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TRACKING COVERAGE OF THE RADIO ASTRONOMY EXPLORER-B

HOBART SWARTWOOD, JR.

RAE-B Mission Analysis Report No. 3

AUGUST 1972

GODDARD SPACE FLIGHT CENTER
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ABSTRACT

Certain of the launch and arrival parameters for the Radio Astronomy Explorer-B mission have been revised to provide better tracking station coverage of the transfer trajectory. It is shown that changing the launch azimuth and flight time is sufficient to provide post-injection tracking by Tananarive and Carnarvon, and redundant lunar orbit insertion coverage by command stations. These changes can be made with no significant influence on the other parameters and without sacrificing any launch opportunities. All acceptable launch opportunities during the RAE-B launch period are tabulated together with pertinent launch and arrival parameters; this table supersedes all those previously published.

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INTRODUCTION

The Radio Astronomy Explorer-B is scheduled to be launched during the period April through September 1973 and will be placed into an inclined, nearly circular orbit about the Moon. Launch opportunities are subject to constraints imposed by spacecraft thermal and electrical power considerations, the on-board propulsion system, and spacecraft gravity gradient utilization considerations. In addition, it is necessary to have adequate tracking station coverage during the critical phases of the mission, in particular, the first few hours after the translunar injection burn, and the retro maneuver at perilune. It is shown that changing the launch azimuth and the nominal flight time can satisfy the coverage requirements for all launch dates which meet the other constraints.

THE RADIO ASTRONOMY EXPLORER-B MISSION

The Radio Astronomy Explorer-B will be launched during the period April through September 1973 and will be placed into a nearly circular lunar orbit, inclined 116.5 degrees to the lunar equator at an altitude of 1100 km. Constraints on the launch and arrival conditions limit the number of launch opportunities, see Ref. 1, 2. Specifically, the spin axis-Sun angle must be maintained between 60 degrees and 120 degrees throughout the spin-stabilized phases of the mission except for maneuver periods. As midcourse guidance corrections will be necessary, the mass of the spacecraft at perilune will vary. But the retro motor for lunar orbit insertion is a solid propellant fixed total impulse motor, and thus the net velocity increment it applies varies accordingly. After lunar orbit insertion the on-board hydrazine system will be used to circularize the orbit and to remove any insertion errors. The total velocity correction necessary for orbit insertion and trim is constrained to be no more than 0.720 km/sec.

The orbit about the Moon is perturbed primarily by the Earth and by lunar gravitational anomalies. The perturbations cause the line of nodes to regress. Part of the orbit will be in lunar shadow for certain values of the node, and for other values, the entire orbit will be sunlit. Launch opportunities are also subject to the constraint that during the first 50 days of lunar orbit, the entire orbit is required to be sunlit.

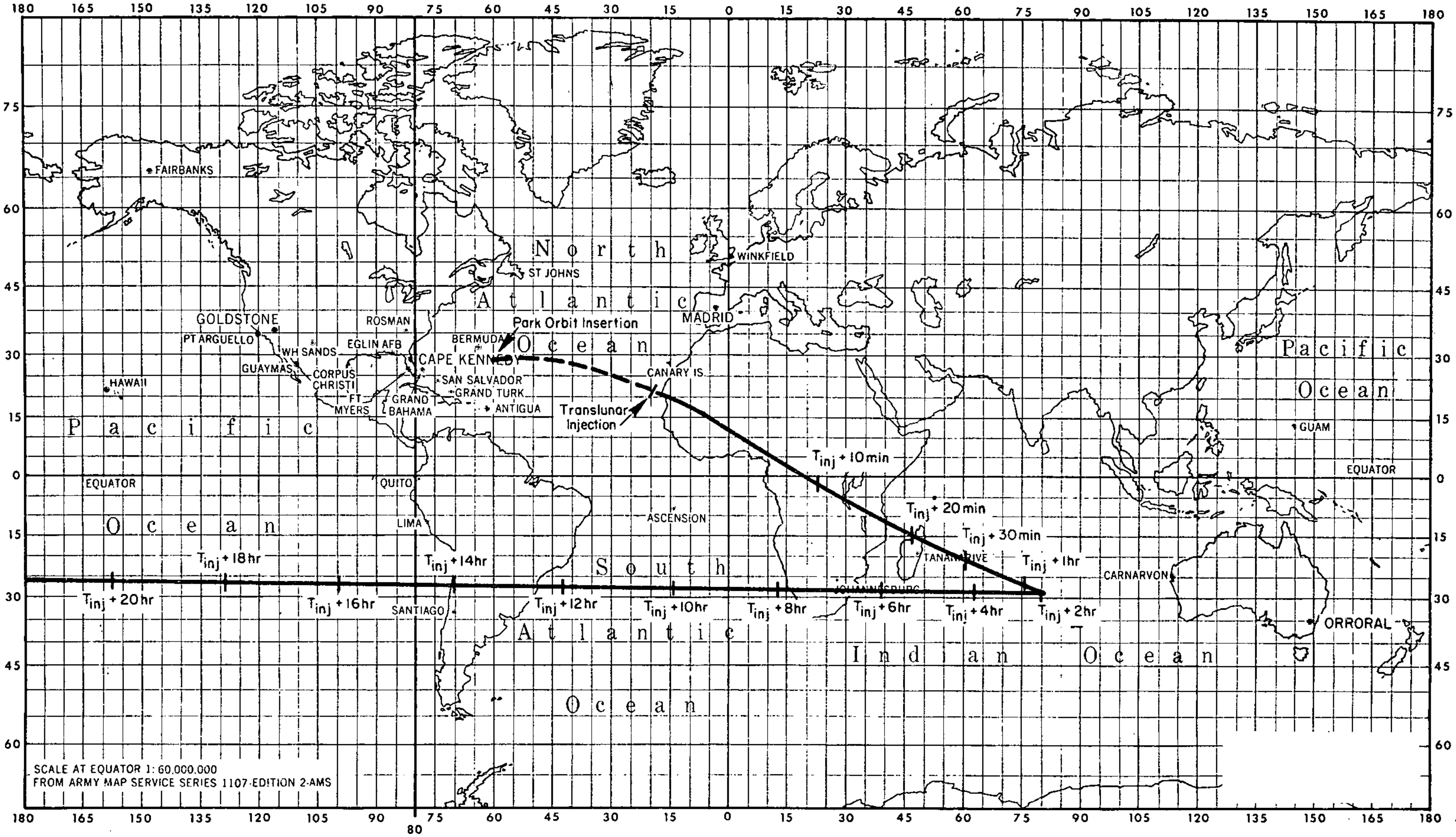
In addition the tracking requirements impose constraints. For orbit determination purposes, only those translunar trajections which are visible during the first few hours from stations at Tananarive and Carnarvon are acceptable. The spacecraft will be inserted into lunar orbit by the solid propellant retro motor. Redundant coverage of the retro maneuver by command tracking stations is another requirement.

TRACKING COVERAGE

Success of the RAE-B mission is largely dependent upon tracking coverage of all phases of the mission. For orbit determination purposes, good tracking coverage is essential during the first few hours after translunar injection. The primary stations for this phase of the mission are Tananarive and Carnarvon. The translunar trajectories must be designed to pass within the visibility limits of these two stations, constraining to some extent the Earth-fixed injection point. This requirement translates into a constraint on launch azimuth and park orbit coast time. It is easier, and more desirable, to vary the coast time and hold launch azimuth fixed. For most launch dates during the RAE-B launch period, a launch azimuth of 81 degrees satisfies the location requirements for the injection point, with park times varying from about 480 sec to about 800 sec. The accompanying figure shows a typical RAE-B ground trace. During the latter months, the Moon is at a higher declination and in order to maintain a short park orbit coast time, the launch azimuth should be changed to 95 degrees to insure the requisite coverage.

The nominal mission calls for the spacecraft to be inserted into lunar orbit at perilune on the hyperbolic approach trajectory. The solid propellant retro motor ignition will be commanded from Earth. For this most important function, it is necessary to provide redundant command capability. By varying the flight time, the time of arrival at perilune can be controlled, and by judiciously choosing the flight time, the required command station coverage can be achieved.

Below is the coverage schedule of the stations under consideration for a 24-hour period during a typical RAE-B arrival period. The visibility times, and even the relative signal acquisition and signal loss times among stations, is affected by the Moon's declination. Similar figures can be generated for all launch dates which meet all the mission constraints for the nominal flight time, 110 hrs. Extending the flight time has little effect on the other launch parameters, so it can be chosen, to some extent, independently. This has been done, and the results are presented in the table.



Ground Trace of RAE-B Park Orbit and Transfer Trajectory

Between April and September there exist three to four opportunities per month. The Spin Axis-Sun Angle as tabulated is determined at the time of injection into the translunar trajectory. Except for altitude maneuvers, this angle should remain approximately inertially constant throughout the trajectory. Shadow Time is zero in all cases, and represents the total time the spacecraft spends in shadow from launch, through the park orbit, the transfer trajectory, and at least the initial 50 days of lunar orbit. Lunar Phase Angle at Arrival is the Earth-Moon-Sun angle, and gives a measure of the phase of the Moon at the time of arrival of the spacecraft. The Sunlit Orbit Time is the time from insertion into the lunar orbit until the spacecraft first enters the lunar shadow. This quantity was determined using an approximation technique which is generally conservative. On those launch dates where it is less than mission requirements, more detailed analyses were made and these results are indicated parenthetically on certain of the launch dates. The column, ΔV for Circular Orbit, is the total velocity increment necessary to achieve a circular lunar orbit if the retro maneuver were to occur at perilune. The Flight Time is measured from translunar injection to perilune, and for the indicated times will provide redundant coverage by command stations. Those stations are Rosman, Santiago, and Orroral during April through August; and Rosman, Santiago and Johannesburg in September.

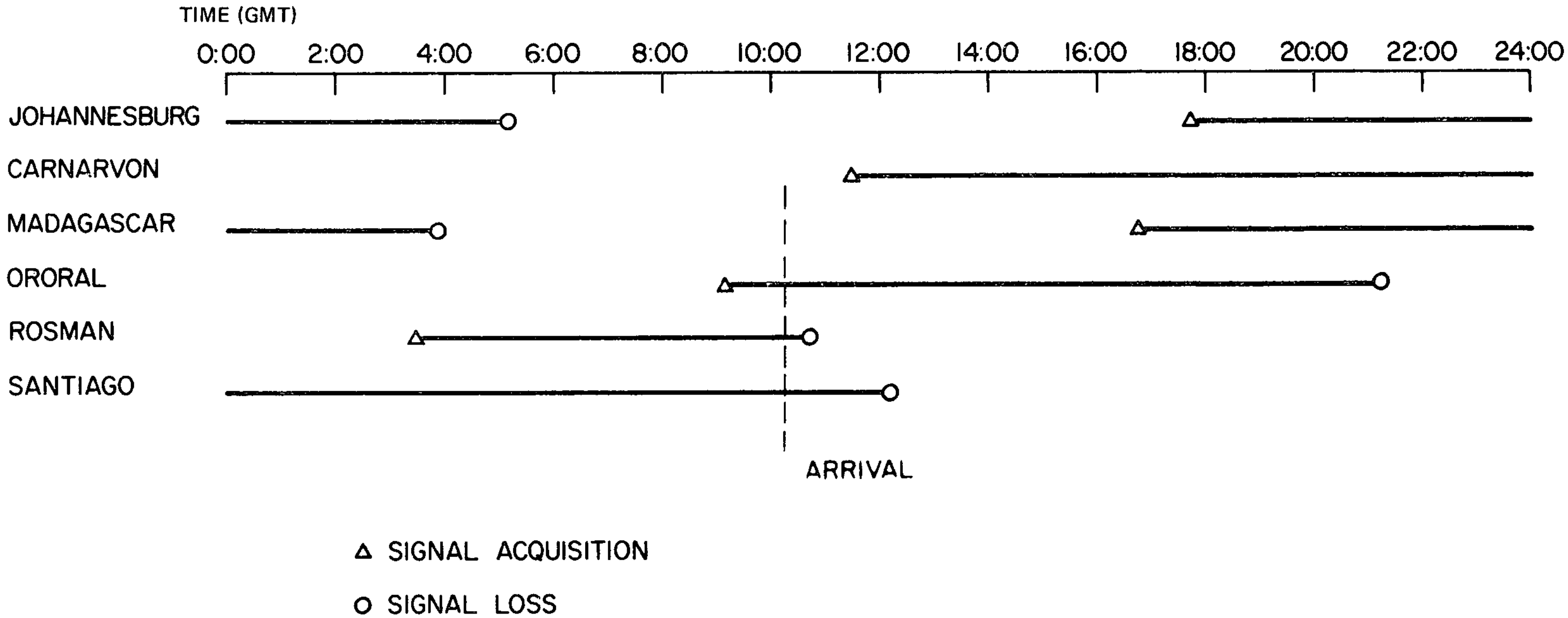
This table supersedes all those previously published.

RAE-B LAUNCH AND ARRIVAL PARAMETERS

LAUNCH DATE	LAUNCH AZIMUTH	LAUNCH TIME (GMT)	PARK ORBIT COAST TIME (SEC)	SPIN AXIS-SUN ANGLE (DEG)	SHADOW TIME	LUNAR PHASE ANGLE AT ARRIVAL (DEG)	SUNLIT ORBIT TIME (DAYS)	Δ V for CIRCULAR ORBIT (KM/SEC)	FLIGHT TIME (HRS)
4-13-73	81°	13:28	701	100	0	9	66	0.724	115
-14-	81°	14:50	583	112	0	21	82	0.715	115
-15-	81°	16:02	502	124	0	32	97	0.709	114.5
5-11-73	81°	12:34	623	87	0	-10	46(53)	0.715	115
-12-	81°	13:50	528	98	0	2	61	0.709	115
-13-	81°	14:52	480	109	0	13	77	0.706	114
-14-	81°	15:42	482	121	0	24	91	0.703	114.5
6-09-73	81°	12:47	489	82	0	-17	41(49)	0.704	115
-10-	81°	13:40	475	93	0	-5	56	0.702	115
-11-	81°	14:18	516	104	0	6	70	0.702	115
-12-	81°	14:43	599	115	0	17	84	0.702	115
7-09-73	81°	12:48	567	86	0	-13	49	0.701	115
-10-	81°	13:07	672	97	0	-1	62	0.702	115.5
-11-	81°	13:19	800	108	0	10	75	0.704	116
8-08-73	95°	13:37	508	90	0	-8	54	0.705	115
-09-	95°	13:43	663	102	0	4	67	0.708	115.5
-10-	95°	13:48	821	114	0	16	80	0.711	116
9-06-73	95°	11:58	726	80	0	-18	45(49)	0.711	110
-07-	95°	12:01	886	92	0	-6	58	0.715	110
-08-	95°	12:05	1050	104	0	6	71	0.718	110

LAUNCH 4-14-73

ARRIVAL 4-19-73, 10:08 GMT



RAE-B Tracking Coverage on April 19, 1973

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