NASA-CR-192643

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(NASA-CR-192643) VOYAGER CAPSULE SYSTEM (Martin Co.) 108 p

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VOYAGER CAPSULE SYSTEM

NASA
7N-18-CR
151431
P-108

Presentation at

Ames Research Center September 1, 1966

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MARTIN COMPANY
DENVER, COLORADO

VOYAGER CAPSULE SYSTEM

Presentation at

Ames Research Center September 1, 1966

PR-22-16-1

MARTIN COMPANY
DENVER, COLORADO

Reports to PROGRAM DIRECTOR, SPACE SCIENCE SYSTEMS

Voyager Program
PROGRAM DIRECTOR
C. de Moraes

VOYAGER ALTERNATE DESIGN CONCEPTS
J. Isenberg

SCIENCE OBJECTIVES
W. Bender

VOYAGER REQUIREMENTS
N. Paradiso

MANAGEMENT OPERATIONS DIRECTOR
C. Castle

- FACILITIES — D. Justice
- CONTRACTS — L. Baldassari
- PLANS & FINANCE — J. Watson
- ADMINISTRATION — R. Bosworth
- CONFIGURATION and DATA MANAGEMENT — R. Jones

ENGINEERING TECHNICAL DIRECTOR
R. Scarborough

- SCIENCE SYSTEM — W. Bender*
- THERMAL CONTROL and PROPULSION — C. Brown
- TELECOMMUNICATION and POWER — W. Mielziner
- GUIDANCE & CONTROL — D. Bjorndahl
- SYSTEMS ENGINEERING — R. Wiltshire
- ENGINEERING MECHANICS — R. Seiferth

RELIABILITY, TEST, STERILIZATION and QUALITY PROGRAM MANAGER
A. Rothstein

- STERILIZATION — H. Kaufman
- TEST — L. Edelstein
- RELIABILITY — A. Rothstein*
- QUALITY — G. Browne

MANUFACTURING and MATERIEL PROGRAM MANAGER
J. Wilson

- MANUFACTURING — A. Rhoads
- PROCUREMENT — P. Shuey

SUMMARY

Carlos deMoraes

VOYAGER PROGRAM DIRECTOR

The scope and complexity of the Voyager Program involves the solution to a technically sophisticated design and to a multiplicity of interfaces - both systems and organizational. This latter task, of "getting ones arms around the total problem", i.e., of defining responsibilities and interfaces, and of allocating resources is at least the magnitude of - and indeed is inseparable from - the technical challenge.

Experience has taught us that the best systems result when our approach has been to "develop it once" and to minimize the number of new developments. Development of sterilizable hardware technology is a formidable task and a requirement. Engineering judgment dictate the rest. The Automated Biological Laboratory - or whatever sophisticated form the '79 capsule takes - will require a soft landing. Adaptation of this approach for the '73 opportunity - even in a modified form - permits concentration on a single technological development. While this technology must be adapted to the particular requirements of the Voyager Capsule, it is already under development - by NASA.

The technical discussion herein addresses the development of a soft landing capsule for 73. The management discussion is based on applying the lessons of PRIME, Gemini Launch Vehicle, SPRINT, and the Titan series to the particular requirements of the Voyager Capsule. In these programs, as with the Capsule, identifying the critical technical/management problems for top management attention and assessing technical progress are the crucial tasks. The described technique of Planned Value Work Accomplished (PVWA), in particular, has proven a powerful tool.

TECHNICAL PRESENTATION

SCIENCE OBJECTIVES

W. Bender

VOYAGER PROGRAM SCIENTIST

We are concerned with understanding the probable experiments in sufficient depth to define requirements on all spacecraft subsystems which affect the performance of these experiments.

A typical reference list of first eschelon experiments for a soft lander during entry and landed phases is chosen. It includes atmospheric, extra-territorial life and planet surface property experiments.

Problems identified include Site Location Chart II, and III showing dark areas in equatorial latitudes, and wave of darkening maximum intensities in the northern hemisphere during the 1973 arrival time. One lander near the equator and one in a northern latitude are feasible from propulsion energy standpoint, but pose difficulties on communication and flight spacecraft orbital inclinations. Seasonal extent of wave of darkening argues for extended life of experiments up to 6 months.

Other problems affecting capsule subsystems include atmospheric properties measurement and TV pictures during entry. Approach to the former is shown, using accelerometers and additional redundancies to improve curve fitting accuracy. Entry TV performance requirement aims for two orders of magnitude improvement in resolution over pictures from the flight spacecraft. Problems posed by this requirement are outlined, and approaches to solutions discussed.

SOFT LANDER TYPICAL EXPERIMENTS

ENTRY SCIENCE

PRESSURE GAUGES
TEMPERATURE SENSORS
MASS SPECTROMETER*
PHOTOMETERS & FILTERS
SOLAR ASPECT SENSOR*
COSMIC RADIATION DETECTORS*
X-RAY DENSITOMETER
TELEVISION CAMERAS

*DENOTES USE OF SAME INSTRUMENT FOR POST LANDING PHASE.

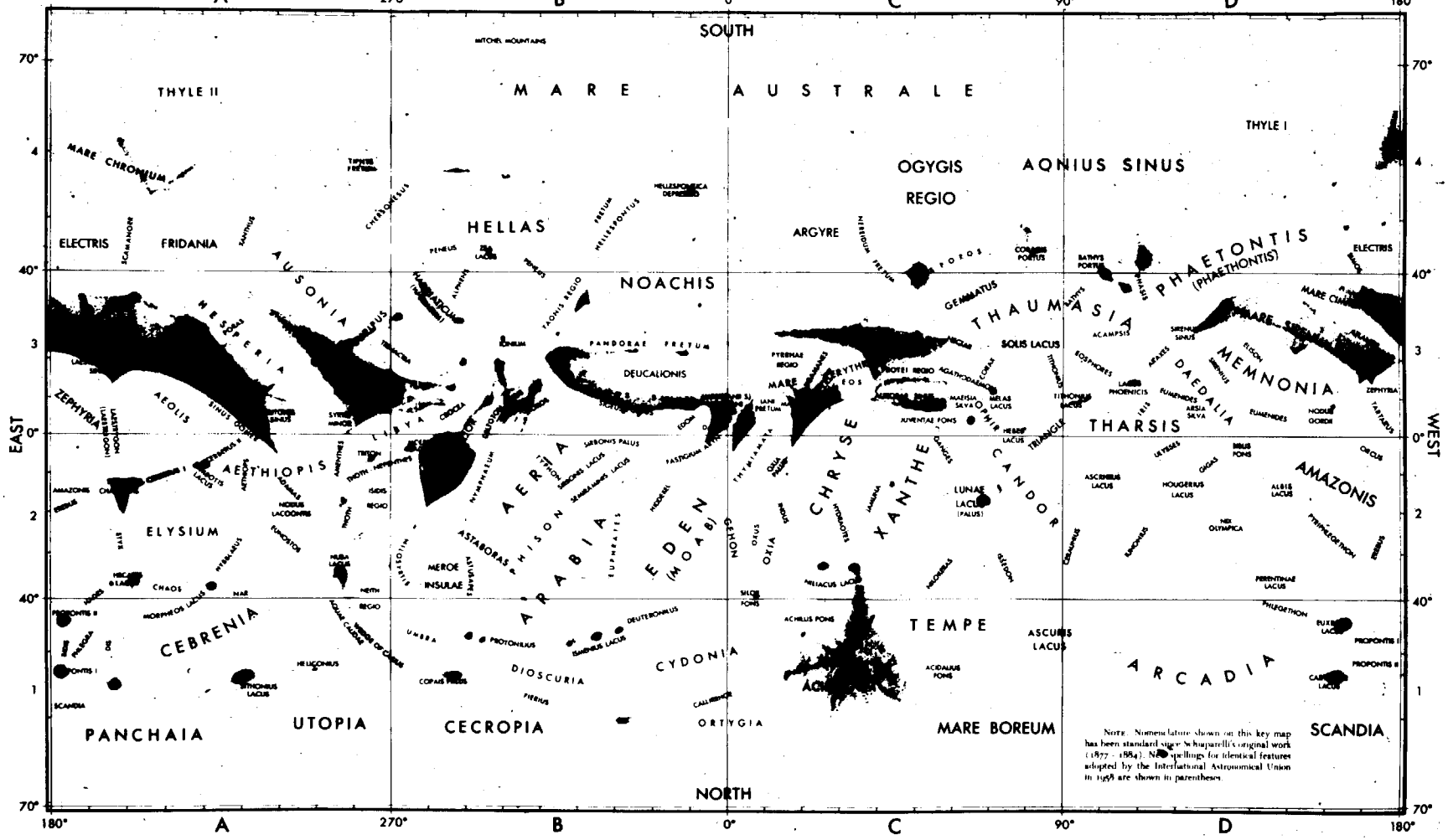
LANDED SCIENCE

ATMOSPHERIC
- PRESSURE GAUGES
- TEMPERATURE SENSORS
- WATER VAPOR DETECTOR
- ACOUSTIC TRANSMISSION LINE
- ANEMOMETER

LIFE
- GULLIVER MINIMUM BIO LAB
- RIAS LIFE DETECTOR
- TELEVISION CAMERA
- GAS CHROMATOGRAPH WITH OVEN

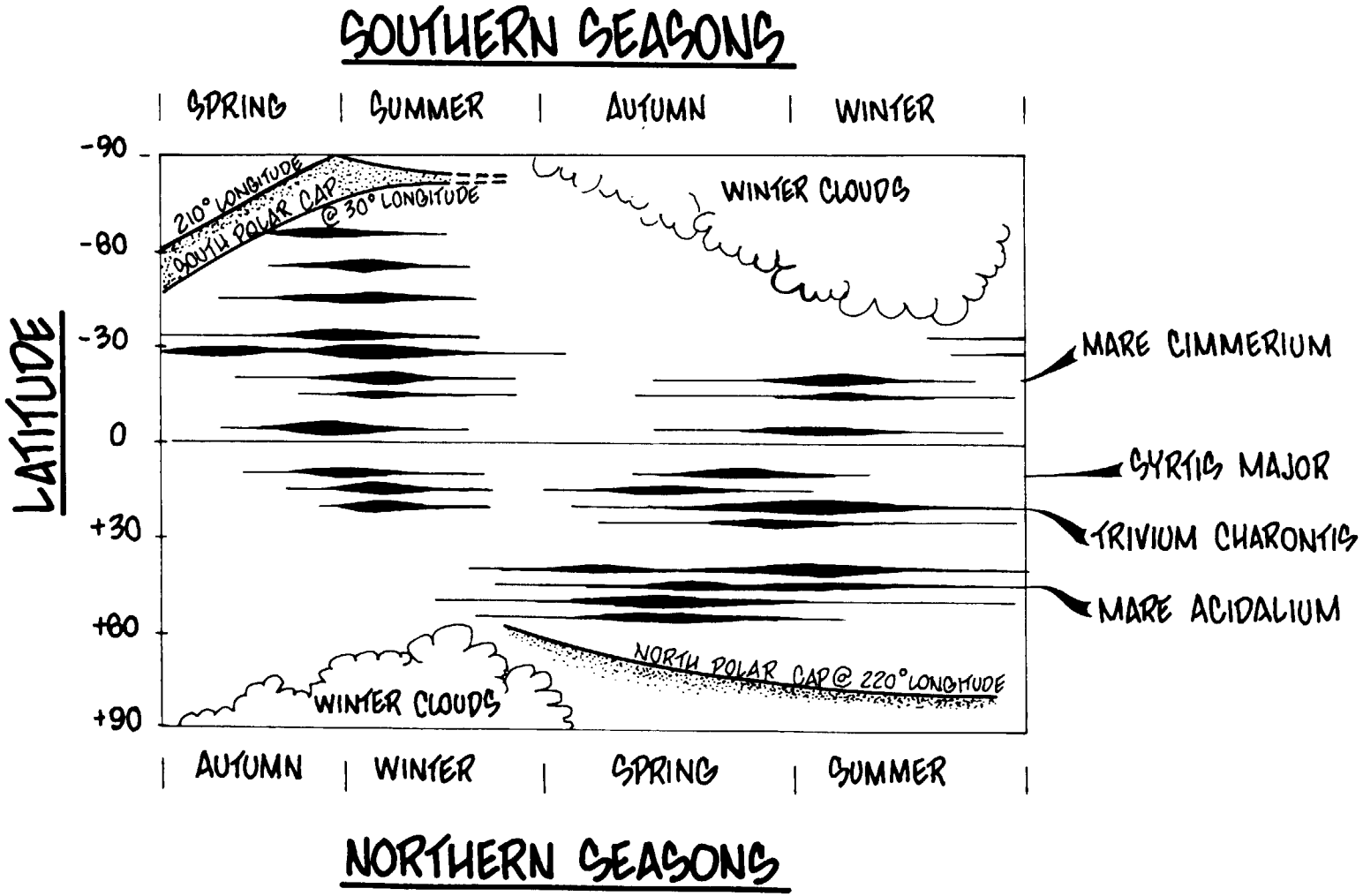
SURFACE
- TELEVISION CAMERA
- GAS CHROMATOGRAPH WITH OVEN
- DUST PARTICLE MICROPHONE
- SEISMOMETER - GRAVITOMETER
- SOIL/ROCK DRILL
- AEROSOLIZER DUST COLLECTOR

MARS – KEY MAP



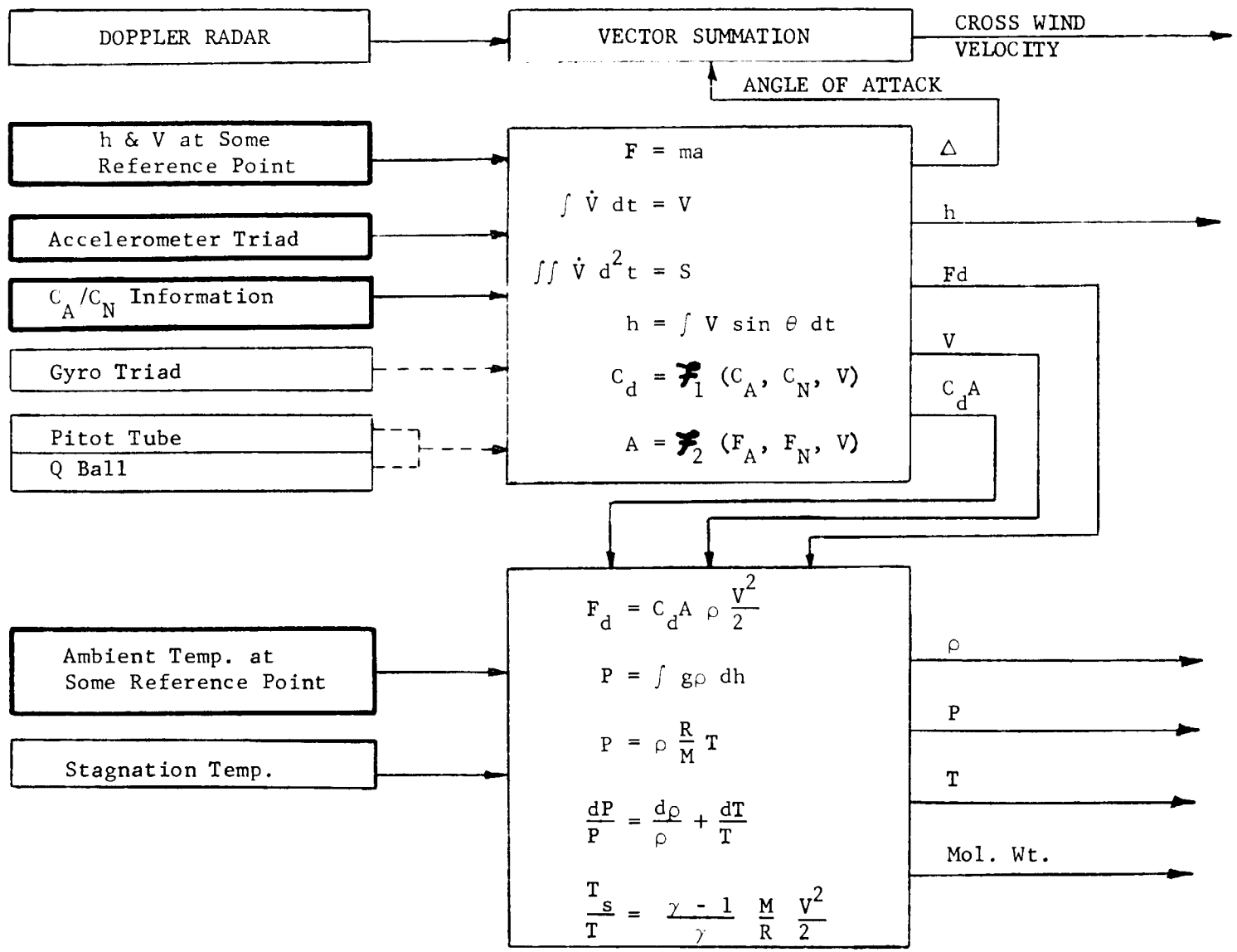
NOTE: Nomenclature shown on this key map has been standardized since Schiaparelli's original work (1877 - 1884). New spellings for identical features adopted by the International Astronomical Union in 1958 are shown in parentheses.

SEASONAL WAVE OF DARKENING



WIDTH OF DARK LINES INDICATES AMOUNT OF DARKENING

ATMOSPHERIC PROPERTIES MEASUREMENT DURING ENTRY



ENTRY TELEVISION

OBJECTIVES

1. OBTAIN 0.2 TO 2 METERS/TV LINE RESOLUTION
2. LOCATE LANDING AREA IN ORBITER PICTURES
3. DETERMINE NEAR-SURFACE PHOTOMETRIC PROPERTIES

PROBLEM AREAS

1. DATA STORAGE/TRANSMISSION LIMITATION
2. LOW ILLUMINANCE AND UNKNOWN PHOTOMETRIC FUNCTION
3. VEHICLE ANGULAR MOTION AND VIBRATION
4. RETRO PLUME TURBULENCE

MISSION CONCEPT

R. Wiltshire

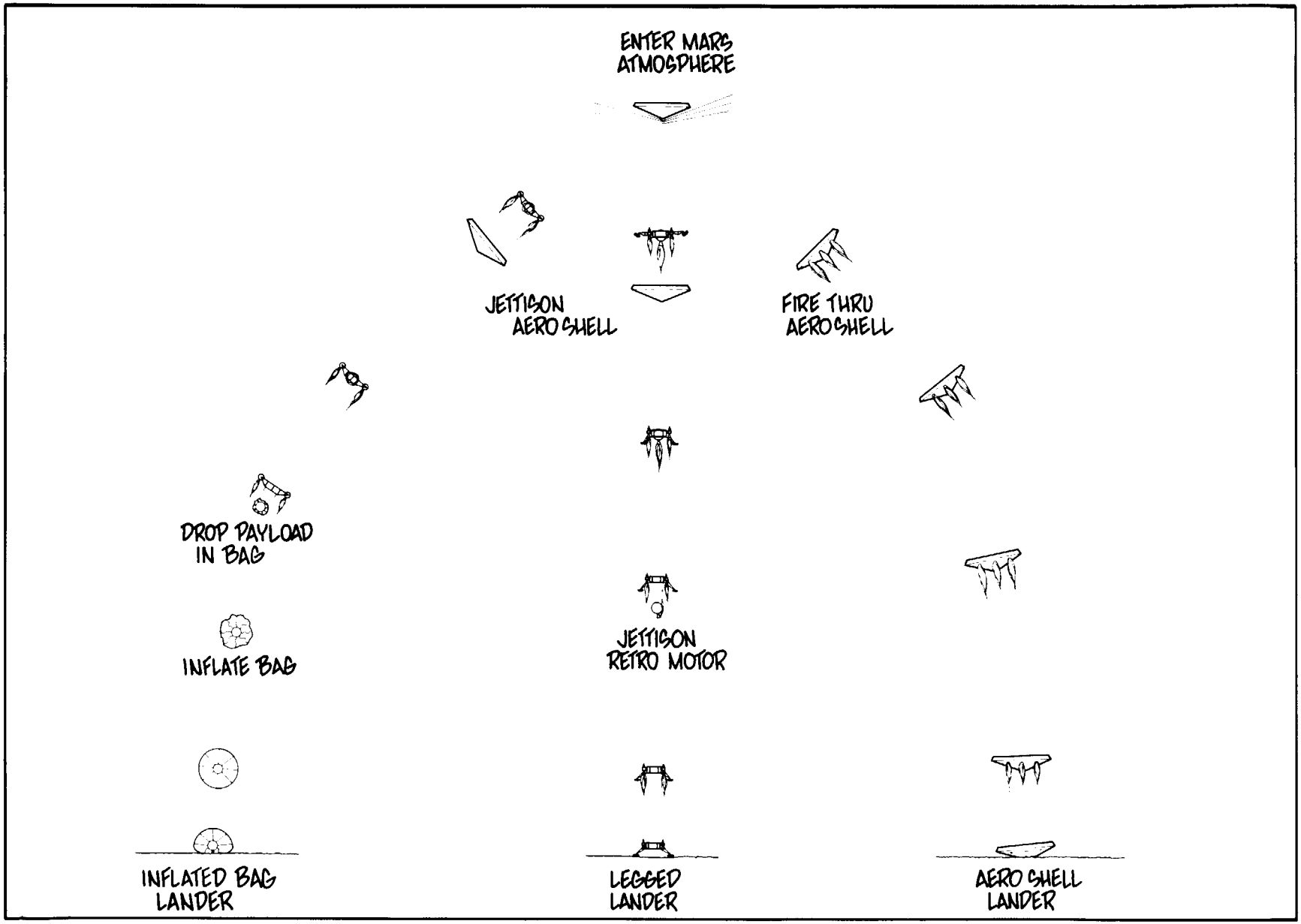
PROJECT ENGINEER,
SYSTEMS ENGINEERING

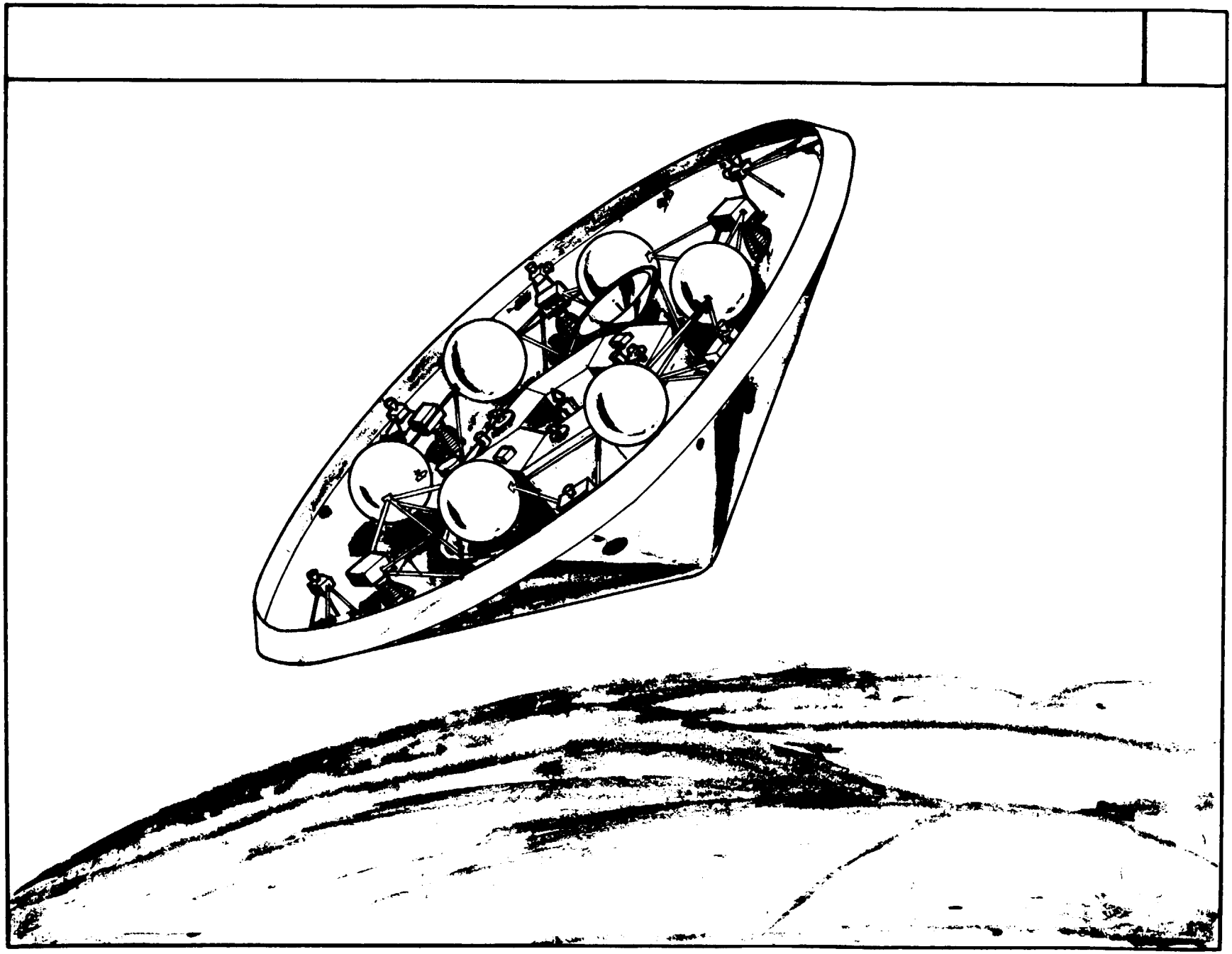
The landing of a capsule on the surface of Mars is probably the most difficult technological task ever undertaken by the Aerospace community - including Surveyor. We must be ambitious only to the degree that we are able to assure success. The simplest design approach consistent with the mission objectives must be chosen for the initial flights. Additionally, the capsule system design must be insensitive to the unknowns of the Martian atmosphere and surface composition and topography.

The Martin Company reference configuration is a retro-thrust soft lander where a predictable crush-up aeroshell design provides stability after landing. The aeroshell is carried to the surface because it is difficult to jettison in most Mars atmosphere models, is less sensitive than a legged lander to the surface environment, and does not greatly complicate the science subsystems operation. A single propulsion system consisting of six storable propellant, throttlable liquid engines, firing through the aeroshell accomplishes the deorbit, retrothrust, and vernier functions. The propulsion system simplification is significant enough to cause us to take on a new set of problems resulting from 16 inch diameter cavities in the aeroshell. A wind tunnel test program of such an aeroshell configuration must be initiated.

The necessary technology in all disciplines to accomplish a soft landing on the surface of Mars nearly exists today. The technology required for a hard landing configuration is not as readily available.

The complex Voyager program needs the discipline to first gather together all the program elements in an understandable fashion and then keep it under control. The Martin Company Voyager project has taken the first steps in this process by generating Systems Specifications, Design Criteria, Functional Requirements, and a Trade-off Study Tree.


ENTER MARS ATMOSPHERE
JETTISON AERO SHELL
FIRE THRU AERO SHELL
DROP PAYLOAD IN BAG
INFLATE BAG
JETTISON RETRO MOTOR
INFLATED BAG LANDER
LEGGED LANDER
AERO SHELL LANDER



WEIGHT BUDGET

W_{SYSTEM}	7500
$W_{SEPARATED}$	6700
W_{ENTRY}	5245
W_{IMPACT}	4255
$W_{EQUIPMENT + INSTALLATION}$	1555

$\epsilon = .62$

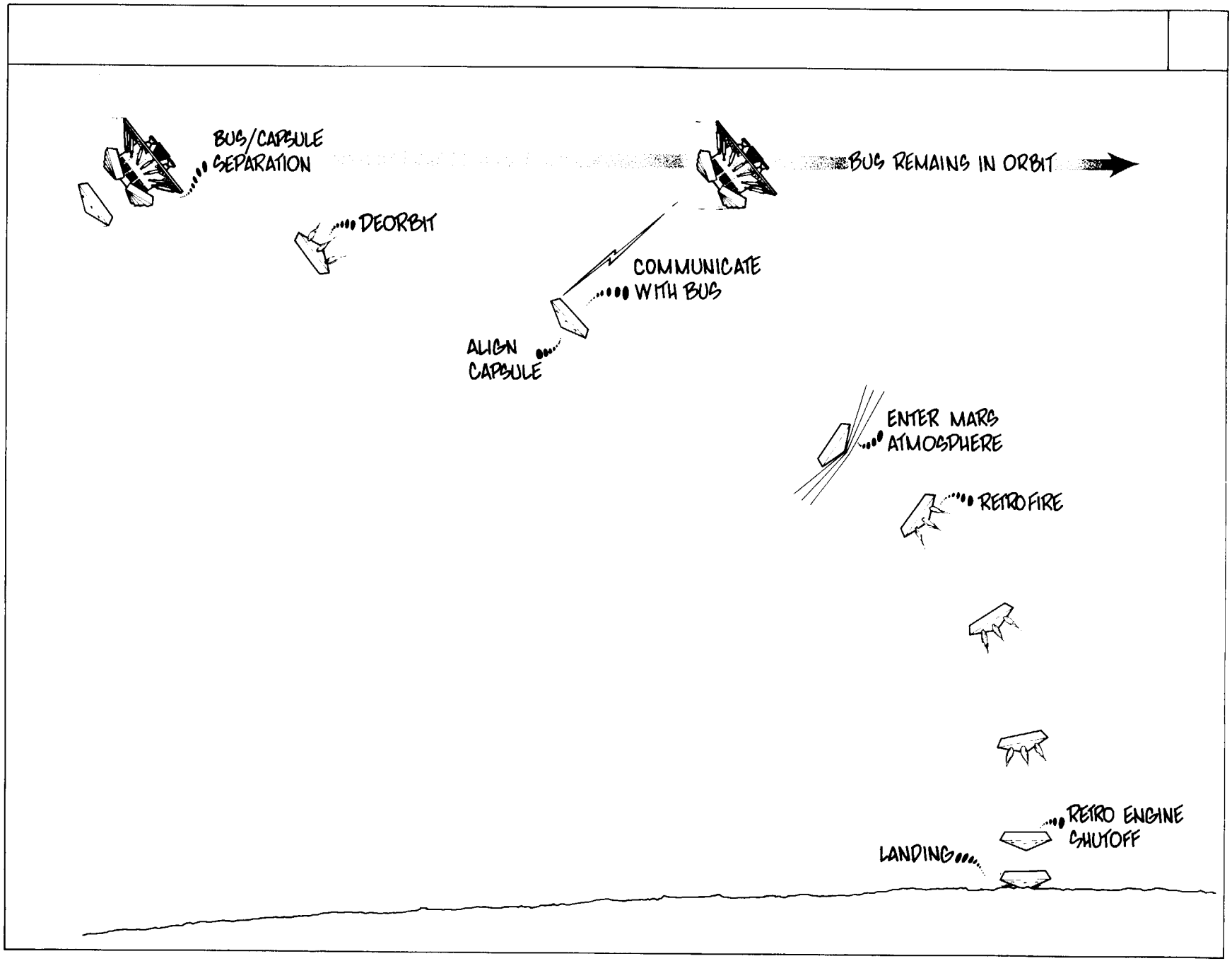
$B = .39$

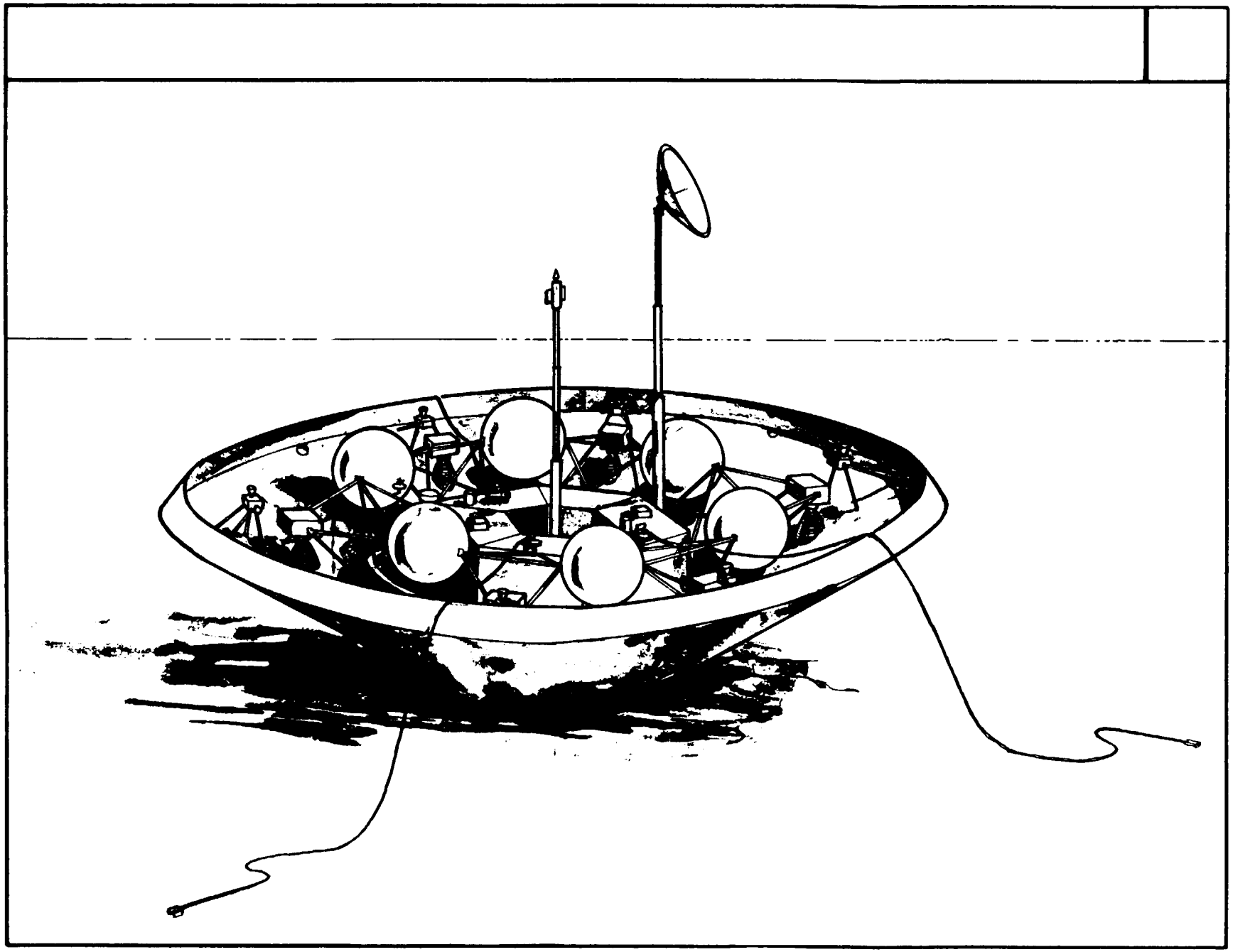
WEIGHT BUDGET

$W_{EQUIPMENT\ \&\ INSTALLATION}$		1555
$W_{FLIGHT\ CONTROL\ SENSOR\ GROUP}$	70	
$W_{ELECTRONICS}$	200	
W_{POWER}	300	
$W_{MECHANISMS}$	100	
$W_{THERMAL\ COMPONENTS}$	280	
$W_{CABLES,\ TUBES,\ CONNECTORS}$	100	
$W_{INSTALLATIONS}$	250	
$W_{SCIENCE}$	315	

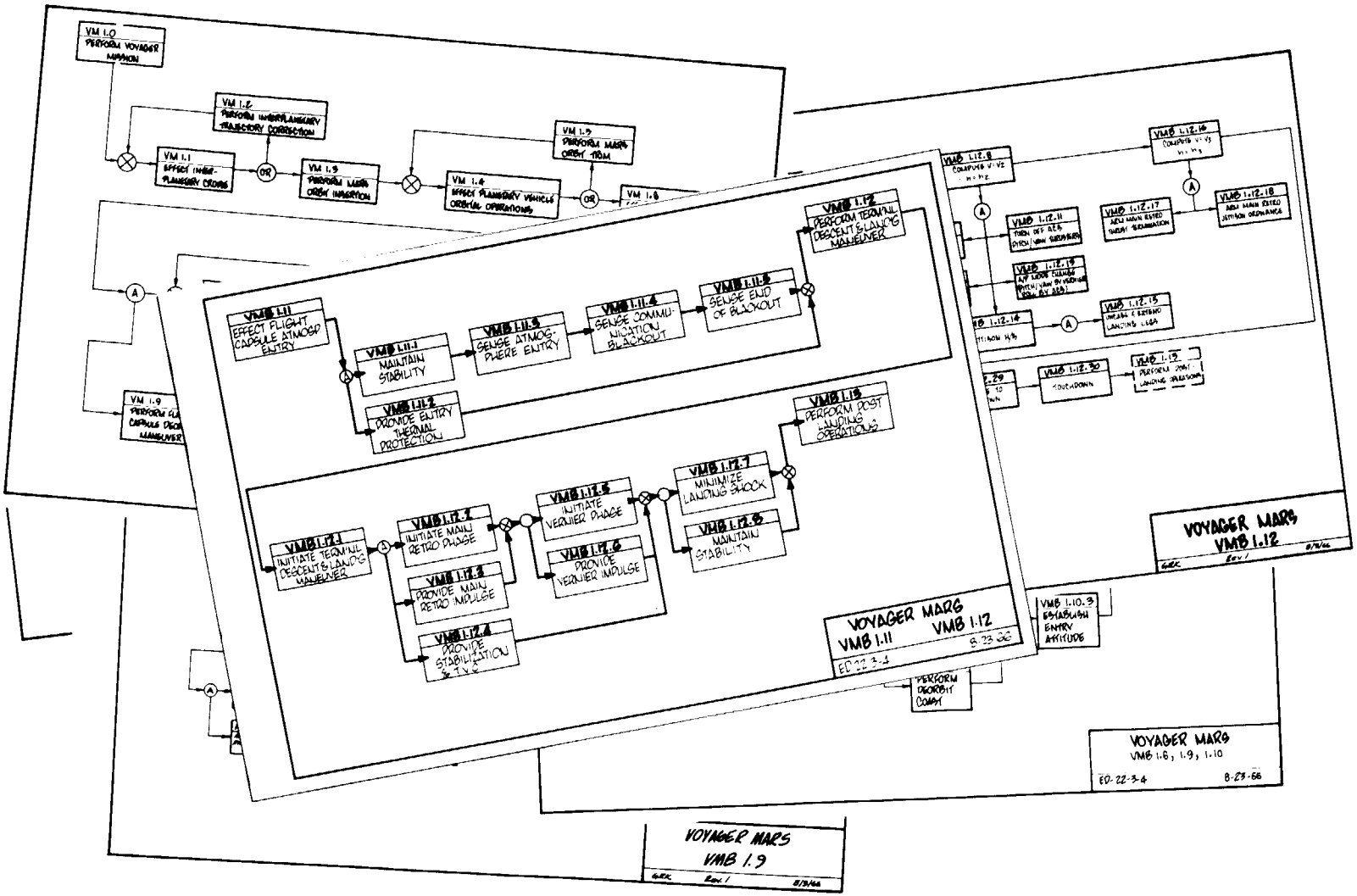
$\epsilon = .62$

$B = .39$

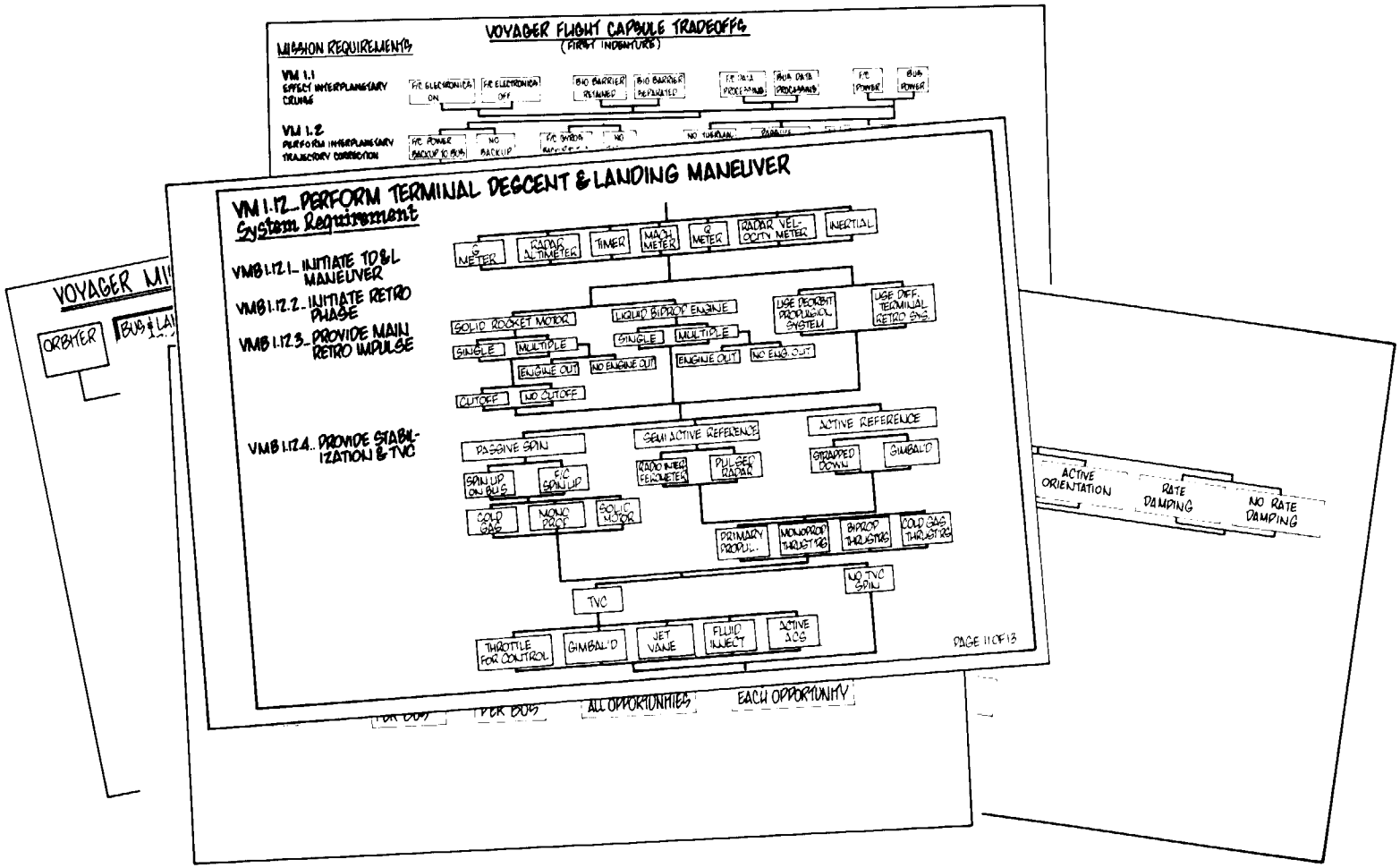

BUS/CAPSULE SEPARATION
BUS REMAINS IN ORBIT
DEORBIT
COMMUNICATE WITH BUS
ALIGN CAPSULE
ENTER MARS ATMOSPHERE
RETROFIRE
RETRO ENGINE SHUTOFF
LANDING



VOYAGER MARS



VM 1.12... Perform Terminal Descent & Landing Maneuver



VOYAGER TRADE STUDIES

1. BIO BARRIER JETTISON
2. CAPSULE THERMAL CONTROL
3. LANDER SUBSYSTEMS THERMAL CONTROL
4. STERILE CAPSULE SYSTEM
5. STERILE COMPONENTS
6. AEROSHELL STRUCTURE
7. ELECTRIC POWER SOURCES
8. ELECTRIC POWER CONTROL & DISTRIBUTION
9. COMMAND CONTROL
10. DATA STORAGE
11. TRANSMISSION FREQUENCY
12. TRANSMISSION MODULATION
13. ANTENNA CONFIGURATION
14. COMMUNICATION SUBSYSTEMS

VOYAGER TRADE STUDIES (CONT'D)

15. IMPACT ATTENUATION
16. LANDED SUBSYSTEM IMPACT VELOCITY
17. CAPSULE IMPACT VELOCITY (RETRO HARD LANDER)
18. CAPSULE IMPACT VELOCITY (RETRO SOFT LANDER)
19. DE-ORBIT PROPULSION
20. ATTITUDE CONTROL SYSTEM
21. THRUST VECTOR CONTROL (DEORBIT)
22. THRUST VECTOR CONTROL (HARD LANDER)
23. THRUST VECTOR CONTROL (SOFT LANDER)
24. ASSEMBLY TECHNIQUE
25. RELIABILITY
26. ATTITUDE REFERENCE COORDINATE SYSTEM
27. TERMINAL DESCENT AND LANDING RADAR
28. LIQUID VERSUS SOLID ENGINES
29. SOFT LANDER CONFIGURATION
30. RF TRANSPARENT HEAT SHIELD MATERIAL
31. EXHAUST PLUME EFFECT

ENGINEERING MECHANICS and PROPULSION

C. Brown

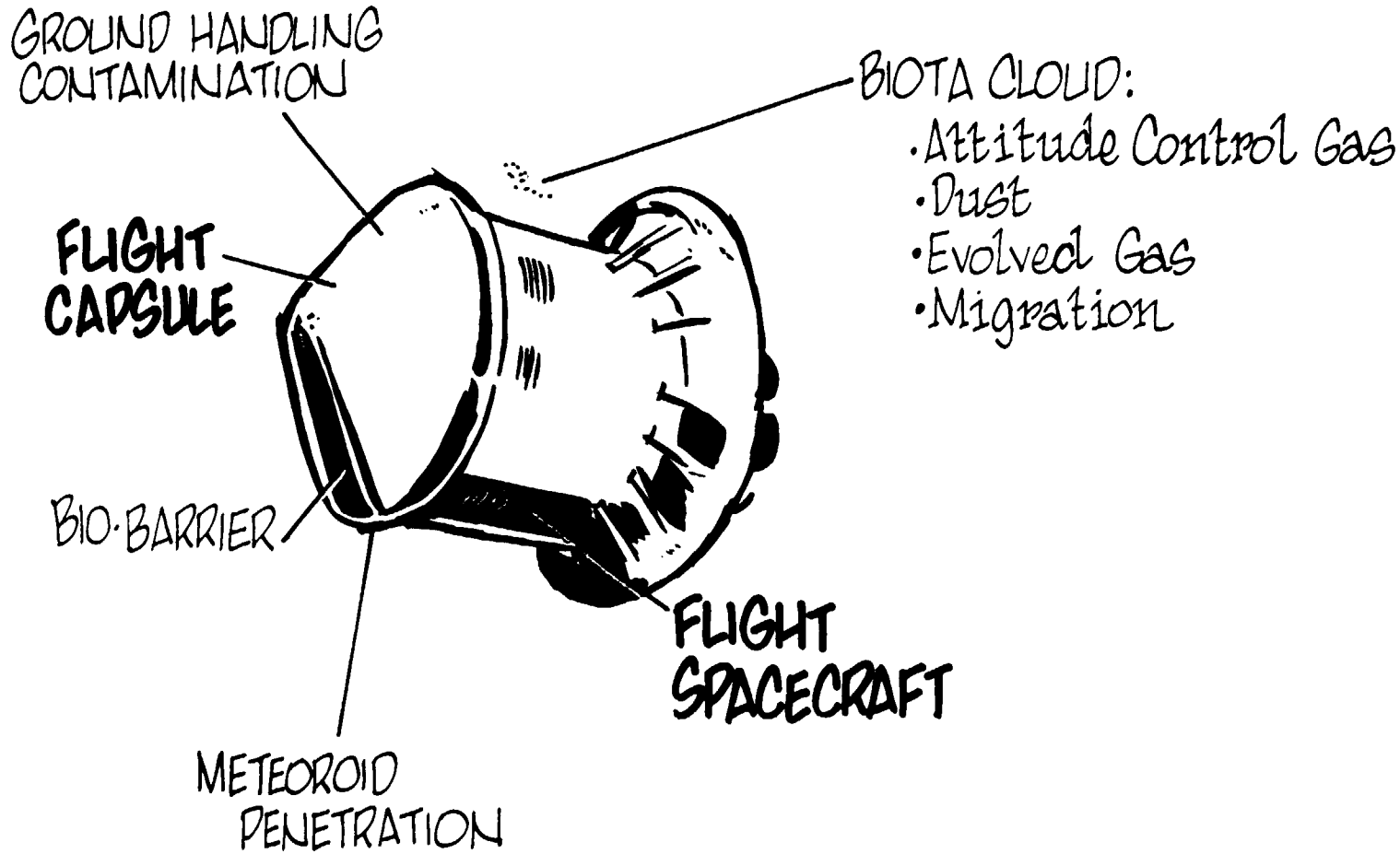
PROJECT ENGINEER,
THERMAL CONTROL
and PROPULSION

BIO BARRIER

The critical design requirement for the bio-barrier arises from the possibility of contamination from the flight spacecraft entering the sterile area through a meteoroid penetration.

Reducing the probability of meteoroid penetration to low values is a prohibitively heavy approach. Therefore, it is necessary to perform an in-flight sterilization cycle just prior to capsule separation or show that the possibility of biota entrance through a penetration is an acceptably low risk.

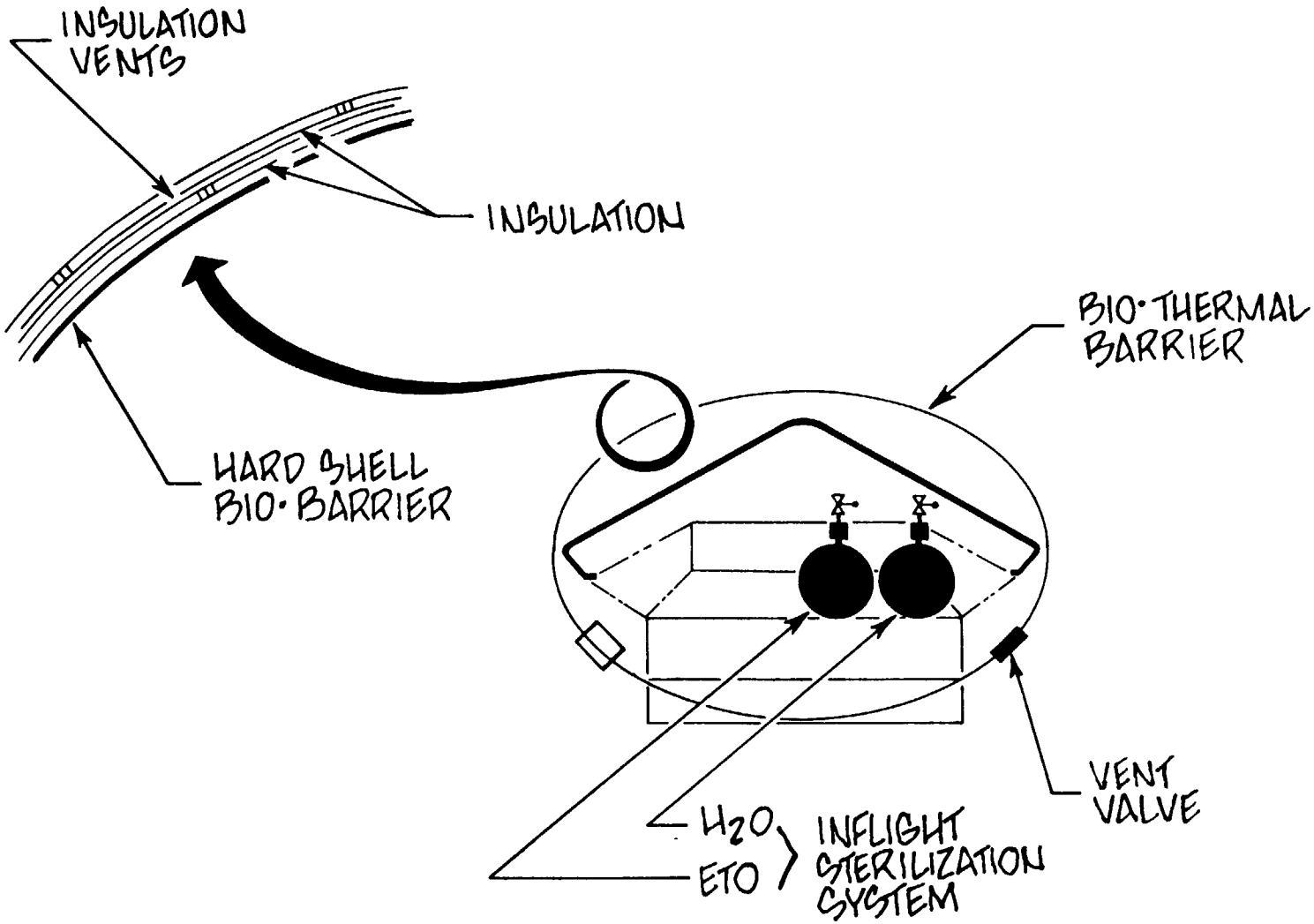
IN FLIGHT BIOLOGICAL *Protection*



IN FLIGHT BIOLOGICAL PROTECTION

CONCEPT		WEIGHT - LB
1. PREVENT PENETRATION		
A. 0.99997 PROBABILITY OF NO PENETRATION	.13 Al 2.0 FIBERGLAS	4300
B. 0.90 PROBABILITY OF NO PENETRATION	.02 Al	1900
2. RE-STERILIZE IN FLIGHT		
A. ETO	.020 Al .005 Al .005 TEFLON	1400 870 630
B. IN FLIGHT HEAT STERILIZATION 105°C FOR 170 HOURS		
3. SHOW THAT IN FLIGHT CONTAMINATION IS AN ACCEPTABLE RISK		590

BIO·THERMAL BARRIER CONCEPT



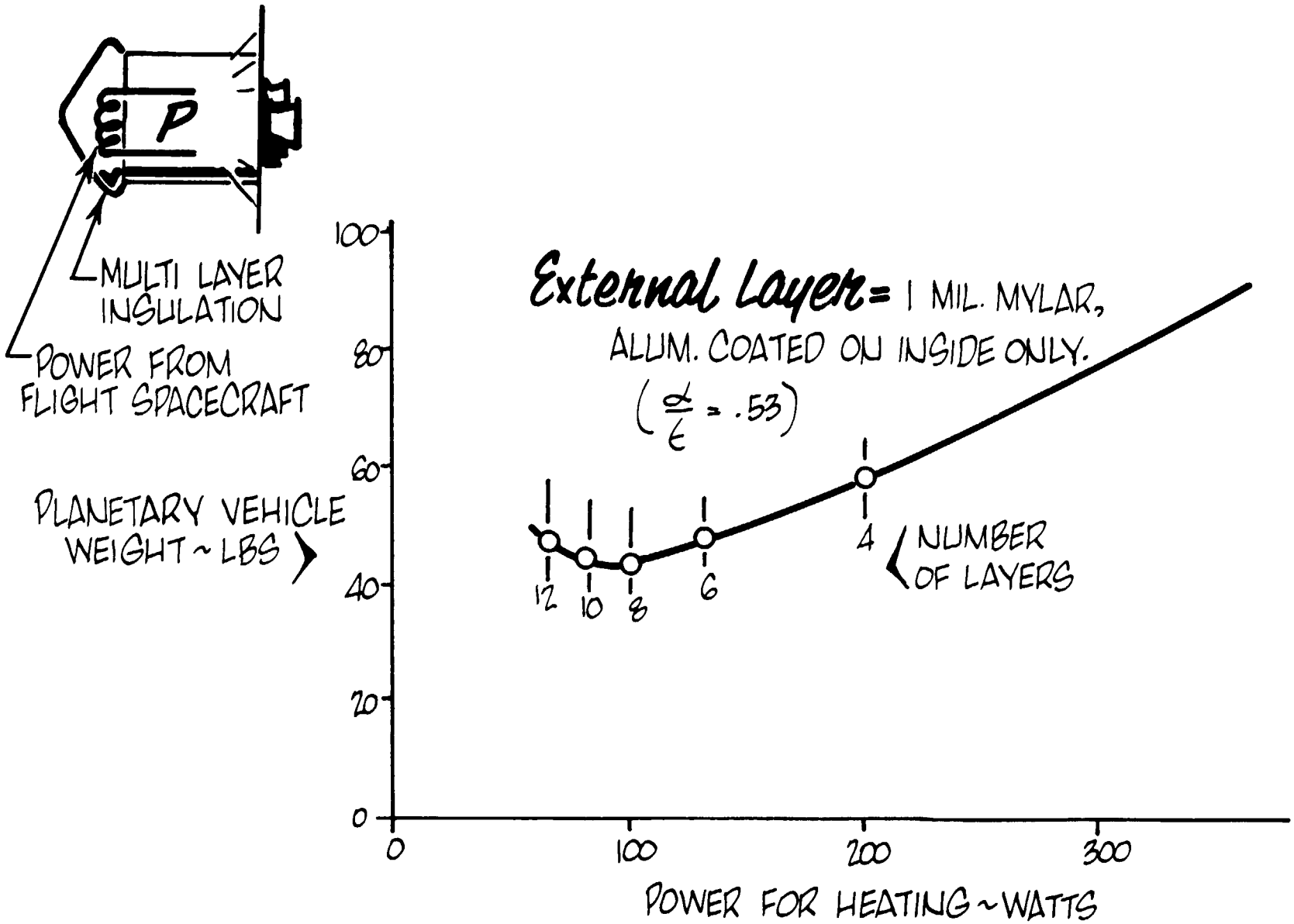
THERMAL CONTROL

The most challenging thermal control problem is the integration of an RTG into the capsule design in a simple manner which is compatible with each of the mission phases from sterilization to Mars surface. One approach is to utilize multiple RTG's to distribute the heat and provide electrical redundancy. During ground handling and sterilization, heat can be removed by ground cooling on the exterior of the bio barrier.

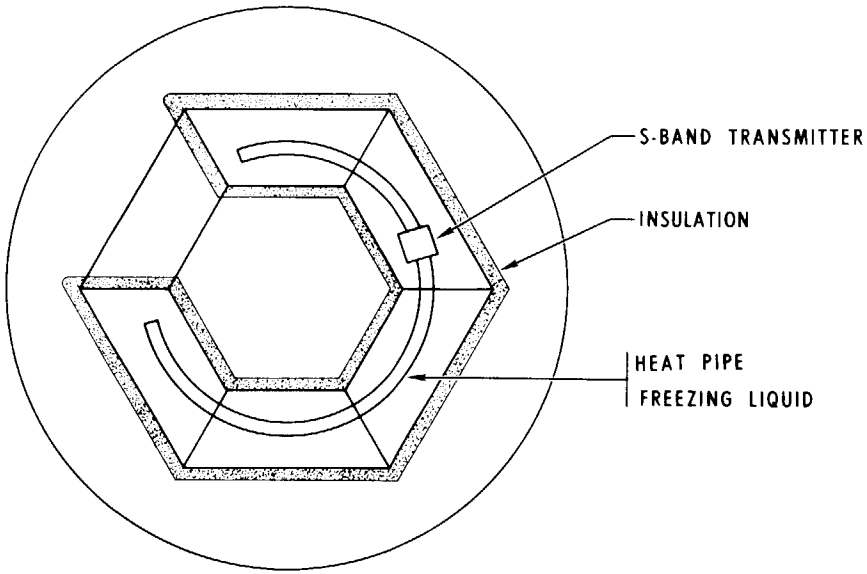
Cruse mode thermal control can be achieved utilizing flight space craft power and flight capsule insulation. An optimum relation between these techniques exists.

Mars surface thermal control can be achieved utilizing RTG heat for such configurations and utilizing chemical, phase change or battery energy for battery configurations.

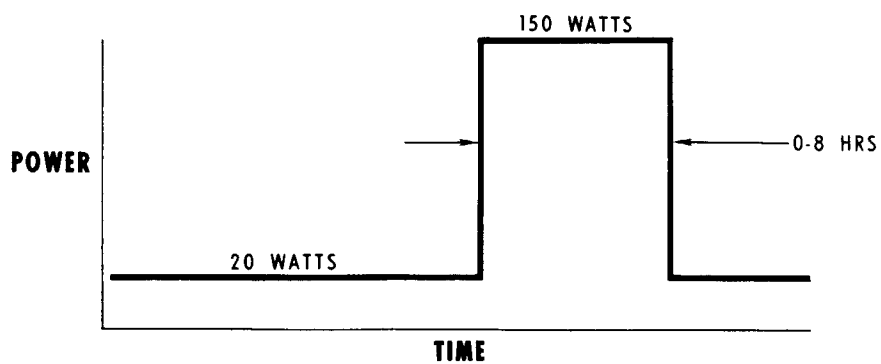
CRUISE MODE *Thermal Control*



MARS SURFACE THERMAL CONTROL CONCEPT

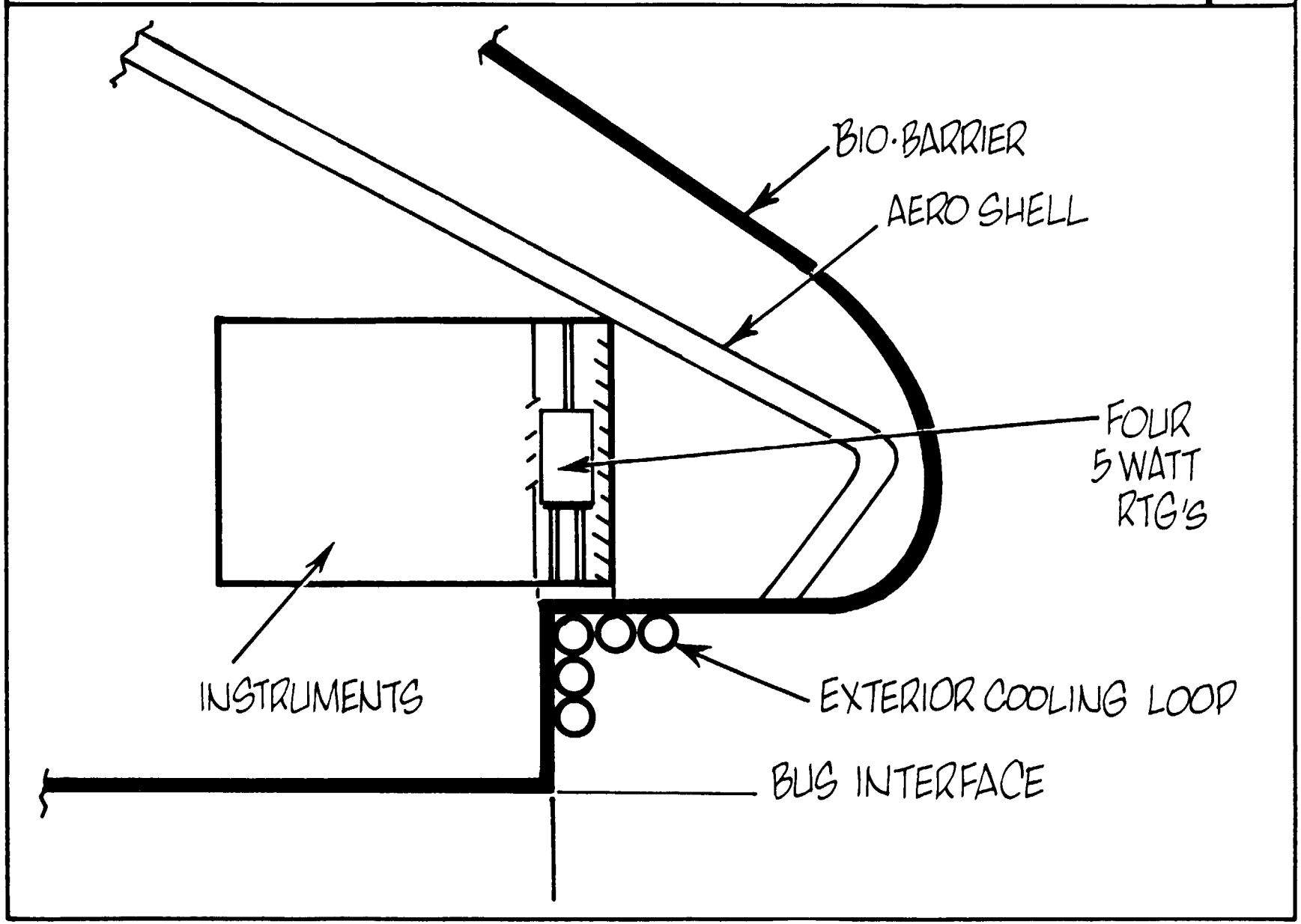


CAPSULE
(PLAN VIEW)



CONTROLLED VOLUME = 35 F^3.
SYSTEM WEIGHT = 250 LBS.

THERMAL CONTROL... RTG

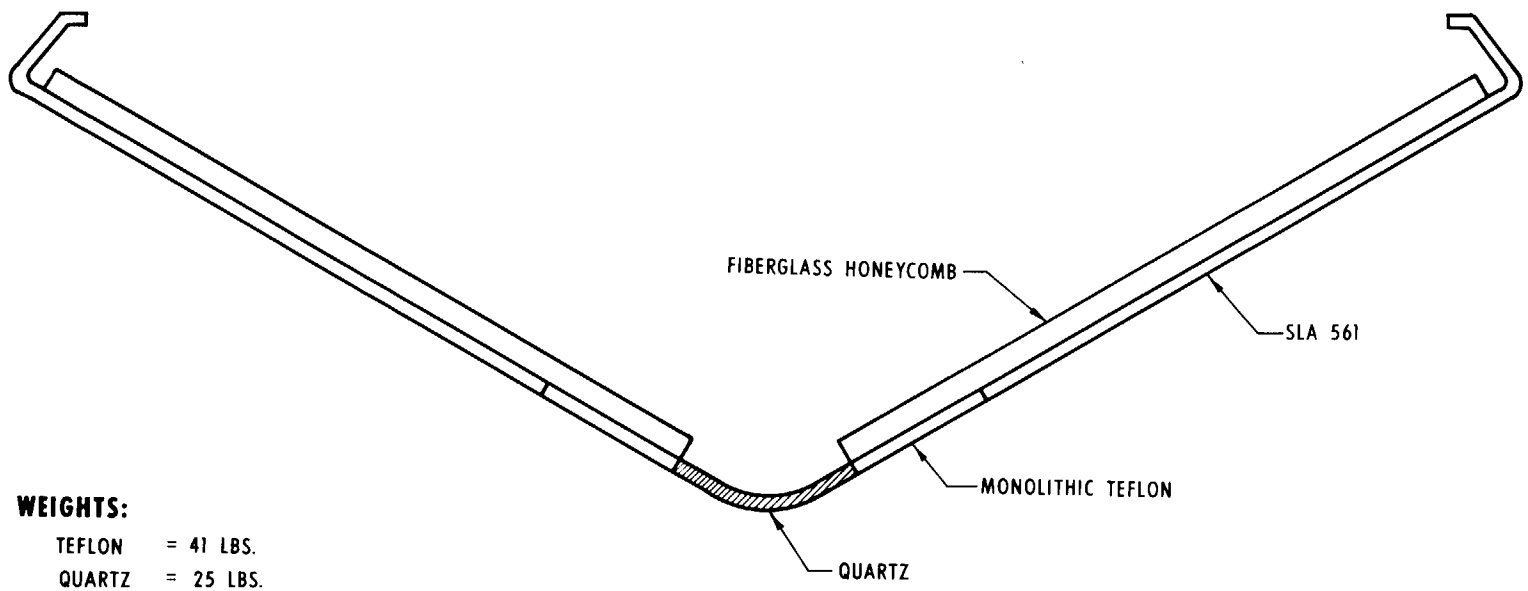


AEROSHELL

The most critical aeroshell problem is the effect of engine exit holes with the attendant possibility of aerodynamic instability, high ablation rate at the edges, and engine contamination. We are planning a test program to evaluate these effects.

The Aeroshell design can be improved by the development of light weight, radar transparent ablators. We are conducting a research program which has this simplification as its objective.

SOFT LANDER - AEROSHELL CONCEPT



WEIGHTS:

TEFLON	= 41 LBS.
QUARTZ	= 25 LBS.
ABLATOR	= 110 LBS.
STRUCTURE	= 1120 LBS.
TOTAL	= 1296 LBS.

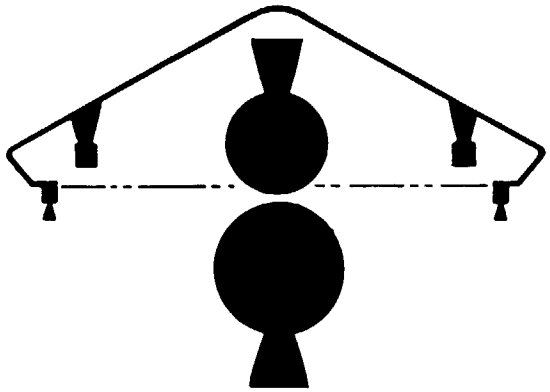
PROPULSION

The desire to simplify the propulsion system has been a powerful influence on the configuration. This was accomplished by utilizing a single liquid propulsion system for de-orbit, retro thrust and vernier modes. The principle problem created by the multipurpose liquid system is the requirement for exit holes in the heat shield.

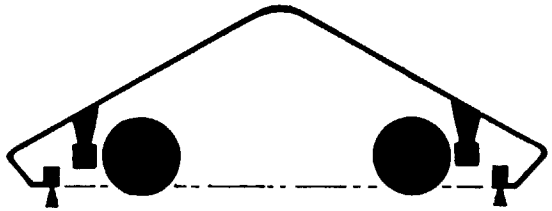
The various design problems created by sterilizing loaded liquid systems are being treated in depth under a contract with JPL.

EVOLUTION OF THE PROPULSION SYSTEM

INITIAL CONFIGURATION



REFERENCE CONFIGURATION



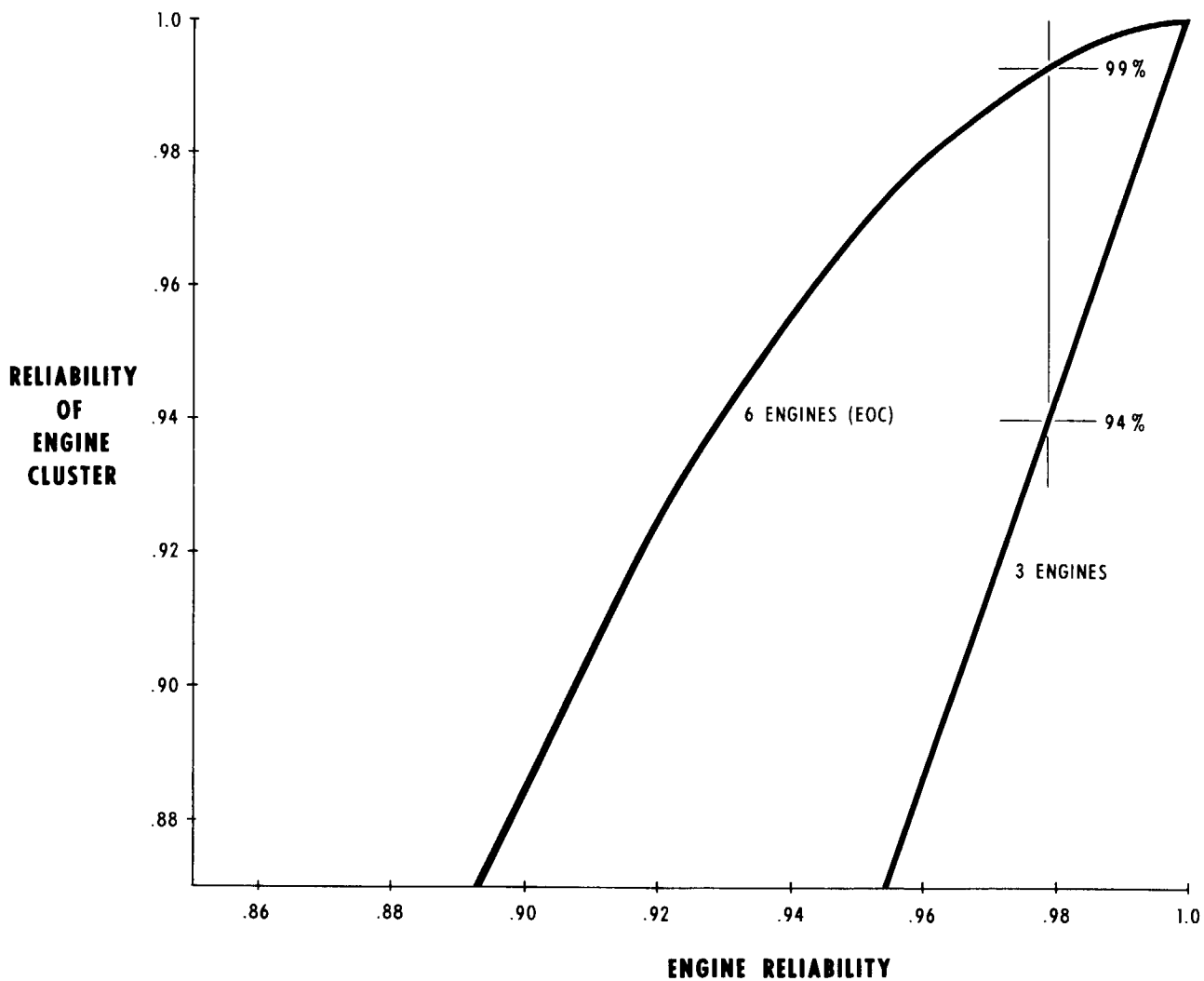
PROPULSION EQUIP.

1 DEORBIT SOLID MOTOR
1 RETRO SOLID MOTOR
4 VERNIER BIPROPELLANT ENGINES
10 ACS BIPROPELLANT ENGINES

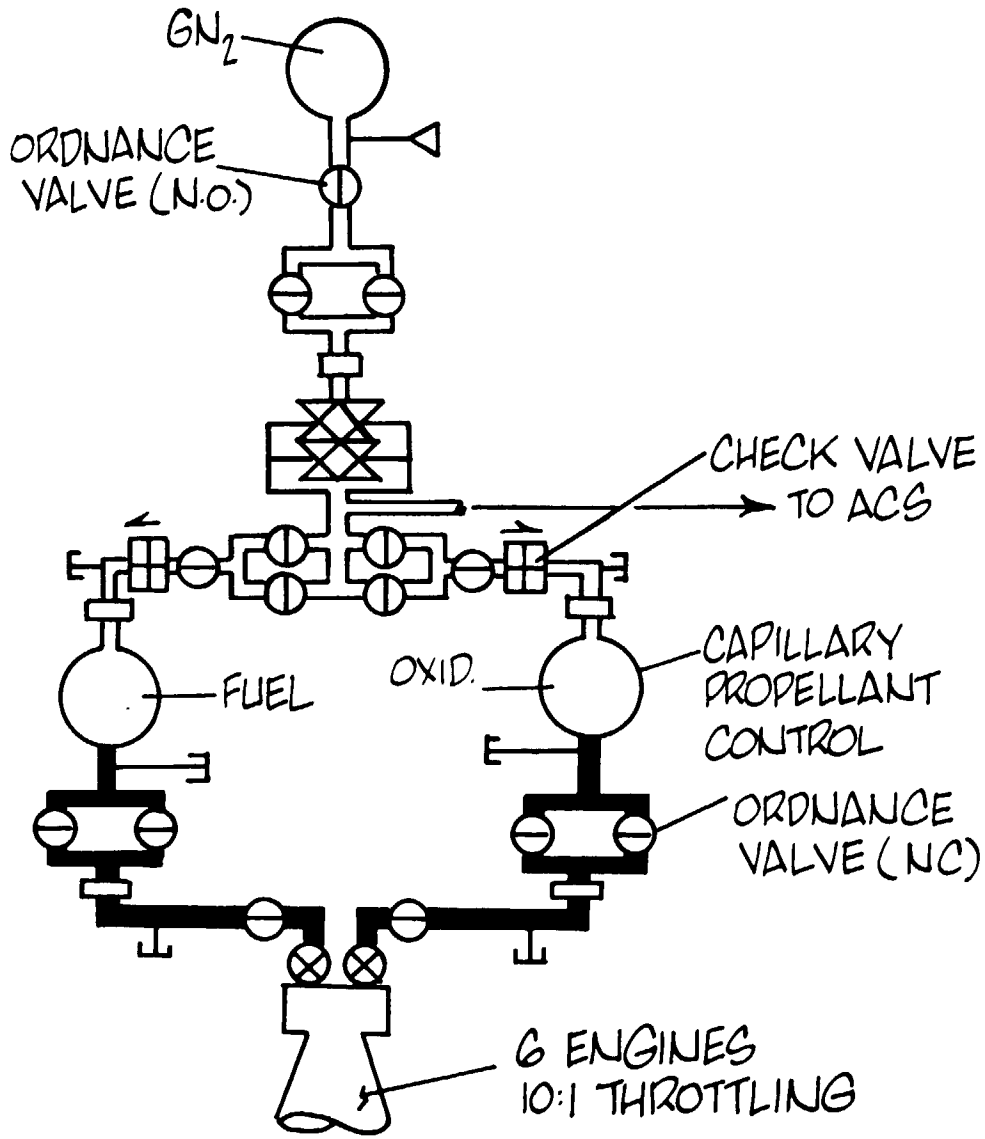
PROPULSION EQUIP.

6 VERNIER BIPROPELLANT ENGINES
10 ACS COLD GAS THRUSTERS
(ENGINE OUT CAPABILITY)

ENGINE RELIABILITY COMPARISON



PROPULSION SYSTEM *Schematic*



ENTRY VEHICLE SOFT LANDER PROPULSION SYSTEM SUMMARY

ΔV DE-ORBIT = 610 M/SEC

ΔV RETRO = 518 M/SEC MAX., 290 M/SEC MIN.

ΔV VERNIER = 38 M/SEC

I_{sp} (MAX. THRUST) = 275 SEC

I_{sp} (MIN. THRUST) = 260 SEC

THRUST PER ENGINE = 2750 - 275 POUNDS

NUMBER OF ENGINES = 6

MASS FRACTION, LIQUID = .75

MASS FRACTION, GAS = .09

BURN TIME, RETRO, NOMINAL = 25 SEC

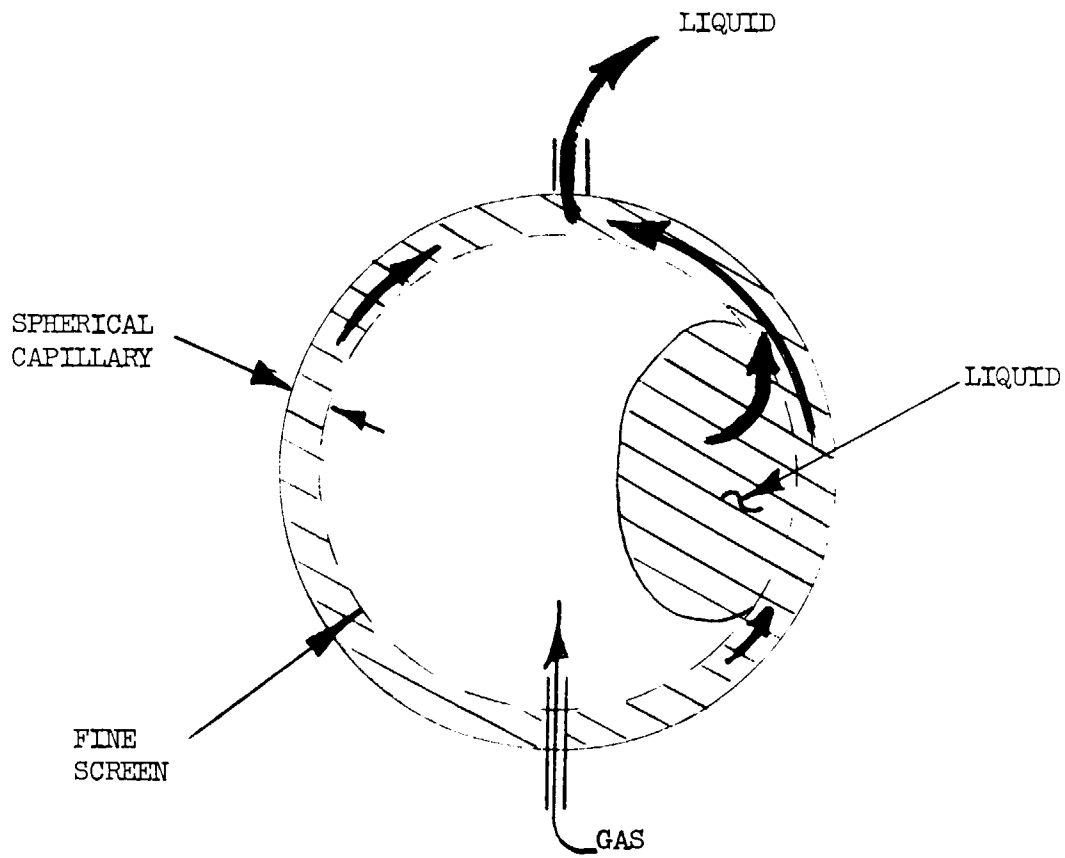
BURN TIME, DE-ORBIT, NOMINAL = 24 SEC

THROTTLING RATIO = 10/1

CHAMBER PRESSURE = 220 PSI

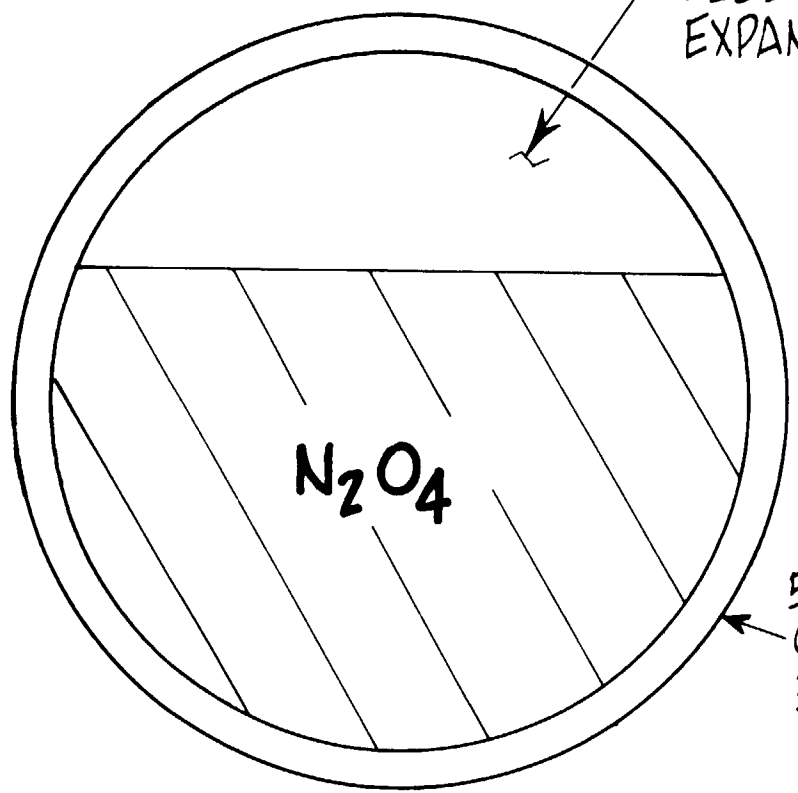
PROPELLANT WEIGHT	2345
ACS GAS WEIGHT	30
MAIN PROPULSION SYSTEM DRY WEIGHT	780
COLD GAS SYSTEM DRY WEIGHT	40
PROPULSION SYSTEM INSTALLATION WEIGHT	300
	3495

CAPILLARY CONTROL OF LIQUIDS



TANK DESIGN *Considerations*

TANK PRESSURE GOES FROM 14.7 → 800 P.S.I.



Result: **HEAVY TANKS**

TELECOMMUNICATION and POWER

W. Mielziner

PROJECT ENGINEER,
TELECOMMUNICATION
and POWER

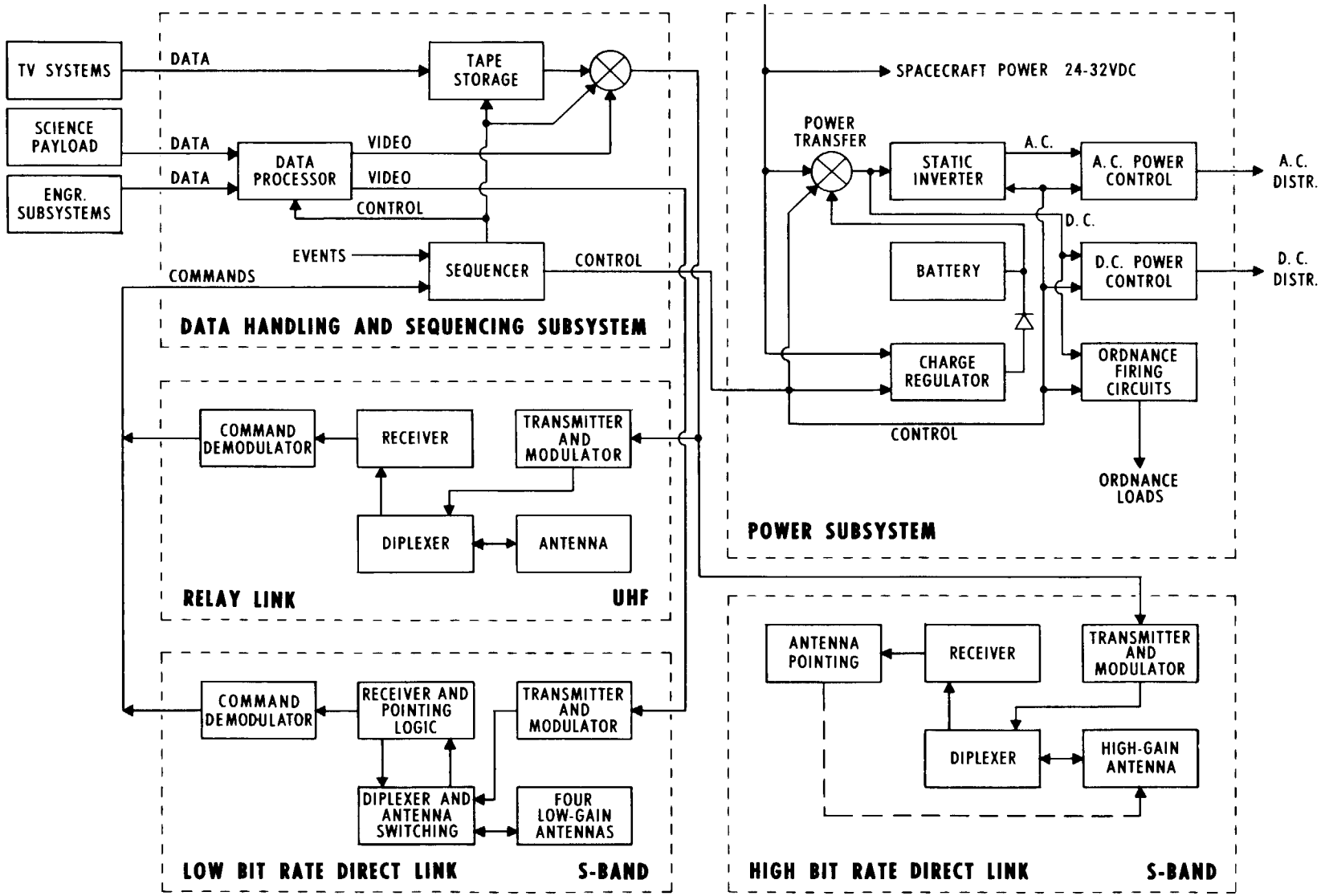
A UHF radio relay link via the spacecraft provides good performance during entry, permitting real-time transmission of descent TV. The relay link is maintained as prime telemetry link after landing and provides a high data volume for repetitive daily communication contacts near periapsis. Non-coherent FSK modulation techniques and broad-beam radiation patterns characterize this link.

The development of a steerable high-gain planetary S-band antenna technology, either dish or electronic array, is an attractive goal to provide growth potential for future missions. A conservative, fail-safe design should be acceptable for 1973, as long as the system is not part of a prime link.

A low-power S-band direct link to earth should serve as a backup for transmission of limited science data. Non-coherent M'ary FSK modulation is required. Four individually selectable turnstile-cup antennas provide near-spherical coverage as a protection against lander attitude misorientations.

For short-term landed missions of about 100 hours duration, a battery is the logical power source. For long-term operations, the RTG is a desirable energy source. However, integration of the RTG into the Voyager system requires an energetic program of studies, analysis, and test to solve the integration problems with science and thermal control systems, and to establish sterilization and safety approaches.

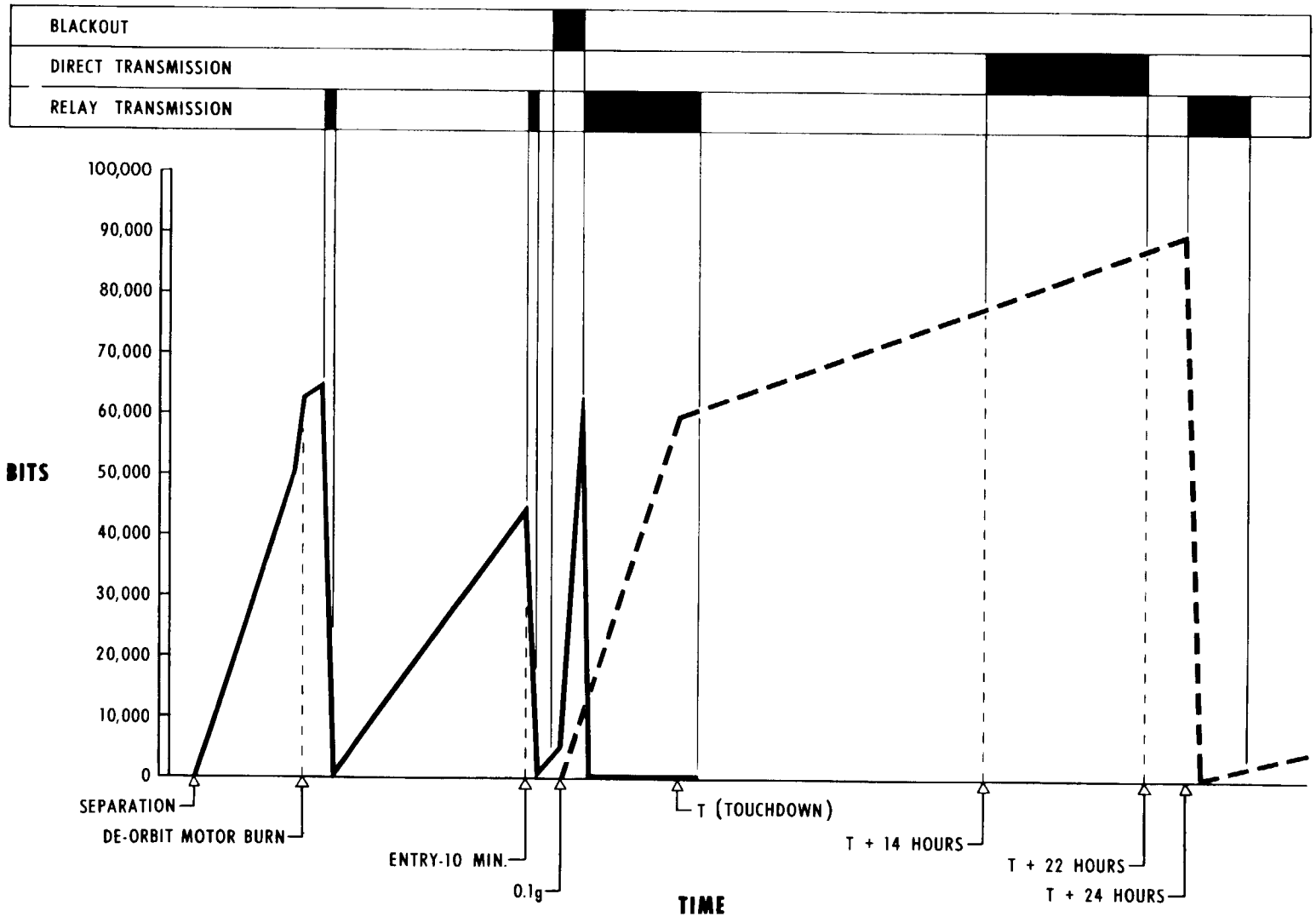
SOFT LANDER - TELECOMMUNICATIONS AND POWER



DATA HANDLING REQUIREMENTS

MEASUREMENTS	ENTRY TO LANDING		POST LANDING	
	CHANNELS	BITS	CHANNELS	BITS
ENGINEERING MEASUREMENTS				
STRUCTURES	14	98	8	56
COMMUNICATIONS	6	42	6	42
DATA HANDLING	25	91	16	79
FLIGHT CONTROLS	39	201	-	-
PROPULSION	30	122	11	53
POWER	14	98	10	70
MECHANISMS AND ORIENTATION	11	11	11	46
TOTAL	139	663	62	346
SCIENTIFIC MEASUREMENTS				
ATMOSPHERIC	11	329	9	2091
SOLAR RADIATION	4	28	8	56
IONIZING RADIATION	-	-	1	14
IMPACT DECELERATION	-	-	1	7
SOIL COMPOSITION	-	-	4	12000
LIFE EXPERIMENTS	-	-	2	525
TOTAL	15	357	25	14693
IMAGING				
TV CAMERAS	2	$.75 \times 10^6$	2	$.5 \times 10^6$

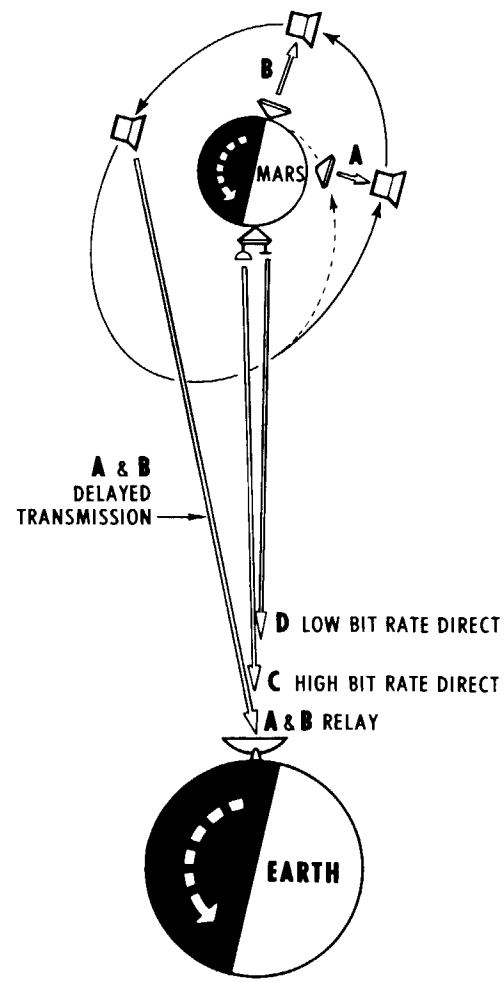
SCIENCE AND ENGINEERING DATA IN STORAGE



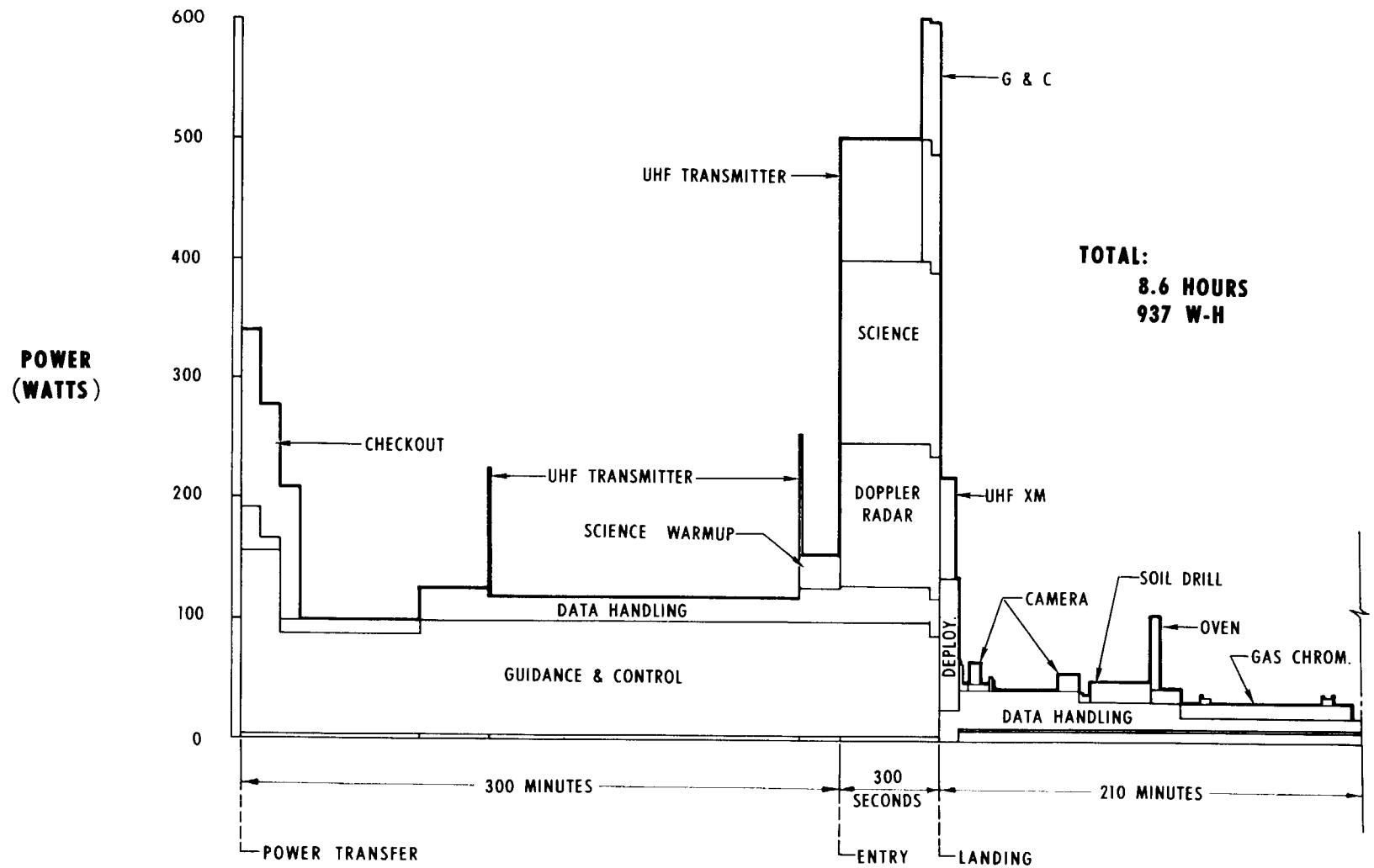
SOFT LANDER - RF COMMUNICATIONS TELEMETRY LINK CHARACTERISTICS

TYPE LINK	RELAY (1)		DIRECT	
SKETCH	A	B	C	D
MODE	ENTRY	LANDED	LANDED	LANDED
USAGE	PRIME	PRIME	BACKUP	BACKUP
FREQUENCY (MHz-NOMINAL)	400	400	2300	2300
RANGE (km-MAXIMUM)	3300	6000	200×10^6	200×10^6
TRANSMITTED POWER (WATTS)	22	22	20	5
TRANSM. ANTENNA GAIN (dB) COVERAGE (DEGR.)	5.0 140	5.0 90	20 16 (2)	4.5 120 (2)
RECEIVING ANTENNA GAIN (dB) COVERAGE (DEGR.)	10 62 (2)	10 62 (2)	61 0.15 (2)	61 0.15 (2)
MODULATION	NON-COH. FSK	NON-COH. FSK	COH. PCM/PSK/PM	NON-COH. M'ARY FSK
BIT ERROR RATE	10^{-4}	10^{-4}	5×10^{-3}	5×10^{-3}
DATA RATE (BPS-MINIMUM)	50,000	25,000	210	1/4
TRANSMISSION TIME (MINUTES)	5	15/DAY	480/DAY	480/DAY
DATA VOLUME (BITS)	15×10^6	22.5×10^6/DAY	6×10^6/DAY	7200/DAY

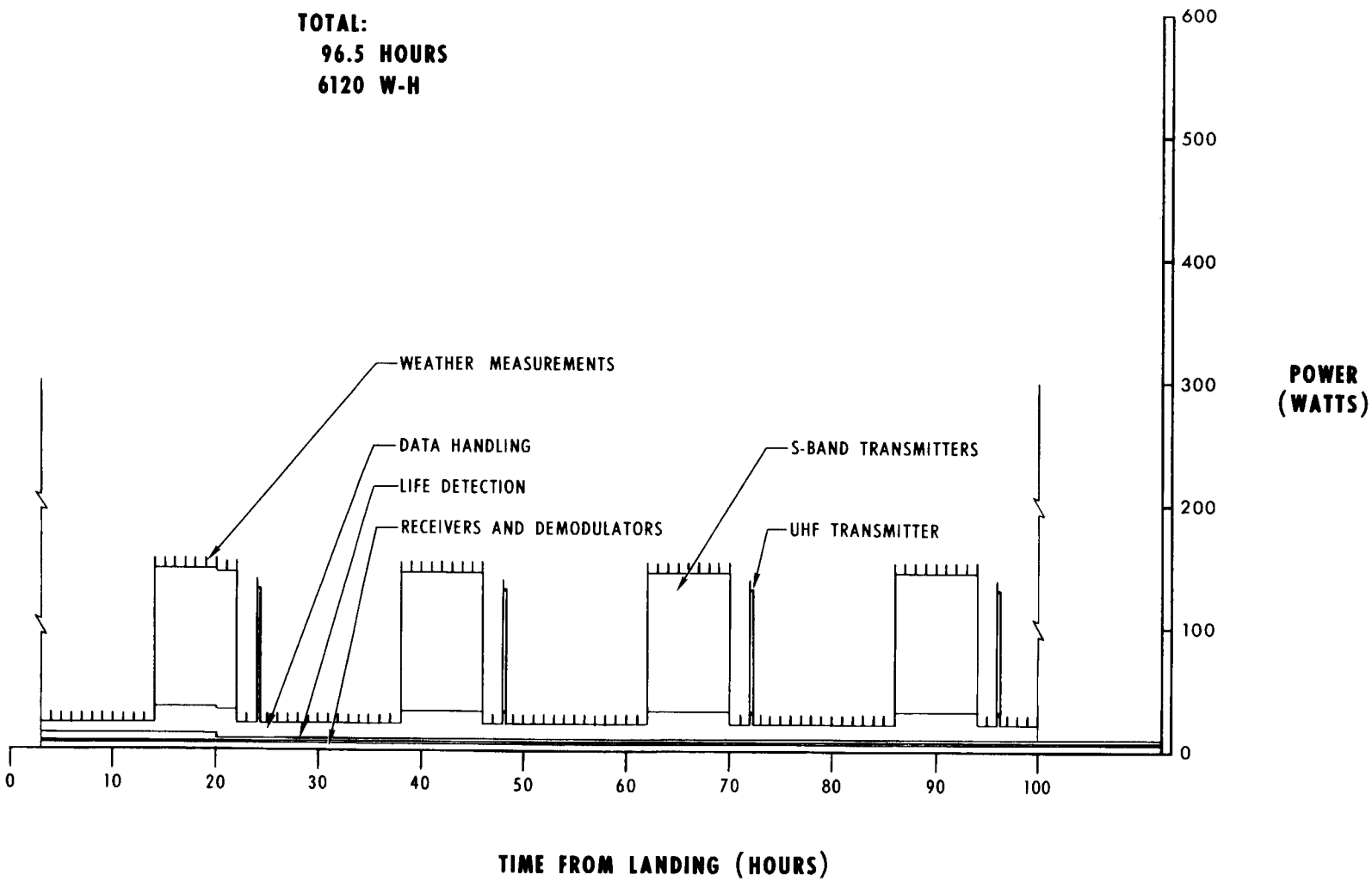
(1) $\epsilon = 0.62$ (2) HALF POWER POINTS hp = 1500 km



SOFT LANDER - POWER PROFILE (EARLY OPERATIONS)



SOFT LANDER - POWER PROFILE (CONTINUING OPERATIONS)



CONSTANT POWER SOURCE CANDIDATES FOR SOFT LANDER

SOLAR CELLS

POWER - WEIGHT RATIO	1 WATT PER POUND
POWER - AREA RATIO	1 WATT PER FOOT^2
POWER REQUIRED	
THERMAL CONTROL	240 WATT
ELECTRONICS	20 WATT
	260 WATT
SOLAR ARRAY WEIGHT	260 LBS.
SOLAR ARRAY AREA	260 FT^2

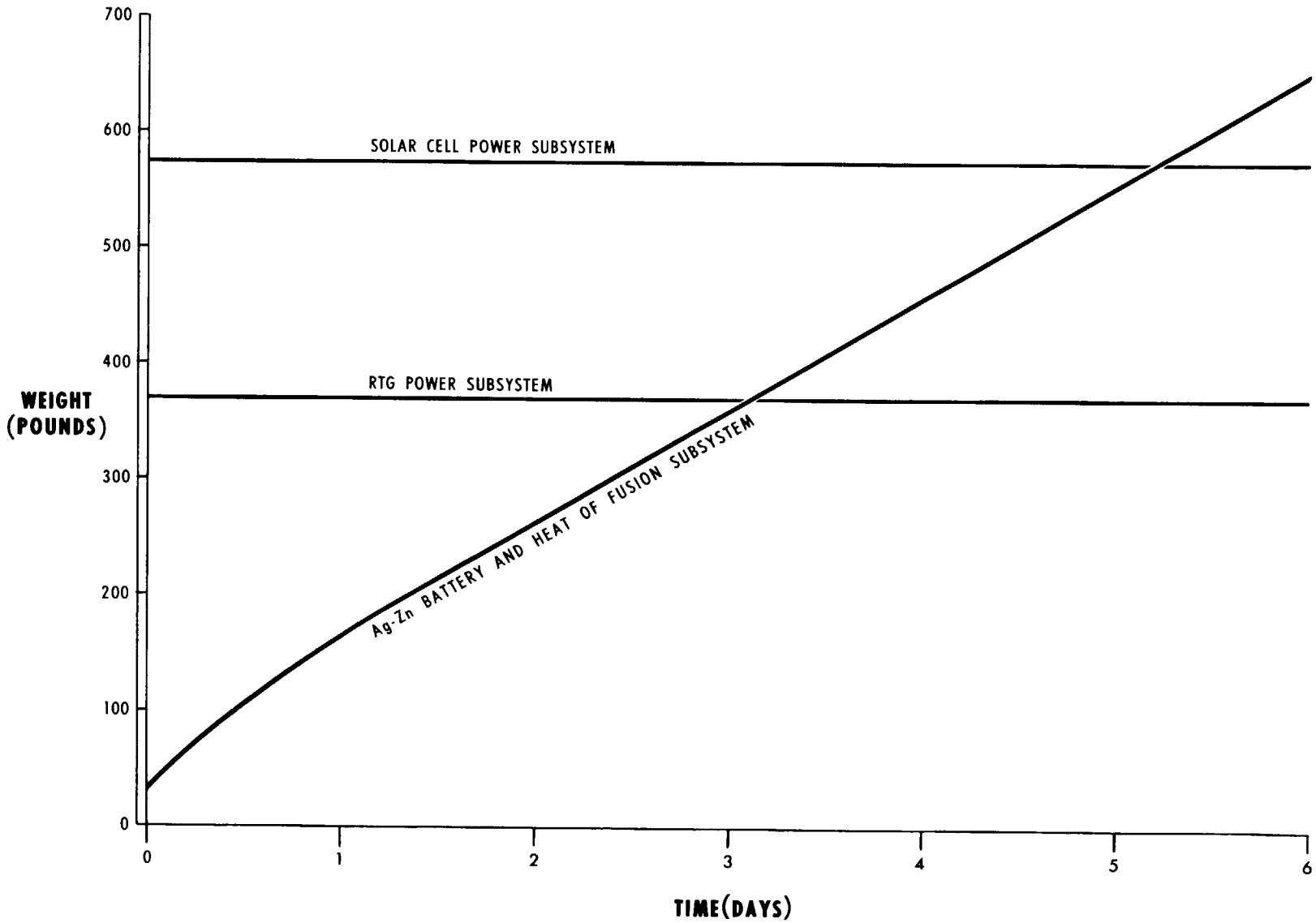
SIZE EXCESSIVE
DEPLOYMENT IMPRACTICAL
POSSIBLE REDUCED EFFICIENCY DUE TO DUST STORMS
AIRLOADS IN DUST STORMS

RTG

LEAD-TELLURIDE THERMOELECTRIC CONVERSION SYSTEM
PU-238 ISOTOPE FUEL
SNAP 19 DESIGN CONCEPT
ARRAY OF 4 RTG's OF 5 WATT EACH

POWER REQUIRED	20 WATT
POWER-WEIGHT RATIO	.15 WATT/LB. (SHIELDED)
SHIELDING REQUIRED	1 γ/CM^2/SEC AT 12 FEET
RTG WEIGHT	132 LB. TOTAL
THERMAL CONTROL REQUIREMENT	240 WATT EQUIVALENT
RTG HEAT OUTPUT	400 WATT

POWER AND THERMAL HEAT SOURCES



MISSION TRAJECTORY CONSIDERATIONS

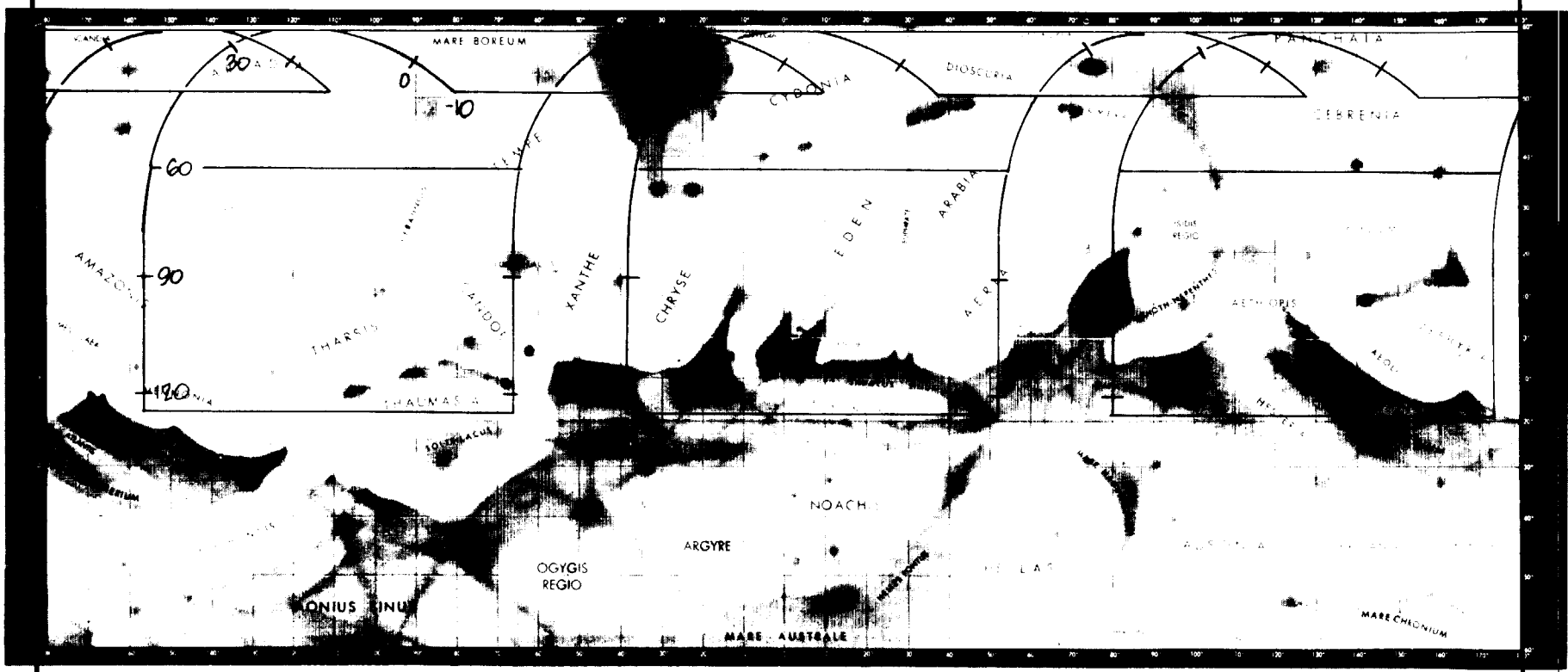
W. Pragluski

PROJECT ENGINEER,
AEROSPACE MECHANICS

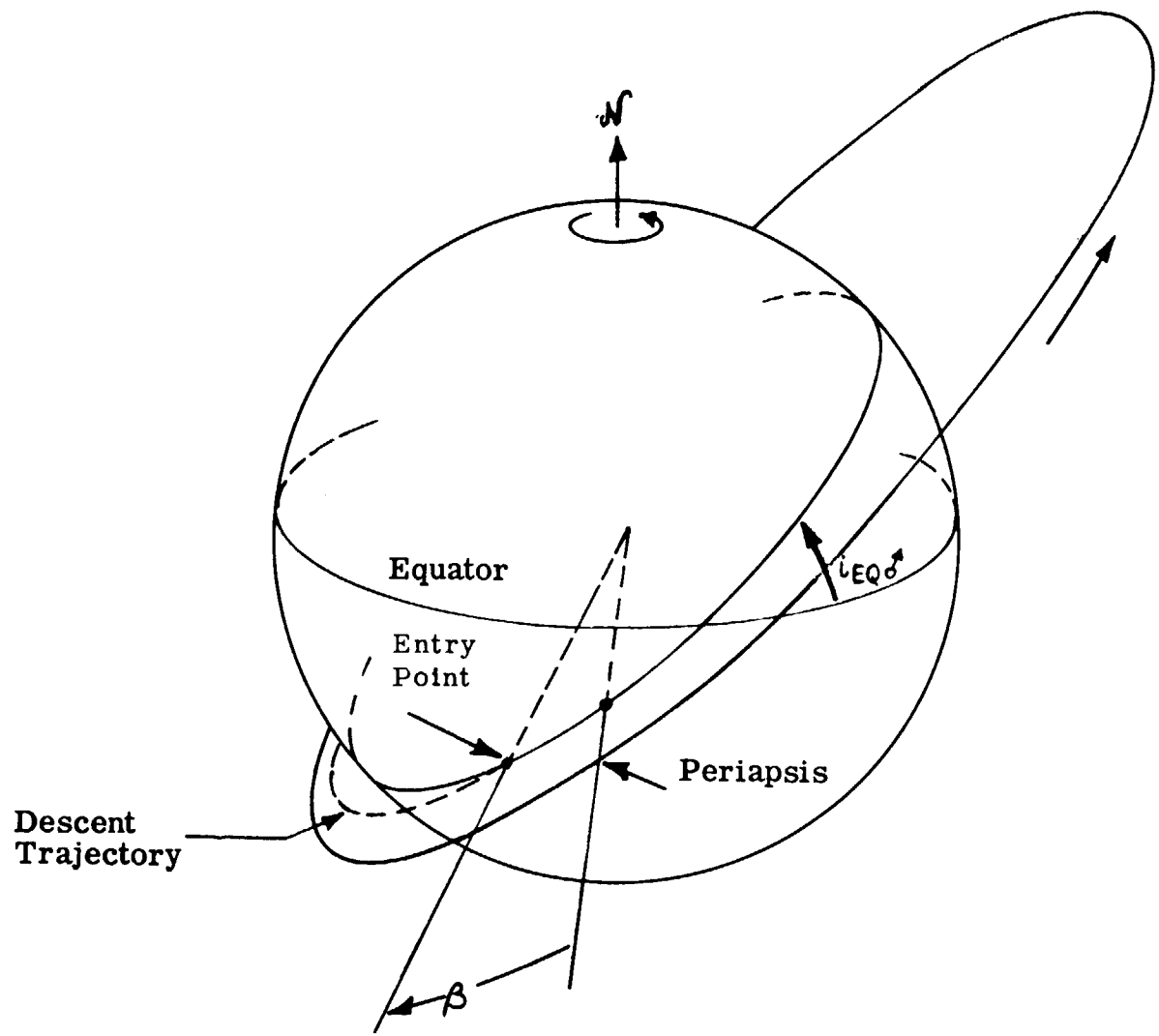
Detailed mission profile analysis is required to properly reflect the Flight Spacecraft and Flight Capsule scientific objectives into the design of the vehicles and to uncover the conflicting desires of each vehicle's mission. The Spacecraft's mapping mission suggests a relatively high inclination orbit with the subperiapsis point near the terminator. Transmars trajectory characteristics in 1973 show that the Spacecraft orbit insertion impulse will have to be increased by approximately 10 percent for periapsis location positioning.

The Capsule's atmospheric and biological science objectives suggests landings in the wave of darkening areas in the equatorial belt or middle northern latitudes (for the 1973 mission). In addition, descent television requires the landing areas to be near the terminator. Satisfying these requirements calls for a deorbit impulse of 400 mps or greater. In addition, one of the Planetary Vehicles must be placed into a low inclination orbit.

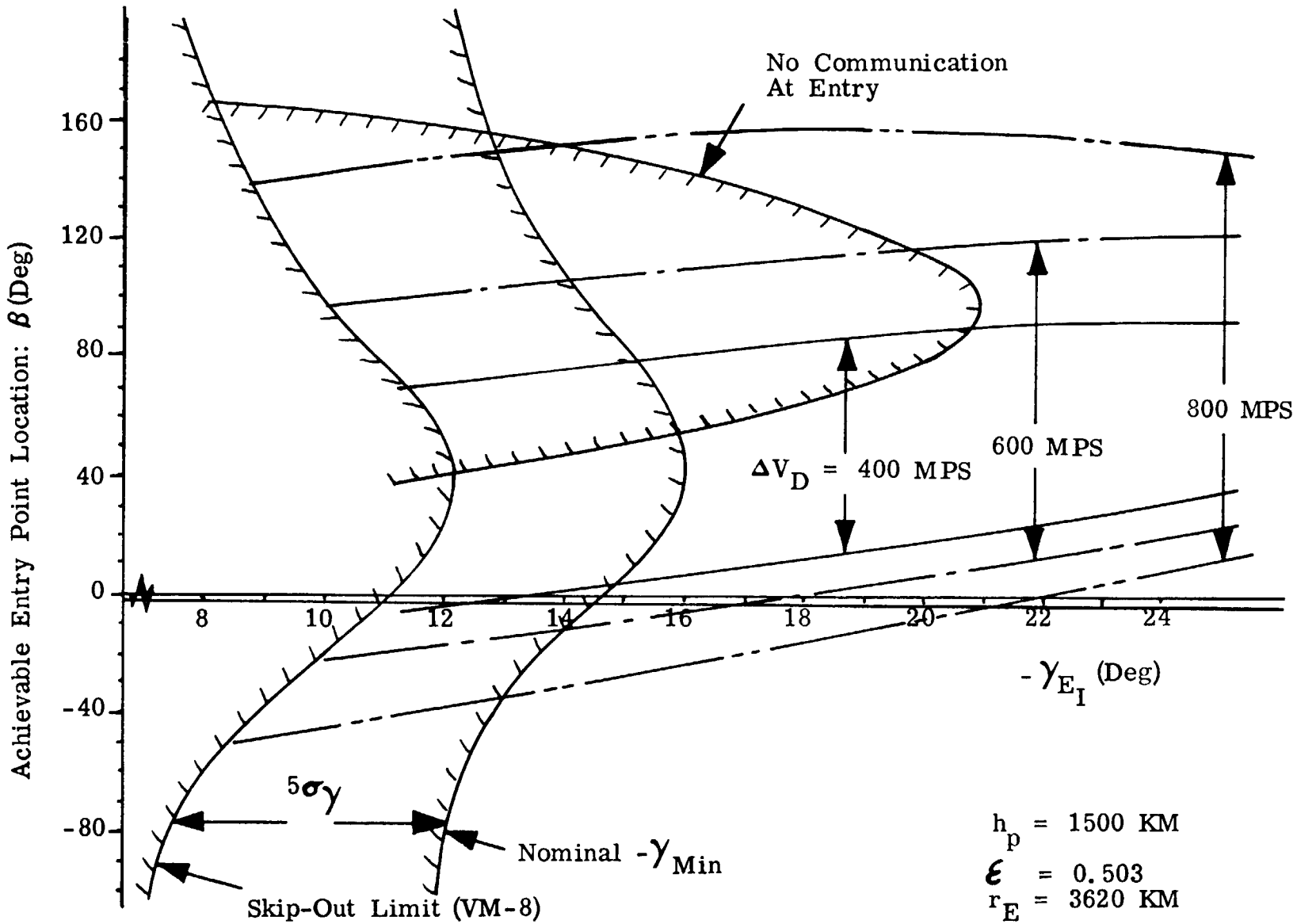
The use of an oversized deorbit motor for targeting capability results in a requirement for a controllable impulse deorbit motor and high orientation accuracy at deorbit. This is necessary to minimize entry flight path angle dispersions and their effect on atmosphere determination during entry. Attitude accuracy at deorbit means that considerable care must be taken in Spacecraft positioning at Capsule separation and attitude reference transfer from the Spacecraft to the Capsule.


MARE BOREUM
30
0
-10
60
90
120
CYDONIA
DIOSCURIA
CEBRENIA
EDEN
ARABIA
AERIA
XANTHE
CHRYSE
THARSIS
THAUMASIA
AMAZONIS
NOACHIS
ARGYRE
OGYGIS
REGIO
MARE AUSTRALE
MARE CHRONIUM

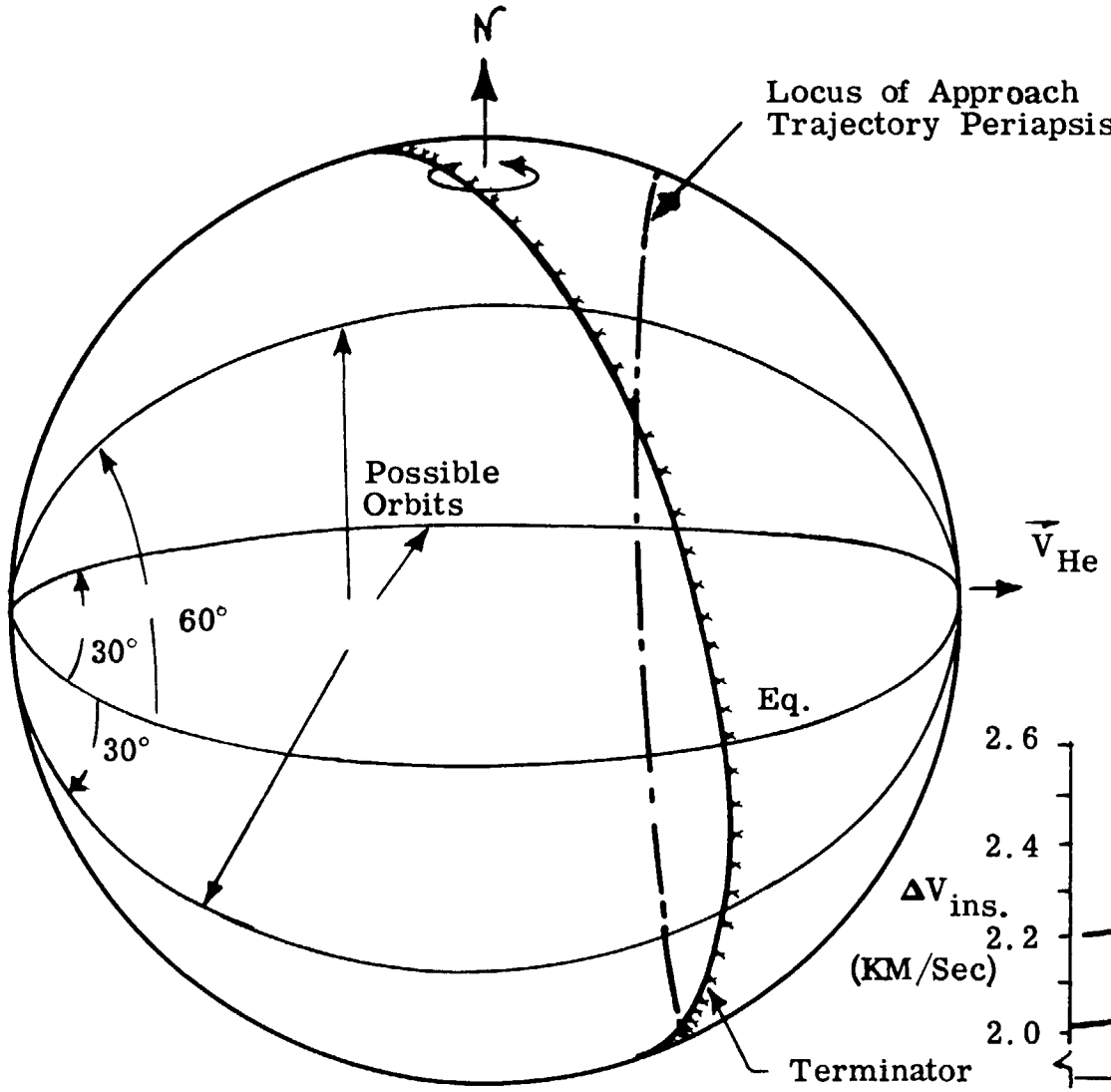
ORBIT-LANDING SITE GEOMETRY



1973 MISSION: TARGETING CAPABILITY



1973 MISSION: TRANSFER TRAJECTORY CHARACTERISTICS



Departure Dates:

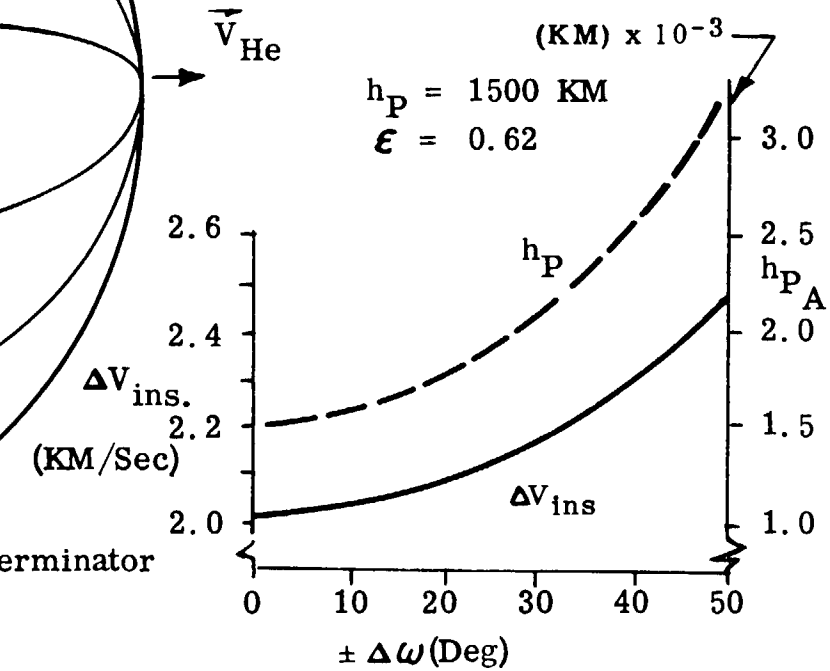
12 July → 10 Aug, 1973

Encounter Date:

14 Jan., 1974

$3.7 < V_{He} < 4.0$ (KM/Sec)

$15.8 < C_3 < 17.5$ (KM/Sec)^2



HARD vs SOFT LANDERS

R. Scarborough

TECHNICAL DIRECTOR

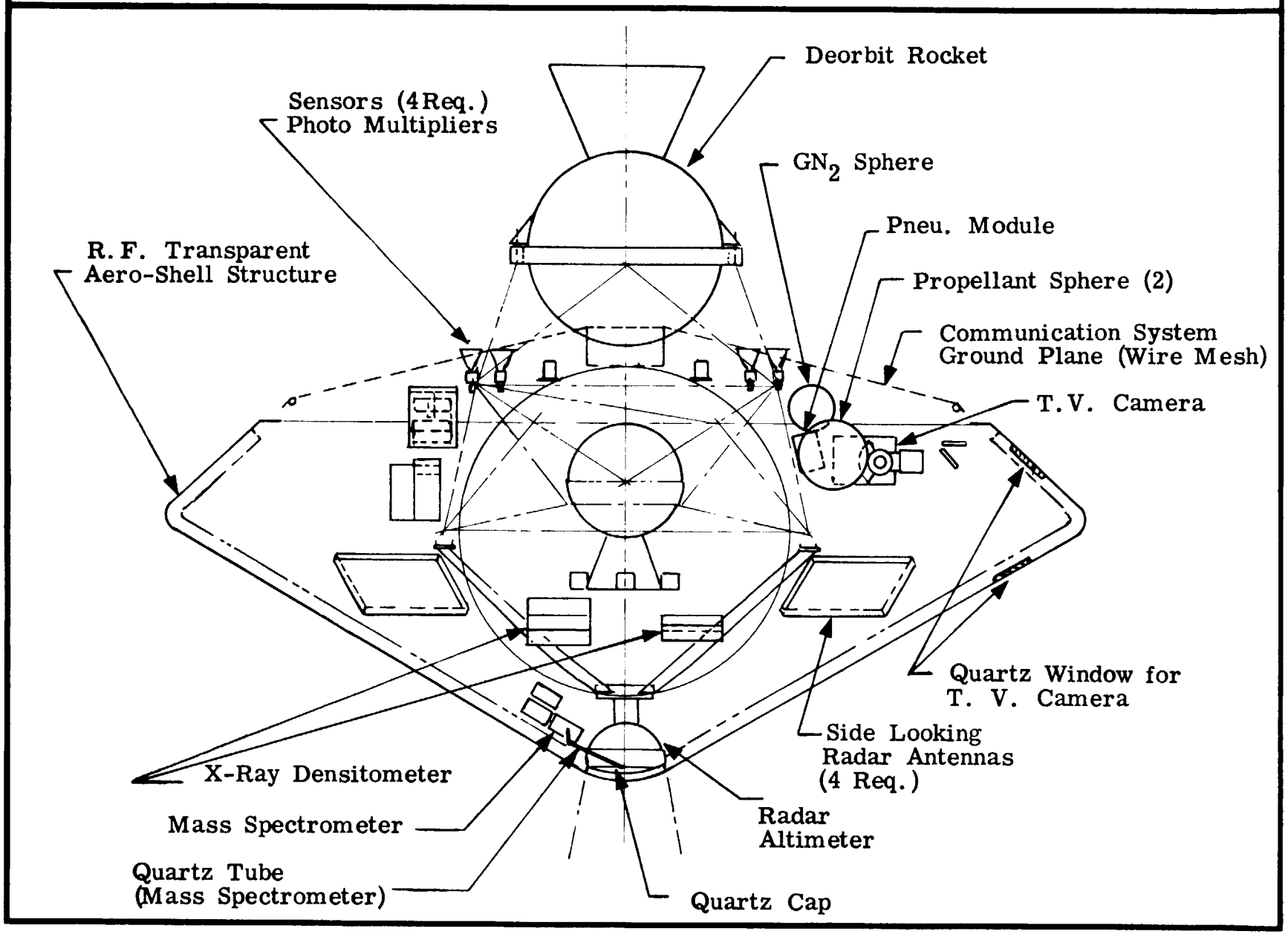
The time span to a 1973 Mars Landing Mission is sufficient to develop either the soft or hard lander with a high degree of confidence; however, three principal factors are in favor of the soft lander: low g impact hardening of equipment, easier accessibility to equipment, and a higher payload capability.

The number of developments required for the 1970 decade of Voyager Mars Capsule exploration can be minimized if a fixed entry weight is flown. This can be accomplished, utilizing dual planetary spacecraft, by restricting the orbital eccentricity of the 1977 mission to greater than 0.65. This implies a liquid propulsion module in the Flight Spacecraft in which propellants can be off loaded, and restrictions upon the number of landing sites that can be acquired by the Flight Capsule.

A 19 ft. diameter aeroshell and 5,000 lb. entry weight can be the basic design for the 1970 decade. The Flight Capsule in this configuration will be entering at a ballistic coefficient of 0.37 slugs/ft^2 instead of the optimum of 0.45 slugs/ft^2. The payload penalty for this is less than 2%. This approach will permit flying at higher gross weight, by providing the maximum fixed drag area possible, on later missions where one Planetary Spacecraft and one Flight Capsule may be selected to accommodate large single unit payloads, such as the Automated Biological Laboratory.

Developments in supporting subsystems can be limited by selecting a single approach applicable to all missions. This is recommended for all subsystems with the exception of: Telecommunications and power, in particular, where dual development of battery and RTG power systems is recommended with the RTG being included in the earliest mission possible to extend life and increase the value of science data.

HARD LANDER


Deorbit Rocket
Sensors (4Req.)
Photo Multipliers
GN_2 Sphere
Pneu. Module
R.F. Transparent
Aero-Shell Structure
Propellant Sphere (2)
Communication System
Ground Plane (Wire Mesh)
T.V. Camera
Quartz Window for
T. V. Camera
Side Looking
Radar Antennas
(4 Req.)
X-Ray Densitometer
Mass Spectrometer
Radar
Altimeter
Quartz Tube
(Mass Spectrometer)
Quartz Cap

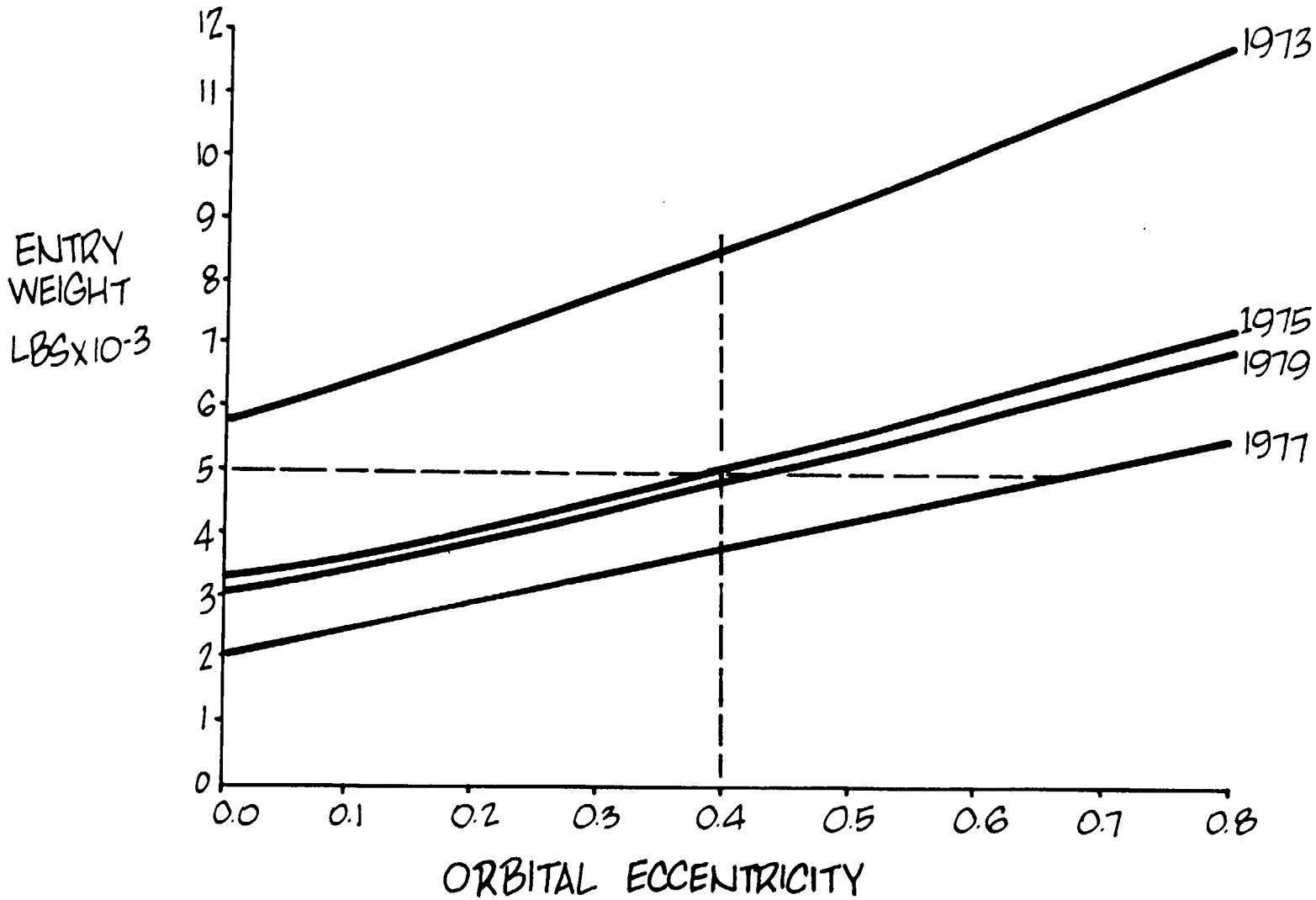
HARD AND SOFT LANDER COMPARISON

	HARD	SOFT
. MISSION SUCCESS		
PROPULSION	3 SOLID MOTORS	6 THROTTLABLE LIQUID
		1 ENGINE OUT CAP.
STAGING SEQUENCES	8	4
CONTROL SYSTEM	1 STAGE	2 STAGE
. PERFORMANCE		
PAYLOAD WEIGHT LBS	1,200	2,000
. DEVELOPMENT RISK	IMPACT HARDENING	THROTTLABLE ENGINES
	HIGH PACKAGING DENSITY	CONTROL SYSTEM
	STERILIZATION	STERILIZATION

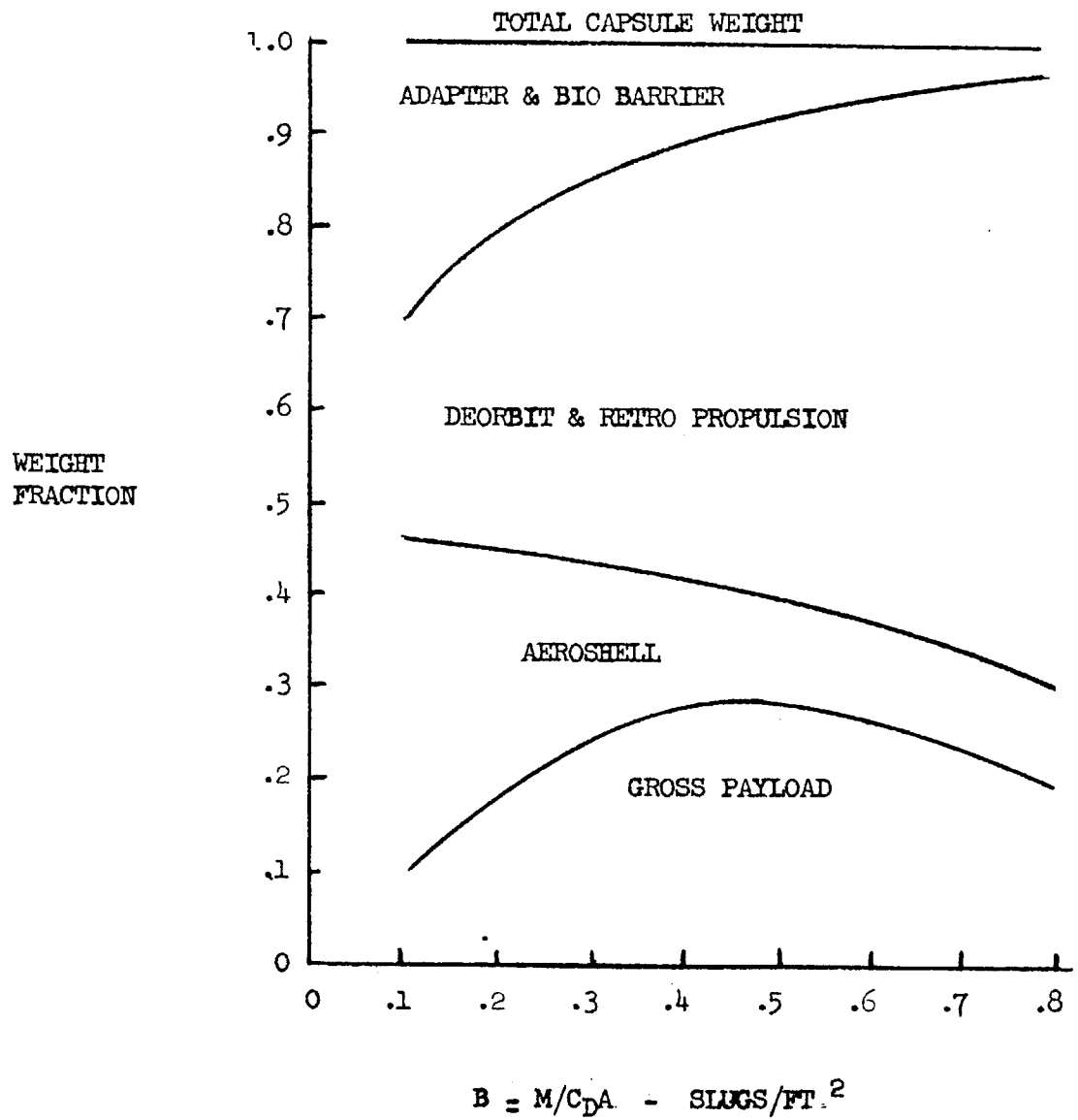
STERILE INSERTION

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

ENTRY WEIGHTS



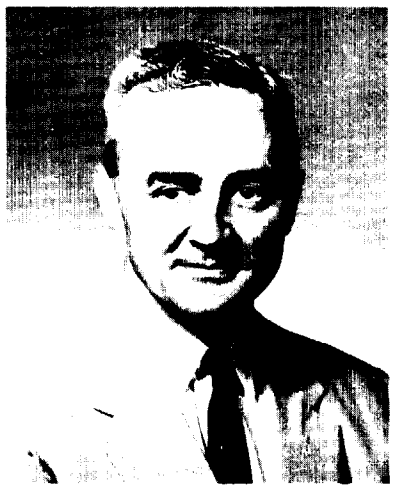
SOFT IMPACTOR NORMALIZED WEIGHT



MINIMUM DEVELOPMENT PROGRAM - 1970 DECADE

- SINGLE AEROSHELL DESIGN
  - DIAMETER - 19 FT.
- SINGLE THROTTLABLE ROCKET ENGINE
  - LBS THRUST -- 3,000
  - THROTTLING RATIO - 10:1
- SINGLE TWO STAGE CONTROL SYSTEM
- SINGLE DATA AUTOMATION SYSTEM
  - 10 MEGABIT STORAGE
- DUAL POWER SYSTEM DEVELOPMENT
  - BATTERY SYSTEM
  - MODULAR RTG SYSTEM

MANAGEMENT PRESENTATION



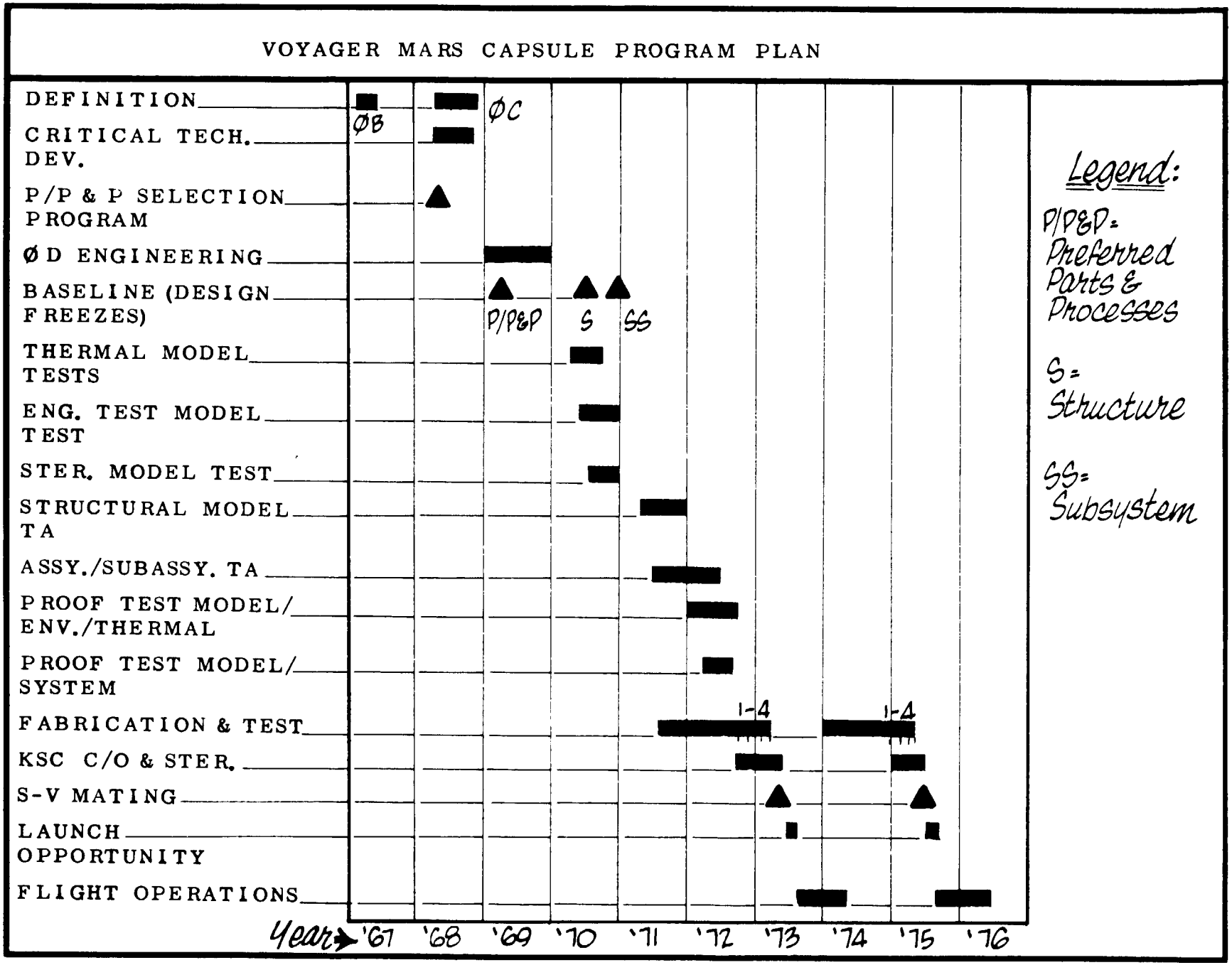
VOYAGER PROJECT CONTROL PLAN

C. Castle

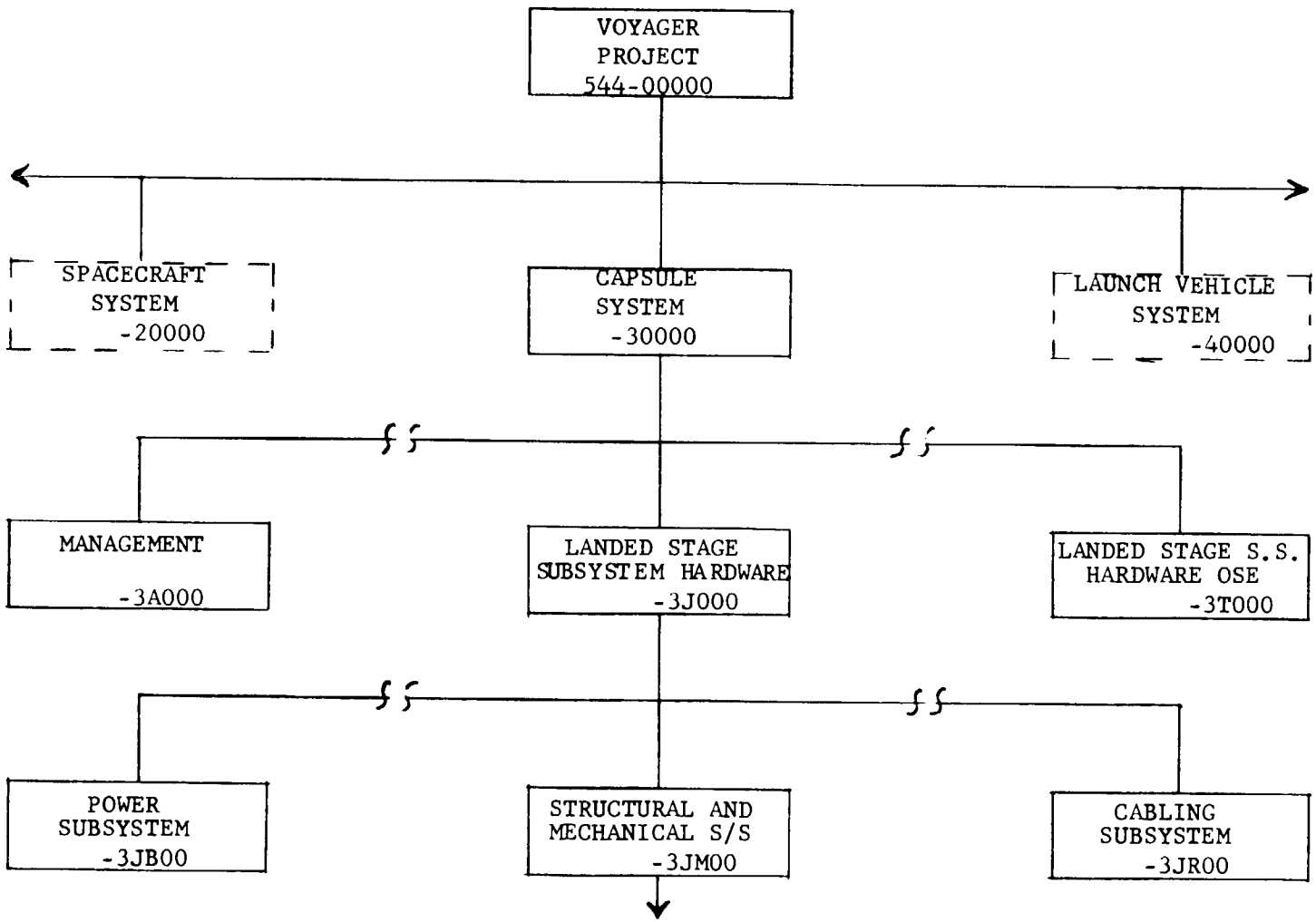
MANAGEMENT OPERATIONS
DIRECTOR

The complexity of the Voyager Capsule System and the multiple interfaces with the other systems and experiments of the Voyager Project represents a management challenge as difficult as any government program in existence. Martin has studied the management system requirements of this program and has developed convictions regarding an approach to the management problem.

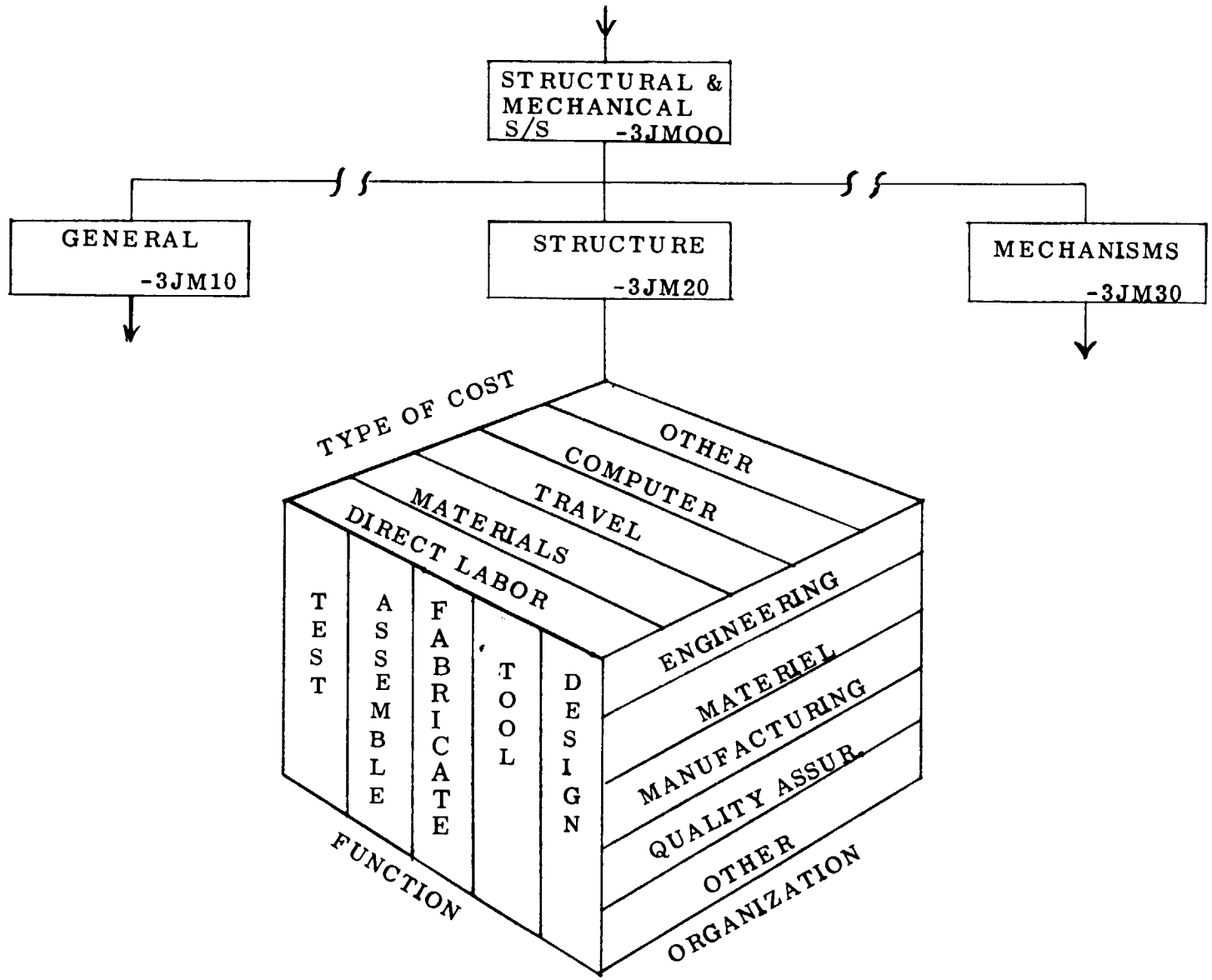
- The Program Plan developed in Phase B establishes the time phased activities of the program and identifies the critical relationships of the design, development, test and build sequences. It is the basis for all lower level schedules and networks.
- The Work Breakdown Structure becomes the key element of the management system. It identifies all elements of the job to be done and is the common reference for specifications, networks, cost accounts, drawing numbers, and hardware element identification.
- To know where the program is in terms of the value of work actually accomplished is essential to program management. Martin uses the "Planned Value of Work Accomplished" or the "Earned Cost" system to provide this data.
- The many thousands of interface events between associated contractors, experimenters, the Jet Propulsion Lab and other NASA agencies requires a disciplined control system. The Schedule Interface Log (SIL) system has been developed to meet this requirement.


VOYAGER MARS CAPSULE PROGRAM PLAN
DEFINITION
CRITICAL TECH. DEV.
P/P & P SELECTION PROGRAM
ØD ENGINEERING
BASELINE (DESIGN FREEZES)
THERMAL MODEL TESTS
ENG. TEST MODEL TEST
STER. MODEL TEST
STRUCTURAL MODEL TA
ASSY./SUBASSY. TA
PROOF TEST MODEL/ ENV./THERMAL
PROOF TEST MODEL/ SYSTEM
FABRICATION & TEST
KSC C/O & STER.
S-V MATING
LAUNCH OPPORTUNITY
FLIGHT OPERATIONS
ØB
ØC
P/P&P
S
SS
1-4
1-4
Year
'67
'68
'69
'70
'71
'72
'73
'74
'75
'76
Legend:
P/P&P = Preferred Parts & Processes
S = Structure
SS = Subsystem

WORK BREAKDOWN STRUCTURE



WORK BREAKDOWN STRUCTURE - Cont'd



MARTIN COMPANY

ENGINEERING DEPARTMENT

MANAGEMENT CONTROL PLAN

RESPONSIBLE INDIVIDUAL J. BLANK

DEPARTMENT NO. 1600

LINE NO.	BASIC IDENT. NO.	SUFFIX	PERT NO.	TASK DESCRIPTION	RESPON. ORGAN.	S/W REFERENCE	FUNCTIONAL PLAN REFERENCE	TASK PRODUCT	SUBSEQUENT USE OR NEED
1	JM00	--	--	STRUCTURAL & MECHANICAL S/S ENGINEERING	1670	1.7	ENGR. PLAN	--	--
2	JM20	--	--	STRUCTURAL ENGINEERING	1670	1.7.1	ENGR. PLAN	--	--
3	JM20	161	002	STRUCTURE BASIC DESIGN	1670	1.7.1.1	ENGR. PLAN	PRODUCTION-DRAWINGS	FABRICATION & ASSEMBLY
4	JM20	163	--	STRUCTURE BASIC DESIGN MAINTENANCE	1670	1.7.1.1	ENGR. PLAN	PRODUCTION-DRAWINGS	FABRICATION & ASSEMBLY
5	JM20	164	--	STRUCTURE RECURRING ENGINEERING	1670	1.7.1	ENGR. PLAN	--	--
6	JM20	171	008	STRUCTURAL COMPONENT VERIFICATION TESTING	1640	1.7.1.2	ENGR. PLAN	TEST REPORTS	DESIGN VERIFICATION
7	JM20	161	001	STRUCTURAL ITEMS LL PROCUREMENT RELEASE PREPARATION	1670	1.7.1.1	ENGR. PLAN	LL RELEASE	PROCUREMENT
8									
9									
10									
11									
12									
13									
14									
15									
16									

NOTE: LINES BELOW ARE EXTENSIONS OF THE SAME NUMBERED LINES ABOVE

SCHEDULE - MANLOADING - PROCUREMENT DOLLARS

	1966							1967												1968												1969												1970					
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M		
1									10	1	15	15	15	15	15	15	15	15	15	15	15	15	15	14	12	10	8	6	4	1	1	1	1																27
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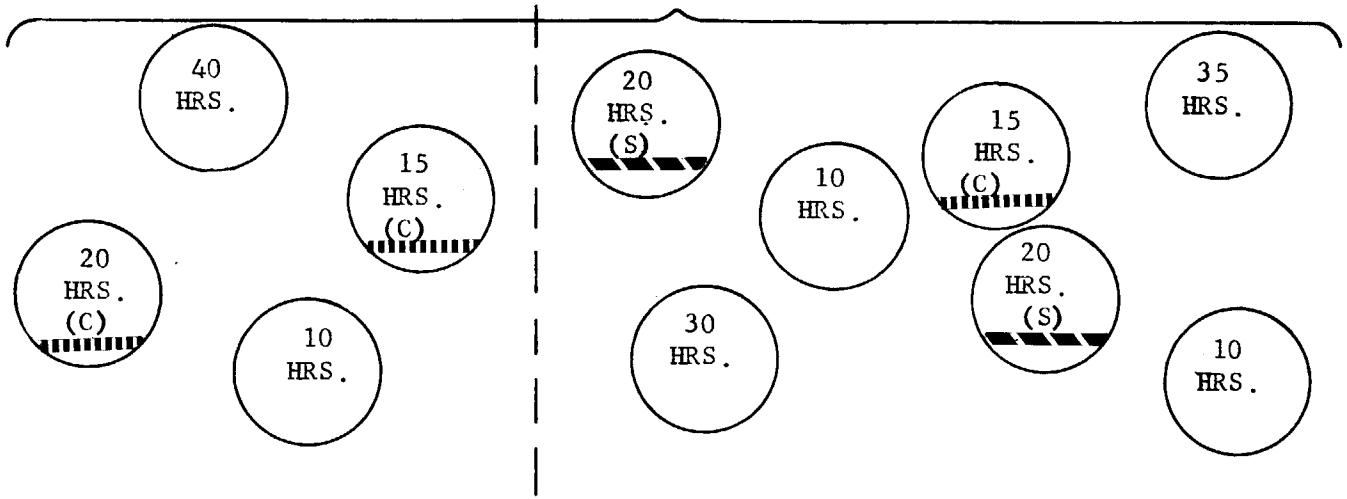
SHEET

PLANNED VALUE OF WORK ACCOMPLISHED

COMPLETED 50 HOURS	TOTAL IN-PROCESS 40 HRS. CREDIT 20 HOURS	NOT STARTED 135 HRS.	=	TOTAL 225 HOURS

COST ACCOUNT



TIME PHASED PLAN TO-DATE	85 HRS.
ACTUAL COST TO-DATE	65 HRS.
TIME PHASED VARIANCE TO-DATE	20 HRS.

PLANNED VALUE TO-DATE	70 HRS.
ACTUAL COSTS TO-DATE	65 HRS.
UNDERRUN VARIANCE TO-DATE	5 HRS.

LEGEND: (C) COMPLETED
(S) STARTED

LOG NO	GIVER TO RECVER	TYPE OF OPER	DESCRIPTION	NEED DATE	PROMISE DATE	SCHEDULE DATE	PRECED RERT SUCCED	TK	SORT CODE	LI	S T C	C H N	C S C
E720	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 1 OF 32) NEED PT DEN 1 SET MAINT BY GVMT/INSTALLED BY MMC	12APR68			600000 701036	07	AAAA	01 02 03 04 10	A	1	
E721	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 2 OF 32) NEED PT WTR 1 SET (SPARE) MAINT BY GVMT/INSTALLED BY MMC	12MAY68			701036 701014	07	AAAB	01 02 03 04 10	A	1	
E722	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 3 OF 32) NEED PT DEN 1 SET (SPARE) MAINT BY GVMT/INSTALLED BY MMC	05JUN68			701036 701014	07	AAAC	01 02 03 04 10	A	1	
E723	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 4 OF 32) NEED PT DEN 1 SET MAINT BY GVMT/INSTALLED BY MMC	26JUL68			600000 702001	07	AAAD	01 02 03 04 10	A	1	
E724	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 5 OF 32) NEED PT DEN 1 SET MAINT BY GVMT/INSTALLED BY MMC	14OCT68			600000 703001	07	AAAE	01 02 03 04 10	A	1	
E725	WECO NC		ANTENNA SET (VENTRAL + DORSAL) VENTRAL G346391, DORSAL G346388 SOURCE WECO (SET 6 OF 32) NEED PT DEN 1 SET	13DEC68			600000 704001	07	AAAF	01 02 03 04	A	1	

DATA MANAGEMENT & CONFIGURATION CONTROL

R. Jones

PROGRAM MANAGER,
CONFIGURATION and
DATA MANAGEMENT

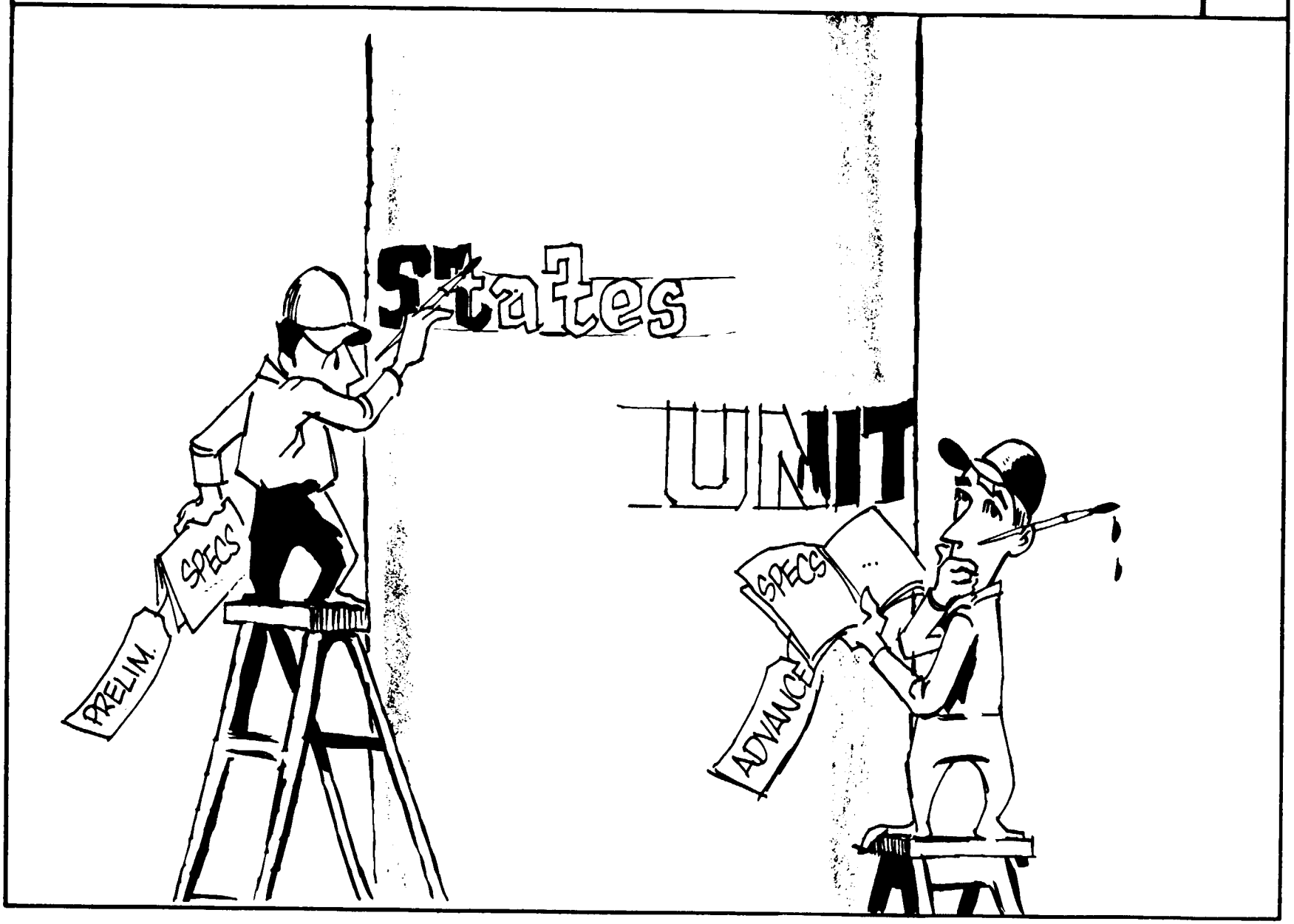
During the last decade, the Martin Company has developed and proven techniques and system for the efficient and timely control of data and configuration. These systems have been developed so that they may be adapted manually to a small prototype program or operated in sophisticated mechanized format on a large development program.

The Configuration Management System provides a detailed contractual definition of software, hardware, and procedures with a technique of controlling changes emphasizing top management participation. This allows up-to-date configuration description of any controlled item from specification negotiation to completion of project. This, when coupled with the Martin Interface Management System and the other interface contractors configuration system, provides for the identification, definition, negotiation, scheduling and control of the large volume of interfaces existing where there are many agencies and contractors participating.

The Data Management System provides the method for evaluating the need for and the use of data on a program, the scheduling and follow-up to guarantee on-time delivery and the management emphasis that make data an important part of the program.

These systems have proven invaluable in providing sufficient definition and understanding of programs to allow fixed price and incentive contracting and in defining and providing an efficient relationship between the customer and various agencies cooperating on a program. We believe they would be of great assistance to JPL on Voyager.

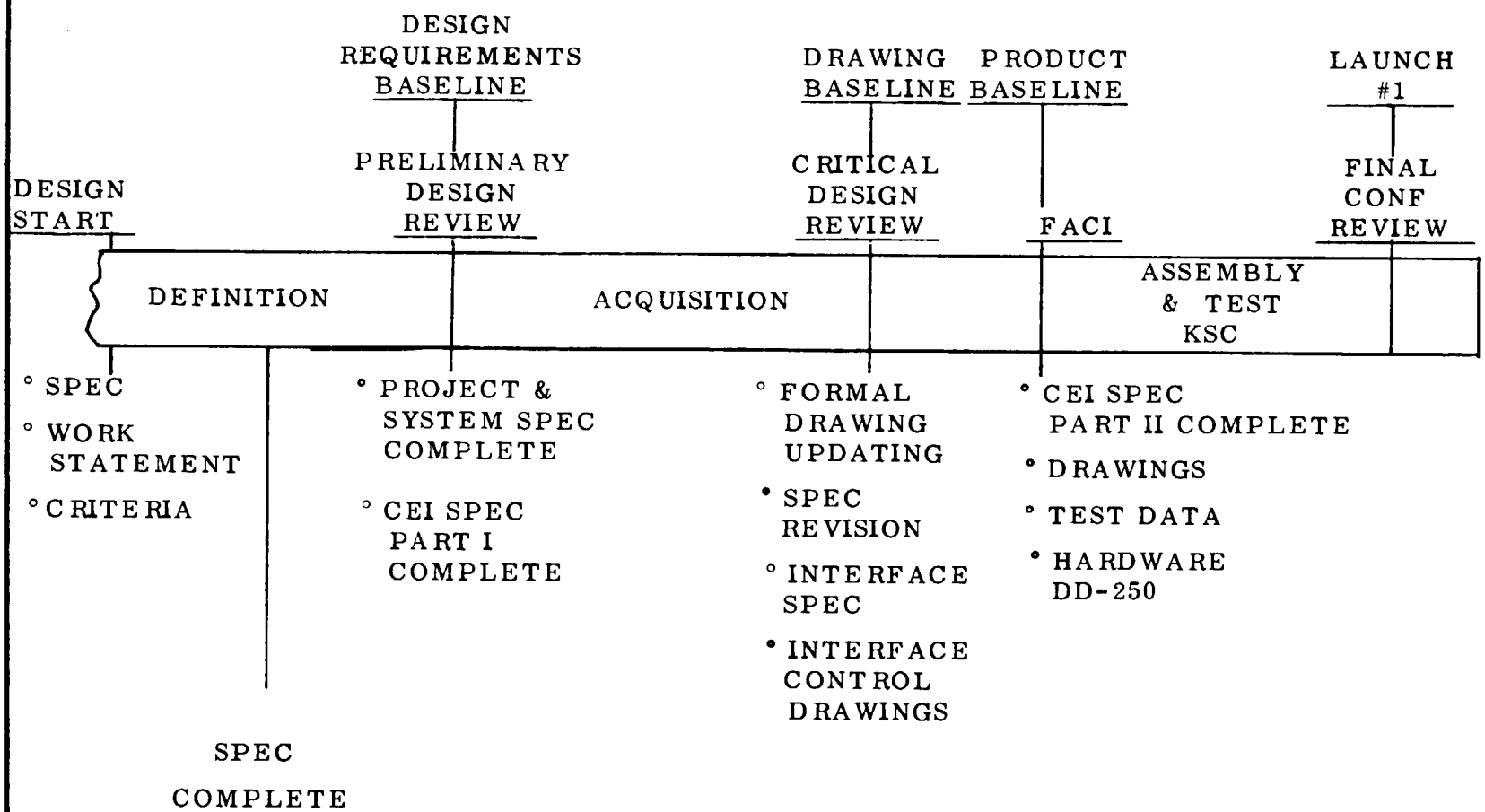
CONFIGURATION *Control*



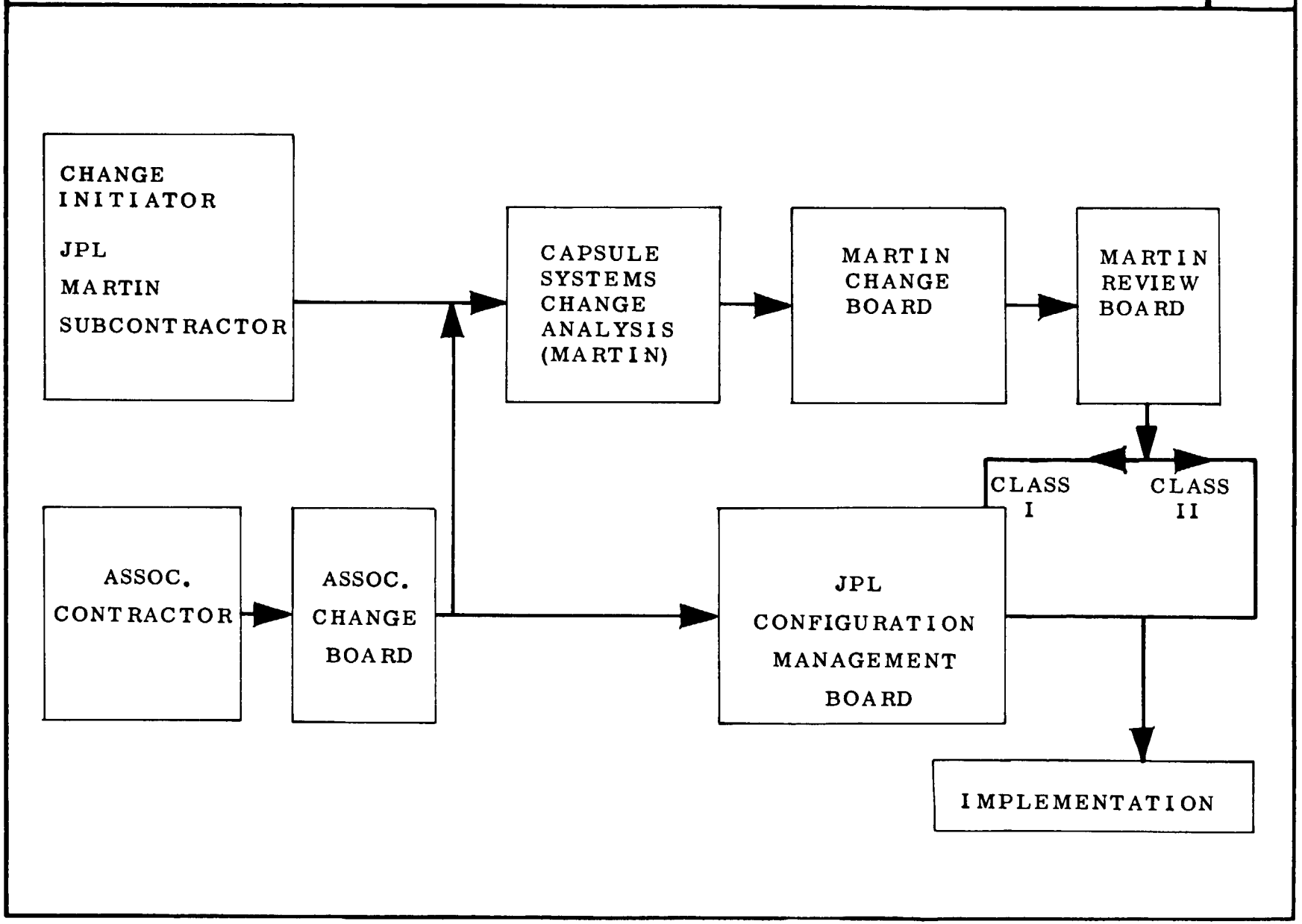
NPC 500-1 PHASING

PHASE A	PHASE B	PHASE C	PHASE D
CONCEPTUAL	PRELIMINARY DEFINITION	FINAL DEFINITION	DEVELOPMENT OPERATION
SYSTEMS SPECS	EXPAND SYSTEM SPECS & PREPARE SUBSYSTEM SPECS & MAJOR INTERFACES	PREPARE CEIs, PARTS & PROCESS, & DETAIL INTERFACE SPECIFICATIONS	PRELIM DESIGN REVIEW CRITICAL DESIGN REVIEW PREPARE PART II OF CEIs & MAINTAIN SPECIFICATIONS
△ SYSTEMS BASELINE		△ DESIGN REQUIREMENT BASELINE	△ FACI PRODUCT BASELINE

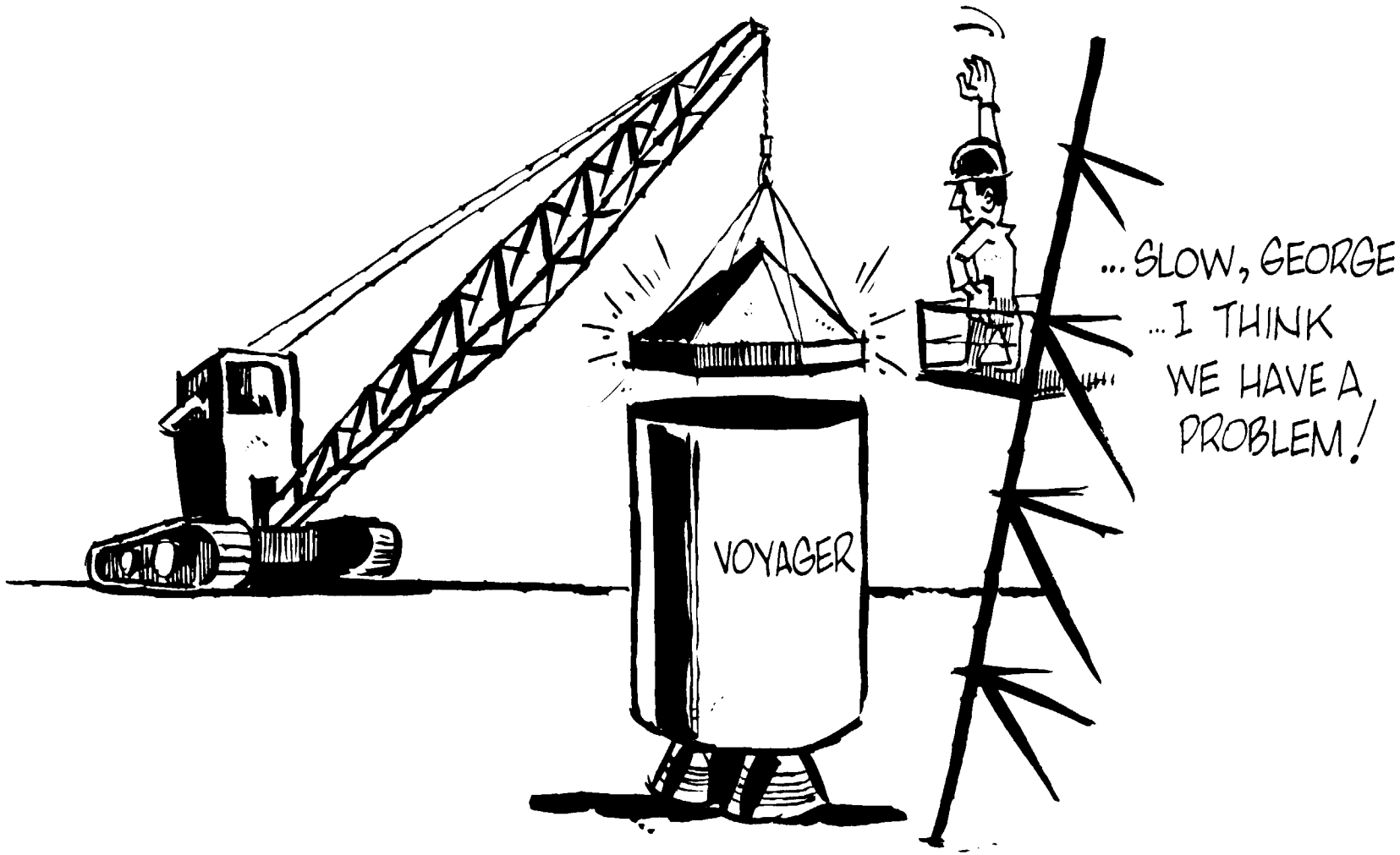
CONFIGURATION MANAGEMENT PHASING

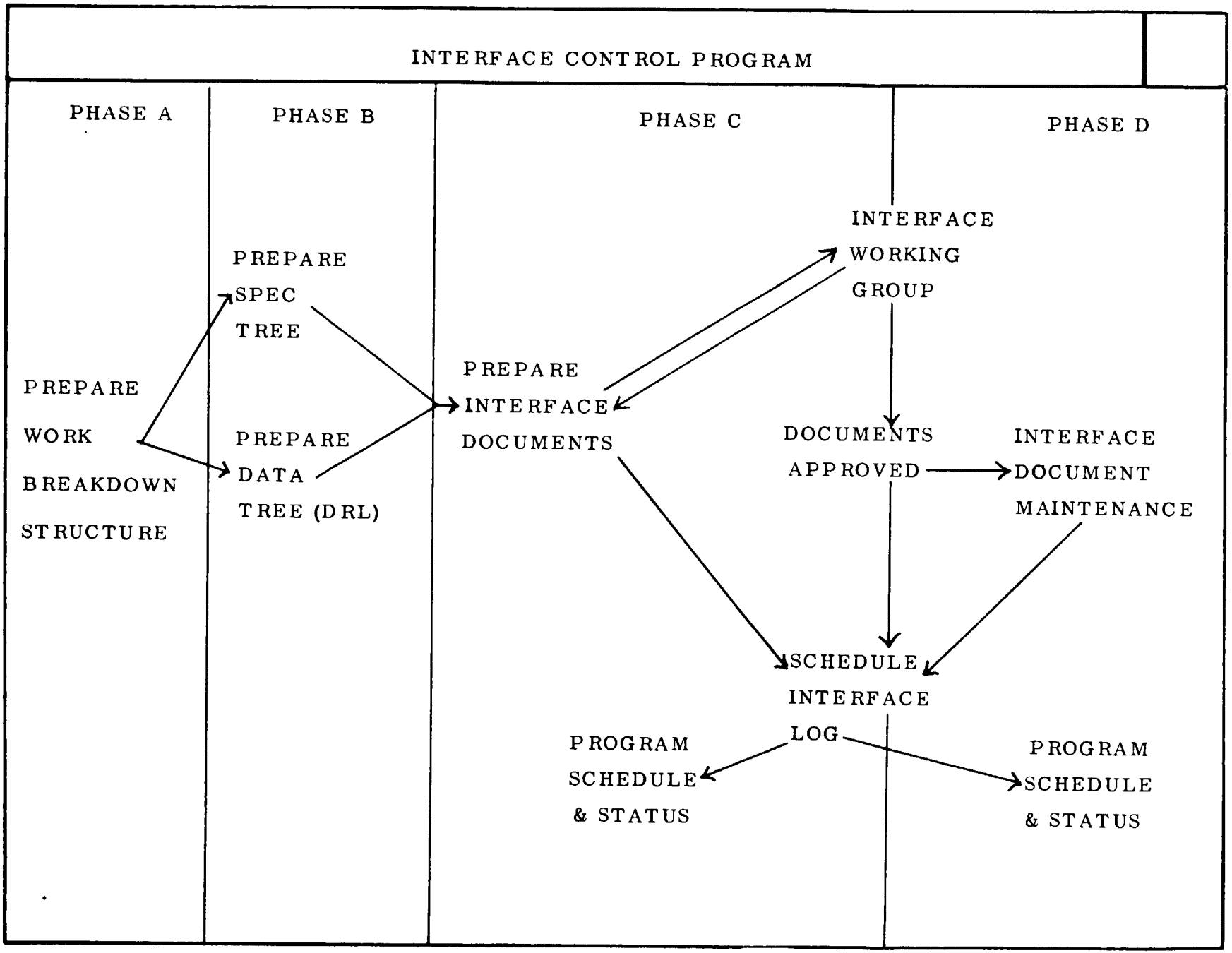


CHANGE CONTROL

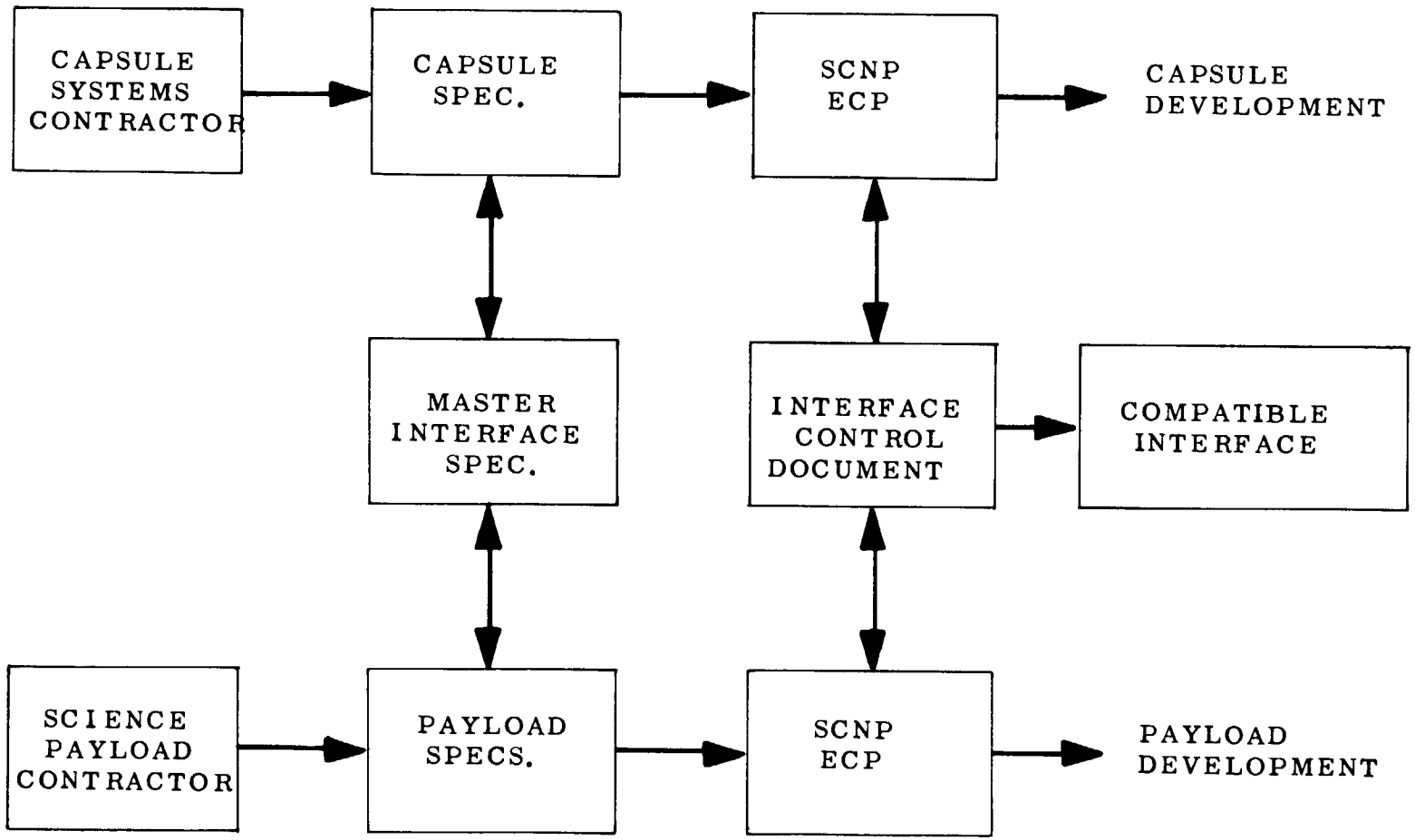


INTERFACE *Control*



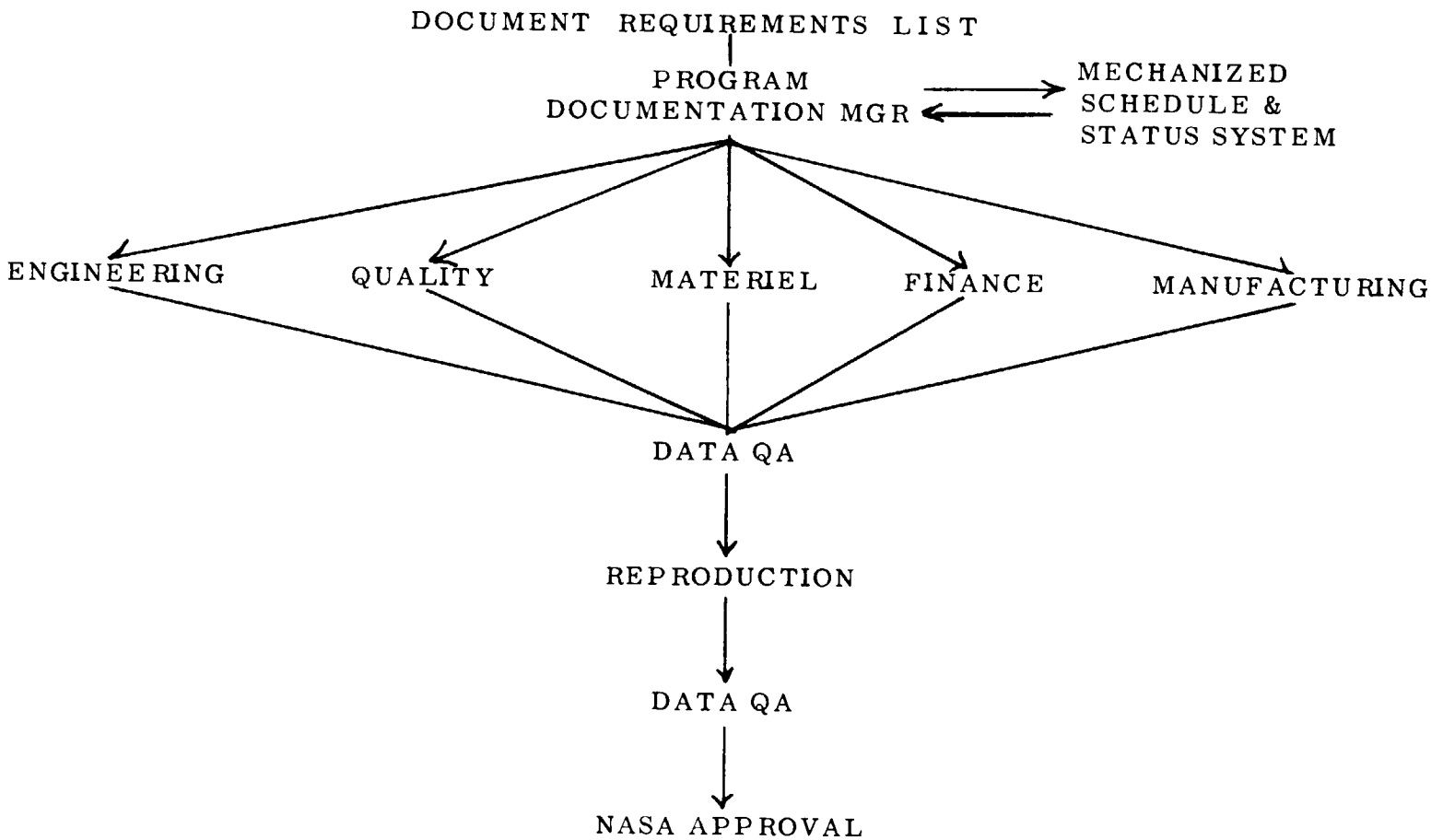

INTERFACE CONTROL PROGRAM
PHASE A
PHASE B
PHASE C
PHASE D
PREPARE WORK BREAKDOWN STRUCTURE
PREPARE SPEC TREE
PREPARE DATA TREE (DRL)
PREPARE INTERFACE DOCUMENTS
INTERFACE WORKING GROUP
DOCUMENTS APPROVED
INTERFACE DOCUMENT MAINTENANCE
SCHEDULE INTERFACE LOG
PROGRAM SCHEDULE & STATUS
PROGRAM SCHEDULE & STATUS

INTERFACE MANAGEMENT



DOCUMENTATION *Control*

DATA MANAGEMENT



TECHNICAL PROGRAM MANAGEMENT

A. Kullas

PROGRAM DIRECTOR,
SPACE SCIENCE SYSTEMS

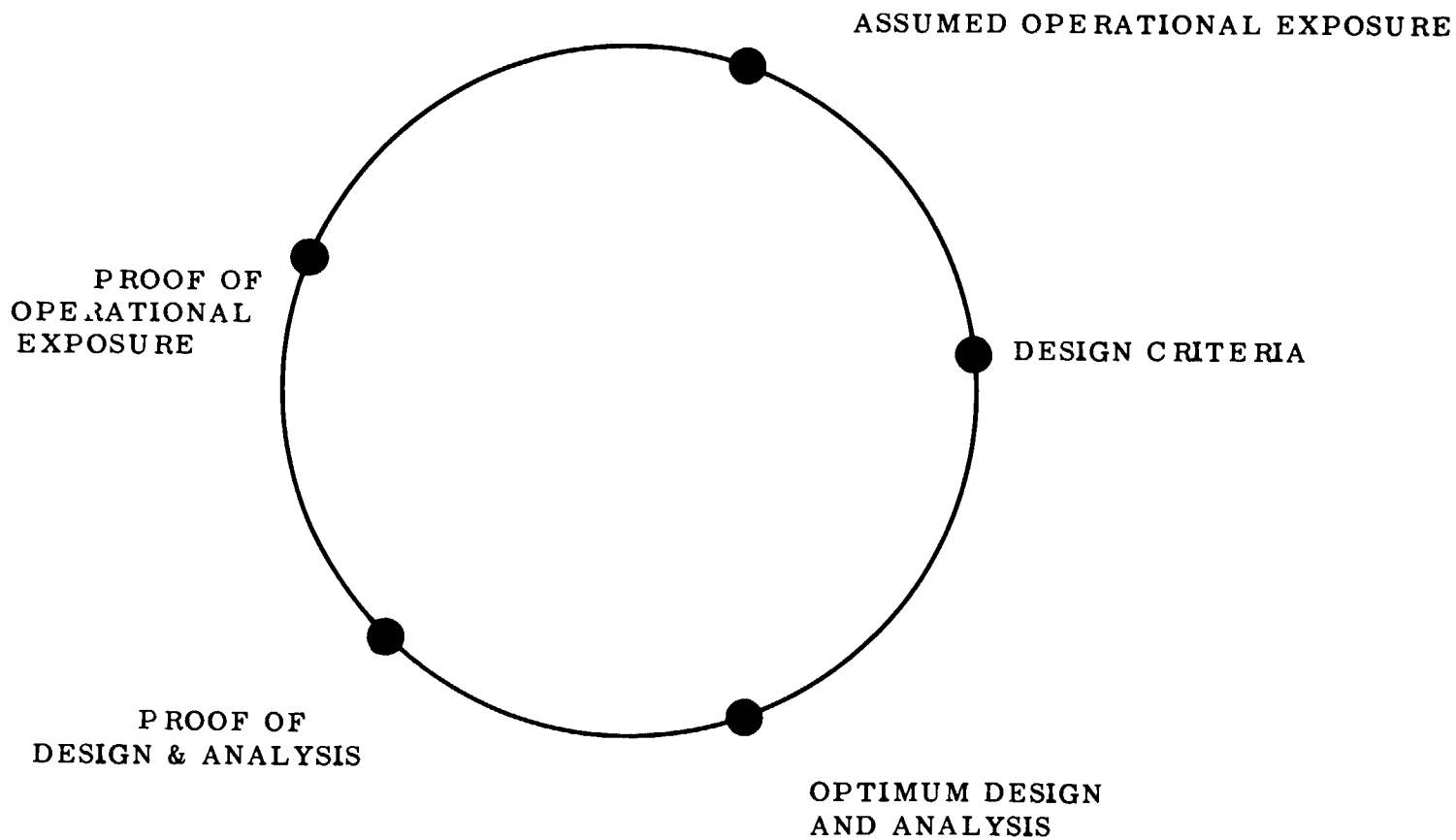
The Capsule System Contractor will evolve some new technical and program management approaches. These will relate to questions like the following:

- How completely will JPL delegate?
- What initiative and independence is sought from the contractor?
- What program parameters shall be monitored?
- How best can the contractor stimulate the initiative and ingenuity of his subs and still maintain clear control?
- What mode of operation involving JPL, the Capsule Systems Contractor, and his subs, and any other source, can best identify and focus on our major technical and management risks?

An exploratory, yet formative, type answer to some of these questions is offered in discussing a mode of operation in Engineering, Procurement, and Manufacturing in the Capsule System Contractor house.

ENGINEERING

DESIGN REVIEWS



WORK PACKAGES
AND
INCENTIVE PERT EVENTS

8000 PKGS AVERAGING 200 HOURS

130 IPE's MADE 127/130

INDEPENDENT CHECKING GROUP

USAF

CONTRACT TYPE

PUSH TO F.P., F.P.I., C.P.I.F.

F.P.	40/68	58.6%
F.P.I.	9.6/68	14.0%
C.P.I.F.	14.2/68	20.8%
C.P.F.F.	0.2/68	0.3%
SCHED. INCEN.	4.3/68	6.3%

PROCUREMENT

SUBCONTRACT MANAGEMENT PLAN

- NSRA (NON STD. REQUEST AUTHORIZATION)
- PD CHECKLIST (PROCUREMENT DWG.)
- SUBCONTRACTOR CAPABILITY EVALUATION
- QUALITY ASSURANCE PLANS
- SUBCONTRACT MANAGEMENT TEAMS
- PIE's (PRODUCT INTEGRITY ENGINEERS)
- PHASED PROCUREMENT CYCLE

MANUFACTURING

- INCREMENTAL ACCEPTANCE
- PERT - TIME - COST

  100 - 600 HR PKGS TO ASST. FOREMAN LEVEL

  110/135 record
- VALIDATION & VERIFICATION OF SHOP PROCESSES

STATISTICS - TIII

	PHASE I	PHASE II	TIME TO FIRST FLT.	FIRST FLT.	CHANGES	% NC
TIII A & C	1/62	12/62	21 MOS.	C - 4/65 & 6/65	1875 / 2098	88%
TIII B	6/64	2/65	18 MOS.			

DOLLARS:	A & C	305 M	362 M	- NOW 95% COMPL.
	B	98 M	107 M	- NOW 55% COMPL.

PARTICIPANTS: A & C AGC, ACEP, UTC, MARTIN, RMP

B AGC, WECO, UTC, MARTIN, STEARNS-ROGERS, LOCKHEED

OBJECTIVES: SPECIFICATIONS
INTERFACE AGREEMENTS
SCHEDULES (SIL)
PROBLEM ORIENTATION & SOLUTIONS

OBJ - COMMON STATE OF MIND

MANAGEMENT TECHNIQUES

D. Burrows

EXECUTIVE DIRECTOR,
MANAGEMENT OPERATIONS

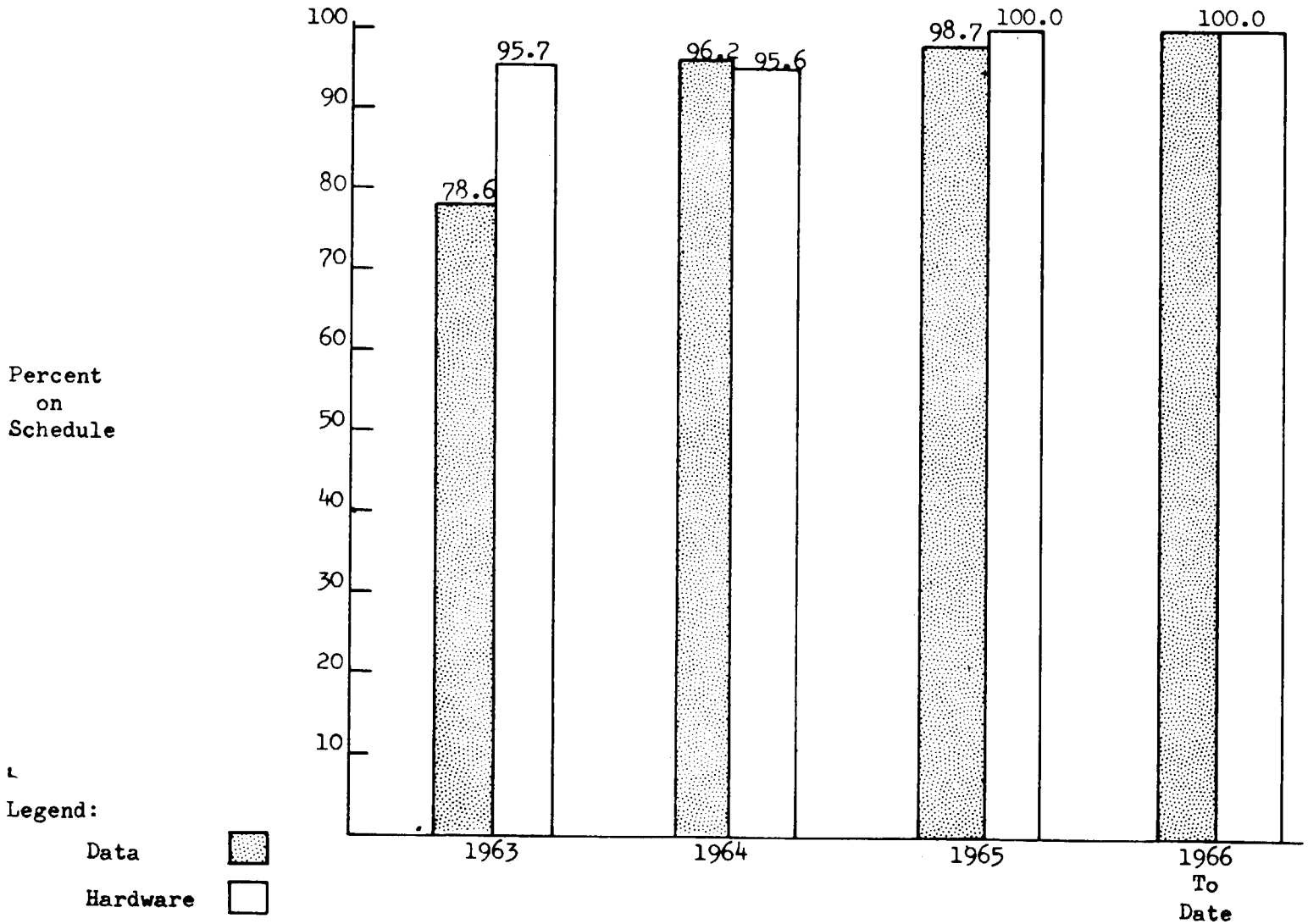
C-2

The management techniques which Martin will apply to the Voyager program have been evolved through use on major space and weapon system developments. Some of these techniques are:

- The creation of a strong Voyager project organization with the authority to commit the required resources.
- Staffing of the project organization with qualified personnel supported as required by the central functions.
- Martin's experience with fixed price and incentive contracting.
- Periodic top management review of project status and progress coupled with monthly management reviews with the customer.

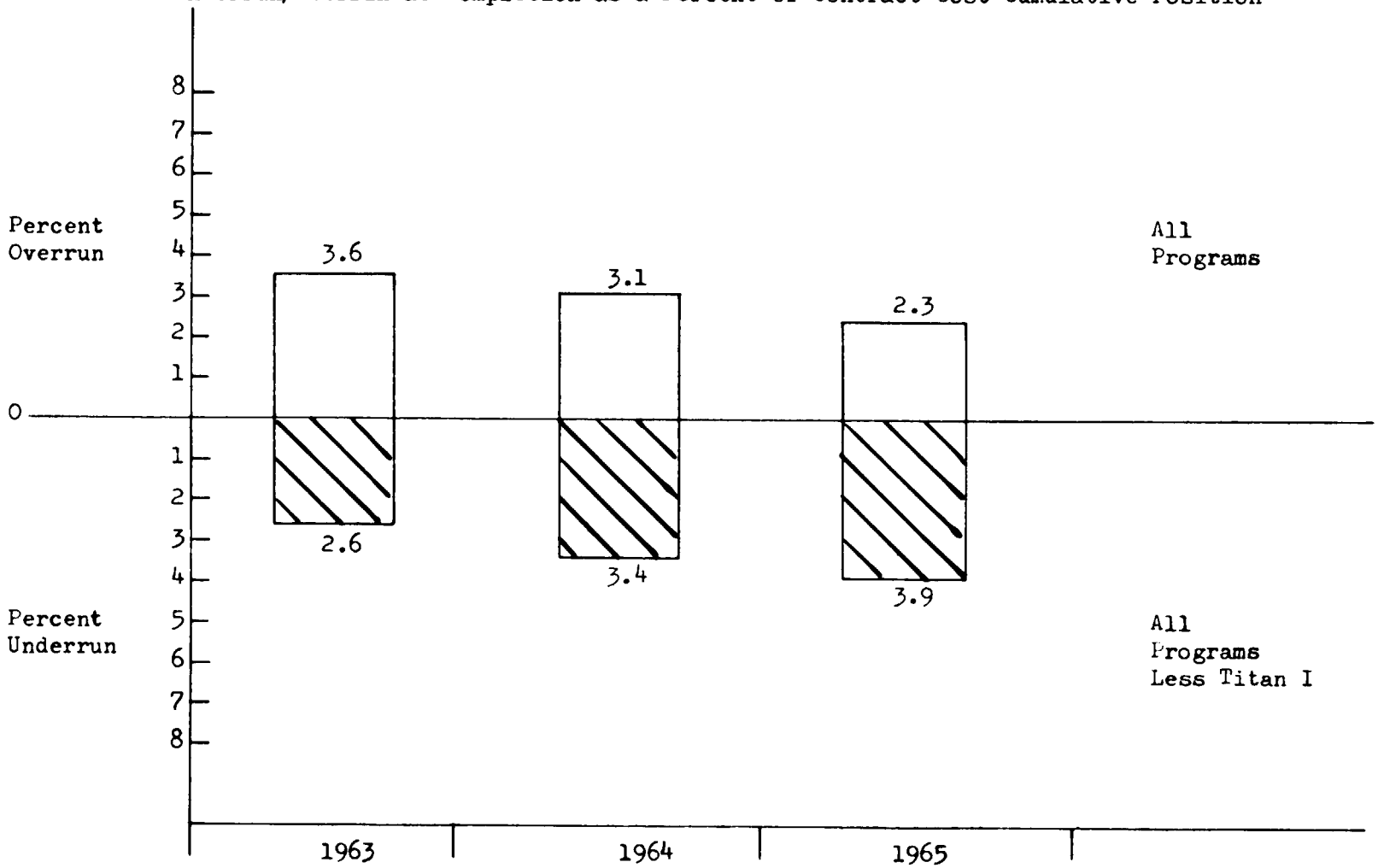
SCHEDULE PERFORMANCE

Contractual Data & Hardware

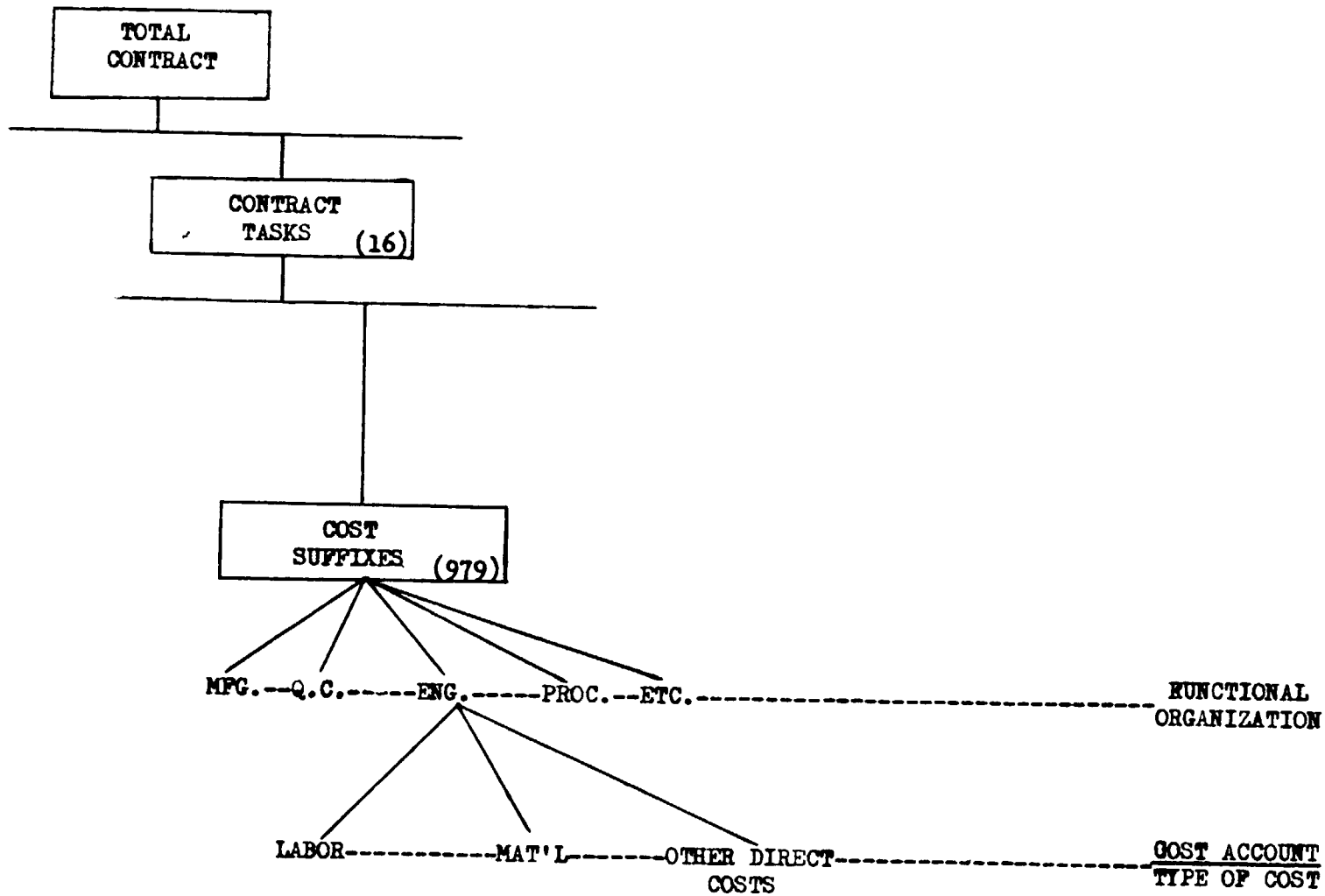


COST PERFORMANCE

Underrun/Overrun at Completion as a Percent of Contract Cost Cumulative Position



BREAKDOWN STRUCTURE



COMPUTERIZED MANAGEMENT CONTROL TOOLS

	MAJOR PROGRAMS
• ENGINEERING SYSTEMS (Auto. Wiring System, Engrg. Data Syst., Auto. Drafting, Etc)	19
• LOGISTIC PROVISIONING SYSTEM (Customer Order thru Inventory, such as SPL, SIS & PSPL)	10
• MANUFACTURING CONTROL SYSTEM (Including Mech. Parts List, Scheduled Build, Procurement Requirements, Mfg. Data Collect, Shop Load Analysis, Prod. Status, Etc.)	21
• PROCUREMENT & INVENTORY MANAGEMENT (Generation of PO's, Receivers, Procurement Status & History)	5
• QUALITY DATA SYSTEM (Failure Data System, Vendor Cert., Alert, Etc.)	7
• CONTRACT & CONFIGURATION MANAGEMENT SYSTEM (Contr. Requirements & Recording System, Contract Data System, Etc.)	4
• FINANCIAL MANAGEMENT & PLANNING (Pert Time, Pert Cost, PVWA, Cost Collection & all Normal Financial Programs)	15
• PERSONNEL SYSTEMS (Talent Bank, Skills Inventory, Locators, Etc.)	3

C. ACCOUNT NUMBER SYSTEM FOR ACCUMULATING COST DATA

XX X XXX

- XXX: Contract Serial No.
- X: Contract Class
  - Major
  - Minor
- XX: Prime Division

XX XX X

- X: Overhead Rate Applicable
  - Basic
  - G&A
  - Basic & G&A
  - Offsite
- XX: Type of Cost
  - Labor - Normal
  - Labor - RW
  - Mat'l.- Normal
  - Mat'l.- RW
  - Mat'l.- Inv.
  - Subcontract
  - Overhead-Basic
  - Overhead-G&A
  - Travel
  - Rental
  - Computer Serv.
- XX: Class of Cost
  - Engineering
  - Tooling
  - Manufacturing
  - Quality Control
  - Test
  - Logistic Support
  - Other Direct Services
  - Vandenberg Activation

XX XXX

- XXX: Task/Function
  - Basic Eng.
  - Mtce. Eng.
  - Basic Tlg.
  - Mtce. Tlg.
  - Detail Mfg.-Lot
  - Sub-Assy-Lot
  - Major Weld-Unit
  - Major Assy-Unit
  - Final Assy-Unit
  - Accept.-Unit
- XX: Contract Item
  - Program Mgt.
  - System Eng.
  - Airborne Des.
  - Airborne Prod.
  - Ground Des.
  - Ground Prod.
  - Logistics

XX — Doing Division

XXXXX — System and Component (WBS)

(9)X — Low Level Work Pkgs. or other Control data

XXXX — Dept. Charged

XX — Work Center

COMPARISON OF RESULTS

SYSTEMS ENGINEERING

TOTAL COST THROUGH JUNE 1966

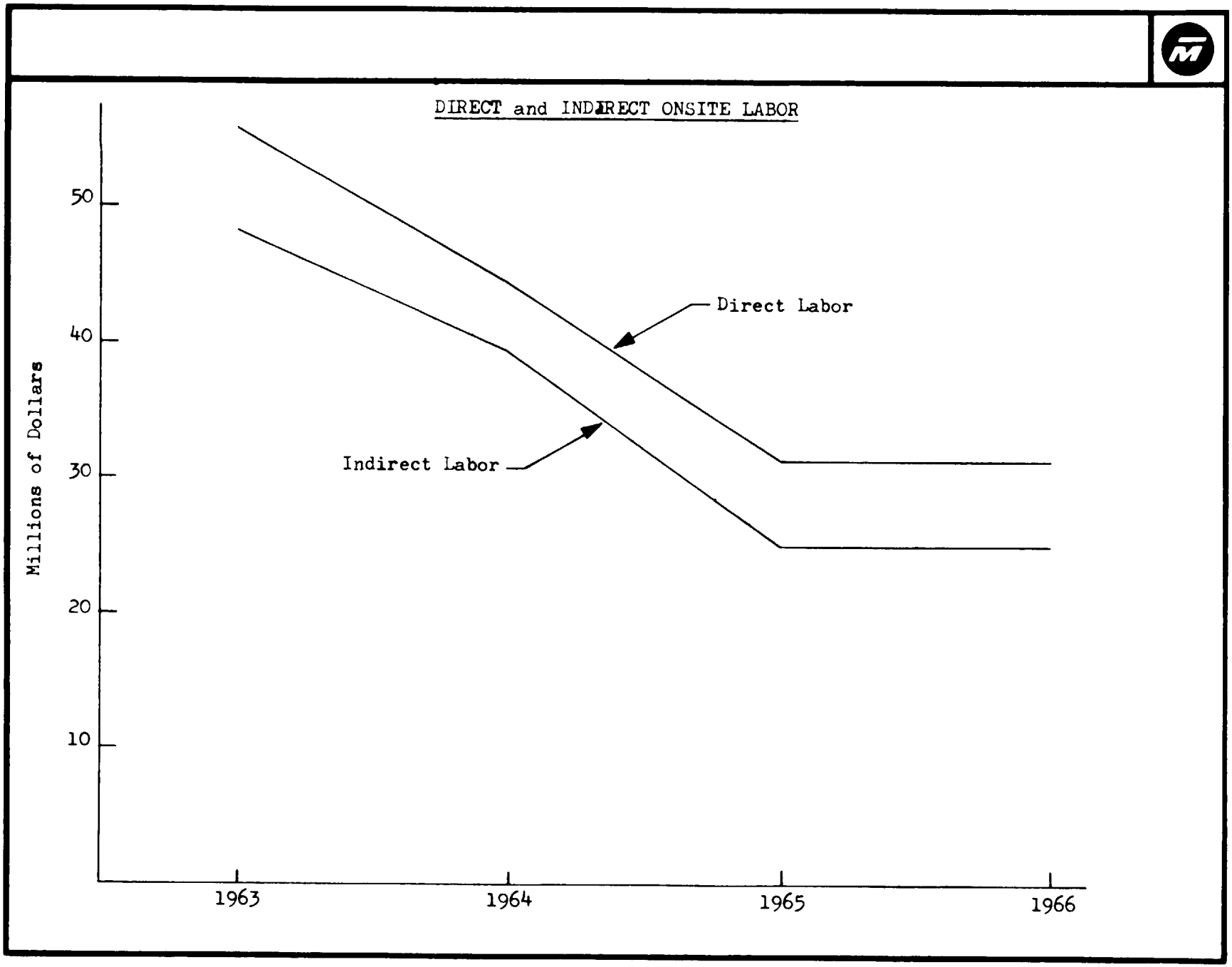
PVWA	*$3,316,735	TIME PHASED PLAN	$3,365,400
ACTUAL	$3,395,200		$3,395,200
VARIANCE	$ (78,465)	TIME PHASED VARIANCE	$ (29,800)

*Based on a task in which 59% of the budget is subpackaged.

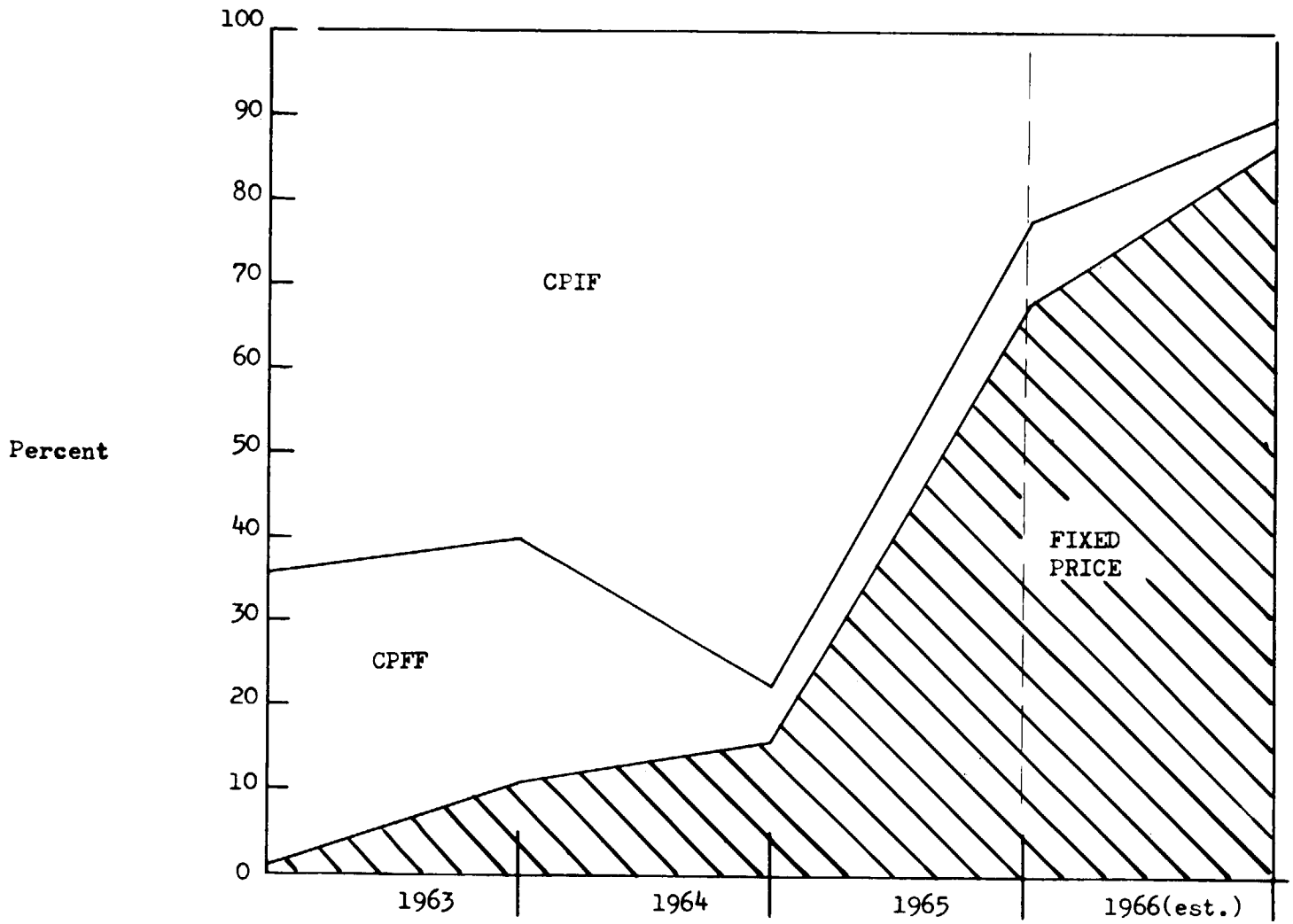
OVERHEAD TREND

	1963	1965	REDUCTION	%
INDIRECT LABOR	$48.0	$25.0	$23.0	48.0%
OTHER INDIRECT COSTS*	$35.4	$24.6	$10.8	30.5%
TOTAL OVERHEAD	$83.4	$49.6	$33.8	40.5%

* Includes Fringe Benefits


DIRECT and INDIRECT ONSITE LABOR
Millions of Dollars
50
40
30
20
10
Direct Labor
Indirect Labor
1963
1964
1965
1966

BACKLOG BY CONTRACT TYPE



COMPANY MANAGEMENT CONTROL

- PERFORMANCE ANALYSIS REPORTS
- PERFORMANCE & FINANCIAL REVIEW MEETINGS
- PROGRAM MANAGEMENT REVIEWS
  INTERNAL-CUSTOMER
- MANAGEMENT CONTROL ROOMS
- MGMT. & PROGRAM SPECIALIST REVIEW & ASSISTANCE
- CORPORATE PROGRAM REVIEW TEAM
- LONG-RANGE PLAN REVIEW