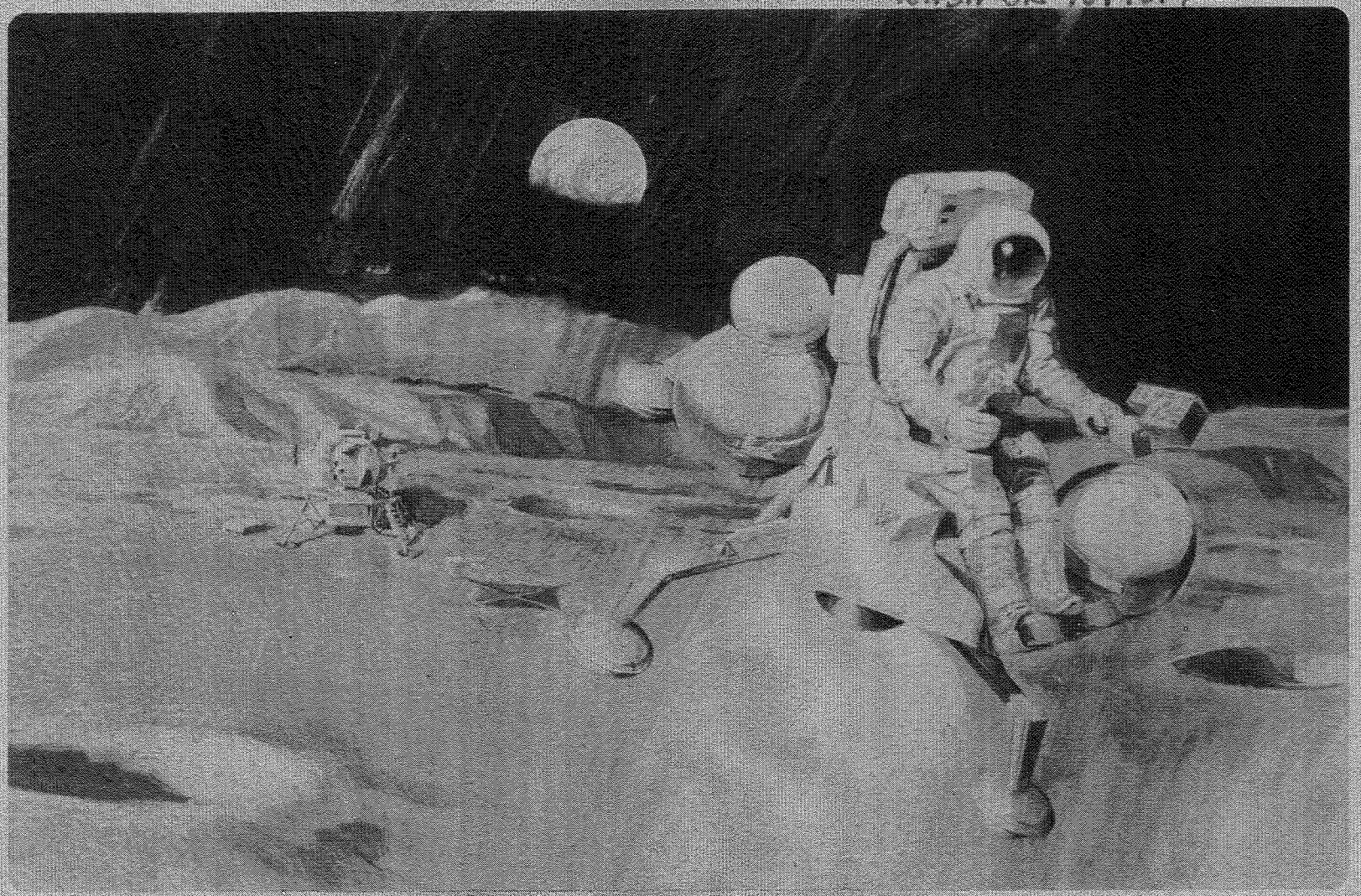
N69-38201
NASA CR-101924

AS69-1

NAS 9-9045



ONE-MAN LUNAR FLYING VEHICLE
Study Contract

CASE FILE COPY

Summary Briefing

Space Division
North American Rockwell

Total Pages 91

AS69-1

ONE-MAN LUNAR FLYING VEHICLE SUMMARY BRIEFING NAS9-9045

July 1969

SPACE DIVISION
NORTH AMERICAN ROCKWELL CORPORATION

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STUDY OBJECTIVES & SCOPE

OBJECTIVE

TO DEVELOP THE PRELIMINARY DESIGN OF A LUNAR FLYING VEHICLE FOR TRANSPORTATION OF ASTRONAUTS, SCIENTIFIC EQUIPMENT, & SAMPLES BETWEEN THE LM & SITES OF SCIENTIFIC INTEREST

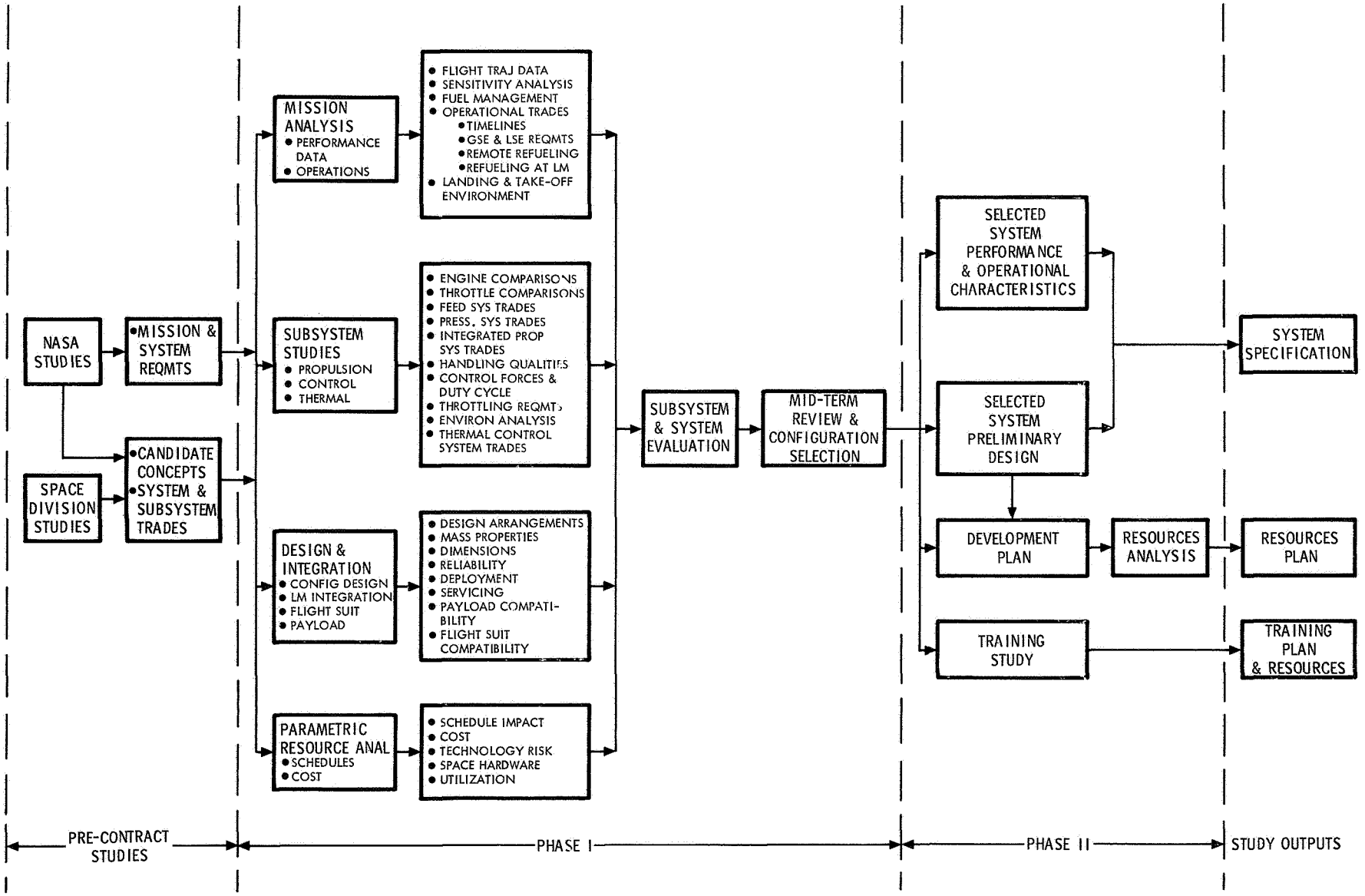
SCOPE

- PARAMETRIC STUDIES
- SYSTEM PRELIMINARY DESIGN & SPECIFICATIONS
- TRAINING PLAN
- RESOURCES PLAN

OUTLINE

- MISSION ANALYSIS
  - MISSION CHARACTERISTICS
  - FLIGHT PERFORMANCE
- PARAMETRIC DESIGN STUDY
  - APPROACH
  - ALTERNATIVES
  - KEY STUDY RESULTS
  - RECOMMENDED CONCEPT
- PRELIMINARY DESIGN STUDY
  - RESOLUTION OF KEY ISSUES
  - GENERAL ARRANGEMENT
  - SUBSYSTEMS DESIGN
  - LM INTERFACES
  - SYSTEM CAPABILITY
- TRAINING PLAN
- RESOURCES PLAN
- CONCLUSIONS & RECOMMENDATIONS

STUDY APPROACH

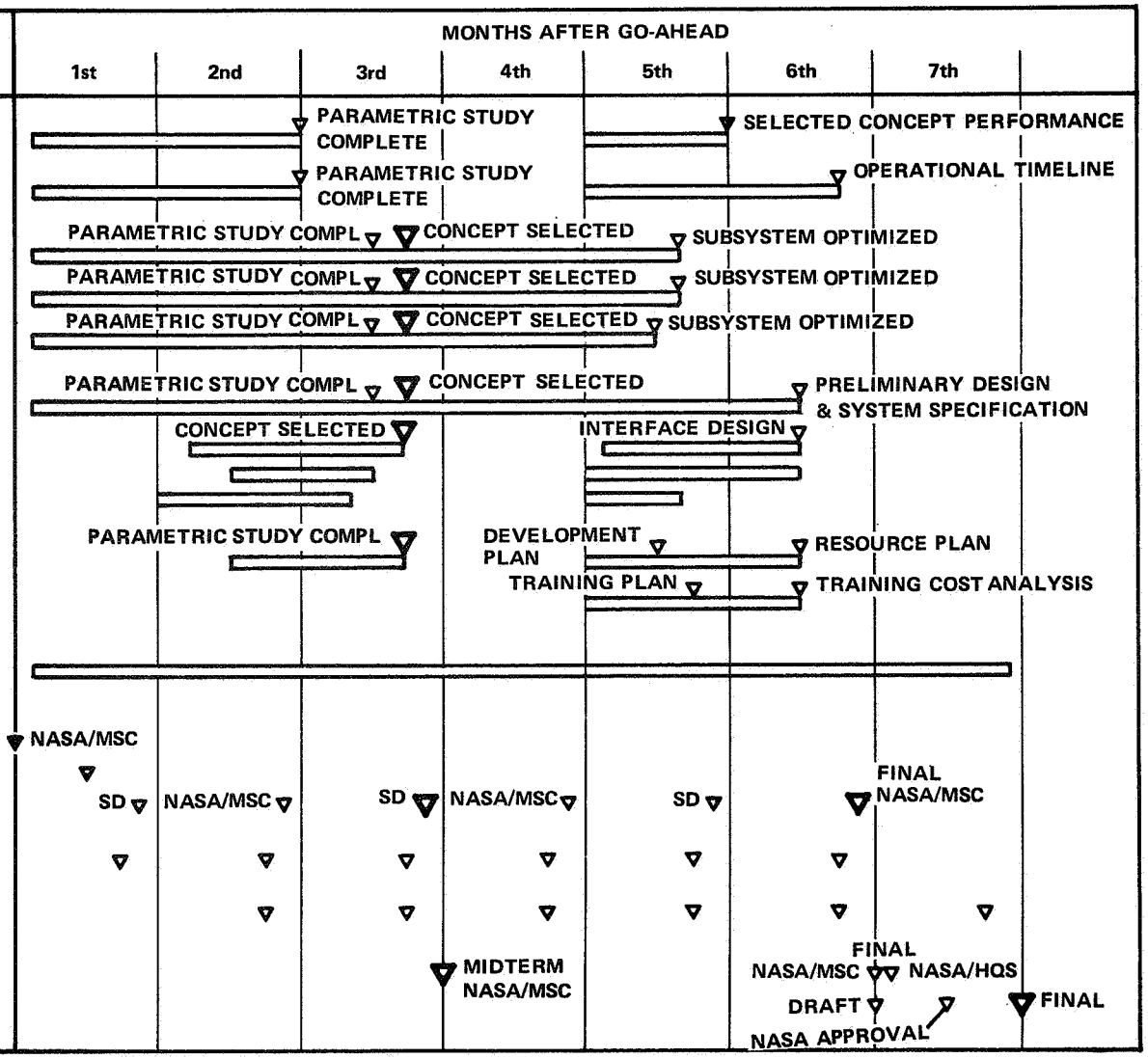


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PROGRAM SCHEDULE

WBS TASK	RFP TASK	TASK DESCRIPTION
1.0		MISSION ANALYSIS
1.1	(4.3.7)	VEHICLE PERFORMANCE DATA
1.2	(4.3.6)	OPERATIONS STUDY
2.0		SUBSYSTEMS STUDIES
2.1	(4.3.2)	PROPULSION STUDIES
2.2	(4.3.3)	CONTROL SYSTEM STUDIES
2.3	(4.3.4)	THERMAL STUDIES
3.0		DESIGN & INTEGRATION
3.1	(4.3.1)	CONFIG DESIGN STUDY
3.2	(4.3.8)	LM INTEGRATION
3.3	(4.3.9)	FLIGHT SUIT STUDIES
3.4	(4.3.5)	PAYLOAD STUDIES
4.0		RESOURCES STUDY
4.1	(5.0)	RESOURCE PLAN
4.2	(4.3.10)	TRAINING STUDY
5.0		PROGRAM MANAGEMENT
5.1	(6.0)	PROGRAM CONTROL
5.2	(6.0)	REPORTS & REVIEWS
		ORIENTATION MEETING
		PROGRAM STUDY OUTLINE
		PRELIMINARY DESIGN REVIEWS
		MONTHLY PROGRESS REPORTS
		ESTIMATED MONTHLY MANHOUR REPORTS
		BRIEFINGS
		SUMMARY & FINAL REPORTS



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MISSION ANALYSIS

LFV MISSION CONSTRAINTS & CHARACTERISTICS

SANTA CRUZ CONFERENCE*

- MINIMUM RANGE 10 KM (5.5 NM) (1971-72)
- RESCUE RANGE UP TO 25 KM (13.7 NM) WITH LSSM (1974-75)
- ASCENT CAPABILITY TO 1000 METERS (3280 FT)

PAYLOAD

- RESCUE CAPABILITY REQUIRES APPROXIMATELY 370 LB MAX INBOUND
- SCIENTIFIC PAYLOADS (RGM, ESS, & MISC EQUIP.) UP TO 300 LB OUTBOUND
- EQUIPMENT & SAMPLES UP TO 100 LB INBOUND

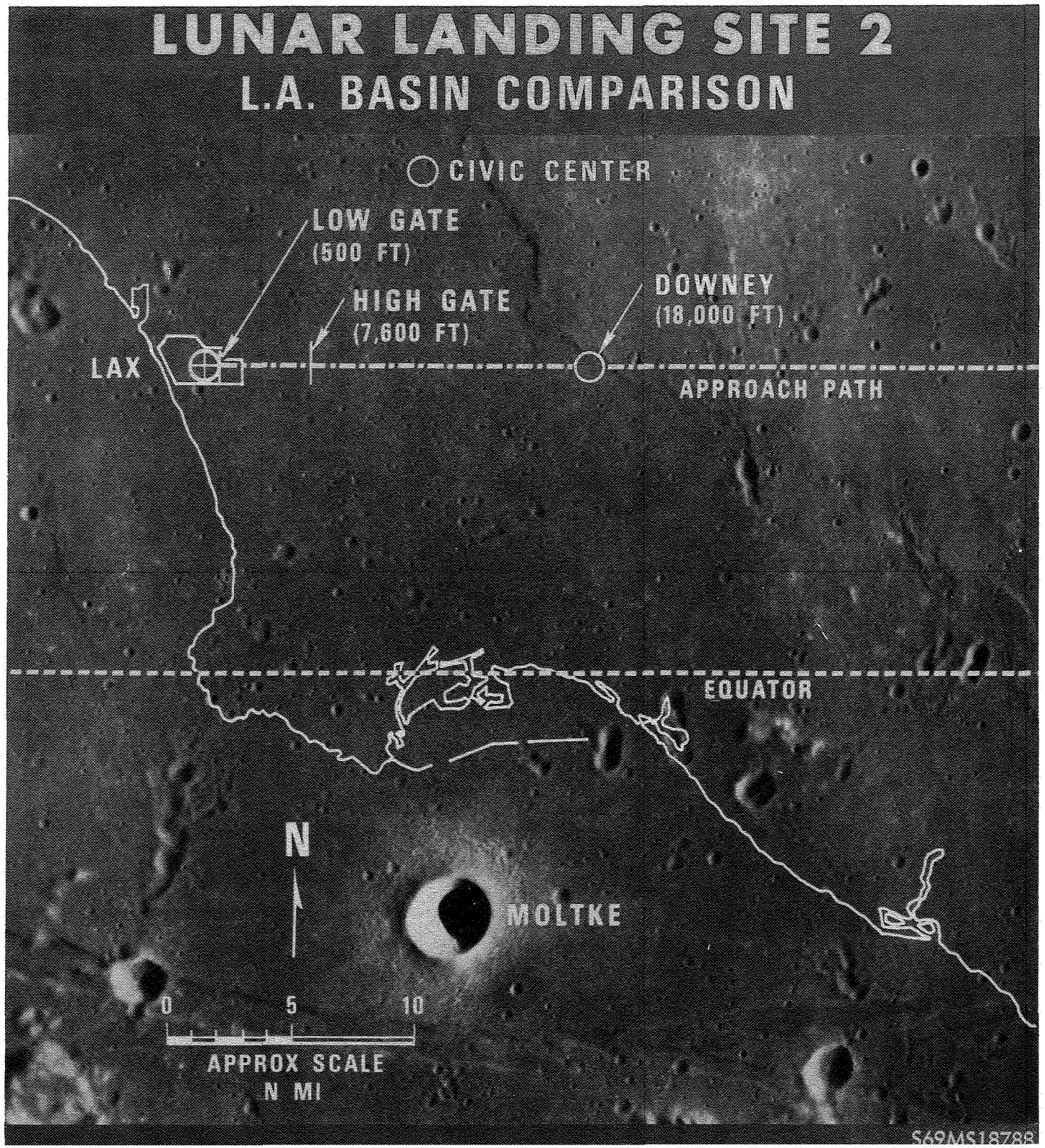
LM INTERFACES

- LM DESCENT STAGE PROPELLANT TRANSFER (MEAN AMT 805 LB)
- ATTACHMENT TO & REMOVAL FROM LM

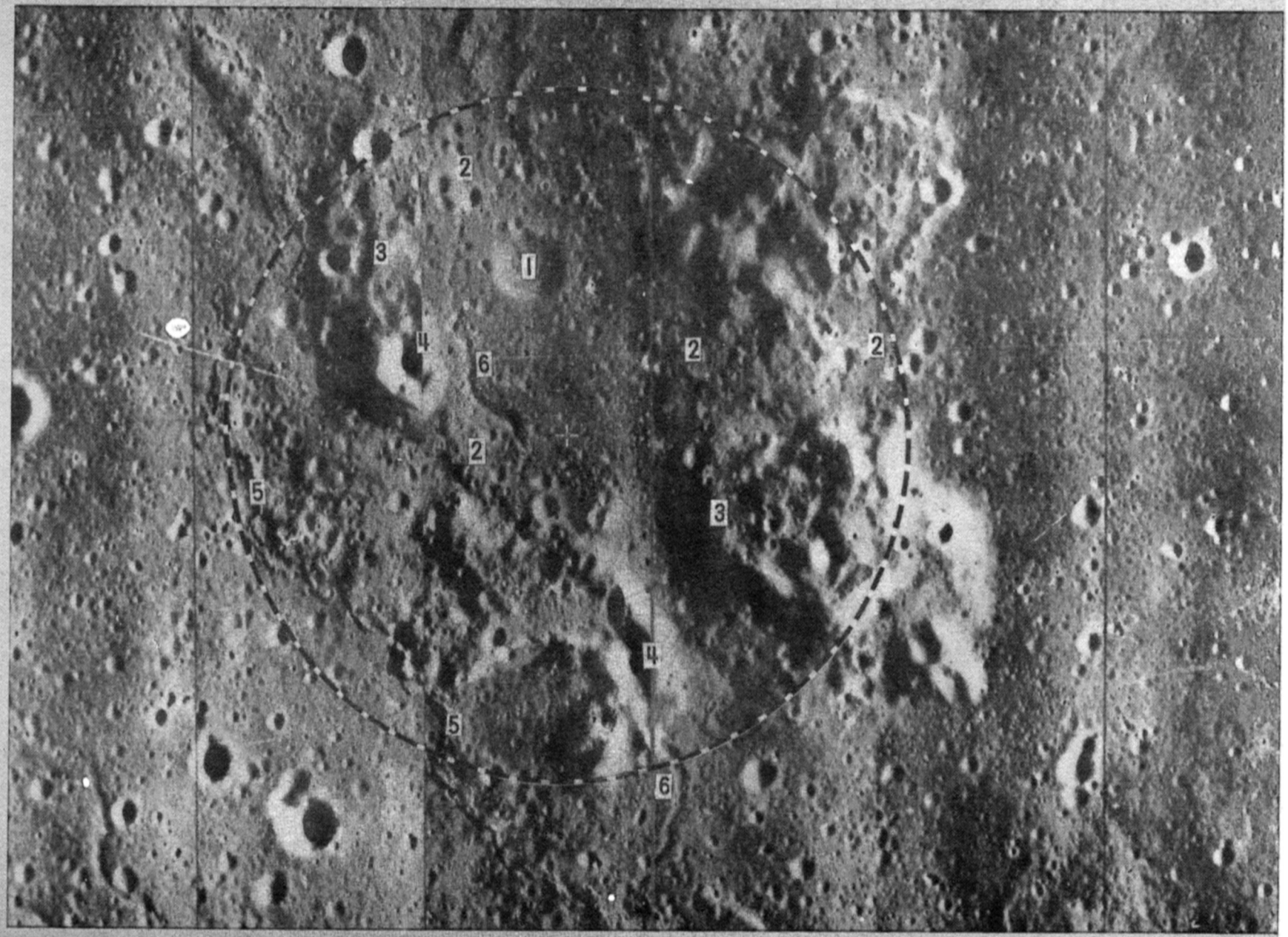
LIFE SUPPORT SYSTEMS

- EVA LIMITED TO 3 HOURS EACH
- EARLY MISSION DURATION ALLOWS APPROXIMATELY 21 MAN-HRS EVA

*NASA SP 157 "SUMMER STUDY OF LUNAR SCIENCE AND EXPLORATION, UNIVERSITY OF CALIFORNIA – SANTA CRUZ", JULY 31 - AUGUST 13, 1967

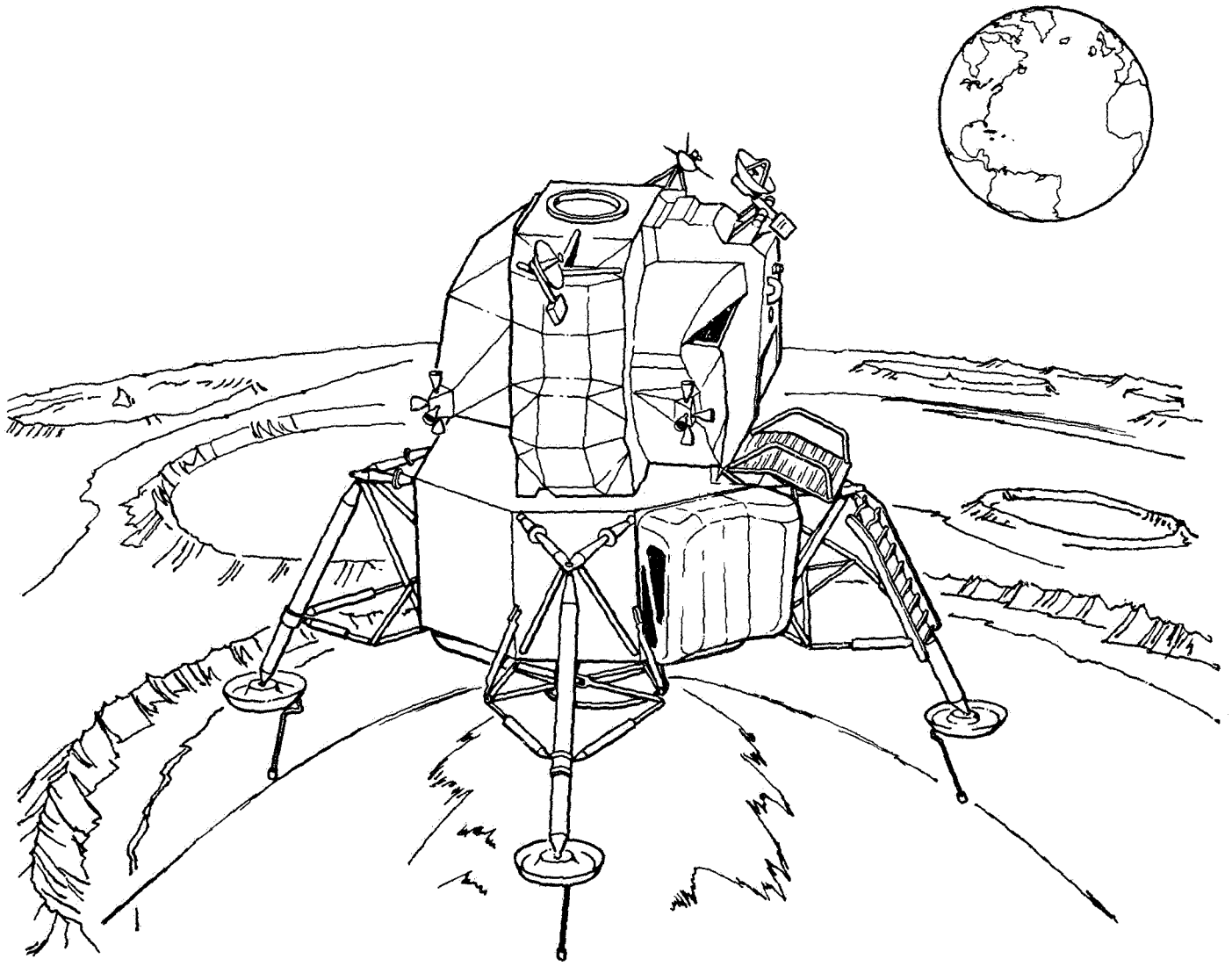

LUNAR LANDING SITE 2
L.A. BASIN COMPARISON
CIVIC CENTER
LOW GATE
(500 FT)
HIGH GATE
(7,600 FT)
DOWNEY
(18,000 FT)
LAX
APPROACH PATH
EQUATOR
N
MOLTKE
0
5
10
APPROX SCALE
N MI
S69MS18788

PROPOSED LANDING SITE IN THE MARIUS HILLS REGION

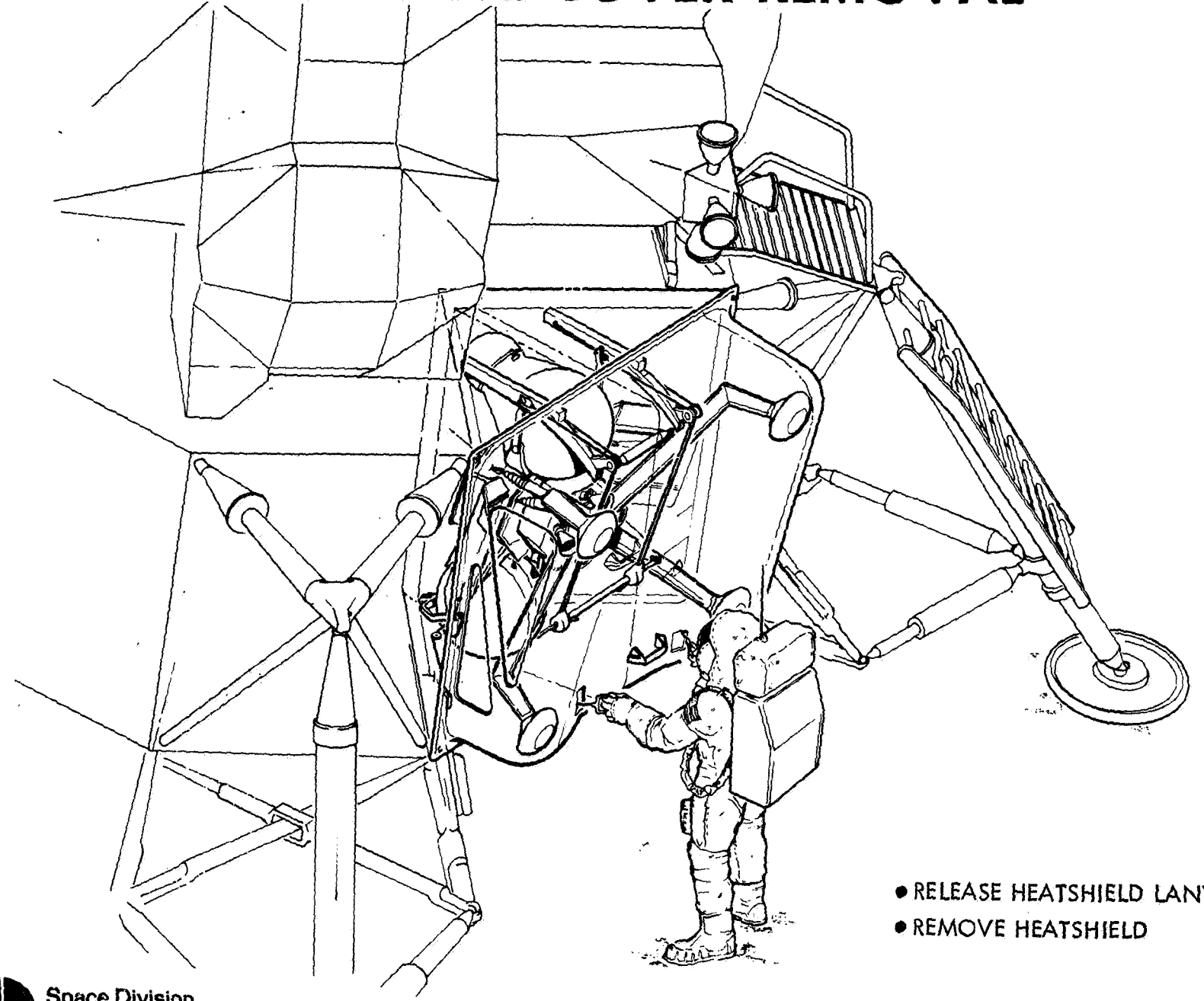


79PD92635

LM LANDING ON LUNAR SURFACE



PROTECTIVE COVER REMOVAL

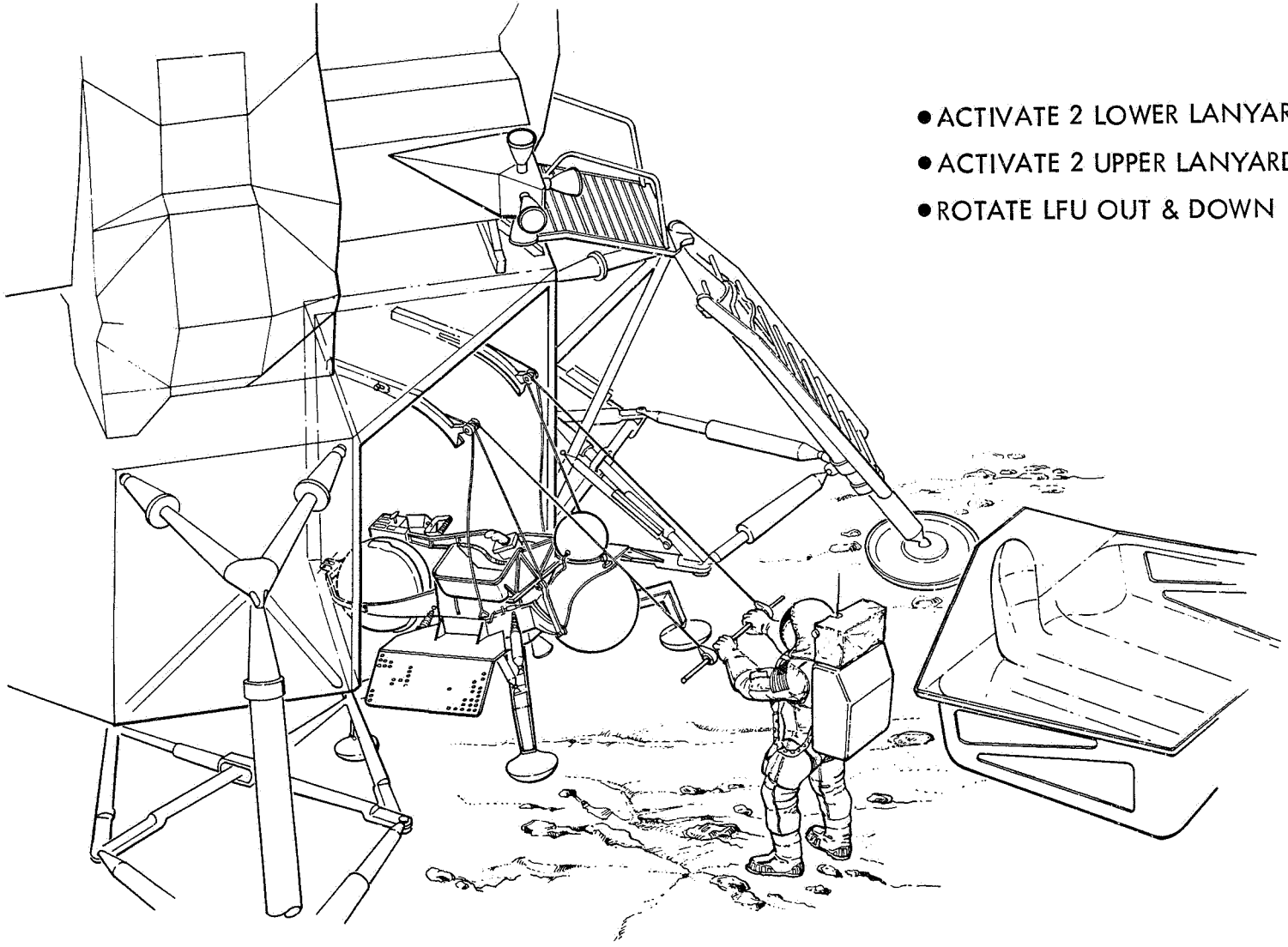


- RELEASE HEATSHIELD LANYARDS
- REMOVE HEATSHIELD

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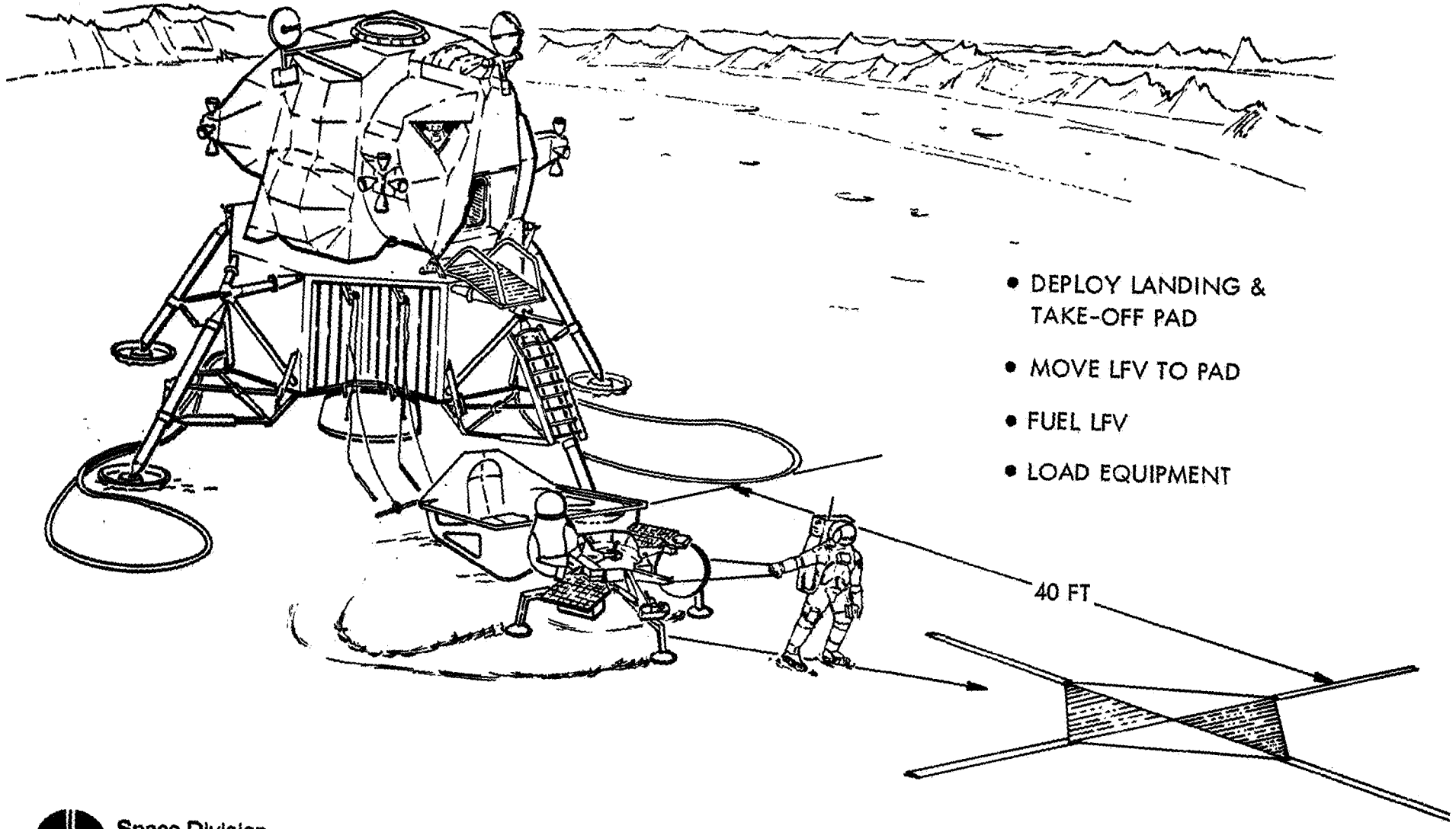
79PD92633

LUNAR FLYING VEHICLE REMOVAL



- ACTIVATE 2 LOWER LANYARDS
- ACTIVATE 2 UPPER LANYARDS
- ROTATE LFU OUT & DOWN

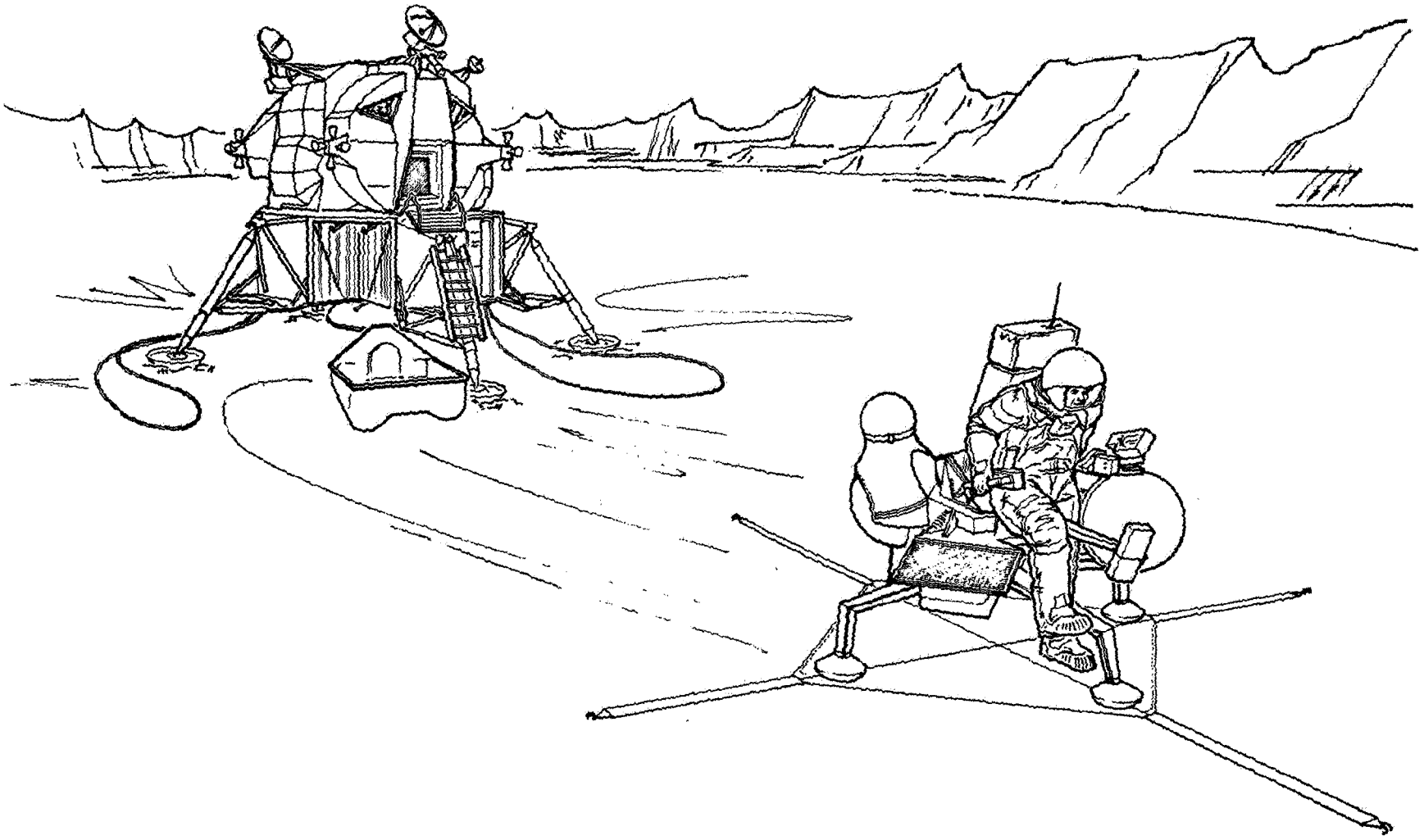
LFV FLIGHT PREPARATION



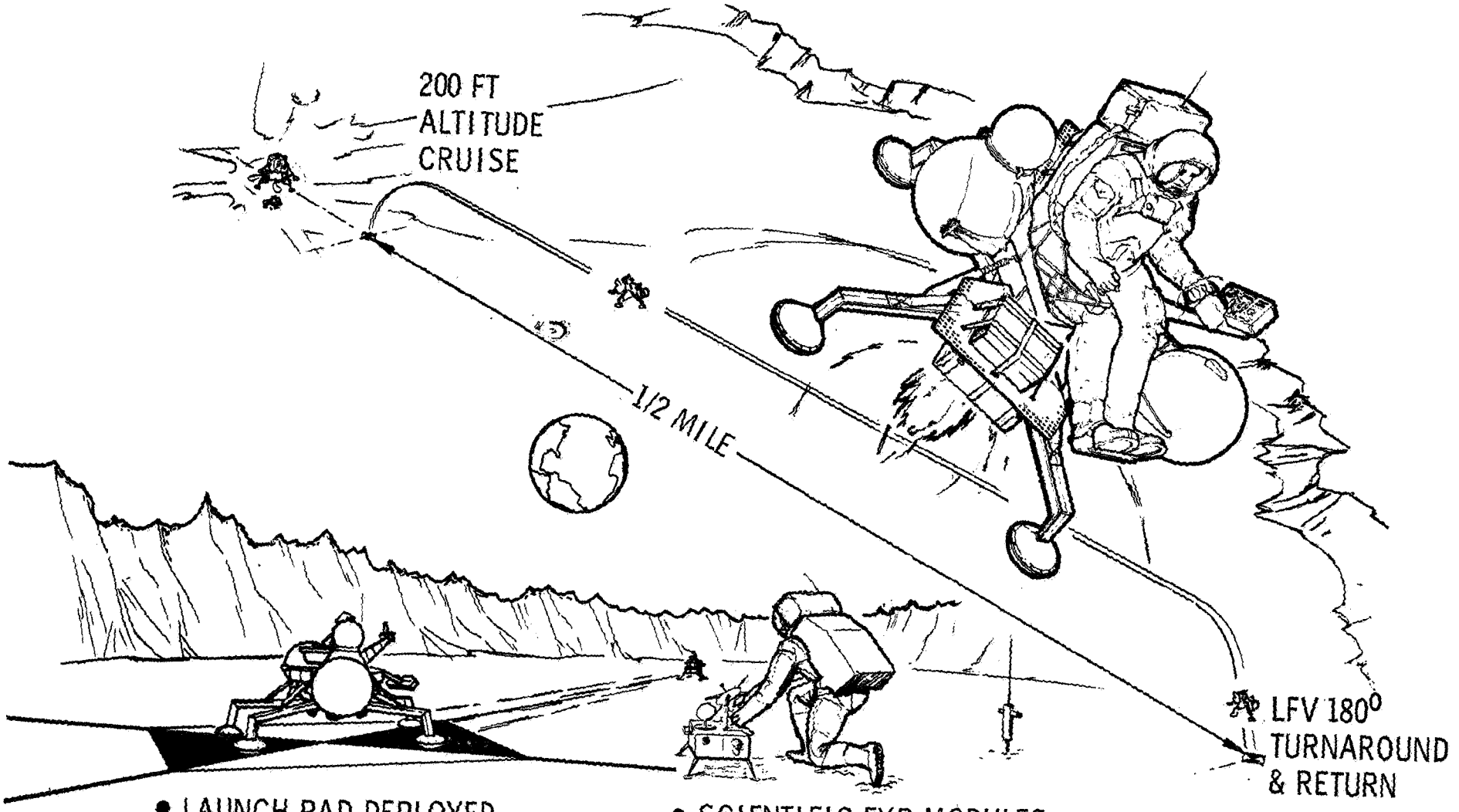
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CREW INGRESS-EGRESS



LFV CHECKOUT FLIGHT



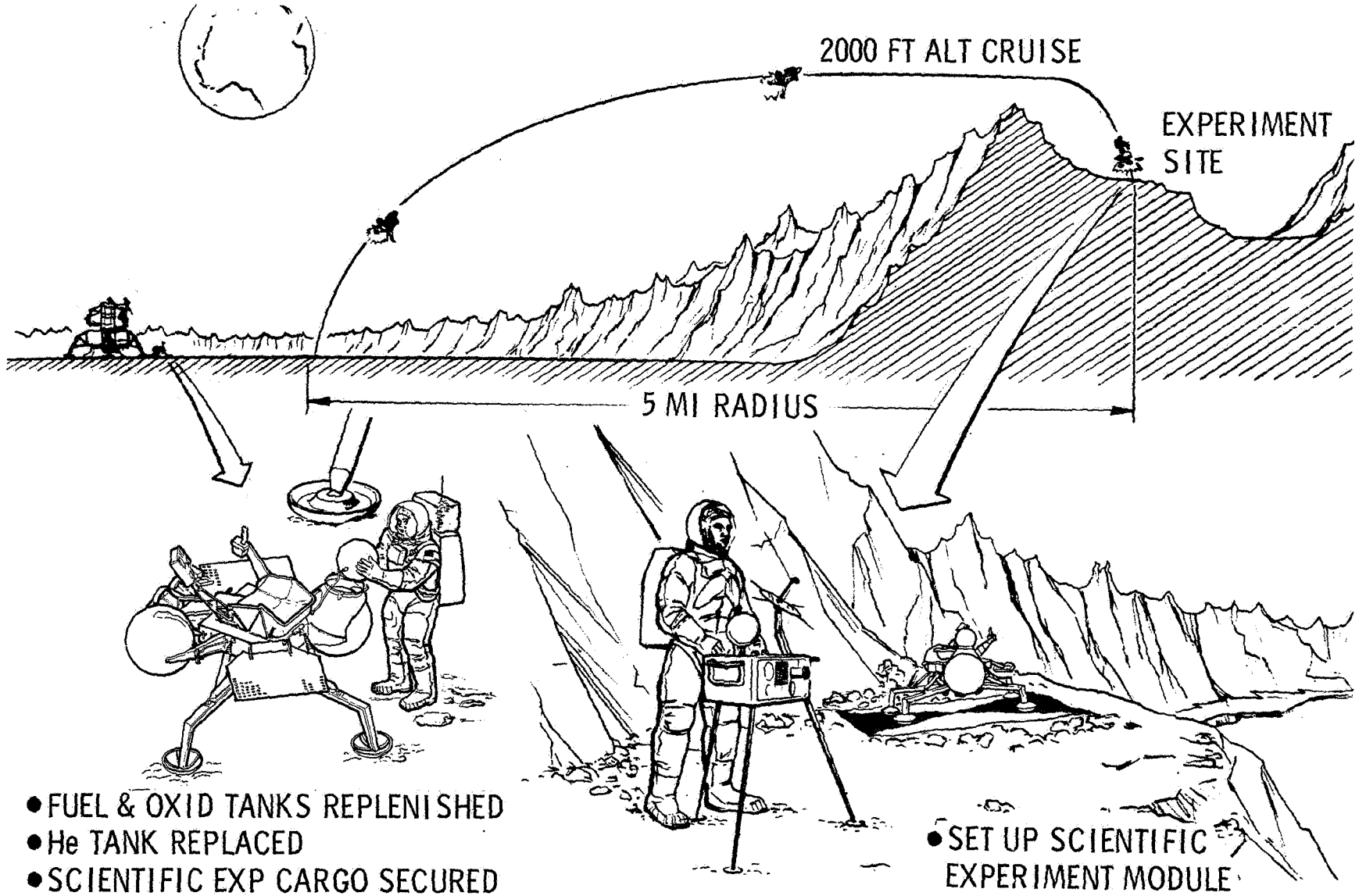
- LAUNCH PAD DEPLOYED
- LFV TURNAROUND
- MAKE READY FOR RETURN LEG

- SCIENTIFIC EXP MODULES DEPLOYED

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TYPICAL LFV MISSION



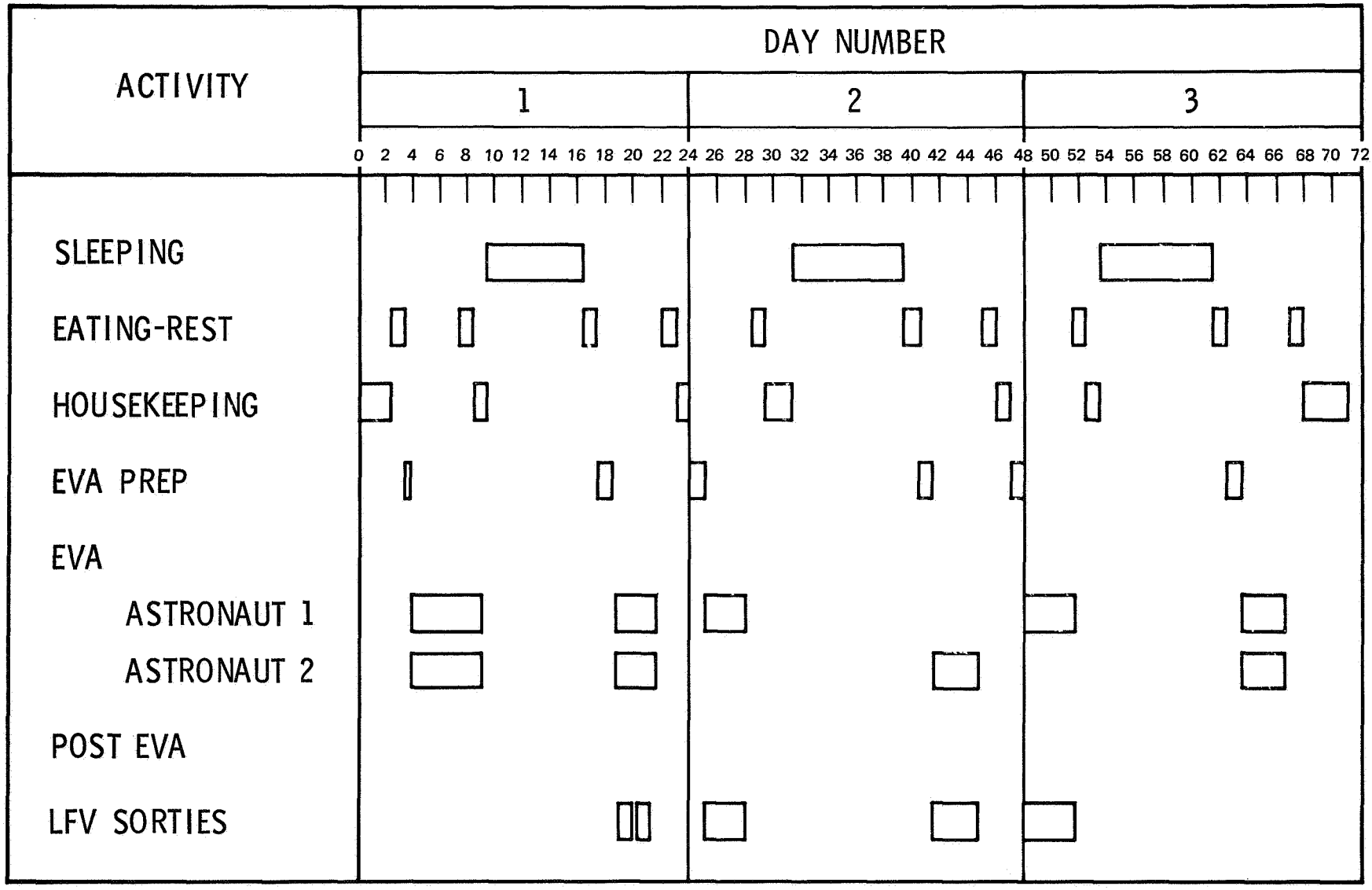
- FUEL & OXID TANKS REPLENISHED
- He TANK REPLACED
- SCIENTIFIC EXP CARGO SECURED

- SET UP SCIENTIFIC EXPERIMENT MODULE

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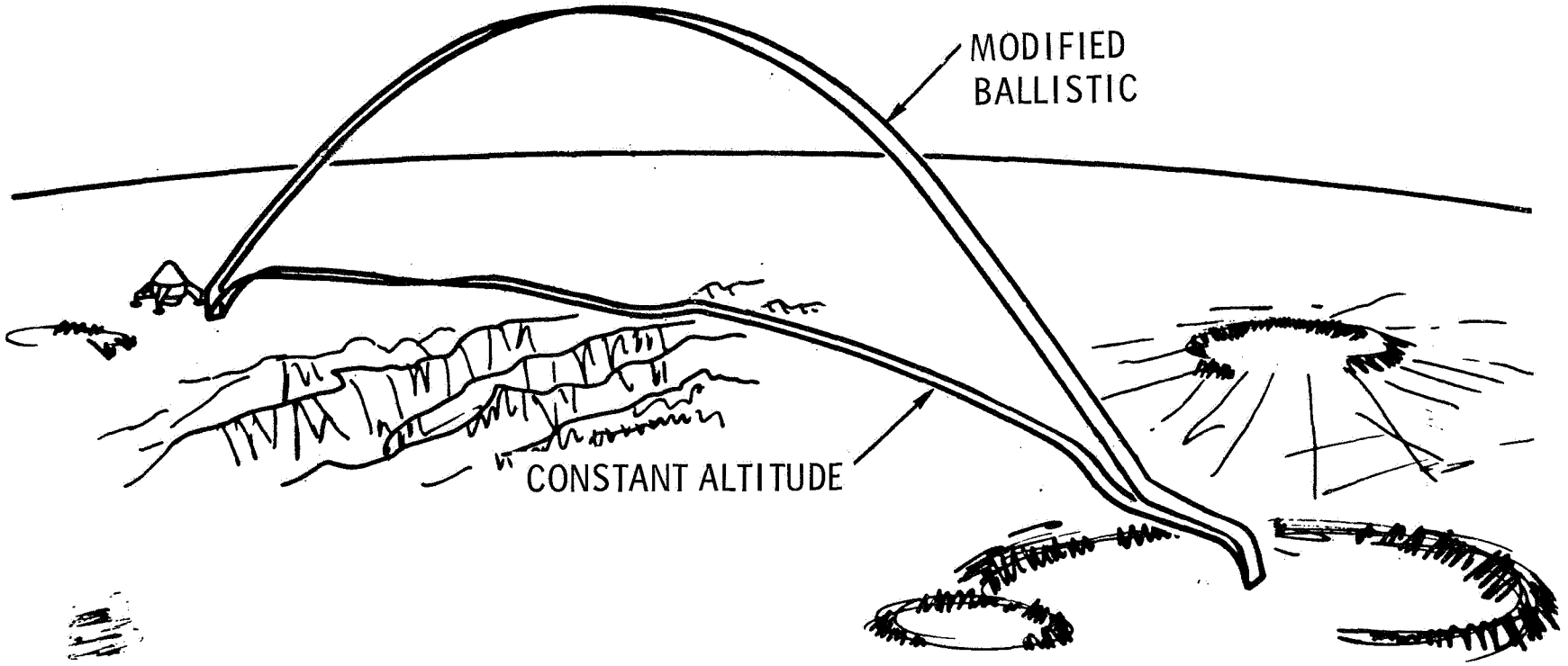
THREE-DAY DAWN MISSION TIMELINE



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ALTERNATIVE FLIGHT PROFILES



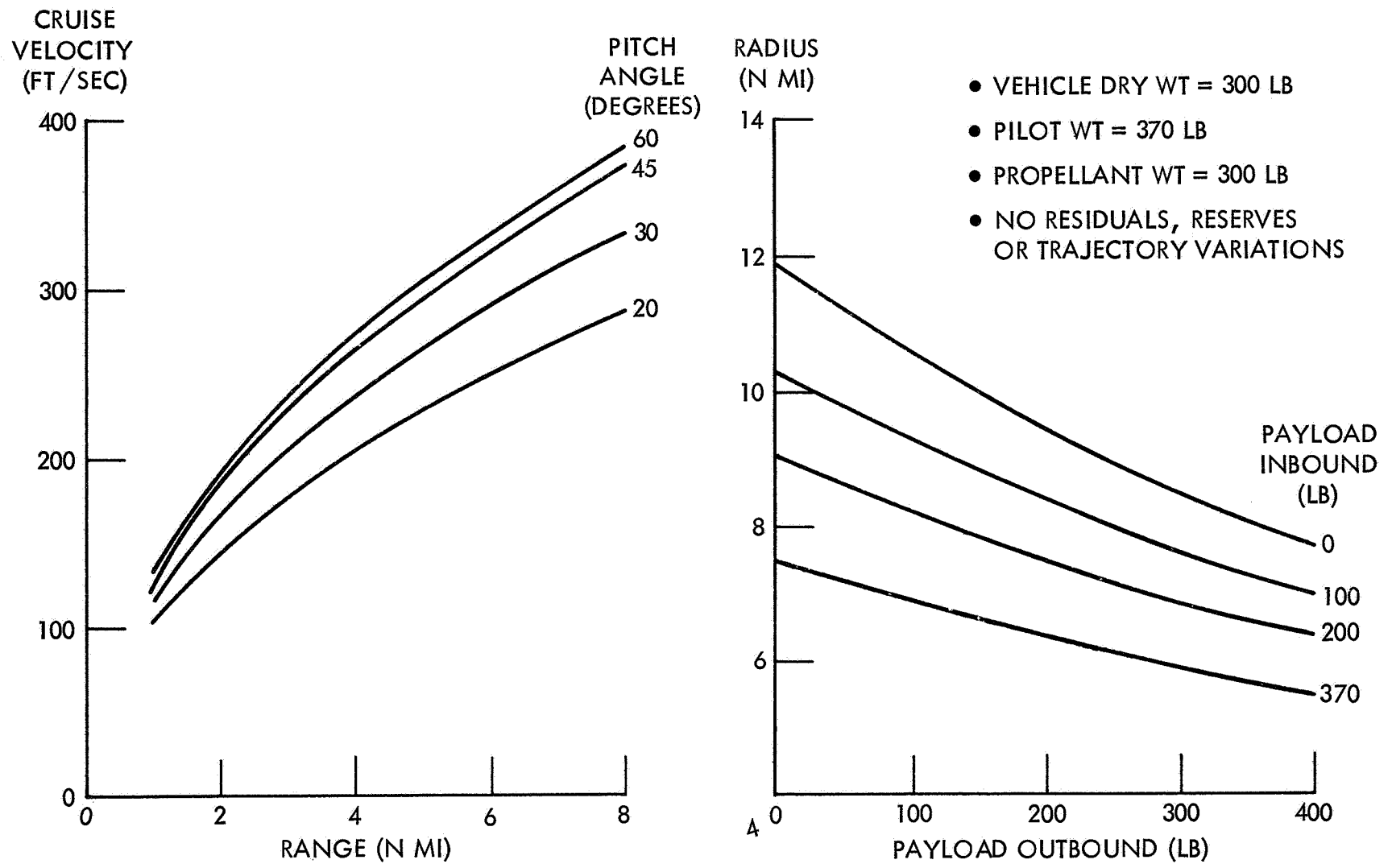
SELECTION CRITERIA

- PROPELLANT REQUIRED
- PILOT DEMANDS
- TARGET VISIBILITY

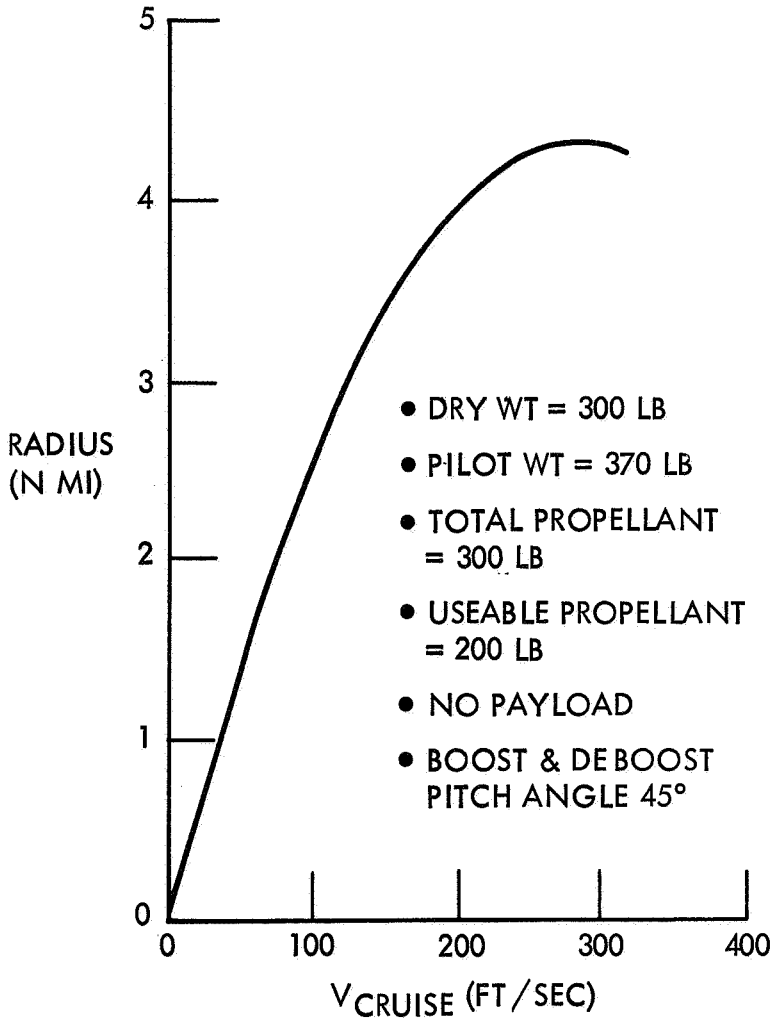
COMPARISON OF FLIGHT PROFILES

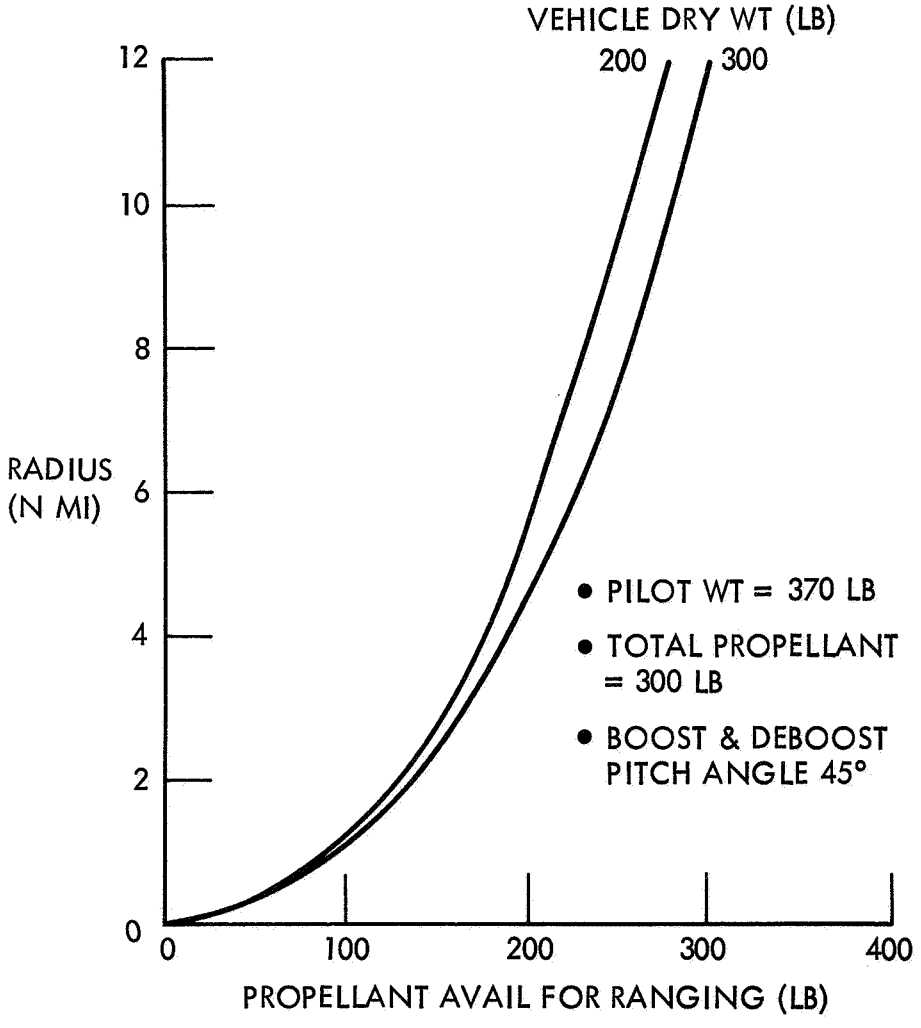
CHARACTERISTIC	CONSTANT ALTITUDE	MODIFIED BALLISTIC
MINIMUM PROPELLANT REQUIRED • 5 N MI RANGE • $(T/W)_{MAX}$ = 1.4 • W_i = 1000 LB	116 LB	114 LB
RANGE SENSITIVITY TO ERRORS		
• BOOST TIME • VEHICLE BOOST ATTITUDE • ATTITUDE RATES	±374 FT/SEC ±625 FT/DEGREE ±130 FT/DEG/SEC	±2242 FT/SEC ±1289 FT/DEGREE ±1663 FT/DEG/SEC
NAVIGATION EASE	CAN READILY USE LANDMARKS	HIGH ALTITUDES CAUSE DISORIENTATION
RESULTS OF PILOT ERROR	OVERSHOOT OR UNDERSHOOT	OVERSHOOT OR UNDER-SHOOT & POSSIBLE HIGH VELOCITY IMPACT

OPTIMUM CONSTANT ALTITUDE FLIGHT CHARACTERISTICS



RANGING SENSITIVITY TO FLIGHT & SYSTEM VARIABLES



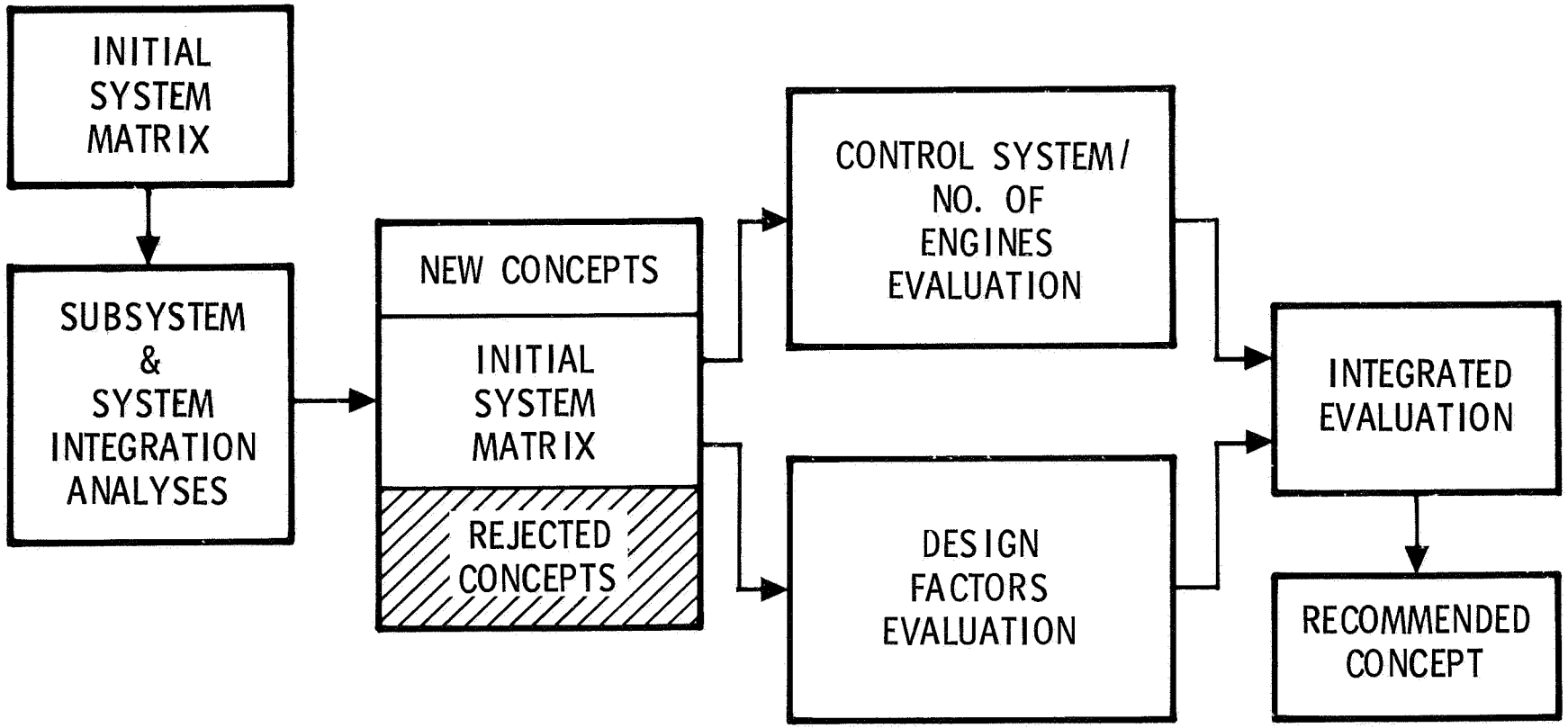


PARAMETRIC DESIGN STUDY

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PARAMETRIC DESIGN STUDY APPROACH



PRIMARY DESIGN ALTERNATIVES

SUBSYSTEMS ALTERNATIVES MATRIX

*	**	Control Subsystem
		Pitch/roll control type
1	2	Kinesthetic
1	2	Manual
1	1	Stability-augmented
1	1	Attitude hold
		Pitch/roll control moment
1	3	Gimbal – above c.g.
1	2	Gimbal – below c.g.
1	1	Diff throttling
1	2	Pulsed jet
1	3	Mass movement – above c.g.
1	3	Mass movement – below c.g.
1	2	Jetavators
		Yaw control moment
1	1	Biprop jets
1	1	Pair gimbal
1	2	Jet vanes
1	2	Cold-gas jets
1	1	Kinesthetic
		Actuation Method
2	1	Boosted
2	1	*Fuel bleed servo*
2	2	Direct manual
2	2	Electric servo
		Control linkage
3	2b	Hydraulic
3	2b	Cable – linkage
		Engine failure cutoff
3	1	Aux solenoid
3	1	Mechanical override
		Hand controls
3	1	LM type
3	2b	Special

*	**	*Instrumentation and Displays Subsystem*
		Propellant gauge
4	1	PVT
4	1	ΔP head
4	1	Thrust – acceleration
4	1	Probe
4	1	*Point sensor*
4	1	Time-integrated thrust
		Stability aids
3	2b	Attitude
3	2b	Attitude rate
3	2b	Thrust-vector angle
		Navigation aids
3	1	Clock
3	2b	Range rate
3	2b	Azimuth
3	2b	Range
3	2b	Descent rate
3	2b	Altitude

*	**	Engine failure warning
3	1	Thrust sensor, discriminator
3	1	Platform tilt
		Propellant available warning
3	2b	Timer
3	2b	Adjustable gauge switch
3	2b	Range to go computed

		Crew Subsystem
		Pilot position
1	2	Standing
1	2	Seated
1	2	Prone
		Pilot restraint – torso
2	2	Grips
2	2	Snubbing tethers
2	2	Attenuating tethers
		Pilot restraint – feet
3	2	Velcro
3	2	Binding

		Propulsion Subsystem
		Gas storage
2	1	Replaceable
2	1	Rechargeable
		Propellant feed
1	1	Two or four tanks
1	1	Series
1	1	Parallel
1	1	Spherical
1	1	Cylindrical
1	1	Vertical
1	1	Horizontal
		Propellant c.g. excursion
1	1	Negligible lateral
1	1	Lateral permitted
		Number of Engines
1	2	Single
1	1	Two (1 redundant)
1	2	Three (1 redundant)
1	2	Four (1 redundant)
		Throttling method
3	1	Inlet valve
3	1	Variable area injector
3	1	He injection
		Cooling method
4	2b	Radiation
4	2b	Inter-regenerative
		Pressurization control
4	1	On-off pressure switch
4	1	Regulator
4	1	Blow down

*	**	Structural Subsystems
		Landing gear frame spread
1	1	Omnidirectional
1	1	Forward-biased
		Landing gear frame type
1	1	Strut
1	1	Truss
1	1	Single member
		Attenuator type
2	2	Hydraulic
2	2	*Inelastic deformation*
2	2	Damped spring
2	2	Damped elastomer
2	2	Spring
2	2	Friction
		Attenuator orientation
1	1	*Total reaction*
1	1	Component split
		Attenuator location
1	2	Pilot and passenger support
1	2	Platform support
1	2	Leg, central
1	1	Leg, strut
1	1	Leg, pad
		Number of landing gear
1	1	Three
1	1	Four
		Platform/propulsion compartmen
2	2b	Skin-stringer
2	2b	Honeycomb
2	2b	Truss, panel
		Handling and micrometeoroid protection
4	2b	Mylar
4	2b	Metal
4	2b	None, integrated
		Plume dust protection
1	2	Engine cutoff
1	2	Shield
1	2	Ground covering

		Thermal-Control System
		Basic type
1	1	Active
3	2	Passive
		Transport phase
3	2b	Blanket
3	2b	Heat conduction
		Stand-by phase
3	2	Blanket
3	2	Propellant boil-off

*Design Interaction

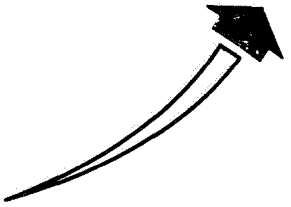
1 = Significant design interaction
2 = Appreciable design interaction
3 = Minor design interaction
4 = Insignificant design interaction

**Study Status Key

1 = Previously studied by SD, results to be incorporated in evaluation.
2 = Previously studied by SD, additional study of principal unresolved issues proposed.
2b= Same as 2, but not a principal issue.
3 = Not studied extensively by SD, study proposed.

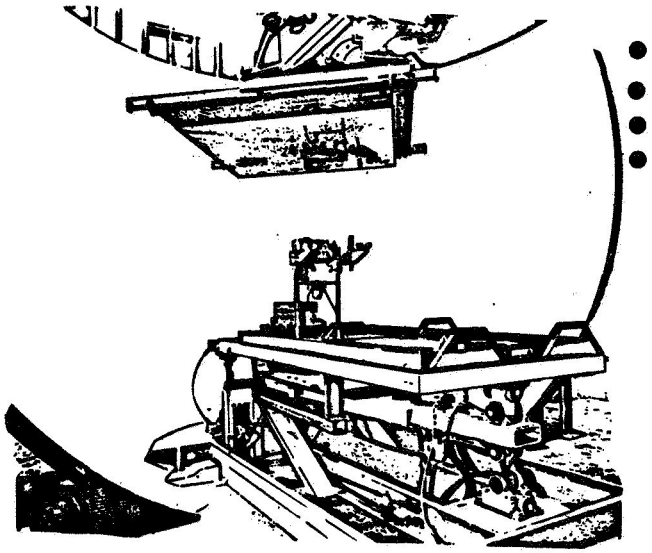
MAJOR TRADE-OFF STUDIES

- CONTROL SYSTEM CONCEPTS
- NUMBER OF ENGINES
- CREW POSITION & RESTRAINTS
- LANDING ATTENUATION CONCEPT



CONTROL SYSTEM STUDIES

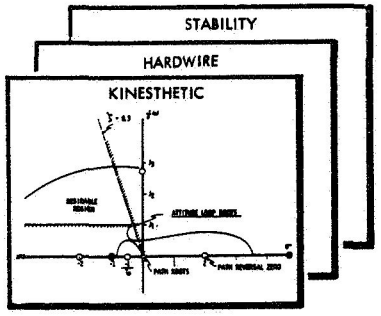
VISUAL SIMULATION



- KINESTHETIC, HARDWIRE, STABILITY AUGMENTED
- HANDLING QUALITIES
- FLIGHT NAVIGATION
- LANDING

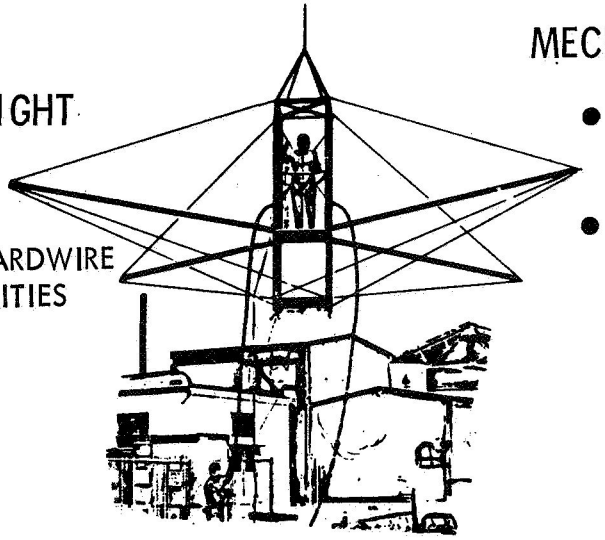
THEORETICAL STUDIES

- KINESTHETIC, HARDWIRE & STABILITY AUG
- HANDLING QUALITIES FOR LFV-TYPE MISSION



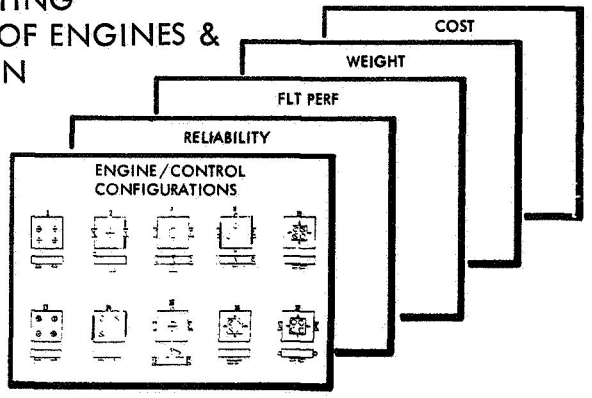
HIGH INERTIA FLIGHT TEST VEHICLE

- KINESTHETIC & HARDWIRE
- HANDLING QUALITIES IN NEAR-HOVER FLIGHT



MECHANIZATION STUDIES

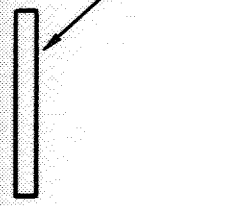
- GIMBALING, DIFF THROTTLING, PULSED ENGINES, JETAVATORS, RCS, TRANSLATING
- NUMBER OF ENGINES & LOCATION



ESTIMATED BAC POGO VEHICLE
1/6-6 HARDWIRE CONTROL:

PRESSURE SUIT
AND BACKPACK

STREET CLOTHES



VISUAL SIMULATION
1/6-6 CONTROL MODES:

STAB AUG GIMB BELOW CG
HRDWR WITH STAB PLATFORM

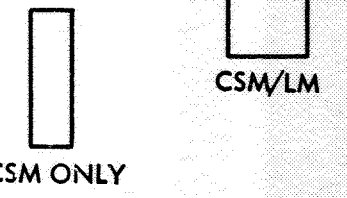
HARDWIRE CONTROL:
- GIMBAL BELOW CG
- GIMBAL ABOVE CG
- GIMBAL BELOW WITH SHAPING NETWORK
- TRANSLATING ENGINES

LONG RANGE FLIGHT

LANDING

KINESTHETIC WITH
STABILIZED YAW

APOLLO CSM
SC 104 HARDWIRE
SIMULATION:



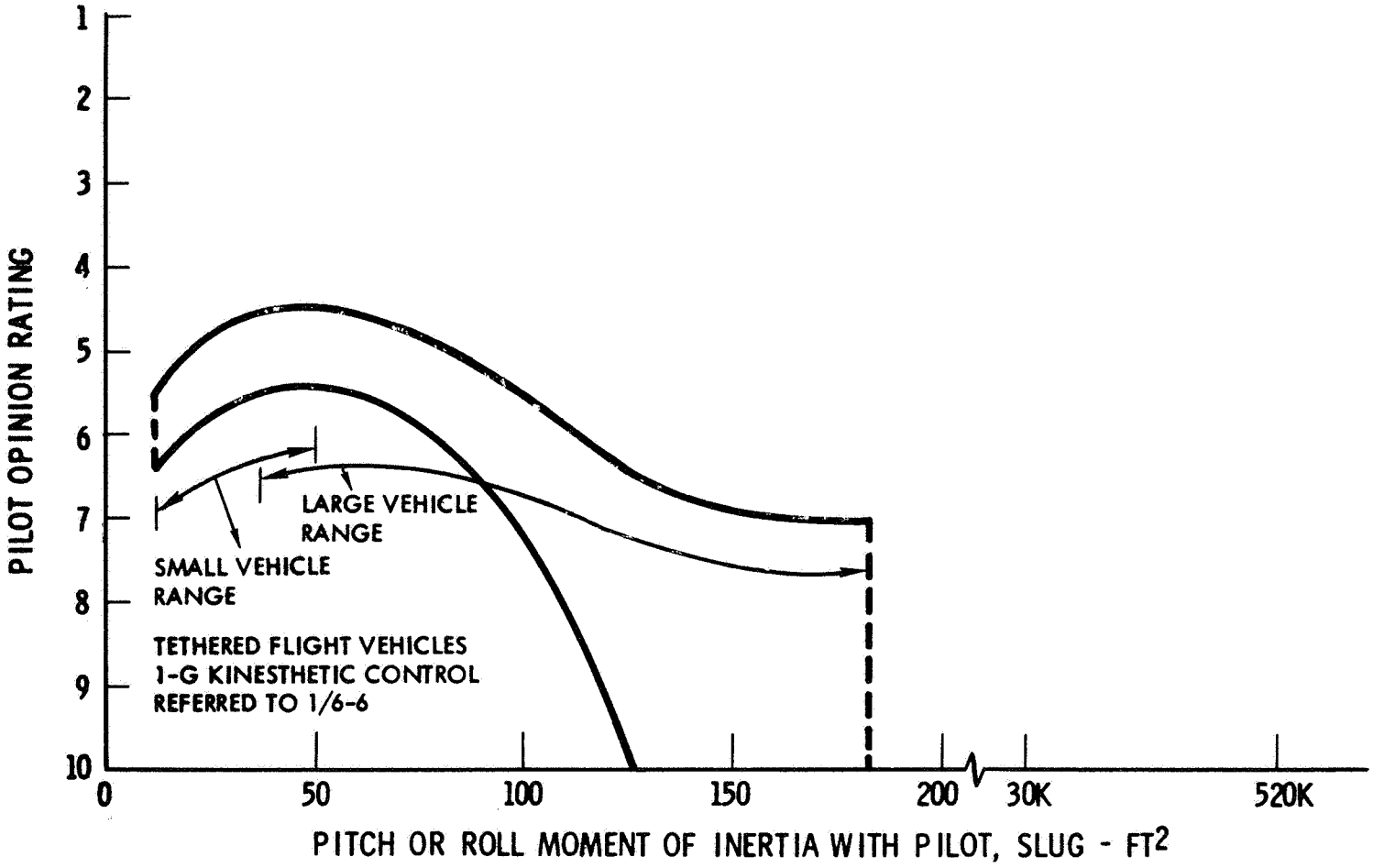
CSM/LM

CSM ONLY

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HANDLING QUALITIES COMPARISONS

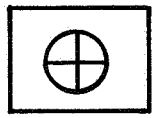
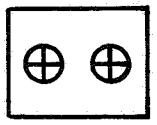
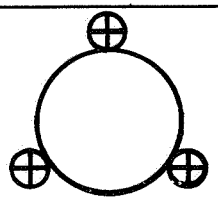
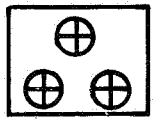
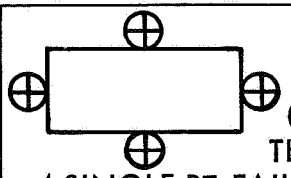
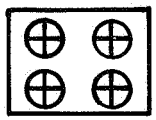
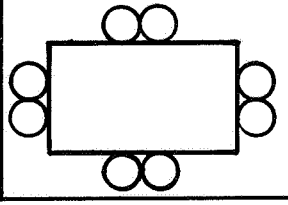
- 3-DIMENSIONAL TESTS USING STABILITY AUGMENTED, HARDWIRE, AND KINESTHETIC CONTROL MODES



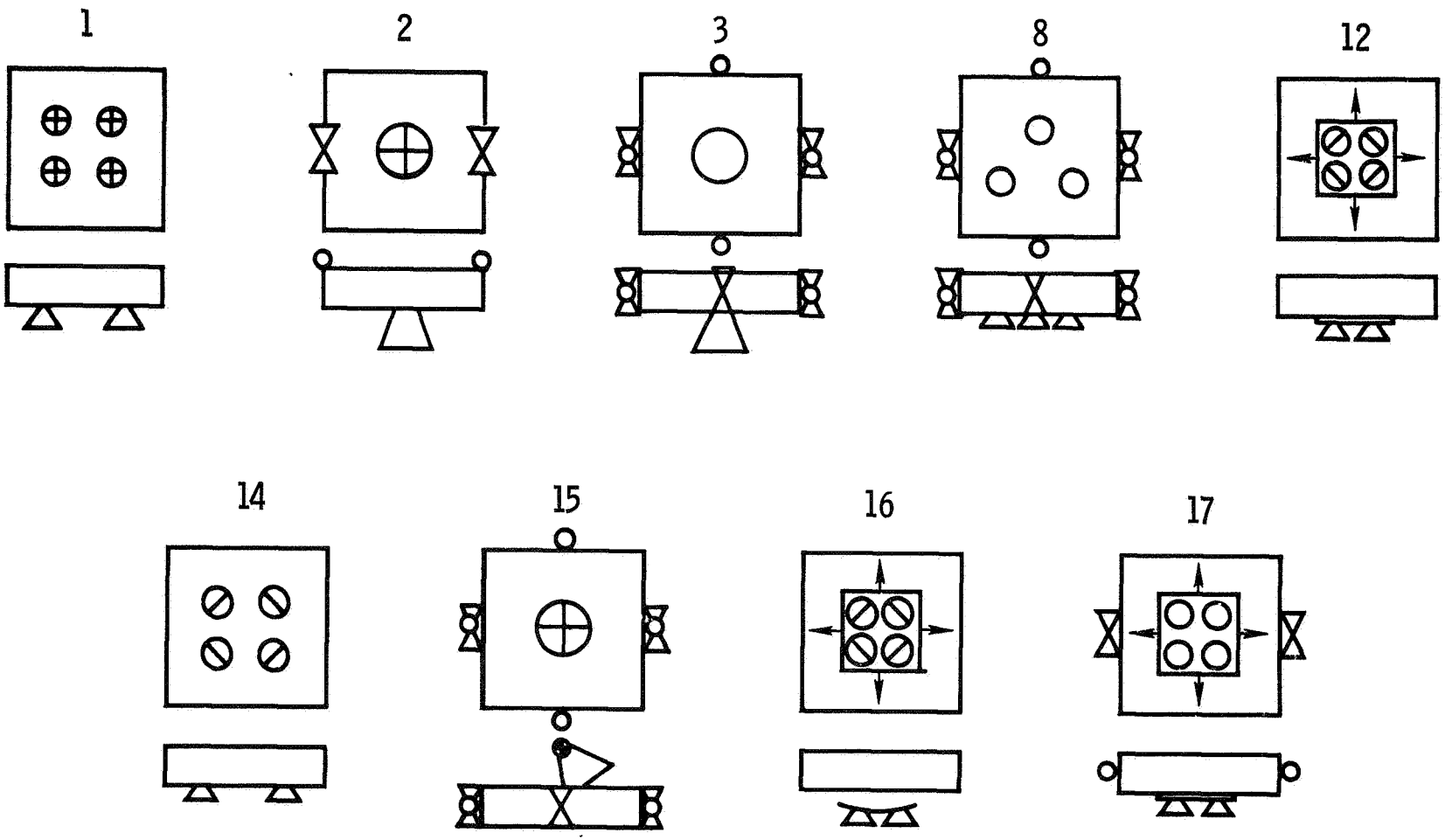
HANDLING QUALITIES SUMMARY

CONTROL METHOD	PILOT OPINION RATINGS		
	THEORETICAL ANALYSIS	VISUAL SIMULATION	FLIGHT VEHICLE
KINESTHETIC	7-8	9-10	5-8
HARDWIRE			
ABOVE C.G.	5-6	6-9	—
BELOW C.G.	5-6	6-9	7-9
STABILITY AUGMENTED			
BELOW C.G.	2-3	3	—
AT C.G. (LEVEL PLATFORM)	1-2	2	—

COMPARISON OF ENGINE LOCATION OPTIONS

NO. OF ENGINES	ENGINE POSITION	
	OUTBOARD & HIGH	CLUSTERED & LOW
1		 • SINGLE POINT FAILURE
2	 • 2 SINGLE POINT FAILURES • HARD-OVER ACTUATOR CATASTROPHIC	 • EXCESSIVE THRUST & THROTTLING FOR REDUNDANCY • HARD-OVER ACTUATOR CATASTROPHIC
3	 • 3 SINGLE POINT FAILURES	 • LOSS OF CONTROL WITH HARD-OVER ACTUATOR FAILURE
4	 • EXCESSIVE THRUST & THROT FOR RED.  (DIFF THROT) • 4 SINGLE PT FAILURES	 • REDUNDANT
8	 (DIFF THROTTLING) • REDUNDANT	

ENGINE/CONTROL CONFIGURATIONS



ENGINE/CONTROL EVALUATION DATA SUMMARY

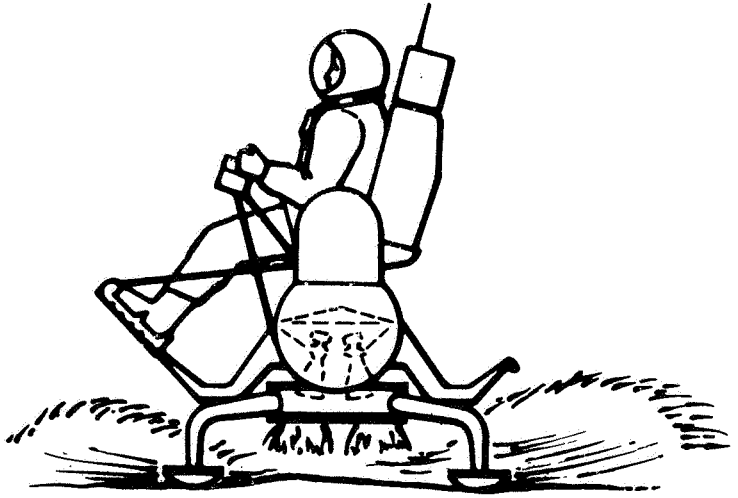
FACTOR	UNITS	CONFIGURATION								
		1	2	3	8	12	14	15	16	17
DRY WEIGHT	LB	301	284	279	290	302	296	302	302	302
Δ RADIUS	N MI	0.00	0.76	0.70	-0.28	0.35	0.06	0.24	0.35	0.12
RELIABILITY										
CREW SAFETY		0.9995	0.998	0.998	0.9995	0.9995	0.9996	0.998	0.9995	0.9995
MISSION SUCCESS		0.984	0.988	0.974	0.970	0.988	0.988	0.974	0.988	0.982
HANDLING QUALITIES	CR	3.00	3.00	2.75	2.75	2.75	3.00	2.75	2.75	
RESOURCES										
COST	RATIO	1.02	1.12	1.11	1.14	1.02	1.02	1.15	1.02	1.15
RISK	PEN. PTS	2	3	2	3	4	2	4	4	6
OPERATIONAL CHARACT										
SERVICING TIME	UNITS	8	8	12	12	6	8	13	6	8

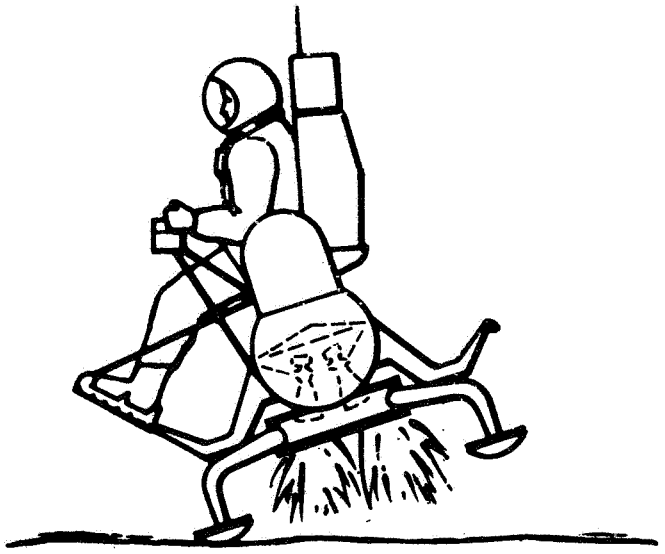
COMPARISON OF SINGLE & FOUR-ENGINE CONFIGURATIONS

FACTOR	SINGLE ENGINE	FOUR ENGINE
WEIGHT	LOWEST WT (279 - 284 LB)	(296 - 302 LB)
COMPLEXITY	• REQUIRES RCS IN ADDITION TO MAIN PROP SYSTEM • ADDITION OF REDUNDANT VALVES INCREASES COMPLEXITY	• ESSENTIALLY FOUR INDEPENDENT ENGINES
RELIABILITY	• CREW SAFETY 0.998 • MISSION SUCCESS 0.988	• CREW SAFETY 0.9995 • MISSION SUCCESS 0.984 - 0.988
OPERATIONAL RADIUS	BEST OF ALL DESIGNS	0.41 - 0.76 N MI LESS

- PRIMARY CHOICE IS BETWEEN HIGH CREW SAFETY OF 4-ENGINE DESIGN & IMPROVED PERFORMANCE OF SINGLE ENGINE DESIGN

PROBLEMS ASSOCIATED WITH THRUSTING AT TOUCHDOWN





- GAS DIFFUSION EROSION AT TOUCHDOWN
  - TANK DAMAGE
  - ENGINE DAMAGE

- TENDENCY TO TIP INCREASED BY THRUST AT TOUCHDOWN
- VERTICAL VELOCITY AT TOUCHDOWN REDUCES TIPPING

COMPARISON OF LANDING PROCEDURES

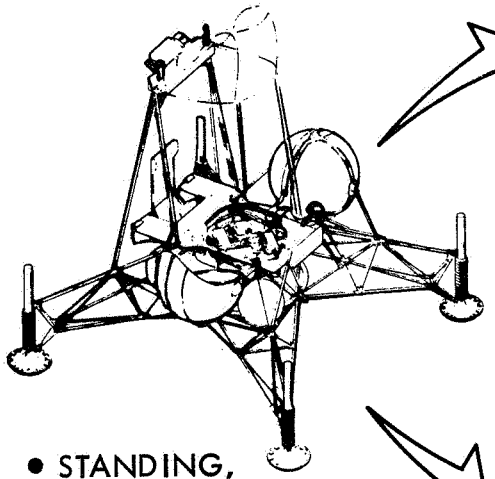
	ADVANTAGES	DISADVANTAGES
SHUT-OFF PRIOR TO LANDING	• REDUCES EROSION PROBLEMS • ELIMINATES THRUST-INDUCED VEHICLE TIPPING • HIGHER VERTICAL VELOCITY REDUCES TENDENCY TO TIP	• REQUIRES VISUAL OR OTHER METHOD TO ESTIMATE ALTITUDE • INCREASES VERTICAL ATTENUATION REQUIREMENTS
SHUT-OFF AFTER LANDING	• DOES NOT REQUIRE CRITICAL ALTITUDE SENSING • ALLOWS VEHICLE CONTROL TO GROUND • REDUCES VERTICAL ATTENUATION REQUIREMENTS	• MUST FACE POORLY DEFINED EROSION EFFECTS • THRUSTING AT AND AFTER LANDING CONTRIBUTES TO UPSETTING VEHICLE

LANDING ATTENUATION/CREW POSITION STUDIES

RESTRAINT & POSITION STUDIES

- STANDING RESTRAINED & UNRESTRAINED, SITTING RESTRAINED
- NASA TESTS
- NR TESTS
- THEORETICAL ANALYSES

INITIAL CONCEPT

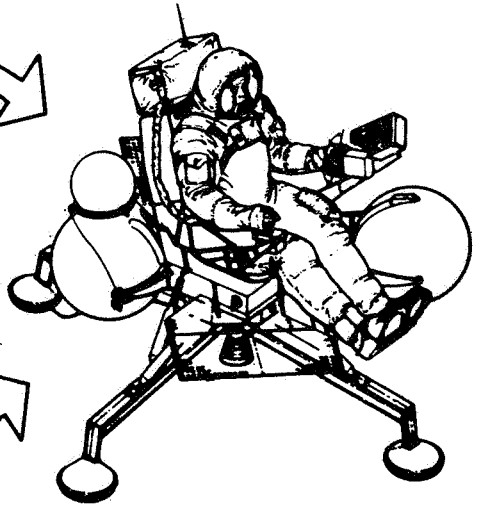


- STANDING, UNRESTRAINED ASTRONAUT
- DIFFICULT LM STOWAGE
- HIGH C.G.
- MULTIPLICITY OF ATTENUATORS

ATTENUATION ALTERNATIVES STUDIES

- TRIPOD
- INTEGRAL LEG FRAME
- 3 & 4 LEGS

RECOMMENDED CONCEPT



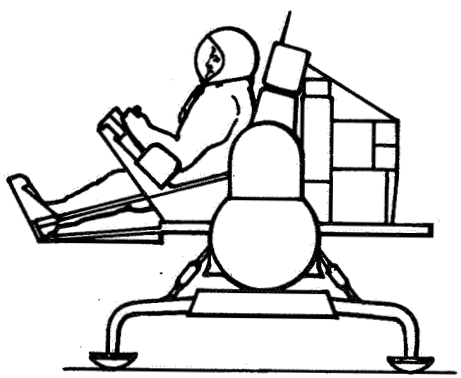
- SIMPLE STOWAGE
- REDUCED NUMBER OF ATTENUATORS
- SMALLER STROKE
- LOWER C.G.

COMPARISON OF ATTENUATION/CREW POSITION OPTIONS

	STANDING, UNRESTRAINED		STANDING, RESTRAINED		SEATED, RESTRAINED	
CHARACTERISTICS	TRIPOD	INTEGRAL L.F.	TRIPOD	INTEGRAL L.F.	TRIPOD	INTEGRAL L.F.
ALLOWABLE G'S						
• VERTICAL	2	2	8	8	8	8
• HORIZONTAL	1	1	4	4	4	4
C.G. HEIGHT (INCHES)	66	60	60	57.1	45	42
LANDING GEAR SPREAD (INCHES)	139	129	129	123	102	96
LM STOWAGE	REMOVE LEGS	FOLD LEGS	REMOVE LEGS	FOLD LEGS	REMOVE LEGS	INTACT
WEIGHT (GEAR & RESTRAINT) (LB)	69.9	68.5	74.4	72.3	66.6	52.5
ATTENUATOR STROKE (IN.)	25.0	13.5	12.5	6.8	12.5	6.8

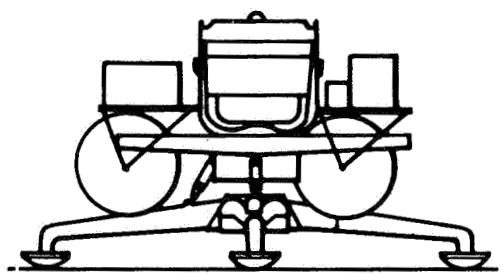
PAYLOAD CONCEPTS

TRUCK



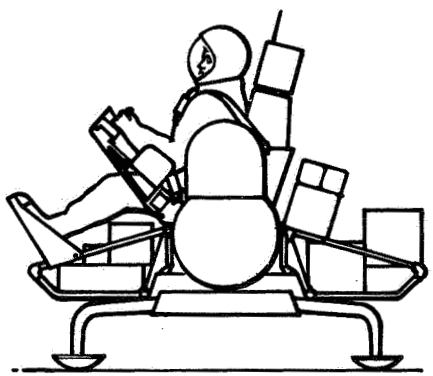
- LARGE SEAT TRAVEL
- HIGH-WT PAYLOAD CAPABILITY
- INCREASES C.G. HEIGHT

ROLL-PLANE LOADING



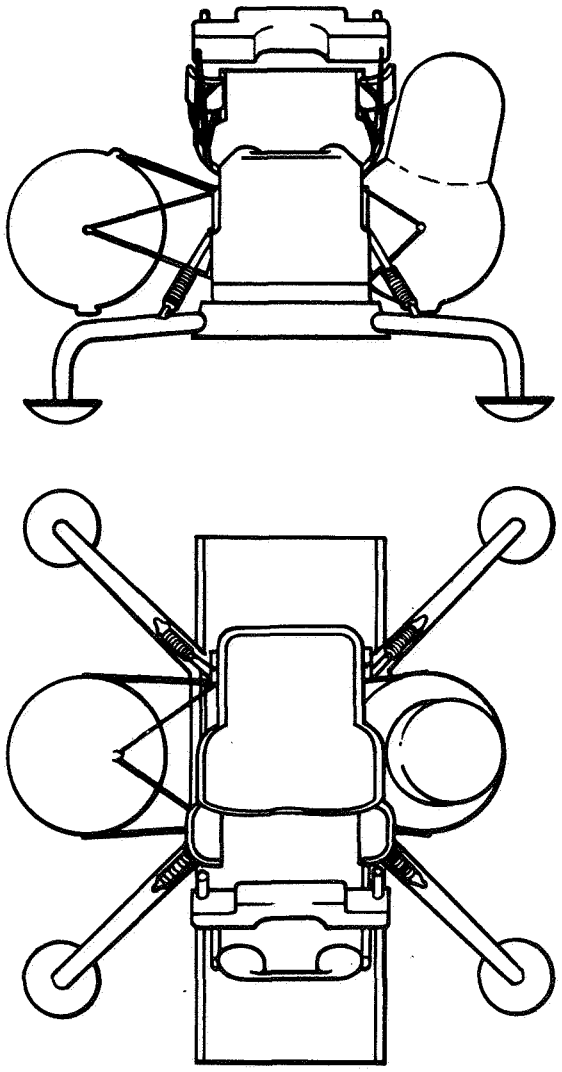
- APPLICABLE TO SMALL PAYLOADS
- INCREASES C.G. HEIGHT

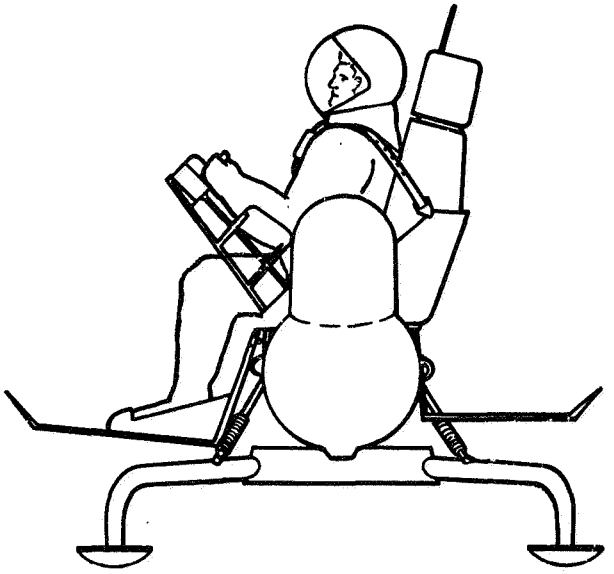
PITCH-PLANE LOADING



- ALLOWS FORE & AFT PAYLOAD TRIM
- LOWERS C.G.
- SMALL SEAT TRIM MOVEMENT
- LARGE PAYLOAD CAPABILITY

RECOMMENDED CONCEPT AT MID-TERM





- TWO PROPELLANT TANKS
- SEATED, RESTRAINED PILOT
- INTEGRAL LEG GEAR (4-LEGS)
- 4 ENGINES
- STABILITY-AUGMENTED CONTROL
- FORE & AFT LOAD PANS

MID-TERM RECOMMENDATIONS

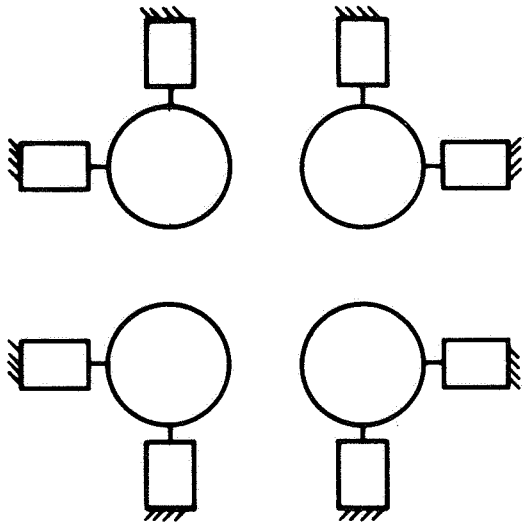
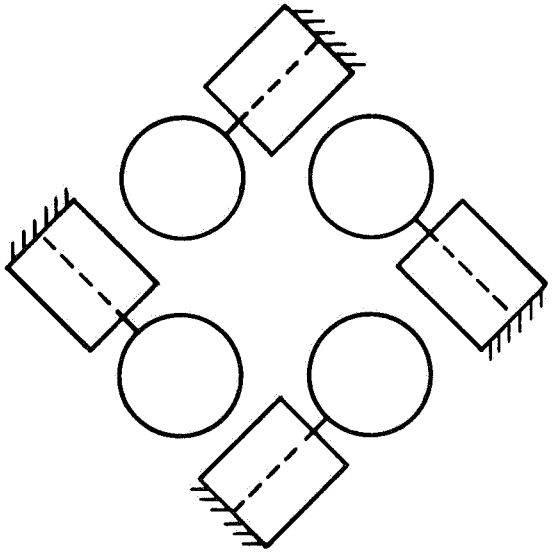
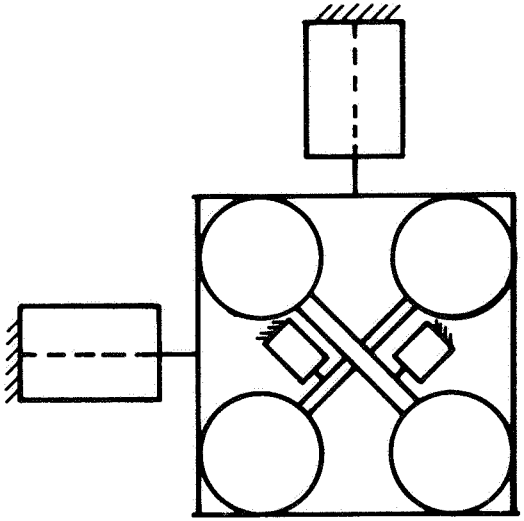
SYSTEM CHARACTERISTICS	REASON
STABILITY AUGMENTED CONTROL	OTHERS DO NOT HAVE ACCEPTABLE HANDLING QUALITIES
4 ENGINES	UNABLE TO ACHIEVE ACCEPTABLE RELIABILITY FOR SINGLE ENGINE IN 24 MO DEV CYCLE
ACTUATION SYSTEM - TBD	POTENTIAL OF ALTERNATIVE DESIGNS TO BE RESOLVED
ASTRONAUT SEATED & RESTRAINED	LOW C.G. REDUCES LANDING GEAR SPREAD, RESTRAINTS PROVIDE POSITIVE ASTRONAUT / PLSS LANDING STABILITY
INTEGRAL LEG-FRAME LANDING GEAR	SIMPLE, LOW WT SOLUTION
FOUR-LEG GEAR	LEG FOLDING OR REMOVAL NOT NECESSARY FOR LM STOWAGE, LOWEST WEIGHT
TWO SPHERICAL PROPELLANT TANKS	LOWEST WT, STOWS IN LM

PRELIMINARY DESIGN STUDY

PRIMARY PRELIMINARY DESIGN ISSUES

- SELECTION OF FOUR-ENGINE CONTROL METHOD
- OPTIMIZATION OF LANDING ATTENUATION SYSTEM
- OPTIMIZATION OF PAYLOAD ARRANGEMENT
- DEFINITION OF INGRESS / EGRESS METHOD

CANDIDATE 4-ENGINE ACTUATION CONFIGURATIONS

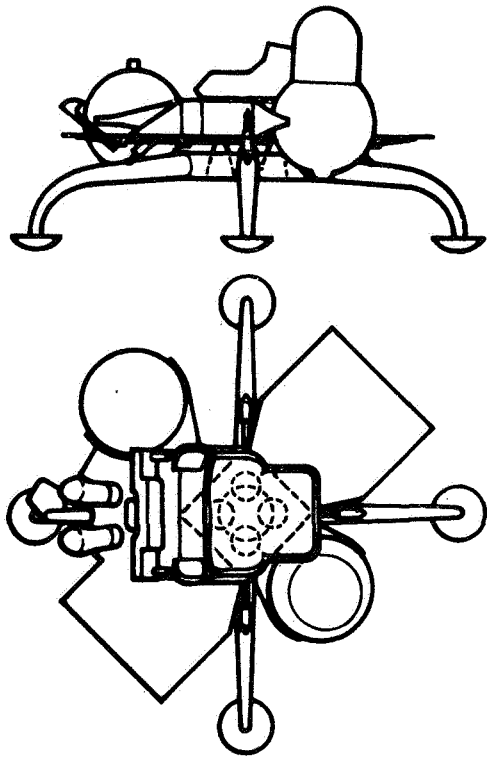
8 - ACTUATORS	4 - ACTUATORS	SLIDING PLATE
		
• TWO-AXIS GIMBAL • 8 - SINGLE ACTUATORS	• SINGLE-AXIS GIMBAL • 4 - DOUBLE ACTUATORS	• 2-DOUBLE ACTUATORS (PITCH & ROLL) • 2-SINGLE ACTUATORS (YAW)

ACTUATION METHODS EVALUATION

	ADVANTAGES	DISADVANTAGES
8 ACTUATORS - 2 AXIS GIMBALED TVC	• LOWEST GIMBAL SWING (12.5°) • POTENTIALLY SIMPLER ACTUATOR (CLUTCHLESS) W/ATTENDANT RELIABILITY & WEIGHT IMPROVEMENTS • OFF-SHELF ACTUATORS AVAIL.	• LOWEST MISSION SUCCESS
4 ACTUATORS - 1 AXIS GIMBALED TVC	• LEAST WEIGHT	• RISK AREAS • SWITCHOVER PROCEDURE • ACTUATOR MOTOR REDUNDANCY PROVISION
TRANSLATING TVC	• NO PATH REVERSAL	• HARDOVER FAILURE RESULTS IN EXCESSIVE ROTATIONAL ACCELERATION • MANUAL TRIM REQD FOR ENGINE OUT • HIGHEST WEIGHT • RISK AREAS (SAME AS 4 ACTUATOR)

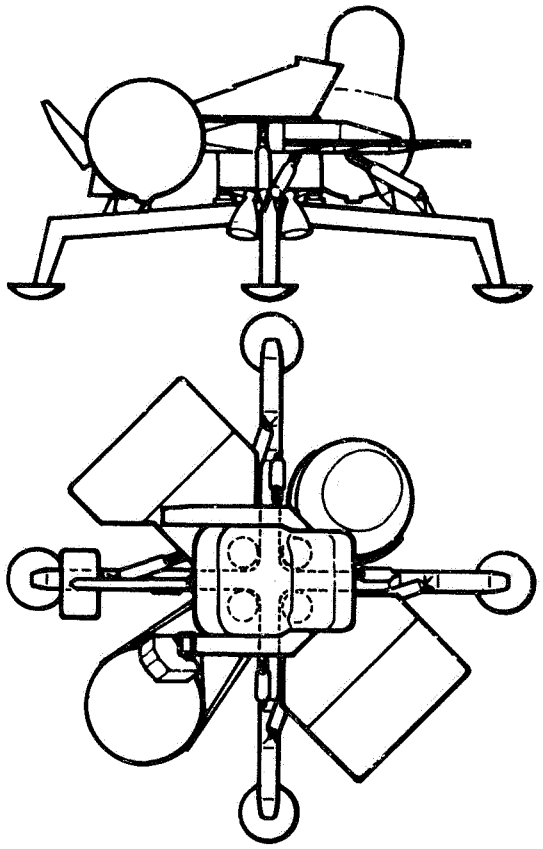
OPTIMIZATION OF LANDING ATTENUATION SYSTEM

BOX-FRAME



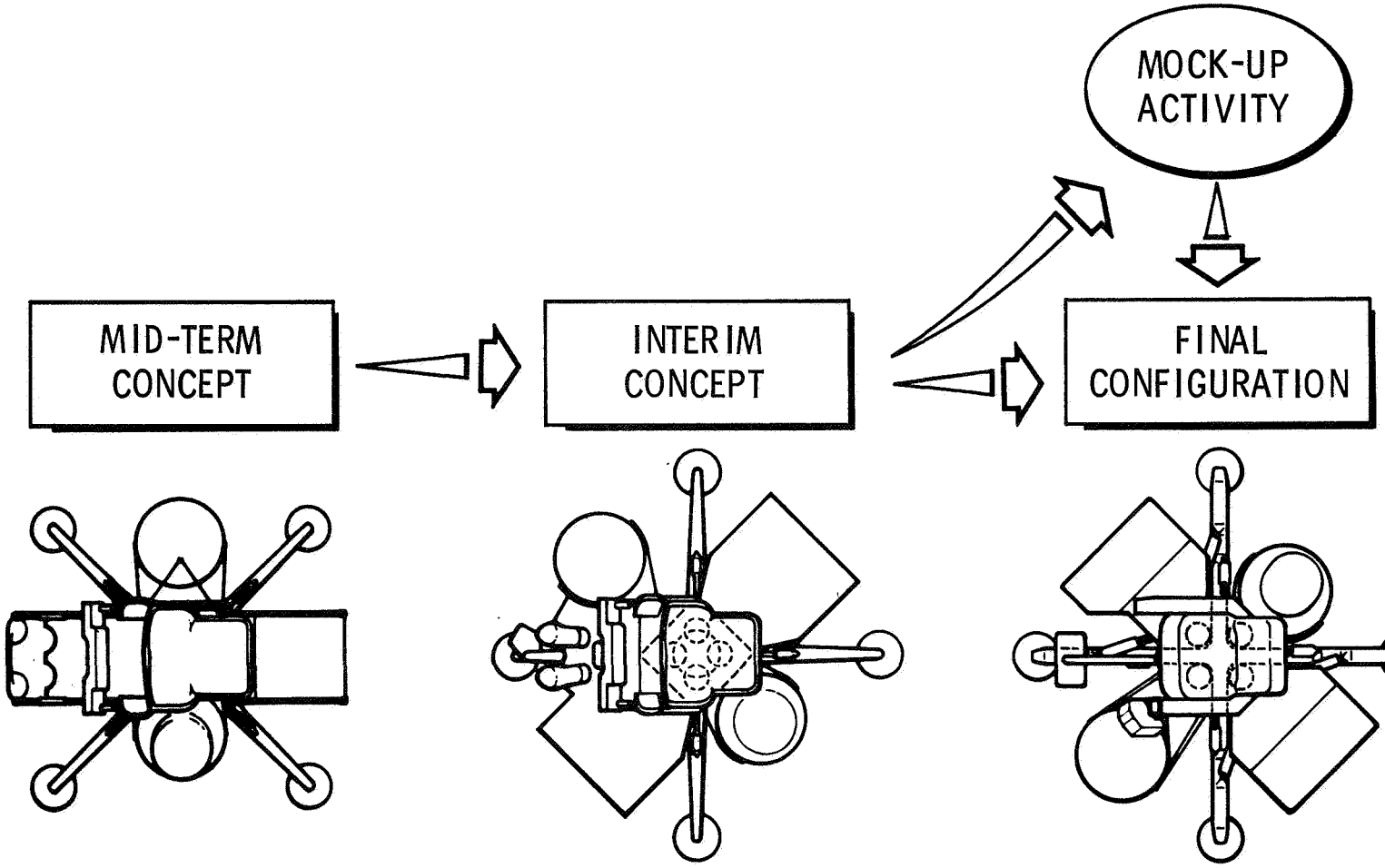
- ENGINES ATTACHED TO BODY STRUCTURE
- BOX STRUCTURE LEADS TO HIGH WEIGHT
- POOR CLEARANCE CHARACTERISTICS

X-FRAME



- ENGINES ATTACHED TO X-LEG FRAME
- LOWEST WEIGHT
- BEST CLEARANCE CHARACTERISTICS

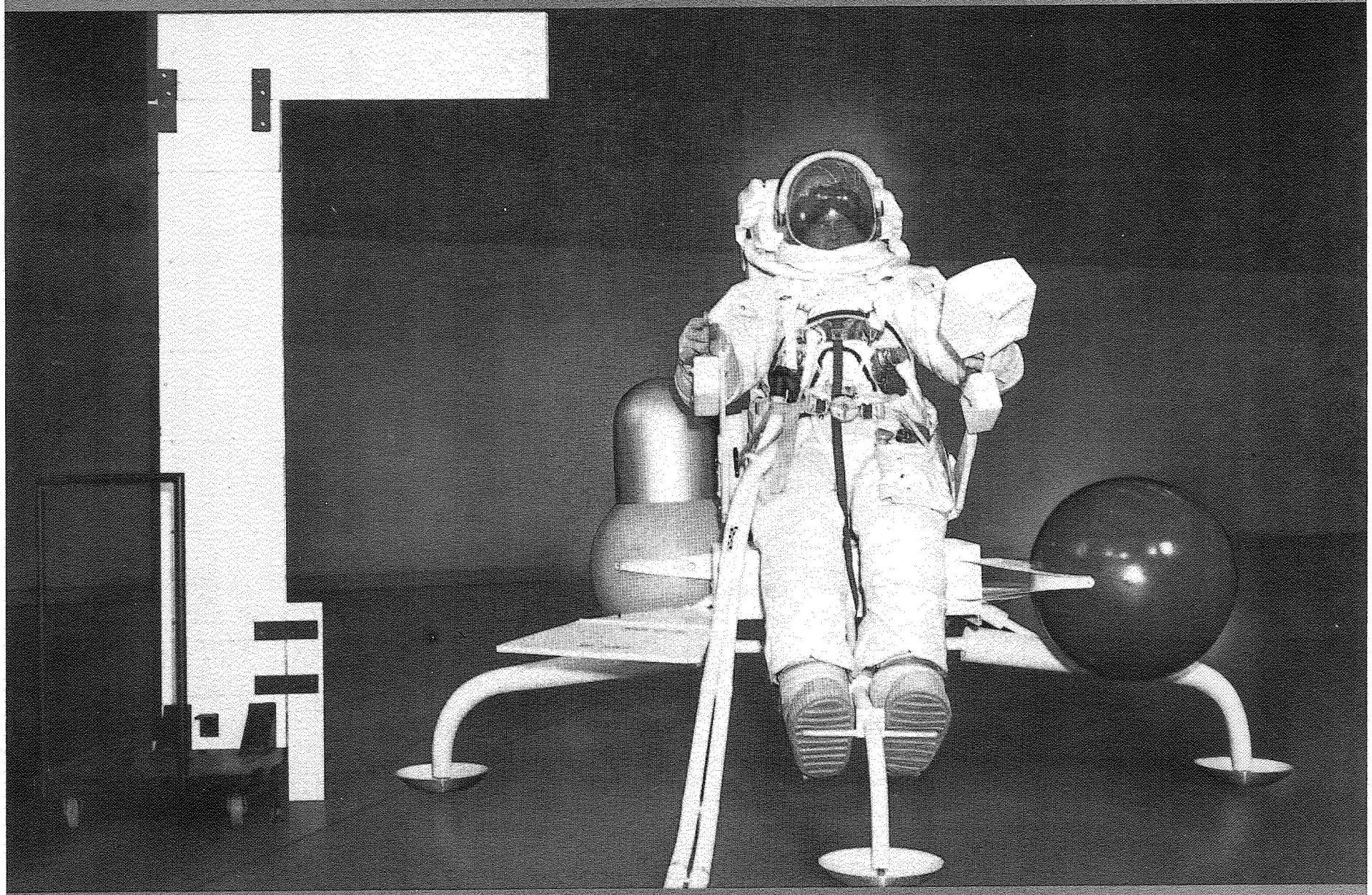
OPTIMIZATION OF INGRESS/EGRESS



- SEAT ROTATED 45 DEGREES FROM PLANE OF SYMMETRY

- PLATFORM REMOVED TO IMPROVE INGRESS/EGRESS
- SEAT TILTED FORWARD 15 DEGREES TO IMPROVE VISIBILITY

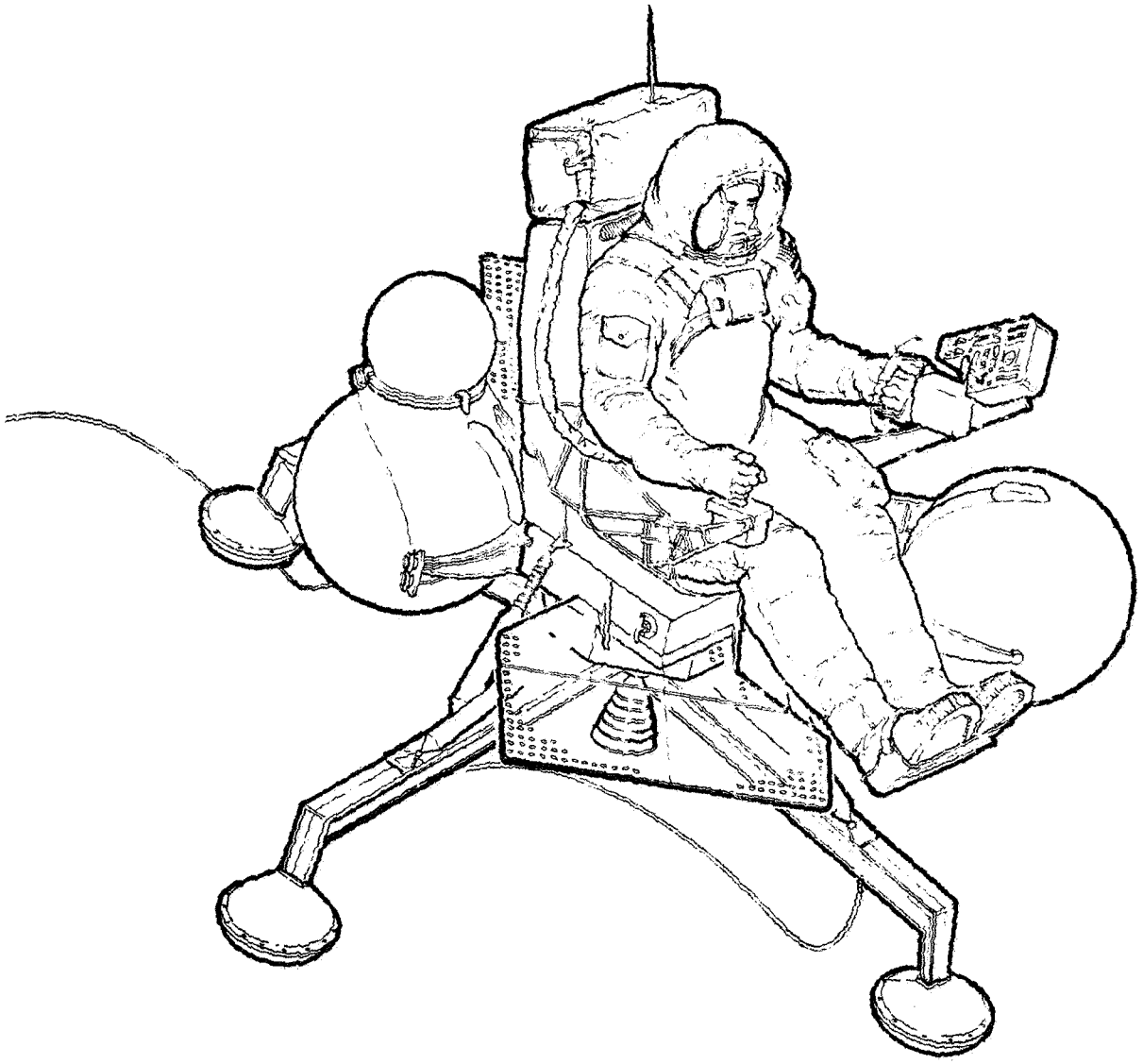
LFV MOCKUP



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GENERAL ARRANGEMENT



CONFIGURATION CHARACTERISTICS SUMMARY

GENERAL ARRANGEMENT

- SEATED & RESTRAINED PILOT
- BALANCED PROPELLANT TANK ARRANGEMENT
- TWO PAYLOAD RACKS (APPROX 45° FROM PITCH AXIS)
- CLUSTERED & LEG-MOUNTED ENGINE

PROPULSION SYSTEM

- 4 ENGINES (105 LB MAX THRUST EACH, THROTTLING RATIO - 5:1)
- 2 SPHERICAL, MODIFIED 20 IN. GEMINI PROPELLANT TANKS (300 LB PROPELLANT CAPACITY)
- 1 APOLLO RCS TITANIUM He VESSEL (ADDITIONAL TANKS FOR REPLACEMENT)
- APOLLO RCS PRESSURIZATION CONTROL COMPONENTS

CONTROL SYSTEM

- 2, 3-AXIS RATE GYROS
- 1 ACCELEROMETER
- REDUNDANT CONTROL UNIT
- 8 ELECTRO-MECHANICAL ENGINE GIMBAL ACTUATORS & SERVO-AMPLIFIERS
- HARD-WIRE THROTTLE CONTROL
- MODIFIED APOLLO ROTATIONAL HAND CONTROLLER

CONFIGURATION CHARACTERISTICS SUMMARY (CONT)

LANDING SYSTEM

- INTEGRAL X-FRAME LANDING GEAR & PADS (4 LEGS)
- 8 SURVEYOR-TYPE ATTENUATORS

POWER SYSTEM

- 2 (REDUNDANT) 28V BATTERIES (NO RECHARGE, 4.6 AMP-HRS EACH)
- REDUNDANT POWER DISTRIBUTION & PROTECTION

DISPLAYS

- PITCH & ROLL ATTITUDE
- AZIMUTH
- 2 PROPELLANT GAGES
- HIGH & LOW PRESSURE
- CLOCK
- ENGINE-OUT LIGHTS & SHUT-OFF
- SURFACE SENSING INDICATOR

SUMMARY WEIGHT STATEMENT

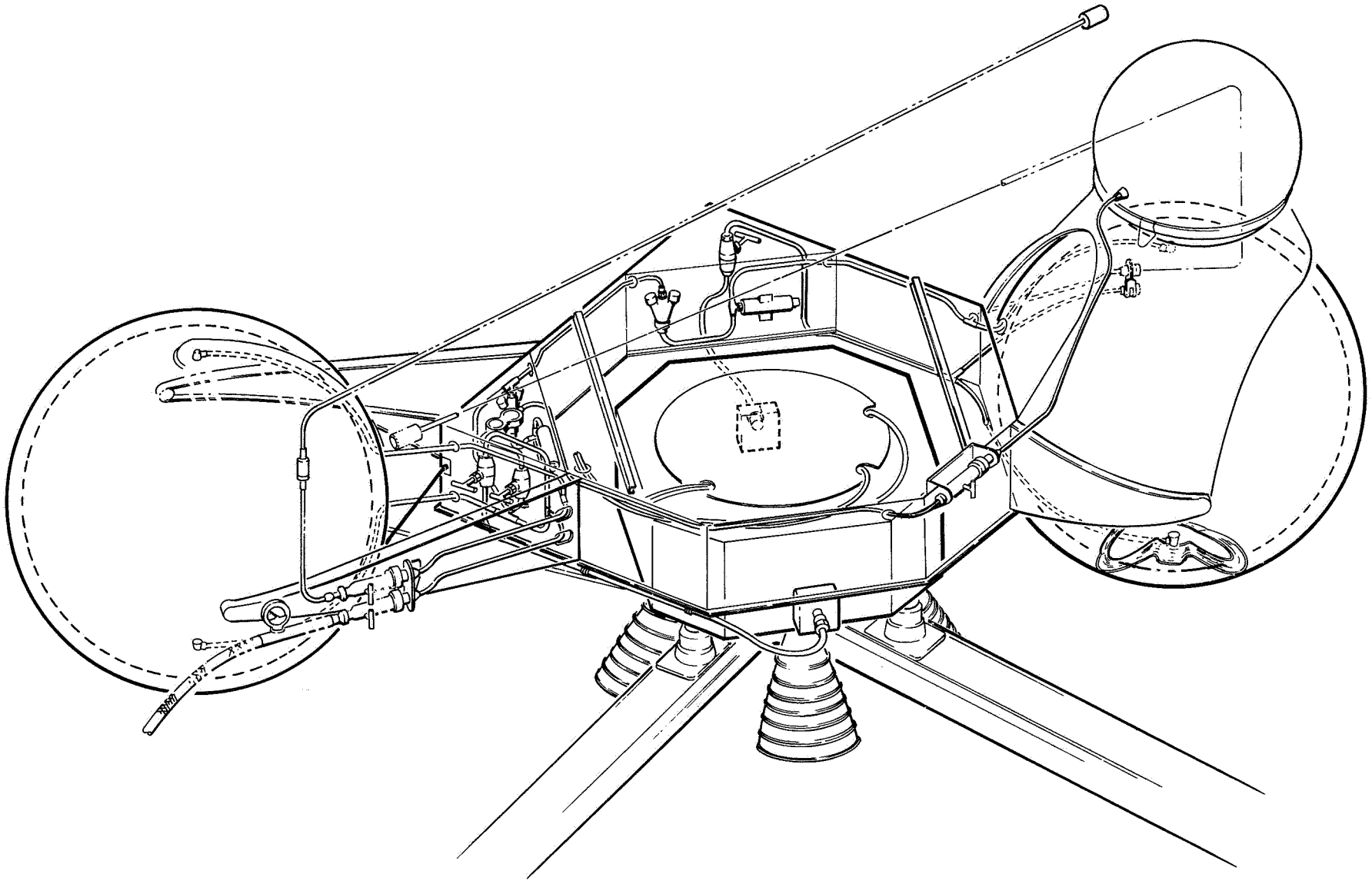
SYSTEM	
BODY STRUCTURE	36.9
ENVIRONMENTAL PROTECTION	11.0
LANDING	62.2
PROPULSION	98.4
POWER	18.3
POWER CONVERSION & DIST	8.8
NAVIGATION & CONTROL	32.9
PERSONNEL PROVISIONS	9.3
CREW STATION CONTROLS & PANELS	25.8
DRY WEIGHT*	303.6
PILOT	380.0
RESIDUALS	9.0
MINIMUM BURNOUT WEIGHT	692.6
MAXIMUM PAYLOAD	370.0
PROPELLANT	300.0
MAXIMUM GROSS WEIGHT	1362.6

*INCLUDES 10% GROWTH FOR ALL SYSTEMS

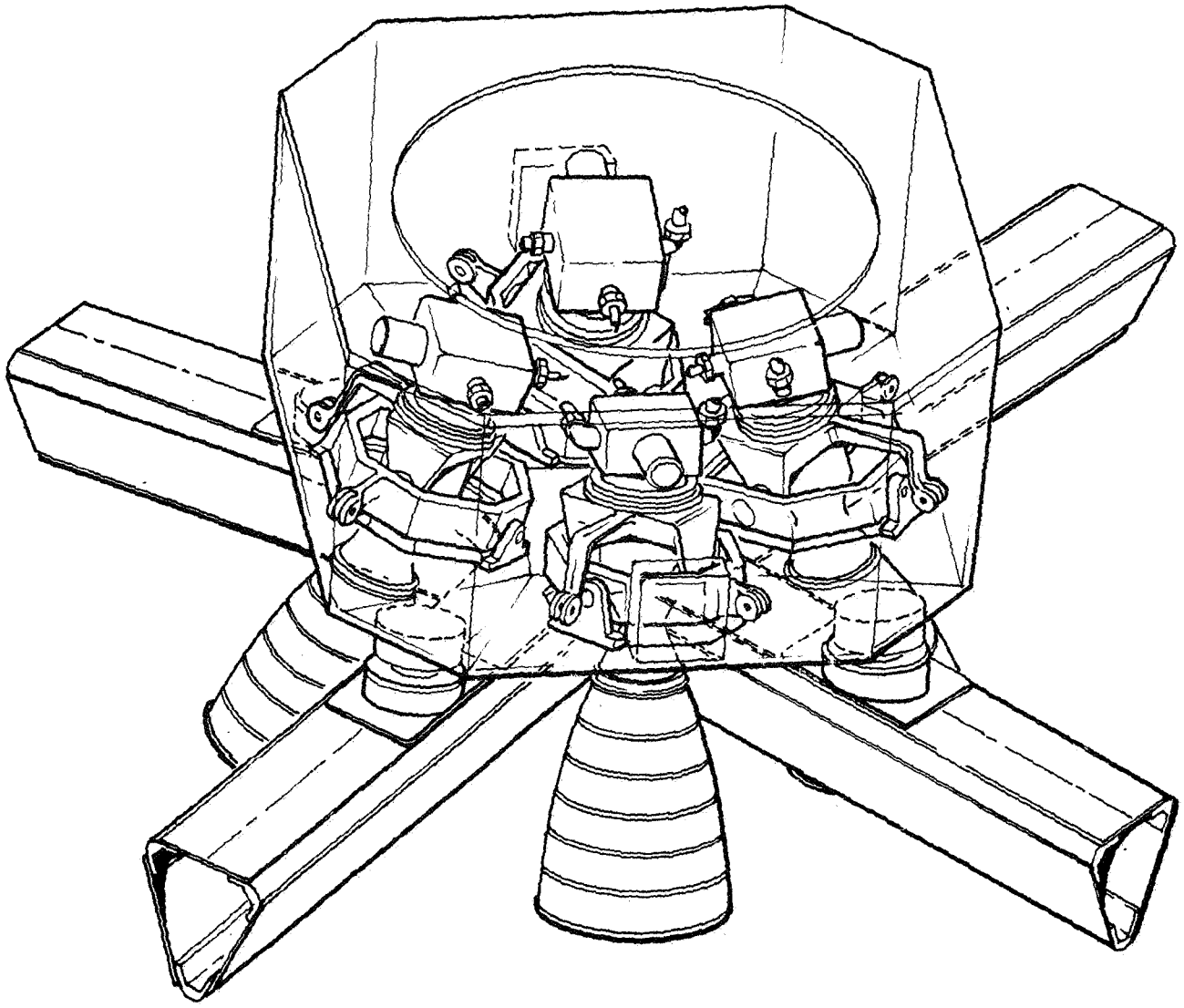
LFV INERTIAL CHARACTERISTICS

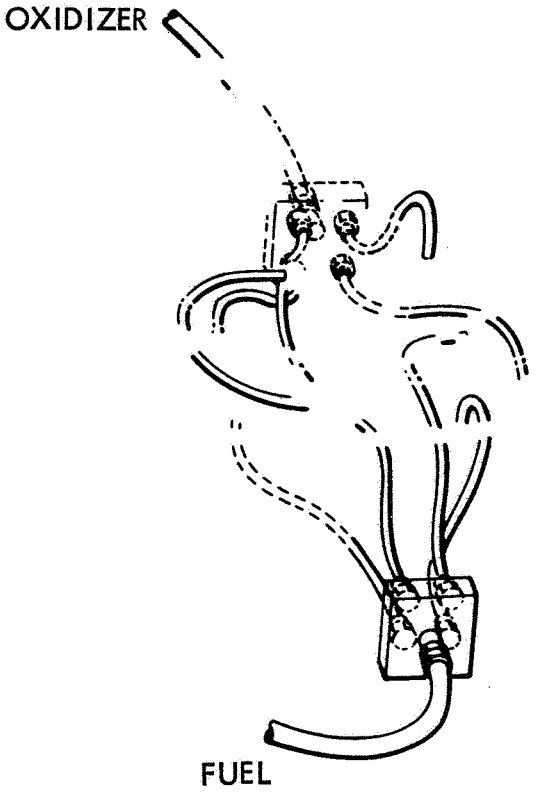
	INERTIA (SLUG FT^2)					
	BURNOUT PILOT ONLY	BURNOUT PILOT + 100 LB PAYLOAD	BURNOUT PILOT + 370 LB PAYLOAD	GROSS WT PILOT ONLY	GROSS WT 100 LB PAYLOAD	GROSS WT 370 LB PAYLOAD
PITCH	53	64	104	84	94	133
ROLL	45	57	96	76	86	125
YAW	37	57	130	87	106	180
PRODUCT	-	-	-	-1.2	-1.3	-1.4
PRINCIPAL AXIS (DEG)	-	-	-	-6.2	-3.6	-1.5

PROPULSION SYSTEM



ENGINE INSTALLATION

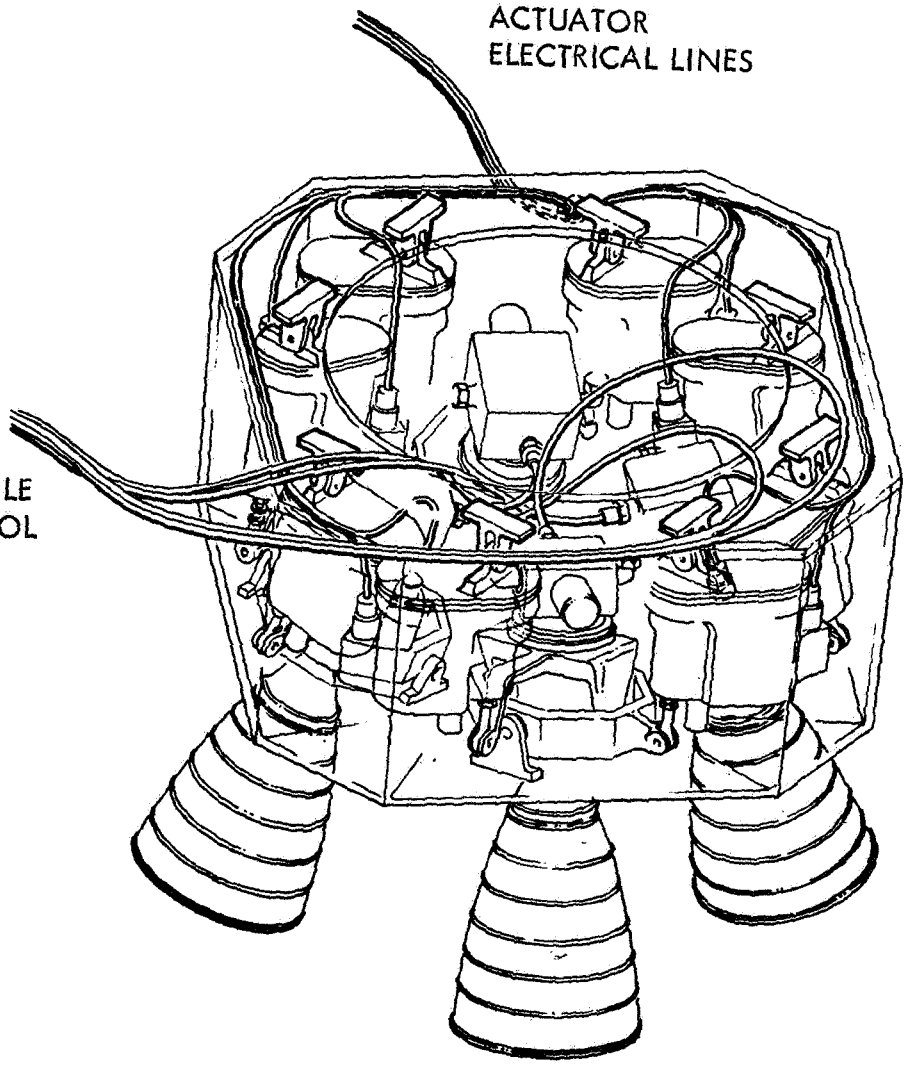




○ OXIDIZER LINES
○ FUEL LINES

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ACTUATOR INSTALLATION



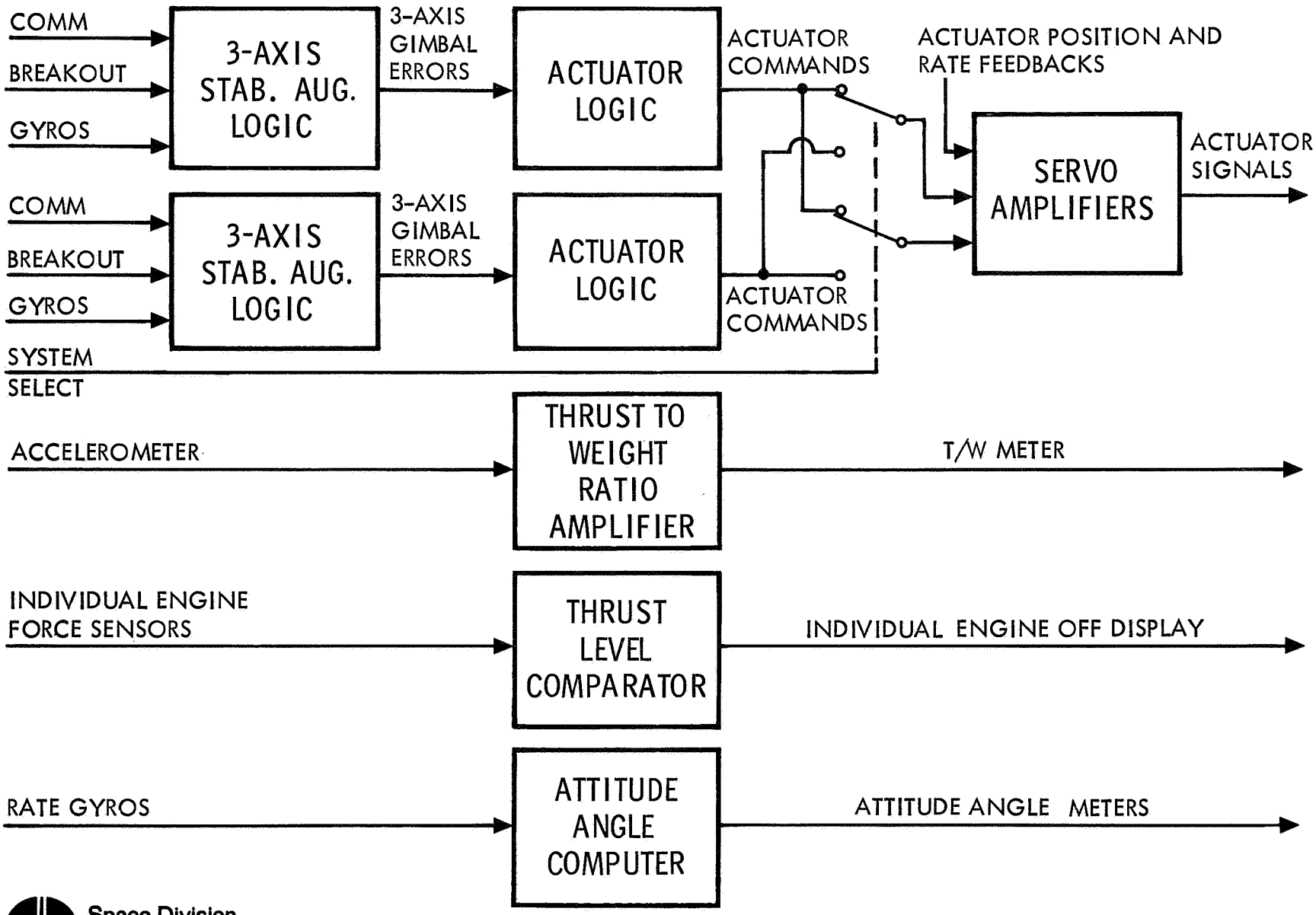
○ THROTTLE CONTROL LINES

○ ACTUATOR ELECTRICAL LINES

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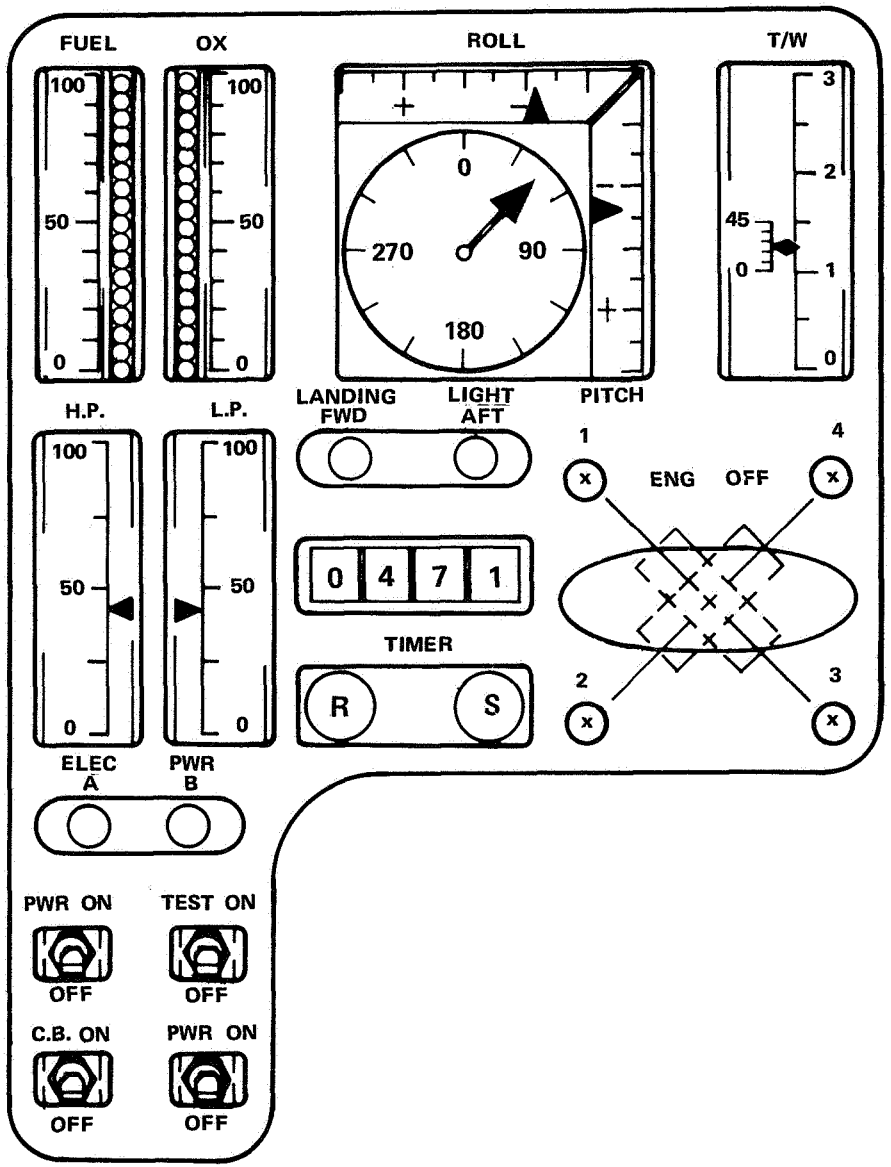
CONTROL UNIT FLOW DIAGRAM



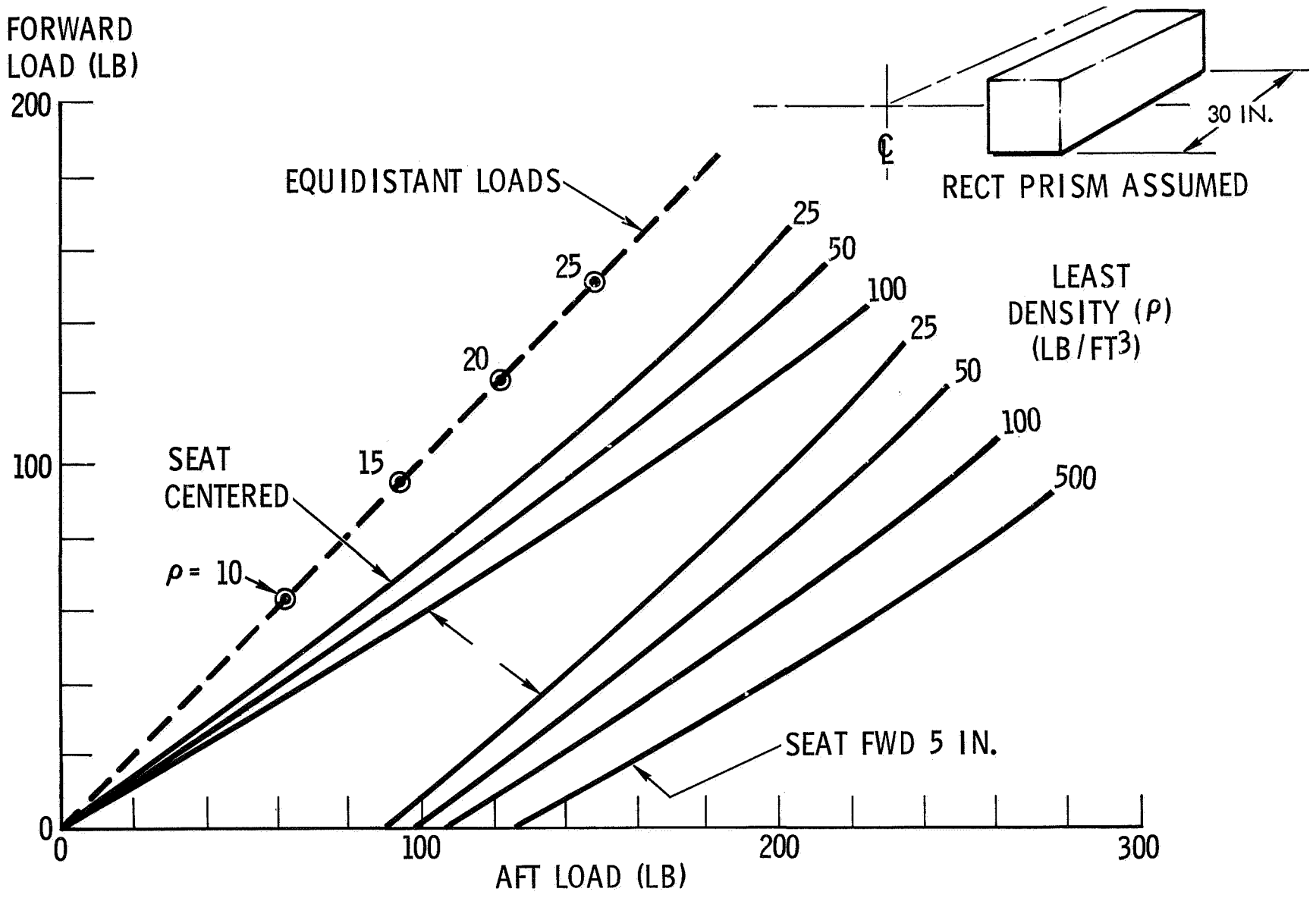
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DISPLAY PANEL LAYOUT

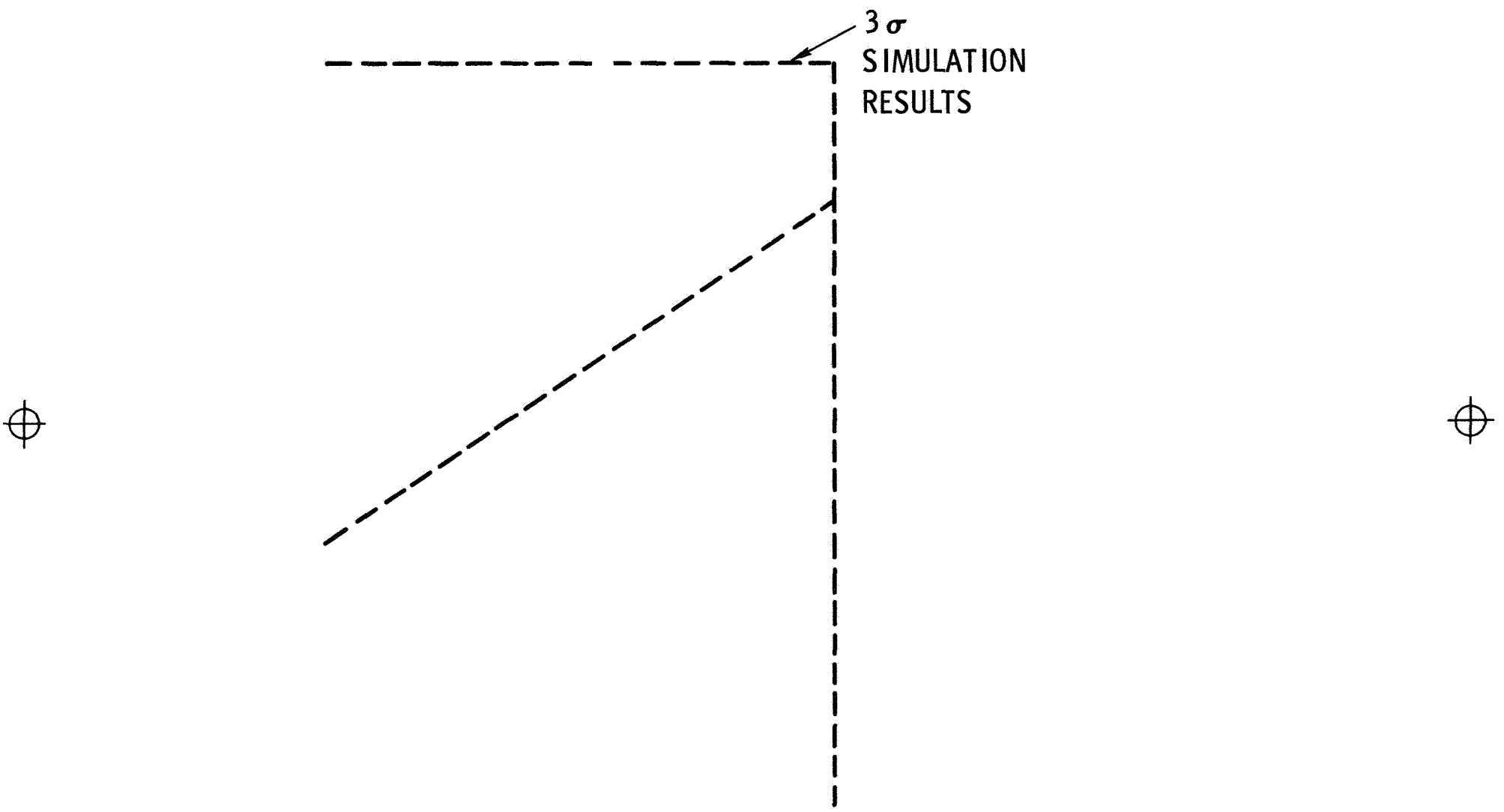


PAYLOAD CAPABILITY ENVELOPE



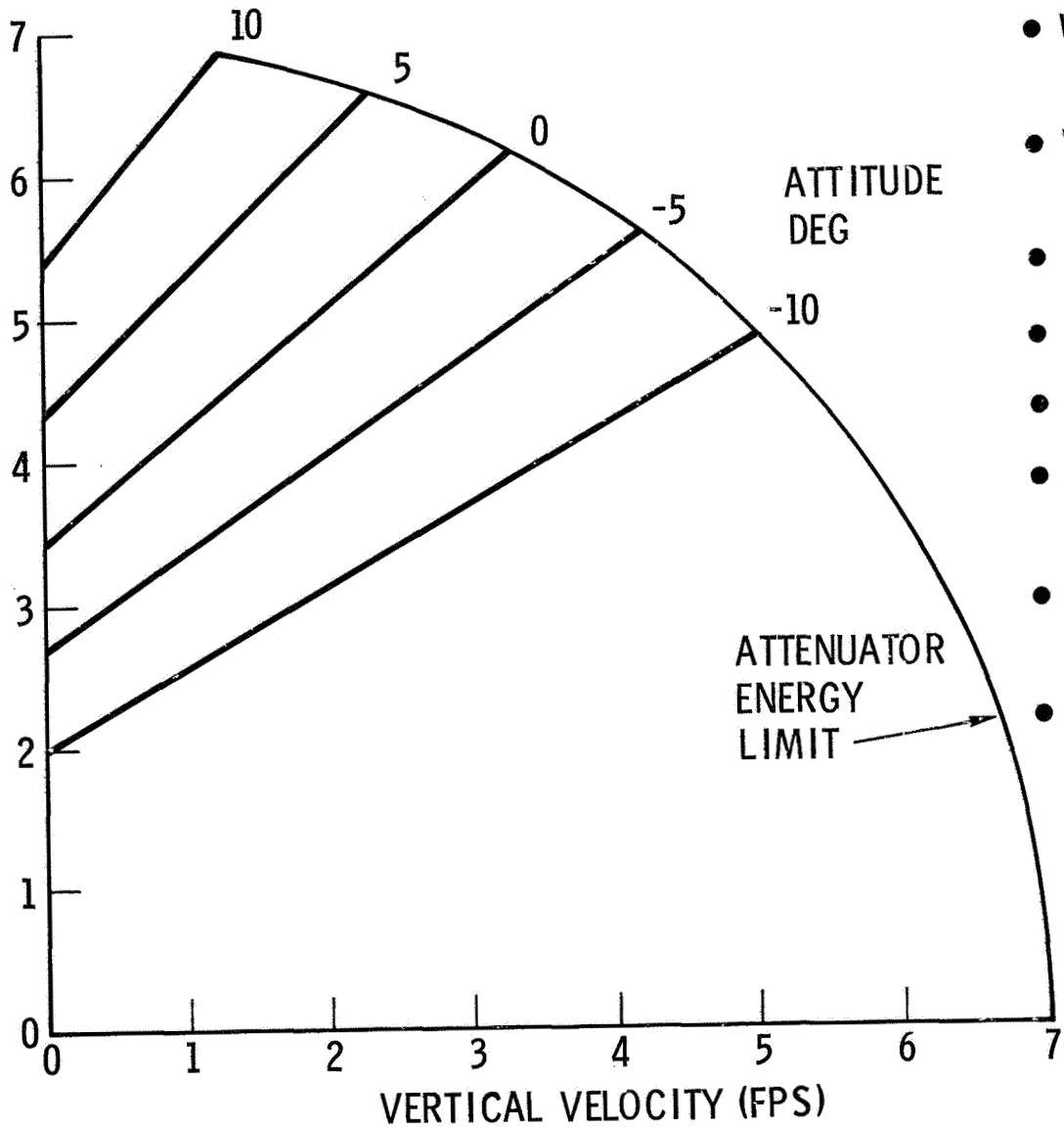
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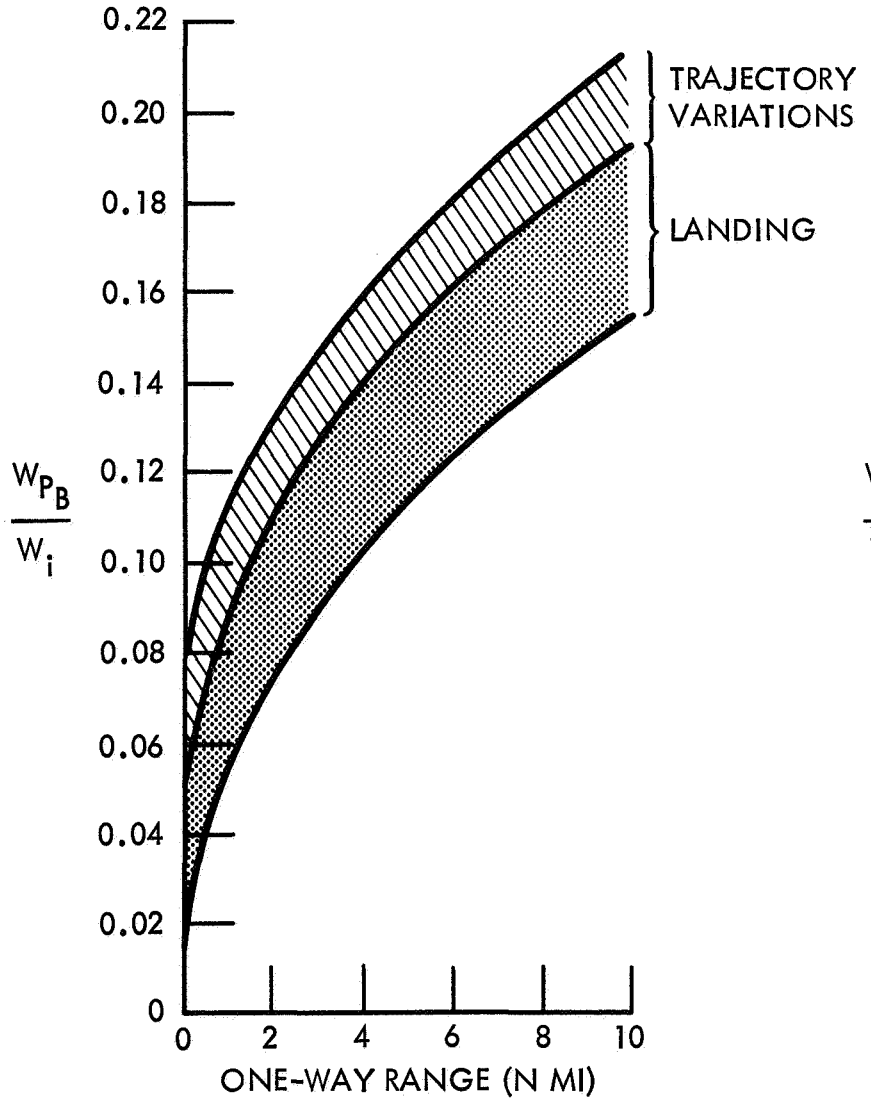
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LANDING ENVELOPE

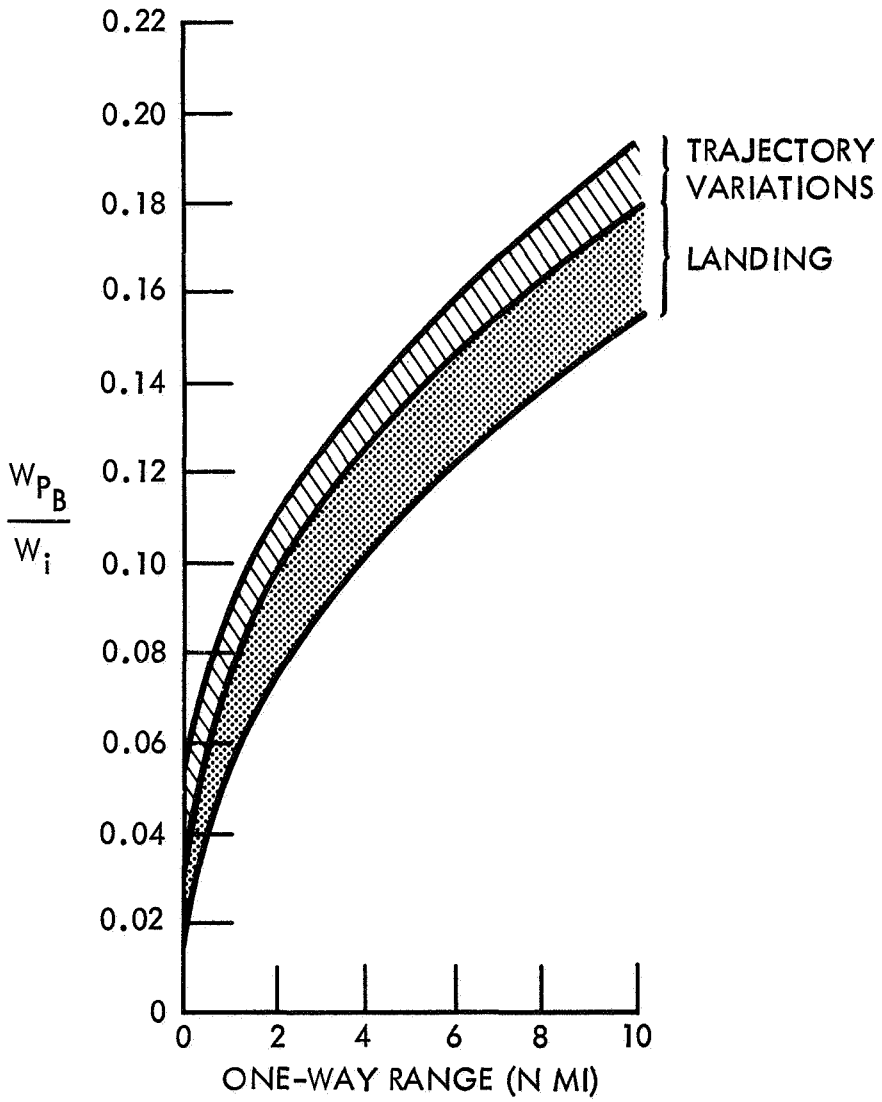


- W_{MAX} = 1346 LB FOR ENERGY
- W_{MIN} = 676 LB FOR TOPPLING
- $\dot{\theta}$ = ±3 DEG / SEC
- TOPPLING MARGIN 20°
- GROUND SLOPE ±10°
- 4-G LATERAL & 8-G VERTICAL (MAX)
- HARD-SURFACE LANDING
- NO-SLIDE CONDITION

PILOT INFLUENCE ON-PROPELLANT REQMTS

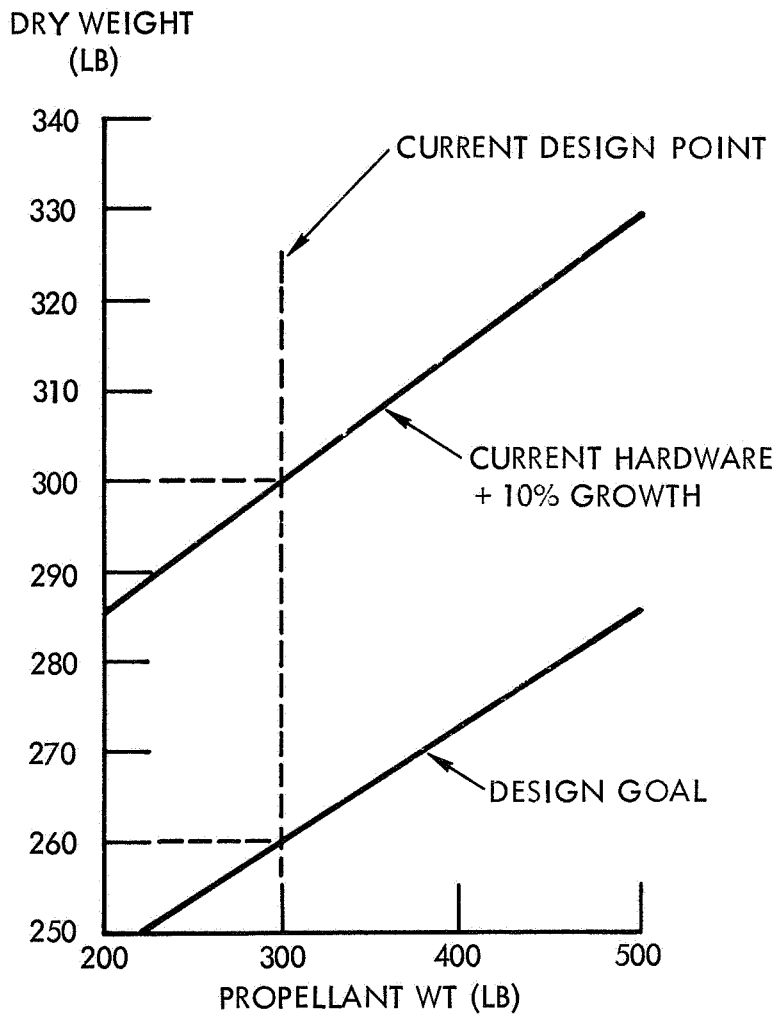


SIMULATION DATA ANALYSIS

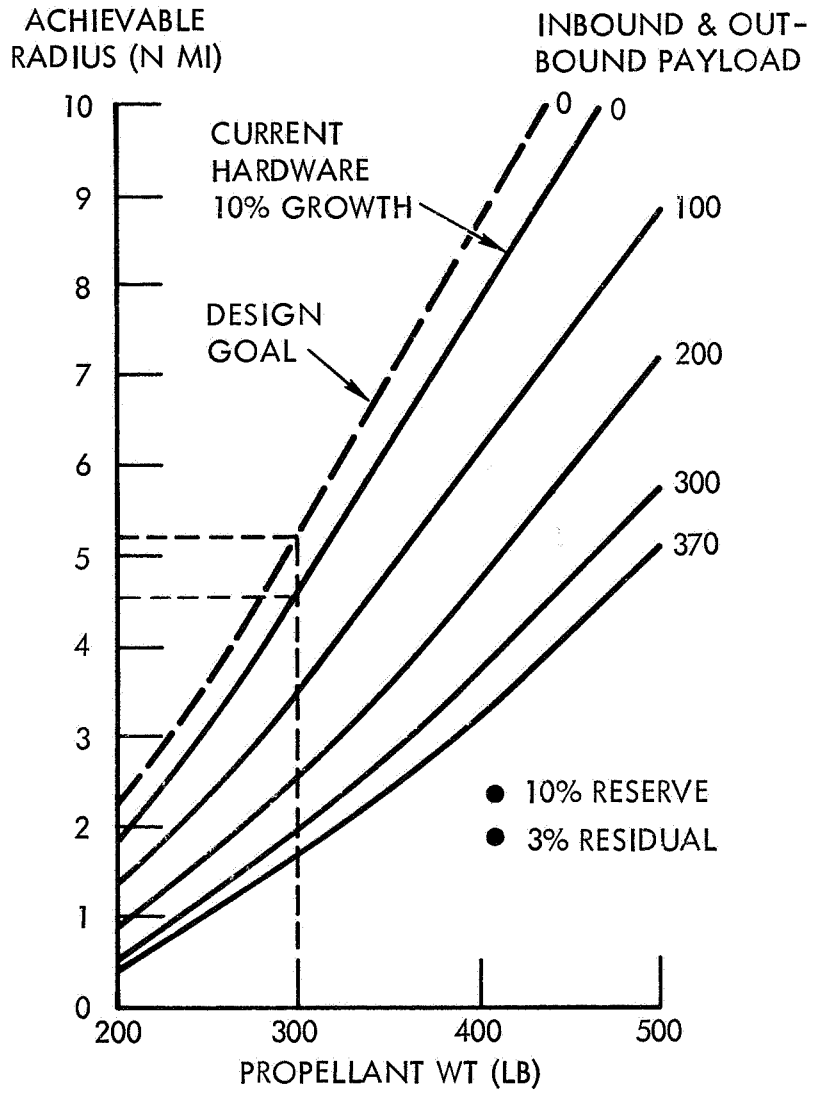


ACHIEVABLE WITH TRAINING

ACHIEVABLE RANGING CAPABILITY & SYSTEM TRADEOFFS



DRY WEIGHT TREND



RANGING CAPABILITY

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TRAINING PLAN

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TRAINING PLAN CONTENTS

- TRAINING REQUIREMENTS
- TRAINING APPROACH
- CURRICULUM OVERVIEW
- COURSE DESCRIPTIONS
- TRAINING SCHEDULES
- TRAINING EQUIPMENT REQUIREMENTS
- POTENTIAL FLIGHT & VISUAL SIMULATION CONCEPTS

TRAINING REQUIREMENTS

- LUNAR SURFACE MISSION CHARACTERISTICS
  - OBJECTIVES
  - MISSION PROFILES & TIMELINES
- LUNAR FLYING VEHICLE SYSTEM CHARACTERISTICS
  - OVERALL SYSTEM DESCRIPTION & INTERFACE WITH LM
  - SYSTEMS FUNCTIONAL OPERATIONAL DESCRIPTION
- FLIGHT TRAINING
  - CONTROL FAMILIARIZATION
  - NAVIGATION TRAINING
  - SPECIFIC MISSION TRAINING

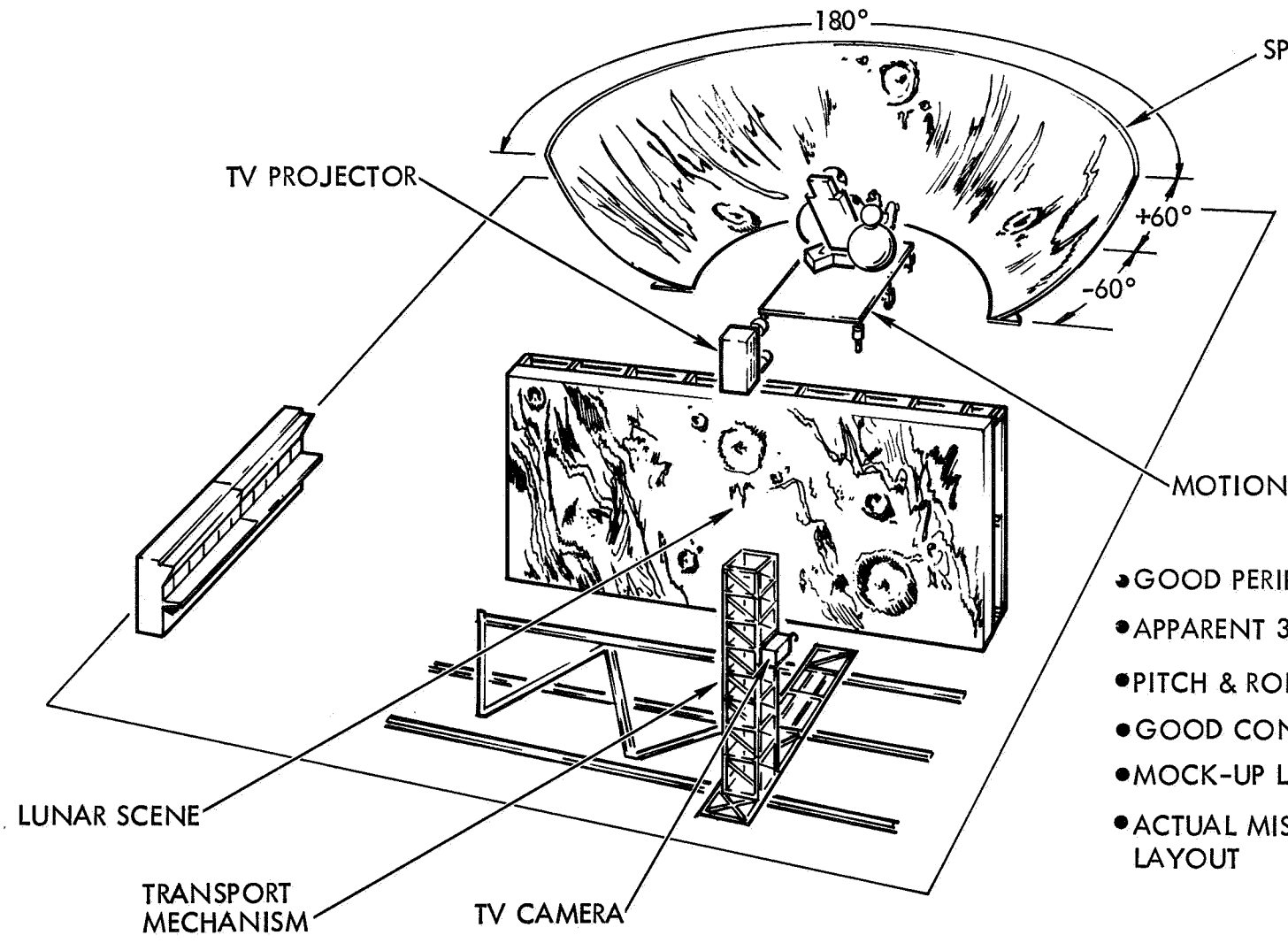
TRAINING APPROACH

PHASE I	PHASE II	PHASE III
	(ALTERNATE ACADEMIC & PRACTICAL SESSIONS)	
TRAINING ORIENTATION	SUBSYSTEMS OPERATIONS	INITIAL VISUAL SIMULATION TRAINING
LFV SURFACE MISSION FAMILIARIZATION	VEHICLE UNLOADING	TETHERED 1/6-g FLIGHT TRAINER
MISSION REQUIREMENTS	FUELING OPERATIONS	FREE-FLIGHT TRAINER
OVERALL DESCRIPTION OF LFV CONCEPT & SYSTEM	VEHICLE TRIM	NAVIGATION TRAINING • FREE FLIGHT • VISUAL SIMULATION
	PREFLIGHT & CHECKOUT	
	FLIGHT CONTROL	
	NAVIGATION	
	CONTINGENCY MODES	

TRAINING EQUIPMENT & PURPOSE

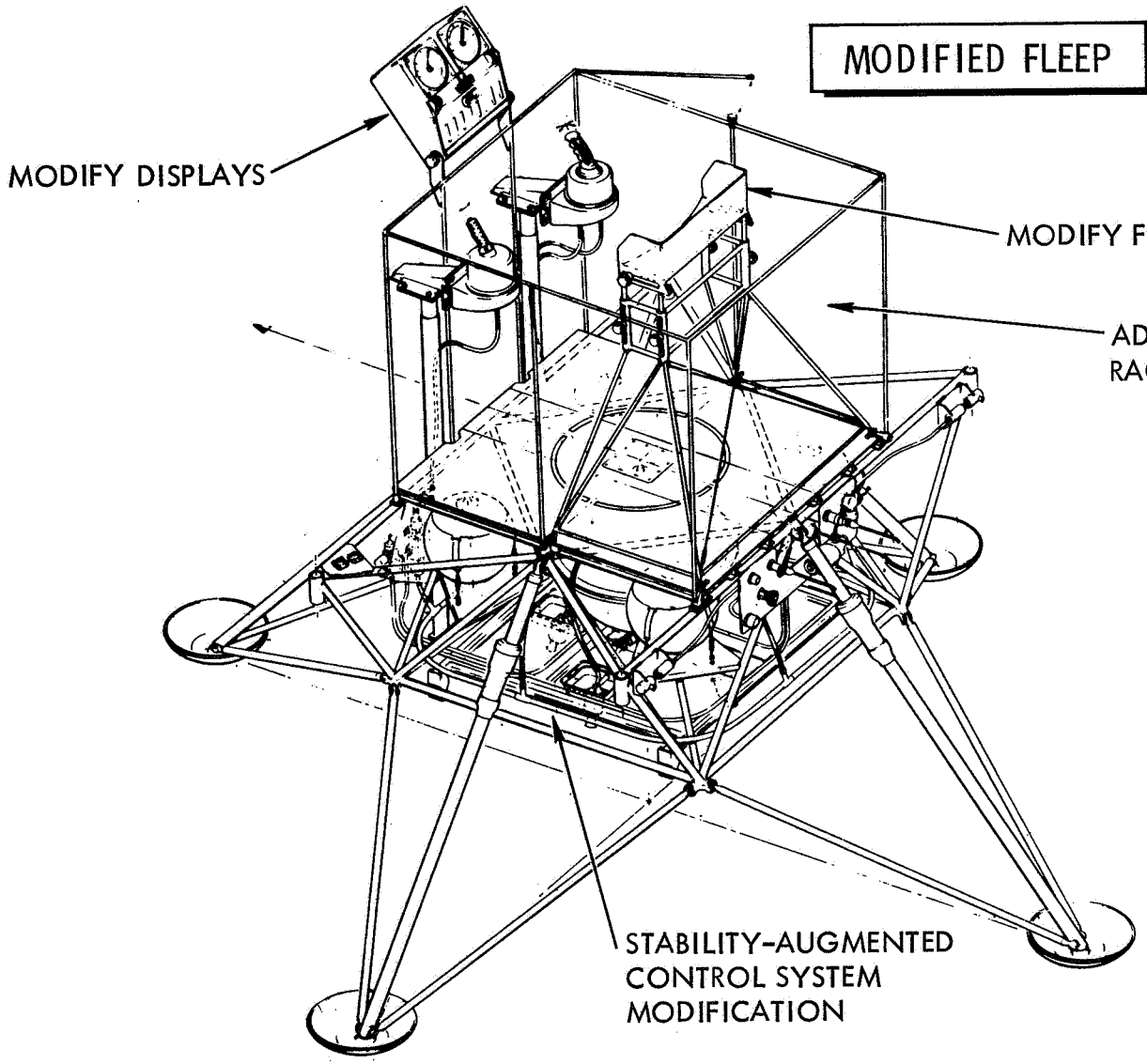
EQUIPMENT	PURPOSE
TRAINING MANUALS	CLASS INSTRUCTION
LM INTERFACE/SIMPLE LFV MOCKUP	SYSTEM FAMILIARIZATION
PARTIALLY FUNCTIONAL LM INTERFACE/LFV MOCKUP	FUELING PRACTICE SUBSYSTEM FUNCTIONAL TRAINING
VISUAL SIMULATOR	INITIAL FLIGHT FAMILIARIZATION NAVIGATION TRAINING MISSION TRAINING
1/6-g TETHERED VEHICLE	TAKE-OFF & LANDING PRACTICE VEHICLE DYNAMIC RESPONSE FAMILIARIZATION
FREE-FLIGHT VEHICLE	ADVANCED TAKE-OFF & LANDING PRACTICE LOW SPEED FLIGHT TRAINING
HELICOPTER	FLIGHT NAVIGATION TRAINING HIGH SPEED, LOW ALTITUDE FLIGHT TRAINING

VISUAL SIMULATOR REQUIREMENTS



- GOOD PERIPHERAL VISION
- APPARENT 3-D EFFECTS
- PITCH & ROLL MOTION CUES
- GOOD CONTRACT
- MOCK-UP LFV
- ACTUAL MISSION SURFACE LAYOUT

TETHERED FLIGHT SYSTEM REQUIREMENTS



- FACILITY FOR 1/6-g FLT SUCH AS LLRF
- LFV DYNAMIC RESPONSE, CREW STATION (SEAT, RESTRAINTS, HAND CONTROLS, & DISPLAYS), LANDING EYEBALL ALTITUDE, & ESSENTIAL VEHICLE VOLUMES

FREE-FLIGHT TRAINER REQUIREMENTS

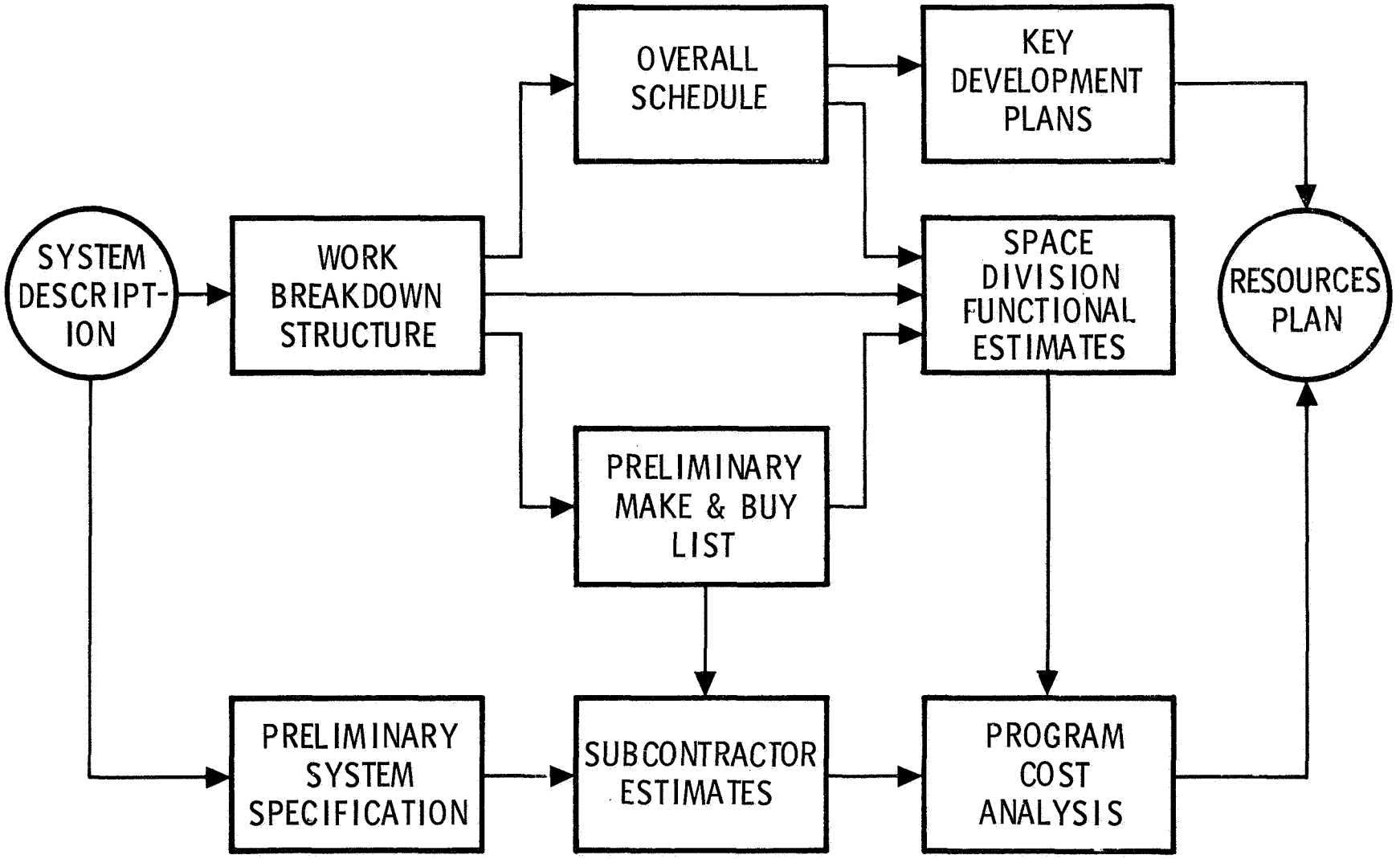
- VERTICAL THRUST OF 5 / 6 SYSTEM WEIGHT PROVIDED BY TURBOJET, REMAINDER OF THRUST CONTROLLED BY PILOT FOR LUNAR SIMULATION
- SAME DYNAMIC, CREW STATION, LANDING EYEBALL ALTITUDE & ESSENTIAL VEHICLE VOLUMES AS LFV REQUIRED
- CANDIDATE SYSTEMS INCLUDE
  - MODIFIED FREE-FLIGHT LM TRAINER
  - NEW FREE-FLIGHT TRAINER

RESOURCES PLAN

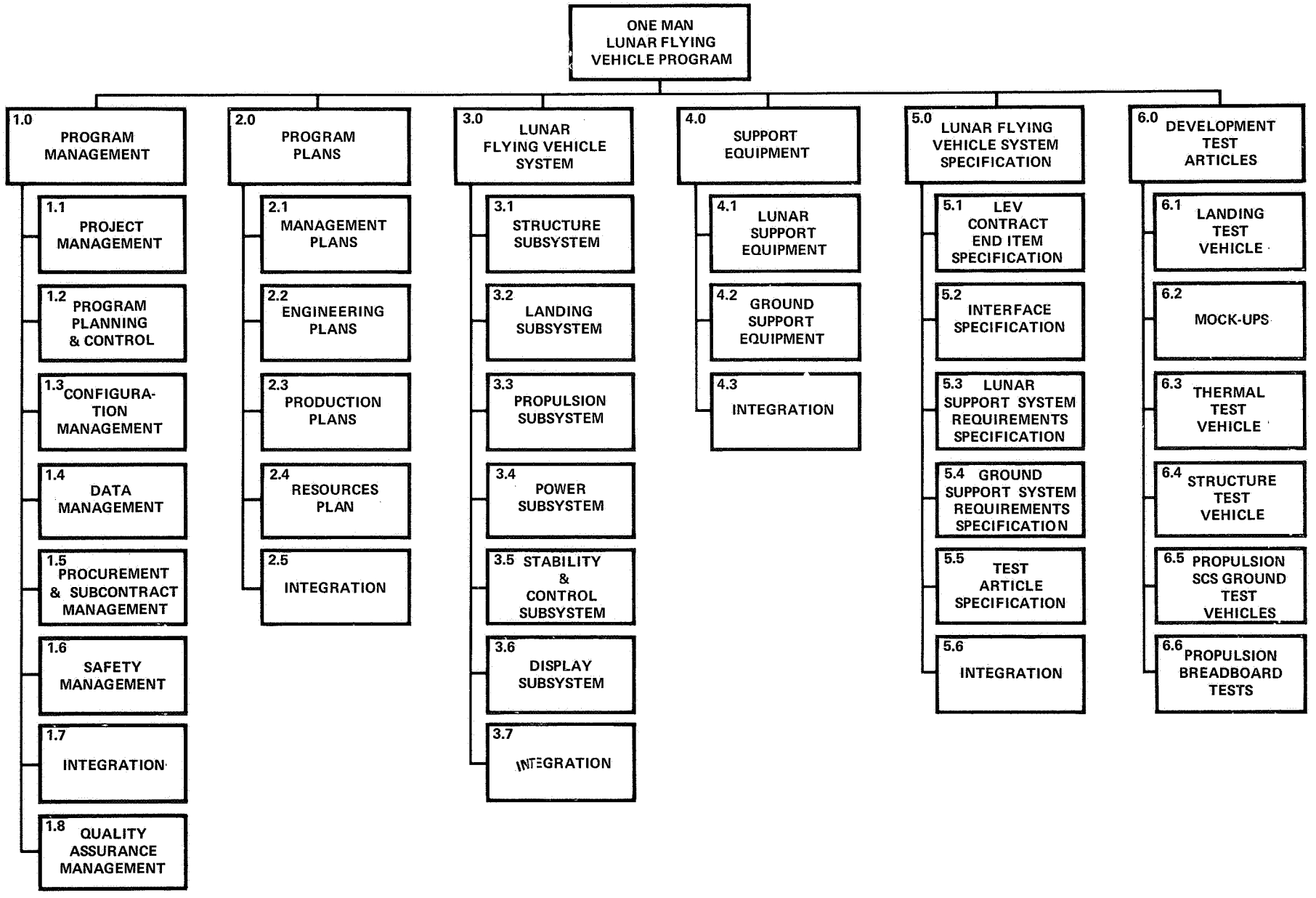
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RESOURCES PLAN APPROACH



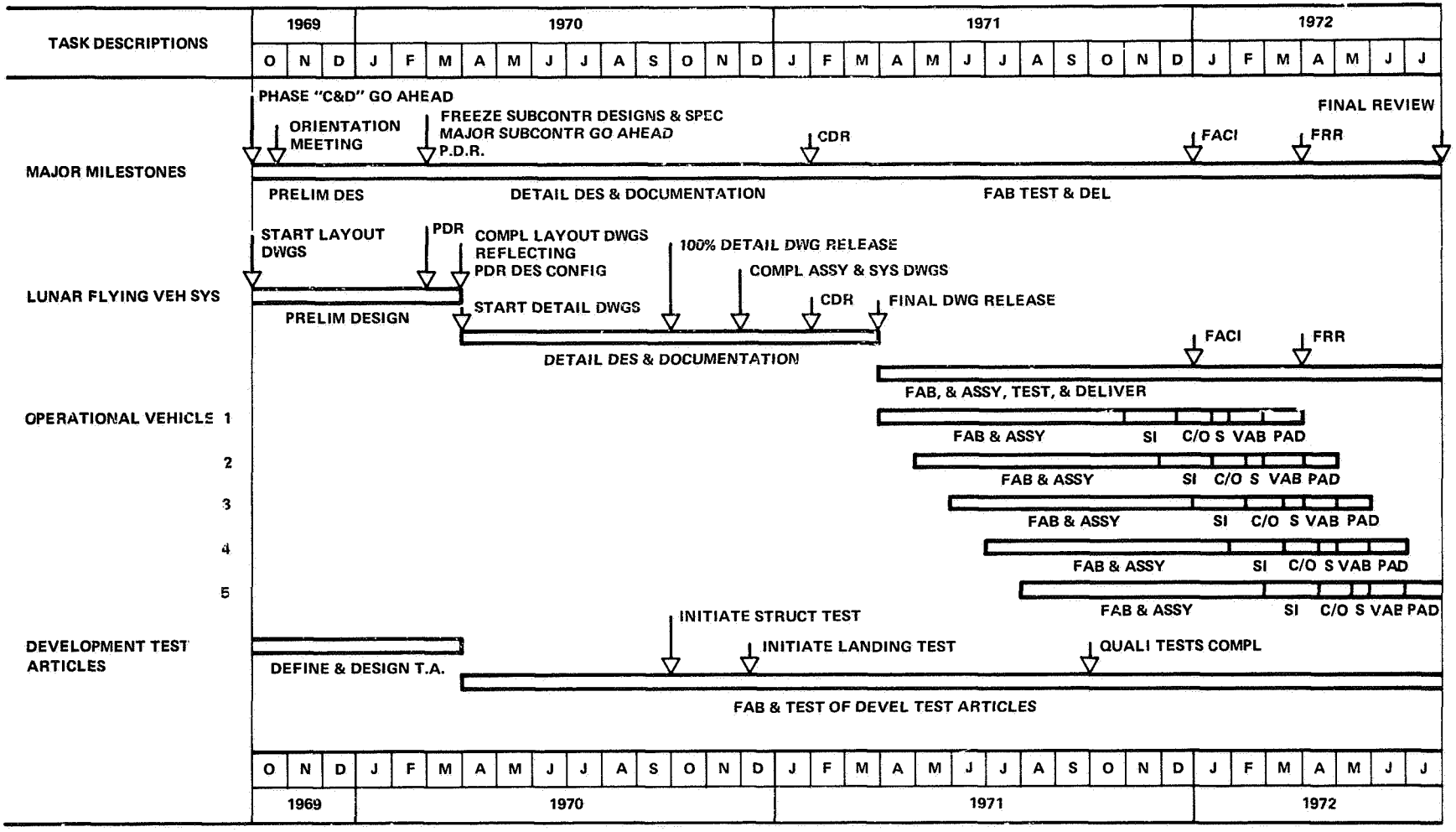
WORK BREAKDOWN STRUCTURE



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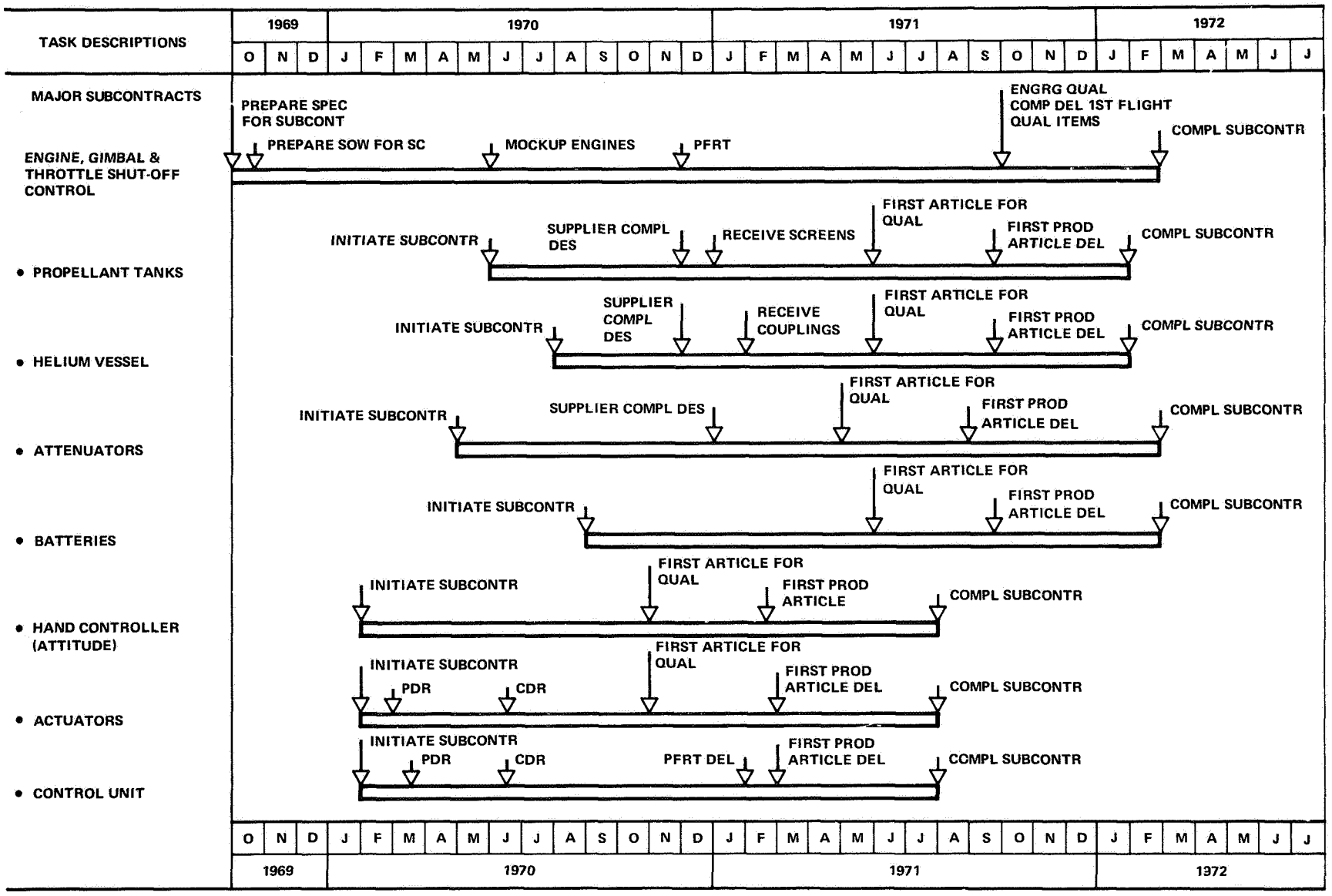
DEVELOPMENT SCHEDULE



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MAJOR SUBCONTRACTS SCHEDULE



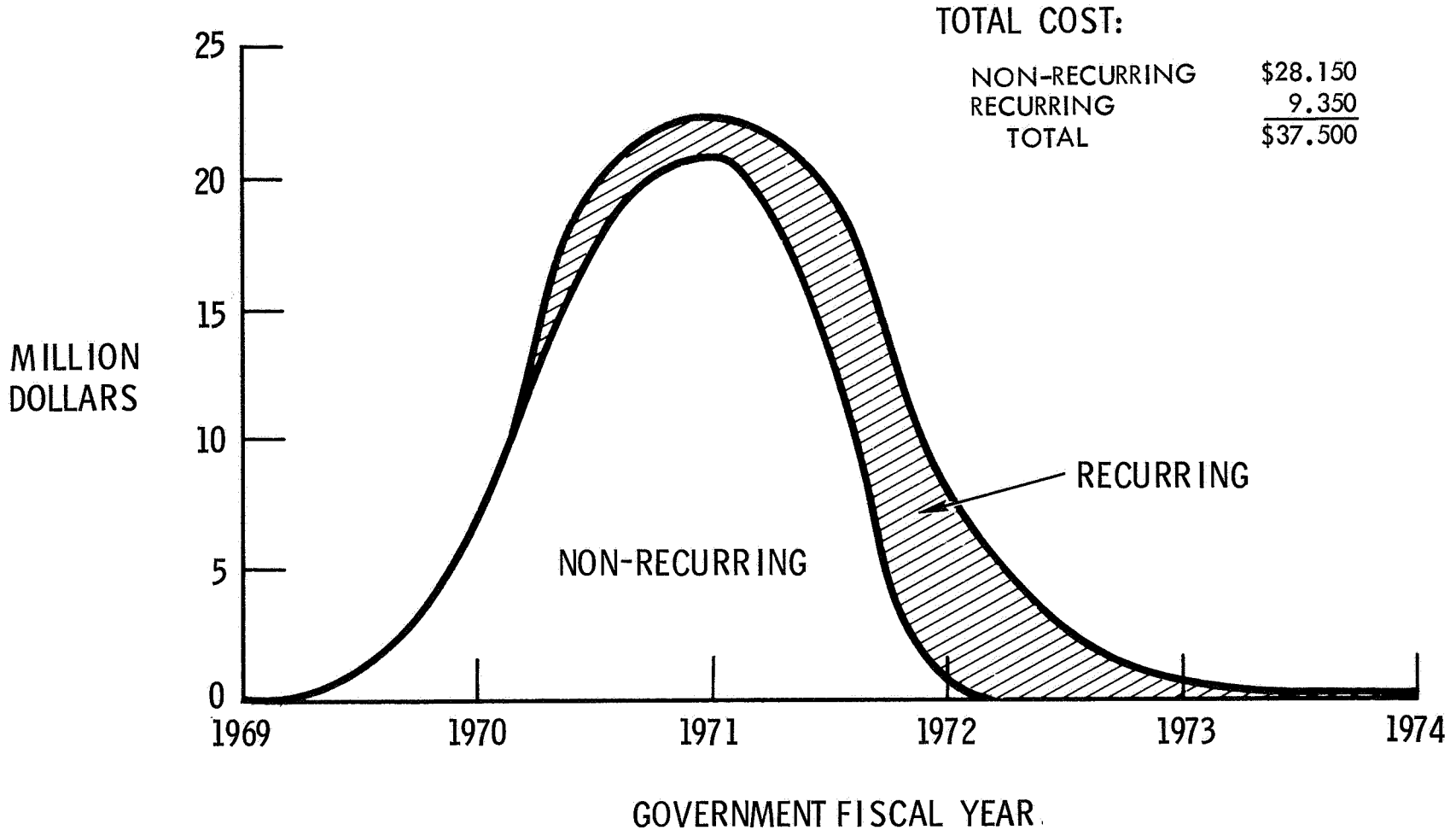
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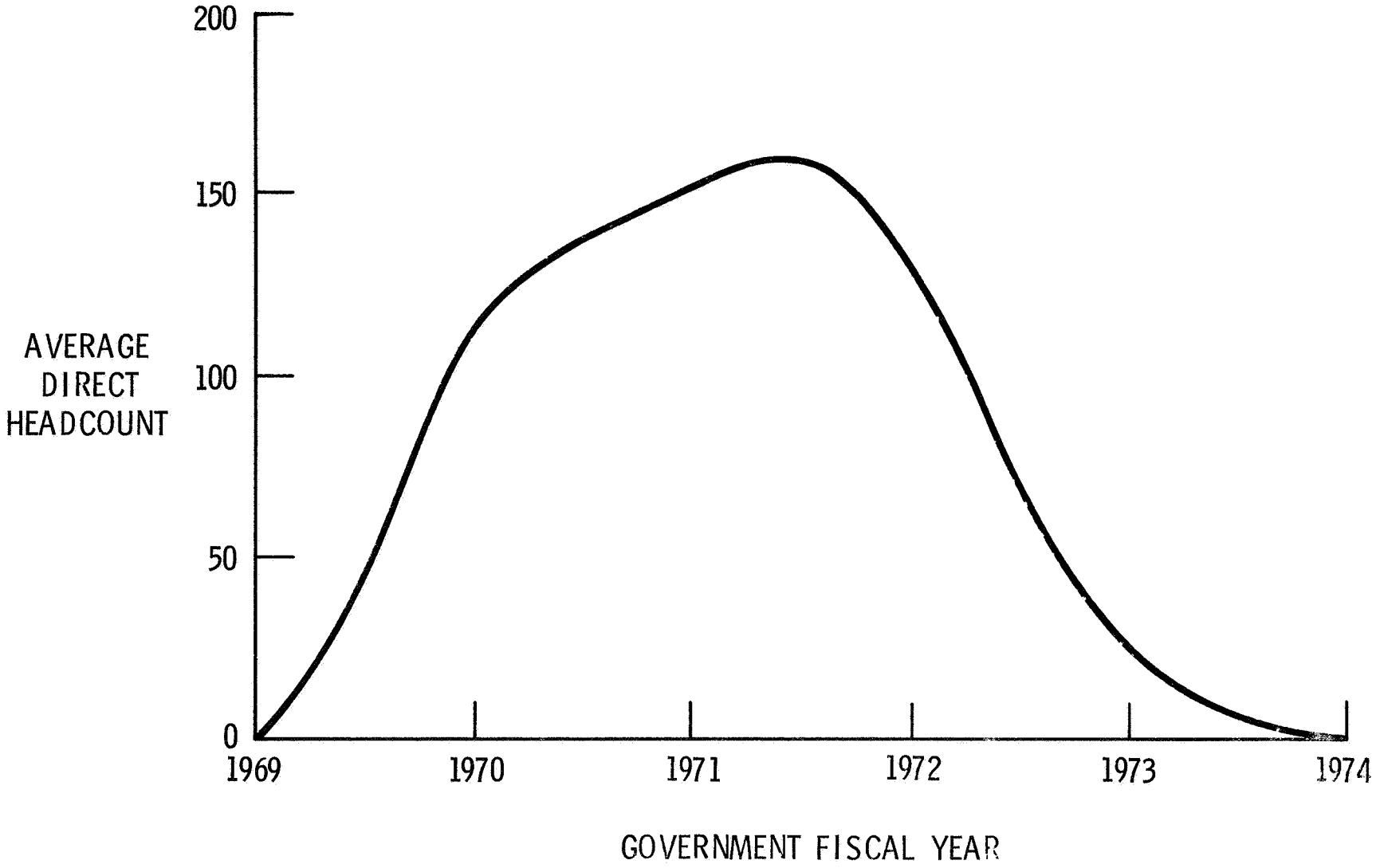
SUBCONTRACTOR DATA SOURCES

VEHICLE ITEMS		SUBCONTRACTOR DATA SOURCE
PROPULSION	PROPELLANT TANKS	FANSTEEL CORP AIRITE DIV
	ENGINES	BELL TRW ROCKETDYNE MARQUARDT AEROJET
CONTROLS	ACTUATORS	CADILLAC CONTROLS AUTONETICS
	GYROS	HONEYWELL
	CONTROL UNIT	HONEYWELL AUTONETICS
	HAND CONTROLLER	HONEYWELL
	SERVO AMPLIFIERS	HONEYWELL
ATTENUATORS		NATIONAL WATER LIFT CO

LUNAR FLYING VEHICLE PROGRAM COST



SPACE DIVISION MANPOWER



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MAJOR STUDY CONCLUSIONS

GENERAL ARRANGEMENT

- SEATED & RESTRAINED PILOT DESIGN PROVIDES:
  - POSITIVE RESTRAINT
  - LOWERED C. G.
  - GOOD INGRESS / EGRESS
  - EXCELLENT VISIBILITY
- PILOT SEAT ROTATED 45° FROM PLANE OF SYMMETRY TO IMPROVE INGRESS / EGRESS, VISIBILITY & PAYLOAD STOWAGE
- INTEGRAL 4-LEGGED DESIGN ALLOWS STOWAGE IN LM WITHOUT GEAR REMOVAL OR FOLDING & REDUCES ATTENUATOR STROKE & NUMBER
- LANDING GEAR DESIGNED FOR FLEXIBLE, SAFE OPERATION

CONTROL SYSTEM

- STABILITY AUGMENTATION REQUIRED FOR SATISFACTORY HANDLING QUALITIES
- 4, 2-AXIS GIMBALLED ENGINES PROVIDE PITCH ROLL & YAW CONTROL & REDUNDANCY FOR ACTUATOR & ENGINE FAILURES
- OVERALL DESIGN ALLOWS NO SINGLE POINT FAILURES

MAJOR STUDY CONCLUSIONS (CONT)

PROPULSION SYSTEM

- TWO PROPELLANT TANK DESIGN SIMPLEST & LIGHTEST
- AVAILABLE OR MODIFIED HARDWARE FOR ALL BUT ENGINES
- ENGINE DEVELOPMENT CYCLE FROM 17 - 20 MONTHS

THERMAL CONTROL

- INSULATION & REFLECTIVE SURFACES ADEQUATE FOR COMPONENT PROTECTION FOR 3-DAY DAWN & SUNSET MISSIONS
- EARTH-SHINE MISSIONS REQUIRE HEATERS FOR CRITICAL COMPONENTS, INCLUDING PROPELLANT TANKS

FLIGHT PERFORMANCE

- CURRENT DESIGN HAS 4.6 N MI RADIUS OF OPERATION
- INCREASING PROPELLANT WT FROM 300 TO 400 LB INCREASES RADIUS TO 7.8 N MI, DRY WT INCREASE 15 LB

MAJOR STUDY CONCLUSIONS (CONT)

GENERAL CONCLUSIONS

- RECOMMENDED CONCEPT PROVIDES:
  - EXCELLENT HANDLING QUALITIES
  - CONSERVATIVE LANDING CAPABILITY FOR CURRENTLY UNKNOWN SURFACE CONDITIONS
  - REDUNDANCY FOR CREW SAFETY
- TRAINING PROGRAM SIMILAR TO LM TRAINING & MAY UTILIZE LM FLIGHT TRAINING HARDWARE
- RECOMMENDED CONFIGURATION BASED ON SIMPLE, FLIGHT PROVEN HARDWARE DESIGNS
- ACCEPTABLE OPERATIONAL SAFETY PROVIDED WITH STABILITY AUGMENTATION
- ADEQUATE PRELIMINARY DEFINITION COMPLETED - READY TO PROCEED INTO FINAL DEFINITION

RECOMMENDATIONS FOR FUTURE EFFORT

- INITIATE DETAILED DESIGN & DEVELOPMENT EFFORT IMMEDIATELY TO MEET LUNAR EXPLORATION SCHEDULE
- COMBINE PHASES C&D EFFORT TO IMPROVE SCHEDULE
- ENGINE DEVELOPMENT IS LONGEST LEAD-TIME - INITIATE DESIGN & DEVELOPMENT IMMEDIATELY