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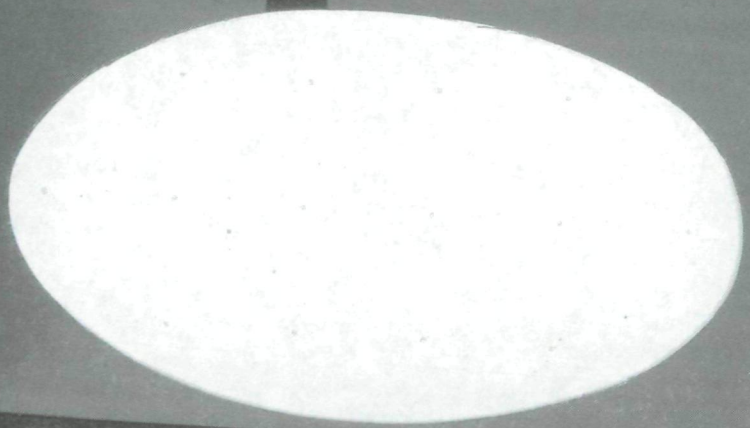

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GUIDANCE AND NAVIGATION

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AS-278

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Error Analysis

October 1966

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SECTION 1

GNCS ERROR ANALYSIS

1.1 Introduction

The results of a GNCS error study for the 278 (CSM) mission are presented herein. These include studies of the effects of IMU component uncertainties

1. on computed orbit parameters after boost of CSM into earth orbit, and
2. on position and velocity uncertainties during CSM deorbit burn, coast, and reentry.

No error studies for the CSM-active rendezvous maneuvers are given in this issue. Perfect navigational update was assumed just prior to deorbit burn. The effects of tracking uncertainties on update were not included, since these data were not available.

1.2 Important Results of Error Study

1. Maximum one-sigma uncertainties in indicated free-fall coast after boost to assumed circular earth orbit were:

   2.15 n. mile in altitude
   8.60 n. mile in track

   Range uncertainty increased at the rate of about 9.8 n. mile per orbit.

2. Deorbit burn uncertainties: (assuming perfect navigational update just prior to deorbit burn ignition):

   Flight path angle uncertainty (1σ) at 400,000-ft altitude (reentry start) was 0.016 mr.
   CEP at reentry end was 0.65 n. mile.

1.3 Error Table Description

The error tables are given at the end of this section. Table 1.1 summarizes data for uncertainties in indicated orbit parameters after SIVB cutoff. Table 1.2 summarizes uncertainty data for CSM deorbit burn, coast, and reentry. The other tables give detailed uncertainty data as follows:

For the error tables for SIVB cutoff and resulting orbit uncertainties, polarities given are those for indication uncertainties, since the CMC and IMU only monitor the earth orbit boost trajectory. The polarities in the error tables for the CSM deorbit burn and resulting reentry are those for actual uncertainties in CSM position and velocity.

The error studies were based on trajectory data printouts for "207-208A Preliminary Spacecraft Reference Trajectory "transmitted from TRW Systems on June 10, 1966.

1.4 IMU Errors and Uncertainties

The CMC will be able to provide compensation for the measured average values of the following IMU component errors:

1. accelerometer bias error
2. accelerometer scale factor error
3. gyro bias drift
4. gyro input axis acceleration sensitive drift
5. gyro spin reference axis acceleration sensitive drift

Since the average IMU errors will be compensated by means of CMC programs during prelaunch and in-flight mission phases, it is the actual unpredictable deviations from the measured average errors that constitute the IMU component uncertainties. The estimated one-sigma IMU error uncertainties at time of 278 (CSM) launch are listed on the next page. (See also MEI PS 2015000 which gives specifications for the Block II IMU.)

The error tables here employ a definition of scale factor error whose polarity is effectively the reverse of that formerly used. The new definition is being adopted, since it is consistent with that employed in component and systems tests for some time past.

One-Sigma IMU Error Uncertainties

Uncertainty	Units	Input Axis X	Y	Z
Accelerometer bias (ACB)	cm/sec^2	0.20	0.20	0.20
Accelerometer Scale factor (SFE)	ppm	116	116	116
Accelerometer non-linearity	$\mu g/g^2$	10	10	10
Gyro bias drift (BD)	meru	2	2	2
Gyro input axis accel. sens. drift (ADIA)	meru/g	8	8	8
Gyro spin ref. axis accel. sens. drift (ADSRA)	meru/g	5	5	5
Gyro acceleration squared sens. drift	$meru/g^2$	0.3	0.3	0.3
Accelerometer I.A. misalignments				
Non-orthogonality Z to X	mr	0.14	---	---
Non-orthogonality Z to Y	mr	0.14	---	---
Y about Z_{SM}	mr	---	0.10	---
Gyro I.A. misalignments				
About SRA	mr	0.50	0.50	0.50
About OA	mr	0.50	0.50	0.50

Relative to earth orbit insertion cutoff uncertainties some IMU component uncertainties affect both the pre-launch alignment of the Stable Member and the in-flight computation of position and velocity. These include: accelerometer bias (which affect the vertical erection of the S.M. about the Y_{SM} and X_{SM} axes) and the gyro bias drift and IA and SRA acceleration sensitive drift. The gyro drift terms affect alignment of the Stable Member about azimuth through their effect on the gyro-compassing loop during pre-launch alignment. Table 1.4 summarizes the effect of IMU uncertainties on pre-launch S.M. alignment uncertainties. Since pre-launch and in-flight IMU uncertainties are assumed correlated, their effects are summed in the error computations for SIVB cutoff uncertainties.

Prior to the CSM deorbit burn maneuver (and also prior to other significant maneuvers during the flight) the CSM IMU Stable Member will be fine aligned on the basis of star sightings and CMC computations. It is assumed that this alignment will be completed 15 minutes prior to deorbit burn start. The assumed one-sigma Stable Member alignment uncertainty (independent of gyro drift) is 0.20 mr about each S.M. axis. Table 1.6 summarizes data on S.M. initial misalignments and drift uncertainties at deorbit burn cutoff.

1.5 Stable Member Orientation

Prior to earth launch, the orientation of IMU Stable Member axes (X_{SM}, Y_{SM}, Z_{SM}) relative to launch inertial axes (X_I, Y_I, Z_I) are shown in Fig. 1.1.

The X, Y, Z accelerometer and gyro input axes are colinear with corresponding Stable Member axes. The launch inertial axis, Z_I, is in the horizontal plane at launch instant and is oriented at the nominal launch azimuth.

Prior to the deorbit burn the IMU Stable Member is aligned as shown in Fig. 1.2 with X_{SM} oriented along the spacecraft X direction at ignition, Y_{SM} along unit ($\underline{X}_{CSM} \times \underline{R}$), and Z_{SM} along unit ($\underline{X}_{SM} \times \underline{Y}_{SM}$).

1.6 Flight Path Angle and Altitude Rate Uncertainty Definitions

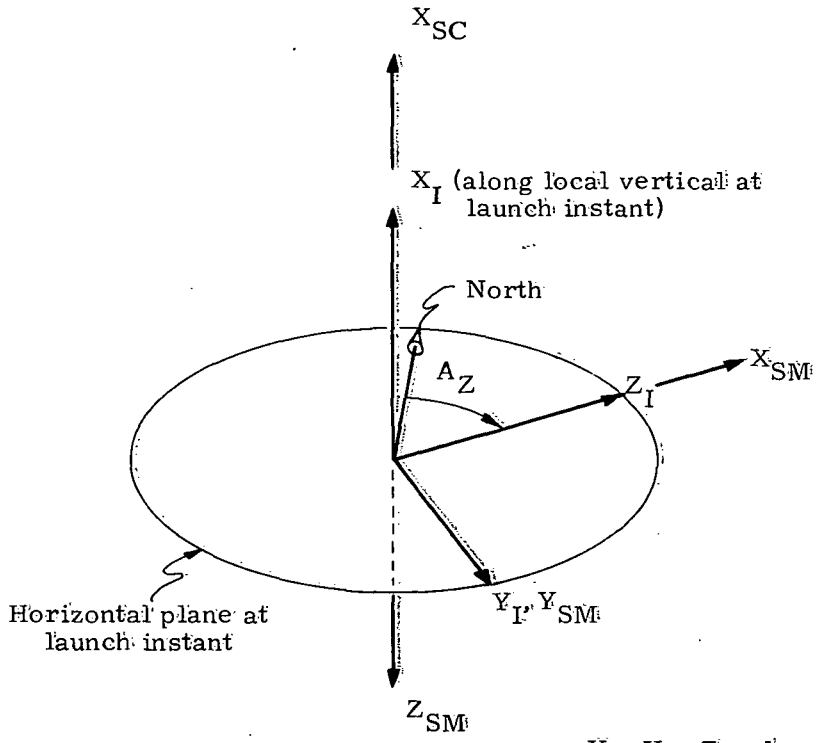
Fig. 1.3 defines the three flight path angle uncertainties, (U)γ_{AI}, (U)γ_{AIN}, and (U)γ_{AA}. Data for (U)γ_{AA} are given only for reentry start (at 400,000-ft altitude) in the summary Table1.2 and in Table 1.6 since the flight path angle uncertainty with the spacecraft actually at 400,000-ft altitude is the desired parameter. For other times, flight data are given for (U)γ_{AI}.

As the range angle uncertainty, (U) Rge/R, increases (as it will for prolonged, non-updated orbital missions, since (U) Rge is unbounded), the uncertainty, (U) γ_{AIN}, will increase correspondingly, since γ_{AIN} is measured relative to the nominal horizontal axis. The uncertainty, (U) γ_{AI}, is the more useful figure. In the previous report data had, however, been given only for (U) γ_{AIN}. In this report data are given for (U) γ_{AI}, with the exception of reentry start where the data are for (U) γ_{AA}.

Data in all error tables for RSS position and velocity uncertainties are given relative to nominal local vertical axes (see Fig. 1.3). These data may be used to compute (U) γ_{AIN}. Unless appropriate transformations are made, (U) γ_{AI} can not be computed from the above data.

1.7 Error Computation Procedure

Position and velocity uncertainties given in the tables were computed as follows. Approximate error equations were derived for the effect of each IMU component error on trajectory position and velocity. The assumptions were: 1) that the errors were small relative to the parameters being measured, and 2) that the IMU component errors were statistically independent of each other. The error equations took into account the effect of the IMU errors on gravity vector computation. The computation program incorporating the error equations requires nominal trajectory acceleration and position vectors (relative to fixed inertial axes) as inputs at discrete time intervals. The nominal trajectory itself was generated in a separate program. At significant events, such as SIVB cutoff, detailed error printouts were made giving the position and velocity uncertainties due to each IMU uncertainty relative to nominal local vertical axes.



X_I, Y_I, Z_I - launch inertial axes

X_{SM}, Y_{SM}, Z_{SM} - IMU Stable Member axes (positive directions shown)

Fig. 1.1 Coordinate axes for 278 CSM Launch Configuration

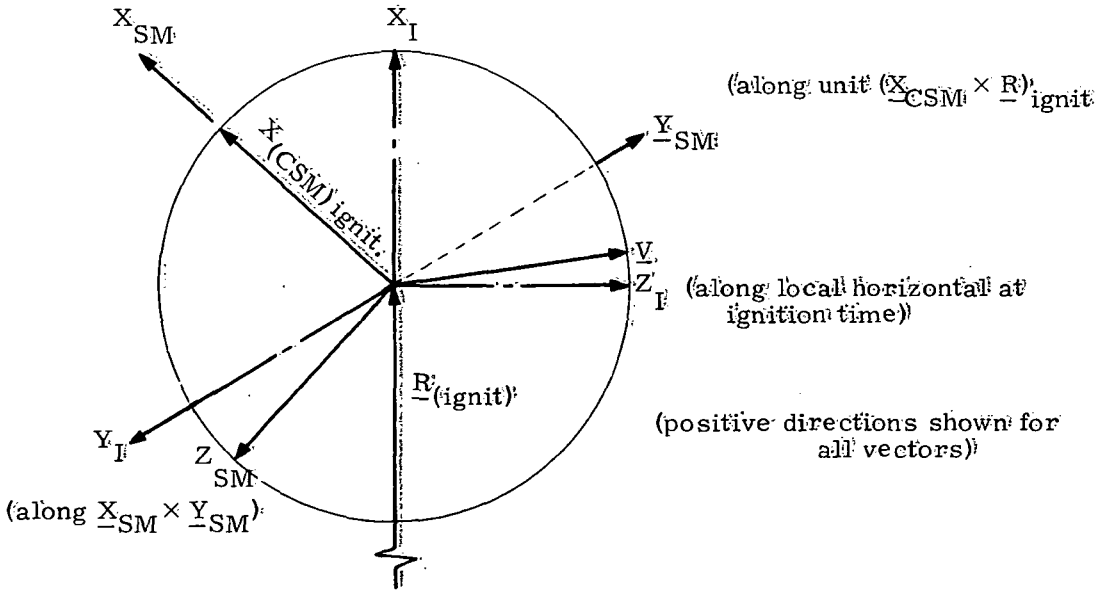
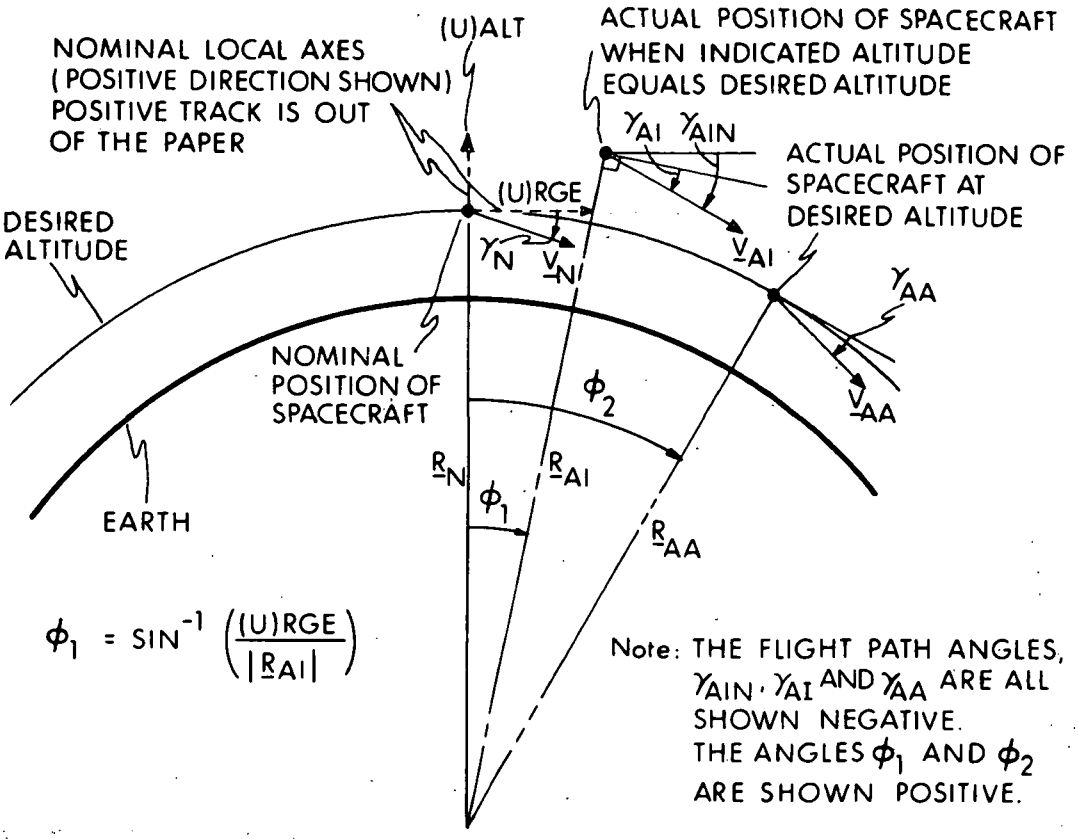


Fig. 1.2 Orientation of IMU SM axes for Deorbit Burn.



Flight Path Angle and Velocity Uncertainty Equations

$$(U)\gamma_{AIN} = \gamma_{AIN} - \gamma_N$$

$$(U)\gamma_{AI} = \gamma_{AI} - \gamma_N \qquad (U)V_{AI} = V_{AI} - V_N$$

$$(U)\gamma_{AA} = \gamma_{AA} - \gamma_N \qquad (U)V_{AA} = V_{AA} - V_N$$

Altitude Rate Uncertainty Equations

$$(U)\dot{Alt}_{AIN} = V_{AI} \sin \gamma_{AIN} - V_N \sin \gamma_N = (\underline{V}_{AI} - \underline{V}_N) \cdot \underline{R}_N / R_N$$

$$(U)\dot{Alt}_{AI} = V_{AI} \sin \gamma_{AI} - V_N \sin \gamma_N$$

$$(U)\dot{Alt}_{AA} = V_{AA} \sin \gamma_{AA} - V_N \sin \gamma_N$$

Note that γ_{AIN} is measured with respect to the same nominal horizontal axis as γ_N, while γ_{AI} and γ_{AA} are measured with respect to their particular local horizontal axes.

Fig. 1-3 Flight Path Angles

TABLE 1.1

Indication Uncertainties in Computed CSM Orbit
After SIVB Cutoff

Event	Time	RSS Position Indication Uncertainty (n. miles)			RSS Velocity Indication Uncertainty (ft/sec)			Other RSS Uncertainties (mr)		
	secs.	Alt.	Track	Range	Alt.	Track	Range	(U)γ_{AI}	(U)AZ	(U)Rge/R
Launch	0	0	0	0	0	0	0	0	0	0
SIVB C.O.	603	0.37	2.58	0.19	9.1	60.1	3.8	0.33	2.34	0.06
Max. Altitude Uncert.	2,638	2.15	3.46	6.11	40.5	57.2	11.9	0.29	2.24	1.72
1/2 Orbit after C.O.	3,244	2.05	2.58	8.26	52.7	60.1	11.0	0.33	2.35	2.33
Max. Track Uncert.	-	-	8.60	-	-	-	-	-	-	-
1 Orbit after C.O.	5,886	0.38	2.58	10.03	76.8	60.1	3.9	0.33	2.35	2.83
1-1/2 Orbits after C.O.	8,528	2.08	2.59	17.83	123.5	60.1	11.1	0.33	2.35	5.04
2 Orbits after C.O.	11,169	0.41	2.59	20.45	152.1	60.0	3.8	0.33	2.35	5.79

Note: 1) For the above table it was assumed that the CSM was inserted at SIVB cutoff into a 100-n. mile altitude circular orbit. Lack of better data was the reason for the above assumption.

Another error run was made with the same SIVB cutoff uncertainties where the CSM was inserted into an elliptical orbit with 82-n. mile pergee and 114-n. mile apogee altitude. Uncertainties after 2 inertial orbits were almost identical with above.

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TABLE 1.2

CSM Deorbit Burn, Coast and Reentry Uncertainties

Event	Time	RSS Position Uncertainty (feet)			RSS Velocity Uncertainty (ft/sec)			Other RSS Uncertainties (mr)		
	secs	Alt.	Track	Range	Alt.	Track	Range	(U)γ_{AI}	(U)AZ	(U)Rge/R
Ullage Ignit. for Deorbit Burn	0	0	0	0	0	0	0	0	0	0
Deorbit Burn Cutoff	29	3	3	3	0.21	0.23	0.21	0.009	0.009	0.009
Reentry Start (at 400,000 ft)	1834	603	171	818	1.22	0.12	0.49	0.016	0.004	0.038
Reentry End (at 24,000 ft)	2516	4912	3805	2934	-	-	-	-	-	0.139

1). The RSS flight path angle uncertainty of 0.016 mr at reentry start is given for (U) γ_{AA}. This is given relative to actual local vertical axes with CSM actually at 400,000-ft altitude.

2) CEP at reentry end is 0.65 n. mile.

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Table 1.3 207 (CSM) SIVB Cutoff Indication Uncertainties

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME FROM LCH.= 0 HR.10 MIN. 2.709 SEC (602.709 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES								
XI	0.500	MR	0.0	3053.7	85.6	0.120	11.703	0.203
YI	0.025	MR	- 122.0	- 6.1	165.1	- 0.587	- 0.010	0.406
ZI	0.025	MR	1.1	- 119.6	- 7.3	0.015	- 0.218	- 0.017
ACCEL.INPUT AXIS MLMS.								
MZTOX	0.141	MR	- 920.7	2.1	294.9	- 3.851	0.008	1.144
MZTOY	0.141	MR	21.0	- 0.0	- 6.8	0.123	- 0.000	- 0.038
MYABTZ	0.100	MR	- 12.6	- 609.9	- 31.1	- 0.052	- 2.336	- 0.119
ACCEL.BIAS								
ACBXINIT			995.3	50.4	- 1347.0	4.796	0.085	- 3.316
ACBXFLGT	0.200	CM/S.SQ	382.0	- 62.4	1074.5	1.344	- 0.198	3.405
ACBXCOMB			1377.3	- 11.9	- 272.5	6.140	- 0.113	0.088
ACBYINIT			9.6	- 976.3	- 59.6	0.130	- 1.778	- 0.145
ACBYFLGT	0.200	CM/S.SQ	23.7	1136.9	58.0	0.083	3.611	0.183
ACBYCOMB			33.4	160.5	- 1.6	0.213	1.833	0.038
ACBZINIT			0.0	0.0	0.0	0.000	0.000	0.000
ACBZFLGT	0.200	CM/S.SQ	- 1232.2	2.8	393.2	- 4.448	0.009	1.285
ACBZCOMB			- 1232.2	2.8	393.2	- 4.448	0.009	1.285
ACCEL.SCALE FACTOR								
SFEX	116	PPM	- 236.8	38.8	- 668.8	- 0.978	0.148	- 2.557
SFEY	116	PPM	- 0.3	- 17.1	- 0.8	- 0.002	- 0.096	- 0.004
SFEZ	116	PPM	- 632.1	1.4	199.2	- 1.583	0.003	0.411
ACCEL.SQ.IND.UNCERT.								
NCXX	10	MG/GSQ	33.3	- 5.4	94.0	0.141	- 0.021	0.370
NCZZ	10	MG/GSQ	- 75.2	0.1	23.6	- 0.186	0.000	0.048
GYRO BIAS DRIFT								
BDXINIT			175.1	13671.3	383.4	0.537	52.394	0.910
BDXFLGT	2.0	MERU	5.6	- 80.4	- 6.5	0.049	- 0.151	- 0.024
BDXCOMB			180.8	13590.9	376.9	0.586	52.242	0.886
BDYINIT			30.8	2410.6	67.6	0.094	9.238	0.160
BDYFLGT	2.0	MERU	- 183.3	- 3.9	144.3	- 1.232	- 0.005	0.549
BDYCOMB			- 152.4	2406.7	211.9	- 1.137	9.233	0.709
BDZINIT			- 11.4	- 890.7	- 24.9	- 0.035	- 3.413	- 0.059
BDZFLGT	2.0	MERU	- 1.7	- 206.0	- 3.5	- 0.008	- 1.233	- 0.013
BDZCOMB			- 13.2	- 1096.7	- 28.5	- 0.043	- 4.647	- 0.073
GYRO ACC.SENS.DRIFT								
ADIAXCOMB	8.0	MERU/G	25.8	- 276.8	- 24.4	0.226	- 0.496	- 0.101
ADSAYCOMB	5.0	MERU/G	- 395.8	6013.4	599.8	- 2.290	23.073	1.744
ADIAZCOMB	8.0	MERU/G	- 36.5	- 2699.6	- 80.9	- 0.106	- 9.673	- 0.182
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	1.0	- 11.9	- 1.0	0.009	- 0.021	- 0.004
ADSYY	0.2	MERU/GSQ	- 27.2	- 0.8	25.6	- 0.137	- 0.001	0.075
ADIZZ	0.2	MERU/GSQ	- 0.3	- 31.1	- 0.7	- 0.001	- 0.133	- 0.001
RSS UNCERT.(FT AND FT/SEC)			2226.7	15651.7	1184.7	9.125	60.068	3.799
RSS UNCERT.(N.MI.AND FT/SEC)			0.366	2.575	0.194	9.125	60.068	3.799

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Table 1.4 CSM IMU Stable Member Misalignments and Drift Angles at SIVB Cutoff

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI= 0.00, AYPI= 90.00, AZPI= 0 DEG) (T= 602.7 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERT.VALUE		MLM. ANGLE ABOUT INERTIAL AXES XI	MR. YI	ZI	MLM. ANGLE ABOUT LOCAL VERTICAL AXES ALT.	MR. TRACK	RANGE
INIT.S.M.MLMS. (UNCORREL.) ABOUT								
XI	0.500	MR.	0.5000	0.0000	0.0000	0.4738	- 0.0012	- 0.1594
YI	0.025	MR.	0.0000	0.0250	0.0000	0.0004	0.0249	0.0012
ZI	0.025	MR.	0.0000	0.0000	0.0250	0.0079	- 0.0013	0.0236
INIT.S.M.MLMS.DUE TO IMU ERROR EFFECTS ON EARTH LAUNCH ERECTION AND ALIGNMENT								
ACBX	0.20	CM/S.SQ	0.0000	- 0.2039	0.0000	- 0.0040	- 0.2036	- 0.0104
ACBY	0.20	CM/S.SQ	0.0000	0.0000	0.2039	0.0649	- 0.0111	0.1930
ACBZ	0.20	CM/S.SQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BDX	2.0	MERU	2.2384	0.0000	0.0000	2.1215	- 0.0053	- 0.7139
BDY	2.0	MERU	0.3947	0.0000	0.0000	0.3740	- 0.0009	- 0.1258
BDZ	2.0	MERU	- 0.1458	0.0000	0.0000	- 0.1382	0.0003	0.0465
ADIAX	8.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADSRAY	5.0	MERU/G	0.9867	0.0000	0.0000	0.9352	- 0.0023	- 0.3147
ADIAZ	8.0	MERU/G	- 0.5833	0.0000	0.0000	- 0.5528	0.0014	0.1860
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)			2.5984	0.2054	0.2054	2.4635	0.2055	0.8513
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START								
BDX	2.0	MERU	0.0000	0.0000	0.0878	0.0279	- 0.0048	0.0831
BDY	2.0	MERU	0.0000	0.0878	0.0000	0.0017	0.0876	0.0044
BDZ	2.0	MERU	- 0.0878	0.0000	0.0000	- 0.0832	0.0002	0.0280
ADIAX	8.0	MERU/G	0.0000	0.0000	0.4543	0.1446	- 0.0248	0.4300
ADSRAX	5.0	MERU/G	0.0000	0.0000	- 0.0097	- 0.0030	0.0005	- 0.0092
ADIAY	8.0	MERU/G	0.0000	0.0155	0.0000	0.0003	0.0155	0.0007
ADSRAY	5.0	MERU/G	0.0000	0.1187	0.0000	0.0023	0.1185	0.0060
ADIAZ	8.0	MERU/G	0.1899	0.0000	0.0000	0.1800	- 0.0004	- 0.0605
ADSRAZ	5.0	MERU/G	- 0.0097	0.0000	0.0000	- 0.0092	0.0000	0.0031
ADIXX	0.2	MERU/GSQ	0.0000	0.0000	0.0190	0.0060	- 0.0010	0.0180
ADSYY	0.2	MERU/GSQ	0.0000	0.0063	0.0000	0.0001	0.0063	0.0003
ADIZZ	0.2	MERU/GSQ	- 0.0063	0.0000	0.0000	- 0.0060	0.0000	0.0020
RSS DRIFT ANGLE			0.2095	0.1486	0.4632	0.2474	0.1505	0.4435
OVERALL RSS MLM			2.6068	0.2535	0.5067	2.4759	0.2548	0.9599

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Table 1.5 CSM Indicated Orbit Uncertainties (after SIVB Cutoff) at Maximum Altitude Uncertainty Point

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME FROM LCH = 0 HR.43 MIN.58.245 SEC (2638.244 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT. ABOUT LAUNCH INERTIAL AXES			VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.		
			TRACK	RANGE		TRACK	RANGE	
INITIAL S.M. MLMS. (UNCORREL.)								
XI	0.500	MR	0.0	4094.3	- 1598.7	2.024	- 11.148	- 0.737
YI	0.025	MR	647.7	- 1.0	451.2	0.195	0.012	- 0.506
ZI	0.025	MR	- 45.3	- 28.3	34.1	- 0.068	0.256	0.037
ACCEL.INPUT AXIS MLMS.								
MZTOX	0.141	MR	- 1083.5	3.0	11605.3	- 10.349	- 0.008	1.356
MZTOY	0.141	MR	7.2	- 0.1	- 319.3	0.258	0.000	- 0.022
MYABTZ	0.100	MR	- 435.1	- 816.9	774.1	- 1.016	2.225	0.383
ACCEL.BIAS								
ACBXINIT			- 5284.2	8.3	- 3680.9	- 1.590	- 0.103	4.132
ACBXFLGT	0.200	CM/S.SQ	12530.4	- 61.2	- 22262.6	29.167	0.197	- 11.052
ACBXCOMB			7246.2	- 52.9	- 25943.6	27.576	0.093	- 6.920
ACBYINIT			- 369.9	- 231.6	278.9	- 0.557	2.094	0.305
ACBYFLGT	0.200	CM/S.SQ	691.3	1115.3	- 1253.0	1.629	- 3.592	- 0.610
ACBYCOMB			321.3	883.7	- 974.0	1.071	- 1.497	- 0.305
ACBZINIT			0.0	0.0	0.0	0.000	0.000	0.000
ACBZFLGT	0.200	CM/S.SQ	- 1791.6	3.1	14426.0	- 13.392	- 0.009	1.971
ACBZCOMB			- 1791.6	3.1	14426.0	- 13.392	- 0.009	1.971
ACCEL.SCALE FACTOR								
SFEX	116	PPM	- 9166.0	52.0	15981.7	- 21.140	- 0.141	8.068
SFEY	116	PPM	- 17.1	- 39.6	29.5	- 0.039	0.085	0.015
SFEZ	116	PPM	- 1271.7	0.5	6326.0	- 6.446	- 0.003	1.178
ACCEL.SQ.IND.UNCERT.								
NCXX	10	MG/GSQ	1322.5	- 7.6	- 2300.9	3.047	0.020	- 1.163
NCZZ	10	MG/GSQ	- 153.4	0.0	752.3	- 0.768	- 0.000	0.141
GYRO BIAS DRIFT								
BDXINIT			3714.2	18330.2	- 7157.5	9.064	- 49.910	- 3.301
BDXFLGT	2.0	MERU	- 34.3	- 21.9	- 65.2	0.018	0.176	0.022
BDXCOMB			3679.8	18308.3	- 7222.7	9.082	- 49.733	- 3.279
BDYINIT			654.9	3232.1	- 1262.0	1.598	- 8.800	- 0.582
BDYFLGT	2.0	MERU	533.4	0.0	2204.9	- 1.241	0.006	- 0.297
BDYCOMB			1188.4	3232.2	942.9	0.356	- 8.793	- 0.879
BDZINIT			- 241.9	- 1194.2	466.3	- 0.590	3.251	0.215
BDZFLGT	2.0	MERU	- 52.2	- 519.8	98.3	- 0.126	1.084	0.046
BDZCOMB			- 294.2	- 1714.0	564.6	- 0.716	4.336	0.261
GYRO ACC.SENS.DRIFT								
ADIAXCOMB	8.0	MERU/G	- 121.3	- 61.3	- 359.7	0.164	0.588	0.071
ADSAYCOMB	5.0	MERU/G	3188.0	8077.6	763.5	2.250	- 21.973	- 2.508
ADIAZCOMB	8.0	MERU/G	- 751.6	- 3250.3	1452.4	- 1.836	9.352	0.668
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	- 5.1	- 2.7	- 13.9	0.006	0.025	0.003
ADSYY	0.2	MERU/GSQ	90.4	- 0.1	203.7	- 0.083	0.001	- 0.063
ADIZZ	0.2	MERU/GSQ	- 7.9	- 49.6	15.1	- 0.019	0.124	0.007
RSS UNCERT. (FT AND FT/SEC)			13069.3	21038.5	37120.1	40.537	57.199	11.868
RSS UNCERT. (N.MI. AND FT/SEC)			2.150	3.462	6.109	40.537	57.199	11.868

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Table 1.6 CSM IMU Stable Member Misalignments and Drift Angles at Deorbit Burn Cutoff

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI= 180.00, AYPI=- 45.00, AZPI= 0 DEG) (T= 29.2 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERT.	VALUE	MLM. ANGLE ABOUT INERTIAL AXES MR. XI	MR. YI	ZI	MLM. ANGLE ABOUT LOCAL VERTICAL AXES MR. ALT.	MR. TRACK	RANGE
INIT.S.M.MLMS. (UNCORREL.) ADJT								
XSM	0.200	MR.	0.1414	0.0000	- 0.1414	0.1365	0.0000	- 0.1461
YSM	0.200	MR.	0.0000	- 0.2000	0.0000	0.0000	- 0.2000	0.0000
ZSM	0.200	MR.	- 0.1414	0.0000	- 0.1414	- 0.1461	0.0000	- 0.1365
INIT. S.M. MLMS. AT TRAJ. START DUE TO GYRO BIAS DRIFT FOR 15 MINS. PRIOR TO START OF TRAJECTORY								
BDX	2.0	MERU	0.0928	0.0000	- 0.0928	0.0896	0.0000	- 0.0958
BDY	2.0	MERU	0.0000	- 0.1312	0.0000	0.0000	- 0.1312	0.0000
BDZ	2.0	MERU	- 0.0928	0.0000	- 0.0928	- 0.0958	0.0000	- 0.0896
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)			0.2392	0.2392	0.2392	0.2392	0.2392	0.2392
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START								
BDX	2.0	MERU	0.0030	0.0000	- 0.0030	0.0029	0.0000	- 0.0031
BDY	2.0	MERU	0.0000	- 0.0042	0.0000	0.0000	- 0.0042	0.0000
BDZ	2.0	MERU	- 0.0030	0.0000	- 0.0030	- 0.0031	0.0000	- 0.0029
ADIAX	8.0	MERU/G	0.0063	0.0000	- 0.0063	0.0061	0.0000	- 0.0065
ADSRAX	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIAY	8.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADSRAY	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIAZ	8.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADSRAZ	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIXX	0.2	MERU/GSQ	0.0001	0.0000	- 0.0001	0.0001	0.0000	- 0.0001
ADSYY	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIZZ	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RSS DRIFT ANGLE			0.0076	0.0042	0.0076	0.0074	0.0042	0.0078
OVERALL RSS MLM			0.2393	0.2392	0.2393	0.2393	0.2392	0.2393

Table 1.7 CSM Reentry Start Uncertainties (at 400,000 feet)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 30 MIN, 33.652 SEC (1833.651 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT S.M. AXES								
XSM	0.200	MR.	0.0	0.0	0.0	0.000	0.000	0.000
YSM	0.200	MR.	236.3	0.0	- 357.0	0.514	0.000	- 0.201
ZSM	0.200	MR.	0.0	- 73.7	- 0.0	0.000	0.053	- 0.000
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100	MR.	0.0	- 36.8	- 0.0	0.000	0.026	- 0.000
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.200	CM/S.SQ	255.9	0.0	10.3	0.296	- 0.000	- 0.166
ACBY	0.200	CM/S.SQ	- 0.0	141.7	0.0	- 0.000	- 0.103	0.000
ACBZ	0.200	CM/S.SQ	459.8	0.0	- 696.1	1.001	- 0.000	- 0.392
ACCEL.SCALE FACTOR								
SFEX	116.0	PPM	- 77.3	0.0	- 2.3	- 0.090	0.000	0.050
SFEY	116.0	PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFEZ	116.0	PPM	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	6.7	0.0	0.2	0.007	0.000	- 0.004
NCYY	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			0.0	0.0	0.0	0.000	0.000	0.000
BDXFLGT	2.0	MERU	0.0	0.0	0.0	0.000	0.000	0.000
BDXCOMB			0.0	0.0	0.0	0.000	0.000	0.000
BDYINIT			155.0	0.0	- 234.3	0.337	0.000	- 0.132
BDYFLGT	2.0	MERU	3.7	0.0	- 5.6	0.008	0.000	- 0.003
BDYCOMB			158.8	0.0	- 239.9	0.345	0.000	- 0.135
BDZINIT			0.0	- 48.3	- 0.0	0.000	0.034	- 0.000
BDZFLGT	2.0	MERU	0.0	- 1.1	0.0	0.000	0.000	0.000
BDZCOMB			0.0	- 49.5	- 0.0	0.000	0.035	- 0.000
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADSRAY	5.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADIAZ	8.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)			603.3	171.2	818.4	1.218	0.124	0.493
RSS UNCERT.(N.MI.AND FT/SEC)			0.099	0.028	0.134	1.218	0.124	0.493

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Table 1.8 Flight Path Angle Uncertainties at Reentry Start

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO NOMINAL AXES AT NOMINAL TIME (EGNM)										(U) γ_{AIN}	
MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX	0.0113	SFEX-	0.0034	NCXX	0.0003 MR.
MLMYSM	0.0197	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ	0.0385	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI	0.0129	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF	0.0003	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.0468 MR.
BDXT	0.0000	BDYT	0.0132	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0026 DEG.
UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT NOMINAL TIME (EG1)										(U) γ_{AI}	
MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX	0.0118	SFEX-	0.0035	NCXX	0.0003 MR.
MLMYSM	0.0030	MXAZ	0.0000	MZAX	0.0000	ACBY -	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ	0.0059	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI	0.0020	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.0141 MR.
BDXT	0.0000	BDYT	0.0020	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0008 DEG.
UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT DESIRED ALTITUDE (EG2)										(U) γ_{AA}	
MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX	0.0126	SFEX-	0.0038	NCXX	0.0003 MR.
MLMYSM	0.0038	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ	0.0074	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI	0.0025	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.0158 MR.
BDXT	0.0000	BDYT	0.0025	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0009 DEG.

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Table 1.9 Reentry End Uncertainties (at drogue chute deployment)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 41 MIN, 55.726 SEC (2515.726 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT S.M. AXES								
XSM	0.200	MR.	8.1	- 1207.3	392.1	0.035	- 3.850	1.274
YSM	0.200	MR.	1984.9	- 101.5	- 347.6	6.749	0.530	1.650
ZSM	0.200	MR.	14.4	555.0	- 176.7	0.072	2.872	- 0.911
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	667.7	- 47.9	- 161.4	2.434	- 0.153	- 0.517
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	1.7	- 606.2	187.8	0.006	- 1.936	0.600
MYAZ	0.100	MR.	- 0.8	278.1	- 86.1	- 0.004	1.439	- 0.445
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.200	CM/S.SQ	2229.6	- 207.7	- 693.8	6.366	- 0.371	- 1.257
ACBY	0.200	CM/S.SQ	- 3.8	1405.7	- 435.5	- 0.010	3.600	- 1.115
ACBZ	0.200	CM/S.SQ	516.0	- 756.7	- 2449.1	0.599	- 1.125	- 3.642
ACCEL.SCALE FACTOR								
SFEX	116.0	PPM	184.2	2.3	6.0	1.557	- 0.109	- 0.366
SFEY	116.0	PPM	0.0	- 9.9	3.0	0.000	- 0.044	0.013
SFEZ	116.0	PPM	- 208.0	- 210.6	- 678.0	- 0.756	- 0.673	- 2.165
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	48.6	- 4.9	- 16.5	0.207	- 0.014	- 0.047
NCYY	10	MG/GSQ	- 0.0	5.5	- 1.7	- 0.000	0.017	- 0.005
NCZZ	10	MG/GSQ	- 35.9	- 36.6	- 117.8	- 0.132	- 0.119	- 0.384
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			5.3	- 792.4	257.3	0.023	- 2.527	0.836
BDXFLGT	2.0	MERU	13.8	- 1929.0	629.3	0.058	- 6.235	2.067
BDXCOMB			19.1	- 2721.4	886.7	0.081	- 8.762	2.904
BDYINIT			1302.7	- 66.6	- 228.1	4.429	0.348	1.083
BDYFLGT	2.0	MERU	2410.8	125.0	380.3	9.305	0.911	2.859
BDYCOMB			3713.5	58.4	152.1	13.734	1.259	3.942
BDZINIT			9.4	364.2	- 115.9	0.047	1.885	- 0.598
BDZFLGT	2.0	MERU	26.1	936.0	- 298.3	0.124	4.692	- 1.490
BDZCOMB			35.5	1300.3	- 414.3	0.171	6.578	- 2.088
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	- 3.8	297.2	- 102.1	- 0.013	1.769	- 0.419
ADSRAY	5.0	MERU/G	788.7	73.0	228.4	3.644	0.578	1.833
ADIAZ	8.0	MERU/G	- 43.4	- 651.0	213.6	- 0.124	- 4.113	1.303
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	0.1	- 9.7	3.3	0.000	- 0.040	0.013
ADSYY	0.2	MERU/GSQ	62.0	6.1	19.2	0.293	0.047	0.151
ADIZZ	0.2	MERU/GSQ	2.7	33.2	- 11.0	0.007	0.211	- 0.067
RSS UNCERT.(FT AND FT/SEC)			4911.7	3805.3	2933.9	17.248	13.587	7.789
RSS UNCERT.(N.MI.AND FT/SEC)			0.808	0.626	0.482	17.248	13.587	7.789

SECTION 2

PGNCS ERROR ANALYSIS

2.1 Introduction

The results of a PGNCS error study for the 278 (LEM) mission are presented herein. This study is concerned with the effects of LM IMU component uncertainties on the 3rd DPS Burn with CSM/LM in docked configuration (during the 5th period maneuvers) and on resulting orbit parameters.

No error studies for the LM-active rendezvous maneuvers are given in this issue. Perfect navigational update was assumed just prior to the 3rd DPS burn. The effects of tracking uncertainties on update were not included, since these data were not available.

2.2 Important Results of Error Study

Maximum one sigma uncertainties in free-fall orbit after 3rd DPS burn cutoff were:

1.52 n. mile in altitude
0.30 n. mile in track

Range uncertainty increased at the rate of about 7.1 n. mile per orbit.

2.3 Error Table Description

The error tables are given at this end of this section. Table 2.1 summarizes uncertainty data for the 3rd DPS burn and the resulting coast up to ullage ignition for FITH staging. Table 2.2 gives detailed uncertainty data at 3rd DPS burn cutoff. Table 2.3 gives S.M. misalignment and drift data at the same time. Table 2.4 gives orbit uncertainties (after 3rd DPS burn cutoff) at max. altitude uncertainty point.

The error studies were based on trajectory printouts for "207-208A Preliminary Spacecraft Reference Trajectory" transmitted from TRW Systems on June 10, 1966.

The polarities in the error tables are those for actual uncertainties in LM position and velocity relative to nominal position and velocity.

2.4 IMU Errors and Uncertainties

The LGC will be able to provide compensation for the measured average values of the following IMU component errors:

1. accelerometer bias error
2. accelerometer scale factor error
3. gyro bias drift
4. gyro input axis acceleration sensitive drift
5. gyro spin reference axis acceleration aensitive drift

Since the average IMU errors will be compensated by means of LGC programs during prelaunch and in-flight mission phases, it is the actual unpredictable deviations from the measured average errors that constitute the IMU component uncertainties. The estimated one-sigma IMU error uncertainties at time of 278 (LM) launch are (see also MEI PS 2015000 which gives specs. for the Block II IMU):

One-Sigma IMU Error Uncertainties

Uncertainty	Units	Input Axis X	Y	Z
Accelerometer bias (ACB)	cm/sec^2	0.20	0.20	0.20
Accelerometer scale factor (SFE)	ppm	116	116	116
Accelerometer non-linearity	$\mu g/g^2$	10	10	10
Gyro bias drift (BD)	meru	2	2	2
Gyro input axis accel. sens. drift (ADIA)	meru/g	8	8	8
Gyro spin ref. axis accel. sens. drift (ADSRA)	meru/g	5	5	5
Gyro acceleration squared sens. drift	meru/g	0.3	0.3	0.3
Accelerometer I.A. misalignments				
About PRA	mr	0.10	0.10	0.10
About OA	mr	0.10	0.10	0.10
Gyro I.A. misalignments				
About SRA	mr	0.50	0.50	0.50
About OA	mr	0.50	0.50	0.50

The error tables here employ a definition of scale factor error whose polarity is effectively the reverse of that formerly used. The new definition is being adopted, since it is consistent with that employed in component and systems tests for some time past.

Prior to the CSM/LM 3rd DPS Burn maneuver (and also prior to other significant maneuvers during the mission), the LM IMU Stable Member will be fine aligned on the basis of star sightings and LGC computations. It is assumed that this alignment will be completed 15 minutes prior to DPS burn ignition. The assumed one sigma Stable Member alignment uncertainty (independent of gyro drift) is 1.0 mr. about each S.M. axis.

2.5 Stable Member Orientation

Prior to the 3rd DPS burn the LM IMU Stable Member is aligned with X_{SM} oriented along unit ($\underline{X}_{LM}$) at ignition, with Y_{SM} along unit ($\underline{X}_{LM} \times \underline{R}$) at ignition, and Z_{SM} along unit ($\underline{X}_{SM} \times \underline{Y}_{SM}$). The inertial axes ($X_I$, Y_I, Z_I) referred to in the error tables are defined to be square with local vertical axes at 3rd DPS burn ignition. X_I is along unit $(\underline{R})_{ignit}$, Y_I is along unit $(\underline{V} \times \underline{R})_{ignit}$, and Z_I is along unit ($\underline{X}_I \times \underline{Y}_I$).

For the 3rd DPS burn the thrust direction is normal to the orbit plane in the negative Y_I direction.

2.6 Error Computation Procedure

Position and velocity uncertainties given in the table were computed as follows. Approximate error equations were derived for the effect of each IMU component error on trajectory position and velocity. The assumptions were: (1) that the errors were small relative to the parameters being measured; and (2) that the IMU component errors were statistically independent of each other. The error equations took into account the effect of the IMU errors on gravity vector computation. The computation programs that use the error equations require nominal trajectory acceleration and position vectors as inputs at discrete time intervals. The nominal trajectory itself was generated in a separate program. At significant events, such as SIVB cutoff, detailed error printouts were made giving the position and velocity uncertainties due to each IMU uncertainty together with the rss of these uncertainties relative to nominal local vertical axes.

TABLE 2.1

3RD DPS BURN AND RESULTING COAST UNCERTAINTIES

Event	Time Secs	RSS Position Uncertainty n. miles			RSS Velocity Uncertainty ft/sec.			Other RSS Uncertainties mr.		
		Alt.	Track	Range	Alt.	Track	Range	$(U)\gamma_{AI}$	$(U)_{AZ}$	$(U)R_{ge/R}$
Ullage Ignit. 3rd DPS Burn	0	0	0	0	0	0	0	0	0	0
3rd DPS Burn Cutoff	319	0.07	0.05	0.07	2.8	2.1	2.6	0.111	0.081	0.018
Max. altitude Uncertainty during coast	2,894	1.52	0.01	3.89	26.2	2.1	8.0	0.106	0.082	1,073
Max. Track Uncertainty during coast	4,251	0.87	0.30	6.93	43.1	0	3.8	0.209	0	1.913
Burn Ignit. for CSM/LM separation	5,761	0.06	0.05	7.13	50.7	2.1	2.6	0.110	0.081	1.970
Ullage Ignit. for FITH staging	8,791	1.07	0.15	10.90	73.8	1.8	5.6	0.125	0.072	3.010

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Table 2.2 Uncertainties at 3rd DPS Burn Cutoff

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 5 MIN, 19.100 SEC (319.100 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT S.M. AXES								
XSM	1.000	MR.	2.0	- 0.0	- 0.5	0.020	- 0.000	- 0.005
YSM	1.000	MR.	218.0	- 2.7	- 82.2	1.578	- 0.018	- 0.581
ZSM	1.000	MR.	82.9	12.1	211.5	0.599	0.079	1.492
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	0.0	0.0	- 0.0	- 0.000	0.000	- 0.000
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100	MR.	8.2	1.4	21.1	0.059	0.010	0.149
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.200	CM/S.SQ	- 3.4	329.6	- 20.9	- 0.021	2.042	- 0.129
ACBY	0.200	CM/S.SQ	- 120.8	- 20.7	- 307.3	- 0.772	- 0.128	- 1.903
ACBZ	0.200	CM/S.SQ	319.1	- 4.3	- 120.0	2.046	- 0.026	- 0.746
ACCEL.SCALE FACTOR								
SFEX	116.0	PPM	0.2	- 26.3	1.6	0.001	- 0.185	0.011
SFEY	116.0	PPM	- 0.0	- 0.0	- 0.2	- 0.000	- 0.000	- 0.002
SFEZ	116.0	PPM	0.0	0.0	- 0.0	0.000	- 0.000	- 0.000
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	- 0.0	0.3	- 0.0	- 0.000	0.002	- 0.000
NCYY	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			0.2	- 0.0	- 0.0	0.002	- 0.000	- 0.000
BDXFLGT	2.0	MERU	0.0	0.0	- 0.0	0.000	- 0.000	- 0.000
BDXCOMB			0.3	- 0.0	- 0.0	0.003	- 0.000	- 0.000
BDYINIT			28.6	- 0.3	- 10.7	0.207	- 0.002	- 0.076
BDYFLGT	2.0	MERU	4.0	- 0.0	- 1.5	0.040	- 0.000	- 0.015
BDYCOMB			32.6	- 0.4	- 12.3	0.247	- 0.002	- 0.091
BDZINIT			10.8	1.6	27.7	0.078	0.010	0.195
BDZFLGT	2.0	MERU	1.5	0.2	3.9	0.015	0.001	0.039
BDZCOMB			12.4	1.8	31.7	0.094	0.012	0.235
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	0.0	0.0	- 0.0	0.000	- 0.000	- 0.000
ADSRAY	5.0	MERU/G	0.0	0.0	0.0	0.000	0.000	- 0.000
ADIAZ	8.0	MERU/G	0.0	0.0	- 0.0	- 0.000	0.000	- 0.000
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)			415.0	331.6	403.0	2.776	2.057	2.617
RSS UNCERT.(N.MI.AND FT/SEC)			0.068	0.054	0.066	2.776	2.057	2.617

Table 2.3 LM IMU Stable Member misalignments and drift angle at 3rd DPS Burn Cutoff

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI= 90.00, AYPI=- 90.00, AZPI= 0 DEG) (T= 319.1 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERT.	VALUE	MLM. ANGLE ABOUT INERTIAL AXES XI	MR. YI	ZI	MLM. ANGLE ABOUT LOCAL VERTICAL AXES ALT.	MR. TRACK	RANGE
INIT.S.M.MLMS. (UNCORREL.) ABOUT								
XSM	1.000	MR.	0.0000	- 1.0000	0.0000	0.0103	- 0.9979	0.0632
YSM	1.000	MR.	0.0000	0.0000	1.0000	0.3585	0.0627	0.9313
ZSM	1.000	MR.	- 1.0000	0.0000	0.0000	- 0.9334	0.0130	0.3584
INIT. S.M. MLMS. AT TRAJ. START DUE TO GYRO BIAS DRIFT FOR 15 MINS. PRIOR TO START OF TRAJECTORY								
BDX	2.0	MERU	0.0000	- 0.1312	0.0000	0.0013	- 0.1309	0.0083
BDY	2.0	MERU	0.0000	0.0000	0.1312	0.0470	0.0082	0.1222
BDZ	2.0	MERU	- 0.1312	0.0000	0.0000	- 0.1225	0.0017	0.0470
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)			1.0085	1.0085	1.0085	1.0085	1.0085	1.0085
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START								
BDX	2.0	MERU	0.0000	- 0.0465	0.0000	0.0004	- 0.0464	0.0029
BDY	2.0	MERU	0.0000	0.0000	0.0465	0.0166	0.0029	0.0433
BDZ	2.0	MERU	- 0.0465	0.0000	0.0000	- 0.0434	0.0006	0.0166
ADIAX	8.0	MERU/G	0.0000	- 0.0295	0.0000	0.0003	- 0.0295	0.0018
ADSRAX	5.0	MERU/G	0.0000	- 0.0002	0.0000	0.0000	- 0.0002	0.0000
ADIAY	8.0	MERU/G	0.0000	0.0000	- 0.0003	- 0.0001	- 0.0000	- 0.0003
ADSRAY	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIAZ	8.0	MERU/G	0.0000	0.0000	0.0000	0.0000	- 0.0000	- 0.0000
ADSRAZ	5.0	MERU/G	0.0002	0.0000	0.0000	0.0002	- 0.0000	- 0.0000
ADIXX	0.2	MERU/GSQ	0.0000	- 0.0001	0.0000	0.0000	- 0.0001	0.0000
ADSYY	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIZZ	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RSS DRIFT ANGLE			0.0465	0.0551	0.0465	0.0465	0.0551	0.0465
OVERALL RSS MLM			1.0096	1.0100	1.0096	1.0096	1.0100	1.0096

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Table 2.4 LM Orbit Uncertainties (after 3rd DPS Burn Cutoff) at Maximum Altitude Uncertainty Point

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 48 MIN, 13.857 SEC (2893.857 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY		POSITION UNCERTAINTIES (REL. TO NOM. AXES) IN FEET ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES (REL. TO NOM. AXES) IN FT/SEC ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT S.M. AXES								
XSM	1.000	MR.	- 9.6	- 0.0	- 48.2	0.034	0.000	0.007
YSM	1.000	MR.	- 1120.1	- 0.2	- 2939.2	1.756	0.019	0.958
ZSM	1.000	MR.	5533.5	0.5	- 13994.8	15.821	- 0.080	- 4.770
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	- 0.0	0.0	0.1	- 0.000	- 0.000	0.000
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	0.7	0.0	- 1.7	0.002	- 0.000	- 0.000
MYAZ	0.100	MR.	552.9	0.1	- 1398.4	1.580	- 0.010	- 0.476
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.200	CM/S.SQ	- 461.8	- 4.0	1079.8	- 1.243	- 2.077	0.398
ACBY	0.200	CM/S.SQ	- 7112.4	0.2	18120.8	- 20.444	0.129	6.129
ACBZ	0.200	CM/S.SQ	- 1319.5	0.0	- 4133.1	2.673	0.027	1.140
ACCEL.SCALE FACTOR								
SFEX	116.0	PPM	41.7	- 3.2	- 97.0	0.112	0.187	- 0.036
SFEY	116.0	PPM	- 8.1	- 0.0	20.3	- 0.023	0.000	0.007
SFEZ	116.0	PPM	- 0.2	0.0	- 0.3	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	- 0.6	0.0	1.4	- 0.001	- 0.002	0.000
NCYY	10	MG/GSQ	- 0.0	0.0	0.0	- 0.000	0.000	0.000
NCZZ	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			- 1.2	0.0	- 6.3	0.004	0.000	0.001
BDXFLGT	2.0	MERU	- 0.3	0.0	- 1.4	0.000	0.000	0.000
BDXCOMB			- 1.6	- 0.0	- 7.7	0.005	0.000	0.001
BDYINIT			- 147.0	- 0.0	- 385.7	0.230	0.002	0.125
BDYFLGT	2.0	MERU	- 34.0	- 0.0	- 62.3	0.028	0.000	0.028
BDYCOMB			- 181.0	- 0.0	- 448.0	0.259	0.002	0.154
BDZINIT			726.3	0.0	- 1836.9	2.076	- 0.010	- 0.626
BDZFLGT	2.0	MERU	143.1	0.0	- 356.5	0.404	- 0.001	- 0.123
BDZCOMB			869.4	0.1	- 2193.5	2.481	- 0.012	- 0.749
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	- 0.2	0.0	- 0.8	0.000	0.000	0.000
ADSRAY	5.0	MERU/G	- 0.0	0.0	- 0.0	0.000	0.000	0.000
ADIAZ	8.0	MERU/G	- 0.0	0.0	0.1	- 0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	0.0	0.0	- 0.0	0.000	0.000	0.000
ADSYY	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)			9247.3	5.1	23623.8	26.244	2.092	7.970
RSS UNCERT.(N.MI.AND FT/SEC)			1.521	0.000	3.887	26.244	2.092	7.970

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