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APOLLO

GUIDANCE AND NAVIGATION

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G&N SYSTEM OPERATIONS PLAN

MISSION AS-204A/205

VOL II

October 1966

MIT INSTRUMENTATION LABORATORY

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R-507

Date 24 Oct. 1966

Revision 507-1

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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-204 and AS-205 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

The operational trajectories to be flown on AS-204/205 are not available at this time.

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 Saturn IVB Engine Shutdown Transients

Thrust decay from 100% to 5% rated thrust	Fig. 6.1
Thrust decay from 5% rated to zero thrust	Fig. 6.2

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 at cutoff signal times ± 0.030 second. The cutoff impulse from 5-percent thrust is derived by multiplying thrust level at engine cutoff signal by 0.0235 second.

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

6.2.5 SIVB/CSM Orbital Maneuver Requirements

The following Fig. 6.3 and 6.4 define the SIVB attitude history required for IMU alignment and landmark tracking during the first three orbits while the CSM is attached. It is assumed that SIVB/CSM separation will take place during the third orbit after passing the U.S. and therefore no more than two IMU alignments would be required.

Figure 6.4 illustrates the attitude vs. timeline requirements for IMU alignments and landmark tracking. The solid line represents the maneuver requirements as defined in MSC Letter PS6/L233, dated 17 August 1965, and modified by MIT/IL. These requirements are acceptable for IMU alignment and landmark tracking.

Also illustrated in Fig. 6.4 is the attitude vs. time history previously defined in the preliminary issue of this document. This attitude vs. time requirement is presented as an option because it appears that some economy in the SIVB APS pitch and roll fuel budget is possible.

6.3 AGC Memory Data

6.3.1 Prelaunch

Launch pad #34:	latitude (geodetic)	28.52196261°N
	longitude	80.56114127°W
	geocentric radius	6373328.10 meters
	geocentric radius to G&N	6373385.0 meters
	ellipsoid (Fischer 1960) radius	6373322.44 meters
	geoidal separation (height of MSL above ellipsoid)	0 meters
	altitude of pad above MSL	5.66 meters
Inertial reference plane azimuth		72.0°E of True North
Optical target #1:	azimuth	not available
	elevation	not available
Optical target #2:	azimuth	not available
	elevation	not available

The information contained in Sec. 6.3.1 is taken from NASA General Working Paper No. 10,020B "Directory of Standard Geodetic and Geophysical Constants for Gemini and Apollo" dated 6 April 1966.

6.3.2 Saturn Boost

Pitch polynomial coefficients:

For the time segment $10 < T \leq 40$ sec.

$A_0 = .450035 \times 10^{-1}$ rad

$A_1 = -.947435 \times 10^{-2}$ rad/sec

$A_2 = .557572 \times 10^{-3}$ rad/sec^2

$A_3 = .581626 \times 10^{-5}$ rad/sec^3

For the time segment $40 < T \le 90$ sec

$B_0 = -.581240 \times 10^{0}$ rad

$B_1 = .300869 \times 10^{-1}$ rad/sec

$B_2 = -.351061 \times 10^{-3}$ rad/sec^2

$B_3 = .195164 \times 10^{-5}$ rad/sec^3

For the time segment $90 < T \le 133$ sec

$C_0 = -.561348 \times 10^{+1}$ rad

$C_1 = .164555 \times 10^{0}$ rad/sec

$C_2 = -.144106 \times 10^{-2}$ rad/sec^2

$C_3 = .436444 \times 10^{-5}$ rad/sec^3

For the time segment $T > 133$ sec

$X_Z = 1.04687$ rad

The above coefficients are for the pitch attitude command (X_Z) polynomial which is of the form:

$$X_Z = A_0 + A_1 T + A_2 T^2 + A_3 T^3$$

where

X_Z = Pitch attitude angle measured positive from the inertial vertical

$T = T_1 + NGMDT$

T_1 = Time from liftoff, approximately 0.2 sec after first motion

NGMDT = bias to account for system delays

The above data are taken from the GN&C Data Exchange Program, MSC-S-12 dated 29 August 1966.

Interval: Lift-off to LET jettison (assumed complete) 171 seconds

6.3.3 Navigational Star List

Refer to Table 6.1

The X and Z coordinates for each star appear directly in the AGC star catalogue section. The star catalogue together with the star selection routine used in the SUNSPOT Program Assembly will permit full utilization of the navigational stars.

The information contained in Sec. 6.3.3 is taken from:

(1) MIT/IL internal O&N Memo No. 45 dated 12 November 1965.

(2) Revision 238 of SUNSPOT Program Assembly dated 18 August 1966.

The Y-component of the coordinate system is such as to make $X^2 + Y^2 + Z^2 = 1$, where X, Y, and Z are components of a unit vector pointing from the center of the sun to the star, as of the first of the Besselian year occurring nearest to the flight date. The Z-axis of the coordinate system is in the direction of the mean axis of rotation of the earth. The X-axis is in the direction of the First of Aries at the beginning of the above-defined Besselian year.

6.3.4 Entry (Normal Mission)

CSM attitude for SM/CM separation:

X-axis above the velocity vector by 60°

Y-axis along momentum vector ($\underline{R} \times \underline{V}$)

Z-axis above velocity vector

CM Pacific pre-entry attitude:

X-axis below the velocity vector by 20°

Y-axis along momentum vector ($\underline{R} \times \underline{V}$)

Z-axis below the velocity vector

Lift vector down attitude

Trim angle of attack	20°
Interval: CM/SM Separation - start maneuver	5 seconds
Pacific recovery point:	
Latitude	not available
Longitude	not available

6.3.4.1 Constants and Gains Unscaled

Interval between steering updates	DT	2 seconds
Maximum acceleration	GMAX	10g = 322 FPSS
Lateral switch gain	KLAT	0.0125
Increment on Q7 to detect end of Kepler phase	KDMIN	0.5 FPSS
Time of flight calculation gain	KTETA	1000
Maximum L/D (Minimum actual vehicle L/D)	LAD	0.3
Lateral switch bias term	LATBIAS	0.4 NM
LAD cos (15°)	L/DCMINR	0.2895
Final phase L/D	LOD	0.18
Velocity to switch to relative velocity	VMIN	12,883 FPS
Velocity to stop steering	VQUIT	1000 FPS
Drag to start final phase	Q7F	6 ft/s/s

6.3.4.2 Conversion Factors and Scaling Constants

Angle in radians to nautical miles	ATK	3437.7468 $\frac{n.mi}{rad}$
Nominal G value for scaling	GS	32.2 FPSS
Atmosphere scale height	HS	28500 ft
Earth radius (entry only)	RE	21202900 ft
Satellite velocity at RE	VSAT	25766.1973 FPS

The information contained in Sec. 6.3.4.1 and 6.3.4.2 is taken from MIT Report R-532, "Re-Entry Guidance for Apollo" Volume 1, dated January 1966.

6.4 Spacecraft Vehicle Data

6.4.1 Apollo Vehicle Coordinate Reference System

Spacecraft CSM-012 reference dimensions	Fig. 6.5

6.4.2 Apollo Vehicle Mass Property Data

6.4.2.1 For Mission AS-204A (See Sec. 6.4.2.2 for Mission AS-205)

Spacecraft - weight, center of gravity, and inertia	Table 6.2
SM - weight, center of gravity, and inertia	Table 6.3
CM-RCS usable propellant - weight vs. inertia	Table 6.4, Fig. 6.7
SM - RCS usable propellant - weight vs. inertia	Table 6.4, Fig. 6.6
CSM SPS usable propellant mass data	Table 6.5

The information contained in Sec. 6.4.1 and 6.4.2 is taken from a TRW Systems document entitled "Apollo Mission Data Specification D Apollo Saturn 204A and 204B" document number 2131-H004-R8-000.

6.4.2.2 For Mission AS-205 (See Sec. 6.4.2.1 for Mission AS-204)

The spacecraft for Mission AS-205 (with CSM 014) is similar to the spacecraft for Mission AS-204 and most of the performance data are identical. Therefore, much of the data presented in Sec. 6. of this document is applicable for use in Mission AS-205.

Section 6.4.2.2 should replace Sec. 6.4.2.1 of Mission AS-204 to make this chapter applicable to Mission AS-205.

Apollo Vehicle Mass Property Data (CSM-014)

Spacecraft - weight, center of gravity, and inertia	Table 6.2A
CSM propellant weight summary	Table 6.3A
SM - weight, center of gravity, and inertia	Table 6.4A
CM - weight, center of gravity, and inertia	Table 6.5A
SPS Fuel in sump tank mass properties	Table 6.6A
SPS Oxidizer in sump tank mass properties	Table 6.7A

The information contained in Sec. 6.4.2.2 is taken from TWR Systems document entitle "Apollo Mission Data Specification D Apollo Saturn 205" document number 2131-H008-R8-000.

6.4.3 SPS Engine Vacuum Performance

Steady State Operation:	Fig. 6.8
Nominal thrust	21,500 ± 215 lb
Specific impulse	311.4 ± 1.5 sec
Start-up transients:	
Time to develop 90% rated thrust	Fig. 6.8
Buildup impulse to 90% rated thrust	300 ± 200 lb-sec
Shutdown - transients:	
Decay to 10% rated thrust	Fig. 6.8
Tail off impulse to 10% rated thrust	10,800 ± 1200 lb-sec
Decay to 0% thrust	Fig. 6.8
Thrust Vector Control Autopilot:	
Block Diagram	Fig. 6.9

6.4.4 SM RCS Jet Data

RCS thrust chambers locations	Fig. 6.10, 6.11, 6.12
RCS thruster moment arm	6.94 feet
SM RCS jet X-location	X_A = 958.905 inches
Offset angle	7.25 degrees
Cant angle	10 degrees
Parametric curves expressing specific impulse, total impulse, etc. vs. electrical pulse width	Fig. 6.13, 6.14
Steady state operations table	Fig. 6.14
Thrust buildup transients	not available
Thrust shutdown transients	not available
RCS Autopilot block diagram	Fig. 6.15

6.4.5 Apollo CM Coordinate Reference System

Spacecraft CSM-012 reference dimensions	Fig. 6.5
CM axes and notation system	Fig. 6.16
Apollo CM Mass Property Data	
CM - weight, center of gravity, and inertia	Table 6.2
CM RSC usable propellant: weight vs. inertia	Fig. 6.7
CM Re-Entry Aerodynamic Data	
Reference area	129.35 $feet^2$
Reference diameter	154.0 inches
Heat shield cant	0.2983 degree
Moment reference centers: X_A - location	1141.25 inches
Y_A - location	0.0 inch
Z_A - location	0.0 inch
Aerodynamic coefficients (corrected for a humped umbilical)	Table 6.6
Trim L/D vs. c.g. locations	Fig. 6.17

The information contained in Sec. 6.4.8 is taken from TRW Systems document entitled "Apollo Mission Data Specification D Apollo Saturn 204 and 204B" document number 2131-H004-R8-000.

6.4.6 Optics Field of View

Figures 6.18 and 6.19 are diagrams showing the minimum optics field of view in terms of trunnion angle vs. shaft angle for the scanning telescope and the sextant. Reference MIT Letter AG 581-66 dated 12 July 1966 with enclosure - MIT/IL MDRB Record of Change Form number Preliminary #204-4.

4.6.7 CM RCS Jet Data

RCS thrust chamber positions	Fig. 6.20
RCS thrust moment arms (R_C)	Fig. 6.20
RCS jet X_C, Y_C, Z_C locations	Fig. 6.20
Parametric curves expressing specific impulse, total impulse, etc. vs. electrical pulse width	Fig. 6.21, 6.22
Steady state operations table	Fig. 6.22
Thrust buildup transients	not available
Thrust shutdown transients	not available
RCS Autopilot block diagram	Fig. 6.15

6.5 Physical Constants

6.5.1 Geophysical parameters

	Symbol	Value
Equatorial earth radius (gravitational)	R_e	$6.378\ 165 \times 10^6$ meters
Flattening	F	$3.352\ 329\ 869 \times 10^{-3}$
Gravitational parameter	U_e	$3.986\ 032 \times 10^{14}\ \frac{\text{meters}^3}{\text{sec}^2}$
Mass of the earth	M_e	5.975×10^{24} kg
Angular velocity of earth's rotation	W_e	$7.292\ 115\ 06 \times 10^{-5}\ \frac{\text{radians}}{\text{sec}}$
Gravitational potential harmonics coefficients	J	$1.623\ 45 \times 10^{-3}$
	H	-0.575×10^{-5}
	D	0.7875×10^{-5}
	K	6.750×10^{-6}

6.5.2 Reference Models

Fischer Ellipsoid of 1960: The accepted mathematical model of the earth.

Equatorial earth radius	a	$6.378\ 166 \times 10^6$ meters
Polar earth radius	b	$6.356\ 784\ 284 \times 10^6$ meters
Flattening (1 - b/a)	f	1/298.30
Eccentricity of ellipsoid	e	$8.181\ 333\ 402 \times 10^{-2}$

Atmospheric Models:

a) The "U.S. Standard Atmosphere of 1962" is to be used for the earth orbit and translunar phase; U.S. Government Printing Office.

b) Above 90 KM - U.S. Standard Atmosphere of 1962 is to be used for the entry phase; U.S. Government Printing Office.

c) Below 90 KM - Air Force Interim Supplemental Atmospheres to 90 kilometers; Air Force Surveys in Geophysics No. 153.

6.5.3 Conversion Factors

	Multiply by
International feet to meters	0.304 8
Nautical miles to kilometers	1.852 0
Statute miles to kilometers	1.609 344 0
Slugs to pounds	32.174 048 0
Slugs to kilograms	14.593 902 680
Pounds to newtons	4.448 221 530
Pounds to kilograms	0.453 592 369
Ft - Lb to newton-meters	1.355 817 922
Inch to meters	0.025400

TABLE 6.1

List of Navigational Stars

Catalogue No.	Star Name	Vis. Mag.	X-Coordinate	Z-Coordinate
1	α Andromedae	2.1	+.8749977835	+.4834543831
2	β Ceti	2.2	+.9342766919	-.3118204677
3	γ Cassiopeiae	2.2	+.4778163663	+.8707281164
4	α Eridani (chernar)	0.6	+.4915952791	-.8425295521
5	α Vrsae Minoris (Polaris)	2.1	+.0132924695	+.9998811678
6	θ Eridani	3.4	+.5451054508	-.6486308798
7	α Ceti	2.8	+.7036628373	+.0690909398
8	α Persei	1.9	+.4110342064	+.7632092298
9	α Tauri (Aldebaran)	1.1	+.3513220851	+.2830955087
10	β Orionis (Rigel)	0.3	+.2016499958	-.1432918501
11	α Aurigae (Capella)	0.2	+.1377394981	+.7189404763
12	α Carinae (Canopus)	-0.9	-.0614208380	-.7952210910
13	α Canis Majoris (Sirius)	-1.6	-.1816329189	-.2868464540
14	α Canis Minoris (Procyon)	0.5	-.4113133007	+.0925568062
15	γ Velorum	1.9	-.3609931072	-.7342632776
16	ι Ursae Majoris	3.1	-.4653358879	+.7451183057
17	α Hydrae	2.2	-.7739264992	-.1480483301
18	α Leonis	1.3	-.8604721512	+.2101000555
19	β Leonis	2.2	-.9655563162	+.2546897675
20	γ Corvi	2.8	-.9526583141	-.2983240329
21	α Crucis	1.6	-.4527184611	-.8903029440
22	α Virginis (Spica)	1.2	-.9173190919	-.1906115874
23	η Ursae Majoris	1.9	-.5812423650	+.7601085228
24	θ Centauri	2.3	-.6903482150	-.5906851838

TABLE 6.1 (Cont'd)

List of Navigational Stars

Catalogue No.		Star Name	Vis. Mag.	X-Coordinate	Z-Coordinate
25	α	Bootis (Arcturus)	0.2	-.7864532894	+.3313726156
26	α	Coronae Borealis	2.3	-.5331115195	+.4512426836
27	α	Scoroii (Antares)	1.2	-.3524228976	-.4440010779
28	α	Trainguli Austr.	1.9	-.1152242526	-.9333826927
29	α	Ophiuchi	2.1	-.1131188071	+.2178504476
30	α	Lyrae (Vega)	0.1	+.1212941902	+.6259631466
31	α	Sagittarii	2.1	+.2061438978	-.4436978290
32	α	Aguilae (Altair)	0.9	+.4530918807	+.1526503866
33	β	Capricorni	3.2	+.5513451257	-.2569243340
34	α	Pavonis	2.1	+.3195525649	-.8372001458
35	α	Cygni (Deneb)	1.3	+.4538746926	+.7091362137
36	ϵ	Pegasi	2.5	+.8136287389	+.1689012500
37	α	Piscis Austr. (Fomalhaut)	1.3	+.8339640287	-.4960787198

Table 6.2 AS-204A Spacecraft Mass Properties Summary

	Weight (lb)	Center of Gravity[1] (in.)			Moments of Inertia[2] (slug-ft²)			Products of Inertia[2] (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	8,500 ± 110	1,298.9 ± 1.0	-0.1 ± 0.5	-0.5 ± 0.5	663	24,020	24,013	17	273	0
Command Module[3]	11,800 ± 200	1,040.8 ± 1.0	0.0 ± 0.5	5.6 ± 0.5	5,761	5,007	4,611	31	265	11
Service Module[4]	19,939 ± 235	891.7 ± 0.7	13.6 ± 0.4	-5.7 ± 0.4	11,120	15,581	16,097	-892	3	843
SLA	3,561 ± 44	640.6 ± 1.0	0.8 ± 0.5	-2.1 ± 0.5	8,946	11,681	11,427	4	-49	34
Spacecraft at Liftoff	43,800 ± 331	990.5 ± 1.0	6.2 ± 0.5	-1.3 ± 0.5	27,120	373,569	373,646	-6,876	3,900	636
Remove LES	-8,500 ± 110	1,298.9 ± 1.0	-0.1 ± 0.5	-0.5 ± 0.5	-663	-24,020	-24,013	-17	-273	0
Spacecraft in Earth Orbit	35,300 ± 312	916.2 ± 0.6	7.7 ± 0.3	0.0 ± 0.3	26,365	132,998	132,986	0	3,039	648
Remove SLA	-3,561 ± 44	640.6 ± 1.0	0.8 ± 0.5	-2.1 ± 0.5	-8,946	-11,681	-11,427	-4	49	-34
Command and Service Module	31,739 ± 309	947.1 ± 0.7	8.5 ± 0.3	-1.5 ± 0.3	17,378	56,364	56,575	0	2,956	610
Remove Service Module	-19,939 ± 235	891.7 ± 0.7	13.6 ± 0.4	-5.7 ± 0.4	-11,120	-15,581	-16,097	+892	-3	+843
Command Module	11,800 ± 200	1,040.8 ± 1.0	0.0 ± 0.5	5.6 ± 0.5	5,761	5,007	4,611	31	265	11

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. Tolerance on moments and products of inertia is ± 10 percent.

(3) Includes 225 pounds of usable and 45 pounds of residual RCS propellant consisting of helium, trapped, tank expulsion efficiency, mixture ratio tolerance and loading tolerance.

(4) See Table 3-4 for service module mass properties breakdown.

All tolerances represent the maximum deviations from nominal values expected to prevail at the time of launch, and shall be used as 3 σ deviations.

Table 6.2A AS-205 Spacecraft Mass Properties Summary [1]

	Weight (lb)	Center of Gravity[2] (in)			Moments of Inertia[3] (slug-ft²)			Products 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	8,550 ± 100	1,299.6 ± 0.5	0.0 ± 0.1	-0.5 . 0.1	665	24,299	24,292	17	273	0
Command Module	11,900 ± 200	1,040.6 ± 1.5	0.2 ± 0.8	5.2 ± 0.5	5,869	5,142	4,632	21	-242	-29
Service Module	19,787 ± 106	893.3 ± 0.6	13.5 ± 0.3	-0.5 ± 0.3	10,957	16,402	16,900	-826	386	827
SLA	3,613 ± 100	639.5 ± 0.5	0.0 ± 0.5	-2.2 ± 0.5	9,128	11,755	11,589	9	-32	-23
Spacecraft at Lift-off	43,850 ± 267	991.6 ± 1.2	6.1 ± 0.3	0.9 ± 0.2	27,107	376,885	377,054	-6,439	1,570	696
Remove LES	8,550 ± 100	1,299.6 ± 0.5	7.6 ± 0.3	-0.5 ± 0.1	665	24,299	24,292	17	273	0
Spacecraft in Earth Orbit	35,300 ± 247	917.0 ± 1.2	1.2 ± 0.2	1.2 ± 0.2	26,351	135,064	135,158	-2,116	2,290	676
Remove SLA	3,613 ± 100	639.5 ± 0.5	-2.2 ± 0.5	-2.2 ± 0.5	9,128	11,755	11,589	-9	-32	-23
Command and Service Module	31,687 ± 226	948.6 ± 0.9	1.6 ± 0.3	1.6 ± 0.3	17,162	56,401	56,620	-3,948	1,491	676
Remove Service Module	19,787 ± 106	893.3 ± 0.6	-0.5 ± 0.3	-0.5 ± 0.3	10,957	16,402	16,900	-826	386	827
Command Module	11,900 ± 200	1,040.6 ± 1.5	5.2 ± 0.5	5.2 ± 0.5	5,869	5,142	4,632	21	-242	-29

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. Tolerance on inertia is ± 15%.

Table 6.3 AS-204A Service Module Mass Properties Summary

	Weight (lb)	Center of Gravity[1] (in) X_A	Y_A	Z_A	Moments of Inertia[2] ($slug\text{-}ft^2$) I_{xx}	I_{yy}	I_{zz}	Products of Inertia[2] ($slug\text{-}ft^2$) I_{xy}	I_{xz}	I_{yz}
Service Module, Inert[3]	9,493	906.7	0.5	-0.8	6,189	10,519	9,979	160	-519	-404
SLA Attach Ring	87	837.1	0	-1.8	93	48	46	0	0	0
SPS Usable Propellant[4]	9,569	871.7	27.3	-11.5	3,190	2,311	2,781	3	2	1,562
RCS Usable Propellant	790	959.0	0	0	-750	450	425	0	0	0
Total Service Module	19,939 ± 235	891.7 ± 0.7	13.6 ± 0.4	-5.7 ± 0.4	11,120	15,581	16,097	-892	3	843

NOTES: (1) Centers of gravity are referenced to the Apollo spacecraft reference system origin.

(2) Moments and products of inertia are about the center of gravity of each item. Tolerance on moments and products o inertia is ± 10 percent.

(3) Includes residual RCS and SPS propellant consisting of trapped, mixture ratio tolerance, loading tolerance, helium, RCS expulsion efficiency tolerance and SPS nitrogen and restart loss propellant.

(4) Only 9400 pounds of usable propellant shall be used for mission planning. The remainder shall be considered ballast for adjustment of future CSM weight growth.

All tolerances represent the maximum deviations from nominal values expected to prevail at the time of launch, and shall be used as 3 σ deviations.

Table 6-3A AS-205 CSM Propellant Weight Summary

	Service Module SPS 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									
Mixture Ratio Tolerance	17	33		3	6		1	2	
Available for Mission	2985	5970		263	527		75	150	
Loading Reserve	15	30		3	5		1	2	
Start Loss	0	0							
Total Usable Propellant in Tanks(1)	(3017)	(6033)	9050	(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)	24	(3)	(6)	9
Total Propellant in Tanks(2) (3)	(3061)	(6188)	9249	(275)	(556)	831	(80)	(160)	240
System Propellant Residuals									
Trapped in Engine	21	48							
Trapped in Transfer Lines	0	0							
Trapped in Engine Lines	18	34		1	3	4			
Total System Propellant Residuals	(39)	(82)	121	(1)	(3)	4	(10)	(19)	29
Total Propellant Loaded (4)	3100	6270	9370	276	559	835	90	179	269
Helium			155			3			1
Nitrogen			2						

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

Mission planning shall include consideration of the Spacecraft SPS "Total Usable Propellant" gauging accuracy, defined as follows:

Fuel gauging accuracy = ± (26. 3 + 0. 35% weight of fuel in tank) pounds.
Oxidizer gauging accuracy = ± (52. 6 + 0. 35% weight of oxidizer in tank) pounds.

(2) See Table 6.4A for service module SPS and RCS propellant mass properties.

(3) See Table 6.5A for command module RCS propellant mass properties.

(4) Spacecraft gauging accuracy of ±0. 35% full tank ±0. 35% of the remaining propellant in the SPS tanks.

Table 6.4 AS-204A Spacecraft Propellant Loading Summary

	Weight (lb)	Center of Gravity (in)			Moments of Inertia(2) (slug-ft^2)			Products of Inertia(2) (slug-ft^2)		
		X_A	Y_A	Z_A	I_{XX}	I_{YY}	I_{ZZ}	I_{XY}	I_{XZ}	I_{YZ}
SPS Usable Propellant 204A(3)(4)	9,569	See Table 6.5			See Table 6.5			See Table 6.7		
GM/RCS Usable Propellant(3)(5)	225	1,022.6	-5.6	57.0	See Fig. 6.7			0	0	0
SM/RCS Usable Propellant(3)(5)	790	959.0	0.0	0.0	See Fig. 6.6			0	0	0

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) Mass properties are based on O/F ratio of 2:1.

(4) Only 9400 pounds of usable propellant shall be used for mission planning. The remainder shall be considered ballast for adjustment of future CSM weight growth.

(5) Center of gravity remains constant through usable propellant depletion.

Table 6.4A AS-205 Service Module Mass Properties

Service Module	Weight (lb)	Center of Gravity[1] (in.)			Moments of Inertia[2] (slug-ft^2)			Products of Inertia[2] (slug-ft^2)		
		X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
Service Module, Inert[3]	9,620	911.9	1.3	1.1	6,032	10,684	10,268	447	-245	-345
SLA Attach Ring	87	837.1	0.0	-1.8	108	56	53	0	0	0
SPS Propellant in Tanks										
Fuel	3,061	868.8	-14.8	-47.8	0	281	281	0	0	0
Oxidizer	6,188	869.0	48.3	6.6	0	601	601	0	0	0
RCS Propellant in Tanks[4]	831	959.0	0.0	0.0	853	544	441	0	0	0
Total Service Module[5]	19,787 ± 106	893.3 ± 0.6	13.5 ± 0.3	-0.5 ± 0.3	10,957	16,402	16,900	-826	386	827

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 6.5 AS-204A SM-SPS Usable Propellant Mass Properties (1)

Weight (lb)	Center of Gravity (2) (in) X_A	Y_A	Z_A	Moments of Inertia (3) (slug-ft^2) I_{xx}	I_{yy}	I_{zz}	Products of Inertia (3) (slug-ft^2) I_{xy}	I_{xz}	I_{yz}
0.0	838.1	27.3	-11.5	0.0	0.0	0.0	0.0	-0.0	-0.0
84.0	838.7	27.3	-11.5	28.0	13.2	17.4	0.1	0.1	13.8
326.5	840.1	27.3	-11.5	108.7	52.2	68.2	0.4	0.3	53.8
660.6	841.7	27.3	-11.5	219.9	107.9	140.3	0.8	0.7	108.8
1050.0	843.3	27.3	-11.5	349.6	174.9	226.4	1.4	1.2	172.9
1481.4	845.2	27.3	-11.5	493.2	251.1	323.8	2.1	1.9	243.9
1941.5	846.8	27.3	-11.5	646.4	334.9	430.1	3.0	2.6	319.7
2496.9	848.8	27.3	-11.5	831.3	439.1	561.5	4.0	3.4	411.1
2975.9	850.4	27.3	-11.5	990.7	531.5	677.4	4.7	4.1	490.0
3455.0	852.0	27.3	-11.5	1150.2	626.9	796.3	5.3	4.6	568.8
3934.0	853.6	27.3	-11.5	1309.7	725.6	918.5	5.7	4.9	647.7
4413.1	855.1	27.3	-11.5	1469.2	828.3	1044.6	6.0	5.2	726.6
4892.1	856.7	27.3	-11.5	1628.7	935.2	1175.1	6.3	5.4	805.5
5371.2	858.2	27.3	-11.5	1788.2	1047.0	1310.4	6.5	5.6	844.3
5850.2	859.8	27.3	-11.5	1947.7	1164.1	1451.0	6.5	5.6	963.2
6329.3	861.3	27.3	-11.5	2107.2	1287.1	1597.4	6.3	5.4	1042.1
6808.3	862.8	27.3	-11.5	2266.7	1416.3	1750.1	6.0	5.2	1121.0
7287.4	864.4	27.3	-11.5	2426.1	1552.1	1909.4	5.7	4.9	1199.8
7766.6	865.9	27.3	-11.5	2585.6	1695.2	2076.0	5.3	4.6	1278.7
8245.5	867.4	27.3	-11.5	2745.1	1846.0	2250.3	4.7	4.1	1357.6
8724.6	868.9	27.3	-11.5	2904.6	2004.9	2432.7	4.0	3.4	1436.5
9203.6	870.5	27.3	-11.5	3064.1	2172.6	2623.8	3.1	2.7	1515.3
9569.0	871.7	27.3	-11.5	3190.0	2311.0	2781.0	2.5	2.1	1562.0
9589.0	871.8	27.3	-11.5	3196.1	2317.9	2788.6	2.5	2.1	1567.8
9682.7	872.0	27.3	-11.5	3223.6	2349.2	2823.9	2.3	1.9	1594.2

NOTES: (1) O/F misture ratio 2:1.

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

(3) Moments and products of inertia are about the propellant center of gravity.

Table 6.5A AS-205 Command Module Mass Properties

Command Module	Weight (lb)	Center of Gravity[1] (in.)			Moments of Inertia[2] (slug-ft^2)			Products 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 Inert[3]	11,660	1,041.0	0.3	4.1	5,674	4,980	4,565	16	-19	-13
RCS Propellant in Tanks[4]	(240)	1,022.6	-5.6	57.0	52	4	48	0	0	0
System A	120	1,022.6	4.8	55.1	24	1	23	0	0	0
System B	120	1,022.6	-16.1	56.6	20	4	16	0	0	0
Total Command Module[5]	11,900 ± 200	1,040.6 ± 1.5	0.2 ± 0.8	5.2 ± 0.5	5,869	5,142	4,632	21	-242	-29

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 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.

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

TABLE 6.6 Command Module (CM-012) Aerodynamic (Pitch Plane) Coefficients

Angle of Attack α (deg)	C_{M_A}	C_N	C_A
M = 0.0 to 0.7			
140.2983	0.08749	0.02501	-0.83499
145.2983	0.08573	0.04745	-0.89520
150.2983	0.06104	0.04133	-0.93657
155.2983	0.04133	0.03218	-0.95207
160.2983	0.03153	0.01953	-0.97161
165.2983	0.02479	0.01271	-0.98972
170.2983	0.00059	0.02141	-0.96663
175.2983	-0.01433	0.03586	-0.98082
180.2983	-0.0212	0.01387	-0.98609
M = 0.9			
140.2983	0.03173	0.07901	-0.95503
145.2983	0.02379	0.07502	-1.00250
150.2983	0.02243	0.06412	-1.03725
155.2983	0.02108	0.05090	-1.07128
160.2983	0.02034	0.03474	-1.09934
165.2983	0.01977	0.02680	-1.10208
170.2983	0.00556	0.02431	-1.08228
175.2983	-0.00897	0.02472	-1.07840
180.2983	-0.02051	0.02537	-1.08315
M = 1.1			
140.2983	-0.02176	0.15683	-1.17721
145.2983	0.00742	0.09593	-1.22972
150.2983	0.01357	0.06905	-1.25324
155.2983	0.01481	0.05055	-1.28011
160.2983	0.01645	0.03629	-1.34065
165.2983	0.01782	0.02443	-1.30452
170.2983	0.02005	0.01323	-1.30433
175.2983	0.01971	0.03261	-1.29187
180.2983	0.02146	0.03326	-1.29519

TABLE 6.6 Command Module (CM-012) Aerodynamic (Pitch Plane) Coefficients (Cont'd)

Angle of Attack, α (deg)	C_{M_A}	C_N	C_A
M = 1.2			
140.2983		0.16425	-1.17170
145.2983	0.00380	0.09655	-1.21555
150.2983	0.01067	0.07134	-1.23571
155.2983	0.01184	0.05596	-1.26145
160.2983	0.01174	0.04044	-1.29859
165.2983	0.00986	0.02607	-1.29746
170.2983	0.00587	0.01107	-1.29506
175.2983	0.00594	-0.00191	-1.29702
180.2983	-0.01446	0.00724	-1.30006
M = 1.35			
140.2983	-0.07148	0.21600	-1.23037
145.2983	-0.03401	0.16110	-1.32228
150.2983	-0.00553	0.10277	-1.38552
155.2983	0.00609	0.07434	-1.40863
160.2983	0.00464	0.05252	-1.41450
165.2983	0.00194	0.03311	-1.40169
170.2983	0.00269	0.02259	-1.41878
175.2983	-0.00249	0.01135	-1.41122
180.2983	-0.01222	0.01070	-1.40407
M = 1.65			
140.2983	-0.06894	0.20800	-1.18307
145.2983	-0.04138	0.16128	-1.29723
150.2983	-0.01231	0.11919	-1.37650
155.2983	-0.00257	0.07717	-1.43980
160.2983	0.00210	0.05079	-1.44975
165.2983	0.00276	0.03274	-1.43932
170.2983	-0.00138	0.02352	-1.46834
175.2983	-0.01858	0.01157	-1.42808

TABLE 6.6 Command Module (CM-012) Aerodynamic (Pitch Plane) Coefficients (Cont'd)

Angle of Attack, α (deg)	C_{M_A}	C_N	C_A
M = 2.0			
140.2983	-0.07090	0.20415	-1.13636
145.2983	-0.04530	0.17387	-1.24360
150.2983	-0.01981	0.11019	-1.34536
155.2983	-0.00297	0.07072	-1.42042
160.2983	-0.00062	0.05738	-1.46651
165.2983	0.00102	0.03773	-1.46861
170.2983	-0.00136	0.02314	-1.49600
175.2983	-0.00704	0.00839	-1.49685
180.2983	-0.01661	0.01021	-1.49707
M = 2.4			
140.2983	-0.06251	0.20165	-1.09637
145.2983	-0.04164	0.17125	-1.21004
150.2983	-0.02953	0.13041	-1.30206
155.2983	-0.01486	0.09484	-1.38203
160.2983	-0.00444	0.06450	-1.44144
165.2983	0.00210	0.03828	-1.46888
170.2983	-0.00334	0.04577	-1.49040
175.2983	0.00620	0.00056	-1.49870
180.2983	0.00631	-0.01275	-1.48995
M = 3.0			
135.2983	-0.07872	0.21582	-0.92269
140.2983	-0.05507	0.17414	-1.04442
145.2983	-0.93723	0.14723	-1.16188
150.2983	-0.02079	0.11646	-1.25852
155.2983	-0.00981	0.08610	-1.32797
160.2983	-0.00036	0.05776	-1.39062
165.2983	0.00405	0.03250	-1.44139
170.2983	-0.00005	0.01167	-1.46188
175.2983	0.01114	-0.01451	-1.47914
180.2983	0.00134	-0.01972	-1.48292

TABLE 6.6 Command Module (CM-012) Aerodynamic (Pitch Plane) Coefficients (Cont'd)

Angle of Attack, α (deg)	C_{M_A}	C_N	C_A
M = 4.0			
140.2983	-0.04565	0.16967	-0.98660
145.2983	-0.03278	0.14301	-1.09316
150.2983	-0.02235	0.11650	-1.19072
155.2983	-0.01159	0.08916	-1.27548
160.2983	-0.00553	0.06552	-1.34146
165.2983	-0.00263	0.04393	-1.39655
170.2983	-0.00073	0.02504	-1.43385
175.2983	-0.00062	0.00753	-1.45426
180.2983	-0.00599	-0.00760	-1.45998
M = 6 to 25			
110.2983	-0.21100	0.36800	-0.20000
115.2983	-0.17400	0.33000	-0.34000
120.2983	-0.13900	0.29300	-0.49000
125.2983	-0.10800	0.25800	-0.61000
130.2983	-0.08200	0.22500	-0.73000
135.2983	-0.05900	0.19300	-0.86000
140.2983	-0.04139	0.16621	-0.97978
145.2983	-0.02859	0.13952	-1.08325
150.2983	-0.01988	0.11646	-1.17693
155.2983	-0.01199	0.09211	-1.26749
160.2983	-0.00770	0.07055	-1.34495
165.2983	-0.00354	0.04845	-1.41400
170.2983	-0.00123	0.02666	-1.46141
175.2983	-0.00023	0.00770	-1.48436
180.2983	0.00413	-0.00775	-1.48992
185.2983	0.00000	-0.01500	-1.47000
190.2983	-0.00200	-0.01500	-1.4500

Table 6-6A Mass Properties of AS-205 Service Module SPS Fuel in Sump Tank

Weight (lb)	Center of Gravity(1) (inches)			Moments of Inertia(2) (slug-ft^2)			Products of Inertia(2) (slug-ft^2)		
	X_A	Y_A	Z_A	I_{xx}	I_{yy}	I_{zz}	I_{xy}	I_{xz}	I_{yz}
31.56	834.5	-14.8	-47.8	-0.0	0.2	0.2	-0.0	-0.0	0.0
92.85	836.5	-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
726.04	845.4	-14.8	-47.8	-9.0	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
1065.04	849.1	-14.8	-47.8	0.0	36.0	36.0	-0.0	-0.0	0.0
1224.82	850.7	-14.8	-47.8	-0.0	45.1	45.1	-0.0	-0.0	0.0
1384.59	852.3	-14.8	-47.8	-0.0	55.5	55.5	-0.0	-0.0	0.0
1544.37	853.9	-14.8	-47.8	-0.0	67.3	67.3	-0.0	-0.0	0.0
1704.14	855.5	-14.8	-47.8	-0.0	80.5	80.5	-0.0	-0.0	0.0
1863.92	857.1	-14.8	-47.8	0.0	95.6	95.6	-0.0	-0.0	0.0
2023.69	858.7	-14.8	-47.8	0.0	112.6	112.6	-0.0	-0.0	0.0
2133.47	860.2	-14.8	-47.8	-0.0	131.6	131.6	-0.0	-0.0	0.0
2503.82	863.4	-14.8	-47.8	0.0	176.6	176.6	-0.0	-0.0	0.0
2662.79	864.9	-14.8	-47.8	-0.0	202.8	202.8	-0.0	-0.0	0.0
2822.57	866.5	-14.8	-47.8	-0.0	231.8	231.8	-0.0	-0.0	0.0
2982.34	868.0	-14.8	-47.8	0.0	263.7	263.7	-0.0	-0.0	0.0
3061.0	868.8	-14.8	-47.8	0.0	281.0	281.0	-0.0	-0.0	0.0
3142.12	869.6	-14.8	-47.8	-0.0	298.7	298.7	-0.0	-0.0	0.0

Notes: (1) Fuel centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(2) Moments and products of inertia are about the fuel centers of gravity.

Table 6.7A Mass Properties of AS-205 Service Module SPS Oxidizer Sump Tank

Weight (lb)	Center of Gravity[1] (inches) X_A	Y_A	Z_A	Moments of Inertia[2] (slug-ft^2) I_{xx}	I_{yy}	I_{zz}	Products of Inertia[2] (slug-ft^2) I_{xy}	I_{xz}	I_{yz}
0.01	832.0	48.3	6.6	-0.0	0.0	-0.	0.	0.	0.
63.86	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.
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	65.9	65.9	0.0	0.0	0.0
2129.05	[illegible]	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	852.8	48.3	6.6	-0.0	127.7	127.7	0.0	0.0	0.0
3067.25	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
3726.05	857.5	48.3	6.6	-0.0	213.5	213.5	0.	0.0	0.0
4045.45	859.0	48.3	6.6	-0.0	249.0	249.0	0.	0.0	0.0
4384.85	860.6	48.3	6.6	0.0	288.3	288.3	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
5981.85	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

Notes: (1) Oxidizer centers of gravity are referenced to the Apollo spacecraft coordinate system origin.

(2) Moments and products of inertia are about the oxidizer centers of gravity.

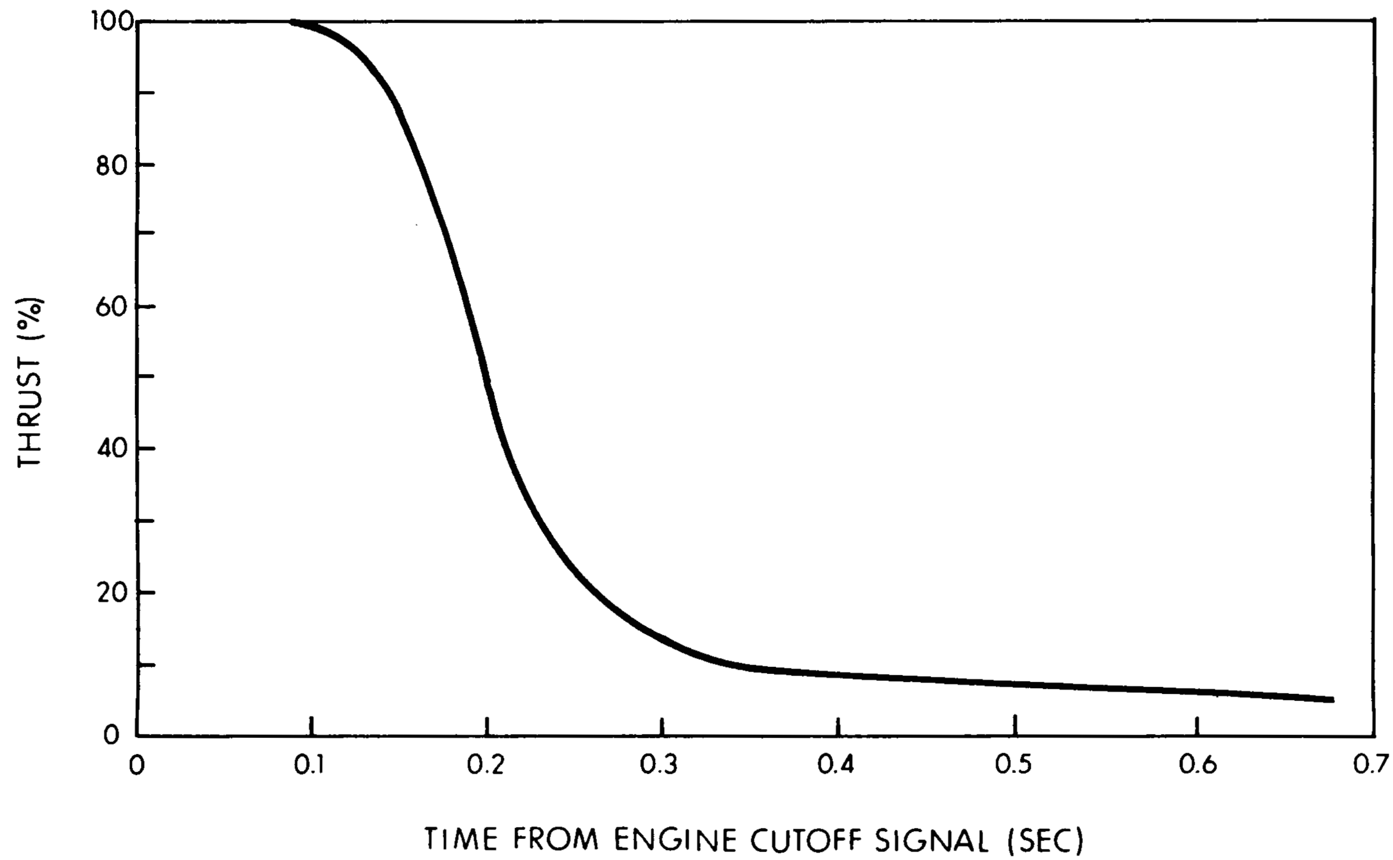


Fig. 6.1 Thrust Decay to 5% Thrust

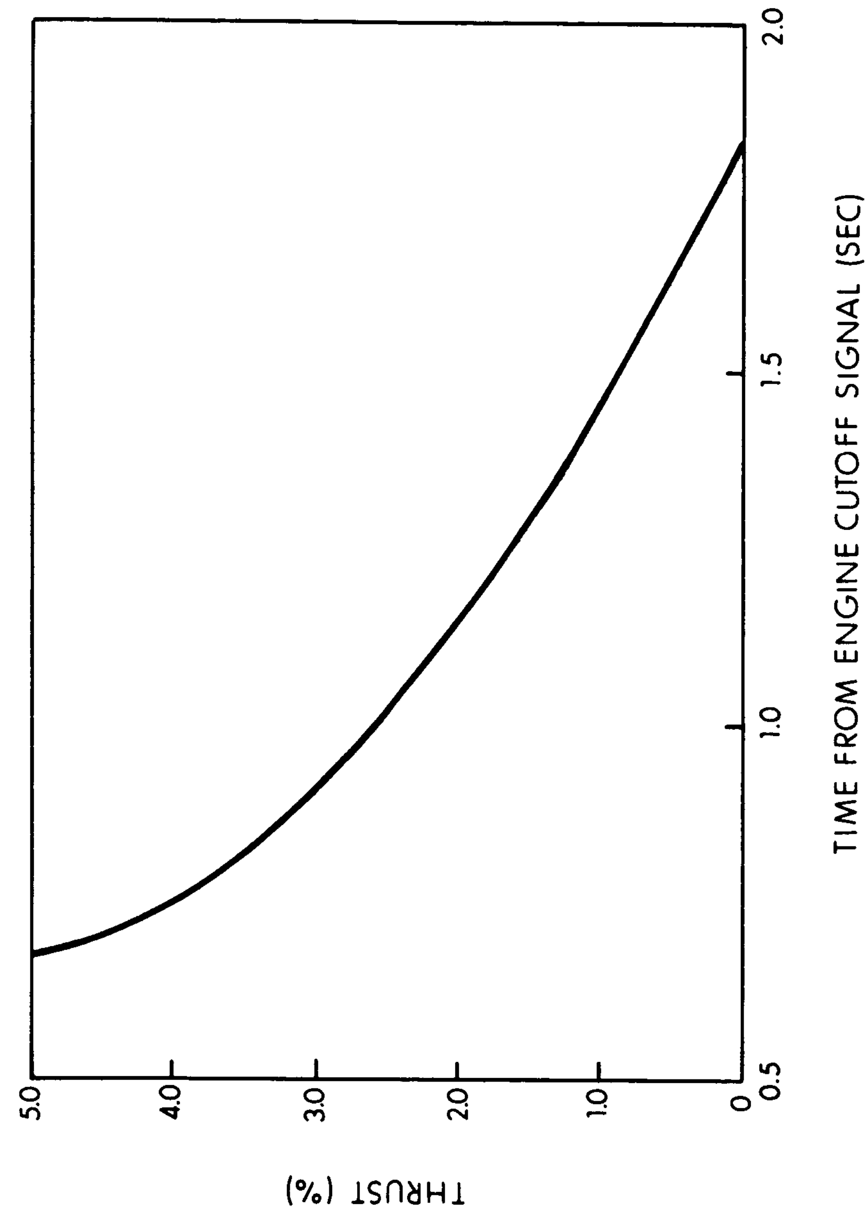
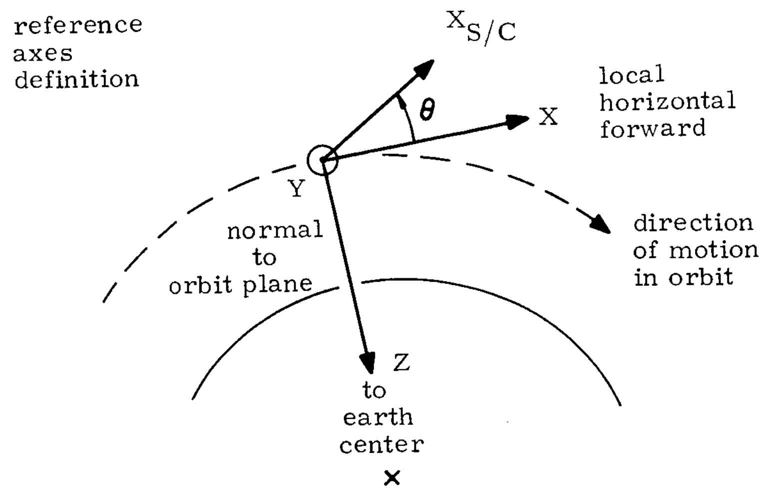


Fig. 6.2 Thrust Decay from 5% Thrust



$X_{S/C}$ (in XZ plane) rotated θ from X positively about Y

$Y_{S/C}$ rotated ϕ from Y positively about $X_{S/C}$

Present best estimate for optimum landmark tracking attitude $\theta = -20^{\circ}$, $\phi = 0$:

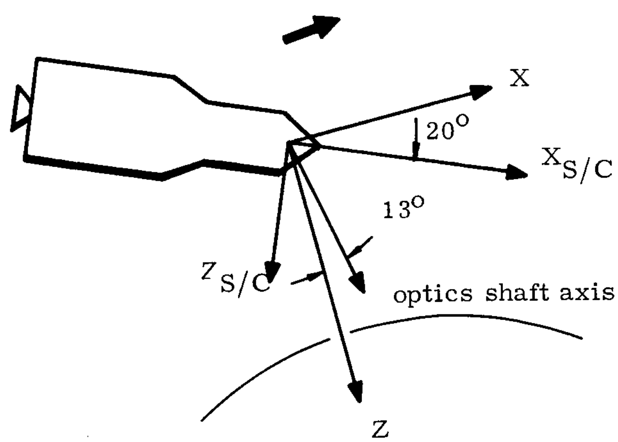


Fig. 6-3 SIVB-CSM Orbit Attitude Definition

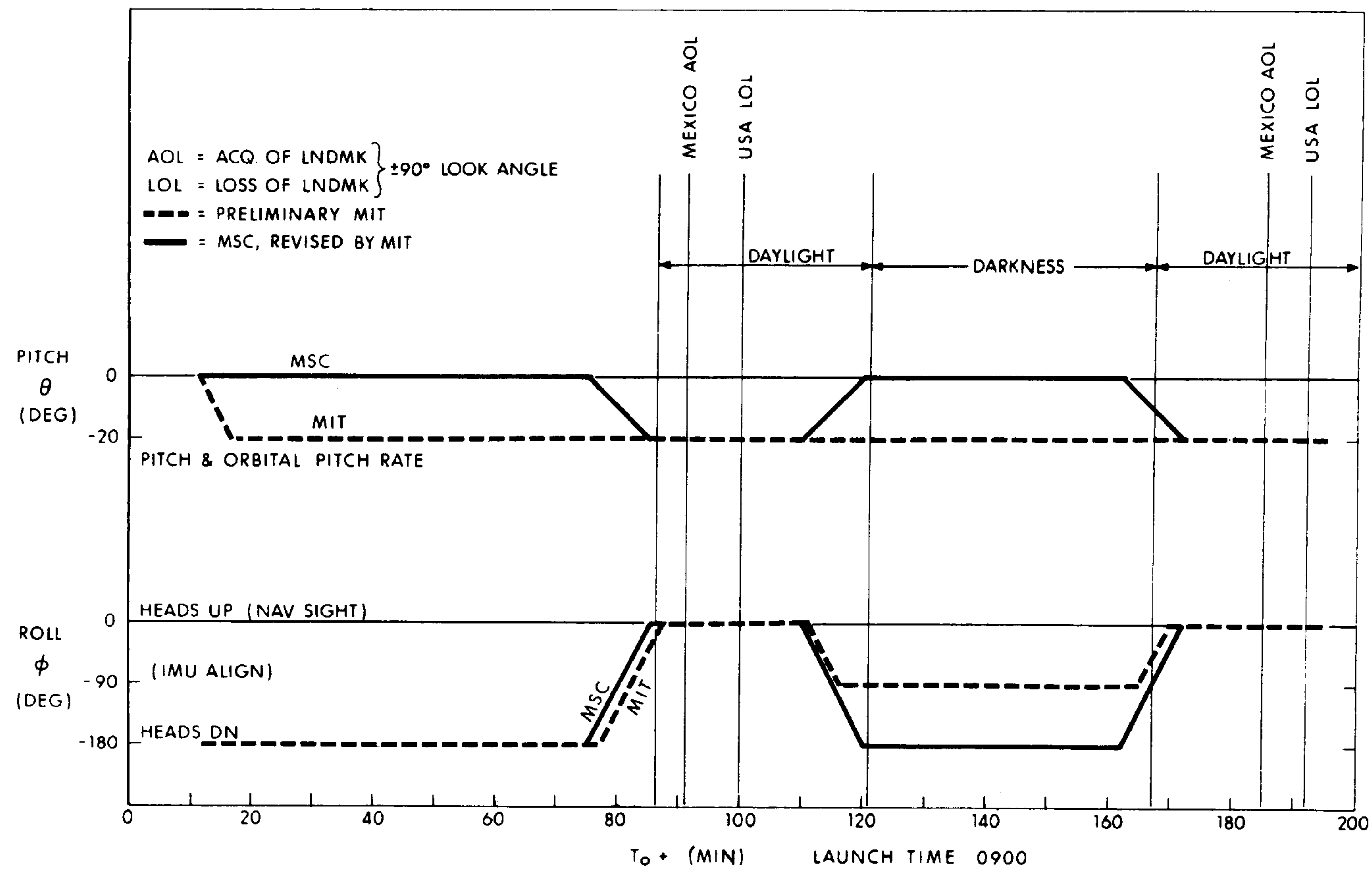
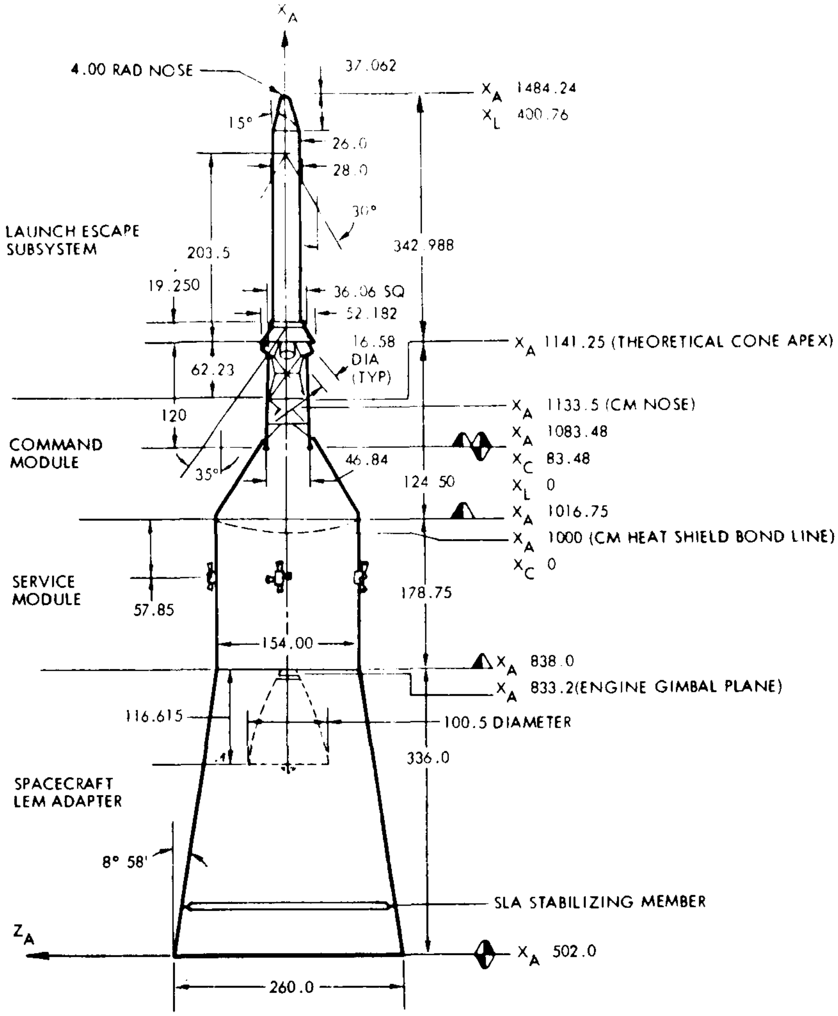


Fig. 6.4 AS-204 SIVB/CSM Maneuver Requirements



Notes: Separation Plane

Field Splice

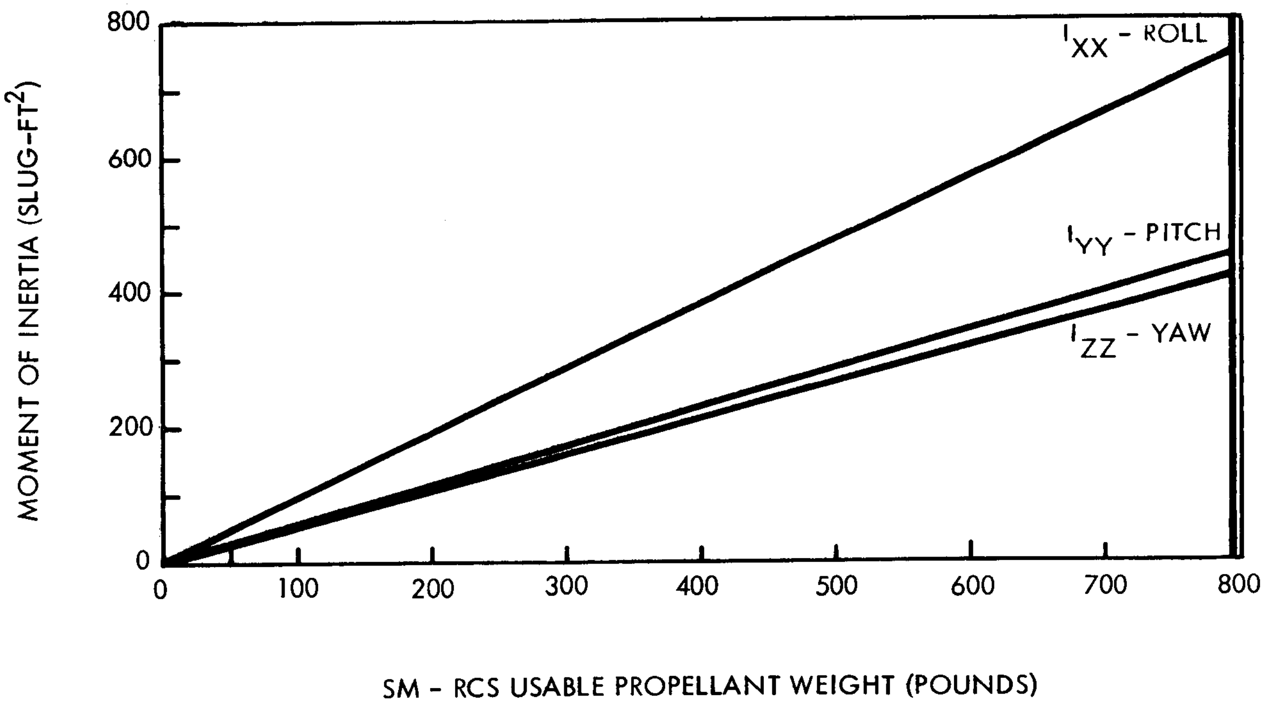
X_A Apollo Spacecraft (CSM) Coordinate System

X_C CM Coordinate System

X_L LES Coordinate System

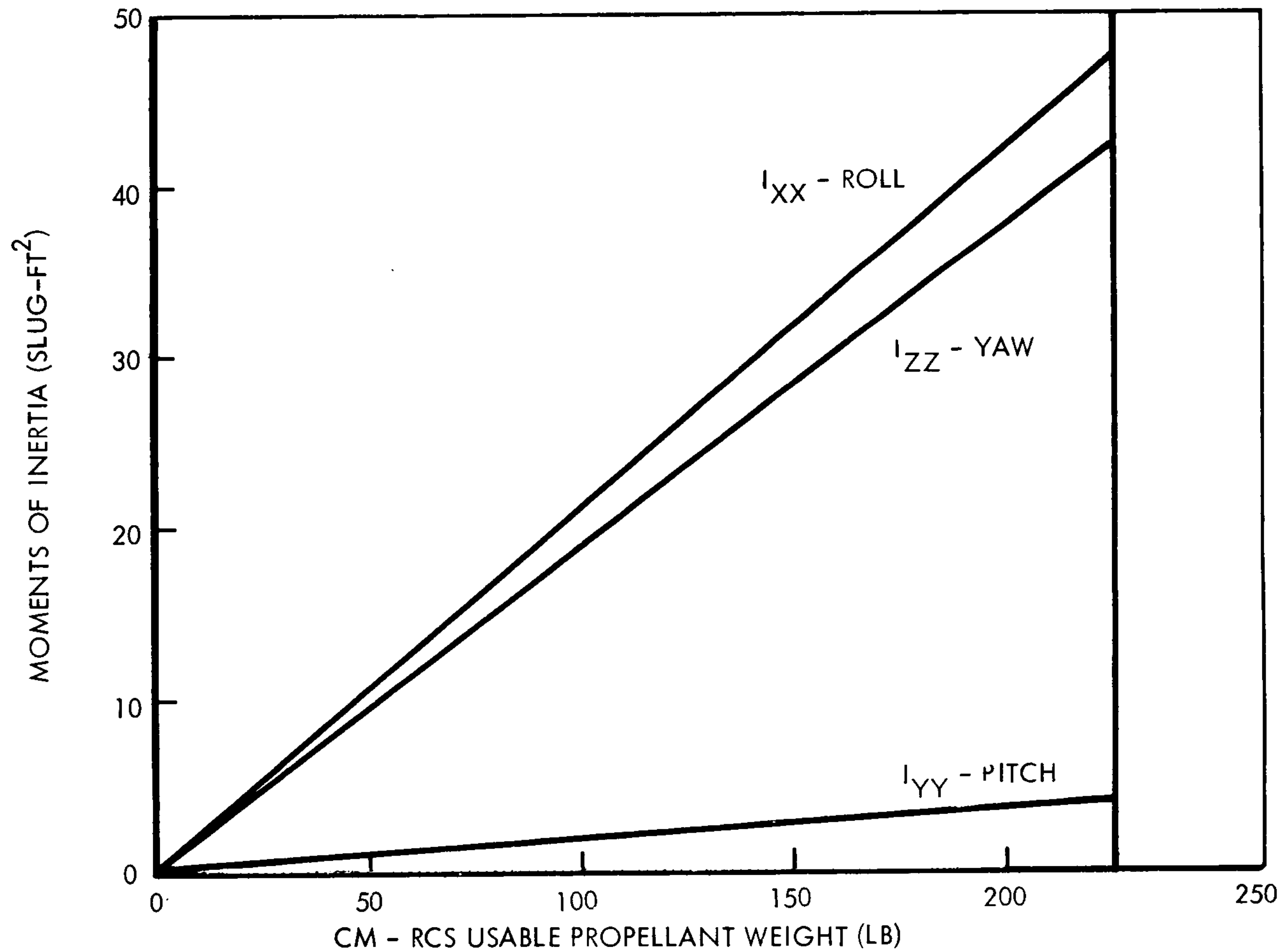
All linear dimensions are in inches.

Fig. 6.5 Spacecraft CSM-012 Reference Dimensions



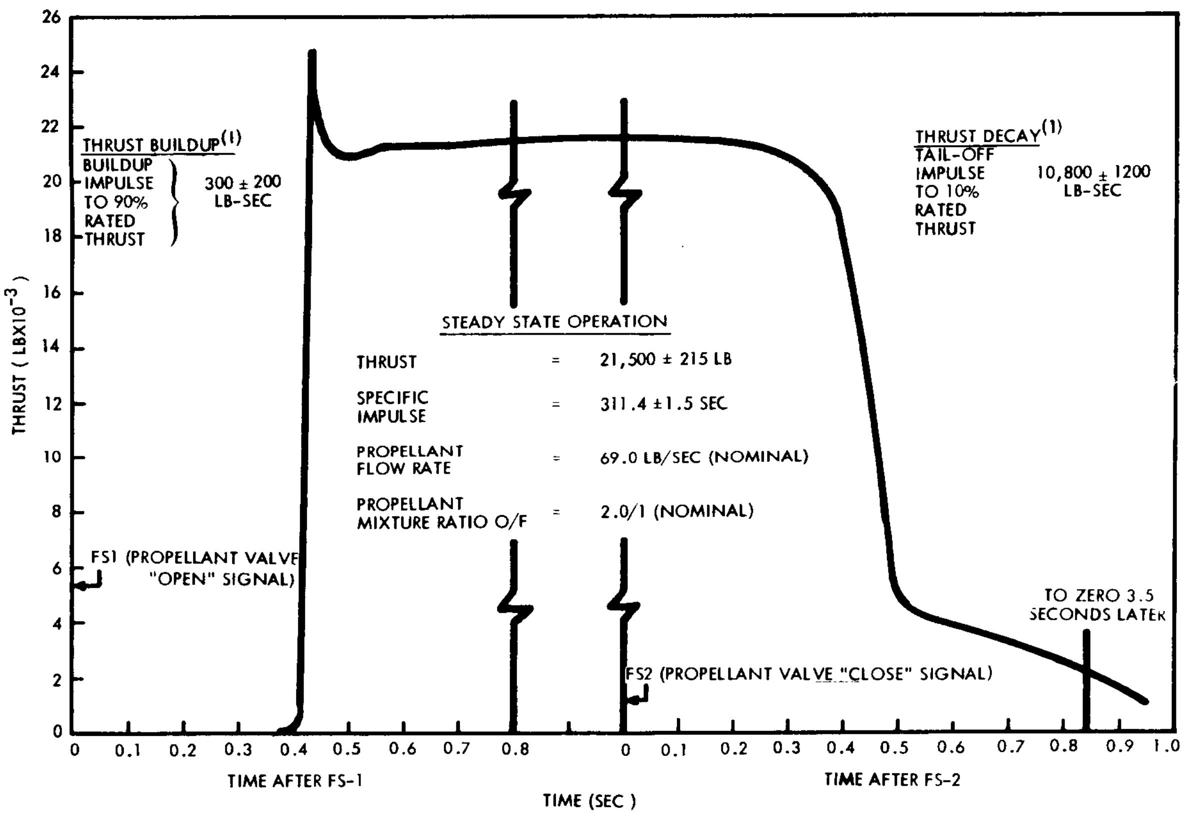
Notes: The propellant center of gravity is presented in Table 6-6 and remains constant. Moments of inertia are about propellant center of gravity.

Fig. 6.6 SM-RCS Usable Propellant Mass Properties



Notes: The propellant center of gravity is presented in Table 6-6 and remains constant. Moments of inertia are about propellant center of gravity.

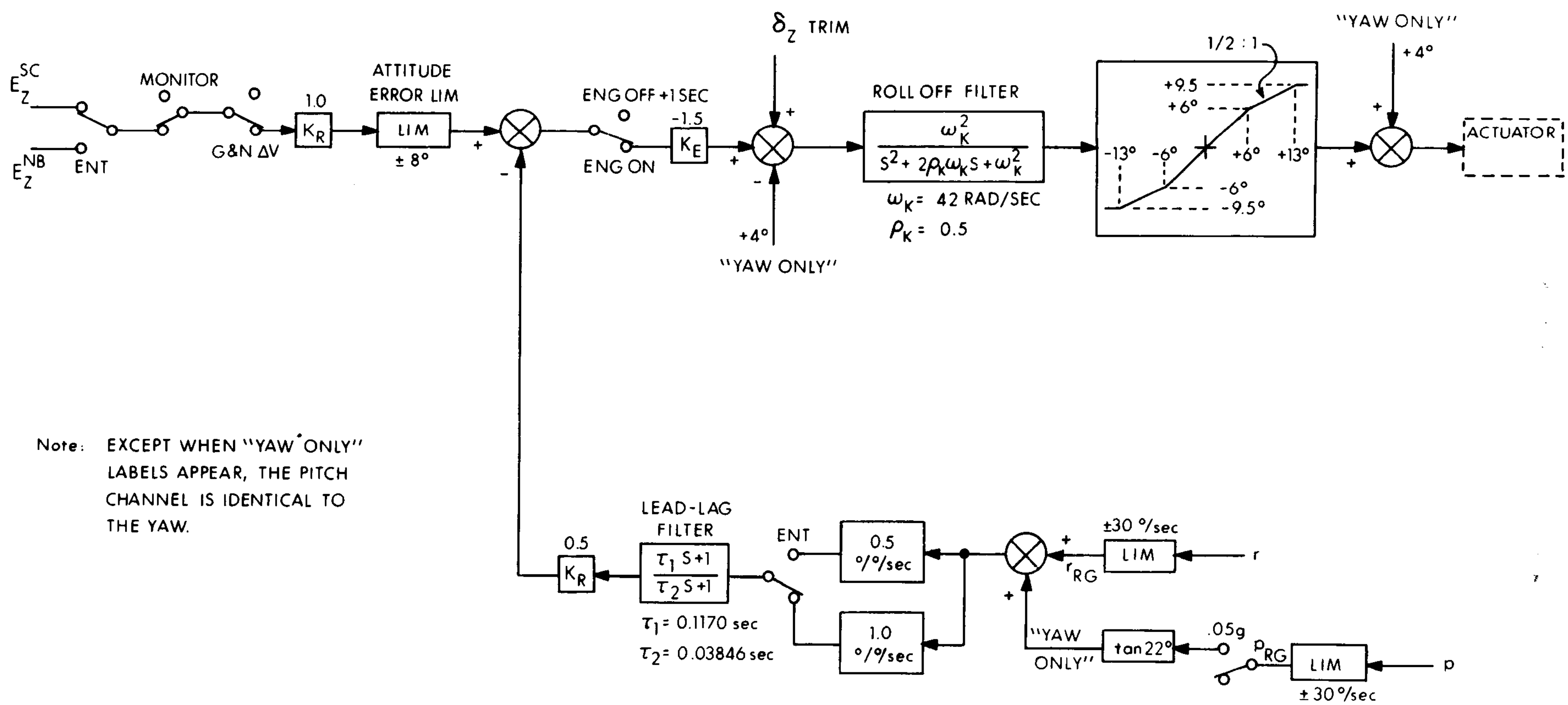
Fig. 6.7 CM-RCS Usable Propellant Mass Properties



Note : (1) 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. 6.8 SPS Engine Vacuum Performance Summary



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

Fig. 6.9 TVC Autopilot Yaw Channel

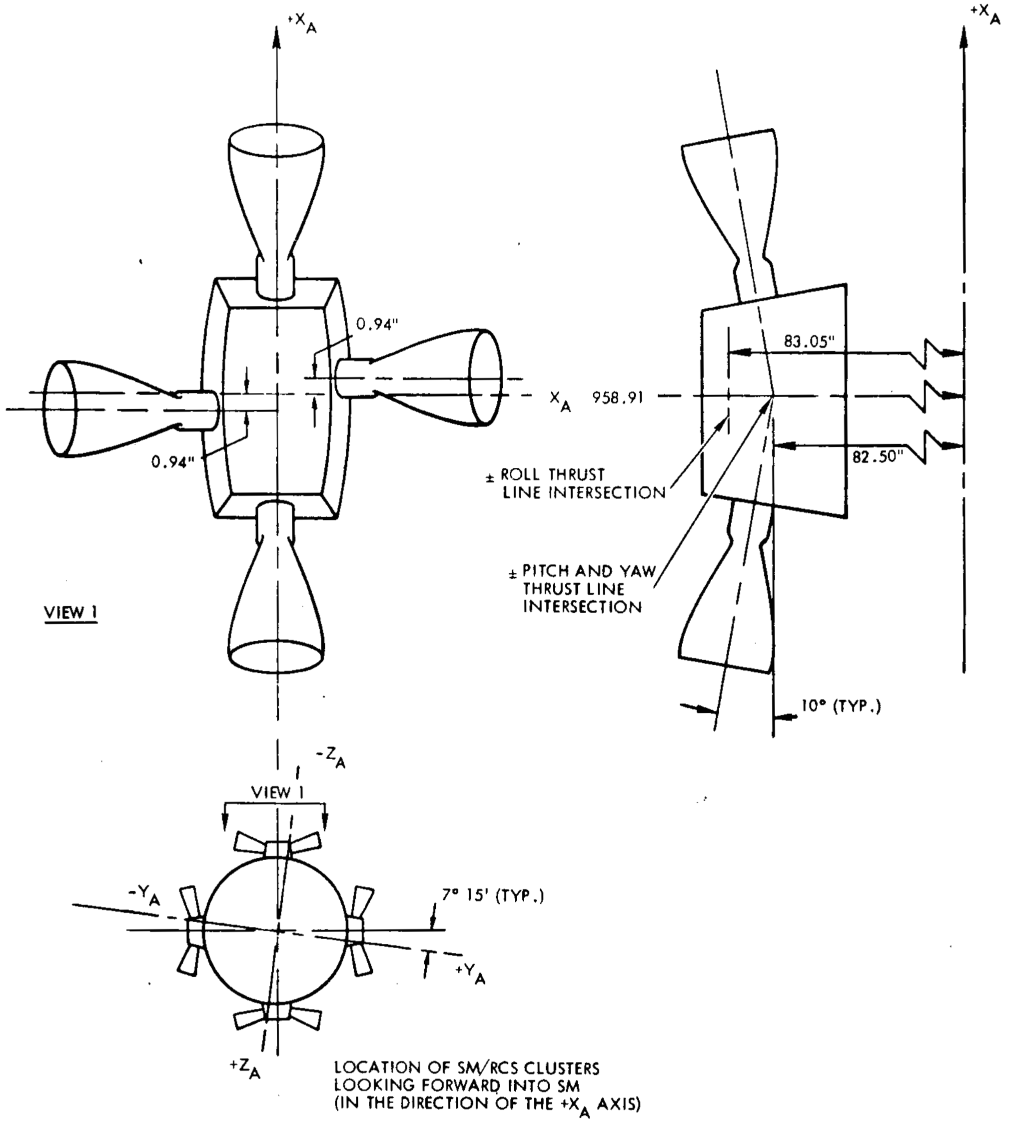


Fig. 6.10 SM/RCS Thrust Chamber Locations

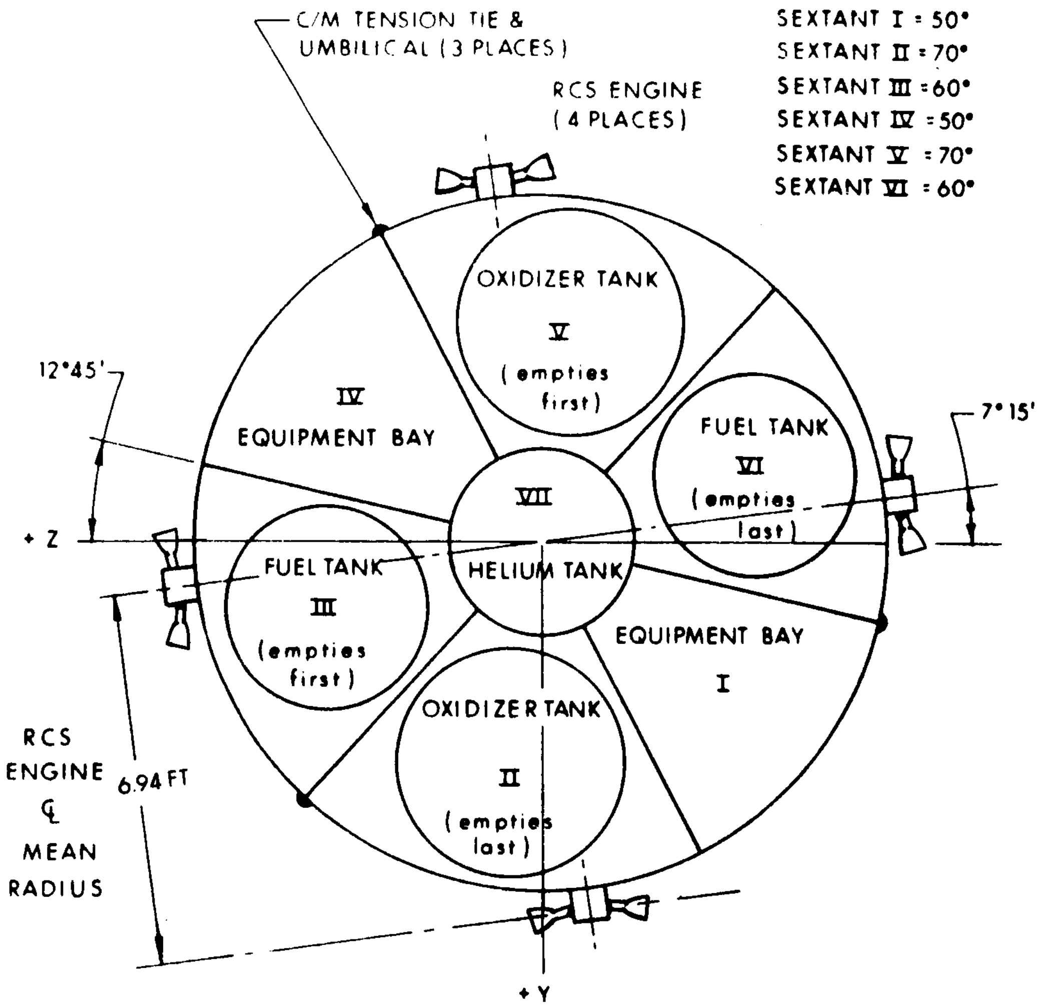


Fig. 6.11 CSM Reachtion Jet Positions

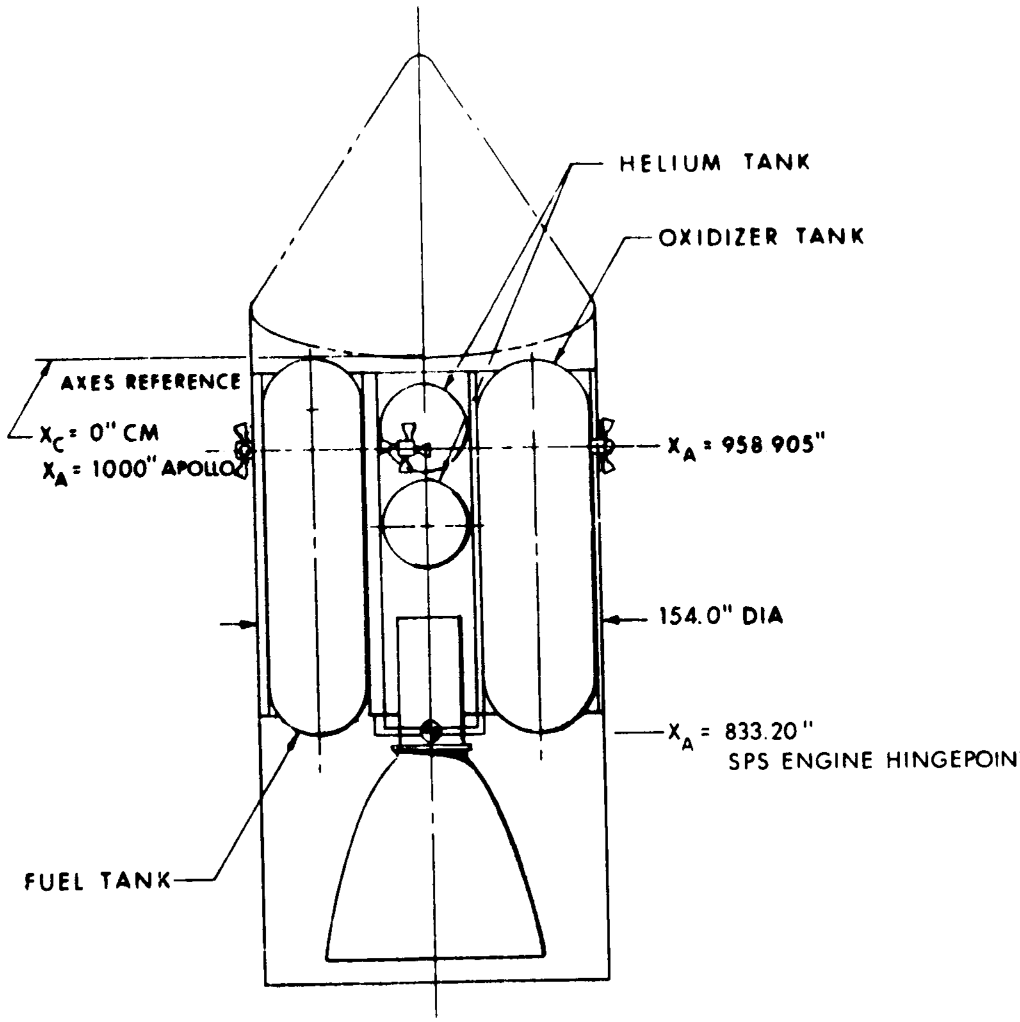
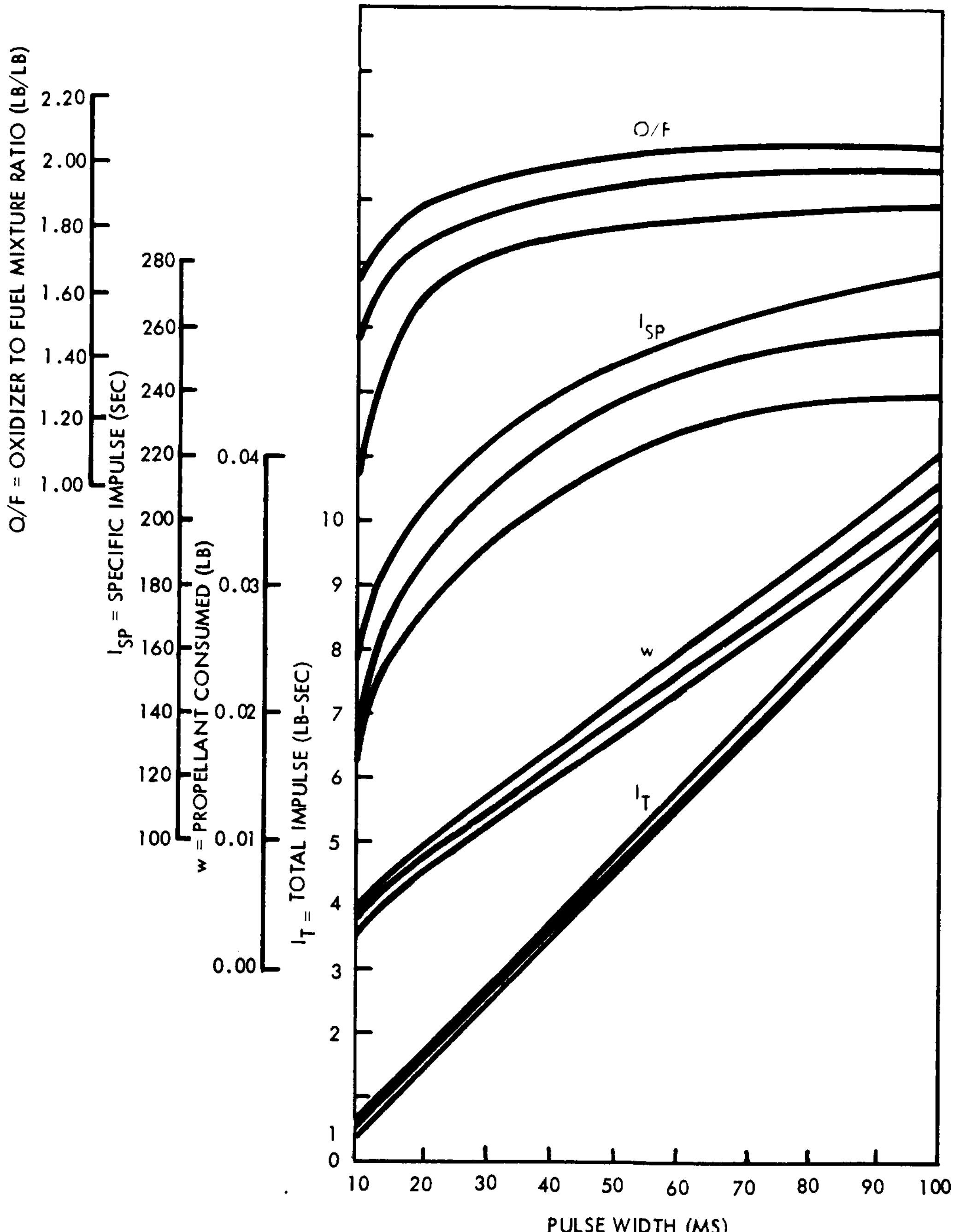


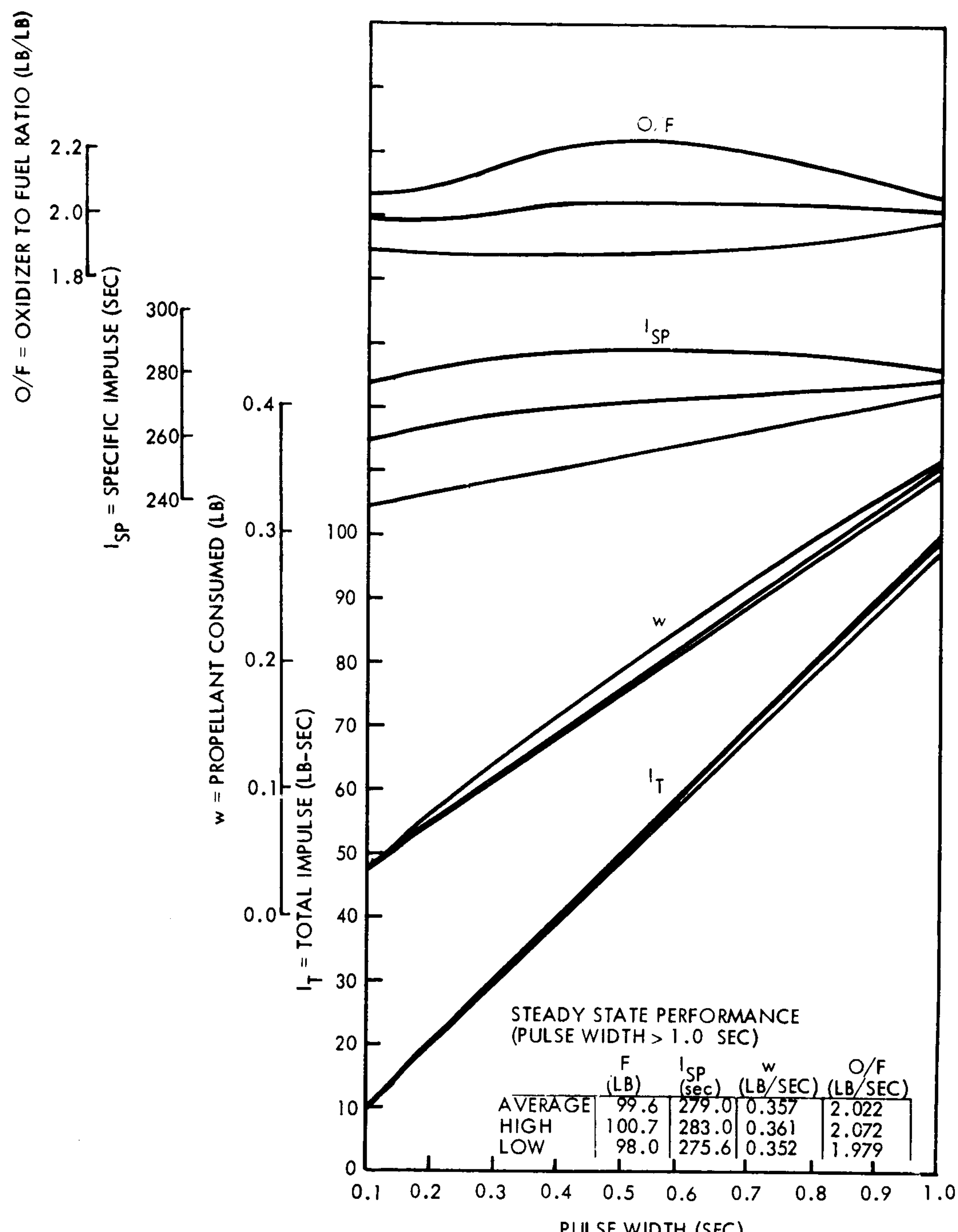
Fig. 6.12 CSM Reaction Jet Positions



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 Vaccuum Performance Data for Pulse Widths Less than 100 ms

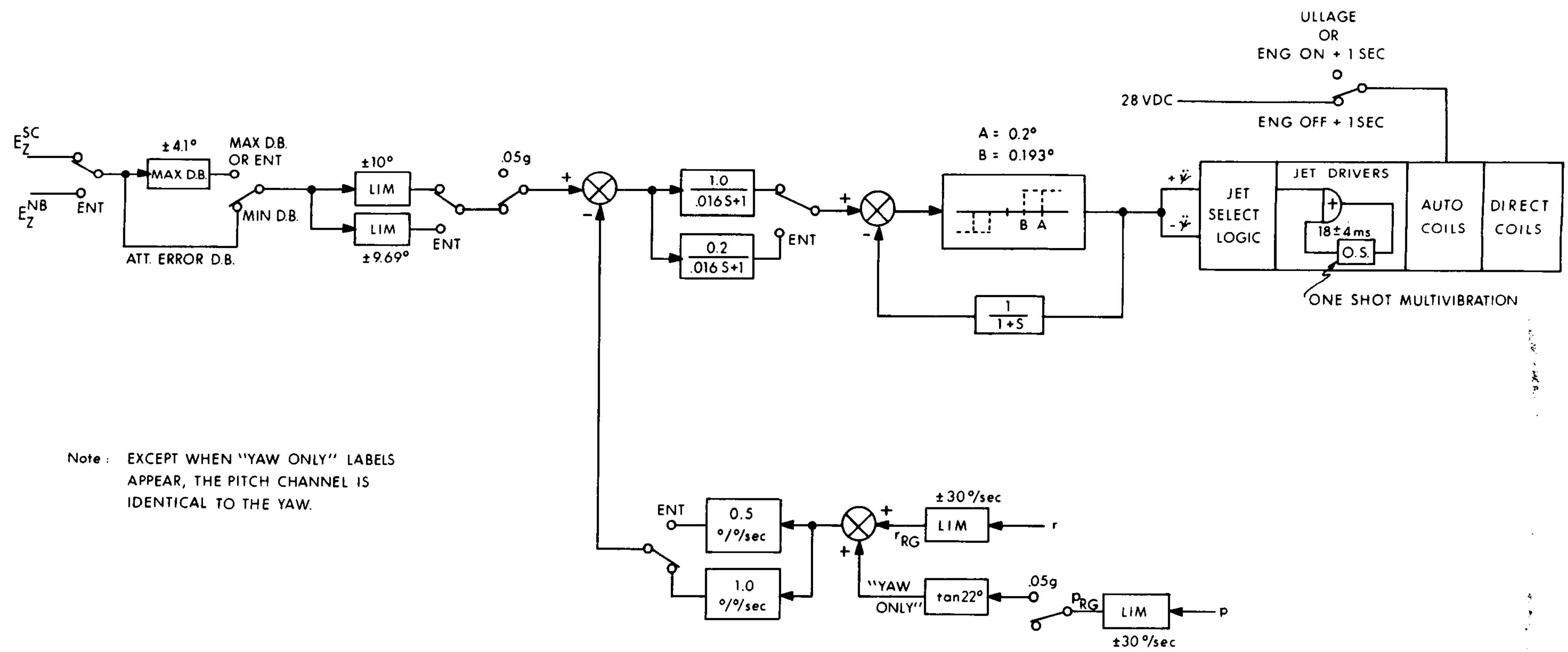


	F (LB)	I_{SP} (sec)	w (LB/SEC)	O/F (LB/SEC)
AVERAGE	99.6	279.0	0.357	2.022
HIGH	100.7	283.0	0.361	2.072
LOW	98.0	275.6	0.352	1.979

Note:

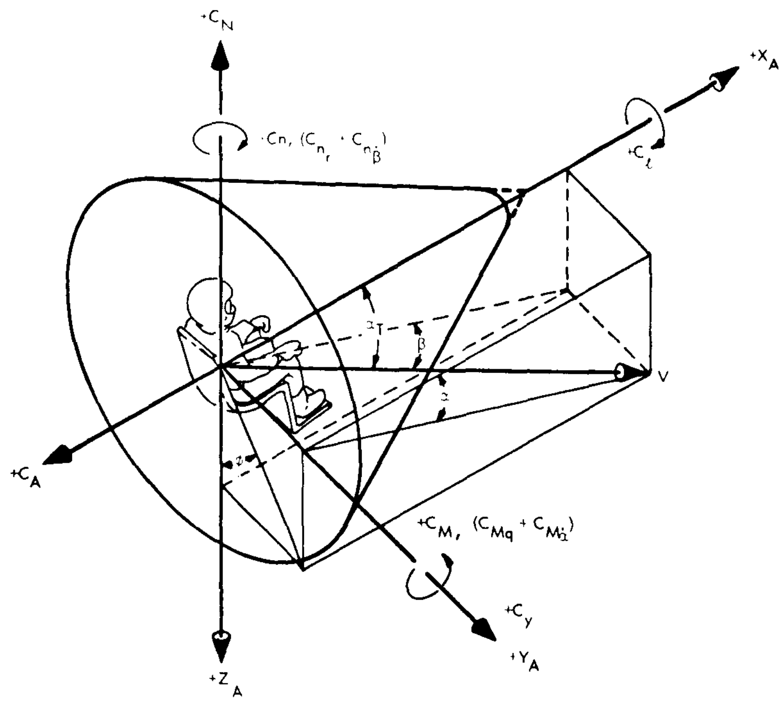
Data are high, low, and average values resulting from a large number of qualification tests. High and low values shall be used as 3σ values.

Fig. 6.14 SM/RCS Vaccuum 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

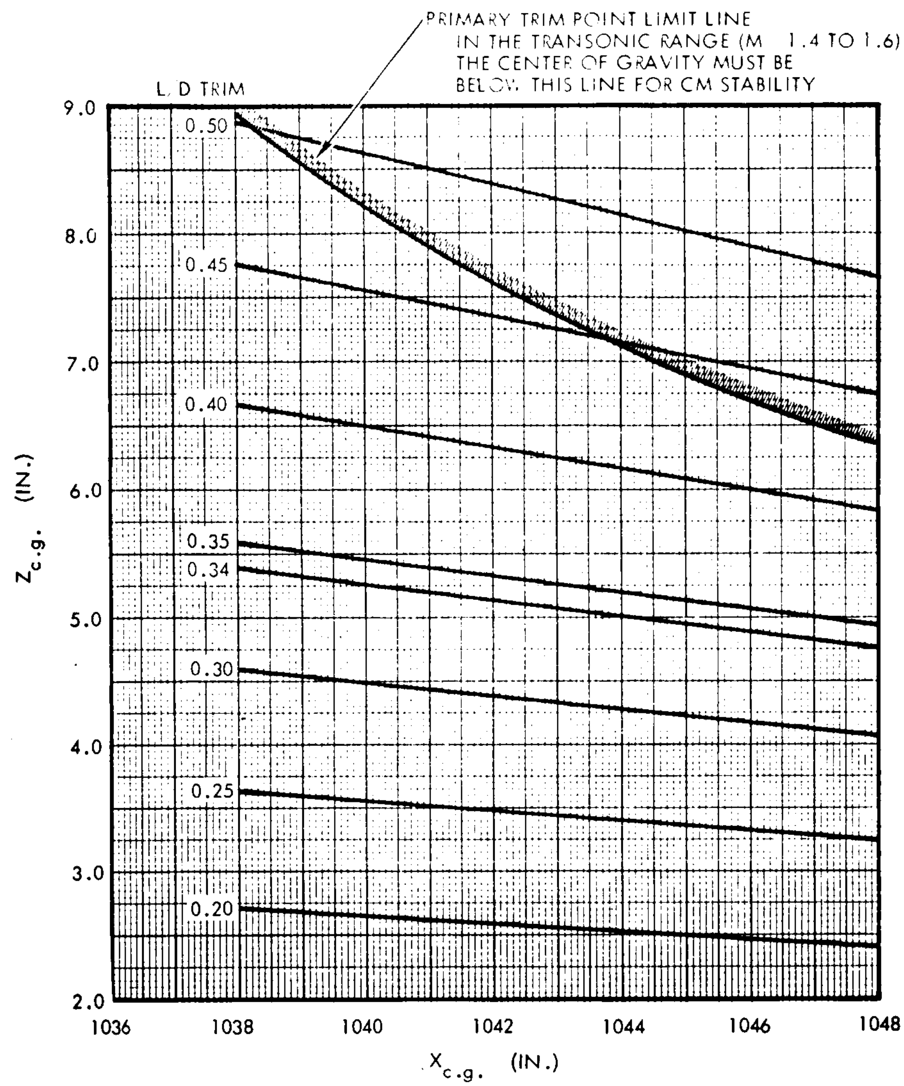


$\cos \alpha_T = \cos \alpha \cos \beta$

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

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
	PITCHING RATE

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



Note: Based on nominal Mach 6 to 25 data presented in Table 6-6.
Data are applicable for the CM without ablation.

Fig. 6.17 Command Module with Perturbances (CM-012) Trim Lift to Drag Ratio vs. c.g. Location

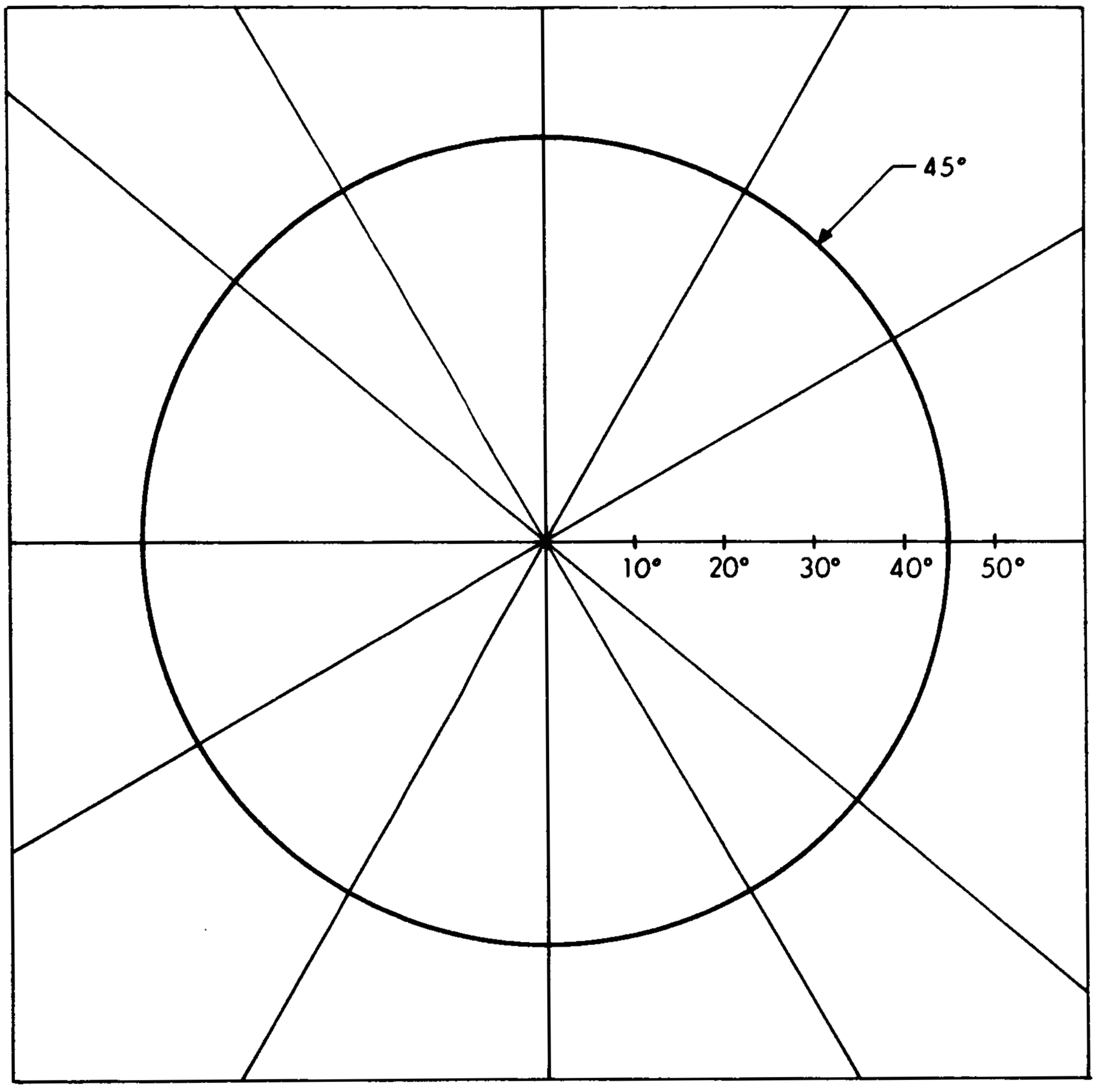


Fig. 6.18 AS-204 SXT Field of View Trunnion Angle Angle Limit vs. Shaft Angle.

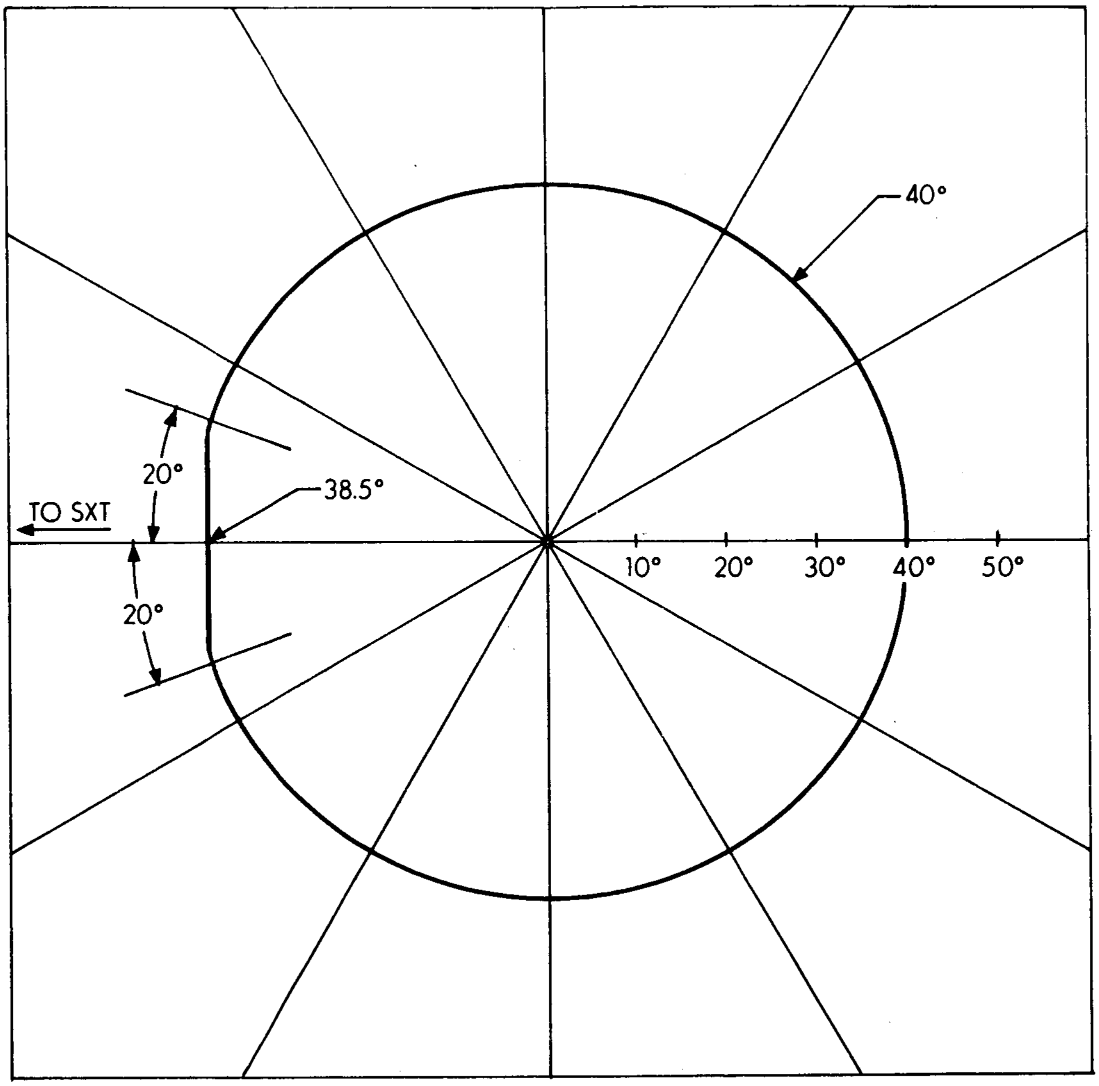
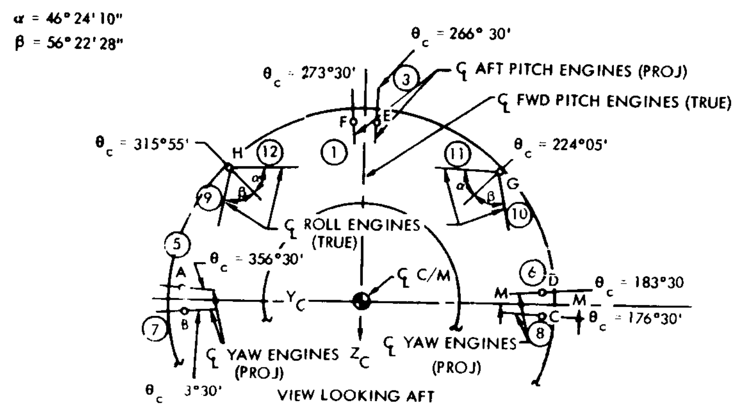
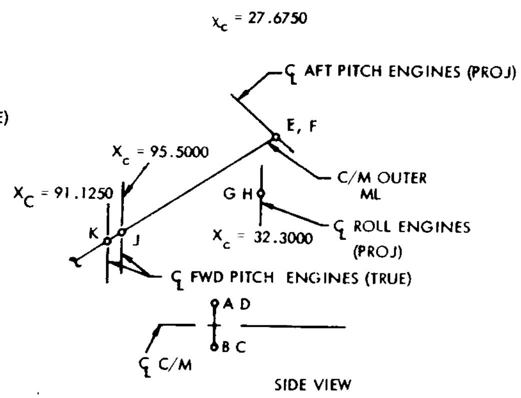
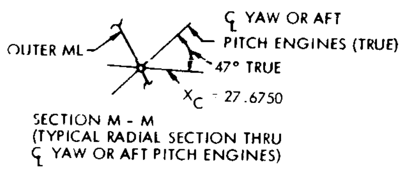


Fig. 6.19 AS-204 SCT Field of View Trunnion Angle vs. Shaft Angle



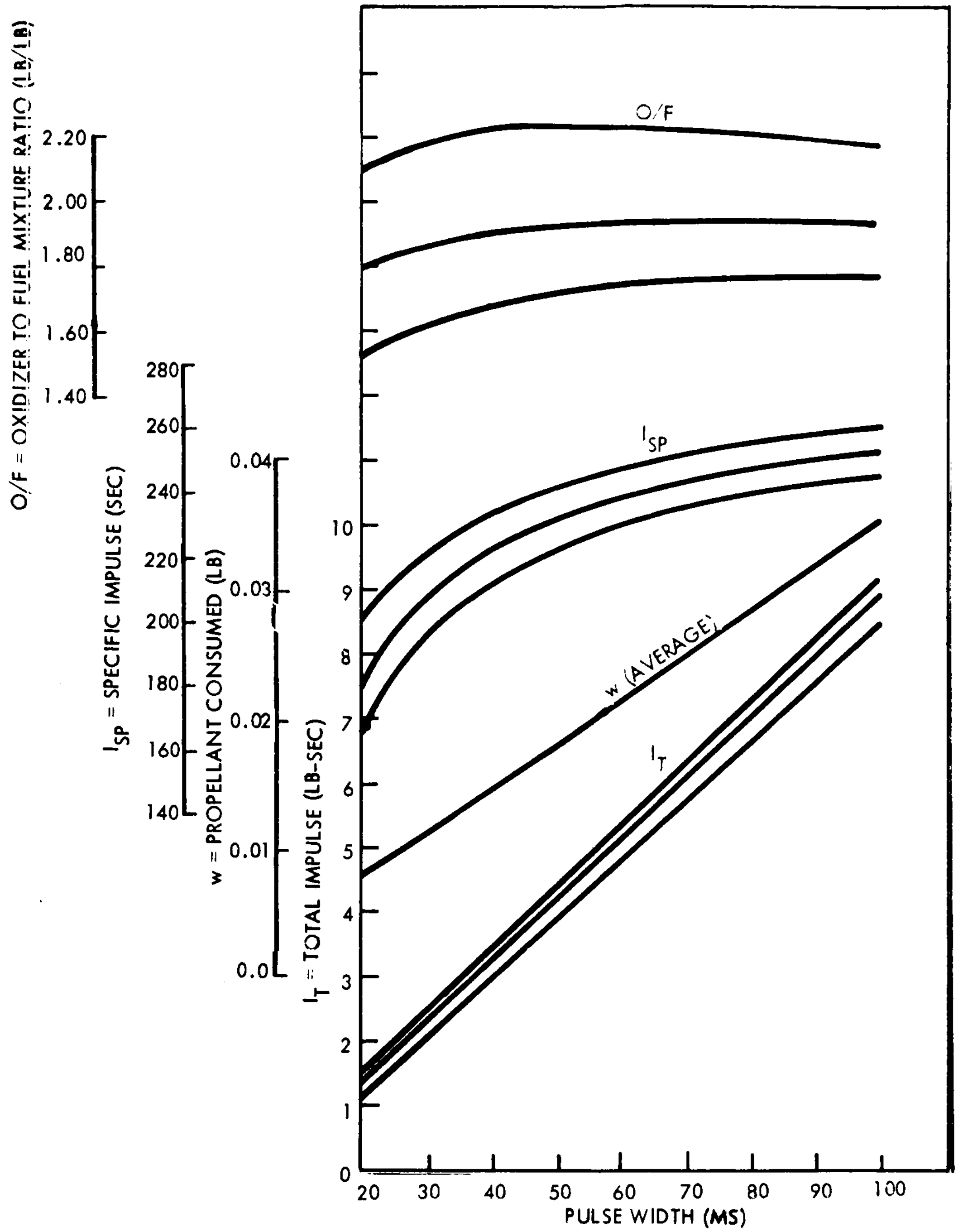


	X_C	Y_C	Z_C	R_C
A	'27.6750	72.2846	-4.4211	72.4197
B	27.6750	72.2846	4.4211	72.4197
C	27.6750	-72.2846	4.4211	72.4197
D	27.6750	-72.2846	-4.4211	72.4197
E	27.6750	-4.4211	-72.2846	72.4197
F	27.6750	4.4211	-72.2846	72.4197
(1)G	32.3000	-51.9826	-50.3454	72.3661
(1)H	32.3000	51.9826	-50.3454	72.3661
J	85.5000	0	-35.5483	35.5483
K	91.1250	0	-31.9616	31.9616



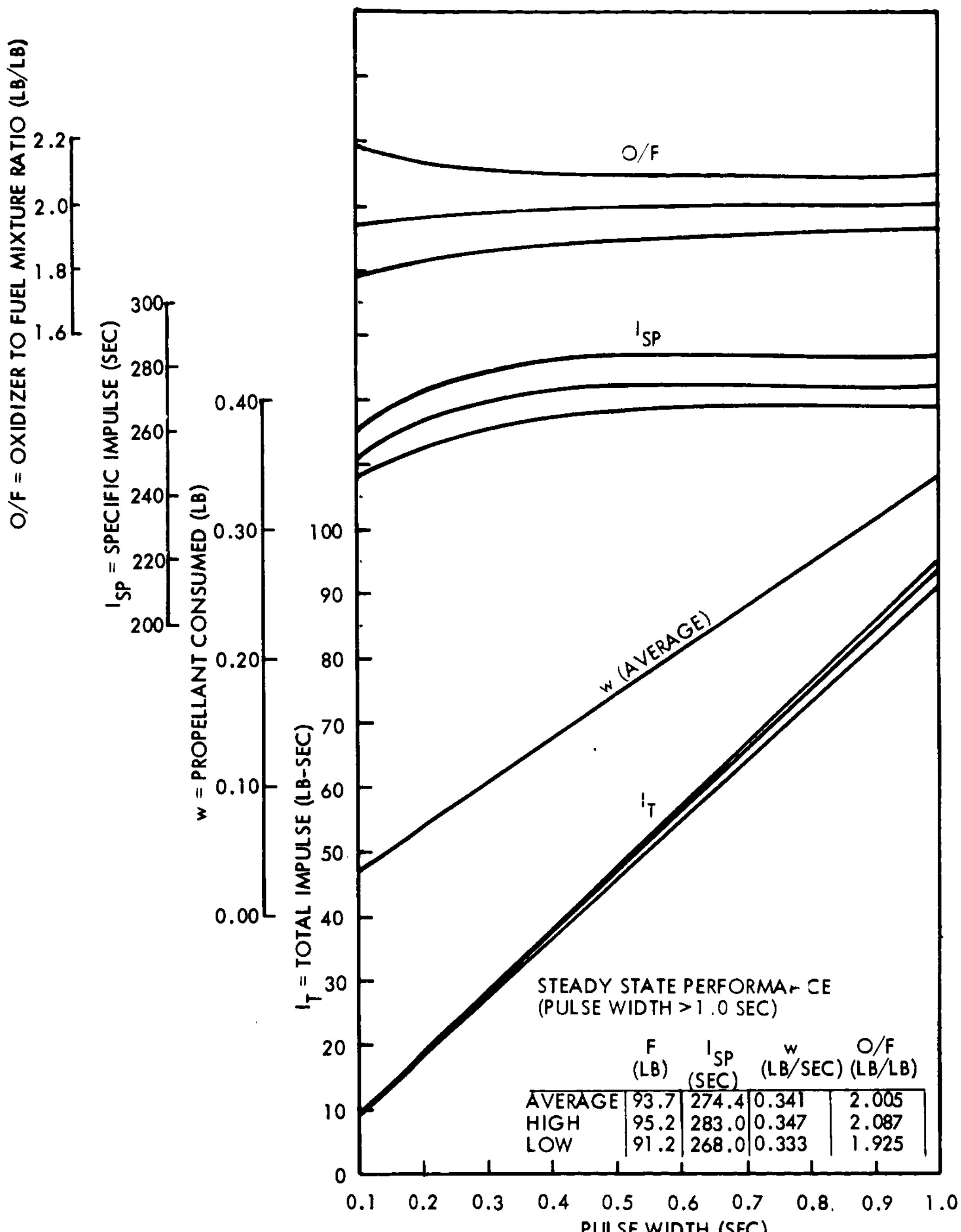
Notes:
(1) Not on outer ML - inters. pt. of ℄ roll engines.
(2) All linear measurements in inches.
(3) Jet numbering suggested by MIT.

Fig. 6.20 CM/RCS Thrust Chamber Positions



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

Fig. 6.21 CM/RCS Vacuum Performance Data for Pulse Width Less than 100 ms



	F (LB)	I_{SP} (SEC)	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. 6.22 SM/RCS Vaccuum Performance Data for Pulse Widths Greater than 100 ms

SECTION 7

G&N ERROR ANALYSIS

7.1 Introduction

The results of a revised G&N error study for the 204 mission are presented herein. Briefly, the effects of G&N IMU component uncertainties on trajectory uncertainties are given for the following three mission phases.

a) Boost to earth orbit and resulting orbit
b) First SPS burn and resulting orbit
c) SPS deorbit burn, coast, and reentry

Perfect navigation $\underline{R}$, $\underline{V}$ updates were assumed prior to the above two SPS burns. The effects of tracking uncertainties on navigational update uncertainties were not included, since tracking uncertainty data were not available.

This study did not consider the effects of Saturn guidance component uncertainties on the earth boost trajectory, nor were the effects of boost trajectory perturbations considered.

This error study is based on trajectory data for the 204 mission described in MSC Internal Note No 65-FM-134 (November 26, 1965). Data for the Design Reference Mission were not available when this section was prepared.

Block I IMU component uncertainties were assumed for the present study. These are given in Sec. 7.4. These differ markedly from the IMU uncertainties assumed for the preliminary error study presented in R-507 (January 1966). For the present study accelerometer bias uncertainties of 0.4 cm/sec^2 and scale factor uncertainties of 150 PPM were assumed, whereas the earlier report assumed uncertainties of 0.2 cm/sec^2 and 100 PPM. Also, for the present study, for gyro drifts, BD was assumed to be 3 meru, ADIA 8 meru/g and ADSRA 5 meru/g, whereas the earlier report assumed drift uncertainties of 5 meru, 15 meru/g and 10 meru/g, respectively.

7.2 Significant Results of Error Study

For boost to earth orbit IMU uncertainties resulted in the following uncertainties in computed (indicated) earth orbit:

Max. RSS altitude uncertainty	3.44 n. miles
RSS altitude uncertainty at nominal perigee	0.65 n. miles
Max. RSS track uncertainty	13.1 n. miles
RSS orbit inclination uncertainty	0.21 deg.
Increase in range uncertainty per orbit revolution	14.4 n. miles/rev.

For the 1st SPS burn we have the following uncertainties in resulting earth orbit after SPS cutoff.

Max. RSS altitude uncertainty	0.40 n. mile
RSS altitude uncertainty at nominal perigee	0.01 n. mile
Max. RSS track uncertainty	0.09 n. mile
RSS orbit inclination uncertainty	0.0015 deg.
Increase in range uncertainty per orbit revolution	1.8 n. mile/rev.

For the SPS and RCS (used only if SPS fails) deorbit burns, coast and reentry, we have the following.

	SPS	RCS
RSS flight path angle uncertainty at reentry start (400 K ft)	0.016	0.207 mr.
CEP at entry	0.69	3.32 n. mile

The following table summarizes the RSS cutoff uncertainties at SIVB cutoff and for the two SPS burns.

Event	RSS Position Uncert. - feet			RSS Velocity, Uncert - ft/sec		
	Alt.	Track	Range	Alt.	Track	Range
SIVB cutoff	3,938	23,590	1,509	16.09	91.15	5.00
1st SPS cutoff	17	17	17	0.71	0.67	0.71
Deorb. Bn. Cutoff	7	7	7	0.44	0.45	0.43

7.3 Error Table Description

At the end of this section detailed error tables are given summarizing the results of the error study.

Please note for all tables concerned with the earth boost trajectory that the polarities given are those for indication uncertainties. For the two SPS burns the polarities are those for uncertainties in actual position and velocity of the spacecraft relative to desired position and velocity. Please see Sec. 7.4 for further discussion of uncertainties and their polarities.

The following is a list of the detailed error tables which show contributions by the different IMU uncertainties.

Aside from the deorbit burn, only one SPS burn was subjected to an error study. This burn was the longest of the SPS burns, the thrust direction being almost normal to the orbital plane. Inspection of Table 7.4 shows how much the accelerometer bias uncertainties predominate. This shows that SPS cutoff uncertainties are, to a first approximation, independent of thrust direction relative to the orbital plane, that velocity uncertainties are proportional to the burn duration, and that position uncertainties vary as the square of the duration. By use of the detailed data given for the first SPS burn, the uncertainties associated with the other shorter burns may be readily estimated.

Data are presented for the SPS deorbit burn, coast, and reentry. In the event that SPS doesn't ignite, the RCS will be used. Hence, data are presented for the RCS deorbit burn, coast, and reentry.

Data are also given for the propagation of initial condition deviations at deorbit burn start to reentry start and end. These data are furnished to facilitate possible update decisions that may be made prior to deorbit burn.

7.4 IMU Errors and Uncertainties

An IMU component error (such as accelerometer bias) can be defined as the actual minus the desired output. This error is characterized by an average component and a time-varying component.

The G&N's AGC has programs to provide compensation for the measured average value of each of the following IMU component errors:

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

If compensation has been properly applied (and this includes the prelaunch phase), only the time varying part of the IMU error remains. An IMU component uncertainty can be defined to be the rms of the time-varying (or unpredictable) deviations of the actual component error from the average error.

All trajectory error data are given for IMU component uncertainties and not errors. However, to make the error tables more useful, the fiction of a positive IMU uncertainty is employed for all error tables. For example, for the SPS burns the tabulated data, give the uncertainties in actual spacecraft position and velocity relative to desired or nominal values.

A new definition of accelerometer scale factor error is used in this report for the first time. In previous reports this was assumed to be positive if the indicated output (in cm/sec^2) was greater than the correct value for a given acceleration input. However, the component and systems test groups have for a long time been using a definition of scale factor error that effectively is opposite in polarity to the above assumed definition. Since scale factor error is measured and computed by these groups, the new definition is used in this report, and all error tables should be so interpreted.

The Block I IMU error uncertainties (see also MEI No. 1015000 - Part I) used 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 (SFE)	150	150	150	PPM
Accelerometer non-linearity (NC)	10	10	10	$\mu g/g^2$
Gyro bias drift (BD)	3	3	3	meru
Gyro input axis accel. sens. drift	8	8	8	meru/g
Gyro spin axis accel. sens. drift	5	5	5	meru/g
Gyro acceleration squared sens. drift	0.3	0.3	0.3	$meru/g^2$
Accelerometer I.A. misalignments	0.1	0.1	0.1	mr
Gyro I.A. Misalignments	0.5	0.5	0.5	mr

It is important to note for the earth boost trajectory that some IMU uncertainties affect both the prelaunch alignment of the Stable Member and the in-flight computation of position and velocity. These include: accelerometer bias, gyro bias drift, and gyro I.A. and SRA acceleration sensitive drift. Since prelaunch and in-flight IMU uncertainties are assumed correlated, their effects are summed in the error computation. During prelaunch the Stable Member alignment uncertainty about azimuth is affected primarily by the effect of Z and Y gyro drift rate uncertainty on the gyrocompassing loop. Table 7.3 shows that the overall rss azimuth alignment uncertainty due to all gyro drift uncertainties is 3.92 milliradians.

Prior to each of the SPS burns the IMU Stable Member will be fine aligned to the desired orientation by means of star sightings and AGC computations. The one-sigma alignment uncertainty is assumed to be 0.2 mr about each SM axis.

7.5 Stable Member Alignment

For the earth boost trajectory 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 at launch instant and is assumed to be oriented at the nominal launch azimuth of 72^o from north.

Prior to most of the SPS burns the IMU Stable Member will be fine aligned to the desired orientation by means of star sightings and AGC computations. At SPS burn (except deorbit burns) ignition, X_{SM} is oriented along unit ($\underline{X}_{SC}$) at ignition, Y_{SM} along unit ($\underline{X}_{SC} \times \underline{R}$), and Z_{SM} along $\underline{Y}_{SM} \times \underline{Z}_{SM}$.

For the SPS deorbit burn the Stable Member will be oriented so that X_{SM} is along unit ($-\underline{X}_{SC}$) at ignition, Y_{SM} is along unit ($\underline{R} \times \underline{X}_{SC}$), and Z_{SM} is along $\underline{Y}_{SM} \times \underline{Z}_{SM}$.

In the error studies for the two SPS burns fine alignment of the Stable Member is assumed to be completed 15 minutes prior to SPS burn ignition. The error studies include the effects of initial S.M. misalignment due to gyro drift for 15 minutes prior to burn start. At 3 meru this about 0.20 mr. These are summed with the in-flights effects in the error tables.

7.6 Flight Path Angle and Altitude Rate Uncertainty Definitions

Figure 7.3 defines the three flight path angle uncertainties, $(U)\gamma_{AI}$, $(U)\gamma_{AIN}$ and $(U)_{AA}$. Data for $(U)\gamma_{AA}$ are given for reentry start since the flight path angle uncertainty with the spacecraft actually at 400,000-foot altitude is the desired parameter. For other events during the mission, data are given for $(U)\gamma_{AI}$.

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

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, $(U)\gamma_{AI}$ cannot be computed from the above data.

7.7 Error Computation Procedure

Position and velocity uncertainties given in the tables were computed as follows. Approximate error equations described the effect of each IMU component error on indicated error in 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 program incorporating the error equations requires nominal trajectory acceleration and position vectors as inputs at discrete time intervals. The nominal trajectory itself is generated in a separate program. At significant events, such as SIVB cutoff, detailed error printouts are made giving position and velocity uncertainties due to each IMU uncertainty relative to nominal local vertical axes.

7.8 Coordinate Axes and Polarity Definitions

In the error tables the position and velocity uncertainties are given relative to nominal local vertical axes. "Local vertical" axes are defined as follows (see also Fig. 2). The altitude vector is along unit ($\underline{R}$). The track vector is along unit ($\underline{V} \times \underline{R}$). The range vector is along $\underline{\text{Alt.}} \times \underline{\text{Track}}$. Positive directions are as shown in Fig. 7.2.

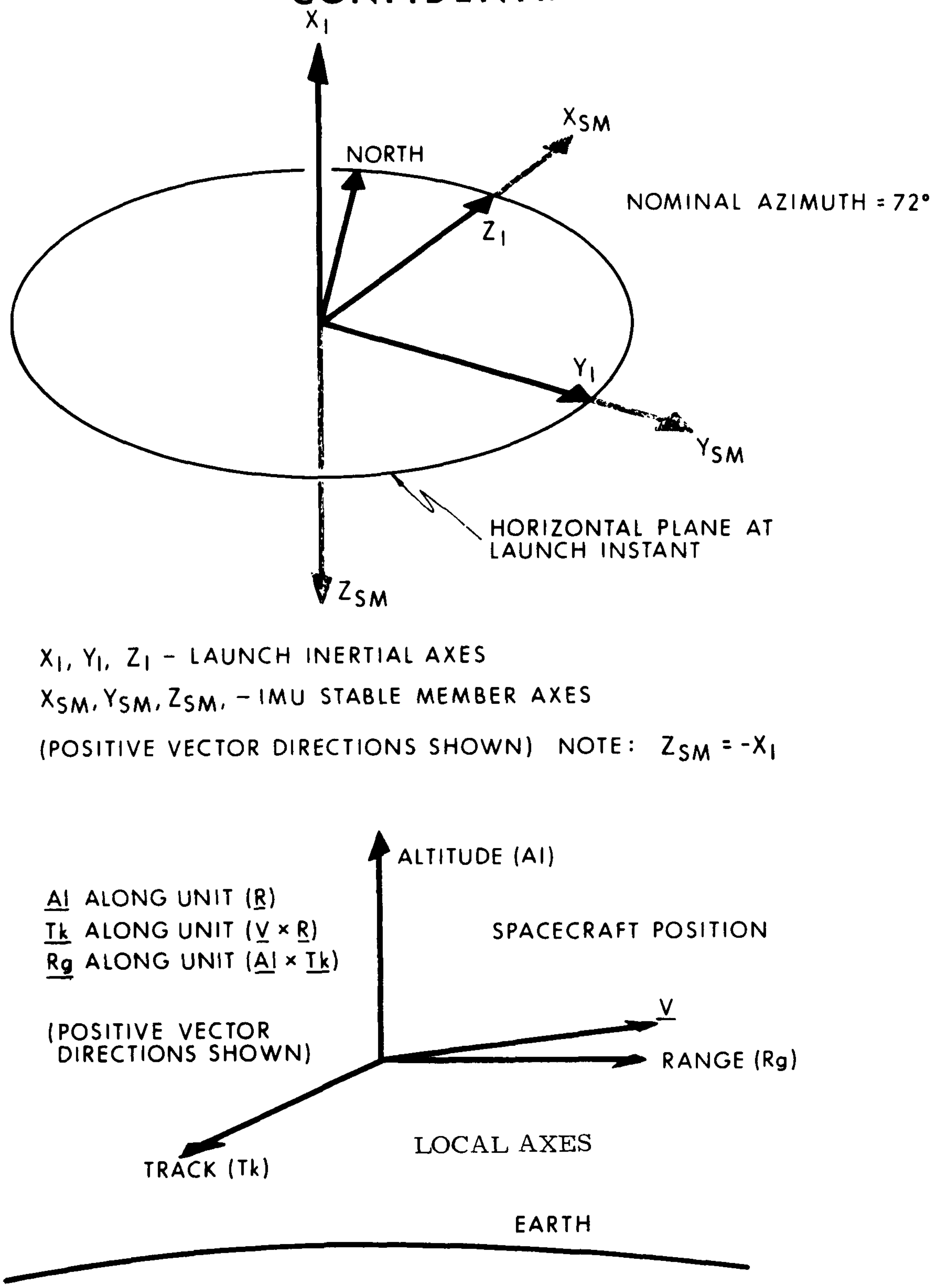
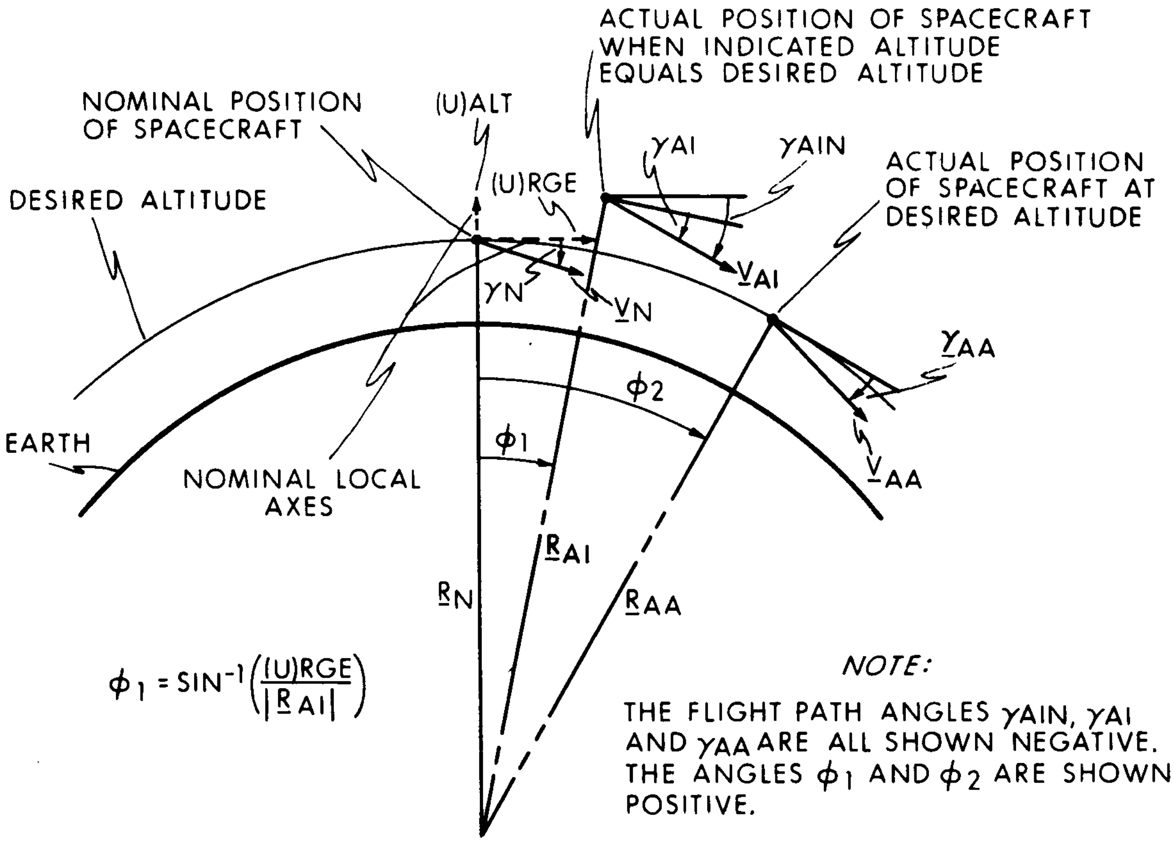


Fig. 7-2 Figures Defining Stable Member and Local Axes



Flight Path Angle and Velocity Uncertainty Equations

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

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

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

Altitude Rate Uncertainty Equations

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

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

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

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

Fig. 7-3 Flight Path Angles

TABLE 7.1 Earth Boost Cutoff Indication Uncertainties

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME FROM LCH.= 0 HR.10 MIN. 3.739 SEC (603.739 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							
XI	0.500 MR	35.6	3034.6	37.5	0.149	11.691	0.143
YI	0.025 MR	-121.3	-0.8	164.5	-0.588	0.000	0.402
ZI	0.025 MR	-1.4	-119.6	-1.4	-0.003	-0.215	-0.002
ACCEL.INPUT AXIS MLMS.							
MZTOX	0.141 MR	-915.3	5.6	291.1	-3.844	0.021	1.136
MZTOY	0.141 MR	0.0	0.0	0.0	0.000	0.000	0.000
MYABTZ	0.100 MR	-7.1	-506.9	-7.5	-0.029	-2.338	-0.028
ACCEL.BIAS							
ACBXINIT		1979.2	13.7	-2684.5	9.598	-0.008	-6.565
ACBXFLGT	0.400 CM/S.SQ	764.3	-35.1	2164.8	2.683	-0.111	6.841
ACBXCOMB		2743.5	-21.3	-519.7	12.282	-0.119	0.275
ACBYINIT		-23.6	-1952.1	-23.9	-0.055	-3.508	-0.041
ACBYFLGT	0.400 CM/S.SQ	27.1	2288.7	28.2	0.096	7.251	0.088
ACBYCOMB		3.4	336.6	4.2	0.040	3.743	0.047
ACBZINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBZFLGT	0.400 CM/S.SQ	-2479.9	15.1	785.8	-8.930	0.047	2.563
ACBZCOMB		-2479.9	15.1	785.8	-8.930	0.047	2.563
ACCEL.SCALE FACTOR							
SFEX	150 PPM	-302.7	13.9	-861.3	-1.257	0.053	-3.313
SFEZ	150 PPM	-816.6	4.8	255.6	-2.027	0.008	0.521
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	32.4	-1.4	92.1	0.139	-0.006	0.369
NCZZ	10 MG/GSQ	-74.0	0.4	23.0	-0.184	0.000	0.047
GYRO BIAS DRIFT							
BDXINIT		231.4	19580.4	243.4	0.968	75.821	0.933
BDXFLGT	3.0 MERU	-1.4	-121.7	-1.5	-0.003	-0.214	-0.002
BDXCOMB		230.0	19558.6	241.9	0.965	75.606	0.931
BDYINIT		75.2	6394.5	79.0	0.314	24.635	0.303
BDYFLGT	3.0 MERU	-275.6	0.1	217.2	-1.866	0.008	0.812
BDYCOMB		-200.4	6394.7	296.3	-1.551	24.644	1.116
BDZINIT		-15.6	-1327.7	-16.4	-0.065	-5.115	-0.062
BDZFLGT	3.0 MERU	-3.5	-309.6	-3.8	-0.022	-1.862	-0.023
BDZCOMB		-19.1	-1637.4	-20.2	-0.087	-6.977	-0.086
GYRO ACC.SENS.DRIFT							
ADIAXCOMB	8.0 MERU/G	-3.2	-476.7	-3.4	-0.006	-0.443	-0.005
ADSAYCOMB	5.0 MERU/G	-341.9	10557.0	558.8	-1.996	41.067	1.826
ADIAZCOMB	8.0 MERU/G	-31.7	-2587.5	-33.2	-0.125	-9.673	-0.118
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	-0.1	-11.6	-0.1	-0.000	-0.018	-0.000
ADSYY	0.2 MERU/GSQ	-26.3	-0.0	25.0	-0.134	0.000	0.073
ADIZZ	0.2 MERU/GSQ	-0.3	-30.2	-0.3	-0.001	-0.131	-0.001
RSS UNCERT.(FT AND FT/SEC)		3938.0	23594.3	1509.3	16.089	91.153	4.998
RSS UNCERT.(N.MI.AND FT/SEC)		0.648	3.883	0.248	16.089	91.153	4.998

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TABLE 7.2 Earth Boost S.M. Misalignment and Drift Uncertainties

9.30.66 18

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI= 0.00, AYPI=- 90.00, AZPI= 0 DEG)(T= 603.7 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	0.4742	-0.0031	-0.1584
YI	0.025 MR.	0.0000	0.0250	0.0000	0.0002	0.0249	0.0003
ZI	0.025 MR.	0.0000	0.0000	0.0250	0.0079	-0.0003	0.0237
INIT.S.M.MLMS.DUE TO IMU ERROR EFFECTS ON EARTH LAUNCH ERECTION AND ALIGNMENT							
ACBX	0.40 CM/S.SQ	0.0000	-0.4078	0.0000	-0.0044	-0.4078	-0.0051
ACBY	0.40 CM/S.SQ	0.0000	0.0000	0.4078	0.1292	-0.0062	0.3868
ACBZ	0.40 CM/S.SQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BDX	3.0 MERU	3.2426	0.0000	0.0000	3.0753	-0.0207	-1.0277
BDY	3.0 MERU	1.0535	0.0000	0.0000	0.9992	-0.0067	-0.3339
BDZ	3.0 MERU	-0.2187	0.0000	0.0000	-0.2074	0.0013	0.0693
ADIAX	8.0 MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADSRAY	5.0 MERU/G	1.7559	0.0000	0.0000	1.6654	-0.0112	-0.5565
ADIAZ	8.0 MERU/G	-0.5833	0.0000	0.0000	-0.5532	0.0037	0.1848
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)		3.9174	0.4086	0.4086	3.7176	0.4094	1.3006
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START							
BDX	3.0 MERU	0.0000	0.0000	0.1320	0.0418	-0.0020	0.1252
BDY	3.0 MERU	0.0000	0.1320	0.0000	0.0014	0.1320	0.0016
BDZ	3.0 MERU	-0.1320	0.0000	0.0000	-0.1252	0.0008	0.0418
ADIAX	8.0 MERU/G	0.0000	0.0000	0.4538	0.1437	-0.0069	0.4304
ADSRAY	5.0 MERU/G	0.0000	0.1171	0.0000	0.0012	0.1171	0.0014
ADIAZ	8.0 MERU/G	0.1874	0.0000	0.0000	0.1778	-0.0011	-0.0594
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
ADSRAZ	5.0 MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIXX	0.2 MERU/GSQ	0.0000	0.0000	0.0189	0.0060	-0.0002	0.0179
ADSYY	0.2 MERU/GSQ	0.0000	0.0062	0.0000	0.0000	0.0062	0.0000
ADIZZ	0.2 MERU/GSQ	-0.0062	0.0000	0.0000	-0.0059	0.0000	0.0019
RSS DRIFT ANGLE		0.2294	0.1766	0.4730	0.2642	0.1768	0.4544
OVERALL RSS MLM		3.9241	0.4452	0.6251	3.7270	0.4459	1.3778

TABLE 7.3 Orbit Indication Uncertainties after SIVB Cutoff at Max. RSS Altitude Uncertainty Point

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME FROM LCH.= 0 HR.38 MIN.45.871 SEC (2325.871 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							
XI	0.500 MR	585.3	7321.4	-908.2	1.275	-8.491	-0.509
YI	0.025 MR	399.1	0.7	776.9	-0.152	0.000	-0.210
ZI	0.025 MR	-13.7	-104.9	23.1	-0.031	0.223	0.012
ACCEL.INPUT AXIS MLMS.							
MZTOX	0.141 MR	-2056.6	13.5	10382.1	-9.604	-0.015	2.524
MZTOY	0.141 MR	0.0	0.0	0.0	0.000	0.000	0.000
MYABTZ	0.100 MR	-117.0	-1464.2	181.6	-0.255	1.698	0.101
ACCEL.BIAS							
ACBXINIT		-6512.5	-12.6	-12675.8	2.493	-0.010	3.432
ACBXFLGT	0.400 CM/S.SQ	22589.7	-66.8	-29008.4	44.739	0.087	-19.088
ACBXCOMB		16077.2	-79.5	-41684.2	47.233	0.076	-15.655
ACBYINIT		-223.7	-1712.4	377.9	-0.506	3.649	0.196
ACBYFLGT	0.400 CM/S.SQ	381.5	4352.1	-603.3	0.838	-5.696	-0.332
ACBYCOMB		157.7	2539.7	-225.3	0.331	-2.047	-0.136
ACBZINIT		0.0	0.0	0.0	0.000	0.000	0.000
ACBZFLGT	0.400 CM/S.SQ	-5738.2	28.7	25617.7	-24.651	-0.037	6.509
ACBZCOMB		-5738.2	28.7	25617.7	-24.651	-0.037	6.509
ACCEL.SCALE FACTOR							
SFEX	150 PPM	-10576.1	33.7	13288.9	-20.820	-0.039	8.891
SFEZ	150 PPM	-2006.4	4.4	6907.6	-7.302	-0.009	1.952
ACCEL.SQ.IND.UNCERT.							
NCXX	10 MG/GSQ	1172.4	-3.7	-1467.9	2.306	0.004	-0.984
NCZZ	10 MG/GSQ	-182.7	0.3	628.4	-0.664	-0.000	0.177
GYRO BIAS DRIFT							
BDXINIT		3796.1	47481.8	-5890.0	8.271	-55.070	-3.305
BDXFLGT	3.0 MERU	-13.6	-103.8	22.9	-0.030	0.225	0.011
BDXCOMB		3782.4	47377.9	-5867.0	8.240	-54.844	-3.293
BDYINIT		1233.4	15427.7	-1913.7	2.687	-17.893	-1.074
BDYFLGT	3.0 MERU	125.8	6.4	3585.9	-2.346	-0.004	0.352
BDYCOMB		1359.2	15434.2	1672.1	0.340	-17.897	-0.721
BDZINIT		-256.1	-3403.3	397.3	-0.558	3.715	0.223
BDZFLGT	3.0 MERU	-85.3	-1247.3	127.5	-0.182	1.169	0.074
BDZCOMB		-341.4	-4450.6	524.8	-0.740	4.884	0.297
GYRO ACC.SENS.DRIFT							
ADIAXCOMB	8.0 MERU/G	-29.3	-202.6	49.4	-0.066	0.493	0.025
ADSAYCOMB	5.0 MERU/G	2657.8	25719.2	1325.5	1.917	-29.825	-1.717
ADIAZCOMB	8.0 MERU/G	-492.4	-5975.4	769.3	-1.076	7.212	0.429
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	-1.2	-8.7	2.0	-0.002	0.020	0.001
ADSYY	0.2 MERU/GSQ	38.1	0.3	235.8	-0.128	-0.000	-0.001
ADIZZ	0.2 MERU/GSQ	-6.3	-83.8	9.7	-0.013	0.091	0.005
RSS UNCERT.(FT AND FT/SEC)		20905.5	57119.7	52629.9	59.150	66.129	19.815
RSS UNCERT.(N.MI.AND FT/SEC)		3.440	9.400	8.661	59.150	66.129	19.815

TABLE 7.4 First SPS Burn Cutoff Uncertainty

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 0 MIN, 50.000 SEC (50.000 SECS)

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 S.M. AXES							
XSM	0.200 MR.	0.0	0.0	0.0	0.000	0.000	0.000
YSM	0.200 MR.	3.1	0.0	-0.1	0.180	0.000	-0.010
ZSM	0.200 MR.	-0.1	0.0	-3.1	-0.010	0.005	-0.180
ACCEL.INPUT AXIS MLMS.							
MXAY	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MXAZ	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100 MR.	-0.0	0.0	-1.5	-0.005	0.002	-0.090
MZAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000 MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS							
ACBX	0.400 CM/S.SQ	-0.0	-16.3	-0.5	-0.000	-0.655	-0.020
ACBY	0.400 CM/S.SQ	0.9	-0.5	16.3	0.039	-0.020	0.654
ACBZ	0.400 CM/S.SQ	16.3	0.0	-0.9	0.655	0.000	-0.039
ACCEL.SCALE FACTOR							
SFEX	150.0 PPM	0.0	2.3	0.0	0.000	0.135	0.004
SFEY	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFEZ	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.							
NCXX	10 MG/GSQ	0.0	-0.1	-0.0	-0.000	-0.007	-0.000
NCYY	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)							
BDXINIT		0.0	0.0	0.0	0.000	0.000	0.000
BDXFLGT	3.0 MERU	0.0	0.0	0.0	0.000	0.000	0.000
BDXCOMB		0.0	0.0	0.0	0.000	0.000	0.000
BDYINIT		3.0	0.0	-0.1	0.177	0.000	-0.010
BDYFLGT	3.0 MERU	0.0	0.0	-0.0	0.006	0.000	-0.000
BDYCOMB		3.1	0.0	-0.1	0.183	0.000	-0.011
BDZINIT		-0.1	0.0	-3.0	-0.010	0.005	-0.177
BDZFLGT	3.0 MERU	-0.0	0.0	-0.0	-0.000	0.000	-0.006
BDZCOMB		-0.1	0.0	-3.1	-0.011	0.005	-0.183
GYRO ACC.SENS.DRIFT							
ADIAX	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADSRAY	5.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADIAZ	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)		17.0	16.5	17.0	0.705	0.669	0.710
RSS UNCERT.(N.MI.AND FT/SEC)		0.002	0.002	0.002	0.705	0.669	0.710

TABLE 7.5 First SPS Burn Cutoff S.M. Misalignment and Drift Uncertainties

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI=- 90.24, AYPI=- 90.00, AZPI= 0 DEG)(T= 50.0 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							
XSM	0.200 MR.	0.0000	0.1999	- 0.0008	0.0000	0.1999	0.0061
YSM	0.200 MR.	0.0000	- 0.0008	- 0.1999	- 0.0119	0.0061	- 0.1995
ZSM	0.200 MR.	- 0.2000	0.0000	0.0000	- 0.1996	- 0.0002	0.0119
INIT. S.M. MLMS. AT TRAJ. START DUE TO GYRO BIAS DRIFT FOR 15 MINS. PRIOR TO START OF TRAJECTORY							
BDX	3.0 MERU	0.0000	0.1968	- 0.0008	0.0000	0.1967	0.0060
BDY	3.0 MERU	0.0000	- 0.0008	- 0.1968	- 0.0117	0.0060	- 0.1964
BDZ	3.0 MERU	- 0.1968	0.0000	0.0000	- 0.1965	- 0.0002	0.0117
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)		0.2806	0.2806	0.2806	0.2806	0.2806	0.2806
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START							
BDX	3.0 MERU	0.0000	0.0109	- 0.0000	0.0000	0.0109	0.0003
BDY	3.0 MERU	0.0000	- 0.0000	- 0.0109	- 0.0006	0.0003	- 0.0109
BDZ	3.0 MERU	- 0.0109	0.0000	0.0000	- 0.0109	- 0.0000	0.0006
ADIAX	8.0 MERU/G	0.0000	0.0163	- 0.0000	0.0000	0.0163	0.0005
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
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
ADSRAZ	5.0 MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIXX	0.2 MERU/GSQ	0.0000	0.0003	- 0.0000	0.0000	0.0003	0.0000
ADSYY	0.2 MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIZZ	0.2 MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RSS DRIFT ANGLE		0.0109	0.0196	0.0109	0.0109	0.0196	0.0109
OVERALL RSS MLM		0.2808	0.2813	0.2808	0.2808	0.2813	0.2808

TABLE 7.6 Orbit Uncertainties after First SPS Cutoff at Max. RSS Altitude Uncertainty Point

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 44 MIN, 38.510 SEC (2678.510 SECS)

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 S.M. AXES							
XSM	0.200 MR.	0.0	0.0	0.0	0.000	0.000	0.000
YSM	0.200 MR.	-23.3	0.0	-548.7	0.465	0.000	0.020
ZSM	0.200 MR.	-611.7	0.0	1451.5	-1.704	-0.005	0.538
ACCEL.INPUT AXIS MLMS.							
MXAY	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MXAZ	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100 MR.	-305.9	0.0	725.8	-0.852	-0.002	0.269
MZAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000 MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS							
ACBX	0.400 CM/S.SQ	-69.1	2.7	168.0	-0.196	0.647	0.060
ACBY	0.400 CM/S.SQ	2224.3	0.0	-5293.3	6.208	0.020	-1.958
ACBZ	0.400 CM/S.SQ	-69.8	0.0	-2041.8	1.749	0.000	0.061
ACCEL.SCALE FACTOR							
SFEX	150.0 PPM	14.2	0.4	-34.5	0.040	-0.133	-0.012
SFEY	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFEZ	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.							
NCXX	10 MG/GSQ	-0.7	-0.0	1.8	-0.002	0.007	0.000
NCYY	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)							
BDXINIT		0.0	0.0	0.0	0.000	0.000	0.000
BDXFLGT	3.0 MERU	0.0	0.0	0.0	0.000	0.000	0.000
BDXCOMB		0.0	0.0	0.0	0.000	0.000	0.000
BDYINIT		-23.0	0.0	-540.2	0.458	0.000	0.019
BDYFLGT	3.0 MERU	-0.8	0.0	-19.3	0.016	0.000	0.000
BDYCOMB		-23.9	-0.0	-559.5	0.475	0.000	0.020
BDZINIT		-602.2	0.0	1428.9	-1.677	-0.005	0.530
BDZFLGT	3.0 MERU	-21.7	0.0	51.6	-0.060	-0.000	0.019
BDZCOMB		-624.0	0.0	1480.5	-1.738	-0.005	0.549
GYRO ACC.SENS.DRIFT							
ADIAX	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADSRAY	5.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADIAZ	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)		2411.6	2.7	6136.6	6.981	0.661	2.123
RSS UNCERT.(N.MI.AND FT/SEC)		0.396	0.000	1.009	6.981	0.661	2.123

TABLE 7.7

Position and Velocity Uncertainties for SPS and RCS Deorbit Burn, Coast and Reentry

Event	RSS Position Uncertainty feet			RSS Velocity Uncertainty feet/sec			RSS Flight Path Angle Uncertainty
	Alt.	Track	Range	Alt.	Track	Range	mr.
SPS Deorbit Burn, Coast and Reentry							
Burn Ignit.	0	0	0	0	0	0	0
Burn Cutoff	7	7	7	0.44	0.45	0.43	-----
Reentry Start	222	201	201	0.57	0.38	0.39	0.016
Reentry End	4,707	3,741	3,397	17.42	12.99	10.71	-----
RCS Deorbit Burn, Coast and Reentry							
Burn Ignit.	0	0	0	0	0	0	0
Burn Cutoff	364	357	357	3.15	3.03	3.03	-----
Reentry Start	4,726	2,498	4,039	8.50	0.66	3.46	0.207
Reentry End	22,336	10,826	23,323	49.08	18.94	15.72	-----

TABLE 7.8 SPS Position and Velocity Uncertainties at Reentry Start

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 8 MIN. 5.258 SEC (485.258 SECS)

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 S.M. AXES								
XSM	0.200	MR.	0.0	0.0	0.0	0.000	0.000	0.000
YSM	0.200	MR.	-25.6	0.0	45.3	-0.069	0.000	0.090
ZSM	0.200	MR.	0.0	-48.5	0.0	0.000	-0.094	0.000
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100	MR.	0.0	-24.2	0.0	0.000	-0.047	0.000
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.400	CM/S.SQ	-191.4	0.0	-73.8	-0.480	0.000	-0.125
ACBY	0.400	CM/S.SQ	0.0	-186.8	0.0	0.000	-0.355	0.000
ACBZ	0.400	CM/S.SQ	99.4	0.0	-174.8	0.268	0.000	-0.344
ACCEL.SCALE FACTOR								
SFEX	150.0	PPM	-37.1	0.0	-14.4	-0.094	0.000	-0.025
SFEY	150.0	PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFEZ	150.0	PPM	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	-2.4	0.0	-0.9	-0.006	0.000	-0.001
NCYY	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10	MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			0.0	0.0	0.0	0.000	0.000	0.000
BDXFLGT	3.0	MERU	0.0	0.0	0.0	0.000	0.000	0.000
BDXCOMB			0.0	0.0	0.0	0.000	0.000	0.000
BDYINIT			-25.2	0.0	44.6	-0.068	0.000	0.089
BDYFLGT	3.0	MERU	-0.6	0.0	1.1	-0.001	0.000	0.002
BDYCOMB			-25.8	0.0	45.7	-0.070	0.000	0.091
BDZINIT			0.0	-47.7	0.0	0.000	-0.092	0.000
BDZFLGT	3.0	MERU	0.0	-1.2	0.0	0.000	-0.002	0.000
BDZCOMB			0.0	-49.0	0.0	0.000	-0.095	0.000
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADSRAY	5.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADIAZ	8.0	MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2	MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)			221.9	200.7	200.9	0.567	0.382	0.389
RSS UNCERT.(N.MI.AND FT/SEC)			0.036	0.033	0.033	0.567	0.382	0.389

TABLE 7.9 SPS Flight Path Angle Uncertainties at Reentry Start

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

MLMXSM-	0.0000	MXAY-	0.0000	MYAZ-	0.0000	ACBX -	0.0190	SFEX-	0.0037	NCXX-	0.0002	MR.
MLMYSM-	0.0026	MXAZ	0.0000	MZAX	0.0000	ACBY -	0.0000	SFEY-	0.0000	NCYY-	0.0000	MR.
MLMZSM-	0.0000	MYAX-	0.0000	MZAY	0.0000	ACBZ	0.0101	SFEZ-	0.0000	NCZZ-	0.0000	MR.
BDXI -	0.0000	BDYI-	0.0026	BDZI-	0.0000	ADIAX-	0.0000	ADIXX-	0.0000			
BDXF -	0.0000	BDYF-	0.0000	BDZF-	0.0000	ADSAY-	0.0000	ADSYY-	0.0000	RSS	0.0222	MR.
BDXT -	0.0000	BDYT-	0.0026	BDZT-	0.0000	ADIAZ-	0.0000	ADIZZ-	0.0000	RSS	0.0012	DEG.

UNCERTAINTIES IN FLIGHT PATH ANGLE RELATIVE TO ACTUAL AXES AT NOMINAL TIME (EG_1) (U)γ_{AI}

MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX -	0.0225	SFEX-	0.0044	NCXX-	0.0002	MR.
MLMYSM-	0.0005	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000	MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ	0.0019	SFEZ	0.0000	NCZZ	0.0000	MR.
BDXI	0.0000	BDYI-	0.0005	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000			
BDXF	0.0000	BDYF-	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.0230	MR.
BDXT	0.0000	BDYT-	0.0005	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0013	DEG.

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

MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX -	0.0153	SFEX-	0.0030	NCXX-	0.0001	MR.
MLMYSM	0.0004	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000	MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ -	0.0017	SFEZ	0.0000	NCZZ	0.0000	MR.
BDXI	0.0000	BDYI	0.0004	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000			
BDXF	0.0000	BDYF	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.0157	MR.
BDXT	0.0000	BDYT	0.0004	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0009	DEG.

TABLE 7.10 SPS S.M. Misalignment and Drift Uncertainties at Reentry Start

INITIAL S.M.MLMS. AND DRIFT ANGLES SUMMARY (INIT.PLATF.ANGLES-AXI= 0.00, AYPI=- 58.00, AZPI= 0 DEG)(T= 485.2 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								
XSM	0.200	MR.	0.1059	0.0000	0.1696	0.1808	0.0000	0.0853
YSM	0.200	MR.	0.0000	0.2000	0.0000	0.0000	0.2000	0.0000
ZSM	0.200	MR.	- 0.1696	0.0000	0.1059	- 0.0853	0.0000	0.1808
INIT. S.M. MLMS. AT TRAJ. START DUE TO GYRO BIAS DRIFT FOR 15 MINS. PRIOR TO START OF TRAJECTORY								
BDX	3.0	MERU	0.1043	0.0000	0.1669	0.1780	0.0000	0.0840
BDY	3.0	MERU	0.0000	0.1968	0.0000	0.0000	0.1968	0.0000
BDZ	3.0	MERU	- 0.1669	0.0000	0.1043	- 0.0840	0.0000	0.1780
RSS INIT.S.M.MLMS. (AT TRAJECTORY START)			0.2806	0.2806	0.2806	0.2806	0.2806	0.2806
DRIFT ANGLES DUE TO GYRO DRIFT AFTER TRAJECTORY START								
BDX	3.0	MERU	0.0562	0.0000	0.0900	0.0959	0.0000	0.0453
BDY	3.0	MERU	0.0000	0.1061	0.0000	0.0000	0.1061	0.0000
BDZ	3.0	MERU	- 0.0900	0.0000	0.0562	- 0.0453	0.0000	0.0959
ADIAX	8.0	MERU/G	- 0.0053	0.0000	- 0.0085	- 0.0090	0.0000	- 0.0042
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
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
ADSRAZ	5.0	MERU/G	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIXX	0.2	MERU/GSQ	0.0001	0.0000	0.0002	0.0002	0.0000	0.0001
ADSYY	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ADIZZ	0.2	MERU/GSQ	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
RSS DRIFT ANGLE			0.1062	0.1061	0.1064	0.1065	0.1061	0.1062
OVERALL RSS MLM			0.3001	0.3000	0.3001	0.3001	0.3000	0.3000

TABLE 7.11 SPS Reentry End Uncertainties

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 18 MIN, 39.160 SEC (1119.160 SECS)

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 S.M. AXES							
XSM	0.200 MR.	20.4	981.4	594.1	0.085	3.997	2.333
YSM	0.200 MR.	-1264.5	52.9	-59.6	-5.535	0.761	-1.245
ZSM	0.200 MR.	-55.8	140.9	80.3	-0.157	1.526	0.841
ACCEL.INPUT AXIS MLMS.							
MXAY	0.100 MR.	-609.1	-7.6	32.2	-2.679	-0.030	0.130
MXAZ	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100 MR.	8.8	503.2	274.2	0.038	2.031	1.106
MYAZ	0.100 MR.	1.1	70.8	38.6	0.012	0.764	0.416
MZAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000 MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS							
ACBX	0.400 CM/S.SQ	-3736.0	-112.4	313.0	-11.615	-0.217	0.684
ACBY	0.400 CM/S.SQ	-47.1	-2578.4	-1404.8	-0.144	-6.760	-3.683
ACBZ	0.400 CM/S.SQ	10.7	1443.1	-2647.8	-0.107	3.726	-6.832
ACCEL.SCALE FACTOR							
SFEX	150.0 PPM	55.8	-9.6	15.6	1.162	0.002	-0.040
SFEY	150.0 PPM	0.6	34.3	18.7	0.001	0.089	0.048
SFEZ	150.0 PPM	-47.0	411.4	-753.5	-0.206	1.660	-3.041
ACCEL.SQ.IND.UNC.							
NCXX	10 MG/GSQ	-19.2	-0.9	2.2	-0.103	-0.002	0.006
NCYY	10 MG/GSQ	-0.1	-8.3	-4.5	-0.000	-0.037	-0.020
NCZZ	10 MG/GSQ	-7.0	61.6	-112.8	-0.031	0.257	-0.470
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)							
BDXINIT		20.1	966.1	584.8	0.084	3.935	2.297
BDXFLGT	3.0 MERU	18.8	924.2	552.4	0.081	3.917	2.266
BDXCOMB		39.0	1890.4	1137.3	0.165	7.852	4.563
BDYINIT		-1244.8	52.1	-58.7	-5.449	0.750	-1.226
BDYFLGT	3.0 MERU	-1154.1	105.6	-159.4	-5.297	0.856	-1.424
BDYCOMB		-2398.9	157.8	-218.2	-10.746	1.606	-2.650
BDZINIT		-54.9	138.7	79.0	-0.155	1.502	0.828
BDZFLGT	3.0 MERU	-43.9	219.8	122.7	-0.124	1.680	0.923
BDZCOMB		-98.9	358.6	201.7	-0.280	3.182	1.752
GYRO ACC.SENS.DRIFT							
ADIAX	8.0 MERU/G	1.3	78.5	42.7	0.009	0.548	0.305
ADSRAY	5.0 MERU/G	-661.8	92.5	-149.8	-3.668	0.872	-1.496
ADIAZ	8.0 MERU/G	4.7	-295.1	-161.4	0.013	-2.683	-1.466
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	0.0	3.2	1.8	0.000	0.017	0.010
ADSYY	0.2 MERU/GSQ	-56.2	8.5	-14.0	-0.325	0.081	-0.140
ADIZZ	0.2 MERU/GSQ	0.0	16.9	9.2	-0.000	0.156	0.085
RSS UNCERT.(FT AND FT/SEC)		4706.6	3740.7	3396.7	17.420	12.991	10.712
RSS UNCERT.(N.MI.AND FT/SEC)		0.774	0.615	0.559	17.420	12.991	10.712

TABLE 7.12 RCS Position and Velocity Uncertainties at Reentry Start

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 20 MIN, 44.533 SEC (1244.533 SECS)

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 S.M. AXES							
XSM	0.200 MR.	0.0	0.0	0.0	0.000	0.000	0.000
YSM	0.200 MR.	-17.5	0.0	35.0	-0.041	0.000	0.024
ZSM	0.200 MR.	0.0	-22.2	0.0	0.000	-0.005	0.000
ACCEL.INPUT AXIS MLMS.							
MXAY	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MXAZ	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAZ	0.100 MR.	0.0	-11.1	0.0	0.000	-0.002	0.000
MZAX	0.100 MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000 MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS							
ACBX	0.400 CM/S.SQ	-4294.4	0.0	895.8	-7.125	0.000	2.103
ACBY	0.400 CM/S.SQ	0.0	-2497.9	0.0	0.000	-0.662	0.000
ACBZ	0.400 CM/S.SQ	1971.9	0.0	-3937.5	4.627	0.000	-2.745
ACCEL.SCALE FACTOR							
SFEX	150.0 PPM	-28.7	0.0	6.0	-0.047	0.000	0.014
SFEY	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
SFEZ	150.0 PPM	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.SQ.IND.UNC.							
NCXX	10 MG/GSQ	-0.0	0.0	0.0	-0.000	0.000	0.000
NCYY	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
NCZZ	10 MG/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)							
BDXINIT		0.0	0.0	0.0	0.000	0.000	0.000
BDXFLGT	3.0 MERU	0.0	0.0	0.0	0.000	0.000	0.000
BDXCOMB		0.0	0.0	0.0	0.000	0.000	0.000
BDYINIT		-17.2	0.0	34.4	-0.040	0.000	0.024
BDYFLGT	3.0 MERU	-2.0	0.0	4.2	-0.004	0.000	0.003
BDYCOMB		-19.3	0.0	38.7	-0.045	0.000	0.027
BDZINIT		0.0	-21.9	0.0	0.000	-0.005	0.000
BDZFLGT	3.0 MERU	0.0	-2.8	0.0	0.000	-0.000	0.000
BDZCOMB		0.0	-24.7	0.0	0.000	-0.006	0.000
GYRO ACC.SENS.DRIFT							
ADIAX	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADSRAY	5.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
ADIAZ	8.0 MERU/G	0.0	0.0	0.0	0.000	0.000	0.000
GYRO ACC.SQ.SENS.DRIFT							
ADIXX	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADSYY	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
ADIZZ	0.2 MERU/GSQ	0.0	0.0	0.0	0.000	0.000	0.000
RSS UNCERT.(FT AND FT/SEC)		4725.7	2498.1	4038.5	8.497	0.662	3.458
RSS UNCERT.(N.MI.AND FT/SEC)		0.777	0.411	0.664	8.497	0.662	3.458

TABLE 7.13 RCS Flight Path Angle Uncertainties at Reentry Start

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

MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX -	0.2761	SFEX-	0.0018	NCXX-	0.0000 MR.
MLMYSM-	0.0015	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ	0.1786	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI-	0.0015	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF-	0.0001	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.3289 MR.
BDXT	0.0000	BDYT-	0.0017	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0188 DEG.

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

MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX -	0.2340	SFEX-	0.0015	NCXX-	0.0000 MR.
MLMYSM	0.0000	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ -	0.0063	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI	0.0000	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.2341 MR.
BDXT	0.0000	BDYT	0.0000	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0134 DEG.

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

MLMXSM	0.0000	MXAY	0.0000	MYAZ	0.0000	ACBX -	0.2058	SFEX-	0.0013	NCXX	0.0000 MR.
MLMYSM	0.0002	MXAZ	0.0000	MZAX	0.0000	ACBY	0.0000	SFEY	0.0000	NCYY	0.0000 MR.
MLMZSM	0.0000	MYAX	0.0000	MZAY	0.0000	ACBZ -	0.0190	SFEZ	0.0000	NCZZ	0.0000 MR.
BDXI	0.0000	BDYI	0.0001	BDZI	0.0000	ADIAX	0.0000	ADIXX	0.0000		
BDXF	0.0000	BDYF	0.0000	BDZF	0.0000	ADSAY	0.0000	ADSYY	0.0000	RSS	0.2066 MR.
BDXT	0.0000	BDYT	0.0002	BDZT	0.0000	ADIAZ	0.0000	ADIZZ	0.0000	RSS	0.0118 DEG.

TABLE 7.14 RCS Reentry End Uncertainties

POSITION AND VELOCITY UNCERTAINTIES ALONG LOCAL VERTICAL AXES AT TIME = 0 HR, 39 MIN, 59.840 SEC (2399.840 SECS)

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 S.M. AXES								
XSM	0.200	MR.	23.0	460.9	138.1	0.082	1.194	0.364
YSM	0.200	MR.	-1260.0	18.9	-56.0	-5.596	0.379	-1.324
ZSM	0.200	MR.	-10.5	1006.4	296.5	-0.034	4.622	1.334
ACCEL.INPUT AXIS MLMS.								
MXAY	0.100	MR.	-138.2	-54.9	200.7	-0.426	-0.142	0.520
MXAZ	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MYAX	0.100	MR.	0.6	231.9	63.8	0.001	0.601	0.165
MYAZ	0.100	MR.	1.4	505.6	139.2	0.006	2.319	0.638
MZAX	0.100	MR.	0.0	0.0	0.0	0.000	0.000	0.000
MZAY	0.000	MR.	0.0	0.0	0.0	0.000	0.000	0.000
ACCEL.BIAS								
ACBX	0.400	CM/S.SQ	-20736.2	-5891.6	20961.0	-42.988	-3.559	13.399
ACBY	0.400	CM/S.SQ	-8.4	-7883.1	-2179.1	0.002	-7.377	-2.040
ACBZ	0.400	CM/S.SQ	-7094.0	2744.3	-9899.2	-13.497	0.744	-2.590
ACCEL.SCALE FACTOR								
SFEX	150.0	PPM	344.3	154.8	-564.9	1.930	0.809	-2.956
SFEY	150.0	PPM	0.0	15.5	4.2	0.000	0.048	0.013
SFEZ	150.0	PPM	-339.9	49.4	-175.9	-1.048	0.128	-0.455
ACCEL.SQ.IND.UNC.								
NCXX	10	MG/GSQ	-71.4	-30.2	110.4	-0.353	-0.139	0.510
NCYY	10	MG/GSQ	-0.0	-10.6	-2.9	-0.000	-0.049	-0.013
NCZZ	10	MG/GSQ	-21.8	3.3	-11.9	-0.107	0.015	-0.054
GYRO BIAS DRIFT (15 MIN.DRIFT TIME BEFORE TRAJ.START)								
BDXINIT			22.6	453.7	135.9	0.080	1.175	0.358
BDXFLGT	3.0	MERU	48.2	1030.0	307.0	0.182	2.634	0.806
BDXCOMB			70.9	1483.8	443.0	0.263	3.810	1.164
BDYINIT			-1240.4	18.6	-55.1	-5.509	0.373	-1.303
BDYFLGT	3.0	MERU	-2839.3	88.9	-293.9	-12.898	0.937	-3.279
BDYCOMB			-4079.7	107.6	-349.1	-18.408	1.311	-4.583
BDZINIT			-10.3	990.7	291.9	-0.033	4.550	1.313
BDZFLGT	3.0	MERU	-21.4	2539.0	684.9	-0.075	10.895	3.141
BDZCOMB			-31.7	3329.8	976.9	-0.109	15.446	4.454
GYRO ACC.SENS.DRIFT								
ADIAX	8.0	MERU/G	15.1	427.1	71.5	0.119	0.246	0.139
ADSRAY	5.0	MERU/G	-317.9	19.5	-67.7	-1.730	0.177	-0.627
ADIAZ	8.0	MERU/G	0.8	-459.9	-130.4	0.017	-2.594	-0.758
GYRO ACC.SQ.SENS.DRIFT								
ADIXX	0.2	MERU/GSQ	1.7	12.7	4.5	0.011	0.011	0.010
ADSYY	0.2	MERU/GSQ	-11.9	0.8	-3.0	-0.068	0.008	-0.029
ADIZZ	0.2	MERU/GSQ	-0.0	11.0	3.2	-0.000	0.066	0.019
RSS UNCERT.(FT AND FT/SEC)			22336.4	10825.9	23322.6	49.077	18.939	15.722
RSS UNCERT.(N.MI.AND FT/SEC)			3.676	1.781	3.838	49.077	18.939	15.722

TABLE 7.15

Propagation of Initial Condition Deviations for
SPS Deorbit Burn, Coast and Reentry

Initial Condition Deviations at SPS Burn Ignition	Resulting Position Deviation Relative to Nominal Axes - feet			Resulting Velocity Deviation Relative to Nominal Axes - ft/sec			Resulting Flight Path Angle Deviation
	Alt.	Track	Range	Alt.	Track	Range	mr.
At Reentry Start (400 K ft)							
1000 ft. in Altitude	1,167	0	-643	1.43	0	-0.19	-0.017
1000 ft. in Track	0	838	0	0	-0.65	0	0
1000 ft. in Range	541	0	679	0.19	0	-0.65	0.019
1 ft/sec in Altitude	461	0	-270	1.17	0	-0.54	0.016
1 ft/sec in Track	0	459	0	0	0.84	0	0
1 ft/sec in Range	270	0	381	0.64	0	0.68	0.034
At Reentry End							
1000 ft. in Altitude	2,371	5	-1,564	-----	-----	-----	-----
1000 ft. in Track	2	212	0	-----	-----	-----	-----
1000 ft. in Range	1,099	2	-293	-----	-----	-----	-----
1 ft/sec in Altitude	1,194	2	-1,049	-----	-----	-----	-----
1 ft/sec in Track	2	810	0	-----	-----	-----	-----
1 ft/sec in Range	1,292	2	220	-----	-----	-----	-----

TABLE 7.16

Summary of Trajectory Data Used for Error Studies

Trajectory	Burn Duration secs	Initial Altitude n. miles	ΔV ft/sec	Initial Pitch Angle deg.	Initial Yaw Angle deg.	Resulting Orbit Perigee - Apogee Altitudes n. miles
Earth Boost	604	88	27,080	-----	-----	88 - 133
1st SPS Burn	35*	87	903	0	-90.2	87 - 131

*This does not include ullage burn.

Trajectory	Burn Duration secs	Initial Altitude n. miles	ΔV ft/sec	Initial Pitch Angle deg.	Initial Yaw Angle deg.	Coast Time to Entry Start secs	Flight Path Angle at Entry Start deg.	Reentry Range (inertial) n. miles
SPS Deorbit Burn	17*	105	553	-148	0	441	-1.57	1,746
RCS Deorbit	234	103	137	180	0	1,010	-0.64	3,800

NOTE: Initial pitch and yaw angles are relative to local vertical axes at burn start.

Reentry range refers to range covered from reentry start (at 400,000 ft) to reentry end.

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