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VAULT NUMBER

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TITLE EVALUATION OF APOLLO X FOR MOL MISSION

AEROSPACE CORPORATION
PRESENTATION

AUTHOR C.L. OLSON, et al DATE FEB. 10, 1965

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REVIEW OF APOLLO X FOR APPLICATION TO THE MOL MISSION

North American Aviation S&ID recently completed a study for NASA, Contract No. NAS9-3140, "Extended Apollo Systems Utilization Study, Final Report," Report No. SID 64-1860-1 through -23, dated November, 1964, concerning the applicability of various Apollo components to a spectrum of follow-on missions, one of which included 45-day earth orbital operations. Aerospace Corporation personnel have reviewed the study summary, with the objective of determining the applicability of the configurations defined by NAA to the MOL mission.

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Appreciation is expressed to the following Aerospace personnel for contributions to this review.

Weights	-	C. Pullen, S. Rice
Attitude Control	-	L. Herman, A. Paynter
Propulsion	-	D. Jaeger
Navigation/Guidance	-	R. Rogers
Structures	-	R. Herndon, V. Ho, G. Ikada
Meteoroid Protection	-	J. Hook, V. Frost
Design Analysis	-	R. Ryder, J. Steinman, K. Ludlow, J. Duroux, J. Fastiggi
A. G. E.	-	H. Lange
Electrical Power	-	W. Sheng, J. Kettler
EC/LS	-	A. Dare, A. Johnson
Reliability	-	T. Romine
Cost	-	J. Wilson
Growth	-	T. Silva
Recovery	-	H. Epple
Communications	-	A. Pope
Booster Performance	-	E. LaPorte

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EVALUATION OF

APOLLO X

FOR

MOL MISSION

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The review, which was conducted by the Laboratory Vehicle Office, Manned Systems Division, with the support of the Electronics and Aeromechanics Divisions, considered the major factors indicated on Chart #2. The initial phase of the review consisted of determining the applicability of the general configuration suggested by North American.

[redacted]

[redacted]

EVALUATION APPROACH

DETERMINE APOLLO X CAPABILITIES AND LIMITATIONS FOR MOL MISSION IN TERMS OF:

- √ ON-ORBIT OPERATIONS
- √ PAYLOAD
- √ CREW UTILIZATION
- √ PROGRAM COST
- √ GROWTH POTENTIAL
    - o EXTENDED DURATION
    - o LARGE PAYLOADS
    - o POLAR ORBITS

[redacted]

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APOLLO X - CONFIGURATION DEFINITION

[redacted]

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Basic Apollo X configuration concepts proposed in the NAA study are illustrated on Chart #4. North American sought to determine a configuration family with the capability to perform a lunar-polar mapping mission. This member of the family is shown on the right hand side of Chart #4. NAA defined derivative configurations as shown in the other two pictures on the chart. The center concept, which is most nearly applicable to the MOL mission, would consist of a 3-man, 45-day, earth-orbiting system, provided with a 1300 cu. ft. pressurized laboratory module initially housed inside the LEM adapter. The concept shown on the left hand side of the chart is proposed by North American as a early earth-orbiting system of limited capability, being limited to 2 men for 14 days. The center configuration shown on Chart #4 is the only one of direct interest to the MOL program in terms of both duration and payload capability, inasmuch as the one shown on the left is capable of only very short orbital durations, and the one shown on the right is configured for Lunar operations and is much too heavy for the earth-orbiting MOL job.

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APOLLO X CONCEPTS

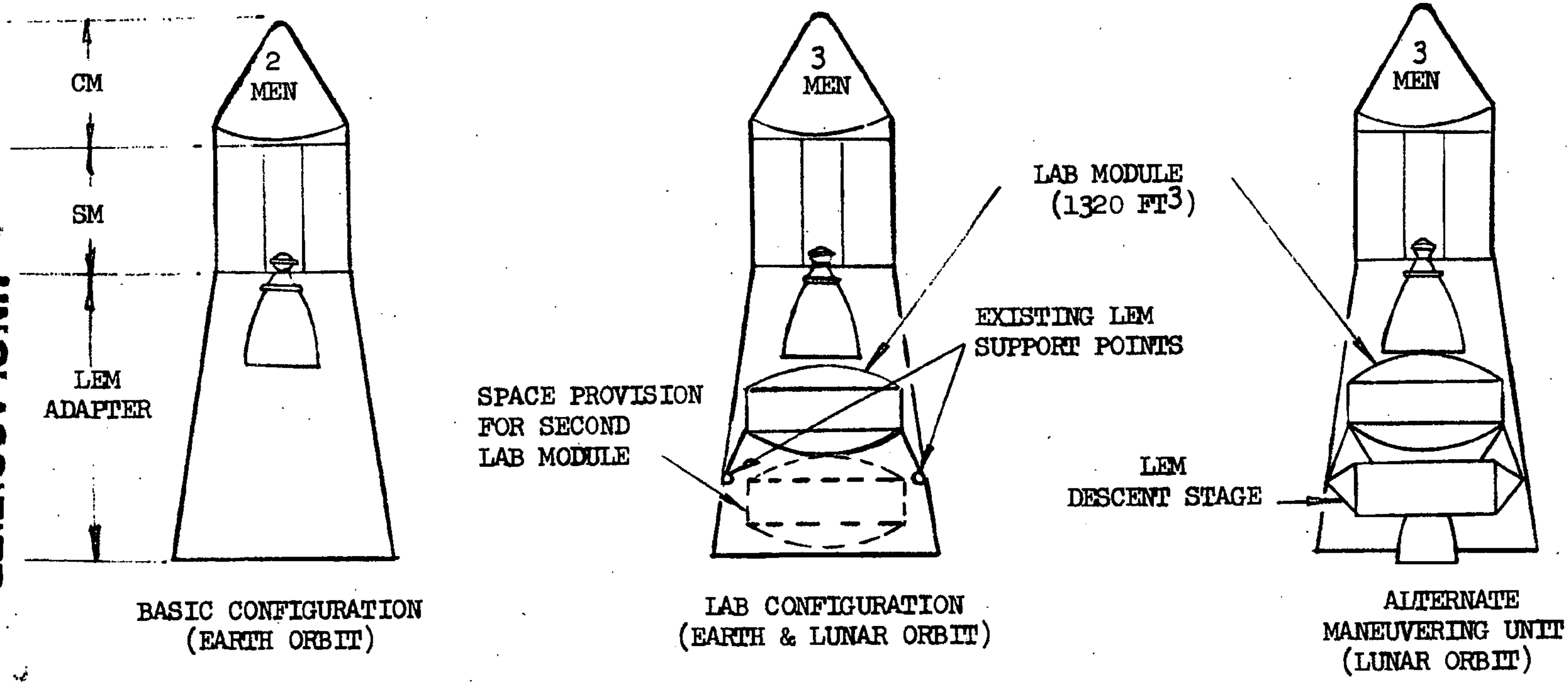

Chart #5 illustrates the all-up launch configuration, which consists of the Saturn IC, Saturn II Second Stage, Saturn IVB Upper Stage, the LEM Adapter, the Apollo Service Module, and the Apollo Command Module, with an escape tower system shown on top.

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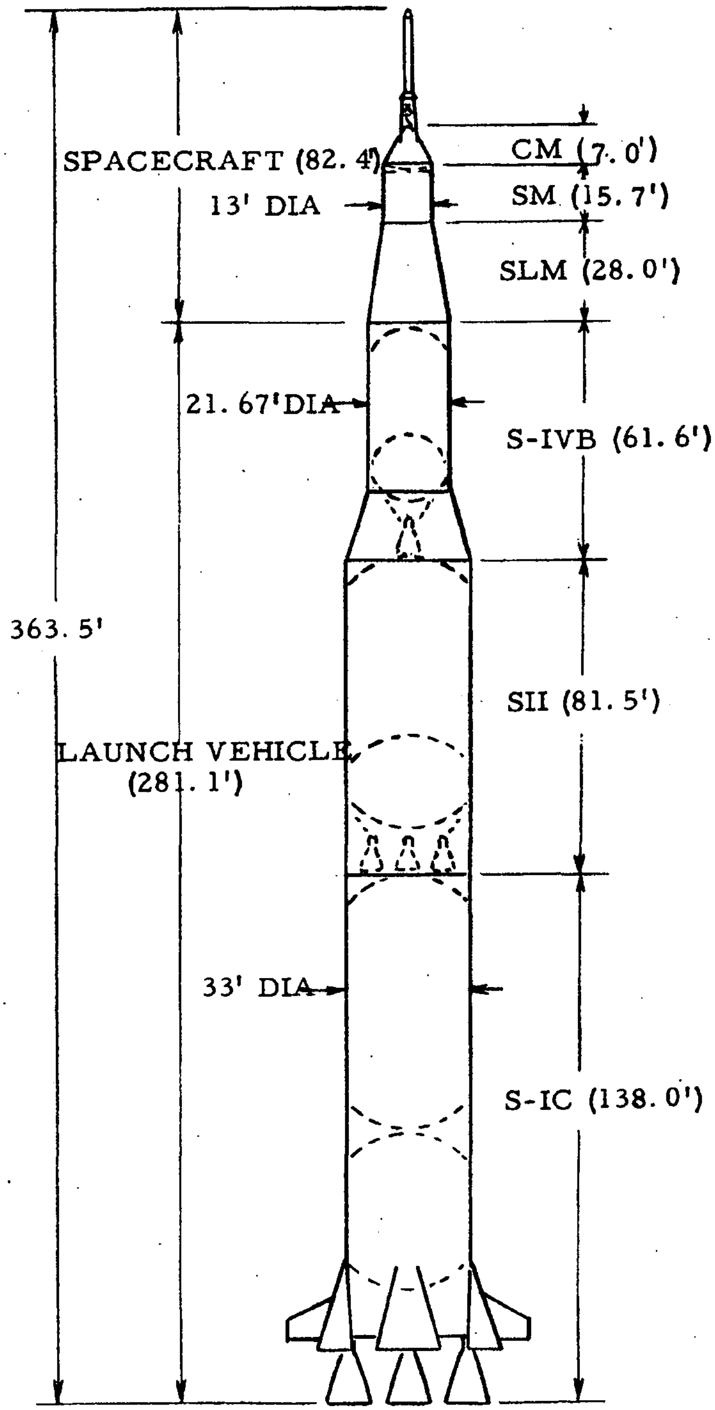

SATURN V LOR CONFIGURATION

[redacted]

The general external geometry of the service module is shown in Chart #6, and some of the major characteristics of the Apollo command module are illustrated in Chart #7. A very important characteristic of the basic Apollo system is that the Command Module contains nearly all of the Vehicle operating equipment, whereas the Service Module contains nearly all of the expendables such as cryogens and propellants. The Command Module thus operates in a parasitic manner from the LEM adapter.

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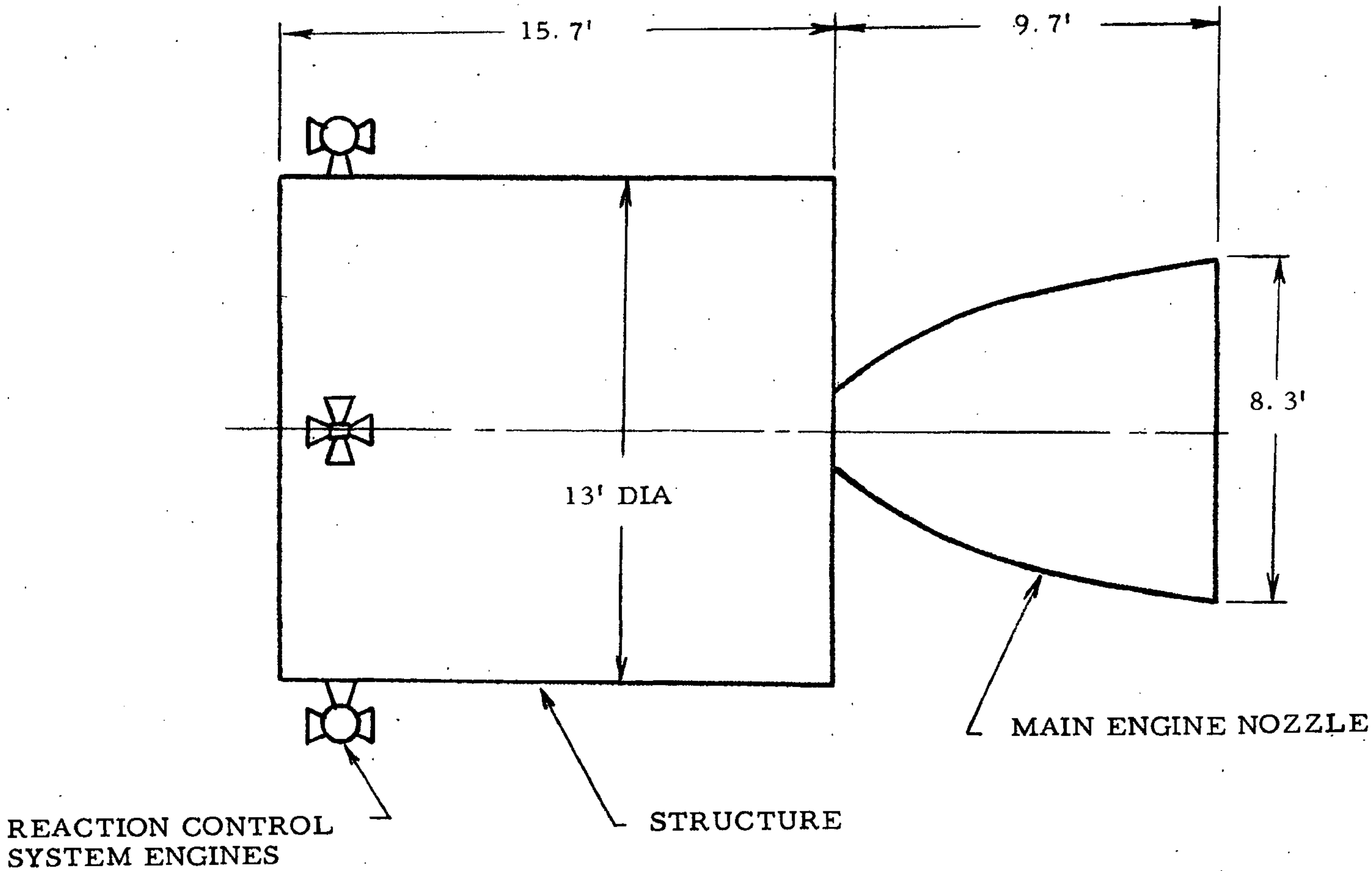

SM EXTERNAL GEOMETRY

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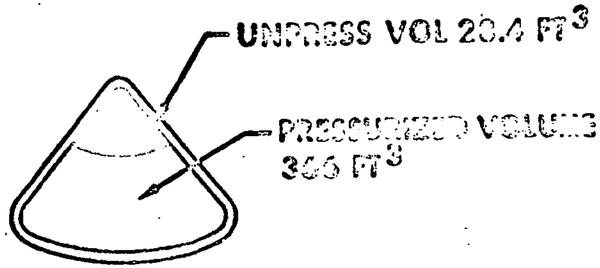
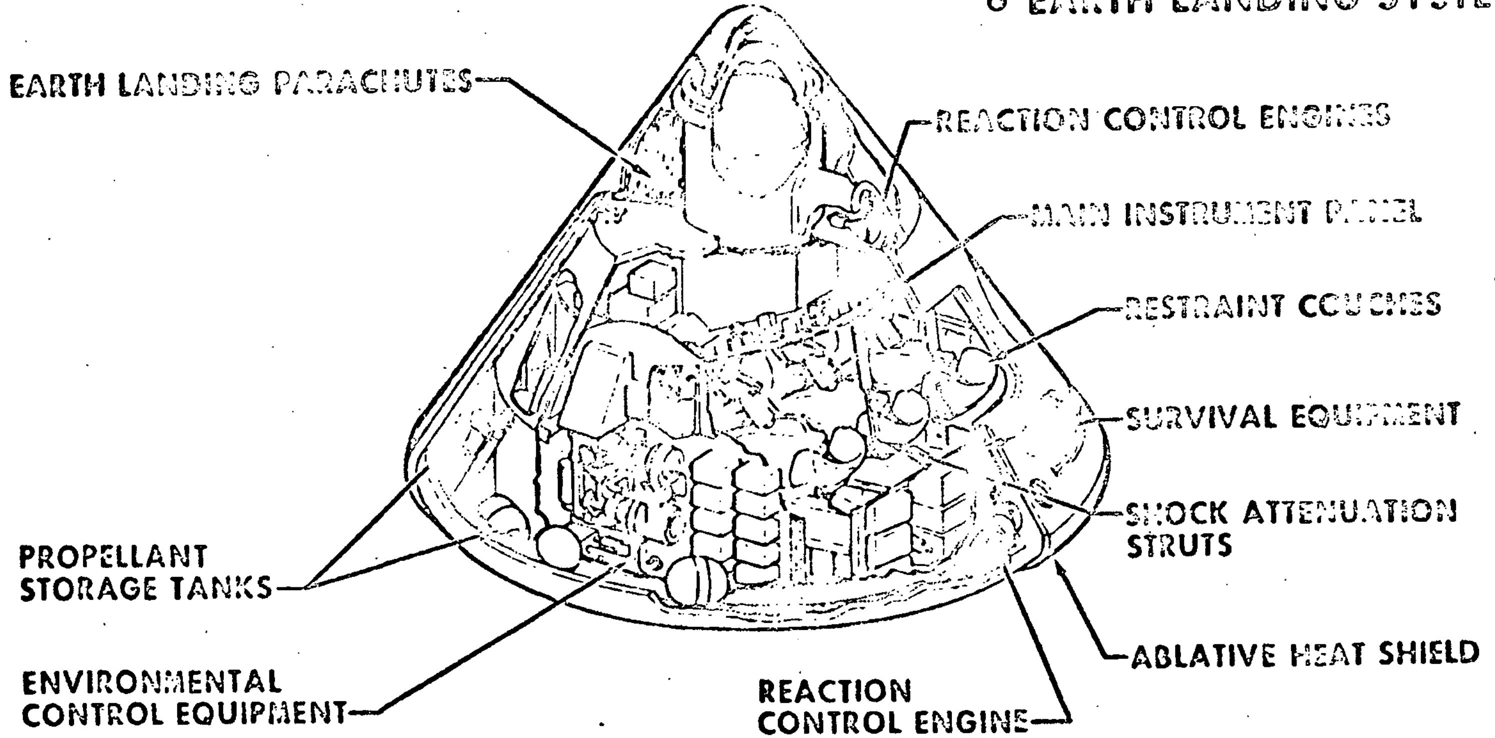
APOLLO COMMAND MODULE



MAJOR SYSTEMS

- GUIDANCE & NAVIGATION
- STABILIZATION & CONTROL
- ENVIRONMENTAL CONTROL
- REACTION CONTROL
- TELECOMMUNICATIONS
- EARTH LANDING SYSTEM



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9-63 AP 19259C

The specific Apollo X Earth-Orbiting Laboratory configuration recommended by North American is illustrated in Chart #8. In the launch configuration, an extendable air lock is stowed inside the laboratory module for later deployment on-orbit. The orbital configuration is shown on the right hand side of the chart, and this configuration is attained in a manner which will be illustrated in the following charts.

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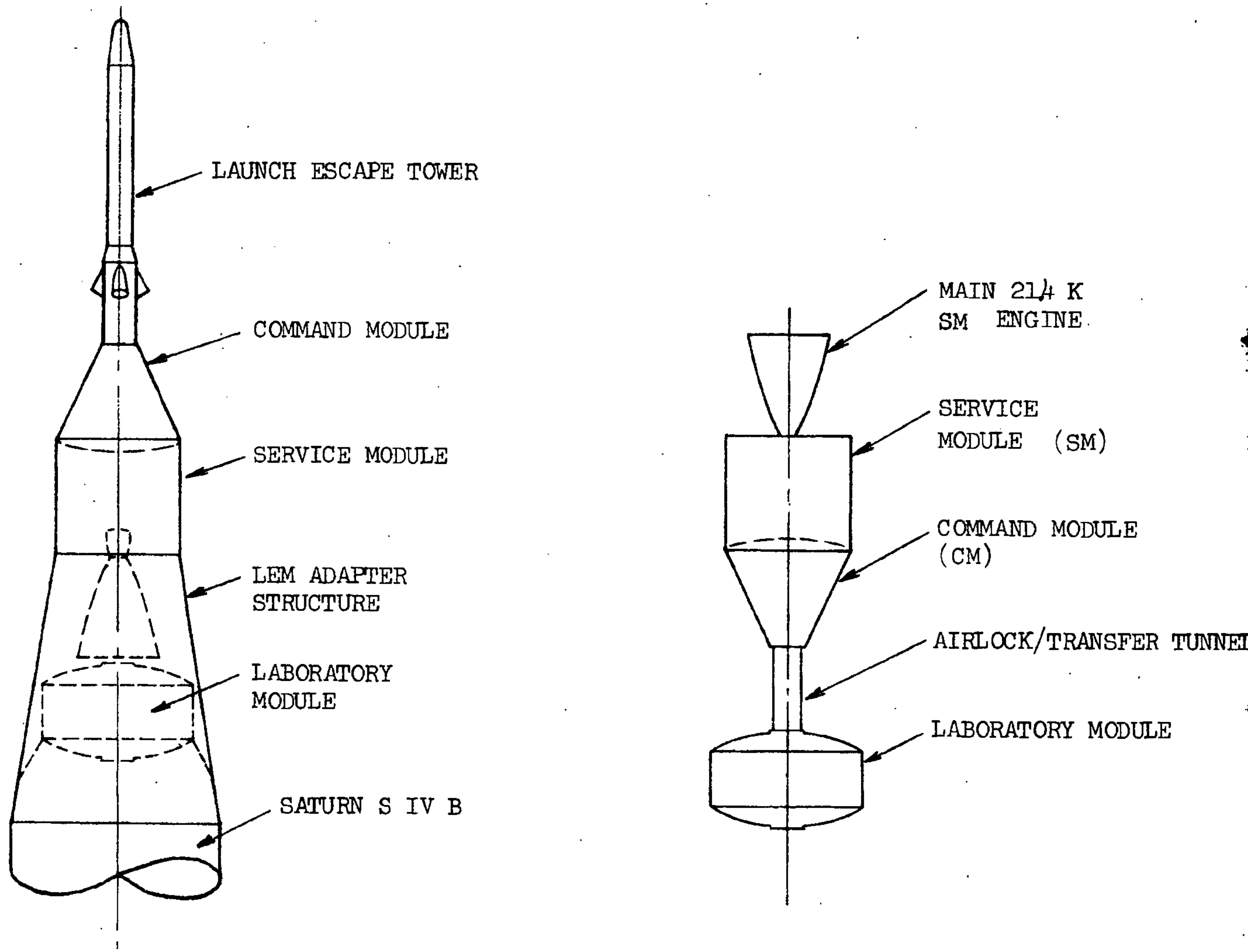
APOLLO "X" CONFIGURATION



LAUNCH ORBITAL

Chart #9 shows the functional arrangement of the suggested orbiting vehicle, and shows that the laboratory module pressurized compartment contains a very minimum of functional equipment. The Laboratory is entirely dependent for its function upon equipment which is housed in the Command Module and upon storables which are housed in the Service Module. All expendables utilizing the laboratory are transferred through the sliding air lock.

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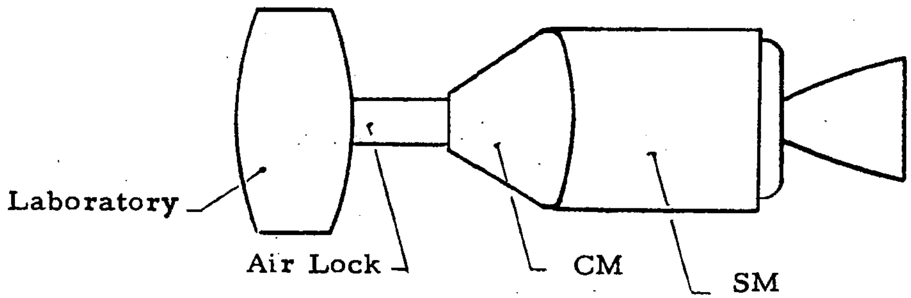
SYSTEMS OPERATION



FUNCTIONAL AREAS

LABORATORY

- EXPERIMENT EQUIPMENT
- FOOD AND WATER STORAGE
- PORTABLE L. S. BOTTLES
- CENTRIFUGE PROVISIONS

AIR-LOCK

- CREW TRANSFER
- ATMOSPHERE TRANSFER
- E. V. ACCESS

CM/SM

- COMMUNICATIONS
- L. S. ATMOSPHERE CONTROL
- THERMAL CONTROL
- ATTITUDE CONTROL
- FOOD PREPARATION
- WASTE MANAGEMENT
- ELECTRICAL POWER

[redacted]

APOLLO X LAUNCH-TO-ORBIT PROFILE

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The operations required to place the orbiting vehicle on orbit are illustrated in Chart #11. The chart shows that eight separate events must successfully occur before the orbiting vehicle can be activated.

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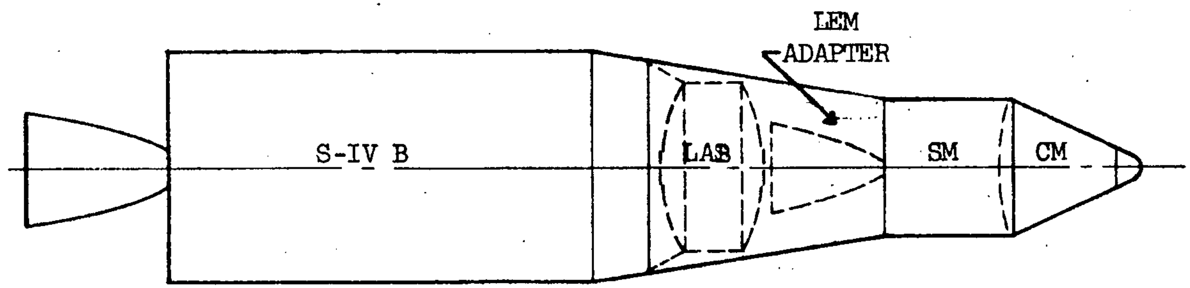
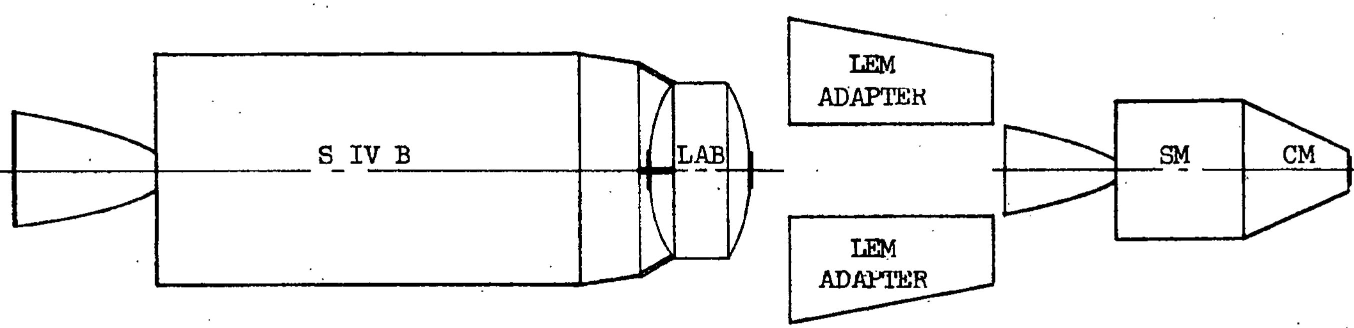
LAUNCH-TO-ORBIT PROFILE



1. S IV B BURNOUT-ELLIPTICAL ORBIT
2. SEPARATE CSM



3. EJECT LEM FAIRING
4. TRANSPOSE CSM
5. STABILIZE LAB WITH S IV B

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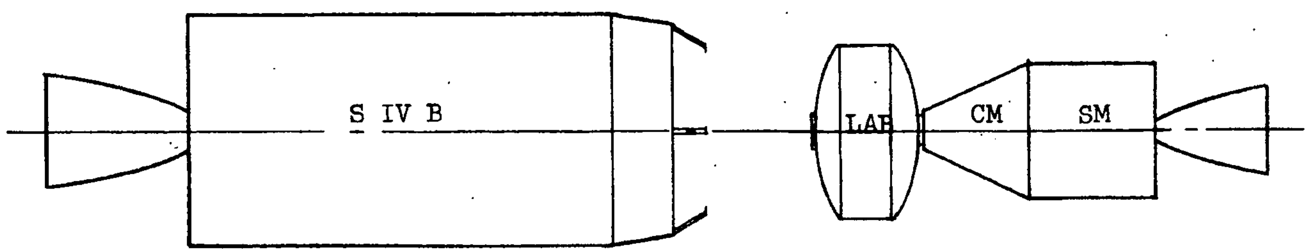

6. DOCK CSM WITH LAB
7. EJECT S IV B
8. INJECT INTO CIRCULAR EARTH ORBIT

[redacted]

APOLLO X - OPERATIONS REVIEW

- √ CONFIGURATION ANALYSIS
- √ SUBSYSTEM ANALYSIS

[redacted]

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The charts which follow summarize the Aerospace analysis of the applicability of the North American Apollo X system to the MOL basic mission. The primary factors examined during the configuration analysis are shown on Chart #13.

[redacted]

APOLLO X

CONFIGURATION ANALYSIS

- √ LABORATORY ACTIVATION
- √ COMPARTMENTATION
- √ EXTRA-VEHICULAR OPERATIONS
- √ EQUIPMENT ARRANGEMENT
- √ DOCKING PROVISIONS
- √ SYSTEMS OPERATION
- √ CREW SAFETY

[redacted]

[redacted]

Chart #14 shows the rather complex procedure required for placing the orbiting vehicle in operation after it has achieved orbit. Following a necessary docking maneuver, it is noteworthy that a large number of manual operations must be performed in the laboratory activation procedure. It is concluded that the Apollo X activation procedure is extremely complex, involving extensive dismantling of components and critical assembly of fluid and electrical lines.

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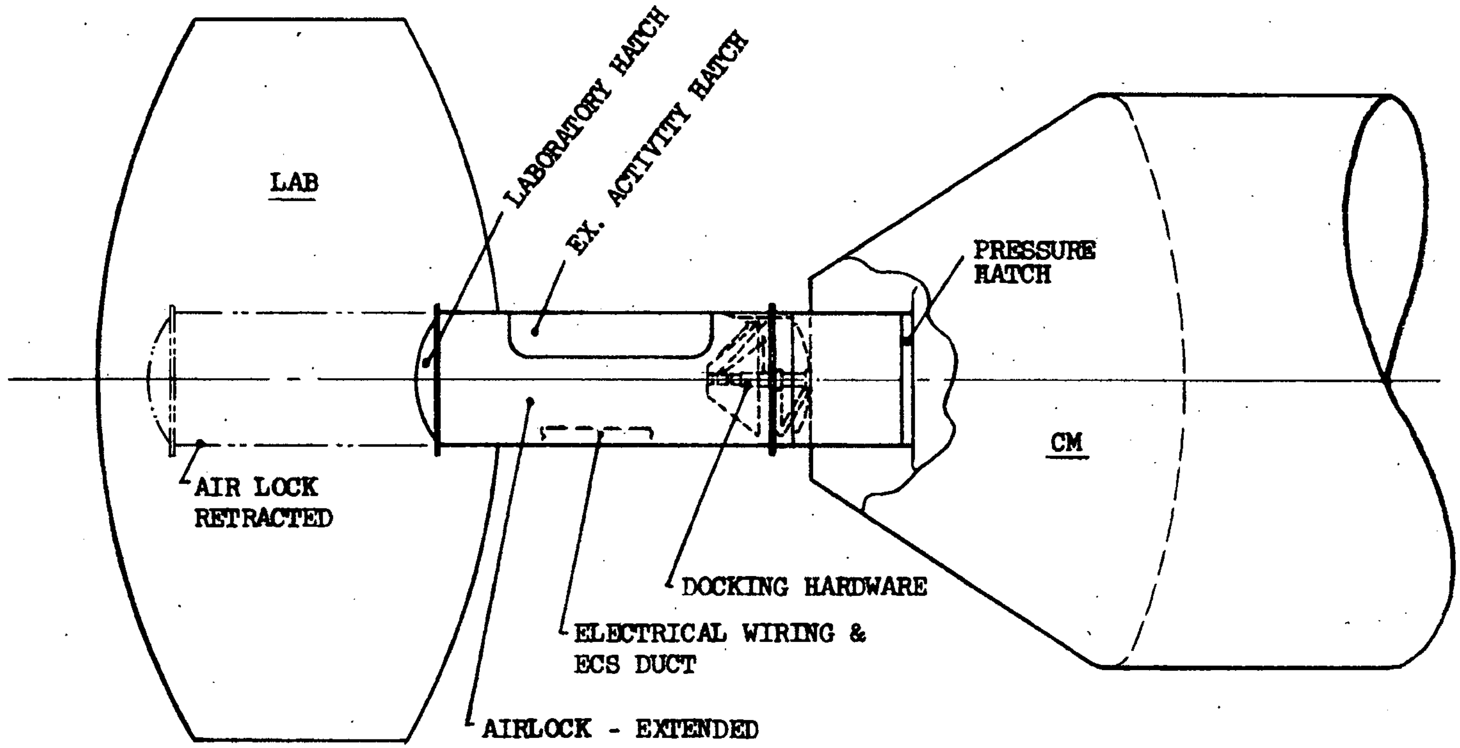
LABORATORY ACTIVATION-ON ORBIT



SEQUENCE

- PRESSURIZE AIRLOCK TO CM PRESSURE
- REMOVE R.H. COUCH
- REMOVE CM PRESSURE HATCH
- REMOVE CM HEAT SHIELD HATCH
- REMOVE DOCKING HARDWARE
- MANUALLY LOCK CM TO LAB
- ATTACH CM UMBILICALS
- EXTEND AIRLOCK FROM LAB
- ATTACH LAB UMBILICALS
- PRESSURIZE LAB TO CM PRESSURE
- ENTER LAB AND CHECKOUT SYSTEMS

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LABORATORY ACTIVATION

CONCLUSIONS

/ APOLLO X ON-ORBIT ACTIVATION EXTREMELY COMPLEX

- EXTENSIVE DISMANTLING OF COMPONENTS REQUIRED
- CRITICAL ASSEMBLY OF FLUID LINES AND ELECTRICAL UMBILICALS

/ APOLLO X DEPENDS ON SUCCESSFUL MANNED ASSEMBLY OPERATIONS

- REQUIRES USE OF UNPROVEN CAPABILITY OF CREW

/ APOLLO X ACTIVATION DEPENDENT ON SUCCESSFUL DEPLOYMENT OF STRUCTURAL AIRLOCK

- CREW TRANSFER
- LIFE SUPPORT AND ELECTRICAL POWER TO LAB.

/ APOLLO X DEPENDS ON SUCCESSFUL DOCKING MANEUVER

- DOCKING ACCIDENT HAZARDOUS TO MISSION OR CREW SAFETY

[redacted]

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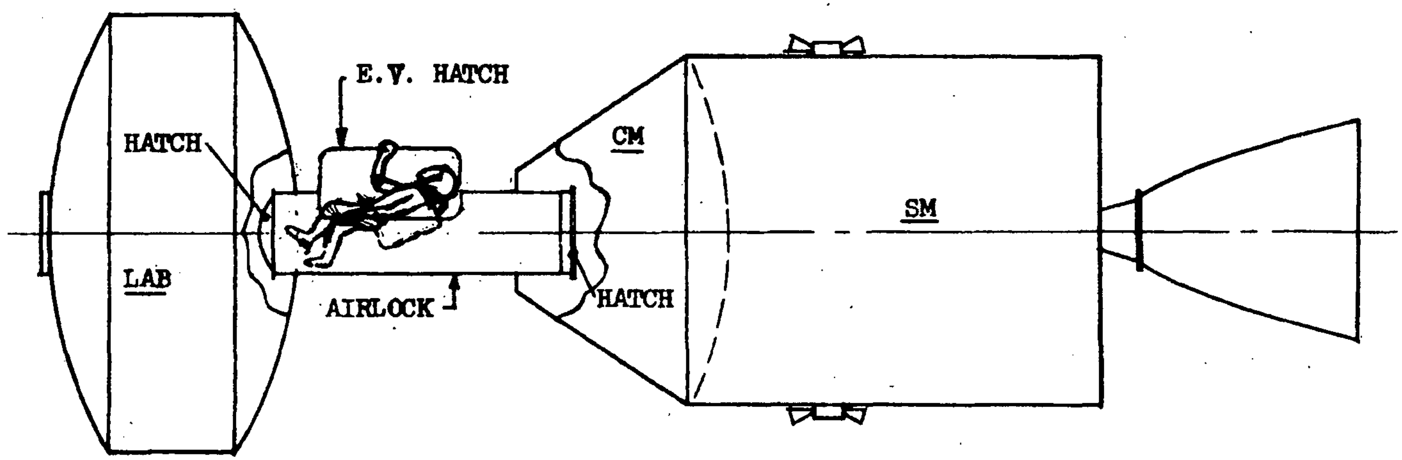
Extravehicular operation of the Apollo X configuration is illustrated in Chart #16. Since the atmosphere supply for the laboratory is obtained through the air lock tunnel, it is evident that either the laboratory must be blown down when the hatch is open or that no circulation in the laboratory is possible during the period of extravehicular operation.

EXTRA-VEHICULAR OPERATIONS



SEQUENCE OF OPERATIONS

- CREW MONITOR RETURNS TO CM
- E.V. EQUIPMENT DONNED AND CHECKED OUT IN LAB
- E.V. EXPERIMENTOR ENTERS AIRLOCK AND CLOSES HATCHES (LAB & CM)
- AIRLOCK DEPRESSURIZED - ASTRONAUT SUIT PRESSURIZED
- E.V. HATCH OPENED FOR EGRESS TO VEHICLE EXTERIOR
- RETURN TO LAB BY REVERSE PROCEDURE

CONCLUSIONS

- LAB IS ESSENTIALLY DEACTIVATED FOR E.V. OPERATIONS
- RESCUE NOT POSSIBLE THRU AIRLOCK DUE TO LIMITED VOLUME
- CHECKOUT OF E.V. EQUIPMENT IN LABORATORY IS UNDESIRABLE

Centrifuge provisions in the Apollo X laboratory suggested by North American are shown in Chart #17. The arrangement consists of a 14 ft. circular track which carries an astronaut and a counterweight. Evidently the usable volume of the laboratory is seriously compromised by such an arrangement. This comment is generally applicable to all "pill box" shaped laboratory compartments, since such configurations afford very limited side area.

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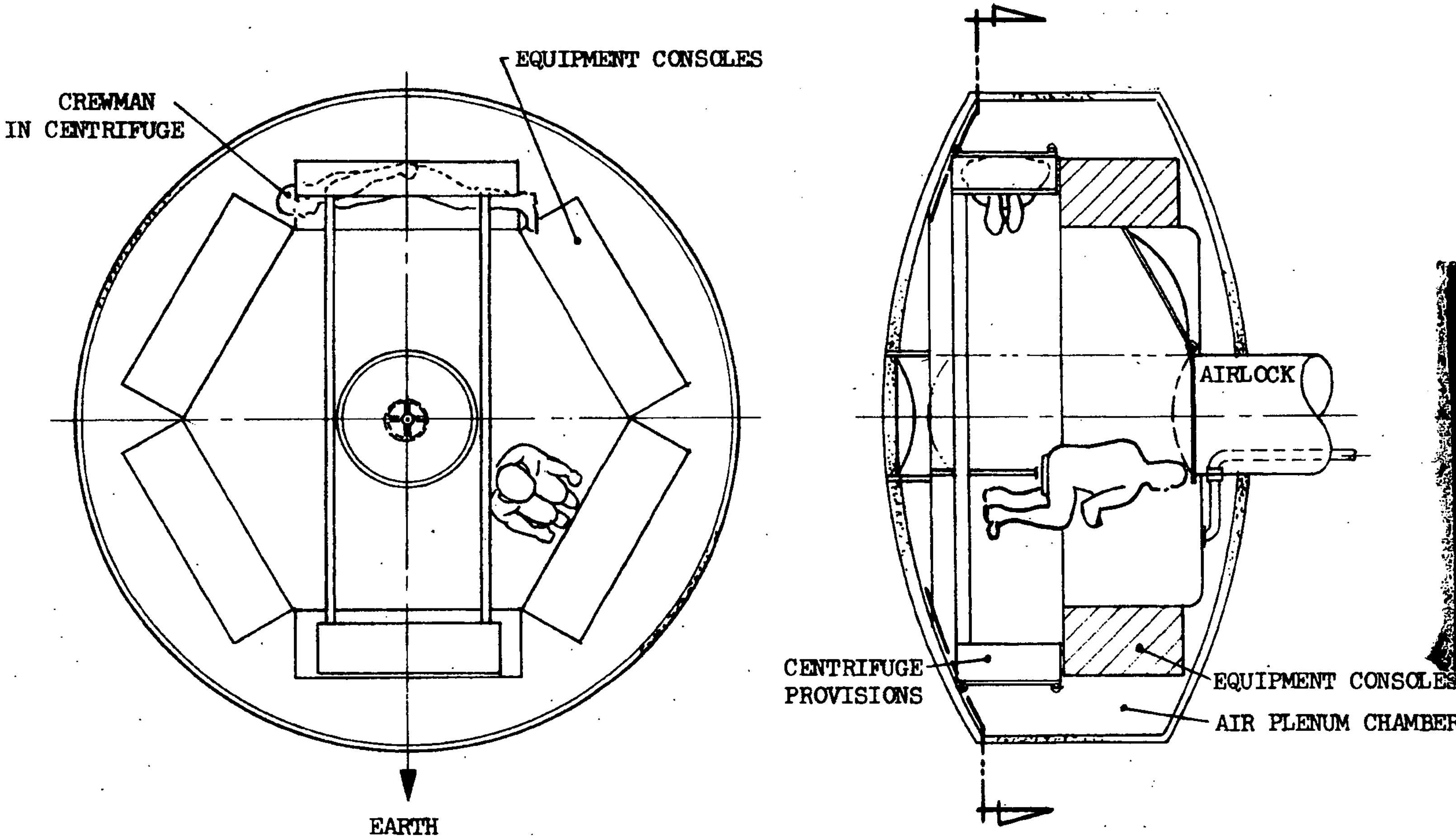
EQUIPMENT ARRANGEMENT



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CONCLUSIONS:

✓ ARRANGEMENT CONSTRAINED BY CENTRIFUGE PROVISIONS

- LIMITED AREA FOR EARTH VIEWING EXPERIMENTS
- AIR PLENUM APPROACH PREVENTS OPTIMUM PLACEMENT OF EQUIPMENT ON WALL

✓ CENTRIFUGE PROVISIONS DEPICTED ARE NOT CONSIDERED SATISFACTORY

- IMPROPER BODY POSITION
- INTERFERS WITH OPERATION OF OTHER EXPERIMENTS

Chart #18 contains some comments concerning the feasibility of docking with the Apollo X configuration in a resupply mode. The chart illustrates possible severe dynamic problems connected with the utilization of a dumbell-like configuration such as the one shown. These problems would be expected to manifest themselves both during limit cycle operation of the orbiting vehicle and during the docking phase of vehicle operations.

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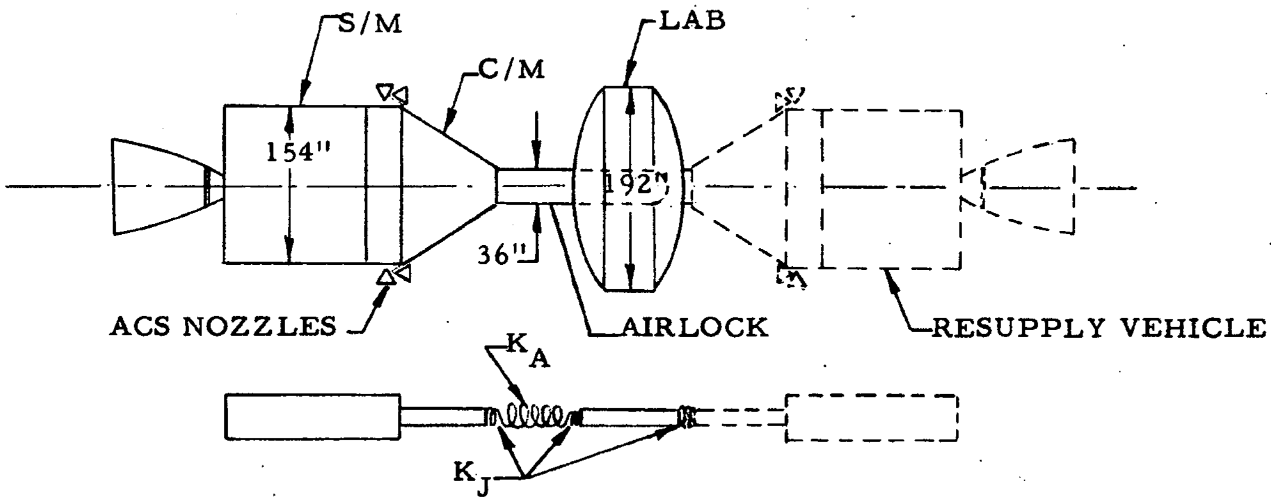
NAA APOLLO X

DOCKING DYNAMIC CONSIDERATIONS

ORBITAL CONFIGURATION

- o MINIMAL JOINT STIFFNESS (LONGITUDINAL & BENDING) ACROSS COMMAND MODULE/AIRLOCK/LABORATORY INTERFACE CONDUCIVE TO -
  - / LARGE LOCAL SPRING RATES
  - / LOW OVERALL VEHICLE FREQUENCIES (LONGITUDINAL & BENDING)
  - / LARGE MODAL AMPLITUDES & SLOPES
  - / LARGE CONSTRAINTS IMPOSED ON ACS
- o CONCLUSION
  - / WEIGHT PENALTY AND/OR REDESIGN REQUIRED TO ASSURE STRUCTURE/ACS COMPATIBILITY



SCHEMATIC REPRESENTATION

K_A = SPRING CONSTANT OF AIRLOCK

K_J = SPRING CONSTANT OF SLIDING JOINT

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A summary of conclusions concerning the Apollo X system operation is presented in Chart #19.

 [redacted]

o Cooperative conduct of experiments in the laboratory compartment would be hampered by the fact that subsystem control can be effected only from the Command Module.

o The large number of crew transfers required between the laboratory compartment and the Command Module would substantially reduce the amount of time available for crew operational duties and would probably contribute to crew hazard.

o The Apollo X concept requires continual on-orbit use of all subsystems in the Command Module, which cannot fail to degrade the probability of successful re-entry. Alternatively, Command Module subsystem degration through continual use on orbit may lead to early mission abort.

o A fundamental shortcoming to the pill-box shaped laboratory is the inherent limitation on side surface which may be utilized for earth viewing instruments. Other surfaces which might be utilized for exterior instrumentation are precluded either by docking considerations or by the attendant necessity to orient the vehicle in a very high drag configuration.

 [redacted]

NAA APOLLO - X
SYSTEMS OPERATION

CONCLUSIONS

- ALL SUBSYSTEMS CONTROL FROM CM ONLY
- CREW OPERATIONS IN LABORATORY LIMITED TO 1/3 OR 2/3 OF CREW
- CREW REQUIRED TO PERFORM LARGE NUMBER OF TRANSFERS BETWEEN LAB AND CM FOR:
  - FOOD PREPARATION
  - WASTE MANAGEMENT
  - EARTH COMMUNICATIONS
  - SLEEP AND RECREATION
  - EXPERIMENT MONITOR AND PERFORMANCE
  - SUBSYSTEM OPERATION AND CONTROL
- EXCESSIVE TRANSFER ACTIVITY WILL CONTRIBUTE TO INJURIOUS CREW OR EQUIPMENT ACCIDENTS
- CONTINUAL USE OF COMMAND MODULE SYSTEMS DEGRADES PROBABILITY OF SUCCESSFUL RE-ENTRY
- LIMITED "EARTH VIEWING" SURFACE ON LAB CONSTRAINTS EQUIPMENT OPERATION AND UTILIZATION

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[redacted]

An over-all summary of the Apollo X configuration review is presented in Chart #20.

It is generally concluded that the Apollo X configuration proposed does not meet the MOL requirements which are summarized on Chart #21.

[redacted]

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CONFIGURATION ANALYSIS

SUMMARY

/ LABORATORY ACTIVATION

- o REQUIRES COMPLEX PROCEDURES AND UNPROVEN MANNED CAPABILITY
- o REQUIRES SUCCESSFUL DOCKING MANEUVER

/ COMPARTMENTATION

- o LABORATORY GEOMETRY DOES NOT PERMIT EFFICIENT VOLUME UTILIZATION
- o INADEQUATE AIRLOCK FOR E. V. OR RETREAT FROM HAZARDOUS CONDITIONS

/ EXTRA-VEHICULAR OPERATIONS

- o IMPOSES SEVERE RESTRICTION ON ALL OTHER LABORATORY ACTIVITY

/ EQUIPMENT ARRANGEMENT

- o LIMITED EARTH VIEWING AREA AVAILABLE ON LABORATORY
- o UNDESIRABLE CENTRIFUGE ARRANGEMENT

/ RESUPPLY DOCKING PROVISIONS

- o NONE PROVIDED

/ SYSTEMS OPERATION

- o LABORATORY ACTIVITY IS LIMITED TO ONE CREWMAN
- o EXTENSIVE CREW TRANSFER REQUIRED BETWEEN LAB AND CM TO PERFORM ALL TASKS

/ CREW SAFETY

- o VEHICLE SYSTEM EXPOSES CREW TO OPERATIONAL HAZARDS NOT FOUND IN OTHER APPROACHES

CONCLUSIONS

/ APOLLO X CONFIGURATION PROPOSED DOES NOT MEET MOL REQUIREMENTS

[redacted]

Although the proposed configuration will not lend itself well to MOL requirements, the present study was extended to include those changes in the Apollo X subsystems which would be required in order to approach the capability of a baseline MOL. The Apollo X alterations which have been found necessary to meet the MOL general requirements shown on Chart #21 are summarized in the following charts.

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MOL REQUIREMENTS

- TWO MAN CREW
- 30 DAYS ON ORBIT (NOMINAL)
- CAPABILITY TO CONDUCT PRIMARY EXPERIMENTS (P-1 → P-13)
- CREW SAFETY/OPERATING CONVENIENCE
- RENDEZVOUS CAPABILITY
- CENTRIFUGE CAPABILITY
- MAINTAINABILITY
- DUAL COMPARTMENTS WITH HATCHES

APOLLO X REVIEW

- ALTERATIONS TO APOLLO X SPACECRAFT NECESSARY TO MEET BASIC MOL REQUIREMENTS

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Those changes and alterations to the Apollo subsystems required to give the Apollo X the inherent subsystem capability required by a MOL baseline are listed in Charts #23 through #27. The increments of weight associated with the list of changes are measured above the weight statement values cited in Report SID 64-1860-4.

[redacted] UNCLASSIFIED

CHANGES TO APOLLO FOR APOLLO X EARTH ORBIT

(NAA PROPOSED)

1. ADD 1200 FT^3 LAB MODULE INCLUDING TUNNEL AND AIRLOCK
2. ADD 2 GAS ATMOSPHERE
3. ADD LiO2 CANNISTERS TO CM
4. ADD CREW SUPPLIES
5. ADD 3 FUEL CELLS TO SM (TOTAL OF 5)
6. ADD REACTANT STORAGE (45 DAY TOTAL) IN SM
7. ADD ECS CRYOGENIC STORAGE (45 DAY TOTAL) IN SM
8. REPLACE SM PROPELLANT TANKS WITH SMALL TANKS
9. REMOVE G & N SYSTEM - EXCEPT OPTICS
10. ADD SPARES & REDUNDANCY TO MEET 45 DAY EARTH MISSION RELIABILITY GOALS

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APOLLO X RE-ENTRY VEHICLE CHANGES FOR MOL REQUIREMENTS

ITEM	CHANGE TO NAA EARTH ORBIT CONFIGURATION	ΔWEIGHT
GUIDANCE & NAVIGATION	Not included in NAA earth orbit configuration. Comparable equipment is in Gemini B.	+229
CREW SYSTEMS	One couch is removed but attenuation weight for 2 couches is increased per NAA, Vol. IV, Table 21.	0
USEFUL LOAD		
CREW SYSTEMS	One crew member removed. (Crew systems weight includes 120 pounds of food for 2 men, 33 days.)	-192
ENVIRONMENTAL CONTROL	6 Day, 3 man lithium hydroxide supply reduced to 2 day, 2 man supply. Supply for 33 days is provided in Laboratory.	-34
CONTINGENCY	Per MOL criteria.	+1440
TOTAL WEIGHT CHANGE (LBS)		+1443

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APOLLO X SERVICE MODULE CHANGES FOR MOL REQUIREMENTS

ITEM	CHANGE TO NAA EARTH ORBIT CONFIGURATION	ΔWEIGHT
ELECTRICAL POWER	Add one fuel cell to make system comparable to MOL.	+240
	Hydrogen storage and supply system for 33 days, 1800 watt average.	-45
	Oxygen storage and supply system for 33 days, 1800 watt average. (Includes oxygen storage for 33 days ECS).	-29
REACTION CONTROL	Block II RCS used in liew of Apollo X. See NAA proposal Vol. IV, Tables 36 and 39. (Usable propellant capacity reduced from 2,465 lbs. to 838 lbs.)	-539
ENVIRONMENTAL CONTROL	Reduce Nitrogen Supply System requirement from 45 days to 33 days, (NAA Vol. 4, Table 37).	-110
PROPULSION	The Propulsion System weight quoted by NAA in Vol. IV, Table 38 is 2,886 pounds (not 1,689 as given in Table 11). The 2,886 pound system is required to provide for the 2,718 pounds propellant used in Table 11 plus capacity for propellants to provide a ΔV capability of 500 fps for experiments.	+1,177
USEFUL LOAD		
ELECTRICAL POWER	Reactant weight based on 1,550 watts average for 33 days. Does not include an estimated 200 pounds of reactants for experiments which are included as part of the experiment weight on MOL.	-719
REACTION CONTROL	Reaction control propellants reduced to correspond to MOL requirements (Experiment requirements not included).	-786
ENVIRONMENTAL CONTROL	Based on O_2 and N_2 requirements for MOL except Apollo leakage rate is assumed to be 0.5 lbs. per day greater than Gemini.	-392
CONTINGENCY	Per MOL criteria.	+1190
TOTAL WEIGHT CHANGE (LBS)		-13

APOLLO X LABORATORY VEHICLE CHANGE FOR MOL REQUIREMENTS

ITEM	CHANGE TO NAA EARTH ORBIT CONFIGURATION	ΔWEIGHT
STRUCTURE	Increase structural shell per analysis	+464
	Add hatches, windows, and provisions for equipment.	+162
	Increase Laboratory to LEM adapter mounting weight per analysis.	+548
ORIENTATION CONTROLS	Add: Redundant electronics equipment to provide equivalent MOL reliability.	+100
	Add: Umbilicals to re-entry vehicle.	+50
ELECTRICAL POWER	Increase electrical distribution system to equivalent of MOL.	+249
COMMUNICATIONS	Add: Command System Decoder (15 lb) and relay assy. (6 lb)	+21
	Add: MOL security system	+10
	Add: Teleprinter	+12
	Add: 2 S-Band amplifiers (34 lb) and an S-Band transmitter (15 lb)	+49
	Add: Umbilicals to re-entry vehicle	+40
	Add: Circuitry	+25
	Add: Mounts	+15
ENVIRONMENTAL CONTROL SYSTEM	Add: Pressure suit circuit	+57
	Increase: CO_2 removal system	+55
	Increase: Thermal control system	+292
PERSONNEL PROVISIONS	Add: Compartment provisions (lights, partitions, seats, trim, etc.) (Assumes bunk is in command module)	+260
	Add: Waste management system	+45
	Add: Crew accessories	+50
	Add: Crew personal gear (spare pressure suits, etc.)	+137
	Add: Recreation equipment	+25
	Add: Exercise equipment	+10
DISPLAYS & CONTROLS	Add: Attitude control and stabilization controls equivalent to MOL	+50
	Add: Leak detection system	+20
	Add: Gas analyzers, pressure indicators and controls	+42
	Increase: Consoles, panels, and circuitry	+129

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APOLLO X LABORATORY VEHICLE CHANGES FOR MOL REQUIREMENTS (Continued)

ITEM	CHANGE TO NAA EARTH ORBIT CONFIGURATION	ΔWEIGHT
SPARE PARTS	Spare parts are in addition to redundant equipment.	+140
EXPENDABLES		
FOOD	Food and food preparation area is located in re-entry vehicle.	-158
LITHIUM HYDROXIDE	Lithium hydroxide requirements based on 2 men for 33 days.	-136
CONTINGENCY	Per MOL criteria	+1090
TOTAL WEIGHT CHANGE (LBS)		+3853

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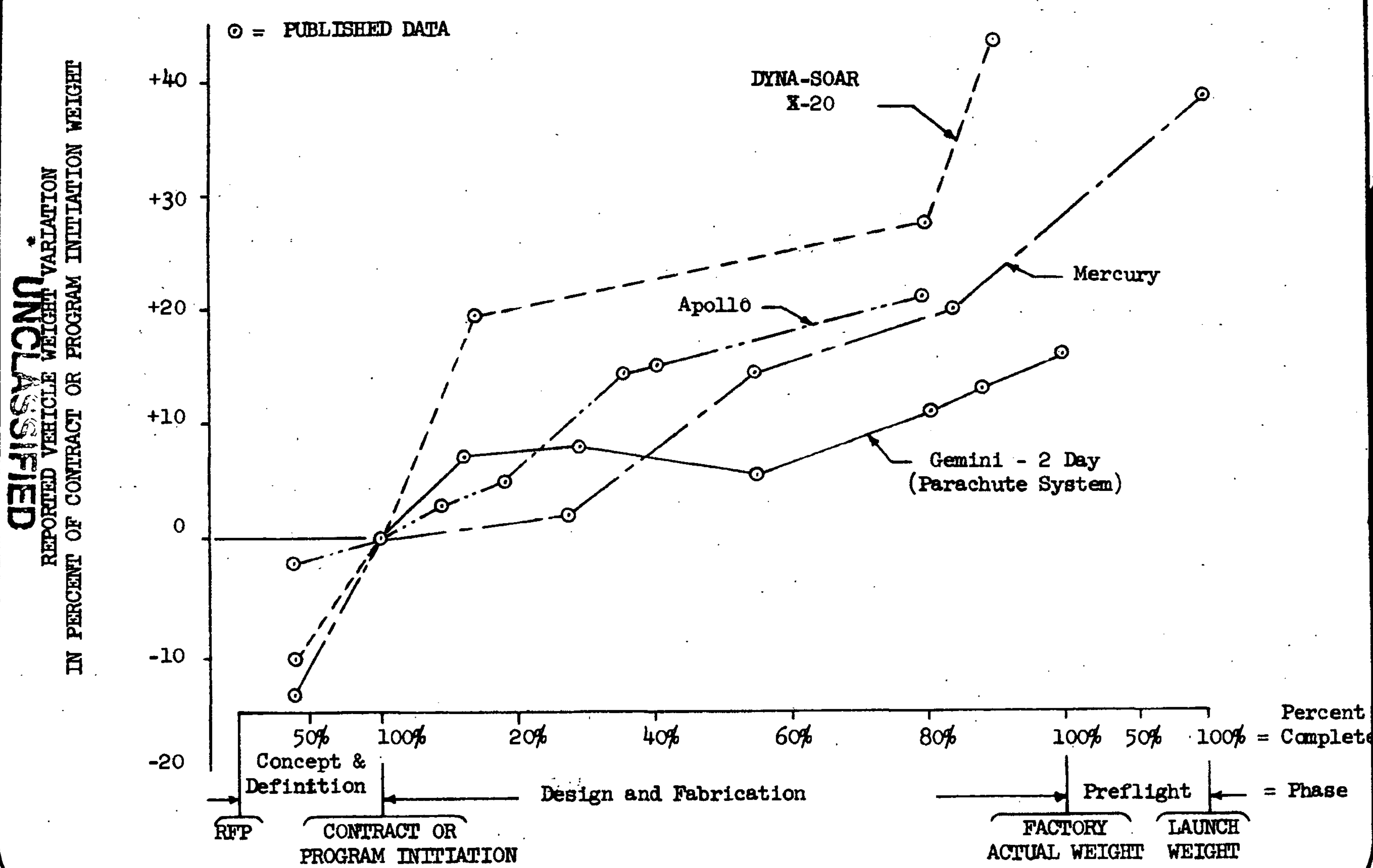
MANNED RE-ENTRY VEHICLE WEIGHT GROWTH HISTORY
(ALL DEVELOPMENT PHASES)



Since a major weight increment has been added to the laboratory structure, Chart #29 is included to indicate the origin of this large increase. The right hand column of the chart displays the structural weight estimates derived from Report SID 64-1860-4. This weight, which includes the laboratory support structure, was based upon a 3700 lb. laboratory vehicle weight as indicated. The necessary changes, shown in previous charts, result in a Command Module weight of approximately 6000 lb. for a 30-day MOL mission. Structural weights derived on this basis are shown in the center column, along with the resulting 1200 lb. increase. The chart shows that the majority of the weight increment is attributable to exceedingly optimistic NAA weight estimates of the structural bulkheads and laboratory support structure.

APOLLO X - LAB

STRUCTURAL WEIGHTS COMPARISON

COMPONENT	*Ⓐ WEIGHTS (LB)		NAA WEIGHTS (LB)
	3695# NAA WT. 30 Days	6000# Ⓐ WT. 30 Days	3694# NAA WT. 45 Days
STRUCTURAL SHELL			
**Bulkheads	430	430	62
Cylinder	86	89	49
Ring Frame	92	92	106
Dome Frame	21	21	21
Fitting Factor (15%)	95	95	24
SUB-TOTAL	724	727	262
METEOROID PROTECTION			
Increase to Inner Wall	82	77	
Face Sheet (Bumper)	81	81	100
Energy Absorber	170	170	340
Bond	74	74	
Fitting Factor (10%)	38	37	
SUB-TOTAL	443	439	440
SECONDARY STRUCTURE Hatches, Windows, Equip Mounts, etc.	510	510	348
LAB SUPPORT STRUCTURE			
Shell	446	540	
Rings	53	67	
Fitting Factor	75	91	
SUB-TOTAL	574	698	150
TOTAL	2,251	2,374	1,200

*σ_{cr}/F_{tu} = 0.60 L_{cr} = 6" - 10" ** a/b = .54 Minimum a/b for reasonable wt. & feasible with NAA Designs

[redacted] UNCLASSIFIED

Weight and payload summaries of the Apollo X concept altered to meet MOL requirements and of the MOL baseline system are presented in the following charts.

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WEIGHTS AND PAYLOAD ANALYSIS

UNCLASSIFIED [redacted]

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Ground rules and rationale for weight analysis are exhibited in Chart #31. A comparison of orbiting vehicle weights for an Apollo X/MOL and a Gemini B/MOL is shown in Chart #32. This chart shows that the Apollo X for MOL has an inherent weight which is approximately 18,000 pounds greater than that of an equivalent Gemini B/MOL system. A large percentage of this weight difference derives from the fact that the service module and LEM adapter structures are designed for a lunar rather than an earth-oriented mission, and the Command Module has been sized for three crew members and earth return from lunar orbit.

It is interesting to note that the December 19, 1964, issue of the Apollo Spacecraft General Specification cites a specification control weight of 11,000 pounds for the Command Module and 3,800 pounds for the LEM adapter.

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APOLLO X

WEIGHT ANALYSIS

EVALUATION RATIONALE

- o COMPARE PROPOSED SYSTEM WITH MOL REQUIREMENTS
  - CREW SIZE
  - MISSION DURATION
  - CONTINGENCY
  - METEOROID PROTECTION
  - RELIABILITY
- o "NORMALIZE" TO EQUIVALENT BASIS FOR COMPARISON

[redacted] UNCLASSIFIED

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ORBITING VEHICLE WEIGHT COMPARISON

(2 MEN - 30 DAYS)

APOLLO X

ITEM	WEIGHT (LBS)
COMMAND MODULE	11,040
SERVICE MODULE	15,370
LEM ADAPTER	3,500
LABORATORY	6,500
TOTAL	36,410

GEMINI B/TITAN IIIC MOL

ITEM	WEIGHT (LBS)
GEMINI B	4,930
GEMINI ADAPTER	1,670
-	-
LABORATORY	11,750
TOTAL	18,350

WEIGHT DIFFERENCE = 18,060 LBS.

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A payload performance comparison, utilizing the orbiting vehicle weights summarized in the previous chart, is shown in Chart #33. The chart shows a clear payload superiority for the MOL/T-IIIC combination over the Apollo X/Saturn system, and indicates that uprating of the Saturn IB payload capability will result in only marginal payloads.

It should be emphasized that the Apollo X/Saturn IB payloads indicated are consistent with the NAA/NASA Apollo X study ground rules, and do not necessarily reflect the capabilities of other systems which might be derived from Apollo system hardware.

PAYLOAD PERFORMANCE COMPARISON

SYSTEM	LAUNCH VEHICLE PAYLOAD ETR (106° AZ) (LBS)	ORBITING VEHICLE WEIGHT LESS EXPERIMENTS (LBS)	PAYLOAD AVAILABLE FOR EXPERIMENTS (LBS)
MOL - TITAN IIIC	23,500 (1)	18,350	5,150
APOLLO X - SATURN IB	32,800 (2)	36,410 (3)	-3,610
APOLLO X - SATURN IB (UPRATED)	37,800 (2)	36,410 (3)	1,390

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(1) 160 N. MI. CIRCULAR ORBIT

(2) 80/160 N. MI. ELLIPTICAL ORBIT

(3) INCLUDES PROPELLANT REQUIRED TO CIRCULARIZE ORBIT AT 160 N. MI.

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The foregoing payload data are presented in terms of duration and payload tradeoffs in Chart #34.

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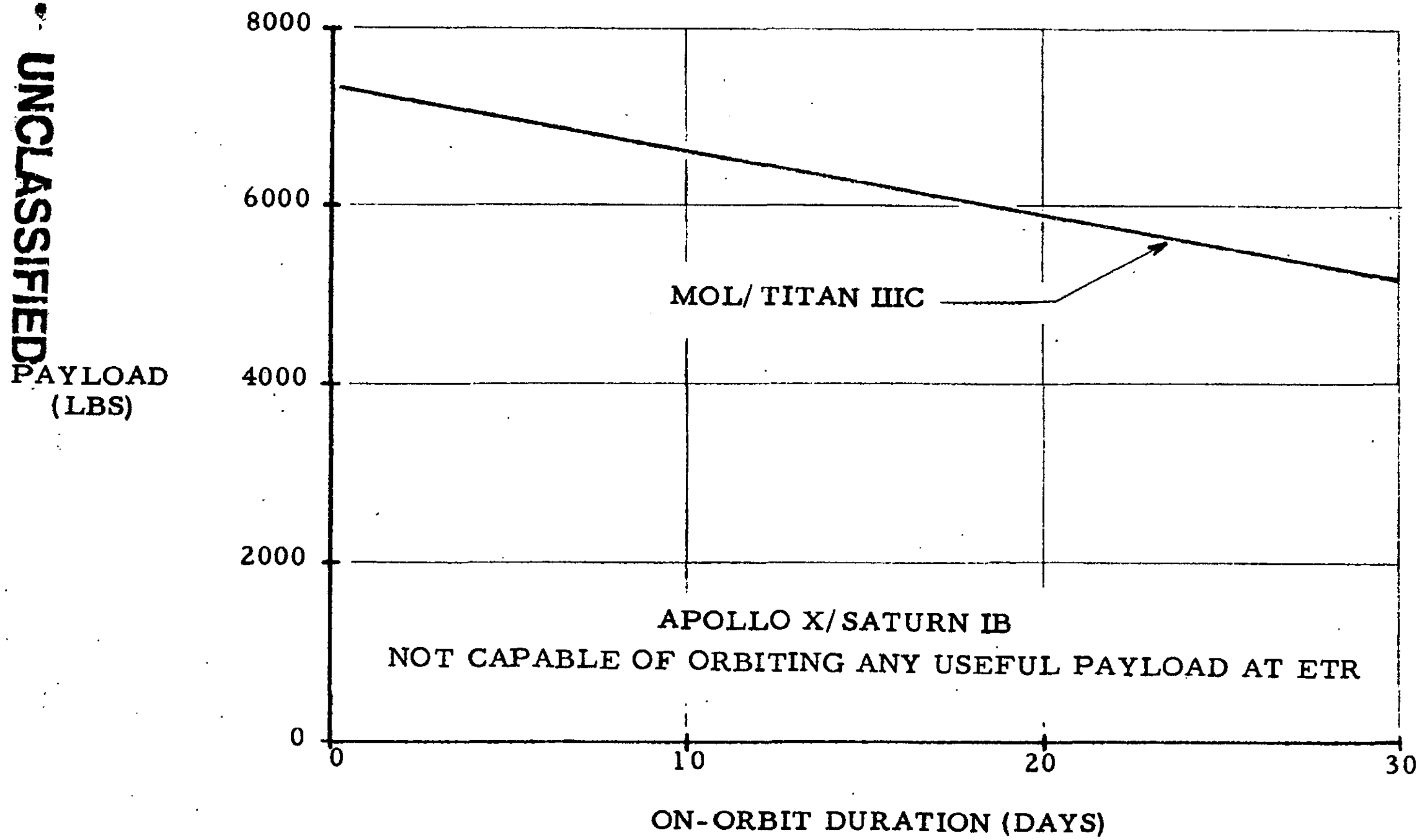
APOLLO X REVIEW

MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION

- ETR OPERATIONS
- INTEGRAL LAUNCH



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The over-all results of the weights analysis are summarized in Chart #35. It is concluded that the Apollo X configuration cannot be made to satisfactorily meet MOL payload requirements.

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APOLLO X REVIEW
WEIGHTS ANALYSIS

RESULTS

- LABORATORY WEIGHTS FOUND TO BE DEFICIENT FOR ALL SUBSYSTEMS
- INADEQUATE REDUNDANCY PROVIDED IN SUBSYSTEMS
- NO ENVIRONMENT PROTECTION PROVIDED FOR APOLLO DE-ORBIT ENGINE
- "NEGATIVE" PAYLOAD INDICATED FOR APOLLO X/SATURN IB ON A 30 DAY MISSION

CONCLUSION

- APOLLO X DOES NOT MEET THE MOL PAYLOAD REQUIREMENTS

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APOLLO X

RELIABILITY & LIFE EXTENSION

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A most important aspect of orbiting vehicle design for MOL operations is that of reliability and subsystem life extension. Life extension concepts considered by NAA for the Apollo X vehicle are summarized on Chart #37. Approaches 1 and 2 are well outside the Apollo X ground rules, in that each of these approaches requires extensive redesign or addition of subsystems. Therefore, NAA indicated preference for approach No. 3, which involves extensive in-flight maintenance and repair and the addition of redundant elements with manual switching. It is not at all evident how this approach can be successfully employed on the Block 2 Apollo system, since the General Specification states that the Command Module, which houses all of the subsystems of primary interest to maintainability, shall not be subject to on-orbit maintenance. It is understood that maintainability of the Command Module for the Block 2 Apollo has been precluded due to serious difficulty with humidity control in the vehicle. The problem has resulted in extensive potting and hard-wiring of many subsystem components, making in-flight maintenance of this system essentially impossible.

APOLLO X
LIFE EXTENSION APPROACHES CONSIDERED
(NAA)

1.
- CONTINUATION OF THE PRESENT APOLLO PHILOSOPHY
- ADD REDUNDANT SYSTEM ELEMENTS WITH AUTOMATIC SWITCHING
- NO IN-FLIGHT MAINTENANCE EXCEPT THE INSTALLATION OF APPROVED SPARES

2.
- REDESIGN CRITICAL SYSTEMS FOR INCREASED RELIABILITY
- REDUCE THE COMPLEXITY OF PRESENT SYSTEMS
- NEW CONCEPTS AND TECHNOLOGICAL ADVANCES

3.
- IN-FLIGHT MAINTENANCE AND REPAIR
- REDUNDANT ELEMENTS WITH MANUAL SWITCHING
- SPARES INSTALLED BY THE CREW
- CREW REPAIR AND SERVICING OF FAILED OR MALFUNCTIONING ITEMS

The NAA Apollo X reliability allocation listing is shown on Chart #38. As noted on Chart #39, these apportioned values appear to exceed the state-of-the-art by a large order. Chart #39 summarizes the problems generated by the NAA approach to Apollo X life extension, and show that the apportioned reliability is probably unattainable.

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APPROLLO X RELIABILITY ALLOCATIONS

(NAA)

SYSTEM	ALLOCATION
GOSS	.99630
GSE	.99984
BOOST	.95
CSM	.955
LABORATORY	.99585
	.90

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LIFE EXTENSION - APOLLO X

GROUND RULE: NO "MAJOR" REDESIGN OF BLOCK II SYSTEMS.

NAA APPROACH	PROBLEM
ASSUMED: "RELIABILITIES CLOSE TO OR ABOVE APPORTIONED VALUES".	APPORTIONED VALUES EXCEED STATE-OF-THE-ART BY UP TO ORDER OF MAGNITUDE.
REDESIGN FOR INCREASED RELIABILITY.	VIOLATES NASA GROUND RULE.
REDUNDANT ELEMENTS MANUALLY SWITCHED.	INADEQUATE AVAILABLE VOLUME.
SPARES INSTALLED BY CREW.	INADEQUATE SPARES STORAGE VOLUME. BLOCK II NOT DESIGNED FOR MAINTENANCE.
CREW REPAIR OF FAILED ITEMS.	REQUIRES DESIGN FOR MAINTENANCE AT DETAIL LEVEL, LARGE STOCK OF SPARES AND TOOLS, EXCESSIVE CREW TIME.
OPERATE UNTIL SINGLE FAILURE WILL CAUSE LOSS OF MISSION.	REQUIRES THAT EMERGENCY CONDITION BE NORMAL OPERATING MODE. COMPROMISES CREW SAFETY.
REDUCE SYSTEM OPERATING TIME e.g., ATTITUDE CONTROL.	REDUCED ORBITAL LIFE. UNACCEPTABLE FOR MILITARY EXPERIMENTS.

NO EVIDENCE HAS BEEN FOUND TO INDICATE THAT THESE PROBLEMS HAVE BEEN CONSIDERED IN THE APOLLO X STUDY.

The present review included a comparison of the growth potential of the MOL baseline and Apollo X systems.

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APOLLO X REVIEW
GROWTH POTENTIAL COMPARISON
MOL AND APOLLO X

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The comparison covered both integral launch and rendezvous operations at both the Eastern and Western Test Ranges. Both the Apollo X and the Baseline MOL Systems were uprated in terms of launch vehicle capability and long duration maintenance capability.

[redacted]

GROWTH COMPARISON

✓ APOLLO X

- o MODIFIED TO MEET MOL REQUIREMENTS
- o UPRATED CO_2 REMOVAL
- o SATURN IB AND UPRATED SATURN IB LAUNCH VEHICLE

✓ MOL

- o UPRATED CO_2 REMOVAL
- o TITAN IIIC WITH 7 SEGMENT AND 156 IN. DIA SRM'S

✓ INTEGRAL LAUNCH AT "ETR" AND "WTR"

✓ RENDEZVOUS OPERATIONS AT "ETR" AND "WTR"

[redacted]

[redacted]

The launch vehicle capabilities assumed in the growth potential study are summarized in Chart #42. The comparative growth performance for integral launch operations is shown for the two systems on Chart #43. This chart indicates that the Apollo X/Saturn IB system is incapable of polar operation from the Western Test Range.

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APOLLO X REVIEW
LAUNCH VEHICLE CAPABILITIES

VEHICLE	PAYLOAD (lbs)	
	ETR (106°AZ)	WTR (180°AZ)
T-IIIC[1]	23,500	18,800
T-IIIC/7 SEG. SRM[1]	28,600	23,800
T-IIIC/156 IN. SRM[1]	37,980	31,000
SATURN I-B[2]	32,800	26,400
SATURN I-B UPRATED[2]	37,800	30,400

----

(1) 160 N. MI. CIRCULAR ORBIT

(2) 80/160 N. MI. ELLIPTICAL ORBIT
500-600 LBS PROPELLANT REQUIRED IN PAYLOAD TO CIRCULARIZE AT 160 N. MI.

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APOLLO X REVIEW
WEIGHT AVAILABLE FOR EXPERIMENTS

- INTEGRAL LAUNCH

SYSTEM	WEIGHT (LBS) ETR (106° AZ)	WTR (180° AZ)
MOL - TITAN IIIC[(1)]	5,150	450
MOL - TITAN IIIC/7 SEG SRM[(1)]	10,250	5,450
MOL - TITAN IIIC/156-IN SRM[(1) (3)]	19,000	12,000
APOLLO X - SATURN IB[(2)]	-3,600	-10,000
APOLLO X - SATURN IB/UPRATED[(2)]	1,400	-6,000

----

(1) 160 N. MI. CIRCULAR ORBIT

(2) 80/160 N. MI. ELLIPTICAL ORBIT
INCLUDES PROPELLANT REQUIRED TO CIRCULARIZE AT 160 N. MI.

(3) INCLUDES ADDITIONAL VOLUME FOR INCREASED PAYLOAD

[redacted]

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Integral launch payload vs. duration trade-off summaries are shown on Charts #44 and #45. Chart #46 defines the expendables rates derivation associated with these data.

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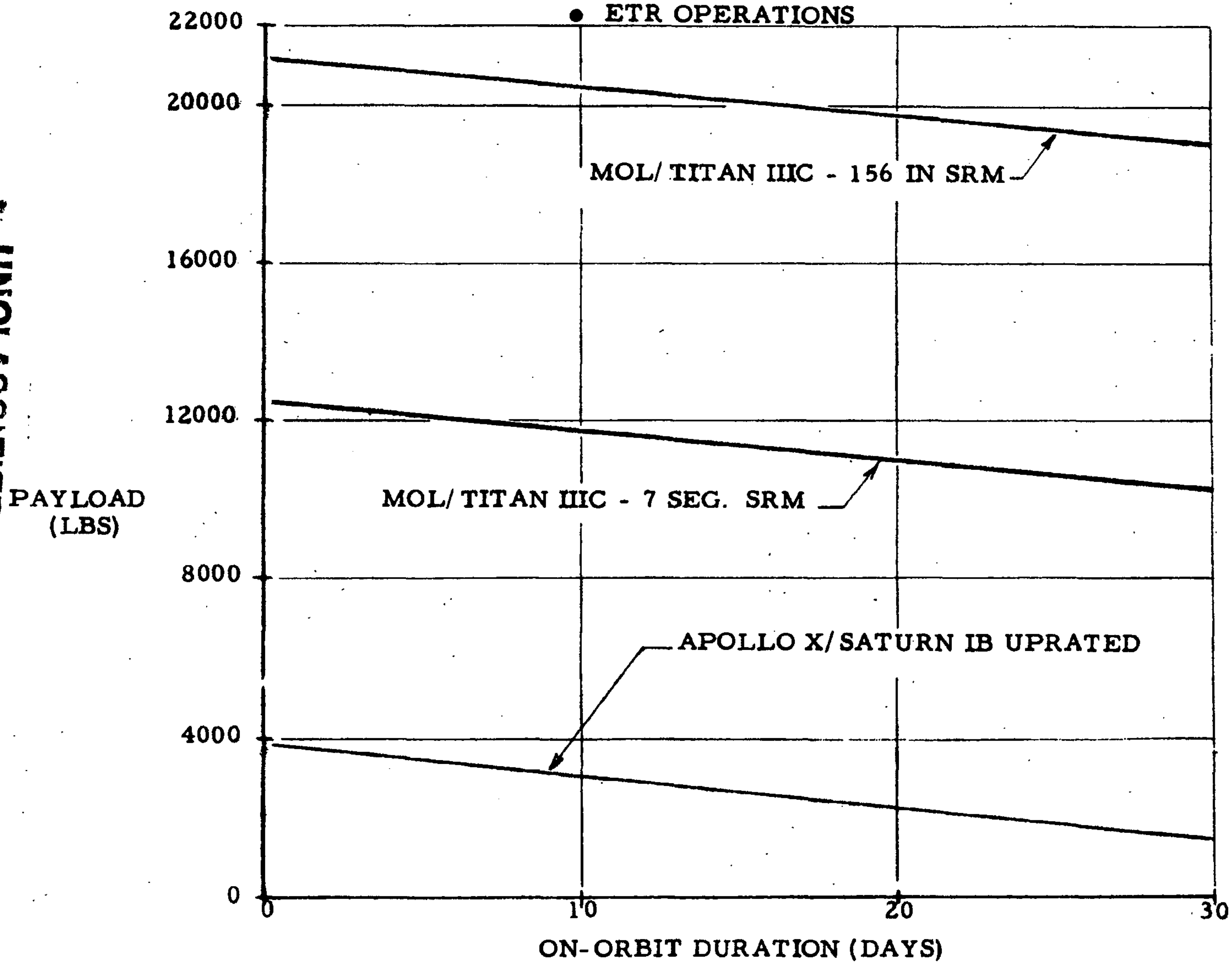
APOLLO X REVIEW

UPRATED MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION
• ETR OPERATIONS



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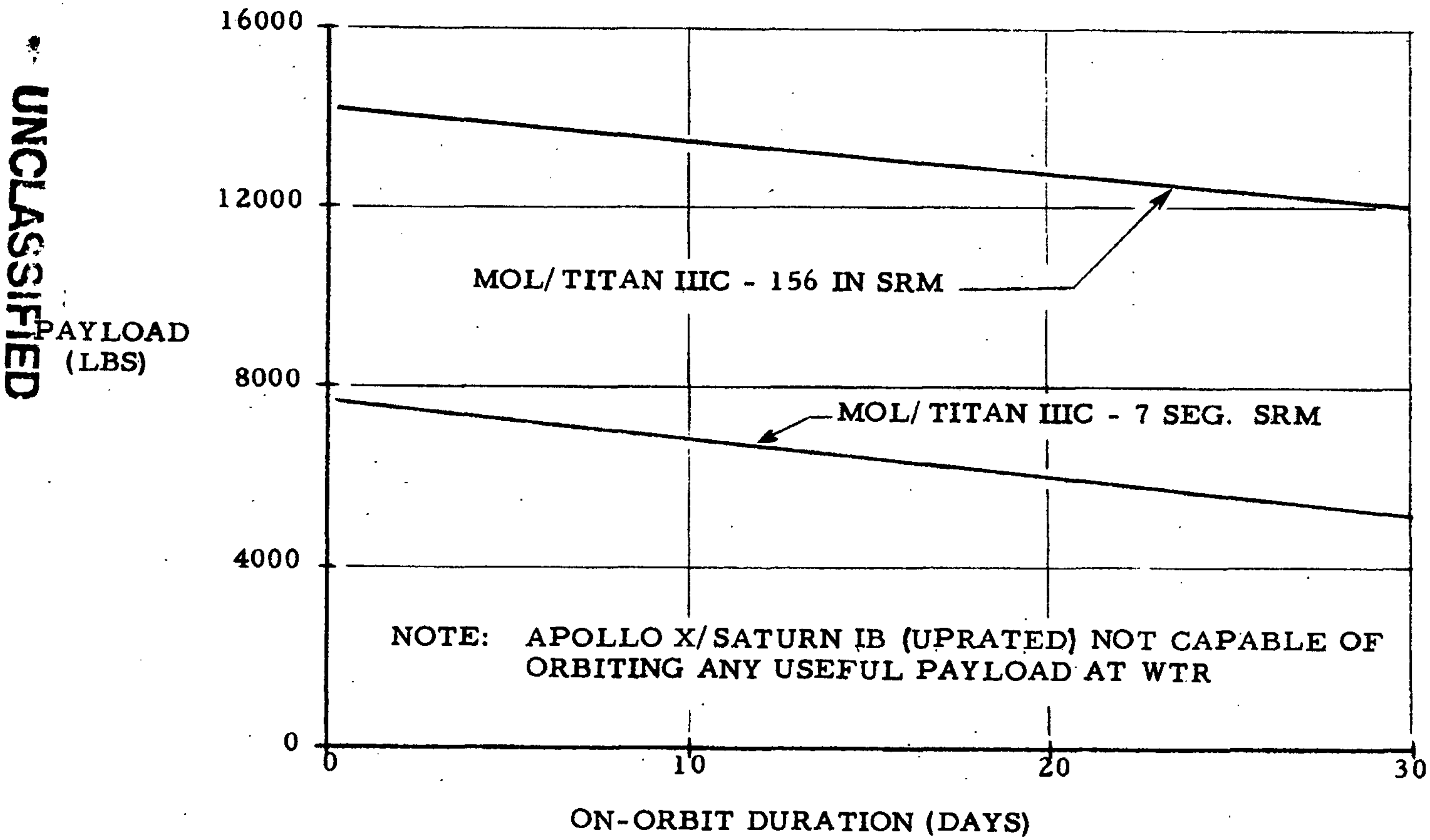
APOLLO X REVIEW

UPRATED MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION

- WTR OPERATIONS
- INTEGRAL LAUNCH



APOLLO X REVIEW

EXPENDABLES SUMMARY

- TWO-MAN CREW
- 30-DAY MISSION

ITEM	MOL (LBS/DAY)	APOLLO X (LBS/DAY)
REACTION CONTROL PROPELLANTS	2.5	13.6
LIFE SUPPORT EXPENDABLES*	(17.3)	(17.7)
OXYGEN - SUPERCRITICAL	8.5	8.7
OXYGEN - HIGH PRESSURE	0.3	0.3
NITROGEN - SUPERCRITICAL	3.3	3.5
DISPOSABLE CLOTHING, TISSUES, CHEMICALS	1.2	1.2
FOOD	4.0	4.0
FUEL CELL REACTANTS (1.8 KW AVERAGE)	44.5	39.8
SPARES AND REDUNDANCY	7.0	7.0
RECREATION, EXERCISE & MEDICAL EQUIPMENT	1.5	1.5
TOTALS	72.8	79.6

----

*INCLUDES 10% RESERVE

APOLLO X REVIEW

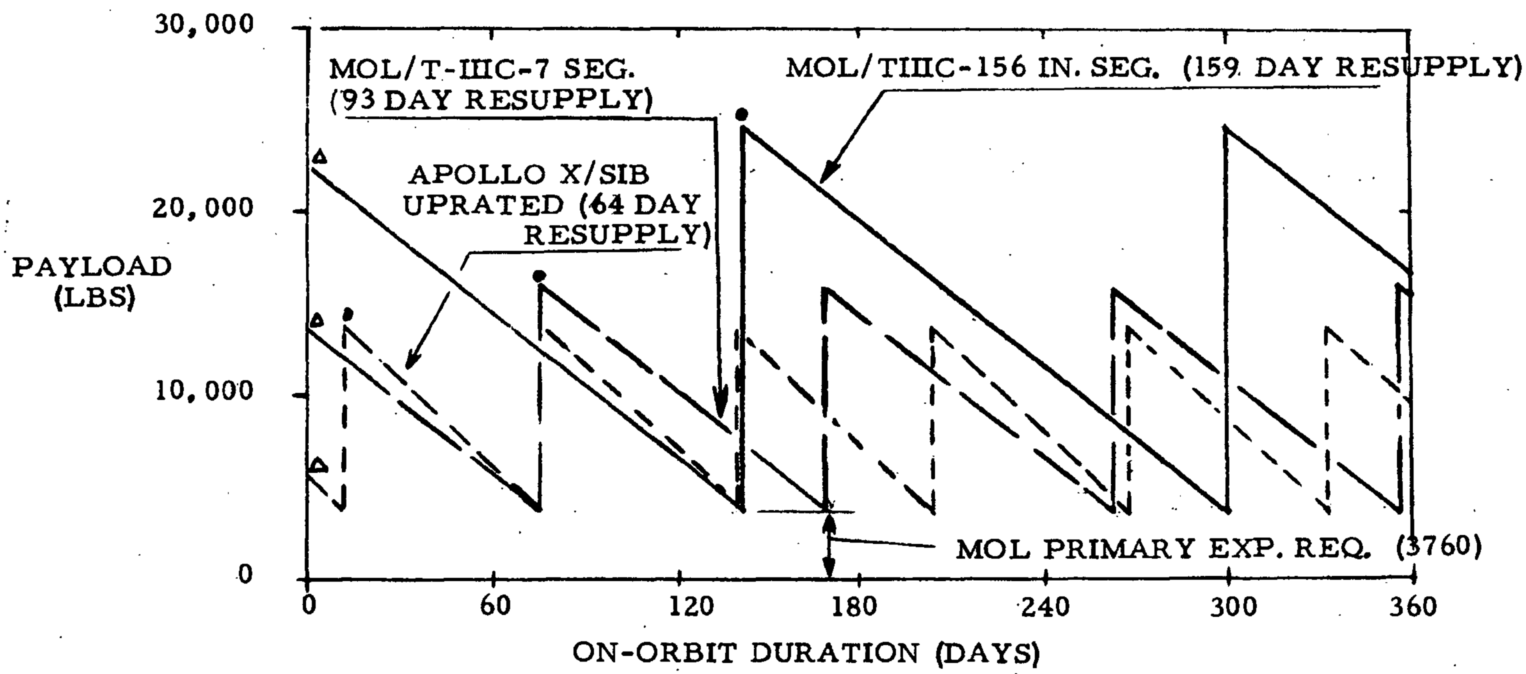
- √ RENDEZVOUS OPERATIONS
  - o ETR AND WTR
  - o 2 MAN CREW
- √ APOLLO X CONFIGURATION
  - o MODIFIED TO MEET MOL MISSION REQUIREMENTS
  - o MODIFIED TO ADD RENDEZVOUS AND DOCKING CAPABILITY
  - o INCLUDES UPRATED CO_2 REMOVAL SUBSYSTEM
  - o CRYOGENIC STORAGE BASED ON 120 DAY DESIGN POINT
- √ MOL CONFIGURATION
  - o INCLUDES RENDEZVOUS AND DOCKING CAPABILITY
  - o INCLUDES UPRATED CO_2 REMOVAL SUBSYSTEM
  - o CRYOGENIC STORAGE BASED ON 120 DAY DESIGN POINT

Chart #48 summarizes the Eastern Test Range rendezvous operation comparison. This chart displays resupply requirements in terms of the primary MOL experiments payload. It is evident that desirably large resupply cycles are available with both versions of the up-rated T-IIIC/MOL. Rendezvous configuration data are included in Charts #50 through #52 for ETR operations.

APOLLO X REVIEW

MOL - APOLLO X PAYLOAD VS. ON-ORBIT DURATION COMPARISON

- ✓ ETR OPERATIONS
- ✓ MOL LABORATORY PRESSURIZED VOL - 2400 FT^3
- ✓ APOLLO X LABORATORY PRESSURIZED VOL - 1260 FT^3



△ INTEGRAL LAUNCH

● RESUPPLY LAUNCH

APOLLO X REVIEW

EXTENDED DURATION MISSION COMPARISON

EXPENDABLES SUMMARY

- TWO-MAN CREW
- CRYOGENIC BOIL-OFF BASED ON 120 DAY DESIGN

ITEM	RATE (LBS/DAY) MOL	RATE (LBS/DAY) APOLLO X
REACTION CONTROL PROPELLANTS	3.8	20.4
LIFE SUPPORT EXPENDABLES	24.2	24.8
FUEL CELL REACTANTS (1.8 KW AVERAGE)	72.0	64.5
FUEL CELLS	15.0	35.2
SPARES AND REDUNDANCY	10.0	10.0
ORBIT SUSTENANCE PROPELLANT (160 N. Mi.)	4.5	6.0
RECREATION, EXERCISE & MEDICAL EQUIPMENT	1.7	1.7
TOTAL EXPENDABLE RATE	131.2	162.6

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APOLLO X REVIEW

APOLLO X RENDEZVOUS VEHICLE WEIGHT ESTIMATE

- ETR OPERATIONS
- LABORATORY PRESSURIZED VOLUME - 1260 FT^3

ITEM	TARGET VEHICLE (LBS)	CHASE/RESUPPLY VEHICLE (LBS)
√ APOLLO X VEHICLE (WITHOUT EXPERIMENT PAYLOAD)	36,090	36,090
o CONVERT TO "O" DAY EXPENDABLES AND TANKAGE	-3,650	-3,650
o FUEL CELL REDUNDANCY (2)	- 960	- 960
o RENDEZVOUS & DOCKING	+ 610	+2,080
o LABORATORY MODULE		-6,220
√ VEHICLE WEIGHT (LESS DISCRETIONARY PAYLOAD)	32,090	27,340
√ DISCRETIONARY PAYLOAD		
o SATURN IB (32,800)	710	5,460
o SATURN IB UPRATED (37,800)	5,710	10,460

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[redacted]

APOLLO X RESUPPLY CAPABILITY

✓ VOLUME AVAILABILITY IN 2 MAN CONCEPT

- o CM
  - TOTAL PRESSURIZED VOLUME - 366 FT^3
  - NET FREE VOLUME - 130 FT^3
  - ASSUMED MAX. FREE VOLUME AVAILABLE FOR STORAGE - 100 FT^3
  - PAYLOAD STORAGE CAPABILITY ~ 2000 LBS (FOOD, CLOTHING, ETC.)
- o SM
  - TOTAL UNPRESSURIZED VOLUME 1560 FT^3
  - AVAILABLE FOR STORAGE - 1125 FT^3
  - PAYLOAD STORAGE CAPABILITY ~ 14,000 LBS

[redacted]

APOLLO X REVIEW

MOL RENDEZVOUS VEHICLE WEIGHT ESTIMATE

- o ETR OPERATIONS
- o LABORATORY PRESSURIZED VOLUME - $2400\ FT^3$

ITEM	TARGET VEHICLE (LBS)	CHASE/RESUPPLY VEHICLE (LBS)
√ BASELINE VEHICLE (WITHOUT EXPERIMENT PAYLOAD)	17,940	17,940
o BASELINE CONVERSION TO "O" DAY EXPENDABLES & TANKAGE	-3,280	-3,280
o RENDEZVOUS & DOCKING SYSTEM	+ 610	+2,080
o FUEL CELL REDUNDANCY (3)	- 410	- 410
√ VEHICLE WEIGHT (LESS DISCRETIONARY PAYLOAD)	14,860	16,330
√ DISCRETIONARY PAYLOAD		
o TIIIC/7 SEGMENT SRM (28,600)	13,740	12,270
o TIIIC/156 IN DIA. SRM (37,980)	22,500*	21,000*

*INCLUDES ADDITIONAL VOLUME FOR INCREASED PAYLOAD

MOL GROWTH POTENTIAL

✓ POSSIBLE RENDEZVOUS MISSION CAPABILITY AT WTR OPERATIONS

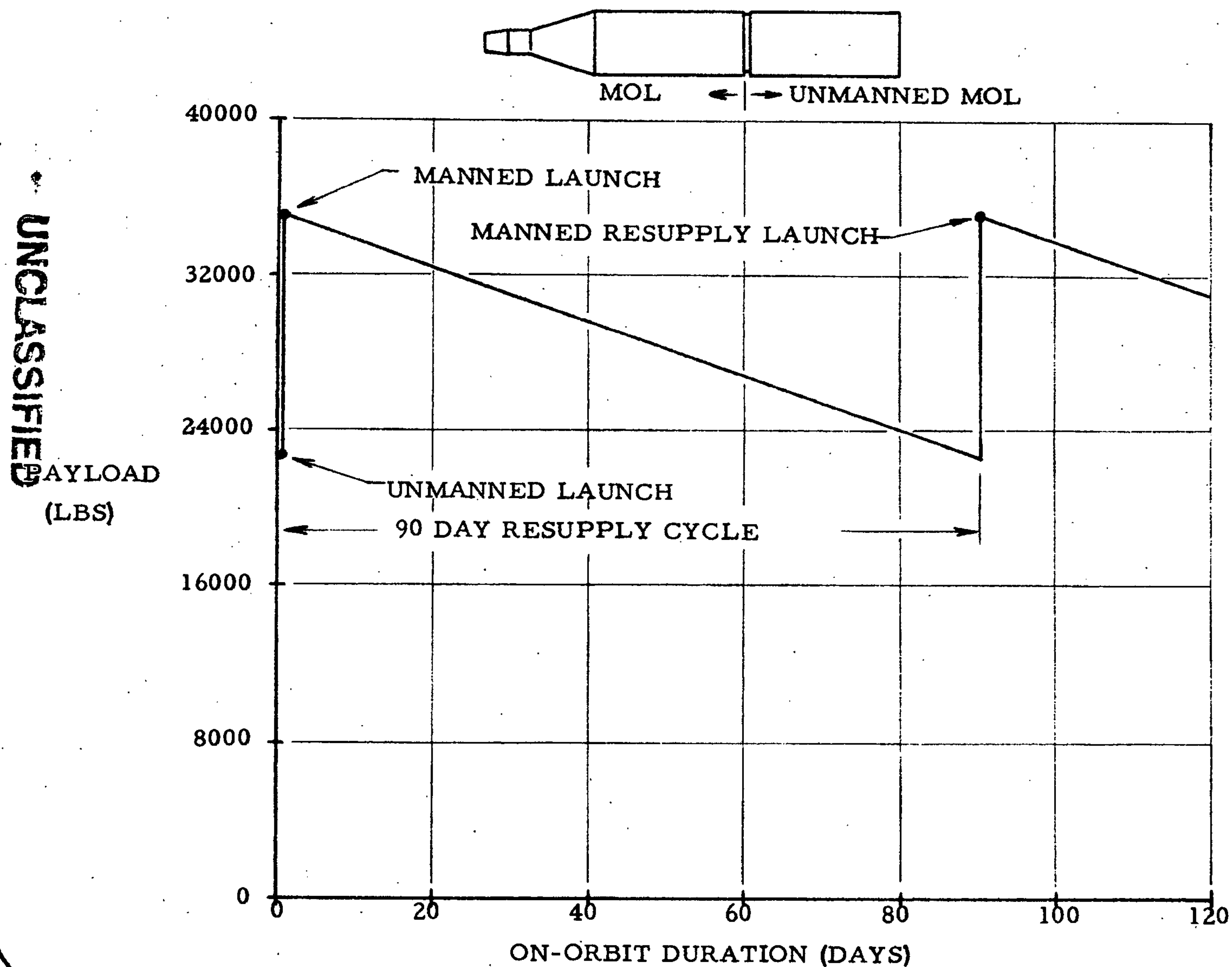
- o UNMANNED MISSION EQUIPMENT MOL
- o MANNED RESUPPLY

Although the Apollo X Saturn IB system has been shown to lack a capability for Polar missions, Chart #54 shows an interesting T-III/MOL capability for operationally oriented growth missions in Polar operations. Supporting data for this mission build-up are presented in Charts #55 and #56.

MOL GROWTH POTENTIAL

PAYLOAD VS. ON-ORBIT DURATION

- WTR OPERATIONS
- TIII C/156 IN SRM



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MOL

RESUPPLY VEHICLE WEIGHT SUMMARY

o	USEFUL VEHICLE PAYLOAD AT WTR (TIIIC/156 IN)	12,000 LBS
o	CONVERT BASIC VEHICLE TO ZERO DAY EXPENDABLES	+3,434
o	ADD FUEL CELL REDUNDANCY (3)	- 244
o	ADD RENDEZVOUS AND DOCKING	-2,580
	TOTAL RESUPPLY PAYLOAD	12,610 LBS

[redacted]

MOL UNMANNED VEHICLE WEIGHT SUMMARY

• PAYLOAD CAPABILITY AT WTR (TIIIC/156 IN)		31,000 LBS
• VEHICLE WEIGHT		-8,400
STRUCTURE (10 FT EQUIP. COMP.)	3,370 LBS	
ORIENTATION CONTROLS	690	
ELECTRICAL POWER	290	
COMMUNICATIONS	200	
ENVIRONMENTAL CONTROL	730	
INSTRUMENTATION	130	
PERSONNEL PROVISIONS	630	
DISPLAYS AND CONTROLS	320	
DOCKING HARDWARE	610	
CONTINGENCY (20%)	1,390	
NOSE FAIRING - EFFECTIVE WGT.	40	
• TOTAL PAYLOAD AVAILABLE FOR MISSION EQUIPMENT AND EXPERIMENTS		22,600 LBS

[redacted]

APOLLO X REVIEW

APOLLO X AND MOL MISSION CAPABILITY

[redacted]

[redacted]

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SUMMARY APOLLO X AND MOL

[redacted]

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APOLLO X AND MOL

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#61

General conclusions of the growth comparison are contained in Chart #62. The T-IIIC/MOL system is concluded to offer superior growth characteristics for both Eastern and Western Test Range Operations. The T-IIIC system appears to afford a very orderly sequence of growth from early 30-day integral launch missions to a wide variety of operationally interesting missions [redacted]

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[redacted] UNCLASSIFIED

APOLLO X REVIEW
GROWTH COMPARISON

CONCLUSIONS:

√ APOLLO X MODIFIED TO MOL REQUIREMENTS HAS NO GROWTH CAPABILITY AT "ETR" OR "WTR"

√ APOLLO X USED IN A RENDEZVOUS/RESUPPLY MODE CAN MEET MOL PAYLOAD REQUIREMENTS WITH A 49 DAY RESUPPLY CYCLE(CURRENT SIB UPRATING)

√ SATURN IB REQUIRES UPRATING TO ~61, 200 LBS. ON-ORBIT PAYLOAD AT ETR TO MEET MOL -

- RESUPPLY CYCLE OF 142 DAYS
- PRESSURIZED LABORATORY VOLUME OF 2400 FT^3
- OPERATIONAL FLEXIBILITY AND CREW CONVENIENCE

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[redacted]

APOLLO X - MOL
COST COMPARISON

[redacted]

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Comparable system costs are presented in Chart #64. The estimates were based upon a six flight program, and include the previously described changes in the NAA/NASA Apollo X system to meet MOL requirements. It is emphasized that cost estimates indicated in Chart #64 do not represent total program cost, but provide a basis for cost differences. Supporting cost data are presented in Chart #65.

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COMPARABLE SYSTEM COSTS

(Dollars in Millions)

	APOLLO X	MOL
NONRECURRING	400.0	403.8
RECURRING (6 FLIGHTS)	480.6	250.8
TOTAL	880.6	654.6

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COMPARABLE SYSTEM COSTS

(Dollars in Millions)

	RECURRING COSTS		NONRECURRING COSTS	
	APOLLO X	MOL	APOLLO X	MOL
LAUNCH VEHICLE	28.9	12.8	---	25.1
PERSONNEL MODULE	40.2	16.8	166.0	125.5
LAB VEHICLE	11.0	12.2	234.0	253.2
TOTAL	80.1	41.8	400.0	403.8

A summary of the over-all conclusions developed by the present review of the Apollo X application to the MOL mission is presented in Chart #66. For the reasons shown, it is concluded that the Gemini B/T-IIIC MOL Vehicle system represents a more effective approach to MOL requirements than does the Apollo X concept.

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SUMMARY
EVALUATION OF APOLLO X FOR MOL MISSION

- O DISADVANTAGES OF APOLLO X AS COMPARED TO GEMINI B/ TITAN IIIC MOL
  - √ BASIC NAA LABORATORY DOES NOT MEET MOL REQUIREMENTS
  - √ HEAVIER ORBITING VEHICLE: LESS EXPERIMENTS PAYLOAD
  - √ LOWER CREW SAFETY & MISSION SUCCESS PROBABILITY
    - COMPLEX OPERATIONAL PROCEDURES
    - LIMITED MAINTENANCE CAPABILITY
    - CONTINUOUS OPERATION OF "LIFE BOAT"
  - √ INCREASED COST
  - √ LESS EFFECTIVE FOR GROWTH MISSIONS
- O CONCLUSION: GEMINI B/TITAN IIIC MOL IS THE BETTER SOLUTION

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APOLLO X REVIEW

BACK UP DATA

- √ CONFIGURATION & OPERATIONS
- √ WEIGHTS
- √ STRUCTURES
- √ ELECTRICAL POWER
- √ ENVIRONMENTAL CONTROL & LIFE SUPPORT
- √ STABILIZATION, CONTROL, & GUIDANCE
- √ COMMUNICATIONS & DATA HANDLING
- √ A. G. E.
- √ COSTS

[redacted]

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APOLLO X REVIEW

CONFIGURATION & OPERATIONS DATA

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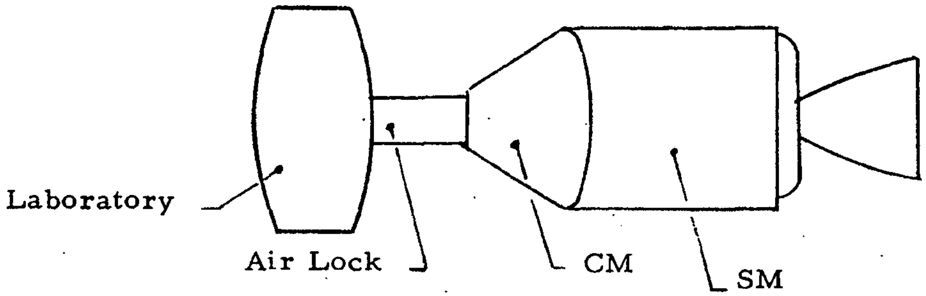
COMPARTMENTATION



√ LABORATORY

- o SINGLE COMPARTMENT INFLEXIBLE FOR OPERATIONAL USE
- o DOES NOT PROVIDE SHELTERED UNPRESSURIZED VOLUME
- o ACCESS THROUGH AIR-LOCK EXTENDS TRAVERSIBLE DISTANCE BETWEEN LAB AND CM
- o FORM FACTOR INEFFICIENT FOR CENTRIFUGE PROVISIONS

√ AIR-LOCK

- o USED AS VENTILATION SYSTEM SUPPLY FROM CM TO LAB
- o INADEQUATE FOR CREW TRANSFER IN PRESSURIZED SUIT
- o VOLUME INADEQUATE FOR EXTRA-VEHICULAR OPERATIONS OF CREW WITH AMU
- o DOES NOT PERMIT STORAGE AND CHECK OUT OF E. V. EQUIPMENTS

√ CM

- o REQUIRES DISMANTLING AND STOWAGE OF COUCH AND DOCKING HARDWARE FOR OPERATION

√ SM

- o AVAILABLE UNPRESSURIZED VOLUME ACCESSIBLE BY E. V. OPERATIONS ONLY

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COMPARTMENTATION

✓ CONCLUSIONS

- o MISSION OPERATIONS RESTRICTED BY CONFIGURATION
  - LABORATORY CAN NOT BE OCCUPIED DURING E. V. EXPERIMENTS
- o RETREAT TO CM IN EMERGENCY DIFFICULT
  - AIR-LOCK CAN NOT BE OCCUPIED BY MORE THAN ONE CREWMAN
  - GEOMETRY OF AIR-LOCK DOES NOT PERMIT TRANSFER OF INCAPACITATED CREW MAN IN PRESSURIZED SUIT
- o VOLUME AVAILABLE IN SM NOT SUITABLE FOR EQUIPMENTS REQUIRING CREW ACCESS
- o FORM FACTOR OF LAB INEFFICIENT FOR CENTRIFUGE PROVISIONS
- o CM VOLUME UTILIZATION REQUIRES UNDESIRABLE DISASSEMBLY TASKS

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DOCKING PROVISIONS
(RESUPPLY)

- o MOL REQUIREMENT FOR LONG DURATION RESUPPLY

- o APOLLO X HAS NO PROVISIONS FOR RENDEZVOUS MISSIONS
  - √ DIFFICULT TO INCLUDE CAPABILITY IN PROPOSED CONFIGURATION
  - √ WEIGHT PENALTY WILL BE INCURRED
  - √ DYNAMICS PROBLEMS TO BE OVERCOME
  - √ DOCKING ACCIDENT COULD RENDER LABORATORY INOPERATIVE OR CAUSE CATASTROPHIC DAMAGE TO CM

- o CONCLUSION
  - √ APOLLO X CONFIGURATION UNDESIRABLE FOR RENDEZVOUS OPERATIONS

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CREW SAFETY

✓ON-ORBIT HAZARD

- o FIRE OR ATMOSPHERE CONTAMINATION IN LABORATORY
  - RETREAT TO CM IS REQUIRED
- o FIRE OR ATMOSPHERE CONTAMINATION IN CM
  - RETREAT TO LABORATORY
  - LIFE SUPPORT AND REPAIR OPERATIONS USING PORTABLE UNITS
- o DOCKING ACCIDENT
  - DAMAGE TO CM
- o CM DEGRADATION
  - CONTINUOUS USE DURING MISSION OPERATIONS

✓MISSION TERMINATION OR ABORT

- o MANUAL DISCONNECT OF FLUID LINES AND ELECT. UMBILICALS
- o REINSTALL CREW COUCH FOR LANDING
- o RESTART LIQUID SM ENGINE FOR DE-ORBIT
  - LONG TERM STORAGE CONSIDERATION
  - REDUNDANT SYSTEM (SOLID ROCKETS)

✓CONCLUSION

- o CREW HAZARD HIGHER THAN MOL IN PROPOSED CONFIGURATION

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MOL RENDEZVOUS OPERATIONS

✓ DUAL LAUNCH AND DOCK TWO MOL'S

- INCREASE COMBINED EQUIPMENT PAYLOAD
- EXTENDED DURATION
- FLEXIBLE CREW SIZE (2 OR 4)

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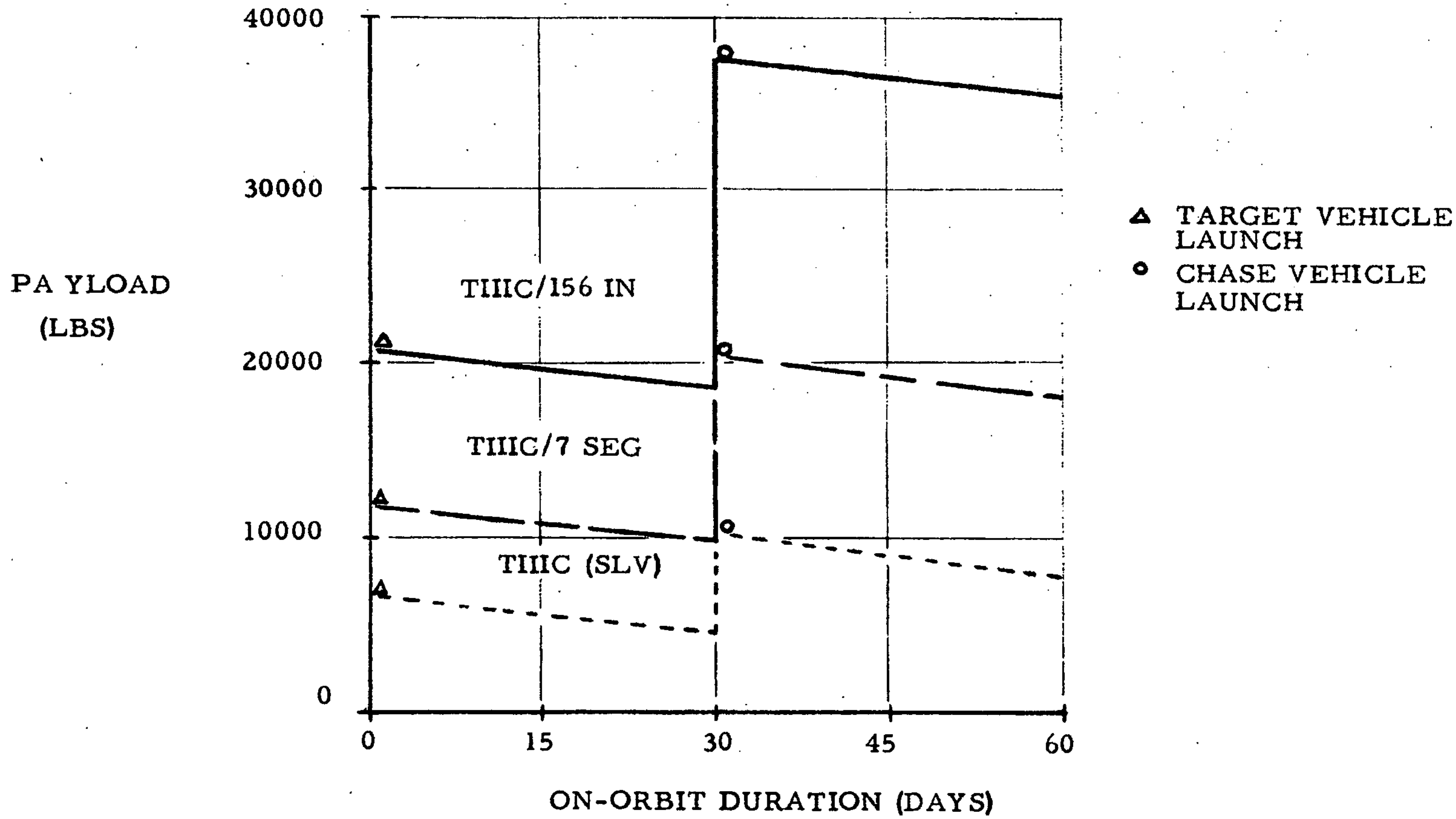
MOL RENDEZVOUS MISSION POTENTIAL

PAYLOAD VS. ON-ORBIT DURATION

- o 2 MAN CREW
- o ETR OPERATIONS
- o 160 N. MI. ORBIT



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MOL

RENDEZVOUS CONFIGURATION WEIGHT SUMMARY

- 160 N. MI.ORBIT
- ETR OPERATIONS

ITEM		TARGET VEHICLE (LBS)	CHASE VEHICLE (LBS)
√GEMINI B SEGMENT		6,600	6,600
√LABORATORY VEHICLE SEGMENT			
o BASELINE (30 DAY PROVISIONS LESS ELECTRICAL POWER REACTANTS)		10,540	10,540
o ELECTRICAL POWER REACTANTS		*1,040	**1,260
o DOCKING PROVISIONS		610	2,080
VEHICLE NET WEIGHT (LESS DISCRETIONARY PAYLOAD)		18,790	20,480
√DISCRETIONARY PAYLOAD			
o TIIIC STANDARD	(23,500)	4,710	3,040
o TIIIC/7 SEGMENT SRM	(28,600)	9,810	8,120
o TIIIC/156 IN. SRM	(37,980)	*** 18,590	*** 16,900

* 30 DAYS AT 1.40 KW AVG. (PRE-RENDEZVOUS)

** 30 DAYS AT 1.58 KW AVG. (DOCKED CONFIGURATION)

*** INCLUDES 600 LB. PENALTY FOR 10 FT. EQUIPMENT COMPARTMENT.

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MOL RENDEZVOUS OPERATIONS

EXPENDABLES SUMMARY

- TWO-MAN CREW
- 60 DAY MISSION
- RENDEZVOUS 30 DAYS AFTER FIRST LAUNCH

ITEM	TARGET VEHICLE (LBS/DAY)	DOCKED CONFIGURATION (LBS/DAY)
REACTION CONTROL PROPELLANTS	2.5	2.5
LIFE SUPPORT EXPENDABLES	(24.5)	(24.5)
OXYGEN - SUPERCRITICAL	8.5	8.5
OXYGEN - HIGH PRESSURE	0.3	0.3
NITROGEN - SUPERCRITICAL	3.3	3.3
LITHIUM HYDROXIDE & ACTIVATED CHARCOAL	7.2	7.2
DISPOSABLE CLOTHING, TISSUES, CHEMICALS	1.2	1.2
FOOD	4.0	4.0
FUEL CELL REACTANTS	*34.7	**42.0
SPARES AND REDUNDANCY	7.0	7.0
RECREATION, EXERCISE & MEDICAL EQUIPMENT	1.5	1.5
TOTALS	70.2	78.5

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* 30 DAYS AT 1.4 KW AVERAGE POWER (PRE-RENDEZVOUS)

** 30 DAYS AT 1.58 KW AVERAGE POWER (DOCKED VEHICLES)

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MOL RENDEZVOUS OPERATIONS

POWER DOWN ELECTRICAL LOADS

	TARGET VEHICLE WATTS AVE.	CHASE VEHICLE WATTS AVE.
COMMUNICATIONS	170	38
ATTITUDE CONTROL	130	-
EC/LSS	325	87
GEMINI B	-	150
LIGHTING	120	-
SUB TOTAL	745	275
EXPERIMENTS & COMPUTER	380	-
DISPLAYS	60	-
MISCELLANEOUS	60	60
TOTALS	1245	335

TOTAL POWER 1580

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MOL GROWTH POTENTIAL

MOL BASELINE POWER DOWN ELECTRICAL LOAD CAPABILITY

SUBSYSTEM	BASELINE 30 DAY MISSION AVE. PWR. (WATTS)	EXTENDED DURATION MISSION AVE. PWR. (WATTS)
COMMUNICATIONS, INSTR. & DATA MANAGEMENT	170	170
ATTITUDE CONTROL (50% DUTY CYCLE)	235	130
EC/LS (SHIRT SLEEVE)	390	325
LIGHTING	120	60
GEMINI B (ORBITAL STORAGE)	150	150
DISPLAYS	60	60
TRANSTAGE	100	0
MISCELLANEOUS	50	0
SUB TOTAL	1275	895
EXPERIMENTS	250	250
COMPUTER	130	130
CONTINGENCIES	145	0
	1800	1275

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APOLLO X REVIEW

WEIGHTS DATA

WEIGHT SUMMARY

NAA PROPOSAL VS. AEROSPACE APOLLO X ESTIMATE

	NAA PROPOSAL APOLLO X/ SATURN IB 3 MEN-45 DAYS	A ESTIMATE OF APOLLO X/ SATURN IB 2 MEN-30 DAYS
RE-ENTRY VEHICLE		
RE-ENTRY VEHICLE	9,600	9,600
CONTINGENCY	0	1,440
SERVICE MODULE (INCLUDING PROPELLANT)		
SERVICE MODULE	15,420	14,180
CONTINGENCY	0	1,190
LABORATORY (LESS EXPERIMENTS)		
LABORATORY VEHICLE SEGMENT	2,630	5,410
CONTINGENCY	0	1,090
BOOSTER ADAPTER	3,500	3,500
AVAILABLE WEIGHT FOR EXPERIMENTS	1,500	-3,610
TOTAL ON-ORBIT WEIGHT	32,650	32,800 (a)

(a) EAST LAUNCH, 80-160 N. M. ELLIPTICAL ORBIT.

RE-ENTRY VEHICLE WEIGHT COMPARISON

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	NAA APOLLO X PROPOSAL 3 MEN-45 DAYS	AEROSPACE ESTIMATE OF APOLLO X 2 MEN-30 DAYS
STRUCTURE	4,683	4,683
STABILITY AND CONTROL	256	256
GUIDANCE AND NAVIGATION	0	229
CREW SYSTEMS	395	395
EARTH LANDING SYSTEMS	743	743
INSTRUMENTATION	198	198
ELECTRICAL POWER	614	614
COMMUNICATIONS	367	367
CONTROL AND DISPLAYS	373	373
REACTION CONTROL	339	339
ENVIRONMENTAL CONTROL	341	341
USEFUL LOAD	(1,290)	(1,064)
CREW SYSTEMS (INCLUDING FOOD)	952	760
REACTION CONTROL	270	270
ENVIRONMENTAL CONTROL	68	34
TOTAL	9,599	9,602

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SERVICE MODULE WEIGHT COMPARISON*

	NAA APOLLO X PROPOSAL 3 MEN-45 DAYS	(A) ESTIMATE OF APOLLO X 2 MEN-30 DAYS
STRUCTURE	2,451	2,451
INSTRUMENTATION	115	115
ELECTRICAL POWER (DRY WEIGHT)	2,499	2,605
COMMUNICATIONS	99	99
REACTION CONTROL (DRY WEIGHT)	1,135	596
ENVIRONMENTAL CONTROL (DRY WEIGHT)	489	379
PROPULSION	1,689	2,886
USEFUL LOAD	(6,947)	(5,050)
ELECTRICAL POWER	1,869	1,150
REACTION CONTROL	1,236	450
ENVIRONMENTAL CONTROL	874	482
RESIDUAL PROPELLANT	250	250
USABLE PROPELLANT	2,718	2,718
TOTAL	15,424	14,181

*LESS EXPERIMENTS, INCLUDES PROPELLANT

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LABORATORY VEHICLE WEIGHT COMPARISON*

	NAA APOLLO X PROPOSAL 3 MEN-45 DAYS	AEROSPACE ESTIMATE OF APOLLO X 2 MEN-30 DAYS
STRUCTURE	1,665	2,839
ORIENTATION CONTROLS (LESS PROP.)	0	150
ELECTRICAL POWER (LESS REACTANTS)	121	370
INSTRUMENTATION	47	130
COMMUNICATIONS	2	174
ENVIRONMENTAL CONTROL SYSTEM (LESS EXPENDABLES)	101	505
PERSONNEL PROVISIONS	81	610
DISPLAYS AND CONTROLS	75	216
SPARE PARTS	0	140
EXPENDABLES	(534)	(275)
FOOD	158	0
OXYGEN-SUPERCRITICAL	0	0
OXYGEN-HIGH PRESSURE	25	10
NITROGEN-SUPERCRITICAL	0	0
WATER-RESERVE	0	15
LITHIUM HYDROXIDE	351	215
DISPOSABLE CLOTHING, TISSUES, CHEMICALS	0	35
REACTANTS - 1,550 WATTS AVE.	0	0
PROPELLANT-USABLE	0	0
TOTAL	2,626	5,409

*LESS CONTINGENCY

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WEIGHT COMPARISON SUMMARY

MOL VS. AEROSPACE ESTIMATE OF APOLLO-X

	MOL EXTIMATE GEMINI B/ TITAN IIIC 2 MEN-30 DAYS	(A) ESTIMATE OF APOLLO X/ SATURN IB 2 MEN-30 DAYS
RE-ENTRY VEHICLE		
RE-ENTRY VEHICLE	4,730	9,600
CONTINGENCY	200	1,440
SERVICE MODULE (INCLUDING PROPELLANT)		
SERVICE MODULE	1,570	14,180
CONTINGENCY	100	1,190
LABORATORY (LESS EXPERIMENTS)		
LABORATORY VEHICLE SEGMENT	9,750	5,410
CONTINGENCY	2,000	1,090
BOOSTER ADAPTER	0	3,500
AVAILABLE WEIGHT FOR EXPERIMENTS	5,150	-3,610
TOTAL ON-ORBIT WEIGHT	23,500	32,800 (a)

(a) EAST LAUNCH, 80-160 N. M. ELLIPTICAL ORBIT.

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LABORATORY VEHICLE WEIGHT COMPARISON*

MOL VS. AEROSPACE ESTIMATE OF APOLLO-X

	AEROSPACE GEMINI B MOL 2 MEN-30 DAYS	AEROSPACE ESTIMATE OF APOLLO X 2 MEN-30 DAYS
STRUCTURE	2,770	2,839
ORIENTATION CONTROLS (LESS PROP.)	690	150
ELECTRICAL POWER (LESS REACTANTS)	1,960	370
INSTRUMENTATION	130	130
COMMUNICATIONS	285	174
ENVIRONMENTAL CONTROL SYSTEM (LESS EXPENDABLES)	890	505
PERSONNEL PROVISIONS	630	610
DISPLAYS AND CONTROLS	315	216
SPARE PARTS	140	140
EXPENDABLES	(1,945)	(275)
FOOD	120	0
OXYGEN-SUPERCRITICAL	255	0
OXYGEN-HIGH PRESSURE	10	10
NITROGEN-SUPERCRITICAL	110	0
WATER-RESERVE	15	15
LITHIUM HYDROXIDE	215	215
DISPOSABLE CLOTHING, TISSUES, CHEMICALS	35	35
REACTANTS - 1,550 WATTS AVE.	1,150	0
PROPELLANT-USABLE	35	0
TOTAL	9,755	5,409

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APOLLO X REVIEW

STRUCTURES/MECHANICAL

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METEOROID DESIGN

- PHILOSOPHY
  - / NAA ACCEPTANCE OF ONE HIT DURING 45 DAY MISSION DURATION CONSIDERED UNCONSERVATIVE AND DETRIMENTAL TO CREW SAFETY ~
    1. INSUFFICIENT FLUX AND PENETRATION DATA WARRANT HIGH PROBABILITY OF NO PENETRATION ($P_o = 0.995$) DESIGN ESPECIALLY FOR RELATIVELY SHORT MISSION DURATIONS ($T \leq 180$ DAYS)
- FLUX AND PENETRATION CRITERION
  - / NO CONSIDERATION OF STREAM FLUX NOR YEARLY VARIATION OF SPORADIC FLUX NOTED ~
    1. FOR MISSIONS LESS THAN ONE YEAR, SPORADIC FLUX CRITERION SHOULD BE INCREASED OVER YEARLY AVERAGE.
  - / EFFICIENCY FACTORS FOR TWO WALL CONFIGURATIONS ARE MORE OPTIMISTIC THAN AEROSPACE CRITERION ~
    1. AEROSPACE FACTORS ARE ACCEPTED BY NASA/MSC
    2. NASA/AEROSPACE FACTORS ARE USED IN CURRENT GEMINI CRITERION
  - / NO CONSIDERATION GIVEN TO RELATIVE THICKNESSES OF BUMPER & BACK-UP PLATE IN APPLICATION OF TWO SHEET CRITERION ($t_B \leq 0.25\ t_{Total}$)
  - / NO SAFETY FACTOR APPLIED TO SAFE LIFE OR THICKNESS
    1. LARGE UNCERTAINTIES INHERENT IN ANALYSES WARRANT A SAFETY FACTOR APPROACH
  - / COMMAND MODULE ANALYSIS APPLICATION OF ALUMINUM PENETRATION CRITERION TO ORGANIC ABLATOR MATERIAL CONSIDERED INVALID
    1. BEHAVIOR OF SHOCK PROPAGATION, ENERGY ABSORPTION, ETC., NOT CONSIDERED ACROSS-THE-BOARD TYPICAL BETWEEN METALLICS & ORGANICS

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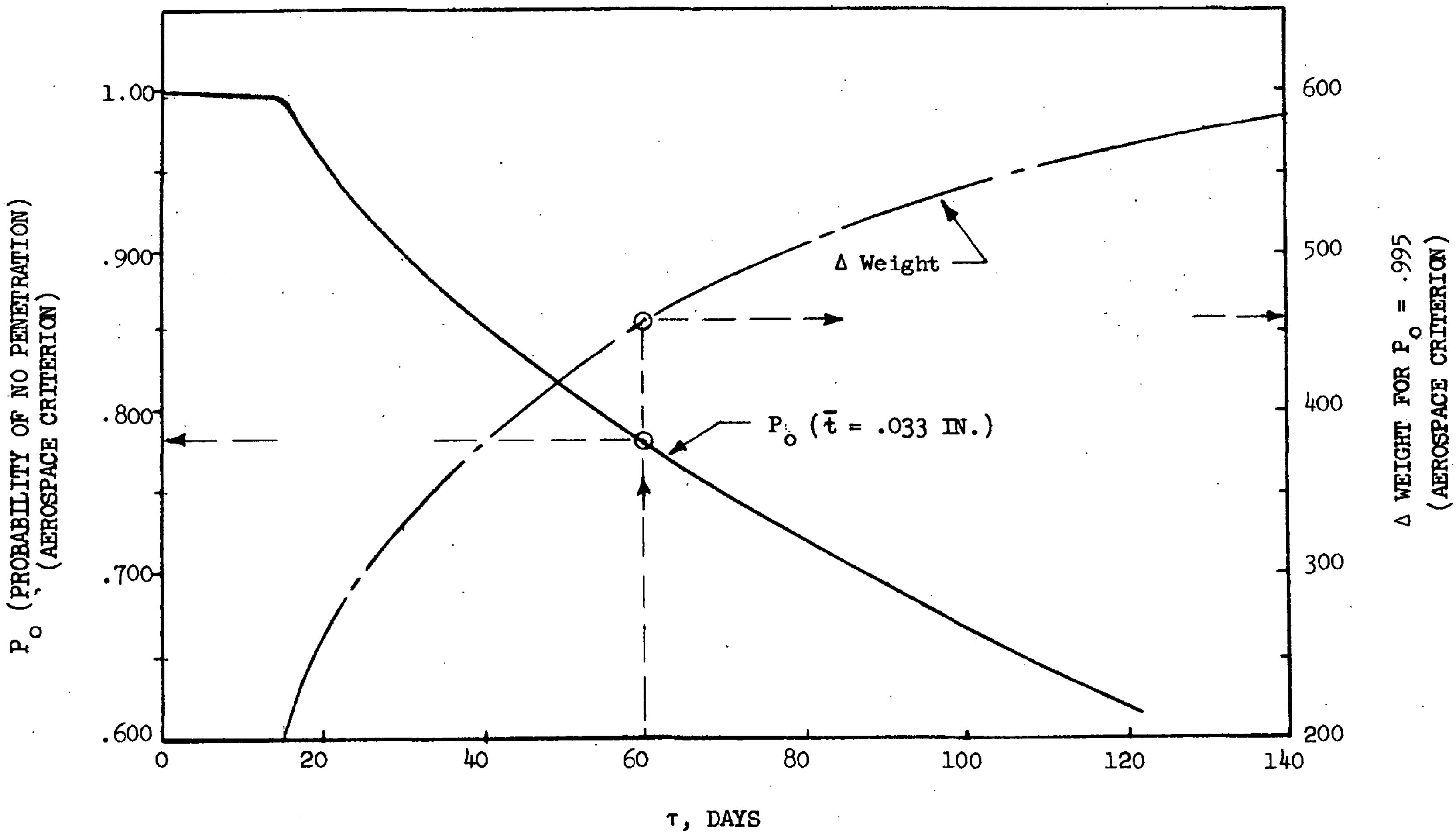
METEOROID CRITERIA COMPARISON

NAA - AEROSPACE CRITERION

NAA BASELINE $\bar{t}$ = .033" ($P_{x=1}$ = 0.995, τ = 45 days)



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STRUCTURAL DESIGN

AN AEROSPACE EVALUATION OF THE NAA DESIGN, SUBJECTED TO MOL REQUIREMENTS AND DESIGN CRITERIA, YIELDED THE FOLLOWING ~

- LABORATORY (PRESSURIZED STRUCTURE)
  - / NO CONSIDERATION GIVEN BY NAA TO HYPERVELOCITY IMPACT (METEOROIDS)/ CRITICAL CRACK LENGTH CONDITIONS
    - o AEROSPACE RATIONALE:
      1. EXPOSURE TO METEOROIDS AND ACCEPTANCE OF "ONE HIT" PHILOSOPHY BY NAA MAKES CONSIDERATION MANDATORY
      2. LOWER OPERATING STRESS (INCREASED GAGE) ELIMINATES CATASTROPHIC FAILURE MODE
  - / NAA END BULKHEAD STRUCTURAL WEIGHTS CONSIDERED GROSSLY UNCONSERVATIVE
    - o AEROSPACE RATIONALE
      1. NAA SHALLOW HEAD GEOMETRY ($a/b \approx .27$) YIELDS MUCH LARGER WEIGHT VALUE THAN NAA QUOTED VALUE (SEE TABLE)
      2. FOR 192" DIA., HEAD GEOMETRY SHOULD RANGE FROM $.5 < a/b < 1.0$ TO PROVIDE NEAR OPTIMUM WEIGHT (SEE TABLE)
  - / NAA CYLINDER WEIGHT CONSIDERED LOW
    - o AEROSPACE RATIONALE
      1. SHELL BUCKLING DESIGN FOR LAUNCH LOADS DICTATE GREATER WEIGHT THAN GIVEN (SEE TABLE)
  - / NAA METEOROID PROTECTION STRUCTURE CONSIDERED INADEQUATE WHEN COMPARED WITH AEROSPACE CRITERION
    - o AEROSPACE RATIONALE
      1. OVERALL WEIGHT (440#) COMPARABLE ($4\#/FT^3$ ENERGY ABSORBER) BUT $\bar{t}_B = .033$ CONSIDERED INADEQUATE ($P_o = 0.995$)

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STRUCTURAL DESIGN (CONT.)

- SUPPORT SYSTEM
  - / NAA WEIGHT FOR SUPPORT STRUCTURE BETWEEN LAB AND LEM ADAPTOR CONSIDERED LOW
    - o AEROSPACE RATIONALE
      1. SHELL BUCKLING DESIGN FOR LAUNCH LOADS DICTATE GREATER WEIGHT THAN GIVEN (SEE TABLE)

•• CONCLUSION

STRUCTURAL DESIGN OF LABORATORY AND SUPPORT SYSTEM TO MEET MOL REQUIREMENTS RESULTS IN APPROXIMATELY 1200 LB INCREASE OVER NAA QUOTES

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CRYOGENIC TANKAGE

COMPARISON WITH CURRENT TECHNOLOGY METHODOLOGY STUDIES PERFORMED BY AEROSPACE RESULTS IN THE FOLLOWING:

- APOLLO X MAXIMUM UTILIZATION OF EXISTING APOLLO HARDWARE CONSIDERED INVALID BECAUSE
  - / PROPOSED SYSTEM NOT COMPATIBLE WITH EXISTING APOLLO
    1. LARGER TANKS - 40" x 58" vs 28"
    2. LONGER MISSION REQUIREMENTS - 45 DAYS vs 14 DAYS
  - / ONLY 60% OF COMPONENT LEVEL ITEMS CAN BE UTILIZED
    1. 40% COMPONENTS REQUIRE DESIGN PROOFING DUE TO LARGE TANK REQUIREMENTS
- ADDITIONAL REQUIREMENTS IMPOSE LONGER SCHEDULES
  - / TANKAGE QUALIFICATION AND AVAILABILITY REQUIRE AS MUCH OR LONGER TIME THAN PROPOSED MOL TANKAGE
    1. MINIMUM OF 20 - 22 MONTHS INSTEAD OF 16 MONTHS
    2. CURRENT APOLLO AND GEMINI PROGRAMS REQUIRED MORE THAN 24 MONTHS

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APOLLO X REVIEW

ELECTRICAL POWER

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APOLLO X REVIEW

ELECTRICAL POWER LOAD ANALYSIS

SUBSYSTEM	TOTAL D.C. AVERAGE POWER (WATTS)		
	APOLLO X	MOL BASELINE	AEROSPACE APOLLO X MOL
COMMUNICATIONS	180	170	180
ECS	453	390	453
ATTITUDE CONTROL	2	235	235
LIGHTING	181	120	181
DISPLAY	7	60	7
CREW SYSTEMS	7		7
SERVICE PROPULSION	16		16
S/M RCS	5		5
GEMINI B (ORBITAL STORAGE)		150	
LAB THERMAL CONTROL			150
TRANSTAGE		100	
MISCELLANEOUS		60	60
SUB-TOTAL	851	1,275	1,294
COMPUTER	119	130	130
EXPERIMENTS	200	250	250
TOTAL	1,170	1,655	1,674

CONCLUSIONS: APOLLO X MOL POWER REQUIREMENTS ARE EQUIVALENT TO THE MOL BASELINE

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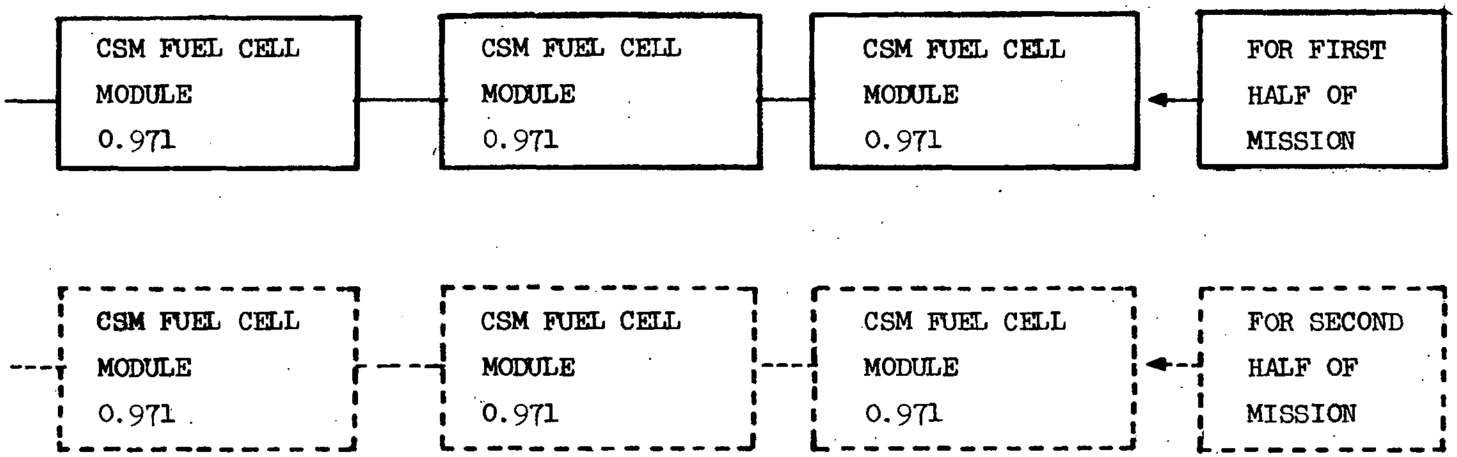
APOLLO X REVIEW

FUEL CELL RELIABILITY LOGIC DIAGRAM

*NAA RECOMMENDED SYSTEM CONFIGURATION FOR MOL.



RELIABILITY = .83814 (30 DAYS)
EPS REL. REQMT. = .984

CONCLUSION: SIX CSM FUEL CELL MODULES REQUIRED

*REFERENCE: SSD-TDR 64-221 "MOL ELECTRICAL POWER SUBSYSTEM STUDY," NORTH AMERICAN AVIATION, INC., OCT., 1964

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APOLLO X REVIEW

ENVIRONMENTAL CONTROL AND LIFE SUPPORT

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APOLLO X - MOL MISSION
EC/LS ADDITIONAL REQUIREMENTS

- ATMOSPHERE SUPPLY
  - 0_2 ACCUMULATOR (FOR EVA AND EMERGENCY REPRESSURIZATION)
  - SINGLE GAS/DUAL GAS MODE SELECTION PROVISIONS
  - 0_2 AND N_2 SUPPLY TO AIRLOCK
  - 0_2 UMBILICAL CONNECTIONS IN AIRLOCK (FOR EVA)
  - 0_2 AND N_2 SUPPLY TO LABORATORY
- ATMOSPHERE CONTROL
  - SUIT LOOP CIRCULATION FAN
  - CABIN LOOP WATER SEPARATION PROVISIONS
  - SUIT LOOP DUCTING TO AND FROM LABORATORY
  - CABIN LOOP DUCTING TO AND FROM LABORATORY
  - VENTILATION FANS IN LABORATORY
- THERMAL CONTROL
  - LABORATORY RADIATOR (SIZED FOR 3.6 KW PEAK EXPERIMENT LOAD)
  - ADEQUATE DEW POINT CONTROL PROVISIONS
- LIFE SUPPORT
  - PROVISIONS FOR THE RETURN TO EARTH OF FECAL SAMPLES

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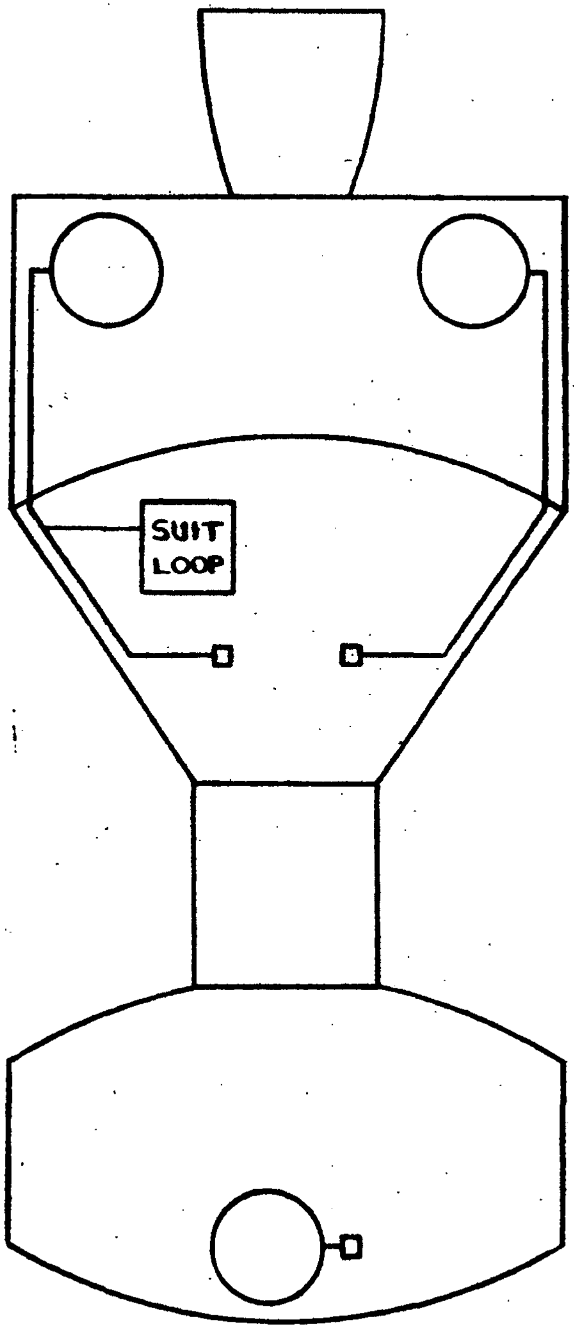

APOLLO X - MOL MISSION

ATMOSPHERE SUPPLY SUBSYSTEM

- IDENTIFIED PROVISIONS
  - O_2 SUPERCRITICAL STORAGE IN SM
  - N_2 SUPERCRITICAL STORAGE IN SM
  - O_2 3.5 PSIA O_2 DEMAND PRESSURE TO CM
  - O_2 3.5 PSIA O_2 PARTIAL PRESSURE TO CM
  - N_2 7.0 PSIA O_2 TOTAL PRESSURE TO CM
  - O_2 GASEOUS STORAGE (25 LB) IN LM

- ADDITIONAL PROVISIONS
  - O_2 ACCUMULATOR STORAGE (26 LB) IN SM
  - O_2 5.0 PSIA O_2 TOTAL PRESSURE TO CM
  - O_2 GASEOUS STORAGE (7 LB) IN CM
  - O_2 SUPPLY (3.5 PSIA PARTIAL/5.0 PSIA TOTAL) TO AIRLOCK
  - N_2 SUPPLY (7.0 PSIA TOTAL) TO AIRLOCK
  - O_2 EVA UMBILICAL SUPPLY (3.5 PSIA TOTAL) TO AIRLOCK
  - O_2 SUPPLY (3.5 PSIA PARTIAL/5.0 PSIA TOTAL) TO LM
  - N_2 SUPPLY (7.0 PSIA TOTAL) TO LM

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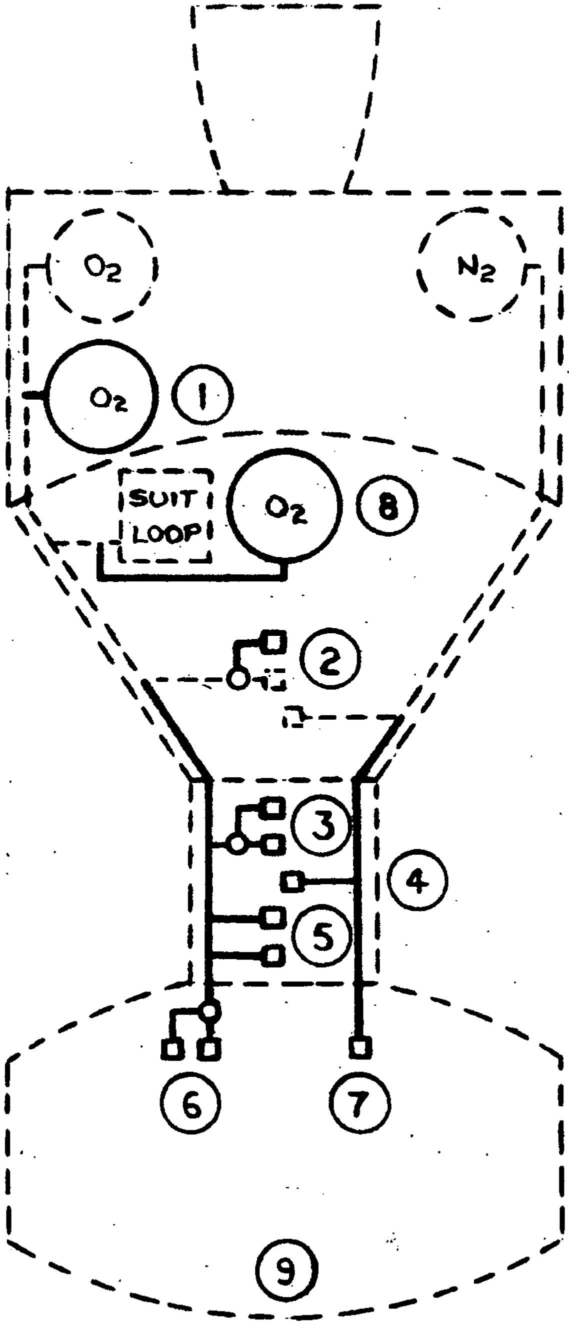
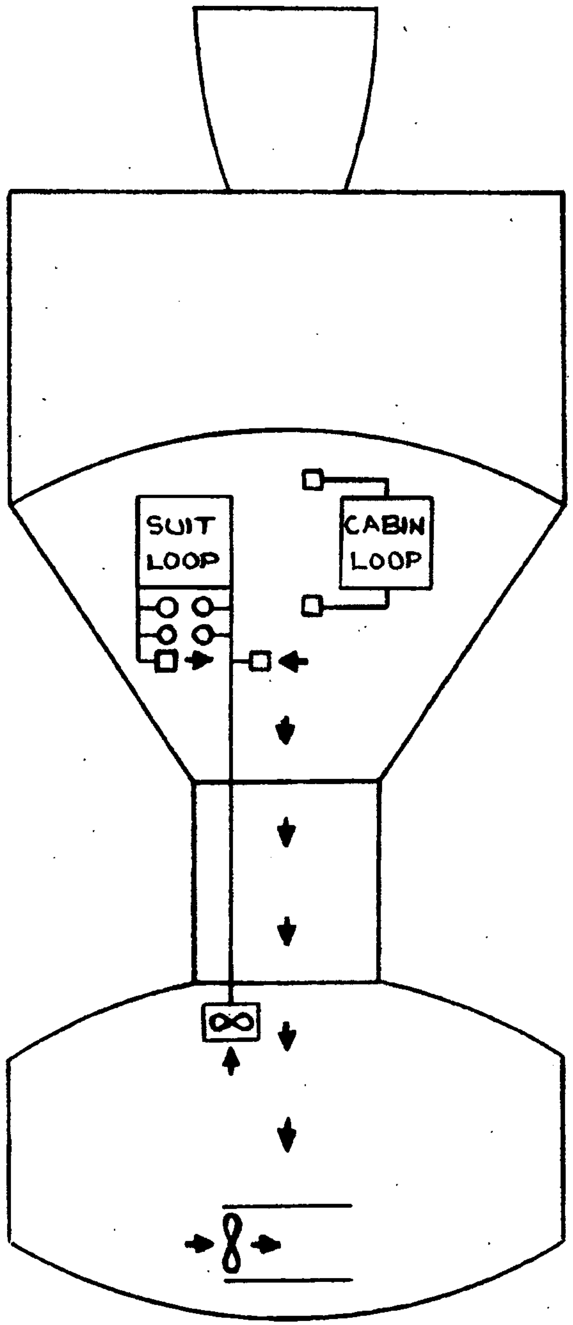


APOLLO X–MOL MISSION
ATMOSPHERE SUPPLY CHANGES

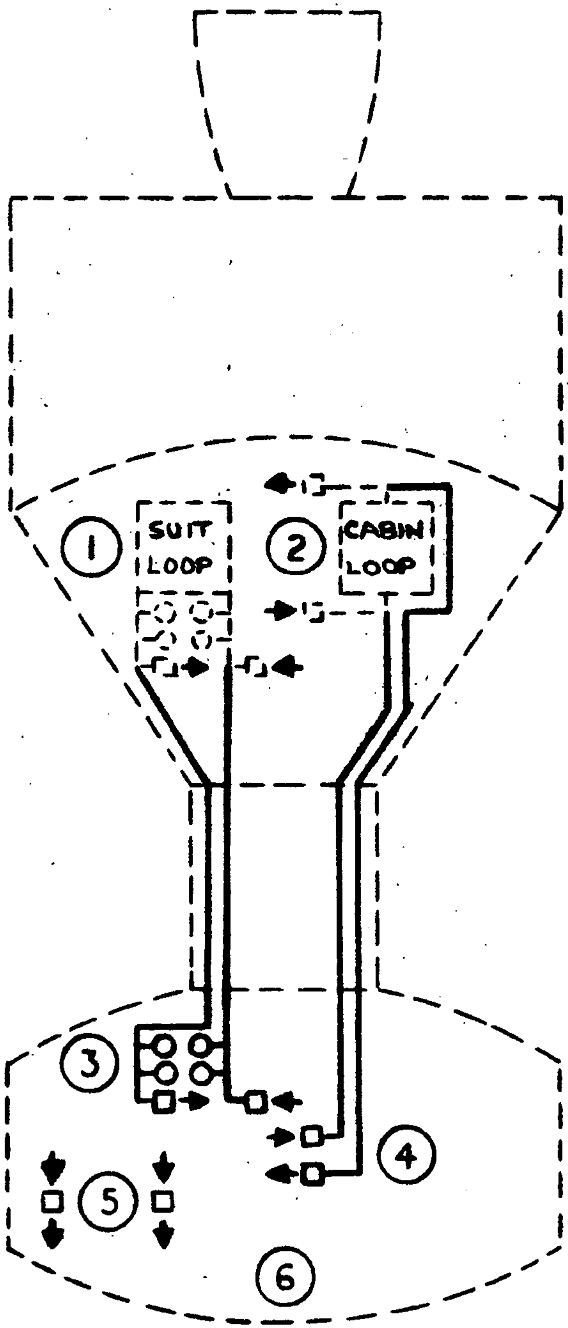
		(LB)
ADDITIONS		
1	O_2 ACCUMULATOR	52
2	GAS MODE SELECTION	4
3	O_2 SUPPLY TO AIRLOCK	12
4	N_2 SUPPLY TO AIRLOCK	6
5	O_2 UMBILICAL CONNECTIONS (EVA)	4
6	O_2 SUPPLY TO LABORATORY	14
7	N_2 SUPPLY TO LABORATORY	8
8	O_2 EMER SUPPLY (7 LB)	28
DELETIONS		
9	O_2 EMER SUPPLY (25 LB)	– 85
WEIGHT INCREASE		43



APPROLLO X - MOL MISSION

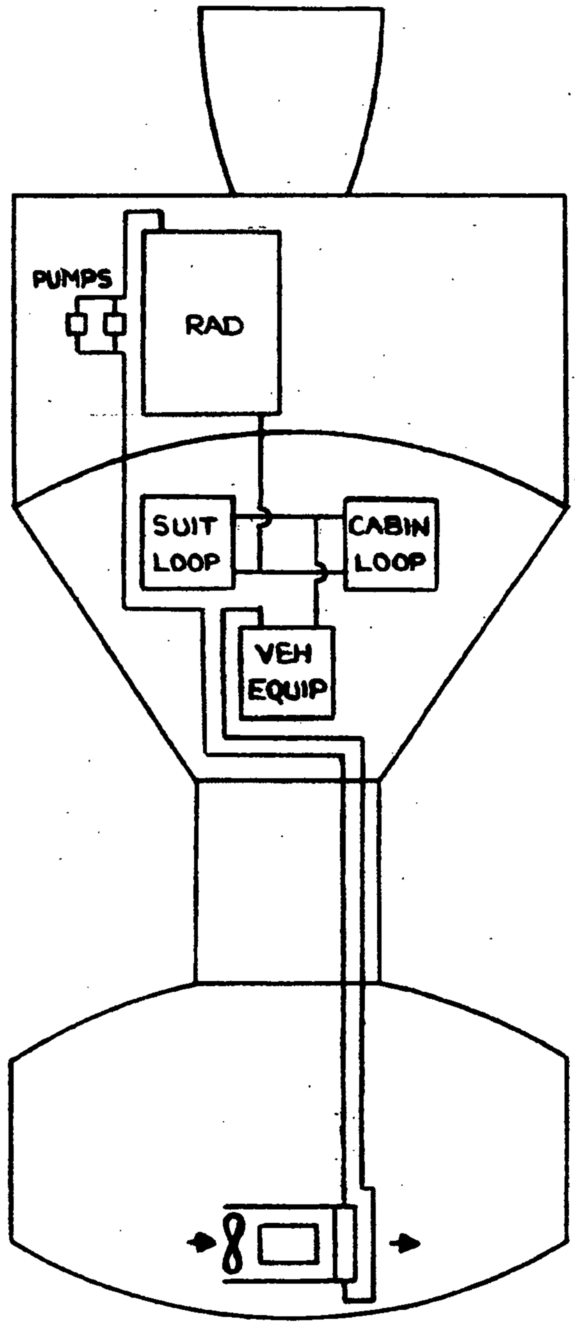
ATMOSPHERE CONTROL SUBSYSTEM

- IDENTIFIED PROVISIONS
  - CM SUIT LOOP
  - CM SUIT CONNECTIONS
  - CM CABIN LOOP
  - LM DUCTING TO CM SUIT LOOP
  - LM VENTILATION
- ADDITIONAL PROVISIONS
  - CM SUIT LOOP VENTILATION FAN
  - CM CABIN LOOP WATER SEPARATION
  - REVISED LM DUCTING TO CM SUIT LOOP
  - LM DUCTING TO CM CABIN LOOP
  - LM SUIT CONNECTIONS
  - REVISED LM VENTILATION



APOLLO X–MOL MISSION
ATMOSPHERE CONTROL CHANGES

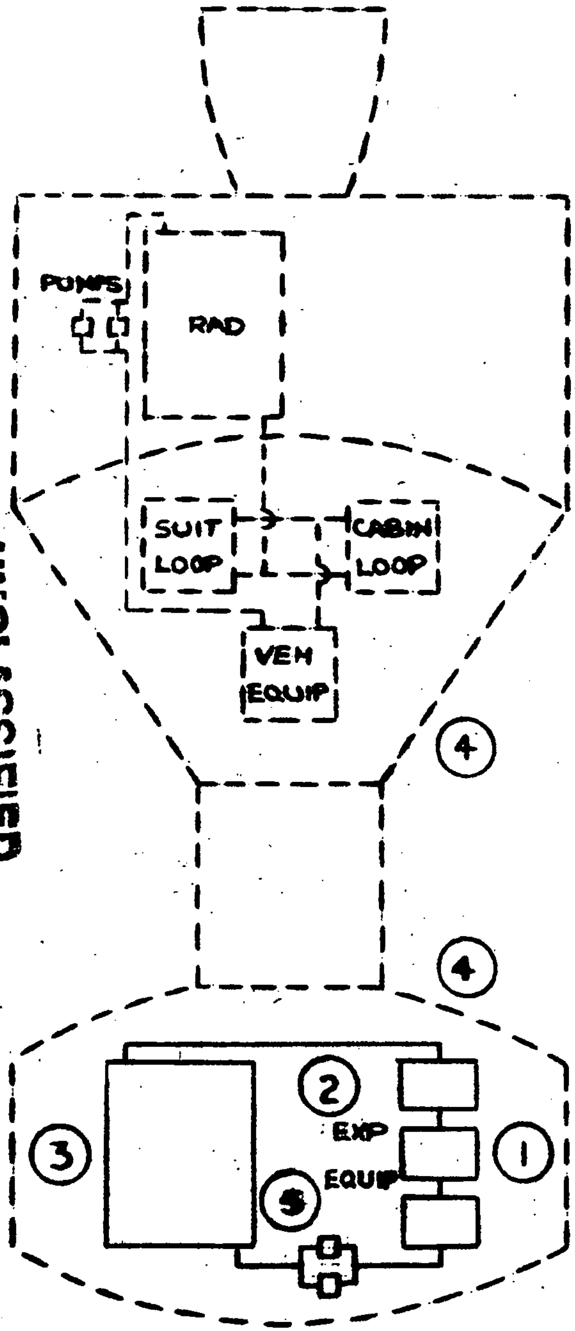
	(LB)
ADDITIONS	
(1) CIRCULATION FAN(2)	8
(2) WATER SEPARATION	12
(3) SUIT LOOP DUCTING	22
(4) CABIN LOOP DUCTING	40
(5) VENTILATION FAN (4)	12
DELETIONS	
(6) DUCTING & FAN	–10
WEIGHT INCREASE	84



APPOLLO X - MOL MISSION

THERMAL CONTROL SUBSYSTEM

- o IDENTIFIED PROVISIONS
  - RADIATOR IN SM
  - CREW TEMP CONTROL IN CM
  - EQUIP. TEMP CONTROL IN CM
  - LM CONNECTION TO SM/CM THERMAL CONTROL
- o ADDITIONAL PROVISIONS
  - PROPER DEW POINT CONTROL, CM
  - PROPER DEW POINT CONTROL, LM
  - SEPARATE LM THERMAL CONTROL [redacted] DESIGNED TO ACCOMMODATE 3.6KW EXP. RADIATOR INTEGRAL WITH LM SURFACE



APOLLO X–MOL MISSION THERMAL CONTROL CHANGES

	(LB)
ADDITIONS	
(1) COLDPLATES	30
(2) PUMPS, LINES, ECT.	60
(3) RADIATOR	40
(4) DEW POINT CONTROL	30
DELETIONS	
(5) DUCTING & FAN	– 17
WEIGHT INCREASE	143

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APOLLO X - MOL MISSION

EC/LS ADDITIONAL REQUIREMENTS

SUMMATION OF WEIGHT CHANGES

	ADDITION	DELETION	NET
ATMOSPHERE SUPPLY	128	-85	43
ATMOSPHERE CONTROL	94	-10	84
THERMAL CONTROL	160	-17	143
TOTAL	382	-112	270

[redacted]

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APOLLO X REVIEW

STABILIZATION AND CONTROL
& GUIDANCE

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[redacted]

[redacted] UNCLASSIFIED

APOLLO X REVIEW

STABILIZATION AND CONTROL SYSTEM

STABILIZING AND CONTROL SYSTEM (SCS)

/ OPERATING TIME LIMITATION

Reliability limits life to 150 hours in order to achieve reliability goal. Increased operating time would require either hardwired redundancy or inflight maintenance of the SCS Either of these solutions would require extensive modifications to Block II Apollo System.

RCS propellant requirements are prohibitive for long periods of operation. (6.4 lb/day) Reduction of impulse consumption would require elimination of couples and reduction of minimum impulse bit.

[redacted] UNCLASSIFIED

APOLLO X REVIEW

REACTION CONTROL SYSTEM

COMMAND MODULE RCS ENGINE

/ Extended exposure to space environment represents only significant potential problem area. This will require additional testing of Block II Apollo engines.

/ Modifications which could be required to solve problems disclosed during environmental tests will be similar for Gemini or Apollo Re-entry vehicles.

[redacted] UNCLASSIFIED

SERVICE MODULE RCS ENGINE

/ Changes from Block II Apollo requirements:

Increased duty cycle

Extended exposure to space environment

More severe thermal environment

Increased reliability allocation

/ Major problems are not anticipated. Requires testing and possible minor fixes

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RCS PROPELLANT TANKS

/ Increased storage life for command and service module systems and increased capacity for service module require changes, testing, and requalification of Block II Apollo equipment

[redacted]

APOLLO X REVIEW

TYPICAL SPECIFIC COMMENTS

In the evaluation of the contractors' studies it was recognized that the study was of a preliminary nature. The specific comments made below indicate that the study may have been too superficial in many areas, and when analyzed in more detail will indicate areas where additional time and money for development and testing are required to modify the Lunar Apollo components for the Apollo X mission.

The contractor evaluates the reliability of the Service Module RCS engine utilizing the operating life requirement of the Lunar Apollo which considers parts replacement, if necessary. The evaluation does not permit part replacement nor is an adjusted reliability figure utilized in the evaluation. The increased reliability requirement will therefore require definite development over Block II hardware.

No complete solution is given to solve the suggested thermal problem on the RCS engine.

No specific modifications to the Service Module engine were presented to achieve the higher reliability. A program of demonstration was suggested, but this additional testing, without modification, will not increase reliability.

[redacted]

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APOLLO X REVIEW

TYPICAL SPECIFIC COMMENTS (CONTINUED)

NAA selected a Service Module propellant tank system that the subcontractor, Bell, did not analyze or evaluate for the study A dual tank arrangement for each propellant is suggested with interconnecting lines and valving. The actual diagram of the selected concept is omitted from the report. All this secondary summarization indicates that a thorough analysis was not made in this area and potential problems may have been overlooked.

The stabilization and control system approach of utilizing drifting flight reduces the operating time in order to achieve the reliability goal, but probably will not be compatible with the control requirements dictated by the experiments as envisioned for MOL. This drifting mode is certainly not feasible for low altitude missions due to aerodynamic effects.

The contractor suggests that the minimum impulse bit can be reduced, but gives no specific system modifications that permit this reduction.

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[redacted]

GUIDANCE

[redacted]

[redacted]

APOLLO X REVIEW

GUIDANCE SYSTEM

/ Block II Apollo Guidance System is presently emerging from evolution and will not complete qual. testing until May, 1968

/ Computer (developed by Raytheon) is a wired program machine with approximately a year lead time for a program change.

/ Limited usage of the Guidance System is required to insure the reliability goals.

/ Apollo Guidance Optics do not have the capability or the growth potential of the MOL pointing and tracking scope.

[redacted]

[redacted]

APOLLO X REVIEW

COMMUNICATIONS AND DATA HANDLING

[redacted]

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[redacted]

APOLLO X REVIEW

COMMUNICATIONS AND DATA HANDLING

APOLLO X

- USES APOLLO BLOCK II EQUIPMENT
- WILL MEET APOLLO C & D REQUIREMENTS
- WILL NOT MEET EXPERIMENT REQUIREMENTS

[redacted]

APOLLO X REVIEW

NAA APOLLO X C & D WEIGHTS

• RE-ENTRY VEHICLE (COMMAND MODULE)	367	LBS
• SERVICE MODULE	99	LBS
• LABORATORY	2	LBS
• TOTAL	468	

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APOLLO X REVIEW

ADDITIONAL C & D EQUIPMENTS REQUIRED

	WEIGHT
S-BAND TRANSMITTER (2)	29.0
S-BAND AMPLIFIER (2)	33.5
PCM TM MULTIPLEXER (2)	4.5
SIGNAL CONDITIONER	50.0
RECORDER (2)	54.0
PREMODULATION PROCESSOR	12.0
COMMAND DECODER AND RELAYS	13.5
TELEPRINTER	12.0
SECURE EQUIPMENT	10.0
WIDEBAND TRANSMITTER	21.0
WIDEBAND RECORDER	73.0
TV CAMERA (2) AND CONTROL	30.0
TV MONITOR	15.0
LABORATORY C & D CONTROL PANEL, ETC.	25.0
MOUNT, ADDITIONAL EQUIPMENT	15.0
UMBILICALS TO RE-ENTRY VEHICLE	40.0
TOTAL	437.5 LBS

[redacted]

APOLLO X REVIEW

CONCLUSION

- APOLLO BLOCK II EQUIPMENT MUST BE AUGMENTED FOR APOLLO X MISSION
- ESTIMATED WEIGHT INCREASE ≈ 450 LBS
- TOTAL APOLLO X C & D - 905 LBS

[redacted]

A. G. E.

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AEROSPACE GROUND EQUIPMENT

APOLLO X

N. A. A. CLAIM	(A) COMMENT
o UNMODIFIED EQUIPMENT AT EACH SITE TO SUPPORT BOTH PROGRAMS ON AN INTEGRATED BASIS	NASA COMMITTMENTS DO NOT PERMIT INTEGRATED BASIS FOR APOLLO X GROUND OPERATIONS IN SAME TIME PERIOD ALLOTTED FOR APOLLO GROUND OPERATIONS
o 385 APOLLO AGE ITEMS, INCLUDING AUTOMATIC ACCEPTANCE CHECKOUT EQUIPMENT, OUT OF 421 AGE ITEMS REQUIRED FOR APOLLO X, ARE AVAILABLE WITHOUT MODIFICATIONS	REQUIREMENTS HAVE NOT BEEN ESTABLISHED FOR ANY OF THESE 385 ITEMS REGARDS PERFORMANCE, QUANTITY, LOCATION ETC.
o 20 APOLLO AGE ITEMS REQUIRE MODIFICATION FOR APOLLO X USE 16 AGE ITEMS ARE NEW FOR APOLLO USE	ABOUT 50% OF THESE ITEMS ARE ELECTRONIC AND ELECTRICAL EQUIPMENT WHICH IS EITHER INCOMPATIBLE FOR APOLLO GRD. OPERATIONS OR NON RELIABLE DUE TO HUMAN SWITCH-OVER ACTIVITIES REQUIRED.

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APOLLO X REVIEW

COST DATA

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APOLLO X - MODS TO APOLLO CSM + LAB

NAA ESTIMATE

1. ADD 1200 FT^3 LAB MODULE INCLUDING TUNNEL AND AIRLOCK
2. ADD 2 GAS ATMOSPHERE
3. ADD Li02 CANNISTERS TO CM
4. ADD CREW SUPPLIES
5. ADD 3 FUEL CELLS TO SM (TOTAL OF 5)
6. ADD REACTANT STORAGE (45 DAY TOTAL) IN SM
7. ADD ECS CRYOGENIC STORAGE (45 DAY TOTAL) IN SM
8. REPLACE SM PROPELLANT TANKS WITH SMALL TANKS
9. REMOVE G & N SYSTEM - EXCEPT OPTICS
10. ADD SPARES & REDUNDANCY TO MEET 45 DAY EARTH MISSION RELIABILITY GOALS

NAA COSTS FOR THE ABOVE:

	STANDARDIZED	OPTIMAL
CSM MODS	$20,246M	$17,146M
1200 FT^3 LAB	$50,000M	$50,000M

APOLLO X - MODS TO APOLLO CSM + LAB

(A) Additions to NAA List of Mods

1. LABORATORY STRUCTURE: Weight increased from 1200 lbs (NAA) to 2360 lbs giving a total Lab weight of 6000 lbs.

2. POWER SYSTEM: Add 1 more Fuel Cell (Total of 6) and 303 lbs of distribution hardware in Lab.

3. EC/LS: ATMOSPHERE SUPPLY

   O_2 Accumulator (for EVA and Emergency Repressurization)
   Single Gas/Dual Gas Mode Selector Provisions
   O_2 + H_2 Supply to Airlock
   O_2 Umbilical Connection in Airlock (For EVA)
   O_2 + N_2 Supply to Lab

   ATMOSPHERE CONTROL

   Suit Loop Circulating Fan
   Cabin Loop Water Separation Provisions
   Suit Loop Ducting to and from Lab
   Cabin Loop Ducting to and from Lab
   Ventilation Fans in Lab

   THERMAL CONTROL

   Lab Radiator (Sized for 3.6 KW Peak Experiment Load)
   Adequate dew point control provisions

   LIFE SUPPORT

   Provisions for Return to Earth of Fecal Samples

4. REACTION CONTROL (CM RCS ENGINE):

   Additional Test (Qualification) of Block 2 Engines

   Propellant Tanks Complete Redesign and Qualifications

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5. STABILIZATION AND CONTROL (HONEYWELL SYSTEM) IN CM:

Reliability now has 150 hour Life requirements:

Either revise Thermal Control System (moisture) to reduce humidity or add Redundancy in the form of additional electronic components to the Stabilization and Control system

6. ADD COMMUNICATIONS AND DATA HANDLING EQUIPMENT:

S-Band Transmitter (2)	29 lbs
S-Band Amplifier (2)	33.5 lbs
PCM TM Multiplexer (2)	4.5 lbs
Signal Conditioners	50.0 lbs
Recorder (2)	54.0 lbs
Pre-modulator Processor	12.0 lbs
Command Decoder & Relays	13.5 lbs
Teleprinter	12.0 lbs
Security Equip.	10.0 lbs
Wide Band Transmitter	21.0 lbs
Wide Band Recorder	73.0 lbs
TV Camera (2) and Control	30.0 lbs
TV Monitor	15.0 lbs
Laboratory Commun. & Data Control Panel	25.0 lbs
Mount, Additional Equip.	15.0 lbs
Umbilicals to RV	40.0 lbs
Total Additional Wt.	437.5 lbs

7. G & N: ADD 200 LBS BACK (REMOVED AT NAA ITEM 9)

8. AGE: ADD 1 SET ACE FOR CM, SM, LAB, LAUNCH VEHICLE

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COMPARABLE SYSTEM COSTS

(DOLLARS IN MILLIONS)

	RECURRING COSTS		NONRECURRING COSTS	
	APOLLO X	MOL	APOLLO X	MOL
LAUNCH VEHICLE	28.9	12.6	----	27.5
PERSONNEL MODULE	40.2	16.9	176.0	134.0
LAB VEHICLE	14.5	16.0	237.5	256.8
SUBTOTAL	83.6	45.5	413.5	418.3
OTHER COSTS	6.7	6.7	15.1	15.1
TOTAL	90.3	52.2	428.6	433.4

[redacted]

COMPARABLE SYSTEM COSTS

(NO EXPERIMENTS)

(Dollars in Millions)

	APOLLO X	MOL
NONRECURRING	428.6	433.4
RECURRING (6 FLIGHTS)	541.8	313.2
TOTAL	970.4	746.6

[redacted]

[redacted]

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SYSTEM EFFECTIVENESS

(EXCLUSIVE OF RECOVERY FORCES)

MISSION: PROVIDE ENVIRONMENTAL CONDITIONS, LIFE SUPPORT, PERFORMANCE AND GROUND SUPPORT AS REQUIRED TO SUSTAIN THE SYSTEM AND TO PERFORM THE EXPERIMENTS; AND

COMPLETE THE TOTAL ORBITAL MAN-HOURS ACTIVITY REQUIRED FOR A SINGLE PERFORMANCE OF ALL PRIMARY EXPERIMENTS; AND

RETRIEVAL AT DESIGNATED GROUND STATIONS OF THE SPECIFIED TYPES, QUANTITIES, AND QUALITIES OF DATA INCLUDING THAT DELIVERED BY THE ASTRONAUT IN PERSON.

APOLLO X

	NAA	Ⓐ EST	MOL
CREW SAFETY	.999*	< .95	.97
MISSION COMPLETION	-	-	.78
RELIABILITY	.90	.70	-
DESIGN ADEQUACY	-	.85	.88
AVAILABILITY	-	.98	.98
SYSTEM EFFECTIVENESS	.899	< .55	.65

* ASSUMED EQUAL TO LUNAR REQUIREMENT

[redacted]

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