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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE AND NAVIGATION

CLASSIFICATION CHANGE

To UNCLASSIFIED

By authority of GDS-[illegible]

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TYPE I DOCUMENT
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Revision 1

R-537

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GUIDANCE SYSTEM OPERATIONS PLAN
AS-501
Vol. II
CONTROL DATA AND ERROR ANALYSIS

December 1966

~~GROUP 4~~
~~Downgraded at 3 year intervals; declassified after 12 years~~

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Table of Contents

6 MISSION AND VEHICLE CONTROL DATA

6.1 Scope

Section 6 presents a summary of all data that either have an effect on AGC programming or are required for simulation and verification of AGC programs.

Numerical values are recorded in the most widely accepted units and may not be found in the memory explicitly as defined. These values are often rescaled, units corrected, or combined with other data in the most convenient and/or economical fashion.

Apollo mission and vehicle data for Flight AS-501 have been collected under the following headings:

Apollo Mission Data (Sec. 6.2) establishes the outline of the mission in terms of trajectories, profiles, etc. This information is required for simulation and verification of computer programs.

AGC Memory Data (Sec. 6.3) contains mission and vehicle dependent data that are written directly into the memory of the AGC. Other memory data are referred to in Sections 3, 4, and 5. The limited erasable section is reserved primarily for storage of computational variables. Those parameters that do not change during flight have been assigned to the fixed section of the memory.

Exceptions have been made for data that will not be available until shortly before the launch date.

Spacecraft Vehicle Data (Sec. 6.4) includes configuration, mass properties, propulsion, and aerodynamics data. With few exceptions, this information will not appear directly in the AGC program. These data will mainly be used for simulation and program verification.

Physical Constants (Sec. 6.5) will be used directly in the AGC programs as well as program verification. The AGC is programmed in the metric set of kilogram, meter, and centisecond (10^{-2} sec). Conversion to other units is accomplished by use of the factors defined in this section.

6.2 Apollo Mission Data

6.2.1 Mission Trajectory

Nominal mission profile	Fig. 6.1, 6.2
Nominal Saturn boost profile	Fig. 6.3, 6.4
Sequence of events	Table 6.1

The information in this section is taken and compiled from:

(1) boost phase; NASA/(MSC & MSFC) Trajectory Document #66-FMP-2 "AS-501/CSM-017 Joint Reference Trajectory" dated 10 May 1966.

(2) spacecraft; NASA/MSC Simulation Run "Nominal AS-501 Mission Profile with AS-202 Guidance Logic " Run Date 10 September 1966.

6.2.2 Nominal CSM/SIVB Separation Attitude Conditions

X_{sc} axis	in plane of the trajectory, and in the direction of the forward horizontal
Y_{sc} axis	is along the momentum vector, $\underline{R} \times \underline{V}$
Z_{sc} axis	points up, and parallel to the geocentric radius vector
Roll rate	0 degree/second
Pitch rate	0 degree/second
Yaw rate	0 degree/second

6.2.3 Dispersions (3 Sigma) for Nominal Separation Attitude Conditions

X_{sc} axis attitude	2 degrees
Y_{sc} axis attitude	2 degrees
Z_{sc} axis attitude	2 degrees
Roll rate residual	0.2 degree/second
Pitch rate residual	0.2 degree/second
Yaw rate residual	0.2 degree/second

6.2.4. SIVB Engine Shutdown Transients

Thrust decay from 100% to 5% rated thrust	Fig. 6.5
Thrust decay from 5% rated to zero thrust	Fig. 6.6

Cutoff impulse from mainstage cutoff to 5-percent thrust is derived by multiplying the thrust level (at engine cutoff signal) by 0.224 second. The deviation about the cutoff impulse is the thrust level (at the cutoff signal) times $\pm$ 0.030 second. The cutoff impulse from 5-percent thrust is derived by multiplying the thrust level (at engine cutoff signal) by 0.0235 second.

The information contained in section 6.2.4 is taken from the GN&C Data Exchange Program, MSC-S-10 submitted 23 August 1966.

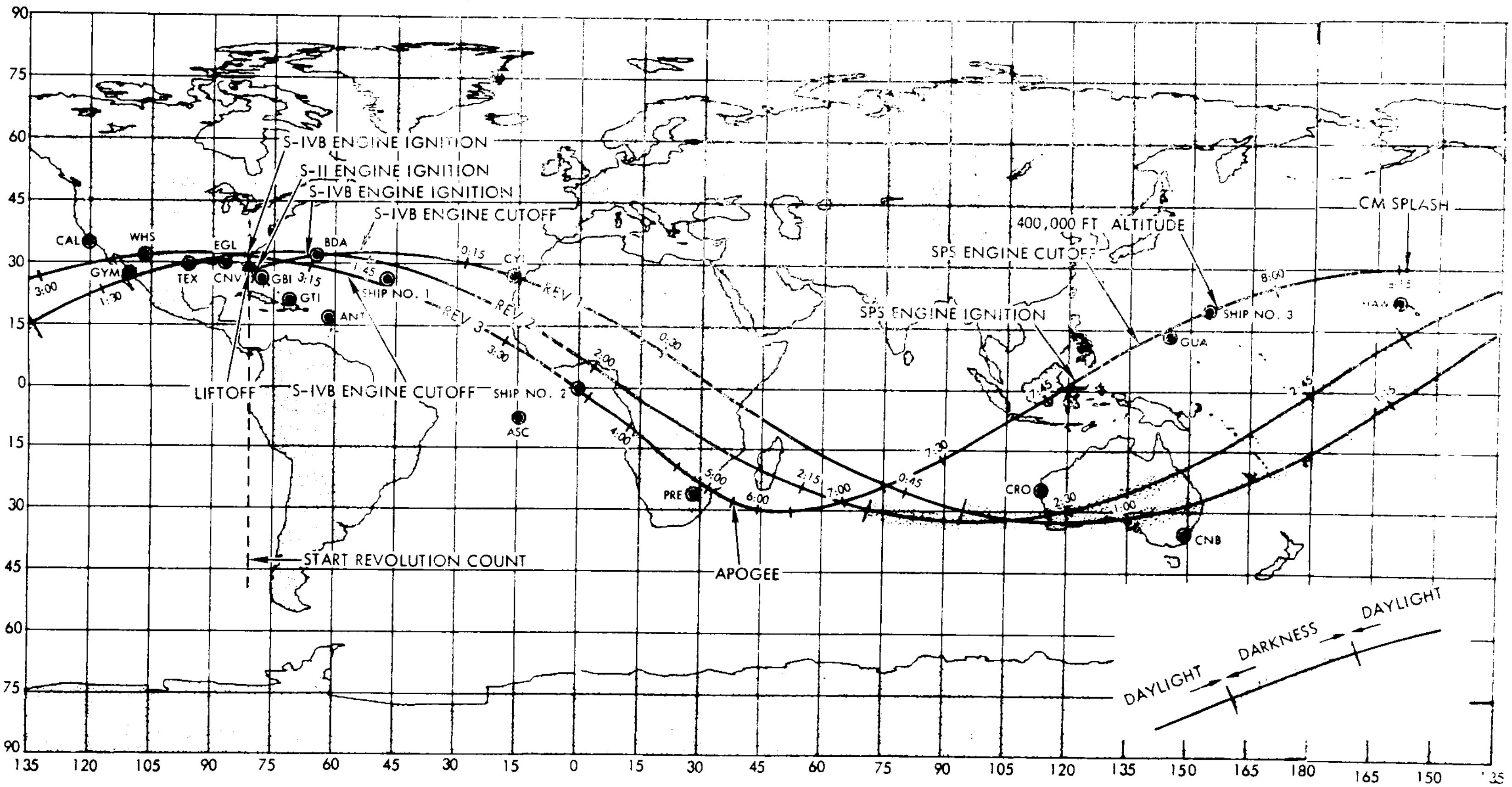


Figure 6-1. Ground Track

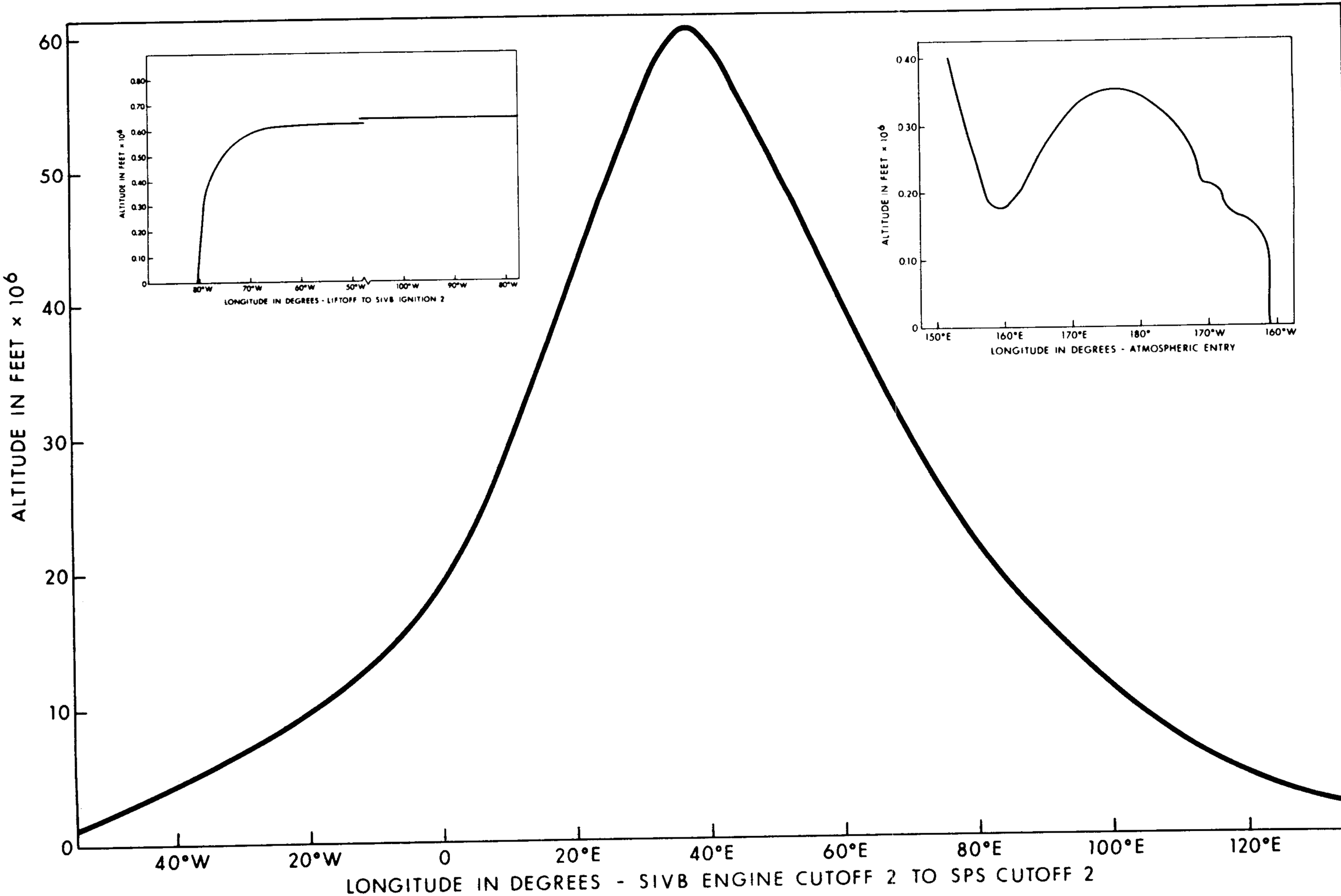


Fig. 6-2 Altitude - Longitude History

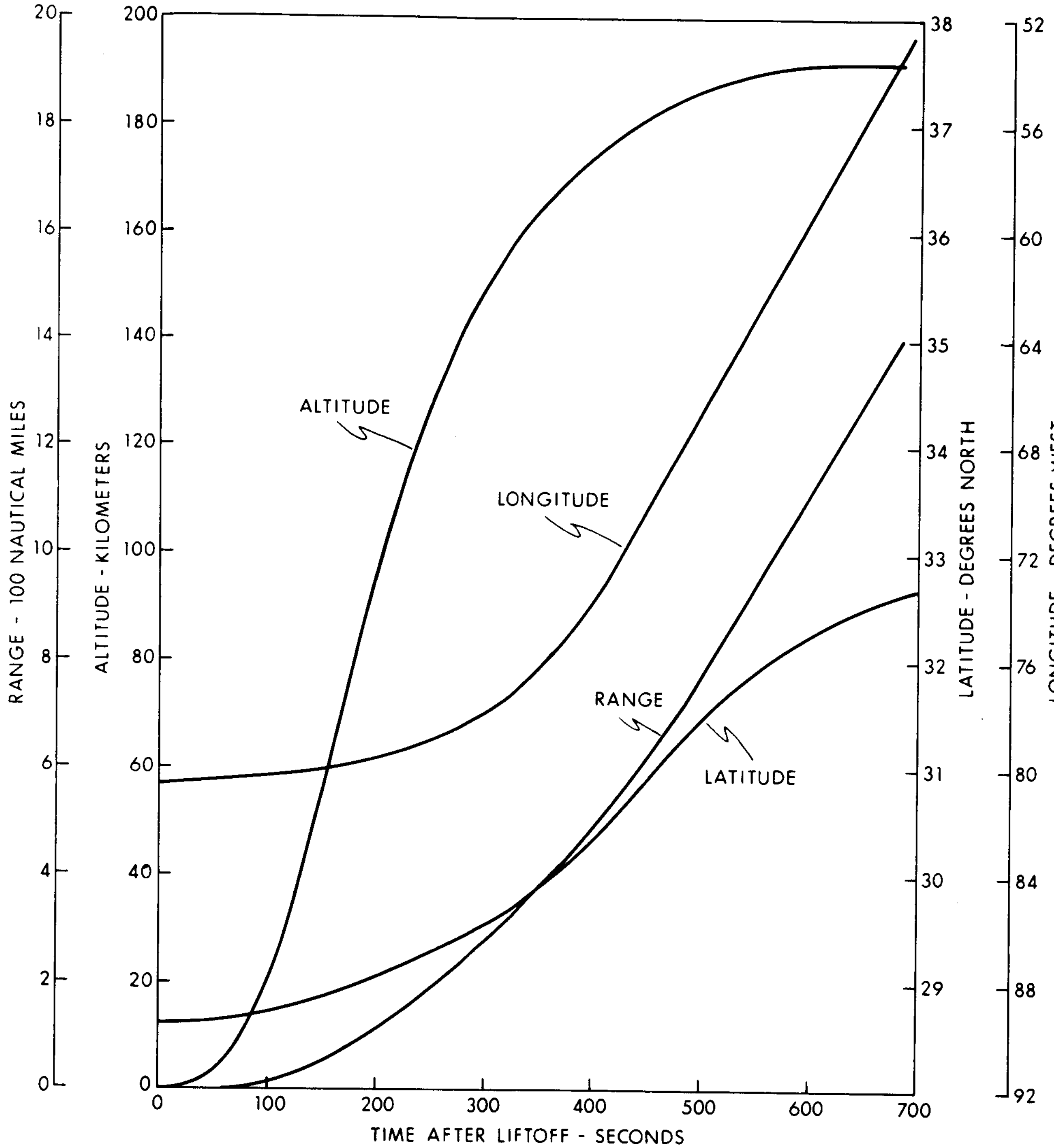


Fig. 6.3 Longitude, Latitude, Altitude, and Range During Boost to Parking Orbit

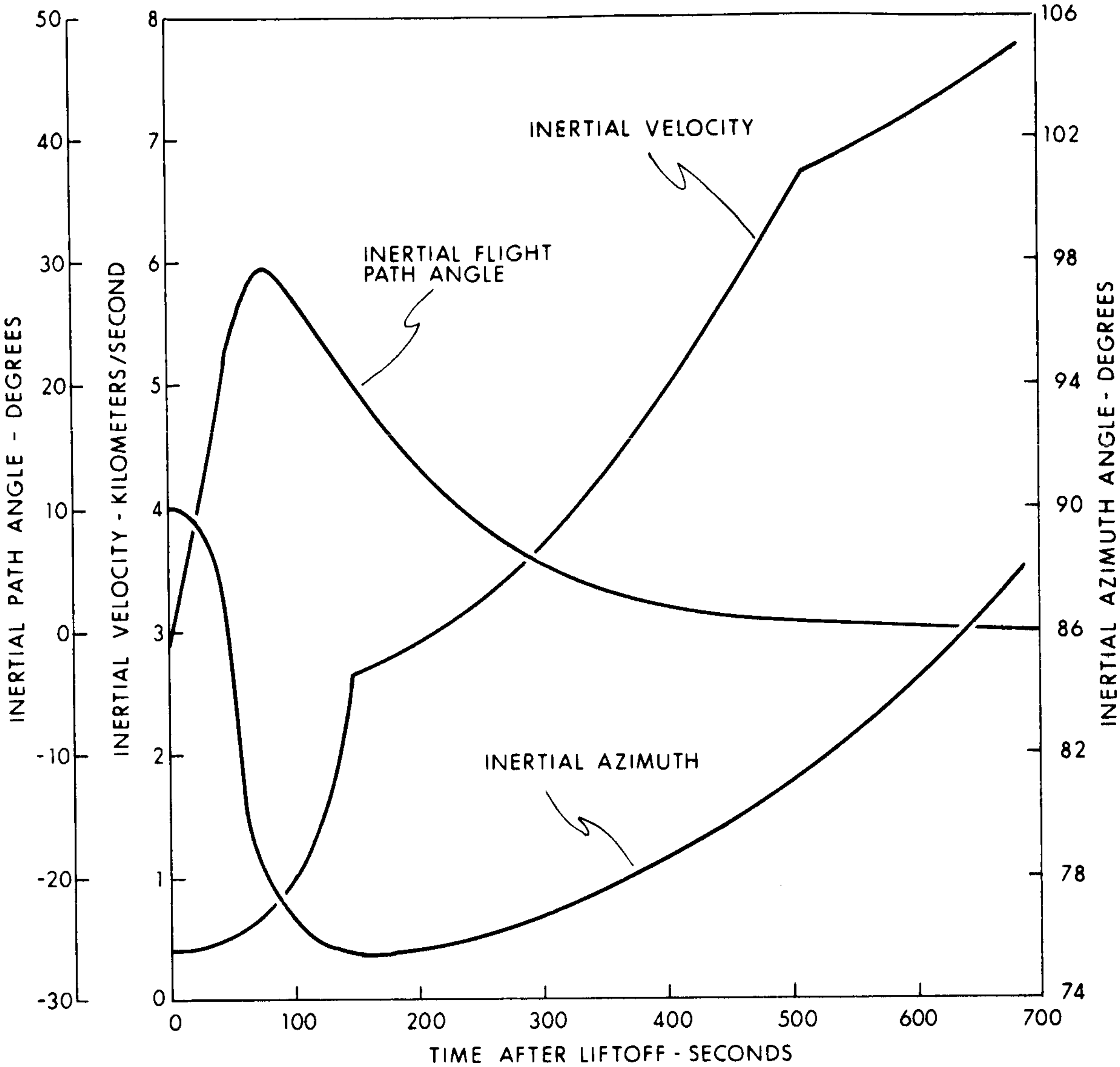


Fig. 6.4 Inertial Azimuth, Inertial Velocity, and Inertial Path Angle During Boost to Parking Orbit

TABLE 6.1 Mission AS-501 Sequence of Events

Event	Time From Launch (second)	Latitude (degree)	Longitude (degree)	Altitude (feet)	Inertial Velocity (ft/sec.)	Inertial Flight Path Angle (degree)	Inertial Azimuth Angle (degree)
Liftoff	0.0	28.608°N	80.604°W	90.00	1340.5	0.000	90.00
S-I C Cutoff	148.846	28.826°N	79.834°W	194,326.00	8776.5	20.255	75.355
LES Jettison	183.846	29.030°N	79.086°W	288,983.00	9263.6	15.044	75.557
S-II Cutoff	511.526	31.634°N	66.218°W	613,705.00	22072.9	0.925	81.213
S-IV B Cutoff #1	687.542	32.681°N	53.916°W	627,948.00	25567.7	0.000	88.049
S-IV B Ignition #2	11486.034	31.8527°N	81.4931°W	646,543.00	25560.2	0.016	97.945
S-IV B Cutoff #2	11821.758	27.5369°N	56.8107°W	1,918,798.75	30669.4	15.487	103.496
CSM/S-IV B Separation	12423.458	14.8071°N	23.6097°W	8,179,087.25	25978.9	26.792	116.796
CSM SPS Ignition #1	12517.758	12.8959°N	20.2074°W	9,289,355.50	25285.4	27.941	117.702
CSM SPS Cutoff #1	12545.303	12.3519°N	19.2727°W	9,620,434.50	25393.3	28.751	117.930
Apogee	20925.644	28.9052°S	37.3390°E	60,079,460.00	8395.4	-0.000	100.036
CSM SPS Ignition #2	29686.215	4.21746°N	118.100° E	5,141,221.00	28349.9	-23.008	59.950
CSM SPS Cutoff #2	29947.752	12.9918°N	132.888°E	2,216,140.75	34874.1	-17.736	62.332
CM/SM Separation	-------(not	available)	--------	---------	-----	-----	-----
Entry 400,000 ft.	30183.329	21.9905°N	152.151°E	400,000.00	36334.2	-7.1209	68.466
Drogue Chute Deployment	31066.774	30.2075°N	161.103°W	23,500.00	1415.3	-18.1694	89.338
Entry (no SPS burns) 399,999 feet	28683.148	21.2845°N	203.299°W	399,999.00	32067.97	-9.1888	67.984

NOTE: Altitudes are measured above the Fischer reference Ellipsoid of 1960. See Section 6.5

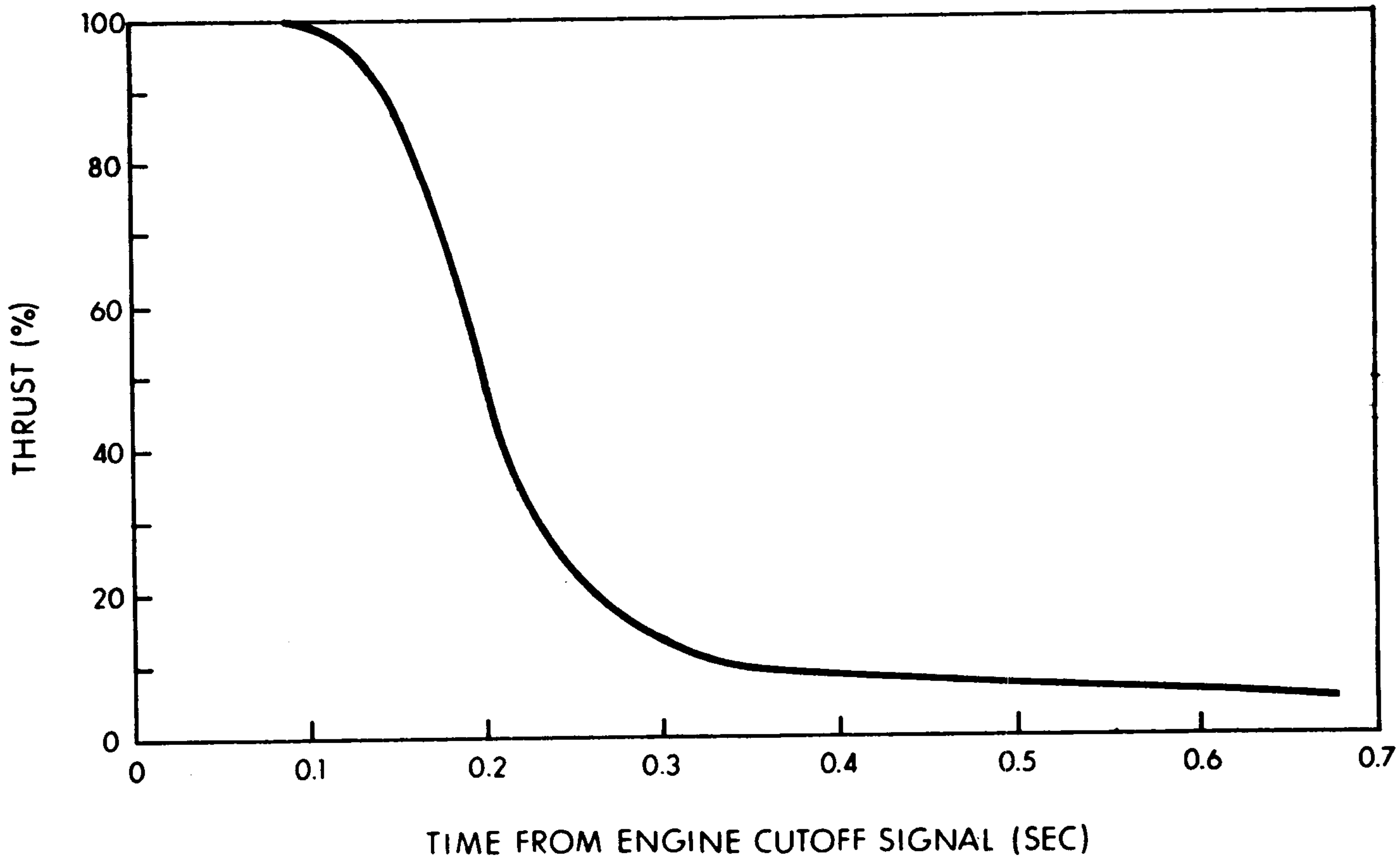


Fig. 6.5 SIVB Thrust Decay to 5% Thrust

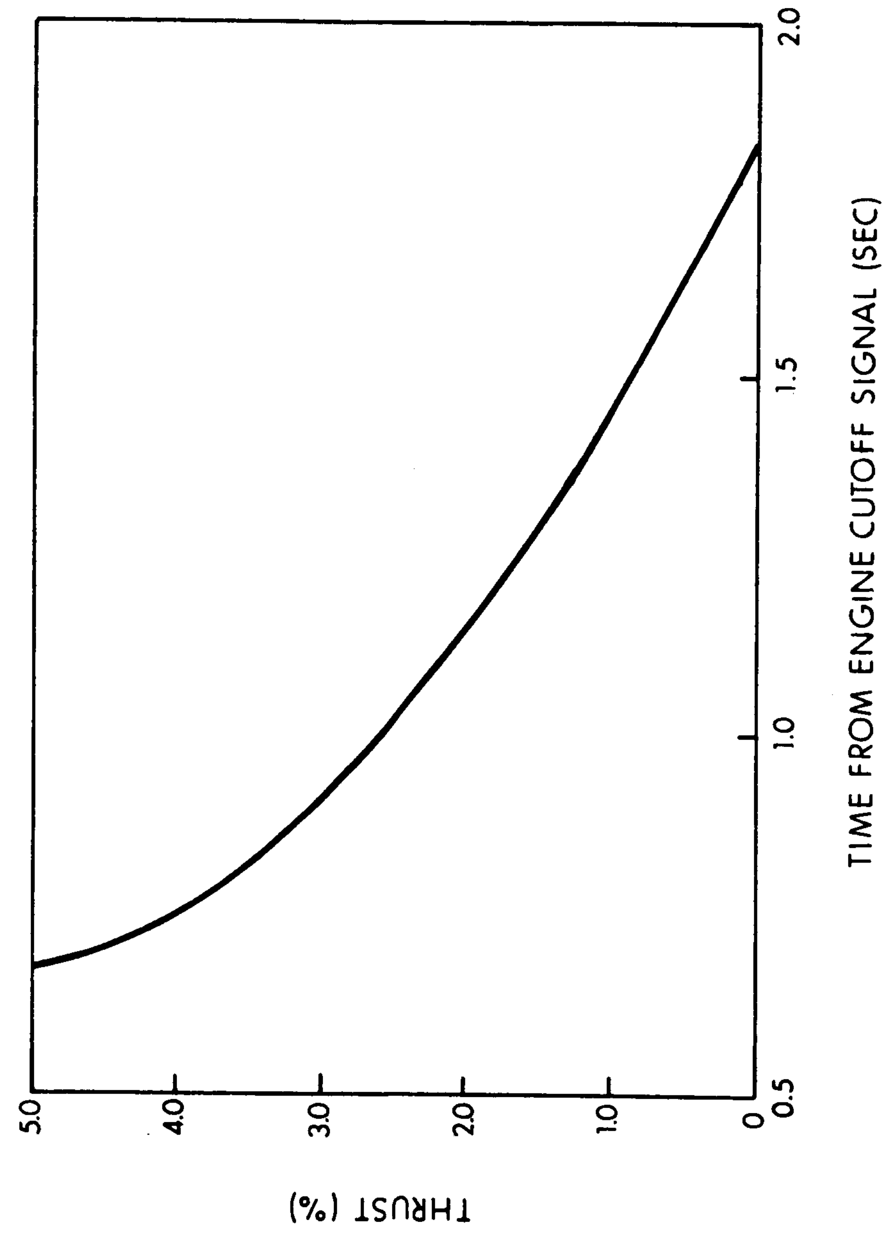


Fig. 6.6 SIVB Thrust Decay from 5% Thrust

6.3 CMC Memory Data

6.3.1 Prelaunch

6.3.1.1 Launch Pad #39A	Memory	Value
Geodetic latitude	E	28° 38' 50.93" N
Longitude	E	279°21' 51.93" E
Geocentric radius	E	6373283 meters
Geocentric radius to G&N	-	not available
Fischer Ellipsoid radius	E	not available
Geoidal separation (ht. of MSL above ellipsoid)	-	0 meter
Attitude of pad above MSL	-	not available
Inertial reference plane azimuth	E	72° E of N
Optical target #1 : azimuth	E	291.00°
elevation	E	-015.02°
Optical target #2: azimuth	E	253.00°
elevation	E	-014.90°

The geophysical data in this section are taken from NASA document M-DE-8020-008B, "Natural Environment and Physical Standards for the Apollo Program", April 1965.

6.3.1.2 Cold Soak Attitude

The cold soak attitude will be a fixed attitude with respect to the stable member. The desired attitude is defined as three angles included in prelaunch erasable memory load.

Angle X	E	37.81762010°
Angle Y	E	-108.9135267°
Angle Z	E	-5.050401772°

The above data are taken from MIT/IL Record of Change Form #501-8.

6.3.1.3 Prelaunch Erasable Memory Load Table 6.2

The following is a list of the terms, their definitions, SOLRUM 55 addresses, scale factors and units, decimal values, and octal equivalents for the erasable data load for digital simulations. Some of these terms will undoubtedly change before flight time. (Table is dated 26 October 1966).

Table 6.2 Prelaunch Erasable Memory Load

ERASABLE NAME	DEFINITION FOR ERASABLE DATA LOAD	ADDRESS	SCALE FACTOR(0)	DECIMAL VALUE		OCTAL LOAD
IMU COMPENSATION						
GBIASX	GYRO BIAS DRIFT	0744	2^{-6} (GYRO PULSES/ CENTI-SEC)	DEC -702	(1)	76501
GBIASY		0745		DEC -383		77200
GBIASZ		0746		DEC 625		01161
ADIAX	ACCELERATION-SENSITIVE GYRO DRIFT ALONG THE INPUT AXIS	0747	GYRO PULSES/ PIPA PULSE	DEC -9		77766
ADIAY		0750		DEC 1		00001
ADIAZ		0751		DEC 6		00006
ADSRAX	ACCELERATION-SENSITIVE GYRO DRIFT ALONG THE SPIN-REFERENCE AXIS	0752	GYRO PULSES/ PIPA PULSE	DEC -2		77775
ADSRAY		0754		DEC -8		77767
ADSRAZ		0756		DEC 2		00002
PBIASX	PIPA BIAS FACTOR	0736	2^{-8} (PIPA PULSES/ CENTI-SEC)	DEC 3011		05703
PBIASY		0740		DEC -3442		71215
PBIASZ		0742		DEC -1291		75364
PIPASCFX	PIPA SCALE FACTOR	0737	2^{-11} (PIPA COUNTS/PIPA COUNT)	DEC -11140		52173
PIPASCFY		0741		DEC -7348		61513
PIPASCFZ		0743		DEC -4765		66542
PRELAUNCH ALIGNMENT						
DTEPOCH	ELAPSED TIME BETWEEN THE TIME THE LAUNCH VECTOR PASSED THROUGH THE INERTIAL Z-X PLANE AND THE TIME THE AGC CLOCK WAS ZEROED	1073	2^{28} CENTI-SEC	2DEC 6200499	(2)	00572 16263
VAZ	AZIMUTH OF VEHICLE Z-AXIS EAST OF NORTH	1352	1 REVOLUTION	2DEC -.25	(3)	67777 77777
LATITUDE	LOCAL VERTICAL ASTRONOMICAL LATITUDE OF LAUNCH PAD 39	1314	1 REVOLUTION	2DEC 0.079576327	(4)	02427 30724

AZIMUTH	AZIMUTH OF STABLE MEMBER Z-AXIZ EAST OF NORTH	1316	1 REVOLUTION	2DEC 0.2	(5)	06314 31463
POLYENTR	TRANSFER TO PITCH MONITOR POLYNOMIAL ROUTINE	1573	-	TC POLY		05554
POLYEND	TRANSFER AT END OF POLYNOMIAL ROUTINE	1613	-	TC DANZIG		04024
POLYCOFF + 0D	COEFFICIENTS A_N OF THE BOOST POLYNOMIAL	1575	16 REVS.	2DEC -4.728695766E-6 B-4		77777 77660
POLYCOFF + 2D		1577		2DEC +4.874580820E-5 B+10		00121 31013
POLYCOFF + 4D	$A_0 + A_1 T + A_2 T^2 + \ldots + A_6 T^6$	1601	16 REV / 2^{14N} CENTISEC	2DEC +8.297180312E-10 B+24		00344 02216
POLYCOFF + 6D		1603		2DEC +8.338358159E-13 B+38		07253 10431
POLYCOFF + 8D		1505		2DEC -1.745826987E-16 B+52		46656 42203
POLYCOFF +10D		1607		2DEC +1.249994672E-20 B+66		35407 20210
POLYCOFF +12D		1611		2DEC -3.118098555E-25 B+80		63736 46417
TROLL	TIME FROM LIFT-OFF AT WHICH ROLL MONITOR BEGINS	1562	2^{28} CENTI-SEC	2DEC 810		00000 01452
TPITCH	TIME FROM LIFT-OFF AT WHICH PITCH MONITOR BEGINS	1564	2^{28} CENTI-SEC	2DEC 1300		00000 02424
TENDPTCH	TIME PITCH MONITOR IS ON	1566	2^{28} CENTI-SEC	2DEC 13185		00000 31601
MAXROLL	FINAL ROLL ANGLE MINUS INITIAL ROLL ANGLE	1702	1 REVOLUTION	2DEC .05	(6)	01463 06315
1/RLLRTE	ONE OVER DESIRED ROLL RATE	1700	$36000/2^{28}$ CENTISEC/REV	2DEC 3.6 E4 B-28	(7)	00002 06240
TTUMON	NOMINAL TIME FROM END OF PITCH MONITOR TO START OF TUMBLE MONITOR	1572	2^{14} CENTI-SEC	DEC 3815		07347
TAZ	AZIMUTH OF LANDMARK 1 AT LAUNCH SITE	1346	ICDU SCALING		(8)	
TAZ +1	AZIMUTH OF LANDMARK 2 AT LAUNCH SITE	1347			(9)	
TEL	ELEVATION OF LANDMARK 1 AT LAUNCH SITE	1350	1/4 REV		(10)	
TEL +1	ELEVATION OF LANDMARK 2 AT LAUNCH SITE	1351			(11)	
TATLAN1	NOMINAL FLIGHT TIME TO ATLANTIC TARGET	1617	2^{28} CENTI-SEC	2DEC 135000	(12)	00010 07530
RTATLAN1	POST-LET ABORT TARGET VECTOR AT LIFT-OFF + TATLAN1 IN IMU COORDINATES. ASSUMING THE PLATFORM GOES INERTIAL AT LIFT-OFF	1621	HALF-UNIT VECTOR	2DEC 5.314826438 E-1 B-1		10401 34771

RTATLANI +2		1623		2DEC 1.447898020 E-2 B-1	00166 23450
RTATLANI +4		1625		2DEC 8.469454276 E-1 B-1	15432 05523
TPACIF1	NOMINAL FLIGHT TIME TO PACIFIC TARGET	1627	2^{28} CENTI-SEC	2DEC 3106677 (13)	00275 23565
RTPACIF1	NOMINAL PACIFIC TARGET VECTOR AT LIFT-OFF + TPACIF1 IN IMU COORDINATES, ASSUMING THE PLATFORM GOES INERTIAL AT LIFT-OFF	1631	HALF-UNIT VECTOR	2DEC +7.352864243 E-1 B-1	13607 16731
RTPACIF1 +2		1633		2DEC +4.233019840 E-2 B-1	00532 30467
RTPACIF1 +4		1635		2DEC +6.764333141 E-1 B-1	12645 12737
UNITW	POLAR AXIS IN STABLE MEMBER COORDINATES	1043	HALF-UNIT VECTOR	2DEC +0.479418298 B-1 (14)	07527 14503
UNITW +2		1045		2DEC -0.834638185 B-1	62512 64466
UNITW +4		1047		2DEC +0.271177423 B-1	00255 17422
RN	POSITION VECTOR AT GRR	0765	2^{25} METERS	2DEC +6.373383925 E+6 B-25	06050 00077
RN +2		0767		2DEC +1.708965500 E+4 B-25	00010 13015
RN +4		0771		2DEC -5.552990700 E+3 B-25	77775 51167

MISSION CONTROL PROGRAM

TDECAμ	EFFECTIVE THRUST DECAμ TIME	1560	2^{10} CENTI-SEC	DEC -41	77726
DELTAT	VALUE OF COMPUTING INTERVAL	1027	2^{9} CENTI-SECS	2DEC 200 B-9	14400 00000
1/PIPADT	VALUE OF ACCELEROMETER SAMPLING INTERVAL	0755	2^{8} CENTI-SECS	DEC 200 B-8	31000
NSHIFT	AVERAGE G ROUTINE SCALING CONSTANT	1040	-	DEC -5	77772
XSHIFT	AVERAGE G ROUTINE SCALING CONSTANT	1041	-	DEC 9	00011
ESQ(VR)	ECCENTRICITY SQUARED FOR SPS1 BURN	1546	2^{4}	2DEC .3538035468 B-4 (15)	00552 11337
ESQ(VR) +2	ECCENTRICITY SQUARED FOR SPS2 BURN	1550		2DEC .9984440601 B-4	01776 15010
SEMILAT	SEMI-LATUS RECTUM FOR SPS1 BURN	1552	2^{27} METERS	2DEC 1.001146995 E7 B-27	02306 03234
SEMILAT +2	SEMI-LATUS RECTUM FOR SPS2 BURN	1554		2DEC 1.279126488 E7 B-27	03031 15702

TFFMIN	TIME-TO-FREE-FALL AT WHICH TO SCHEDULE SPS2 IGNITION IN 2 MINUTES	1676	2^{28} CENTI-SEC	2DEC 72000	(16)	00004 14500
TFFNOM	VALUE OF TFF TO USE TO COMPUTE TIME-OF-COAST IF TFF IS NOT COMPUTABLE	1720	2^{28} CENTI-SEC	2DEC 1620000	(17)	00102 24040
CGY	SPS1 C.G. ROTATION ABOUT S/C Y-AXIS	1704	RADIANS	2DEC 0.0276	(18)	00704 06263
CGY +2	SPS2 C.G. ROTATION ABOUR S/C Y-AXIS	1706		2DEC 0.0350		01075 16051
CGZ	SPS1 C.G. ROTATION ABOUT S/C Z-AXIS	1710		2DEC 0.0935		02773 34733
CGZ +2	SPS2 C.G. ROTATION ABOUT S/C Z-AXIS	1712		2DEC 0.1105		03422 15646
ATDT	SPS1 INTEGRATED INITIAL THRUST ACC. MAG.	1714	2^{5} M/CENTISEC	2DEC 9.589 E-2 B-5	(19)	00061 03040
ATDT +2	SPS2 INTEGRATED INITIAL THRUST ACC. MAG.	1716		2DEC 30.48 E-2 B-5		00234 01660
S2SWITCH	SWITCH TO RE-COMPUTE SPS2 BURN ATTITUDE	1722	-	OCT 0		00000
REFSWTCH	SWITCH TO FORCE 280K FT FF REFERENCE	1723	-	OCT 0		00000
REDOSPS1	SWITCH TO REPEAT SPS1 AT SPS2 IGNITION	1724	-	OCT 0		00000
ANGLEX	DESIRED COLD SOAK GIMBAL ANGLES	1673	ICDU SCALING	DEC +0.210097	(20)	06562
ANGLEY		1674		DEC -0.605075		54505
ANGLEZ		1675		DEC -0.0280577		77063
UPTIME	TIME TO INCORPORATE 1ST R.V.T. UPDATE	1671	2^{28} CENTI-SEC	OCT 37777	(21)	37777
UPTIME +1		1672	2^{14} CENTI-SEC	OCT 37777		37777

NOTES

```
0)  SCALE FACTOR IS THE MAXIMUM VALUE THAT CAN BE REPRESENTED IN THE AGC FOR THIS VARIABLE
1)  MEASURED VALUES AS OF 9/22/66
2)  ASSUMES AGC CLOCK ZEROED AT 1 P.M. ON FEB. 15, 1967
3)  DUE WEST
4)  28 DEG, 38 MIN, 50.92 SEC
5)  72 DEGS
6)  18 DEGS
7)  DESIRED ROLL RATE = 1 DEG/SEC
8)  V21 N66 DSKY LOAD IS +291.00 DEG
9)  V21 N66 DSKY LOAD IS +253.00 DEG
10) V21 N66 DSKY LOAD IS -015.02 DEG
11) V21 N66 DSKY LOAD IS -014.90 DEG
12) 28.35 DEG LAT, -19.5 DEG LONG, AT 1350 SECS AFTER LIFT-OFF
13) 30.20752703 DEG LAT, -161.1032543 DEG LONG, AT L/O + 31,066.77
14) 28.64747778 DEG LAT, 279.364425 DEG LONG, AT LAUNCH SITE
15) SPS1 ECC = .5948138758, SEMILAT = 32,846,030 FT
    SPS2 ECC = .9992217272, SEMILAT = 41,966,092 FT
16) 12 MINUTES
17) 4 HOURS, 30 MINUTES
18) 1.58136351, 2.00535228, 5.35715536, 6.3311836 DEGS
19) CORRESPONDS TO VELOCITY INCREMENTS OF 0.09585, 0.3048 METER/CENTISEC
20) 37.81762010, -108.9135267, -5.050401772 DEGS
21) INITIALIZED TO 31 DAYS, 1 HOUR, 40 MINUTES, 54.56 SECONDS
```

6.3.2 Saturn Launch Vehicle Boost Phase

		Memory	Value
Interval from liftoff to LET jettison (assumed complete)		E	184.0 seconds
Interval from liftoff to start of roll maneuver		E	8.1 seconds
Duration of roll maneuver		E	18.0 seconds
Total roll maneuver angle		E	18.0 degrees
Maximum roll maneuver rate		E	1 degree/second
Interval from liftoff to start of pitch maneuver		E	13 seconds
Duration of pitch maneuver		E	131.85 seconds
Pitch polynominal coefficients:	A_0	E	$-4.728695766 \times 10^{-6}$
	A_1	E	$+4.874580890 \times 10^{-6}$
	A_2	E	$+8.297180312 \times 10^{-10}$
	A_3	E	$+8.338368159 \times 10^{-13}$
	A_4	E	$-1.745826987 \times 10^{-16}$
	A_5	E	$+1.249994672 \times 10^{-20}$
	A_6	E	$-3.118989855 \times 10^{-25}$

NOTE 1 The form of the pitch polynomial is:

$$\Theta = \sum_{n=0}^{6} A_n t^n$$

where Θ = angle between inertial horizontal at launch and the vehicle X - axis, in degrees.

t = time in seconds when t = 0 at liftoff +10 seconds.

6.3.3 Attitude Maneuver Memory Data

Attitude maneuver constants will be found in the CSM guidance equation section of this document. These referenced values are found in the fixed memory.

6.3.4 Thrust Vector Control (TVC) Memory Data

Refer to CSM guidance equation section of this document. These referenced values are found in the fixed memory. (For nominal and abort missions.)

6.3.5 Programmed Time Delays

The preset delays between events are outlined in the mission logic and timeline section of this document. Some of these delays are in fixed memory and others in erasable memory. Erasable memory delays are underlined.

6.3.6 Guidance and Navigation Constants

The constants used in the guidance and navigation equations are presented in Section 5 of this document. These constants are in the fixed portion of the memory.

6.3.7 Re-Entry Memory Data

CSM attitude for CM/SM separation:

X_{sc} - axis is above the velocity vector by 60^o

Y_{sc} - axis along the momentum vector $\underline{R} \times \underline{V}$

Z_{sc} - axis above the velocity vector

CM Re-Entry Attitude:

X_{sc} - axis is above the velocity vector by 158^o

Y_{sc} - axis is along the momentum vector $\underline{R} \times \underline{V}$

Z_{sc} - axis above the velocity vector

(Assume a lift-vector up attitude)

Trim angle of attack	22^o
Nominal recovery point:	
Geodetic latitude	30.2075 ^oN
Longitude	161.103 ^oW

A complete listing of (1) computer variables in the CMC erasable memory, and (2) constants and gains in the CMC fixed memory may be found in the CM re-entry guidance equation section of this document.

6.4 Spacecraft Vehicle Data

6.4.1 Apollo Vehicle Coordinate Reference System

Spacecraft CSM-017 reference dimensions Fig. 6.7

The above figure is taken from TRW Systems Document #2131-H009-R8-000 "Apollo Mission Data Specification D" dated 15 August 1966.

SM RCS, SPS, and fuel tank configuration Fig. 6.8

Source unknown

6.4.1.1 Specific Station Locations

RCS jet thruster locations and vectors Table 6.3

The information in this table is compiled from the GN&C Data Exchange Program, NAA-S-22 submitted 7 April 1965.

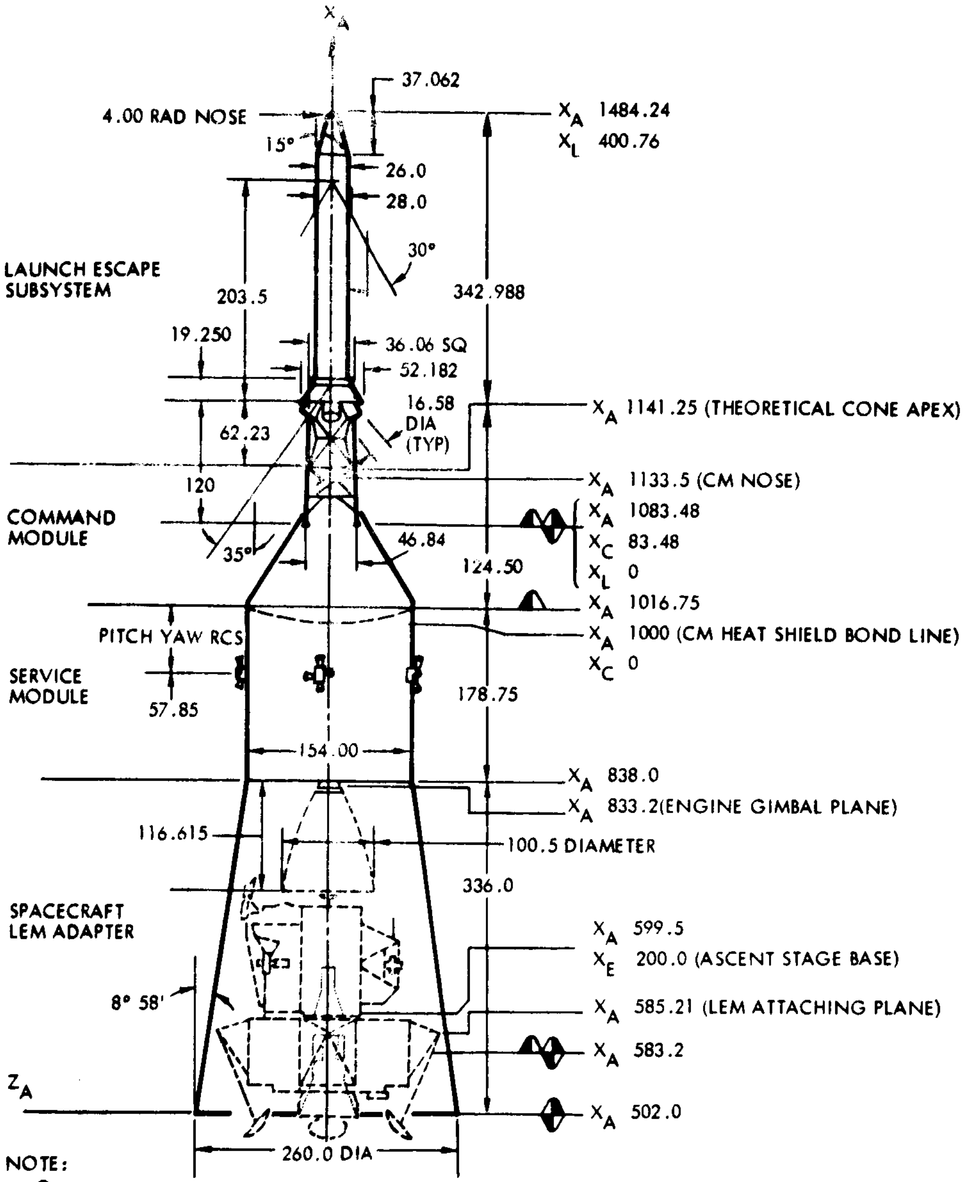
SPS fuel and oxidizer tank dimensions and locations Table 6.4

The information in this table is taken from the GN&C Data Exchange Program, NAA-S-68 submitted 11 March 1966.

SPS engine gimbal plane

X_A location	833.20	inches
Y_A location	0.0	inches
Z_A location	0.0	inches

This information is taken from the GN&C Data Exchange Program, NAA-S-68 submitted 11 March 1966.



NOTE:

- SEPARATION PLANE
- FIELD SPLICE

X_A APOLLO SPACECRAFT (CSM) COORDINATE SYSTEM

X_E LEM COORDINATE SYSTEM

X_C CM COORDINATE SYSTEM

X_L LES COORDINATE SYSTEM

ALL LINEAR DIMENSIONS ARE IN INCHES

Fig. 6.7 Spacecraft CSM-017 Reference Dimensions

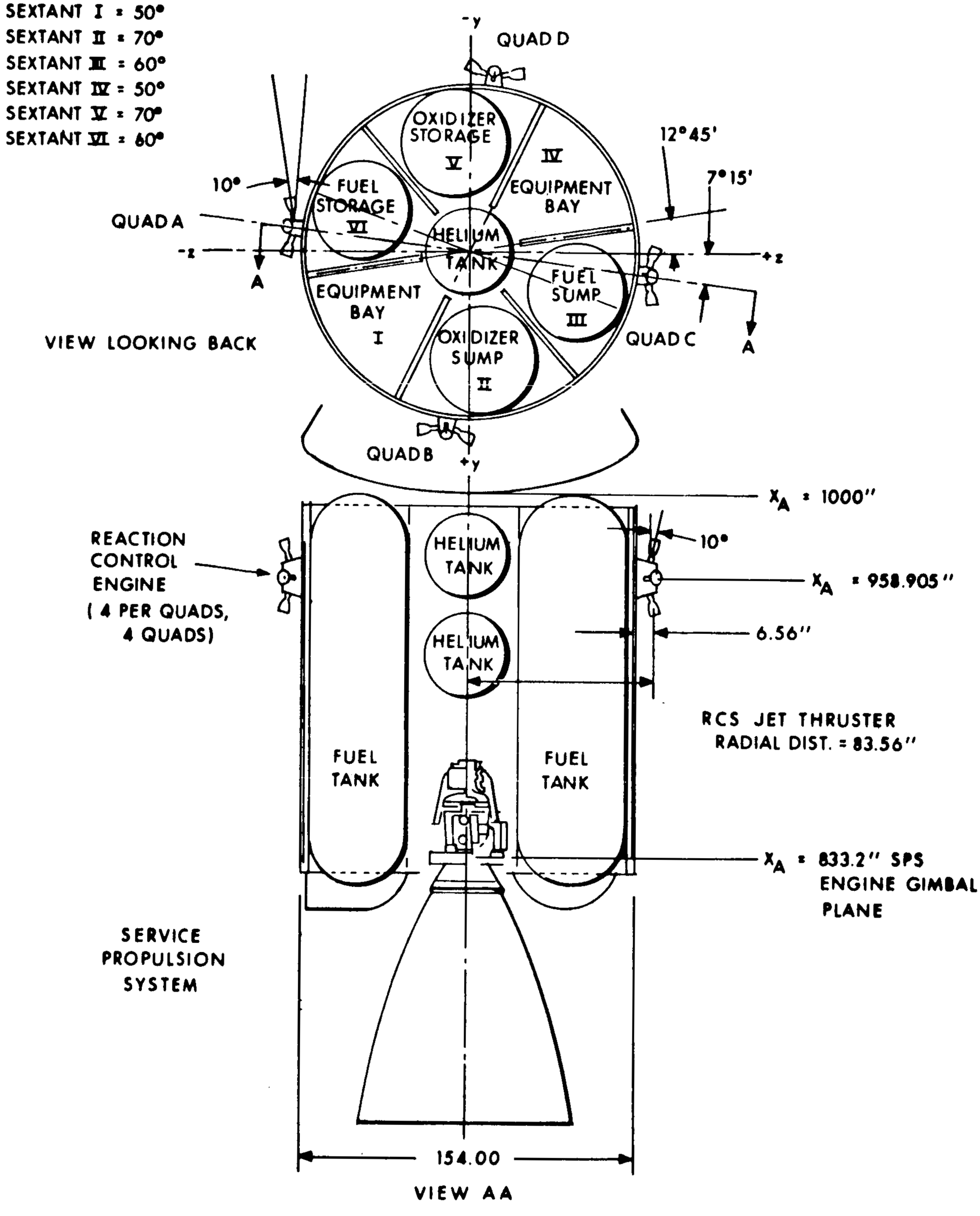


Fig. 6. 8 CSM-017 RCS, SPS and Fuel Tank Configuration

Table 6.3 RCS Jet Thruster Locations and Vectors

Apollo Stations of Four Jet Quads	X_A - Component in Inches	Y_A - Component in Inches	Z_A - Component in Inches
Quad A	958.905	-83.56 sin (7, 25°)	-83.56 cos (7.25°)
Quad B	958.905	83.56 cos (7.25°)	-83.56 sin (7.25°)
Quad C	958.905	83.56 sin (7.25°)	83.56 cos (7.25°)
Quad D	958.905	-83.56 cos (7.25°)	83.56 sin (7.25°)

Thrust Unit Vector*	X - Component	Y - Component	Z - Component
RCS Jet 1, Quad C	cos (10°)	0	-sin (10°)
2, Quad A	cos (10°)	0	sin (10°)
3, Quad A	-cos (10°)	0	sin (10°)
4, Quad C	-cos (10°)	0	-sin (10°)
5, Quad D	cos (10°)	sin (10°)	0
6, Quad B	cos (10°)	-sin (10°)	0
7, Quad B	-cos (10°)	-sin (10°)	0
8, Quad D	-cos (10°)	sin (10°)	0
9, Quad B	0	-sin (10°)	cos (10°)
10, Quad D	0	sin (10°)	cos (10°)
11, Quad D	0	sin (10°)	-cos (10°)
12, Quad B	0	-sin (10°)	-cos (10°)
13, Quad A	0	cos (10°)	sin (10°)
14, Quad C	0	cos (10°)	-sin (10°)
15, Quad C	0	-cos (10°)	-sin (10°)
16, Quad A	0	-cos (10°)	sin (10°)

*Thrust vectors are specified as though the quad centers were on the Apollo **Y and Z axes.**

Table 6.4 SPS Fuel and Oxidizer Tank Dimensions and Locations

Tank Position in Spacecraft's X_A, Y_A, Z_A Coordinates*	Radius in inches	X_A - Top in inches	X_A - Bottom in inches	Y_A in inches	Z_A in incnes
V Oxidizer Storage Tank	25.5	985.8	832.0	-48.3	-6.6
II Oxidizer Sump Tank	25.5	985.8	832.0	48.3	6.6
VI Fuel Storage Tank	22.5	988.65	832.0	-14.8	-47.8
III Fuel Sump Tank	22.5	988.65	832.0	14.8	47.8

*Mixture ratio = 2.0

6.4.2 Apollo Vehicle Mass Property Data

CSM spacecraft mass properties summary	Table 6.5
SM vehicle mass properties summary	Table 6.6
CSM spacecraft propellant loading summary	Table 6.7
SM-SPS usable propellant data	Table 6.8

The information in this section is taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501" dated 15 August 1966.

6.4.3 Apollo Vehicle Dynamic Data

6.4.3.1 Slosh - Mixture Ratio of 2.0/1.0

Oxidizer slosh frequency	3.82 rad/second
Fuel slosh frequency	4.07 rad/second
Oxidizer equivalent slosh mass	44.55 slugs
Fuel equivalent slosh mass	13.7 slugs
Oxidizer slosh C.G. X-location	970 to 840 inches
Fuel slosh C. G. X-location	974 to 840 inches
Oxidizer slosh C.G. Y-location	-48.3 to 48.3 inches
Fuel slosh C.G. Y-location	14.8 to -14.8 inches
Oxidizer slosh C.G. Z-location	-6.6 to 6.6 inches
Fuel slosh C. G. Z-location	47.8 to -47.8 inches
Oxidizer slosh damping ration	0.005
Fuel slosh damping ration	0.005

The X-locations of the sloshing masses were obtained by eyeballing the SM diagram in NAA XTASI entry 13 page 3, together with XTASI 24 page 8. The Y- and Z- locations are taken from the GN&C Data Exchange Program, NAA-S-68 submitted 11 March 1966. Allowance has been made for the fact that fuel and ozidizer tank assignments differ between Block I and Block II.

Table 6.5 AS-501 Spacecraft Mass Properties Summary[1]

Spacecraft Systems/Subsystems	Weight (lb)	Center of Gravity[2] (in)			Moment of Inertia[3] (slug-ft²)			Product of Inertia[3] (slug-ft²)		
		X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
Spacecraft Systems/Subsystems										
Launch Escape Subsystem	8,420 ± 100	1,296.6 ± 0.5	0.0 ± 0.1	-0.6 ± 0.1	677	23,707	23,699	18	290	1
Command Module	11,250 ± 300	1,040.4 ± 1.5	0.7 ± 0.8	5.5 ± 0.5	5,658	4,962	4,387	-3	-231	12
Service Module	40,512 ± 313	906.8 ± 0.5	18.4 ± 0.3	-1.0 ± 0.3	18,526	30,065	28,880	516	-2,030	2,790
SLA	3,738 ± 100	638.0 ± 0.5	1.3 ± 0.5	-1.0 ± 0.5	9,611	12,394	12,092	-3	-2,028	49
LTA-10	29,500 ± 200	587.5 ± 1.0	0.1 ± 0.5	0 ± 0.5	19,900	21,600	22,000	0	0	0
Spacecraft at Liftoff	93,420 ± 498	846.5 ± 1.0	8.2 ± 0.2	0.1 ± 0.3	56,089	1,046,653	1,046,409	10,232	-7,679	2,675
Remove Launch Escape System	8,420 ± 100	1,296.6 ± 0.5	0.0 ± 0.1	-0.6 ± 0.1	677	23,707	23,699	18	290	1
Spacecraft in Earth Orbit	85,000 ± 488	801.9 ± 1.1	9.0 ± 0.3	0.2 ± 0.3	55,277	613,065	617,820	17,564	-7,314	2,662
Remove SLA	3,738 ± 100	638.0 ± 0.5	1.3 ± 0.5	-1.0 ± 0.5	9,611	12,394	12,092	-3	-2,028	49
Remove LTA-10	29,500 ± 200	587.5 ± 1.0	0.1 ± 0.5	0 ± 0.5	19,900	21,600	22,000	0	0	0
CSM-017 in Earth Orbit	51,762 ± 434	935.9 ± 0.8	14.6 ± 0.3	0.4 ± 0.2	24,862	69,021	67,777	-3,985	-6,016	2,582

NOTES:

(1) All tolerances shall be used as 3σ values.

(2) Centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(3) Moments and products of inertia are about the center of gravity of each item. The 3σ tolerance on moments and products of inertia are ± 15%.

Table 6.6 AS-501 Service Module Mass Properties

	Weight (lb)	Center of Gravity[2] (in)			Moment of Inertia[3] (slug-ft²)			Product of Inertia[3] (slug-ft²)		
		X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
Service Module, Inert[3]	9,193	908.2	0.7	-0.6	5,705	10,011	9,732	337	-579	-361
SLA Attach Ring	62	837.1	0.0	-1.8	93	48	46	0	0	0
SPS Propellant in Tank										
Fuel	10,127	901.8	-7.8	-36.5	1,244	5,468	4,913	-609	-984	557
Oxidizer	20,299	906.8	40.3	16.4	2,242	9,292	8,835	706	-868	-1,097
RCS Propellant in Tank[4]	831	959.0	0.0	0.0	853	544	441	0	0	0
Total Service Module[5]	40,512 ± 313	906.8 ± 0.5	18.4 ± 0.3	-1.0 ± 0.3	18,526	30,065	28,880	516	-2,030	2,790

Notes:

(1) Centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(2) Moments and products of inertia are about the center of gravity of each item

(3) Service Module less SPS and RCS propellant in tanks.

(4) Centers of gravity of the propellants in the service module RCS tanks remain constant through usable propellant consumption. Products of inertia are zero and moments of inertia are directly proportional to propellant weight.

(5) All tolerances shall be used as 3σ values

Table 6.7 AS-501 CSM Propellant Weight Summary

	Service Module SPS[4] Weight (lb)			Service Module RCS Weight (lb)			Command Module RCS Weight (lb)		
	Fuel	Oxidizer	Total	Fuel	Oxidizer	Total	Fuel	Oxidizer	Total
Usable Propellant In Tanks									
Available for Mission	9,729	19,441		3	6		1	2	
Mixture Ratio Tolerance	292	584		263	527		75	150	
Loading Reserve	51	101		3	5		1	2	
Start Loss	11	18.			.				
Total Usable Propellant In Tanks[1]	(10,083)	(20,144)	30,277.	(269)	(538)	807	(77)	(154)	231
Unusable Propellant In Tanks									
Propellant In Retention Reservoir	42	74							
Vapor In Tanks	2	81							
Expulsion Efficiency	0	0		6	18		3	6	
Total Unusable Propellant In Tanks	(44)	(155)	199	(6)	(18)		(3)	(6)	9
Total Propellant In Tanks[2] [3]	(10,127)	(20,299)	30,426	(275)	(556)	831	(80)	(160)	240
System Propellant Residuals									
Propellant Trapped In Engine	21	48							
Propellant Trapped In Transfer Lines	3	7							
Propellant Trapped In Engine Lines	11	42		1	3		10	19	
Total System Propellant Residuals	(35)	(97)	132	(1)	(3)	4	(10)	(19)	29
Total Propellant Loaded	(10,162)	(20,396)	30,558			835			269
Helium			155			3			1
Nitrogen			2						

Notes:

(1) Usable quantities are based on O/F ratio of 2:1.

(2) See table 3-3 for service module SPS and RCS propellant mass properties.

(3) See table 3-7 for command module RCS propellant mass properties.

(4) The SPS primary propellant gauging system accuracy is ±(0.35% of the capacity of the tanks + 0.35% of the propellant remaining in the tanks). The SPS auxiliary propellant gauging system accuracy is ±(0.35% of the capacity of the tanks + 0.35% of the propellant remaining in the tanks + 2.3% of the propellant remaining in the storage tank).

Table 6.8 SPS Propellant by Tank Block I Fuel Sump

Weight (lb)	Center of Gravity (in.) X_{cg}	Y_{cg}	Z_{cg}	Moment of Inertia (slug-ft^2) I_{xx}	I_{yy}	I_{zz}	Product of Inertia (slug-ft^2) I_{xy}	I_{xz}	I_{yz}
0.01	832.0	-14.8	-47.8	0.0	0.0	0.0	-0.0	-0.0	0.0
31.56	834.5	-14.8	-47.8	-0.0	0.2	0.2	-0.0	-0.0	0.0
92.85	836.4	-14.8	-47.8	-0.0	0.9	0.9	-0.0	-0.0	0.0
181.44	838.3	-14.8	-47.8	-0.0	2.6	2.6	-0.0	-0.0	0.0
292.87	840.1	-14.8	-47.8	-0.0	5.2	5.2	-0.0	-0.0	0.0
422.73	841.9	-14.8	-47.8	0.0	9.0	9.0	-0.0	-0.0	0.0
566.59	843.7	-14.8	-47.8	-0.0	13.9	13.9	-0.0	-0.0	0.0
720.04	845.4	-14.8	-47.8	-0.0	19.9	19.9	-0.0	-0.0	0.0
905.27	847.4	-14.8	-47.8	0.0	28.0	28.0	-0.0	-0.0	0.0
1,065.04	849.1	-14.8	-47.8	0.0	36.0	36.0	-0.0	-0.0	0.0
1,224.82	850.7	-14.8	-47.8	-0.0	45.1	45.1	-0.0	-0.0	0.0
1,384.59	852.3	-14.8	-47.8	-0.0	55.5	55.5	-0.0	-0.0	0.0
1,544.37	853.9	-14.8	-47.8	-0.0	67.3	67.3	-0.0	-0.0	0.0
1,704.14	855.5	-14.8	-47.8	-0.0	80.5	80.5	-0.0	-0.0	0.0
1,863.92	857.1	-14.8	-47.8	0.0	95.6	95.6	-0.0	-0.0	0.0
2,023.69	858.7	-14.8	-47.8	0.0	112.6	112.6	-0.0	-0.0	0.0
2,183.47	860.2	-14.8	-47.8	-0.0	131.6	131.6	-0.0	-0.0	0.0
2,343.24	861.8	-14.8	-47.8	-0.0	153.0	153.0	-0.0	-0.0	0.0
2,503.02	863.4	-14.8	-47.8	0.0	176.6	176.6	-0.0	-0.0	0.0
2,662.79	864.9	-14.8	-47.8	-0.0	202.8	202.8	-0.0	-0.0	0.0
2,822.57	866.5	-14.8	-47.8	-0.0	231.8	231.8	-0.0	-0.0	0.0
2,982.34	868.0	-14.8	-47.8	0.0	263.7	263.7	-0.0	-0.0	0.0
3,142.12	869.6	-14.8	-47.8	-0.0	298.7	298.7	-0.0	-0.0	0.0
3,301.89	871.1	-14.8	-47.8	0.0	338.7	336.7	-0.0	-0.0	0.0
3,461.67	872.7	-14.8	-47.8	0.0	378.2	378.2	-0.0	-0.0	0.0
3,621.44	874.2	-14.8	-47.8	0.0	423.2	423.2	-0.0	-0.0	0.0
3,781.22	875.8	-14.8	-47.8	0.0	472.1	472.1	-0.0	-0.0	0.0
3,940.99	877.3	-14.8	-47.8	-0.0	524.8	524.8	-0.0	-0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Fuel Sump (Continued)

Weight (lb)	Center of Gravity (in.)			Moment of Inertia (slug-ft^2)			Product of Inertia (slug-ft^2)		
	X_{cg}	Y_{cg}	Z_{cg}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
4,100.77	878.9	-14.8	-47.8	-0.0	581.4	581.4	-0.0	-0.0	0.0
4,260.54	880.4	-14.8	-47.8	0.0	642.2	642.2	-0.0	-0.0	0.0
4,420.32	882.0	-14.8	-47.8	0.0	707.4	707.4	-0.0	-0.0	0.0
4,580.09	883.5	-14.8	-47.8	0.0	777.2	777.2	-0.0	-0.0	0.0
4,739.87	885.1	-14.8	-47.8	0.0	851.8	851.8	-0.0	-0.0	0.0
4,899.64	886.6	-14.8	-47.8	0.0	930.9	930.9	-0.0	-0.0	0.0
5,059.42	888.1	-14.8	-47.8	0.0	1,015.2	1,015.2	-0.0	-0.0	0.0
5,219.19	889.7	-14.8	-47.8	0.0	1,104.7	1,104.7	-0.0	-0.0	0.0
5,378.97	891.2	-14.8	-47.8	0.0	1,199.6	1,199.6	-0.0	-0.0	0.0
5,538.74	892.8	-14.8	-47.8	-0.0	1,300.1	1,300.1	-0.0	-0.0	0.0
5,698.52	894.8	-14.8	-47.8	-0.0	1,405.9	1,405.9	-0.0	-0.0	0.0
5,858.29	895.9	-14.8	-47.8	0.0	1,517.7	1,517.7	-0.0	-0.0	0.0
6,018.07	897.4	-14.8	-47.8	0.0	1,635.5	1,635.5	-0.0	-0.0	0.0
6,177.94	899.0	-14.8	-47.8	0.0	1,759.6	1,759.6	-0.0	-0.0	0.0
6,337.62	900.5	-14.8	-47.8	0.0	1,890.1	1,890.1	-0.0	-0.0	0.0
6,497.39	902.0	-14.8	-47.8	-0.0	2,206.8	2,026.8	-0.0	-0.0	0.0
6,657.17	903.6	-14.8	-47.8	0.0	2,170.1	2,170.1	-0.0	-0.0	0.0
6,816.94	905.1	-14.8	-47.8	0.0	2,320.4	2,320.4	-0.0	-0.0	0.0
6,998.02	906.9	-14.8	-47.8	0.0	2,499.3	2,499.3	-0.0	-0.0	0.0
7,157.06	909.4	-14.8	-47.8	0.0	2,664.0	2,664.0	-0.0	-0.0	0.0
7,311.68	909.9	-14.8	-47.8	0.0	2,831.1	2,831.1	-0.0	-0.0	0.0
7,457.44	911.3	-14.8	-47.8	0.0	2,995.2	2,995.2	-0.0	-0.0	0.0
7,604.74	912.7	-14.8	-47.8	-0.0	3,168.8	3,168.8	-0.0	-0.0	0.0
7,738.10	914.1	-14.8	-47.8	-0.0	3,335.1	3,335.1	-0.0	-0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Fuel Storage

Weight (lb)	Center of Gravity (in.)			Moment of Inertia (slug-ft^2)			Product of Inertia (slug-ft^2)		
	X_{cg}	Y_{cg}	Z_{cg}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
0.01	832.0	14.8	47.8	0.0	0.0	0.0	0.0	0.0	0.0
31.56	834.5	14.8	47.8	-0.0	0.2	0.2	0.0	0.0	0.0
92.85	836.4	14.8	47.8	-0.0	0.9	0.9	0.9	0.0	0.0
181.44	838.3	14.8	47.8	-0.0	2.6	2.6	0.0	0.0	0.0
292.87	840.1	14.8	47.8	-0.0	5.2	5.2	0.0	0.0	0.0
422.73	841.9	14.8	47.8	0.0	9.0	9.0	0.0	0.0	0.0
566.59	843.7	14.8	47.8	-0.0	13.9	13.9	0.0	0.0	0.0
720.04	845.4	14.8	47.8	-0.0	19.9	19.9	0.0	0.0	0.0
905.27	847.4	14.8	47.8	0.0	28.0	28.0	0.0	0.0	0.0
1,065.04	849.1	14.8	47.8	0.0	36.0	36.0	0.0	0.0	0.0
1,224.82	850.7	14.8	47.8	-0.0	45.1	45.1	0.0	0.0	0.0
1,384.59	852.3	14.8	47.8	-0.0	55.5	55.5	0.0	0.0	0.0
1,544.37	853.9	14.8	47.8	-0.0	67.3	67.3	0.0	0.0	0.0
1,704.14	855.5	14.8	47.8	-0.0	80.5	80.5	0.0	0.0	0.0
1,863.92	857.1	14.8	47.8	0.0	95.6	95.6	0.0	0.0	0.0
2,023.69	858.7	14.8	47.8	0.0	112.6	112.6	0.0	0.0	0.0
2,183.47	860.2	14.8	47.8	-0.0	131.6	131.6	0.0	0.0	0.0
2,343.24	861.8	14.8	47.8	-0.0	153.0	153.0	0.0	0.0	0.0
2,503.02	863.4	14.8	47.8	0.0	176.6	176.6	0.0	0.0	0.0
2,662.79	864.9	14.8	47.8	-0.0	202.8	202.8	0.0	0.0	0.0
2,822.57	866.5	14.8	47.8	-0.0	231.8	231.8	0.0	0.0	0.0
2,982.34	868.0	14.8	47.8	0.0	263.7	263.7	0.0	0.0	0.0
3,142.12	869.6	14.8	47.8	-0.0	298.7	298.7	0.0	0.0	0.0
3,301.89	871.1	14.8	47.8	0.0	336.7	336.7	0.0	0.0	0.0
3,461.67	872.7	14.8	47.8	0.0	378.2	378.2	0.0	0.0	0.0
3,621.44	874.2	14.8	47.8	0.0	423.2	423.2	0.0	0.0	0.0
3,781.22	875.8	14.8	47.8	0.0	472.1	472.1	0.0	0.0	0.0
3,940.99	877.3	14.8	47.8	-0.0	524.8	524.8	0.0	0.0	0.0
4,100.77	878.9	14.8	47.8	-0.0	581.4	581.4	0.0	0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Fuel Storage (Continued)

Weight (lb)	Center of Gravity (in.)			Moments of Inertia (slug-ft^2)			Products of Inertia (slug-ft^2)		
	X_{cg}	Y_{cg}	Z_{cg}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
4,260.54	880.4	14.8	47.8	0.0	642.2	642.2	0.0	0.0	0.0
4,420.32	882.0	14.8	47.8	0.0	707.4	707.4	0.0	0.0	0.0
4,580.09	883.5	14.8	47.8	0.0	777.2	777.2	0.0	0.0	0.0
4,739.87	885.1	14.8	47.8	0.0	851.8	851.8	0.0	0.0	0.0
4,899.64	886.6	14.8	47.8	0.0	930.9	930.9	0.0	0.0	0.0
5,059.42	888.1	14.8	47.8	0.0	1,015.2	1,015.2	0.0	0.0	0.0
5,219.19	889.7	14.8	47.8	0.0	1,104.7	1,104.7	0.0	0.0	0.0
5,378.97	891.2	14.8	47.8	0.0	1,199.6	1,199.6	0.0	0.0	0.0
5,538.74	892.8	14.8	47.8	-0.0	1,300.1	1,300.1	0.0	0.0	0.0
5,698.52	894.3	14.8	47.8	-0.0	1,405.9	1,405.9	0.0	0.0	0.0
5,858.29	895.9	14.8	47.8	0.0	1,517.7	1,517.7	0.0	0.0	0.0
6,018.07	897.4	14.8	47.8	0.0	1,635.5	1,635.5	0.0	0.0	0.0
6,177.84	899.0	14.8	47.8	0.0	1,759.6	1,759.6	0.0	0.0	0.0
6,337.62	900.5	14.8	47.8	0.0	1,890.1	1,890.1	0.0	0.0	0.0
6,497.39	902.0	14.8	47.8	-0.0	2,026.8	2,026.8	0.0	0.0	0.0
6,657.17	903.6	14.8	47.8	0.0	2,170.1	2,170.1	0.0	0.0	0.0
6,816.94	905.1	14.8	47.8	0.0	2,320.4	2,320.4	0.0	0.0	0.0
6,998.02	906.9	14.8	47.8	0.0	2,499.3	2,499.3	0.0	0.0	0.0
7,157.06	908.4	14.8	47.8	0.0	2,663.6	2,663.6	0.0	0.0	0.0
7,311.68	909.9	14.8	47.8	-0.0	2,830.6	2,830.6	0.0	0.0	0.0
7,433.60	911.1	14.8	47.8	0.0	2,967.1	2,967.1	0.0	0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Oxidizer Sump

Weight (lb)	Center of Gravity[1] (inches)			Moment of Inertia[2] ($slug\text{-}ft^2$)			Product of Inertia[2] ($slug\text{-}ft^2$)		
	X_{CG}	Y_{CG}	Z_{CG}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
0.01	832.0	48.3	6.6	-0.0	0.0	-0.0	0.0	0.0	0.0
63.06	834.7	48.3	6.6	-0.0	0.5	0.5	0.0	0.0	0.0
185.58	836.6	48.3	6.6	0.0	2.3	2.3	-0.0	-0.0	0.0
362.66	839.6	48.3	6.6	-0.0	6.0	6.0	0.0	0.0	0.0
585.42	840.4	48.3	6.6	-0.0	12.4	12.4	0.0	0.0	0.0
845.02	842.3	48.3	6.6	-0.0	21.2	21.2	0.0	0.0	0.0
1132.60	844.1	48.3	6.6	-0.0	32.6	32.6	0.0	0.0	0.0
1439.36	845.9	48.3	6.6	-0.0	46.7	46.7	0.0	0.0	0.0
1809.65	847.9	48.3	6.6	-0.0	85.9	85.9	0.0	0.0	0.0
2129.05	849.6	48.3	6.6	-0.0	84.3	84.3	0.0	0.0	0.0
2448.45	851.2	48.3	6.6	-0.0	104.8	104.8	0.0	0.0	0.0
2767.85	852.3	48.3	6.6	-0.0	127.7	127.7	0.0	0.0	0.0
3087.25	854.4	48.3	6.6	-0.0	153.2	153.2	0.0	0.0	0.0
3406.65	855.9	48.3	6.6	-0.0	181.7	181.7	0.0	0.0	0.0
3726.05	857.5	48.3	6.6	-0.0	213.5	213.5	0.0	0.0	0.0
4045.45	859.0	48.3	6.6	-0.0	249.0	249.0	0.0	0.0	0.0
4364.85	860.6	48.3	6.6	0.0	288.3	288.3	0.0	0.0	0.0
4684.25	862.1	48.3	6.6	-0.0	331.9	331.9	0.0	0.0	0.0
5003.65	863.6	48.3	6.6	-0.0	380.1	380.1	0.0	0.0	0.0
5323.05	865.1	48.3	6.6	-0.0	433.1	433.1	-0.0	0.0	0.0
5642.45	866.7	48.3	6.6	-0.0	491.3	491.3	0.0	0.0	0.0
5961.85	868.2	48.3	6.6	-0.0	554.9	554.9	0.0	0.0	0.0
6188.0	869.0	48.3	6.6	-0.0	601.0	601.0	0.0	0.0	0.0
6281.25	869.7	48.3	6.6	-0.0	624.4	624.4	0.0	0.0	0.0
6600.65	871.2	48.3	6.6	-0.0	699.9	699.9	0.0	0.0	0.0
6920.05	872.7	48.3	6.6	-0.0	781.9	781.9	0.0	0.0	0.0
7239.45	874.2	48.3	6.6	-0.0	870.6	870.6	0.0	0.0	0.0
7558.85	875.7	48.3	6.6	-0.0	966.3	966.3	0.0	0.0	0.0
7878.25	877.3	48.3	6.6	0.0	1069.3	1069.3	0.0	0.0	0.0
8197.65	878.8	48.3	6.6	-0.0	1180.0	1180.0	0.0	0.0	0.0
8517.05	880.3	48.3	6.6	-0.0	1298.7	1298.7	0.0	0.0	0.0
8838.45	881.8	48.3	6.6	-0.0	1425.6	1425.6	-0.0	0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Oxidizer Sump (Continued)

Weight (lb)	Center of Gravity[1] (inches)			Moment of Inertia[2] (slug-ft^2)			Product of Inertia[2] (slug-ft^2)		
	X_{CG}	Y_{CG}	Z_{CG}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
9155.85	883.3	48.3	6.6	-0.0	1561.2	1561.2	-0.0	0.0	0.0
9475.25	884.8	48.3	6.6	0.0	1705.6	1705.6	-0.0	0.0	0.0
9794.65	886.3	48.3	6.6	-0.0	1859.2	1859.2	0	0.0	0.0
10114.05	887.8	48.3	6.6	-0.0	2016.0	2016.0	0.0	0.0	0.0
10433.45	889.3	48.3	6.6	-0.0	2189.2	2189.2	0.0	0.0	0.0
10752.85	890.8	48.3	6.6	-0.0	2372.5	2372.5	0.0	0.0	0.0
11072.25	892.3	48.3	6.6	-0.0	2566.2	2566.2	0.0	0.0	0.0
11391.65	893.8	48.3	6.6	-0.0	2770.7	2770.7	0.0	0.0	0.0
11711.05	895.3	48.3	6.6	-0.0	2986.3	2986.3	0.0	0.0	0.0
12030.45	896.8	48.3	6.6	-0.0	3213.2	3213.2	0.0	0.0	0.0
12349.85	898.3	48.3	6.6	-0.0	3451.8	3451.8	0.0	0.0	0.0
12669.25	899.8	48.3	6.6	-0.0	3702.4	3702.4	0.0	0.0	0.0
12988.65	901.3	48.3	6.6	-0.0	3965.4	3965.4	0.0	0.0	0.0
13308.05	902.8	48.3	6.6	0.0	4240.9	4240.9	0.0	0.0	0.0
13627.45	904.3	48.3	6.6	-0.0	4529.4	4529.4	0.0	0.0	0.0
13989.44	906.0	48.3	6.6	-0.0	4872.3	4872.3	0.0	0.0	0.0
14307.37	907.5	48.3	6.6	-0.0	5187.9	5187.9	0.0	0.0	0.0
14616.47	909.0	48.3	6.6	-0.0	5508.1	5508.1	0.0	0.0	0.0
14907.85	910.4	48.3	6.6	-0.0	5823.2	5823.2	0.0	0.0	0.0
15202.31	911.8	48.3	6.6	-0.0	6155.9	6155.9	0.0	0.0	0.0
15481.01	913.1	48.3	6.6	-0.0	6489.0	6489.0	0.0	0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Oxidizer Storage

Weight (lb)	Center of Gravity[1] (inches)			Moment of Inertia[2] (slug-ft²)			Product of Inertia[2] (slug-ft²)		
	X_{CG}	Y_{CG}	Z_{CG}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
0.01	832.0	-48.3	-6.6	-0.0	0.0	-0.	-0.0	-0.0	0.0
63.06	834.7	-48.3	-6.6	-0.0	0.5	0.5	-0.0	-0.0	0.0
185.58	836.6	-48.3	-6.6	0.0	2.3	2.3	0.0	0.0	0.0
362.66	838.6	-48.3	-6.6	-0.0	6.0	6.0	-0.0	-0.0	0.0
585.42	840.4	-48.3	-6.6	-0.0	12.4	12.4	-0.0	-0.0	0.0
845.02	842.3	-48.3	-6.6	-0.0	21.2	21.2	-0.0	-0.0	0.0
1132.60	844.1	-48.3	-6.6	-0.0	32.6	32.6	-0.0	-0.0	0.0
1439.36	845.9	-48.3	-6.6	-0.0	46.7	46.7	-0.0	-0.0	0.0
1809.65	847.9	-48.3	-6.6	-0.0	66.0	66.0	-0.0	-0.0	0.0
2129.05	849.6	-48.3	-6.6	-0.0	84.4	84.4	-0.0	-0.0	0.0
2448.45	851.2	-48.3	-6.6	-0.0	104.9	104.9	-0.0	-0.0	0.0
2767.85	852.8	-48.3	-6.6	-0.0	127.7	127.7	-0.0	-0.0	0.0
3087.25	854.4	-48.3	-6.6	-0.0	153.2	153.2	-0.0	-0.0	0.0
3406.65	855.9	-48.3	-6.6	-0.0	181.8	181.8	-0.0	-0.0	0.0
3726.05	857.5	-48.3	-6.6	-0.0	213.6	213.6	-0.0	-0.0	0.0
4045.45	859.0	-48.3	-6.6	-0.0	249.0	249.0	-0.0	-0.0	0.0
4364.85	860.6	-48.3	-6.6	0.0	288.4	288.4	-0.0	-0.0	0.0
4684.25	862.1	-48.3	-6.6	-0.0	332.0	332.0	-0.0	-0.0	0.0
5003.65	863.6	-48.3	-6.6	-0.0	380.1	380.1	-0.0	-0.0	0.0
5323.05	865.1	-48.3	-6.6	-0.0	433.1	433.1	0.0	-0.0	0.0
5642.45	866.7	-48.3	-6.6	-0.0	491.3	491.3	-0.0	-0.0	0.0
5961.85	868.2	-48.3	-6.6	-0.0	555.0	555.0	-0.0	-0.0	0.0
6281.25	869.7	-48.3	-6.6	-0.0	624.4	624.4	-0.0	-0.0	0.0
6600.65	871.2	-48.3	-6.6	-0.0	700.0	700.0	-0.0	-0.0	0.0
6920.05	872.7	-48.3	-6.6	-0.0	781.9	781.9	-0.0	-0.0	0.0

Table 6.8 SPS Propellant by Tank Block I Oxidizer Storage (Continued)

Weight (lb)	Center of Gravity[1] (inches)			Moment of Inertia[2] (slug-ft²)			Product of Inertia[2] (slug-ft²)		
	X_{CG}	Y_{CG}	Z_{CG}	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
7239.45	874.2	-48.3	-6.6	-0.0	870.6	870.6	-0.0	-0.0	0.0
7558.85	875.7	-48.3	-6.6	-0.0	966.3	966.3	-0.0	-0.0	0.0
7878.25	877.3	-48.3	-6.6	0.0	1069.4	1069.4	-0.0	-0.0	0.0
8197.65	878.8	-48.3	-6.6	-0.0	1180.1	1180.1	-0.0	10.0	0.0
8517.05	880.3	-48.3	-6.6	-0.0	1298.8	1298.8	-0.0	-0.0	0.0
8836.45	881.8	-48.3	-6.6	-0.0	1425.7	1425.7	0.0	-0.0	0.0
9155.85	883.3	-48.3	-6.6	-0.0	1561.2	1561.2	0.0	-0.0	0.0
9475.25	884.8	-48.3	-6.6	0.0	1705.6	1705.6	0.0	-0.0	0.0
9794.65	886.3	-48.3	-6.6	-0.0	1859.2	1859.2	-0.0	-0.0	0.0
10114.05	887.8	-48.3	-6.6	-0.0	2022.4	2022.4	-0.0	-0.0	0.0
10433.45	889.3	-48.3	-6.6	-0.0	2195.3	2195.3	-0.0	-0.0	0.0
10752.85	890.8	-48.3	-6.6	0.0	2378.4	2378.4	-0.0	-0.0	0.0
11072.25	892.3	-48.3	-6.6	-0.0	2572.0	2572.0	-0.0	-0.0	0.0
11391.65	893.8	-48.3	-6.6	-0.0	2776.2	2776.2	-0.0	-0.0	0.0
11711.05	895.3	-48.3	-6.6	-0.0	2991.6	2991.6	-0.0	-0.0	0.0
12030.45	896.8	-48.3	-6.6	-0.0	3218.3	3218.3	-0.0	-0.0	0.0
12349.85	898.3	-48.3	-6.6	-0.0	3456.7	3456.7	-0.0	-0.0	0.0
12669.25	899.8	-48.3	-6.6	-0.0	3707.1	3707.1	-0.0	-0.0	0.0
12988.65	901.4	-48.3	-6.6	-0.0	3969.8	3969.8	-0.0	-0.0	0.0
13308.05	902.9	-48.3	-6.6	0.0	4245.2	4245.2	-0.0	-0.0	0.0
13627.45	904.4	-48.3	-6.6	-0.0	4533.4	4533.4	-0.0	-0.0	0.0
13989.44	906.1	-48.3	-6.6	-0.0	4876.1	4876.1	-0.0	-0.0	0.0
14307.37	907.6	-48.3	-6.6	-0.0	5191.5	5191.5	-0.0	-0.0	0.0
14616.47	909.0	-48.3	-6.6	-0.0	5511.5	5511.5	-0.0	-0.0	0.0
14862.40	910.2	-48.3	-6.6	-0.0	5770.1	5770.1	-0.0	-0.0	0.0

6.4.4 Service Propulsion System (SPS) Data

6.4.4.1. Engine Physical Properties

Mass	25 slugs

The source for the above datum is unofficial, telecon with Mr. Jack Potts S&ID/NAA.

Engine inertia	246.1 slug feet ^{2}
Engine c.g. to gimbal	8 inches

This information is taken from the GN&C Data Exchange Program, NAA-S-46 submitted 8 October 1965.

6.4.4.2 Gimbal Actuator System (MOD II)

SPS thrust vector orientation	Fig. 6.9

The above figure is taken from TRW Systems Document #2131-H009-R8-000 "Apollo Mission Data Specification D A/S-501" dated 15 August 1966.

Pitch gimbal limit	± 6 degrees
Pitch gimbal offset	- 4 degrees
Yaw gimbal limit	± 7 degrees
Yaw gimbal offset	0 degrees
Thrust- to - gimbal offset	± 1/8 inch

The above information is taken from TRW Systems Document #2131-H009-R8-000 "Apollo Mission Data Specification D AS-501 " dated 15 August 1966.

Jet damping coefficient	171 foot-pound/rad/sec
Hose stiffness	285 foot-pound/rad

The above information is taken from discussions of S&ID/MIT Meeting #66B of 17 September 1963.

Thrust angular misalignment	0.5 degree

The above datum was taken from NAA XTASI #10.

Actuator inertia	IA	65 slug - feet ^{2}
Actuator lag	WA	6.6 rad/second
Total amplifier - clutch gain	KS•KT	20(3530) ft. -lb/rad.
Torque limit	LMT	1500 ft-lb.
Slew rate limit	LMR	0.1 rad/sec.

NOTE: Because of the inclusion of a Block II actuator in the AS-501 vehicle, the above actuator parameters (LMT and LMR) are speculative. In particular, a worst case LMR should be sufficient to detect anomalies caused by the Block II actuator.

Reference MIT/IL MDRB Record of Change Form # 501-18 dated 31 October 1966.

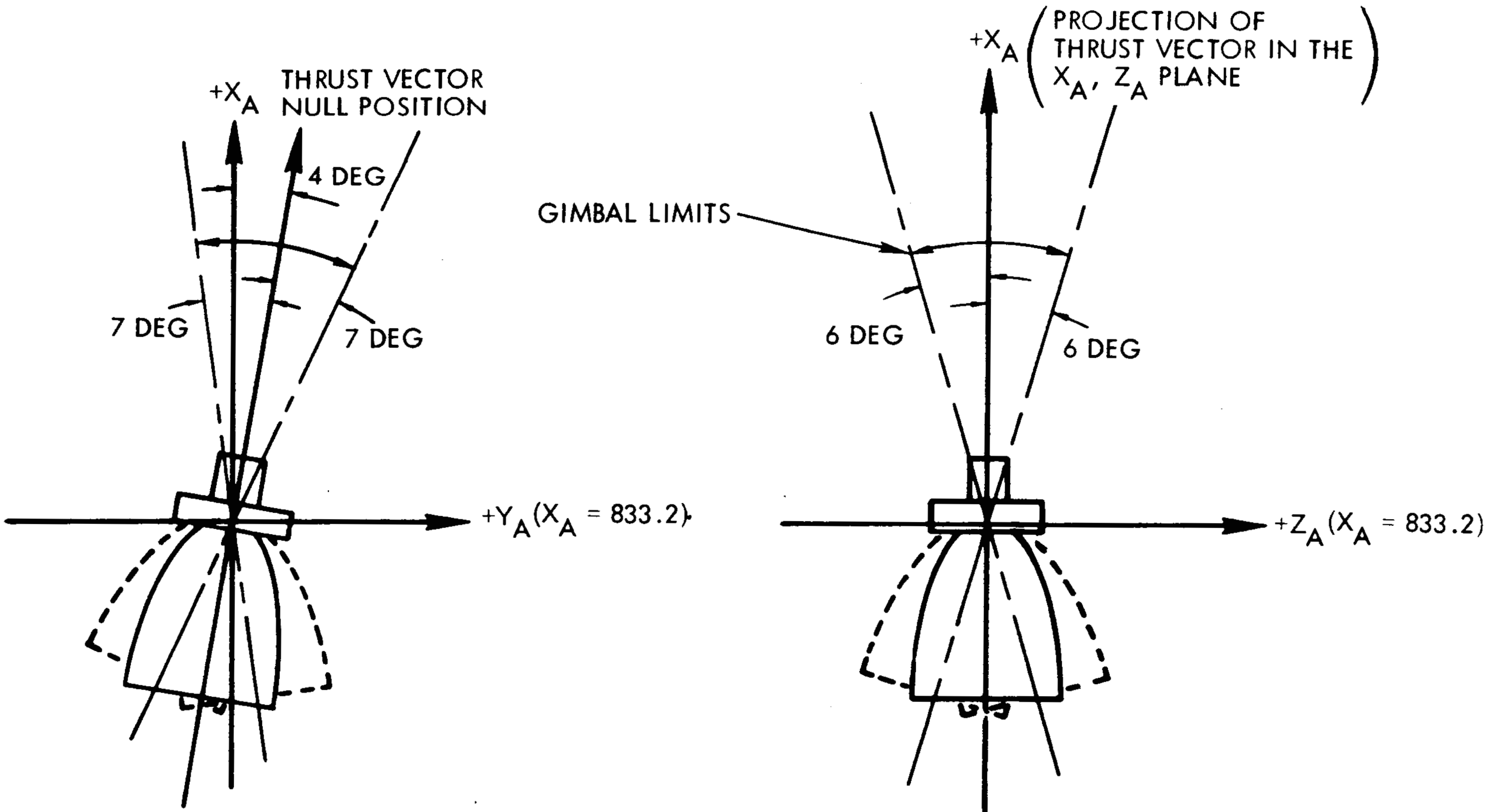


Fig. 6.9 Service Propulsion Subsystem Thrust Vector Orientation

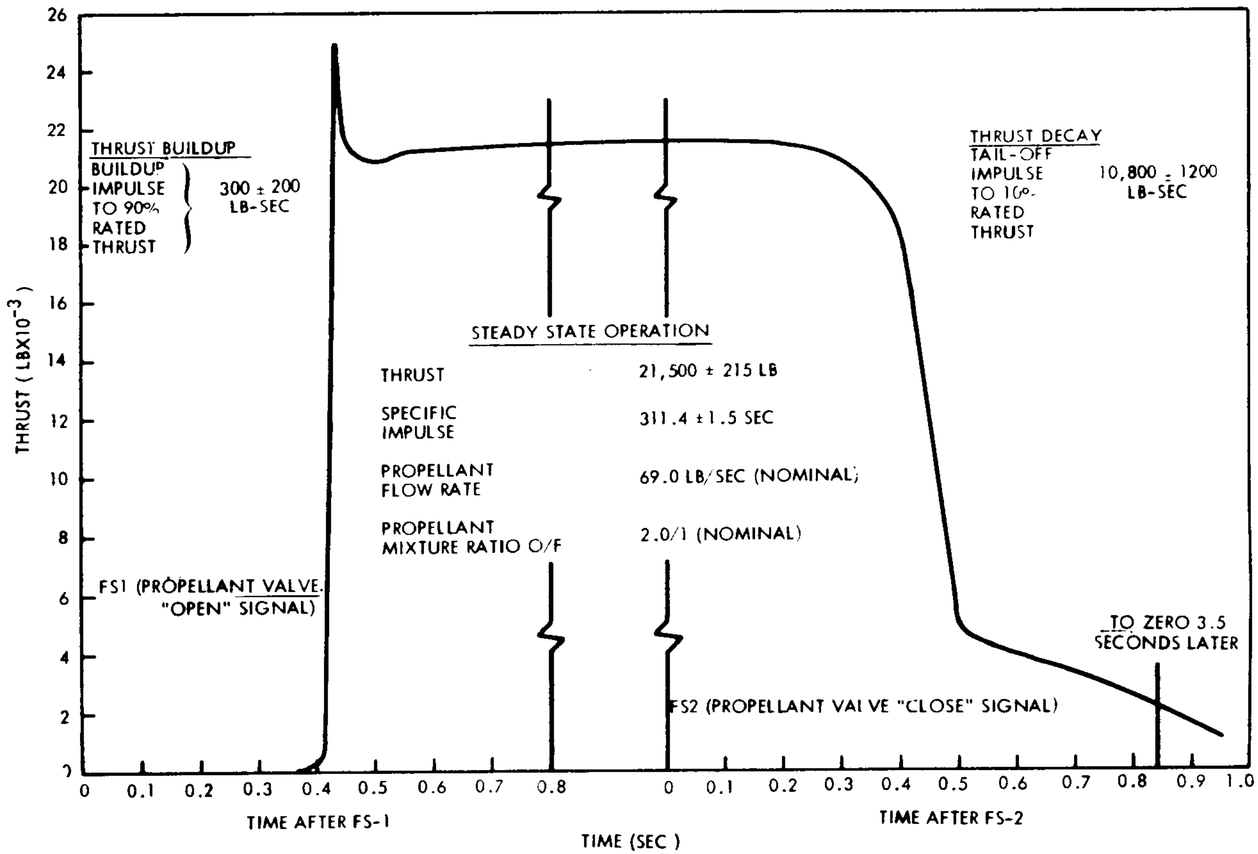
6.4.4.3 SPS Engine Vacuum Performance

Turn-on-off step transient		0.27 second
Buildup impulse to 90% rated thrust		300 ± 200 lb - second
Thrust buildup vs time of engine-on signal		Fig. 6.10
Specific impulse	steady-state operation	311.4 ± 1.5 seconds
Thrust	steady-state operation	21,500 ± 215 lbs.
Propellant flow rate	steady-state operation	69.0 lb/second
Thrust decay vs time of engine-off signal		Fig. 6.10
Tail-off impulse to 10% rated thrust		10,800 ± 1200 lb.-sec.

The information contained in this section is taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501" dated 15 August 1966.

Thrust Vector Control Autopilot block diagram Fig 6.11

Reference MIT/IL MDRB Record of Change Form #501-18 dated 31 October 1966.



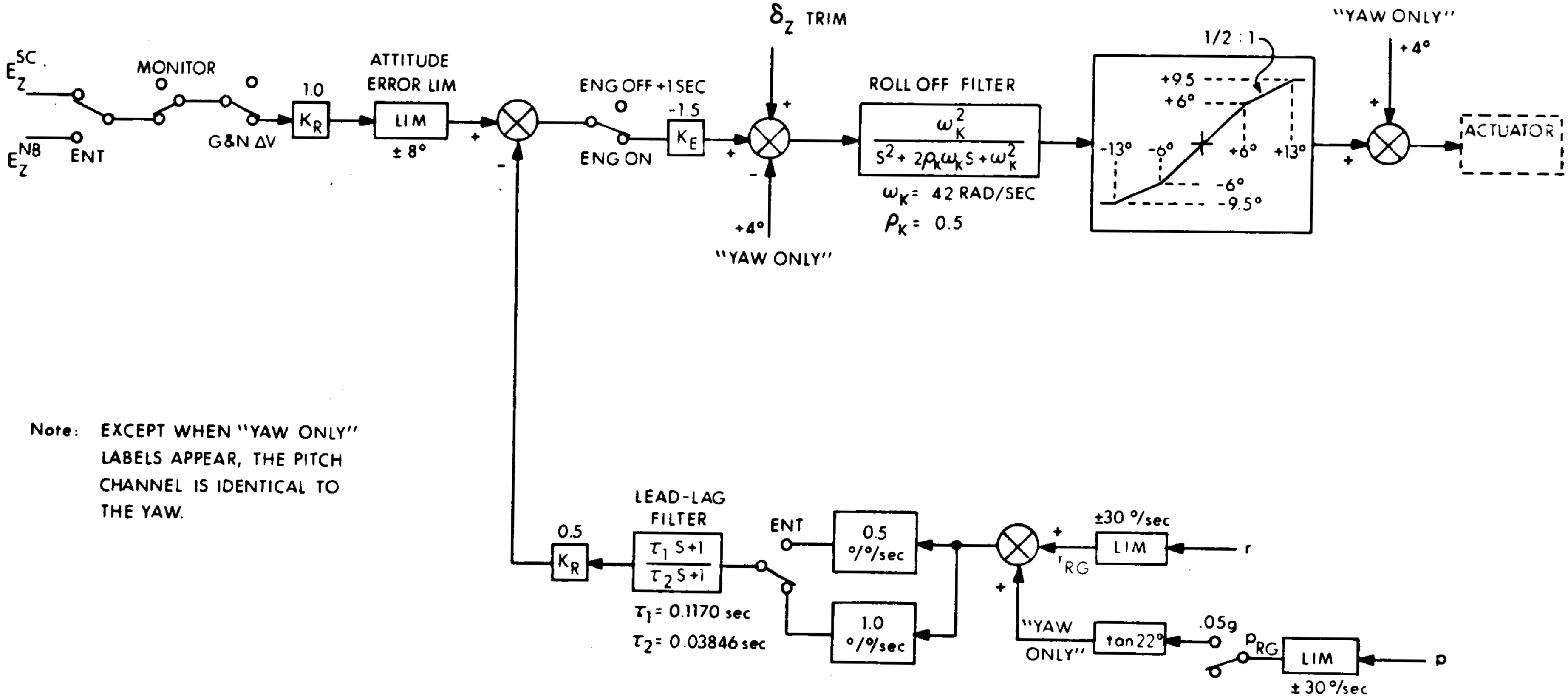
Notes:

Thrust build up and decay data are based on results of 23 altitude tests of the SPS engine.

All tolerances shall be used as 3σ deviations.

Fig. 6.10 SPS Engine Vacuum Performance Summary

NOTE: MECHANICAL AND ELECTRICAL NULLS ARE COINCIDENT



Note: EXCEPT WHEN "YAW ONLY" LABELS APPEAR, THE PITCH CHANNEL IS IDENTICAL TO THE YAW.

Fig. 6.11 TVC Autopilot Yaw Channel

6.4.5 CSM Reaction Control System (RCS)

6.4.5.1 RCS Jet Physical Properties

RCS thrust chamber configuration — Fig. 6.12

This figure is taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501", 15 August 1966.

Offset angle	7.25 degrees
Cant angle	10.0 degrees
Thrust radial arm	83.5596 inches

The above data are taken from the GN&C Data Exchange Program, NAA-S-22 submitted 7 April 1965.

6.4.5.2 Jet Vacuum Performance

Total impulse, Propellant consumed, Specific impulse	vs electrical pulse width	Fig. 6.13, 6.14
Thrust, Specific impulse, Propellant flow rate	steady-state operation	Fig. 6.14
Thrust buildup transients		not available
Thrust decay transients		not available

The figures referenced in this section are taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501" dated 15 August 1966.

RCS Autopilot block diagram — Fig. 6.15

Reference MIT/IL MDRB Record of Change Form #501-18 dated 31 October 1966.

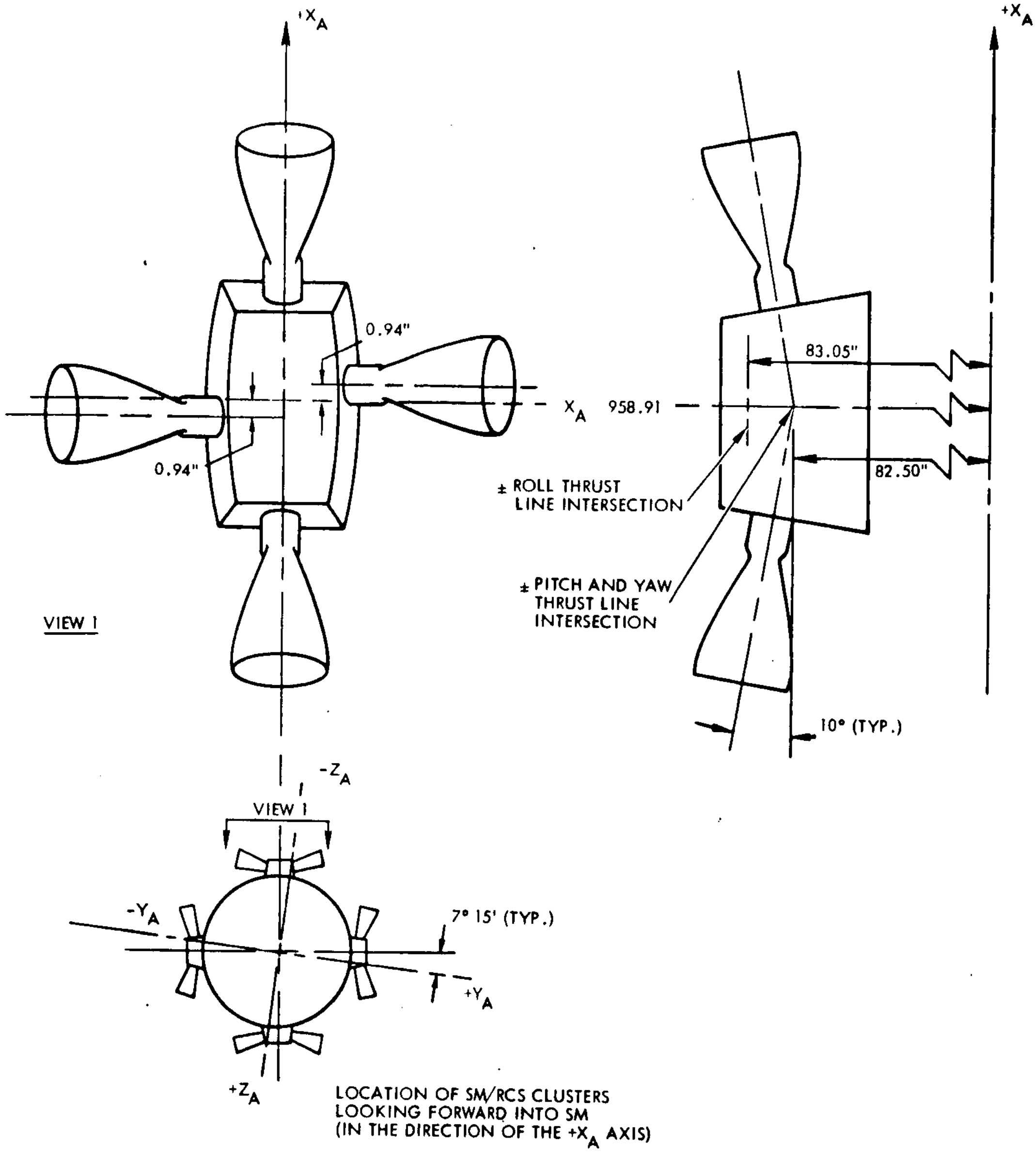
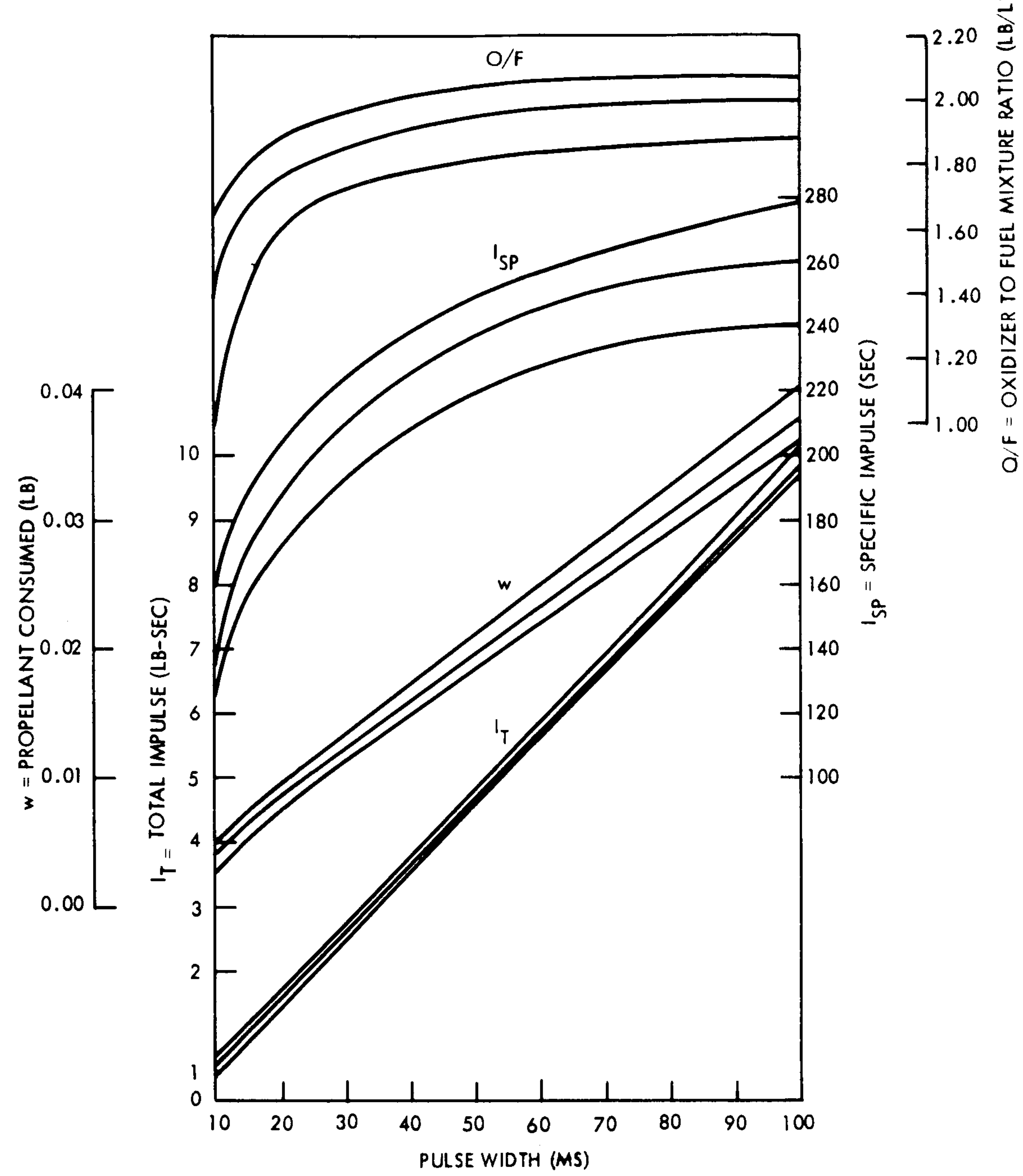
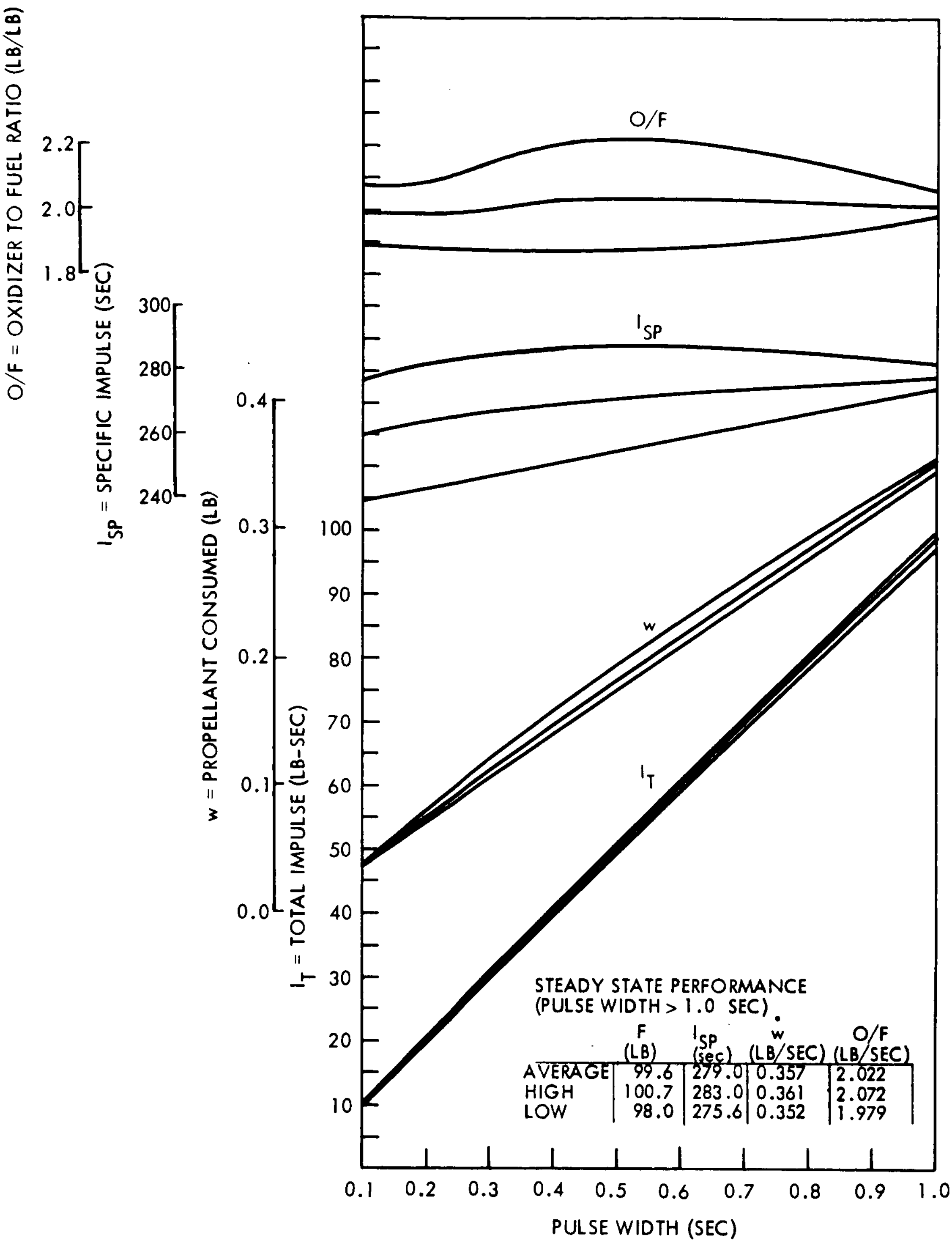


Fig. 6.12 SM/RCS Thrust Chamber Locations



Note: Data are high, low, and average values resulting from a large number of qualification tests. High and low values shall be used as 3σ values.

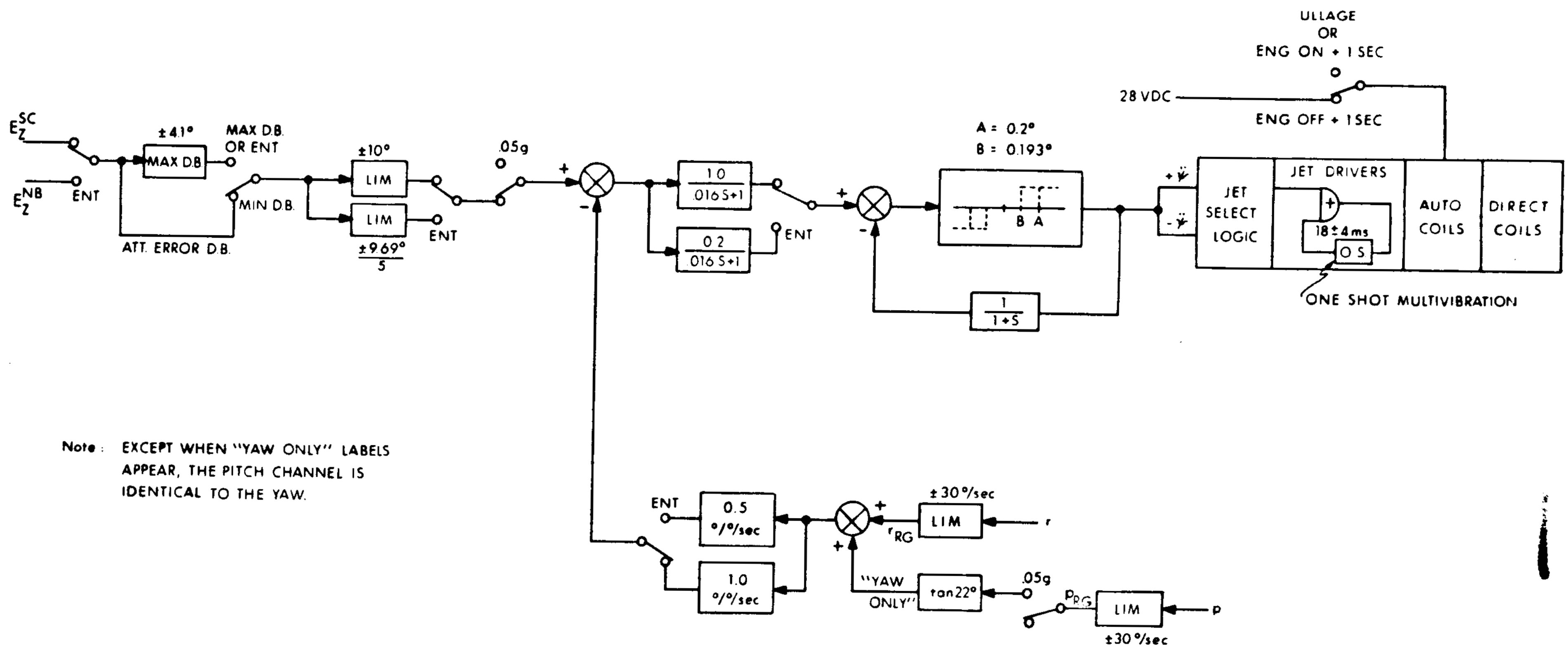
Fig. 6.13 SM/RCS Vacuum Performance Data for Pulse Widths Less than 100 ms



	F (LB)	I_{SP} (sec)	$\dot{w}$ (LB/SEC)	O/F (LB/SEC)
AVERAGE	99.6	279.0	0.357	2.022
HIGH	100.7	283.0	0.361	2.072
LOW	98.0	275.6	0.352	1.979

Note: Data are high, low, and average values resulting from a large number of qualification tests. High and low values shall be used as 3σ values.

Fig. 6.14 SM/RCS Vacuum Performance Data for Pulse Widths Greater than 100 ms



Note: EXCEPT WHEN "YAW ONLY" LABELS APPEAR, THE PITCH CHANNEL IS IDENTICAL TO THE YAW.

Fig. 6.15 RCS Autopilot Yaw Channel

6.4.6 CM Vehicle Data

6.4.6.1 Apollo CM Coordinate Reference System

Spacecraft CSM-017 reference dimensions	Fig. 6.7
CM axes and notation system	Fig. 6.16

The figures shown above are taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501", dated 15 August 1966.

6.4.6.2 Specific Station Locations

IMU location 1056.6 inches

This number is taken from NAA-MIT/IL ICD MH01-01301-116

RCS jet thruster locations Table 6.9

This table is taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501", dated 15 August 1966.

6.4.6.3 Apollo CM Mass Property Data

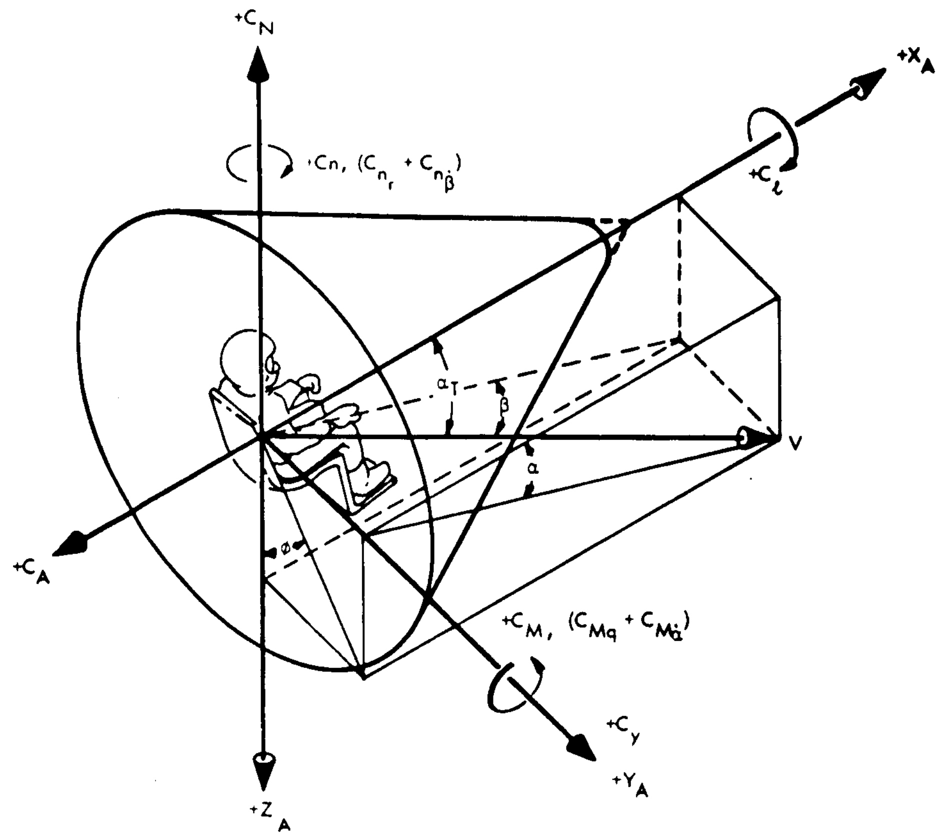
CM mass properties summary	Table 6.10
CM sequential mass properties	Table 6.11

The data contained in this section are taken from TRW Systems Document #2131-H009-R8-000, "Apollo Mission Data Specification D AS-501", dated 15 August 1966.

Table 6.9

RCS Jet Thruster Locations

Thrust Chamber	C_L of Thrust Exit Plane on Outer ML				
		X_C	Y_C	Z_C	R_C
5	A	27.6750	72.2846	-4.4211	72.4197
7	B	27.6750	72.2846	4.4211	72.4197
8	C	27.6750	-72.2846	4.4211	72.4197
6	D	27.6750	-72.2846	-4.4211	72.4197
3	E	27.6750	-4.4211	-72.2846	72.4197
1	F	27.6750	4.4211	-72.2846	72.4197
10,11	(I)G	32.3000	-51.9826	-50.3454	72.3661
9,12	(II)H	32.3000	51.9826	-50.3454	72.3661
2	J	85.5000	0	-35.5483	35.5483
4	K	91.1250	0	-31.9616	31.9616



$\cos \alpha_T = \cos \alpha \ \cos \beta$

$\tan \phi = \dfrac{\tan \beta}{\sin \alpha}$

C_A	AXIAL FORCE COEFFICIENT (BODY AXIS), AXIAL FORCE/$q_\infty S$
C_ℓ	ROLLING MOMENT COEFFICIENT ABOUT CG (BODY AXIS), ROLLING MOMENT/$q_\infty Sd$
$C_{\ell A}$	ROLLING MOMENT COEFFICIENT ABOUT THEORETICAL CONE APEX (BODY AXIS), ROLLING MOMENT/$q_\infty Sd$
C_M	PITCHING MOMENT COEFFICIENT ABOUT CG, PITCHING MOMENT/$q_\infty Sd$
C_{M_A}	PITCHING MOMENT COEFFICIENT ABOUT THEORETICAL CONE APEX, PITCHING MOMENT/$q_\infty Sd$
C_N	NORMAL FORCE COEFFICIENT (BODY AXIS), NORMAL FORCE/$q_\infty S$
C_n	YAWING MOMENT COEFFICIENT (BODY AXIS), YAWING MOMENT/qSd
C_Y	SIDE FORCE COEFFICIENT (BODY AXIS), SIDE FORCE/qS
$C_{M_q} + C_{M_{\dot{\alpha}}}$	PITCH DAMPING COEFFICIENT , PER RADIAN
$C_{n_r} + C_{n_{\dot{\beta}}}$	YAW DAMPING COEFFICIENT , PER RADIAN
α	ANGLE OF ATTACK, DEGREES
α_T	TOTAL ANGLE OF ATTACK, DEGREES
β	ANGLE OF SIDESLIP, DEGREES
ϕ	ROLL ANGLE, DEGREES
d	REFERENCE LENGTH = 154 INCHES
S	REFERENCE AREA = 129.35 SQUARE FEET
V	FREESTREAM VELOCITY, FEET PER SECOND
q_∞	DYNAMIC PRESSURE, POUNDS PER SQUARE FOOT
q	PITCHING RATE

Fig. 6.16 Command Module Axes, Aerodynamic Coefficient, and Notation System

Table 6.10 AS-501 Command Module Mass Properties

	Weight (lb)	Center of Gravity[1] (in)			Moment of Inertia[2] (slug-ft^2)			Product of Inertia[2] (slug-ft^2)		
		X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
Command Module										
Command Module Inert[3]	11,010	1,040.8	0.8	4.4	5,464	4,801	4,320	-9	-182	29
RCS Propellant In Tanks[4]	(240)	1,022.6	-5.6	57.0	52	4	48	0	0	0
System A	120	1,022.5	4.8	55.1	24	1	23	0	0	0
System B	120	1,022.6	-16.1	56.6	20	4	6	0	0	0
Total Command Module	11,250 ± 300	1,040.4 ± 1.5	0.7 ± 0.8	5.5 ± 0.5	5,658	4,962	4,387	-3	-231	12

Notes:

(1) Centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(2) Moments of inertia are about the center of gravity of each item.

(3) Command Module less RCS propellant in tanks.

(4) Centers of gravity of the propellants in the command module RCS tanks remain constant through usable propellant consumption. Products of inertia are zero and moments of inertia are directly proportional to propellant weight.

Table 6.11 AS-501 Command Module Sequential Mass Properties

	Weight (lb)	Center of Gravity[1] (in)			Moment of Inertia[2] (slug-ft^2)			Product of Inertia[2] (slug-ft^2)		
		X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
CM - Launch, Boost and Mission	11,250	1,040.4	0.7	5.5	5,658	4,962	4,387	-3	-231	12
Less:										
Pre-entry RCS Propellant Consumed	10	1,022.6	-5.6	57.0	2	0	2	0	0	0
CM - Prior to Entry[3]	11,240 ± 300	1,040.4 ± 1.5	0.7 ± 0.8	5.5 ± 0.5	5,650	4,956	4,384	-3	-229	13
Less:										
RCS Propellant Consumed	69	1,022.6	-5.6	57.0	15	1	14	0	0	0
Ablator Burnoff[4]	261	1,011.6	0.0	6.7	178	142	135	0	0	0
Forward Heat Shield	367	1,100.4	0.1	0.6	63	45	45	0	0	0
Drogue Chutes	63	1,090.3	0.0	-20.9	1	1	2	0	0	0
CM - Prior to Main Chute Deployment	10,480	1,038.9	0.8	5.4	5,342	4,340	3,812	-2	-173	17
Less:										
RCS Propellant Jettisoned	191	1,022.6	-5.6	57.0	42	4	38	0	0	0
CM at main chute deployment (and at splashdown)										
Main Chutes	412	1,090.5	-0.7	6.3	50	21	37	0	0	0
CM - Post Landing	9,877	1,037.0	1.0	4.4	5,135	3,947	3,479	1	-146	31

Notes:

(1) Centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(2) Moments and products of inertia are about the center of gravity of each item.

(3) All tolerances shall be used as 3σ values.

(4) Ablator burnoff does not change L/D trim. See Section 6.1.

6.4.6.4 CM Re-Entry Aerodynamic Data

Reference area	129.4 feet^2
Reference diameter	145 inches
Heat shield cant	0.1300 degree
Moment reference center: X-component	1141.25 inches
Y-component	0.0 inch
Z-component	0.0 inch
Aerodynamic coefficients	Table 6.12
Lift and drag characteristics for M = 6 → 25	Fig. 6.17
Trim L/D vs C.G. locations	Fig. 6.18

The information contained in this section is taken from TRW Systems Document # 2131-H009-R8-000, "Apollo Mission Data Specification D AS-501," dated 15 August 1966 as amended by United States Goverment Memorandum PM 3/M-170/66 dated 14 November 1966.

TABLE 1

Command Module - Spacecraft 017

Aerodynamic Coefficients

ALPHA	C_M	C_N	C_A
		M = 0.4	
110.1300	-0.1021	0.2359	-0.0405
115.1300	-0.0866	0.2186	-0.1605
120.1300	-0.0590	0.1902	-0.3604
125.1300	-0.0289	0.1529	-0.5003
130.1300	0.0037	0.1076	-0.6102
135.1300	0.0392	0.0554	-0.7001
140.1300	0.0770	-0.0018	-0.7800
145.1300	0.1068	-0.0509	-0.8449
150.1300	0.1210	-0.0810	-0.8998
155.1300	0.1186	-0.0921	-0.9398
160.1300	0.0950	-0.0782	-0.9498
165.1300	0.0630	-0.0531	-0.9449
170.1300	0.0333	-0.0331	-0.9299
175.1300	0.0068	-0.0181	-0.9200
180.1300	-0.0198	-0.0031	-0.9150
185.1300	-0.0467	0.0129	-0.9170
190.1300	-0.0739	0.0279	-0.9201
		M = 0.7	
110.1300	-0.1455	0.3139	-0.0607
115.1300	-0.1070	0.2775	-0.2006
120.1300	-0.0690	0.2391	-0.3805
125.1300	-0.0377	0.1988	-0.5505
130.1300	-0.0085	0.1544	-0.7004
135.1300	0.0177	0.1111	-0.8203
140.1300	0.0383	0.0700	-0.8902
145.1300	0.0432	0.0478	-0.9501
150.1300	0.0267	0.0518	-0.9851
155.1300	0.0116	0.0497	-1.0101
160.1300	0.0097	0.0287	-1.0281
165.1300	0.0208	-0.0084	-1.0380
170.1300	0.0304	-0.0424	-1.0399
175.1300	0.0242	-0.0524	-1.0379
180.1300	-0.0096	-0.0223	-1.0200
185.1300	-0.0357	-0.0003	-1.0300
190.1300	-0.0443	-0.0034	-1.0500
		M = 0.9	
110.1300	-0.2519	0.4947	-0.1111
115.1300	-0.1902	0.4213	-0.2960
120.1300	-0.1357	0.3529	-0.4808
125.1300	-0.0918	0.2845	-0.6406
130.1300	-0.0600	0.2232	-0.7805
135.1300	-0.0288	0.1630	-0.8904
140.1300	-0.0087	0.1168	-0.9753
145.1300	-0.0076	0.0976	-1.0402
150.1300	-0.0167	0.0935	-1.0902
155.1300	-0.0224	0.0844	-1.1302
160.1300	-0.0057	0.0424	-1.1501
165.1300	0.0094	0.0024	-1.1600
170.1300	0.0178	-0.0276	-1.1549
175.1300	0.0145	-0.0406	-1.1349
180.1300	-0.0046	-0.0276	-1.1249
185.1300	-0.0207	-0.0156	-1.1350
190.1300	-0.0217	-0.0226	-1.1550

TABLE 1 (Cont'd)

Command Module - Spacecraft 017

Aerodynamic Coefficients

ALPHA	C_M	C_N	C_A
		M = 1.1	
110.1300	-0.2942	0.5113	-0.2962
115.1300	-0.2548	0.4670	-0.4411
120.1300	-0.2075	0.4126	-0.6009
125.1300	-0.1529	0.3502	-0.7908
130.1300	-0.1046	0.2798	-0.9506
135.1300	-0.0561	0.2025	-1.1005
140.1300	-0.0083	0.1173	-1.2003
145.1300	0.0169	0.0582	-1.2401
150.1300	0.0136	0.0421	-1.2751
155.1300	0.0083	0.0311	-1.3001
160.1300	0.0046	0.0190	-1.3250
165.1300	0.0027	0.0050	-1.3400
170.1300	0.0046	-0.0141	-1.3450
175.1300	0.0069	-0.0330	-1.3399
180.1300	-0.0078	-0.0250	-1.3379
185.1300	-0.0192	-0.0160	-1.3350
190.1300	-0.0082	-0.0321	-1.3499
		M = 1.2	
110.1300	-0.3004	0.5093	-0.3112
115.1300	-0.2591	0.4629	-0.4711
120.1300	-0.2103	0.4056	-0.6309
125.1300	-0.1537	0.3382	-0.8058
130.1300	-0.0932	0.2608	-0.9706
135.1300	-0.0384	0.1725	-1.1004
140.1300	-0.0016	0.1023	-1.1902
145.1300	0.0186	0.0492	-1.2401
150.1300	0.0209	0.0232	-1.2551
155.1300	0.0143	0.0121	-1.2750
160.1300	0.0100	0.0031	-1.3000
165.1300	0.0126	-0.0120	-1.3200
170.1300	0.0161	-0.0280	-1.3349
175.1300	0.0138	-0.0340	-1.3399
180.1300	0.0101	-0.0381	-1.3449
185.1300	0.0082	-0.0411	-1.3449
190.1300	0.0064	-0.0430	-1.3349
		M = 1.35	
110.1300	-0.3589	0.5994	-0.2864
115.1300	-0.3202	0.5590	-0.4563
120.1300	-0.2534	0.4776	-0.6311
125.1300	-0.1862	0.3922	-0.8009
130.1300	-0.1179	0.3038	-0.9707
135.1300	-0.0579	0.2215	-1.1205
140.1300	-0.0096	0.1422	-1.2303
145.1300	0.0272	0.0779	-1.3452
150.1300	0.0415	0.0388	-1.4001
155.1300	0.0428	0.0148	-1.4200
160.1300	0.0361	0.0008	-1.4300
165.1300	0.0270	-0.0113	-1.4400
170.1300	0.0189	-0.0213	-1.4400
175.1300	0.0151	-0.0303	-1.4399
180.1300	0.0126	-0.0383	-1.4399
185.1300	0.0114	-0.0453	-1.4399
190.1300	0.0102	-0.0523	-1.4399

TABLE 1 (Cont'd)

Command Module - Spacecraft 017

Aerodynamic Coefficients

ALPHA	C_M	C_N	C_A
		M = 1.65	
110.1300	-0.3294	0.5493	-0.3112
115.1300	-0.2976	0.5130	-0.4612
120.1300	-0.2552	0.4696	-0.6111
125.1300	-0.2103	0.4173	-0.7709
130.1300	-0.1624	0.3569	-0.9308
135.1300	-0.1160	0.2926	-1.0707
140.1300	-0.0713	0.2243	-1.1955
145.1300	-0.0350	0.1620	-1.3004
150.1300	-0.0083	0.1089	-1.3753
155.1300	0.0081	0.0628	-1.4251
160.1300	0.0161	0.0277	-1.4551
165.1300	0.0150	0.0067	-1.4700
170.1300	0.0130	-0.0094	-1.4780
175.1300	0.0102	-0.0204	-1.4800
180.1300	0.0083	-0.0284	-1.4819
185.1300	0.0078	-0.0344	-1.4799
190.1300	0.0097	-0.0424	-1.4779
		M = 2.0	
110.1300	-0.3199	0.5293	-0.2912
115.1300	-0.2776	0.4860	-0.4451
120.1300	-0.2372	0.4407	-0.5870
125.1300	-0.1954	0.3904	-0.7269
130.1300	-0.1564	0.3390	-0.8608
135.1300	-0.1185	0.2877	-1.0007
140.1300	-0.0837	0.2364	-1.1305
145.1300	-0.0514	0.1822	-1.2504
150.1300	-0.0241	0.1289	-1.3503
155.1300	-0.0050	0.0798	-1.4202
160.1300	0.0097	0.0367	-1.4601
165.1300	0.0195	0.0016	-1.4800
170.1300	0.0211	-0.0204	-1.4950
175.1300	0.0155	-0.0284	-1.4999
180.1300	0.0109	-0.0334	-1.4999
185.1300	0.0063	-0.0354	-1.4999
190.1300	0.0027	-0.0374	-1.4999
		M = 2.4	
110.1300	-0.2974	0.4944	-0.2811
115.1300	-0.2579	0.4541	-0.4160
120.1300	-0.2203	0.4127	-0.5559
125.1300	-0.1833	0.3704	-0.7008
130.1300	-0.1492	0.3281	-0.8307
135.1300	-0.1165	0.2828	-0.9606
140.1300	-0.0852	0.2355	-1.0955
145.1300	-0.0566	0.1872	-1.2154
150.1300	-0.0336	0.1420	-1.3253
155.1300	-0.0156	0.0978	-1.4002
160.1300	-0.0046	0.0597	-1.4451
165.1300	0.0047	0.0246	-1.4801
170.1300	0.0087	-0.0014	-1.5050
175.1300	0.0073	-0.0154	-1.5200
180.1300	0.0058	-0.0264	-1.5199
185.1300	0.0079	-0.0364	-1.5149
190.1300	0.0112	-0.0454	-1.4999

TABLE 1 (Cont'd)

Command Module - Spacecraft 017

Aerodynamic Coefficients

ALPHA	C_M	C_N	C_A
		M = 3.0	
110.1300	-0.2624	0.4394	-0.2510
115.1300	-0.2223	0.4001	-0.3909
120.1300	-0.1840	0.3598	-0.5208
125.1300	-0.1499	0.3205	-0.6607
130.1300	-0.1191	0.2832	-0.8006
135.1300	-0.0952	0.2479	-0.9156
140.1300	-0.0694	0.2086	-1.0505
145.1300	-0.0481	0.1694	-1.1604
150.1300	-0.0275	0.1291	-1.2653
155.1300	-0.0113	0.0929	-1.3502
160.1300	-0.0056	0.0668	-1.4102
165.1300	-0.0067	0.0467	-1.4601
170.1300	-0.0112	0.0326	-1.4901
175.1300	-0.0110	0.0146	-1.5100
180.1300	-0.0078	-0.0034	-1.5150
185.1300	-0.0010	-0.0214	-1.5050
190.1300	0.0102	-0.0384	-1.4899
		M = 4.0	
110.1300	-0.2332	0.3935	-0.2109
115.1300	-0.1891	0.3492	-0.3508
120.1300	-0.1494	0.3069	-0.4907
125.1300	-0.1147	0.2686	-0.6256
130.1300	-0.0866	0.2323	-0.7505
135.1300	-0.0647	0.2020	-0.8805
140.1300	-0.0482	0.1737	-0.9954
145.1300	-0.0345	0.1465	-1.1003
150.1300	-0.0233	0.1203	-1.2003
155.1300	-0.0117	0.0921	-1.2852
160.1300	-0.0044	0.0659	-1.3552
165.1300	-0.0001	0.0428	-1.4101
170.1300	0.0015	0.0237	-1.4501
175.1300	0.0001	0.0077	-1.4750
180.1300	0.0007	-0.0084	-1.4850
185.1300	0.0028	-0.0234	-1.4800
190.1300	0.0098	-0.0383	-1.4599
		M = 6→25	
110.1300	-0.2150	0.3701	-0.1978
115.1300	-0.1660	0.3197	-0.3407
120.1300	-0.1229	0.2724	-0.4806
125.1300	-0.0841	0.2241	-0.6195
130.1300	-0.0597	0.1998	-0.7435
135.1300	-0.0460	0.1835	-0.8734
140.1300	-0.0383	0.1703	-0.9894
145.1300	-0.0244	0.1440	-1.0928
150.1300	-0.0154	0.1218	-1.1863
155.1300	-0.0066	0.0976	-1.2772
160.1300	-0.0017	0.0764	-1.3552
165.1300	0.0032	0.0543	-1.4238
170.1300	0.0064	0.0322	-1.4711
175.1300	0.0079	0.0131	-1.4940
180.1300	0.0087	-0.0019	-1.5000

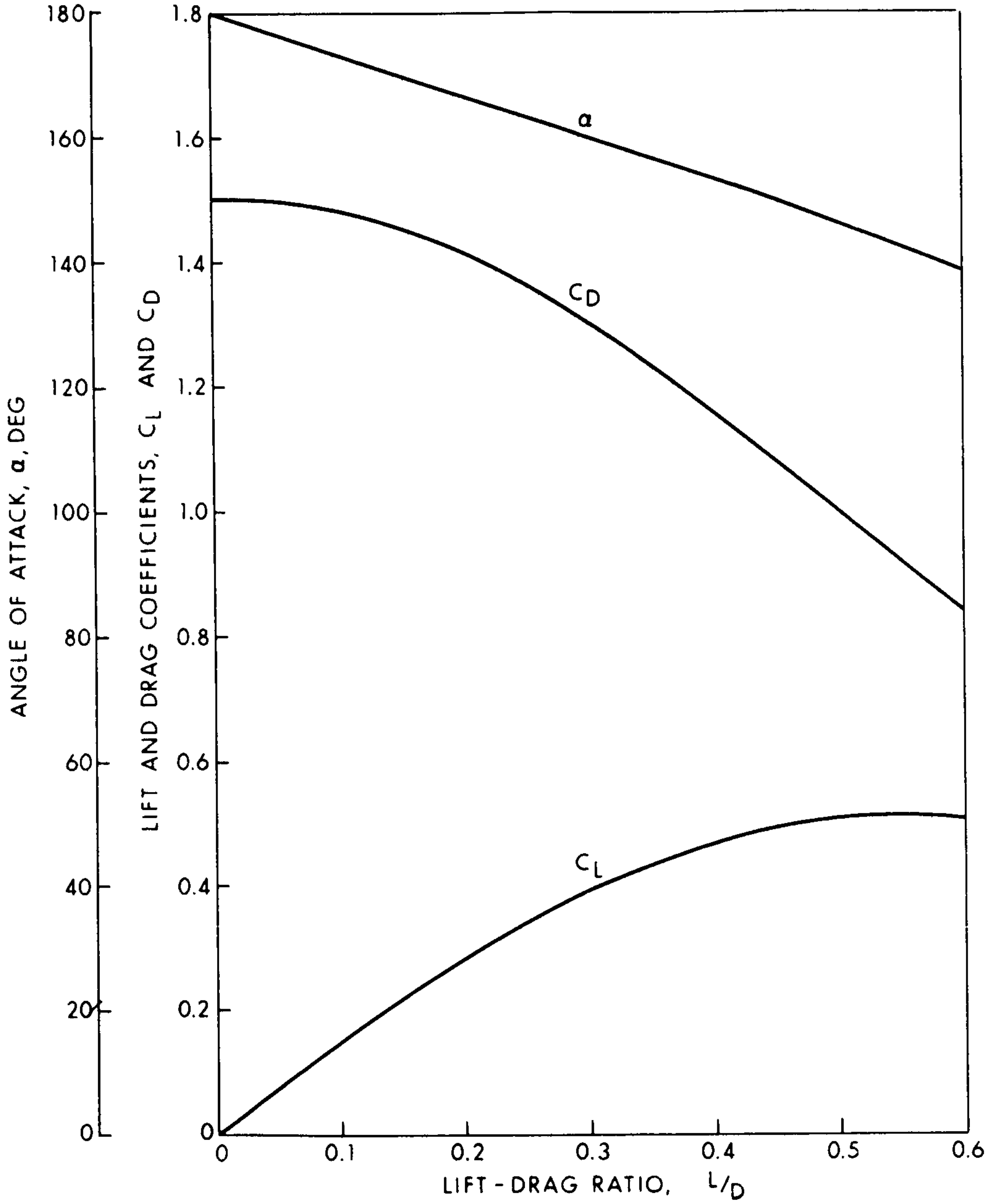


Fig. 6.17 CM (AF-017, 020) M = 6→25, Lift and Drag Characteristics

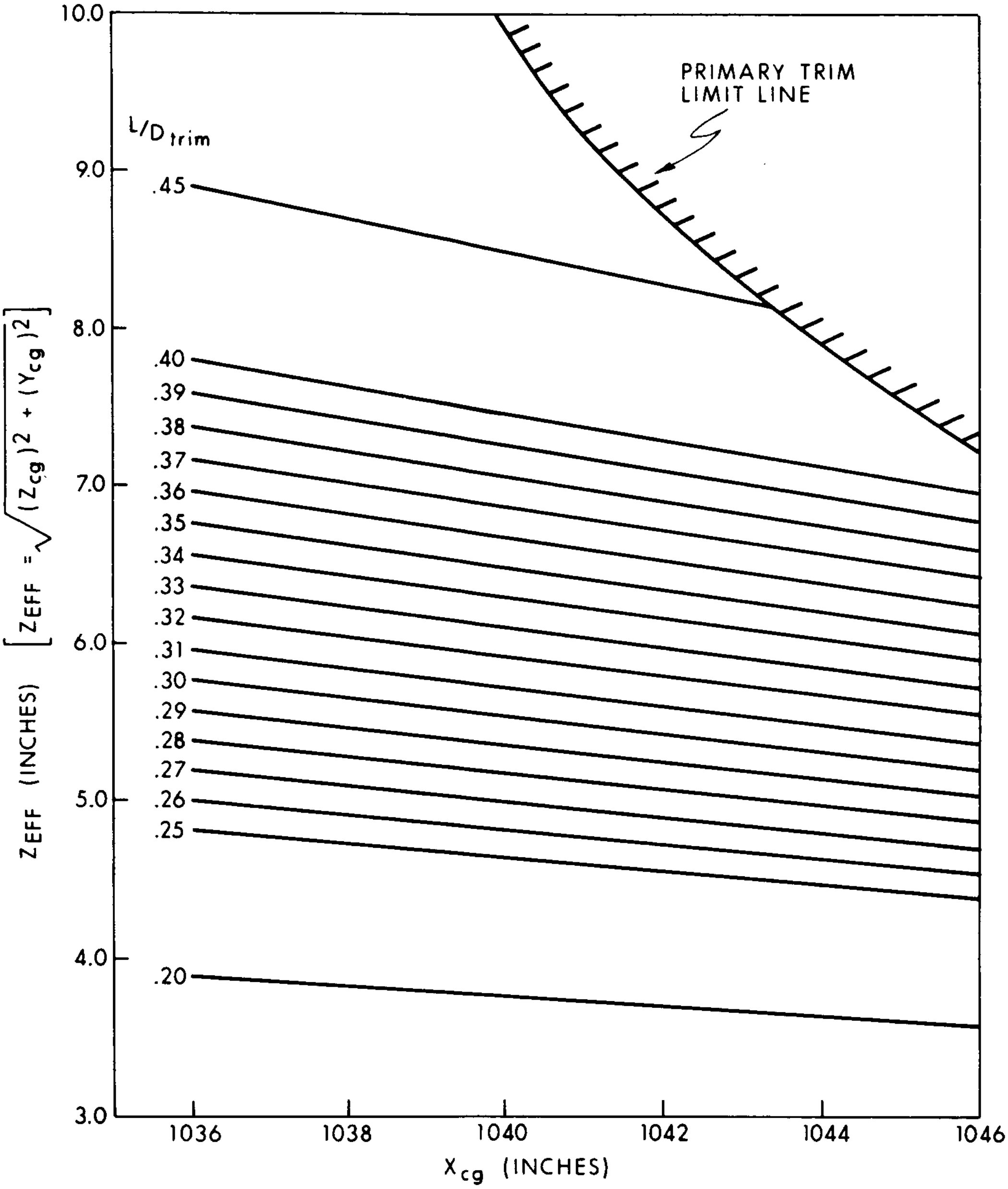
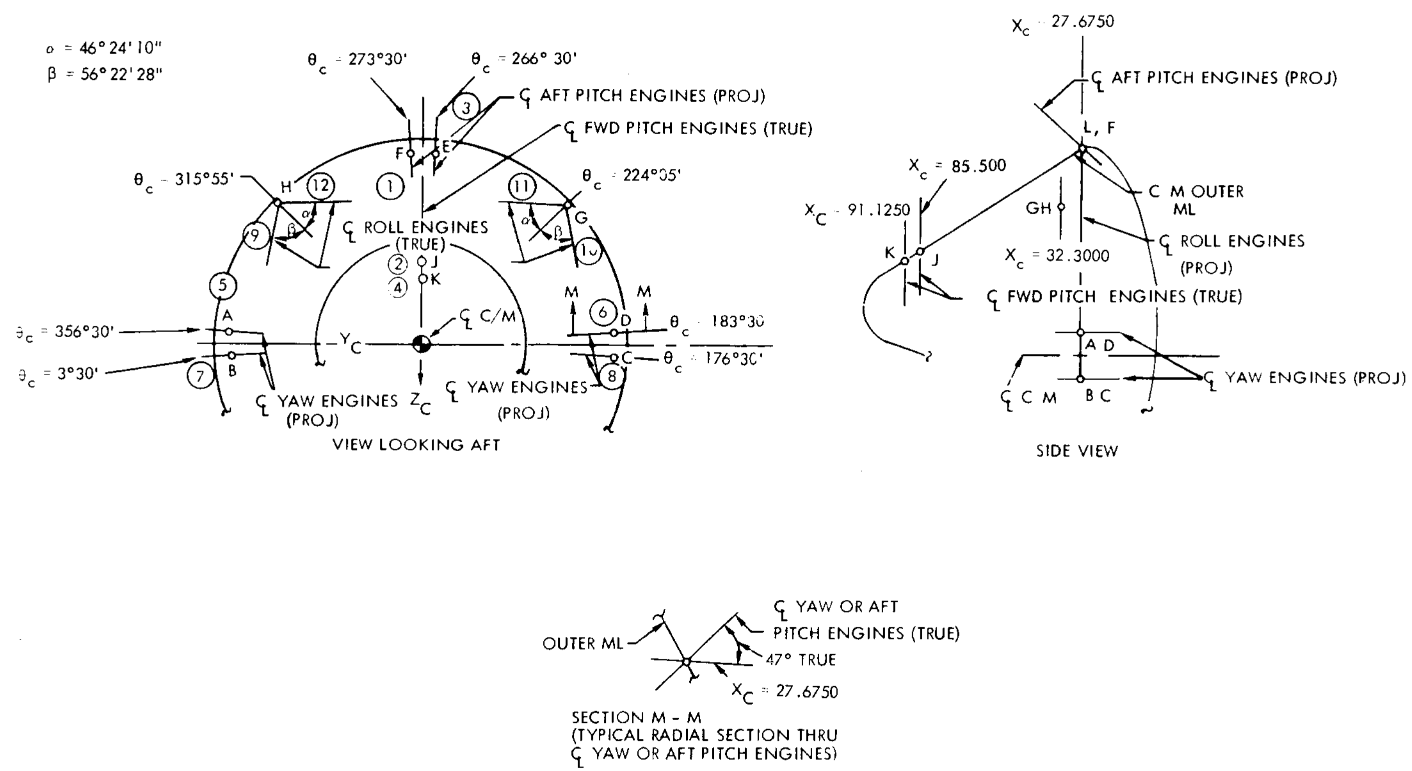


Fig. 6.18 Command Module (AF-017, 20) L/D_{trim} As A Function of Center-of-Gravity Location Using M = 6-25 Data. Heat Shield Cant is 0.13°.

6.4.6.5 CM Reaction Control System (RCS) Data

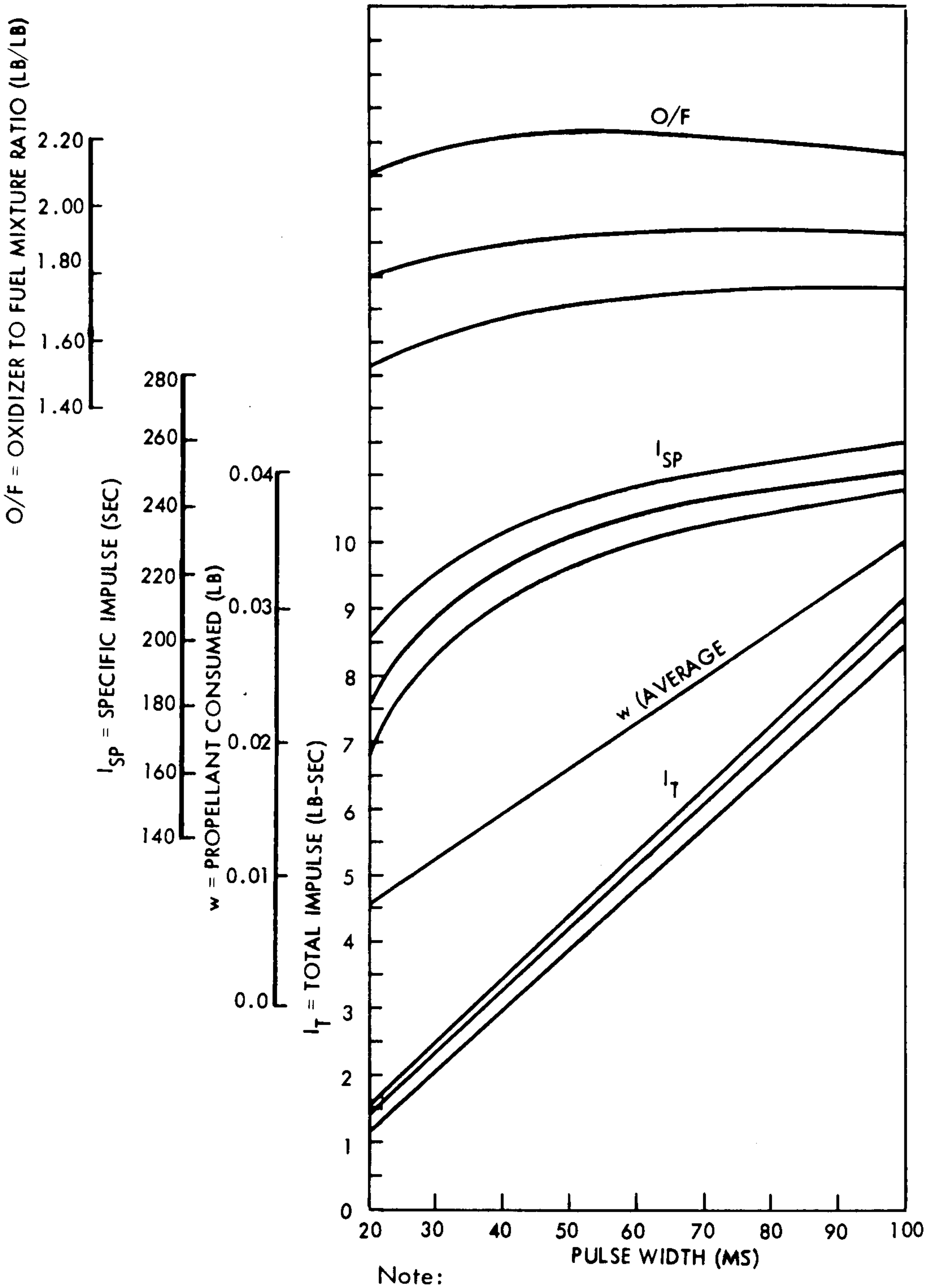
RCS thrust chamber configuration		Fig. 6.19
Total impulse		
Propellant consumed	vs electrical pulse width	Fig. 6.20, 6.21
Specific impulse		
Thrust		
Specific impulse	steady state operation	Fig. 6.21
Propellant flow rate		
Thrust buildup transients		not available
Thrust decay transients		not available

The figures referenced in this section are taken from TRW Systems Document # 2131-H009-R8-000, "Apollo Mission Data Specification D AS-501," dated 15 August 1966.



Notes:
(1) Not on outer ML - inters. pt. of ℄ roll engines.
(2) All linear measurements in inches.
(3) Jet numbering suggested by MIT.

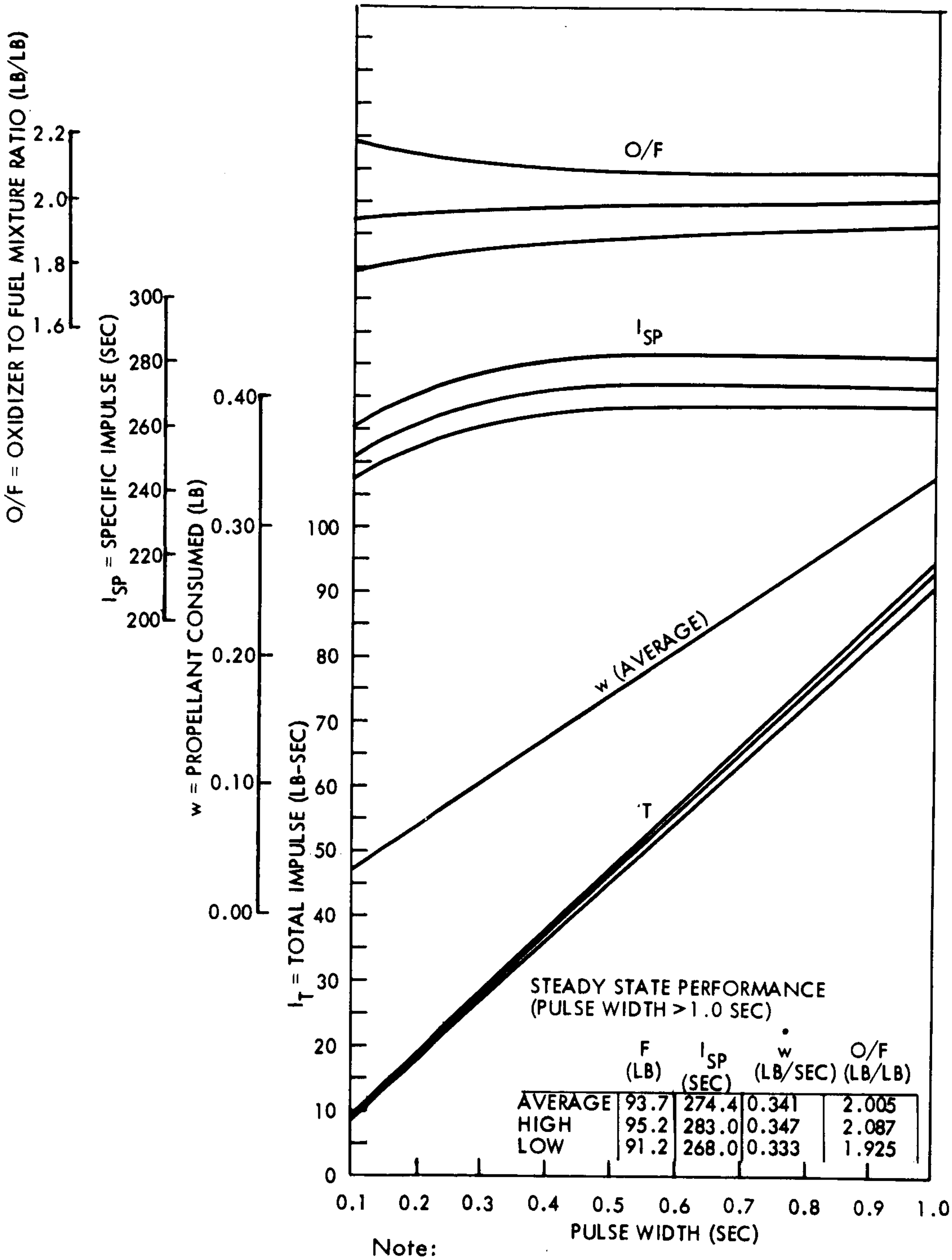
Fig. 6.19 CM/RCS Thrust Chamber Locations



Note:

Data are high, low, and average values resulting from a large number of qualification tests, with the exception of w, where only average values are available. High and low values shall be used as 3σ values.

Fig. 6.20 CM/RCS Vacuum Performance Data for Pulse Width Less than 100 ms.



STEADY STATE PERFORMANCE
(PULSE WIDTH > 1.0 SEC)

	F (LB)	I_{SP} (SEC)	$\dot{w}$ (LB/SEC)	O/F (LB/LB)
AVERAGE	93.7	274.4	0.341	2.005
HIGH	95.2	283.0	0.347	2.087
LOW	91.2	268.0	0.333	1.925

Note:

Data are high, low and average values resulting from a large number of qualification tests, with the exception of w, where only average values are available. However, high and low values of w are presented for steady state operation. High and low values shall be used as 3σ values.

Fig. 6.21 CM/RCS Vacuum Performance Data for Pulse Widths Greater than 100 ms.

7. G&N ERROR ANALYSIS

7.1 Introduction

The results of a revised G&N error study for the 501 mission are given here. This study was primarily concerned with the effects of IMU component uncertainties on trajectory uncertainties for two update cases. These were:

1) Navigational update 5 minutes before injection burn ignition (2nd SIVB burn). Referred to as update 1 in tables.

2) Navigational update 13 minutes before 2nd SPS burn ignition (22.2 min of free-fall coast to 400,000 ft). Referred to as update 2 in tables.

The case where update was made 20 minutes before injection burn ignition (considered in the previous revision) was not included in the present study, since the T_{ff} uncertainties for this case were not markedly different from the update 1 case.

The simulation of the state vector, or navigational R, V update, included the effects of tracking uncertainties. Updating did not apply to the alignment of the IMU Stable Member, since the SM is not realigned during the 501 flight.

The error studies assume a prelaunch Stable Member orientation as shown in Fig. 7.1. $\underline{X}_{SM}$ is up along the local vertical at launch instant, while $\underline{Z}_{SM}$ is horizontal down-range at the nominal azimuth. The gyro and accelerometer input axes are colinear with Stable Member axes.

Block 1 IMU uncertainties were assumed for these studies (see section 7.9 for data). These were the same as those assumed for the previous revision of July 1966, with one important exception: 3-meru bias drift uncertainty is used in this error study, whereas in the previous revision 2-meru bias drift was inadvertently used.

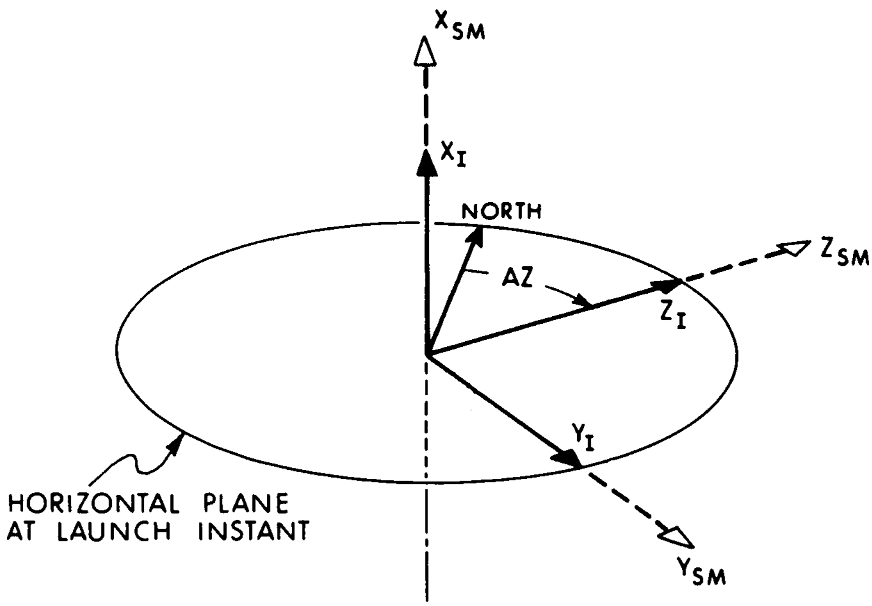
7.2 Significant Results of Error Study

Of primary concern in the error studies were the effects of IMU uncertainties on:

1) Uncertainty in computed free-fall time of flight, $(U)T_{ff}$, to the reentry start altitude of 400,000 feet.

2) Flight path angle uncertainty, $(U)\gamma_{AA}$, at reentry start.

3) CEP at reentry end.



X_I, Y_I, Z_I - LAUNCH INERTIAL AXES

X_{SM}, Y_{SM}, Z_{SM} - IMU STABLE MEMBER AXES

Note: NOMINAL AZIMUTH IS 72°.

Fig. 7.1 Coordinate Axes for 501 Launch Configuration

Table 7.1 gives these data in summary form. All uncertainties represent the combined effect of 1σ Block 1 IMU uncertainties and tracking update uncertainties. Tables 7.7 and 7.10 give detailed data on IMU component contributions to $(U)T_{ff}$. Table 7.13 gives detailed data on contributions to $(U)\gamma_{AA}$ for the two update cases. The reader should consult Section 7.11 and Fig. 7.2 on the definition used for flight-path-angle uncertainty.

7.3 Accelerometer Inputs to AGC

For normal free-fall flight periods the AGC does not receive acceleration information from the IMU accelerometers. Accelerometer bias has then no effect on AGC inputs.

For the 501 mission AGC programming similar to that for the 202 mission will be used. For the 202 mission the AGC was left sensitive to accelerometer outputs from SIVB cutoff to 1st SPS burn ignition. Correspondingly, for the 501 mission the AGC will accept output ΔV's from the accelerometers from 1st SIVB cutoff through the whole parking orbit and from 2nd SIVB burn (injection burn) cutoff for about 12 minutes to 1st SPS burn ignition.

After 1st SPS burn cutoff the AGC is then insensitive to accelerometer outputs until 30 seconds before 2nd SPS burn ignition (time of ullage start). The AGC then accepts accelerometer data the rest of the flight including the coast to reentry start.

Table 7.2 gives indication uncertainties before update at 5 minutes before injection burn. These relatively large uncertainties show the effect of the AGC's continuing sensitivity to accelerometer bias while in parking orbit. An update before injection burn ignition is imperative; otherwise, computed T_{ff} uncertainties after the burn would be excessively large.

7.4 Error Table Description

The following tables, summarizing the results of the error studies, are to be found at the end of this section. Tables 7.3 through 7.15 are detailed error tables showing individual contributions by IMU component uncertainties.

TABLE 7.1

Summary of Significant Uncertainties

Uncertainty in	Event	Timing of Navigational Update: Update 1, 5 min before Injection Burn Ignition — IMU Uncert. Polarity: Pos.	Update 1 — Neg.	Update 2, 13 min before 2nd SPS Burn Ignition — IMU Uncert. Polarity: Pos.	Update 2 — Neg.
Computed Free-Fall Time of Flight to 400,000-ft Altitude $(U)T_{ff}$	Injection burn cutoff	132	131 sec.	-	-
	1st SPS burn cutoff	178	177 sec.	-	-
	13 min. before 2nd SPS burn ignition	188	134 sec.	0.16	0.16 sec.
	2 min. before 2nd SPS burn ignition	205	126 sec.	0.17	0.17 sec.
Flight Path Angle, $(U)\gamma_{AA}$	Reentry Start (400,000-ft alt)	3.88 (67.7 mr)	2.07 deg. (36.1 mr)	0.177 (3.1 mr)	0.174 deg. (3.0 mr)
CEP	Reentry End (24,000-ft alt)	455.0 n. mile		11.9 n. mile	

TABLE 7.2

Summary of 501 Flight Uncertainties

Event	Time from Launch secs	Update	RSS Position Uncert. n. miles			RSS Velocity Uncert. ft/sec			Flight Path Angle Uncert. $(U)\gamma_{AI}$ mr	$(U)T_{ff}$ secs	
			Alt	Track	Range	Alt	Track	Range		Pos	Neg*
Earth Launch	0		0	0	0	0	0	0	0	0	0
SIVB Cutoff	687.5	No	0.90	4.96	0.39	18.2	78.5	5.7	-	-	-
5 min. before Injection Ignition	11,186	No 1 Now	28.5 0.10	4.02 0.04	112.0 0.41	601.9 2.6	81.9 0.6	208.3 0.4	- -	- -	- -
Injection Ignition	11,486	1	0.15	0.11	0.41	4.9	3.9	3.9	-	-	-
Injection Cutoff	11,822	1	0.56	0.87	0.86	18.0	41.2	23.6	0.57	132	131
SPS1 Ignition	12,518	1	3.37	5.21	3.39	33.1	34.4	23.7	1.20	152	151
SPS1 Cutoff	12,545	1	3.52	5.37	3.49	33.8	35.8	24.4	1.20	178	177
	16,000	1	31.11	14.9	27.3	84.3	4.6	38.2	5.07	179	177
Apogee	20,926	1	99.9	11.8	97.4	172.4	10.0	55.4	13.5	179	176
	25,000	1	201.0	3.2	204.1	370.4	15.5	64.2	8.6	182	174
13 min. before SPS2 Ignition	28,906	1 2 Now	355.6 0.02	6.2 0.07	536.3 0.08	1840 0.3	6.9 0.6	77.4 0.1	25.8 -	188 .16	134 .16
2 min. before SPS2 Ignition	29,566	1 2	329.8 0.03	6.4 0.07	703.8 0.08	3127 0.6	10.2 0.7	52.4 0.4	53.6 -	205 .17	126 .17
SPS2 Ignition	29,686	1 2	312.4 0.03	6.2 0.07	741.0 0.08	3469 0.6	9.8 0.7	39.2 0.4	60.9 0.016	208 .17	128 .17
SPS2 Cutoff	29,948	1 2	232.7 0.52	5.1 0.72	829.0 0.30	4282 26.5	52.1 35.5	72.0 14.3	101.0 0.92	99 2.4	77 2.5
Reentry Start (at 400,000 ft)	30,183	1 2	89.1 1.8	2.4 2.1	892.9 0.4	4838 34.4	61.9 33.3	148.0 7.0	53.8 3.07	- -	- -
Reentry End (at 24,000 ft)	31,067	1 2	193.3 14.0	35.6 17.3	736.3 2.8	5852 255	170 235	3253 53	- -	- -	- -

* $(U)T_{ff}$ for positive and negative IMU uncertainties.

			Alt	North	East	Alt	North	East
Reentry Start	30,183	1 2	88.8 1.8	326.4 1.9	831.6 0.8	4840 34	99 31	129 14
Reentry End	31,067	1 2	193.3 14.0	30.4 17.3	736.5 2.8	5852 255	172 235	3254 53

7.9 Uncertainties at 2 mins. before SPS2 ignition (Update 1)

7.10 T_{ff} uncertainties at 13 and 2 mins. before SPS2 ignition

7.11 Reentry start uncertainties (Update 1)

7.12 Reentry start uncertainties (Update 2)

7.13 Flight path angle uncertainties at reentry start (Updates 1 & 2)

7.14 Reentry end uncertainties (Update 1)

7.15 Reentry end uncertainties (Update 2)

7.16 Stable Member drift angles and misalignments

7.17 Propagation of Initial Condition Errors from SPS1 cutoff

7.18 Propagation of Initial Condition Errors from Update 2 point

All tables for position and velocity uncertainty and for computed time-of-flight uncertainty ((U)T_{ff}) are for indication uncertainties (i.e. indicated-minus-actual). However, Table 7.13 for flight-path-angle uncertainties are for actual-minus-indicated flight-path angle.

Most tables give uncertainties relative to local axes at event time. Positive local axes are defined as follows:

Altitude	-	outwards along $\underline{R}$ at event time.
Track	-	along $\underline{V} \times \underline{R}$
Range	-	along $\underline{Alt} \times \underline{Track}$

7.5 Initial Error Condition Propagation Tables

The last two tables at the end of this section are given to show how unit initial-condition errors propagate, first, from SPS1 cutoff conditions, and second, from update time 13 minutes before SPS2 ignition. The first table, 7.17, shows how velocity magnitude and angle errors as well as altitude errors propagate during the long coast. The second table, 7.18, shows how unit position and velocity errors propagate from the update 2 point, and may be useful for decisions relative to this update.

7.6 T_{ff} Computation Uncertainties

The uncertainties in computed free-fall time of flight, (U)T_{ff}, were calculated by perturbing the equation for T_{ff} (see Section 5.7) with the position and velocity uncertainties due to each IMU component uncertainty. As indicated in Section 5.7 the approximate equation for T_{ff} is used when $e \geqslant 0.8$ and $a > 5 \times 10^7$ ft. This condition exists at SPS2 cutoff, although it does not exist at SPS2 ignition.

Tables 7.1 and 7.2 give rss data on the effect of IMU component uncertainties on the computation of free-fall time of flight to the reentry start altitude of 400,000 feet. Tables 7.7 and 7.10 give detailed data on contributions to (U)T_{ff} at various event times.

The relatively large increase in $(U)T_{ff}$ between injection burn and 1st SPS burn cutoff is primarily due to the effect of accelerometer bias during the intervening coast. The AGC accepts accelerometer outputs during this time interval.

During most of the long coast the rss uncertainty in T_{ff} (with update 5 min before injection burn) remains almost constant at 178 seconds. The magnitude of $(U)T_{ff}$ is approximately the same for positive and negative IMU uncertainties. However, by the time that Update 2 time is reached (13 minutes before SPS2 burn ignition) the T_{ff} uncertainties for positive and negative IMU uncertainties have diverged considerably as can be seen from Tables 7.1 and 7.2. The prime contributors to $(U)T_{ff}$ during the long coast are X- and Z- accelerometer biases and Y- and Z- gyro bias drift.

7.7 Flight-Path-Angle Uncertainty

Data on flight-path-angle uncertainty at reentry start is given in Tables 7.1 and 7.2. Tables 7.13 gives detailed data on IMU component contributions to $(U)\gamma_{AA}$. Section 7.11 and Fig. 7.2 should be consulted for definitions.

Of primary interest are the data for the Update 2 case. Table 7.13 shows that Y-gyro bias drift uncertainty (NBDY) is by far the most important contributor to the rss uncertainty of 0.175^o (3.05 mr). Positive NBDY is responsible for 0.172^o (3.01 mr), while negative NBDY is responsible for -0.168^o (-2.94 mr).

Table 7.13 shows that for NBDY the flight-path-angle uncertainty relative to spacecraft actual location axes at nominal time, $(U)\gamma_{AI}$, is 0.96 mr. At nominal time, assuming that BDY is the only uncertainty, the S/C is 10,725 feet above the nominal altitude of 400,000 feet. The coefficient, $d\gamma/dAlt$, relating change in flight-path angle to altitude change is 0.188 (10^{-3}) mr/feet. The change in path angle from nominal time to the time that the S/C actually reaches 400,000 feet is then 2.02 mr (0.116 deg). Summing this with $(U)\gamma_{AI}$ gives an approximation to $(U)\gamma_{AA}$ of 2.98 mr. This is close to the $(U)\gamma_{AA}$ given above, and clearly shows the altitude dependency of $(U)\gamma_{AA}$ for this situation.

7.8 Navigation Update Conditions and Uncertainties

Because the AGC accepts accelerometer outputs during the parking orbit, by the time of injection burn ignition relatively large position and velocity indication uncertainties develop due to the presence of accelerometer bias uncertainties. Because of this, a navigational update before injection burn ignition is provided for. For the error studies an update 5 minutes before injection burn ignition was assumed.

A 2nd navigational update 13 minutes before the 2nd SPS burn ignition (or 22.2 minutes of free-fall coast to 400,000-ft altitude) is also made. At this time the T_{ff} to $T_{ff(min)}$ comparison is started, where $T_{ff(min)}$ is nominally 2 minutes before SPS2 burn ignition.

At both update times the uncertainties in position and velocity are reduced to those represented by the tracking update uncertainties.

The navigational updates would be performed on the basis of orbit computations made using observations by the MSFN (Manned Space Flight Network). The tracking-station-computed position and velocity vectors would be subject to uncertainties because of noise and bias in tracking measurements.

In this IMU error study, simulation of tracking update uncertainties was based on data available in MSC Internal Note No. 66-FM-46, "Error Analysis of MSFN Tracking Data for AS-501" by P. T. Pixley and M. L. Alexander. Tracking uncertainty covariance matrices for times just before injection burn ignition and the 2nd SPS burn ignition were available in this report. The one-sigma position and velocity uncertainties for the two update times relative to local vertical axes were as follows:

	Position Uncertainty (in nautical miles)			Velocity Uncertainty (in ft/sec)		
	Alt.	Track	Range	Alt.	Track	Range
5 min before Inject. Burn Ignit.	0.10	0.04	0.41	2.6	0.6	0.4
13 min before 2nd SPS Ignit.	0.02	0.07	0.08	0.3	0.6	0.1

In the error tables, after updating time, the uncertainties include the effects of both navigational update and IMU uncertainties.

7.9 IMU Errors and Uncertainties

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

1) accelerometer bias error (ACB)
2) accelerometer scale factor error (SFE)
3) gyro bias drift (NBD)
4) gyro input axis acceleration sensitive drift (ADIA)
5) gyro spin reference axis acceleration sensitive drift (ADSRA)

Since the average IMU errors will be compensated by means of AGC programs during prelaunch and in flight, it is the actual unpredictable deviations from the measured average errors that constitute the IMU component uncertainties.

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.

The Block I IMU error uncertainties (see also MEI No. 1015000-Part I) for the present error studies are as follows:

Block I One-Sigma IMU Error Uncertainties

	Input Axis			
	X	Y	Z	Units
Accelerometer bias (ACB)	0.40	0.40	0.40	cm/sec^2
Accelerometer scale factor (SFU)	150	150	150	PPM
Accelerometer nonlinearity (NC)	10	10	10	$\mu g/g^2$
Gyro bias drift (BD)	3	3	3	meru
Gyro input axis accel. sens. drift (ADIA)	8	8	8	meru/g
Gyro spin axis accel. sens. drift (ADSRA)	5	5	5	meru/g
Gyro acceleration squared sens. drift	0.2	0.2	0.2	$meru/g^2$
Accelerometer I. A. misalignments				
Non-orthogonality X to Z	0.14	-	-	mr
Non-orthogonality X to Y	0.14	-	-	mr
Y about X_{SM}	-	0.10	-	mr
Gyro I. A. misalignment				
About SRA	0.50	0.50	0.50	mr
About OA	0.50	0.50	0.50	mr

Certain IMU component uncertainties affect both the pre-launch alignment of the Stable Member and the in-flight computation by the AGC of position and velocity. The accelerometer bias uncertainties affect the vertical erection of the Stable Member about Y_I and Z_I (see Fig. 7.1). The gyro bias and acceleration sensitive drift rate uncertainties affect the azimuth alignment of the SM through their effect on the gyro-compassing loop during pre-launch alignment. Table 7.4 shows the effects of the various gyro drift uncertainties on azimuth alignment uncertainty. This table shows that the rss azimuth alignment uncertainty is 3.5 mr.

The IMU uncertainties affecting pre-launch SM alignment and the in-flight navigation computations are assumed to be correlated. Their effects on position and velocity uncertainties are accordingly summed arithmetically in the error tables.

7.10 Stable Member Orientation

The orientation of the 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. 7.1. 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 of launch instant and oriented at the nominal launch azimuth of 72° from north. The X_I - Z_I plane will be the initial pitch plane as well as initial reference trajectory plane. The Stable Member is not realigned during flight.

Table 7.16 gives data on SM drifts and misalignments throughout the flight. Table 7.4 gives detailed data on SM misalignments at SIVB cutoff.

7.11 Flight-Path-Angle and Altitude-Rate Uncertainty Definitions

Fig. 7.2 defines the three flight-path-angle uncertainties, $(U)\gamma_{AI}$, $(U)\gamma_{AIN}$ and $(U)\gamma_{AA}$. Data for $(U)\gamma_{AA}$ are given only for reentry start (at 400,000-ft altitude) in the summary tables, 7.1 and 7.2, since the flight-path-angle uncertainty with the spacecraft actually at 400,000-ft altitude is the desired parameter. For all other times during the 501 flight, data are given for $(U)\gamma_{AI}$.

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, $(U)\gamma_{AIN}$, will increase correspondingly, since γ_{AIN} is measured relative to the nominal horizontal axis.

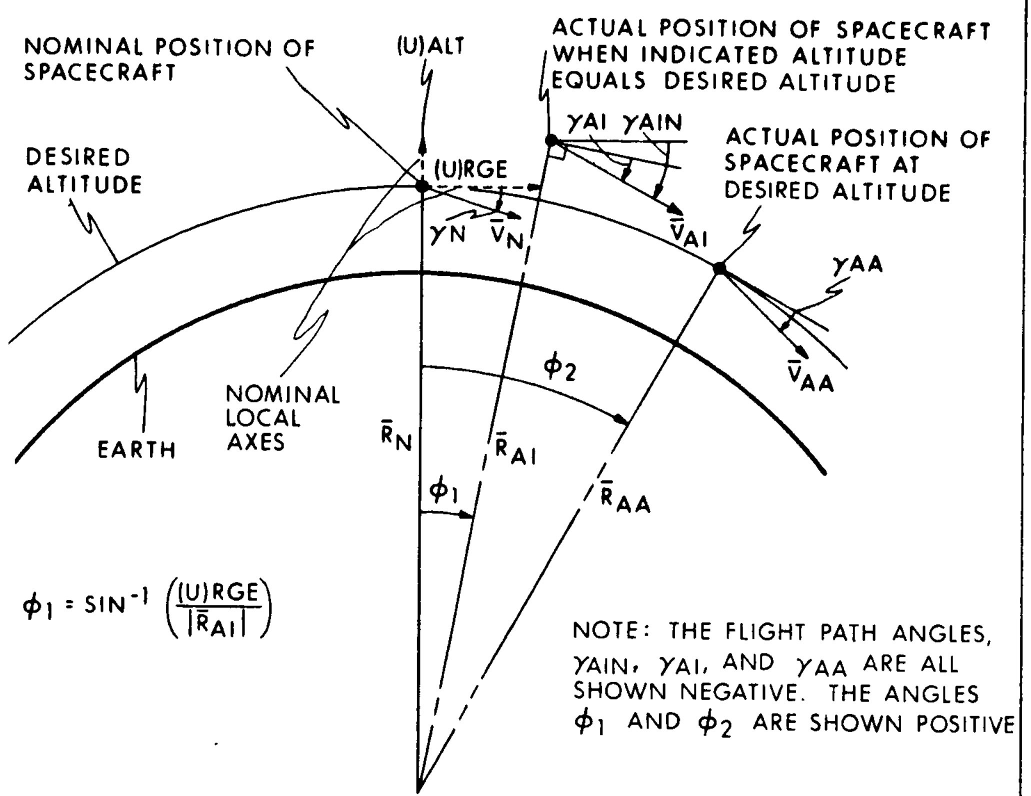
Data in all error tables for RSS position and velocity uncertainties are given relative to nominal local vertical axes (see Fig. 7.2). These data may be used to compute $(U)\gamma_{AIN}$. Unless appropriate transformations are made, $(U)\gamma_{AI}$ can not be computed from the tabulated position and velocity uncertainties.

7.12 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 require 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.

7.13 Error Table Explanation

To make up a one-page error table format some of the more insignificant error sources were omitted. These included certain accelerometer input axis misalignments and gyro acceleration and acceleration squared sensitive drift uncertainties.



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

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

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

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

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. 7-2 Flight Path Angles

The principal IMU component uncertainties are denoted by the following abbreviations:

ACB - accelerometer bias. Units are cm/sec^2.

SFU - accelerometer scale factor uncertainty. Units are parts per million.

NC - acceleration squared indication uncertainty. Units are micro-g per g^2 $(10^{-6} g/g^2)$

NBD - gyro null bias drift uncertainty. Units are meru (milli-earth rate units)

ADIA - gyro input axis acceleration sensitive drift. Units are meru/g.

ADSRA - gyro spin reference axis acceleration sensitive drift. Units are meru/g.

AD - gyro acceleration squared sensitive drift. Units are $meru/g^2$ (e.g., ADIXX - gyro input axis acceleration squared sensitive drift)

The symbols X, Y, Z denote the input axis of the IMU gyro or accelerometer to which the uncertainty applies. IMU component input axes are identical with SM axes.

Initial SM Misalignments (Uncorrelated) - The misalignment uncertainty about X_I (azimuth) of 0.5 mr is primarily due to gyro input axis misalignments relative to SM axes. This misalignment as well as those about Y_I and Z_I are independent of the SM misalignments caused by the effect of IMU component uncertainty on SM vertical erection and azimuth alignment. These pre-launch SM misalignments are partially given elsewhere in the error tables. For SIVB cutoff, Table 7.4 gives the individual SM pre-launch alignment uncertainties.

The subscript "INIT", used with some of the IMU uncertainties such as ACBX, denotes those uncertainties (position and velocity) due to the initial pre-launch SM misalignment caused by the particular IMU uncertainty. The subscript "FLGT" denotes those uncertainties due to the effect of the IMU uncertainty on in-flight navigation computations. For gyro drift terms it also includes the effect of gyro drift since launch. The subscript "COMB" denotes the arithmetic sum of the above two effects.

TABLE 7.3 SIVB Cutoff Indication Uncertainties

OSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 0 HR, 11 MIN, 27.542 SEC (687.542 SEC)

NCERT. OURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
NITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	54.9	4279.3	46.9	0.168	11.076	0.118
ABOUT YI	0.025 MR	- 163.0	- 0.8	421.8	- 0.581	0.000	0.437
ABOUT ZI	0.025 MR	- 1.8	- 134.6	- 1.4	- 0.003	- 0.187	- 0.001
CCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	- 1284.3	6.6	275.5	- 3.996	0.016	1.554
X ABOUT Z	0.141 MR	0.0	0.0	0.0	0.000	0.000	0.000
Y ABOUT X	0.100 MR	10.9	855.8	9.3	0.033	2.215	0.023
CCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	3135.7	- 16.0	- 1402.9	10.165	- 0.042	- 3.988
ACBXCOMB		3135.7	- 16.0	- 1402.9	10.165	- 0.042	- 3.988
ACBYINIT		- 29.5	- 2197.1	- 23.6	- 0.061	- 3.051	- 0.030
ACBYFLGT	0.400 CM/S.SQ	37.6	2923.9	31.9	0.121	8.039	0.086
ACBYCOMB		8.1	726.7	8.3	0.059	4.987	0.056
ACBZINIT		2659.4	14.1	- 3019.3	9.492	- 0.002	- 7.138
ACBZFLGT	0.400 CM/S.SQ	1360.3	- 44.2	2015.6	4.282	- 0.121	7.146
ACBZCOMB		4019.8	- 30.0	- 1003.7	13.775	- 0.123	0.007
CCEL.SCALE FACTOR							
SFUX	150 PPM	- 934.8	4.4	510.0	- 2.070	0.005	0.688
SFUY	150 PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFUZ	150 PPM	- 596.4	19.4	- 1148.7	- 1.788	0.050	- 2.952
CCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	85.2	- 0.4	- 37.2	0.192	- 0.000	- 0.064
NCZZ	10 MG/GSQ	71.6	- 2.3	437.2	0.194	- 0.005	0.308
YRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	24.0	1872.3	20.5	0.073	4.846	0.052
NBDXFLGT(0.150 MR.DRIFT		5.6	455.9	5.0	0.022	1.653	0.018
NBDXCOMB	SINCE LAUNCH)	29.7	2328.2	25.5	0.096	6.500	0.070
NBDYINIT	3.0 MERU	115.8	9023.8	98.9	0.356	23.357	0.250
NBDYFLGT(0.150 MR.DRIFT		- 397.0	0.4	326.5	- 1.732	0.006	0.887
NBDYCOMB	SINCE LAUNCH)	- 281.1	9024.3	425.4	- 1.375	23.364	1.138
NBDZINIT	3.0 MERU	356.6	27772.4	304.4	1.096	71.887	0.771
NBDZFLGT(0.150 MR.DRIFT		- 1.7	- 131.4	- 1.4	- 0.003	- 0.139	- 0.001
NBDZCOMB	SINCE LAUNCH)	354.8	27640.9	302.9	1.093	71.747	0.770
YRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	79.6	6217.3	68.2	0.249	16.530	0.177
ADSAYCOMB	5.0 MERU/G	790.7	- 1.6	- 294.5	3.465	- 0.014	- 1.706
ADIAZCOMB	8.0 MERU/G	- 4.3	- 337.2	- 3.6	- 0.007	- 0.339	- 0.003
YRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	0.5	43.2	0.4	0.001	0.121	0.001
ADSYY	0.2 MERU/GSQ	- 59.9	0.1	45.7	- 0.252	0.000	0.127
ADIZZ	0.2 MERU/GSQ	- 0.2	- 16.6	- 0.1	- 0.000	- 0.019	- 0.000
SS UNCERT.(FT AND FT/SEC)		5454.7	30153.7	2345.2	18.227	78.497	5.716
SS UNCERT.(N.MI.AND FT/SEC)		0.897	4.962	0.385	18.227	78.497	5.716

TABLE 7.4 IMU Stable Member Misalignments at SIVB Cutoff

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (S.M.ORIENT.ANGLES AXI= 0.00, AYI= 0.00, AZSM= 0 DEG) (T= 687.5 SECS)

UNCERT. SOURCE	ONE SIGMA UNCERT.VALUE		MLM. ANGLE ABOUT INERTIAL AXES MR. XI	YI	ZI	MLM. ANGLE ABOUT LOCAL VERTICAL AXES MR. ALT.	TRACK	RANGE
INIT.S.M.MLMS. (UNCORREL.) ABOUT								
XI	0.500	MR.	0.5000	0.0000	0.0000	0.4504	- 0.0027	- 0.2169
YI	0.025	MR.	0.0000	0.0250	0.0000	0.0002	0.0249	0.0002
ZI	0.025	MR.	0.0000	0.0000	0.0250	0.0108	- 0.0003	0.0225
INIT.S.M.MLMS.DUE TO IMU ERROR EFFECTS ON EARTH LAUNCH ERECTION AND ALIGNMENT								
ACBX	0.40	CM/S.SQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ACBY	0.40	CM/S.SQ	0.0000	0.0000	0.4078	0.1769	- 0.0061	0.3674
ACBZ	0.40	CM/S.SQ	0.0000	- 0.4078	0.0000	- 0.0046	- 0.4078	- 0.0045
NBDX	3.0	MERU	0.2187	0.0000	0.0000	0.1971	- 0.0011	- 0.0949
NBDY	3.0	MERU	1.0543	0.0000	0.0000	0.9499	- 0.0057	- 0.4574
NBDZ	3.0	MERU	3.2449	0.0000	0.0000	2.9236	- 0.0177	- 1.4077
ADIAX	8.0	MERU/G	0.5833	0.0000	0.0000	0.5256	- 0.0031	- 0.2530
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
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)			3.5042	0.4086	0.4086	3.1622	0.4090	1.5641
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START								
NBDX	3.0	MERU	0.1502	0.0000	0.0000	0.1353	- 0.0008	- 0.0651
NBDY	3.0	MERU	0.0000	0.1502	0.0000	0.0017	0.1502	0.0016
NBDZ	3.0	MERU	0.0000	0.0000	0.1502	0.0651	- 0.0022	0.1353
ADIAX	8.0	MERU/G	0.1775	0.0000	0.0000	0.1600	- 0.0009	- 0.0770
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	- 0.2825	0.0000	- 0.0032	- 0.2824	- 0.0031
ADIAZ	8.0	MERU/G	0.0000	0.0000	0.4520	0.1960	- 0.0068	0.4072
ADSRAZ	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIXX	0.2	MERU/GSQ	0.0061	0.0000	0.0000	0.0055	- 0.0000	- 0.0026
ADSYY	0.2	MERU/GSQ	0.0000	0.0181	0.0000	0.0002	0.0181	0.0002
ADIZZ	0.2	MERU/GSQ	0.0000	0.0000	0.0181	0.0078	- 0.0002	0.0163
RSS DRIFT ANGLE			0.2326	0.3204	0.4766	0.2944	0.3205	0.4411
OVERALL RSS MLM			3.5119	0.5193	0.6478	3.1758	0.5197	1.6252

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TABLE 7.5 Injection Burn Cutoff Uncertainties (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 3 HR, 17 MIN, 1.758 SEC (11821.759 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MEMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	233.8	590.1	45.3	1.684	4.318	0.299
ABOUT YI	0.025 MR	-2.6	3.5	30.7	-0.097	0.021	0.187
ABOUT ZI	0.025 MR	-5.9	-9.9	12.7	-0.043	0.012	0.080
ACCEL.INPUT AXIS MEMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	-75.6	16.2	146.3	-0.566	0.121	1.071
X ABOUT Z	0.141 MR	-33.7	7.3	64.9	-0.243	0.051	0.457
Y ABOUT X	0.100 MR	-0.6	115.1	-13.4	-0.004	0.843	-0.098
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MEMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.9	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	1368.5	-261.4	-2334.9	4.742	-0.786	-7.077
ACBXCOMB		1368.5	-261.4	-2334.9	4.742	-0.786	-7.077
ACBYINIT		-96.3	-162.0	208.5	-0.702	0.211	1.311
ACBYFLGT	0.400 CM/S.SQ	-10.2	2514.9	-294.0	-0.025	7.572	-0.886
ACBYCOMB		-106.5	2352.9	-85.4	-0.727	7.783	0.425
ACBZINIT		43.9	-58.2	-501.8	1.594	-0.346	-3.052
ACBZFLGT	0.400 CM/S.SQ	2516.8	138.3	1044.7	8.543	0.415	3.060
ACBZCOMB		2560.8	80.1	542.8	10.137	0.068	0.008
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-32.6	6.8	60.8	-0.012	-0.002	-0.017
SFUY	150 PPM	-0.4	76.5	-8.9	-0.002	-0.539	-0.062
SFUZ	150 PPM	-159.7	-9.1	-76.1	-1.194	-0.071	-0.557
ACCEL.SG.IND.UNCERT.							
NCXX	10 MG/GSQ	1.3	-0.2	-2.5	0.010	-0.002	-0.020
NCZZ	10 MG/GSQ	7.9	0.4	3.8	0.070	0.004	0.033
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MEMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	102.3	258.1	19.8	0.736	1.889	0.131
NBDXFLGT	(2.585 MR.DRIFT	1188.1	3002.3	229.8	8.603	22.079	1.530
NBDXCOMB	SINCE LAUNCH)	1290.4	3260.4	249.6	9.340	23.969	1.661
NBDYINIT	3.0 MERU	493.0	1244.3	95.5	3.551	9.105	0.631
NBDYFLGT	(2.585 MR.DRIFT	-285.2	362.2	3124.5	-10.084	2.166	19.088
NBDYCOMB	SINCE LAUNCH)	207.8	1606.6	3220.0	-6.532	11.272	19.720
NBDZINIT	3.0 MERU	1517.5	3829.8	293.9	10.929	28.024	1.944
NBDZFLGT	(2.585 MR.DRIFT	-599.9	-998.5	1298.1	-4.397	1.426	8.207
NBDZCOMB	SINCE LAUNCH)	917.5	2831.2	1592.1	6.532	29.450	10.152
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MEMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	367.5	930.3	70.9	2.646	6.802	0.469
ADSAYCOMB	5.0 MERU/G	47.6	-43.8	-378.8	1.428	-0.273	-2.420
ADIAZCOMB	8.0 MERU/G	-117.1	-175.1	251.2	-0.907	0.502	1.675
RSS UNCERT.(FT AND FT/SEC)		3351.7	5301.4	4355.7	17.694	41.187	23.575
RSS UNCERT.(N.MI.AND FT/SEC)		0.551	0.872	0.716	17.694	41.187	23.575
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		0.561	0.873	0.856	17.958	41.190	23.581

TABLE 7.6 SPS1 Burn Cutoff Uncertainties (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 3 HR, 29 MIN, 5.303 SEC (12545.304 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	1538.2	3372.0	-839.3	2.355	3.404	-1.017
ABOUT YI	0.025 MR	46.0	17.0	159.1	0.036	0.016	0.165
ABOUT ZI	0.025 MR	13.1	1.1	72.5	0.010	0.022	0.070
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	168.2	94.2	948.3	0.160	0.095	0.974
X ABOUT Z	0.141 MR	70.6	40.5	407.7	0.062	0.039	0.404
Y ABOUT X	0.100 MR	-60.5	658.4	-52.9	-0.086	0.665	-0.049
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	-1123.3	-1065.1	-11399.5	-1.436	-1.415	-14.970
ACBXCOMB		-1123.3	-1065.1	-11399.5	-1.436	-1.415	-14.970
ACBYINIT		214.6	19.0	1183.3	0.171	0.361	1.144
ACBYFLGT	0.400 CM/S.SQ	-937.1	10357.6	-846.3	-1.588	13.854	-1.077
ACBYCOMB		-722.5	10376.7	337.0	-1.417	14.216	0.066
ACBZINIT		-751.9	-277.9	-2597.3	-0.593	-0.261	-2.707
ACBZFLGT	0.400 CM/S.SQ	14218.7	574.2	-5072.7	24.975	0.776	-7.421
ACBZCOMB		13466.7	296.6	-7670.0	24.381	0.514	-10.128
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-15.4	3.7	55.7	-0.063	-0.009	-0.062
SFUY	150 PPM	-38.9	423.3	-34.0	-0.054	0.412	-0.030
SFUZ	150 PPM	-1281.9	-55.9	396.8	-1.973	-0.056	0.541
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	-3.1	-1.7	-17.9	-0.003	-0.001	-0.018
NCZZ	10 MG/GSQ	73.6	3.2	-22.2	0.113	0.003	-0.030
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	673.0	1475.3	-367.2	1.030	1.489	-0.445
NBDXFLGT	(2.744 MR.DRIFT	7849.9	17231.4	-4283.6	12.027	17.470	-5.201
NBDXCOMB	SINCE LAUNCH)	8523.0	18706.8	-4650.8	13.058	18.960	-5.647
NBDYINIT	3.0 MERU	3243.7	7110.1	-1769.9	4.966	7.179	-2.145
NBDYFLGT	(2.744 MR.DRIFT	4606.6	1736.2	16301.6	3.542	1.636	17.078
NBDYCOMB	SINCE LAUNCH)	7850.3	8846.9	14531.7	8.508	8.816	14.932
NBDZINIT	3.0 MERU	9983.1	21884.5	-5447.2	15.284	22.097	-6.602
NBDZFLGT	(2.744 MR.DRIFT	1338.8	199.9	7400.1	1.065	2.383	7.170
NBDZCOMB	SINCE LAUNCH)	11321.9	22084.4	1952.9	16.350	24.480	0.567
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	2416.7	5312.2	-1319.9	3.699	5.354	-1.598
ADSAYCOMB	5.0 MERU/G	-463.2	-218.0	-2140.7	-0.264	-0.208	-2.287
ADIAZCOMB	8.0 MERU/G	264.8	205.4	1504.0	0.210	0.658	1.477
RSS UNCERT.(FT AND FT/SEC)		21352.2	32636.8	20884.3	33.651	35.809	24.382
RSS UNCERT.(N.MI.AND FT/SEC)		3.514	5.371	3.437	33.651	35.809	24.382
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		3.515	5.371	3.492	33.800	35.811	24.400

TABLE 7.7a T_{ff} Uncertainties at Injection Burn Cutoff (Update 1)

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR POSITIVE ERRORS (SECS)

MLMXI	5.177	MXABTY	4.711	ACBXI	0.000	ACBYI	5.730	ACBZI -	14.291	SFEX -	0.292	NCXX-	0.090	SEC.
MLMYI	0.876	MXABTZ	2.000	ACBXF-	24.994	ACBYF -	4.913	ACBZF	41.483	SFEY -	0.350	NCYY-	0.008	SEC.
MLMZI	0.351	MYABTX-	0.548	ACBXT-	24.994	ACBYT	0.814	ACBZT	27.139	SFEZ -	5.529	NCZZ	0.322	SEC.
NBDXI	2.264	NBDYI	10.925	NBDZI	33.721	ADIAXT	8.132	ADSAXT	0.194	ADIXX	0.067			
NBDXF	25.489	NBDYF	89.619	NBDZF	35.914	ADIAYT-	0.832	ADSAYT-	11.047	ADSYY	0.670	RSS	132.334	SEC.
NBDXT	28.768	NBDYT	100.653	NBDZT	67.747	ADIAZT	7.340	ADSAZT-	0.271	ADIZZ	0.274			

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR NEGATIVE ERRORS (SECS)

MLMXI-	5.170	MXABTY-	4.709	ACBXI	0.000	ACBYI -	5.727	ACBZI	14.311	SFEX	0.292	NCXX	0.090	SEC.
MLMYI-	0.876	MXABTZ-	1.999	ACBXF	25.062	ACBYF	4.927	ACBZF -	41.309	SFEY	0.350	NCYY	0.008	SEC.
MLMZI-	0.351	MYABTX	0.548	ACBXT	25.062	ACBYT -	0.802	ACBZT -	27.050	SFEZ	5.532	NCZZ-	0.322	SEC.
NBDXI-	2.263	NBDYI -	10.896	NBDZI-	33.440	ADIAXT-	8.116	ADSAXT-	0.194	ADIXX-	0.067			
NBDXF-	25.315	NBDYF -	88.640	NBDZF-	35.787	ADIAYT	0.832	ADSAYT	11.059	ADSYY-	0.670	RSS	131.203	SEC.
NBDXT-	28.563	NBDYT -	99.649	NBDZT-	69.117	ADIAZT-	7.335	ADSAZT	0.271	ADIZZ-	0.274			

TABLE 7.7b T_{ff} Uncertainties at SPS1 Burn Cutoff (Update 1)

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR POSITIVE ERRORS (SECS)

MLMXI	6.022	MXABTY	5.628	ACBXI	0.000	ACBYI	6.610	ACBZI -	16.931	SFEX -	0.532	NCXX-	0.107	SEC.
MLMYI	1.038	MXABTZ	2.328	ACBXF-	79.347	ACBYF -	12.206	ACBZF	73.217	SFEY -	0.408	NCYY-	0.010	SEC.
MLMZI	0.404	MYABTX-	0.649	ACBXT-	79.347	ACBYT -	5.602	ACBZT	56.187	SFEZ -	6.506	NCZZ	0.377	SEC.
NBDXI	2.634	NBDYI	12.709	NBDZI	39.227	ADIAXT	9.463	ADSAXT	0.223	ADIXX	0.078			
NBDXF	30.790	NBDYF	106.455	NBDZF	41.447	ADIAYT-	1.033	ADSAYT-	13.160	ADSYY	0.796	RSS	178.372	SEC.
NBDXT	33.442	NBDYT	119.271	NBDZT	80.809	ADIAZT	8.473	ADSAZT-	0.315	ADIZZ	0.316			

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR NEGATIVE ERRORS (SECS)

MLMXI-	6.014	MXABTY-	5.626	ACBXI	0.000	ACBYI -	6.606	ACBZI	16.956	SFEX	0.532	NCXX	0.107	SEC.
MLMYI-	1.038	MXABTZ-	2.327	ACBXF	79.917	ACBYF	12.272	ACBZF -	72.636	SFEY	0.408	NCYY	0.009	SEC.
MLMZI-	0.405	MYABTX	0.649	ACBXT	79.917	ACBYT	5.659	ACBZT -	55.777	SFEZ	6.510	NCZZ-	0.377	SEC.
NBDXI-	2.632	NBDYI -	12.674	NBDZI-	38.894	ADIAXT-	9.444	ADSAXT-	0.223	ADIXX-	0.078			
NBDXF-	30.584	NBDYF -	105.458	NBDZF-	41.291	ADIAYT	1.033	ADSAYT	13.176	ADSYY-	0.796	RSS	177.281	SEC.
NBDXT-	33.199	NBDYT -	118.026	NBDZT-	80.052	ADIAZT-	8.467	ADSAZT	0.314	ADIZZ-	0.316			

TABLE 7.8 Uncertainties at 13 mins. before SPS2 Ignition (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR, 1 MIN, 46.215 SEC (28906.217 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	75956.5	-3915.9	-117925.5	66.537	-0.439	0.184
ABOUT YI	0.025 MR	12723.9	-19.7	-18278.9	10.449	-0.001	-0.419
ABOUT ZI	0.025 MR	4975.9	-1.9	-7151.7	4.085	-0.018	-0.165
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	69051.4	-109.7	-99130.5	56.650	-0.012	-2.317
X ABOUT Z	0.141 MR	28588.4	-47.9	-41068.9	23.463	-0.004	-0.953
Y ABOUT X	0.100 MR	-8040.4	-764.4	11819.6	-6.727	-0.086	0.185
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	-970494.0	1231.7	1380551.7	-790.996	0.430	35.934
ACBXCOMB		-970494.0	1231.7	1380551.7	-790.996	0.430	35.934
ACBYINIT		81184.6	-17.2	-116684.7	66.654	-0.296	-2.692
ACBYFLGT	0.400 CM/S.SQ	-151074.6	-11976.6	221145.4	-125.997	-4.270	3.742
ACBYCOMB		-69890.0	-11993.9	104460.7	-59.343	-4.566	1.049
ACBZINIT		-207596.8	322.9	298229.8	-170.491	0.019	6.849
ACBZFLGT	0.400 CM/S.SQ	922180.5	-664.2	-1420191.0	801.338	-0.243	-2.013
ACBZCOMB		714583.7	-341.2	-1121961.2	630.847	-0.223	4.835
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-6364.6	-4.5	8977.8	-5.177	0.010	0.242
SFUY	150 PPM	-5052.9	-491.6	7431.9	-4.229	-0.042	0.115
SFUZ	150 PPM	-81643.3	64.9	124515.7	-70.443	0.007	0.498
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	-1322.0	2.9	1896.9	-1.084	0.000	0.044
NCZZ	10 MG/GSQ	4730.5	-3.7	-7211.3	4.080	-0.000	-0.029
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	33233.0	-1712.9	-51595.6	29.112	-0.192	0.080
NBDXFLGT	(6.323 MR.DRIFT	387328.7	-20004.7	-601446.6	339.344	-2.308	0.967
NBDXCOMB	SINCE LAUNCH)	420561.7	-21717.6	-653042.2	368.456	-2.501	1.048
NBDYINIT	3.0 MERU	160169.7	-8255.2	-248669.9	140.308	-0.927	0.388
NBDYFLGT	(6.323 MR.DRIFT	1297783.8	-2017.4	-1863436.3	1065.407	-0.126	-43.084
NBDYCOMB	SINCE LAUNCH)	1457953.6	-10273.0	-2112106.2	1205.716	-1.053	-42.695
NBDZINIT	3.0 MERU	492951.8	-25408.0	-765327.4	431.825	-2.853	1.195
NBDZFLGT	(6.323 MR.DRIFT	508179.1	-200.8	-730333.1	417.202	-1.901	-16.869
NBDZCOMB	SINCE LAUNCH)	1001130.9	-25606.8	-1495660.5	849.028	-4.755	-15.674
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	119312.1	-6167.7	-185235.4	104.517	-0.684	0.289
ADSAYCOMB	5.0 MERU/G	-161048.8	253.2	230424.8	-131.834	0.018	5.590
ADIAZCOMB	6.0 MERU/G	104007.1	-232.0	-149385.6	85.350	-0.414	-3.476
RSS UNCERT.(FT AND FT/SEC)		2198253.5	37853.1	3233154.2	1840.405	7.205	58.619
RSS UNCERT.(N.MI.AND FT/SEC)		361.786	6.229	532.108	1840.405	7.205	58.619
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		361.973	6.239	532.389	1841.390	7.207	58.627

TABLE 7.9 Uncertainties at 2 mins. before SPS2 Ignition (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR, 12 MIN, 46.215 SEC (29566.217 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	68803.2	-3842.3	-152499.5	111.726	0.807	0.869
ABOUT YI	0.025 MR	11624.3	-17.0	-24404.4	17.835	0.008	-0.330
ABOUT ZI	0.025 MR	4543.3	-11.8	-9546.7	6.973	-0.014	-0.128
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	63065.1	-98.1	-132390.6	96.714	0.041	-1.816
X ABOUT Z	0.141 MR	26105.5	-41.4	-54833.2	40.052	0.018	-0.743
Y ABOUT X	0.100 MR	-7324.9	-753.6	15629.9	-11.427	0.149	0.122
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	-685973.1	976.5	1852930.0	-1346.851	-1.098	35.765
ACBXCOMB		-685973.1	976.5	1852930.0	-1346.851	-1.098	35.765
ACBYINIT		74126.6	-193.4	-155759.1	113.768	-0.234	-2.092
ACBYFLGT	0.400 CM/S.SQ	-137401.3	-10863.9	293055.0	-213.185	8.011	2.907
ACBYCOMB		-63274.7	-11077.4	137295.8	-99.417	7.777	0.815
ACBZINIT		-189657.0	277.3	398170.3	-291.001	-0.139	5.387
ACBZFLGT	0.400 CM/S.SQ	632955.9	-482.5	-1840778.7	1340.913	0.748	12.323
ACBZCOMB		643298.9	-205.1	-1442608.3	1049.911	0.609	17.711
ACCEL.SCALE FACTOR							
SFJX	150 PPM	-5849.2	1.7	12077.5	-8.864	0.008	0.217
SFJY	150 PPM	-4602.8	-476.0	9825.6	-7.183	0.108	0.075
SFJZ	150 PPM	-74085.4	52.9	162186.5	-118.727	-0.039	-0.210
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	-1207.5	1.8	2533.9	-1.851	-0.000	0.035
NCZZ	10 MG/GSQ	4292.8	-3.1	-9394.8	6.877	0.002	0.011
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	30103.2	-1681.1	-66722.6	48.883	0.353	0.380
NBDXFLGT	(5.467 MR.DRIFT	350840.6	-19672.9	-777728.1	569.787	4.072	4.464
NBDXCOMB	SINCE LAUNCH)	380943.9	-21354.1	-844450.8	618.671	4.425	4.844
NBDYINIT	3.0 MERU	145085.5	-8102.2	-321576.1	235.598	1.703	1.832
NBDYFLGT	(5.467 MR.DRIFT	1185719.5	-1735.2	-2488420.8	1818.669	0.869	-33.979
NBDYCOMB	SINCE LAUNCH)	1330805.1	-9837.5	-2809997.0	2054.268	2.572	-32.147
NBDZINIT	3.0 MERU	446527.3	-24936.2	-989709.6	725.096	5.242	5.640
NBDZFLGT	(5.467 MR.DRIFT	464006.1	-1323.9	-974934.7	712.106	-1.478	-13.114
NBDZCOMB	SINCE LAUNCH)	910533.5	-26260.2	-1964644.4	1437.203	3.764	-7.474
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	108075.1	-6048.0	-239544.3	175.499	1.279	1.364
ADSAYCOMB	5.0 MERU/G	-147204.7	219.6	308167.1	-225.213	-0.106	4.480
ADIAZCOMB	8.0 MERU/G	94975.6	-461.3	-199467.1	145.698	-0.267	-2.712
RSS UNCERT.(FT AND FT/SEC)		2001559.7	37563.3	4274224.9	3120.448	10.240	52.352
RSS UNCERT.(N.MI.AND FT/SEC)		329.414	6.198	703.446	3120.448	10.240	52.352
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		329.587	6.199	703.815	3122.113	10.243	52.357

TABLE 7.10a T_{ff} Uncertainties at 13 mins. before SPS2 Ignition (Update 1)

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR POSITIVE ERRORS (SECS)

MLMXI	5.409	MXABTY	5.096	ACBXI	0.000	ACBYI	5.998	ACBZI -	14.485	SFEX -	0.477	NCXX-	0.096	SEC.
MLMYI	0.929	MXABTZ	2.090	ACBXF-	56.985	ACBYF -	10.540	ACBZF	79.031	SFEY -	0.362	NCYY-	0.008	SEC.
MLMZI	0.361	MYABTX-	0.577	ACBXT-	56.985	ACBYT -	4.916	ACBZT	98.282	SFEZ -	5.645	NCZZ	0.334	SEC.
N3DXI	2.342	N3DYI	11.639	N3DZI	38.666	ADIAXT	8.586	ADSAXT	0.197	ADIXX	0.069			
N3DXF	29.666	N3DYF	120.877	N3DZF	40.818	ADIAYT-	0.925	ADSAYT-	11.381	ADSYY	0.713	RSS	188.063	SEC.
N3DXT	32.454	N3DYT	139.886	N3DZT	87.850	ADIAZT	7.724	ADSAZT-	0.281	ADIZZ	0.282			

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR NEGATIVE ERRORS (SECS)

MLMXI-	5.209	MXABTY-	4.953	ACBXI	0.000	ACBYI -	5.801	ACBZI	15.777	SFEX	0.478	NCXX	0.096	SEC.
MLMYI-	0.925	MXABTZ-	2.066	ACBXF	85.403	ACBYF	11.251	ACBZF -	49.243	SFEY	0.363	NCYY	0.008	SEC.
MLMZI-	0.361	MYABTX	0.579	ACBXT	85.403	ACBYT	5.076	ACBZT -	39.939	SFEZ	5.868	NCZZ-	0.333	SEC.
N3DXI-	2.303	N3DYI -	10.749	N3DZI-	30.132	ADIAXT-	8.092	ADSAXT-	0.197	ADIXX-	0.069			
N3DXF-	24.442	N3DYF -	58.002	N3DZF-	33.029	ADIAYT	0.930	ADSAYT	12.152	ADSYY-	0.710	RSS	134.111	SEC.
N3DXT-	25.290	N3DYT -	70.989	N3DZT-	54.553	ADIAZT-	7.401	ADSAZT	0.281	ADIZZ-	0.282			

TABLE 7.10b T_{ff} Uncertainties at 2 mins. before SPS2 Ignition (Update 1)

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR POSITIVE ERRORS (SECS)

MLMXI	5.443	MXABTY	5.126	ACBXI	0.000	ACBYI	6.039	ACBZI -	14.226	SFEX -	0.477	NCXX-	0.096	SEC.
MLMYI	0.930	MXABTZ	2.095	ACBXF-	49.042	ACBYF -	10.185	ACBZF	84.486	SFEY -	0.362	NCYY-	0.008	SEC.
MLMZI	0.362	MYABTX-	0.576	ACBXT-	49.042	ACBYT -	4.667	ACBZT	61.107	SFEZ -	5.607	NCZZ	0.334	SEC.
N3DXI	2.348	N3DYI	11.792	N3DZI	40.191	ADIAXT	8.670	ADSAXT	0.197	ADIXX	0.069			
N3DXF	30.588	N3DYF	135.032	N3DZF	42.524	ADIAYT-	0.924	ADSAYT-	11.225	ADSYY	0.713	RSS	204.981	SEC.
N3DXT	33.548	N3DYT	159.055	N3DZT	95.249	ADIAZT	7.792	ADSAZT-	0.281	ADIZZ	0.282			

UNCERTAINTIES IN TIME OF FLIGHT COMPUTATION FOR NEGATIVE ERRORS (SECS)

MLMXI-	5.176	MXABTY-	4.925	ACBXI	0.000	ACBYI -	5.761	ACBZI	16.048	SFEX	0.478	NCXX	0.096	SEC.
MLMYI-	0.924	MXABTZ-	2.061	ACBXF	90.157	ACBYF	11.166	ACBZF -	43.738	SFEY	0.363	NCYY	0.008	SEC.
MLMZI-	0.361	MYABTX	0.579	ACBXT	90.157	ACBYT	4.881	ACBZT -	36.598	SFEZ	5.908	NCZZ-	0.333	SEC.
N3DXI-	2.297	N3DYI -	10.603	N3DZI-	28.791	ADIAXT-	8.011	ADSAXT-	0.197	ADIXX-	0.069			
N3DXF-	23.586	N3DYF -	56.782	N3DZF-	31.486	ADIAYT	0.931	ADSAYT	12.315	ADSYY-	0.709	RSS	126.382	SEC.
N3DXT-	25.281	N3DYT -	56.015	N3DZT-	48.351	ADIAZT-	7.336	ADSAZT	0.281	ADIZZ-	0.282			

TABLE 7.11 Reentry Start Uncertainties (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR. 23 MIN. 3.329 SEC (30183.332 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	18166.2	-1921.3	-190128.2	172.778	5.014	-3.855
ABOUT YI	0.025 MR	3237.0	-0.8	-31212.9	27.785	0.026	-0.960
ABOUT ZI	0.025 MR	1274.5	-13.7	-12403.1	10.903	0.002	-0.368
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0. Z ABOUT Y = 0. Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	17522.5	-10.5	-169307.6	150.633	0.147	-5.159
X ABOUT Z	0.141 MR	7327.1	-11.9	-70102.2	62.630	0.042	-2.123
Y ABOUT X	0.100 MR	-2003.6	-387.6	19844.4	-17.755	0.984	0.520
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	-241169.6	-409.4	2373299.7	-2096.894	-2.148	73.032
ACBXCOMB		-241169.6	-409.4	2373299.7	-2096.894	-2.148	73.032
ACBYINIT		20794.9	-224.5	-199100.5	177.897	0.039	-6.019
ACBYFLGT	0.400 CM/S.SQ	-36864.1	-2088.3	371903.2	-331.317	20.278	9.306
ACBYCOMB		-16069.1	-2312.8	172802.6	-153.420	20.318	3.287
ACBZINIT		-52814.4	13.9	509454.3	-453.328	-0.429	15.671
ACBZFLGT	0.400 CM/S.SQ	217457.4	500.9	-2297114.2	2077.647	1.239	-33.283
ACBZCOMB		164642.9	514.9	-1788259.8	1624.318	0.809	-17.611
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-1699.2	2.9	15565.8	-13.882	0.002	0.546
SFUY	150 PPM	-1267.6	-320.3	12477.3	-11.190	0.412	0.338
SFUZ	150 PPM	-19761.1	-21.3	203826.7	-183.809	-0.092	3.971
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	-340.2	0.6	3440.9	-2.897	-0.001	0.098
NCZZ	10 MG/GSQ	1145.9	0.8	-11802.1	10.649	0.004	-0.244
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	7948.2	-840.6	-83448.7	75.595	2.194	-1.687
NBDXFLGT	(6.602 MR.DRIFT	93281.1	-3683.4	-972565.1	883.192	41.985	-19.490
NBDXCOMB	SINCE LAUNCH)	101229.3	-4524.1	-1056013.9	958.788	44.179	-21.177
NBDYINIT	3.0 MERU	38307.1	-4051.6	-402189.0	364.339	10.574	-8.130
NBDYFLGT	(6.602 MR.DRIFT	323732.4	512.8	-3183151.4	2812.841	4.282	-99.353
NBDYCOMB	SINCE LAUNCH)	362039.6	-3538.8	-3585940.4	3177.180	14.856	-107.484
NBDZINIT	3.0 MERU	117897.2	-12469.5	-1237810.7	1121.321	32.544	-25.024
NBDZFLGT	(6.602 MR.DRIFT	129800.6	-1090.7	-1246488.3	1112.337	1.376	-37.762
NBDZCOMB	SINCE LAUNCH)	247697.9	-13560.3	-2484099.0	2233.658	33.920	-62.786
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	28530.9	-3072.7	-299295.3	271.383	7.758	-6.058
ADSAYCOMB	5.0 MERU/G	-41002.0	2.3	394627.9	-350.615	-0.371	12.394
ADIAZCOMB	8.0 MERU/G	26655.2	-433.6	-255029.3	227.816	0.240	-7.742
RSS UNCERT.(FT AND FT/SEC)		540890.3	15370.0	5425402.1	4838.012	61.871	148.039
RSS UNCERT.(N.MI.AND FT/SEC)		89.019	2.529	892.906	4838.012	61.871	148.039
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		89.071	2.529	893.374	4840.613	61.873	148.132

TABLE 7.12 Reentry Start Uncertainties (Update 2)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR, 23 MIN, 3.329 SEC (30183.332 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	84.4	781.4	8.8	0.261	2.062	0.018
ABOUT YI	0.025 MR	-41.8	3.8	-3.7	-0.129	0.010	-0.007
ABOUT ZI	0.025 MR	-2.4	2.6	-0.2	-0.007	0.006	-0.000
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	-237.5	22.2	-7.8	-0.736	0.058	-0.005
X ABOUT Z	0.141 MR	-15.1	1.4	-0.4	-0.047	0.003	-0.000
Y ABOUT X	0.100 MR	17.6	155.7	-8.3	0.055	0.411	-0.023
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	1894.0	-178.2	63.8	7.634	-0.654	0.168
ACBXCOMB		1894.0	-178.2	63.8	7.634	-0.654	0.168
ACBYINIT		-39.3	42.7	-3.5	-0.122	0.110	-0.006
ACBYFLGT	0.400 CM/S.SQ	199.4	1763.6	-94.1	0.807	6.471	-0.352
ACBYCOMB		160.1	1806.3	-97.6	0.685	6.581	-0.359
ACBZINIT		682.0	-62.0	61.7	2.111	-0.163	0.118
ACBZFLGT	0.400 CM/S.SQ	-142.9	99.1	1788.5	-0.638	0.363	6.573
ACBZCOMB		539.0	37.1	1850.2	1.473	0.200	6.692
ACCEL.SCALE FACTOR							
SFUX	150 PPM	15.3	-1.4	0.4	0.046	-0.003	0.000
SFUY	150 PPM	1.6	14.9	-0.7	0.005	0.039	-0.002
SFUZ	150 PPM	19.1	-13.1	-236.8	0.074	-0.034	-0.629
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10 MG/GSQ	-0.6	0.4	8.3	-0.002	0.001	0.022
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	36.9	341.9	3.8	0.114	0.902	0.007
NBDXFLGT	(6.602 MR.DRIFT	1100.8	10192.6	114.9	3.408	26.922	0.237
NBDXCOMB	SINCE LAUNCH)	1137.8	10534.5	118.7	3.523	27.825	0.245
NBDYINIT	3.0 MERU	177.9	1647.8	18.5	0.550	4.350	0.038
NBDYFLGT	(6.602 MR.DRIFT	-10903.4	991.7	-787.4	-33.774	2.622	-1.898
NBDYCOMB	SINCE LAUNCH)	-10725.4	2639.6	-968.8	-33.224	6.972	-1.860
NBDZINIT	3.0 MERU	547.8	5071.6	57.1	1.695	13.388	0.117
NBDZFLGT	(6.602 MR.DRIFT	-629.1	682.9	-56.1	-1.953	1.759	-0.107
NBDZCOMB	SINCE LAUNCH)	-81.3	5754.6	1.0	-0.258	15.147	0.010
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	127.1	1177.1	13.2	0.393	3.106	0.027
ADSAYCOMB	5.0 MERU/G	678.6	-61.7	61.5	2.114	-0.164	0.120
ADIAZCOMB	8.0 MERU/G	-62.6	67.8	-5.6	-0.195	0.176	-0.010
RSS UNCERT.(FT AND FT/SEC)		10991.0	12505.6	2109.6	34.390	33.320	6.991
RSS UNCERT.(N.MI.AND FT/SEC)		1.808	2.058	0.347	34.390	33.320	6.991
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		1.809	2.059	0.356	34.393	33.323	6.992

TABLE 7.13a Flight Path Angle Uncertainties at Reentry Start (Update 1)

UNCERTAINTIES IN ACTUAL FLIGHT PATH ANGLE FOR POSITIVE IMU UNCERTAINTIES

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO NOMINAL AXES AT NOMINAL TIME (EGNM) (U)γ AIN

MLMXI- 4.7021	MXABTY- 4.0935	ACBXI 0.0000	ACBYI - 4.8340	ACBZI 12.3506	SFEX 0.3772	NCXX 0.0787 MR.
MLMYI- 0.7554	MXABTZ- 1.7027	ACBXF 57.4801	ACBYF 9.0287	ACBZF- 56.1187	SFEY 0.3044	NCYY 0.0074 MR.
MLMZI- 0.2965	MYABTX 0.4831	ACBXT 57.4801	ACBYT 4.1812	ACBZT- 44.0064	SFEZ 5.0099	NCZZ- 0.2899 MR.
NBDXI- 2.0581	NBDYI - 9.9075	NBDZI- 30.3914	ADIAXT- 7.3826	ADSAXT- 0.1766	ADIXX- 0.0616	
NBDXF- 23.9639	NBDYF - 75.4064	NBDZF- 30.0947	ADIAXT 0.7636	ADSAYT 9.5473	ADSYY- 0.5778	RSS 130.5240 MR.
NBDXT- 26.0062	NBDYT - 85.0226	NBDZT- 60.1521	ADIAXT- 6.1890	ADSAZT 0.2292	ADIZZ- 0.2316	(7.4784 DEG.)

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT NOMINAL TIME (EG1) (U)γ AI

MLMXI 4.2529	MXABTY 3.8556	ACBXI 0.0000	ACBYI 4.5152	ACBZI- 11.4764	SFEX- 0.3528	NCXX- 0.0732 MR.
MLMYI 0.7090	MXABTZ 1.5870	ACBXF- 52.1717	ACBYF - 8.3864	ACBZF 52.3578	SFEY- 0.2808	NCYY- 0.0068 MR.
MLMZI 0.2760	MYABTX- 0.4477	ACBXT- 52.1717	ACBYT - 3.9191	ACBZT 40.3483	SFEZ- 4.5337	NCZZ 0.2637 MR.
NBDXI 1.8581	NBDYI 8.9921	NBDZI 27.9348	ADIAXT 6.6902	ADSAXT 0.1583	ADIXX 0.0555	
NBDXF 21.8306	NBDYF 75.1096	NBDZF 28.6631	ADIAXT- 0.6786	ADSAYT- 8.9282	ADSYY 0.5435	RSS 124.7177 MR.
NBDXT 23.7300	NBDYT 84.4699	NBDZT 57.2130	ADIAXT 5.7895	ADSAZT- 0.2139	ADIZZ 0.2156	(7.1457 DEG.)

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT DESIRED ALTITUDE (EG2) (U)γ AA

MLMXI 0.9305	MXABTY 0.6315	ACBXI 0.0000	ACBYI 0.7021	ACBZI- 0.9842	SFEX- 0.0334	NCXX- 0.0093 MR.
MLMYI 0.1037	MXABTZ 0.2230	ACBXF 6.1211	ACBYF - 1.1539	ACBZF 26.3896	SFEY- 0.0425	NCYY- 0.0010 MR.
MLMZI 0.0371	MYABTX- 0.0707	ACBXT 6.1211	ACBYT - 0.8342	ACBZT 18.1565	SFEZ- 0.7277	NCZZ 0.0489 MR.
NBDXI 0.3830	NBDYI 2.1928	NBDZI 9.6776	ADIAXT 1.5511	ADSAXT 0.0315	ADIXX 0.0109	
NBDXF 6.6710	NBDYF 43.9987	NBDZF 7.9549	ADIAXT- 0.0734	ADSAYT- 0.8860	ADSYY 0.0790	RSS 67.6845 MR.
NBDXT 7.5127	NBDYT 58.2295	NBDZT 27.5726	ADIAXT 0.9342	ADSAZT- 0.0275	ADIZZ 0.0289	(3.8780 DEG.)

TABLE 7.13b Flight Path Angle Uncertainties at Reentry Start (Update 2)

UNCERTAINTIES IN ACTUAL FLIGHT PATH ANGLE FOR POSITIVE IMU UNCERTAINTIES

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO NOMINAL AXES AT NOMINAL TIME (EGNM) (U)γ AIN

MLMXI- 0.0071	MXABTY 0.0201	ACBXI 0.0000	ACBYI 0.0033	ACBZI- 0.0580	SFEX- 0.0012	NCXX- 0.0000 MR.
MLMYI 0.0035	MXABTZ 0.0012	ACBXF- 0.2090	ACBYF - 0.0208	ACBZF- 0.0049	SFEY- 0.0001	NCYY- 0.0000 MR.
MLMZI 0.0002	MYABTX- 0.0014	ACBXT- 0.2090	ACBYT - 0.0174	ACBZT- 0.0630	SFEZ 0.0001	NCZZ- 0.0000 MR.
NBDXI- 0.0031	NBDYI - 0.0151	NBDZI- 0.0467	ADIAXT- 0.0108	ADSAXT- 0.0006	ADIXX- 0.0001	
NBDXF- 0.0939	NBDYF 0.9289	NBDZF 0.0537	ADIAXT- 0.0099	ADSAYT- 0.0581	ADSYY 0.0031	RSS 0.9468 MR.
NBDXT- 0.0970	NBDYT 0.9137	NBDZT 0.0070	ADIAXT 0.0053	ADSAZT- 0.0003	ADIZZ 0.0001	(0.0542 DEG.)

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT NOMINAL TIME (EG1) (U)γ AI

MLMXI- 0.0076	MXABTY 0.0204	ACBXI 0.0000	ACBYI 0.0035	ACBZI- 0.0609	SFEX- 0.0012	NCXX- 0.0000 MR.
MLMYI 0.0037	MXABTZ 0.0013	ACBXF- 0.2120	ACBYF - 0.0164	ACBZF- 0.0889	SFEY- 0.0001	NCYY- 0.0000 MR.
MLMZI 0.0002	MYABTX- 0.0010	ACBXT- 0.2120	ACBYT - 0.0129	ACBZT- 0.1498	SFEZ 0.0112	NCZZ- 0.0003 MR.
NBDXI- 0.0033	NBDYI - 0.0160	NBDZI- 0.0493	ADIAXT- 0.0114	ADSAXT- 0.0006	ADIXX- 0.0001	
NBDXF- 0.0992	NBDYF 0.9754	NBDZF 0.0563	ADIAXT- 0.0104	ADSAYT- 0.0610	ADSYY 0.0033	RSS 1.0014 MR.
NBDXT- 0.1026	NBDYT 0.9591	NBDZT 0.0069	ADIAXT 0.0056	ADSAZT- 0.0003	ADIZZ 0.0001	(0.0573 DEG.)

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT DESIRED ALTITUDE (EG2) (U)γ AA

MLMXI- 0.0234	MXABTY 0.0651	ACBXI 0.0000	ACBYI 0.0109	ACBZI- 0.1888	SFEX- 0.0041	NCXX- 0.0000 MR.
MLMYI 0.0115	MXABTZ 0.0041	ACBXF- 0.5663	ACBYF - 0.0538	ACBZF- 0.0620	SFEY- 0.0004	NCYY 0.0000 MR.
MLMZI 0.0006	MYABTX- 0.0043	ACBXT- 0.5663	ACBYT - 0.0429	ACBZT- 0.2508	SFEZ 0.0076	NCZZ- 0.0002 MR.
NBDXI- 0.0102	NBDYI - 0.0494	NBDZI- 0.1518	ADIAXT- 0.0353	ADSAXT- 0.0020	ADIXX- 0.0003	
NBDXF- 0.3047	NBDYF 3.0559	NBDZF 0.1745	ADIAXT- 0.0324	ADSAYT- 0.1882	ADSYY 0.0102	RSS 3.0920 MR.
NBDXT- 0.3148	NBDYT 3.0054	NBDZT 0.0225	ADIAXT 0.0174	ADSAZT- 0.0011	ADIZZ 0.0005	(0.1771 DEG.)

TABLE 7.14 Reentry End Uncertainties (Update 1)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR, 38 MIN, 37.329 SEC (31117.332 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	38587.0	-8493.9	-156540.8	198.291	0.052	112.094
ABOUT YI	0.025 MR	6802.3	-854.8	-25836.2	33.718	0.595	18.668
ABOUT ZI	0.025 MR	2544.2	-552.6	-10099.4	12.846	-0.342	7.257
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	35922.4	-4732.3	-140914.1	179.828	2.978	98.944
X ABOUT Z	0.141 MR	14681.6	-1920.3	-58196.1	74.002	1.287	41.221
Y ABOUT X	0.100 MR	-4120.9	-124.0	16504.0	-20.882	-1.048	-11.560
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM. DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	-478421.4	63329.5	1961844.7	-2459.431	-46.849	-1416.752
ACBXCOMB		-478421.4	63329.5	1961844.7	-2459.431	-46.849	-1416.752
ACBYINIT		41510.4	-9016.3	-164777.0	209.602	-5.581	118.413
ACBYFLGT	0.400 CM/S.SQ	-75988.6	21951.1	306257.5	-388.531	19.546	-222.683
ACBYCOMB		-34478.1	12934.8	141480.5	-178.928	13.965	-104.270
ACBZINIT		-110983.7	13947.6	421531.3	-550.126	-9.714	-304.585
ACBZFLGT	0.400 CM/S.SQ	481493.5	-61378.2	-1886054.6	2436.942	44.080	1368.324
ACBZCOMB		370509.8	-47430.6	-1464523.2	1886.815	34.366	1063.739
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-4545.0	590.7	13872.4	-20.416	0.140	-6.821
SFUY	150 PPM	-2586.4	281.6	10331.4	-13.112	-0.180	-7.328
SFUZ	150 PPM	-40850.8	5600.7	168598.9	-211.154	-3.633	-118.600
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	-508.9	68.0	2573.6	-2.916	-0.110	-2.192
NCZZ	10 MG/GSQ	2957.7	-276.3	-9337.4	13.414	0.255	7.261
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	16882.9	-3716.3	-68490.8	86.757	0.023	49.044
NBDXFLGT	(6.807 MR.DRIFT	191502.5	-79736.4	-797721.3	995.325	-63.413	570.545
NBDXCOMB	SINCE LAUNCH)	208385.3	-83452.7	-866212.1	1082.083	-63.390	619.589
NBDYINIT	3.0 MERU	81368.6	-17911.1	-330098.0	418.138	0.111	236.373
NBDYFLGT	(6.807 MR.DRIFT	746072.1	-88757.8	-2628482.0	3597.197	60.762	1936.076
NBDYCOMB	SINCE LAUNCH)	827440.7	-106668.9	-2958580.1	4015.335	60.873	2172.449
NBDZINIT	3.0 MERU	250426.8	-55124.7	-1015937.3	1286.896	0.341	727.483
NBDZFLGT	(6.807 MR.DRIFT	262694.8	-90985.9	-1029915.0	1320.564	-133.134	746.331
NBDZCOMB	SINCE LAUNCH)	513121.7	-146110.6	-2045852.3	2607.461	-132.792	1473.814
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	60461.8	-14073.3	-245885.8	310.908	-1.312	175.856
ADSAYCOMB	5.0 MERU/G	-85422.3	10813.3	326800.8	-423.770	-7.416	-234.828
ADIAZCOMB	8.0 MERU/G	53169.5	-10822.3	-211145.3	268.357	-2.890	151.380
RSS UNCERT.(FT AND FT/SEC)		1173673.3	216070.2	4471648.0	5849.088	170.359	3251.881
RSS UNCERT.(N.MI.AND FT/SEC)		193.151	35.560	735.938	5849.088	170.359	3251.881
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.T(G.UPDATE UNCERT.)		193.250	35.568	736.318	5851.987	170.396	3253.458

TABLE 7.15 Reentry End Uncertainties (Update 2)

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL AXES AT TIME FROM LAUNCH = 8 HR, 38 MIN, 37.329 SEC (31117.332 SEC)

UNCERT. SOURCE	ONE SIGMA UNCERTAINTY	POSITION UNCERTAINTIES IN FEET (REL. TO NOM. AXES) ALT.	TRACK	RANGE	VELOCITY UNCERTAINTIES IN FT/SEC (REL. TO NOM. AXES) ALT.	TRACK	RANGE
INITIAL S.M. MLMS. (UNCORREL.) ABOUT LAUNCH INERTIAL AXES							
ABOUT XI	0.500 MR	-624.1	-4379.9	60.4	-1.887	-7.715	-0.122
ABOUT YI	0.025 MR	310.3	-9.3	42.0	0.943	-0.000	0.190
ABOUT ZI	0.025 MR	16.9	-208.2	9.2	0.050	-0.586	0.030
ACCEL.INPUT AXIS MLMS. (Y ABOUT Z = 0, Z ABOUT Y = 0, Z ABOUT X = 0.100 MR.)							
X ABOUT Y	0.141 MR	807.3	-144.9	-605.0	2.220	-0.263	-1.324
X ABOUT Z	0.141 MR	156.7	-22.7	-114.5	0.485	-0.055	-0.298
Y ABOUT X	0.100 MR	-17.2	-865.5	106.7	-0.059	-1.517	0.207
ACCEL.BIAS (INIT.EARTH LAUNCH S.M. MLMS. - DUE TO ACBY 0.407 MR.ABOUT ZSM, DUE TO ACBZ -0.407 MR.ABOUT YSM)							
ACBXINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBXFLGT	0.400 CM/S.SQ	17623.3	-1435.6	-10393.1	36.548	-1.428	-10.585
ACBXCOMB		17623.3	-1435.6	-10393.1	36.548	-1.428	-10.585
ACBYINIT		275.8	-3398.0	151.5	0.830	-9.575	0.498
ACBYFLGT	0.400 CM/S.SQ	1197.1	10593.1	-1830.7	2.498	10.322	-1.792
ACBYCOMB		1473.0	7195.0	-1679.2	3.329	0.746	-1.294
ACBZINIT		-5063.1	152.1	-686.5	-15.390	0.006	-3.104
ACBZFLGT	0.400 CM/S.SQ	10515.1	837.7	7563.9	21.386	0.787	6.705
ACBZCOMB		5452.0	989.8	6877.4	5.996	0.793	3.600
ACCEL.SCALE FACTOR							
SFUX	150 PPM	-1192.0	153.5	850.0	-3.880	0.432	2.378
SFUY	150 PPM	-7.8	-196.3	26.8	-0.025	-0.473	0.067
SFUZ	150 PPM	1094.9	102.7	924.6	2.690	0.180	1.649
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	163.5	-19.7	-112.7	0.483	-0.048	-0.272
NCZZ	10 MG/GSQ	527.6	42.1	376.9	1.026	0.034	0.294
GYRO BIAS DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO BDX 0.218 MR., DUE TO BDY 1.054 MR., DUE TO BDZ 3.244 MR.)							
NBDXINIT	3.0 MERU	-273.0	-1916.3	26.4	-0.825	-3.375	-0.053
NBDXFLGT	(6.807 MR.DRIFT	-8435.4	-58727.1	846.9	-25.474	-103.137	-1.709
NBDXCOMB	SINCE LAUNCH)	-8708.5	-60643.4	873.3	-26.299	-106.513	-1.762
NBDYINIT	3.0 MERU	-1316.1	-9235.9	127.4	-3.980	-16.270	-0.258
NBDYFLGT	(6.807 MR.DRIFT	83848.5	-2515.9	10891.2	254.570	-0.003	51.603
NBDYCOMB	SINCE LAUNCH)	82532.3	-11751.9	11018.7	250.590	-16.273	51.345
NBDZINIT	3.0 MERU	-4050.6	-28425.2	392.1	-12.250	-50.075	-0.795
NBDZFLGT	(6.807 MR.DRIFT	4572.5	-55820.0	2464.4	13.748	-158.274	8.253
NBDZCOMB	SINCE LAUNCH)	521.8	-84245.3	2656.5	1.497	-208.350	7.457
GYRO ACC.SENS.DRIFT (INIT.EARTH LCH.S.M.MLMS.ABT.XI - DUE TO ADIAX 0.583 MR., DUE TO ADSAY 0.000 MR.)							
ADIAXCOMB	8.0 MERU/G	-1132.6	-7621.2	104.4	-3.535	-13.526	-0.412
ADSAYCOMB	5.0 MERU/G	-3248.5	115.1	-577.2	-9.312	0.123	-1.166
ADIAZCOMB	8.0 MERU/G	324.8	-3672.9	149.4	0.901	-8.247	0.348
RSS UNCERT.(FT AND FT/SEC)		85129.3	105165.4	17058.3	254.974	235.241	53.236
RSS UNCERT.(N.MI.AND FT/SEC)		14.010	17.308	2.807	254.974	235.241	53.236
RSS UNCERT.(N.MI.AND FT/SEC) (INCL.TKG.UPDATE UNCERT.)		14.010	17.308	2.808	254.976	235.242	53.237

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TABLE 7.16

IMU Stable Member Drift Angles & Misalignments

Event	Misalignment (in millirad) about					
	Launch Inertial Axes			Local Axes		
	X_I	Y_I	Z_I	Alt.	Track	Range
RSS Initial SM Misalignment at Earth Launch	3.50	0.41	0.41	-	-	-
Stable Member RSS Drift Angles						
At SIVB cutoff	0.23	0.32	0.48	0.29	0.32	0.44
At injection burn cutoff	2.59	2.61	2.66	2.64	2.61	2.61
At 1st SPS burn cutoff	2.75	2.77	2.81	2.81	2.77	2.75
13 mins before 2nd SPS burn ignition	6.33	6.34	6.35	6.35	6.34	6.33
At 2nd SPS burn ignition	6.50	6.51	6.52	6.51	6.51	6.51
At reentry start (400Kft)	6.61	6.62	6.64	6.61	6.62	6.64
At reentry end (24Kft)	6.84	6.81	6.81	6.83	6.81	6.82
Overall RSS Stable Member Misalignments						
At SIVB cutoff	3.51	0.52	0.63	3.18	0.52	1.63
At injection burn cutoff	4.36	2.65	2.69	3.09	2.67	4.07
At 1st SPS burn cutoff	4.45	2.80	2.84	2.96	2.82	4.36
13 mins before 2nd SPS burn ignition	7.23	6.35	6.37	6.42	6.36	7.17
At 2nd SPS burn ignition	7.38	6.52	6.54	7.00	6.53	6.93
At reentry start (400Kft)	7.48	6.63	6.65	7.47	6.64	6.66
At reentry end (24Kft)	7.68	6.82	6.83	7.31	6.84	7.21

TABLE 7.17

Propagation of Initial Condition Errors from SPS1 Cutoff Through Long Coast

Initial Condition Error	Event	Time from SPS1 C.O. sec	Position Error n. miles		Velocity Error ft/sec		Error in Computed Time of Flight sec
			Alt.	Range	Alt.	Range	
Velocity Magnitude, $(E)V_{mag}$ of 1 ft/sec	SPS1 cutoff	0	0	0	0.48	0.88	5.55
		3,455	0.79	-0.19	2.09	-0.49	5.55
	Apogee	8,380	2.92	-2.02	4.75	-1.50	5.55
		12,455	6.03	-5.29	10.61	-2.16	5.55
	13 mins. before SPS2 Ignit.	16,361	11.04	-15.65	54.63	-2.51	5.62
	SPS2 Ignit.	17,141	9.60	-22.2	103.9	-1.80	5.70
	Reentry Start	17,638	2.92	-27.0	146.7	-5.47	-
Velocity Flight Path Angle, $(E)\gamma$, of 0.1 mr	SPS1 cutoff	0	0	0	2.23	-1.22	-0.57
		3,455	0.45	-1.39	1.59	-1.91	-0.57
	Apogee	8,380	0.50	-2.79	1.72	-0.78	-0.57
		12,455	0.42	-3.11	2.37	0.60	-0.57
	13 mins. before SPS2 Ignit.	16,361	0.01	-2.18	5.44	3.47	-0.60
	SPS2 Ignit.	17,141	-0.31	-1.59	6.90	4.31	-0.63
	Reentry Start	17,638	-0.60	-0.93	6.61	3.77	-
Initial Altitude Error of 1,000 ft	SPS1 cutoff	0	0.16	0	0	0	3.31
		3,455	0.49	-0.37	1.33	-0.37	3.31
	Apogee	8,380	1.65	-1.41	2.86	-0.76	3.31
		12,455	3.44	-3.17	6.25	-1.05	3.32
	13 mins. before SPS2 Ignit.	16,361	6.40	-9.02	31.77	-1.36	3.34
	SPS2 Ignit.	17,141	5.60	-12.80	60.41	-1.15	3.37
	Reentry Start	17,638	1.77	-15.70	85.50	-3.50	-

TABLE 7.18

Propagation of Initial Condition Errors from Update Point at 13 Minutes before SPS2 Ignition

Initial Condition Error	Event	Time from Update Point sec	Position Error feet			Velocity Error ft/sec			Error in Flight Path Angle, $(E)\gamma_{AA}$ mr	Error in Computed Time of Flight sec
			Alt	Track	Range	Alt	Track	Range		
Altitude Error of 1000 ft	Update Point	0	1000	0	0	0	0	0	-	0.218
	SPS2 Ignit.	780	1092	0	-619	0.81	0	-0.09	-	0.219
	SPS2 Cutoff	1042	1113	0	-1007	1.32	0	-0.23	-	0.228
	Reentry Start	1277	1024	0	-1484	1.86	0	-0.43	0.17	-
	Reentry End	2161	2368	0	-2615	5.13	0	0.56	-	-
Track Error of 1000 ft	Update Point	0	0	1000	0	0	0	0	-	0
	SPS2 Ignit.	780	0	872	0	0	-0.38	0	-	0
	SPS2 Cutoff	1042	0	747	0	0	-0.58	0	-	0
	Reentry Start	1277	0	586	0	0	-0.79	0	0	-
	Reentry End	2161	0	-339	0	0	-0.98	0	-	-
Range Error of 1000 ft	Update Point	0	0	0	1000	0	0	0	-	0.186
	SPS2 Ignit.	780	545	0	710	0.13	0	-0.38	-	0.187
	SPS2 Cutoff	1042	772	0	377	0.31	0	-0.58	-	0.207
	Reentry Start	1277	928	0	-105	0.58	0	-0.79	0.18	-
	Reentry End	2161	1810	0	-1682	3.17	0	-0.32	-	-
Altitude Rate Error of 1 ft/sec	Update Point	0	0	0	0	1.00	0	0	-	0.170
	SPS2 Ignit.	780	730	0	-437	1.19	0	-0.55	-	0.170
	SPS2 Cutoff	1042	862	0	-865	1.38	0	-0.79	-	0.176
	Reentry Start	1277	791	0	-1389	1.57	0	-0.99	0.12	-
	Reentry End	2161	1206	0	-2447	3.00	0	0.49	-	-
Track Rate Error of 1 ft/sec	Update Point	0	0	0	0	0	1.00	0	-	0
	SPS2 Ignit.	780	0	740	0	0	0.83	0	-	0
	SPS2 Cutoff	1042	0	932	0	0	0.61	0	-	0
	Reentry Start	1277	0	1043	0	0	0.31	0	0	-
	Reentry End	2161	0	666	0	0	-1.03	0	-	-
Range Rate Error of 1 ft/sec	Update Point	0	0	0	0	0	0	1.00	-	0.274
	SPS2 Ignit.	780	435	0	614	0.65	0	0.66	-	0.274
	SPS2 Cutoff	1042	847	0	538	1.11	0	0.24	-	0.293
	Reentry Start	1277	1313	0	120	1.76	0	-0.40	0.30	-
	Reentry End	2161	4386	0	-2614	7.74	0	-1.03	-	-

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