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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

RE-ORDER NO. 64-825
Vol I, III

MARINER MARS ORBITER STUDY

FINAL PRESENTATION

27 AUGUST 1964

BY LMSC FOR JPL

JPL CONTRACT NO. 950877

under NAS 7-100

1 of 25

64-825
Vol. I

GROUND RULES OF STUDY

- ORBITER AND CAPSULE MISSIONS TO MARS IN 1969 AND 1971
- ORBITER MISSION TO VENUS IN 1970
- 20% FLOX ATLAS-CENTAUR LAUNCH SYSTEM WITH FLOX VARIATIONS TO 0% & 30%
- SURVEYOR LAUNCH SHROUD
- 30-DAY LAUNCH WINDOW
- PLANETARY ENVIRONMENT DATA AS PROVIDED BY NASA/JPL
- 210-FT DISH DSIF NETWORK AVAILABLE
- PROBABILITY OF BIOLOGICAL CONTAMINATION OF MARS $<10^{-4}$; VENUS $<10^{-2}$
- UTILIZE MARINER C COMPONENTS AND SUBSYSTEMS WHERE FEASIBLE

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MISSION PRIME OBJECTIVES

- DEMONSTRATE ORBIT CAPABILITY & TRACKING -- USE ORBITER IN DETERMINING PLANET SHAPE AND SIZE
- DEMONSTRATE CAPABILITY OF SUCCESSFUL LANDING AND SURVIVAL FOR SEVERAL HOURS
- DEMONSTRATE SUCCESSFUL PERFORMANCE OF A TELEVISION MISSION ON THE ORBITER

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Vol I

MISSION CONCEPTS

MARS 1969	ORBITER ORBITER PLUS ATMOSPHERIC CAPSULE RELEASED BEFORE ORBIT ORBITER PLUS BIO-CAPSULE RELEASED BEFORE ORBIT
MARS 1971	ORBITER ORBITER PLUS ATMOSPHERIC/BIO CAPSULE RELEASED BEFORE ORBIT ORBITER PLUS ATMOSPHERIC/BIO CAPSULE RELEASED FROM ORBIT
VENUS 1970	ORBITER

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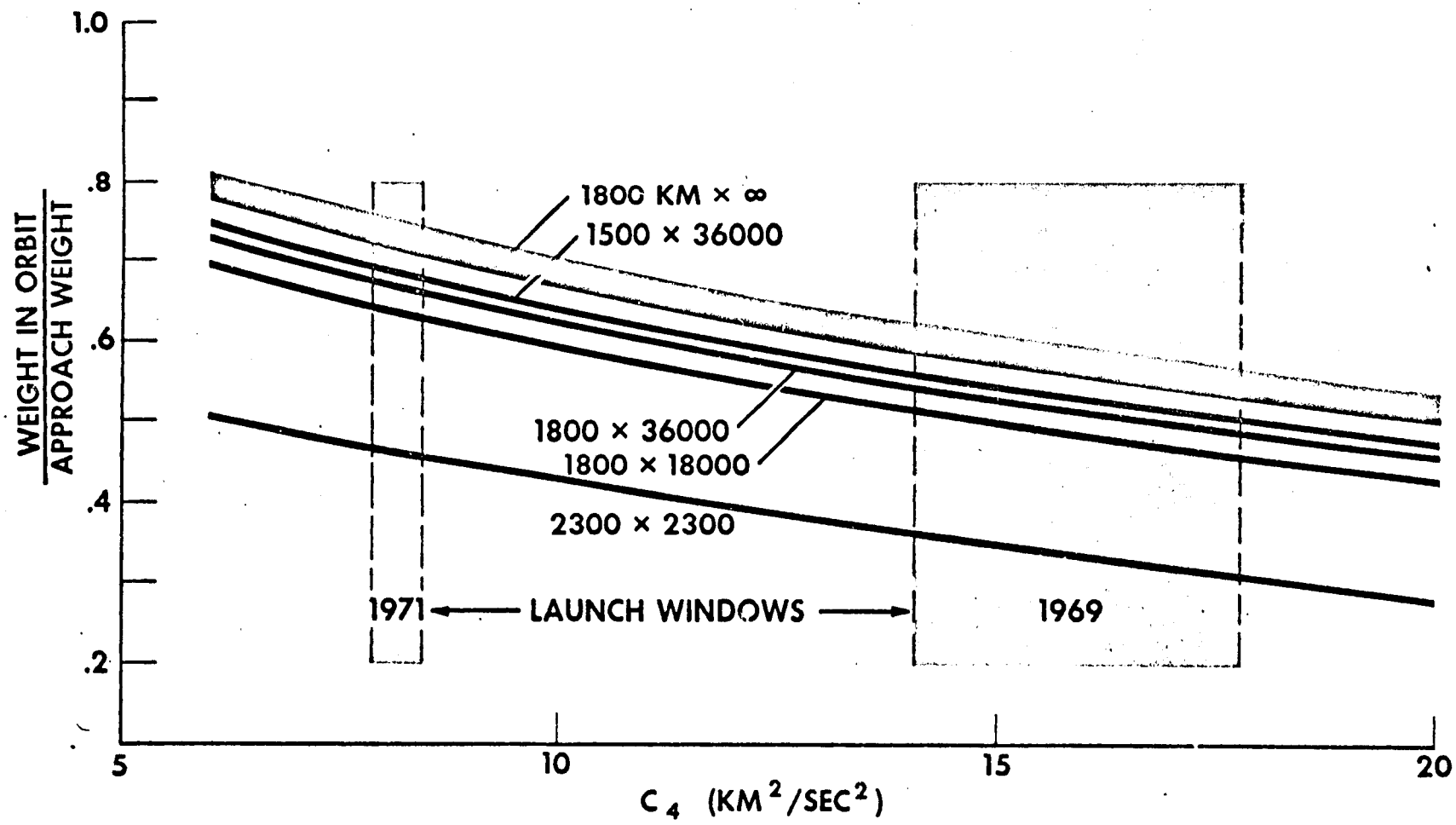
Vol. I

WEIGHT IN ORBIT CAPABILITY

I_{SP} 302 Seconds



4

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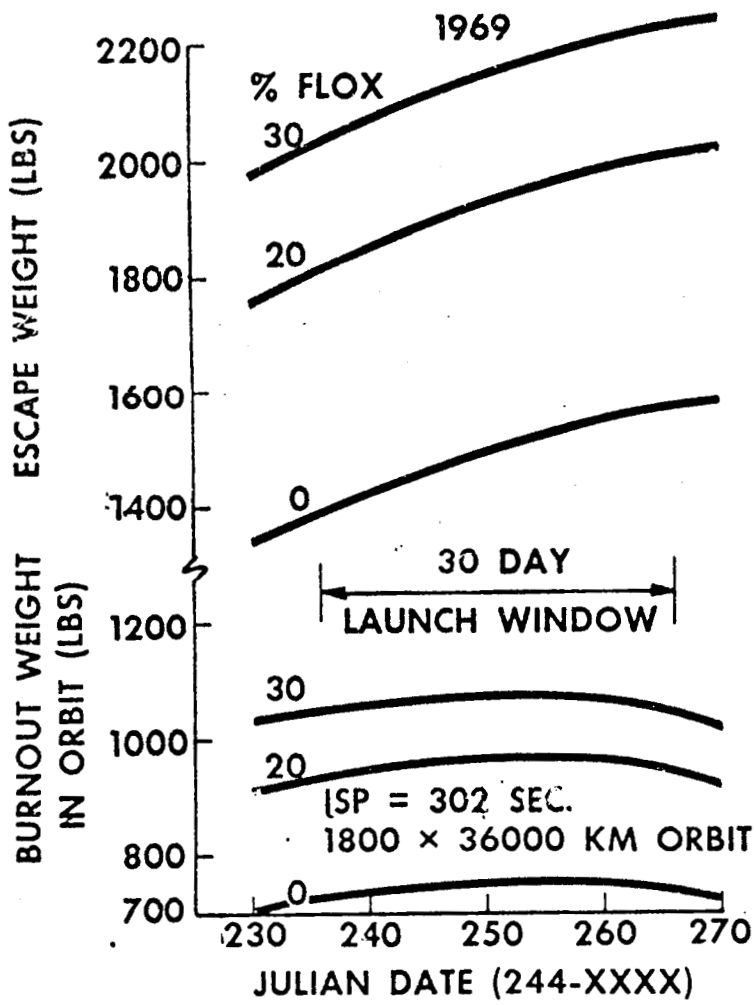
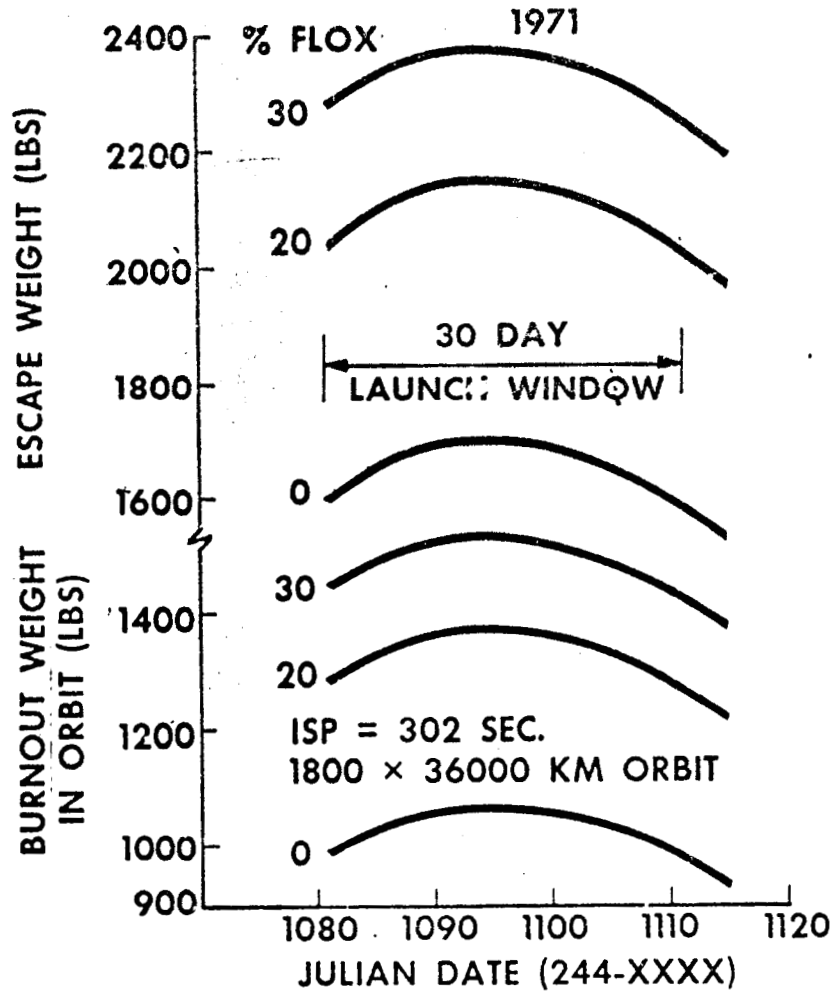
Vol. I

MARS PERFORMANCE CAPABILITY
Flox Atlas-Centaur





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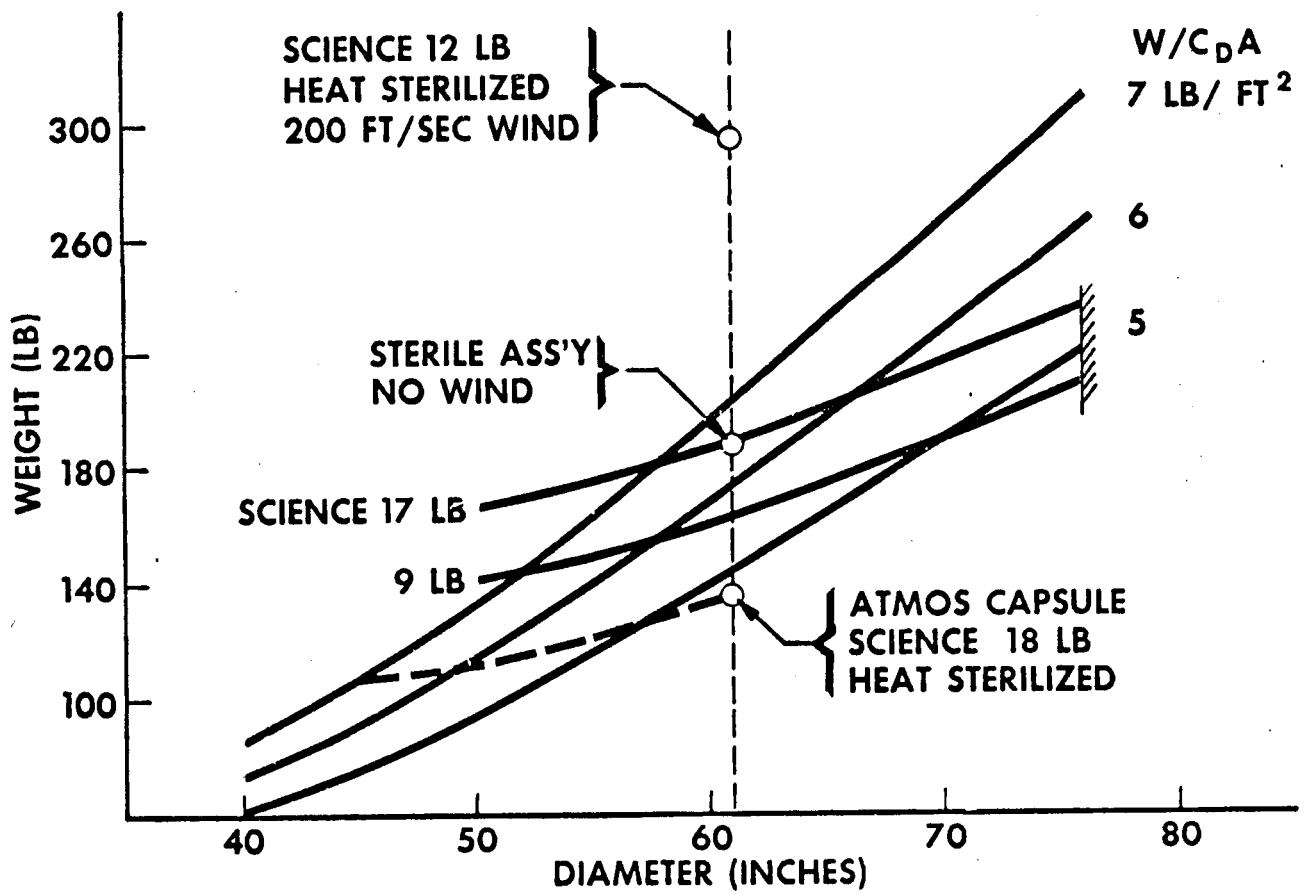
CAPSULE ENTRY WEIGHT



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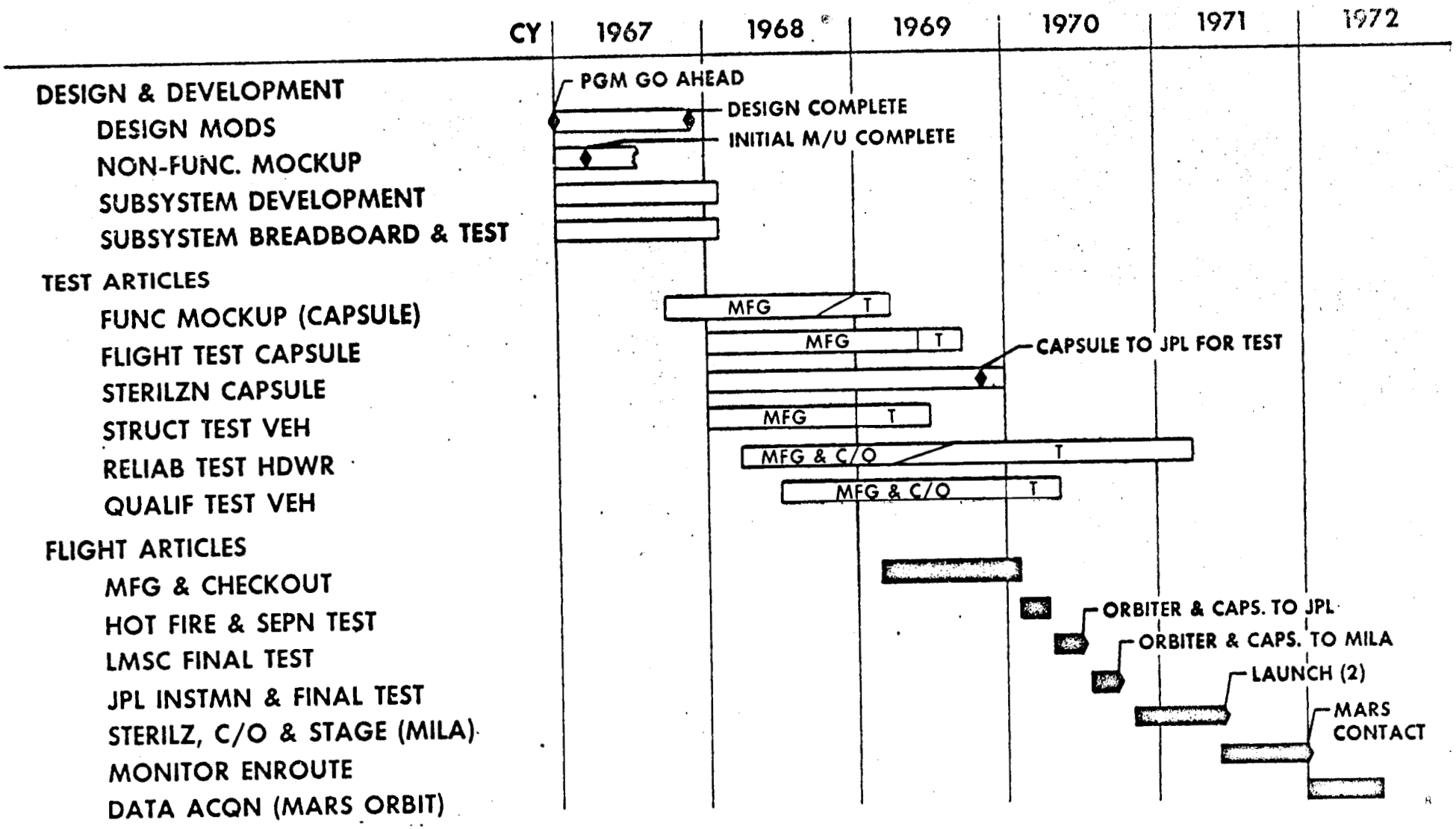
PROGRAM MASTER SCHEDULE - 1971 MISSION



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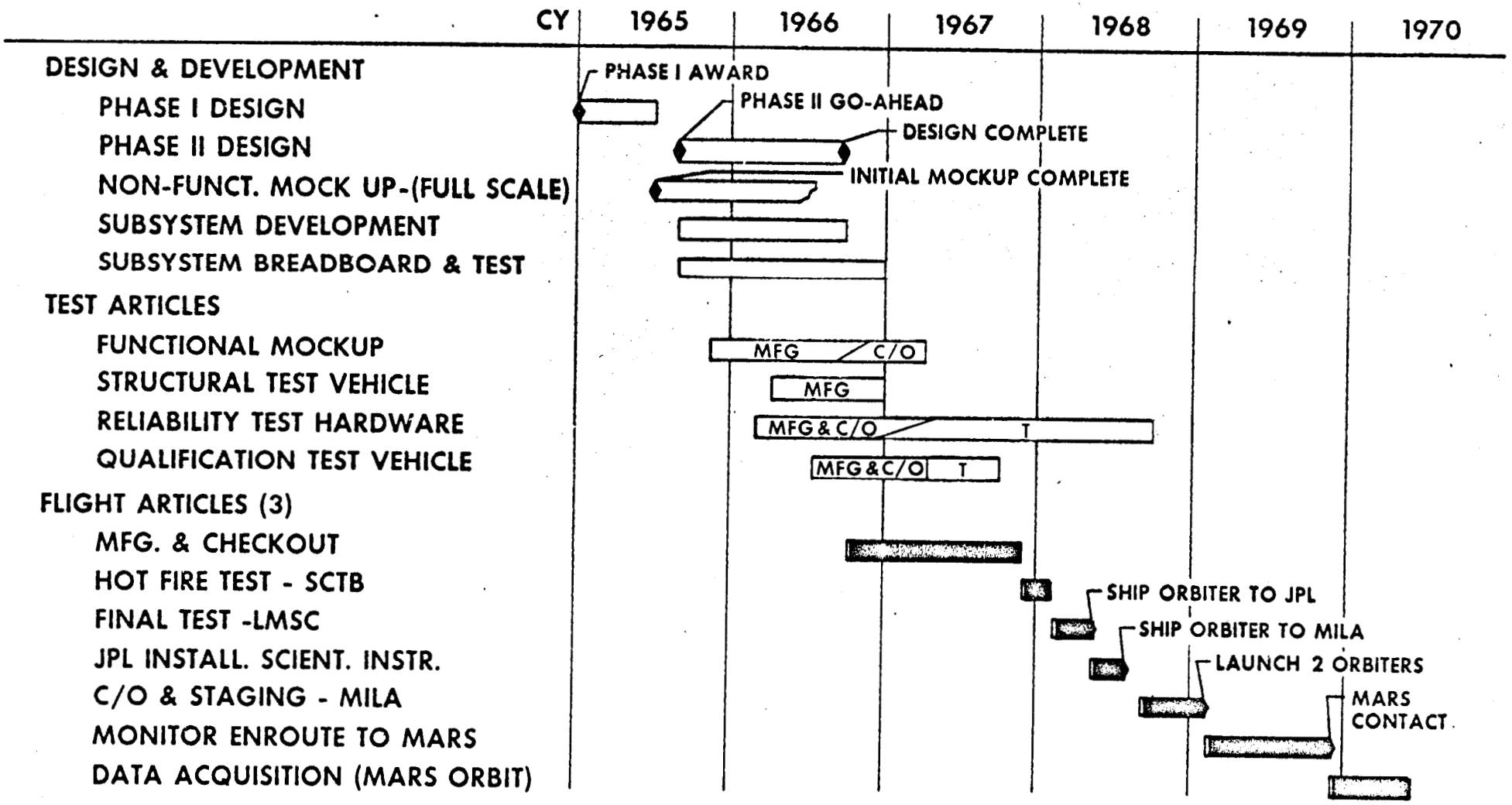
PROGRAM MASTER SCHEDULE 1969 MISSION



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PROGRAM COSTING - GROUND RULES

COSTS INCLUDED:

- PROGRAM MANAGEMENT
- DESIGN & DEVELOPMENT (ORBITER & CAPSULE)
- QUALIFICATION & RELIABILITY TESTING
- FLIGHT ARTICLE FAB, ASSY, & TEST
- SPECIAL TOOLING & TEST EQUIPMENT
- GROUND SUPPORT EQUIPMENT (AGE)
- SPECIAL FACILITIES (NEW OR MODIFIED)
- LAUNCH OPERATIONS SUPPORT
- SPARE PARTS
- DATA REDUCTION

COSTS EXCLUDED:

- LAUNCH VEHICLES
- LAUNCH CENTER OPERATIONS
- TRACKINGCENTER OPERATIONS
- LAUNCH PAD SYSTEMS OPERATIONS

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Vol. I

SUMMARY - PROGRAM COSTS

COST SEGMENT	1969 MISSION (ORBITER ONLY)	1969 MISSION (CAPSULE ADDED COST)	1971 MISSION (ORBITER & CAPSULE)
PROGRAM MANAGEMENT	$ 4.5	$ 2.5	$ 6.1
ENGINEERING & DEVELOPMENT (INCL. DEVEL. TEST HARDWARE)	21.8	9.9	17.6
RELIABILITY & QUAL TESTING (INCL. TEST HARDWARE)	12.4	3.6	6.8
MANUFACTURING (FLIGHT ARTICLES & AGE)	12.0	3.6	13.3
SPARES	1.2	0.3	1.7
SUPPORT OF LAUNCH OPERATIONS	6.4	—	6.3
SPECIAL FACILITIES	0.6	—	—
TOTAL COSTS	$ 58.9	$ 19.9	$ 51.8

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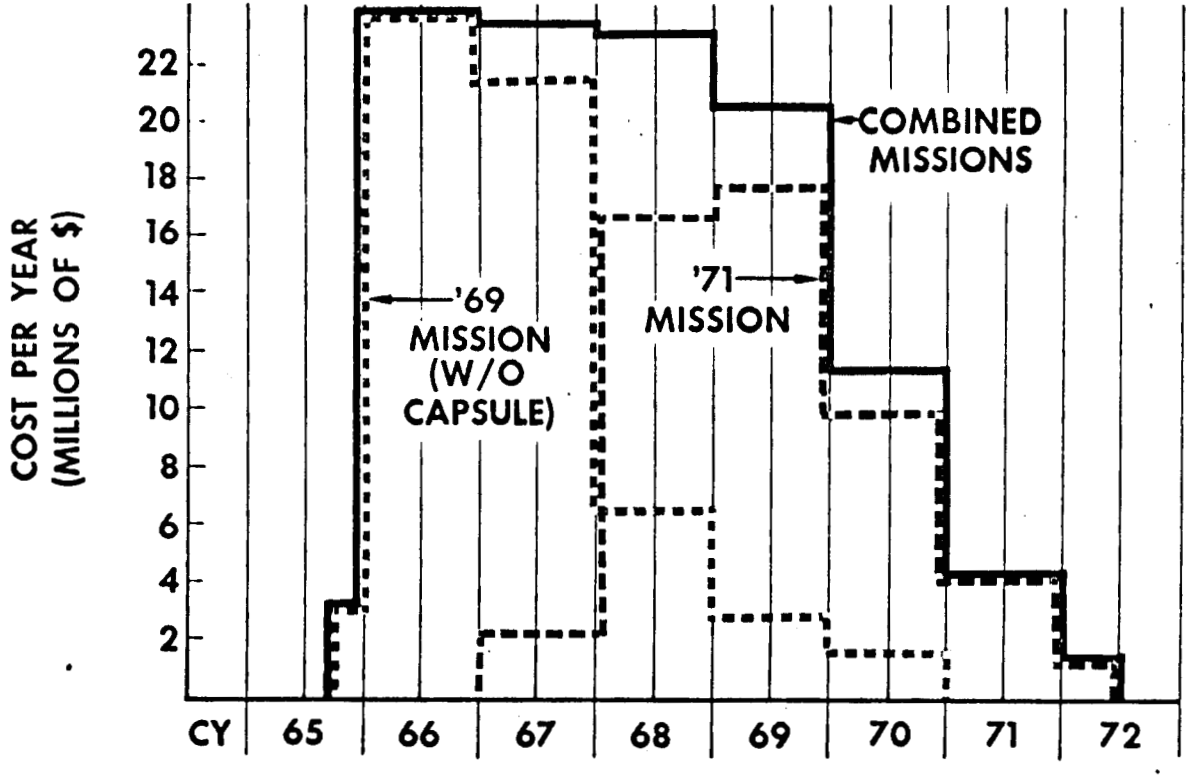
PROGRAM COST DISTRIBUTION



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Vol. I

LONG LEAD TIME DEVELOPMENT ITEMS

- POWER AMPLIFIER - 20 WATT (TWT) - 36 MONTH DEVELOPMENT TIME

FUNCTIONAL MOCKUP ITEM REQ'D	1 NOV. 1965	(14 MONTHS FROM GO-AHEAD)
QUALIFICATION TEST ARTICLE REQ'D	1 JAN. 1966	(16 MONTHS FROM GO-AHEAD)
1ST FLIGHT ARTICLE REQ'D	1 JUN. 1966	(22 MONTHS FROM GO-AHEAD)

- PROPULSION UNIT - 18 TO 24 MONTHS DEVELOPMENT TIME

QUALIFICATION TEST ARTICLE REQ'D	1 MAR. 1966	(18 MONTHS FROM GO-AHEAD)
1ST FLIGHT ARTICLES REQ'D	1 JUN. 1966	(22 MONTHS FROM GO-AHEAD)

- SCIENTIFIC INSTRUMENTS

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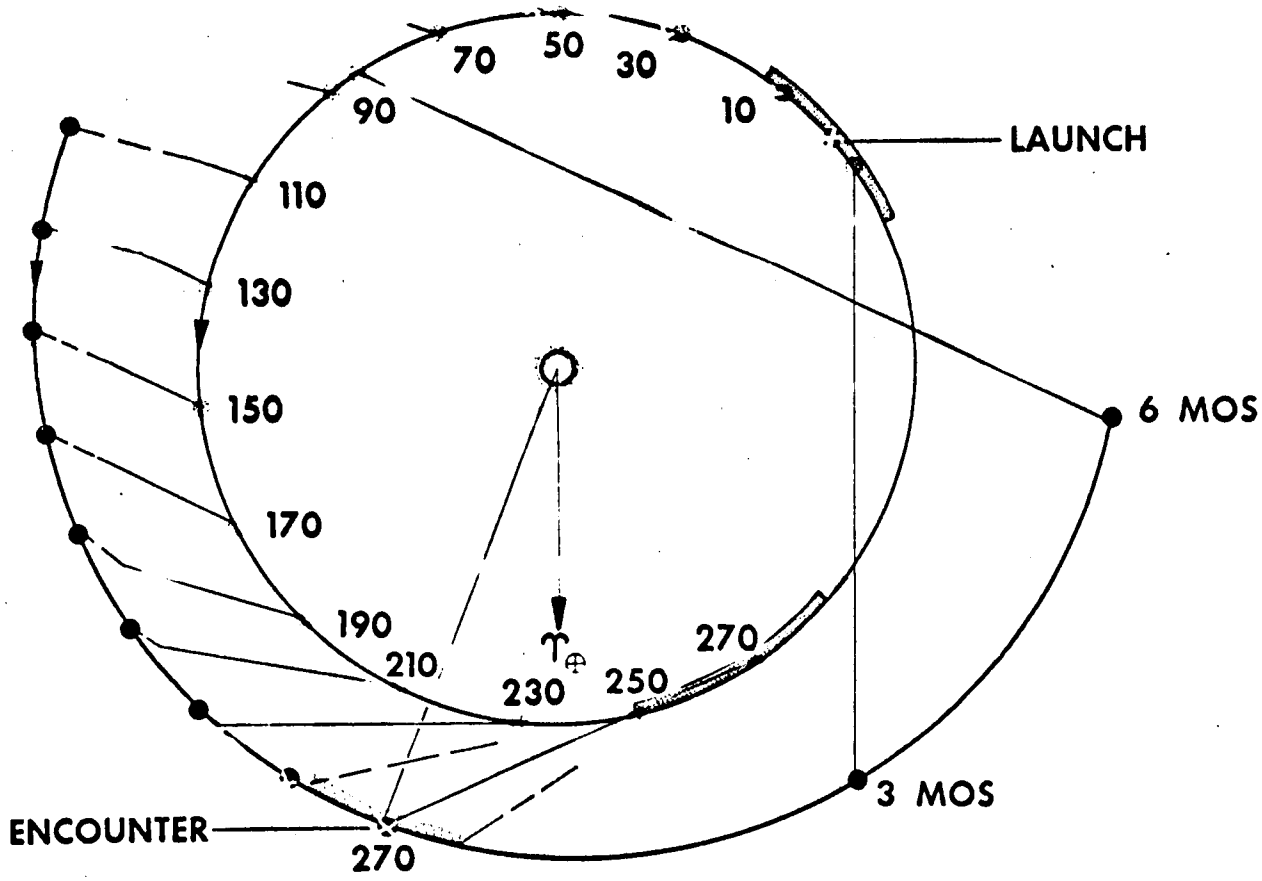
MARINER TRANSFER ORBIT GEOMETRY

MARS 1969



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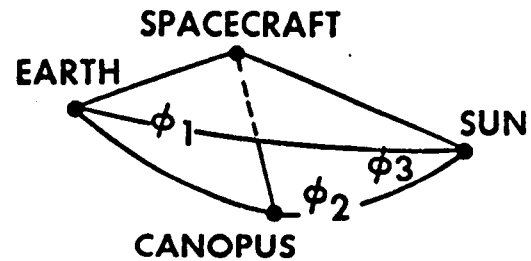
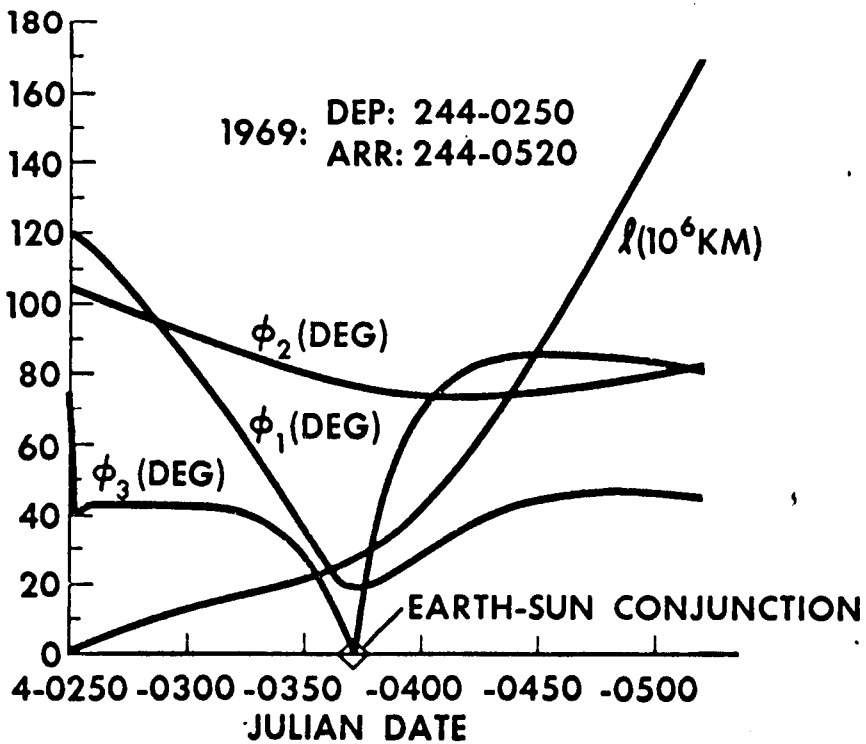
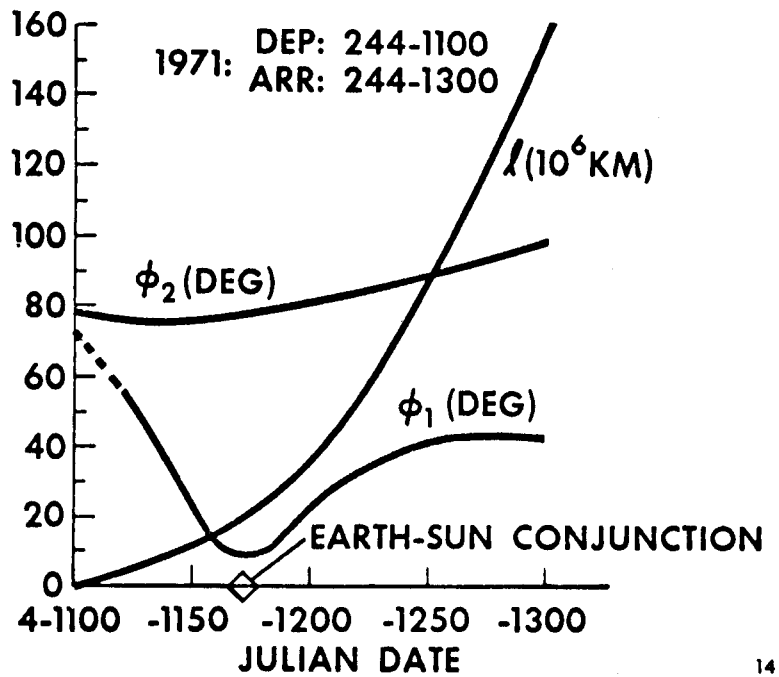
MID-COURSE COMMUNICATION & GUIDANCE GEOMETRY







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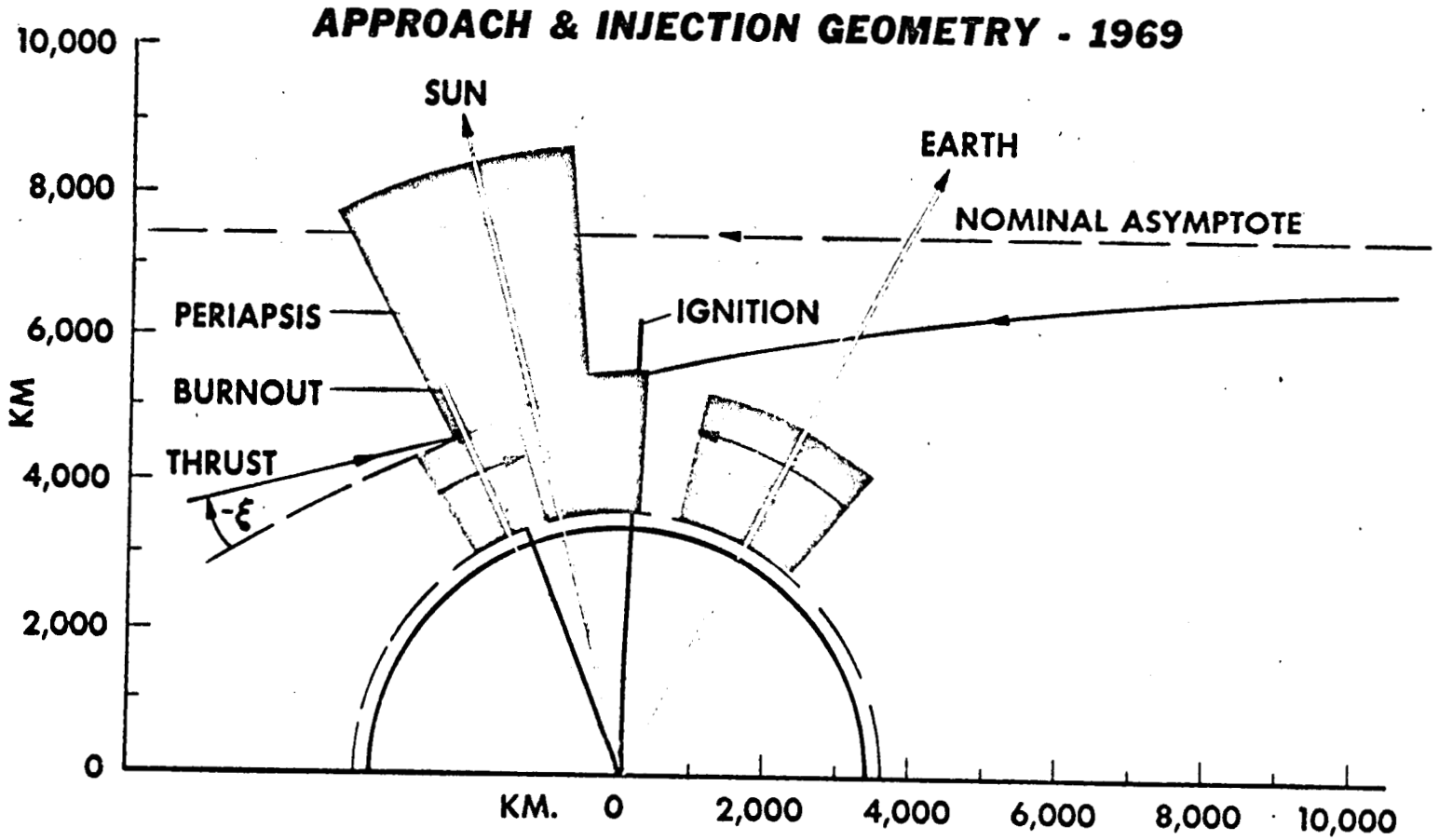
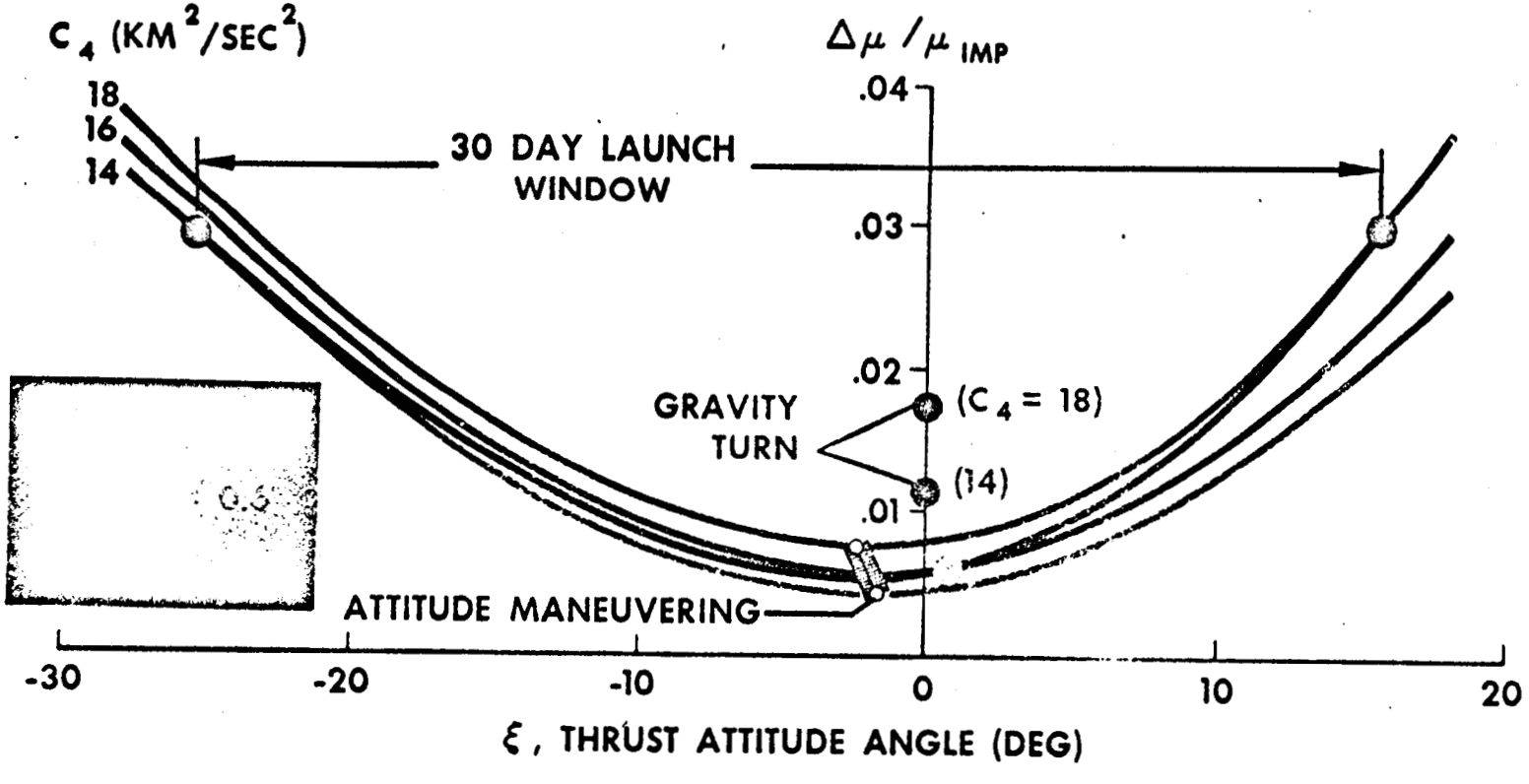
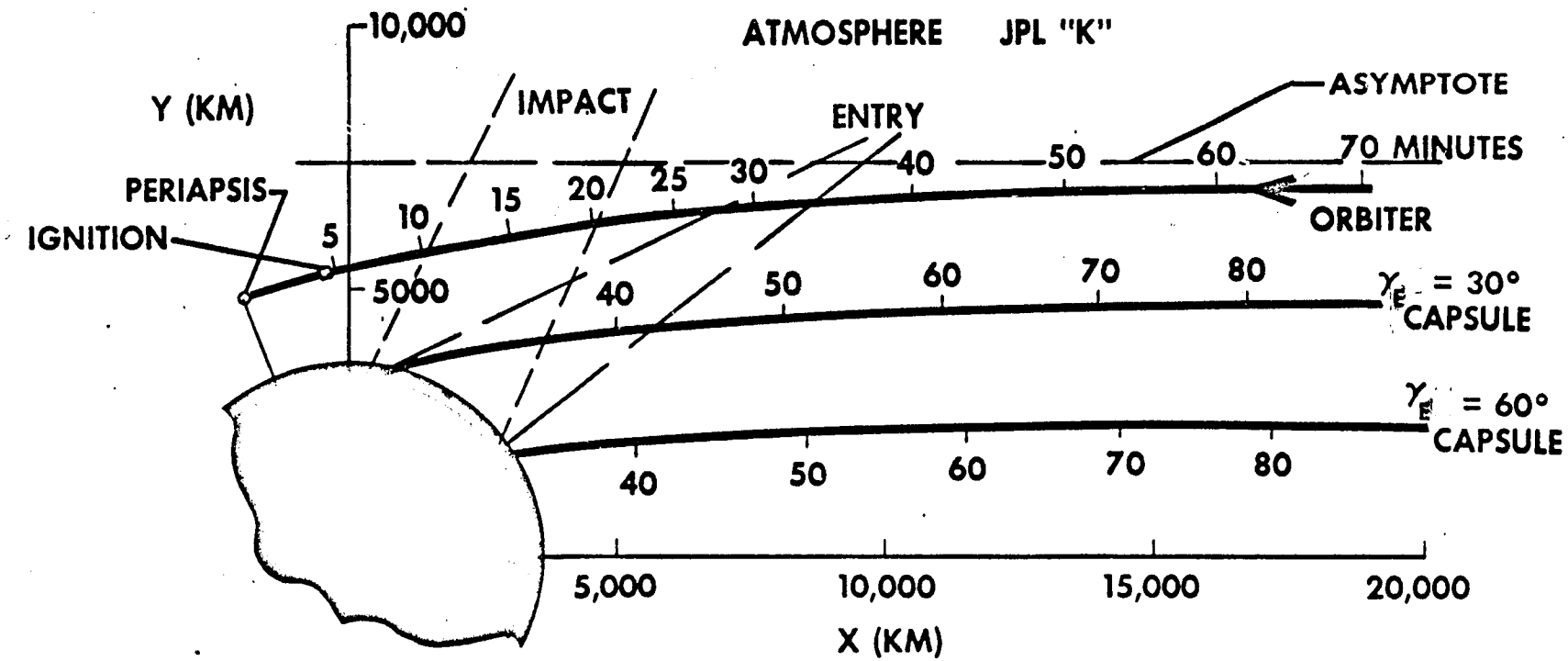


PENALTY FOR CONSTANT ATTITUDE ORBIT INJECTION
Mars 1969



MARS APPROACH GEOMETRY

ORBITER hp = 1,800 KM
C_4 = 16 KM^2/SEC^2
SEPARATION 2 DAYS OUT
$\Delta\dot{X}$ = 26 M/SEC
ATMOSPHERE JPL "K"



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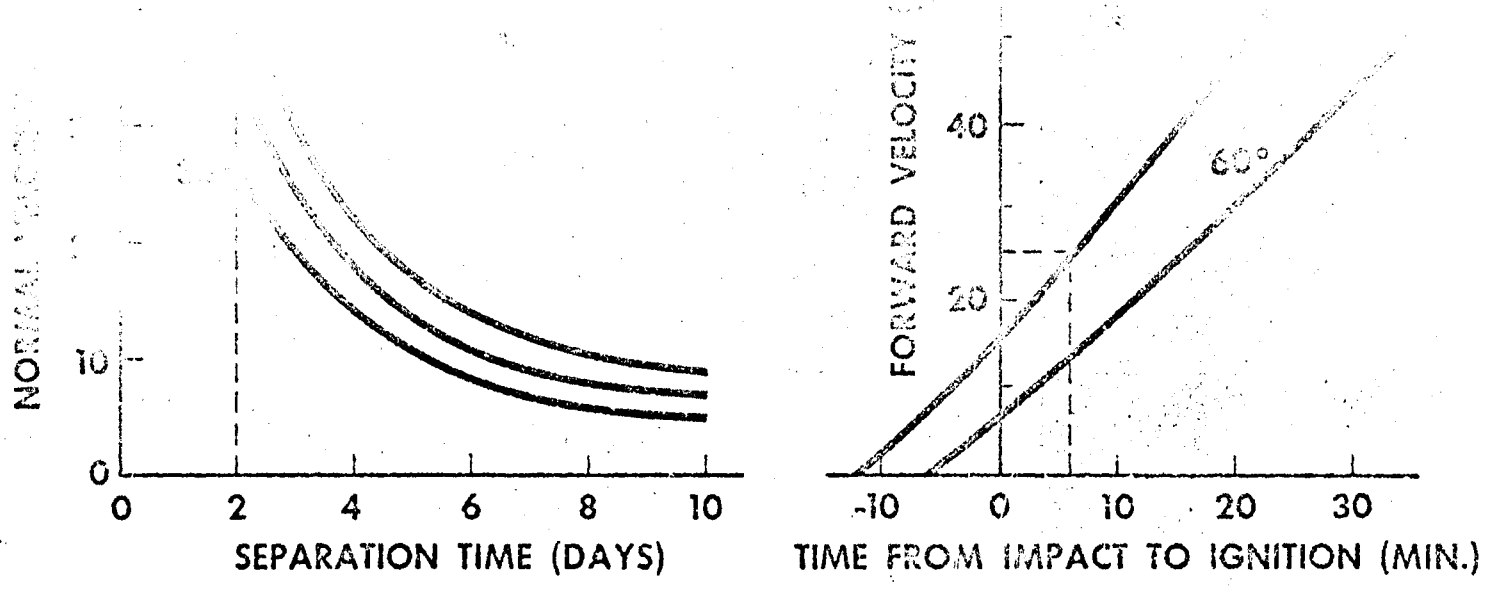
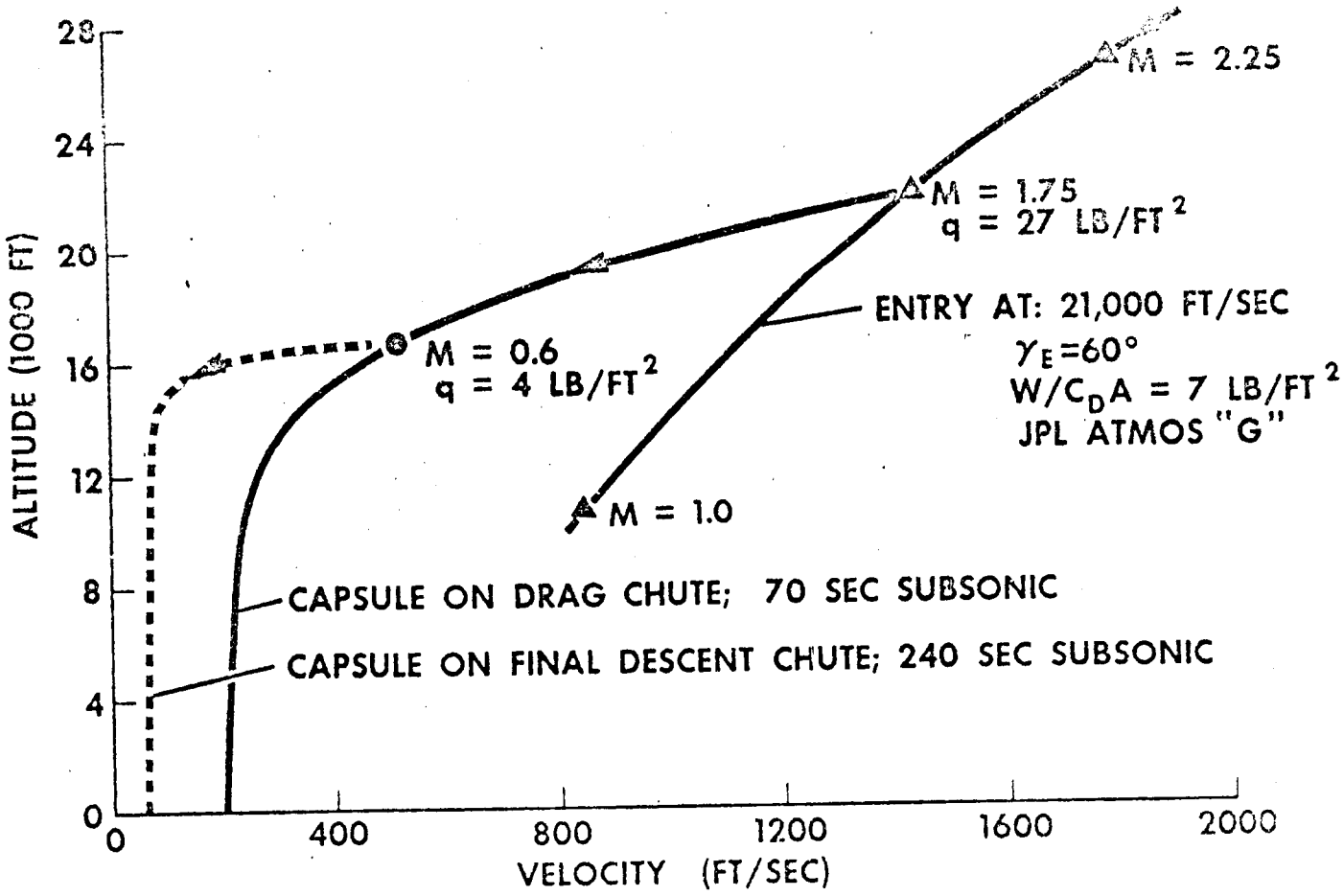

NORMAL
10
0
0
2
4
6
8
10
SEPARATION TIME (DAYS)
FORWARD VELOCITY
40
20
60°
-10
0
10
20
30
TIME FROM IMPACT TO IGNITION (MIN.)

PARACHUTE DESIGN



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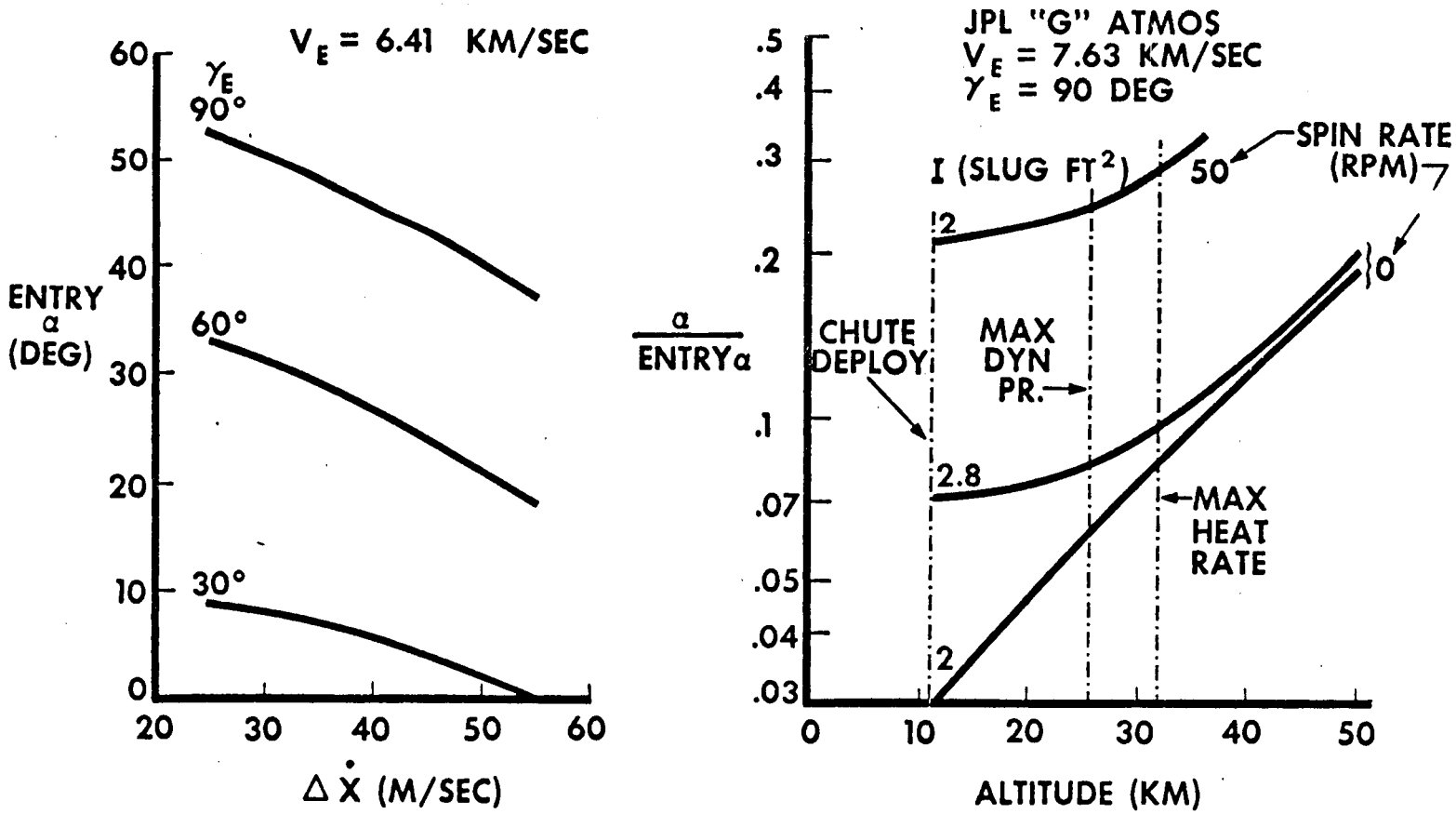
CAPSULE ENTRY ATTITUDE CONSIDERATIONS



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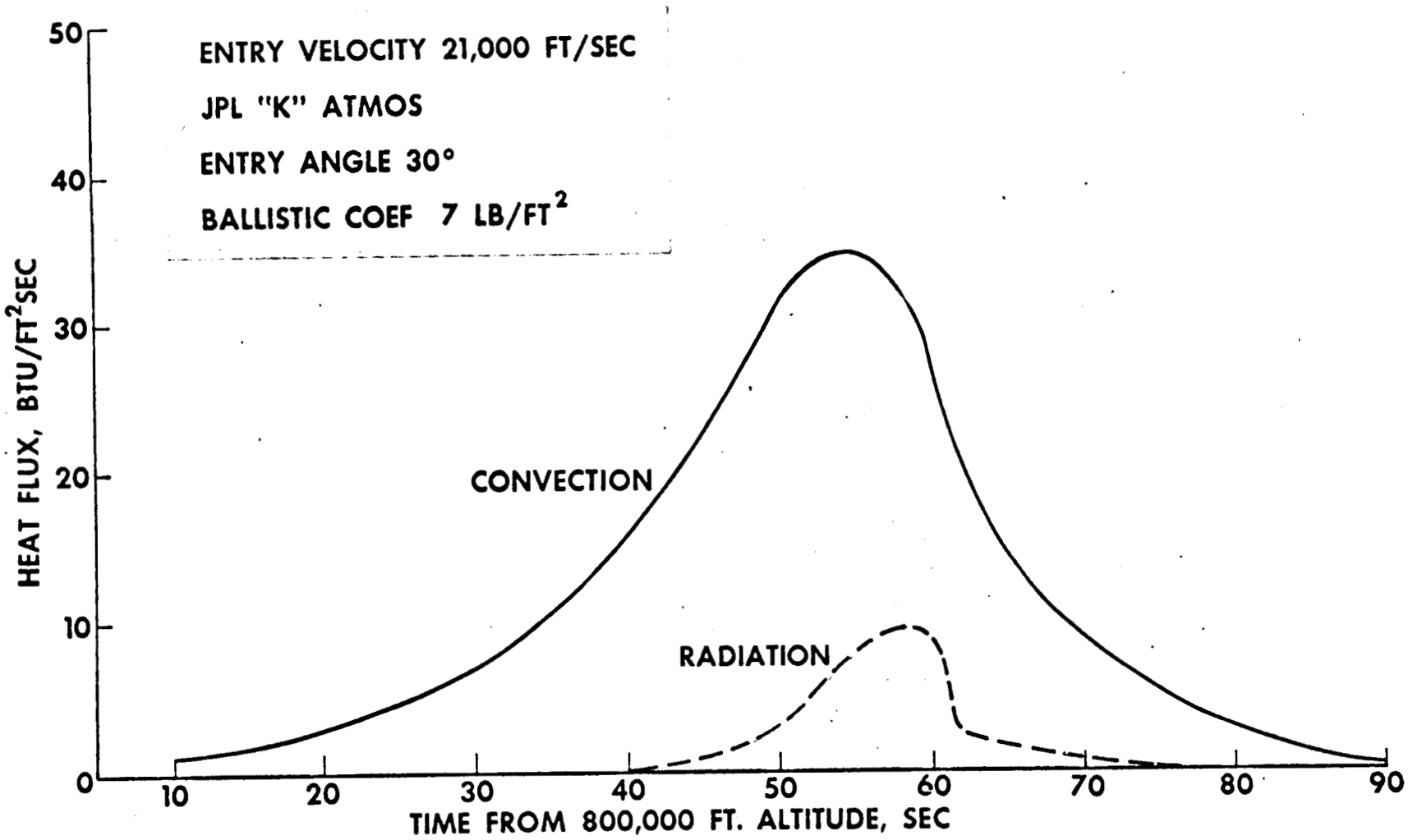
STAGNATION POINT HEATING



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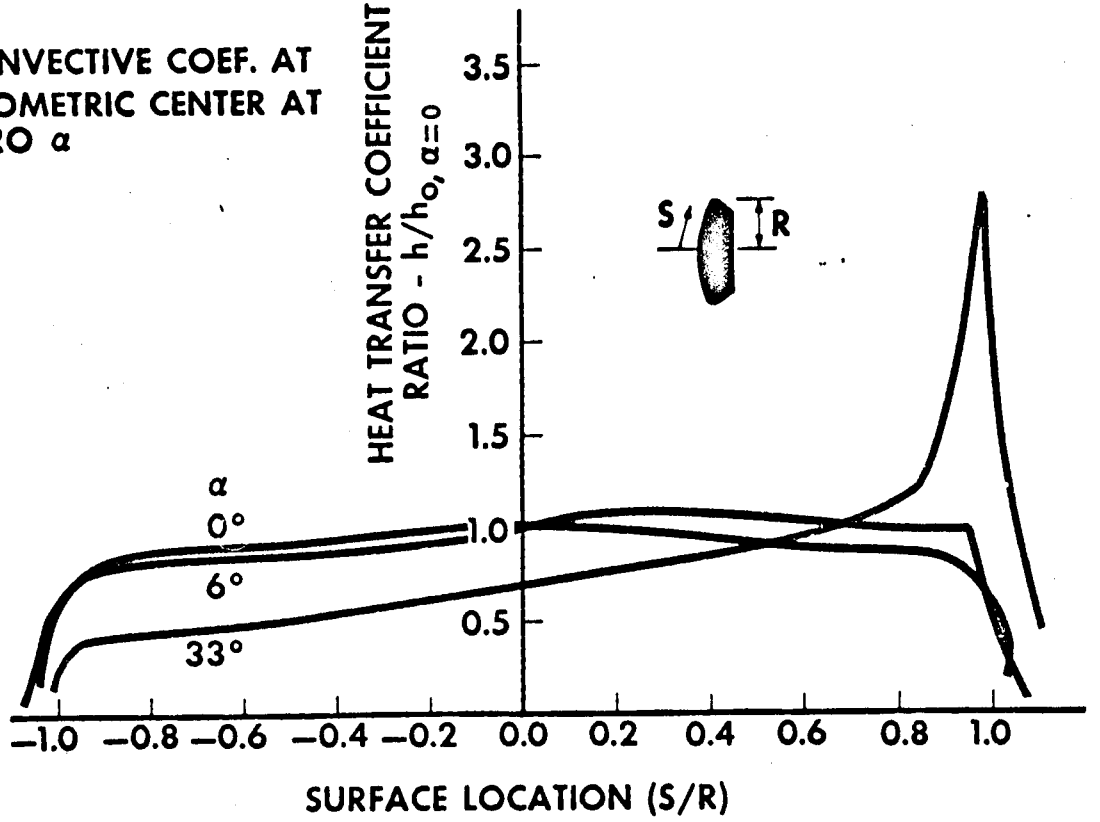
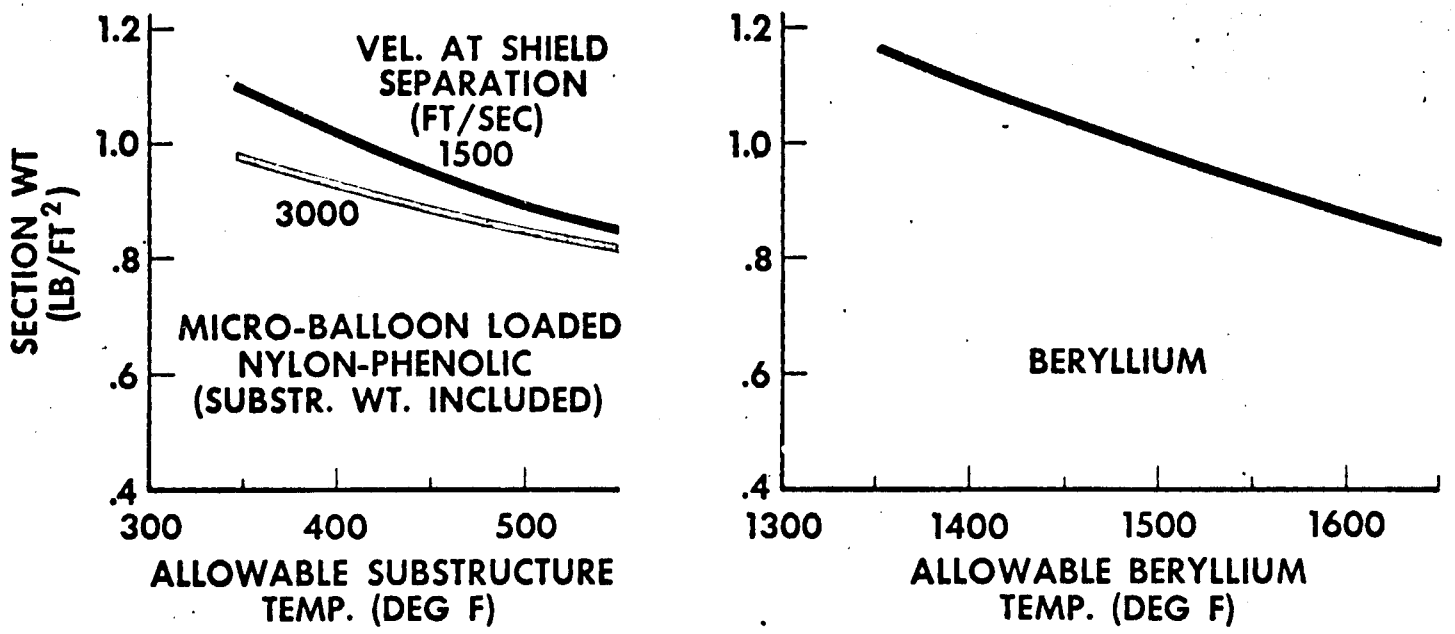
FOREBODY CONVECTIVE HEAT TRANSFER DISTRIBUTION

h_o, $\alpha = 0$: CONVECTIVE COEF. AT GEOMETRIC CENTER AT ZERO α

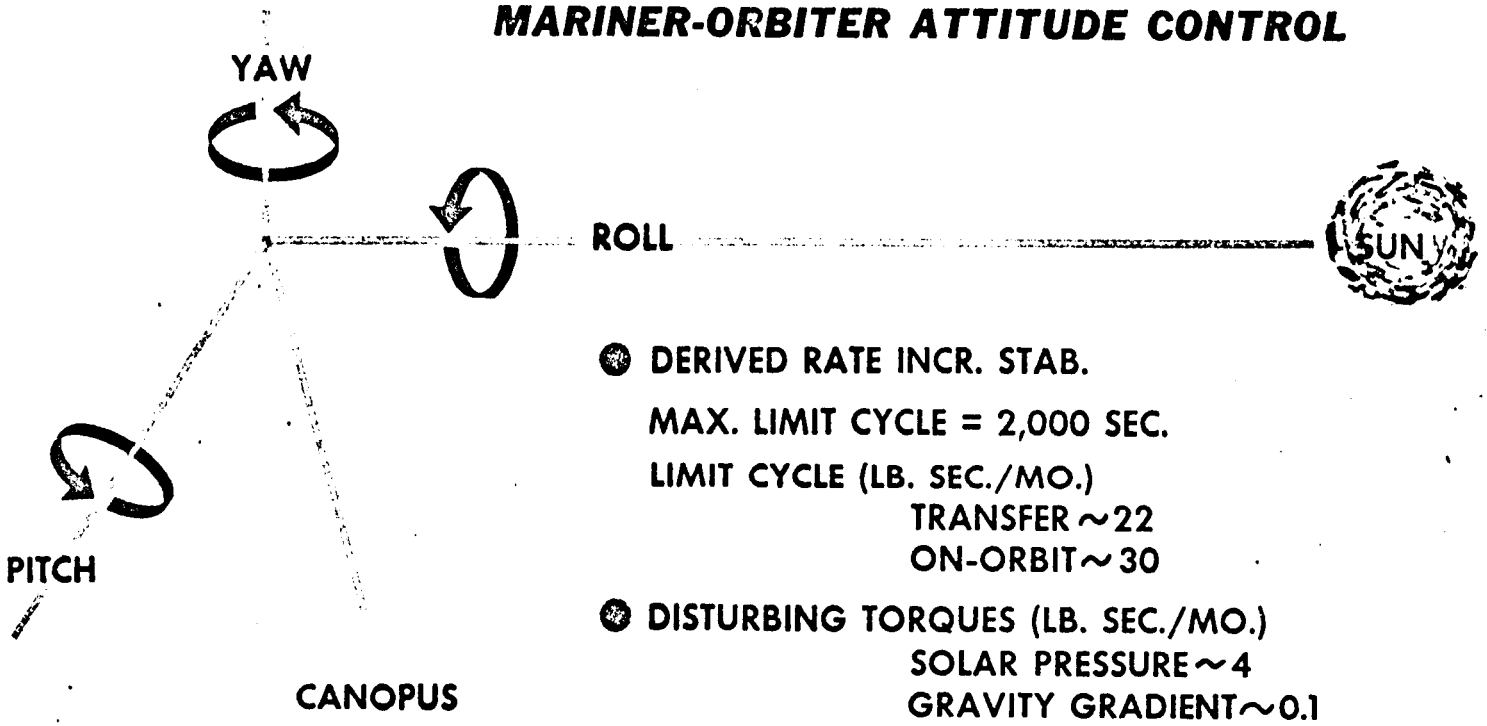


HEAT SHIELDING REQMTS AT STAGNATION POINT

TRAJECTORY CONDITIONS
- ENTRY VEL: 21,000 FT/SEC
- ENTRY ANGLE: 30 DEG
- BALLISTIC COEF: 7 LB/FT^2
- ATMOSPHERE: JPL "K"



MARINER-ORBITER ATTITUDE CONTROL



- DERIVED RATE INCR. STAB.

  MAX. LIMIT CYCLE = 2,000 SEC.

  LIMIT CYCLE (LB. SEC./MO.)

  TRANSFER ~ 22

  ON-ORBIT ~ 30

- DISTURBING TORQUES (LB. SEC./MO.)

  SOLAR PRESSURE ~ 4

  GRAVITY GRADIENT ~ 0.1

  MICROMETEORITE ~ 0.1 (3σ)

- TOTAL IMPULSE (LB. SEC.)

TRANSFER	193
MANEUVERS	24
ACQUISITIONS	24
6 MO. ON-ORBIT	179
TOTAL	420

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PRINCIPAL GUIDANCE ERRORS

Std. Deviation

ERROR SOURCES	ERROR COMPONENTS AT MARS (KM)		
	L.O.S.	ECLIPTIC	
PHYSICAL MODEL (A.U. 200 KM) (EPHEMERIS 0.05 SEC.)	250	50	
DSIF TRACKING (RANGE (FILTERED) 10 KM) (VELOCITY (FILTERED) 0.03 M/SEC)	10	220	[illegible]
MANEUVER EXECUTION MAGNITUDE 0.1 M/SEC DIRECTION 0.6 DEG.			
1ST CORRECTION (LAUNCH + 2 DAYS)	6000	6000	3000
2ND CORRECTION (ARR - 26 DAYS)	225	225	225

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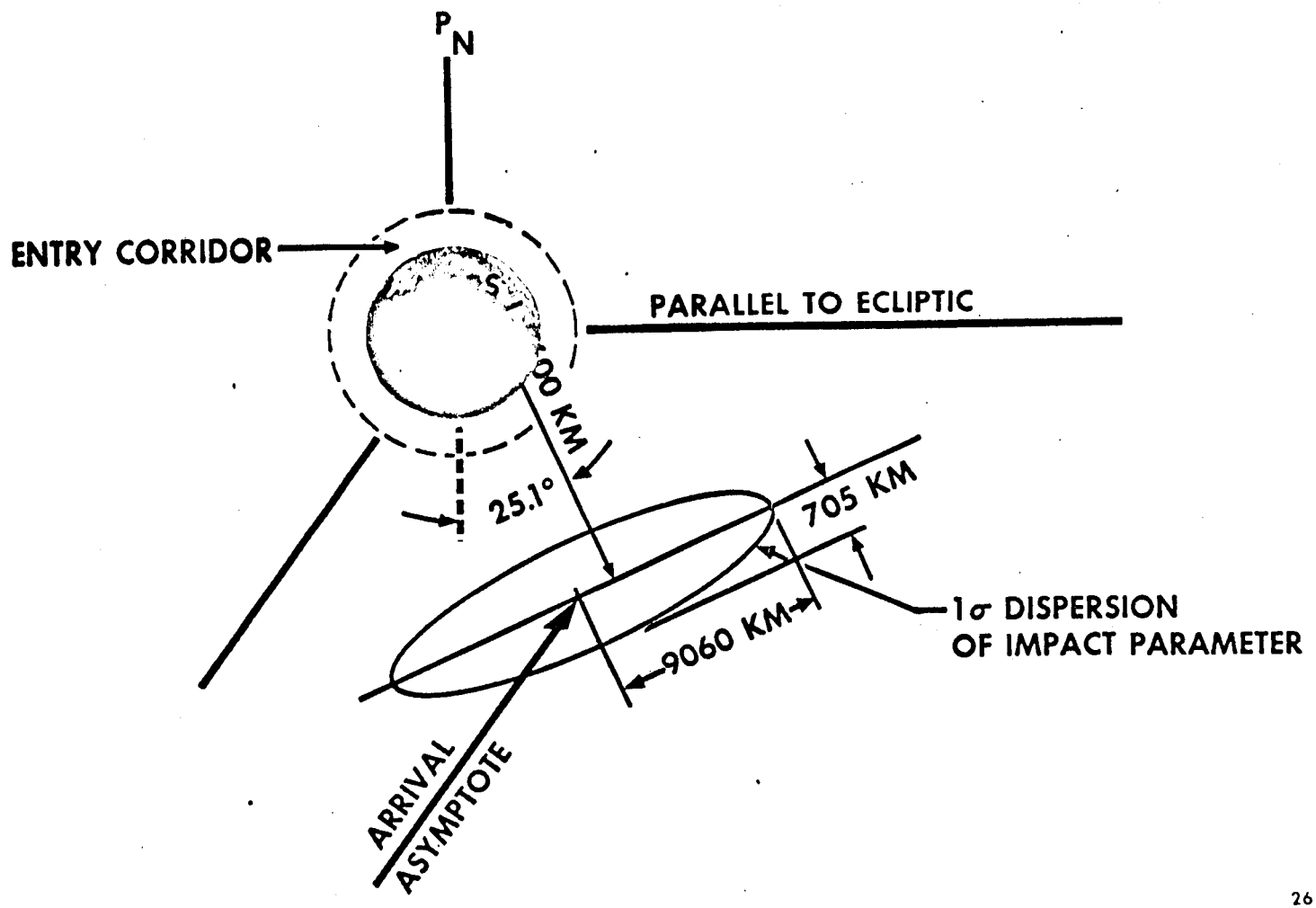
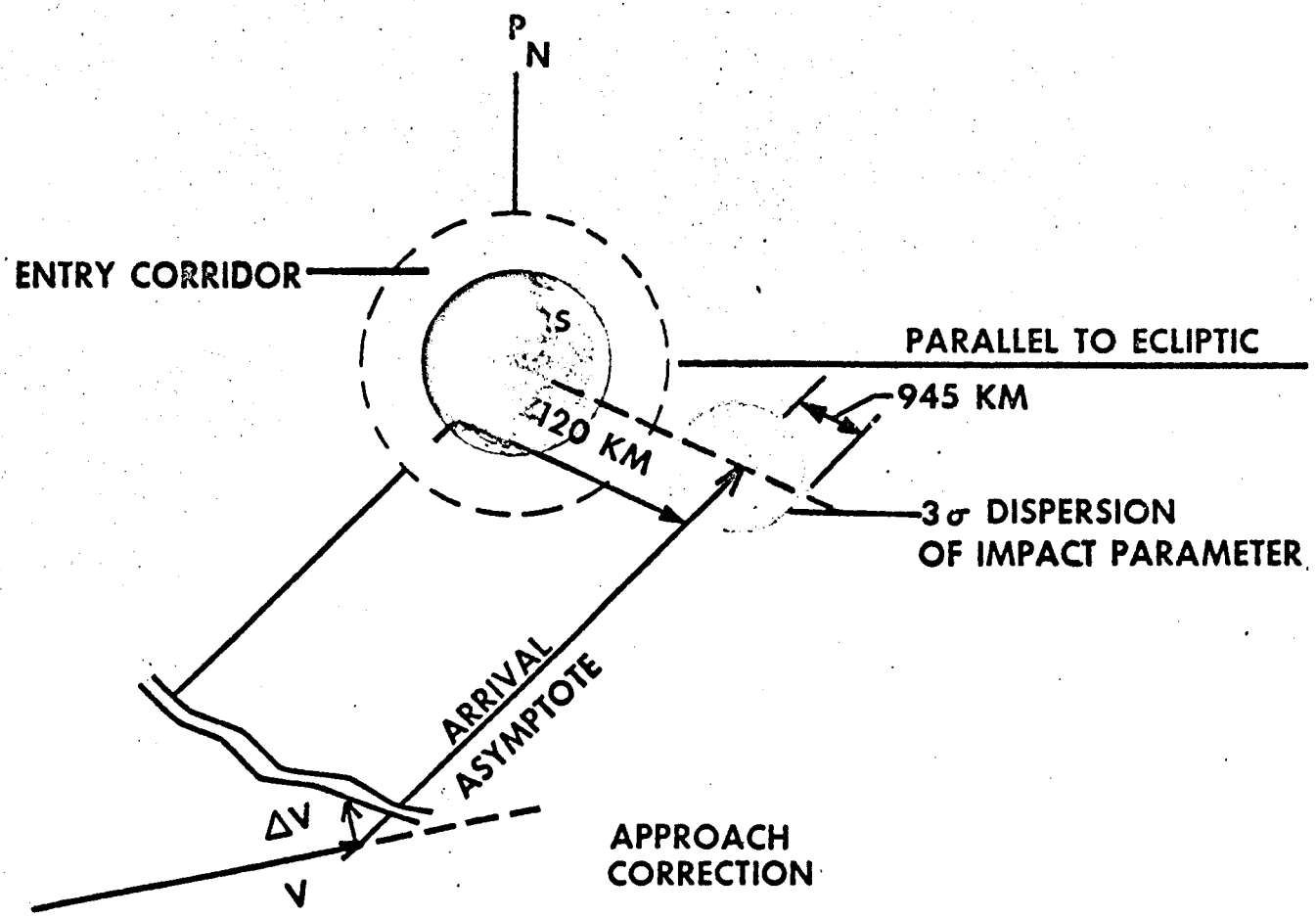
DISPERSION OF IMPACT PARAMETER AFTER FIRST CORRECTION



DISPERSION OF IMPACT PARAMETER AFTER SECOND CORRECTION



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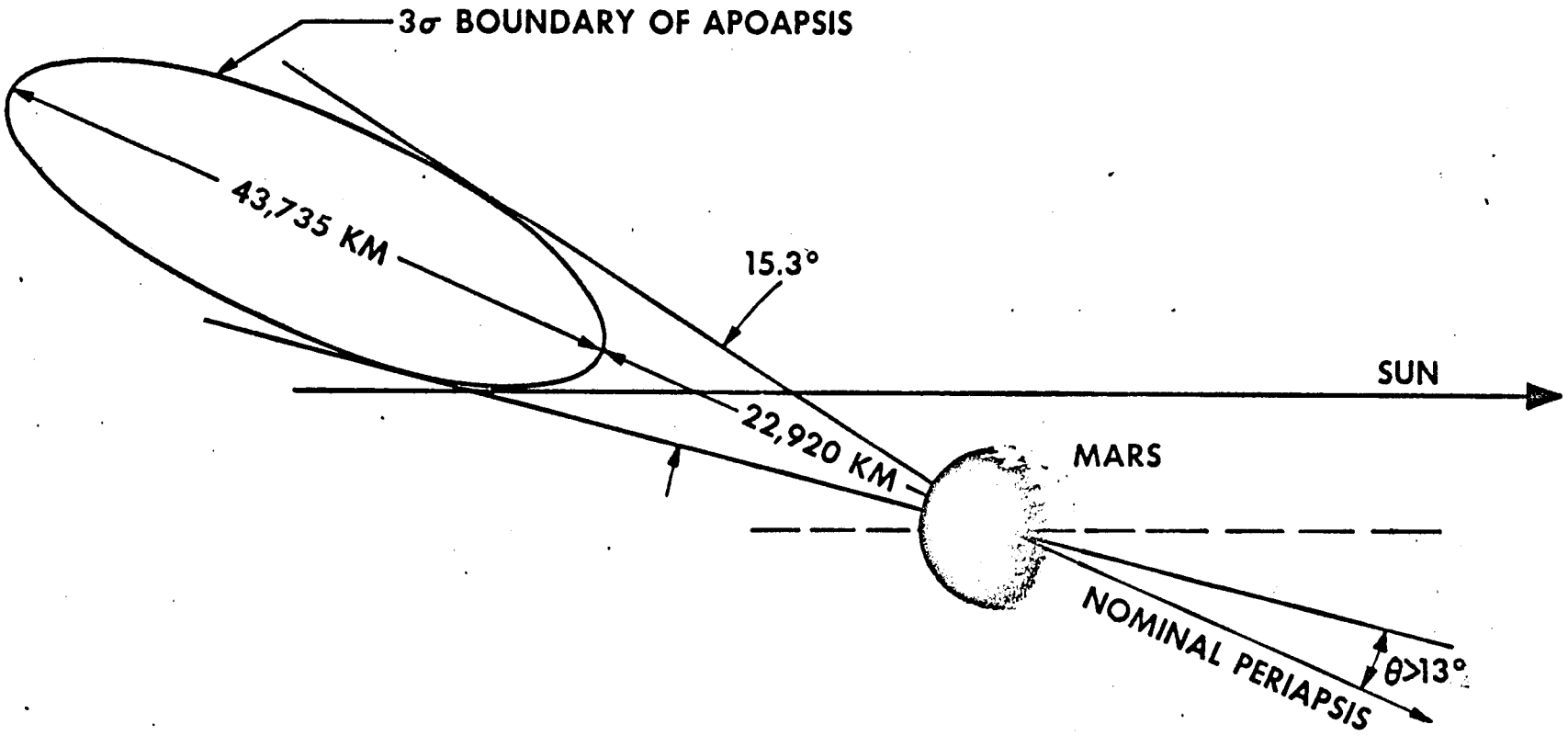
DISPERSION OF APOAPSIS



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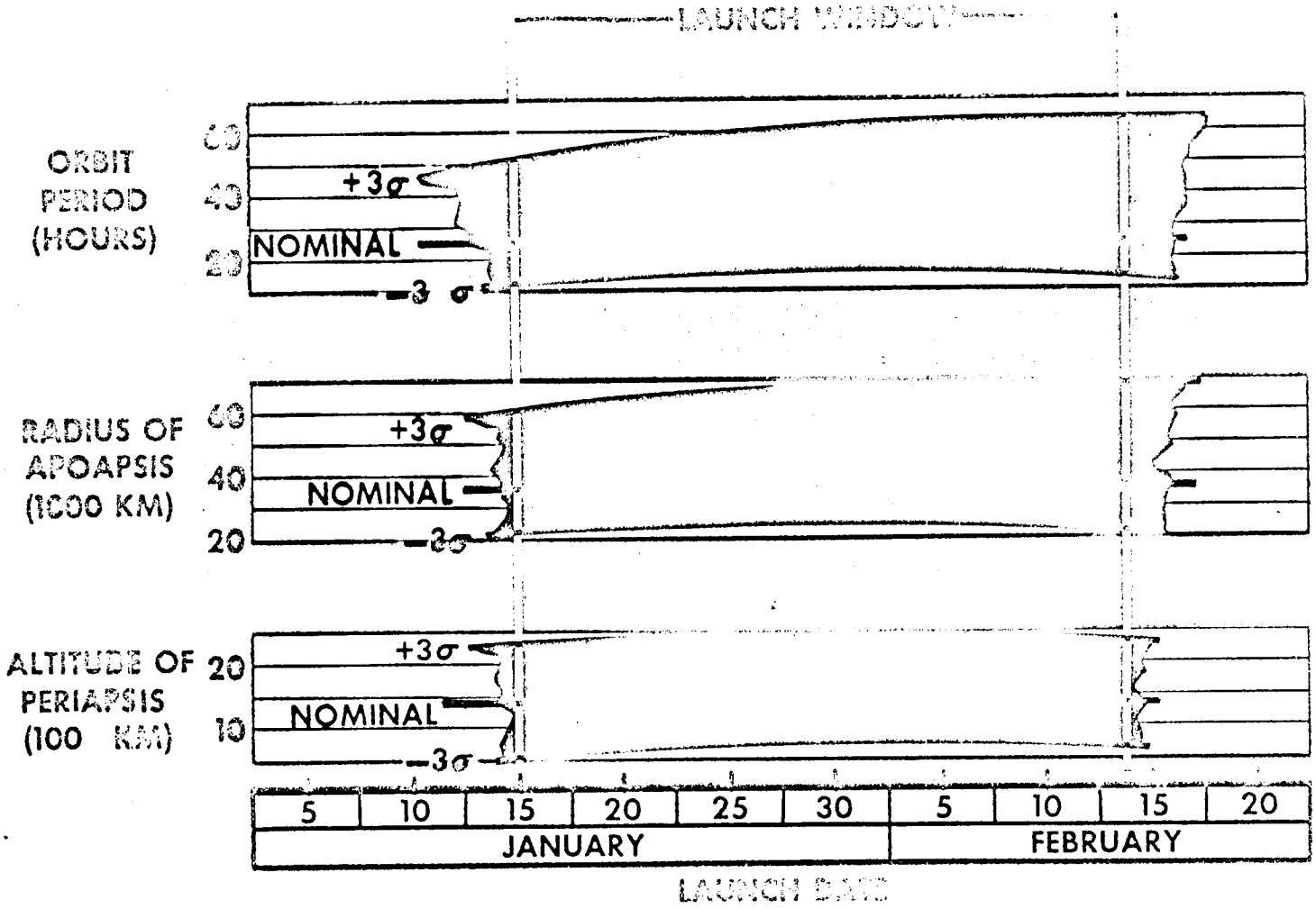
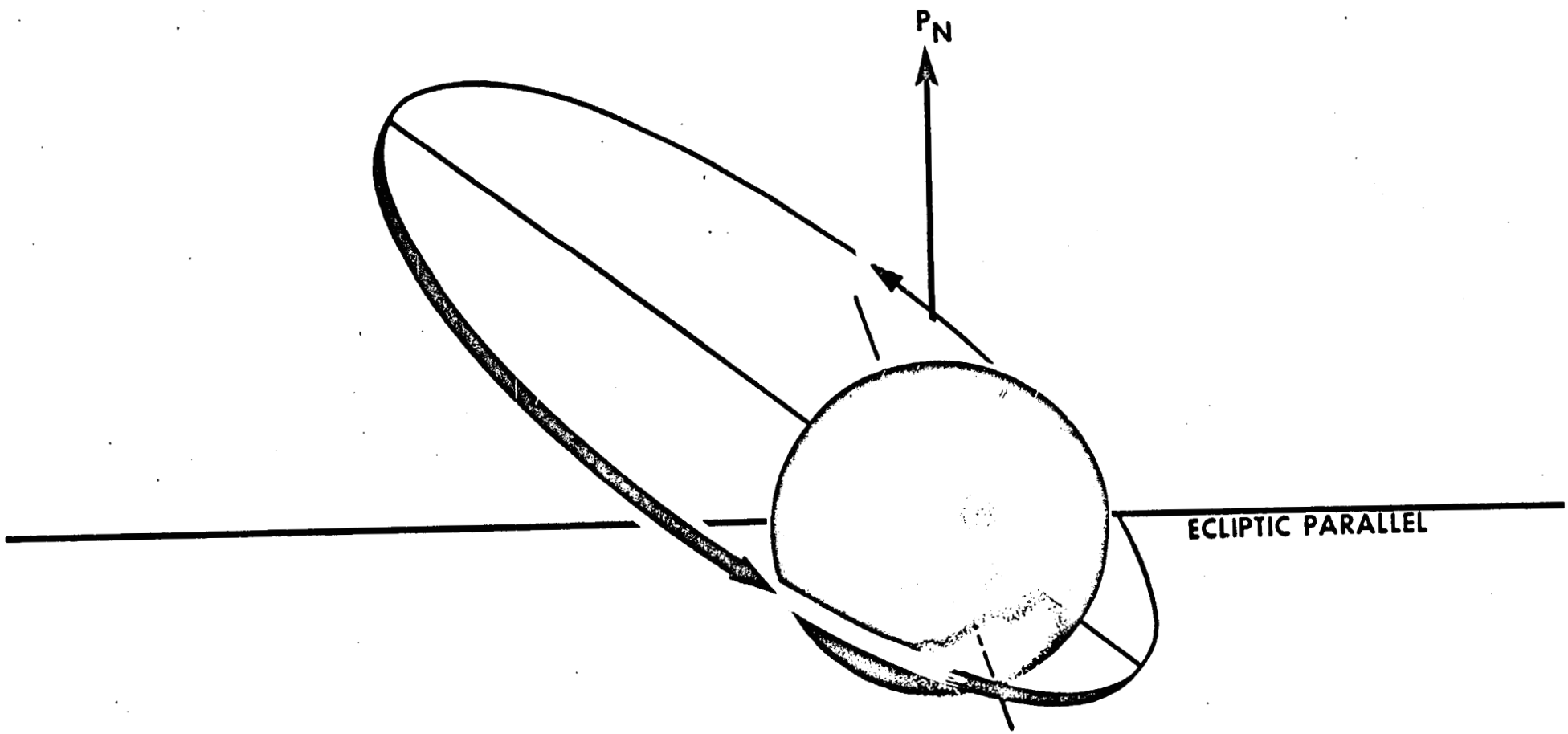
Vol. I


LAUNCH WINDOW
ORBIT PERIOD (HOURS)
60
40
20
+3σ
NOMINAL
-3 σ
RADIUS OF APOAPSIS (1000 KM)
60
40
20
+3σ
NOMINAL
-3σ
ALTITUDE OF PERIAPSIS (100 KM)
20
10
+3σ
NOMINAL
-3σ
5
10
15
20
25
30
5
10
15
20
JANUARY
FEBRUARY
LAUNCH DATE

LINE-OF-SIGHT OCCULTATION



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ORBITER EXPERIMENTAL INSTRUMENTATION

	WEIGHT (LB)	POWER (WATTS)	DATA SAMPLE (BITS)	NO CAPSULE	WITH CAPSULE
● FIXED MOUNT					
ION CHAMBER	1.3	0.1	15	X	X
PARTICLE FLUX METER	2.5	0.35	27	X	X
LOW ENERGY PLASMA MONITOR	7	1.25	12	X	
MEDIUM ENERGY PROTON MONITOR	3	1	32	X	
HIGH ENERGY PROTON MONITOR	4	0.5	25	X	
TRAPPED RADIATION DETECTOR	4	0.7	30		X
MAGNETOMETER	5	5	12	X	X
BI-STATIC RADAR	10	5	—	X	
COSMIC DUST DETECTOR	2.5	0.2	22	X	X
MICROMETEOROID DETECTOR	8	0.3	20	X	X
● PLANET PLATFORM MOUNT					
VISUAL TV (2 CAMERAS)	60	30	3.6×10^6	X	X
INFRARED TV	10	6	2×10^5	X	
ULTRAVIOLET PHOTOMETER	6	5	20	X	X
INFRARED RADIOMETER	3	3	11	X	X
PLANET DIAMETER SCANNER	10	5	26	X	
		TOTAL WEIGHT		132	92

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CAPSULE EXPERIMENTAL INSTRUMENTATION

MULTIVATOR	4	2	140	X	
ACCELEROMETER	2.5	4	21	X	X
PRESSURE GAGES	0.8	0.2	14	X	X
TEMPERATURE GAGES	0.6	0.2	14	X	X
MASS SPECTROMETER	6	6	133	X	X
ULTRAVIOLET PHOTOMETER	1.5	5	7		X
INFRARED RADIOMETER	3	3	7		X
			TOTAL WEIGHT	12.4	18.4

DETERMINATION OF MARS' RADIUS

BASIC INFORMATION	TECHNIQUE							
ORBIT PARAMETERS	X	X	X	X	X	X	X	
RADIO OCCULTATION TIME	X							
STAR OCCULTATION TIME		X						
PLANET ANGULAR DIAMETER			X					X
RADAR ALTITUDE				X				X
TV LOCATION OF SURFACE FEATURES					X			
SURFACE TRANSPONDER DOPPLER SIGNALS						X		
SURFACE GRAVITY							X	
ADDED WEIGHT, LB	0	10	10	37	0	20	26	47
ADDED POWER, WATTS	0	2	2	39	0	10	4	41
ESTIMATED UNCERTAINTY, KM	3.5	2.4	1.2	1.3	4	1.4	0.4	3.7

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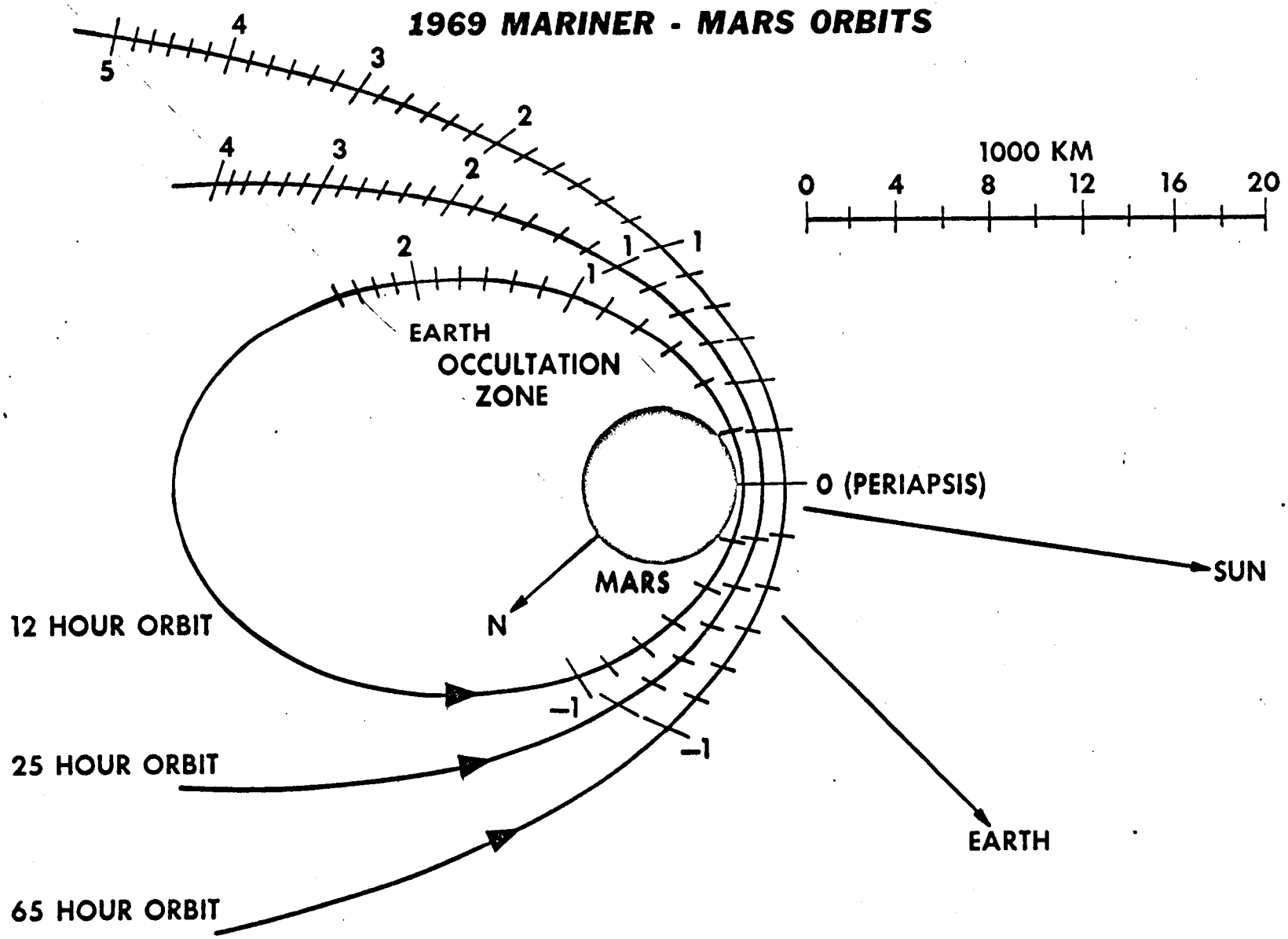
1969 MARINER - MARS ORBITS



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Vol I

1969 SEQUENCE OF EVENTS

ORBITER

	EVENT	TIME
1	LAUNCH SEQUENCE	T
2	MIDCOURSE CORRECTION	T + 3 DAYS
3	MIDCOURSE CORRECTION (BACK-UP)	T + 5 DAYS
4	SWITCH TO HIGH GAIN ANTENNA	T + 170 DAYS
5	MARS APPROACH CORRECTION	E — 26 DAYS
5A	CAPSULE SEPARATION	E — 2 DAYS
5B	ATMOSPHERIC CAPSULE READ OUT	E — 40 MINUTES
6	ORBIT INJECTION	E — 5 MINUTES
7	START DATA ACQUISITION	E
8	MISSION COMPLETE	E + 6 MONTHS

CAPSULE

	EVENT	TIME
C1	PRE-SEPARATION CHECK OUT	E — 2 DAYS
C2	SEPARATION SEQUENCE	E — 2 DAYS
C3	ATMOSPHERIC ENTRY	E — 10 TO —33 MINUTES
C4	IMPACT	I

E = ENCOUNTER = 270 DAYS NOMINAL

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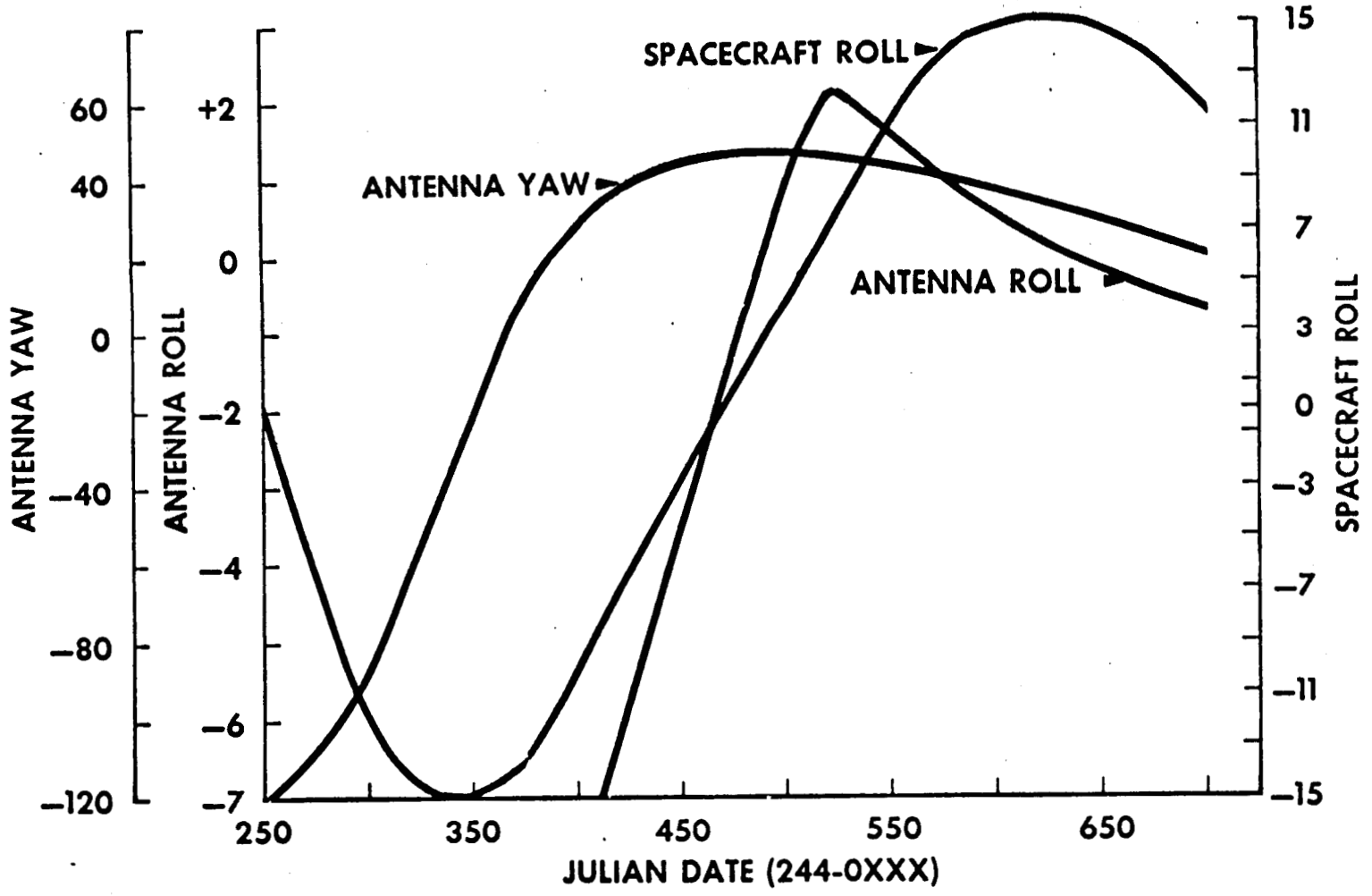
COMMUNICATIONS GROUND RULES

- SPACECRAFT-EARTH LINKS: SINGLE SUBCARRIER COHERENT PSK MODULATION
- NEAR-EARTH TRACKING: ENHANCED BY MTS.
- DEEP SPACE INFORMATION FACILITY:

AVAILABILITY	LAUNCH	6 DAYS
	MANEUVERS	48 HOURS
	CRUISE	1 DAY IN 4
	ON-ORBIT (0-30 DAYS)	CONTINUOUS
	ON-ORBIT (>30 DAYS)	8 HOURS IN 24
COMMAND SYSTEM	TRANSMITTER	GOLDSTONE ONLY
	FREQUENCY	2110-2120 MC
	POWER OUTPUT	100 KW
	ANTENNA	85 FT
RECEIVING SYSTEM	FREQUENCY	2290-2300MC
	ANTENNA	210 FT
	EFFEC. NOISE TEMP.	30° K

ANTENNA VIEW ANGLES (DEG)
1969 Flight



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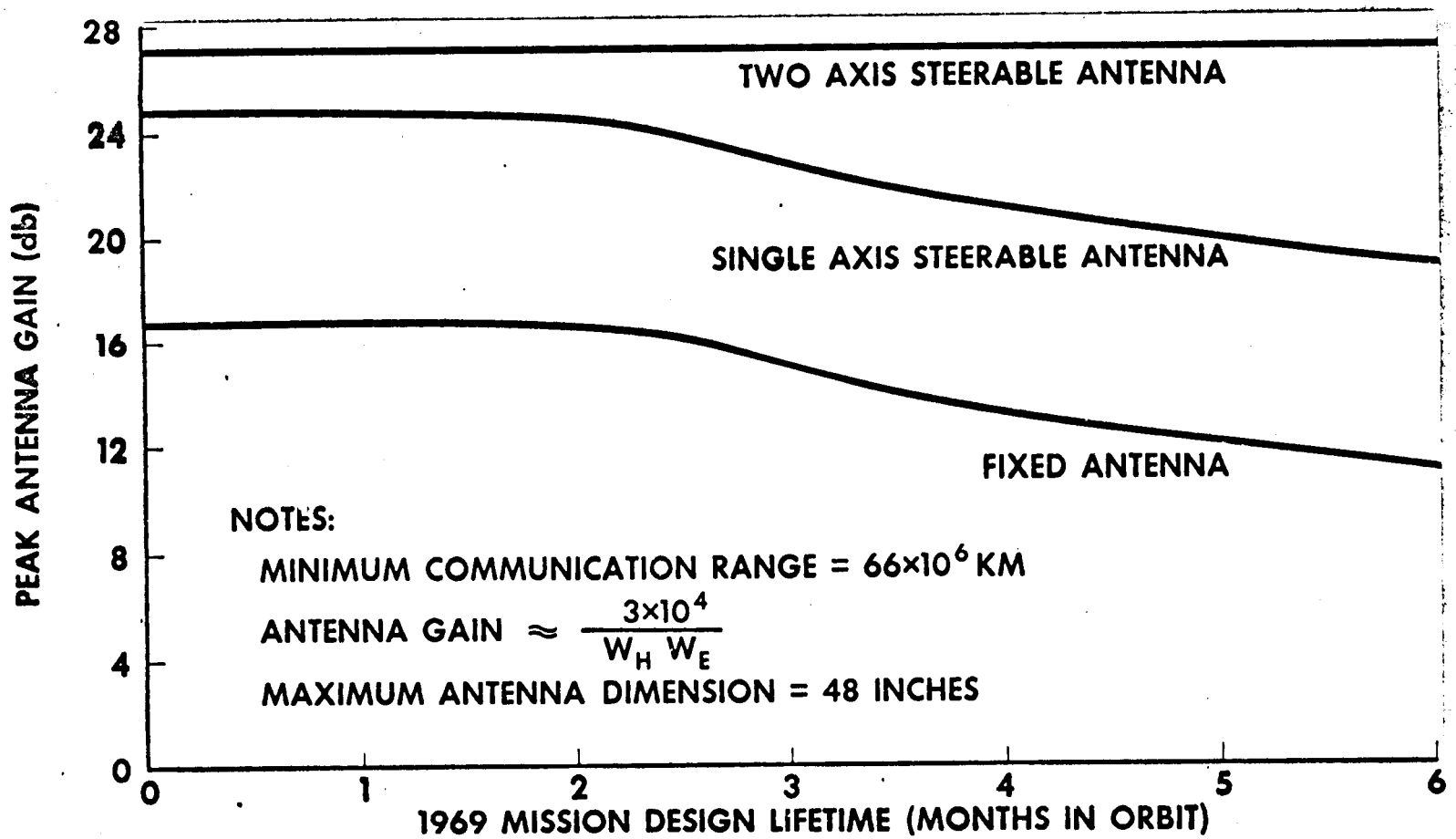
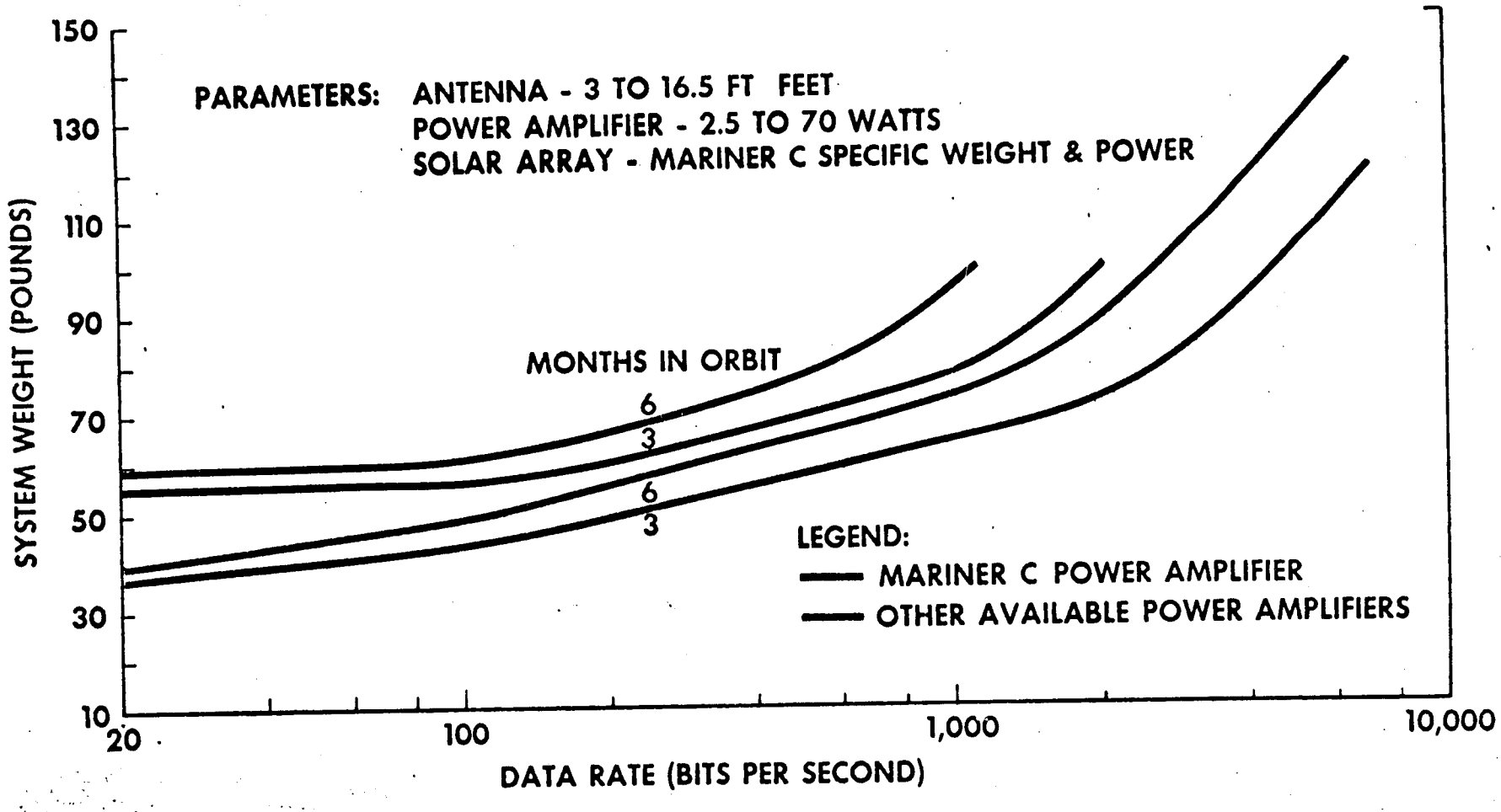
ANTENNA GAIN AT ENCOUNTER VS MISSION DESIGN LIFETIME 1969



ELECTRONICS SYSTEM WEIGHT VARIATION



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SPACECRAFT-EARTH COMMUNICATIONS CAPABILITY

ORBITER-EARTH LINK

- FREQUENCY: S-BAND
- MODULATION: COHERENT PSK
- ORBITER TRANSMITTER: 10 WATT TWT
- HIGH GAIN ANTENNA: 4 FEET
- COMMAND RATE: 1 bps
- DATA RATE:
  - INTERPLANETARY: 9 3/8 bps
  - AT ENCOUNTER: 300 bps
  - MISSION COMPLETION: 75 bps

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ORBITER DATA HANDLING SYSTEM

COMMAND

RATE	1 bps
DISCRETE CMDS	45 TO 47
QUANTITATIVE CMDS	17 OR 18
STORAGE	NDRO CORES

SEQUENCE TIMERS (10^{-4} ACCURACY)

TIMER	EVENTS	CAPACITY	RESOLUTION
SEPARATION	3	5 MIN.	1 SEC
MANEUVER	9	180 MIN.	1 SEC
DATA ACQUISITION	16	62 HRS	1 SEC
CAPSULE	2	96 HRS	1 MIN

DATA ACQUISITION SYSTEM

T/M MODE	CHANNEL REPETITION RATE (SECONDS) NON-VIDEO SCIENCE	VIDEO	STATUS
MANEUVERS	0	0	130
CRUISE	80	0	160
ORBIT (<17 DAYS)	90	3.7 HRS	21 MIN.
ORBIT (<2.5 MOS.)	180	7.4 HRS	42 MIN.
ORBIT (<2.5 MOS.)	360	14.8 HRS	84 MIN.

TAPE RECORDER

CAPACITY	6.6×10^7 BITS
RECORD RATE	33×10^3 bps
RECORD SPEED	11 IPS
MAX. SPEED REDUCTION	440: 1
BIT PACKING DENSITY	3000 BPI
TAPE LENGTH	1850 FT

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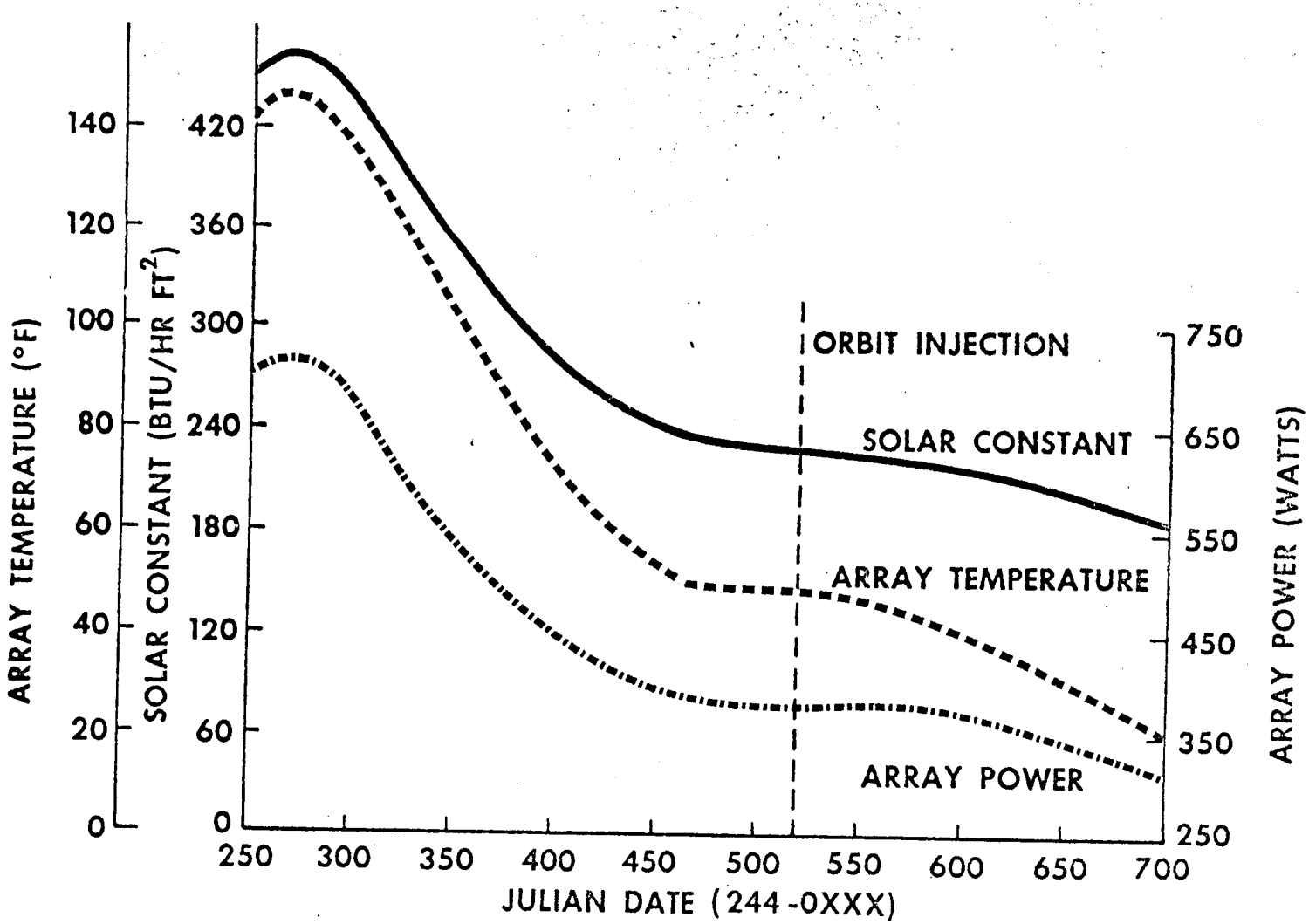
SOLAR ARRAY CHARACTERISTICS USING MARINER C PANELS
1969 Mission



SOLAR ARRAY POWER (WATTS)

REQUIREMENTS:

FUNCT \ MODE	CRUISE (NO CAP)		ON-ORBIT		CRUISE (W/CAP)	
	REG	UNREG	REG	UNREG	REG	UNREG
G & C	16	–	16	–	16	–
ELECTR	31	64	34	64	35	64
SCI. INST	14	–	27	–	14	–
THERM CONTR	–	5	–	–	–	15
BTRY CHG.	–	12	–	20	–	12
STATUS INST.	10	–	10	–	11	–
FAIL. SENSORS	10	–	15	–	10	–
SUB TOTALS	81	81	102	84	86	91
TOTALS (60% REG. EFF.)	216		254		234	

- MARINER-C ARRAY OUTPUT POWER: >310 WATTS
- PERFORMANCE MARGIN (MISSION END): 18%

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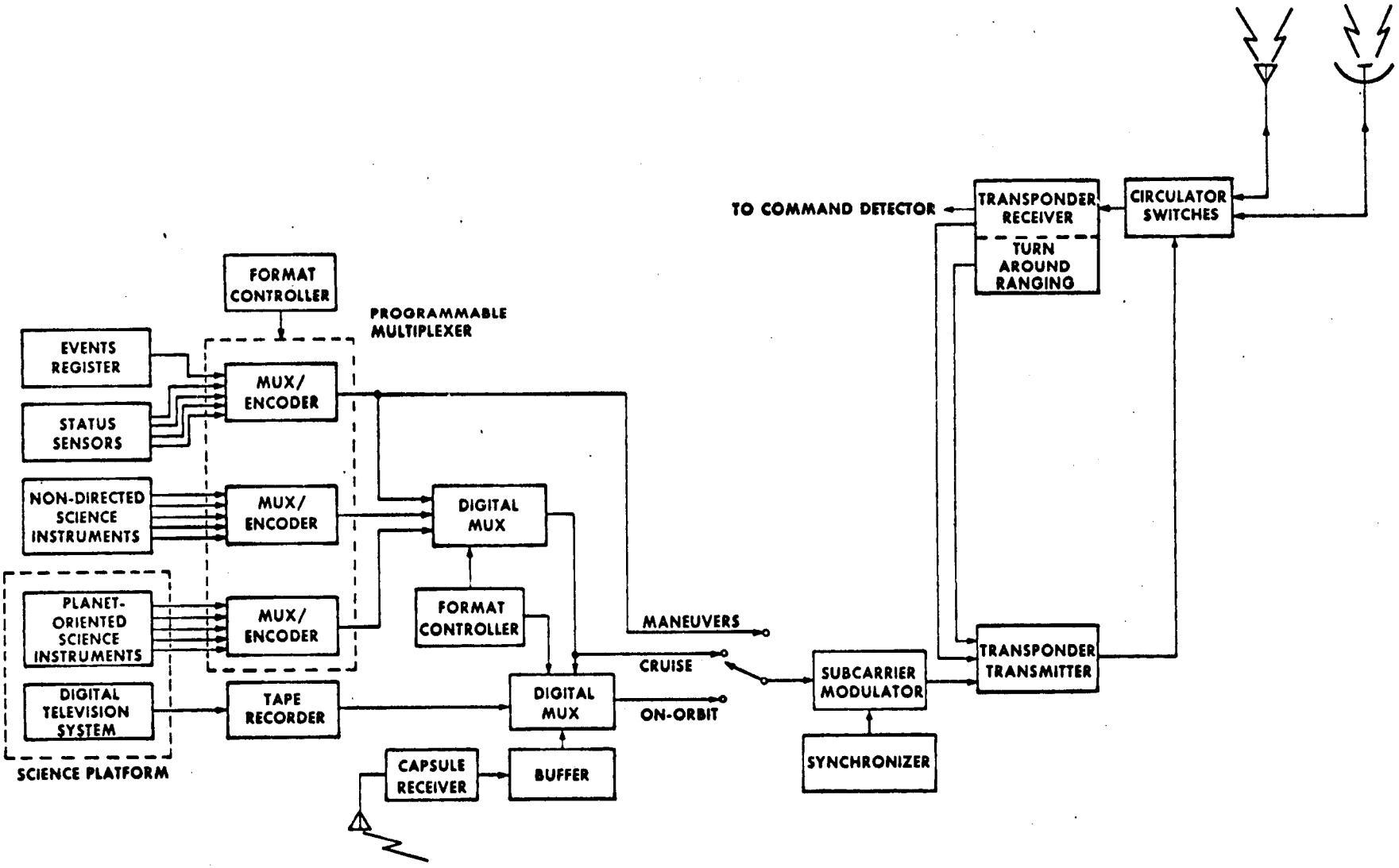
SYSTEM FUNCTIONAL BLOCK DIAGRAM
Part 1



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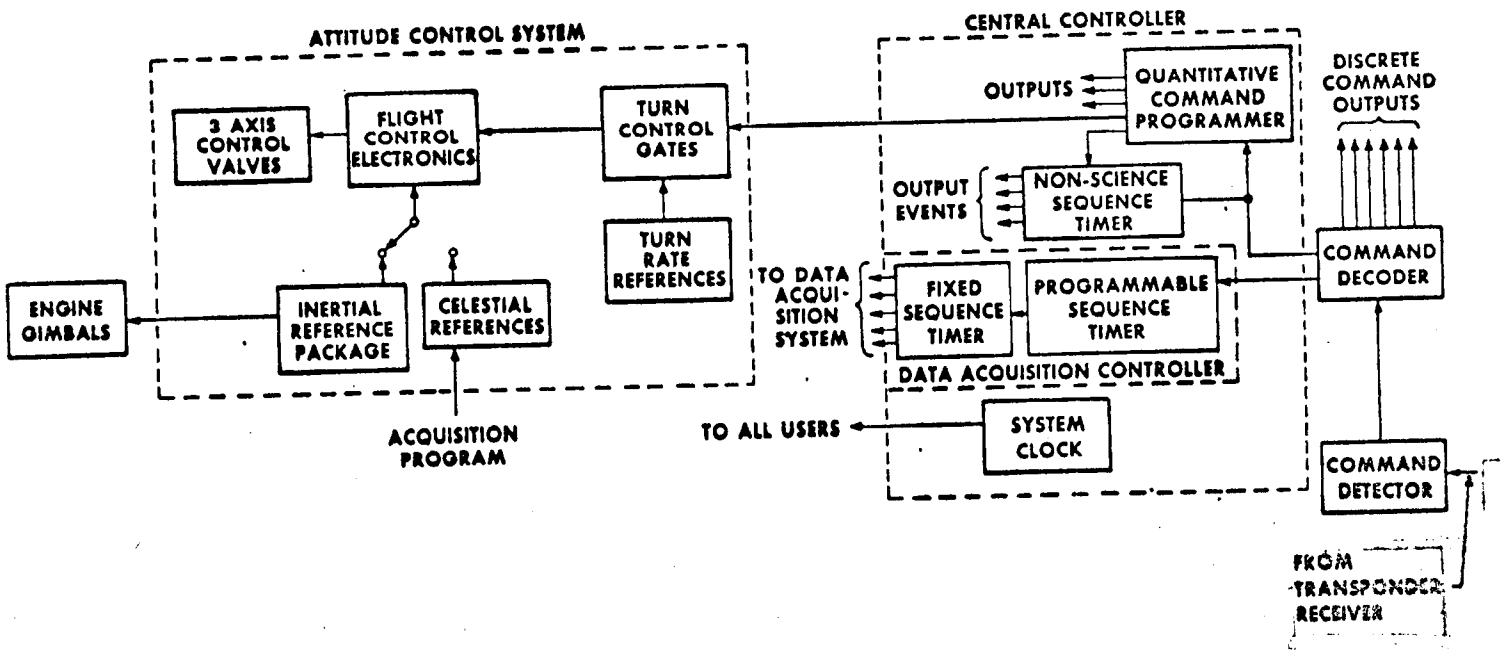
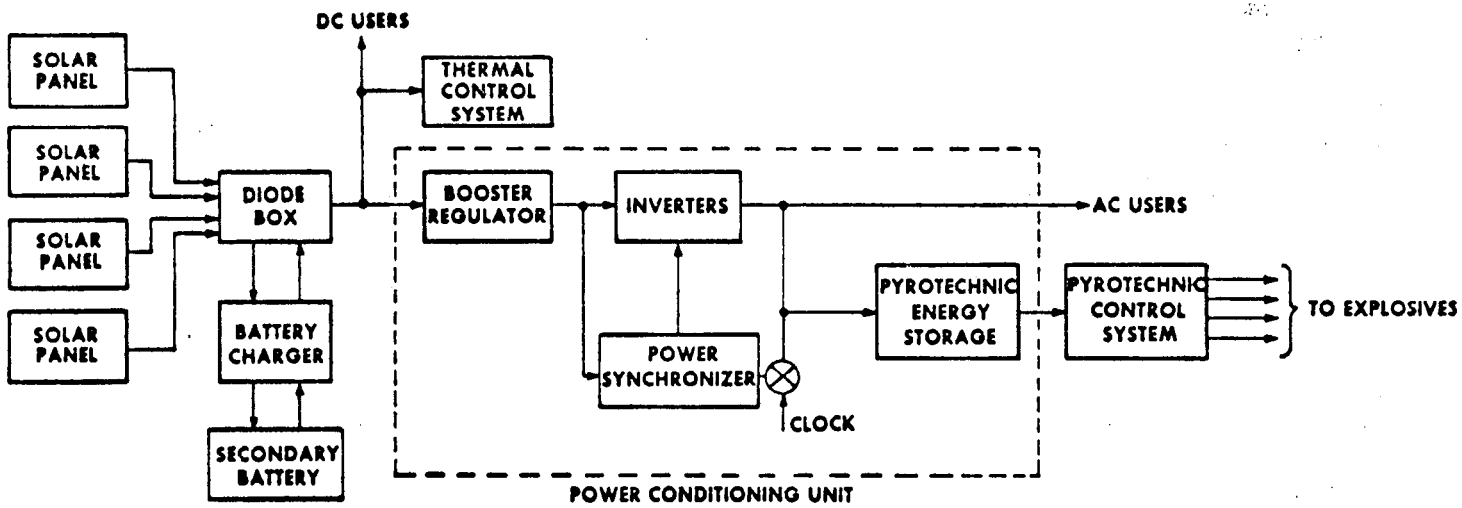
VOL I

SYSTEM FUNCTIONAL BLOCK DIAGRAM
Part 2



SYSTEM FUNCTIONAL BLOCK DIAGRAM
Part 3



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CAPSULE-ORBITER COMMUNICATIONS

SEPARATION LINK

FREQUENCY:	500 KC
MODULATION:	PCM-FM
ANTENNA:	LOOPS
TRANSMITTER:	10^{-3} WATTS
MAX. RANGE:	1000 FT
DATA RATE:	50 bps

ATMOSPHERIC ENTRY LINK

FREQUENCY:	250 MC
MODULATION:	PCM-FM
CAPSULE ANTENNA:	WHIP
ORBITER ANTENNA:	CROSSED DIPOLE
CAPSULE TRANSMITTER:	8 WATTS
MAX. RANGE:	10,000 KM
DATA RATE:	50 bps

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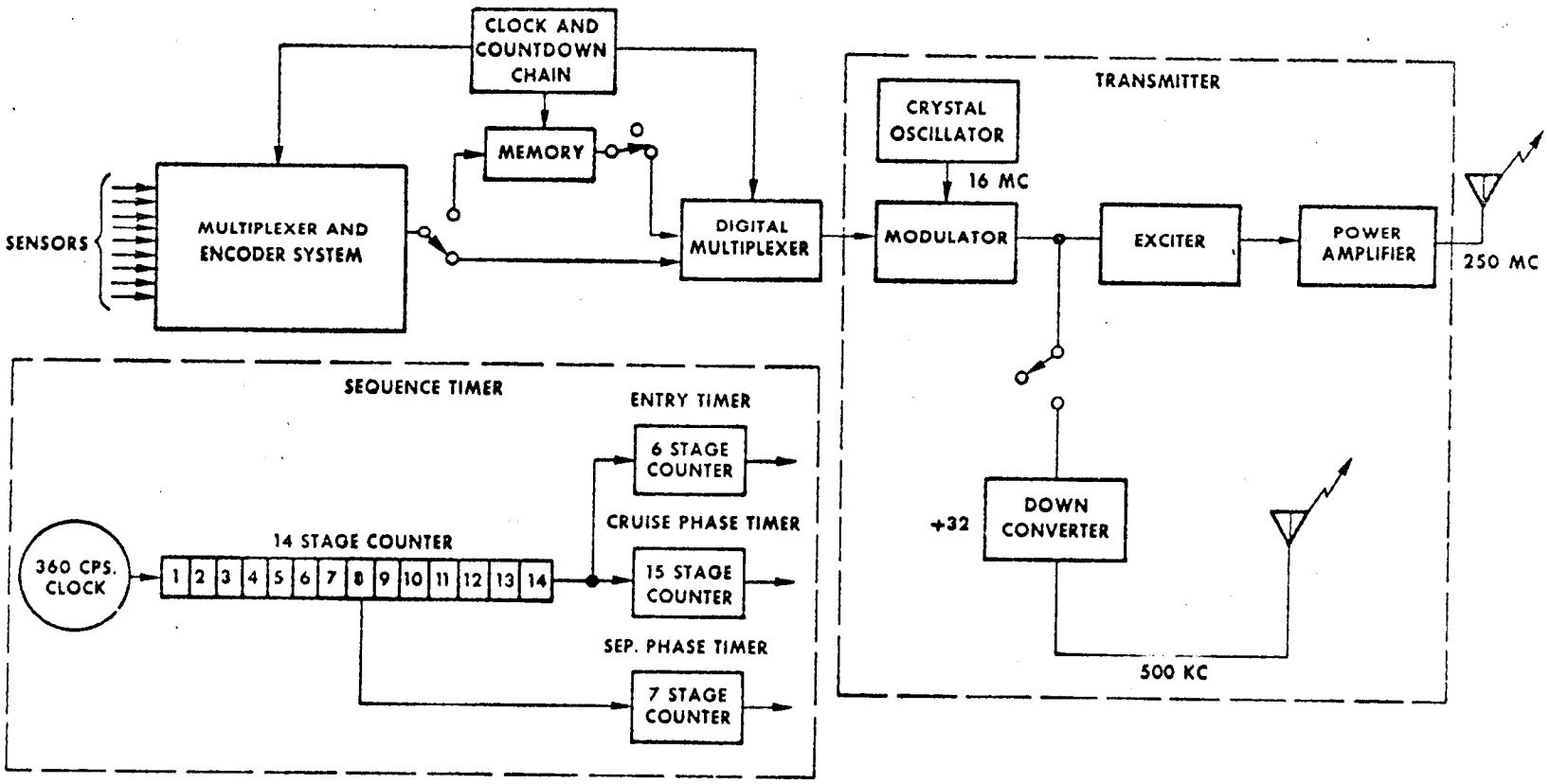
CAPSULE DATA HANDLING
Capsule



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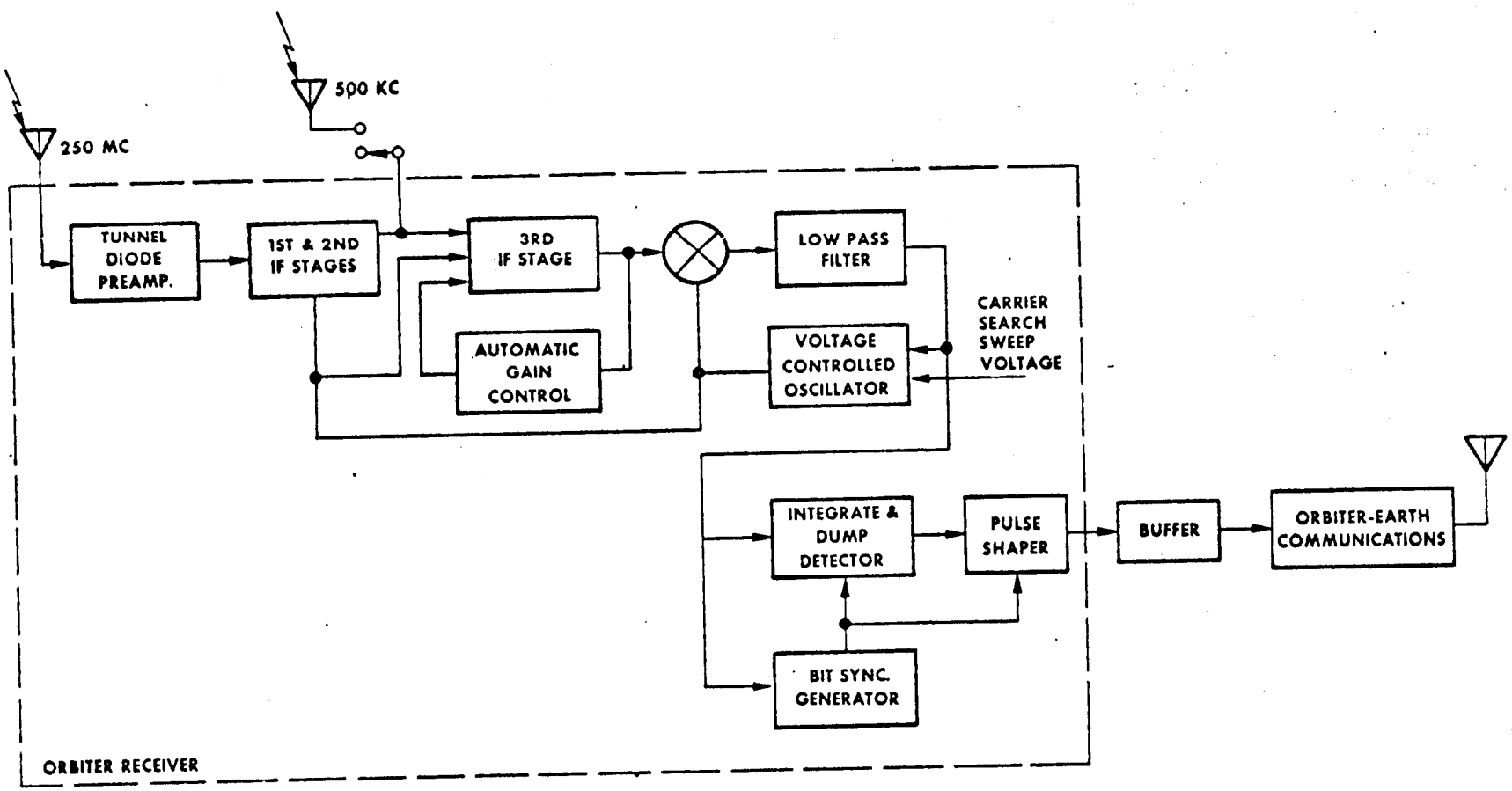
CAPSULE DATA HANDLING
Orbiter



BATTERY POWER

ORBITER

- TYPE: ..... Ag-Cd-KOH
- ENERGY REQUIRED: ..... 700 WATT HOURS
- SPECIFIC ENERGY: ..... 30 WATT HOURS/POUND
- BATTERY WEIGHT: ..... 23 POUNDS

ATMOSPHERIC CAPSULE

- TYPE: ..... Ag-Zn-KOH
- ENERGY REQUIRED: ..... 120 WATT HOURS
- ASSUMED SPECIFIC ENERGY: ..... 10 WATT HOURS/POUND
- BATTERY WEIGHT: ..... 12 POUNDS

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SELECTION OF PRIMARY PROPULSION SYSTEM

CANDIDATES

- DUAL LIQUID SYSTEM
  - BIPROPELLANT SYSTEM FOR ORBIT INJECTION
  - HYDRAZINE MONOPROPELLANT SYSTEM FOR TRAJECTORY CORRECTIONS
- SOLID-LIQUID SYSTEM
  - SOLID PROPELLANT MOTOR FOR ORBIT INJECTION
  - HYDRAZINE MONOPROPELLANT SYSTEM FOR TRAJECTORY CORRECTIONS
- SINGLE LIQUID SYSTEM
  - GAS FED STORABLE LIQUID BIPROPELLANT SYSTEM FOR BOTH ORBIT INJECTION AND TRAJECTORY CORRECTIONS

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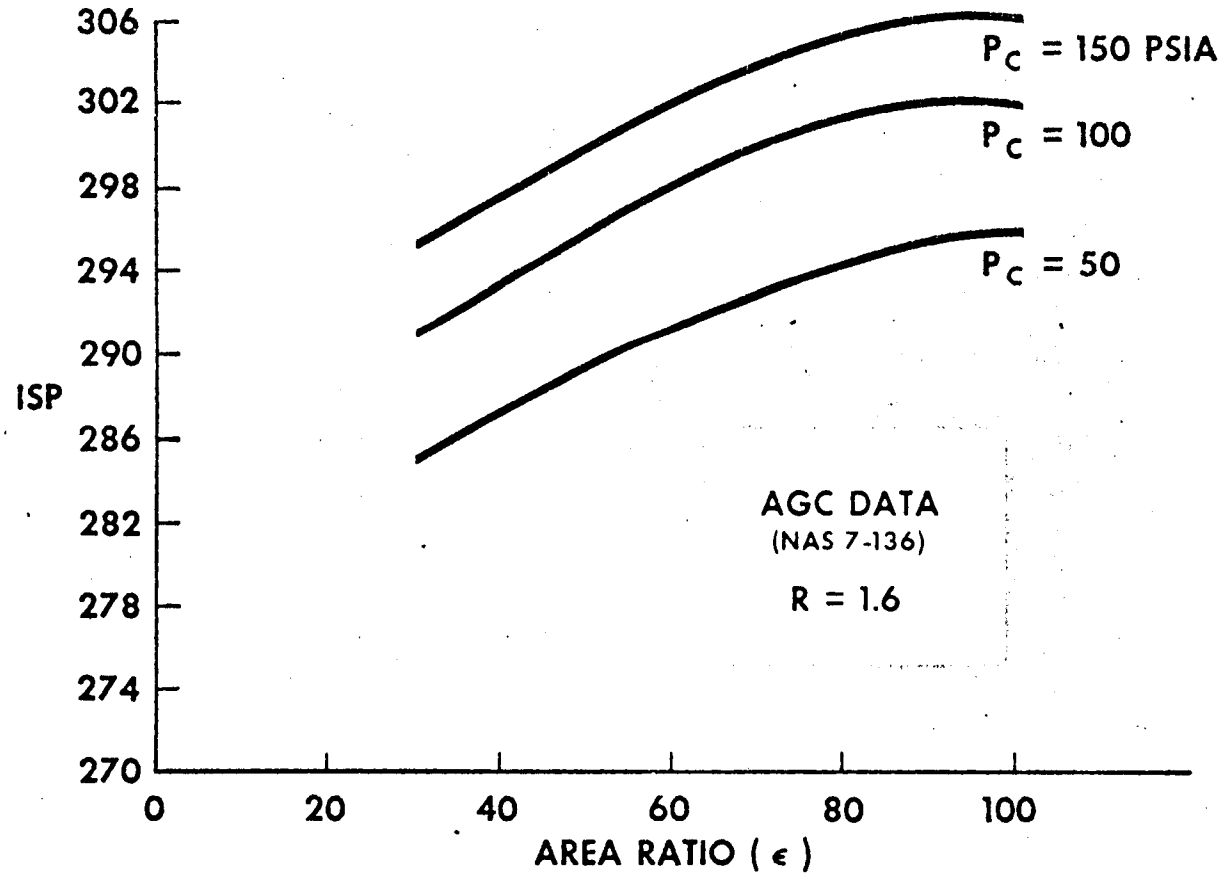
THRUST CHAMBER PERFORMANCE (N_2O_4/[illegible])



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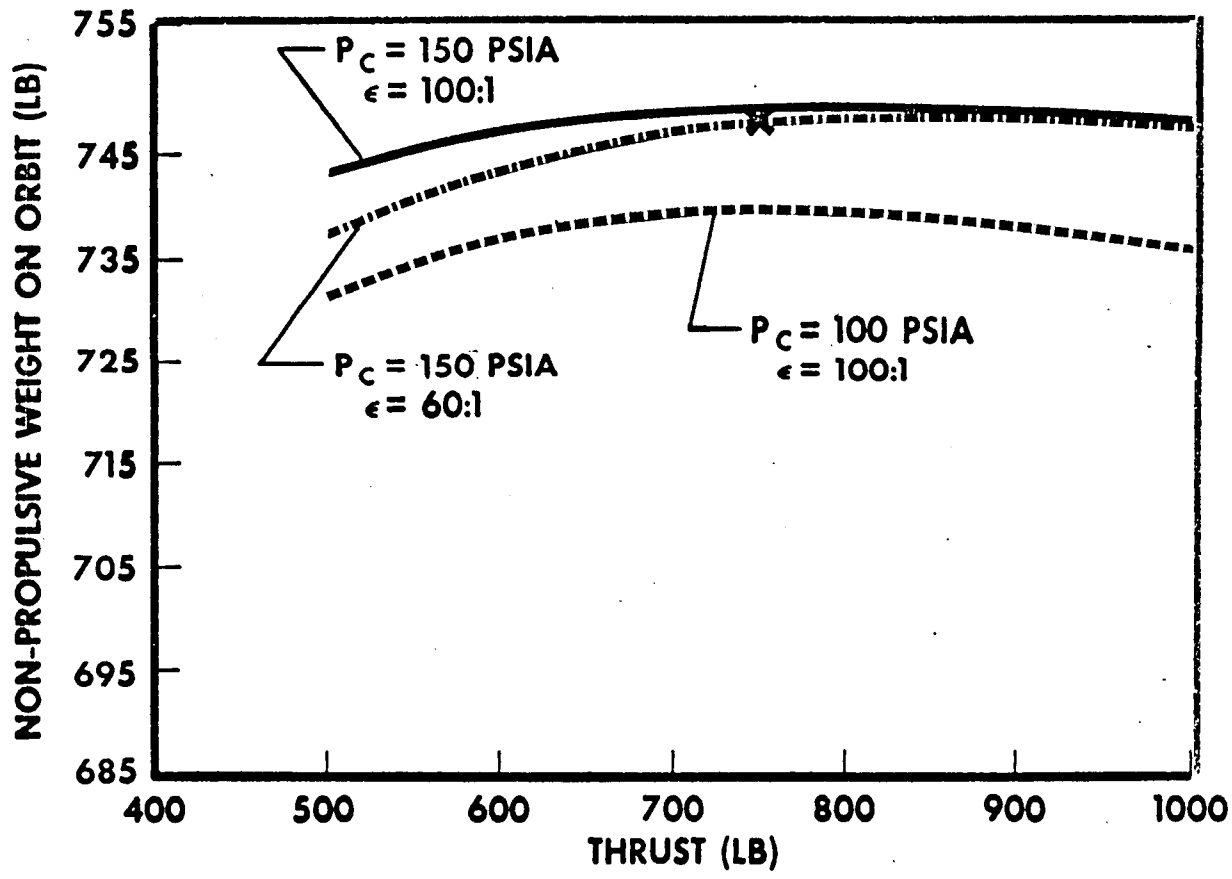
THRUST CHAMBER OPTIMIZATION



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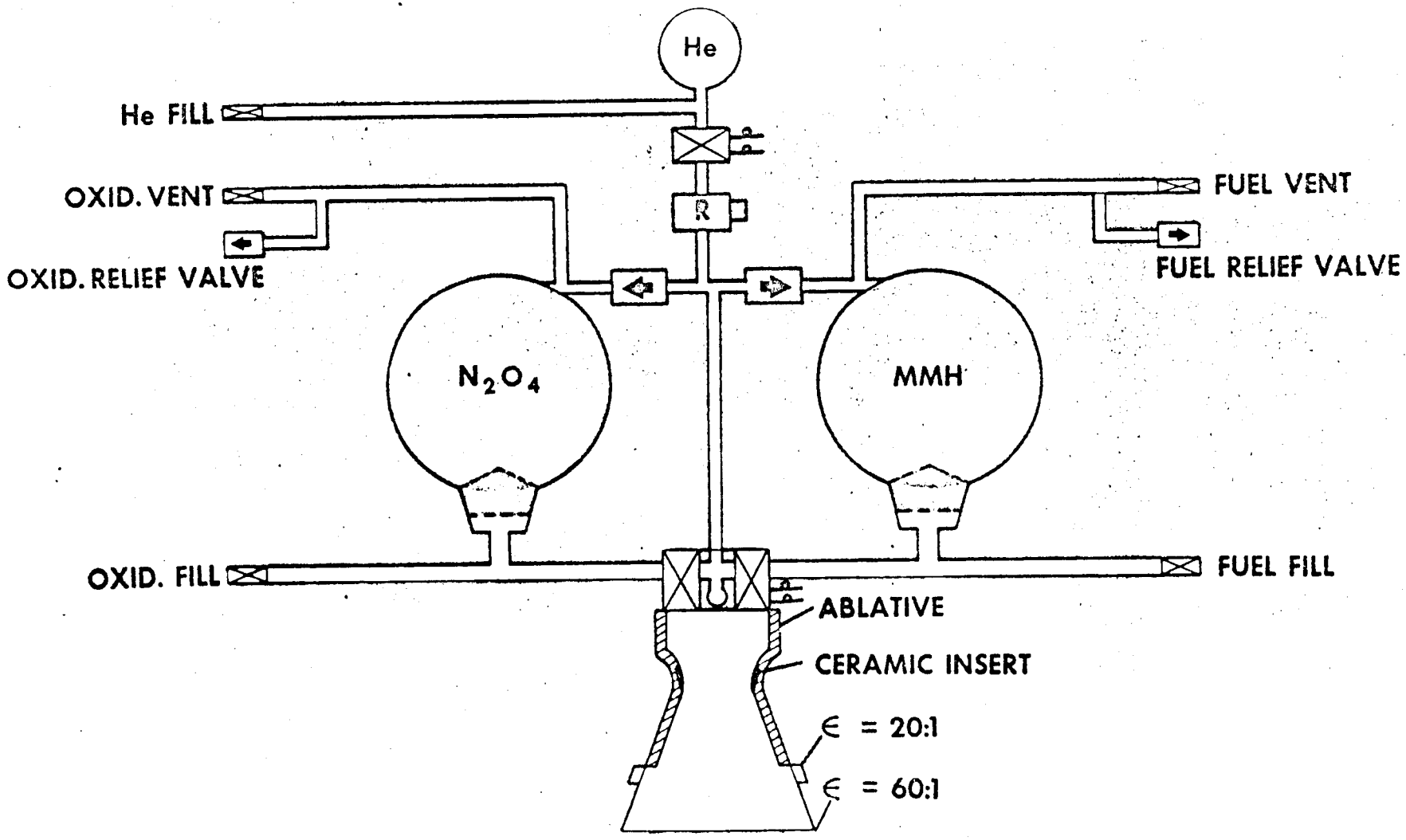
PRIMARY PROPULSION SYSTEM SCHEMATIC



PROPULSION SYSTEM DESIGN POINT

SPECIFIC IMPULSE	302 SEC
THRUST	750 LB
MIXTURE RATIO	1.6
AREA RATIO	60:1
CHAMBER PRESSURE	150 PSIA
TOTAL FLOWRATE	2.48 LB/SEC
OXIDIZER FLOWRATE	1.52 LB/SEC
FUEL FLOWRATE	0.96 LB/SEC
TANK OPERATING PRESSURE	250 PSIA

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ACP SYSTEM REQUIREMENTS

- TOTAL IMPULSE: 428 LB SEC (1285)
- MINIMUM IMPULSE BIT: .00260 LB SEC/20 M SEC
- THRUST/JET: .1084 LB
- DUTY CYCLE
  - MIN: 1 PULSE/2000 SEC
  - MAX: 0.374 SEC (SS)/1200 SEC

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SELECTION OF ACP SYSTEM

CANDIDATES

- COLD GAS
- LIQUID MONOPROPELLANT
- LIQUID BIPROPELLANT
  - LIQUID INJECTION
  - GAS INJECTION
- ENCAPSULATED SOLID PROPELLANT
- DECOMPOSING OR SUBLIMING SOLID PROPELLANT
- HYBRID

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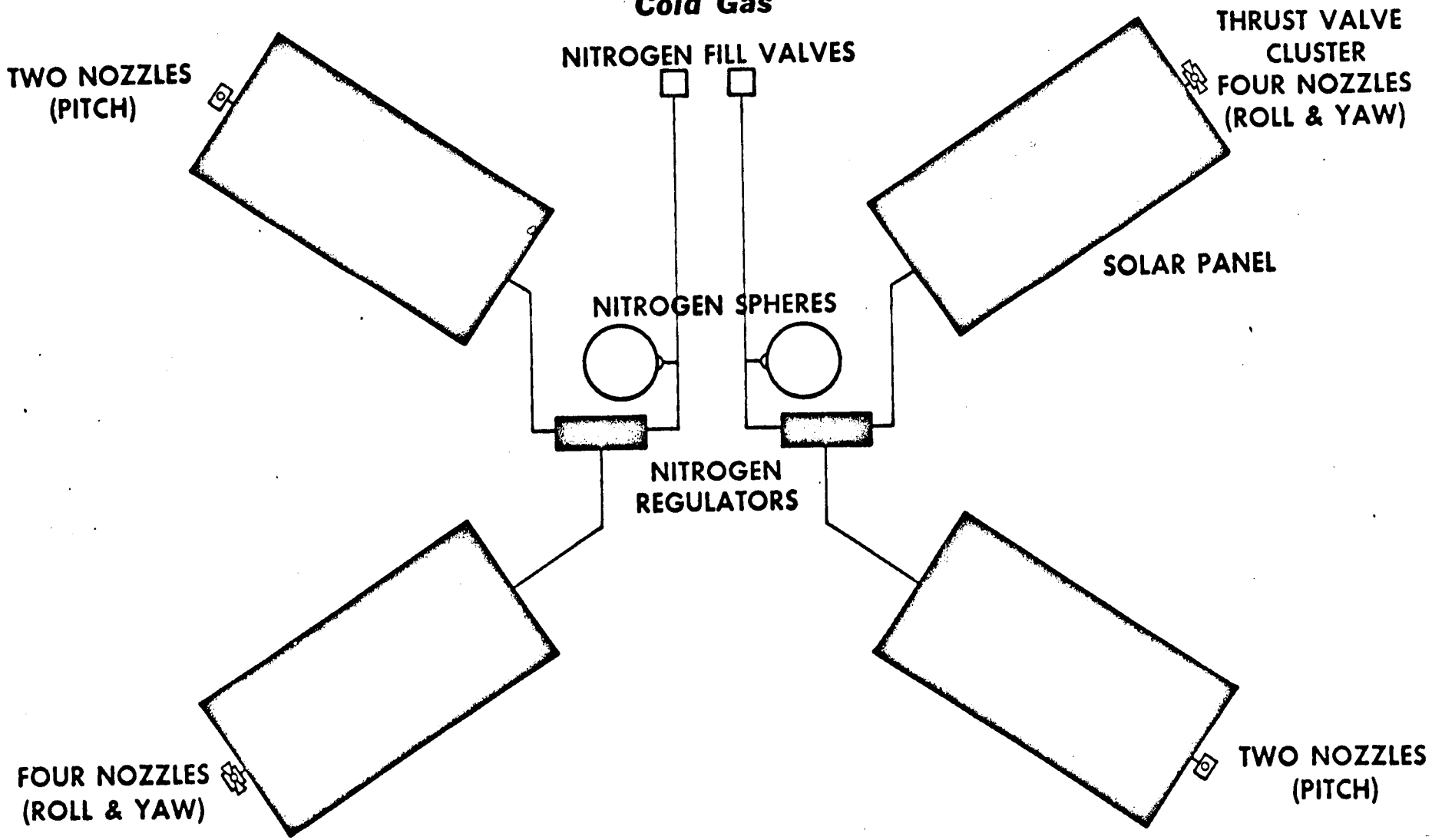
ACP SCHEMATIC
Cold Gas



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CAPSULE PROPULSION SYSTEM

- REQUIREMENTS
  - VELOCITY INCREMENT — 50 METERS/SECOND
  - TOTAL IMPULSE — 765 LB-SECONDS
  - BURN TIME — ≈ 10 SECOND
  - STERILIZATION — 293°F-36 HOURS (3 CYCLES)
  - EMI — NO METALS

- DESIGN DATA
  - ARC STERILIZABLE PROPELLANT "ARCITE 413"
    - CURED @ 350°F
    - I_{SP} 220
    - SYS. WT ≈ 6 LB

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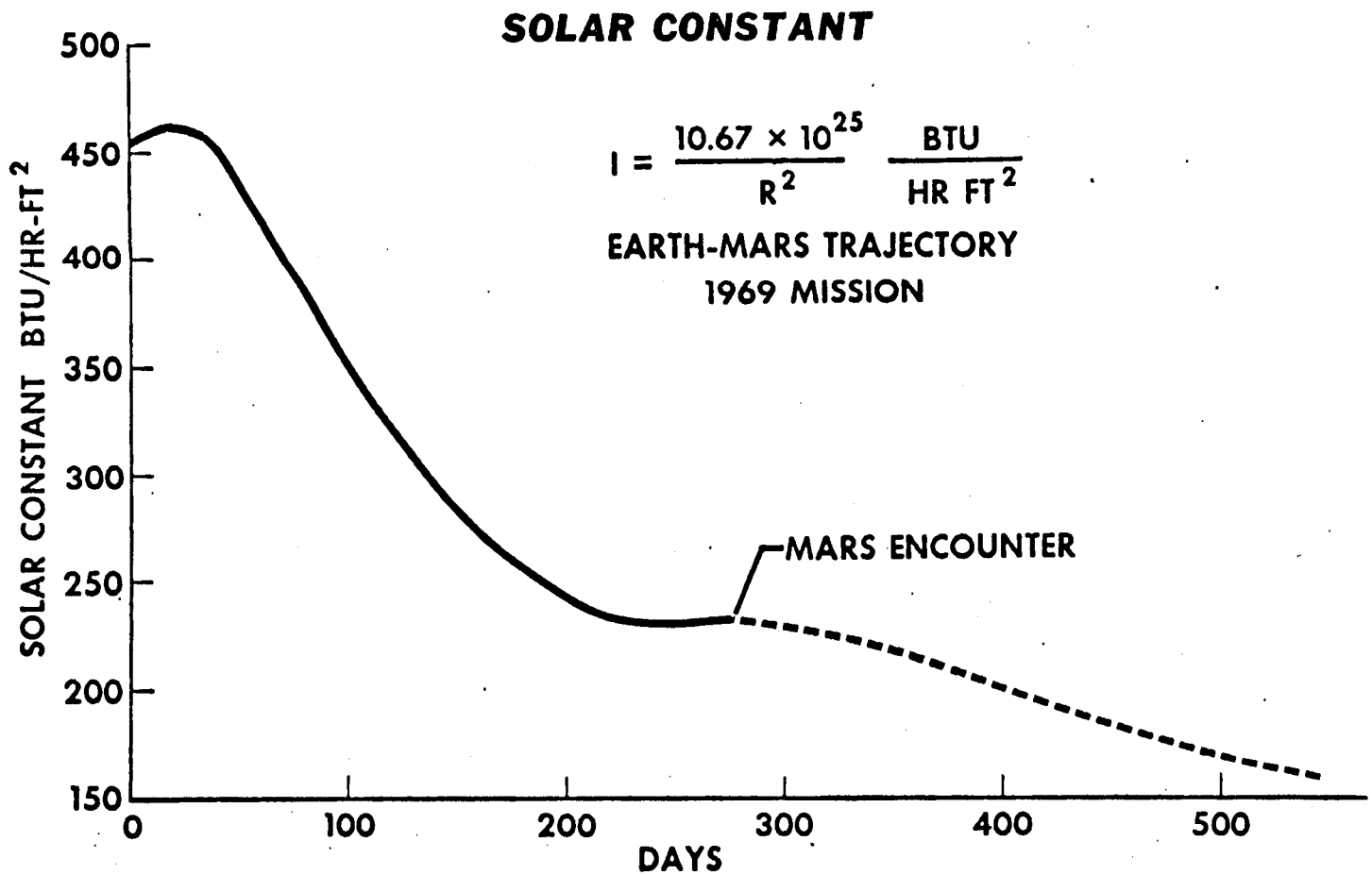
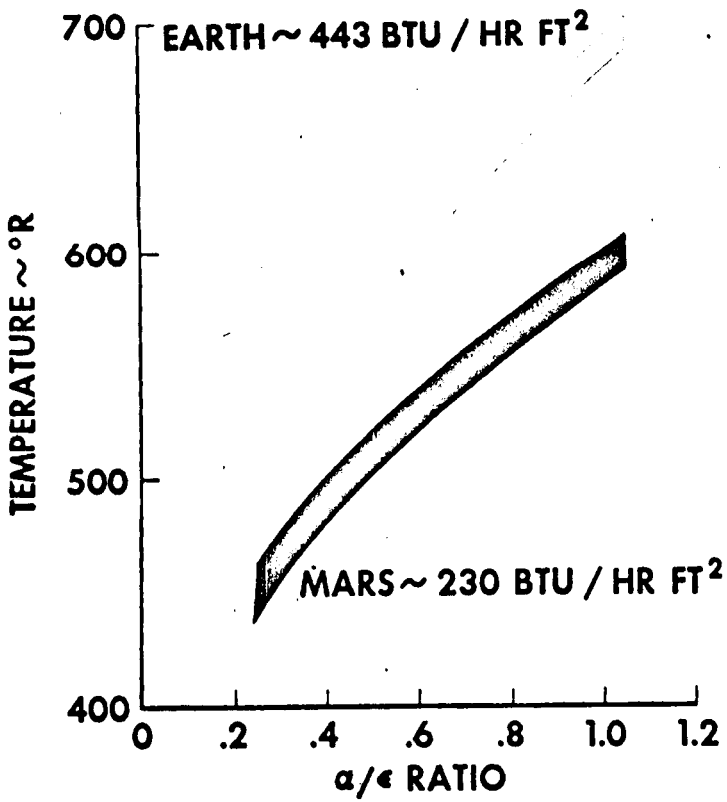
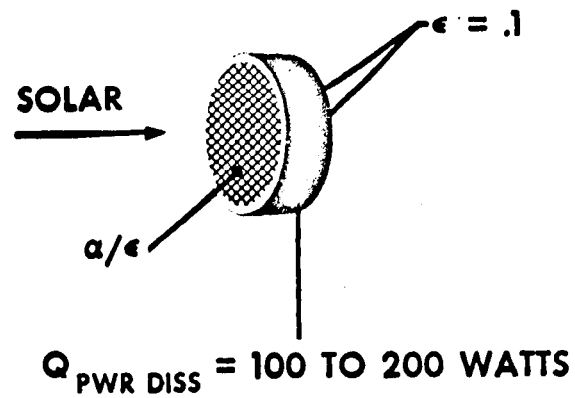
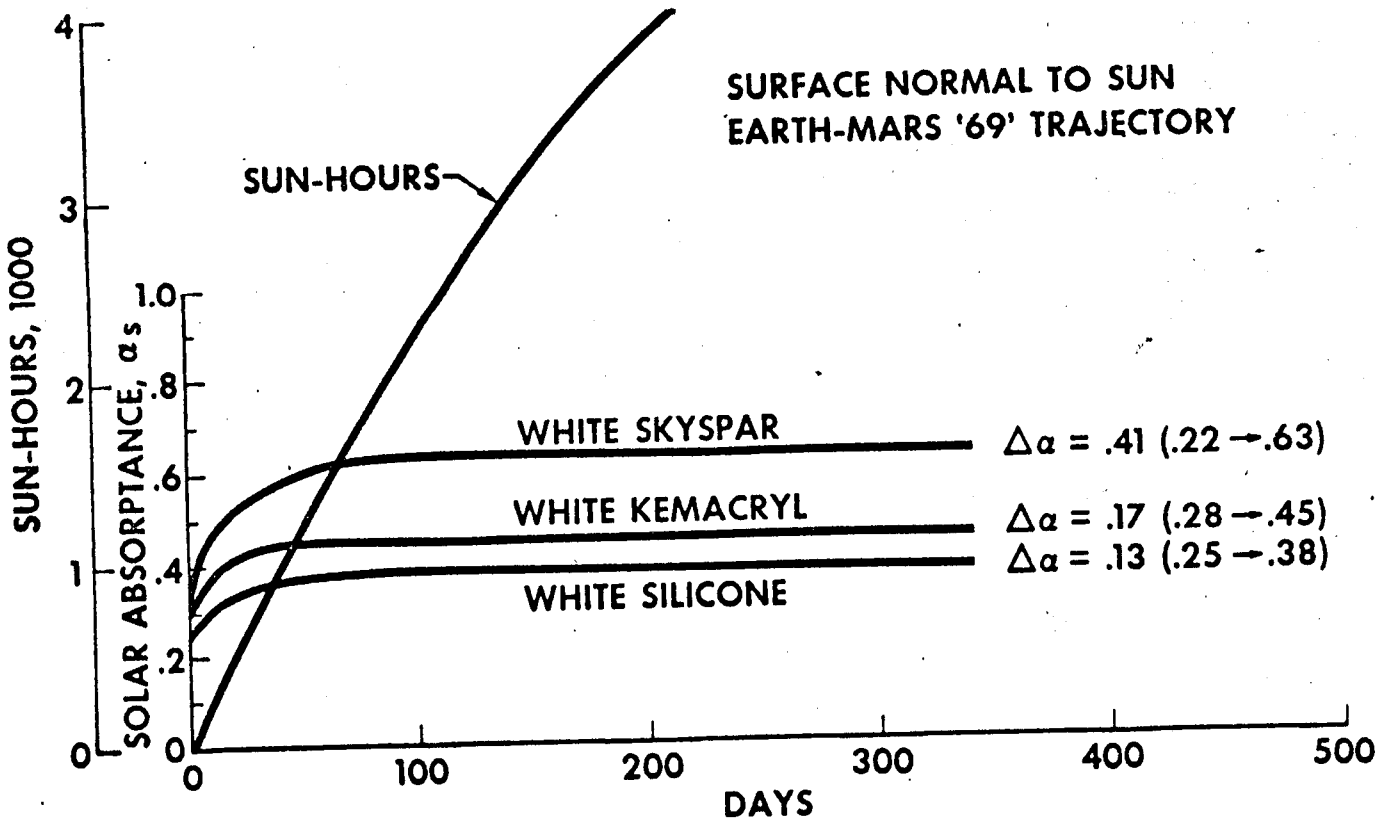


ORBITER TEMPERATURES vs α/ϵ RATIO





DEGRADATION OF WHITE PAINTS



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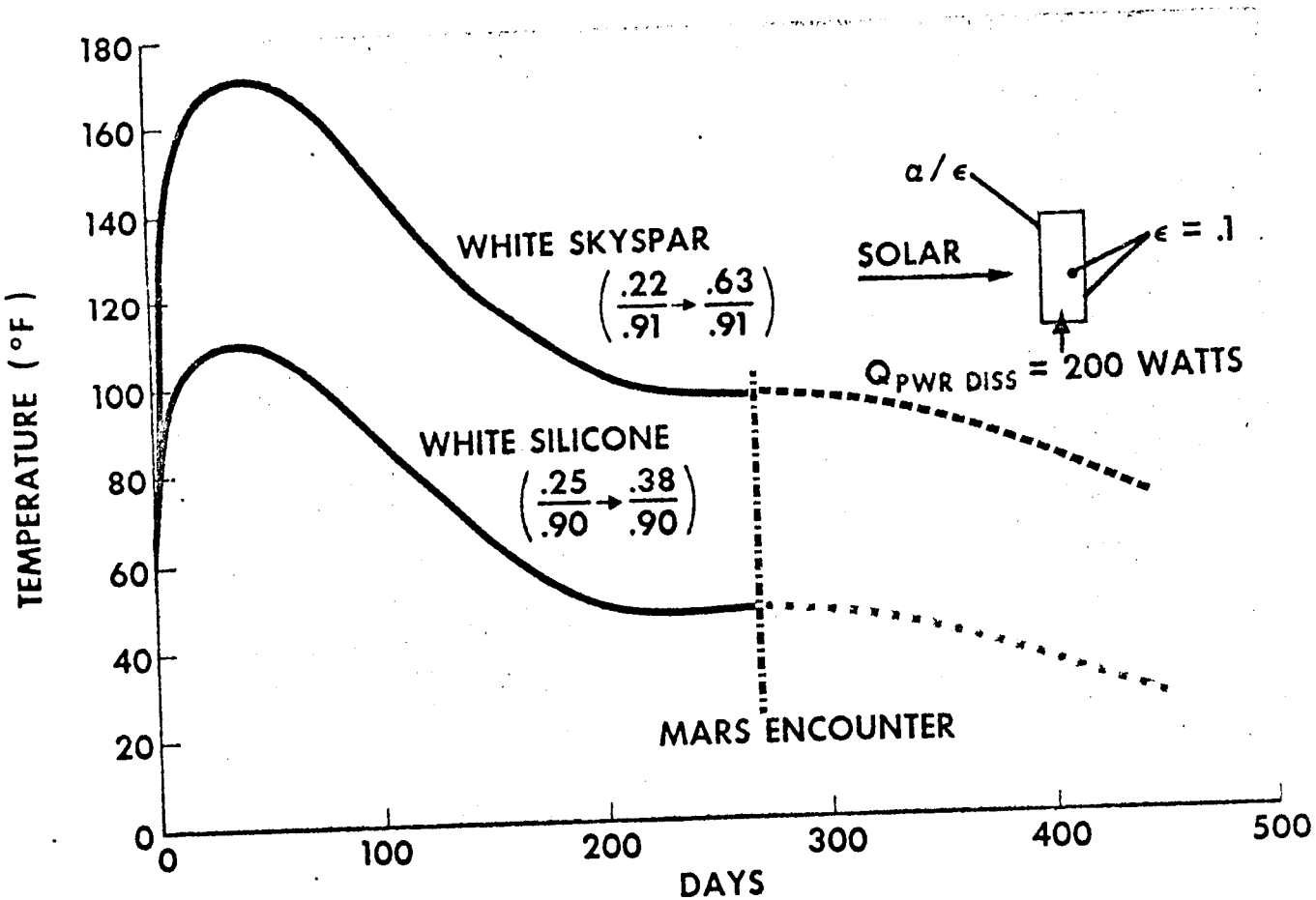
ORBITER TEMPERATURES
Earth-Mars 1969 Trajectory



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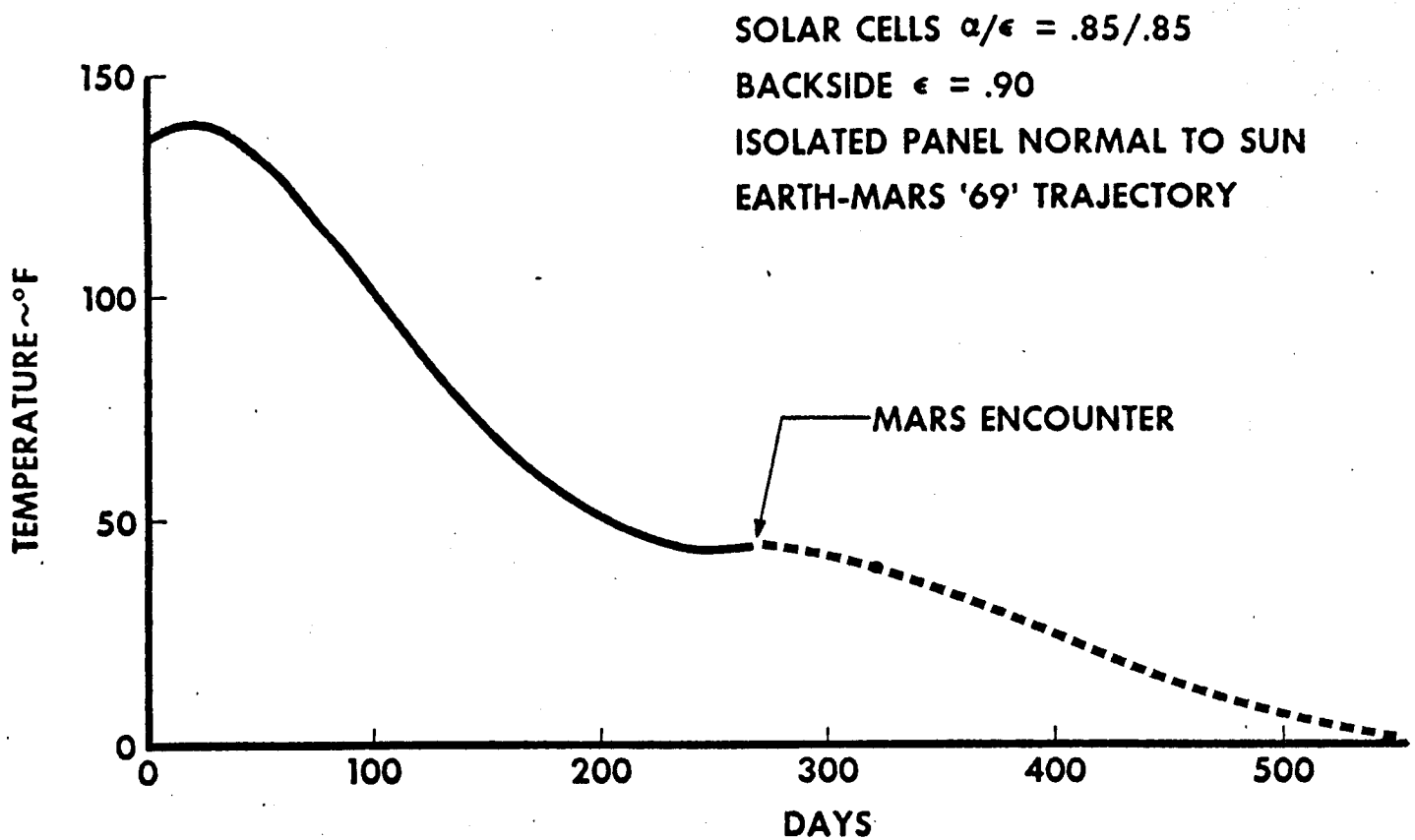
SOLAR PANEL TEMPERATURES



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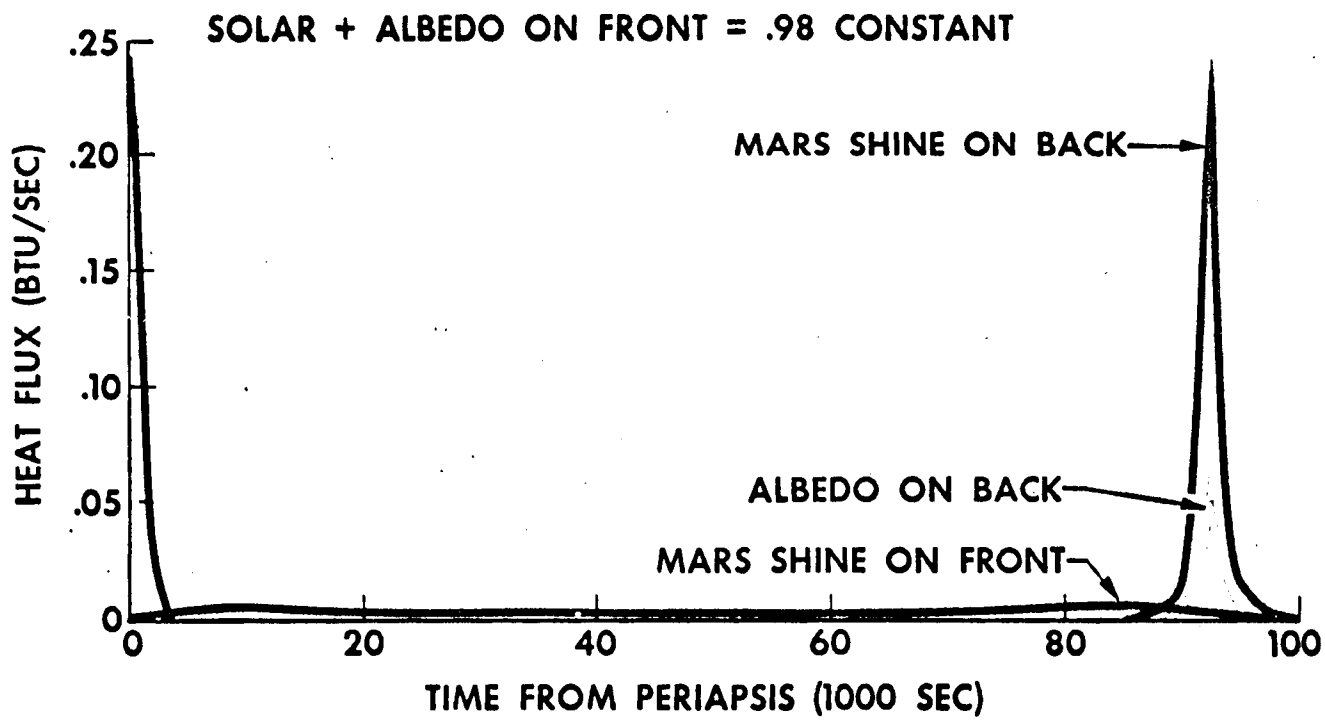
ABSORBED FLUXES ON TYPICAL SOLAR PANEL



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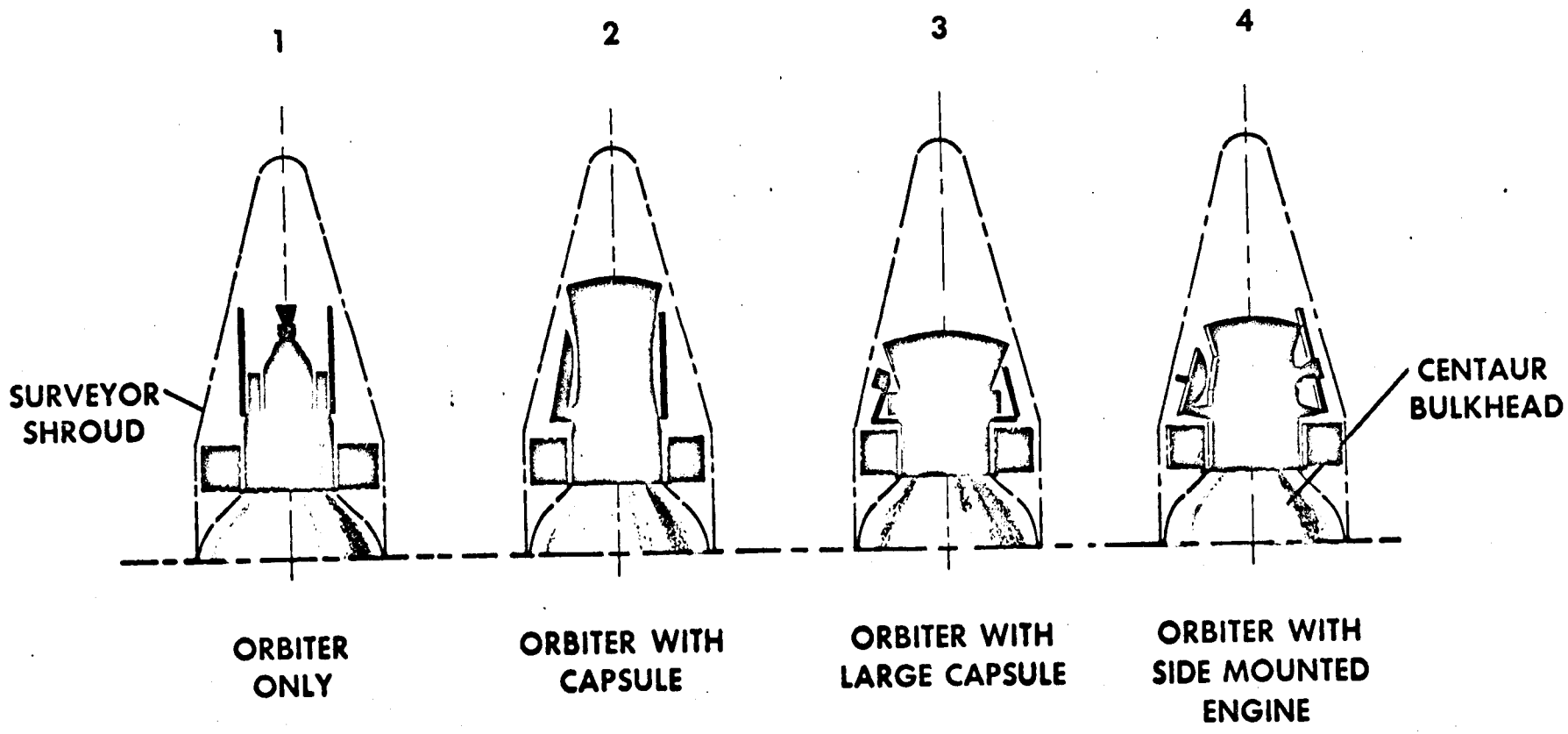
SPACECRAFT CONCEPTS



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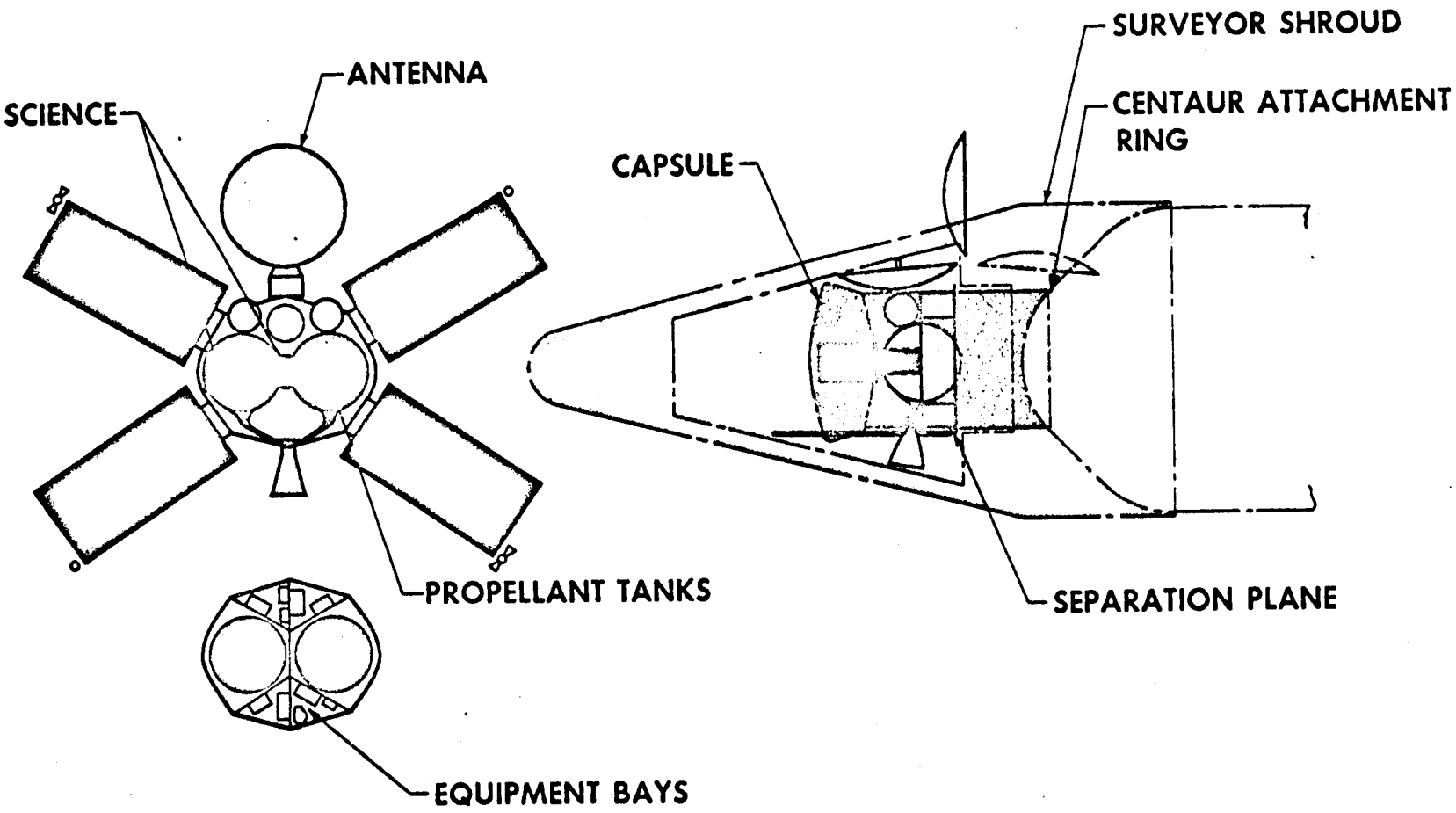
DETAIL OF CONFIGURATION 4



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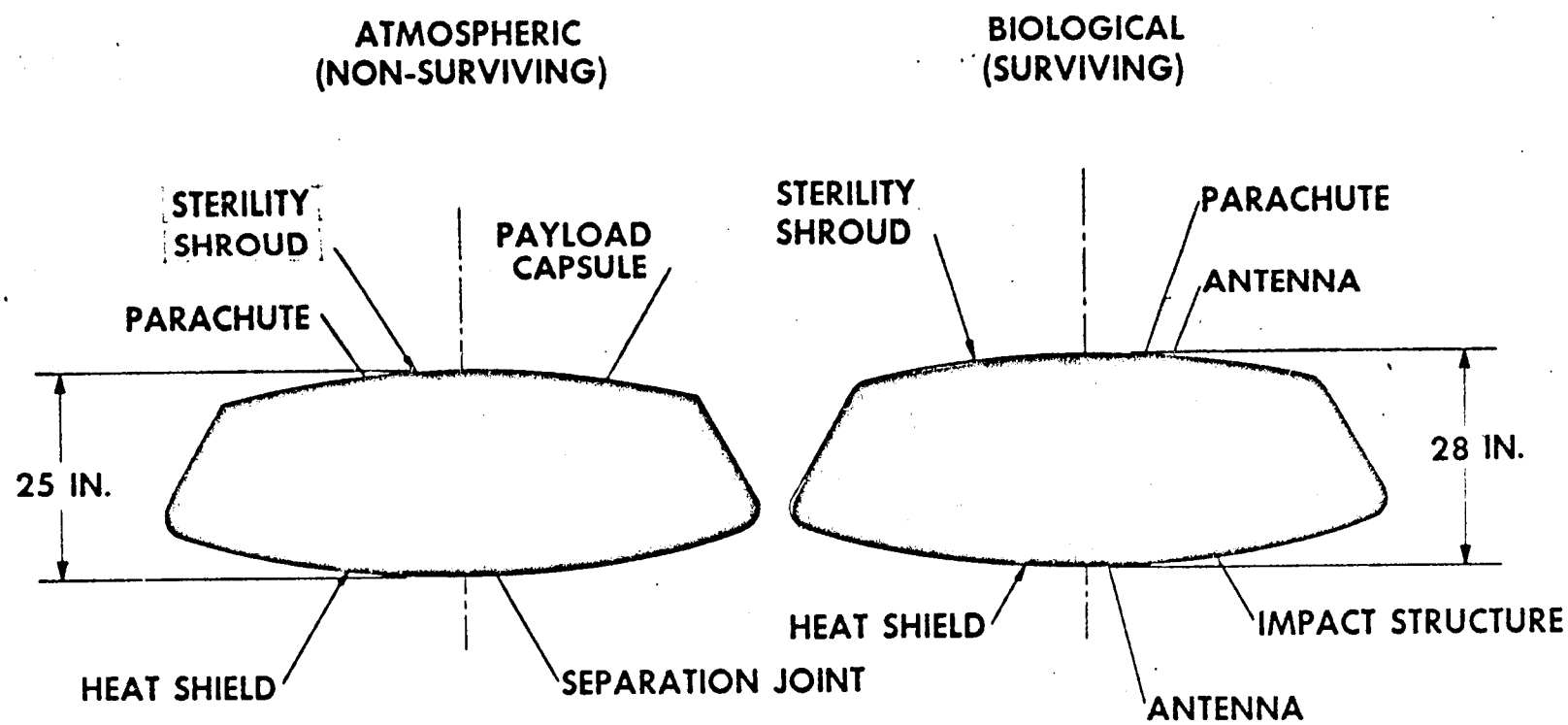
CAPSULE CONCEPTS
61 In. Diameter



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STRUCTURAL CONCEPTS

- SPACECRAFT
  - SPACEFRAME

    TUBULAR OR CRUCIFORM TRUSSES WITH PRIMARY EQUIPMENT MODULES ADDED
  - RING/SKIN/STRINGER

    COMPLETELY ENCLOSED PRIMARY STRUCTURAL SHELL WITH EQUIPMENT INSTALLED ON FLOOR & SHEAR BEAMS
- SPACECRAFT/CENTAUR ADAPTER
  - SPACEFRAME
  - HONEYCOMB SANDWICH
  - STIFFENED SHELL
  - RING/SKIN/STRINGER
- CAPSULE SUPPORT STRUCTURE
  - SPACEFRAME (TUBULAR TRUSS)

MATERIAL SELECTION

- PRIMARY STRUCTURE
  - ALUMINUM 7075-T6
  - BERYLLIUM/ALUM ALLOY (LOCKALLOY)
  - MAGNESIUM HK31A-H24 (SHEET & PLATE)
    ZK60A-T5 (EXT. & FORGINGS)
    HM21-T8 (HIGH TEMP.)

- PROPELLANT TANKS
  - FIBERGLASS
  - TITANIUM
  - STAINLESS STEEL
  - ALUMINUM 2219-T87 (7106,7039)

- SPACECRAFT/CENTAUR ADAPTER & CAPSULE SUPPORT STRUCTURE
  - LOCKALLOY
  - ALUMINUM
  - MAGNESIUM HM31A-H24, ZK60A-T5

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WEIGHT BREAKDOWN-CONFIGURATION 4 BASIC SPACECRAFT
Less Impulse Propellants

SUBSYSTEM	WEIGHT (LB)
STRUCTURE	87
PROPULSION	112
POWER	189
ELECTRONICS	146
THERMAL CONTROL	15
*GUIDANCE	29
*ATTITUDE CONTROL	82
TOTAL	660

*INCLUDES 100% REDUNDANCY ON COMPONENTS AND 200% REDUNDANCY ON CONTROL GAS

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WEIGHT SUMMARY 1969 ORBITER NO CAPSULE
Config. 4

	0% FLOX	20% FLOX	30% FLOX
BASIC SPACECRAFT	645	660	665
SCIENCE PAYLOAD	18	132	132
ORBIT INJECTION-WT. REQD.	663	792	797
REDUNDANCY & CONTINGENCY	72	148	253
ORBIT INJECTION WT. CAPABILITY	735	940	1050
PROPELLANT +9 LB GAS	805	1020	1125
CENTAUR ADAPTER	40	50	55
TOTAL VEHICLE WT.	1580	2010	2230

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WEIGHT SUMMARY 1969 ORBITER WITH ATMOS CAPSULE
Config. 4

	0% FLOX	20% FLOX	30% FLOX
BASIC SPACECRAFT	668	683	688
SCIENCE PAYLOAD ON BASIC SPACECRAFT	18	88	88
CAPSULE ADAPTER & SEPARATION MECHM.	18	18	18
ORBIT INJECTION WT. REQUIRED	704	789	794
REDUNDANCY & CONTINGENCY	(–49)	71	171
ORBIT INJECTION WT. CAPABILITY	655	860	965
CAPSULE COMPLETE (SCIENCE 18 LB)	164	164	164
PROPELLANT +9 LB GAS	721	936	1046
ADAPTER, CENTAUR	40	50	55
TOTAL VEHICLE WEIGHT (LBS)	1580	2010	2230

WEIGHT SUMMARY ATMOSPHERIC CAPSULE

	STERILE ASSEMBLY 61 IN. DIA	HEAT STERILIZED 61 IN. DIA	HEAT STERILIZED 45 IN. DIA
SCIENCE	18 LB	18 LB	18 LB
STERILITY SHROUD ASSEMBLY	22	24	13
HEATSHIELD	33	33	18
HEATSHIELD BACKUP STRUCTURE	17	19	10
GUIDANCE ROCKET	10	11	8
PAYLOAD CAPSULE STRUCTURE	11	12	12
ELECTRONICS	25	25	25
BATTERY & CONVERTER	5	15	15
INSULATION ETC.	2	2	2
PARACHUTE SYSTEM	3	4	4
TOTAL CAPSULE WEIGHT	146	163	125
TOTAL WEIGHT AT ENTRY	121	135	109
WEIGHT ON PARACHUTE	64	76	76