting, F. Barnes (Ref. 8). T. A. Magness and J. B. McGuire have developed mathematical expressions to contrast the performance of LS, MLS, and minimum covariance estimators (under JPL Contract 950045) in terms of the eigenvalues and eigen-vectors of the data noise covariance matrix (Ref. 9).

APPENDIX A

Definition of the miss parameter B

The miss parameter **B** is used at the Jet Propulsion Laboratory to measure miss distances for lunar and interplanetary trajectories and is described by W. Kizner in Ref. 10. **B** has the desirable feature of being very nearly a linear function of changes in injection conditions.

The osculating conic at closest approach to the target body is used in defining **B**. **B** is the vector from the target's center of mass perpendicular to the incoming asymptote. Let $\mathbf{S}_I$ be a unit vector in the direction of the incoming asymptote. The orientation of **B** in the plane normal to $\mathbf{S}_I$ is described in terms of two unit vectors **R** and **T**, normal to $\mathbf{S}_I$. **T** is taken parallel to a fixed *reference plane* and **R** completes a right-handed orthogonal system. Figure A-1 illustrates the situation.

Our *Ranger 4* work has used the orbital plane of the Moon as the reference plane. If **W** is a unit vector normal to the orbital plane (**W** in direction of $\mathbf{R}_M \times \mathbf{V}_M$, where $\mathbf{R}_M$ is radius vector to Moon from Earth and $\mathbf{V}_M$ is the space-fixed velocity of the Moon relative to the Earth's center) then $\mathbf{T} = \mathbf{S}_I \times \mathbf{W}$ defines our coordinate system.

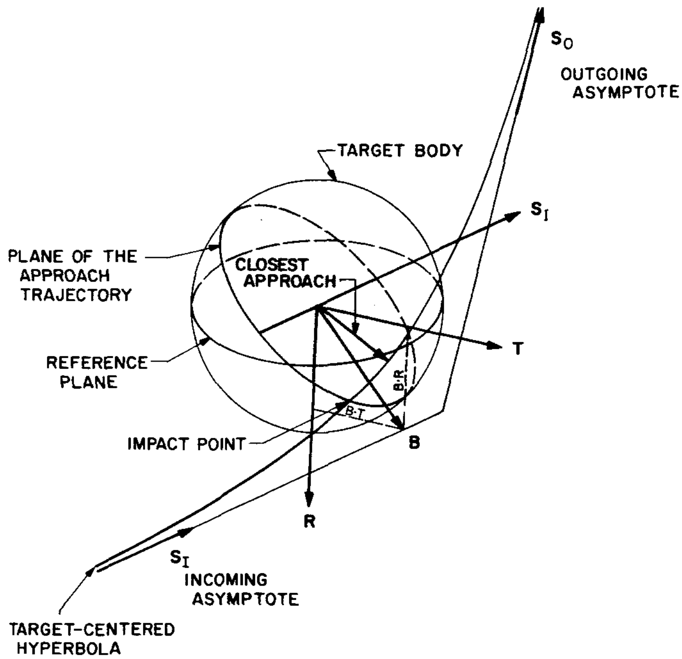

Fig. A-1. Definition of B·T, B·R system

APPENDIX B

Ranger 4 trajectory printout based on DSIF transponder orbit

```
CASE  1                                  SPACE TRAJECTORIES                                                        1

                          RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY
   EPHEMERIDES WITH VENUS VELOCITIES

  GME  .39860320 06     J  .16234500-02     H -.57499999-05     D  .78749999-05    RE  .63781650 04    REM  .63781650 04
    G  .66709998-19     A  .88745998 29     B  .88763998 29     C  .88800998 29   OME  .41780741-02     AU  .14959900 09
  GMM  .49007589 04   GMS  .13271544 12   GMV  .32476950 06   GMA  .42977799 05   GMB  .00000000 00    GMJ  .12671060 09

INJECTION CONDITIONS          MOON           JULIAN DATE 2437778.37799768              APRIL 23,1962    21 04 19.000

GEOCENTRIC        X0-.38930894 04  Y0 .50261205 04  Z0 .16529350 04 DX0-.86979759 01 DY0-.48240304 01 DZ0-.45972463 01
CARTESIAN                                           T0 .75859000 05 GHA .16750137 03 GHO .21055684 03

  0 DAYS  0 HRS.  0 MIN.  0.000 SEC.         JULIAN DATE 2437778.37799768              APRIL 23,1962    21 04 19.000

GEOCENTRIC                                                                                    EQUATORIAL COORDINATES

    X -.38930893 04     Y  .50261202 04     Z  .16529350 04    DX -.86979755 01    DY -.48240301 01     DZ -.45972462 01
    R  .65688828 04   DEC  .14574050 02    RA  .12776034 03     V  .10957222 02   PTH  .16057194 01     AZ  .11616584 03
    R  .65688828 04   LAT  .14574050 02   LON  .32025897 03    VE  .10543285 02   PTE  .16687783 01    AZE  .11727733 03
   XS  .12585905 09    YS  .75630276 08    ZS  .32795152 08   DXS -.15823241 02   DYS  .22958091 02    DZS  .99543703 01
   XM -.81001605 05    YM -.35864251 06    ZM -.12461998 06   DXM  .99683747 00   DYM -.13864919 00    DZM -.11693229 00
   XT -.81001605 05    YT -.35864251 06    ZT -.12461998 06   DXT  .99683747 00   DYT -.13864919 00    DZT -.11693229 00
   RS  .15045252 09    VS  .29606391 02    RM  .38822139 06    VM  .10132037 01    RT  .38822139 06     VT  .10132037 01
  GED  .14669099 02   ALT  .19204352 03   LOS  .22350081 03   RAS  .31002181 02   RAM  .25727293 03    LOM  .89771561 02
  DUT  .34000000 02    DT  .15000000 02    DR  .30703719 00   SHA  .65584625 04   DES  .12590225 02    DEM -.18723552 02

GEOCENTRIC                                        CONIC        ORBITAL B.T AND B.R            EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE                  JULIAN DATE 2437778.37760476              APRIL 23,1962    21 03 45.053
  SMA  .30654356 06   ECC  .97858813 00   INC  .29698774 02   LAN  .33487970 03   APF  .14622976 03    RCA  .65636683 04
   VH  .11862434 00    C3 -.13003150 01    C1  .71948444 05   SLR  .12986796 05   APO  .60652344 06    TFP  .33947350 02
   TA  .32465848 01    EA  .33782285 00    MA  .72353677-02   DAO  .15985688 02   RAO  .12472946 03    MTA  .18000000 03
   WX -.21032427 00    WY -.44858062 00    WZ  .86864211 00    PX -.54767205 00    PY  .79007062 00     PZ  .27539724 00
   QX -.80982647 00    QY -.41780829 00    QZ -.41184609 00    RX  .33828478-01    RY  .34978968 00     RZ -.93621723 00
  SXO -.54767205 00   SYO  .79007062 00   SZO  .27539724 00    TX  .83600894 00    TY  .50342379 00     TZ  .21829694 00
   BX  .80982652 00    BY  .41780832 00    BZ  .41184611 00    MX -.77751032 00    MY -.46188203 00     MZ -.42678176 00
  B.T  .61660632 05   B.R -.13378554 05     B  .63095319 05   PER  .28151174 05   OMD  .99809485-02    NOD -.62537497-02

HELIOCENTRIC                                                                                  EQUATORIAL COORDINATES

    X -.12586294 09     Y -.75625249 08     Z -.32793499 08    DX  .71252656 01    DY -.27782121 02     DZ -.14551616 02
    R  .15045289 09   LAT -.12589549 02   LON  .21099971 03     V  .32161548 02   PTH  .20333709 02     AZ  .11430829 03
   XE -.12585905 09    YE -.75630276 08    ZE -.32795152 08   DXE  .15823241 02   DYE -.22958091 02    DZE -.99543703 01
   XT -.12594005 09    YT -.75988918 08    ZT -.32919772 08   DXT  .16820078 02   DYT -.23096740 02    DZT -.10071303 02
  LTE -.12590225 02   LOE  .21100218 03   LTT -.12615378 02   LOT  .21110567 03   RST  .15072798 09    VST  .30295306 02
  EPS  .86769819 02   ESP  .27453512-18   SEP  .93227681 02   EPM  .47680428 02   EMP  .71682454 00    MEP  .13160272 03
  MPS  .13442655 03   MSP  .10653118 00   SMP  .45466863 02   SEM  .13514533 03   EMS  .44750584 02    ESM  .10397499 00
  EPT  .47680428 02   ETP  .71682454 00   TEP  .13160272 03   TPS  .13442655 03   TSP  .10653118 00    STP  .45466863 02
  SET  .13514533 03   STE  .44750584 02   EST  .10397499 00   RPM  .39261360 06   RPT  .39261360 06    SPN  .10616088 02

  0 DAYS  0 HRS.  5 MIN.  0.000 SEC.         JULIAN DATE 2437778.38146991              APRIL 23,1962    21 09 19.000
```

CASE 1 SPACE TRAJECTORIES 2

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC EQUATORIAL COORDINATES

X	-.62174357 04	Y	.33049653 04	Z	.20109286 03	DX	-.67168266 01	DY	-.64815417 01	DZ	-.49746107 01
R	.70441281 04	DEC	.16358781 01	RA	.15200649 03	V	.10576998 02	PTH	.15044831 02	AZ	.11966262 03
R	.70441281 04	LAT	.16358781 01	LON	.34325170 03	VE	.10149963 02	PTE	.15693767 02	AZE	.12115274 03
XS	.12585430 09	YS	.75637164 08	ZS	.32798139 08	DXS	-.15824710 02	DYS	.22957216 02	DZS	.99539900 01
XM	-.80702529 05	YM	-.35868400 06	ZM	-.12465502 06	DXM	.99699762 00	DYM	-.13790786 00	DZM	-.11667509 00
XT	-.80702529 05	YT	-.35868400 06	ZT	-.12465502 06	DXT	.99699762 00	DYT	-.13790786 00	DZT	-.11667509 00
RS	.15045266 09	VS	.29606370 02	RM	.38820868 06	VM	.10132304 01	RT	.38820868 06	VT	.10132304 01
GED	.16470201 01	ALT	.66593945 03	LOS	.22225064 03	RAS	.31005439 02	RAM	.25731982 03	LOM	.88565025 02
CUT	.34000000 02	DT	.30000000 02	DR	.27455219 01	SHA	.61156154 04	DES	.12591378 02	DEM	-.18729649 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12586052 09	Y	-.75633859 08	Z	-.32797937 08	DX	.91078836 01	DY	-.29438758 02	DZ	-.14928601 02
R	.15045616 09	LAT	-.12591003 02	LON	.21100308 03	V	.34241161 02	PTH	.17741512 02	AZ	.11342649 03
XE	-.12585430 09	YE	-.75637164 08	ZE	-.32798139 08	DXE	.15824710 02	DYE	-.22957216 02	DZE	-.99539900 01
XT	-.12593501 09	YT	-.75995848 08	ZT	-.32922794 08	DXT	.16821708 02	DYT	-.23095124 02	DZT	-.10070665 02
LTE	-.12591378 02	LOE	.21100543 03	LTT	-.12616561 02	LOT	.21110900 03	RST	.15072792 09	VST	.30294767 02
EPS	.60246223 02	ESP	.27453512-18	SEP	.11975145 03	EPM	.73979462 02	EMP	.99933908 00	MEP	.10502122 03
MPS	.13410525 03	MSP	.10630134 00	SMP	.45788267 02	SEM	.13510420 03	EMS	.44791637 02	ESM	.10397499 00
EPT	.73979462 02	ETP	.99933908 00	TEP	.10502122 03	TPS	.13410525 03	TSP	.10630134 00	STP	.45788267 02
SET	.13510420 03	STE	.44791637 02	EST	.10397499 00	RPM	.39009368 06	RPT	.39009368 06	SPN	-.46357050 01

0 DAYS 0 HRS. 10 MIN. 0.000 SEC. JULIAN DATE 2437778.38494213 APRIL 23,1962 21 14 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	-.79249038 04	Y	.12392433 04	Z	-.12793959 04	DX	-.47286271 01	DY	-.71467783 01	DZ	-.48363469 01
R	.81226028 04	DEC	-.90624323 01	RA	.17111244 03	V	.98400510 01	PTH	.25814556 02	AZ	.11840662 03
R	.81226028 04	LAT	-.90624323 01	LON	.11042298 01	VE	.93837070 01	PTE	.27170303 02	AZE	.12031673 03
XS	.12584956 09	YS	.75644051 08	ZS	.32801124 08	DXS	-.15826180 02	DYS	.22956341 02	DZS	.99536096 01
XM	-.80403405 05	YM	-.35872525 06	ZM	-.12468998 06	DXM	.99715717 00	DYM	-.13716637 00	DZM	-.11641779 00
XT	-.80403405 05	YT	-.35872525 06	ZT	-.12468998 06	DXT	.99715717 00	DYT	-.13716637 00	DZT	-.11641779 00
RS	.15045281 09	VS	.29606349 02	RM	.38819596 06	VM	.10132572 01	RT	.38819596 06	VT	.10132572 01
GED	-.91231555 01	ALT	.17449321 04	LOS	.22100048 03	RAS	.31008697 02	RAM	.25736671 03	LOM	.87358497 02
CUT	.34000000 02	DT	.59999999 02	DR	.42849467 01	SHA	.51456417 04	DES	.12592531 02	DEM	-.18735735 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12585748 09	Y	-.75642812 08	Z	-.32802404 08	DX	.11097552 02	DY	-.30103119 02	DZ	-.14789956 02
R	.15045909 09	LAT	-.12592496 02	LON	.21100669 03	V	.35328406 02	PTH	.14885906 02	AZ	.11261123 03
XE	-.12584956 09	YE	-.75644051 08	ZE	-.32801124 08	DXE	.15826180 02	DYE	-.22956341 02	DZE	-.99536096 01
XT	-.12592996 09	YT	-.76002776 08	ZT	-.32925814 08	DXT	.16823337 02	DYT	-.23093507 02	DZT	-.10070027 02
LTE	-.12592531 02	LOE	.21100869 03	LTT	-.12617743 02	LOT	.21111232 03	RST	.15072785 09	VST	.30294227 02
EPS	.39306611 02	ESP	.27453512-18	SEP	.14069143 03	EPM	.95218637 02	EMP	.11939682 01	MEP	.83587386 02
MPS	.13387923 03	MSP	.10630134 00	SMP	.46014623 02	SEM	.13506307 03	EMS	.44832692 02	ESM	.10397499 00
EPT	.95218637 02	ETP	.11939682 01	TEP	.83587386 02	TPS	.13387923 03	TSP	.10630134 00	STP	.46014623 02
SET	.13506307 03	STE	.44832692 02	EST	.10397499 00	RPM	.38737287 06	RPT	.38737287 06	SPN	-.12434074 02

0 DAYS 0 HRS. 20 MIN. 0.000 SEC. JULIAN DATE 2437778.39188657 APRIL 23,1962 21 24 19.000

CASE 1 SPACE TRAJECTORIES 3

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC EQUATORIAL COORDINATES

X	-.99037209 04	Y	-.30502711 04	Z	-.39737249 04	DX	-.21721846 01	DY	-.69795193 01	DZ	-.41297783 01
R	.11098573 05	DEC	-.20979827 02	RA	.19711843 03	V	.83956622 01	PTH	.39454631 02	AZ	.11151251 03
R	.11098573 05	LAT	-.20979828 02	LON	.24603373 02	VE	.78704131 01	PTE	.42677909 02	AZE	.11425754 03
XS	.12584006 09	YS	.75657824 08	ZS	.32807096 08	DXS	-.15829118 02	DYS	.22954590 02	DZS	.99528489 01
XM	-.79805017 05	YM	-.35880711 06	ZM	-.12475968 06	DXM	.99747449 00	DYM	-.13568290 00	DZM	-.11590289 00
XT	-.79805017 05	YT	-.35880711 06	ZT	-.12475968 06	DXT	.99747449 00	DYT	-.13568290 00	DZT	-.11590289 00
RS	.15045309 09	VS	.29606306 02	RM	.38817053 06	VM	.10133107 01	RT	.38817053 06	VT	.10133107 01
GED	-.21110246 02	ALT	.47231348 04	LOS	.21850015 03	RAS	.31015212 02	RAM	.25746052 03	LOM	.84945457 02
DUT	.34000000 02	DT	.12000000 03	DR	.53351666 01	SHA	.30053763 04	DES	.12594837 02	DEM	-.18747871 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12584997 09	Y	-.75660874 08	Z	-.32811070 08	DX	.13656933 02	DY	-.29934109 02	DZ	-.14082627 02
R	.15046377 09	LAT	-.12595478 02	LON	.21101424 03	V	.35789427 02	PTH	.10790595 02	AZ	.11158371 03
XE	-.12584006 09	YE	-.75657824 08	ZE	-.32807096 08	DXE	.15829118 02	DYE	-.22954590 02	DZE	-.99528489 01
XT	-.12591987 09	YT	-.76016631 08	ZT	-.32931856 08	DXT	.16826592 02	DYT	-.23090273 02	DZT	-.10068752 02
LTE	-.12594837 02	LOE	.21101521 03	LTT	-.12620108 02	LOT	.21111898 03	RST	.15072773 09	VST	.30293145 02
EPS	.15710104 02	ESP	.98911702-02	SEP	.16428875 03	EPM	.12215708 03	EMP	.13869862 01	MEP	.56455892 02
MPS	.13363325 03	MSP	.10514460 00	SMP	.46261606 02	SEM	.13498081 03	EMS	.44914813 02	ESM	.10444440 00
EPT	.12215708 03	ETP	.13869862 01	TEP	.56455892 02	TPS	.13363325 03	TSP	.10514460 00	STP	.46261606 02
SET	.13498081 03	STE	.44914813 02	EST	.10444440 00	RPM	.38214966 06	RPT	.38214966 06	SPN	-.19366312 02

0 DAYS 0 HRS. 40 MIN. 0.000 SEC. JULIAN DATE 2437778.40577546 APRIL 23,1962 21 44 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	-.11130819 05	Y	-.10741573 05	Z	-.82415521 04	DX	-.26653217 00	DY	-.58720259 01	DZ	-.30956743 01
R	.17527113 05	DEC	-.28048405 02	RA	.22398046 03	V	.66434122 01	PTH	.51839502 02	AZ	.10016676 03
R	.17527113 05	LAT	-.28048405 02	LON	.46451707 02	VE	.60243257 01	PTE	.60121647 02	AZE	.10397080 03
XS	.12582106 09	YS	.75685370 08	ZS	.32819040 08	DXS	-.15834994 02	DYS	.22951087 02	DZS	.99513268 01
XM	-.78607664 05	YM	-.35896815 06	ZM	-.12489814 06	DXM	.99810191 00	DYM	-.13271403 00	DZM	-.11487191 00
XT	-.78607664 05	YT	-.35896815 06	ZT	-.12489814 06	DXT	.99810191 00	DYT	-.13271403 00	DZT	-.11487191 00
RS	.15045366 09	VS	.29606221 02	RM	.38811962 06	VM	.10134180 01	RT	.38811962 06	VT	.10134180 01
GED	-.28210197 02	ALT	.11153682 05	LOS	.21349949 03	RAS	.31028244 02	RAM	.25764821 03	LOM	.80119457 02
DUT	.34000000 02	DT	.12000000 03	DR	.52236027 01	SHA	.58845663 04	DES	.12599449 02	DEM	-.18772010 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12583219 09	Y	-.75696111 08	Z	-.32827281 08	DX	.15568462 02	DY	-.28823113 02	DZ	-.13047001 02
R	.15047017 09	LAT	-.12601260 02	LON	.21102959 03	V	.35261496 02	PTH	.70486006 01	AZ	.11075582 03
XE	-.12582106 09	YE	-.75685370 08	ZE	-.32819040 08	DXE	.15834994 02	DYE	-.22951087 02	DZE	-.99513268 01
XT	-.12589967 09	YT	-.76044338 08	ZT	-.32943938 08	DXT	.16833096 02	DYT	-.23083801 02	DZT	-.10066199 02
LTE	-.12599449 02	LOE	.21102824 03	LTT	-.12624835 02	LOT	.21113228 03	RST	.15072747 09	VST	.30290978 02
EPS	.19615343 02	ESP	.27453512-18	SEP	.16038241 03	EPM	.14643047 03	EMP	.14308762 01	MEP	.32138665 02
MPS	.13350651 03	MSP	.10302974 00	SMP	.46390541 02	SEM	.13481625 03	EMS	.45079091 02	ESM	.10491172 00
EPT	.14643047 03	ETP	.14308762 01	TEP	.32138665 02	TPS	.13350651 03	TSP	.10302974 00	STP	.46390541 02
SET	.13481625 03	STE	.45079091 02	EST	.10491172 00	RPM	.37339474 06	RPT	.37339474 06	SPN	-.17241495 01

0 DAYS 1 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437778.41966435 APRIL 23,1962 22 04 19.000

GASE 1 SPACE TRAJECTORIES 4

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GECCENTRIC EQUATORIAL COORDINATES

X	-.11010598 C5	Y	-.17287770 05	Z	-.11591394 05	DX	.37217164 00	DY	-.50917754 01	DZ	-.25379640 01
R	.23546989 C5	CEC	-.29489661 02	RA	.23750690 03	V	.57014077 01	PTH	.57595638 02	AZ	.93630356 02
R	.23546989 C5	LAT	-.29489662 02	LON	.54964453 02	VE	.50621289 01	PTE	.71972711 02	AZE	.97093748 02
XS	.12580206 09	YS	.75712910 08	ZS	.32830981 08	DXS	-.15840870 02	DYS	.22947584 02	DZS	.99498042 01
XM	-.77409564 05	YM	-.35912562 06	ZM	-.12503537 06	DXM	.99871972 00	DYM	-.12974261 00	DZM	-.11383934 00
XT	-.77409564 C5	YT	-.35912562 06	ZT	-.12503537 06	DXT	.99871972 00	DYT	-.12974261 00	DZT	-.11383934 00
RS	.15045423 09	VS	.29606137 02	RM	.38806867 06	VM	.10135253 01	RT	.38806867 06	VT	.10135253 01
GED	-.29656693 C2	ALT	.17174015 05	LOS	.20849883 03	RAS	.31041276 02	RAM	.25783599 03	LOM	.75293550 02
CUT	.34000000 02	DT	.24000000 03	DR	.48136253 01	SHA	.11698187 05	DES	.12604061 02	DEM	-.18795967 02

HELICCENTRIC EQUATORIAL COORDINATES

X	-.12581306 09	Y	-.75730197 08	Z	-.32842572 08	DX	.16213042 02	DY	-.28039359 02	DZ	-.12487788 02
R	.15047466 09	LAT	-.12606844 02	LON	.21104483 03	V	.34713301 02	PTH	.54239385 01	AZ	.11042925 03
XE	-.12580206 C9	YE	-.75712910 08	ZE	-.32830981 08	DXE	.15840870 02	DYE	-.22947584 02	DZE	-.99498042 01
XT	-.12587946 C9	YT	-.76072035 08	ZT	-.32956016 08	DXT	.16839590 02	DYT	-.23077326 02	DZT	-.10063643 02
LTE	-.12604C61 02	LOE	.21104127 03	LTT	-.12629563 02	LOT	.21114559 03	RST	.15072721 09	VST	.30288805 02
EPS	.29784178 02	ESP	.27453512-18	SEP	.15021136 03	EPM	.15729757 03	EMP	.13418254 01	MEP	.21360544 02
MPS	.13354591 03	MSP	.10111274 00	SMP	.46353176 02	SEM	.13465163 03	EMS	.45243419 02	ESM	.10514460 00
EPT	.15729757 03	ETP	.13418254 01	TEP	.21360544 02	TPS	.13354591 03	TSP	.10111274 00	STP	.46353176 02
SET	.13465163 C3	STE	.45243419 02	EST	.10514460 00	RPM	.36623963 06	RPT	.36623963 06	SPN	.14068573 02

C DAYS 1 HRS. 30 MIN. 0.000 SEC. JULIAN DATE 2437778.44049768 APRIL 23,1962 22 34 19.000

GECCENTRIC EQUATORIAL COORDINATES

X	-.99489607 04	Y	-.25732368 05	Z	-.15692801 05	DX	.74596762 00	DY	-.43524158 01	DZ	-.20656878 01
R	.31739574 05	CEC	-.29631764 02	RA	.24886189 03	V	.48751468 01	PTH	.62293094 02	AZ	.88012832 02
R	.31739574 C5	LAT	-.29631764 02	LON	.58798922 02	VE	.43243049 01	PTE	.86480850 02	AZE	.72775615 02
XS	.12577353 C9	YS	.75754214 08	ZS	.32848889 08	DXS	-.15849682 02	DYS	.22942325 02	DZS	.99475196 01
XM	-.75611C41 05	YM	-.35935516 06	ZM	-.12523888 06	DXM	.99962838 00	DYM	-.12528077 00	DZM	-.11228756 00
XT	-.75611041 05	YT	-.35935516 06	ZT	-.12523888 06	DXT	.99962838 00	DYT	-.12528077 00	DZT	-.11228756 00
RS	.15045508 09	VS	.29606010 02	RM	.38799218 06	VM	.10136867 01	RT	.38799218 06	VT	.10136867 01
GED	-.29799289 02	ALT	.25366646 05	LOS	.20099785 03	RAS	.31060826 02	RAM	.25811785 03	LOM	.68054876 02
CUT	.340CCC00 C2	DT	.24000000 03	DR	.43161507 01	SHA	.19933461 05	DES	.12610976 02	DEM	-.18831562 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12578348 C9	Y	-.75779946 08	Z	-.32864581 08	DX	.16595649 02	DY	-.27294741 02	DZ	-.12013207 02
R	.15047978 09	LAT	-.12614996 02	LON	.21106742 03	V	.34128223 02	PTH	.41957698 01	AZ	.11019772 03
XE	-.12577353 09	YE	-.75754214 08	ZE	-.32848889 08	DXE	.15849682 02	DYE	-.22942325 02	DZE	-.99475196 01
XT	-.12584914 09	YT	-.76113569 08	ZT	-.32974127 08	DXT	.16849310 02	DYT	-.23067606 02	DZT	-.10059807 02
LTE	-.12610976 C2	LOE	.21106082 03	LTT	-.12636651 02	LOT	.21116555 03	RST	.15072682 09	VST	.30285531 02
EPS	.38897466 02	ESP	.13988227-01	SEP	.14109494 03	EPM	.16510102 03	EMP	.12051427 01	MEP	.13693772 02
MPS	.13370281 03	MSP	.98167074-01	SMP	.46199016 02	SEM	.13440462 03	EMS	.45490004 02	ESM	.10560881 00
EPT	.16510102 03	ETP	.12051427 01	TEP	.13693772 02	TPS	.13370281 03	TSP	.98167074-01	STP	.46199016 02
SET	.13440462 C3	STE	.45490004 02	EST	.10560881 00	RPM	.35723383 06	RPT	.35723383 06	SPN	.27305072 02

C DAYS 3 HRS. C MIN. 0.000 SEC. JULIAN DATE 2437778.50299768 APRIL 24,1962 00 04 19.000

CASE 1

SPACE TRAJECTORIES

5

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC

EQUATORIAL COORDINATES

X	-.49788C86 C4	Y	-.45888029 05	Z	-.24891268 05	DX	.10063196 01	DY	-.32776912 01	DZ	-.14478074 01
R	.52441157 05	DEC	-.28336655 02	RA	.26380768 03	V	.37218389 01	PTH	.68370344 02	AZ	.80736554 02
R	.52441155 C5	LAT	-.28336656 02	LON	.51183062 02	VE	.40082783 01	PTE	.59672786 02	AZE	.27626424 03
XS	.12568787 C9	YS	.75878068 08	ZS	.32902589 08	DXS	-.15876106 02	DYS	.22926535 02	DZS	.99406582 01
XM	-.70205931 C5	YM	-.35999546 06	ZM	-.12583262 06	DXM	.10022236 01	DYM	-.11186206 00	DZM	-.10761121 00
XT	-.70205931 05	YT	-.35999546 06	ZT	-.12583262 06	DXT	.10022236 01	DYT	-.11186206 00	DZT	-.10761121 00
RS	.15045764 C9	VS	.29605632 02	RM	.38776210 06	VM	.10141722 01	RT	.38776210 06	VT	.10141722 01
GED	-.28499530 C2	ALT	.46067815 05	LOS	.17849486 03	RAS	.31119479 02	RAM	.25896474 03	LOM	.46340120 02
CUT	.34000C00 C2	DT	.48000000 03	DR	.34597687 01	SHA	.40961857 05	DES	.12631714 02	DEM	-.18935881 02

HELIOCENTRIC

EQUATORIAL COORDINATES

X	-.12569284 C9	Y	-.75923956 08	Z	-.32927480 08	DX	.16882426 02	DY	-.26204226 02	DZ	-.11388465 02
R	.15049C39 C9	LAT	-.12638632 02	LON	.21113380 03	V	.33186969 02	PTH	.27833499 01	AZ	.10994976 03
XE	-.12568787 09	YE	-.75878068 08	ZE	-.32902589 08	DXE	.15876106 02	DYE	-.22926535 02	DZE	-.99406582 01
XT	-.12575807 C9	YT	-.76238063 08	ZT	-.33028422 08	DXT	.16878330 02	DYT	-.23038397 02	DZT	-.10048269 02
LTE	-.12631714 02	LOE	.21111947 03	LTT	-.12657906 02	LOT	.21122541 03	RST	.15072561 09	VST	.30275625 02
EPS	.51345924 02	ESP	.15639313-01	SEP	.12863848 03	EPM	.16799661 03	EMP	.16116918 01	MEP	.10391678 02
MPS	.13433540 03	MSP	.90923484-01	SMP	.45573150 02	SEM	.13366294 03	EMS	.46230428 02	ESM	.10630134 00
EPT	.16799661 03	ETP	.16116918 01	TEP	.10391678 02	TPS	.13433540 03	TSP	.90923484-01	STP	.45573150 02
SET	.13366294 C3	STE	.46230428 02	EST	.10630134 00	RPM	.33631415 06	RPT	.33631415 06	SPN	.44360200 02

0 DAYS 5 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437778.58633102 APRIL 24,1962 02 04 19.000

GEOCENTRIC

EQUATORIAL COORDINATES

X	.24122909 C4	Y	-.66925512 05	Z	-.33957722 05	DX	.10289458 01	DY	-.26400630 01	DZ	-.11131699 01
R	.75086418 05	DEC	-.26888040 02	RA	.27206430 03	V	.30443077 01	PTH	.71656040 02	AZ	.76901942 02
R	.75086418 05	LAT	-.26888040 02	LON	.29357544 02	VE	.48991477 01	PTE	.36144144 02	AZE	.27314606 03
XS	.12557342 09	YS	.76043070 08	ZS	.32974131 08	DXS	-.15911312 02	DYS	.22905442 02	DZS	.99314931 01
XM	-.62978327 C5	YM	-.36073625 06	ZM	-.12658484 06	DXM	.10053782 01	DYM	-.93896716-01	DZM	-.10132866 00
XT	-.62978327 05	YT	-.36073625 06	ZT	-.12658484 06	DXT	.10053782 01	DYT	-.93896716-01	DZT	-.10132866 00
RS	.15046105 09	VS	.29605129 02	RM	.38745403 06	VM	.10148248 01	RT	.38745403 06	VT	.10148248 01
GED	-.27045314 02	ALT	.68712628 05	LOS	.14849094 03	RAS	.31197694 02	RAM	.26009694 03	LOM	.17390188 02
CUT	.34000C00 C2	DT	.48000000 03	DR	.28896091 01	SHA	.64009236 05	DES	.12659345 02	DEM	-.19069164 02

HELIOCENTRIC

EQUATORIAL COORDINATES

X	-.12557101 09	Y	-.76109995 08	Z	-.33008089 08	DX	.16940258 02	DY	-.25545504 02	DZ	-.11044663 02
R	.15050031 09	LAT	-.12669237 02	LON	.21122052 03	V	.32581124 02	PTH	.21227382 01	AZ	.10983761 03
XE	-.12557342 C9	YE	-.76043070 08	ZE	-.32974131 08	DXE	.15911312 02	DYE	-.22905442 02	DZE	-.99314931 01
XT	-.12563640 09	YT	-.76403806 08	ZT	-.33100716 08	DXT	.16916691 02	DYT	-.22999338 02	DZT	-.10032822 02
LTE	-.12659345 02	LOE	.21119769 03	LTT	-.12686218 02	LOT	.21130521 03	RST	.15072393 09	VST	.30262212 02
EPS	.58457439 02	ESP	.27088086-01	SEP	.12151819 03	EPM	.16331310 03	EMP	.31899348 01	MEP	.13496943 02
MPS	.13519837 C3	MSP	.84220286-01	SMP	.44717271 02	SEM	.13267248 03	EMS	.47219221 02	ESM	.10835236 00
EPT	.16331310 03	ETP	.31899348 01	TEP	.13496943 02	TPS	.13519837 03	TSP	.84220286-01	STP	.44717271 02
SET	.13267248 03	STE	.47219221 02	EST	.10835236 00	RPM	.31492929 06	RPT	.31492929 06	SPN	.53584741 02

0 DAYS 7 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437778.66966435 APRIL 24,1962 04 04 19.000

CASE 1 SPACE TRAJECTORIES 6

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC EQUATORIAL COORDINATES

X	.97321565 04	Y	-.84542879 05	Z	-.41275824 05	DX	.10017071 01	DY	-.22810636 01	DZ	-.93442374 00
R	.94582802 05	DEC	-.25874336 02	RA	.27656670 03	V	.26607923 01	PTH	.73391331 02	AZ	.74896993 02
R	.94582802 05	LAT	-.25874336 02	LON	.37778177 01	VE	.60396120 01	PTE	.24972075 02	AZE	.27207423 03
XS	.12545873 09	YS	.76207924 08	ZS	.33045608 08	DXS	-.15946488 02	DYS	.22884305 02	DZS	.99223094 01
XM	-.55729271 05	YM	-.36134740 06	ZM	-.12729162 06	DXM	.10081806 01	DYM	-.75852415-01	DZM	-.94993522-01
XT	-.55729271 05	YT	-.36134740 06	ZT	-.12729162 06	DXT	.10081806 01	DYT	-.75852415-01	DZT	-.94993522-01
RS	.15046446 09	VS	.29604630 02	RM	.38714448 06	VM	.10154829 01	RT	.38714448 06	VT	.10154829 01
GED	-.26027451 02	ALT	.88208707 05	LOS	.11848704 03	RAS	.31275924 02	RAM	.26123255 03	LOM	.34844367 03
CUT	.34000000 02	DT	.95999999 03	DR	.25497823 01	SHA	.83845624 05	DES	.12686950 02	DEM	-.19195723 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12544900 09	Y	-.76292466 08	Z	-.33086884 08	DX	.16948196 02	DY	-.25165368 02	DZ	-.10856733 02
R	.15050825 09	LAT	-.12699304 02	LON	.21130609 03	V	.32224303 02	PTH	.18078751 01	AZ	.10978058 03
XE	-.12545873 09	YE	-.76207924 08	ZE	-.33045608 08	DXE	.15946488 02	DYE	-.22884305 02	DZE	-.99223094 01
XT	-.12551446 09	YT	-.76569271 08	ZT	-.33172899 08	DXT	.16954669 02	DYT	-.22960157 02	DZT	-.10017303 02
LTE	-.12686950 02	LOE	.21127592 03	LTT	-.12714496 02	LOT	.21138500 03	RST	.15072217 09	VST	.30248570 02
EPS	.62402102 02	ESP	.32051055-01	SEP	.11756598 03	EPM	.15943452 03	EMP	.49231942 01	MEP	.15642283 02
MPS	.13600656 03	MSP	.77883157-01	SMP	.43914970 02	SEM	.13168028 03	EMS	.48209799 02	ESM	.10992114 00
EPT	.15943452 03	ETP	.49231942 01	TEP	.15642283 02	TPS	.13600656 03	TSP	.77883157-01	STP	.43914970 02
SET	.13168028 03	STE	.48209799 02	EST	.10992114 00	RPM	.29716100 06	RPT	.29716100 06	SPN	.58535543 02

0 DAYS 10 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437778.79466435 APRIL 24,1962 07 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.20273767 05	Y	-.10721795 06	Z	-.50422303 05	DX	.95040084 00	DY	-.19449705 01	DZ	-.77328204 00
R	.12020450 06	DEC	-.24801194 02	RA	.28070760 03	V	.22987251 01	PTH	.74914331 02	AZ	.73115670 02
R	.12020450 06	LAT	-.24801194 02	LON	.32279551 03	VE	.77128150 01	PTE	.16724410 02	AZE	.27134796 03
XS	.12528621 09	YS	.76454913 08	ZS	.33152698 08	DXS	-.15999195 02	DYS	.22852518 02	DZS	.99084986 01
XM	-.44821058 05	YM	-.36201986 06	ZM	-.12826582 06	DXM	.10117180 01	DYM	-.48651097-01	DZM	-.85396571-01
XT	-.44821058 05	YT	-.36201986 06	ZT	-.12826582 06	DXT	.10117180 01	DYT	-.48651097-01	DZT	-.85396571-01
RS	.15046957 09	VS	.29603887 02	RM	.38667742 06	VM	.10164806 01	RT	.38667742 06	VT	.10164806 01
GED	-.24949696 02	ALT	.11383010 06	LOS	.73481204 02	RAS	.31393293 02	RAM	.26294221 03	LOM	.30503012 03
CUT	.34000000 02	DT	.95999999 03	DR	.22195059 01	SHA	.10989418 06	DES	.12728314 02	DEM	-.19372764 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12526594 09	Y	-.76562130 08	Z	-.33203121 08	DX	.16949596 02	DY	-.24797488 02	DZ	-.10681781 02
R	.15051831 09	LAT	-.12743800 02	LON	.21143313 03	V	.31879533 02	PTH	.15525669 01	AZ	.10972620 03
XE	-.12528621 09	YE	-.76454913 08	ZE	-.33152698 08	DXE	.15999195 02	DYE	-.22852518 02	DZE	-.99084986 01
XT	-.12533104 09	YT	-.76816932 08	ZT	-.33280964 08	DXT	.17010913 02	DYT	-.22901169 02	DZT	-.99938951 01
LTE	-.12728314 02	LOE	.21139329 03	LTT	-.12756853 02	LOT	.21150464 03	RST	.15071938 09	VST	.30227679 02
EPS	.66054334 02	ESP	.42543532-01	SEP	.11390383 03	EPM	.15518852 03	EMP	.74955759 01	MEP	.17315907 02
MPS	.13711282 03	MSP	.71326247-01	SMP	.42816222 02	SEM	.13018869 03	EMS	.49699011 02	ESM	.11234211 00
EPT	.15518852 03	ETP	.74955759 01	TEP	.17315907 02	TPS	.13711282 03	TSP	.71326247-01	STP	.42816222 02
SET	.13018869 03	STE	.49699011 02	EST	.11234211 00	RPM	.27426440 06	RPT	.27426440 06	SPN	.63012817 02

0 DAYS 15 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437779.00299768 APRIL 24,1962 12 04 19.000

CASE 1 | SPACE TRAJECTORIES | 7

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC | EQUATORIAL COORDINATES

X	.36669410 05	Y	-.13893836 06	Z	-.62814099 05	DX	.87394933 00	DY	-.16096418 01	DZ	-.61847980 00
R	.15682514 06	DEC	-.23611685 02	RA	.28478470 03	V	.19331972 01	PTH	.76291296 02	AZ	.71416859 02
R	.15682514 06	LAT	-.23611685 02	LON	.25166726 03	VE	.10219343 02	PTE	.10590101 02	AZE	.27083278 03
XS	.12499742 09	YS	.76865805 08	ZS	.33330851 08	DXS	-.16086888 02	DYS	.22799319 02	DZS	.98853865 01
XM	-.26569782 05	YM	-.36248532 06	ZM	-.12965732 06	DXM	.10158166 01	DYM	-.30068058-02	DZM	-.69167291-01
XT	-.26569782 05	YT	-.36248532 06	ZT	-.12965732 06	DXT	.10158166 01	DYT	-.30068058-02	DZT	-.69167291-01
RS	.15047808 09	VS	.29602665 02	RM	.38589193 06	VM	.10181731 01	RT	.38589193 06	VT	.10181731 01
GED	-.23754827 02	ALT	.15045040 06	LOS	.35847155 03	RAS	.31588982 02	RAM	.26580777 03	LOM	.23269034 03
DUT	.34000000 02	DT	.19200000 04	DR	.18781265 01	SHA	.14707859 06	DES	.12797133 02	DEM	-.19632984 02

HELIOCENTRIC | EQUATORIAL COORDINATES

X	-.12496075 09	Y	-.77004743 08	Z	-.33393665 08	DX	.16960838 02	DY	-.24408961 02	DZ	-.10503866 02
R	.15053258 09	LAT	-.12816939 02	LON	.21164268 03	V	.31524571 02	PTH	.13394556 01	AZ	.10966281 03
XE	-.12499742 09	YE	-.76865805 08	ZE	-.33330851 08	DXE	.16086888 02	DYE	-.22799319 02	DZE	-.98853865 01
XT	-.12502399 09	YT	-.77228290 08	ZT	-.33460508 08	DXT	.17102705 02	DYT	-.22802325 02	DZT	-.99545538 01
LTE	-.12797133 02	LOE	.21158898 03	LTT	-.12827280 02	LOT	.21170394 03	RST	.15071434 09	VST	.30191749 02
EPS	.69637732 02	ESP	.56820448-01	SEP	.11030628 03	EPM	.15032368 03	EMP	.11607531 02	MEP	.18068777 02
MPS	.13872362 03	MSP	.61373100-01	SMP	.41215747 02	SEM	.12769395 03	EMS	.52189969 02	ESM	.11682475 00
EPT	.15032368 03	ETP	.11607531 02	TEP	.18068777 02	TPS	.13872362 03	TSP	.61373100-01	STP	.41215747 02
SET	.12769395 03	STE	.52189969 02	EST	.11682475 00	RPM	.24174460 06	RPT	.24174460 06	SPN	.67306900 02

0 DAYS 20 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437779.21133102 APRIL 24,1962 17 04 19.000

GEOCENTRIC | EQUATORIAL COORDINATES

X	.51823088 05	Y	-.16587884 06	Z	-.73034156 05	DX	.81187177 00	DY	-.13971235 01	DZ	-.52346106 00
R	.18850838 06	DEC	-.22794798 02	RA	.28734960 03	V	.16985586 01	PTH	.77056952 02	AZ	.70358207 02
R	.18850838 06	LAT	-.22794798 02	LON	.17902684 03	VE	.12425759 02	PTE	.76559094 01	AZE	.27059498 03
XS	.12470706 09	YS	.77275735 08	ZS	.33508587 08	DXS	-.16174392 02	DYS	.22745844 02	DZS	.98621568 01
XM	-.82651769 04	YM	-.36212632 06	ZM	-.13075425 06	DXM	.10176376 01	DYM	.42938872-01	DZM	-.52673470-01
XT	-.82651769 04	YT	-.36212632 06	ZT	-.13075425 06	DXT	.10176376 01	DYT	.42938872-01	DZT	-.52673470-01
RS	.15048659 09	VS	.29601461 02	RM	.38509798 06	VM	.10199042 01	RT	.38509798 06	VT	.10199042 01
GED	-.22934116 02	ALT	.18213341 06	LOS	.28346199 03	RAS	.31784757 02	RAM	.26869250 03	LOM	.16036974 03
DUT	.34000000 02	DT	.19200000 04	DR	.16554037 01	SHA	.17920251 06	DES	.12865800 02	DEM	-.19848546 02

HELIOCENTRIC | EQUATORIAL COORDINATES

X	-.12465523 09	Y	-.77441613 08	Z	-.33581621 08	DX	.16986264 02	DY	-.24142968 02	DZ	-.10385618 02
R	.15054519 09	LAT	-.12889219 02	LON	.21185046 03	V	.31293403 02	PTH	.12285658 01	AZ	.10961073 03
XE	-.12470706 09	YE	-.77275735 08	ZE	-.33508587 08	DXE	.16174392 02	DYE	-.22745844 02	DZE	-.98621568 01
XT	-.12471532 09	YT	-.77637861 08	ZT	-.33639341 08	DXT	.17192029 02	DYT	-.22702905 02	DZT	-.99148303 01
LTE	-.12865800 02	LOE	.21178475 03	LTT	-.12897493 02	LOT	.21190311 03	RST	.15070884 09	VST	.30154463 02
EPS	.71853656 02	ESP	.67810450-01	SEP	.10807814 03	EPM	.14686502 03	EMP	.15519797 02	MEP	.17615181 02
MPS	.14010828 03	MSP	.51396029-01	SMP	.39839732 02	SEM	.12518819 03	EMS	.54692156 02	ESM	.11971996 00
EPT	.14686502 03	ETP	.15519797 02	TEP	.17615181 02	TPS	.14010828 03	TSP	.51396029-01	STP	.39839732 02
SET	.12518819 03	STE	.54692156 02	EST	.11971996 00	RPM	.21320244 06	RPT	.21320244 06	SPN	.69914740 02

1 DAYS 1 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437779.41966435 APRIL 24,1962 22 04 19.000

CASE 1 SPACE TRAJECTORIES 8

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC EQUATORIAL COORDINATES

X	.65959945 05	Y	-.18959020 06	Z	-.81825897 05	DX	.76034877 00	DY	-.12448643 01	DZ	-.45683056 00
R	.21677323 06	DEC	-.22177200 02	RA	.28918320 03	V	.15285652 01	PTH	.77539643 02	AZ	.69577521 02
R	.21677323 06	LAT	-.22177201 02	LON	.10565509 03	VE	.14406845 02	PTE	.59465590 01	AZE	.27046016 03
XS	.12441512 09	YS	.77684699 08	ZS	.33685904 08	DXS	-.16261704 02	DYS	.22692095 02	DZS	.98388094 01
XM	.10051462 05	YM	-.36093833 06	ZM	-.13155216 06	DXM	.10171491 01	DYM	.89085963-01	DZM	-.35949019-01
XT	.10051462 05	YT	-.36093833 06	ZT	-.13155216 06	DXT	.10171491 01	DYT	.89085963-01	DZT	-.35949019-01
RS	.15049510 09	VS	.29600276 02	RM	.38429607 06	VM	.10216755 01	RT	.38429607 06	VT	.10216755 01
GED	-.22313552 02	ALT	.21039810 06	LOS	.20845252 03	RAS	.31980620 02	RAM	.27159517 03	LOM	.88067066 02
DUT	.34000000 02	DT	.19200000 04	DR	.14925607 01	SHA	.20782143 06	DES	.12934316 02	DEM	-.20018271 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12434916 09	Y	-.77874289 08	Z	-.33767729 08	DX	.17022053 02	DY	-.23936959 02	DZ	-.10295640 02
R	.15055689 09	LAT	-.12960867 02	LON	.21205706 03	V	.31124403 02	PTH	.11623325 01	AZ	.10956268 03
XE	-.12441512 09	YE	-.77684699 08	ZE	-.33685904 08	DXE	.16261704 02	DYE	-.22692095 02	DZE	-.98388094 01
XT	-.12440506 09	YT	-.78045637 08	ZT	-.33817456 08	DXT	.17278853 02	DYT	-.22603008 02	DZT	-.98747584 01
LTE	-.12934316 02	LOE	.21198062 03	LTT	-.12967491 02	LOT	.21210214 03	RST	.15070289 09	VST	.30115870 02
EPS	.73397642 02	ESP	.79129368-01	SEP	.10652327 03	EPM	.14418600 03	EMP	.19273261 02	MEP	.16540735 02
MPS	.14131901 03	MSP	.43678226-01	SMP	.38636561 02	SEM	.12267135 03	EMS	.57205658 02	ESM	.12314410 00
EPT	.14418600 03	ETP	.19273261 02	TEP	.16540735 02	TPS	.14131901 03	TSP	.43678226-01	STP	.38636561 02
SET	.12267135 03	STE	.57205658 02	EST	.12314410 00	RPM	.18697230 06	RPT	.18697230 06	SPN	.71711619 02

1 DAYS 6 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437779.62799768 APRIL 25,1962 03 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.79240100 05	Y	-.21090410 06	Z	-.89576488 05	DX	.71625490 00	DY	-.11280128 01	DZ	-.40646102 00
R	.24245305 06	DEC	-.21682263 02	RA	.29059201 03	V	.13966547 01	PTH	.77874104 02	AZ	.68924990 02
R	.24245305 06	LAT	-.21682263 02	LON	.31858536 02	VE	.16213235 02	PTE	.48312250 01	AZE	.27037415 03
XS	.12412160 09	YS	.78092694 08	ZS	.33862800 08	DXS	-.16348826 02	DYS	.22638069 02	DZS	.98153442 01
XM	.28338321 05	YM	-.35891863 06	ZM	-.13204722 06	DXM	.10143237 01	DYM	.13533162 00	DZM	-.19029268-01
XT	.28338321 05	YT	-.35891863 06	ZT	-.13204722 06	DXT	.10143237 01	DYT	.13533162 00	DZT	-.19029268-01
RS	.15050359 09	VS	.29599109 02	RM	.38348678 06	VM	.10234888 01	RT	.38348678 06	VT	.10234888 01
GED	-.21816190 02	ALT	.23607779 06	LOS	.13344309 03	RAS	.32176573 02	RAM	.27451440 03	LOM	.15780922 02
DUT	.34000000 02	DT	.19200000 04	DR	.13654931 01	SHA	.23378843 06	DES	.13002680 02	DEM	-.20141095 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12404236 09	Y	-.78303598 08	Z	-.33952376 08	DX	.17065081 02	DY	-.23766081 02	DZ	-.10221805 02
R	.15056801 09	LAT	-.13032004 02	LON	.21226278 03	V	.30992400 02	PTH	.11202270 01	AZ	.10951627 03
XE	-.12412160 09	YE	-.78092694 08	ZE	-.33862800 08	DXE	.16348826 02	DYE	-.22638069 02	DZE	-.98153442 01
XT	-.12409326 09	YT	-.78451612 08	ZT	-.33994847 08	DXT	.17363150 02	DYT	-.22502737 02	DZT	-.98343734 01
LTE	-.13002680 02	LOE	.21217657 03	LTT	-.13037269 02	LOT	.21230102 03	RST	.15069652 09	VST	.30076021 02
EPS	.74547165 02	ESP	.89294872-01	SEP	.10536387 03	EPM	.14200467 03	EMP	.22904786 02	MEP	.15090534 02
MPS	.14239521 03	MSP	.37664454-01	SMP	.37567158 02	SEM	.12014333 03	EMS	.59730583 02	ESM	.12628203 00
EPT	.14200467 03	ETP	.22904786 02	TEP	.15090534 02	TPS	.14239521 03	TSP	.37664454-01	STP	.37567158 02
SET	.12014333 03	STE	.59730583 02	EST	.12628203 00	RPM	.16218216 06	RPT	.16218216 06	SPN	.73039761 02

1 DAYS 11 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437779.83633102 APRIL 25,1962 08 04 19.000

CASE 1

SPACE TRAJECTORIES

9

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC

EQUATORIAL COORDINATES

X	.91776808 05	Y	-.23033793 06	Z	-.96520860 05	DX	.67744622 00	DY	-.10345526 01	DZ	-.36657166 00
R	.26607296 06	DEC	-.21269847 02	RA	.29172452 03	V	.12898090 01	PTH	.78136020 02	AZ	.68310368 02
R	.26607295 06	LAT	-.21269847 02	LON	.31778570 03	VE	.17879187 02	PTE	.40484050 01	AZE	.27031484 03
XS	.12382652 09	YS	.78499715 08	ZS	.34039273 08	DXS	-.16435755 02	DYS	.22583766 02	DZS	.97917611 01
XM	.46553108 05	YM	-.35606641 06	ZM	-.13223624 06	DXM	.10091383 01	DYM	.18157161 00	DZM	-.19500911-02
XT	.46553108 05	YT	-.35606641 06	ZT	-.13223624 06	DXT	.10091383 01	DYT	.18157161 00	DZT	-.19500911-02
RS	.15051208 09	VS	.29597958 02	RM	.38267075 06	VM	.10253449 01	RT	.38267075 06	VT	.10253449 01
GED	-.21401723 02	ALT	.25969759 06	LOS	.58433796 02	RAS	.32372615 02	RAM	.27744876 03	LOM	.30350994 03
DUT	.34000000 02	DT	.19200000 04	DR	.12622567 01	SHA	.25763988 06	DES	.13070889 02	DEM	-.20216069 02

HELIOCENTRIC

EQUATORIAL COORDINATES

X	-.12373475 09	Y	-.78730052 08	Z	-.34135793 08	DX	.17113201 02	DY	-.23618319 02	DZ	-.10158333 02
R	.15057875 09	LAT	-.13102704 02	LON	.21246781 03	V	.30884921 02	PTH	.10933049 01	AZ	.10947045 03
XE	-.12382652 09	YE	-.78499715 08	ZE	-.34039273 08	DXE	.16435755 02	DYE	-.22583766 02	DZE	-.97917611 01
XT	-.12377597 09	YT	-.78855781 08	ZT	-.34171509 08	DXT	.17444894 02	DYT	-.22402194 02	DZT	-.97937112 01
LTE	-.13070889 02	LOE	.21237261 03	LTT	-.13106822 02	LOT	.21249975 03	RST	.15068977 09	VST	.30034969 02
EPS	.75438107 02	ESP	.98415912-01	SEP	.10446386 03	EPM	.14016227 03	EMP	.26450418 02	MEP	.13387299 02
MPS	.14337301 03	MSP	.32051055-01	SMP	.36595617 02	SEM	.11760400 03	EMS	.62267058 02	ESM	.12896511 00
EPT	.14016227 03	ETP	.26450418 02	TEP	.13387299 02	TPS	.14337301 03	TSP	.32051055-01	STP	.36595617 02
SET	.11760400 03	STE	.62267058 02	EST	.12896511 00	RPM	.13830554 06	RPT	.13830554 06	SPN	.74064546 02

1 DAYS 16 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.04466435 APRIL 25,1962 13 04 19.000

GEOCENTRIC

EQUATORIAL COORDINATES

X	.10365051 06	Y	-.24824957 06	Z	-.10281718 06	DX	.64235358 00	DY	-.95812584 00	DZ	-.33408216 00
R	.28799766 06	DEC	-.20916499 02	RA	.29266178 03	V	.12009305 01	PTH	.78386014 02	AZ	.67649038 02
R	.28799766 06	LAT	-.20916499 02	LON	.24351761 03	VE	.19429439 02	PTE	.34710585 01	AZE	.27027161 03
XS	.12352988 09	YS	.78905754 08	ZS	.34215321 08	DXS	-.16522491 02	DYS	.22529187 02	DZS	.97680603 01
XM	.64653180 05	YM	-.35238272 06	ZM	-.13211668 06	DXM	.10015750 01	DYM	.22769826 00	DZM	.15250762-01
XT	.64653180 05	YT	-.35238272 06	ZT	-.13211668 06	DXT	.10015750 01	DYT	.22769826 00	DZT	.15250762-01
RS	.15052056 09	VS	.29596823 02	RM	.38184870 06	VM	.10272446 01	RT	.38184870 06	VT	.10272446 01
GED	-.21046596 02	ALT	.28162220 06	LOS	.34342458 03	RAS	.32568746 02	RAM	.28039667 03	LOM	.23125252 03
DUT	.34000000 02	DT	.19200000 04	DR	.11763429 01	SHA	.27974632 06	DES	.13138944 02	DEM	-.20242375 02

HELIOCENTRIC

EQUATORIAL COORDINATES

X	-.12342623 09	Y	-.79154003 08	Z	-.34318138 08	DX	.17164845 02	DY	-.23487313 02	DZ	-.10102142 02
R	.15058926 09	LAT	-.13173016 02	LON	.21267230 03	V	.30795113 02	PTH	.10775443 01	AZ	.10942462 03
XE	-.12352988 09	YE	-.78905754 08	ZE	-.34215321 08	DXE	.16522491 02	DYE	-.22529187 02	DZE	-.97680603 01
XT	-.12346523 09	YT	-.79258136 08	ZT	-.34347437 08	DXT	.17524066 02	DYT	-.22301488 02	DZT	-.97528095 01
LTE	-.13138944 02	LOE	.21256874 03	LTT	-.13176146 02	LOT	.21269831 03	RST	.15068265 09	VST	.29992775 02
EPS	.76145297 02	ESP	.10584016 00	SEP	.10374826 03	EPM	.13854729 03	EMP	.29953328 02	MEP	.11499380 02
MPS	.14429412 03	MSP	.24228320-01	SMP	.35680356 02	SEM	.11505324 03	EMS	.64815219 02	ESM	.13140749 00
EPT	.13854729 03	ETP	.29953328 02	TEP	.11499380 02	TPS	.14429412 03	TSP	.24228320-01	STP	.35680356 02
SET	.11505324 03	STE	.64815219 02	EST	.13140749 00	RPM	.11499115 06	RPT	.11499115 06	SPN	.74876320 02

1 DAYS 21 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.25299768 APRIL 25,1962 18 04 19.000

CASE 1 — SPACE TRAJECTORIES — 10

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC — EQUATORIAL COORDINATES

X	.11491575 06	Y	-.26491318 06	Z	-.10858206 06	DX	.60960381 00	DY	-.89557925 00	DZ	-.30733578 00
R	.30850394 06	DEC	-.20607444 02	RA	.29345055 03	V	.11261147 01	PTH	.78699008 02	AZ	.66812306 02
R	.30850394 06	LAT	-.20607444 02	LON	.16910105 03	VE	.20883545 02	PTE	.30311004 01	AZE	.27023872 03
XS	.12323168 09	YS	.79310810 08	ZS	.34390941 08	DXS	-.16609034 02	DYS	.22474329 02	DZS	.97442411 01
XM	.82595612 05	YM	-.34787059 06	ZM	-.13168670 06	DXM	.99162086 00	DYM	.27360205 00	DZM	.32534580-01
XT	.82595612 05	YT	-.34787059 06	ZT	-.13168670 06	DXT	.99162086 00	DYT	.27360205 00	DZT	.32534580-01
RS	.15052903 09	VS	.29595704 02	RM	.38102148 06	VM	.10291883 01	RT	.38102148 06	VT	.10291883 01
GED	-.20735969 02	ALT	.30212841 06	LOS	.26841547 03	RAS	.32764968 02	RAM	.28335653 03	LOM	.15900703 03
DUT	.34000000 02	DT	.19200000 04	DR	.11042808 01	SHA	.30038543 06	DES	.13206844 02	DEM	-.20219335 02

HELIOCENTRIC — EQUATORIAL COORDINATES

X	-.12311677 09	Y	-.79575723 08	Z	-.34499523 08	DX	.17218638 02	DY	-.23369908 02	DZ	-.10051577 02
R	.15059964 09	LAT	-.13242975 02	LON	.21287634 03	V	.30719184 02	PTH	.10719529 01	AZ	.10937824 03
XE	-.12323168 09	YE	-.79310810 08	ZE	-.34390941 08	DXE	.16609034 02	DYE	-.22474329 02	DZE	-.97442411 01
XT	-.12314909 09	YT	-.79658680 08	ZT	-.34522628 08	DXT	.17600655 02	DYT	-.22200727 02	DZT	-.97117065 01
LTE	-.13206844 02	LOE	.21276497 03	LTT	-.13245239 02	LOT	.21289670 03	RST	.15067519 09	VST	.29949500 02
EPS	.76712181 02	ESP	.11513766 00	SEP	.10317353 03	EPM	.13705361 03	EMP	.33479822 02	MEP	.94665521 01
MPS	.14522132 03	MSP	.19782341-01	SMP	.34758723 02	SEM	.11249092 03	EMS	.67375211 02	ESM	.13398797 00
EPT	.13705361 03	ETP	.33479822 02	TEP	.94665521 01	TPS	.14522132 03	TSP	.19782341-01	STP	.34758723 02
SET	.11249092 03	STE	.67375211 02	EST	.13398797 00	RPM	.91980152 05	RPT	.91980152 05	SPN	.75527567 02

2 DAYS 2 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.46133102 APRIL 25,1962 23 04 19.000

GEOCENTRIC — EQUATORIAL COORDINATES

X	.12560039 06	Y	-.28057101 06	Z	-.11391189 06	DX	.57747397 00	DY	-.84662575 00	DZ	-.28574185 00
R	.32782841 06	DEC	-.20332897 02	RA	.29411615 03	V	.10639078 01	PTH	.79215463 02	AZ	.65500513 02
R	.32782841 06	LAT	-.20332897 02	LON	.94561318 02	VE	.22259605 02	PTE	.26910979 01	AZE	.27021272 03
XS	.12293192 09	YS	.79714873 08	ZS	.34566132 08	DXS	-.16695382 02	DYS	.22419194 02	DZS	.97203037 01
XM	.10033728 06	YM	-.34253502 06	ZM	-.13094517 06	DXM	.97926839 00	DYM	.31917130 00	DZM	.49861484-01
XT	.10033728 06	YT	-.34253502 06	ZT	-.13094517 06	DXT	.97926839 00	DYT	.31917130 00	DZT	.49861484-01
RS	.15053749 09	VS	.29594599 02	RM	.38019001 06	VM	.10311756 01	RT	.38019001 06	VT	.10311756 01
GED	-.20460013 02	ALT	.32145282 06	LOS	.19340645 03	RAS	.32961281 02	RAM	.28632666 03	LOM	.86771829 02
DUT	.34000000 02	DT	.19200000 04	DR	.10451168 01	SHA	.31978792 06	DES	.13274588 02	DEM	-.20146413 02

HELIOCENTRIC — EQUATORIAL COORDINATES

X	-.12280632 09	Y	-.79995444 08	Z	-.34680043 08	DX	.17272856 02	DY	-.23265819 02	DZ	-.10006046 02
R	.15060999 09	LAT	-.13312608 02	LON	.21308002 03	V	.30655682 02	PTH	.10791238 01	AZ	.10933049 03
XE	-.12293192 09	YE	-.79714873 08	ZE	-.34566132 08	DXE	.16695382 02	DYE	-.22419194 02	DZE	-.97203037 01
XT	-.12283159 09	YT	-.80057408 08	ZT	-.34697077 08	DXT	.17674650 02	DYT	-.22100022 02	DZT	-.96704422 01
LTE	-.13274588 02	LOE	.21296128 03	LTT	-.13314096 02	LOT	.21309492 03	RST	.15066743 09	VST	.29905212 02
EPS	.77162438 02	ESP	.12154476 00	SEP	.10271590 03	EPM	.13552536 03	EMP	.37164421 02	MEP	.73102176 01
MPS	.14628037 03	MSP	.13988227-01	SMP	.33705053 02	SEM	.10991688 03	EMS	.69947186 02	ESM	.13580115 00
EPT	.13552536 03	ETP	.37164421 02	TEP	.73102176 01	TPS	.14628037 03	TSP	.13988227-01	STP	.33705053 02
SET	.10991688 03	STE	.69947186 02	EST	.13580115 00	RPM	.69049949 05	RPT	.69049949 05	SPN	.76047661 02

2 DAYS 7 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.66966435 APRIL 26,1962 04 04 19.000

CASE 1 SPACE TRAJECTORIES 11

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

GEOCENTRIC EQUATORIAL COORDINATES

X	.13568718 06	Y	-.29550269 06	Z	-.11890533 06	DX	.54210080 00	DY	-.81677651 00	DZ	-.27040234 00
R	.34622439 06	DEC	-.20086248 02	RA	.29466336 03	V	.10169142 01	PTH	.80320371 02	AZ	.62612610 02
R	.34622438 06	LAT	-.20086248 02	LON	.19903155 02	VE	.23581097 02	PTE	.24363865 01	AZE	.27019127 03
XS	.12263062 09	YS	.80117943 08	ZS	.34740891 08	DXS	-.16781534 02	DYS	.22363779 02	DZS	.96962480 01
XM	.11783501 06	YM	-.33638306 06	ZM	-.12989166 06	DXM	.96451556 00	DYM	.36429282 00	DZM	.67190717-01
XT	.11783501 06	YT	-.33638306 06	ZT	-.12989166 06	DXT	.96451556 00	DYT	.36429282 00	DZT	.67190717-01
RS	.15054595 09	VS	.29593508 02	RM	.37935537 06	VM	.10332057 01	RT	.37935537 06	VT	.10332057 01
GED	-.20212087 02	ALT	.33984872 06	LOS	.11839747 03	RAS	.33157684 02	RAM	.28930536 03	LOM	.14545151 02
DUT	.34000000 02	DT	.19200000 04	DR	.10024368 01	SHA	.33818574 06	DES	.13342174 02	DEM	-.20023223 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12249493 09	Y	-.80413445 08	Z	-.34859795 08	DX	.17323635 02	DY	-.23180556 02	DZ	-.99666503 01
R	.15062050 09	LAT	-.13381938 02	LON	.21328343 03	V	.30606871 02	PTH	.11112581 01	AZ	.10927914 03
XE	-.12263062 09	YE	-.80117943 08	ZE	-.34740891 08	DXE	.16781534 02	DYE	-.22363779 02	DZE	-.96962480 01
XT	-.12251278 09	YT	-.80454326 08	ZT	-.34870782 08	DXT	.17746050 02	DYT	-.21999486 02	DZT	-.96290573 01
LTE	-.13342174 02	LOE	.21315768 03	LTT	-.13382714 02	LOT	.21329296 03	RST	.15065939 09	VST	.29859980 02
EPS	.77500658 02	ESP	.12839488 00	SEP	.10237069 03	EPM	.13357609 03	EMP	.41390612 02	MEP	.50332937 01
MPS	.14782653 03	MSP	.27453512-18	SMP	.32164159 02	SEM	.10733099 03	EMS	.72531290 02	ESM	.13759044 00
EPT	.13357609 03	ETP	.41390612 02	TEP	.50332937 01	TPS	.14782653 03	TSP	.27453512-18	STP	.32164159 02
SET	.10733099 03	STE	.72531290 02	EST	.13759044 00	RPM	.45941319 05	RPT	.45941319 05	SPN	.76445120 02

2 DAYS 12 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.87799768 APRIL 26,1962 09 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14499554 06	Y	-.31027603 06	Z	-.12372945 06	DX	.48295484 00	DY	-.84335940 00	DZ	-.27038303 00
R	.36414818 06	DEC	-.19863334 02	RA	.29504722 03	V	.10087653 01	PTH	.83747335 02	AZ	.47104307 02
R	.36414817 06	LAT	-.19863334 02	LON	.30508168 03	VE	.24914098 02	PTE	.23067128 01	AZE	.27017212 03
XS	.12232776 09	YS	.80520009 08	ZS	.34915215 08	DXS	-.16867490 02	DYS	.22308085 02	DZS	.96720734 01
XM	.13504560 06	YM	-.32942382 06	ZM	-.12852653 06	DXM	.94736679 00	DYM	.40885081 00	DZM	.84479913-01
XT	.13504560 06	YT	-.32942382 06	ZT	-.12852653 06	DXT	.94736679 00	DYT	.40885081 00	DZT	.84479913-01
RS	.15055439 09	VS	.29592429 02	RM	.37851873 06	VM	.10352776 01	RT	.37851873 06	VT	.10352776 01
GED	-.19988012 02	ALT	.35777246 06	LOS	.43388633 02	RAS	.33354178 02	RAM	.29229093 03	LOM	.30232538 03
DUT	.34000000 02	DT	.48000000 03	DR	.10027644 01	SHA	.35595177 06	DES	.13409604 02	DEM	-.19849538 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12218276 09	Y	-.80830285 08	Z	-.35038944 08	DX	.17350445 02	DY	-.23151445 02	DZ	-.99424566 01
R	.15063164 09	LAT	-.13450985 02	LON	.21348672 03	V	.30592152 02	PTH	.12407909 01	AZ	.10921202 03
XE	-.12232776 09	YE	-.80520009 08	ZE	-.34915215 08	DXE	.16867490 02	DYE	-.22308085 02	DZE	-.96720734 01
XT	-.12219271 09	YT	-.80849433 08	ZT	-.35043742 08	DXT	.17814857 02	DYT	-.21899235 02	DZT	-.95875937 01
LTE	-.13409604 02	LOE	.21335418 03	LTT	-.13451090 02	LOT	.21349081 03	RST	.15065110 09	VST	.29813882 02
EPS	.77685136 02	ESP	.13580115 00	SEP	.10217947 03	EPM	.12923970 03	EMP	.48167866 02	MEP	.25924155 01
MPS	.15168985 03	MSP	.98911702-02	SMP	.28306155 02	SEM	.10473310 03	EMS	.75127672 02	ESM	.13918114 00
EPT	.12923970 03	ETP	.48167866 02	TEP	.25924155 01	TPS	.15168985 03	TSP	.98911702-02	STP	.28306155 02
SET	.10473310 03	STE	.75127672 02	EST	.13918114 00	RPM	.22105449 05	RPT	.22105449 05	SPN	.76681558 02

CASE 1 SPACE TRAJECTORIES 12

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

SELENOCENTRIC EQUATORIAL COORDINATES

X	.99499386 04	Y	.19147785 05	Z	.47970751 04	DX	-.46441194 00	DY	-.12522102 01	DZ	-.35486295 00
R	.22105449 05	DEC	.12533400 02	RA	.62541845 02	V	.13818960 01	PTH	-.82705871 02	AZ	.25041630 03
R	.22105444 05	LAT	-.98162785 01	LON	.30620179 03	VR	.13903579 01	PTR	-.80356925 02	AZR	.26295117 03
LTS	-.15096468 01	LNS	.27898196 03	LTE	-.26100637 01	LNE	.35415975 03				
ALT	.20367449 05	SHA	-.10482023 05	ALP	.15835751 02	DR	-.13707130 01	DP	.45475220-03	ASD	.45094291 01
HGE	.28231486 03	SVL	-.76319952 01	HNG	.15265566 03	SIA	.12473027 03				

2 DAYS 13 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.91966435 APRIL 26,1962 10 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14669100 06	Y	-.31336151 06	Z	-.12471252 06	DX	.45687656 00	DY	-.87413708 00	DZ	-.27652440 00
R	.36778648 06	DEC	-.19821408 02	RA	.29508526 03	V	.10243620 01	PTH	.85202618 02	AZ	.30265459 02
R	.36778648 06	LAT	-.19821408 02	LON	.29007865 03	VE	.25208079 02	PTE	.23207625 01	AZE	.27016832 03
XS	.12226700 09	YS	.80600302 08	ZS	.34950028 08	DXS	-.16884657 02	DYS	.22296913 02	DZS	.96672244 01
XM	.13844948 06	YM	-.32793604 06	ZM	-.12821619 06	DXM	.94365028 00	DYM	.41768459 00	DZM	.87929218-01
XT	.13844948 06	YT	-.32793604 06	ZT	-.12821619 06	DXT	.94365028 00	DYT	.41768459 00	DZT	.87929218-01
RS	.15055608 09	VS	.29592215 02	RM	.37835128 06	VM	.10356968 01	RT	.37835128 06	VT	.10356968 01
GED	-.19945866 02	ALT	.36141076 06	LOS	.28386872 02	RAS	.33393489 02	RAM	.29288871 03	LOM	.28788209 03
DUT	.34000000 02	DT	.24000000 03	DR	.10207734 01	SHA	.35951093 06	DES	.13423071 02	DEM	-.19808732 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12212031 09	Y	-.80913664 08	Z	-.35074741 08	DX	.17341534 02	DY	-.23171050 02	DZ	-.99437488 01
R	.15063409 09	LAT	-.13464762 02	LON	.21352739 03	V	.30602360 02	PTH	.13160656 01	AZ	.10919022 03
XE	-.12226700 09	YE	-.80600302 08	ZE	-.34950028 08	DXE	.16884657 02	DYE	-.22296913 02	DZE	-.96672244 01
XT	-.12212855 09	YT	-.80928239 08	ZT	-.35078245 08	DXT	.17828307 02	DYT	-.21879228 02	DZT	-.95792952 01
LTE	-.13423071 02	LOE	.21339349 03	LTT	-.13464737 02	LOT	.21353036 03	RST	.15064941 09	VST	.29804565 02
EPS	.77685813 02	ESP	.13669873 00	SEP	.10217744 03	EPM	.12710106 03	EMP	.50832418 02	MEP	.20665145 01
MPS	.15363022 03	MSP	.98911702-02	SMP	.26366889 02	SEM	.10421207 03	EMS	.75648433 02	ESM	.13970734 00
EPT	.12710106 03	ETP	.50832418 02	TEP	.20665145 01	TPS	.15363022 03	TSP	.98911702-02	STP	.26366889 02
SET	.10421207 03	STE	.75648433 02	EST	.13970734 00	RPM	.17105998 05	RPT	.17105998 05	SPN	.76692163 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.82415261 04	Y	.14674524 05	Z	.35036678 04	DX	-.48677371 00	DY	-.12918217 01	DZ	-.36445362 00
R	.17105998 05	DEC	.11819022 02	RA	.60512935 02	V	.14277879 01	PTH	-.80900482 02	AZ	.24997222 03
R	.17105995 05	LAT	-.10153062 02	LON	.30353993 03	VR	.14354788 01	PTR	-.79150392 02	AZR	.26246749 03
LTS	-.15094470 01	LNS	.27847379 03	LTE	-.25504379 01	LNE	.35417200 03				
ALT	.15367998 05	SHA	-.75970728 04	ALP	.17941962 02	DR	-.14098194 01	DP	.75632159-03	ASD	.58314165 01
HGE	.28231419 03	SVL	-.79908098 01	HNG	.15478704 03	SIA	.12126964 03				

2 DAYS 14 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437780.96133102 APRIL 26,1962 11 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14825973 06	Y	-.31660725 06	Z	-.12572850 06	DX	.40856424 00	DY	-.93732694 00	DZ	-.28958947 00
R	.37152221 06	DEC	-.19780304 02	RA	.29509259 03	V	.10627175 01	PTH	.85770195 02	AZ	.33946245 03
R	.37152221 06	LAT	-.19780304 02	LON	.27504490 03	VE	.25542931 02	PTE	.23779884 01	AZE	.27016478 03
XS	.12220618 09	YS	.80680555 08	ZS	.34984823 08	DXS	-.16901817 02	DYS	.22285729 02	DZS	.96623704 01
XM	.14183980 06	YM	-.32641651 06	ZM	-.12789344 06	DXM	.93983840 00	DYM	.42649025 00	DZM	.91374867-01
XT	.14183980 06	YT	-.32641651 06	ZT	-.12789344 06	DXT	.93983840 00	DYT	.42649025 00	DZT	.91374867-01
RS	.15065776 09	VS	.29592001 02	RM	.37818381 06	VM	.10361175 01	RT	.37818381 06	VT	.10361175 01
GED	-.19904547 02	ALT	.36514647 06	LOS	.13385118 02	RAS	.33432802 02	RAM	.29348669 03	LOM	.27343901 03
DUT	.34000000 02	DT	.24000000 03	DR	.10598230 01	SHA	.36312623 06	DES	.13436532 02	DEM	-.19765905 02

CASE 1 SPACE TRAJECTORIES 13

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

HELICCENTRIC EQUATORIAL COORDINATES

X	-.12205792 09	Y	-.80997162 08	Z	-.35110551 08	DX	.17310381 02	DY	-.23223056 02	DZ	-.99519599 01
R	.15063674 C9	LAT	-.13478526 02	LON	.21356809 03	V	.30626804 02	PTH	.14600391 01	AZ	.10915626 03
XE	-.12220618 C9	YE	-.80680555 08	ZE	-.34984823 08	DXE	.16901817 02	DYE	-.22285729 02	DZE	-.96623704 01
XT	-.12206434 09	YT	-.81006972 08	ZT	-.35112717 08	DXT	.17841655 02	DYT	-.21859239 02	DZT	-.95709956 01
LTE	-.13436532 02	LOE	.21343280 03	LTT	-.13478372 02	LOT	.21356990 03	RST	.15064772 09	VST	.29795217 02
EPS	.77657884 02	ESP	.13776809 00	SEP	.10220399 03	EPM	.12321284 03	EMP	.55275887 02	MEP	.15112418 01
MPS	.15708750 03	MSP	.27453512-18	SMP	.22910731 02	SEM	.10369056 03	EMS	.76169693 02	ESM	.13970734 00
EPT	.12321284 03	ETP	.55275887 02	TEP	.15112418 01	TPS	.15708750 03	TSP	.27453512-18	STP	.22910731 02
SET	.10369056 03	STE	.76169693 02	EST	.13970734 00	RPM	.11921581 05	RPT	.11921581 05	SPN	.76674227 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.64199328 04	Y	.98092602 04	Z	.21649408 04	DX	-.53127416 00	DY	-.13638172 01	DZ	-.38096434 00
R	.11921581 05	DEC	.10462881 02	RA	.56796185 02	V	.15124098 01	PTH	-.77656917 02	AZ	.24924542 03
R	.11921579 05	LAT	-.10739816 02	LON	.29908004 03	VR	.15193164 01	PTR	-.76518233 02	AZR	.26240684 03
LTS	-.15092472 01	LNS	.27796561 03	LTE	-.24905166 01	LNE	.35418468 03				
ALT	.10183581 05	SHA	-.46410293 04	ALP	.22649810 02	DR	-.14774506 01	DP	.15537985-02	ASD	.83828003 01
HGE	.28234211 03	SVL	-.86409089 01	HNG	.15869753 03	SIA	.11483003 03				

2 DAYS 14 HRS. 30 MIN. 0.000 SEC. JULIAN DATE 2437780.98216435 APRIL 26,1962 11 34 19.000

GECCENTRIC EQUATORIAL COORDINATES

X	.14895664 06	Y	-.31834406 06	Z	-.12625967 06	DX	.36124253 00	DY	-.99761955 00	DZ	-.30148362 00
R	.37346020 C6	DEC	-.19759979 02	RA	.29507540 03	V	.11030110 01	PTH	.83722729 02	AZ	.30755842 03
R	.37346020 06	LAT	-.19759979 02	LON	.26750718 03	VE	.25748646 02	PTE	.24404368 01	AZE	.27016373 03
XS	.12217575 09	YS	.80720666 08	ZS	.35002214 08	DXS	-.16910393 02	DYS	.22280134 02	DZS	.96599418 01
XM	.14352977 06	YM	-.32564487 06	ZM	-.12772741 06	DXM	.93789675 00	DYM	.43088223 00	DZM	.93096215-01
XT	.14352977 06	YT	-.32564487 06	ZT	-.12772741 06	DXT	.93789675 00	DYT	.43088223 00	DZT	.93096215-01
RS	.15055861 09	VS	.29591894 02	RM	.37810007 06	VM	.10363285 01	RT	.37810007 06	VT	.10363285 01
GED	-.19884116 02	ALT	.36708446 06	LOS	.58842409 01	RAS	.33452460 02	RAM	.29378575 03	LOM	.26621753 03
DUT	.34000000 02	DT	.12000000 03	DR	.10963978 01	SHA	.36497541 06	DES	.13443260 02	DEM	-.19743733 02

HELICCENTRIC EQUATORIAL COORDINATES

X	-.12202679 C9	Y	-.81039010 08	Z	-.35128474 08	DX	.17271636 02	DY	-.23277753 02	DZ	-.99614254 01
R	.15063820 09	LAT	-.13485403 02	LON	.21358846 03	V	.30649522 02	PTH	.15977580 01	AZ	.10912720 03
XE	-.12217575 09	YE	-.80720666 08	ZE	-.35002214 08	DXE	.16910393 02	DYE	-.22280134 02	DZE	-.96599418 01
XT	-.12203222 09	YT	-.81046311 08	ZT	-.35129942 08	DXT	.17848290 02	DYT	-.21849251 02	DZT	-.95668456 01
LTE	-.13443260 02	LOE	.21345246 03	LTT	-.13485186 02	LOT	.21358967 03	RST	.15064687 09	VST	.29790532 02
EPS	.77624555 02	ESP	.13865293 00	SEP	.10223662 03	EPM	.11962562 03	EMP	.59160489 02	MEP	.12137987 01
MPS	.16013174 03	MSP	.27453512-18	SMP	.19867066 02	SEM	.10342962 03	EMS	.76430510 02	ESM	.14005705 00
EPT	.11962562 03	ETP	.59160489 02	TEP	.12137987 01	TPS	.16013174 03	TSP	.27453512-18	STP	.19867066 02
SET	.10342962 03	STE	.76430510 02	EST	.14005705 00	RPM	.92145034 04	RPT	.92145034 04	SPN	.76646003 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.54268788 04	Y	.73008080 04	Z	.14677412 04	DX	-.57665422 00	DY	-.14285018 01	DZ	-.39457983 00
R	.92145034 04	DEC	.91654546 01	RA	.53375623 02	V	.15902329 01	PTH	-.74758364 02	AZ	.24866021 03
R	.92145019 04	LAT	-.11241065 02	LON	.29516217 03	VR	.15966762 01	PTR	-.73931620 02	AZR	.26278341 03
LTS	-.15091482 C1	LNS	.27771151 03	LTE	-.24604475 01	LNE	.35419118 03				
ALT	.74765034 04	SHA	-.31314477 04	ALP	.28325205 02	DR	-.15342976 01	DP	.25994769-02	ASD	.10872010 02
HGE	.28237544 03	SVL	-.92182307 01	HNG	.16232261 03	SIA	.10875361 03				

CASE 1 SPACE TRAJECTORIES 14

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

2 DAYS 15 HRS. 0 MIN. 0.000 SEC. JULIAN DATE 2437781.00299768 APRIL 26,1962 12 04 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14953208 06	Y	-.32022712 06	Z	-.12681801 06	DX	.26440588 00	DY	-.11069486 01	DZ	-.32034195 00
R	.37548376 06	DEC	-.19739585 02	RA	.29503052 03	V	.11823132 01	PTH	.78250223 02	AZ	.28815526 03
R	.37548375 06	LAT	-.19739585 02	LON	.25994176 03	VE	.26026385 02	PTE	.25491042 01	AZE	.27016532 03
XS	.12214530 09	YS	.80760768 08	ZS	.35019601 08	DXS	-.16918968 02	DYS	.22274535 02	DZS	.96575118 01
XM	.14521622 06	YM	-.32486534 06	ZM	-.12755829 06	DXM	.93593130 00	DYM	.43526684 00	DZM	.94816516-01
XT	.14521622 06	YT	-.32486534 06	ZT	-.12755829 06	DXT	.93593130 00	DYT	.43526684 00	DZT	.94816516-01
RS	.15055945 09	VS	.29591787 02	RM	.37801634 06	VM	.10365398 01	RT	.37801634 06	VT	.10365398 01
GED	-.19863614 02	ALT	.36910801 06	LOS	.35838336 03	RAS	.33472119 02	RAM	.29408485 03	LOM	.25899610 03
DUT	.34000000 02	DT	.12000000 03	DR	.11575393 01	SHA	.36687184 06	DES	.13449986 02	DEM	-.19721054 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12199577 09	Y	-.81080996 08	Z	-.35146419 08	DX	.17183374 02	DY	-.23381483 02	DZ	-.99778537 01
R	.15063985 09	LAT	-.13492271 02	LON	.21360886 03	V	.30684192 02	PTH	.18619104 01	AZ	.10907375 03
XE	-.12214530 09	YE	-.80760768 08	ZE	-.35019601 08	DXE	.16918968 02	DYE	-.22274535 02	DZE	-.96575118 01
XT	-.12200008 09	YT	-.81085634 08	ZT	-.35147159 08	DXT	.17854899 02	DYT	-.21839268 02	DZT	-.95626953 01
LTE	-.13449986 02	LOE	.21347211 03	LTT	-.13491998 02	LOT	.21360943 03	RST	.15064602 09	VST	.29785839 02
EPS	.77565548 02	ESP	.13882922 00	SEP	.10229491 03	EPM	.11294718 03	EMP	.66162472 02	MEP	.89032418 00
MPS	.16510685 03	MSP	.27453512-18	SMP	.14892527 02	SEM	.10316855 03	EMS	.76691451 02	ESM	.14005705 00
EPT	.11294718 03	ETP	.66162472 02	TEP	.89032418 00	TPS	.16510685 03	TSP	.27453512-18	STP	.14892527 02
SET	.10316855 03	STE	.76691451 02	EST	.14005705 00	RPM	.63786975 04	RPT	.63786975 04	SPN	.76592270 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.43158611 04	Y	.46382219 04	Z	.74028640 03	DX	-.67152542 00	DY	-.15422154 01	DZ	-.41515847 00
R	.63786975 04	DEC	.66645408 01	RA	.47061844 02	V	.17325505 01	PTH	-.69605808 02	AZ	.24778885 03
R	.63786963 04	LAT	-.12055858 02	LON	.28806175 03	VR	.17383775 01	PTR	-.69095312 02	AZR	.26391489 03
LTS	-.15090500 01	LNS	.27745742 03	LTE	-.24303051 01	LNE	.35419779 03				
ALT	.46406975 04	SHA	-.16393683 04	ALP	.44334111 02	DR	-.16239496 01	DP	.54231367-02	ASD	.15811263 02
HGE	.28243445 03	SVL	-.10207121 02	HNG	.16909660 03	SIA	.97135919 02				

2 DAYS 15 HRS. 30 MIN. 0.000 SEC. JULIAN DATE 2437781.02383102 APRIL 26,1962 12 34 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14979114 06	Y	-.32240909 06	Z	-.12741616 06	DX	-.57228460-01	DY	-.13567238 01	DZ	-.34077454 00
R	.37765047 06	DEC	-.19718045 02	RA	.29491956 03	V	.14000363 01	PTH	.63280876 02	AZ	.27787098 03
R	.37765047 06	LAT	-.19718045 02	LON	.25231027 03	VE	.26577083 02	PTE	.26969565 01	AZE	.27018604 03
XS	.12211484 09	YS	.80800861 08	ZS	.35036982 08	DXS	-.16927541 02	DYS	.22268933 02	DZS	.96550807 01
XM	.14689912 06	YM	-.32407791 06	ZM	-.12738607 06	DXM	.93394207 00	DYM	.43964395 00	DZM	.96535736-01
XT	.14689912 06	YT	-.32407791 06	ZT	-.12738607 06	DXT	.93394207 00	DYT	.43964395 00	DZT	.96535736-01
RS	.15056029 09	VS	.29591681 02	RM	.37793260 06	VM	.10367515 01	RT	.37793260 06	VT	.10367515 01
GED	-.19841962 02	ALT	.37127472 06	LOS	.35088249 03	RAS	.33491780 02	RAM	.29438399 03	LOM	.25177471 03
DUT	.34000000 02	DT	.59999999 02	DR	.12505424 01	SHA	.36882055 06	DES	.13456710 02	DEM	-.19697871 02

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

HELIOCENTRIC — EQUATORIAL COORDINATES

X	-.12196505 C9	Y	-.81123270 08	Z	-.35164399 08	DX	.16870313 02	DY	-.23625657 02	DZ	-.99958553 01
R	.15064193 09	LAT	-.13499115 02	LON	.21362928 03	V	.30703358 02	PTH	.26085158 01	AZ	.10891846 03
XE	-.12211484 09	YE	-.80800861 08	ZE	-.35036982 08	DXE	.16927541 02	DYE	-.22268933 02	DZE	-.96550807 01
XT	-.12196794 C9	YT	-.81124939 08	ZT	-.35164369 08	DXT	.17861483 02	DYT	-.21829289 02	DZT	-.95585451 01
LTE	-.13456710 C2	LOE	.21349178 03	LTT	-.13498808 02	LOT	.21362920 03	RST	.15064517 09	VST	.29781139 02
EPS	.77445463 02	ESP	.14005705 00	SEP	.10241425 03	EPM	.94594457 02	EMP	.84900940 02	MEP	.50445131 00
MPS	.16552715 03	MSP	.27453512-18	SMP	.14472529 02	SEM	.10290737 03	EMS	.76952517 02	ESM	.14005705 00
EPT	.94594457 02	ETP	.84900940 02	TEP	.50445131 00	TPS	.16552715 03	TSP	.27453512-18	STP	.14472529 02
SET	.10290737 03	STE	.76952517 02	EST	.14005705 00	RPM	.33391061 04	RPT	.33391061 04	SPN	.76477768 02

SELENOCENTRIC — EQUATORIAL COORDINATES

X	.28920165 04	Y	.16688214 04	Z	-.30092232 02	DX	-.99117053 00	DY	-.17963677 01	DZ	-.43731028 00
R	.33391061 04	DEC	-.51636059 00	RA	.29986843 02	V	.20977598 01	PTH	-.56649479 02	AZ	.24686475 03
R	.33391055 04	LAT	-.13406515 02	LON	.26887684 03	VR	.21025266 01	PTR	-.56452601 02	AZR	.26796711 03
LTS	-.15089501 C1	LNS	.27720332 03	LTE	-.24000926 01	LNE	.35420450 03				
ALT	.16011062 04	SHA	-.83449535 03	ALP	.12493300 03	DR	-.17523069 01	DP	.19788868-01	ASD	.31365701 02
HGE	.28255453 03	SVL	-.12194961 02	HNG	.18785377 03	SIA	.63228756 02				

2 DAYS 15 HRS. 35 MIN. 0.000 SEC. JULIAN DATE 2437781.02730323 APRIL 26,1962 12 39 19.000

GEOCENTRIC — EQUATORIAL COORDINATES

X	.14975436 06	Y	-.32282635 06	Z	-.12751781 06	DX	-.19720494 00	DY	-.14263678 01	DZ	-.33529724 00
R	.37802647 06	DEC	-.19713985 02	RA	.29488588 03	V	.14784583 01	PTH	.57946288 02	AZ	.27679494 03
R	.37802646 C6	LAT	-.19713986 02	LON	.25102317 03	VE	.26759068 02	PTE	.26840159 01	AZE	.27019899 03
XS	.12210976 09	YS	.80807539 08	ZS	.35039879 08	DXS	-.16928970 02	DYS	.22267999 02	DZS	.96546756 01
XM	.14717926 06	YM	-.32394591 06	ZM	-.12735707 06	DXM	.93360823 00	DYM	.44037273 00	DZM	.96822162-01
XT	.14717926 06	YT	-.32394591 06	ZT	-.12735707 06	DXT	.93360823 00	DYT	.44037273 00	DZT	.96822162-01
RS	.15056043 09	VS	.29591664 02	RM	.37791865 06	VM	.10367868 01	RT	.37791865 06	VT	.10367868 01
GED	-.19837881 02	ALT	.37165072 06	LOS	.34963235 03	RAS	.33495056 02	RAM	.29443385 03	LOM	.25057115 03
CUT	.34000000 02	DT	.30000000 02	DR	.12530688 01	SHA	.36913963 06	DES	.13457831 02	DEM	-.19693958 02

HELIOCENTRIC — EQUATORIAL COORDINATES

X	-.12196000 09	Y	-.81130365 08	Z	-.35167397 08	DX	.16731765 02	DY	-.23694367 02	DZ	-.99899728 01
R	.15064237 C9	LAT	-.13500248 02	LON	.21363268 03	V	.30678568 02	PTH	.28904780 01	AZ	.10885604 03
XE	-.12210976 09	YE	-.80807539 08	ZE	-.35039879 08	DXE	.16928970 02	DYE	-.22267999 02	DZE	-.96546756 01
XT	-.12196258 09	YT	-.81131485 08	ZT	-.35167237 08	DXT	.17862578 02	DYT	-.21827627 02	DZT	-.95578534 01
LTE	-.13457831 C2	LOE	.21349505 03	LTT	-.13499942 02	LOT	.21363249 03	RST	.15064502 09	VST	.29780355 02
EPS	.77411456 C2	ESP	.14057998 00	SEP	.10244814 03	EPM	.87590076 02	EMP	.91983888 02	MEP	.42589599 00
MPS	.16043966 03	MSP	.27453512-18	SMP	.19559978 02	SEM	.10286383 03	EMS	.76996041 02	ESM	.14023158 00
EPT	.87590076 02	ETP	.91983888 02	TEP	.42589599 00	TPS	.16043966 03	TSP	.27453512-18	STP	.19559978 02
SET	.10286383 03	STE	.76996041 02	EST	.14023158 00	RPM	.28125514 04	RPT	.28125514 04	SPN	.76444726 02

SELENOCENTRIC — EQUATORIAL COORDINATES

X	.25751097 04	Y	.11195618 04	Z	-.16073911 03	DX	-.11308132 01	DY	-.18667405 01	DZ	-.43211940 00
R	.28125514 04	DEC	-.32762744 01	RA	.23497610 02	V	.22249012 01	PTH	-.52020019 02	AZ	.24708004 03
R	.28125511 04	LAT	-.13554590 02	LON	.26158484 03	VR	.22293914 01	PTR	-.51872443 02	AZR	.26964533 03
LTS	-.15089331 01	LNS	.27716096 03	LTE	-.23950502 01	LNE	.35420562 03				
ALT	.10745514 04	SHA	-.94162376 03	ALP	.14264996 03	DR	-.17537246 01	DP	.27892059-01	ASD	.38166167 02
HGE	.28258854 C3	SVL	-.12631611 02	HNG	.19505827 03	SIA	.49423909 02				

CASE 1 SPACE TRAJECTORIES 16

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

2 DAYS 15 HRS. 40 MIN. 0.000 SEC. JULIAN DATE 2437781.03077546 APRIL 26,1962 12 44 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14966537 06	Y	-.32326525 06	Z	-.12761582 06	DX	-.41257302 00	DY	-.14986226 01	DZ	-.31407841 00
R	.37839917 06	DEC	-.19709528 02	RA	.29484320 03	V	.15857905 01	PTH	.50464530 02	AZ	.27594241 03
R	.37839917 06	LAT	-.19709528 02	LON	.24972706 03	VE	.27008661 02	PTE	.25953626 01	AZE	.27022193 03
XS	.12210468 09	YS	.80814220 08	ZS	.35042775 08	DXS	-.16930398 02	DYS	.22267065 02	DZS	.96542701 01
XM	.14745929 06	YM	-.32381369 06	ZM	-.12732798 06	DXM	.93327372 00	DYM	.44110129 00	DZM	.97108557-01
XT	.14745929 06	YT	-.32381369 06	ZT	-.12732798 06	DXT	.93327372 00	DYT	.44110129 00	DZT	.97108557-01
RS	.15056057 09	VS	.29591646 02	RM	.37790470 06	VM	.10368222 01	RT	.37790470 06	VT	.10368222 01
GED	-.19833400 02	ALT	.37202342 06	LOS	.34838220 03	RAS	.33498333 02	RAM	.29448372 03	LOM	.24936759 03
DUT	.34000000 02	DT	.59999999 02	DR	.12230103 01	SHA	.36944343 06	DES	.13458952 02	DEM	-.19690031 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12195501 09	Y	-.81137485 08	Z	-.35170391 08	DX	.16517825 02	DY	-.23765688 02	DZ	-.99683486 01
R	.15064286 09	LAT	-.13501373 02	LON	.21363608 03	V	.30610691 02	PTH	.32875945 01	AZ	.10876361 03
XE	-.12210468 09	YE	-.80814220 08	ZE	-.35042775 08	DXE	.16930398 02	DYE	-.22267065 02	DZE	-.96542701 01
XT	-.12195722 09	YT	-.81138034 08	ZT	-.35170104 08	DXT	.17863672 02	DYT	-.21825964 02	DZT	-.95571616 01
LTE	-.13458952 02	LOE	.21349833 03	LTT	-.13501077 02	LOT	.21363579 03	RST	.15064488 09	VST	.29779571 02
EPS	.77369164 02	ESP	.14110097 00	SEP	.10249032 03	EPM	.77367941 02	EMP	.10229306 03	MEP	.33890842 00
MPS	.15152358 03	MSP	.27453512-18	SMP	.28476004 02	SEM	.10282028 03	EMS	.77039567 02	ESM	.14057998 00
EPT	.77367941 02	ETP	.10229306 03	TEP	.33890842 00	TPS	.15152358 03	TSP	.27453512-18	STP	.28476004 02
SET	.10282028 03	STE	.77039567 02	EST	.14057998 00	RPM	.22913823 04	RPT	.22913823 04	SPN	.76403385 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.22060820 04	Y	.54843752 03	Z	-.28783891 03	DX	-.13458467 01	DY	-.19397239 01	DZ	-.41118697 00
R	.22913823 04	DEC	-.72164482 01	RA	.13960857 02	V	.23964363 01	PTH	-.45469393 02	AZ	.24795506 03
R	.22913819 04	LAT	-.13396486 02	LON	.25096862 03	VR	.24006019 01	PTR	-.45368411 02	AZR	.27210633 03
LTS	-.15080168 01	LNS	.27711860 03	LTE	-.23900053 01	LNE	.35420674 03				
ALT	.55338226 03	SHA	-.10925097 04	ALP	.15662508 03	DR	-.17083618 01	DP	.42023159-01	ASD	.49331622 02
HGE	.28263083 03	SVL	-.12923142 02	HNG	.20559680 03	SIA	.28036319 02				

2 DAYS 15 HRS. 45 MIN. 0.000 SEC. JULIAN DATE 2437781.03424768 APRIL 26,1962 12 49 19.000

GEOCENTRIC EQUATORIAL COORDINATES

X	.14949351 06	Y	-.32372244 06	Z	-.12770218 06	DX	-.76191926 00	DY	-.15369364 01	DZ	-.25077590 00
R	.37875107 06	DEC	-.19704336 02	RA	.29478727 03	V	.17336617 01	PTH	.39273950 02	AZ	.27541572 03
R	.37875107 06	LAT	-.19704336 02	LON	.24841771 03	VE	.27360133 02	PTE	.22988393 01	AZE	.27026547 03
XS	.12209960 09	YS	.80820899 08	ZS	.35045671 08	DXS	-.16931827 02	DYS	.22266131 02	DZS	.96538648 01
XM	.14773922 06	YM	-.32368125 06	ZM	-.12729881 06	DXM	.93293856 00	DYM	.44182965 00	DZM	.97394919-01
XT	.14773922 06	YT	-.32368125 06	ZT	-.12729881 06	DXT	.93293856 00	DYT	.44182965 00	DZT	.97394919-01
RS	.15056071 09	VS	.29591628 02	RM	.37789074 06	VM	.10368575 01	RT	.37789074 06	VT	.10368575 01
GED	-.19828181 02	ALT	.37237532 06	LOS	.34713206 03	RAS	.33501610 02	RAM	.29453358 03	LOM	.24816403 03
DUT	.34000000 02	DT	.59999999 02	DR	.10974582 01	SHA	.36970918 06	DES	.13460072 02	DEM	-.19686090 02

CASE 1 SPACE TRAJECTORIES 17

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12195010 09	Y	-.81144622 08	Z	-.35173374 08	DX	.16169908 02	DY	-.23803068 02	DZ	-.99046408 01
R	.15064343 09	LAT	-.13502488 02	LON	.21363947 03	V	.30432776 02	PTH	.38515556 01	AZ	.10862076 03
XE	-.12209960 09	YE	-.80820899 08	ZE	-.35045671 08	DXE	.16931827 02	DYE	-.22266131 02	DZE	-.96538648 01
XT	-.12195186 09	YT	-.81144581 08	ZT	-.35172971 08	DXT	.17864766 02	DYT	-.21824302 02	DZT	-.95564700 01
LTE	-.13460072 02	LOE	.21350161 03	LTT	-.13502211 02	LOT	.21363908 03	RST	.15064474 09	VST	.29778786 02
EPS	.77314740 02	ESP	.14023158 00	SEP	.10254464 03	EPM	.61337105 02	EMP	.11842335 03	MEP	.23923566 00
MPS	.13639405 03	MSP	.27453512-18	SMP	.43605474 02	SEM	.10277673 03	EMS	.77083097 02	ESM	.14057998 00
EPT	.61337105 02	ETP	.11842335 03	TEP	.23923566 00	TPS	.13639405 03	TSP	.27453512-18	STP	.43605474 02
SET	.10277673 03	STE	.77083097 02	EST	.14057998 00	RPM	.18005420 04	RPT	.18005420 04	SPN	.76349859 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.17542917 04	Y	-.41198168 02	Z	-.40337930 03	DX	-.16948578 01	DY	-.19787661 01	DZ	-.34817082 00
R	.18005420 04	DEC	-.12945971 02	RA	.35865470 03	V	.26285511 01	PTH	-.35543846 02	AZ	.25065415 03
R	.18005419 04	LAT	-.12276164 02	LON	.23443217 03	VR	.26323470 01	PTR	-.35484836 02	AZR	.27579008 03
LTS	-.15088998 01	LNS	.27707627 03	LTE	-.23849595 01	LNE	.35420790 03				
ALT	.62542053 02	SHA	-.12418135 04	ALP	.16786451 03	DR	-.15280446 01	DP	.68058841-01	ASD	.74854369 02
HGE	.28268525 03	SVL	-.12537189 02	HNG	.22211605 03	SIA	-.13517265 02				

2 DAYS 15 HRS. 45 MIN. 41.481 SEC. JULIAN DATE 2437781.03472778 APRIL 26,1962 12 50 00.481

GEOCENTRIC EQUATORIAL COORDINATES

X	.14946061 06	Y	-.32378615 06	Z	-.12771228 06	DX	-.82509346 00	DY	-.15337984 01	DZ	-.23564499 00
R	.37879594 06	DEC	-.19703527 02	RA	.29477818 03	V	.17575111 01	PTH	.37296634 02	AZ	.27537969 03
R	.37879594 06	LAT	-.19703527 02	LON	.24823531 03	VE	.27417907 02	PTE	.22260056 01	AZE	.27027413 03
XS	.12209890 09	YS	.80821825 08	ZS	.35046072 08	DXS	-.16932024 02	DYS	.22266002 02	DZS	.96538088 01
XM	.14777792 06	YM	-.32366292 06	ZM	-.12729476 06	DXM	.93289217 00	DYM	.44193034 00	DZM	.97434513-01
XT	.14777792 06	YT	-.32366292 06	ZT	-.12729476 06	DXT	.93289217 00	DYT	.44193034 00	DZT	.97434513-01
RS	.15056074 09	VS	.29591626 02	RM	.37788881 06	VM	.10368624 01	RT	.37788881 06	VT	.10368624 01
GED	-.19827367 02	ALT	.37242019 06	LOS	.34695920 03	RAS	.33502063 02	RAM	.29454048 03	LOM	.24799761 03
DUT	.34000000 02	DT	.59999999 02	DR	.10649492 01	SHA	.36974040 06	DES	.13460227 02	DEM	-.19685544 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12194944 09	Y	-.81145611 08	Z	-.35173785 08	DX	.16106930 02	DY	-.23799801 02	DZ	-.98894539 01
R	.15064352 09	LAT	-.13502641 02	LON	.21363994 03	V	.30391857 02	PTH	.39435377 01	AZ	.10859573 03
XE	-.12209890 09	YE	-.80821825 08	ZE	-.35046072 08	DXE	.16932024 02	DYE	-.22266002 02	DZE	-.96538088 01
XT	-.12195112 09	YT	-.81145488 08	ZT	-.35173367 08	DXT	.17864916 02	DYT	-.21824072 02	DZT	-.95563744 01
LTE	-.13460227 02	LOE	.21350206 03	LTT	-.13502368 02	LOT	.21363954 03	RST	.15064472 09	VST	.29778677 02
EPS	.77305976 02	ESP	.14092752 00	SEP	.10255339 03	EPM	.58427063 02	EMP	.12134841 03	MEP	.22468434 00
MPS	.13358604 03	MSP	.27453512-18	SMP	.46413475 02	SEM	.10277071 03	EMS	.77089117 02	ESM	.14057998 00
EPT	.58427063 02	ETP	.12134841 03	TEP	.22468434 00	TPS	.13358604 03	TSP	.27453512-18	STP	.46413475 02
SET	.10277071 03	STE	.77089117 02	EST	.14057998 00	RPM	.17380899 04	RPT	.17380899 04	SPN	.76341209 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.16826918 04	Y	-.12322817 03	Z	-.41751613 03	DX	-.17579856 01	DY	-.19757287 01	DZ	-.33307951 00
R	.17380899 04	DEC	-.13899259 02	RA	.35581155 03	V	.26655129 01	PTH	-.33775504 02	AZ	.25131446 03
R	.17380897 04	LAT	-.11964484 02	LON	.23145102 03	VR	.26692558 01	PTR	-.33721780 02	AZR	.27641459 03
LTS	-.15088972 01	LNS	.27707041 03	LTE	-.23842619 01	LNE	.35420805 03				
ALT	.89950561-01	SHA	-.12589577 04	ALP	.16926349 03	DR	-.14818661 01	DP	.73037905-01	ASD	.89417046 02
HGE	.28269402 03	SVL	-.12358167 02	HNG	.22510600 03	SIA	-.30989981 02				

CASE 1 SPACE TRAJECTORIES 18

RANGER-4 ORBIT BASED ON TRANSPONDER DATA ONLY

SELENOCENTRIC CONIC ORBITAL B.T AND B.R EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE JULIAN DATE 2437781.04080820 APRIL 26,1962 12 58 45.829

SMA	-.33436015 04	ECC	.13802279 01	INC	.15686098 03	LAN	.21119683 03	APF	.27521114 03	RCA	.12713306 04
VH	.12106662 01	C3	.14657126 01	C1	.38509705 04	SLR	.30260565 04	APO	.00000000 00	TFP	-.52534771 03
TA	-.57528145 02	EA	-.25556837 02	MA	-.10898818 02	DAI	-.15006681 02	RAI	.25004857 03	MTA	.13642876 03
WX	-.20354709 00	WY	.33613800 00	WZ	-.91955414 00	PX	.39664958 00	PY	-.83037508 00	PZ	-.39133909 00
QX	-.89511878 00	QY	-.44439669 00	QZ	.35691434-01	RX	-.78094672-01	RY	.29953260 00	RZ	-.95088450 00
SXO	-.90434562 00	SYO	.29531871 00	SZO	.30813276 00	DAO	.17946737 02	RAO	.16191528 03	TF	.63907452 02
SXI	-.32958607 00	SYI	-.90792473 00	SZI	-.25893170 00	TX	-.94089013 00	TY	.29317712 00	TZ	.16962587 00
BX	.92192277 00	BY	-.25036746 00	BZ	-.29559185 00	MX	-.91989552 00	MY	-.20766146-03	MZ	.20354674 00
B.T	-.31521456 04	B.R	.42650115 03	B	.31808686 04	PER	.88998181 03				

614744547542	215472620534	213636320606	604426727545	603463165640	603445451541
	620402321		419000		000000000000

APPENDIX C

Comparison of nominal flight trajectory and *Ranger 4* trajectory based on DSIF transponder orbit

a. Nominal flight trajectory printout at injection and lunar impact only

```
CASE  1                                    SPACE TRAJECTORIES                                                  1

                      RA-4  04/23/62                                           BK
   EPHEMERIDES WITH VENUS VELOCITIES

  GME  .39860320 06     J  .16234500-02    H -.57499999-05     D  .78749999-05    RE  .63781650 04    REM  .63781650 04
    G  .66709998-19     A  .88745998 29    B  .88763998 29     C  .88800998 29   OME  .41780741-02     AU  .14959900 09
  GMM  .49007589 04   GMS  .13271544 12  GMV  .32476950 06   GMA  .42977799 05   GMB  .00000000 00    GMJ  .12671060 09

INJECTION CONDITIONS    1950.0     MOON             JULIAN DATE 2437778.37796992               APRIL 23,1962    21 04 16.602

GEOCENTRIC         X0-.38557687 04   Y0 .50492263 04   Z0 .16686919 04 DX0-.87296651 01 DY0-.47558583 01 DZ0-.45972010 01
CARTESIAN                                         00   T0 .75856601 05 GHA .16749135 03 GHO .21055684 03

  0 DAYS  0 HRS.  0 MIN.  0.000 SEC.               JULIAN DATE 2437778.37796992               APRIL 23,1962    21 04 16.602

GEOCENTRIC                                                                                     EQUATORIAL COORDINATES

   X -.38712850 04     Y  .50388842 04     Z  .16640211 04    DX -.87114587 01    DY -.47794545 01     DZ -.46072546 01
   R  .65685742 04   DEC  .14674689 02    RA  .12753443 03     V  .10952602 02   PTH  .15729797 01     AZ  .11624392 03
   R  .65685741 04   LAT  .14674689 02   LON  .32004307 03    VE  .10539157 02   PTE  .16347042 01    AZE  .11735835 03
  XS  .12585909 09    YS  .75630222 08    ZS  .32795128 08   DXS -.15823229 02   DYS  .22958099 02    DZS  .99543735 01
  XM -.81003997 05    YM -.35864219 06    ZM -.12461970 06   DXM  .99683619 00   DYM -.13865511 00    DZM -.11693435 00
  XT -.81003997 05    YT -.35864219 06    ZT -.12461970 06   DXT  .99683619 00   DYT -.13865511 00    DZT -.11693435 00
  RS  .15045252 09    VS  .29606391 02    RM  .38822149 06    VM  .10132035 01    RT  .38822149 06     VT  .10132035 01
 GED  .14770335 02   ALT  .19175342 03   LOS  .22351080 03   RAS  .31002155 02   RAM  .25727255 03    LOM  .89781204 02
 DUT  .34000000 02    DT  .15000000 02    DR  .30065174 00   SHA  .65596239 04   DES  .12590217 02    DEM -.18723503 02

GEOCENTRIC                                        CONIC         ORBITAL B.T AND B.R            EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE                     JULIAN DATE 2437778.37758452               APRIL 23,1962    21 03 43.303
 SMA  .28325193 06   ECC  .97682782 00   INC  .29811932 02   LAN  .33473038 03   APF  .14618212 03    RCA  .65635660 04
  VH  .12843489 00    C3 -.14072391 01    C1  .71915869 05   SLR  .12975040 05   APO  .55994029 06    TFP  .33298825 02
  TA  .31832877 01    EA  .34473330 00    MA  .79902913-02   DAO  .16062981 02   RAO  .12456347 03    MTA  .18000000 03
  WX -.21222449 00    WY -.44958152 00    WZ  .86766193 00    PX -.54516970 00    PY  .79134724 00     PZ  .27669385 00
  QX -.81101831 00    QY -.41430178 00    QZ -.41304149 00    RX  .33300224-01    RY  .35023668 00     RZ -.93606906 00
 SXO -.54516970 00   SYO  .79134724 00   SZO  .27669385 00    TX  .83766406 00    TY  .50110256 00     TZ  .21729048 00
  BX  .81101834 00    BY  .41430180 00    BZ  .41304151 00    MX -.77949352 00    MY -.45760624 00     MZ -.42776906 00
 B.T  .59212068 05   B.R -.13005225 05     B  .60623468 05   PER  .25004463 05   OMD  .11222834-01    NOD -.70455647-02

HELIOCENTRIC                                                                                   EQUATORIAL COORDINATES

   X -.12586296 09     Y -.75625182 08     Z -.32793464 08    DX  .71117705 01    DY -.27737553 02     DZ -.14561628 02
   R  .15045286 09   LAT -.12589537 02   LON  .21099969 03     V  .32124603 02   PTH  .20341114 02     AZ  .11436489 03
  XE -.12585909 09    YE -.75630222 08    ZE -.32795128 08   DXE  .15823229 02   DYE -.22958099 02    DZE -.99543735 01
  XT -.12594009 09    YT -.75988863 08    ZT -.32919748 08   DXT  .16820065 02   DYT -.23096753 02    DZT -.10071308 02
 LTE -.12590217 02   LCE  .21100215 03   LTT -.12615369 02   LOT  .21110564 03   RST  .15072798 09    VST  .30295311 02
 EPS  .87006138 02   ESP  .98911702-02   SEP  .92991363 02   EPM  .47448519 02   EMP  .71408957 00    MEP  .13183731 03
 MPS  .13442959 03   MSP  .10698938 00   SMP  .45463820 02   SEM  .13514566 03   EMS  .44750256 02    ESM  .10444440 00
 EPT  .47448519 02   ETP  .71408957 00   TEP  .13183731 03   TPS  .13442959 03   TSP  .10698938 00    STP  .45463820 02
 SET  .13514566 03   STE  .44750256 02   EST  .10444440 00   RPM  .39263335 06   RPT  .39263335 06    SPN  .10841482 02

  2 DAYS 16 HRS. 46 MIN. 38.343 SEC.            JULIAN DATE 2437781.07702482               APRIL 26,1962    13 50 54.946
RECTIFICATION             .20946881-01    -.23819936 02  .40002120 02  .17113297 02
```

CASE 1 SPACE TRAJECTORIES 2

RA-4 04/23/62 BK

GEOCENTRIC EQUATORIAL COORDINATES

X	.15150742 06	Y	-.32041239 06	Z	-.12628168 06	DX	.14345329 00	DY	-.19627122 01	DZ	-.65899561 00
R	.37625212 06	DEC	-.19610880 02	RA	.29530719 03	V	.20753538 01	PTH	.70014106 02	AZ	.26962337 03
R	.37625213 06	LAT	-.19610880 02	LON	.23323726 03	VE	.26626081 02	PTE	.42006961 01	AZE	.26998993 03
XS	.12203594 09	YS	.80904553 08	ZS	.35081942 08	DXS	-.16949715 02	DYS	.22254425 02	DZS	.96487845 01
XM	.15123707 06	YM	-.32200382 06	ZM	-.12692607 06	DXM	.92868439 00	DYM	.45093478 00	DZM	.10097914 00
XT	.15123707 06	YT	-.32200382 C6	ZT	-.12692607 06	DXT	.92868439 00	DYT	.45093478 00	DZT	.10097914 00
RS	.15056248 09	VS	.29591406 02	RM	.37771595 06	VM	.10373011 01	RT	.37771595 06	VT	.10373011 01
GED	-.19734233 02	ALT	.36987635 06	LOS	.33147273 03	RAS	.33542656 02	RAM	.29515826 03	LOM	.23308834 03
DUT	.34000000 02	DT	.11920929-06	DR	.19503694 01	SHA	.36790881 06	DES	.13474104 02	DEM	-.19635535 02

HELIOCENTRIC EQUATORIAL COORDINATES

X	-.12188443 09	Y	-.81224965 08	Z	-.35208224 08	DX	.17093168 02	DY	-.24217138 02	DZ	-.10307780 02
R	.15064172 09	LAT	-.13516276 02	LON	.21367987 03	V	.31383060 02	PTH	.29895652 01	AZ	.10900878 03
XE	-.12203594 09	YE	-.80904553 08	ZE	-.35081942 08	DXE	.16949715 02	DYE	-.22254425 02	DZE	-.96487845 01
XT	-.1218847C 09	YT	-.81226557 08	ZT	-.35208868 08	DXT	.17878400 02	DYT	-.21803491 02	DZT	-.95478054 01
LTE	-.13474104 02	LOE	.21354265 03	LTT	-.13516417 02	LOT	.21368033 03	RST	.15064295 09	VST	.29768943 02
EPS	.77771548 02	ESP	.13970734 00	SEP	.10208852 03	EPM	.14730171 03	EMP	.32555854 02	MEP	.14196504 00
MPS	.13492652 03	MSP	.27453512-18	SMP	.45073012 02	SEM	.10223094 03	EMS	.77628651 02	ESM	.14057998 00
EPT	.14730171 03	ETP	.32555854 02	TEP	.14196504 00	TPS	.13492652 03	TSP	.27453512-18	STP	.45073012 02
SET	.10223094 03	STE	.77628651 02	EST	.14057998 00	RPM	.17380900 04	RPT	.17380900 04	SPN	.76800258 02

SELENOCENTRIC EQUATORIAL COORDINATES

X	.27035696 03	Y	.15914199 04	Z	.64439634 03	DX	-.78523111 00	DY	-.24136470 01	DZ	-.75997475 00
R	.17380900 04	DEC	.21761860 02	RA	.80358404 02	V	.26494983 01	PTH	-.80593375 02	AZ	.58669845 02
R	.17380897 04	LAT	-.26119625 01	LON	.32163675 03	VR	.26488368 01	PTR	-.80680092 02	AZR	.61299505 02
LTS	-.15086931 01	LNS	.27654579 03	LTE	-.23215855 01	LNE	.35422238 03				
ALT	.89965820-01	SHA	-.12305803 04	ALP	.13721987 01	DR	-.26138713 01	DP	.14274872-01	ASD	.89417003 02
HGE	.28222845 03	SVL	-.98113103-01	HNG	.13492660 03	SIA	.57884712 02				

SELENOCENTRIC CONIC ORBITAL B.T AND B.R EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE JULIAN DATE 2437781.08326234 APRIL 26,1962 13 59 53.867

SMA	-.35497447 04	ECC	.10161512 01	INC	.37504072 02	LAN	.49014741 02	APF	.19424544 03	RCA	.57332594 02
VH	.11749871 01	C3	.13805948 01	C1	.75265164 03	SLR	.11559118 03	APO	.00000000 00	TFP	-.47706601 03
TA	-.15673065 03	EA	-.53361556 02	MA	-.90476774 01	DAI	-.14609313 02	RAI	.24886973 03	MTA	.16977089 03
WX	.45958366 00	WY	-.39930237 00	WZ	.79331006 00	PX	-.48833380 00	PY	-.85970073 00	PZ	-.14981572 00
QX	.74183104 00	QY	-.31854722 00	QZ	-.59009723 00	RX	-.80118201-01	RY	.29686801 00	RZ	-.95155159 00
SXO	.61230975 00	SYO	.78946716 00	SZO	.42642305-01	DAO	.24439637 01	RAO	.52202886 02	TF	.64927017 02
SXI	-.34883424 00	SYI	-.90260532 00	SZI	-.25222665 00	TX	-.93375359 00	TY	.31172583 00	TZ	.17587284 00
BX	-.81676044 00	BY	.16081445 00	BZ	.55411288 00	MX	-.79443947 00	MY	-.13045254-02	MZ	.45958134 00
B.T	.58306234 03	B.R	-.26524941 C3	B	.64056144 03	PER	.48404291 02				

614741761145 215473447174 213641130440 604427262653 603460277756 603446161053
F20402321 416602 000000000000

APPENDIX C (Cont'd)

b. *Ranger 4* trajectory based on the DSIF transponder orbit printout at the nominal injection epoch and at lunar impact only

0 DAYS 0 HRS. 0 MIN. 0 SEC. JULIAN DATE 2437778.37796992 APRIL 23,1962 21 04 16.602

GEOCENTRIC EQUATORIAL COORDINATES

X -.38722156 04	Y .50376674 04	Z .16639526 04	DX -.87110835 01	DY -.48070404 01	DZ -.45916293 01
R .65681721 04	DEC .14674990 02	RA .12754777 03	V .10957813 02	PTH .14925457 01	AZ .11611209 03
R .65681721 04	LAT .14674990 02	LON .32005641 03	VE .10543888 02	PTE .15511530 01	AZE .11722071 03
XS .12585909 09	YS .75630222 08	ZS .32795128 08	DXS -.15823229 02	DYS .22958099 02	DZS .99543735 01
XM -.81003997 05	YM -.35864219 06	ZM -.12461970 06	DXM .99683619 00	DYM -.13865511 00	DZM -.11693435 00
XT -.81003997 05	YT -.35864219 06	ZT -.12461970 06	DXT .99683619 00	DYT -.13865511 00	DZT -.11693435 00
RS .15045252 09	VS .29606391 02	RM .38822149 06	VM .10132035 01	RT .38822149 06	VT .10132035 01
GED .14770638 02	ALT .19135132 03	LOS .22351080 03	RAS .31002155 02	RAM .25727255 03	LOM .89781204 02
DUT .34000000 02	DT .13020000 01	DR .28541718 00	SHA .65591476 04	DES .12590217 02	DEM -.18723503 02

CASE 1 SPACE TRAJECTORIES 2

RA-4 04/23/62

GEOCENTRIC CONIC ORBITAL B.T AND B.R EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE JULIAN DATE 2437778.37760473 APRIL 23,1962 21 03 45.050

SMA .30650169 06	ECC .97858521 00	INC .29698706 02	LAN .33487978 03	APF .14622939 03	RCA .65636671 04
VH .11864061 00	C3 -.13004926 01	C1 .71948384 05	SLR .12986775 05	APO .60643972 06	TFP .31552460 02
TA .30177640 01	EA .31402306 00	MA .67263107-02	DAO .15985812 02	RAO .12472918 03	MTA .18000000 03
WX -.21032319 00	WY -.44858004 00	WZ .86864270 00	PX -.54766787 00	PY .79007280 00	PZ .27539935 00
QX -.80982961 00	QY -.41780482 00	QZ -.41184350 00	RX .33827630-01	RY .34979038 00	RZ -.93621701 00
SXO -.54766787 00	SYO .79007280 00	SZO .27539935 00	TX .83601171 00	TY .50341991 00	TZ .21829526 00
BX .80982964 00	BY .41780484 00	BZ .41184352 00	MX -.77987434 00	MY -.45881927 00	MZ -.42577095 00
B.T .61656384 05	B.R -.13377566 05	B .63090958 05	PER .28145408 05	OMD .99830454-02	NOD -.62550562-02

2 DAYS 15 HRS. 45 MIN. 43.879 SEC. JULIAN DATE 2437781.03472778 APRIL 26,1962 12 50 00.481

CASE 1 SPACE TRAJECTORIES 17

TRAJECTORY PRINTOUT RA-4 ORBIT BK

GEOCENTRIC — EQUATORIAL COORDINATES

X	.14946061 06	Y	-.32378615 06	Z	-.12771228 06	DX	-.82509349 00	DY	-.15337984 01	DZ	-.23564498 00
R	.37879594 06	DEC	-.19703527 02	RA	.29477818 03	V	.17575111 01	PTH	.37296633 02	AZ	.27537969 03
R	.37879594 06	LAT	-.19703527 02	LON	.24823531 03	VE	.27417908 02	PTE	.22260056 01	AZE	.27027413 03
XS	.12209890 09	YS	.80821825 08	ZS	.35046072 08	DXS	-.16932024 02	DYS	.22266002 02	DZS	.96538088 01
XM	.14777792 06	YM	-.32366292 06	ZM	-.12729476 06	DXM	.93289217 00	DYM	.44193034 00	DZM	.97434513-01
XT	.14777792 06	YT	-.32366292 06	ZT	-.12729476 06	DXT	.93289217 00	DYT	.44193034 00	DZT	.97434513-01
RS	.15056074 09	VS	.29591626 02	RM	.37788881 06	VM	.10368624 01	RT	.37788881 06	VT	.10368624 01
GED	-.19827367 02	ALT	.37242019 06	LCS	.34695920 03	RAS	.33502063 02	RAM	.29454048 03	LOM	.24799761 03
DUT	.34000000 02	DT	.59999999 02	DR	.10649492 01	SHA	.36974040 06	DES	.13460227 02	DEM	-.19685544 02

HELIOCENTRIC — EQUATORIAL COORDINATES

X	-.12194944 09	Y	-.81145611 08	Z	-.35173785 08	DX	.16106930 02	DY	-.23799801 02	DZ	-.98894539 01
R	.15064352 09	LAT	-.13502641 02	LON	.21363994 03	V	.30391857 02	PTH	.39435377 01	AZ	.10859573 03
XE	-.12209890 09	YE	-.80821825 08	ZE	-.35046072 08	DXE	.16932024 02	DYE	-.22266002 02	DZE	-.96538088 01
XT	-.12195112 09	YT	-.81145488 08	ZT	-.35173367 08	DXT	.17864916 02	DYT	-.21824072 02	DZT	-.95563744 01
LTE	-.13460227 02	LOE	.21350206 03	LTT	-.13502368 02	LOT	.21363954 03	RST	.15064472 09	VST	.29778677 02
EPS	.77305976 02	ESP	.14092752 00	SEP	.10255339 03	EPM	.58427066 02	EMP	.12134841 03	MEP	.22468434 00
MPS	.13358604 03	MSP	.27453512-18	SMP	.46413474 02	SEM	.10277071 03	EMS	.77089117 02	ESM	.14057998 00
EPT	.58427066 02	ETP	.12134841 03	TEP	.22468434 00	TPS	.13358604 03	TSP	.27453512-18	STP	.46413474 02
SET	.10277071 03	STE	.77089117 02	EST	.14057998 00	RPM	.17380900 04	RPT	.17380900 04	SPN	.76341209 02

SELENOCENTRIC — EQUATORIAL COORDINATES

X	.16826918 04	Y	-.12322813 03	Z	-.41751612 03	DX	-.17579857 01	DY	-.19757287 01	DZ	-.33307950 00
R	.17380900 04	DEC	-.13899258 02	RA	.35581155 03	V	.26655129 01	PTH	-.33775506 02	AZ	.25131446 03
R	.17380897 04	LAT	-.11964484 02	LON	.23145102 03	VR	.26692558 01	PTR	-.33721782 02	AZR	.27641459 03
LTS	-.15088972 01	LNS	.27707041 03	LTE	-.23842619 01	LNE	.35420805 03				
ALT	.89965820-01	SHA	-.12589577 04	ALP	.16926349 03	DR	-.14818661 01	DP	.73037903-01	ASD	.89417003 02
HGE	.28269402 03	SVL	-.12358167 02	HNG	.22510600 03	SIA	-.30989937 02				

SELENOCENTRIC — CONIC — ORBITAL B.T AND B.R — EQUATORIAL COORDINATES

EPOCH OF PERICENTER PASSAGE — JULIAN DATE 2437781.04080820 — APRIL 26,1962 12 58 45.829

SMA	-.33436013 04	ECC	.13802279 01	INC	.15686098 03	LAN	.21119683 03	APF	.27521114 03	RCA	.12713305 04
VH	.12106662 01	C3	.14657127 01	C1	.38509704 04	SLR	.30260564 04	APO	.00000000 00	TFP	-.52534769 03
TA	-.57528149 02	EA	-.25556839 02	MA	-.10898818 02	DAI	-.15006681 02	RAI	.25004857 03	MTA	.13642876 03
WX	-.20354708 00	WY	.33613800 00	WZ	-.91955414 00	PX	.39664958 00	PY	-.83037509 00	PZ	-.39133909 00
QX	-.89511882 00	QY	-.44439668 00	QZ	.35691443-01	RX	-.78094678-01	RY	.29953260 00	RZ	-.95088451 00
SXO	-.90434564 00	SYO	.29531872 00	SZO	.30813276 00	DAO	.17946737 02	RAO	.16191528 03	TF	.63907452 02
SXI	-.32958610 00	SYI	-.90792473 00	SZI	-.25893169 00	TX	-.94089012 00	TY	.29317715 00	TZ	.16962588 00
BX	.92192277 00	BY	-.25036748 00	BZ	-.29559185 00	MX	-.92157583 00	MY	-.12383598-02	MZ	.20354191 00
B.T	-.31521456 04	B.R	.42650113 03	B	.31808686 04	PER	.88998175 03				

614744547542	215472620534	213636320606	604426727545	603463165640	603445451541
	620402321		419000		000000000000

APPENDIX D

Tables related to trajectory printout

Table D-1. *Ranger 4 trajectory key*

	COLUMN / ROW	1	2	3	4	5	6
	1	GME	J	H	D	RE	REM
GROUP A	2	G	A	B	C	OME	AU
	3	GMM	GMS	GMV	GMA	GMB	GMJ
		INJECTION CONDITIONS		TARGET	JULIAN DATE	MONTH DAY, YEAR	HR. MIN. SEC.
GROUP B	4	GEOCENTRIC XO	YO	ZO	DXO	DYO	DZO
	5	CARTESIAN		TO	GHA	GHO	
		TIME PAST INJECTION			JULIAN DATE	MONTH DAY, YEAR	HR. MIN. SEC.
		GEOCENTRIC				EQUATORIAL COORDINATES	
	6	X	Y	Z	DX	DY	DZ
	7	R	DEC	RA	V	PTH	AZ
GROUP C	8	R	LAT	LON	VE	PTE	AZE
	9	XS	YS	ZS	DXS	DYS	DZS
	10	XM	YM	ZM	DXM	DYM	DZM
	11	XT	YT	ZT	DXT	DYT	DZT
	12	RS	VS	RM	VM	RT	VT
	13	GED	ALT	LOS	RAS	RAM	LOM
	14	DUT	DT	DR	SHA	DES	DEM
		GEOCENTRIC		CONIC	ORBITAL	B • T AND B • R	EQUATORIAL COORDINATES
		EPOCH OF PERICENTER PASSAGE			JULIAN DATE	MONTH DAY, YEAR	HR. MIN. SEC.
	15	SMA	ECC	INC	LAN	APF	RCA
	16	VH	C3	C1	SLR	APO	TFP
GROUP D	17	TA	EA	MA	DAO	RAO	MTA
	18	WX	WY	WZ	PX	PY	PZ
	19	QX	QY	QZ	RX	RY	RZ
	20	SXO	SYO	SZO	TX	TY	TZ
	21	BX	BY	BZ	MX	MY	MZ
	22	B•T	B•R	B	PER	OMD	NOD
		HELIOCENTRIC				EQUATORIAL COORDINATES	
	23	X	Y	Z	DX	DY	DZ
	24	R	LAT	LON	V	PTH	AZ
	25	XE	YE	ZE	DXE	DYE	DZE
GROUP E	26	XT	YT	ZT	DXT	DYT	DZT
	27	LTE	LOE	LTT	LOT	RST	VST
	28	EPS	ESP	SEP	EPM	EMP	MEP
	29	MPS	MSP	SMP	SEM	EMS	ESM
	30	EPT	ETP	TEP	TPS	TSP	STP
	31	SET	STE	EST	RPM	RPT	SPN
		SELENOCENTRIC				EQUATORIAL COORDINATES	
	32	X	Y	Z	DX	DY	DZ
	33	R	DEC	RA	V	PTH	AZ
GROUP F	34	R	LAT	LON	VR	PTR	AZR
	35	LTS	LNS	LTE	LNE		
	36	ALT	SHA	ALP	DR	DP	ASD
	37	HGE	SVL	HNG	SIA		
		SELENOCENTRIC		CONIC	ORBITAL	B • T AND B • R	EQUATORIAL COORDINATES
		EPOCH OF PERICENTER PASSAGE			JULIAN DATE	MONTH DAY, YEAR	HR. MIN. SEC.
	38	SMA	ECC	INC	LAN	APF	RCA
	39	VH	C3	C1	SLR	APO	TFP
GROUP G	40	TA	EA	MA	DAI	RAI	MTA
	41	WX	WY	WZ	PX	PY	PZ
	42	QX	QY	QZ	RX	RY	RZ
	43	SXO	SYO	SZO	DAO	RAO	TF
	44	SXI	SYI	SZI	TX	TY	TZ
	45	BX	BY	BZ	MX	MY	MZ
	46	B•T	B•R	B	PER		
GROUP H	47	XOCTAL	YOCTAL	ZOCTAL	$\dot{X}$OCTAL	$\dot{Y}$OCTAL	$\dot{Z}$OCTAL
	48		YY MM DDD HH	TT SS SSS	SOCTAL		

Table D-2. *Ranger 4* trajectory key definitions

Group		Trajectory constant
Group A		
Row 1	GME	Universal gravitational constant times the mass of Earth, km^3/sec^2
	J	Coefficient of the second harmonic in the Earth's potential function
	H	Coefficient of the third harmonic in the Earth's potential function
	D	Coefficient of the fourth harmonic in the Earth's potential function
	RE	Earth radius, km
	REM	Conversion factor for converting lunar ephemerides into km, 1 e.r. = 6378.150 km
Row 2	G	Universal constant of gravitation, $km^3/kg\ sec^2$
	A B C	Moments of inertia about principal axis for the Moon, $kg\ km^2$
	OME	Sidereal rotation rate of the Earth, deg/sec
	AU	Astronomical unit, km
Row 3	GMM	Universal gravitational constant times the mass of Moon, km^3/sec^2
	GMS	Universal gravitational constant times the mass of Sun, km^3/sec^2
	GMV	Universal gravitational constant times the mass of Venus, km^3/sec^2
	GMA	Universal gravitational constant times the mass of Mars, km^3/sec^2
	GMB	Universal gravitational constant times the mass of Earth-Moon, km^3/sec^2
	GMJ	Universal gravitational constant times the mass of Jupiter, km^3/sec^2
Group B		Injection conditions are vernal equinox cartesian coordinates in a geocentric equatorial system. The principal direction (X) is the vernal equinox direction of date and the principal plane XY is the equatorial plane of date. Z is along the direction of the Earth's spin axis of date.
Row 4	XO YO ZO	Cartesian components of the probe radius vector, km
	DXO DYO DZO	Cartesian components of the probe space-fixed velocity vector, km/sec
Row 5	TO	Time of injection in seconds past midnight of day before launch, sec
	GHA	HA of Greenwich at injection epoch, deg
	GHO	HA of Greenwich at midnight of day before launch, deg
Group C		Inertial position and velocity of the probe, Sun, Moon and target body in a geocentric equatorial system. The principal direction (X) is the vernal equinox direction of date and the principal plane XY is the equatorial plane of date. Z is along the direction of the Earth's spin axis of date. Miscellaneous parameters are also included.
Row 6	X Y Z	Cartesian components of the probe radius vector, km
	DX DY DZ	Cartesian components of the probe space-fixed velocity vector, km/sec
Row 7	R	Probe radius distance, km
	DEC	Probe declination angle, deg
	RA	Probe right Ascension angle, deg
	V	Probe space-fixed velocity, km/sec
	PTH	Pitch angle of the probe space-fixed velocity vector with respect to the local horizontal, deg
	AZ	Azimuth angle of the probe space-fixed velocity vector measured East of true North, deg
Row 8[a]	R	Probe radius distance, km
	LAT	Probe geocentric latitude, deg
	LON	Probe East longitude, deg
	VE	Probe Earth-fixed velocity, km/sec
	PTE	Pitch angle of the probe Earth-fixed velocity vector with respect to the local horizontal, deg
	AZE	Azimuth angle of the probe Earth-fixed velocity vector measured East of true North, deg
Row 9	XS YS ZS	Cartesian components of the Sun radius vector, km
	DXS DYS DZS	Cartesian components of the Sun space-fixed velocity vector, km/sec
Row 10	XM YM ZM	Cartesian components of the Moon radius vector, km
	DXM DYM DZM	Cartesian components of the Moon space-fixed velocity vector, km/sec
Row 11	XT YT ZT	Cartesian components of the target radius vector, km
	DXT DYT DZT	Cartesian components of the target space-fixed velocity vector, km/sec
Row 12	RS	Sun radius distance, km
	VS	Sun space-fixed velocity, km/sec
	RM	Moon radius distance, km
	VM	Moon space-fixed velocity, km/sec
	RT	Target radius distance, km
	VT	Target space-fixed velocity, km/sec
Row 13	GED	Geodetic latitude of the probe, deg
	ALT	Altitude of the probe above the Earth's surface, km
	LOS	East longitude of the Sun in coordinate system defined in Row 8, deg
	RAS	Right ascension of the Sun, deg
	RAM	Right ascension of the Moon, deg
	LOM	East longitude of the Moon in coordinate system defined in Row 8, deg

[a]These are Earth-fixed spherical coordinates in a geocentric equatorial system. The principal direction x is directed towards Greenwich and is the intersection of the meridian plane of Greenwich with the equatorial plane. The principal plane is the Earth's geometrical equatorial plane x y. z is along the direction of the Earth's geometrical north direction.

Table D-2 (Cont'd)

Group		Trajectory constant
Row 14	DUT	Ephemeris time minus Universal Time, sec
	DT	Adams-Moulton step size, sec
	DR	Radial velocity of probe, km/sec
	SHA	Sun shadow parameter, km
	DES	Declination of the Sun, deg
	DEM	Declination of the Moon, deg
Group D		Characteristics of the Earth conic in the geocentric equatorial system described under Group B
Row 15	SMA	Semi-major axis, km
	ECC	Eccentricity
	INC	Inclination of the orbit plane to the equatorial plane, deg
	LAN	Longitude of the ascending node, deg
	APF	Argument of pericenter, deg
	RCA	Magnitude of the closest approach vector, km
Row 16	VH	Hyperbolic excess speed, km/sec
	C3	Twice the energy (*vis viva* energy integral, km^2/sec^2)
	C1	Angular momentum, km^2/sec
	SLR	Semi-latus rectum, km
	APO	Apogee distance, km
	TFP	Time from pericenter passage, sec
Row 17	TA	True anomaly, deg
	EA	Eccentric anomaly, deg
	MA	Mean anomaly, deg
	DAO	Declination of the outgoing asymptote,[b] deg
	RAO	Right ascension of the outgoing asymptote,[b] deg
	MTA	Maximum true anomaly, deg
Row 18	WX, WY, WZ	Components of a unit vector normal to the conic $\mathbf{W} = \dfrac{\mathbf{R} \times \mathbf{V}}{\lvert \mathbf{R} \times \mathbf{V} \rvert}$
	PX, PY, PZ	Components of a unit vector in the direction of perigee
Row 19	QX, QY, QZ	Components of a unit vector perpendicular to the perigee direction, vector $\mathbf{P}$, and being in the orbit plane $\mathbf{Q} = \mathbf{W} \times \mathbf{P}$
	RX, RY, RZ	Components of the unit vector $\mathbf{R}$[b]
Row 20	SXO, SYO, SZO	Components of the unit vector $\mathbf{S}_0$[b] along the direction of the outgoing asymptote
	TX, TY, TZ	Components of the unit vector $\mathbf{T}$[b]
Row 21	BX, BY, BZ	Components of the impact parameter $\mathbf{B}$,[b] km
	MX, MY, MZ	Components of a unit vector which lies in the orbit plane and is normal to the radius vector $\mathbf{R}$. $\mathbf{M} = \mathbf{W} \times \dfrac{\mathbf{R}}{\lvert \mathbf{R} \rvert}$

[b] See appendix A.

Group		Trajectory constant
Row 22	$\mathbf{B} \cdot \mathbf{T}$	Projection of the impact parameter $\mathbf{B}$[b] upon the vector $\mathbf{T}$, km
	$\mathbf{B} \cdot \mathbf{R}$	Projection of the impact parameter $\mathbf{B}$[b] upon the vector $\mathbf{R}$, km
	B	The magnitude of the impact parameter,[b] km
	PER	Period, min
	OMD	Rate of change of argument of perigee, deg/day
	NOD	Rate of change of RA of the ascending node, deg/day
Group E		Inertial position and velocity of the probe, Sun, Moon, and target body in a heliocentric equatorial system. The principal direction $\mathbf{X}$ is the vernal equinox direction of date and the principal plane $\mathbf{XY}$ is the equatorial plane of date. $\mathbf{Z}$ is along the direction of the Earth's spin axis of date. Miscellaneous parameters are also included.
Row 23	X, Y, Z	Cartesian components of the probe radius vector, km
	DX, DY, DZ	Cartesian components of the probe space-fixed velocity vector, km/sec
Row 24	R	Sun probe radius distance, km
	LAT	Probe celestial declination, deg
	LON	Probe celestial right ascension, deg
	V	Probe space-fixed velocity, km/sec
	PTH	Pitch angle of the probe space-fixed velocity vector with respect to the local horizontal, deg
	AZ	Azimuth angle of the probe space-fixed velocity vector measured East of true North, deg
Row 25	XE, YE, ZE	Cartesian components of the Earth radius vector, km
	DXE, DYE, DZE	Cartesian components of the Earth-space-fixed velocity vector, km/sec
Row 26	XT, YT, ZT	Cartesian components of the target radius vector, km
	DXT, DYT, DZT	Cartesian components of the target space-fixed velocity vector, km/sec
Row 27	LTE	Celestial latitude of the Earth, deg
	LOE	Celestial longitude of the Earth, deg
	LTT	Celestial latitude of the target, deg
	LOT	Celestial longitude of the target, deg
	RST	Sun–target range, km
	VST	Sun–target velocity, km/sec
Row 28	EPS	Earth–probe–Sun angle, deg
	ESP	Earth–Sun–probe angle, deg
	SEP	Sun–Earth–probe angle, deg
	EPM	Earth–probe–Moon angle, deg
	EMP	Earth–Moon–probe angle, deg
	MEP	Moon–Earth–probe angle, deg

[b] See appendix A.

Table D-2 (Cont'd)

Group		Trajectory constant
Row 29	MPS	Moon–probe–Sun angle, deg
	MSP	Moon–Sun–probe angle, deg
	SMP	Sun–Moon–probe angle, deg
	SEM	Sun–Earth–Moon angle, deg
	EMS	Earth–Moon–Sun angle, deg
	ESM	Earth–Sun–Moon angle, deg
Row 30	EPT	Earth-probe-target angle, deg
	ETP	Earth-target-probe angle, deg
	TEP	Target-Earth-probe angle, deg
	TPS	Target-probe-Sun angle, deg
	TSP	Target-Sun-probe angle, deg
	STP	Sun-target-probe angle, deg
Row 31	SET	Sun-Earth-target angle, deg
	STE	Sun-target-Earth angle, deg
	EST	Earth-Sun-target angle, deg
	RPM	Moon probe radius distance, km
	RPT	Target probe radius distance, km
	SPN	Sun-probe-near limb of Earth angle, deg
Group F Row 32, 33		Inertial position of probe in a selenocentric equatorial system. The principal direction **X** is the vernal equinox direction of date and the principal plane **XY** is the geocentric equatorial plane of date. **Z** is along the direction of the Earth's spin axis of date.
Row 34, 35, 36		Selenocentric-fixed spherical coordinates of the probe, Sun and Earth in a selenocentric equatorial system. The principal direction **X** is in the direction of the mean Moon-Earth line. The principal plane **XY** is the mean selenocentric equatorial plane. **Z** is along the direction of the Moon's mean spin axis. Miscellaneous parameters are also included.
Row 32	X Y Z	Cartesian components of the probe radius vector, km
	DX DY DZ	Cartesian components of the probe velocity vector, km/sec
Row 33	R	Probe radius distance, km
	DEC	Probe declination angle, deg
	RA	Probe right ascension angle, deg
	V	Probe space-fixed velocity, km/sec
	PTH	Pitch angle of the probe space-fixed velocity vector with respect to the local horizontal, deg
	AZ	Azimuth angle of the probe space-fixed velocity vector measured East of true North, deg
Row 34	R	Probe radius distance, km
	LAT	Probe selenocentric latitude, deg
	LON	Probe selenocentric East longitude, deg
	VR	Probe selenocentric-fixed velocity, km/sec
	RTR	Pitch angle of the probe selenocentric-fixed velocity vector with respect to the local horizontal, deg
	AZR	Azimuth angle of the probe selenocentric-fixed velocity vector measured East of the Moon's mean spin axis, deg

Group		Trajectory constant
Row 35	LTS	Selenocentric latitude of the Sun, deg
	LNS	Selenocentric longitude of the Sun, deg
	LTE	Selenocentric latitude of the Earth, deg
	LNE	Selenocentric longitude of the Earth, deg
Row 36	ALT	Altitude of the probe above the Moon's surface, km
	SHA	Sun shadow parameter, km
	ALP	Illuminated crescent orientation viewing angle, deg
	DR	First time derivative of the probe radius distance, km/sec
	DP	First time derivative of the probe radius direction, deg/sec
	ASD	Angular semidiameter of Moon as seen from the probe, deg
Row 37	HGE	Right ascension of Earth in probe coordinate system,[c] deg
	SVL	Declination of the Moon in probe coordinate system,[c] deg
	HNG	Right ascension of the Moon in probe coordinate system,[c] deg
	SIA	Earth–probe–Moon angle minus ASD, deg
Group G		Characteristics of the selenocentric conic in the geocentric equatorial system described under Group B except centered at the Moon
Row 38	SMA	Semimajor axis, km
	ECC	Eccentricity
	INC	Inclination of the orbit plane to the equatorial plane, deg
	LAN	Longitude of the ascending node, deg
	APF	Argument of pericenter, deg
	RCA	Magnitude of the closest approach vector, km
Row 39	VH	Hyperbolic excess speed, km/sec
	C3	Twice the energy (Vis viva energy integral, km^2/sec^2)
	C1	Angular momentum, km^2/sec
	SLR	Semi-latus rectum, km
	APO	Apogee distance, km
	TFP	Time from pericenter passage, sec
Row 40	TA	True anomaly, deg
	EA	Eccentric anomaly, deg
	MA	Mean anomaly, deg
	DAI	Declination of the incoming asymptote,[b] deg
	RAI	Right ascension of the incoming asymptote,[b] deg
	MTA	Maximum true anomaly, deg
Row 41	WX WY WZ	Components of a unit vector normal to the conic $\mathbf{W} = \dfrac{\mathbf{R} \times \mathbf{V}}{\lvert \mathbf{R} \times \mathbf{V} \rvert}$
	PX PY PZ	Components of a unit vector in the direction of perigee

[b] See appendix A.
[c] Same coordinate system as defined under B except centered at the probe.

Table D-2 (Cont'd)

Group		Trajectory constant
Row 42	QX QY QZ	Components of a unit vector perpendicular to the perigee direction, vector **P**, and being in the orbit plane $\mathbf{Q} = \mathbf{W} \times \mathbf{P}$
	RX RY RZ	Components of the unit vector **R**[b]
Row 43	SXO SYO SZO	Components of the unit vector $\mathbf{S}_0$[b] along the direction of the outgoing asymptote
	DAO	Declination of the outgoing asymptote,[b] deg
	RAO	Right ascension of the outgoing asymptote,[b] deg
	TF	Time from injection to epoch of pericenter passage, hr
Row 44	SXI SYI SZI	Components of the unit vector $\mathbf{S}_I$[b] along the direction of the incoming asymptote
	TX TY TZ	Components of the unit vector **T**[b]
Row 45	BX BY BZ	Components of the impact parameter **B**,[b] km
	MX MY MZ	Components of a unit vector which lies in the orbit plane and is normal to the radius vector **R** $\mathbf{M} = \mathbf{W} \times \frac{\mathbf{R}}{\lvert\mathbf{R}\rvert}$

[b] See appendix A.

Group		Trajectory constant
Row 46	$\mathbf{B} \cdot \mathbf{T}$	Projection of the impact parameter **B**[b] upon the vector **T**, km
	$\mathbf{B} \cdot \mathbf{R}$	Projection of the impact parameter **B**[b] upon the vector **R**, km
	B	The magnitude of the impact parameter,[b] km
	PER	Period, min
Group H		Cartesian coordinates and epoch of injection conditions in the geocentric equatorial system described under Group B.
Row 47	XOCTAL YOCTAL ZOCTAL	Cartesian components of the probe radius vector at injection in octal representation, km
	$\dot{\text{X}}$OCTAL $\dot{\text{Y}}$OCTAL $\dot{\text{Z}}$OCTAL	Cartesian components of the probe space-fixed velocity vector at injection in octal representation, km/sec
Row 48		Epoch of injection
	YY	Years past 1900
	MM	Month
	DDD	Day of month
	HH	Hours
	TT	Min
	SSSSS	Msec
	SOCTAL	Sec in octal representation
		The time past midnight Greenwich Meridian Time on (DD), month (MM) and year (YY + 1900) at which the injection epoch occurs is the time determined by the sum of HH, TT, SSSSS, and SOCTAL.

[b] See appendix A.

Table D-3. ***Ranger 4*** **trajectory constants and conversion factors**

Constants	Conversion factors
GM_{Sun}	$1.32715445 \times 10^{11}$ km^3/sec^2
GM_{Venus}	3.247695×10^5 km^3/sec^2
GM_{Earth}	3.986032×10^5 km^3/sec^2
$GM_{Earth-Moon}$	4.03503×10^5 km^3/sec^2
GM_{Moon}	4.900759×10^3 km^3/sec^2
GM_{Mars}	4.297780×10^4 km^3/sec^2
$GM_{Jupiter}$	1.267106×10^8 km^3/sec^2
M_{Sun}/M_{Venus}	408645
M_{Sun}/M_{Earth}	332951.3
M_{Earth}/M_{Moon}	81.335
$M_{Sun}/M_{Earth-Moon}$	328908
M_{Sun}/M_{Mars}	3,088,000
$M_{Sun}/M_{Jupiter}$	1047.39
Equatorial radius of Earth	6378.165 km
1 AU	1.495990×10^8 km
Ellipticity of Earth	1/298.3
Conversion from feet to meters	0.3048
Atmospheric model	1959 ARDC
Sidereal rotation rate of Earth	4.1780742×10^{-3} deg/sec
Universal constant of gravitation	6.671×10^{-20} km^3/kg sec^2
Speed of light	2.997925×10^5 km/sec
Mean Moon radius	1738.09 km

Constants	Conversion factors
Moon moments of inertia about principal axis	$A = 0.88746 \times 10^{29}$ kg km^2 $B = 0.88764 \times 10^{29}$ kg km^2 $C = 0.88801 \times 10^{29}$ kg km^2
Lunar and solar ephemerides	The Moon and Sun positions are obtained from the joint JPL–STL ephemerides. For purposes of converting into kilometers, the conversion factors are: 1 AU = 1.495990×10^8 km 1 e.r. = 6378.165 km
Geometrical Earth model, used in locating tracking and launching facilities upon the Earth	Clarke spheroid of 1866 $a = 6378.2064$ km $b = 6356.5838$ km $e^2 = 0.006768657997291$

Earth potential function:

$$\Phi(R, \phi) = \frac{GM_E}{R}\left[1 + \frac{JR_E^2}{3R^2}(1 - 3\sin^2\phi) + \frac{H}{5}\frac{R_E^3}{R^3}(3 - 5\sin^2\phi)(\sin\phi) + \frac{D}{35}\frac{R_E^4}{R^4}(3 - 30\sin^2\phi + 35\sin^4\phi)\right]$$

where

R = geocentric distance

ϕ = geocentric latitude

$J = 1.62345 \times 10^{-3}$

$H = -0.575 \times 10^{-5}$

$D = 0.7875 \times 10^{-5}$

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The development of the digital computer programs is a joint responsibility of the Systems Analysis Section (312) and the Computer Applications and Data Systems Section (372) at the Jet Propulsion Laboratory. While these responsibilities often considerably overlap, Section 372's responsibility includes programming the numerical analysis aspects, while Section 312 is responsible for the physical models, specification of operational output, in-flight control, and overall coordination.

JPL's basic trajectory program has been developed almost completely by D. B. Holdridge of Section 372. His work includes the physical model as well as the programming. Additional contributors are acknowledged in Ref. 2.

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REFERENCES

1. *NASA/AGENA-B Ranger Program Launch Report for Atlas 133D/Agena-B 10205-6004 Ranger Spacecraft RA-4*, Lockheed Missiles and Space Company, Space Systems, AMFTC Test Operations, Control No. AF 04(647)-592, LMSC-271596 (CONFIDENTIAL).

2. Holdridge, D. B., *Space Trajectories Program for the IBM 7090 Computer*, Technical Report No. 32-223, Jet Propulsion Laboratory, Pasadena, March 2, 1962.

3. *Post-Launch Nominal Trajectory-Ranger IV First Month*, Vol. IV, 8990-6003-0C004, Space Technology Laboratories, Inc., Redondo Beach, Calif., April 25, 1962 (CONFIDENTIAL).

4. Space Technology Laboratories, Inc., *A Dynamical Determination of the Astronomical Unit by Least Squares Fit of the Orbit of Pioneer V*, by J. B. McGuire and L. Wong, STL Report 2301-0004-RV-000, Space Technology Laboratories, Inc., Redondo Beach, Calif., May 15, 1961.

5. Jet Propulsion Laboratory, *Capability of the DSIF for Lunar Missions of Project Ranger—1961 through Mid-1963*, External Publication Document 48 (Rev. 1), Jet Propulsion Laboratory, Pasadena, April 20, 1962.

6. Jet Propulsion Laboratory, *Ranger 4 Tracking Information Memorandum 332-4*, External Publication Document 63, Jet Propulsion Laboratory, Pasadena, March 26, 1962.

7. Clarke, V. C. Jr., *Constants and Related Data Used in Trajectory Calculations at the Jet Propulsion Laboratory*, Technical Report No. 32-273, Jet Propulsion Laboratory, Pasadena, May 1, 1962.

8. Noton, A. R. M., E. Cutting, and F. L. Barnes, *Analysis of Radio-Command Midcourse Guidance*, Technical Report No. 32-28, Jet Propulsion Laboratory, Pasadena, September 8, 1960.

9. Magness, T. A., and J. B. McGuire, "Comparison of Least Squares and Minimum Variance Estimates of Regression Parameters," *The Annuals of Mathematical Statistics*, Vol. 33, No. 2, June 1962.

10. Kizner, W., *A Method of Describing Miss Distances for Lunar and Interplanetary Trajectories*, External Publication No. 674, Jet Propulsion Laboratory, Pasadena, August 1, 1959.

11. Carr, R. E., and R. H. Hudson, *Tracking and Orbit-Determination Program of the Jet Propulsion Laboratory*, Technical Report No. 32-7, Jet Propulsion Laboratory, Pasadena, February 22, 1960.