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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE AND NAVIGATION

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REPORT E-1212 (Preliminar[redacted]

IMU ERROR DATA

FOR APOLLO TRAJECTORI[redacted]

by

Frederic D. Grant, Jr.

September 1962

[redacted]

INSTRUMENTATION LABORATORY

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(Preliminary)

IMU ERROR DATA FOR APOLLO TRAJECTORIES

This report contains summaries of position, velocity, and orientation errors due to IMU errors for seven trajectories of interest. The error data presented herein are purely preliminary.

For example, the trajectories used in this study represent simple first-order approximations to thrusting and reentry phases typical to but not necessarily matching those of the Apollo mission.

The data presented for each trajectory are as follows:

1) Trajectory description & data
2) Over-all system studies of position and velocity errors
3) Over-all system study of stable member drift angles
4) Graphs showing RSS position and velocity errors and stable member drift angle vs. stable member orientation angle
5) Graphs showing RSS position and velocity errors vs. time from last IMU stable member alignment to trajectory start
6) Tables for position and velocity error coefficients and for SM drift angle coefficient

The trajectories covered in this preliminary report are as follows:

A) Earth launch into orbit
B) Translunar injection
C) Lunar deboost to orbit
D) Lunar landing
E) Lunar takeoff
F) Transearth injection
G) Earth reentry (4 trajectories)

ASSUMED RMS IMU ERRORS FOR SYSTEM ERROR STUDIES

Nonorthogonality of accelerometer input axes	0.1 mr
Accelerometer bias errors	0.2 cm/sec^2
Accelerometer scale-factor errors	110 PPM
Accelerometer acceleration-sensitive scale-factor errors	10 PPM/g
Gyro bias drift	10 meru
Gyro acceleration-sensitive drift	10 meru/g
Gyro acceleration-squared-sensitive drift	1 $meru/g^2$

SECTION A

EARTH LAUNCH INTO ORBIT TRAJECTORY

Trajectory Description & Data

1) Description = Launch from earth into parking orbit with 127 n mile cut off altitude.

2) Total trajectory time: 857.1 seconds

3) Total earth angle, θ_R, subtended by trajectory : 30.75 degrees

4) Initial & final altitudes: 0 and 127.3 n miles

5) Initial & final velocities: 1,250 and 25,344 ft/sec

6) Initial & final velocity angles relative to Z_I axis : 0 and -30.6 degrees

7) Initial & final thrust acceleration: 47.9 and 44.9 ft/sec^2

8) Initial & final pitch angle relative to X_I axis: 0 and 112.2 degrees

9) Thrust acceleration history in ft/sec^2:

$a_T = 47.9 + 0.41t - 0.0103t^2$ for $0<t<126.3$ sec

$a_T = 15.6 + 0.0096t + 0.000038t^2$ for $126.3<t<522.3$ sec

$a_T = 0.00705t + 0.00024t^2$ for $522.3<t<857.1$ sec

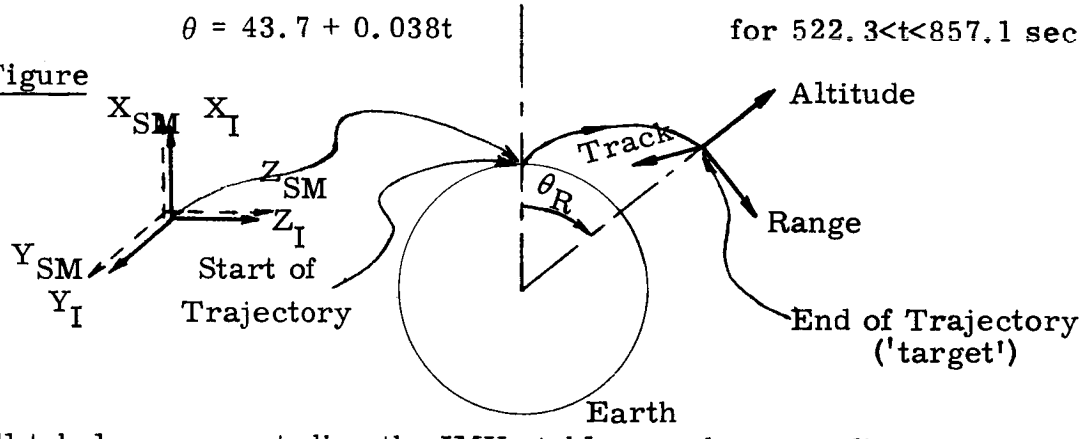
10) Pitch angle history in degrees relative to X_I axis:

$\theta = 0.096t + 0.0155t^2$ for $0<t<126.3$ sec

$\theta = 52.5 + 0.048t$ for $126.3<t<522.3$ sec

$\theta = 43.7 + 0.038t$ for $522.3<t<857.1$ sec

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Earth Launch into Orbit Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	2,088	0	0	2,088	0
		$A_{(SM)YI}$	0.206 mr	2,566	0	1,503	2,603	0	1,437
		$A_{(SM)ZI}$	0.206 mr	0	1,611	0	0	1,611	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	1,311	0	72	608	0	1,163
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	2,804	0	146	1,308	0	2,484
		ACBY	0.2 cm/sec^2	0	2,215	0	0	2,215	0
		ACBZ	0.2 cm/sec^2	135	0	2,257	1,871	0	1,270
	Scale Factor Error	SFEX	100 PPM	1,105	0	72	503	0	987
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	66	0	1,034	854	0	585
	Accel. Sens Scale Factor Error	SFNCX	10 PPM/g	189	0	13	85	0	169
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	14	0	184	151	0	106
GYRO	Bias Drift	BDX	10 meru	0	1,975	0	0	1,975	0
		BDY	10 meru	2,250	0	740	1,786	0	1,556
		BDZ	10 meru	0	813	0	0	813	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	1,968	0	0	1,968	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	808	0	0	808	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	2,266	0	729	1,785	0	1,575
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	351	0	0	351	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	465	0	156	371	0	320
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	173	0	0	173	0
Root Sum Square Error				5,278	4,594	3,097	4,459	4,594	4,191
				7,652			7,652		

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Earth Launch into Orbit Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	4.35	0	0	4.35	0
		$A_{(SM)YI}$	0.206 mr	6.22	0	1.04	4.08	0	4.61
		$A_{(SM)ZI}$	0.206 mr	0	1.68	0	0	1.68	0
S. M.	Accel. IA Non-ortho-gonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	3.39	0	0.46	1.34	0	3.14
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	7.35	0	0.95	2.94	0	6.80
		ACBY	0.2 cm/sec^2	0	4.73	0	0	4.73	0
		ACBZ	0.2 cm/sec^2	0.86	0	5.08	3.93	0	3.34
	Scale Factor Error	SFEX	100 PPM	2.07	0	0.43	0.69	0	2.00
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0.41	0	2.28	1.75	0	1.52
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.35	0	0.07	0.12	0	0.34
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0.08	0	0.31	0.23	0	0.23
GYRO	Bias Drift	BDX	10 meru	0	7.19	0	0	7.19	0
		BDY	10 meru	8.56	0	0.34	4.67	0	7.19
		BDZ	10 meru	0	0.87	0	0	0.87	0
	Acceler-ation Sensitive Drift	ADIAX	10 meru/g	0	5.12	0	0	5.12	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0.88	0	0	0.88	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	8.17	0	0.33	4.46	0	6.85
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceler-ation Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0.84	0	0	0.84	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	1.48	0	0.09	0.84	0	1.23
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0.12	0	0	0.12	0
Root Sum Square Error				15.87	11.15	5.81	9.41	11.15	14.03
				20.24			20.24		

Earth Launch into Orbit Trajectory

OVERALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES

(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.625	0	0	0.320	0	0.537
	BDY	10 meru	0	0.625	0	0	0.625	0
	BDZ	10 meru	0	0	0.625	0.537	0	0.320
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0.278	0	0	0.142	0	0.239
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.577	0.496	0	0.295
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.577	0	0	0.577	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0.045	0	0	0.023	0	0.039
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.084	0.072	0	0.043
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.084	0	0	0.084	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.686	0.854	0.854	0.814	0.854	0.734
			1.389			1.389		

Earth Launch into Orbit Trajectory
IMU POSITION ERROR COEFFICIENTS (PART I)
(SM axes colinear with inertial axes)

Error			Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes									
Initial Position Error	$(E)X_{IO}$		foot	+2.199	0	+0.217	-0.938	0	+2.001
	$(E)Y_{IO}$		foot	0	+0.517	0	0	+0.517	0
	$(E)Z_{IO}$		foot	+0.138	0	+0.548	+0.400	0	+0.399
Initial Velocity Error	$(E)V_{XIO}$		ft/sec	+1,158	0	+86	-518	0	+1,039
	$(E)V_{YIO}$		ft/sec	0	+718	0	0	+718	0
	$(E)V_{ZIO}$		ft/sec	+74	0	+738	+597	0	+441
B. Accelerometer Errors (In-flight Effect only)									
Bias	ACBX		cm/sec^2	-14,020	0	-728	+6,543	0	-12,421
	ACBY		cm/sec^2	0	-11,076	0	0	-11,076	0
	ACBZ		cm/sec^2	-676	0	-11,286	-9,354	0	-6,352
Scale Factor Error	SFEX		PPM	-11,055	0	-0.720	+5.034	0	-9.869
	SFEY		PPM	0	0	0	0	0	0
	SFEZ		PPM	-0.663	0	-10.34	-8.544	0	-5.855
Accel. Sens. Scale Factor Error	SFNCX		PPM/g	-18.90	0	-1.30	+8.543	0	-16.91
	SFNCY		PPM/g	0	0	0	0	0	0
	SFNCZ		PPM/g	-1.41	0	-18.40	-15.09	0	-10.61
C. Misalignments of Accelerometer Input Axes									
Accel.	About Axis								
X	Y_{SM}	$A_{(X)Y}$	milliradian	+13,106	0	+718	-6,085	0	+11,631
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	-	-	-	-	-	-
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Earth Launch into Orbit Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		'milliradian	0	-10,134	0	0	-10,134	0
$A_{(SM)YI}$		milliradian	+12,456	0	-7,294	-12,637	0	+6,976
$A_{(SM)ZI}$		milliradian	0	+7,823	0	0	+7,823	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-197.5	0	0	-197.5	0
	BDY	meru	+225.0	0	-74.0	-178.6	0	+155.5
	BDZ	meru	0	+81.3	0	0	+81.3	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-196.8	0	0	-196.8	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	+80.8	0	0	+80.8	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-226.6	0	+72.9	+178.4	0	-157.5
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-351.4	0	0	-351.4	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+173.3	0	0	+173.3	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+464.9	0	-155.5	-371.4	0	+320.0
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Earth Launch into Orbit Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	$+2.995(10^{-3})$	0	$+1.037(10^{-3})$	$-0.640(10^{-3})$	0	$+3.104(10^{-3})$
	$(E)Y_{IO}$	foot	0	$-1.008(10^{-3})$	0	0	$-1.008(10^{-3})$	0
	$(E)Z_{IO}$	foot	$+0.530(10^{-3})$	0	$-0.830(10^{-3})$	$-0.984(10^{-3})$	0	$+0.031(10^{-3})$
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+2.026	0	+0.475	-0.627	0	+1.984
	$(E)V_{YIO}$	ft/sec	0	+0.534	0	0	+0.534	0
	$(E)V_{ZIO}$	ft/sec	+0.382	0	+0.682	+0.391	0	+0.677
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-36.73	0	-4.76	+14.69	0	-34.00
	ACBY	cm/sec^2	0	-23.64	0	0	-23.64	0
	ACBZ	cm/sec^2	-4.29	0	-25.42	-19.65	0	-16.69
Scale Factor Error	SFEX	PPM	-0.02069	0	-0.00426	+0.00692	0	-0.01996
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	-0.00408	0	-0.02279	-0.01750	0	-0.01516
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.0351	0	-0.0075	+0.0115	0	-0.0340
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	-0.0081	0	-0.0313	-0.0227	0	-0.0229
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+33.88	0	+4.56	-13.40	0	+31.45
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	-	-	-	-	-	-
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Earth Launch into Orbit Trajectory
IMU VELOCITY ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-21.11	0	0	-21.11	0
$A_{(SM)YI}$		milliradian	+30.21	0	-5.07	-19.80	0	+23.37
$A_{(SM)ZI}$		milliradian	0	+8.17	0	0	+8.17	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-0.719	0	0	-0.719	0
	BDY	meru	+0.856	0	-0.034	-0.467	0	+0.719
	BDZ	meru	0	+0.087	0	0	+0.087	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-0.512	0	0	-0.512	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	+0.088	0	0	+0.088	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.817	0	+0.033	+0.446	0	-0.685
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-0.844	0	0	-0.844	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.209	0	0	+0.209	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+1.482	0	-0.090	-0.835	0	+1.228
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Earth Launch into Orbit Trajectory
IMU SM DRIFT ANGLE COEFFICIENTS
(SM axes colinear with inertial axes)

Error		RMS Error Dimension	Drift Angle about Inertial Axes in milliradian per unit error			Drift Angle about Target Axes in milliradian per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	+0.0625	0	0	-0.0320	0	+0.0537
	BDY	meru	0	+0.0625	0	0	+0.0625	0
	BDZ	meru	0	0	+0.0625	+0.0537	0	+0.0320
Acceleration Sensitive Drift	ADIAX	meru/g	+0.0278	0	0	-0.0142	0	+0.0239
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	+0.0577	+0.0496	0	+0.0295
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	-0.0577	0	0	-0.0577	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	+0.0452	0	0	-0.0231	0	+0.0389
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	+0.0836	+0.0719	0	+0.0428
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0836	0	0	+0.0836	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
Root Sum Square Error								

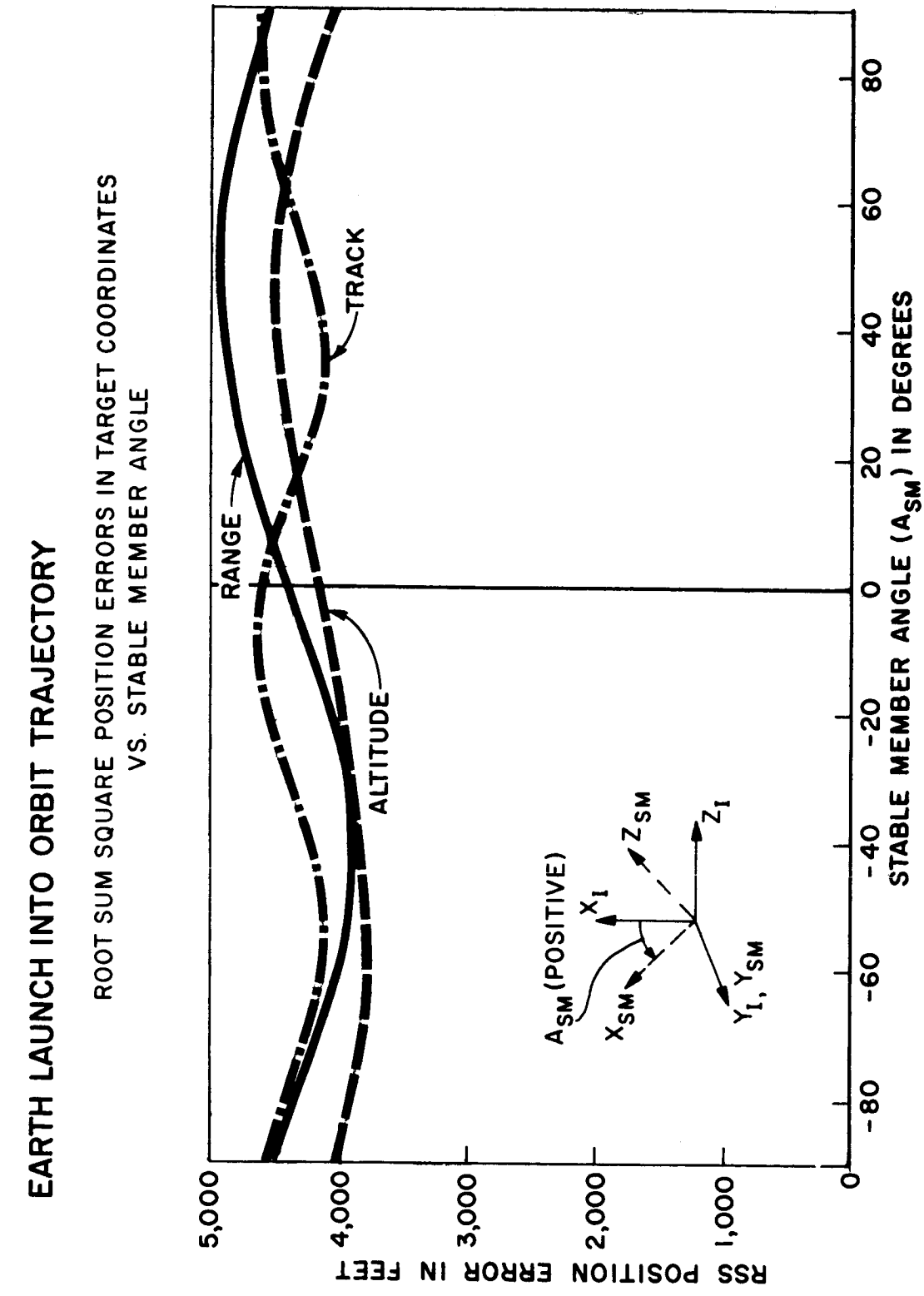

EARTH LAUNCH INTO ORBIT TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
RANGE
TRACK
ALTITUDE
RSS POSITION ERROR IN FEET
5,000
4,000
3,000
2,000
1,000
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
A_{SM} (POSITIVE)
X_{SM}
X_I
Z_{SM}
Z_I
Y_I, Y_{SM}

Fig. A-1

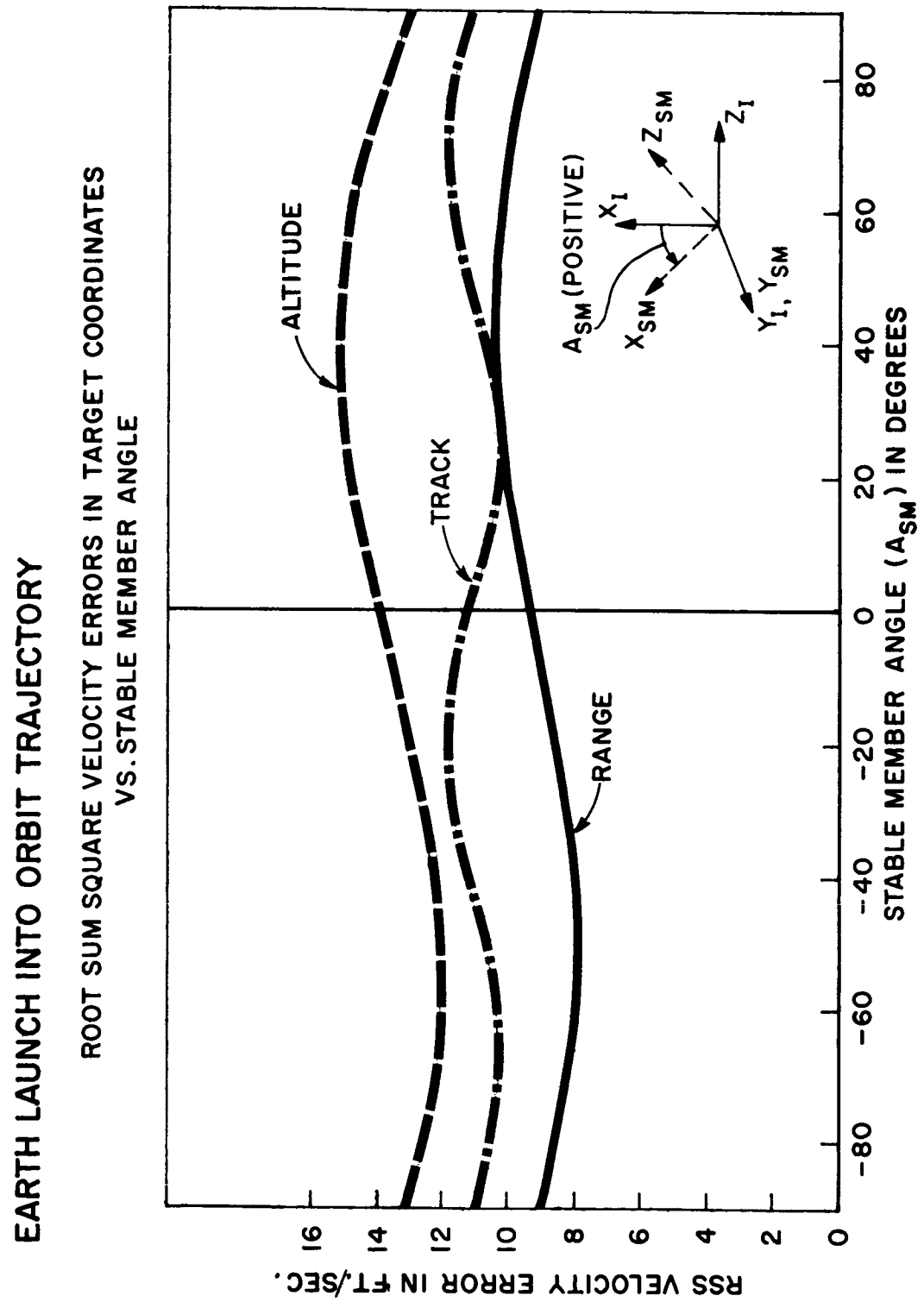

EARTH LAUNCH INTO ORBIT TRAJECTORY
ROOT SUM SQUARE VELOCITY ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS VELOCITY ERROR IN FT./SEC.
0
2
4
6
8
10
12
14
16
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. A-2

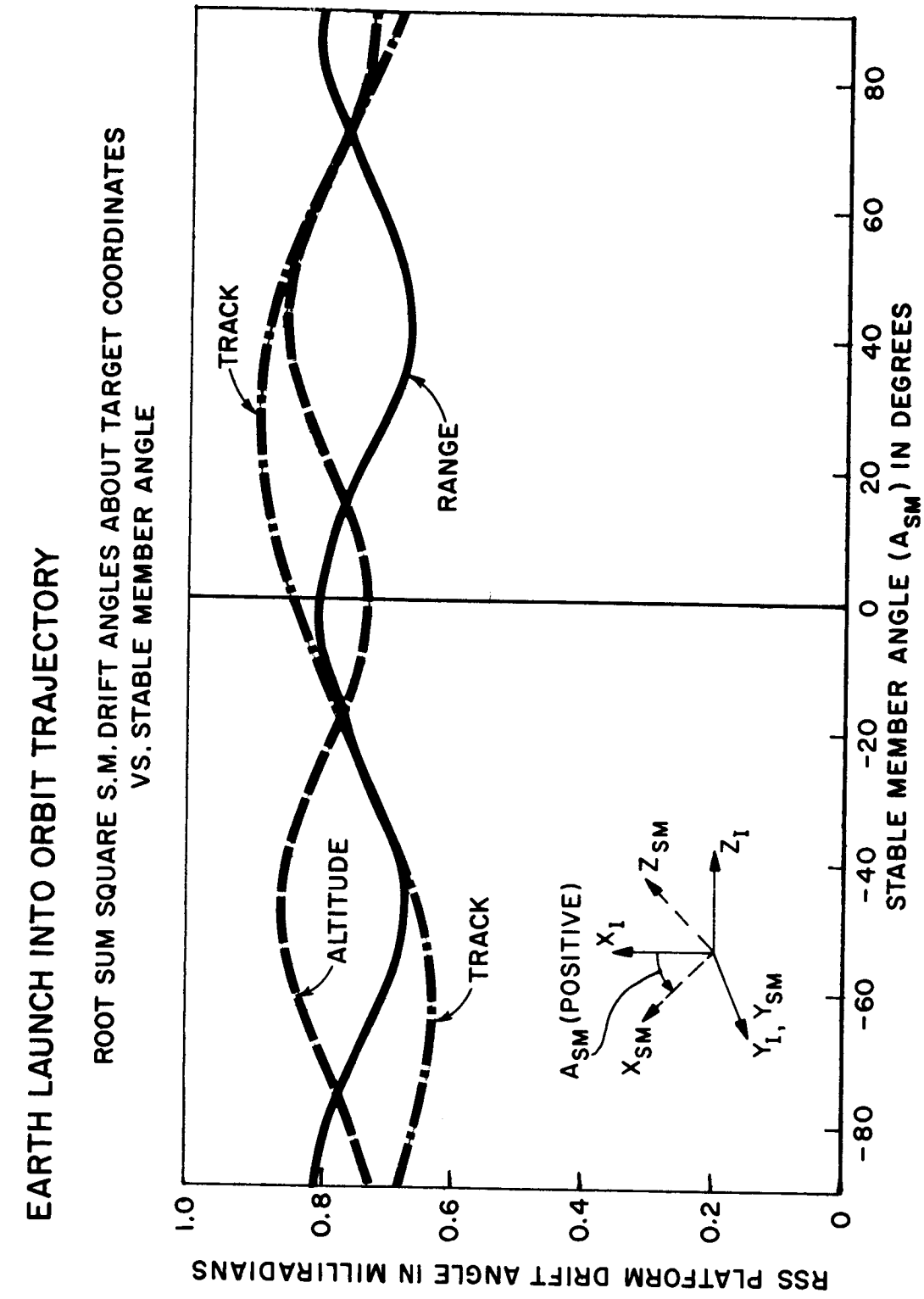

EARTH LAUNCH INTO ORBIT TRAJECTORY
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
TRACK
RANGE
ALTITUDE
TRACK
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS PLATFORM DRIFT ANGLE IN MILLIRADIANS
1.0
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. A-3

EARTH LAUNCH INTO ORBIT TRAJECTORY

RSS TRACK ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH AZIMUTH GYRO BIAS AND ACCELERATION SENSITIVE DRIFT
OF 1 MERU

NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.

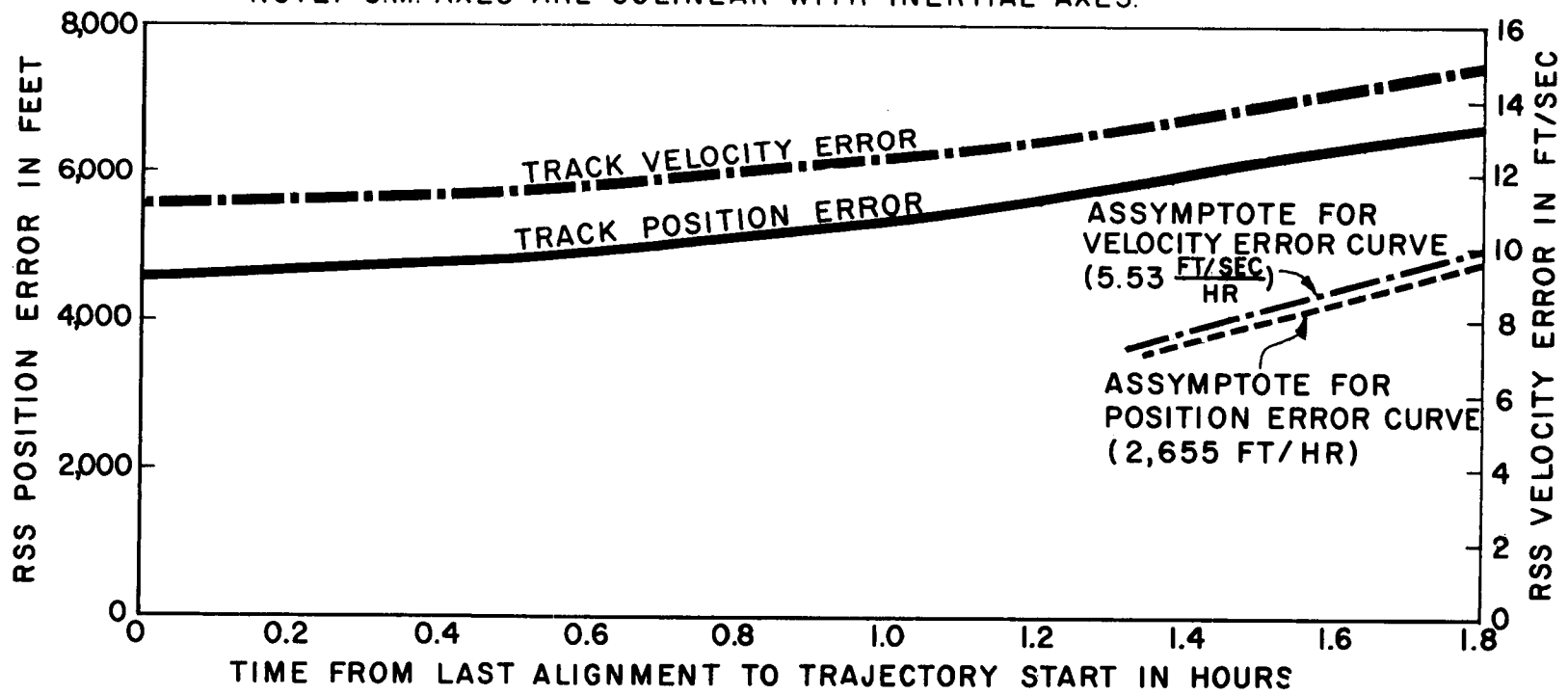


Fig. A-4

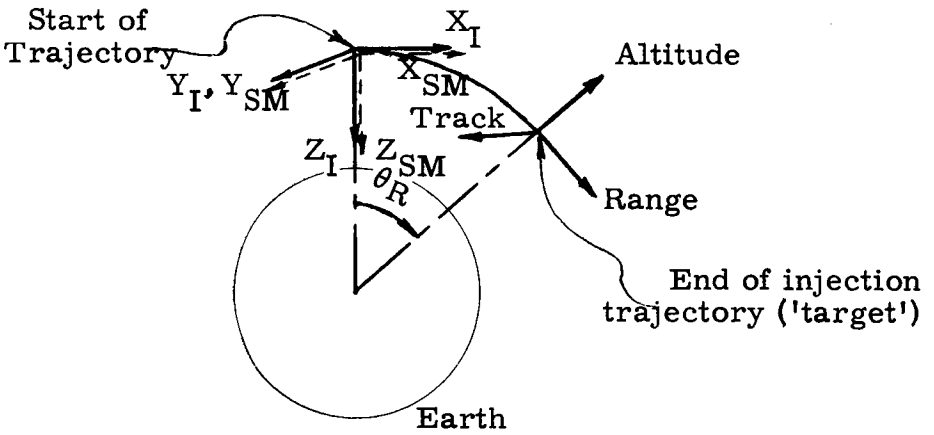
SECTION B

TRANSLUNAR INJECTION

Trajectory Description & Data

1) Description = Powered injection into free-fall translunar trajectory from 100 n mile circular earth parking orbit.
2) Total trajectory time : 361.25 seconds
3) Total earth angle, θ_R, subtended by trajectory : 28.785 degrees
4) Initial & final altitudes : 100.0 and 187.9 n miles
5) Initial & final velocities : 25,557 and 35,776 ft/sec
6) Initial & final velocity angles relative to $+X_I$ axis : 0 and -21.3 degrees
7) Initial & final thrust acceleration : 19.1 and 40.1 ft/sec^2
8) Initial & final pitch angle relative to $-Z_I$ axis : 0 and 24.6 degrees
9) Thrust acceleration history in ft/sec^2 : $a_T = (19.1 + 0.058t)$ for $0<t<361$ sec
10) Pitch angle history in degrees relative to $-Z_I$ axis : $\theta = (0.0681t)$ for $0<t<361$ sec

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Translunar Injection Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S.M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	55.8	0	0	55.8	0
		$A_{(SM)YI}$	0.206 mr	59.8	0	352.7	115.2	0	337.0
		$A_{(SM)ZI}$	0.206 mr	0	339.4	0	0	339.4	0
S.M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	27.2	0	0.2	23.7	0	13.1
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	423.8	0	5.1	368.4	0	205.8
		ACBY	0.2 cm/sec^2	0	422.1	0	0	422.1	0
		ACBZ	0.2 cm/sec^2	5.2	0	440.0	204.4	0	387.4
	Scale Factor Error	SFEX	100 PPM	165.4	0	1.8	143.8	0	80.2
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0.2	0	27.7	13.0	0	24.3
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	13.5	0	0.1	11.8	0	6.6
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.6	0.3	0	0.5
GYRO	Bias Drift	BDX	10 meru	0	38.2	0	0	38.2	0
		BDY	10 meru	39.5	0	166.7	44.6	0	164.6
		BDZ	10 meru	0	162.9	0	0	162.9	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	30.0	0	0	30.0	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	15.9	0	0	15.9	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	4.6	0	16.2	3.7	0	16.4
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	2.4	0	0	2.4	0
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0.1	0	0.3	0.1	0	0.3
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0.3	0	0	0.3	0
Root Sum Square Error				461.6	570.6	588.9	462.9	570.6	583.6
				941.0			941.0		

Translunar Injection Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	0.51	0	0	0.51	0
		$A_{(SM)YI}$	0.206 mr	0.57	0	2.21	0.57	0	2.21
		$A_{(SM)ZI}$	0.206 mr	0	2.07	0	0	2.07	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	0.25	0	0	0.22	0	0.12
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	2.33	0	0.07	2.01	0	1.17
		ACBY	0.2 cm/sec^2	0	2.30	0	0	2.30	0
		ACBZ	0.2 cm/sec^2	0.07	0	2.49	1.12	0	2.21
	Scale Factor Error	SFEX	100 PPM	1.02	0	0.03	0.88	0	0.50
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	0.26	0.12	0	0.23
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.09	0	0	0.08	0	0.05
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.01	0	0	0.01
GYRO	Bias Drift	BDX	10 meru	0	0.46	0	0	0.46	0
		BDY	10 meru	0.48	0	1.53	0.30	0	1.57
		BDZ	10 meru	0	1.48	0	0	1.48	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0.38	0	0	0.38	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0.20	0	0	0.20	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	0.07	0	0.21	0.04	0	0.22
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0.03	0	0	0.03	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.002	0	0.005	0	0	0.005
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0.005	0	0	0.005	0
Root Sum Square Error				2.67	3.53	3.68	2.56	3.53	3.74
				5.76			5.76		

Translunar Injection Trajectory

OVERALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES

(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.263	0	0	0.230	0	0.125
	BDY	10 meru	0	0.263	0	0	0.263	0
	BDZ	10 meru	0	0	0.263	0.125	0	0.230
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0.233	0	0	0.204	0	0.111
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.057	0.027	0	0.050
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.057	0	0	0.057	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0.021	0	0	0.019	0	0.010
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.002	0.001	0	0.002
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.002	0	0	0.002	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.353	0.270	0.270	0.335	0.270	0.291
			0.519			0.519		

Translunar Injection Trajectory
IMU POSITION ERROR COEFFICIENTS (PART I)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+0.919	0	-0.040	+0.787	0	+0.478
	$(E)Y_{IO}$	foot	0	+0.910	0	0	+0.910	0
	$(E)Z_{IO}$	foot	-0.042	0	+1.179	+0.531	0	-1.054
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+353	0	-7	+306	0	+176
	$(E)V_{YIO}$	ft/sec	0	+350	0	0	+350	0
	$(E)V_{ZIO}$	ft/sec	-7	0	+381	+177	0	-338
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-2,119	0	+26	-1,845	0	-1,043
	ACBY	cm/sec^2	0	-2,110	0	0	-2,110	0
	ACBZ	cm/sec^2	+26	0	-2,199	-1,036	0	+1,940
Scale Factor Error	SFEX	PPM	-1,654	0	+0.018	-1.441	0	-0.812
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	+0.002	0	-0.277	-0.132	0	+0.244
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-1.354	0	+0.014	-1.180	0	-0.664
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.062	-0.030	0	+0.055
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+272	0	-2	+237	0	+131
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	-	-	-	-	-	-
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Translunar Injection Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-271	0	0	-271	0
$A_{(SM)YI}$		milliradian	+290	0	-1, 712	-559	0	+1, 636
$A_{(SM)ZI}$		milliradian	0	+1, 648	0	0	+1, 648	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-3. 82	0	0	-3. 82	0
	BDY	meru	+3. 95	0	-16. 67	-4. 46	0	+16. 46
	BDZ	meru	0	+16. 29	0	0	+16. 29	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-3. 00	0	0	-3. 00	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	+1. 59	0	0	+1. 59	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0. 46	0	+1. 62	-0. 37	0	-1. 64
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	0	-2. 41	0	0	-2. 41	0
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	+0. 28	0	0	+0. 28	0
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	+0. 09	0	-0. 29	-0. 06	0	+0. 29
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0

Translunar Injection Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	$-0.379(10^{-3})$	0	$-0.322(10^{-3})$	$-0.488(10^{-3})$	0	$+0.099(10^{-3})$
	$(E)Y_{IO}$	foot	0	$-0.488(10^{-3})$	0	0	$-0.488(10^{-3})$	0
	$(E)Z_{IO}$	foot	$-0.354(10^{-3})$	0	$+0.949(10^{-3})$	$+0.147(10^{-3})$	0	$-1.002(10^{-3})$
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+0.941	0	-0.078	+0.788	0	+0.522
	$(E)V_{YIO}$	ft/sec	0	+0.912	0	0	+0.912	0
	$(E)V_{ZIO}$	ft/sec	-0.080	0	+1.155	+0.486	0	-1.051
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-11.65	0	+0.34	-10.05	0	-5.91
	ACBY	cm/sec^2	0	-11.51	0	0	-11.51	0
	ACBZ	cm/sec^2	+0.35	0	-12.44	-5.60	0	+11.05
Scale Factor Error	SFEX	PPM	-0.01015	0	+0.00026	-0.00876	0	-0.00505
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	+0.00003	0	-0.00257	-0.00119	0	+0.00226
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.0093	0	+0.0002	-0.00804	0	-0.00459
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.008	-0.00038	0	+0.00072
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+2.50	0	-0.03	+2.18	0	+1.22
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	-	-	-	-	-	-
	Y_{SM}	$A_{(Z)Y}$	milliradian		0	0	0	0	0

Translunar Injection Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART II)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-2.49	0	0	-2.49	0
$A_{(SM)YI}$		milliradian	+2.76	0	-10.75	-2.69	0	+10.72
$A_{(SM)ZI}$		milliradian	0	+10.04	0	0	+10.04	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-0.0461	0	0	-0.0461	0
	BDY	meru	+0.0483	0	-0.1529	-0.0303	0	+0.1567
	BDZ	meru	0	+0.1477	0	0	+0.1477	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-0.0381	0	0	-0.0381	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	+0.0203	0	0	+0.0203	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.0073	0	+0.0207	+0.0035	0	-0.0217
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-0.0323	0	0	-0.0323	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.0047	0	0	+0.0047	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+0.0018	0	-0.0048	-0.007	0	+0.0051
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Translunar Injection Trajectory
IMU SM DRIFT ANGLE COEFFICIENTS
(SM axes colinear with inertial axes)

Error		RMS Error Dimension	Drift Angle about Inertial Axes in milliradians per unit error			Drift Angle about Target Axes in milliradians per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	+0.0263	0	0	+0.0230	0	+0.0125
	BDY	meru	0	+0.0263	0	0	+0.0263	0
	BDZ	meru	0	0	+0.0263	+0.0125	0	-0.0230
Acceleration Sensitive Drift	ADIAX	meru/g	+0.0233	0	0	+0.0204	0	+0.0111
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	+0.0057	+0.0027	0	-0.0050
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	-0.0057	0	0	-0.0057	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	+0.0213	0	0	+0.019	0	+0.010
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	+0.0018	+0.001	0	-0.002
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0018	0	0	+0.0018	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
Root Sum Square Error								

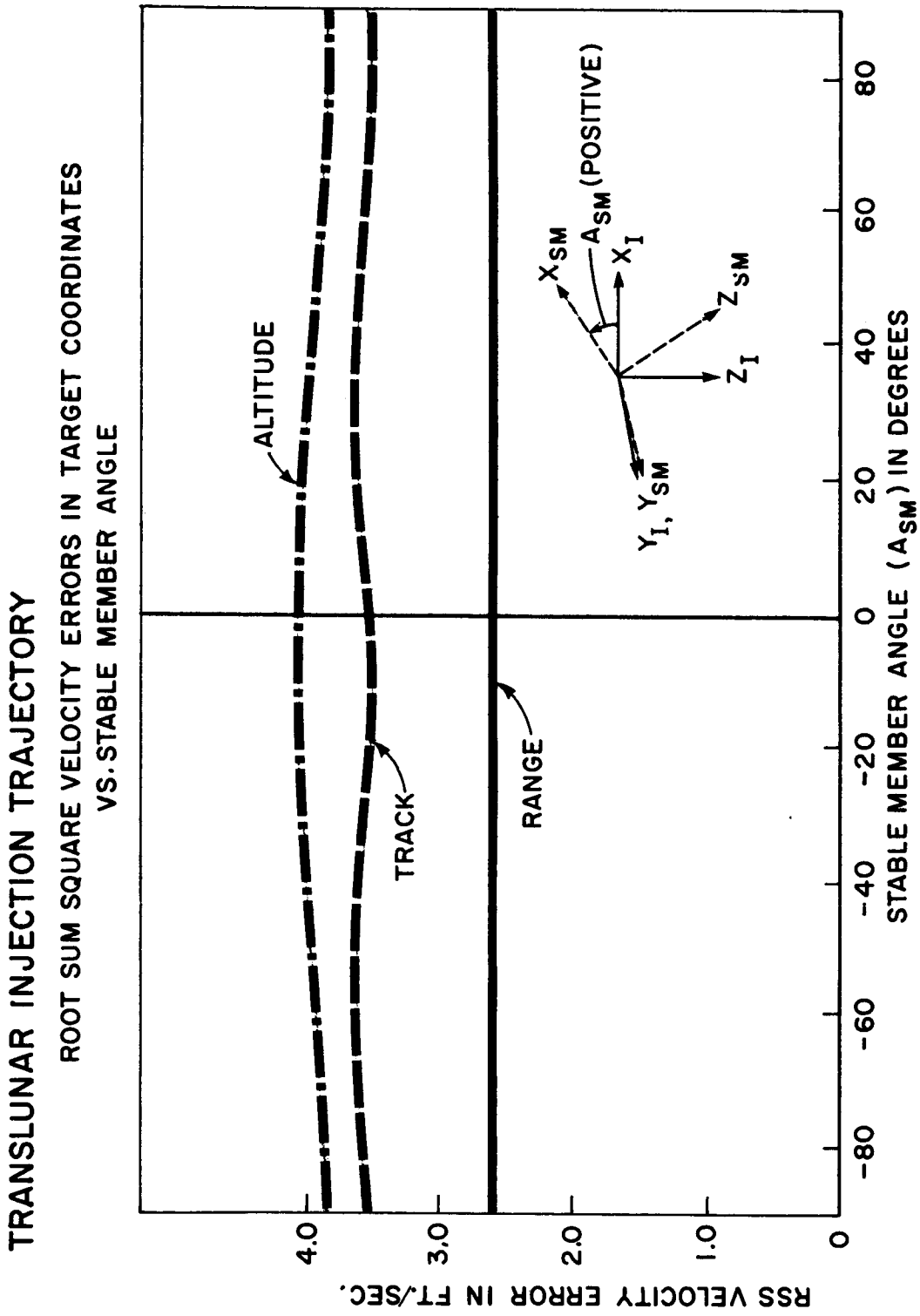

TRANSLUNAR INJECTION TRAJECTORY
ROOT SUM SQUARE VELOCITY ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
X_{SM}
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
Y_I, Y_{SM}
RSS VELOCITY ERROR IN FT./SEC.
4.0
3.0
2.0
1.0
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. B-1

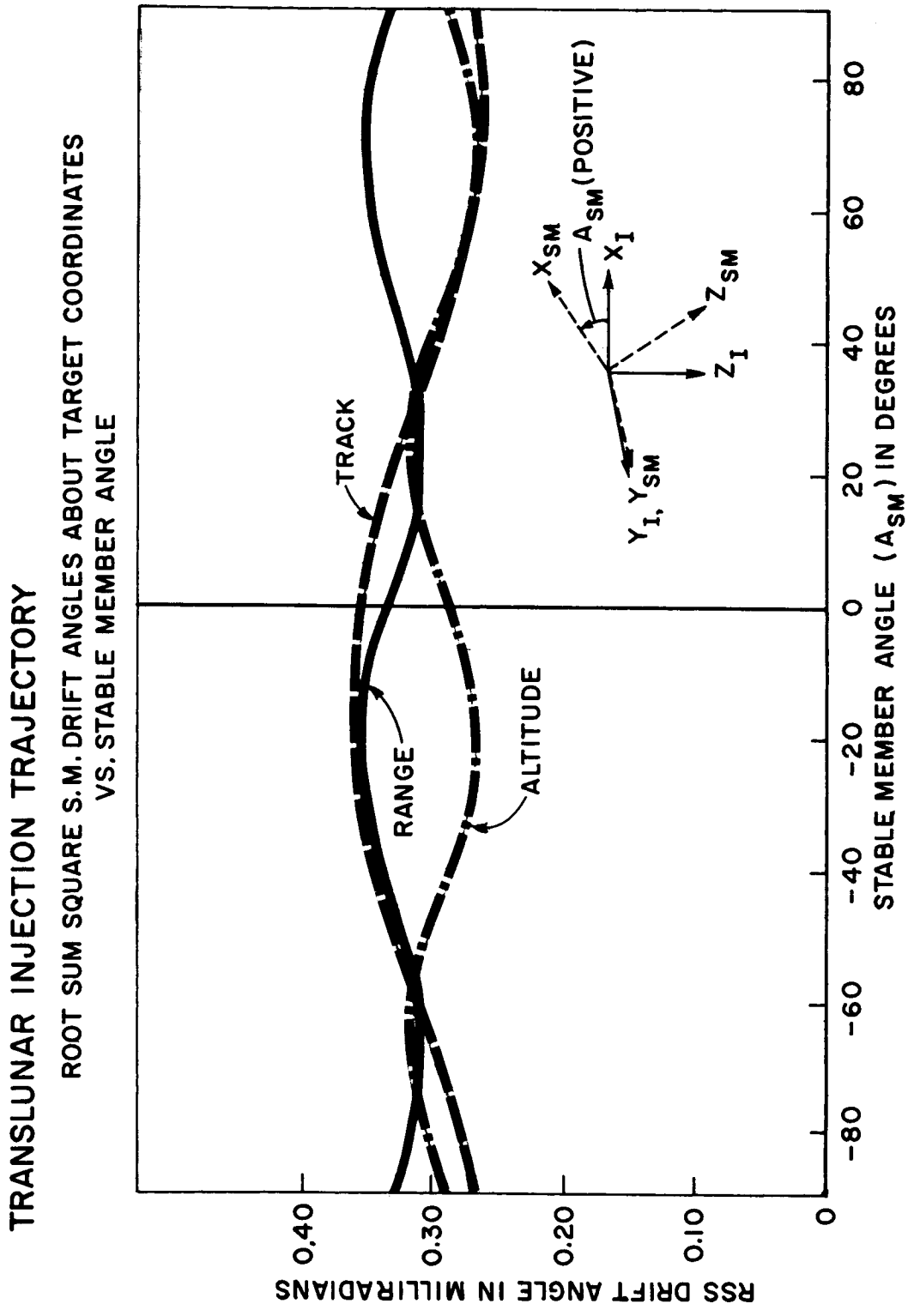

TRANSLUNAR INJECTION TRAJECTORY
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
RSS DRIFT ANGLE IN MILLIRADIANS
0.40
0.30
0.20
0.10
0
TRACK
RANGE
ALTITUDE
X_{SM}
A_{SM}(POSITIVE)
X_I
Z_{SM}
Z_I
Y_I, Y_{SM}
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. B-2

TRANSLUNAR INJECTION TRAJECTORY

RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF POWERED INJECTION TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

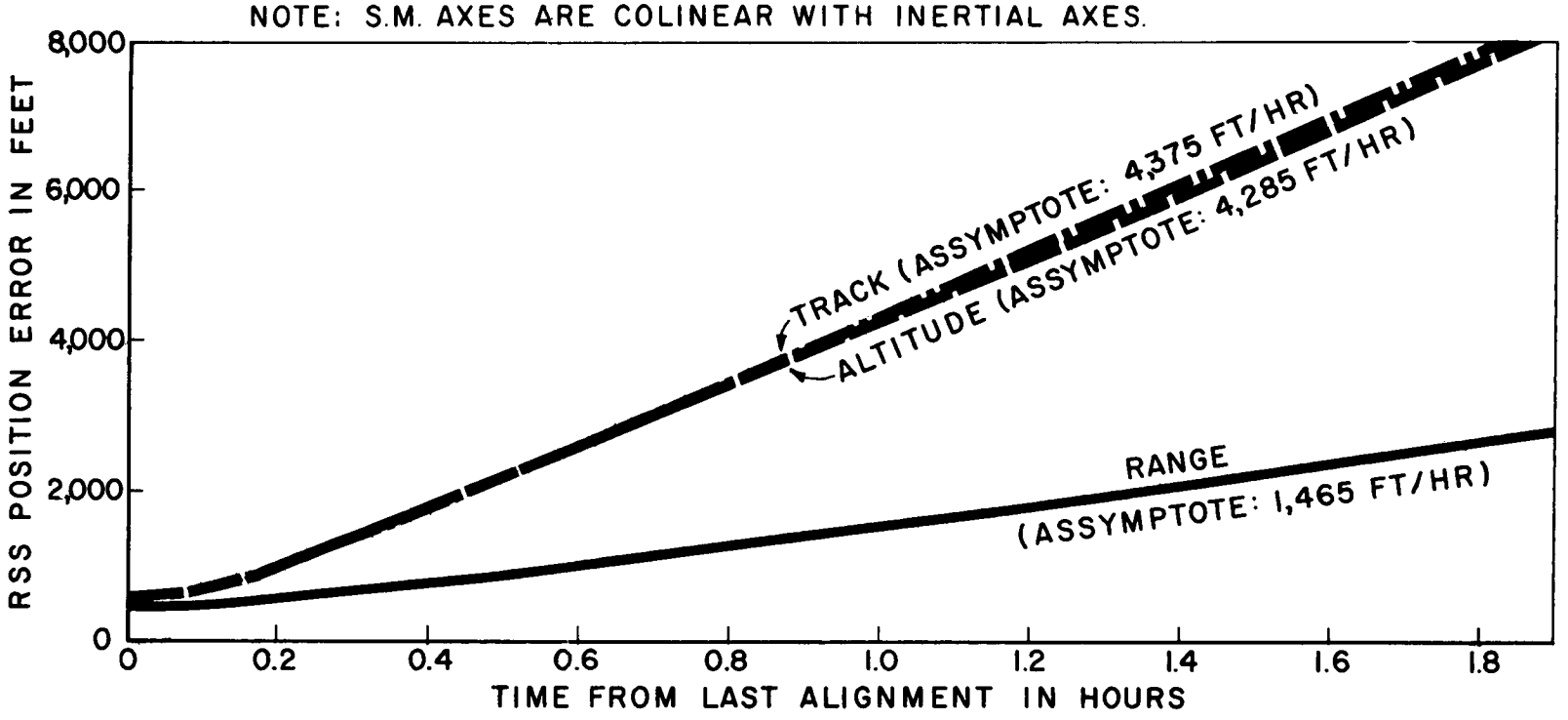


Fig. B-3

TRANSLUNAR INJECTION TRAJECTORY

RSS VELOCITY ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF POWERED INJECTION TRAJECTORY
WITH X, Y, Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

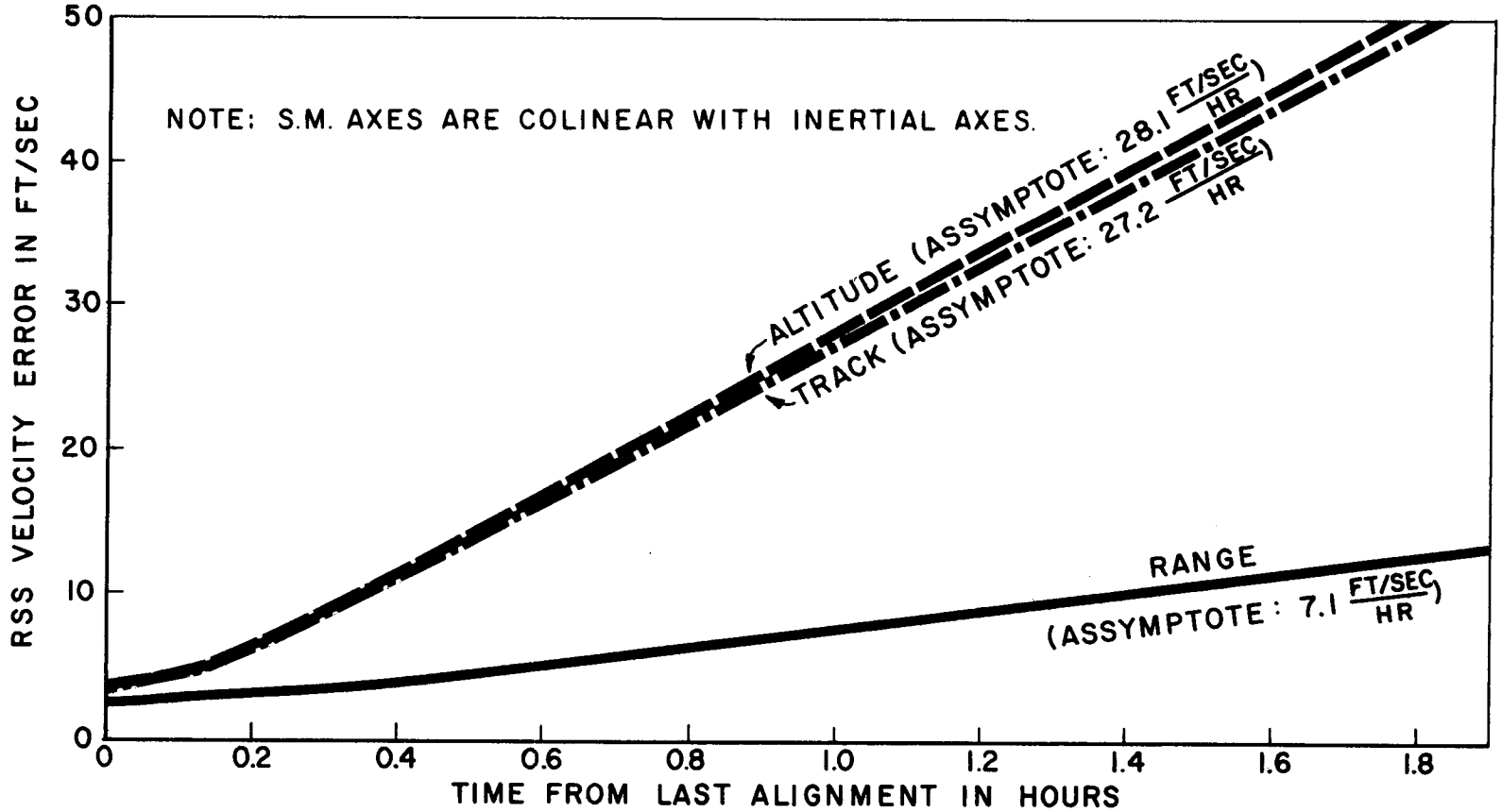


Fig. B-4

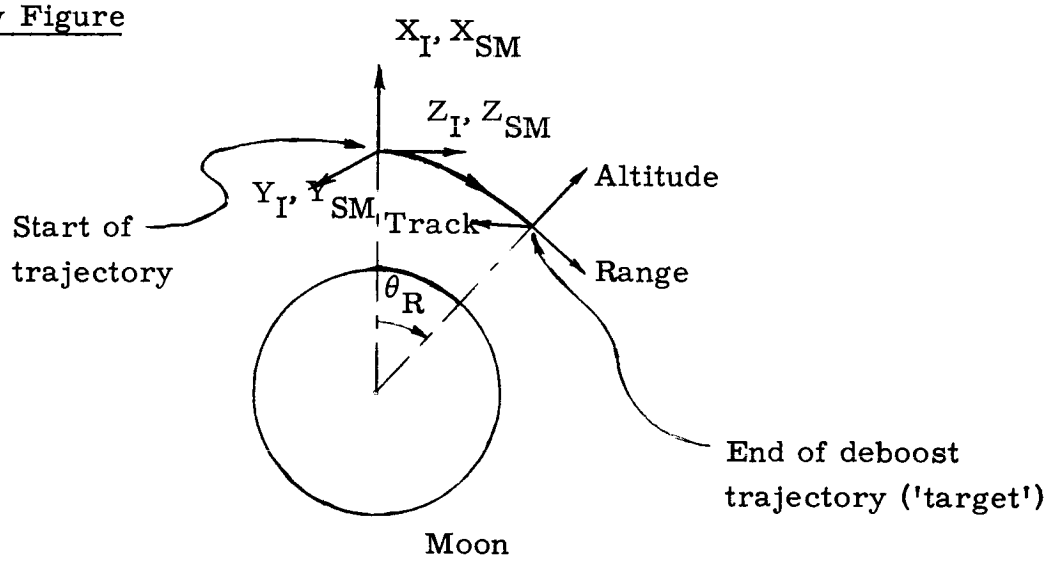
SECTION C

LUNAR DEBOOST TO ORBIT

Trajectory Description & Data

1) Description: Lunar approach trajectory putting spaceship into 100 n. mile circular orbit around moon.
2) Total trajectory time: 245.15 seconds
3) Total earth angle, θ_R, subtended by trajectory: 15.02 degrees
4) Initial & final altitudes: 121.3 and 98.1 n. miles
5) Initial & final velocities: 8,218 and 5,253 ft/sec.
6) Initial & final velocity angles relative to Z_I axis: -9.0 and -17.6 degrees
7) Initial & final thrust acceleration: 10.73 and 14.46 ft/sec^2
8) Initial & final pitch angle relative to X_I axis: -76 and -76 degrees
9) Thrust acceleration history in ft/sec^2: $a_T = 10.73 + 0.01173t + 1.414(10^{-5})t^2$ for $0 < t < 245.15$ secs.
10) Pitch angle history in degree relative to X_I axis: $\theta = -76.0$ for $0 < t < 245.15$ secs.

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Lunar Deboost to Orbit Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in feet			RMS Error in Target Axes in feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	70.8	0	0	70.8	0
		$A_{(SM)YI}$	0.206 mr	71.5	0	17.8	1.4	0	73.7
		$A_{(SM)ZI}$	0.206 mr	0	17.7	0	0	17.7	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	34.7	0	0.1	8.9	0	33.5
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	198.6	0	0.3	51.2	0	191.9
		ACBY	0.2 cm/sec^2	0	196.7	0	0	196.7	0
		ACBZ	0.2 cm/sec^2	0.3	0	196.7	189.9	0	51.3
	Scale Factor Error	SFEX	100 PPM	8.7	0	0	2.2	0	8.4
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0.1	0	34.4	33.2	0	9.0
	Accel. Sens Scale Factor Error	SFNCX	10 PPM/g	0.1	0	0	0	0	0.1
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	1.2	1.2	0	0
GYRO	Bias Drift	BDX	10 meru	0	21.5	0	0	21.5	0
		BDY	10 meru	21.7	0	0.5	0.4	0	22.3
		BDZ	10 meru	0	5.4	0	0	5.4	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	1.9	0	0	1.9	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	1.9	0	0	1.9	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	7.5	0	1.9	0.1	0	7.8
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0	0	0	0	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.3	0	0.1	0	0	0.3
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0.1	0	0	0.1	0
Root Sum Square Error				215.3	211.0	200.6	199.7	211.0	216.2
				362.1			362.1		

Lunar Deboost to Orbit Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	0.606	0	0	0.606	0
		$A_{(SM)YI}$	0.206 mr	0.618	0	0.154	0.012	0	0.637
		$A_{(SM)ZI}$	0.206 mr	0	0.151	0	0	0.151	0
S. M.	Accel. IA Non-ortho-gonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	0.300	0	0.001	0.077	0	0.290
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	1.631	0	0.007	0.416	0	1.577
		ACBY	0.2 cm/sec^2	0	1.599	0	0	1.599	0
		ACBZ	0.2 cm/sec^2	0.007	0	1.600	1.544	0	0.421
	Scale Factor Error	SFEX	100 PPM	0.075	0	0	0.019	0	0.072
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0.001	0	0.295	0.284	0	0.077
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.001	0	0	0	0	0.001
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.011	0.011	0	0
GYRO	Bias Drift	BDX	10 meru	0	0.277	0	0	0.277	0
		BDY	10 meru	0.280	0	0.070	0.005	0	0.288
		BDZ	10 meru	0	0.069	0	0	0.069	0
	Acceler-ation Sensitive Drift	ADIAX	10 meru/g	0	0.025	0	0	0.025	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0.025	0	0	0.025	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	0.100	0	0.025	0.002	0	0.103
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceler-ation Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0	0	0	0	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.036	0	0.009	0.001	0	0.037
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0	0	0	0	0
Root Sum Square Error				1.796	1.741	1.636	1.626	1.741	1.805
				2.988			2.988		

Lunar Deboost to Orbit Trajectory
OVER-ALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES
(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.179	0	0	0.046	0	0.173
	BDY	10 meru	0	0.179	0	0	0.179	0
	BDZ	10 meru	0	0	0.179	0.173	0	0.046
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0.017	0	0	0.004	0	0.016
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.067	0.065	0	0.017
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.067	0	0	0.067	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.003	0.002	0	0.001
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.003	0	0	0.003	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.180	0.191	0.191	0.190	0.191	0.180
			0.324			0.324		

Lunar Deboost to Orbit Trajectory

IMU POSITION ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error			Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes									
Initial Position Error	$(E)X_{IO}$		foot	+1.040	0	+0.006	-0.264	0	+1.006
	$(E)Y_{IO}$		foot	0	+0.980	0	0	+0.980	0
	$(E)Z_{IO}$		foot	+0.006	0	+0.981	+0.946	0	+0.260
Initial Velocity Error	$(E)V_{XIO}$		ft/sec	+248.4	0	+0.7	-63.7	0	+240.1
	$(E)V_{YIO}$		ft/sec	0	+243.5	0	0	+ 243.5	0
	$(E)V_{ZIO}$		ft/sec	+0.7	0	+243.6	+235.1	0	+63.8
B. Accelerometer Errors (In-flight Effect only)									
Bias	ACBX		cm/sec^2	-993.1	0	-1.7	+255.8	0	-959.6
	ACBY		cm/sec^2	0	-983.3	0	0	-983.3	0
	ACBZ		cm/sec^2	-1.7	0	-983.6	-949.6	0	-256.6
Scale Factor Error	SFEX		PPM	-0.087	0	0	+0.022	0	-0.084
	SFEY		PPM	0	0	0	0	0	0
	SFEZ		PPM	+0.001	0	+0.344	+0.332	0	+0.090
Accel. Sens. Scale Factor Error	SFNCX		PPM/g	-0.008	0	0	+0.002	0	-0.007
	SFNCY		PPM/g	0	0	0	0	0	0
	SFNCZ		PPM/g	0	0	-0.123	-0.119	0	-0.032
C. Misalignments of Accelerometer Input Axes									
Accel.	About Axis								
X	Y_{SM}	$A_{(X)Y}$	milliradian	-347.1	0	-0.1	+89.4	0	-335.4
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	0	0	0	0	0	0
	Y_{SM}	$A_{(Z)Y}$	milliradian	--	--	--	--	--	--

Lunar Deboost to Orbit Trajectory
IMU POSITION ERROR COEFFICIENTS (PART 2)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	+343.8	0	0	+343.8	0
$A_{(SM)YI}$		milliradian	-347.2	0	-86.3	+6.7	0	-357.7
$A_{(SM)ZI}$		milliradian	0	+85.7	0	0	+85.7	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	+2.154	0	0	+2.154	0
	BDY	meru	-2.167	0	-0.540	+0.041	0	-2.233
	BDZ	meru	0	+0.537	0	0	+0.537	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	+0.187	0	0	+0.187	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-0.187	0	0	-0.187	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.755	0	-0.188	+0.014	0	-0.778
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	+0.016	0	0	+0.016	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.065	0	0	+0.065	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-0.264	0	-0.066	+0.005	0	-0.272
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Lunar Deboost to Orbit Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART 1)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	$+0.323(10^{-3})$	0	$+0.07(10^{-3})$	$-0.016(10^{-3})$	0	$+0.330(10^{-3})$
	$(E)Y_{IO}$	foot	0	$-0.165(10^{-3})$	0	0	$-0.165(10^{-3})$	0
	$(E)Z_{IO}$	foot	$+0.068(10^{-3})$	0	$-0.152(10^{-3})$	$-0.165(10^{-3})$	0	$+0.027(10^{-3})$
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+1.039	0	+0.011	-0.259	0	+1.006
	$(E)V_{YIO}$	ft/sec	0	+0.980	0	0	+0.980	0
	$(E)V_{ZIO}$	ft/sec	+0.011	0	+0.982	+0.945	0	+0.265
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-8.154	0	-0.033	+2.082	0	-7.883
	ACBY	cm/sec^2	0	-7.994	0	0	-7.994	0
	ACBZ	cm/sec^2	-0.033	0	-8.002	-7.720	0	-2.106
Scale Factor Error	SFEX	PPM	-0.00075	0	0	+0.00019	0	-0.00072
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	+0.00001	0	+0.00295	+0.00284	0	+0.00077
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.00007	0	0	+0.00002	0	-0.00006
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.00111	-0.00107	0	-0.00029
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-2.997	0	-0.011	+0.766	0	-2.898
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	0	0	0	0	0	0
	Y_{SM}	$A_{(Z)Y}$	milliradian	--	--	--	--	--	--

Lunar Deboost to Orbit Trajectory
IMU VELOCITY ERROR COEFFICIENTS (PART 1)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	+2.943	0	0	+2.943	0
$A_{(SM)YI}$		milliradian	-3.000	0	-0.746	+0.057	0	-3.091
$A_{(SM)ZI}$		milliradian	0	+0.734	0	0	+0.734	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	+0.0277	0	0	+0.0277	0
	BDY	meru	-0.0280	0	-0.0070	+0.0005	0	-0.0288
	BDZ	meru	0	+0.0069	0	0	+0.0069	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	+0.0025	0	0	+0.0025	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-0.0025	0	0	-0.0025	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.0100	0	-0.0025	+0.0002	0	-0.0103
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	+0.0002	0	0	+0.0002	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.0009	0	0	+0.0009	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-0.0036	0	-0.0009	+0.0001	0	-0.0037
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Lunar Deboost to Orbit Trajectory
IMU S. M. DRIFT ANGLE COEFFICIENTS
(SM axes colinear with inertial axes)

Error		RMS Error Dimension	Drift Angle about Inertial Axes in milliradian per unit error			Drift Angle about Target Axes in milliradian per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	+0.0179	0	0	-0.0046	0	+0.0173
	BDY	meru	0	+0.0179	0	0	+0.0179	0
	BDZ	meru	0	0	+0.0179	+0.0173	0	+0.0046
Acceleration Sensitive Drift	ADIAX	meru/g	+0.0017	0	0	-0.0004	0	+0.0016
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	-0.0067	-0.0065	0	-0.0017
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	+0.0067	0	0	+0.0067	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	+0.0002	0	0	0	0	+0.0002
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	+0.0025	+0.0024	0	+0.0007
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0025	0	0	+0.0025	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0

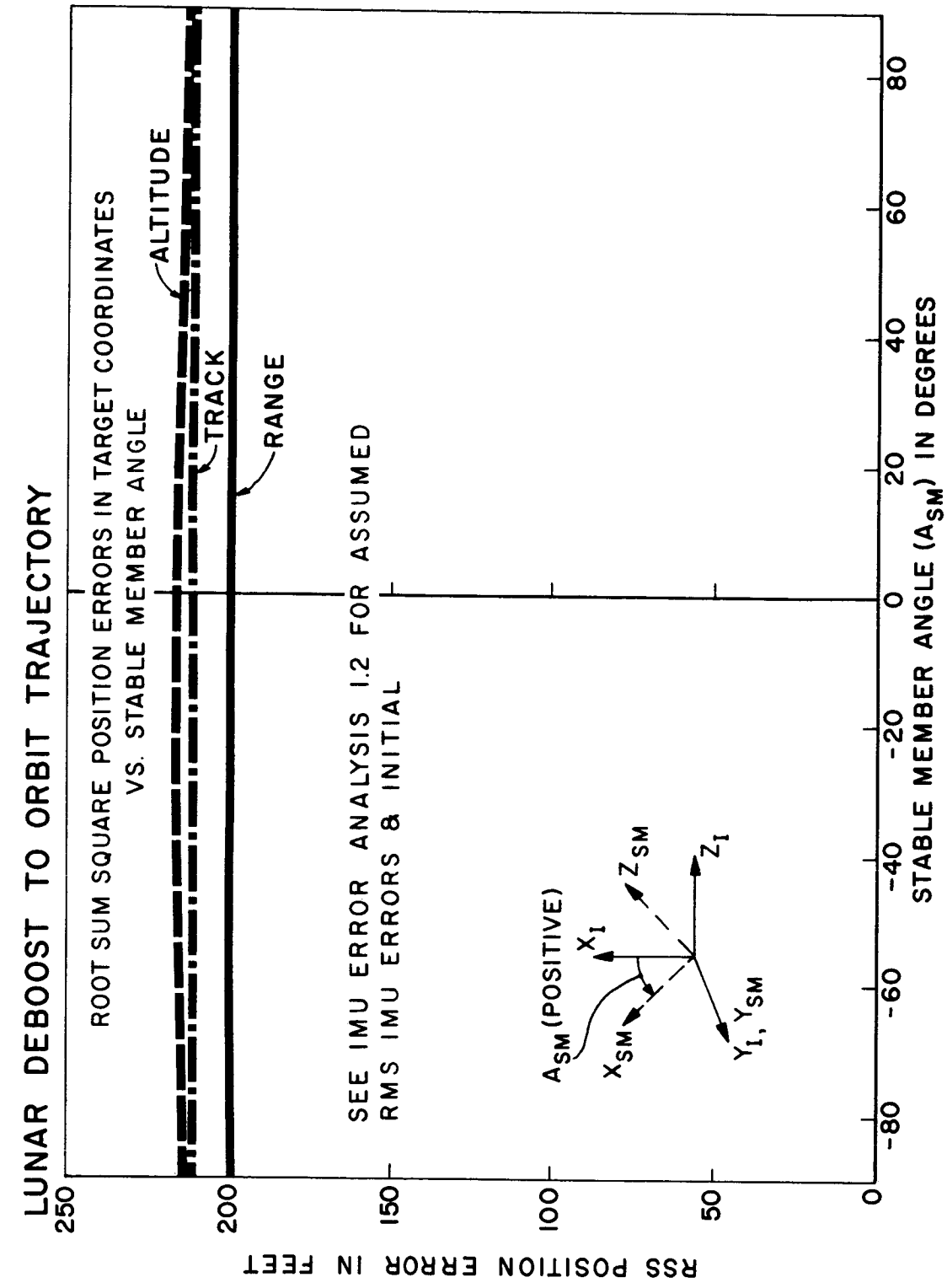

LUNAR DEBOOST TO ORBIT TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS IMU ERRORS & INITIAL
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS POSITION ERROR IN FEET
250
200
150
100
50
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. C-1

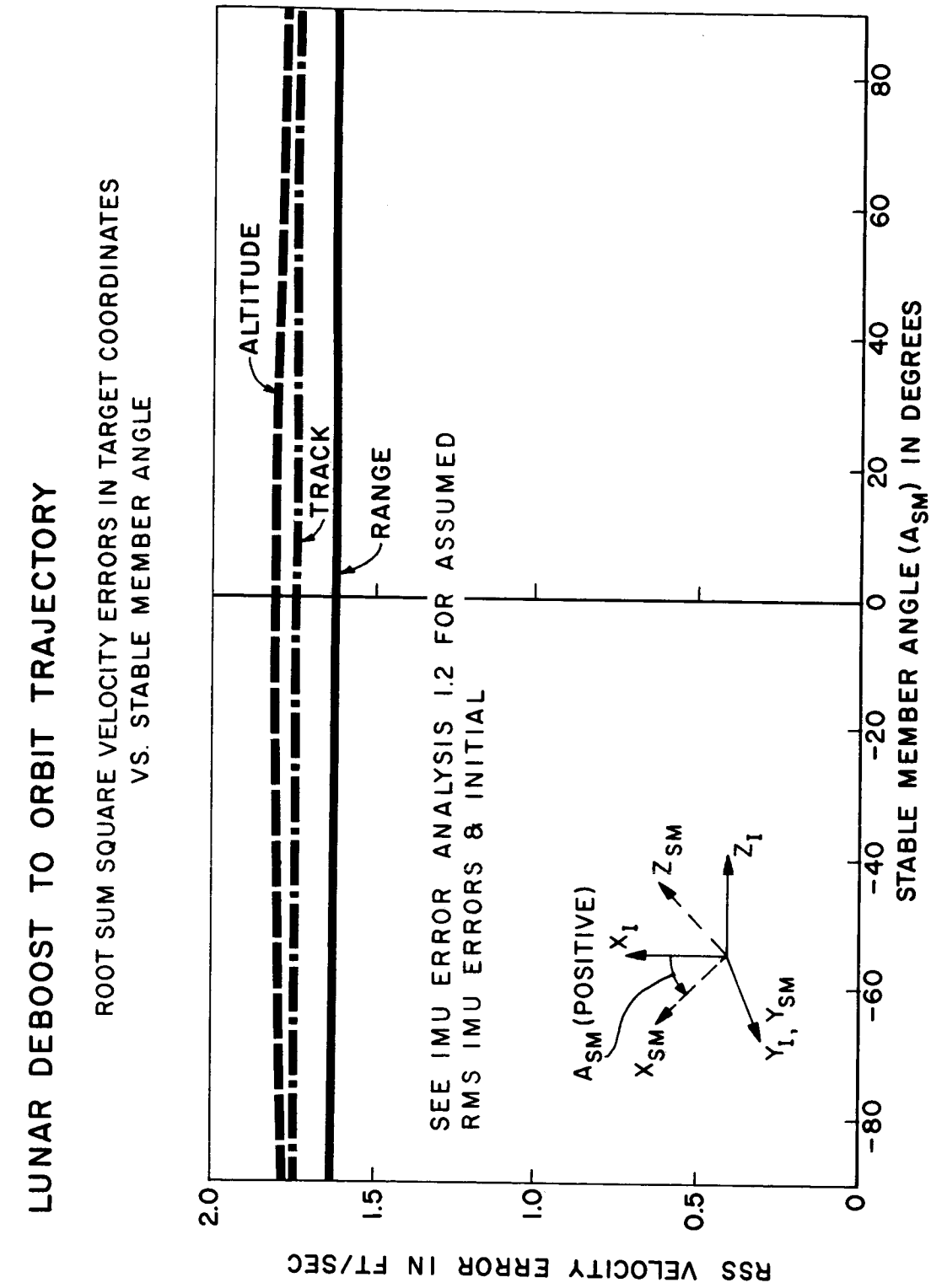

LUNAR DEBOOST TO ORBIT TRAJECTORY
ROOT SUM SQUARE VELOCITY ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS IMU ERRORS & INITIAL
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS VELOCITY ERROR IN FT/SEC
2.0
1.5
1.0
0.5
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. C-2

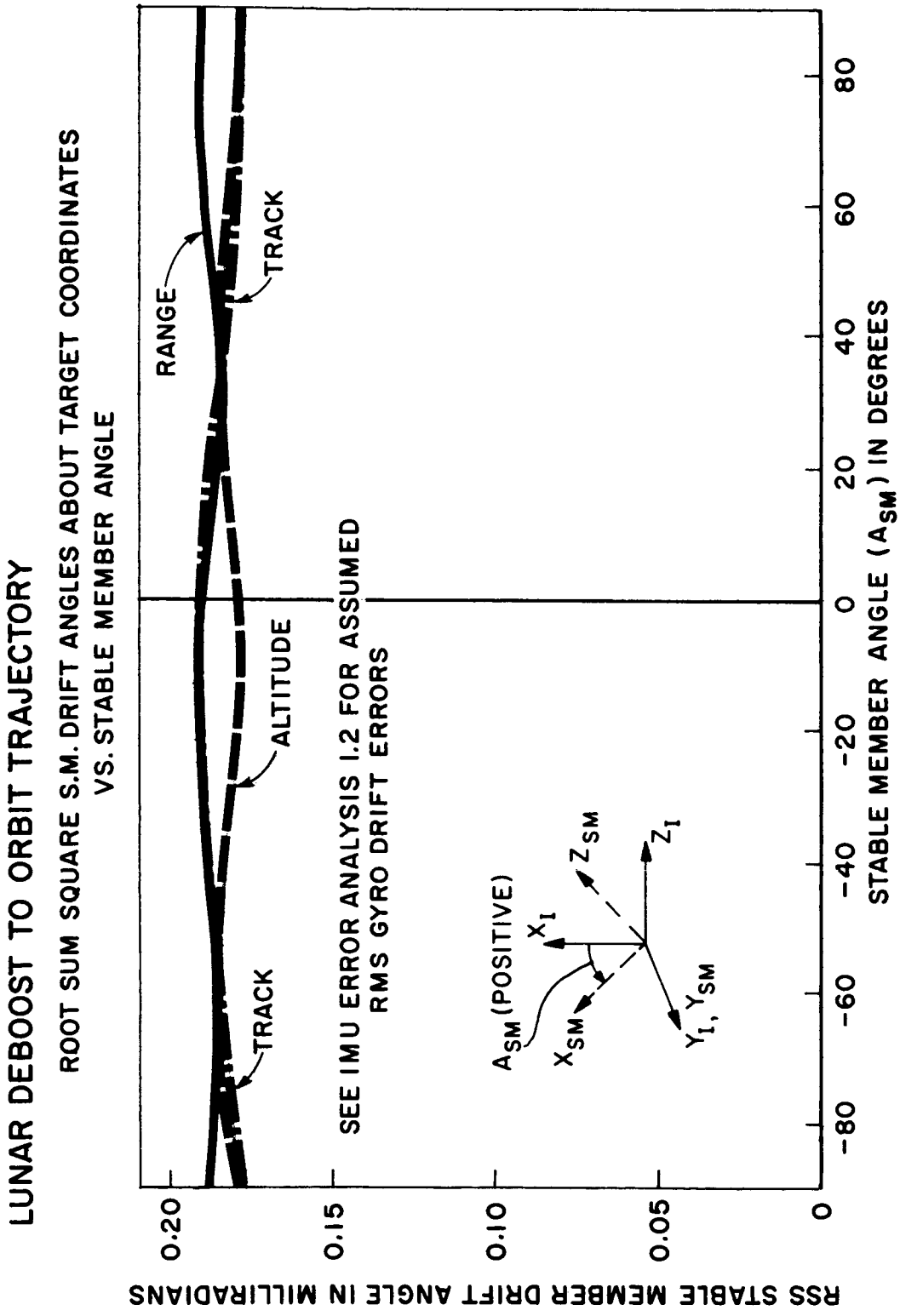

LUNAR DEBOOST TO ORBIT TRAJECTORY
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS GYRO DRIFT ERRORS
RANGE
TRACK
ALTITUDE
TRACK
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS STABLE MEMBER DRIFT ANGLE IN MILLIRADIANS
0.20
0.15
0.10
0.05
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. C-3

LUNAR DEBOOST TO ORBIT TRAJECTORY

RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH X, Y, Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

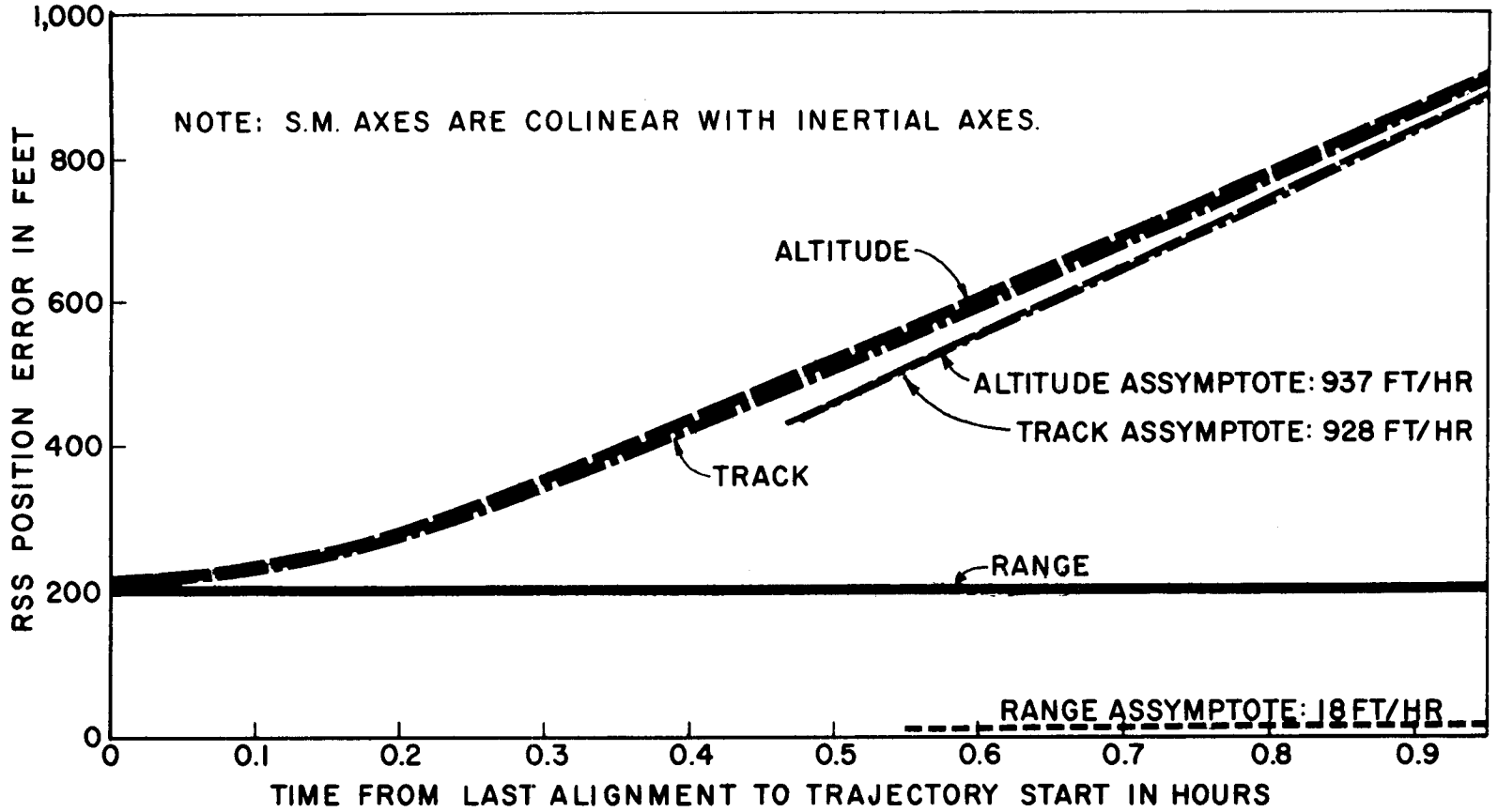


Fig. C-4

LUNAR DEBOOST TO ORBIT TRAJECTORY

RSS VELOCITY ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH X, Y, Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

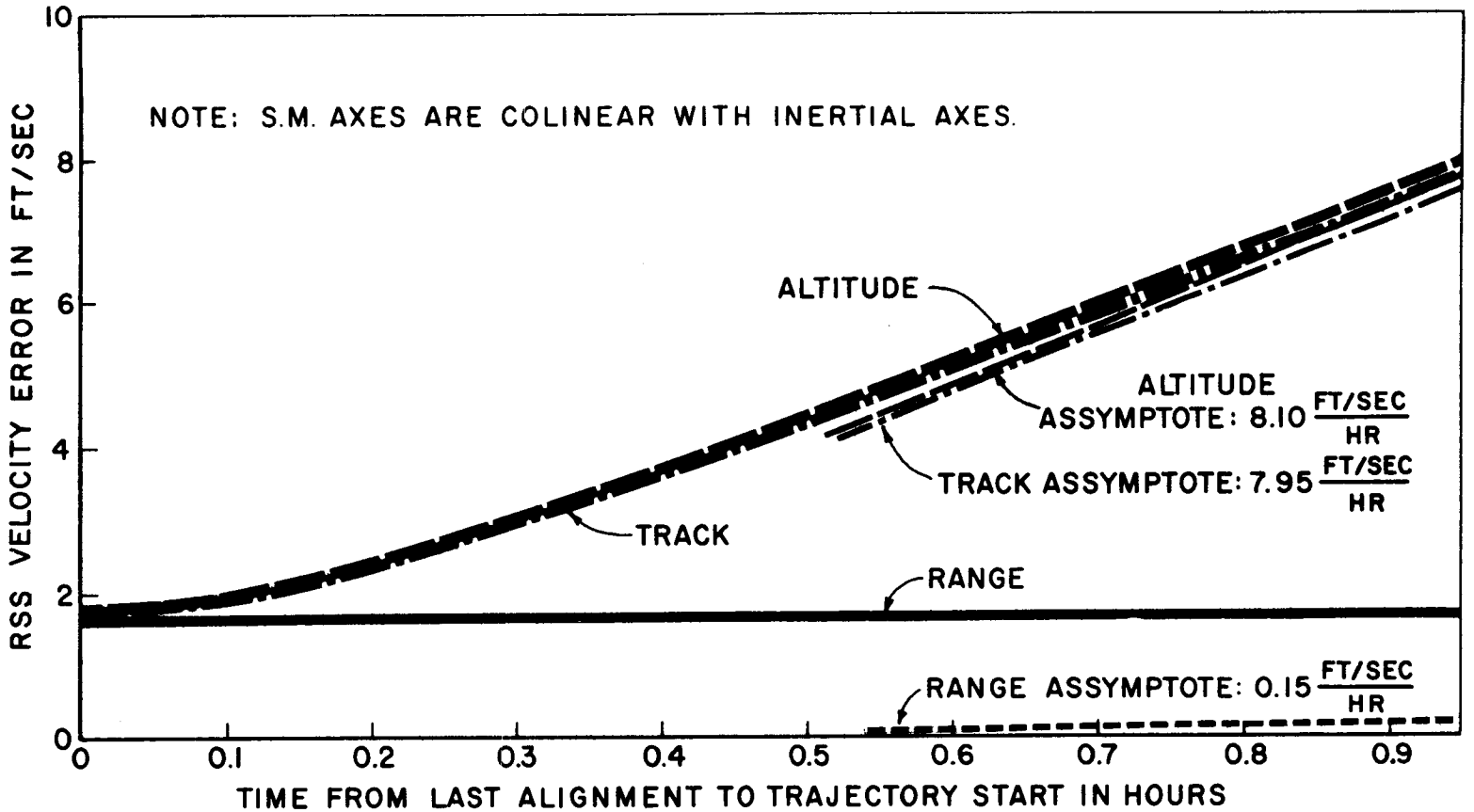


Fig. C-5

SECTION D

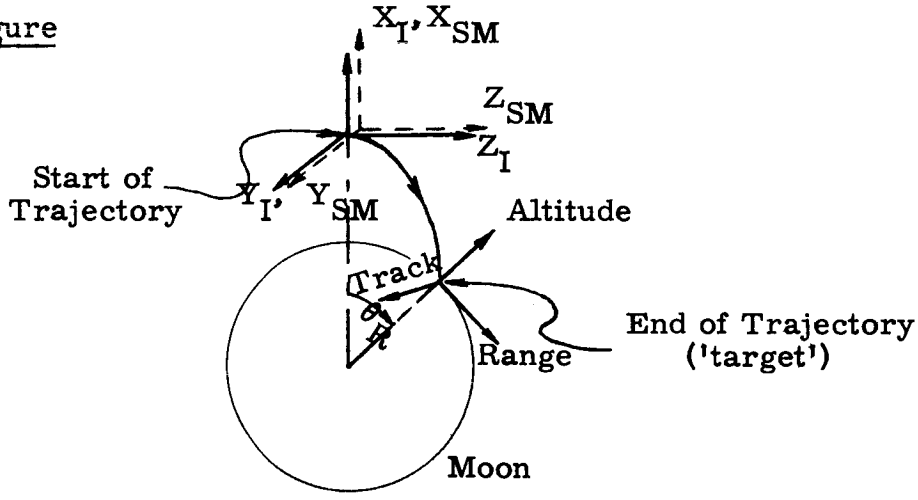
LUNAR LANDING

LUNAR LANDING TRAJECTORY

Trajectory Description & Data

1) Description = Descent to Moon Surface from Initial Altitude of 50,000 ft
2) Total trajectory time : 375 seconds
3) Total earth angle, θ_R, subtended by trajectory : 11.0 degrees
4) Initial & final altitudes : 50,000 and 0 ft
5) Initial & final velocities : 5,607.5 and 0 ft/sec
6) Initial & final velocity angles relative to Z_I axis : 0 and -14.5 degrees
7) Initial & final thrust acceleration : 12.9 and 17.2 ft/sec^2
8) Inital & final pitch angle relative to X_I axis : 91.5 and 57.5 degrees
9) Thrust acceleration history in ft/sec^2 :
   $a_T = 12.9 + 1.80(10^{-3})t + 2.04(10^{-5})t^2$ for $0<t<180$ sec
   $a_T = 17.2$ for $180<t<375$ sec
10) Pitch angle history in degrees relative to X_I axis :
   $\theta = 91.5 - 0.056t + 0.69(10^{-4})t^2$ for $0<t<180$ sec
   $\theta = 57.5$ for $180<t<375$ sec

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Lunar Landing Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	194	0	0	194	0
		$A_{(SM)YI}$	0.206 mr	201	0	43	4	0	205
		$A_{(SM)ZI}$	0.206 mr	0	42	0	0	42	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	97	0	46	18	0	96
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	471	0	2	88	0	463
		ACBY	0.2 cm/sec^2	0	457	0	0	457	0
		ACBZ	0.2 cm/sec^2	2	0	457	448	0	89
	Scale Factor Error	SFEX	100 PPM	21	0	0	4	0	20
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	94	93	0	18
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	1	0	0	0	0	1
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	4	4	0	1
GYRO	Bias Drift	BDX	10 meru	0	89	0	0	89	0
		BDY	10 meru	91	0	34	16	0	96
		BDZ	10 meru	0	34	0	0	34	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	5	0	0	5	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	14	0	0	14	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	38	0	14	7	0	40
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	0	0	0	0	0
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	2	0	1	0	0	2
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	1	0	0	1	0
Root Sum Square Error				531	507	470	467	507	534
				872			872		

[redacted]

Lunar Landing Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	1.052	0	0	1.052	0
		$A_{(SM)YI}$	0.206 mr	1.119	0	0.405	0.184	0	1.176
		$A_{(SM)ZI}$	0.206 mr	0	0.393	0	0	0.393	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	0.542	0	0.006	0.098	0	0.534
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	2.566	0	0.028	0.462	0	2.524
		ACBY	0.2 cm/sec^2	0	2.409	0	0	2.409	0
		ACBZ	0.2 cm/sec^2	0.028	0	2.414	2.365	0	0.488
	Scale Factor Error	SFEX	100 PPM	0.195	0	0.001	0.036	0	0.191
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0.006	0	0.512	0.501	0	0.103
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.005	0	0	0.001	0	0.005
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.022	0.022	0	0.004
GYRO	Bias Drift	BDX	10 meru	0	0.723	0	0	0.723	0
		BDY	10 meru	0.747	0	0.378	0.229	0	0.805
		BDZ	10 meru	0	0.374	0	0	0.374	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0.067	0	0	0.067	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0.159	0	0	0.159	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	0.314	0	0.161	0.098	0	0.339
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0.002	0	0	0.002	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.013	0	0.007	0.004	0	0.014
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0.007	0	0	0.007	0
Root Sum Square Error				2.971	2.785	2.535	2,483	2.785	3.015
				4.797			4.797		

[redacted]

Lunar Landing Trajectory

OVER-ALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES

(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.273	0	0	0.052	0	0.268
	BDY	10 meru	0	0.273	0	0	0.273	0
	BDZ	10 meru	0	0	0.273	0.268	0	0.052
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0.043	0	0	0.008	0	0.043
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.118	0.116	0	0.023
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.118	0	0	0.118	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0.001	0	0	0	0	0.001
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.005	0.005	0	0.001
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.005	0	0	0.005	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.277	0.298	0.298	0.297	0.298	0.278
			0.504			0.504		

Lunar Landing Trajectory

IMU POSITION ERROR COEFFICIENTS (PART 1)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+1.129	0	+0.019	-0.197	0	+1.112
	$(E)Y_{IO}$	foot	0	+0.936	0	0	+0.936	0
	$(E)Z_{IO}$	foot	+0.018	0	+0.939	+0.918	0	+0.197
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+391	0	+3	-71	0	+384
	$(E)V_{YIO}$	ft/sec	0	+367	0	0	+367	0
	$(E)V_{ZIO}$	ft/sec	+3	0	+367	+360	0	+73
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-2,357	0	-11	+439	0	-2,316
	ACBY	cm/sec^2	0	-2,284	0	0	-2,284	0
	ACBZ	cm/sec^2	-11	0	-2,286	-2,242	0	-447
Scale Factor Error	SFEX	PPM	-0.2059	0	-0.0004	+0.0389	0	-0.2022
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	+0.0046	0	+0.9441	+0.9258	0	+0.1846
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.0517	0	-0.0001	+0.0098	0	-0.0507
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	-0.0019	0	-0.3985	-0.3908	0	-0.0779
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-972.9	0	-4.6	+181.1	0	-955.9
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	--	--	--	--	--	--
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Lunar Landing Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	+943.3	0	0	+943.3	0
$A_{(SM)YI}$		milliradian	-973.3	0	-208.3	-18.8	0	-995.1
$A_{(SM)ZI}$		milliradian	0	+203.6	0	0	+203.6	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	+8.896	0	0	+8.896	0
	BDY	meru	-9.067	0	-3.427	-1.634	0	-9.554
	BDZ	meru	0	+3.398	0	0	+3.396	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	+0.487	0	0	+0.487	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-1.430		0	+1.430	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-3.763	0	-1.442	-0.698	0	-3.969
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	+0.111	0	0	+0.111	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.603	0	0	+0.603	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-1.564	0	-0.608	-0.298	0	-1.651
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Lunar Landing Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART 1)

(SM axes colinear with inertial axes)

Error			Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes									
Initial Position Error	$(E)X_{IO}$		foot						
	$(E)Y_{IO}$		foot						
	$(E)Z_{IO}$		foot						
Initial Velocity Error	$(E)V_{XIO}$		ft/sec						
	$(E)V_{YIO}$		ft/sec						
	$(E)V_{ZIO}$		ft/sec						
B. Accelerometer Errors (In-flight Effect only)									
Bias	ACBX		cm/sec^2	-12.831	0	-0.139	+2.312	0	-12.622
	ACBY		cm/sec^2	0	-12.407	0	0	-12.047	0
	ACBZ		cm/sec^2	-0.138	0	-12.072	-11.824	0	-2.439
Scale Factor Error	SFEX		PPM	-0.00195	0	-0.00001	+0.00036	0	-0.00191
	SFEY		PPM	0	0	0	0	0	0
	SFEZ		PPM	+0.00006	0	+0.00512	+0.00501	0	+0.00103
Accel. Sens. Scale Factor Error	SFNCX		PPM/g	-0.00053	0	0	+0.00010	0	-0.00052
	SFNCY		PPM/g	0	0	0	0	0	0
	SFNCZ		PPM/g	-0.00002	0	-0.00022	-0.00217	0	-0.00045
C. Misalignments of Accelerometer Input Axes									
Accel.	About Axis								
X	Y_{SM}	$A_{(X)Y}$	milliradian	-5.425	0	-0.057	+0.979	0	-5.336
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	--	--	--	--	--	--
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Lunar Landing Trajectory
IMU VELOCITY ERROR COEFFICIENTS (PART 2)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	+5.106	0	0	+5.106	0
$A_{(SM)YI}$		milliradian	-5.433	0	-1.964	-0.892	0	-5.707
$A_{(SM)ZI}$		milliradian	0	+1.906	0	0	+1.906	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	+0.07230	0	0	+0.07230	0
	BDY	meru	-0.07465	0	-0.03783	-0.02289	0	-0.08049
	BDZ	meru	0	+0.03740	0	0	+0.03740	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	+0.00668	0	0	+0.00668	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-0.01589	0	0	-0.01589	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.03144	0	-0.01606	-0.00977	0	-0.03392
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	+0.00168	0	0	+0.00168	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.00676	0	0	+0.00676	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-0.01327	0	-0.00684	-0.00418	0	-0.01433
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

[redacted]

Lunar Landing Trajectory

IMU SM DRIFT ANGLE COEFFICIENTS

(SM axes colinear with inertial axes)

Error		RMS Error Dimension	Drift Angle about Inertial Axes in milliradian per unit error			Drift Angle about Target Axes in millirdian per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	+0.0273	0	0	-0.0052	0	+0.0268
	BDY	meru	0	+0.0273	0	0	+0.0273	0
	BDZ	meru	0	0	+0.0273	+0.0268	0	+0.0052
Acceleration Sensitive Drift	ADIAX	meru/g	+0.0043	0	0	-0.0008	0	+0.0043
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	-0.0118	-0.0116	0	-0.0023
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	+0.0118	0	0	+0.0118	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	+0.0012	0	0	-0.0002	0	+0.0012
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	+0.0051	+0.0050	0	+0.0010
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0051	0	0	+0.0051	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
Root Sum Square Error								

[redacted]

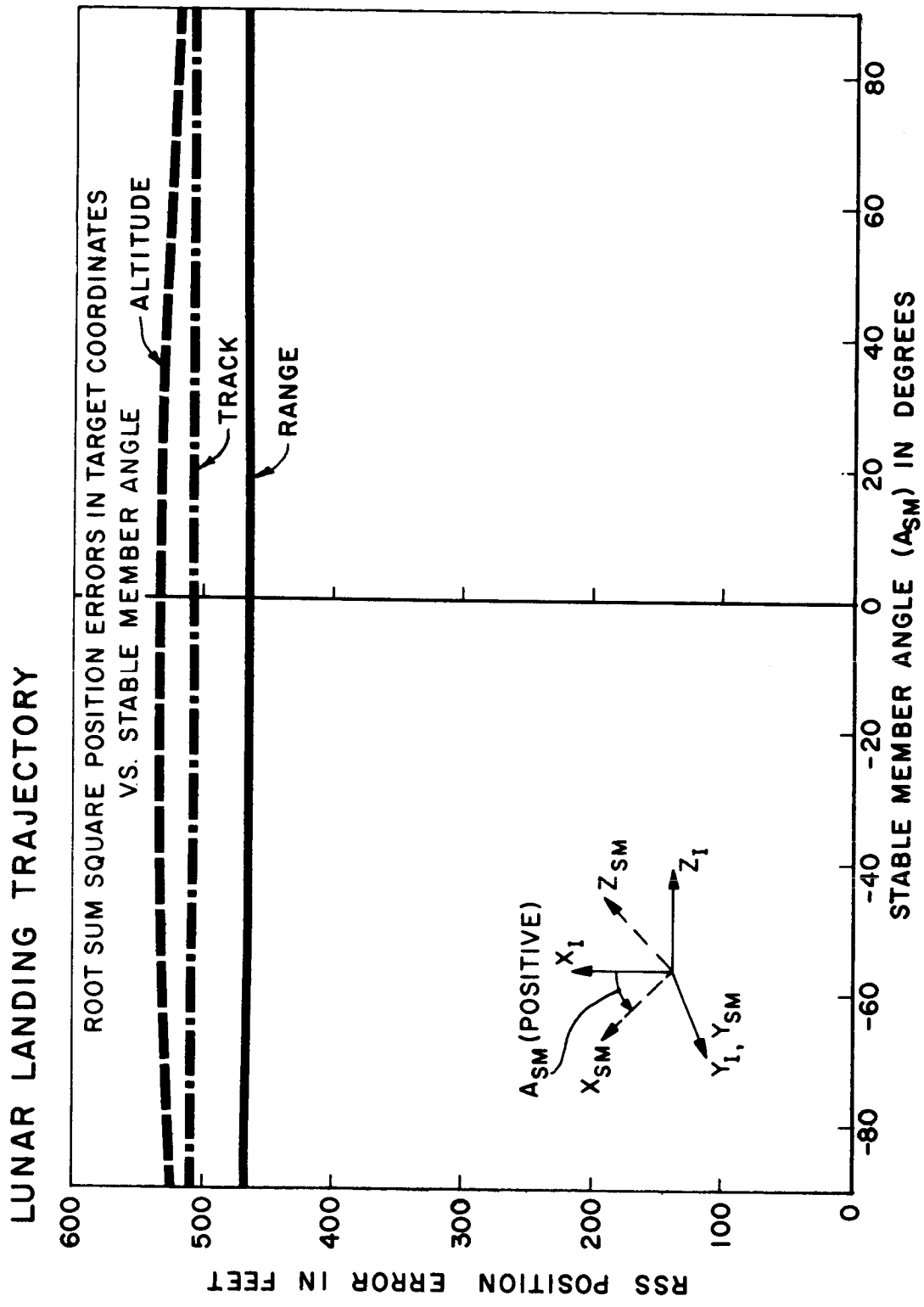

LUNAR LANDING TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
RSS POSITION ERROR IN FEET
600
500
400
300
200
100
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}

Fig. D-1

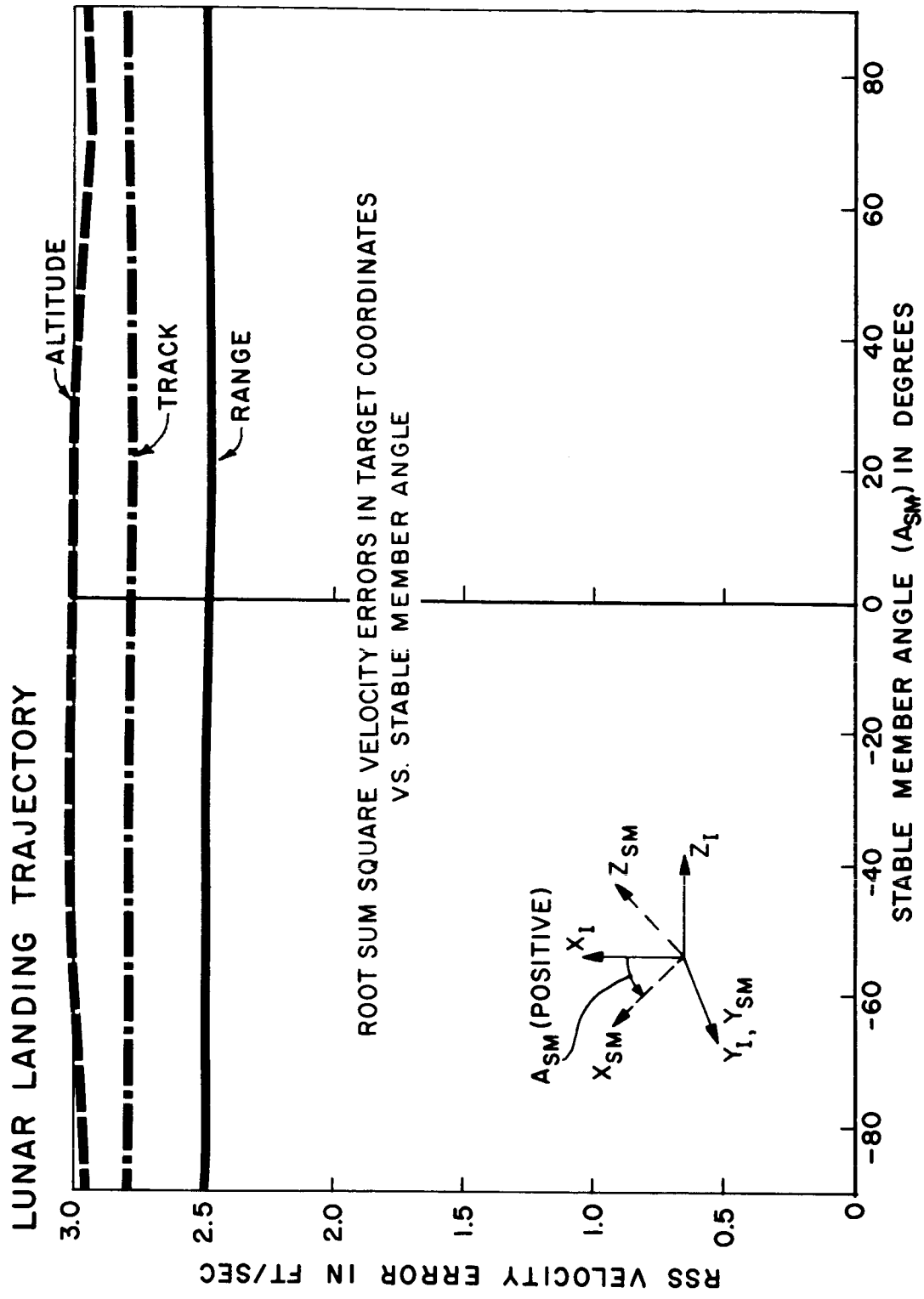

LUNAR LANDING TRAJECTORY
ALTITUDE
TRACK
RANGE
ROOT SUM SQUARE VELOCITY ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
RSS VELOCITY ERROR IN FT/SEC
3.0
2.5
2.0
1.5
1.0
0.5
0
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
80
60
40
20
0
-20
-40
-60
-80
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}

Fig. D-2

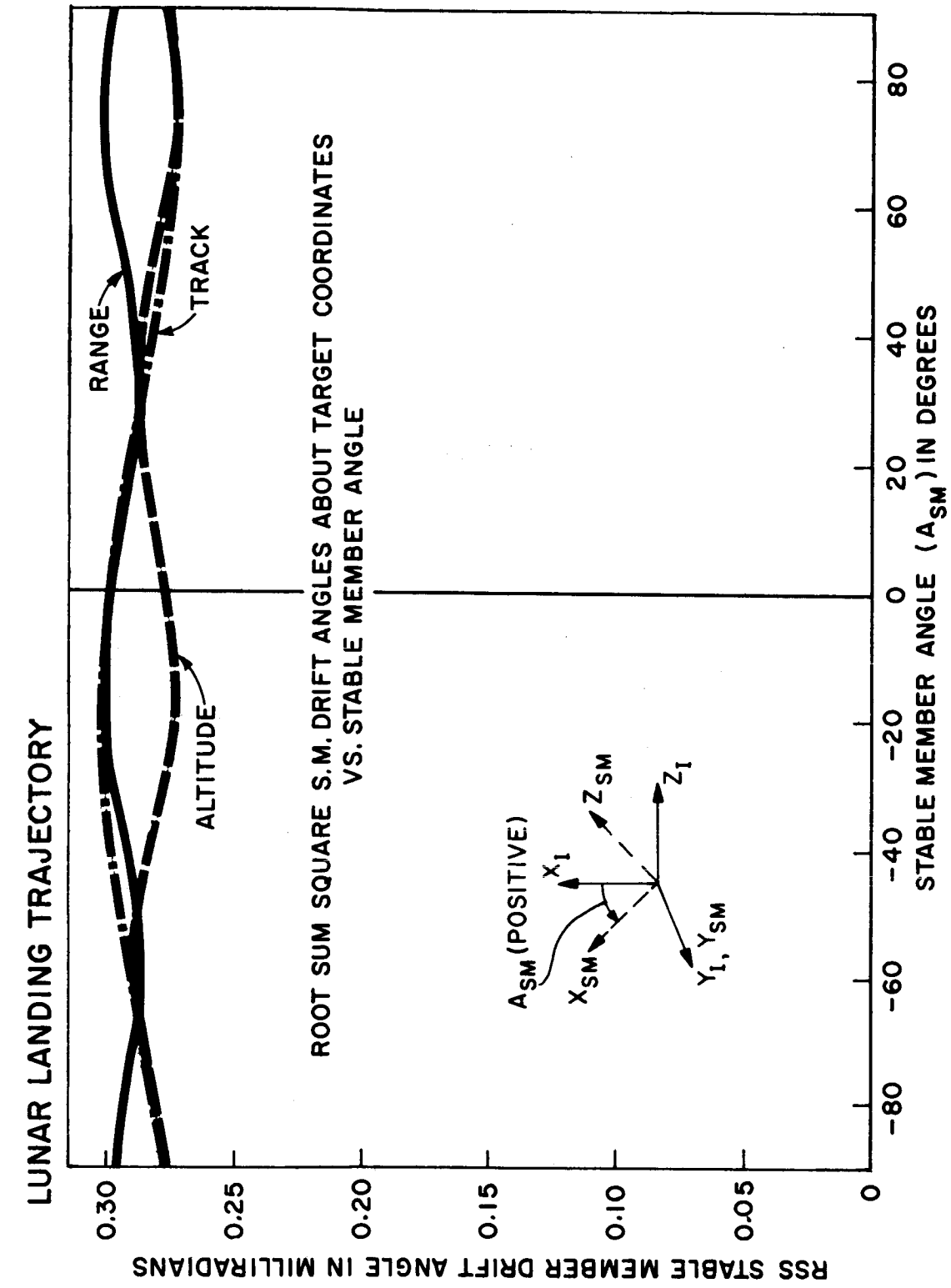

LUNAR LANDING TRAJECTORY
RANGE
TRACK
ALTITUDE
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS STABLE MEMBER DRIFT ANGLE IN MILLIRADIANS
0.30
0.25
0.20
0.15
0.10
0.05
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. D-3

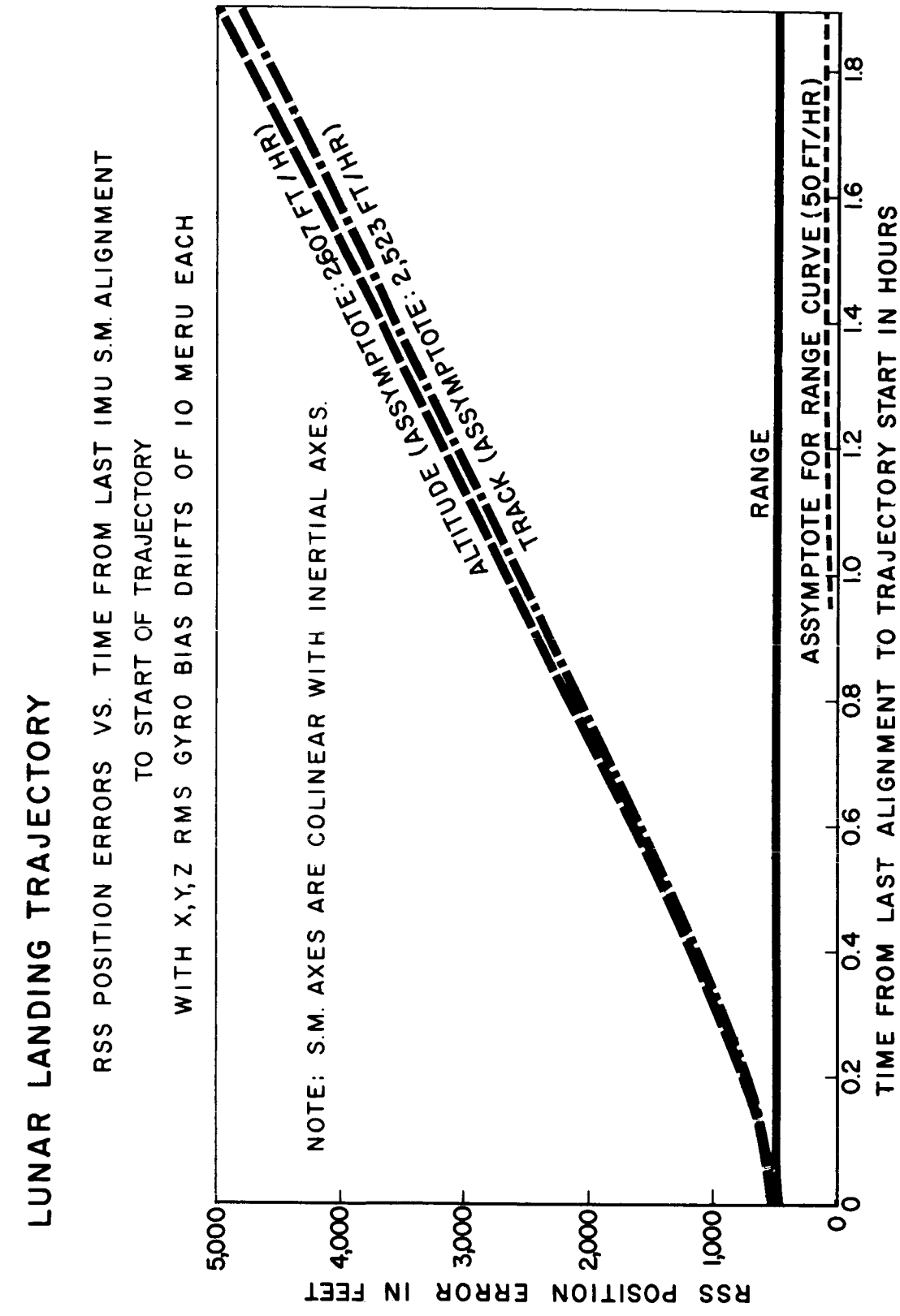

LUNAR LANDING TRAJECTORY
RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH
NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.
ALTITUDE (ASSYMPTOTE: 2607 FT/HR)
TRACK (ASSYMPTOTE: 2,523 FT/HR)
RANGE
ASSYMPTOTE FOR RANGE CURVE (50 FT/HR)
RSS POSITION ERROR IN FEET
5,000
4,000
3,000
2,000
1,000
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
TIME FROM LAST ALIGNMENT TO TRAJECTORY START IN HOURS

Fig. D-4

SECTION E

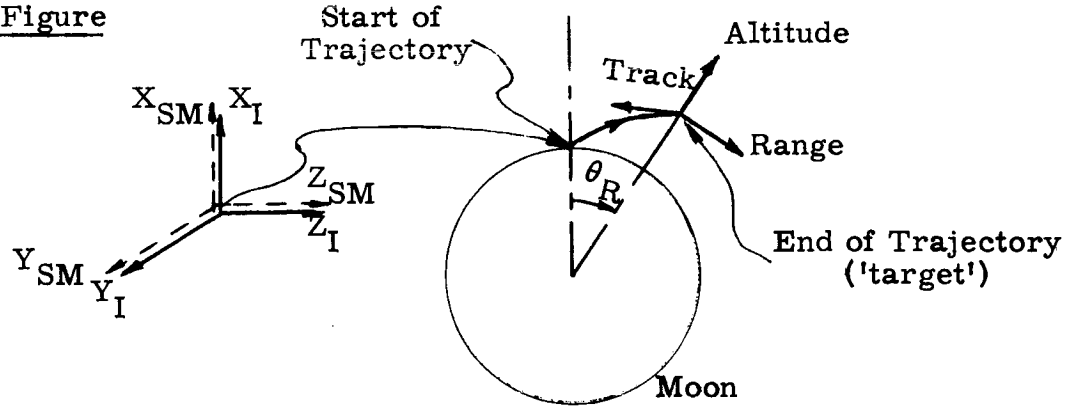
LUNAR TAKEOFF

LUNAR TAKEOFF TRAJECTORY

Trajectory Description & Data

1) Description: Launch from Moon Surface to 50,000 ft altitude
2) Total Trajectory Time : 136.3 seconds
3) Total earth angle, θ_R, subtended by trajectory : 3.10 degrees
4) Initial & final altitudes : 0 and 50,000 feet
5) Initial & final velocities : 15 and 5,034 ft/sec
6) Initial & final velocity angles relative to Z_I axis : 0 and -1.5 degrees
7) Initial & final thrust acceleration : 32.2 and 46.1 ft/sec^2
8) Initial & final pitch angle relative to X_I axis : 0 and 106.8 degrees
9) Thrust acceleration history in ft/sec^2 : $a_T = 32.2 + 0.105t$ for $0<t<3.7$ sec
   $a_T = 31.8 + 0.105t$ for $3.7<t<136.3$ sec
10) Pitch angle history in degrees relative to X_I axis: $\theta = 0$ for $0<t<3.7$ sec
    $\theta = [58.7 + 0.35t + 0.21(10^{-4})t^2]$ for $3.7<t<136.3$ sec

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Lunar Takeoff Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	63.5	0	0	63.5	0
		$A_{(SM)YI}$	0.206 mr	63.8	0	18.6	22.0	0	62.7
		$A_{(SM)ZI}$	0.206 mr	0	18.6	0	0	18.6	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	31.0	0	0	1.7	0	30.9
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	61.2	0	0	3.3	0	61.1
		ACBY	0.2 cm/sec^2	0	60.9	0	0	60.9	0
		ACBZ	0.2 cm/sec^2	0	0	60.9	60.8	0	3.3
	Scale Factor Error	SFEX	100 PPM	9.1	0	0	0.5	0	9.1
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	30.8	30.8	0	1.7
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.5	0	0	0	0	0.5
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	3.4	3.4	0	0.2
GYRO	Bias Drift	BDX	10 meru	0	11.7	0	0	11.7	0
		BDY	10 meru	11.7	0	1.3	2.0	0	11.6
		BDZ	10 meru	0	1.3	0	0	1.3	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	4.3	0	0	4.3	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	1.0	0	0	1.0	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	11.4	0	1.0	1.6	0	11.3
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	0.2	0	0	0.2	0
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	1.2	0	0.1	0.2	0	1.2
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0.1	0	0	0.1	0
Root Sum Square Error				95.5	90.8	70.9	71.9	90.8	94.7
				149.6			149.6		

Lunar Takeoff Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	1.033	0	0	1.033	0
		$A_{(SM)YI}$	0.206 mr	1.041	0	0.119	0.175	0	1.033
		$A_{(SM)ZI}$	0.206 mr	0	0.119	0	0	0.119	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	0.505	0	0	0.027	0	0.505
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	0.900	0	0	0.048	0	0.899
		ACBY	0.2 cm/sec^2	0	0.893	0	0	0.893	0
		ACBZ	0.2 cm/sec^2	0	0	0.893	0.891	0	0.049
	Scale Factor Error	SFEX	100 PPM	0.059	0	0	0.003	0	0.059
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	0.502	0.501	0	0.027
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0.005	0	0	0	0	0.005
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.060	0.060	0	0.003
GYRO	Bias Drift	BDX	10 meru	0	0.274	0	0	0.274	0
		BDY	10 meru	0.275	0	0.008	0.007	0	0.275
		BDZ	10 meru	0	0.008	0	0	0.008	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0.080	0	0	0.080	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0.014	0	0	0.014	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	0.287	0	0.014	0.002	0	0.287
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0.004	0	0	0.004	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.032	0	0.002	0	0	0.032
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0.002	0	0	0.002	0
Root Sum Square Error				1.520	1.400	1.033	1.040	1.400	1.515
				2.311			2.311		

Lunar Takeoff Trajectory

OVER-ALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES

(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.0994	0	0	0.0054	0	0.0992
	BDY	10 meru	0	0.0994	0	0	0.0994	0
	BDZ	10 meru	0	0	0.0994	0.0992	0	0.0054
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0.0132	0	0	0.0007	0	0.0132
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.1139	0.1137	0	0.0062
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.1139	0	0	0.1139	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0.0011	0	0	0	0	0.0011
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.0136	0.0136	0	0.0007
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.0136	0	0	0.0136	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.1003	0.1518	0.1518	0.1516	0.1518	0.1005
			0.2369			0.2369		

Lunar Takeoff Trajectory

IMU POSITION ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+1.0172	0	+0.0002	-0.0548	0	+1.0157
	$(E)Y_{IO}$	foot	0	+0.9914	+0.9899	0	+0.9914	0
	$(E)Z_{IO}$	foot	+0.0002	0	+0.9914	+0.9899	0	+0.0538
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+137.08	0	+0.02	-7.40	0	+136.87
	$(E)V_{YIO}$	ft/sec	0	+135.91	0	0	+135.91	0
	$(E)V_{ZIO}$	ft/sec	+0.02	0	+135.91	+135.71	0	+7.37
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-305.9	0	0	+16.5	0	-305.4
	ACBY	cm/sec^2	0	-304.5	0	0	-304.6	0
	ACBZ	cm/sec^2	0	0	-304.5	-304.1	0	-16.5
Scale Factor Error	SFEX	PPM	-0.091	0	0	+0.005	0	-0.091
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	0	0	-0.308	-0.308	0	-0.017
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.05	0	0	0	0	-0.047
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.342	-0.342	0	-0.019
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+309.5	0	0	-16.7	0	+309.1
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	---	---	---	---	---	---
	Z_{SM}	$A_{(Y)Z}$	milliradian	---	---	---	---	---	---
Z	X_{SM}	$A_{(Z)X}$	milliradian	---	---	---	---	---	---
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Lunar Takeoff Trajectory

IMU POSITION ERROR COEFFICIENTS (PART 2)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-308.4	0	0	-308.4	0
$A_{(SM)YI}$		milliradian	+309.5	0	-90.1	-106.7	0	+304.2
$A_{(SM)ZI}$		milliradian	0	+90.2	0	0	+90.2	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-1.17	0	0	-1.17	0
	BDY	meru	+1.17	0	-0.13	-0.20	0	+1.16
	BDZ	meru	0	+0.13	0	0	+0.13	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-0.43	0	0	-0.43	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	+0.10	0	0	+0.10	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-1.14	0	+0.10	+0.16	0	-1.13
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-0.22	0	0	-0.22	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+0.09	0	0	+0.09	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+1.21	0	-0.09	-0.16	0	+1.20
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Lunar Takeoff Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot						
	$(E)Y_{IO}$	foot						
	$(E)Z_{IO}$	foot						
Initial Velocity Error	$(E)V_{XIO}$	ft/sec						
	$(E)V_{YIO}$	ft/sec						
	$(E)V_{ZIO}$	ft/sec						
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-4.50	0	0	+0.242	0	-4.494
	ACBY	cm/sec^2	0	-4.463	0	0	-4.463	0
	ACBZ	cm/sec^2	0	0	-4.46	-4.456	0	-0.243
Scale Factor Error	SFEX	PPM	-0.00059	0	0	+0.00003	0	-0.00059
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	0	0	-0.00502	-0.00501	0	-0.00027
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-0.0005	0	0	+0	0	-0.0005
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.0060	-0.0060	0	-0.0003
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+5.05	0	0	-0.27	0	+5.05
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	---	---	---	---	---	---
	Z_{SM}	$A_{(Y)Z}$	milliradian	---	---	---	---	---	---
Z	X_{SM}	$A_{(Z)X}$	milliradian	---	---	---	---	---	---
	Y_{SM}	$A_{(Z)Y}$	milliradian	0	0	0	0	0	0

Lunar Takeoff Trajectory

IMU VELOCITY ERROR COEFFICIENTS (PART 2)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-5.017	0	0	-5.017	0
$A_{(SM)YI}$		milliradian	+5.052	0	-0.577	-0.850	0	+5.014
$A_{(SM)ZI}$		milliradian	0	+0.578	0	0	+0.578	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-0.0274	0	0	-0.0274	0
	BDY	meru	+0.0275	0	+0.0008	-0.0007	0	+0.0275
	BDZ	meru	0	-0.0008	0	0	-0.0008	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-0.0080	0	0	-0.0080	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-0.0014	0	0	-0.0014	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.0287	0	-0.0014	+0.0002	0	-0.0287
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-0.0041	0	0	-0.0041	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	-0.0019	0	0	-0.0019	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+0.0320	0	+0.0019	0	0	+0.0321
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Lunar Takeoff Trajectory
IMU S. M. DRIFT ANGLE COEFFICIENTS
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Drift Angle about Inertial Axes in milliradian per unit error			Drift Angle about Target Axes in milliradian per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	0.00994	0	0	-0.00054	0	0.00992
	BDY	meru	0	0.00994	0	0	0.00994	0
	BDZ	meru	0	0	0.00994	0.00992	0	0.00054
Acceleration Sensitive Drift	ADIAX	meru/g	0.01320	0	0	-0.00007	0	0.00132
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	0.01139	0.01137	0	0.00062
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	-0.01139	0	0	-0.01139	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	0.0011	0	0	0	0	0.00011
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	0.0136	0.0136	0	0.0007
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0136	0	0	+0.0136	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0

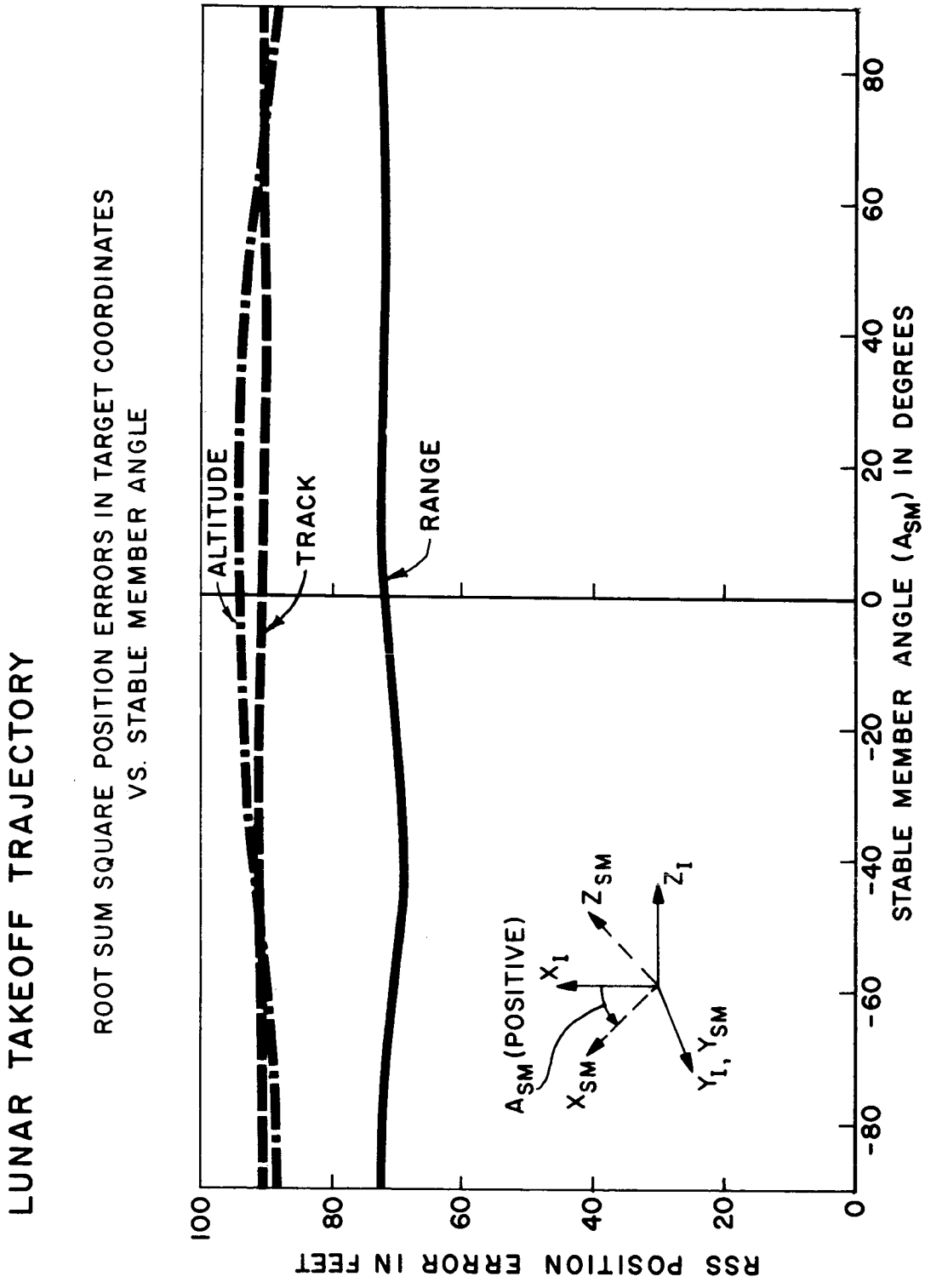

LUNAR TAKEOFF TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
RSS POSITION ERROR IN FEET
100
80
60
40
20
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}

Fig. E-1

LUNAR TAKEOFF TRAJECTORY

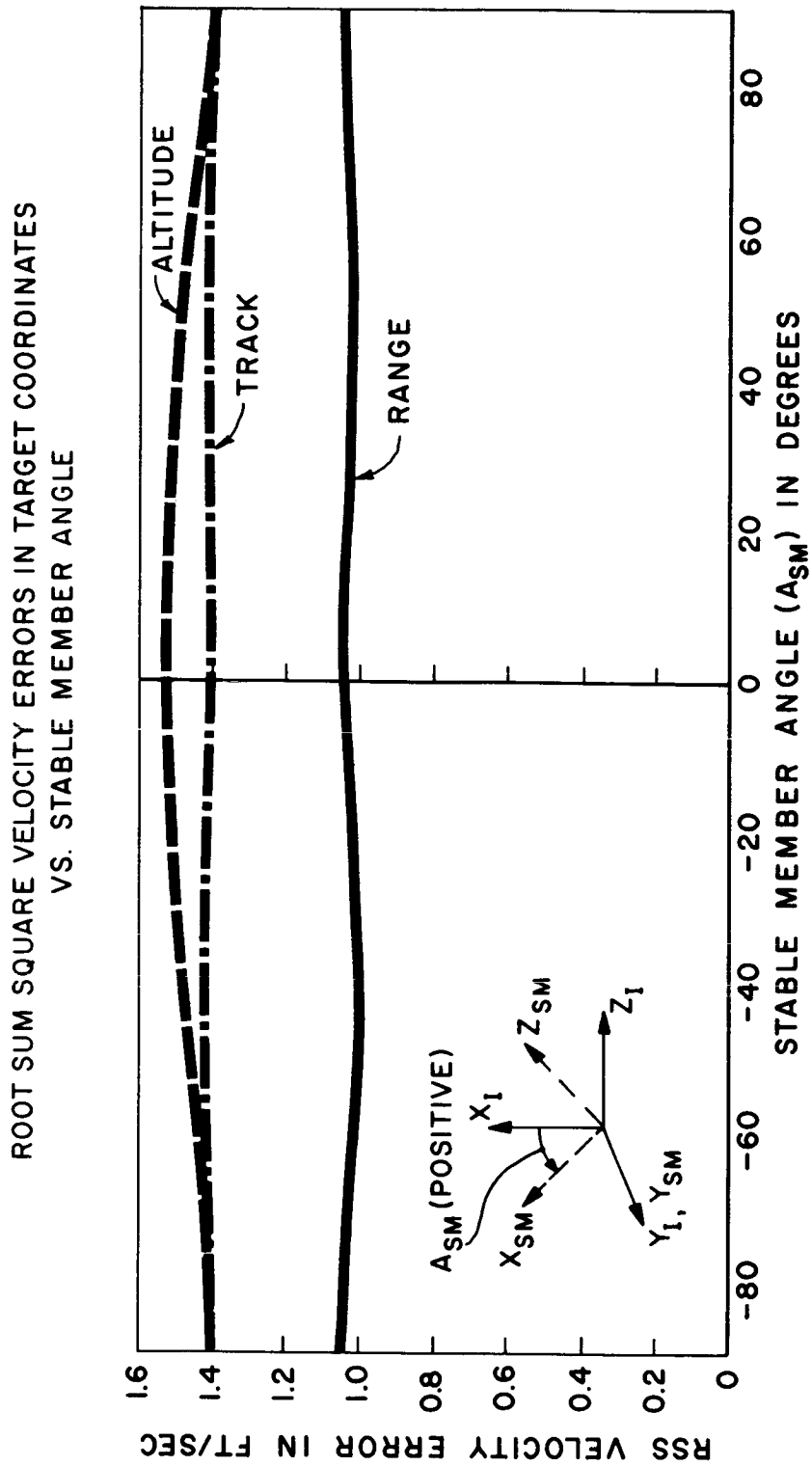


Fig. E-2

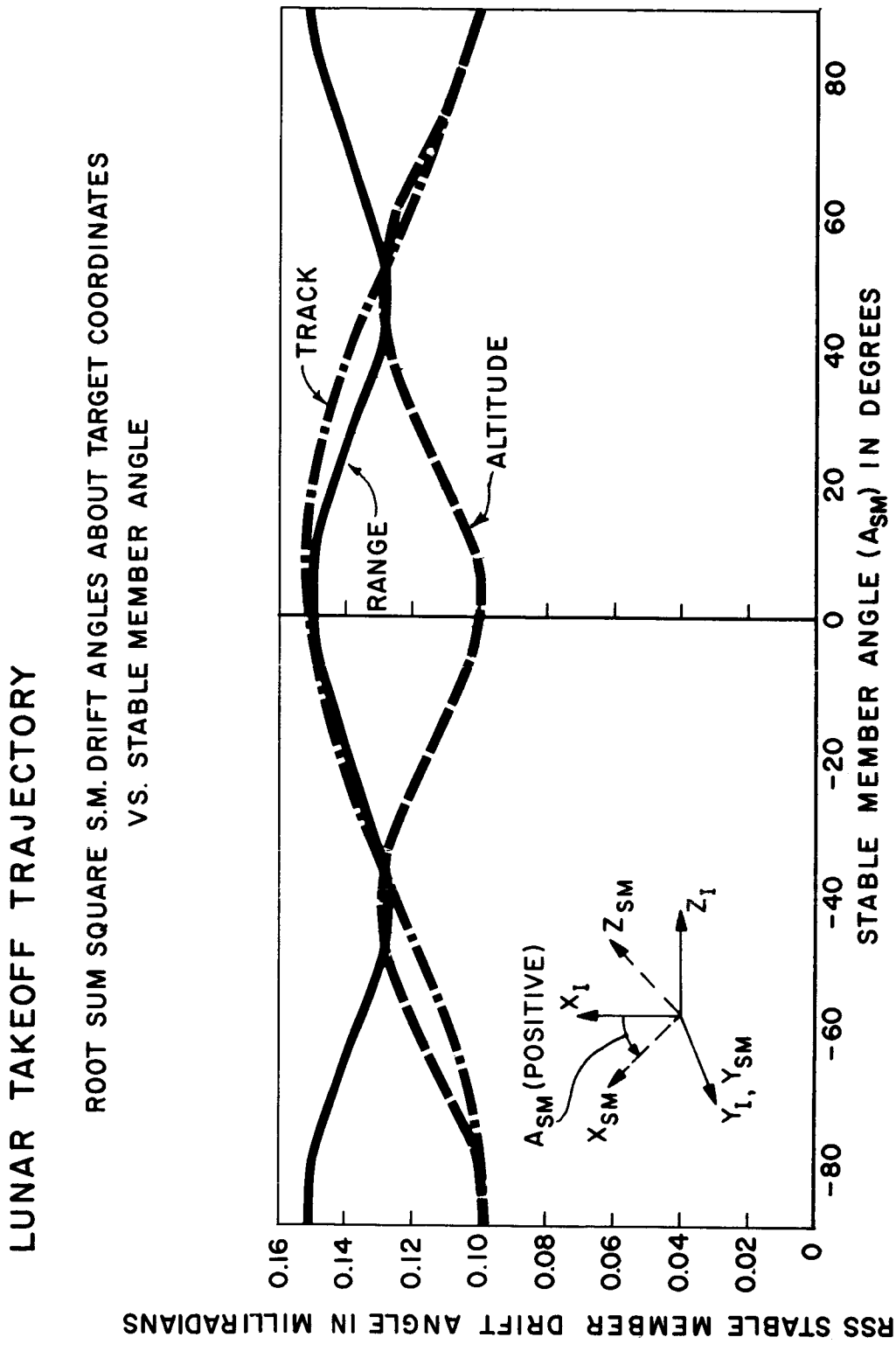

LUNAR TAKEOFF TRAJECTORY
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
TRACK
RANGE
ALTITUDE
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS STABLE MEMBER DRIFT ANGLE IN MILLIRADIANS
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. E-3

LUNAR TAKEOFF TRAJECTORY

RSS POSITION ERRORS VS TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF POWERED INJECTION TAKEOFF TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

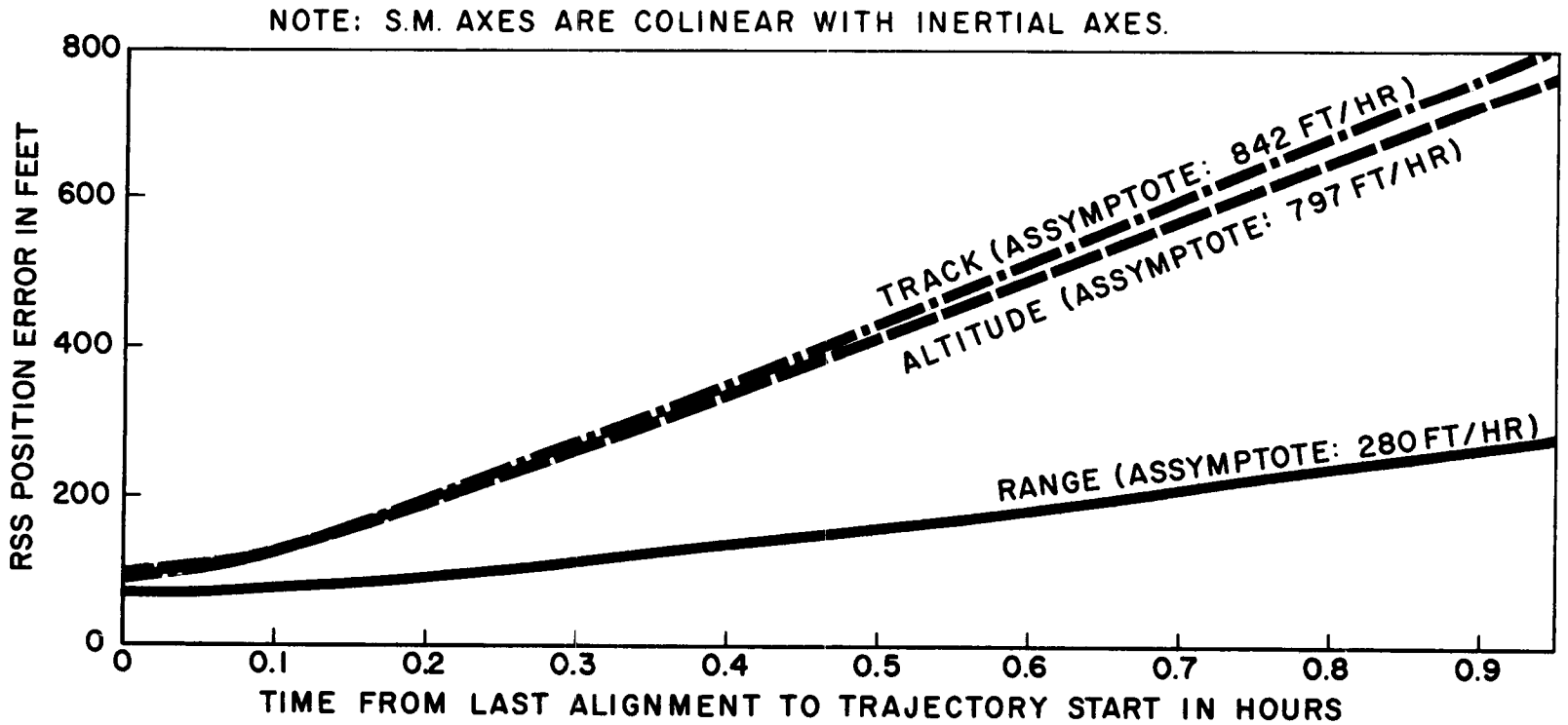


Fig. E-4

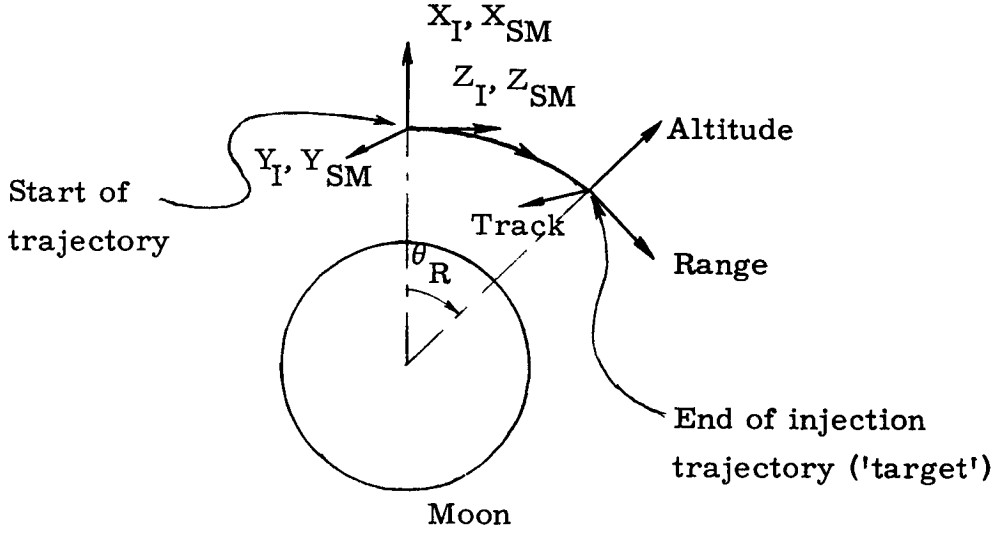
SECTION F

TRANSEARTH INJECTION

Trajectory Description & Data

1) Description: Powered injection into free-fall transearth trajectory from 100 n. mile circular lunar parking orbit.
2) Total trajectory time: 103.5 seconds
3) Total earth angle, θ_R, subtended by trajectory: 6.28 degrees
4) Initial & final altitudes 100.0 and 102.4 n. miles
5) Initial & final velocities: 5,234 and 8,278 ft/sec.
6) Initial & final velocity angles relative to Z_I axis: 0 and -3.10 degrees
7) Initial & final thrust acceleration: 25.76 and 33.28 ft/sec^2
8) Initial & final pitch angle relative to Z_I axis: 0 and 0 degrees
9) Thrust acceleration history in ft/sec^2: $a_T = 25.76 + 0.0724t + 2.4\,(10^{-6})t^2$ for $0 < t < 103.5$ secs.
10) Pitch angle history in degrees relative to Z_I axis: $\theta = 0$ for $0 < t < 103.5$ secs.

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

Transearth Injection Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in feet			RMS Error in Target Axes in feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	31.2	0	0	31.2	0
		$A_{(SM)YI}$	0.206 mr	31.2	0	0	3.4	0	31.0
		$A_{(SM)ZI}$	0.206 mr	0	0	0	0	0	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	15.2	0	0	1.7	0	15.1
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	35.2	0	0	3.9	0	35.0
		ACBY	0.2 cm/sec^2	0	35.2	0	0	35.2	0
		ACBZ	0.2 cm/sec^2	0	0	35.2	34.9	0	3.9
	Scale Factor Error	SFEX	100 PPM	0	0	0	0	0	0
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	15.1	15.0	0	1.7
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0	0	0	0	0	0
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	1.3	1.3	0	0.1
GYRO	Bias Drift	BDX	10 meru	0	4.0	0	0	4.0	0
		BDY	10 meru	4.0	0	0	0	0	4.0
		BDZ	10 meru	0	0	0	0	0	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0	0	0	0	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0	0	0	0	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	3.4	0	0	0.4	0	3.4
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	0	0	0	0	0
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0.3	0	0	0	0	0.3
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error				49.7	47.1	38.3	38.4	47.1	49.6
				78.5			78.5		

Transearth Injection Trajectory

OVERALL SYSTEM STUDY OF RMS VELOCITY ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in ft/sec			RMS Error in Target Axes in ft/sec		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.206 mr	0	0.629	0	0	0.629	0
		$A_{(SM)YI}$	0.206 mr	0.631	0	0	0.069	0	0.627
		$A_{(SM)ZI}$	0.206 mr	0	0	0	0	0	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	0.306	0	0	0.033	0	0.304
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	0.681	0	0	0.074	0	0.677
		ACBY	0.2 cm/sec^2	0	0.679	0	0	0.679	0
		ACBZ	0.2 cm/sec^2	0	0	0.679	0.675	0	0.075
	Scale Factor Error	SFEX	100 PPM	0	0	0	0	0	0
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	0	0	0.305	0.303	0	0.033
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	0	0	0	0	0	0
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	0	0	0.028	0.028	0	0
GYRO	Bias Drift	BDX	10 meru	0	0.120	0	0	0.120	0
		BDY	10 meru	0.120	0	0	0.013	0	0.120
		BDZ	10 meru	0	0	0	0	0	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0	0	0	0	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	0	0	0	0	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	0.106	0	0	0.012	0	0.105
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	0	0	0	0	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	0.009	0	0	0.001	0	0.009
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	0	0	0	0	0
Root Sum Square Error				0.991	0.933	0.745	0.748	0.933	0.988
				1.551			1.551		

Transearth Injection Trajectory

OVER-ALL SYSTEM STUDY OF RMS PLATFORM DRIFT ANGLES

(SM axes colinear with inertial axes)

Error		RMS Error	Drift Angle about Inertial Axes (in milliradians)			Drift Angle about Target Axes (in milliradians)		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Gyro Bias Drift	BDX	10 meru	0.075	0	0	0.008	0	0.075
	BDY	10 meru	0	0.075	0	0	0.075	0
	BDZ	10 meru	0	0	0.075	0.075	0	0.008
Gyro Acceleration Sensitive Drift	ADIAX	10 meru/g	0	0	0	0	0	0
	ADIAY	10 meru/g	0	0	0	0	0	0
	ADIAZ	10 meru/g	0	0	0.069	0.069	0	0.008
	ADSRAX	10 meru/g	0	0	0	0	0	0
	ADSRAY	10 meru/g	0	0.069	0	0	0.069	0
	ADSRAZ	10 meru/g	0	0	0	0	0	0
Gyro Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	1 meru/g^2	0	0	0.006	0.006	0	0.001
	$A^2D_{(SRA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	0	0.006	0	0	0.006	0
	$A^2D_{(SRA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	1 meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	1 meru/g^2	0	0	0	0	0	0
Root Sum Square Error			0.075	0.103	0.103	0.102	0.103	0.076
			0.164			0.164		

Transearth Injection Trajectory
IMU POSITION ERROR COEFFICIENTS (PART 1)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+1.007	0	0	-0.110	0	+1.001
	$(E)Y_{IO}$	foot	0	+0.996	0	0	+0.996	0
	$(E)Z_{IO}$	foot	0	0	+0.996	+0.990	0	+0.109
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+103.8	0	0	-11.3	0	+103.1
	$(E)V_{YIO}$	ft/sec	0	+103.4	0	0	+103.4	0
	$(E)V_{ZIO}$	ft/sec	0	0	+103.4	+102.8	0	+11.3
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-176.1	0	0	+19.3	0	-175.0
	ACBY	cm/sec^2	0	-175.8	0	0	-175.8	0
	ACBZ	cm/sec^2	0	0	-175.8	-174.7	0	-19.3
Scale Factor Error	SFEX	PPM	0	0	0	0	0	0
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	0	0	-0.151	-0.151	0	-0.017
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	0	0	0	0	0	0
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	0	0	-0.133	-0.133	0	-0.015
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	+151.6	0	0	-16.6	0	+150.6
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	0	0	0	0	0	0
	Y_{SM}	$A_{(Z)Y}$	milliradian	--	--	--	--	--	--

Transearth Injection Trajectory

IMU POSITION ERROR COEFFICIENTS (PART 2)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-151.3	0	0	-151.3	0
$A_{(SM)YI}$		milliradian	+151.6	0	0	-16.6	0	+150.6
$A_{(SM)ZI}$		milliradian	0	0	0	0	0	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-0.398	0	0	-0.398	0
	BDY	meru	+0.398	0	0	-0.044	0	+0.396
	BDZ	meru	0	0	0	0	0	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	0	0	0	0	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	0	0	0	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.342	0	0	+0.037	0	-0.340
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+0.295	0	0	-0.032	0	+0.293
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Transearth Injection Trajectory
IMU VELOCITY ERROR COEFFICIENTS (PART 1)
(SM axes colinear with inertial axes)

Error			Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
				$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes									
Initial Position Error	$(E)X_{IO}$		foot	$+0.142(10^{-3})$	0	$+0.011(10^{-3})$	$-0.005(10^{-3})$	0	$+0.142(10^{-3})$
	$(E)Y_{IO}$		foot	0	$-0.071(10^{-3})$	0	0	$-0.071(10^{-3})$	0
	$(E)Z_{IO}$		foot	$+0.011(10^{-3})$	0	$-0.070(10^{-3})$	$-0.071(10^{-3})$	0	$+0.003(10^{-3})$
Initial Velocity Error	$(E)V_{XIO}$		ft/sec	+1.007	0	+0.001	-0.110	0	+1.001
	$(E)V_{YIO}$		ft/sec	0	+0.996	0	0	+0.996	0
	$(E)V_{ZIO}$		ft/sec	+0.001	0	+0.996	+0.990	0	+0.110
B. Accelerometer Errors (In-flight Effect only)									
Bias	ACBX		cm/sec^2	-3.407	0	-0.001	+0.372	0	-3.386
	ACBY		cm/sec^2	0	-3.394	0	0	-3.394	0
	ACBZ		cm/sec^2	-0.001	0	-3.394	-3.374	0	-0.373
Scale Factor Error	SFEX		PPM	0	0	0	0	0	0
	SFEY		PPM	0	0	0	0	0	0
	SFEZ		PPM	0	0	-0.0031	-0.0030	0	-0.0003
Accel. Sens. Scale Factor Error	SFNCX		PPM/g	0	0	0	0	0	0
	SFNCY		PPM/g	0	0	0	0	0	0
	SFNCZ		PPM/g	0	0	-0.0028	-0.0028	0	-0.0003
C. Misalignments of Accelerometer Input Axes									
Accel.	About Axis								
X	Y_{SM}	$A_{(X)Y}$	milliradian	+3.062	0	0	-0.334	0	+3.043
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	--	--	--	--	--	--
	Z_{SM}	$A_{(Y)Z}$	milliradian	--	--	--	--	--	--
Z	X_{SM}	$A_{(Z)X}$	milliradian	0	0	0	0	0	0
	Y_{SM}	$A_{(Z)Y}$	milliradian	--	--	--	--	--	--

Transearth Injection Trajectory
IMU VELOCITY ERROR COEFFICIENTS (PART 2)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in ft/sec per unit error			Error in Target Axes in ft/sec per unit error		
			$(E)V_{XI}$	$(E)V_{YI}$	$(E)V_{ZI}$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-3.051	0	0	-3.051	0
$A_{(SM)YI}$		milliradian	+3.062	0	+0.008	-0.334	0	+3.043
$A_{(SM)ZI}$		milliradian	0	0	0	0	0	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-0.0120	0	0	-0.0120	0
	BDY	meru	+0.0120	0	0	-0.0013	0	+0.0120
	BDZ	meru	0	0	0	0	0	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	0	0	0	0	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	0	0	0	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-0.0106	0	0	+0.0012	0	-0.0105
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+0.0093	0	0	-0.0010	0	+0.0093
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

Transearth Injection Trajectory
IMU S. M. DRIFT ANGLE COEFFICIENTS
(SM axes colinear with inertial axes)

Error		RMS Error Dimension	Drift Angle about Inertial axes in milliradian per unit error			Drift Angle about Target Axes in milliradian per unit error		
			ϕ_{XI}	ϕ_{YI}	ϕ_{ZI}	ϕ_{Range}	ϕ_{Track}	$\phi_{Altitude}$
Bias Drift	BDX	meru	+0.0075	0	0	-0.0008	0	+0.0075
	BDY	meru	0	+0.0075	0	0	+0.0075	0
	BDZ	meru	0	0	+0.0075	+0.0075	0	+0.0008
Acceleration Sensitive Drift	ADIAX	meru/g	0	0	0	0	0	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	0	+0.0069	+0.0069	0	+0.0008
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	0	-0.0069	0	0	-0.0069	0
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	meru/g^2	0	0	+0.0064	+0.0063	0	+0.0007
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	0	+0.0064	0	0	+0.0064	0
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	0	0	0	0	0	0

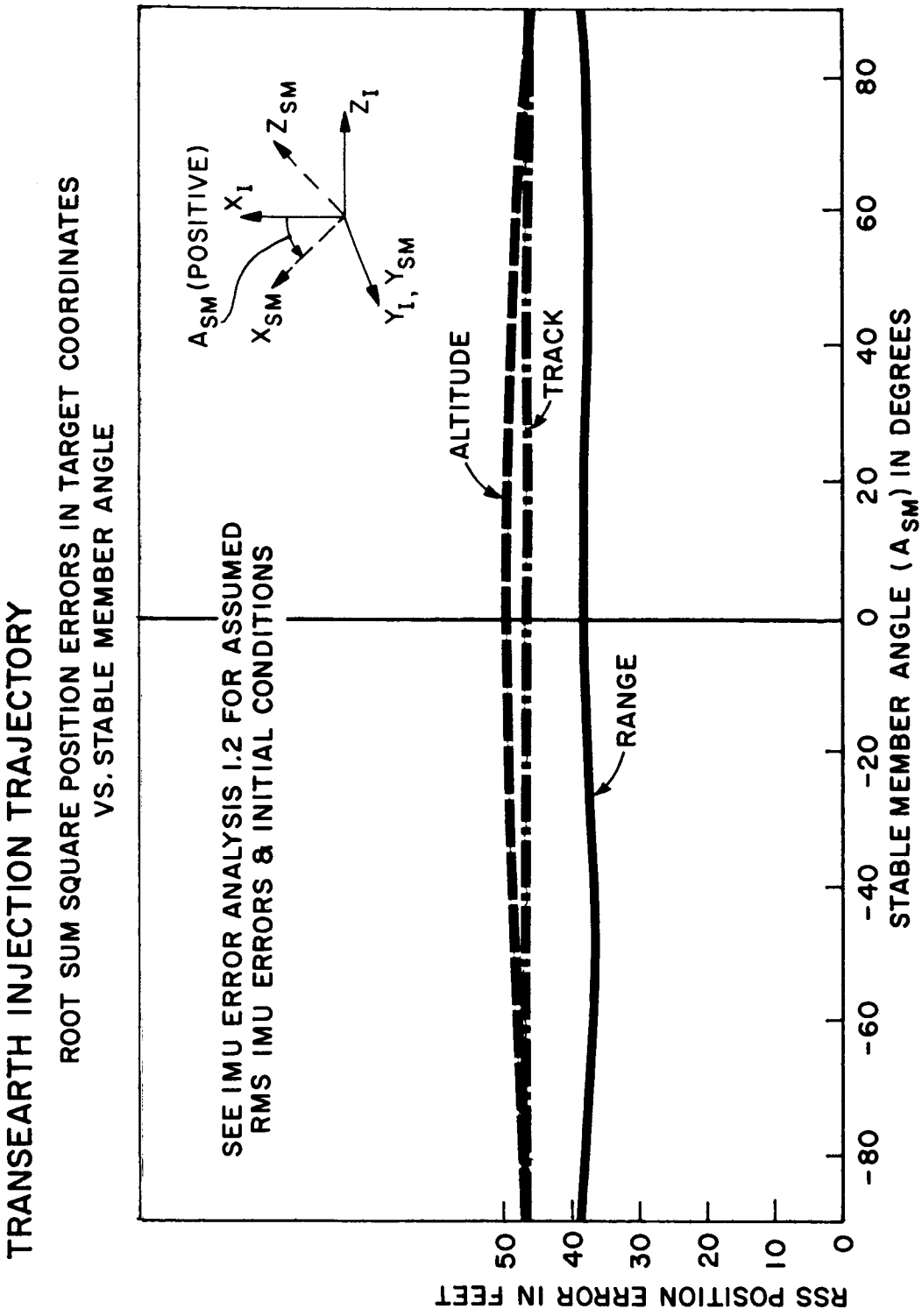

TRANSEARTH INJECTION TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS IMU ERRORS & INITIAL CONDITIONS
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
ALTITUDE
TRACK
RANGE
RSS POSITION ERROR IN FEET
0
10
20
30
40
50
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
-80
-60
-40
-20
0
20
40
60
80

Fig. F-1

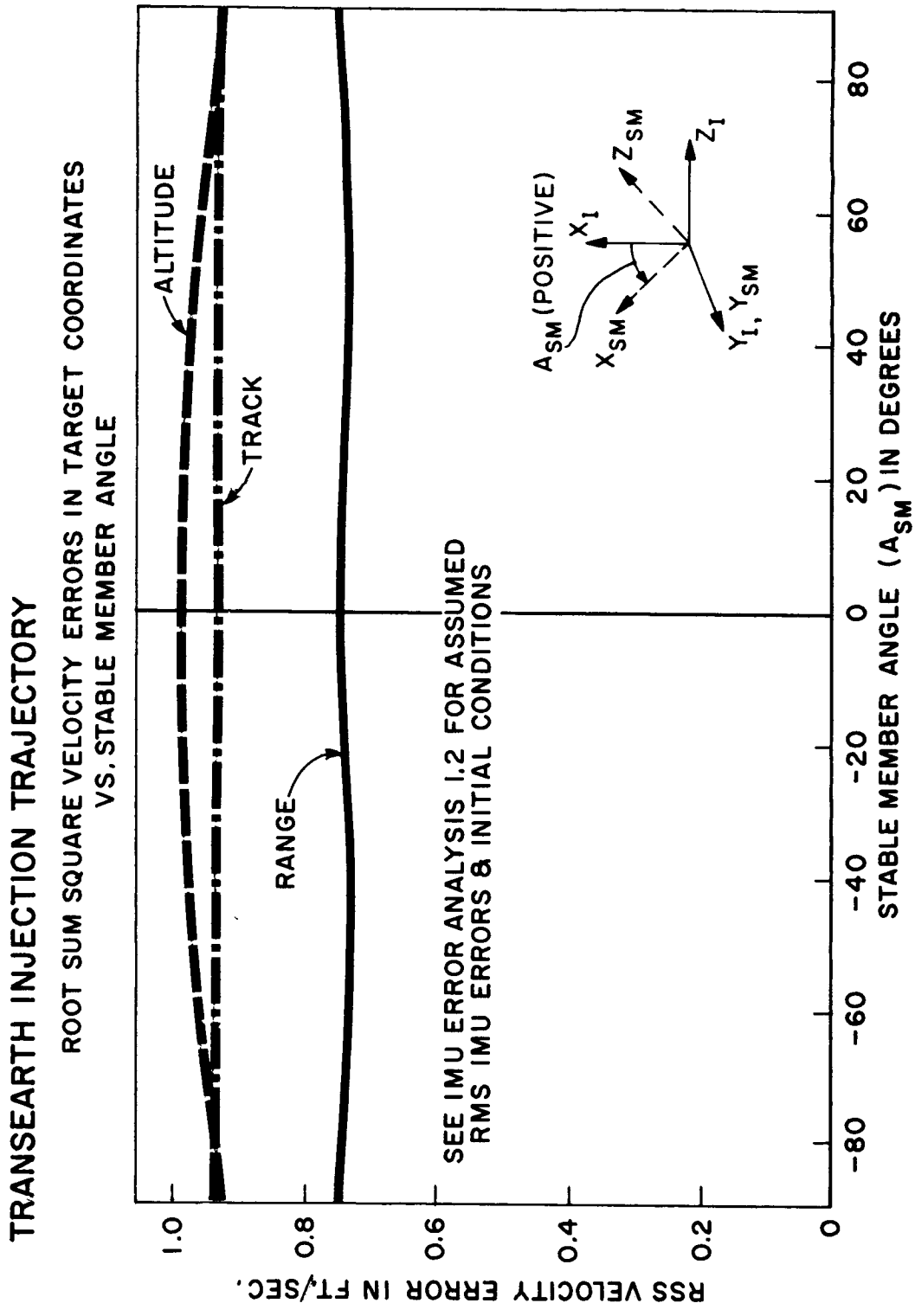

TRANSEARTH INJECTION TRAJECTORY
ROOT SUM SQUARE VELOCITY ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS IMU ERRORS & INITIAL CONDITIONS
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS VELOCITY ERROR IN FT/SEC.
1.0
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. F-2

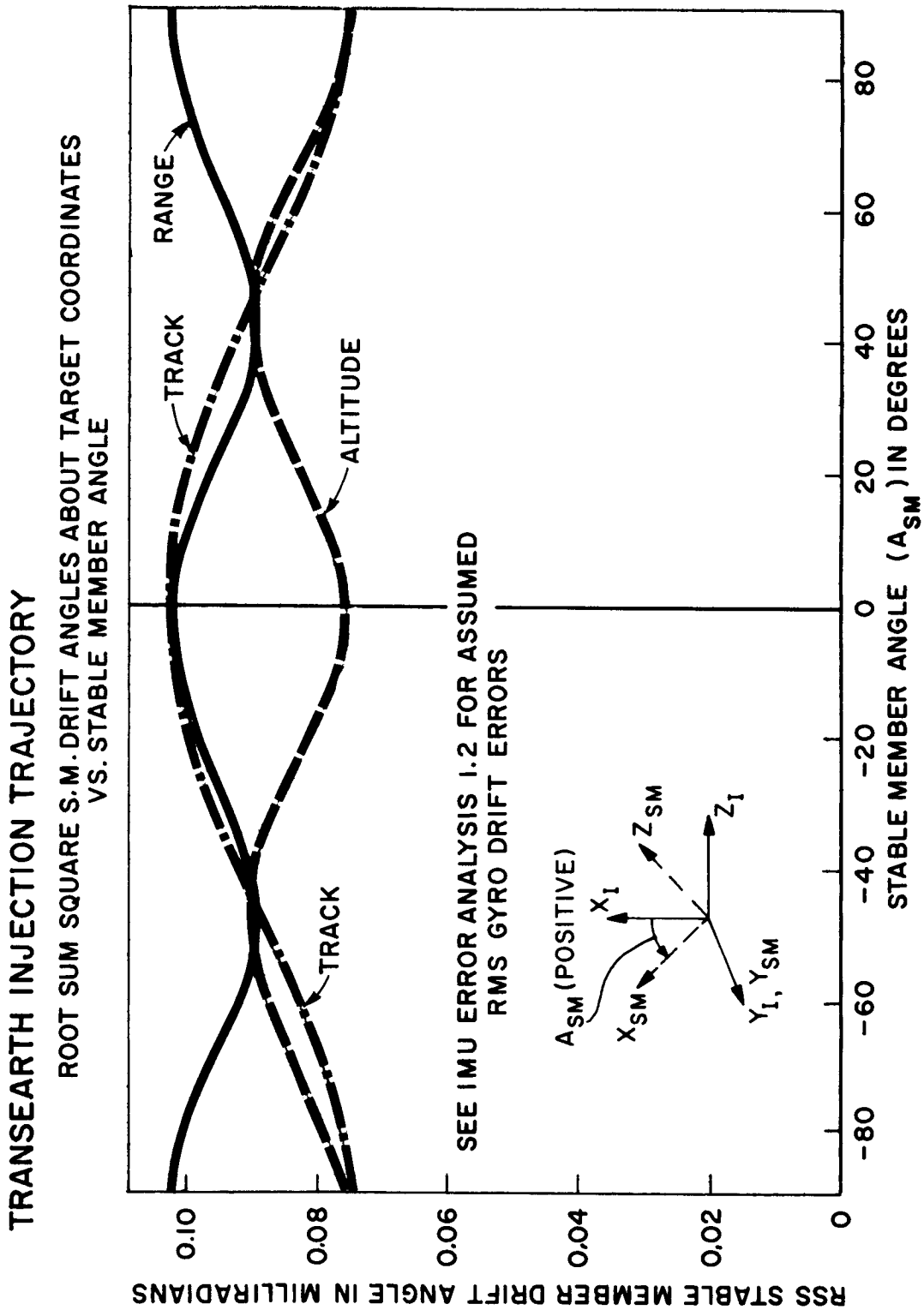

TRANSEARTH INJECTION TRAJECTORY
ROOT SUM SQUARE S.M. DRIFT ANGLES ABOUT TARGET COORDINATES
VS. STABLE MEMBER ANGLE
RANGE
TRACK
ALTITUDE
TRACK
SEE IMU ERROR ANALYSIS 1.2 FOR ASSUMED
RMS GYRO DRIFT ERRORS
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}
RSS STABLE MEMBER DRIFT ANGLE IN MILLIRADIANS
0.10
0.08
0.06
0.04
0.02
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. F-3

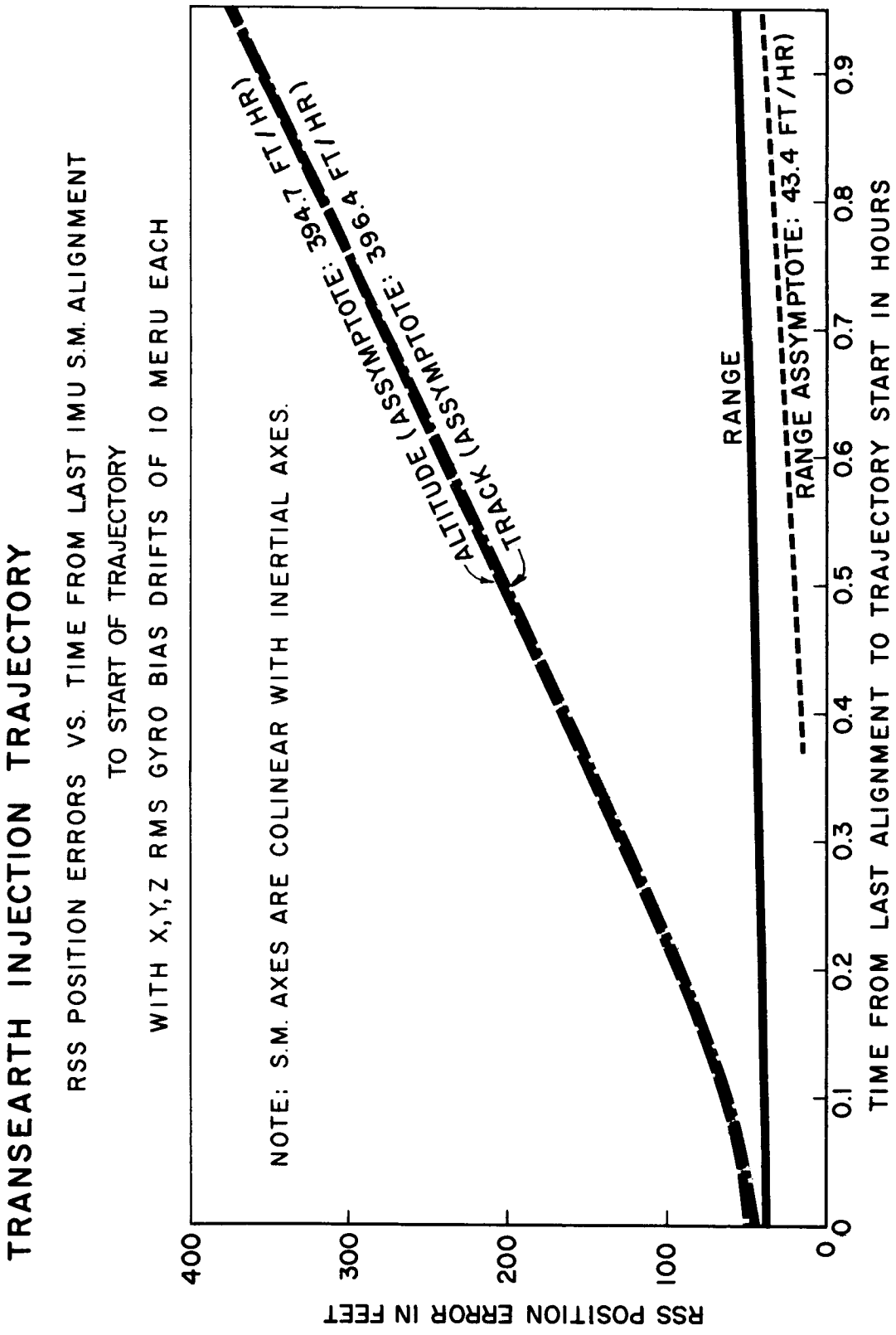

TRANSEARTH INJECTION TRAJECTORY
RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH
NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.
ALTITUDE (ASSYMPTOTE: 394.7 FT/HR)
TRACK (ASSYMPTOTE: 396.4 FT/HR)
RANGE
RANGE ASSYMPTOTE: 43.4 FT/HR)
RSS POSITION ERROR IN FEET
TIME FROM LAST ALIGNMENT TO TRAJECTORY START IN HOURS
0
100
200
300
400
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9

Fig. F-4

TRANSEARTH INJECTION TRAJECTORY

RSS VELOCITY ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.

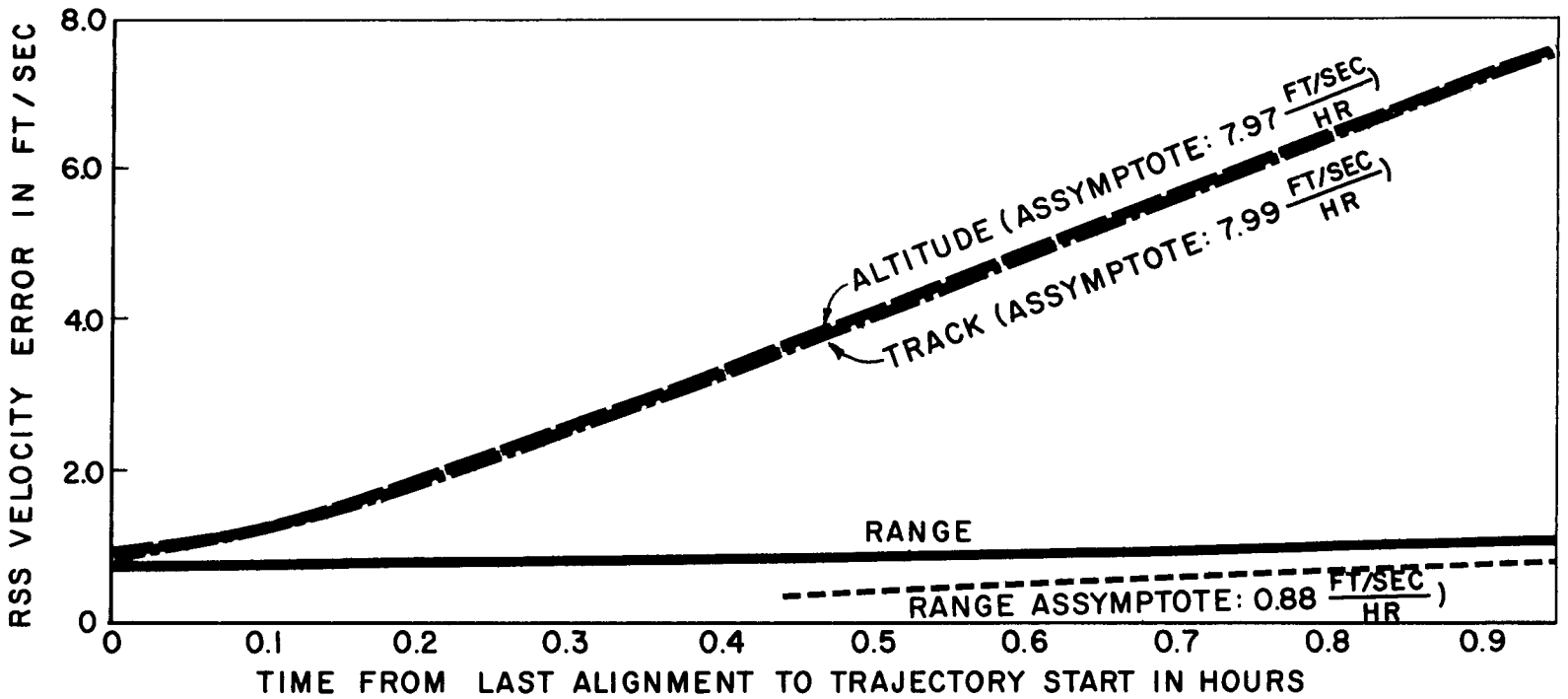


Fig. F-5

SECTION G

EARTH REENTRY TRAJECTORIES

Trajectory Description	Peak acceleration for trajectory G's	Total Trajectory time seconds	Total Earth Angle, θ_R, subtended by Trajectory	
			degrees	naut. miles
High G	10.3	599	21.32	1,279
Medium G	5.6	733	29.85	1,791
Low G	3.1	1,154	58.18	3,491
Low G (Ext. Rge.)	?	?	150.00	9,000

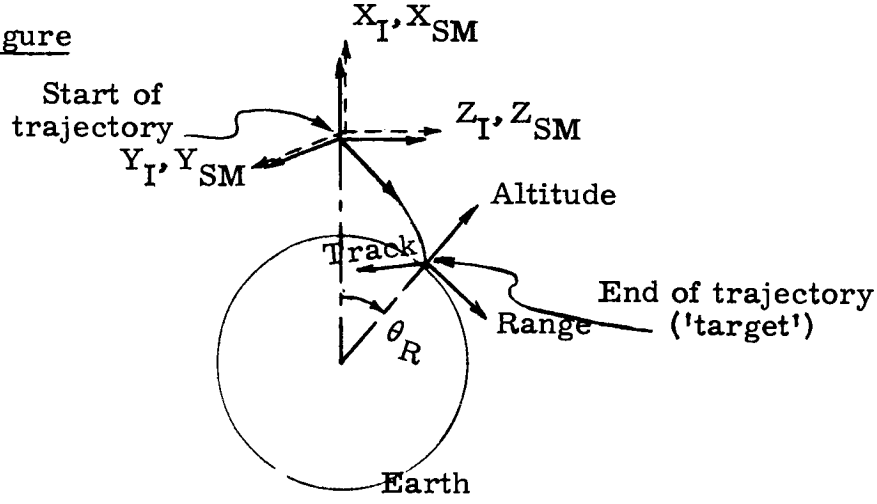
Other trajectory data:

Altitude at start of reentry trajectory : 400,000 ft

Altitude at end of reentry trajectory : 50,000 ft

Velocity at start of reentry trajectory : 36,800 ft/sec

Trajectory Figure



Note: For all tabular error studies the IMU stable member coordinates, X_{SM}, Y_{SM}, Z_{SM} are colinear with inertial coordinates, X_I, Y_I, Z_I.

High G Earth Re-entry Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.1 mr	0	1,229	2	2	1,229	1
		$A_{(SM)YI}$	0.1 mr	1,449	0	702	127	0	1,605
		$A_{(SM)ZI}$	0.1 mr	2	628	0	1	628	2
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	2	0	0	1	0	2
		X to Z	0.1 mr	1,423	0	65	457	0	1,350
		Y to Z	0.1 mr	0	0	2	2	0	1
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	1,270	0	49	416	0	1,200
		ACBY	0.2 cm/sec^2	0	1,124	0	0	1,124	0
		ACBZ	0.2 cm/sec^2	48	0	1,141	1,045	0	460
	Scale Factor Error	SFEX	100 PPM	706	0	26	232	0	668
		SFEY	100 PPM	0	2	0	0	2	0
		SFEZ	100 PPM	64	0	1,251	1,142	0	514
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	208	0	10	66	0	197
		SFNCY	10 PPM/g	0	23	0	0	23	0
		SFNCZ	10 PPM/g	30	0	499	454	0	209
GYRO	Bias Drift	BDX	10 meru	1	1,312	7	6	1,312	3
		BDY	10 meru	1,487	0	1,023	413	0	1,757
		BDZ	10 meru	8	963	0	3	963	8
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	1,533	4	4	1,533	2
		ADIAY	10 meru/g	24	0	11	19	0	19
		ADIAZ	10 meru/g	43	2,357	2	14	2,357	41
		ADSRAX	10 meru/g	0	20	0	0	20	0
		ADSRAY	10 meru/g	4,166	0	2,530	842	0	4,801
		ADSRAZ	10 meru/g	0	13	0	0	13	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	613	3	2	613	1
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	2,082	0	1,101	268	0	2,339
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	21	1,009	1	7	1,009	20
Root Sum Square Error				5,496	3,889	3,504	2,003	3,889	6,202
					7,590			7,590	

Medium G Earth Re-entry Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.1 mr	0	1,291	3	3	1,291	1
		$A_{(SM)YI}$	0.1 mr	1,614	0	899	24	0	1,848
		$A_{(SM)ZI}$	0.1 mr	2	743	0	1	743	2
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	2	0	0	1	0	2
		X to Z	0.1 mr	1,564	0	130	665	0	1,421
		Y to Z	0.1 mr	0	0	3	3	0	1
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	1,948	0	142	846	0	1,760
		ACBY	0.2 cm/sec^2	0	1,650	0	0	1,650	0
		ACBZ	0.2 cm/sec^2	139	0	1,719	1,422	0	976
	Scale Factor Error	SFEX	100 PPM	849	0	51	378	0	762
		SFEY	100 PPM	0	3	0	0	3	0
		SFEZ	100 PPM	127	0	1,354	1,111	0	784
	Accel. Sens Scale Factor Error	SFNCX	10 PPM/g	157	0	11	68	0	142
		SFNCY	10 PPM/g	0	21	0	0	21	0
		SFNCZ	10 PPM/g	36	0	334	271	0	198
GYRO	Bias Drift	BDX	10 meru	1	1,838	12	9	1,838	7
		BDY	10 meru	2,181	0	1,846	516	0	2,811
		BDZ	10 meru	13	1,675	1	6	1,675	12
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	1,378	3	3	1,378	1
		ADIAY	10 meru/g	20	0	13	21	0	11
		ADIAZ	10 meru/g	41	2,880	3	18	2,880	38
		ADSRAX	10 meru/g	0	15	0	0	15	0
		ADSRAY	10 meru/g	4,131	0	3,210	728	0	5,181
		ADSRAZ	10 meru/g	0	15	0	0	15	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 meru/g^2	0	316	1	1	316	1
		$A^2D_{(SRA)(SRA)Y}$	1 meru/g^2	1,230	0	843	119	0	1,487
		$A^2D_{(IA)(IA)Z}$	1 meru/g^2	13	740	1	6	740	12
Root Sum Square Error				5,742	4,688	4,491	2,334	4,688	6,907
				8,667			8,667		

Low G Earth Re-entry Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.1 mr	6	1,174	12	1	1,174	13
		$A_{(SM)YI}$	0.1 mr	1,830	2	1,750	632	2	2,451
		$A_{(SM)ZI}$	0.1 mr	11	1,046	5	7	1,046	10
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	11	0	5	7	0	10
		X to Z	0.1 mr	1,681	2	516	1,156	2	1,324
		Y to Z	0.1 mr	4	0	10	2	0	11
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	4,779	4	1,142	3,459	4	3,490
		ACBY	0.2 cm/sec^2	3	3,693	4	1	3,693	5
		ACBZ	0.2 cm/sec^2	1,032	4	4,906	1,709	4	4,713
	Scale Factor Error	SFEX	100 PPM	1,185	1	159	923	1	760
		SFEY	100 PPM	0	6	0	0	6	0
		SFEZ	100 PPM	461	2	1,698	504	2	1,685
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	156	0	24	120	0	102
		SFNCY	10 PPM/g	0	6	0	0	6	0
		SFNCZ	10 PPM/g	67	0	220	59	0	222
GYRO	Bias Drift	BDX	10 meru	2	2,093	5	4	2,093	3
		BDY	10 meru	3,099	4	6,059	561	4	6,782
		BDZ	10 meru	7	4,847	1	5	4,847	5
	Acceleration Sensitive Drift	ADIAX	10 meru/g	2	537	5	1	537	6
		ADIAY	10 meru/g	38	0	24	20	0	41
		ADIAZ	10 meru/g	10	3,353	2	7	3,353	7
		ADSRAX	10 meru/g	0	26	0	0	26	0
		ADSRAY	10 meru/g	3,009	4	4,480	195	4	5,393
		ADSRAZ	10 meru/g	0	12	0	0	12	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	87	0	0	87	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	471	1	580	95	1	741
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	1	407	0	1	407	1
Root Sum Square Error				7,114	7,463	9,422	4,255	7,463	11,012
				13,967			13,967		

Low G, Extended Range, Earth Re-entry Trajectory

OVERALL SYSTEM STUDY OF RMS POSITION ERRORS

Component	Error		RMS Error	RMS Error in Inertial Axes in Feet			RMS Error in Target Axes in Feet		
				$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
Initial Condition Errors	Initial Position Error	$(E)X_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Y_{Io}$	0 ft	0	0	0	0	0	0
		$(E)Z_{Io}$	0 ft	0	0	0	0	0	0
	Initial Velocity Error	$(E)V_{XIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{YIo}$	0 ft/sec	0	0	0	0	0	0
		$(E)V_{ZIo}$	0 ft/sec	0	0	0	0	0	0
IMU & External	Initial S. M. Alignment Errors	$A_{(SM)XI}$	0.1 mr	0	94	0	0	94	0
		$A_{(SM)YI}$	0.1 mr	62	0	2,669	2,333	0	1,299
		$A_{(SM)ZI}$	0.1 mr	0	282	0	0	282	0
S. M.	Accel. IA Non-orthogonality	X to Y	0.1 mr	0	0	0	0	0	0
		X to Z	0.1 mr	327	0	1,597	1,543	0	527
		Y to Z	0.1 mr	0	0	0	0	0	0
ACCELEROMETER	Bias	ACBX	0.2 cm/sec^2	13,672	0	227	7,123	0	11,673
		ACBY	0.2 cm/sec^2	0	8,684	0	0	8,684	0
		ACBZ	0.2 cm/sec^2	11,912	0	36,368	25,320	0	28,695
	Scale Factor Error	SFEX	100 PPM	358	0	193	348	0	210
		SFEY	100 PPM	0	0	0	0	0	0
		SFEZ	100 PPM	2,075	0	6,356	4,428	0	5,009
	Accel. Sens. Scale Factor Error	SFNCX	10 PPM/g	37	0	43	56	0	10
		SFNCY	10 PPM/g	0	0	0	0	0	0
		SFNCZ	10 PPM/g	289	0	1,105	806	0	809
GYRO	Bias Drift	BDX	10 meru	0	7,636	0	0	7,636	0
		BDY	10 meru	7,879	0	5,956	1,143	0	9,810
		BDZ	10 meru	0	3,359	0	0	3,359	0
	Acceleration Sensitive Drift	ADIAX	10 meru/g	0	627	0	0	627	0
		ADIAY	10 meru/g	0	0	0	0	0	0
		ADIAZ	10 meru/g	0	365	0	0	365	0
		ADSRAX	10 meru/g	0	0	0	0	0	0
		ADSRAY	10 meru/g	825	0	2,299	2,401	0	453
		ADSRAZ	10 meru/g	0	0	0	0	0	0
	Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	1 $meru/g^2$	0	52	0	0	52	0
		$A^2D_{(SRA)(SRA)Y}$	1 $meru/g^2$	238	0	451	268	0	434
		$A^2D_{(IA)(IA)Z}$	1 $meru/g^2$	0	122	0	0	122	0
Root Sum Square Error				19,906	12,068	37,616	26,967	12,068	32,925
				44,237			44,237		

High G Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART I)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+1.536	0	+0.183	-0.388	0	+1.497
	$(E)Y_{IO}$	foot	0	+0.744	0	0	+0.744	0
	$(E)Z_{IO}$	foot	+0.166	0	+0.790	+0.676		+0.442
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+697.5	0	+45.7	-211.1	0	+666.4
	$(E)V_{YIO}$	ft/sec	0	+546.2	0	0	+546.2	0
	$(E)V_{ZIO}$	ft/sec	+44.3	0	+560.5	+506.1	0	+245.0
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-6,348	+ 0	-243	+2,081	+ 0	-6,002
	ACBY	cm/sec^2	+ 0	-5,622	+0	+0	-5,662	+0
	ACBZ	cm/sec^2	-240	+0	-5,705	-5,227	+0	-2,298
Scale Factor Error	SFEX	PPM	-7.063	+0	-0.265	+2.321	0	-6.676
	SFEY	PPM	0	+0.021	0	0	+0.021	0
	SFEZ	PPM	+0.641	0	+12.510	+11.421	0	+5.145
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-20.79	0	-1.00	+6.63	0	-19.73
	SFNCY	PPM/g	0	-2.29	0	0	-2.29	0
	SFNCZ	PPM/g	-2.98	0	-49.9	-45.39	0	-20.92
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-14,233	0	-649	+4,570	0	-13,495
	Z_{SM}	$A_{(X)Z}$	milliradian	+17	0	-1	-7	0	+15
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	+1	0	-21	-20	0	-7
	Y_{SM}	$A_{(Z)Y}$	milliradian	-	-	-	-	-	-

High G Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	+12, 290	-21	-20	+12, 290	-7
$A_{(SM)YI}$		milliradian	+14, 495	-0	+7, 016	+1, 266	-10	+13, 053
$A_{(SM)ZI}$		milliradian	-17	-6, 276	+1	+7	-6, 276	-15
E. Gyro Drift Errors								
Bias Drift	BDX	meru	-0.1	+131.2	-0.7	-0.6	+131.2	-0.3
	BDY	meru	-148.7	0	-102.3	-41.3	0	-175.7
	BDZ	meru	+0.8	+96.3	0	-0.3	+96.3	+0.8
Acceleration Sensitive Drift	ADIAX	meru/g	+0	+153.3	+0.4	+0.4	+153.3	+0.2
	ADIAY	meru/g	-2.4	0	+1.1	+1.9	0	-1.9
	ADIAZ	meru/g	-4.3	-235.7	-0.2	+1.4	-235.7	-4.1
	ADSRAX	meru/g	0	-2.0	0	0	-2.0	0
	ADSRAY	meru/g	-416.6	0	-253.0	-84.2	0	-480.1
	ADSRAZ	meru/g	0	-1.3	0	0	-1.3	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	meru/g^2	0	+613.0	-2.5	-2.3	+613.0	-1.0
	$A^2D_{(IA)(IA)Y}$	meru/g^2	-80.2	0	-48.3	-15.8	0	-92.3
	$A^2D_{(IA)(IA)Z}$	meru/g^2	+20.6	+1, 008.6	+0.8	-6.7	+1, 008.6	+19.5
	$A^2D_{(SRA)(SRA)X}$	meru/g^2	-0.1	+71.0	-1.3	-1.2	+71.0	-0.6
	$A^2D_{(SRA)(SRA)Y}$	meru/g^2	-2, 081.6	+0.1	-1, 100.5	-268.4	+0.1	-2, 339.2
	$A^2D_{(SRA)(SRA)Z}$	meru/g^2	+1.5	+45.0	+0.1	-0.5	+45.0	+1.4
	$A^2D_{(IA)(SRA)X}$	meru/g^2	0	-3.3	0	0	-3.3	0
	$A^2D_{(IA)(SRA)Y}$	meru/g^2	-41.0	0	-11.7	+4.0	0	-42.4
	$A^2D_{(IA)(SRA)Z}$	meru/g^2	-0.3	-9.8	0	+0.1	-9.8	-0.3

Medium G Earth Re-entry Trajectory

IMU POSITION ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+1.776	0	+0.370	-0.563	0	+1.724
	$(E)Y_{IO}$	foot	0	+0.624	0	0	+0.624	0
	$(E)Z_{IO}$	foot	+0.313	0	+0.749	+0.494	0	+0.644
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+898.0	0	+109.8	-351.7	0	+833.5
	$(E)V_{YIO}$	ft/sec	0	+638.6	0	0	+638.6	0
	$(E)V_{ZIO}$	ft/sec	+104.1	0	+686.5	+543.7	0	+431.9
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-9.738	+ 0	-710	+4.230	0	-8.800
	ACBY	cm/sec^2	0	-8.249	0	0	-8.249	0
	ACBZ	cm/sec^2	-649	0	-8.594	-7.109	0	-4.878
Scale Factor Error	SFEX	PPM	-8.489	0	-0.515	+3.777	0	-7.617
	SFEY	PPM	0	+0.029	0	0	+0.029	0
	SFEZ	PPM	+1.274	0	+13.536	+11.107	0	+7.841
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-15.72	0	-1.15	+6.83	0	-14.20
	SFNCY	PPM/g	0	-2.09	0	0	-2.09	0
	SFNCZ	PPM/g	-3.64	+0.14	-33.35	-27.12	+0.14	-19.75
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-15,639	0	-1,303	+6,653	0	-14,213
	Z_{SM}	$A_{(X)Z}$	milliradian	+22	0	-2	-12	0	+18
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	+2	0	-28	-25	0	-13
	Y_{SM}	$A_{(Z)Y}$	milliradian	-	-	-	-	-	-

Medium G Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	+1	+12,907	-29	-25	+12,907	-13
$A_{(SM)YI}$		milliradian	+16,144	-1	+8,991	-236	-1	+13,478
$A_{(SM)ZI}$		milliradian	-21	-7,433	+2	+12	-7,433	-17
E. Gyro Drift Errors								
Bias Drift	BDX	meru	-0.1	+183.8	-1.2	-0.9	+183.8	-0.7
	BDY	meru	-218.1	0	-184.6	-51.6	0	-281.1
	BDZ	meru	+1.3	+167.5	+0.1	-0.6	+167.5	+1.2
Acceleration Sensitive Drift	ADIAX	meru/g	0	+137.8	+0.3	+0.3	+137.8	+0.1
	ADIAY	meru/g	-2.0	0	+1.3	+2.1	0	-1.1
	ADIAZ	meru/g	-4.1	-288.0	-0.3	+1.8	-288.0	-3.8
	ADSRAX	meru/g	0	-1.5	0	0	-1.5	0
	ADSRAY	meru/g	-413.1	0	-321.0	-72.8	0	-518.1
	ADSRAZ	meru/g	0	-1.5	0	0	-1.5	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	-0.1	+315.7	-1.0	-0.8	+315.7	-0.6
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	-75.9	0	-55.6	-10.4	0	-93.5
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	+13.3	+740.3	+1.0	-0.6	+740.3	+12.1
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	+63.8	+1.0	-0.8	+63.8	-0.6
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-1,230.3	+0.1	-843.1	-119.0	+0.1	-1,486.8
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	+1.1	+49.5	+0.1	-0.5	+49.5	+1.0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	-0.6	0	0	-0.6	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	20.2	0	-6.6	+4.3	0	-20.8
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	-0.1	-4.8	0	0	-4.8	-0.1

Low G Earth Re-entry Trajectory

IMU POSITION ERROR COEFFICIENTS (PART I)

(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	+2.523	0	+1.570	-1.316	0	+2.664
	$(E)Y_{IO}$	foot	0	+0.162	0	0	+0.162	0
	$(E)Z_{IO}$	foot	+0.976	0	+0.982	-0.312	0	+1.348
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+1,504	0	+617	-953	0	+1,317
	$(E)V_{YIO}$	ft/sec	0	+808	0	0	+808	+2
	$(E)V_{ZIO}$	ft/sec	+508	0	+1,337	+273	0	+1,404
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-31,063	-18	-5,709	+17,294	-18	-17,449
	ACBY	cm/sec^2	-16	-18,466	-19	+4	-18,466	-25
	ACBZ	cm/sec^2	-5,161	-19	-24,529	-8,547	-19	-23,564
Scale Factor Error	SFEX	PPM	-11.847	-0.005	-1.594	+9.226	-0.005	-7.601
	SFEY	PPM	-0	-0.056	-0	0	-0.056	0
	SFEZ	PPM	+4.607	+0.017	+16.98	+5.037	+0.017	+16.855
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-15.57	-0.01	-2.36	+11.99	-0.01	-10.21
	SFNCY	PPM/g	0	-0.58	0	0	-0.58	0
	SFNCZ	PPM/g	-6.71	-0.02	-21.95	-5.87	-0.02	-22.19
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-16,811	-16	-5,156	+11,566	-16	-13,245
	Z_{SM}	$A_{(X)Z}$	milliradian	-113	0	-51	+69	0	-103
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	+43	0	+100	+16	0	+108
	Y_{SM}	$A_{(Z)Y}$	milliradian	-	-	-	-	-	-

Low G Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	+58	+11, 744	+117	+13	+11, 744	+130
$A_{(SM)YI}$		milliradian	+18, 295	+22	+17, 498	-6, 320	+22	+24, 514
$A_{(SM)ZI}$		milliradian	+108	- 10, 459	+45	-68	-10, 459	+96
E. Gyro Drift Errors								
Bias Drift	BDX	meru	+0. 2	+209. 3	-0. 5	-0. 4	+209. 3	-0. 3
	BDY	meru	-309. 9	-0. 4	-605. 9	-56. 1	-0. 4	-678. 2
	BDZ	meru	+0. 7	+484. 7	+0. 1	+0. 5	+484. 7	+0. 5
Acceleration Sensitive Drift	ADIAX	meru/g	+0. 2	+53. 7	+0. 5	+0. 1	+53. 7	+0. 6
	ADIAY	meru/g	-3. 8	-0	-2. 4	+2. 0	-0	-4. 1
	ADIAZ	meru/g	-1. 0	-335. 3	-0. 2	+0. 7	-335. 3	-0. 7
	ADSRAX	meru/g	0	-2. 6	0	0	-2. 6	0
	ADSRAY	meru/g	-300. 9	-0. 4	-448. 0	+19. 5	-0. 4	-539. 3
	ADSRAZ	meru/g	0	+1. 2	0	0	+1. 2	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	+0. 3	+86. 7	+0. 4	0	+86. 7	+0. 5
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	-14. 7	-0	-22. 0	+0. 9	0	-26. 5
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	+10. 6	+407. 1	+0. 2	-0. 8	+417. 1	+0. 7
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	+10. 1	0	0	+10. 1	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	-471. 3	-0. 6	-580. 1	+94. 6	-0. 6	-741. 5
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	+16. 5	0	0	+16. 5	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	-1. 2	0	0	-1. 2	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	+11. 4	0	-10. 4	+4. 2	0	-14. 8
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	-6. 4	0	0	-6. 4	0

Low G, Extended Range, Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART I)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
A. Initial Condition Errors along Inertial Axes								
Initial Position Error	$(E)X_{IO}$	foot	-1.239	0	+7.918	-6.199	0	+5.080
	$(E)Y_{IO}$	foot	0	-0.953	0	0	-0.953	0
	$(E)Z_{IO}$	foot	+0.158	0	+3.501	-3.098	0	+1.637
Initial Velocity Error	$(E)V_{XIO}$	ft/sec	+570	0	+2,586	-2,518	0	+819
	$(E)V_{YIO}$	ft/sec	0	+249	0	0	+249	0
	$(E)V_{ZIO}$	ft/sec	-1,892	0	+6,913	-5,002	0	+5,133
B. Accelerometer Errors (In-flight Effect only)								
Bias	ACBX	cm/sec^2	-68,362	0	-1,137	+35,615	0	+58,363
	ACBY	cm/sec^2	0	-43,421	0	0	-43,421	0
	ACBZ	cm/sec^2	+59,558	0	-181,840	+126,601	0	-143,475
Scale Factor Error	SFEX	PPM	-3.577	0	-1.943	+3.480	0	+2.104
	SFEY	PPM	0	0	0	0	0	0
	SFEZ	PPM	-20.752	0	+63.558	-44.283	0	+50.092
Accel. Sens. Scale Factor Error	SFNCX	PPM/g	-3.71	0	-4.30	+5.59	0	+1.02
	SFNCY	PPM/g	0	0	0	0	0	0
	SFNCZ	PPM/g	+28.95	0	-110.47	+80.57	0	-80.92
C. Misalignments of Accelerometer Input Axes								
Accel.	About Axis							
X	Y_{SM}	$A_{(X)Y}$	milliradian	-3,269	0	-15,972	+15,427	0	-5,273
	Z_{SM}	$A_{(X)Z}$	milliradian	0	0	0	0	0	0
Y	X_{SM}	$A_{(Y)X}$	milliradian	-	-	-	-	-	-
	Z_{SM}	$A_{(Y)Z}$	milliradian	-	-	-	-	-	-
Z	X_{SM}	$A_{(Z)X}$	milliradian	0	0	0	0	0	0
	Y_{SM}	$A_{(Z)Y}$	milliradian	-	-	-	-	-	-

Low G, Extended Range, Earth Re-entry Trajectory
IMU POSITION ERROR COEFFICIENTS (PART II)
(SM axes colinear with inertial axes)

Error		Unit Error Dimension	Error in Inertial Axes in feet per unit error			Error in Target Axes in feet per unit error		
			$(E)X_I$	$(E)Y_I$	$(E)Z_I$	Range	Track	Altitude
D. Initial Platform Misalignments about Inertial Axes								
$A_{(SM)XI}$		milliradian	0	-939	0	0	-939	0
$A_{(SM)YI}$		milliradian	+624	0	+26,695	-23,331	0	+12,987
$A_{(SM)ZI}$		milliradian	0	-2,822	0	0	-2,822	0
E. Gyro Drift Errors								
Bias Drift	BDX	meru	0	-763.6	0	0	-763.6	0
	BDY	meru	+787.9	0	-595.6	+114.3	0	-981.0
	BDZ	meru	0	+335.9	0	0	+335.9	0
Acceleration Sensitive Drift	ADIAX	meru/g	0	-62.7	0	0	-62.7	0
	ADIAY	meru/g	0	0	0	0	0	0
	ADIAZ	meru/g	0	-36.5	0	0	-36.5	0
	ADSRAX	meru/g	0	0	0	0	0	0
	ADSRAY	meru/g	-82.5	0	-229.9	+240.1	0	-45.3
	ADSRAZ	meru/g	0	0	0	0	0	0
Acceleration Squared Sensitive Drift	$A^2D_{(IA)(IA)X}$	$meru/g^2$	0	-51.7	0	0	-51.7	0
	$A^2D_{(IA)(IA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(IA)Z}$	$meru/g^2$	0	+12.2	0	0	+12.2	0
	$A^2D_{(SRA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(SRA)(SRA)Y}$	$meru/g^2$	+238.4	0	-451.0	+268.0	0	-434.0
	$A^2D_{(SRA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)X}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Y}$	$meru/g^2$	0	0	0	0	0	0
	$A^2D_{(IA)(SRA)Z}$	$meru/g^2$	0	0	0	0	0	0

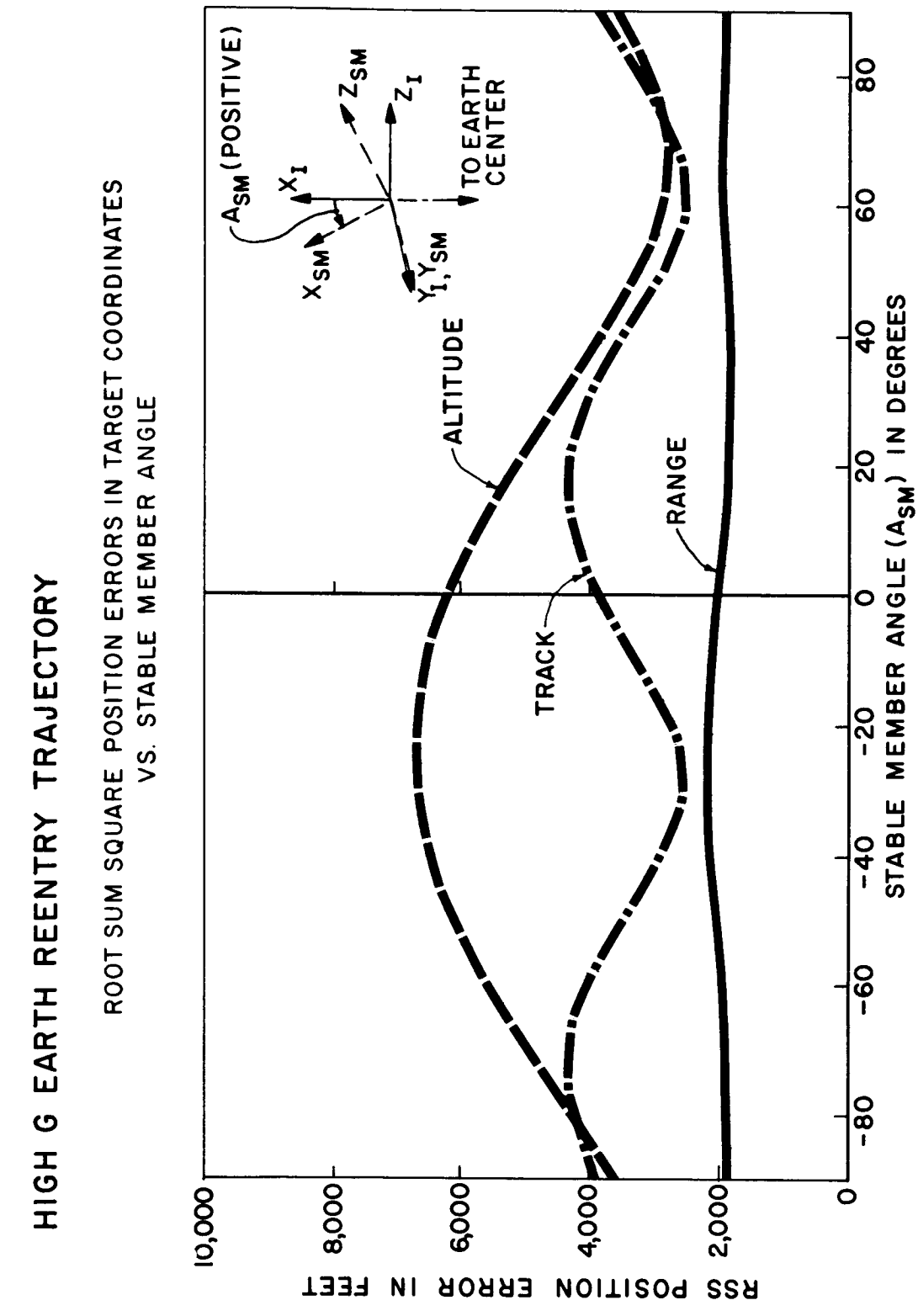

HIGH G EARTH REENTRY TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
RSS POSITION ERROR IN FEET
10,000
8,000
6,000
4,000
2,000
0
-80
-60
-40
-20
0
20
40
60
80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
ALTITUDE
RANGE
TRACK
A_{SM} (POSITIVE)
X_{SM}
X_I
Z_{SM}
Z_I
Y_I, Y_{SM}
TO EARTH CENTER

Fig. G-1

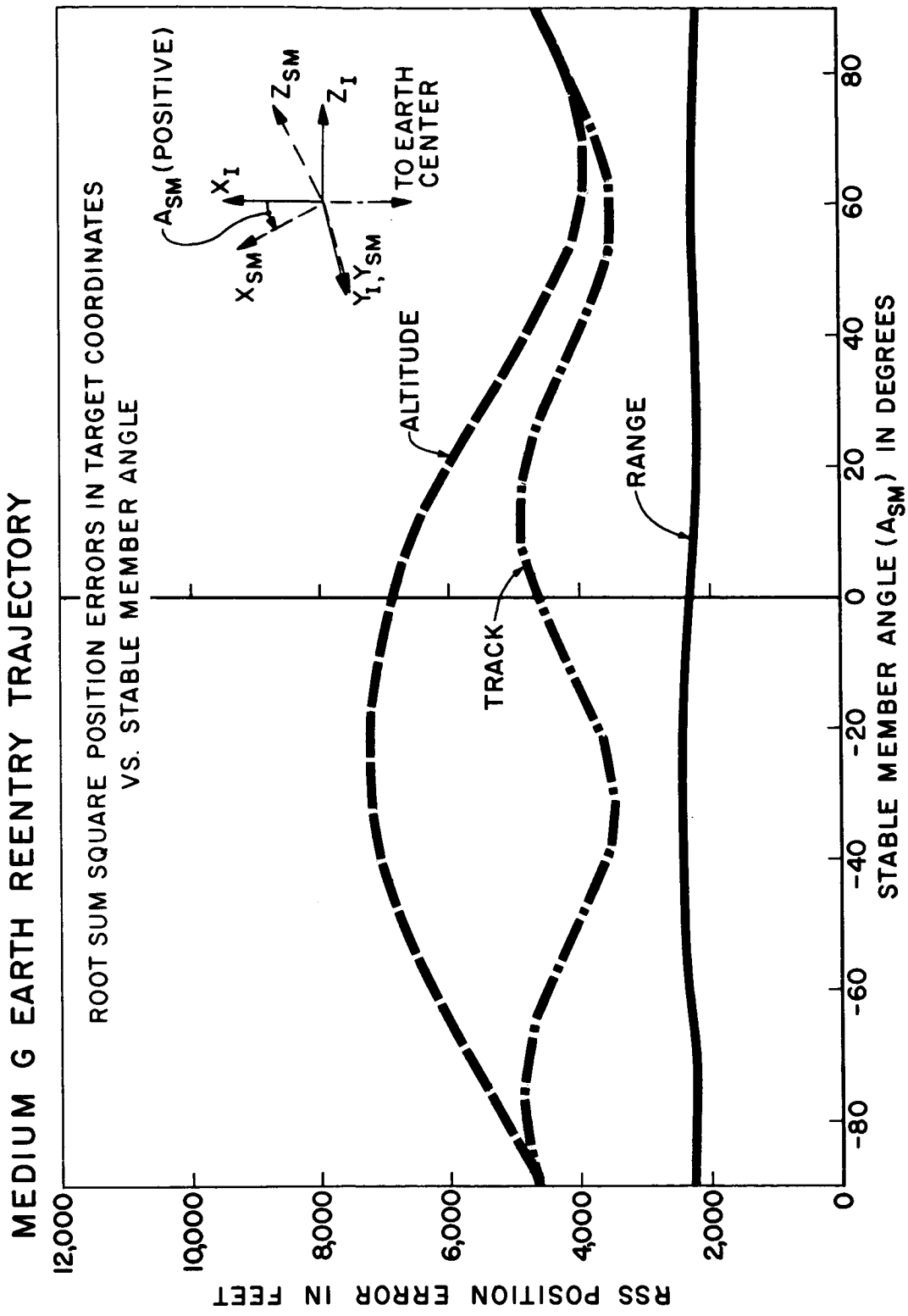

MEDIUM G EARTH REENTRY TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
TO EARTH CENTER
X_{SM}
Y_I, Y_{SM}
ALTITUDE
RANGE
TRACK
RSS POSITION ERROR IN FEET
12,000
10,000
8,000
6,000
4,000
2,000
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES

Fig. G-2

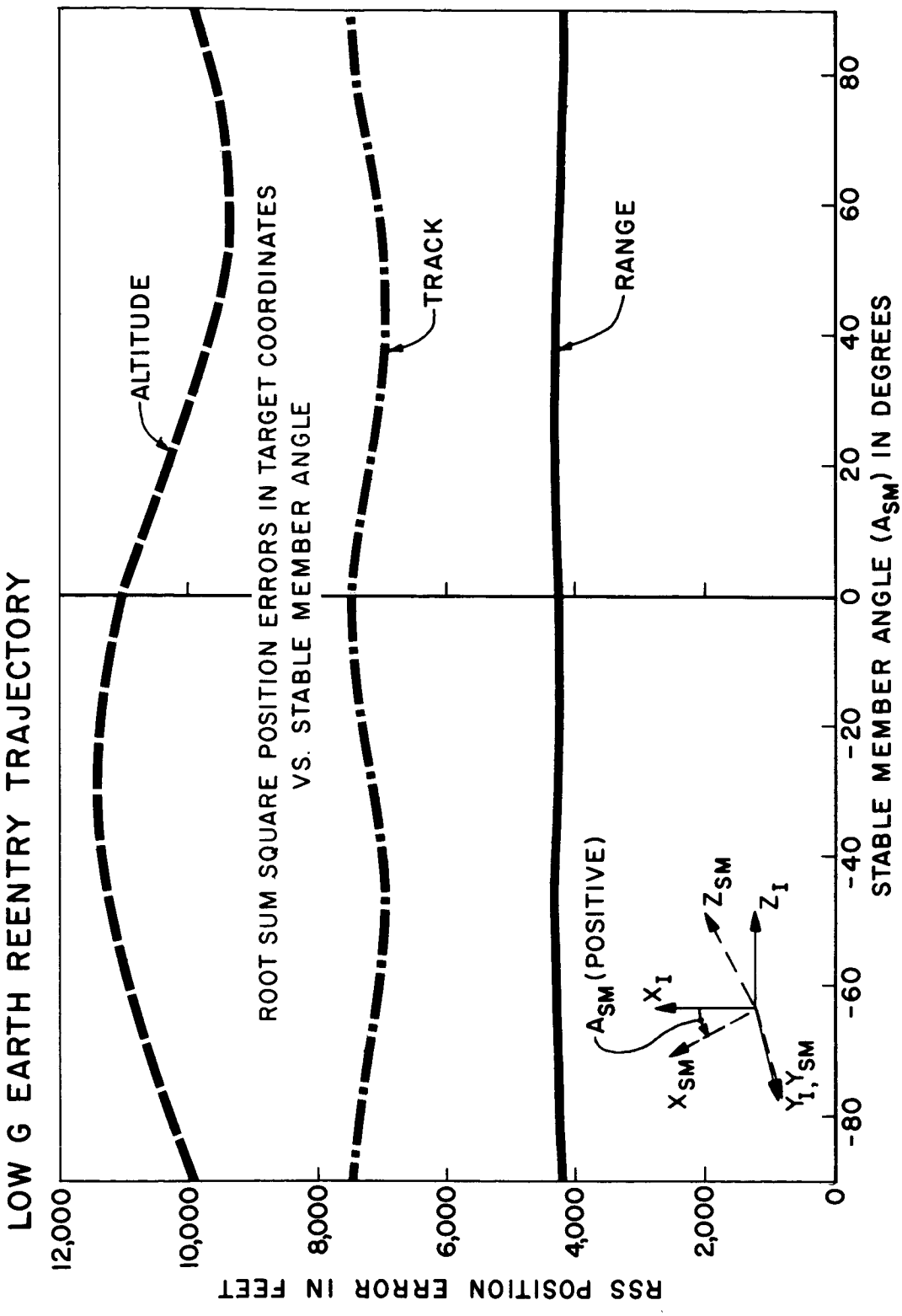

LOW G EARTH REENTRY TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
TRACK
RANGE
RSS POSITION ERROR IN FEET
12,000
10,000
8,000
6,000
4,000
2,000
0
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
80
60
40
20
0
-20
-40
-60
-80
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}

Fig. G-3

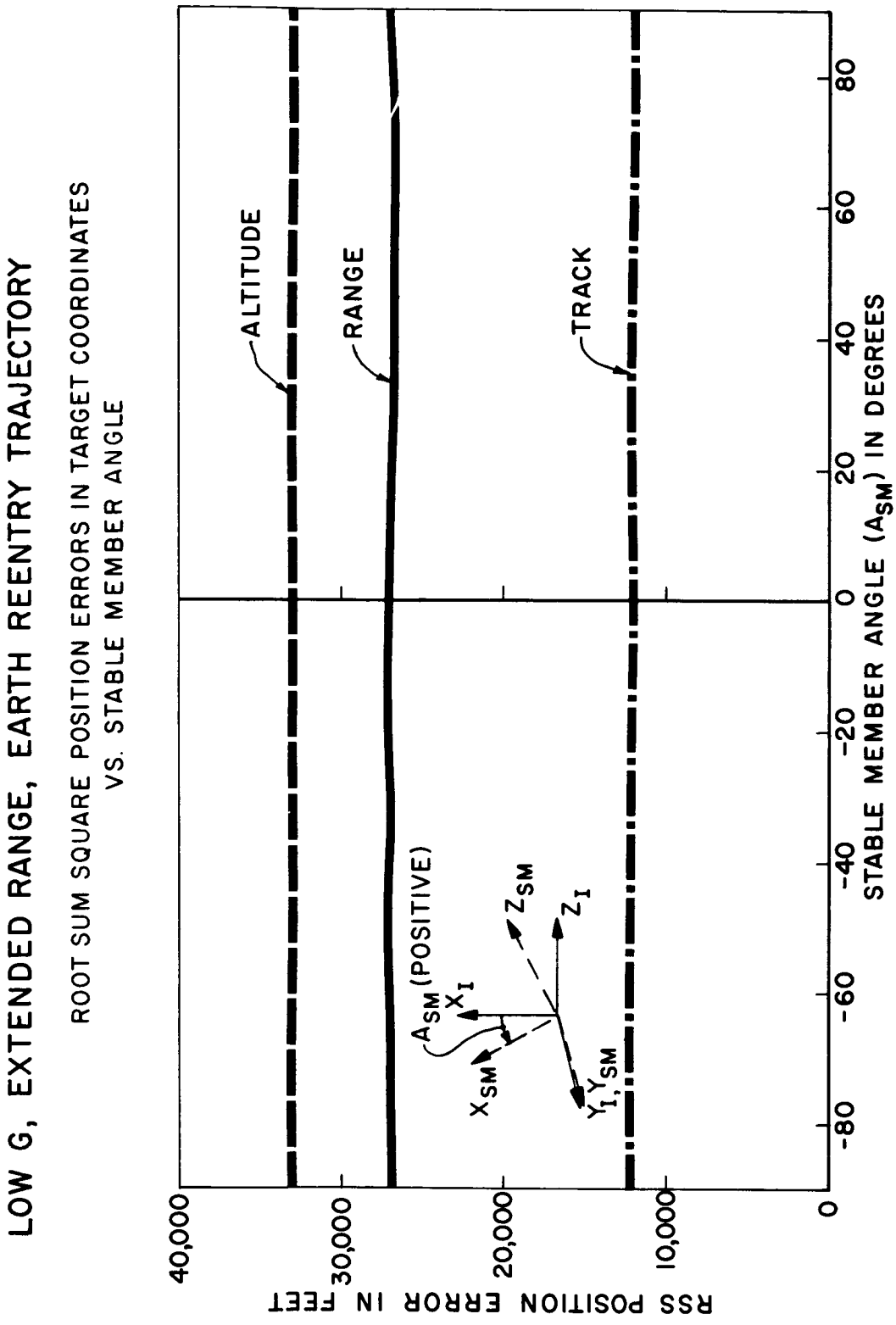

LOW G, EXTENDED RANGE, EARTH REENTRY TRAJECTORY
ROOT SUM SQUARE POSITION ERRORS IN TARGET COORDINATES
VS. STABLE MEMBER ANGLE
ALTITUDE
RANGE
TRACK
RSS POSITION ERROR IN FEET
40,000
30,000
20,000
10,000
0
80
60
40
20
0
-20
-40
-60
-80
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
X_{SM}
Y_I, Y_{SM}

Fig. G-4

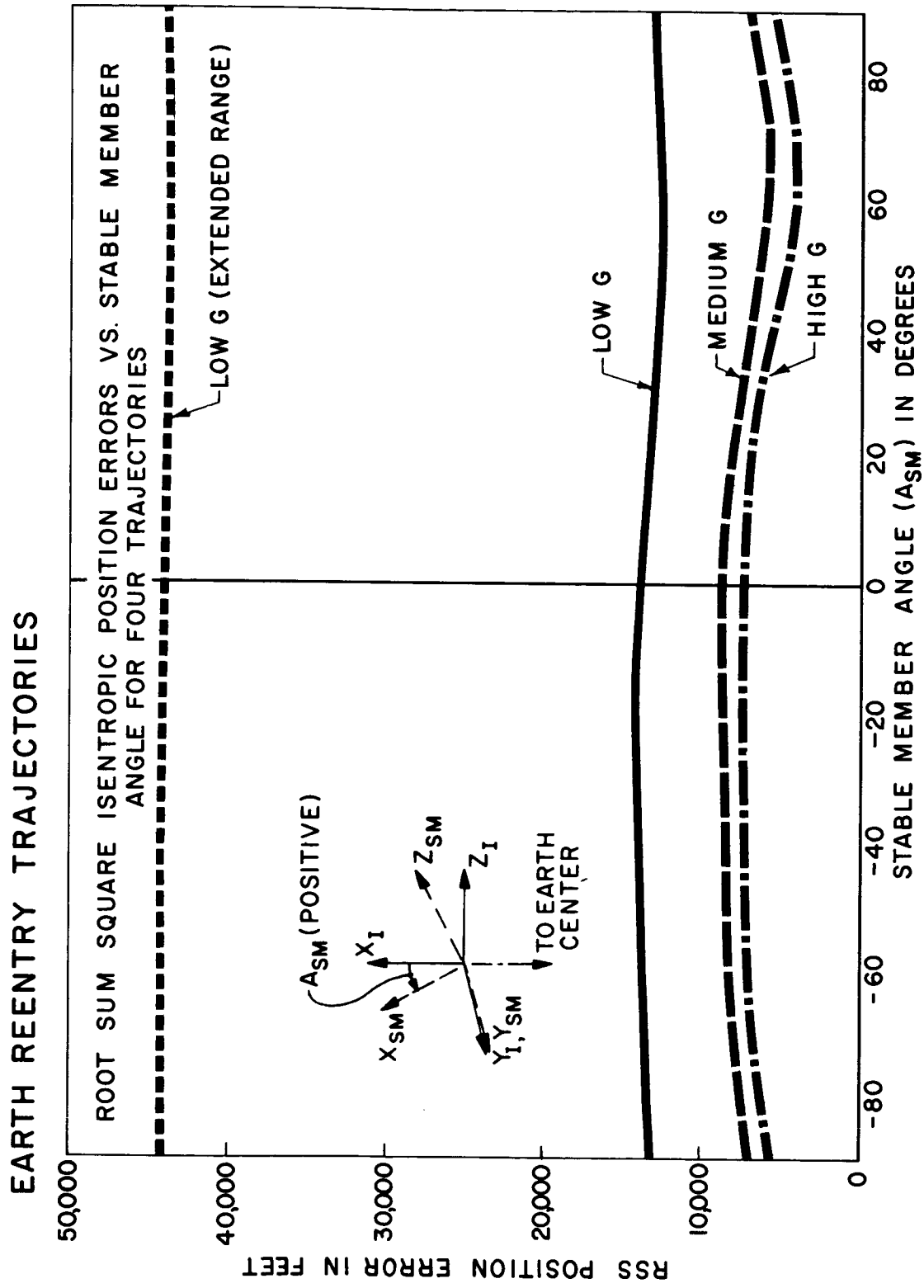

EARTH REENTRY TRAJECTORIES
ROOT SUM SQUARE ISENTROPIC POSITION ERRORS VS. STABLE MEMBER ANGLE FOR FOUR TRAJECTORIES
LOW G (EXTENDED RANGE)
LOW G
MEDIUM G
HIGH G
RSS POSITION ERROR IN FEET
50,000
40,000
30,000
20,000
10,000
0
STABLE MEMBER ANGLE (A_{SM}) IN DEGREES
80
60
40
20
0
-20
-40
-60
-80
A_{SM} (POSITIVE)
X_I
Z_{SM}
Z_I
TO EARTH CENTER
X_{SM}
Y_I, Y_{SM}

Fig. G-5

HIGH G EARTH REENTRY TRAJECTORY

RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF REENTRY TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH

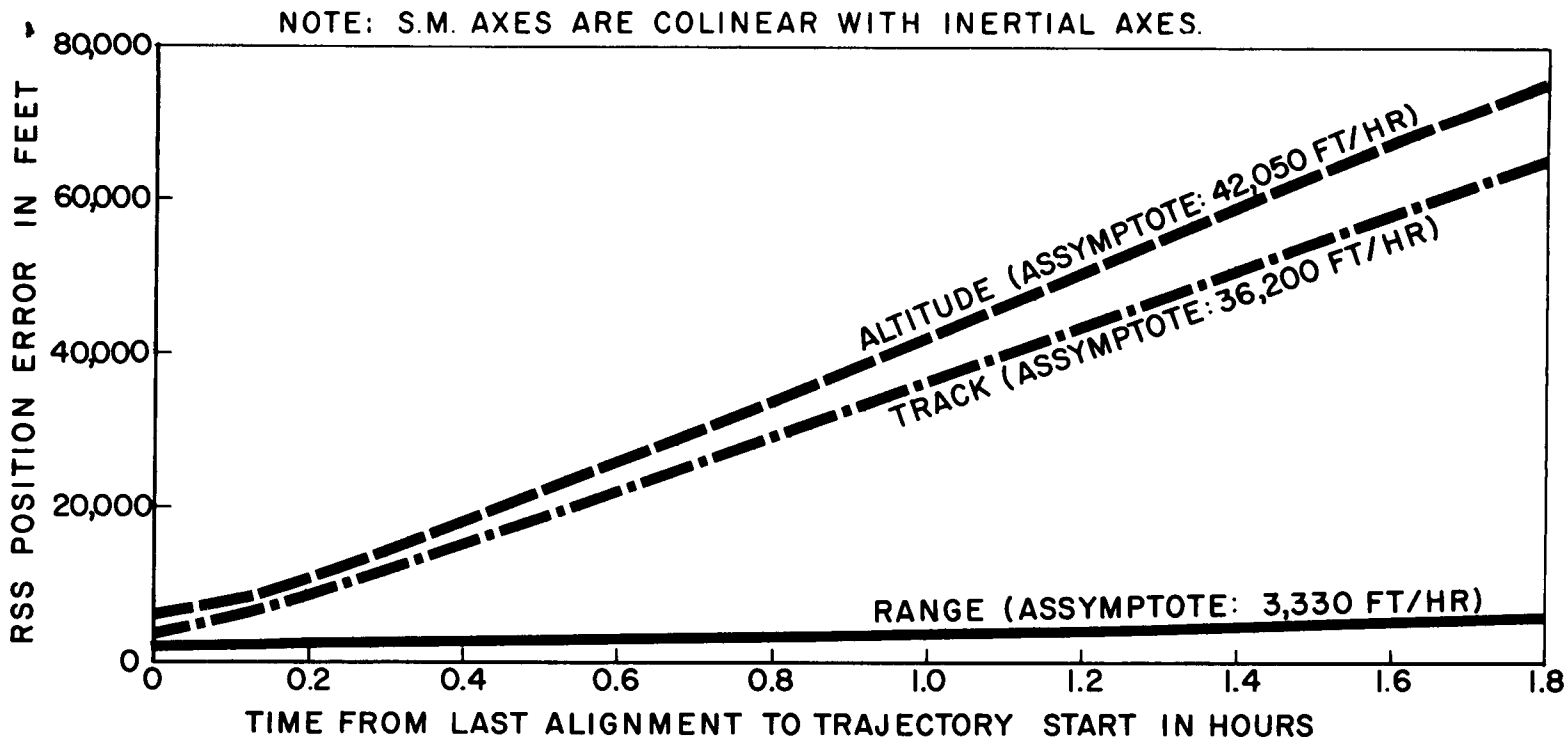


Fig. G-6

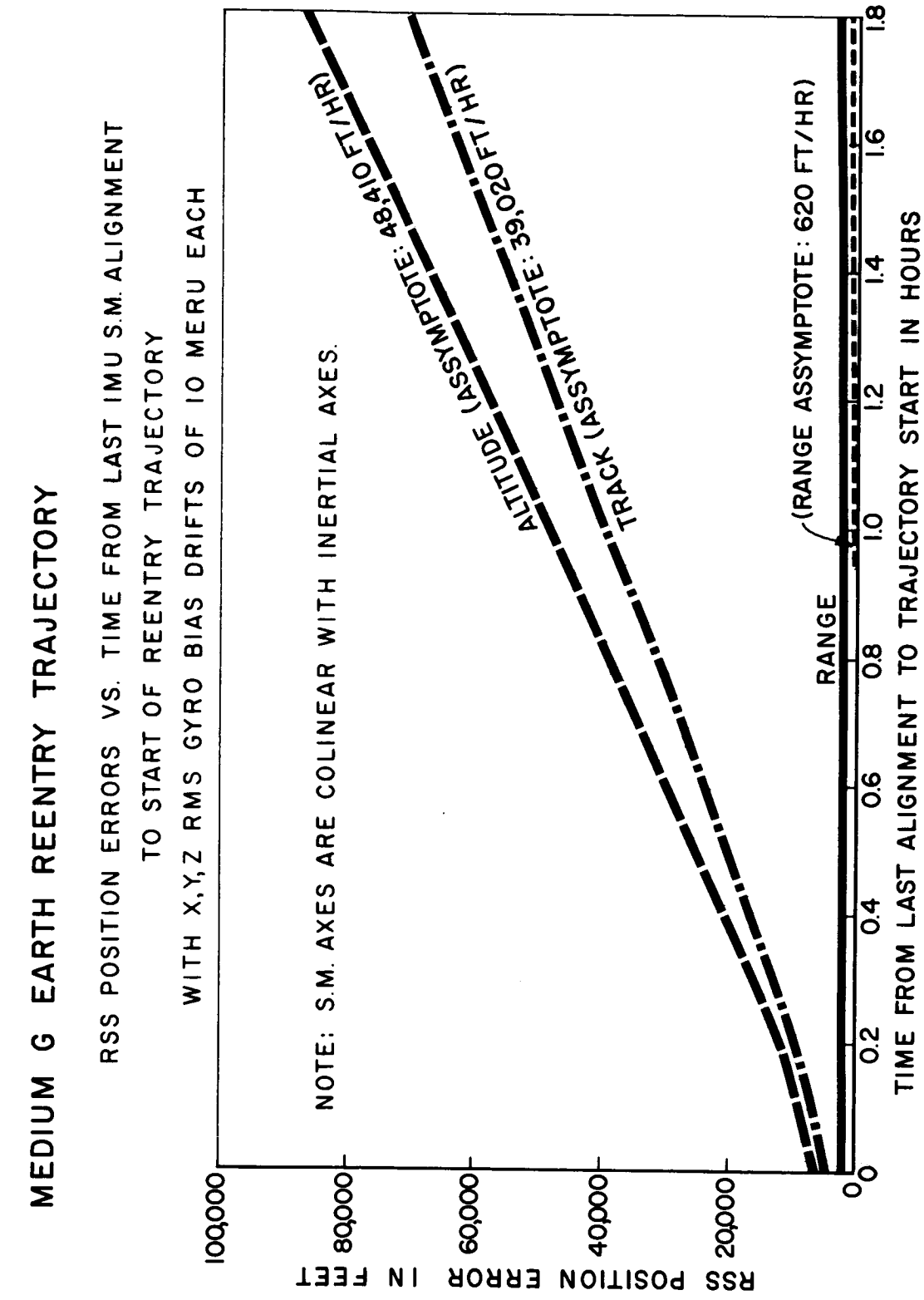

MEDIUM G EARTH REENTRY TRAJECTORY
RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF REENTRY TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH
NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.
ALTITUDE (ASSYMPTOTE: 48,410 FT/HR)
TRACK (ASSYMPTOTE: 39,020 FT/HR)
RANGE
(RANGE ASSYMPTOTE: 620 FT/HR)
RSS POSITION ERROR IN FEET
100,000
80,000
60,000
40,000
20,000
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
TIME FROM LAST ALIGNMENT TO TRAJECTORY START IN HOURS

Fig. G-7

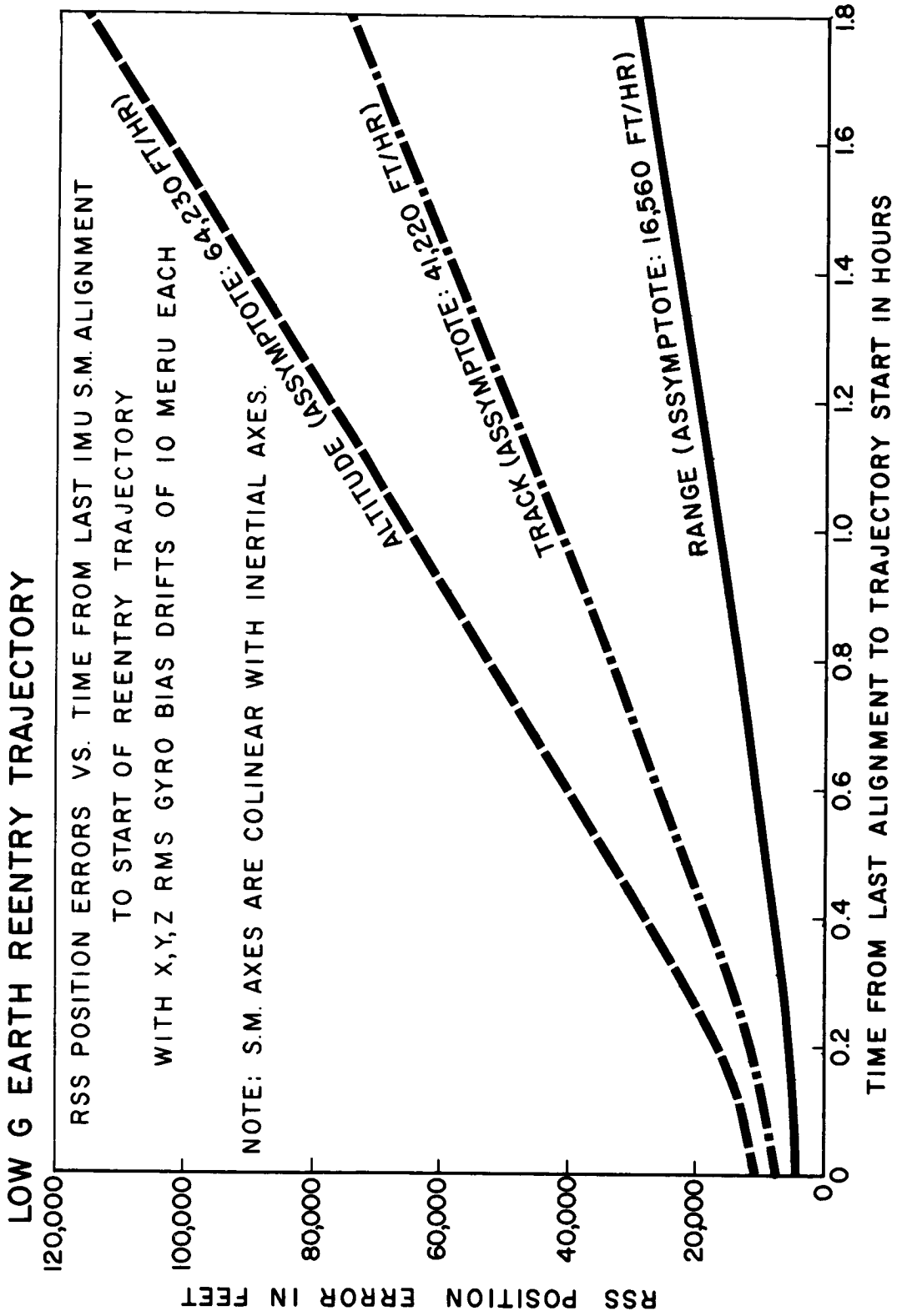

LOW G EARTH REENTRY TRAJECTORY
RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF REENTRY TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH
NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.
ALTITUDE (ASSYMPTOTE: 64,230 FT/HR)
TRACK (ASSYMPTOTE: 41,220 FT/HR)
RANGE (ASSYMPTOTE: 16,560 FT/HR)
RSS POSITION ERROR IN FEET
120,000
100,000
80,000
60,000
40,000
20,000
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
TIME FROM LAST ALIGNMENT TO TRAJECTORY START IN HOURS

Fig. G-8

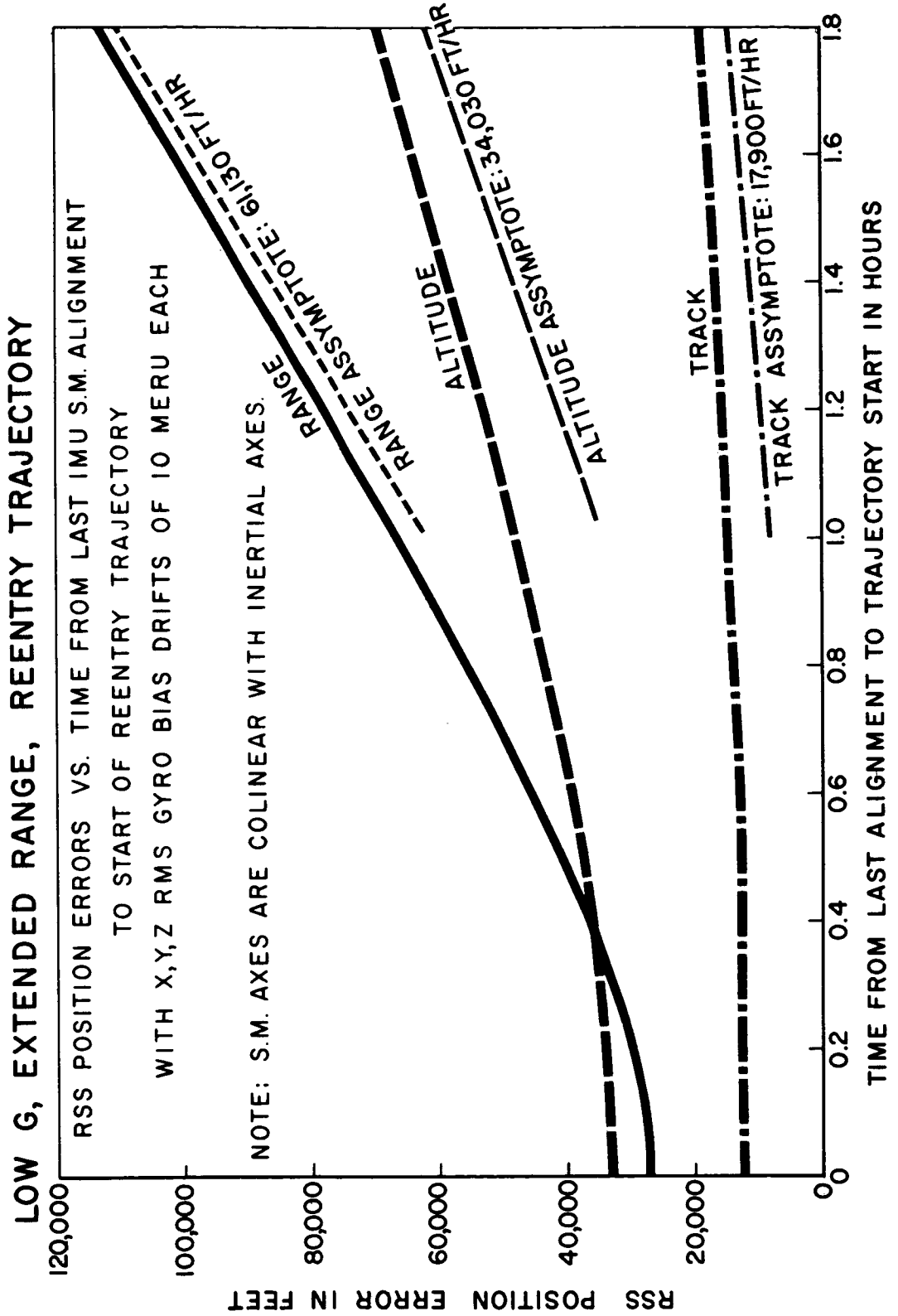

LOW G, EXTENDED RANGE, REENTRY TRAJECTORY
RSS POSITION ERRORS VS. TIME FROM LAST IMU S.M. ALIGNMENT
TO START OF REENTRY TRAJECTORY
WITH X,Y,Z RMS GYRO BIAS DRIFTS OF 10 MERU EACH
NOTE: S.M. AXES ARE COLINEAR WITH INERTIAL AXES.
RANGE
RANGE ASSYMPTOTE: 61,130 FT/HR
ALTITUDE
ALTITUDE ASSYMPTOTE: 34,030 FT/HR
TRACK
TRACK ASSYMPTOTE: 17,900 FT/HR
RSS POSITION ERROR IN FEET
120,000
100,000
80,000
60,000
40,000
20,000
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
TIME FROM LAST ALIGNMENT TO TRAJECTORY START IN HOURS

Fig. G-9