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TITLE
EVALUATION OF APOLLO X FOR MOL MISSION

AEROSPACE CORPORATION
PRESENTATION

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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.
For contributions to this review:

Appreciation is expressed to the following Aerospace personnel:

- E. Laporte
- A. Pope
- H. Apple
- T. Silva
- J. Wilson
- J. Romaine
- A. Dare, A. Johnson
- W. Shen, J. Kerlier
- H. Lane
- J. Drouin, J. Paquette
- R. Ryder, J. Steinmann, K. Ludlow,
- J. Hook, Y. Frost
- R. Hendon, Y. Ho, C. Iwada
- R. Rogers
- D. Gage
- L. Hermann, A. Payne
- C. Pullen, S. Rice

Booster Performance
Communications
Recovery
Growth
Cost
Reliability
EC/TS
Electrical Power
A. C. E.

Design Analysis
Meteoroid Protection
Structures
Navigation/Guidance
Propulsion
Attitude Control
Weights
EVALUATION OF
APOLLO X
FOR
MOL MISSION
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.
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
APOLLO X - CONFIGURATION DEFINITION
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 an 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.
APOLLO X CONCEPTS

BASIC CONFIGURATION (EARTH ORBIT)

LAB CONFIGURATION (EARTH & LUNAR ORBIT)

LAB MODULE (1320 FT³)

EXISTING LEM SUPPORT POINTS

SPACE PROVISION FOR SECOND LAB MODULE

LEM DESCENT STAGE

ALTERNATE MANEUVERING UNIT (LUNAR ORBIT)
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.
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.
APOLLO COMMAND MODULE

MAJOR SYSTEMS

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

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EARTH LANDING PARACHUTES

REACTIOM CONTROL ENGINES

MAIN INSTRUMENT PANEL

RESTRAINT COUCHES

SURVIVAL EQUIPMENT

SHOCK ATTENUATION STRUTS

ABLATIVE HEAT SHIELD

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NORTH AMERICAN AVIATION, INC.
SPACE AND INFORMATION SYSTEMS DIVISION

9.63 AP 19259C

#7
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.
APOLLO "X" CONFIGURATION

LAUNCH ESCAPE TOWER

COMMAND MODULE

SERVICE MODULE

LEM ADAPTER STRUCTURE

LABORATORY MODULE

SATURN S IV B

MAIN 21/4 K SM ENGINE

SERVICE MODULE (SM)

COMMAND MODULE (CM)

AIRLOCK/TRANSFER TUNNEL

LABORATORY MODULE

LAUNCH

ORBITAL

#8
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.
SYSTEMS OPERATION

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

FUNCTIONAL AREAS
APOLLO X LAUNCH-TO-ORBIT PROFILE
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.
1. S IV B BURNOUT - ELLIPTICAL ORBIT
2. SEPARATE CSM
3. EJECT LEM FAIRING
4. TRANPOSE CSM
5. STABILIZE LAB WITH S IV B
6. DOCK CSM WITH LAB
7. EJECT S IV B
8. INJECT INTO CIRCULAR EARTH ORBIT
APOLLO X - OPERATIONS REVIEW

✓ CONFIGURATION ANALYSIS
✓ SUBSYSTEM ANALYSIS
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.
APOLLO X
CONFIGURATION ANALYSIS

/ LABORATORY ACTIVATION
/ COMPARTMENTATION
/ EXTRA-VEHICULAR OPERATIONS
/ EQUIPMENT ARRANGEMENT
/ DOCKING PROVISIONS
/ SYSTEMS OPERATION
/ CREW SAFETY
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.
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
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
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. experimenter 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.
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.
NAA APOLLO X
DOCKING DYNAMIC CONSIDERATIONS

ORBITAL CONFIGURATION
- 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

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

S/M  C/M  LAB

ACS NOZZLES  AIRLOCK  RESUPPLY VEHICLE
A summary of conclusions concerning the Apollo X system operation is presented in Chart #19.

- 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.

- 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.

- 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 degradation through continual use on orbit may lead to early mission abort.

- 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.
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
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.
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
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.
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
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.
CHANGES TO APOLLO FOR APOLLO X EARTH ORBIT
(NAA PROPOSED)

1. ADD 1200 FT³ 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
# APOLLO X RE-ENTRY VEHICLE CHANGES FOR MOL REQUIREMENTS

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

## Change to NAA Earth Orbit Configuration

<table>
<thead>
<tr>
<th>Item</th>
<th>Change to NAA Earth Orbit Configuration</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical Power</strong></td>
<td>Add one fuel cell to make system comparable to MOL.</td>
<td>+240</td>
</tr>
<tr>
<td></td>
<td>Hydrogen storage and supply system for 33 days, 1800 watt average.</td>
<td>-45</td>
</tr>
<tr>
<td></td>
<td>Oxygen storage and supply system for 33 days, 1800 watt average. (Includes oxygen storage for 33 days ECS).</td>
<td>-29</td>
</tr>
<tr>
<td><strong>Reaction Control</strong></td>
<td>Block II RCS used in lieu of Apollo X. See NAA proposal Vol. IV, Tables 36 and 39. (Usable propellant capacity reduced from 2,465 lbs. to 838 lbs.).</td>
<td>-539</td>
</tr>
<tr>
<td><strong>Environmental Control</strong></td>
<td>Reduce Nitrogen Supply System requirement from 45 days to 33 days, (NAA Vol. 4, Table 37).</td>
<td>-110</td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
<td>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.</td>
<td>+1,177</td>
</tr>
</tbody>
</table>

## 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

<table>
<thead>
<tr>
<th>ITEM</th>
<th>CHANGE TO NAA EARTH ORBIT CONFIGURATION</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STRUCTURE</strong></td>
<td>Increase structural shell per analysis</td>
<td>+464</td>
</tr>
<tr>
<td></td>
<td>Add hatches, windows, and provisions for equipment.</td>
<td>+162</td>
</tr>
<tr>
<td></td>
<td>Increase Laboratory to LEM adapter mounting weight per analysis.</td>
<td>+548</td>
</tr>
<tr>
<td><strong>ORIENTATION CONTROLS</strong></td>
<td>Add: Redundant electronics equipment to provide equivalent MOL reliability.</td>
<td>+100</td>
</tr>
<tr>
<td></td>
<td>Add: Umbilicals to re-entry vehicle.</td>
<td>+50</td>
</tr>
<tr>
<td><strong>ELECTRICAL POWER</strong></td>
<td>Increase electrical distribution system to equivalent of MOL.</td>
<td>+249</td>
</tr>
<tr>
<td><strong>COMMUNICATIONS</strong></td>
<td>Add: Command System Decoder (15 lb) and relay Assy. (6 lb)</td>
<td>+21</td>
</tr>
<tr>
<td></td>
<td>Add: MOL security system</td>
<td>+10</td>
</tr>
<tr>
<td></td>
<td>Add: Teleprinter</td>
<td>+12</td>
</tr>
<tr>
<td></td>
<td>Add: 2 S-Band amplifiers (34 lb) and an S-Band transmitter (15 lb)</td>
<td>+49</td>
</tr>
<tr>
<td></td>
<td>Add: Umbilicals to re-entry vehicle</td>
<td>+40</td>
</tr>
<tr>
<td></td>
<td>Add: Circuitry</td>
<td>+25</td>
</tr>
<tr>
<td></td>
<td>Add: Mounts</td>
<td>+15</td>
</tr>
<tr>
<td><strong>ENVIRONMENTAL CONTROL SYSTEM</strong></td>
<td>Add: Pressure suit circuit</td>
<td>+57</td>
</tr>
<tr>
<td></td>
<td>Increase: CO₂ removal system</td>
<td>+55</td>
</tr>
<tr>
<td></td>
<td>Increase: Thermal control system</td>
<td>+292</td>
</tr>
<tr>
<td><strong>PERSONNEL PROVISIONS</strong></td>
<td>Add: Compartment provisions (lights, partitions, seats, trim, etc.) (Assumes bunk is in command module)</td>
<td>+260</td>
</tr>
<tr>
<td></td>
<td>Add: Waste management system</td>
<td>+45</td>
</tr>
<tr>
<td></td>
<td>Add: Crew accessories</td>
<td>+50</td>
</tr>
<tr>
<td></td>
<td>Add: Crew personal gear (spare pressure suits, etc.)</td>
<td>+137</td>
</tr>
<tr>
<td></td>
<td>Add: Recreation equipment</td>
<td>+25</td>
</tr>
<tr>
<td></td>
<td>Add: Exercise equipment</td>
<td>+10</td>
</tr>
<tr>
<td><strong>DISPLAYS &amp; CONTROLS</strong></td>
<td>Add: Attitude control and stabilization controls equivalent to MOL</td>
<td>+50</td>
</tr>
<tr>
<td></td>
<td>Add: Leak detection system</td>
<td>+20</td>
</tr>
<tr>
<td></td>
<td>Add: Gas analyzers, pressure indicators and controls</td>
<td>+42</td>
</tr>
<tr>
<td></td>
<td>Increase: Consoles, panels, and circuitry</td>
<td>+129</td>
</tr>
<tr>
<td>ITEM</td>
<td>CHANGE TO NAA EARTH ORBIT CONFIGURATION</td>
<td>△WEIGHT</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>SPARE PARTS</td>
<td>Spare parts are in addition to redundant equipment.</td>
<td>+140</td>
</tr>
<tr>
<td>EXPENDABLES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOOD</td>
<td>Food and food preparation area is located in re-entry vehicle.</td>
<td>-158</td>
</tr>
<tr>
<td>LITHIUM HYDROXIDE</td>
<td>Lithium hydroxide requirements based on 2 men for 33 days.</td>
<td>-136</td>
</tr>
<tr>
<td>CONTINGENCY</td>
<td>Per MOL criteria</td>
<td>+1090</td>
</tr>
<tr>
<td>TOTAL WEIGHT CHANGE (LBS)</td>
<td></td>
<td>+3853</td>
</tr>
</tbody>
</table>
MANNED RE-ENTRY VEHICLE WEIGHT GROWTH HISTORY
(ALL DEVELOPMENT PHASES)

- DYNA-SOAR
- X-20
- Mercury
- Apollo
- Gemini - 2 Day (Parachute System)

% = PUBLISHED DATA

Percent Complete

Concept & Definition
Design and Fabrication
Preflight

FSP
CONTRACT OR PROGRAM INITIATION
FACTORY ACTUAL WEIGHT
LAUNCH WEIGHT

#28
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

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>*( A ) Weights (LB)</th>
<th>NAA Weights (LB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3695# NAA WT.</td>
<td>6000# A WT.</td>
</tr>
<tr>
<td></td>
<td>30 Days</td>
<td>30 Days</td>
</tr>
<tr>
<td>Structural Shell</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bulkheads</strong></td>
<td>430</td>
<td>430</td>
</tr>
<tr>
<td>Cylinder</td>
<td>86</td>
<td>89</td>
</tr>
<tr>
<td>Ring Frame</td>
<td>92</td>
<td>92</td>
</tr>
<tr>
<td>Dome Frame</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>Fitting Factor (15%)</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>724</td>
<td>727</td>
</tr>
<tr>
<td><strong>Meteoroid Protection</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase to Inner Wall</td>
<td>82</td>
<td>77</td>
</tr>
<tr>
<td>Face Sheet (Bumper)</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>Energy Absorber</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Bond</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>Fitting Factor (10%)</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>443</td>
<td>439</td>
</tr>
<tr>
<td><strong>Secondary Structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hatches, Windows, Equip.</td>
<td>510</td>
<td>510</td>
</tr>
<tr>
<td>Mounts, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lab Support Structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell</td>
<td>446</td>
<td>540</td>
</tr>
<tr>
<td>Rings</td>
<td>53</td>
<td>67</td>
</tr>
<tr>
<td>Fitting Factor</td>
<td>75</td>
<td>91</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td>574</td>
<td>698</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,251</td>
<td>2,374</td>
</tr>
</tbody>
</table>

\[
\sigma_{cr} = \frac{F_{tu}}{0.60} \quad L_{cr} = 6'' - 10'' \quad ** a/b = 0.54
\]

Minimum a/b for reasonable wt. & feasible with NAA Designs.
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.
WEIGHTS AND PAYLOAD ANALYSIS
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.
APOLLO X
WEIGHT ANALYSIS

EVALUATION RATIONALE

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

(2 MEN - 30 DAYS)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>WEIGHT (LBS)</th>
<th>ITEM</th>
<th>WEIGHT (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND MODULE</td>
<td>11,040</td>
<td>GEMINI B</td>
<td>4,930</td>
</tr>
<tr>
<td>SERVICE MODULE</td>
<td>15,370</td>
<td>GEMINI ADAPTER</td>
<td>1,670</td>
</tr>
<tr>
<td>LEM ADAPTER</td>
<td>3,500</td>
<td>LABORATORY</td>
<td>11,750</td>
</tr>
<tr>
<td>LABORATORY</td>
<td>6,500</td>
<td>TOTAL</td>
<td>18,350</td>
</tr>
</tbody>
</table>

**TOTAL**                        | **36,410**                        | **WEIGHT DIFFERENCE = 18,060 LBS.**
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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MOL - Titan IIIC</td>
<td>23,500&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>18,350</td>
<td>5,150</td>
</tr>
<tr>
<td>Apollo X - Saturn IB</td>
<td>32,800&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>36,410&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>-3,610</td>
</tr>
<tr>
<td>Apollo X - Saturn IB (Upgraded)</td>
<td>37,800&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>36,410&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>1,390</td>
</tr>
</tbody>
</table>

---

1. 160 N. MI. Circular Orbit
2. 80/160 N. MI. Elliptical Orbit
3. Includes propellant required to circularize orbit at 160 N. MI.
The foregoing payload data are presented in terms of duration and payload tradeoffs in Chart #34.
APOLLO X REVIEW
MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION

- ETR OPERATIONS
- INTEGRAL LAUNCH

MOL/ TITAN IIIIC

APOLLO X/ SATURN IB
NOT CAPABLE OF ORBITING ANY USEFUL PAYLOAD AT ETR
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.
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
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.
# APOLLO X RELIABILITY ALLOCATIONS
## (NAA)

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>ALLOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOSS</td>
<td>.99630</td>
</tr>
<tr>
<td>GSE</td>
<td>.99984</td>
</tr>
<tr>
<td>BOOST</td>
<td>.95</td>
</tr>
<tr>
<td>CSM</td>
<td>.955</td>
</tr>
<tr>
<td>LABORATORY</td>
<td>.99585</td>
</tr>
<tr>
<td></td>
<td>.90</td>
</tr>
</tbody>
</table>
### LIFE EXTENSION - APOLLO X

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

**NAA APPROACH**

- Assumed: "RELIABILITIES CLOSE TO OR ABOVE APPORTIONED VALUES".
- Redesign for increased reliability.
- Redundant elements manually switched.
- Spares installed by crew.
- Crew repair of failed items.
- Operate until single failure will cause loss of mission.
- Reduce system operating time e.g., attitude control.

**PROBLEM**

- Appportioned values exceed state-of-the-art by up to order of magnitude.
- Violates NASA ground rule.
- Inadequate available volume.
- Inadequate spares storage volume.
- Block II not designed for maintenance.
- Requires design for maintenance at detail level, large stock of spares and tools, excessive crew time.
- Requires that emergency condition be normal operating mode, compromises crew safety.
- 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.
APOLLO X REVIEW
GROWTH POTENTIAL COMPARISON
MOL AND APOLLO X
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.
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"
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.
APOLLO X REVIEW

LAUNCH VEHICLE CAPABILITIES

<table>
<thead>
<tr>
<th>VEHICLE</th>
<th>PAYLOAD (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ETR (106°AZ)</td>
</tr>
<tr>
<td>T-IIIC(1)</td>
<td>23,500</td>
</tr>
<tr>
<td>T-IIIC/7 SEG. SRM(1)</td>
<td>28,600</td>
</tr>
<tr>
<td>T-IIIC/156 IN. SRM(1)</td>
<td>37,980</td>
</tr>
<tr>
<td>SATURN I-B(2)</td>
<td>32,800</td>
</tr>
<tr>
<td>SATURN I-B UPRATED(2)</td>
<td>37,800</td>
</tr>
</tbody>
</table>

(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.
## Apollo X Review

### Weight Available for Experiments

- **Integral Launch**

<table>
<thead>
<tr>
<th>System</th>
<th>ETR (106° AZ)</th>
<th>WTR (180° AZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOL - Titan IIIC (1)</td>
<td>5,150</td>
<td>450</td>
</tr>
<tr>
<td>MOL - Titan IIIC/7 SEG SRM (1)</td>
<td>10,250</td>
<td>5,450</td>
</tr>
<tr>
<td>MOL - Titan IIIC/156-IN SRM (1) (3)</td>
<td>19,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Apollo X - Saturn IB (2)</td>
<td>-3,600</td>
<td>-10,000</td>
</tr>
<tr>
<td>Apollo X - Saturn IB/Upgraded (2)</td>
<td>1,400</td>
<td>-6,000</td>
</tr>
</tbody>
</table>

---

(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
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.
APOLLO X REVIEW
UPRATED MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION

- ETR OPERATIONS

MOL/TITAN IIIIC - 156 IN SRM

MOL/TITAN IIIIC - 7 SEG. SRM

APOLLO X/SATURN IB UPRATED

PAYLOAD (LBS)

ON-ORBIT DURATION (DAYS)
APOLLO X REVIEW
UPRATED MOL AND APOLLO X SYSTEMS COMPARISON

PAYLOAD VS ON-ORBIT DURATION
- WTR OPERATIONS
- INTEGRAL LAUNCH

NOTE: APOLLO X/SATURN IB (UPRATED) NOT CAPABLE OF ORBITING ANY USEFUL PAYLOAD AT WTR
## APOLLO X REVIEW

### EXPENDABLES SUMMARY

- **TWO-MAN CREW**
- **30-DAY MISSION**

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

*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 CO₂ REMOVAL SUBSYSTEM
  o CRYOGENIC STORAGE BASED ON 120 DAY DESIGN POINT

✓ MOL CONFIGURATION
  o INCLUDES RENDEZVOUS AND DOCKING CAPABILITY
  o INCLUDES UPRATED CO₂ 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$^3$

ON-ORBIT DURATION (DAYS)

PAYLOAD (LBS)

MOL/T-IIC-7 SEG. (93 DAY RESUPPLY)

APOLLO X/SIB UPRATED (64 DAY RESUPPLY)

MOL/TIIC-156 IN. SEG. (159 DAY RESUPPLY)

MOL PRIMARY EXP. REQ. (3760)

△ INTEGRAL LAUNCH

● RESUPPLY LAUNCH
### APOLLO X REVIEW

**EXTENDED DURATION MISSION COMPARISON**

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

<table>
<thead>
<tr>
<th>ITEM</th>
<th>MOL (LBS/DAY)</th>
<th>APOLLO X (LBS/DAY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>REACTION CONTROL PROPELLANTS</td>
<td>3.8</td>
<td>20.4</td>
</tr>
<tr>
<td>LIFE SUPPORT EXPENDABLES</td>
<td>24.2</td>
<td>24.8</td>
</tr>
<tr>
<td>FUEL CELL REACTANTS (1.8 KW AVERAGE)</td>
<td>72.0</td>
<td>64.5</td>
</tr>
<tr>
<td>FUEL CELLS</td>
<td>15.0</td>
<td>35.2</td>
</tr>
<tr>
<td>SPARES AND REDUNDANCY</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>ORBIT SUSTENANCE PROPELLANT (160 N. Mi.)</td>
<td>4.5</td>
<td>6.0</td>
</tr>
<tr>
<td>RECREATION, EXERCISE &amp; MEDICAL EQUIPMENT</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>TOTAL EXPENDABLE RATE</strong></td>
<td>131.2</td>
<td>162.6</td>
</tr>
</tbody>
</table>
### Apollo X Review

#### Apollo X Rendezvous Vehicle Weight Estimate

- **ETR Operations**
- **Laboratory Pressurized Volume** - 1260 ft³

<table>
<thead>
<tr>
<th>Item</th>
<th>Target Vehicle (LBS)</th>
<th>Chase/Resupply Vehicle (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Apollo X Vehicle</strong> (without experiment payload)</td>
<td>36,090</td>
<td>36,090</td>
</tr>
<tr>
<td>- Convert to &quot;O&quot; Day Expendables and Tankage</td>
<td>-3,650</td>
<td>-3,650</td>
</tr>
<tr>
<td>- Fuel Cell Redundancy (2)</td>
<td>-960</td>
<td>-960</td>
</tr>
<tr>
<td>- Rendezvous &amp; Docking</td>
<td>+610</td>
<td>+2,080</td>
</tr>
<tr>
<td>- Laboratory Module</td>
<td></td>
<td>-6,220</td>
</tr>
<tr>
<td><strong>Vehicle Weight</strong> (less discretionary payload)</td>
<td>32,090</td>
<td>27,340</td>
</tr>
<tr>
<td><strong>Discretionary Payload</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Saturn IB (32,800)</td>
<td>710</td>
<td>5,460</td>
</tr>
<tr>
<td>- Saturn IB Uprated (37,800)</td>
<td>5,710</td>
<td>10,460</td>
</tr>
</tbody>
</table>
APOLLO X RESUPPLY CAPABILITY

✓ VOLUME AVAILABILITY IN 2 MAN CONCEPT

○ CM
- TOTAL PRESSURIZED VOLUME - 366 FT³
- NET FREE VOLUME - 130 FT³
- ASSUMED MAX. FREE VOLUME AVAILABLE FOR STORAGE - 100 FT³
- PAYLOAD STORAGE CAPABILITY ~ 2000 LBS (FOOD, CLOTHING, ETC.)

○ SM
- TOTAL UNPRESSURIZED VOLUME 1560 FT³
- AVAILABLE FOR STORAGE - 1125 FT³
- PAYLOAD STORAGE CAPABILITY ~ 14,000 LBS
## APOLLO X REVIEW

**MOL RENDEZVOUS VEHICLE WEIGHT ESTIMATE**

- ETR OPERATIONS
- LABORATORY PRESSURIZED VOLUME - 2400 FT³

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TARGET VEHICLE (LBS)</th>
<th>CHASE/RESUPPLY VEHICLE (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASELINE VEHICLE (WITHOUT EXPERIMENT PAYLOAD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- BASELINE CONVERSION TO &quot;O&quot; DAY EXPENDABLES &amp; TANKAGE</td>
<td>-3,280</td>
<td>-3,280</td>
</tr>
<tr>
<td>- RENDEZVOUS &amp; DOCKING SYSTEM</td>
<td>+610</td>
<td>+2,080</td>
</tr>
<tr>
<td>- FUEL CELL REDUNDANCY (3)</td>
<td>-410</td>
<td>-410</td>
</tr>
<tr>
<td>VEHICLE WEIGHT (LESS DISCRETIONARY PAYLOAD)</td>
<td>14,860</td>
<td>16,330</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DISCRETIONARY PAYLOAD</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- TIIIC/7 SEGMENT SRM (28,600)</td>
<td>13,740</td>
<td>12,270</td>
</tr>
<tr>
<td>- TIIIC/156 IN DIA. SRM (37,980)</td>
<td>22,500*</td>
<td>21,000*</td>
</tr>
</tbody>
</table>

*INCLUDES ADDITIONAL VOLUME FOR INCREASED PAYLOAD
MOL GROWTH POTENTIAL

✓ POSSIBLE RENDEZVOUS MISSION CAPABILITY AT WTR OPERATIONS
  - UNMANNED MISSION EQUIPMENT MOL
  - 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
- THI C/156 IN SRM

MANNED LAUNCH
MANNED RESUPPLY LAUNCH
UNMANNED LAUNCH
90 DAY RESUPPLY CYCLE
MOL
RESUPPLY VEHICLE WEIGHT SUMMARY

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

TOTAL RESUPPLY PAYLOAD 12,610 LBS
### MOL Unmanned Vehicle Weight Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Capability at WTR (TIIC/156 IN)</td>
<td>31,000</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td></td>
</tr>
<tr>
<td>Structure (10 ft Equip. Comp.)</td>
<td>3,370</td>
</tr>
<tr>
<td>Orientation Controls</td>
<td>690</td>
</tr>
<tr>
<td>Electrical Power</td>
<td>290</td>
</tr>
<tr>
<td>Communications</td>
<td>200</td>
</tr>
<tr>
<td>Environmental Control</td>
<td>730</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>130</td>
</tr>
<tr>
<td>Personnel Provisions</td>
<td>630</td>
</tr>
<tr>
<td>Displays and Controls</td>
<td>320</td>
</tr>
<tr>
<td>Docking Hardware</td>
<td>610</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td>1,390</td>
</tr>
<tr>
<td>Nose Fairing - Effective WGT.</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total Payload Available for Mission</strong></td>
<td><strong>22,600</strong></td>
</tr>
<tr>
<td>Equipment and Experiments</td>
<td></td>
</tr>
</tbody>
</table>
APOLLO X REVIEW

APOLLO X AND MOL MISSION CAPABILITY
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.
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 -
  o RESUPPLY CYCLE OF 142 DAYS
  o PRESSURIZED LABORATORY VOLUME OF 2400 FT$^3$
  o OPERATIONAL FLEXIBILITY AND CREW CONVENIENCE
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.
<table>
<thead>
<tr>
<th></th>
<th>APOLLO X</th>
<th>MOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>NONRECURRING</td>
<td>400.0</td>
<td>403.8</td>
</tr>
<tr>
<td>RECURRING (6 FLIGHTS)</td>
<td>480.6</td>
<td>250.8</td>
</tr>
<tr>
<td>TOTAL</td>
<td>880.6</td>
<td>654.6</td>
</tr>
</tbody>
</table>

COMPARABLE SYSTEM COSTS
(Dollars in Millions)
## COMPARABLE SYSTEM COSTS
(Dollars in Millions)

<table>
<thead>
<tr>
<th></th>
<th>RECURRING COSTS</th>
<th>NONRECURRING COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>APOLLO X</td>
<td>MOL</td>
</tr>
<tr>
<td>LAUNCH VEHICLE</td>
<td>28.9</td>
<td>12.8</td>
</tr>
<tr>
<td>PERSONNEL MODULE</td>
<td>40.2</td>
<td>16.8</td>
</tr>
<tr>
<td>LAB VEHICLE</td>
<td>11.0</td>
<td>12.2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>80.1</strong></td>
<td><strong>41.8</strong></td>
</tr>
</tbody>
</table>
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.
SUMMARY
EVALUATION OF APOLLO X FOR MOL MISSION

O DISADVANTAGES OF APOLLO X AS COMPARED TO GEMINI B/TITAN III C 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 III C MOL IS THE BETTER SOLUTION
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
APOLLO X REVIEW

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

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

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

SM
- AVAILABLE UNPRESSURIZED VOLUME ACCESSIBLE BY E. V. OPERATIONS ONLY
COMPARTMENTATION

CONCLUSIONS

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

- MOL REQUIREMENT FOR LONG DURATION RESUPPLY

- 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

- CONCLUSION
  - APOLLO X CONFIGURATION UNDESIRABLE FOR RENDEZVOUS OPERATIONS
CREW SAFETY

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

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

CONCLUSION
- CREW HAZARD HIGHER THAN MOL IN PROPOSED CONFIGURATION
MOL RENDEZVOUS OPERATIONS

- DUAL LAUNCH AND DOCK TWO MOL'S
- INCREASE COMBINED EQUIPMENT PAYLOAD
- EXTENDED DURATION
- FLEXIBLE CREW SIZE (2 OR 4)
MOL RENDEZVOUS MISSION POTENTIAL
PAYLOAD VS. ON-ORBIT DURATION

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

PAYLOAD (LBS)
ON-ORBIT DURATION (DAYS)

TARGET VEHICLE LAUNCH
CHASE VEHICLE LAUNCH
MOL

RENDZVOUS CONFIGURATION WEIGHT SUMMARY

- 160 N. MI. ORBIT
- ETR OPERATIONS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>TARGET VEHICLE (LBS)</th>
<th>CHASE VEHICLE (LBS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ GEMINI B SEGMENT</td>
<td>6,600</td>
<td>6,600</td>
</tr>
<tr>
<td>✓ LABORATORY VEHICLE SEGMENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o BASELINE (30 DAY PROVISIONS</td>
<td>10,540</td>
<td>10,540</td>
</tr>
<tr>
<td>LESS ELECTRICAL POWER REACTANTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o ELECTRICAL POWER REACTANTS</td>
<td>*1,040</td>
<td>**1,260</td>
</tr>
<tr>
<td>o DOCKING PROVISIONS</td>
<td>610</td>
<td>2,080</td>
</tr>
<tr>
<td>VEHICLE NET WEIGHT (LESS DISCRETIONARY PAYLOAD)</td>
<td>18,790</td>
<td>20,480</td>
</tr>
</tbody>
</table>

✓ DISCRETIONARY PAYLOAD

- TIIIC STANDARD (23,500)                      | 4,710                | 3,040                |
- TIIIC/7 SEGMENT SRM (28,600)                 | 9,810                | 8,120                |
- 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.
MOL RENDEZVOUS OPERATIONS

EXPENDABLES SUMMARY

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

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

**TOTALS** 70.2 78.5

* 30 DAYS AT 1.4 KW AVERAGE POWER (PRE-RENDEZVOUS)
** 30 DAYS AT 1.58 KW AVERAGE POWER (DOCKED VEHICLES)
### MOL RENDEZVOUS OPERATIONS
POWER DOWN ELECTRICAL LOADS

<table>
<thead>
<tr>
<th></th>
<th>TARGET VEHICLE</th>
<th>CHASE VEHICLE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WATTS AVE.</td>
<td>WATTS AVE.</td>
</tr>
<tr>
<td>COMMUNICATIONS</td>
<td>170</td>
<td>38</td>
</tr>
<tr>
<td>ATTITUDE CONTROL</td>
<td>130</td>
<td>-</td>
</tr>
<tr>
<td>EC/ISS</td>
<td>325</td>
<td>87</td>
</tr>
<tr>
<td>GEMINI B</td>
<td>-</td>
<td>150</td>
</tr>
<tr>
<td>LIGHTING</td>
<td>120</td>
<td>-</td>
</tr>
<tr>
<td><strong>SUB TOTAL</strong></td>
<td><strong>745</strong></td>
<td><strong>275</strong></td>
</tr>
<tr>
<td>EXPERIMENTS &amp; COMPUTER</td>
<td>380</td>
<td>-</td>
</tr>
<tr>
<td>DISPLAYS</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>MISCELLANEOUS</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>1245</strong></td>
<td><strong>335</strong></td>
</tr>
</tbody>
</table>

**TOTAL POWER** 1580
## MOL GROWTH POTENTIAL

### MOL BASELINE POWER DOWN ELECTRICAL LOAD CAPABILITY

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>BASELINE 30 DAY MISSION</th>
<th>EXTENDED DURATION MISSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AVE. PWR. (WATTS)</td>
<td>AVE. PWR. (WATTS)</td>
</tr>
<tr>
<td>Communications, Instr. &amp; Data Management</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Attitude Control (50% Duty Cycle)</td>
<td>235</td>
<td>130</td>
</tr>
<tr>
<td>EC/LS (Shirt Sleeve)</td>
<td>390</td>
<td>325</td>
</tr>
<tr>
<td>Lighting</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Gemini B (Orbital Storage)</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Displays</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Transstage</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td><strong>50</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td></td>
<td><strong>SUB TOTAL: 1275</strong></td>
<td><strong>895</strong></td>
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<tr>
<td>Experiments</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Computer</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>Contingencies</td>
<td><strong>145</strong></td>
<td><strong>0</strong></td>
</tr>
<tr>
<td></td>
<td><strong>1800</strong></td>
<td><strong>1275</strong></td>
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</tbody>
</table>
APOLLO X REVIEW

WEIGHTS DATA
**WEIGHT SUMMARY**

NAA PROPOSAL VS. AEROSPACE APOLLO X ESTIMATE

<table>
<thead>
<tr>
<th></th>
<th>NAA PROPOSAL APOLLO X/ SATURN IB</th>
<th>A ESTIMATE OF APOLLO X/ SATURN IB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RE-ENTRY VEHICLE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE-ENTRY VEHICLE</td>
<td>9,600</td>
<td>9,600</td>
</tr>
<tr>
<td>CONTINGENCY</td>
<td>0</td>
<td>1,440</td>
</tr>
<tr>
<td><strong>SERVICE MODULE (INCLUDING PROPellant)</strong></td>
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<td></td>
</tr>
<tr>
<td>SERVICE MODULE</td>
<td>15,420</td>
<td>14,180</td>
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<tr>
<td>CONTINGENCY</td>
<td>0</td>
<td>1,190</td>
</tr>
<tr>
<td><strong>LABORATORY (LESS EXPERIMENTS)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LABORATORY VEHICLE SEGMENT</td>
<td>2,630</td>
<td>5,410</td>
</tr>
<tr>
<td>CONTINGENCY</td>
<td>0</td>
<td>1,090</td>
</tr>
<tr>
<td><strong>BOOSTER ADAPTER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVAILABLE WEIGHT FOR EXPERIMENTS</td>
<td>1,500</td>
<td>-3,610</td>
</tr>
<tr>
<td><strong>TOTAL ON-ORBIT WEIGHT</strong></td>
<td>32,650</td>
<td>32,800 (a)</td>
</tr>
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</table>

(a) EAST LAUNCH, 80-160 N.M. ELLIPTICAL ORBIT.
# RE-ENTRY VEHICLE WEIGHT COMPARISON

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

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

*LESS EXPERIMENTS, INCLUDES PROPELLANT*
LABORATORY VEHICLE WEIGHT COMPARISON*

<table>
<thead>
<tr>
<th></th>
<th>NAA</th>
<th>AEROSPACE ESTIMATE OF</th>
</tr>
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<td></td>
<td>APOLLO X PROPOSAL</td>
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<td>EXPENDABLES</td>
<td>(534)</td>
<td>(275)</td>
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<tr>
<td>FOOD</td>
<td>158</td>
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<td>OXYGEN-SUPERCritical</td>
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<td>0</td>
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<tr>
<td>OXYGEN-HIGH PRESSURE</td>
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<td>10</td>
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<tr>
<td>NITROGEN-SUPERCritical</td>
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<td>WATER-RESERVE</td>
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<td>LITHIUM HYDROXIDE</td>
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<td>REACTANTS - 1,550 WATTS AVE.</td>
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<td>PROPELLANT-USABLE</td>
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<tr>
<td>TOTAL</td>
<td>2,626</td>
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*LESS CONTINGENCY
**WEIGHT COMPARISON SUMMARY**

**MOL VS. AEROSPACE ESTIMATE OF APOLLO-X**

<table>
<thead>
<tr>
<th></th>
<th>MOL ESTIMATE</th>
<th>ESTIMATE OF</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>GEMINI B/</td>
<td>APOLLO X/</td>
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<tr>
<td></td>
<td>TITAN IIIC</td>
<td>SATURN IB</td>
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<td></td>
<td>2 MEN-30 DAYS</td>
<td>2 MEN-30 DAYS</td>
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<tr>
<td><strong>RE-ENTRY VEHICLE</strong></td>
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<td>CONTINGENCY</td>
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<td><strong>BOOSTER ADAPTER</strong></td>
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<td>AVAILABLE WEIGHT FOR EXPERIMENTS</td>
<td>5,150</td>
<td>-3,610</td>
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<td><strong>TOTAL ON-ORBIT WEIGHT</strong></td>
<td>23,500</td>
<td>32,800 (a)</td>
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</table>

(a) EAST LAUNCH, 80-160 N. M. ELLIPTICAL ORBIT.
# LABORATORY VEHICLE WEIGHT COMPARISON*

## MOL VS. AEROSPACE ESTIMATE OF APOLLO-X

<table>
<thead>
<tr>
<th>AEROSPACE</th>
<th>AEROSPACE ESTIMATE OF APOLLO X</th>
</tr>
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<tbody>
<tr>
<td>GEMINI B</td>
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<td></td>
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<td>ELECTRICAL POWER (LESS REACTANTS)</td>
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<tr>
<td>EXPENDABLES</td>
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<tr>
<td>REACTANTS - 1,550 WATTS AVE.</td>
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<td>PROPELLANT-USABLE</td>
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<tr>
<td>TOTAL</td>
<td>9,755</td>
</tr>
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</table>
METEOROID DESIGN

- PHILOSOPHY
- NAA acceptance of one hit during 45 day mission duration considered unconservative and detrimental to crew safety.
- Insufficient flux and penetration data warrant high probability of no penetration ($P_0 = 0.995$) design especially for relatively short mission durations ($\tau \leq 180$ days).

- FLUX AND PENETRATION CRITERION
- No consideration of stream flux nor yearly variation of sporadic flux noted.
- 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.
- Aerospace factors are accepted by NASA/MSC.
- 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 ($t_0 = 0.25 t_{total}$).
- No safety factor applied to safe life or thickness.
- Large uncertainties inherent in analyses warrant a safety factor approach.
- Command module analysis application of aluminum penetration criterion to organic ablator material considered invalid.
- Behavior of shock propagation, energy absorption, etc., not considered across-the-board typical between metallics & organics.
METEOROID CRITERIA COMPARISON

NAA - AEROSPACE CRITERION

NAA BASELINE $\bar{t} = .033"$ ($P_x = 1 = 0.995$, $\tau = 45$ days)
STRUCTURAL DESIGN

AN AEROSPACE EVALUATION OF THE NAA DESIGN, SUBJECT 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 \(\frac{a}{b} = 0.27\) YIELDS MUCH LARGER WEIGHT VALUE THAN NAA QUOTED VALUE (SEE TABLE)
    2. FOR 192" DIA., HEAD GEOMETRY SHOULD RANGE FROM \(.5 < \frac{a}{b} < 1.0\) 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#/FT³ ENERGY ABSORBER) BUT \(t_B = 0.033\) CONSIDERED INADEQUATE \((P_0 = 0.995)\)
STRUCTURAL DESIGN (CONT.)

- SUPPORT SYSTEM
  / NAA WEIGHT FOR SUPPORT STRUCTURE BETWEEN LAB AND LEM ADAPTOR CONSIDERED LOW
  
  ○ 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
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
APOLLO X REVIEW

ELECTRICAL POWER
### ELECTRICAL POWER LOAD ANALYSIS

<table>
<thead>
<tr>
<th>SUBSYSTEM</th>
<th>APOLLO X</th>
<th>MOL BASELINE</th>
<th>AEROSPACE APOLO X MOL</th>
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<td>ECS</td>
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<tr>
<td>GEMINI B (ORBITAL STORAGE)</td>
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<td>MISCELLANEOUS</td>
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<td>250</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,170</strong></td>
<td><strong>1,655</strong></td>
<td><strong>1,674</strong></td>
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**CONCLUSIONS:** APOLLO X MOL POWER REQUIREMENTS ARE EQUIVALENT TO THE MOL BASELINE
APOLLO X REVIEW

FUEL CELL RELIABILITY LOGIC DIAGRAM

*NAA RECOMMENDED SYSTEM CONFIGURATION FOR MOL.

CSM FUEL CELL MODULE
0.971

CSM FUEL CELL MODULE
0.971

CSM FUEL CELL MODULE
0.971

FOR FIRST HALF OF MISSION

CSM FUEL CELL MODULE
0.971

CSM FUEL CELL MODULE
0.971

CSM FUEL CELL MODULE
0.971

FOR SECOND HALF OF MISSION

RELIABILITY = 0.83814 (30 DAYS)
EPS REL. REQMT. = 0.984

CONCLUSION: SIX CSM FUEL CELL MODULES REQUIRED

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

ENVIRONMENTAL CONTROL AND LIFE SUPPORT
APOLLO X - MOL MISSION
EC/LS ADDITIONAL REQUIREMENTS

- ATMOSPHERE SUPPLY
  - O₂ ACCUMULATOR (FOR EVA AND EMERGENCY REPRESSURIZATION)
  - SINGLE GAS/DUAL GAS MODE SELECTION PROVISIONS
  - O₂ AND N₂ SUPPLY TO AIRLOCK
  - O₂ UMBILICAL CONNECTIONS IN AIRLOCK (FOR EVA)
  - O₂ AND N₂ 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
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
APOLLO X-MOL MISSION
ATMOSPHERE SUPPLY CHANGES

**ADDITIONS**

1. $O_2$ ACCUMULATOR (52 LB)
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
**APOLLO 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

ADDITIONS
1. CIRCULATION FAN (2)  (LB)
2. WATER SEPARATION
3. SUIT LOOP DUCTING
4. CABIN LOOP DUCTING
5. VENTILATION FAN (4)

DELETIONS
6. DUCTING & FAN

WEIGHT INCREASE

84
APOLLO X - MOL MISSION

THERMAL CONTROL SUBSYSTEM

- IDENTIFIED PROVISIONS
  - RADIATOR IN SM
  - CREW TEMP CONTROL IN CM
  - EQUIP. TEMP CONTROL IN CM
  - LM CONNECTION TO SM/CM
  - THERMAL CONTROL

- ADDITIONAL PROVISIONS
  - PROPER DEW POINT CONTROL, CM
  - PROPER DEW POINT CONTROL, LM
  - SEPARATE LM THERMAL CONTROL
    DESIGNED TO ACCOMMODATE 3.6KW
    EXP. RADIATOR INTEGRAL WITH LM SURFACE
APOLLO X-MOL MISSION
THERMAL CONTROL CHANGES

**ADDITIONS**
1. COLDPLATES (LB) 30
2. PUMPS, LINES, ECT. 60
3. RADIATOR 40
4. DEW POINT CONTROL 30

**DELETIONS**
5. DUCTING & FAN - 17

**WEIGHT INCREASE** 143
<table>
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<th>Addition</th>
<th>Deletion</th>
<th>Net</th>
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<tr>
<td>Atmosphere Supply</td>
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<tr>
<td>Atmosphere Control</td>
<td>94</td>
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<tr>
<td>Thermal Control</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>382</strong></td>
<td><strong>-112</strong></td>
<td><strong>270</strong></td>
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</table>
APOLLO X REVIEW

STABILIZATION AND CONTROL
& GUIDANCE
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.
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.

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

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
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.
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.
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 MCL pointing and tracking scope.
APOLLO X REVIEW

COMMUNICATIONS AND DATA HANDLING
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
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
### APOLLO X REVIEW

**ADDITIONAL C & D EQUIPMENTS REQUIRED**

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<thead>
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<th>Equipment</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-BAND TRANSMITTER (2)</td>
<td>29.0</td>
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<tr>
<td>S-BAND AMPLIFIER (2)</td>
<td>33.5</td>
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<tr>
<td>PCM TM MULTIPLEXER (2)</td>
<td>4.5</td>
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<tr>
<td>SIGNAL CONDITIONER</td>
<td>50.0</td>
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<tr>
<td>RECORDER (2)</td>
<td>54.0</td>
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<tr>
<td>PREMODULATION PROCESSOR</td>
<td>12.0</td>
</tr>
<tr>
<td>COMMAND DECODER AND RELAYS</td>
<td>13.5</td>
</tr>
<tr>
<td>TELEPRINTER</td>
<td>12.0</td>
</tr>
<tr>
<td>SECURE EQUIPMENT</td>
<td>10.0</td>
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<tr>
<td>WIDEBAND TRANSMITTER</td>
<td>21.0</td>
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<tr>
<td>WIDEBAND RECORDER</td>
<td>73.0</td>
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<tr>
<td>TV CAMERA (2) AND CONTROL</td>
<td>30.0</td>
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<tr>
<td>TV MONITOR</td>
<td>15.0</td>
</tr>
<tr>
<td>LABORATORY C &amp; D CONTROL PANEL, ETC.</td>
<td>25.0</td>
</tr>
<tr>
<td>MOUNT, ADDITIONAL EQUIPMENT</td>
<td>15.0</td>
</tr>
<tr>
<td>UMBILICALS TO RE-ENTRY VEHICLE</td>
<td>40.0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>437.5 LBS</strong></td>
</tr>
</tbody>
</table>
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
AEROSPACE GROUND EQUIPMENT

APOLLO X

N. A. A. CLAIM

- UNMODIFIED EQUIPMENT AT EACH SITE TO SUPPORT BOTH PROGRAMS ON AN INTEGRATED BASIS

- 385 APOLLO AGE ITEMS, INCLUDING AUTOMATIC ACCEPTANCE CHECKOUT EQUIPMENT, OUT OF 421 AGE ITEMS REQUIRED FOR APOLLO X, ARE AVAILABLE WITHOUT MODIFICATIONS

- 20 APOLLO AGE ITEMS REQUIRE MODIFICATION FOR APOLLO X USE

16 AGE ITEMS ARE NEW FOR APOLLO USE

A COMMENT

NASA COMMITMENTS DO NOT PERMIT INTEGRATED BASIS FOR APOLLO X GROUND OPERATIONS IN SAME TIME PERIOD ALLOTTED FOR APOLLO GROUND OPERATIONS

REQUIREMENTS HAVE NOT BEEN ESTABLISHED FOR ANY OF THESE 385 ITEMS REGARDS PERFORMANCE, QUANTITY, LOCATION ETC.

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.
APOLLO X REVIEW

COST DATA
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 LiO$_2$ 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:

<table>
<thead>
<tr>
<th>Description</th>
<th>Standardized</th>
<th>Optimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSM MODS</td>
<td>$20,246M</td>
<td>$17,146M</td>
</tr>
<tr>
<td>1200 FT$^3$ LAB</td>
<td>$50,000M</td>
<td>$50,000M</td>
</tr>
</tbody>
</table>
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

   - \( \text{O}_2 \) Accumulator (for EVA and Emergency Repressurization)
   - \( \text{O}_2 + \text{H}_2 \) Supply to Airlock
   - \( \text{O}_2 \) Umbilical Connection in Airlock (For EVA)
   - \( \text{O}_2 + \text{N}_2 \) 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
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 AGE FOR CM, SM, LAB, LAUNCH VEHICLE
## Comparable System Costs

(Dollars in Millions)

<table>
<thead>
<tr>
<th></th>
<th>Recurring Costs</th>
<th>Nonrecurring Costs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>APOLLO X</td>
<td>MOL</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>28.9</td>
<td>12.6</td>
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<tr>
<td>Personnel Module</td>
<td>40.2</td>
<td>16.9</td>
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<tr>
<td>Lab Vehicle</td>
<td>14.5</td>
<td>16.0</td>
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<tr>
<td><strong>Subtotal</strong></td>
<td><strong>83.6</strong></td>
<td><strong>45.5</strong></td>
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<tr>
<td>Other Costs</td>
<td>6.7</td>
<td>6.7</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>90.3</strong></td>
<td><strong>52.2</strong></td>
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### COMPARABLE SYSTEM COSTS

(NO EXPERIMENTS)

(Dollars in Millions)

<table>
<thead>
<tr>
<th></th>
<th>APOLLO X</th>
<th>MOL</th>
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<tbody>
<tr>
<td>NONRECURRING</td>
<td>428.6</td>
<td>433.4</td>
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<tr>
<td>RECURRING (6 FLIGHTS)</td>
<td>541.8</td>
<td>313.2</td>
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<td>TOTAL</td>
<td>970.4</td>
<td>746.6</td>
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</table>
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

<table>
<thead>
<tr>
<th></th>
<th>NAA</th>
<th>EST</th>
<th>MOL</th>
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</thead>
<tbody>
<tr>
<td>Crew Safety</td>
<td>.999*</td>
<td>&lt; .95</td>
<td>.97</td>
</tr>
<tr>
<td>Mission Completion</td>
<td>-</td>
<td>-</td>
<td>.78</td>
</tr>
<tr>
<td>Reliability</td>
<td>.90</td>
<td>.70</td>
<td>-</td>
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<tr>
<td>Design Adequacy</td>
<td>-</td>
<td>.85</td>
<td>.88</td>
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<tr>
<td>Availability</td>
<td>-</td>
<td>.98</td>
<td>.98</td>
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</tbody>
</table>

System Effectiveness

.899 < .55 .65

* Assumed equal to lunar requirement