

**NASA Technical Memorandum 100598**

**Manned Mars Mission Accommodation -  
Sprint Mission**

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**William M. Cirillo  
Martin J. Kaszubowski  
J. Kirk Ayers  
Charles P. Llewellyn  
Deene J. Weidman  
Barry D. Meredith**

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**NASA**

**National Aeronautics and  
Space Administration**

**Langley Research Center  
Hampton, Virginia 23665-5225**

**Manned Mars Mission Accommodation -  
Sprint Mission**

**April 1988**

**Mars Sprint Mission Accommodation Study**

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# M<sup>3</sup> ACCOMMODATION STUDY - SPRINT MISSION

## INTRODUCTION

MANNED MISSIONS TO MARS HAVE BEEN THE SUBJECT OF SIGNIFICANT ENGINEERING STUDY SINCE THE EARLIEST DAYS OF NASA. WITH THE ESTABLISHMENT OF THE US NATIONAL COMMISSION ON SPACE IN 1985 CHAIRED BY THOMAS PAINE, AND THE DECISION TO PROCEED WITH A SPACE STATION, IT WAS AN APPROPRIATE TIME TO REASSESS MANNED MARS MISSIONS. SEVERAL INTENSIVE WORKSHOPS (THE CASE FOR MARS I, II AND III) HAVE PROVIDED ABUNDANT DATA AND CONCEPTS FOR ACCOMPLISHING THE MISSION. TYPICAL MISSION CLASSES ARE SHOWN HERE. AS IS WELL KNOWN, THE MINIMUM ENERGY MISSION REQUIRES A TRIP TIME OF ABOUT 3 YEARS WITH A ONE YEAR STAY AT MARS AND A MASS IN LOW EARTH ORBIT (LEO) OF ABOUT 1 MILLION POUNDS IF HYDROGEN/OXYGEN PROPULSION IS USED. OPPOSITION MISSIONS, WHICH MAY OR MAY NOT USE VENUS SWINGBYS, REDUCE TRIP TIME SIGNIFICANTLY BUT AT A SIGNIFICANT PENALTY IN LAUNCH MASS. THE "SPRINT" MISSION HAS A ROUND TRIP TIME OF ONE YEAR WHICH IS HIGHLY DESIRABLE FROM THE VIEWPOINT OF CREW CAPABILITY IN ZERO G OVER TIME; BUT AT A MAJOR COST IN LEO MASS. OUR GOAL HERE IS TO USE THESE PRIOR STUDIES AS STARTING POINTS TO ESTABLISH THE REQUIREMENTS ON THE SPACE STATION TO ACCOMMODATE SUCH MISSIONS AND TO ASSESS THE IMPACT OF THESE REQUIREMENTS ON THE SPACE STATION INFRASTRUCTURE.

THIS REPORT FOCUSES ON ACCOMMODATION OF THE "SPRINT" MISSION.

THE BASIC SPACE STATION CONFIGURATION USED AS THE STARTING POINT FOR THIS STUDY IS THE "CRITICAL EVALUATION TASK FORCE" (CETF) DUAL KEEL SPACE STATION. THIS CONFIGURATION IS GENERALLY CONSIDERED TO BE THE NEXT STEP AFTER THE "PHASE 1" STATION IS ASSEMBLED ON ORBIT. THUS THE RESULTS OF THIS STUDY ARE APPLICABLE TO THE CURRENT SPACE STATION CONFIGURATION.

## Mars Sprint Mission Accommodation Study

# TYPICAL MANNED MARS MISSION CHARACTERISTICS

<u>MISSION CLASS</u>	<u>MARS STAY TIME</u>	<u>TRIP TIME</u>	<u>MASS</u>
CONJUNCTION (MINIMUM ENERGY)	ONE YEAR PLUS	3 YEARS	$10^6$ LB
OPPOSITION	30 TO 60 DAYS	2 YEARS	$1.5 - 2 \times 10^6$ LB
SPRINT	30 TO 60 DAYS	1 YEAR	$5 \times 10^6$ LB
SPLIT SPRINT (CARGO VEHICLE ON NEAR MINIMUM ENERGY TRAJECTORY 1 YEAR AHEAD OF CREW VEHICLE)	30 TO 60 DAYS	1 YEAR (CREW)	$1.6 \times 10^6$ LB (CREW) $1.3 \times 10^6$ LB (CARGO)

**Mars Sprint Mission Accommodation Study**

**STUDY TEAM**

**INTRODUCTION**

**E. BRIAN PRITCHARD**

**MISSION AND VEHICLE DESCRIPTION**

**WILLIAM M. CIRILLO  
MARTIN J. KASZUBOWSKI  
J. KIRK AYERS**

**LIFE SCIENCE ACTIVITIES**

**BARRY D. MEREDITH**

**ORBITAL TECHNOLOGY DEVELOPMENT/  
DEMONSTRATION PROGRAM**

**CHARLES P. LLEWELLYN  
DEENE J. WEIDMAN**

**VEHICLE ACCOMMODATION**

**MARTIN J. KASZUBOWSKI  
J. KIRK AYERS  
CHARLES P. LLEWELLYN  
WILLIAM M. CIRILLO**

**CONCLUSIONS/OBSERVATIONS**

**E. BRIAN PRITCHARD**

**APPENDIX - MISSION MANIFEST**

**MARTIN J. KASZUBOWSKI  
J. KIRK AYERS**

## **Mars Sprint Mission Accommodation Study**

# **GROUND RULES**

The mission and vehicle descriptions described in his report are those outlined in "Humans to Mars, a Space Leadership Initiative," written by John Niehoff of SAIC, and information contained in the Civil Needs DataBase (CNDB).

The Phase 2 International Space Station (125 Kw) was used as a baseline from which to begin the study. The Mars Sprint vehicles will be assembled in Low Earth Orbit (LEO) either attached to the Space Station or on a separate co-orbiting facility.

## Mars Sprint Mission Accommodation Study

### GROUND RULES

- o MISSION AND VEHICLE INFORMATION WAS OBTAINED FROM THE CIVIL NEEDS DATA BASE (CNDB) AND MR. JOHN NIEHOFF'S REPORT TO NASA MSFC, "HUMANS TO MARS, A SPACE LEADERSHIP INITIATIVE".
- o PHASE 2 SPACE STATION CONFIGURATION (125 Kw) USED AS BASELINE
- o MARS MISSION VEHICLES ARE ASSEMBLED IN LEO; ONLY ONE VEHICLE STACK IS ASSEMBLED AND VERIFIED IN LEO AT A TIME
- o 2 MAN RATED OMVs ARE AVAILABLE FOR ROUTINE CREW TRANSFER IF REMOTE ASSEMBLY FACILITIES ARE NECESSARY
- o LIQUID OXYGEN AND HYDROGEN PROPELLANT FOR THE MARS VEHICLES, HYDRAZINE FOR THE OMVs (WITH COLD GAS JETS FOR SPACE STATION PROXIMITY OPERATIONS)



## **Mars Sprint Mission Accommodation Study**

### **MISSION DESCRIPTION**

The following section outlines the specifics of a Sprint class mission to Mars, including mission timelines, trajectories, and operations.

## **Mars Sprint Mission Accommodation Study**

### **MISSION DESCRIPTION**

## Mars Sprint Mission Accommodation Study

### **MISSION DESCRIPTION**

The Mars Sprint Mission program consists of three manned missions to Mars starting in 2002 and ending in 2010. Each of the three missions is comprised of two phases. The first phase involves the on-orbit assembly and launch of an unmanned cargo vehicle, containing the Mars lander and launcher vehicles, surface habitation modules and laboratories, and the propellant for the manned return home. After eighteen months, the second phase, a piloted Mars vehicle, is launched from LEO to rendezvous with the unmanned cargo vehicle in Mars orbit. By separating the cargo and manned portions of the mission the propellant required to complete the mission is drastically reduced and the crew trip time is shortened by using a higher energy mission profile.

## Mars Sprint Mission Accommodation Study

### MISSION DESCRIPTION

- o THREE MANNED MISSIONS TO MARS
  - ROUND TRIP TIME APPROXIMATELY 420 DAYS
  - 30 DAY STAY TIME IN MARS ORBIT, 20 DAYS ON SURFACE
  
- o EACH MANNED MISSION IS PROCEEDED BY AN UNMANNED CARGO MISSION
  - LAUNCHED FROM LEO 18 MONTHS BEFORE CORRESPONDING MANNED MISSION
  - CARGO MUST BE MAINTAINED FOR APPROXIMATELY 18 MONTHS IN MARS ORBIT BEFORE RENDEZVOUS WITH THE PILOTED VEHICLE
  - EQUIPMENT DELIVERED TO MARS ORBIT FOR USE BY MANNED MISSION INCLUDES:
    - o MARS LANDER/ASCENT VEHICLE, AND SURFACE ROVERS
    - o HABITATION MODULES, LABORATORIES, ETC. FOR USE ON MARS SURFACE
    - o PROPELLANT FOR MANNED RETURN TRIP

## Mars Sprint Mission Accommodation Study

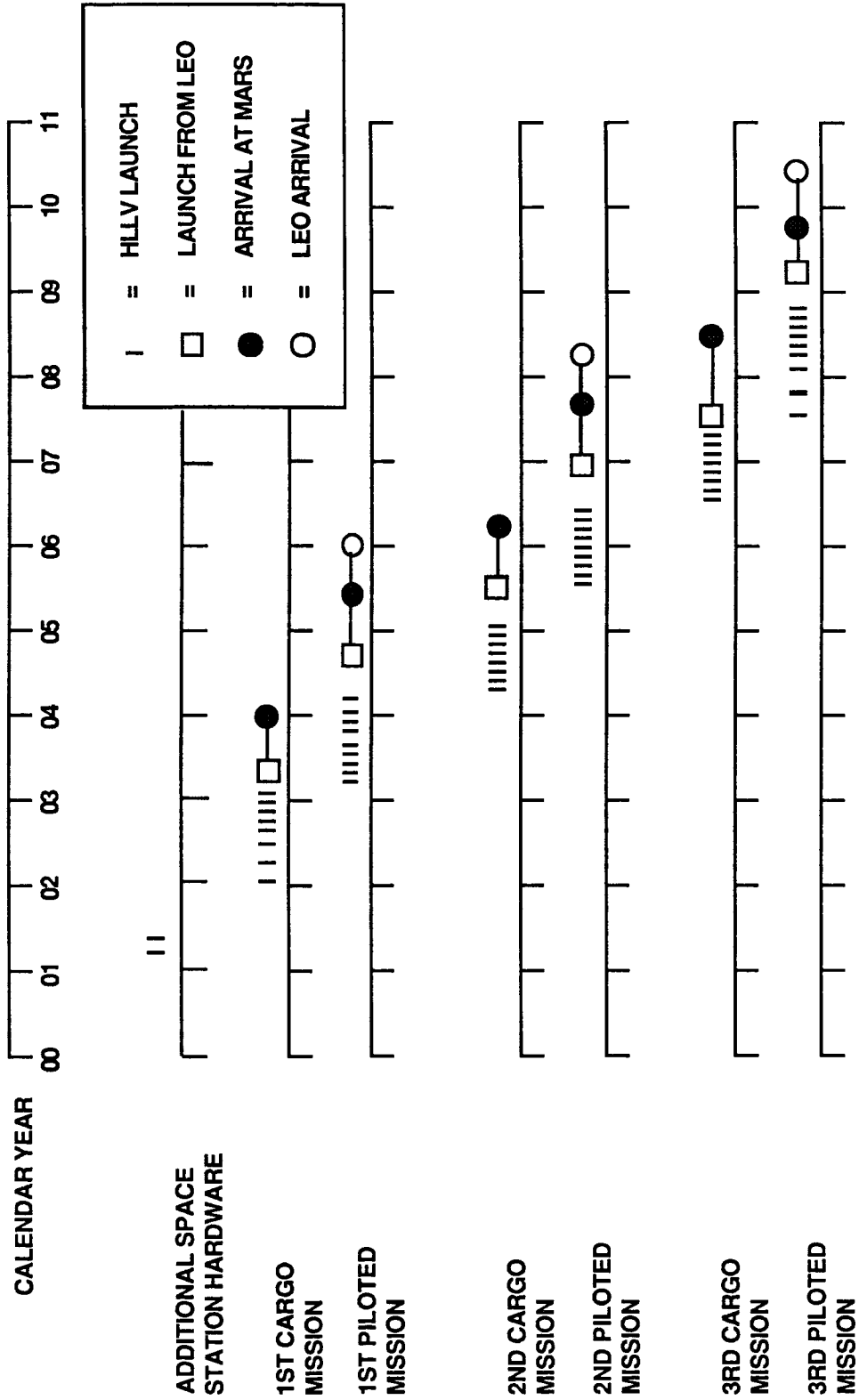
### **MISSION TIMELINE**

The mission timeline illustrates the required Heavy Lift Launch Vehicle (HLLV) flights necessary for each of the cargo and manned Mars flights. The HLLV used in this study has a payload lift capability of 200,000 pounds. Eight HLLV flights are required for each of the unmanned cargo missions and nine HLLV flights are necessary for the manned missions to deliver all of the required program hardware and propellants. Two HLLV flights are necessary at the beginning of the Mars program to deliver the additional Space Station hardware (modules, solar dynamics, truss, shielding, robotics, etc.) that is required to support the assembly and verification of the Mars Sprint Mission vehicles.

The issue of crew transportation via the shuttle, is discussed in a later section of the report.

# Mars Sprint Mission Accommodation Study

## MISSION TIMELINE



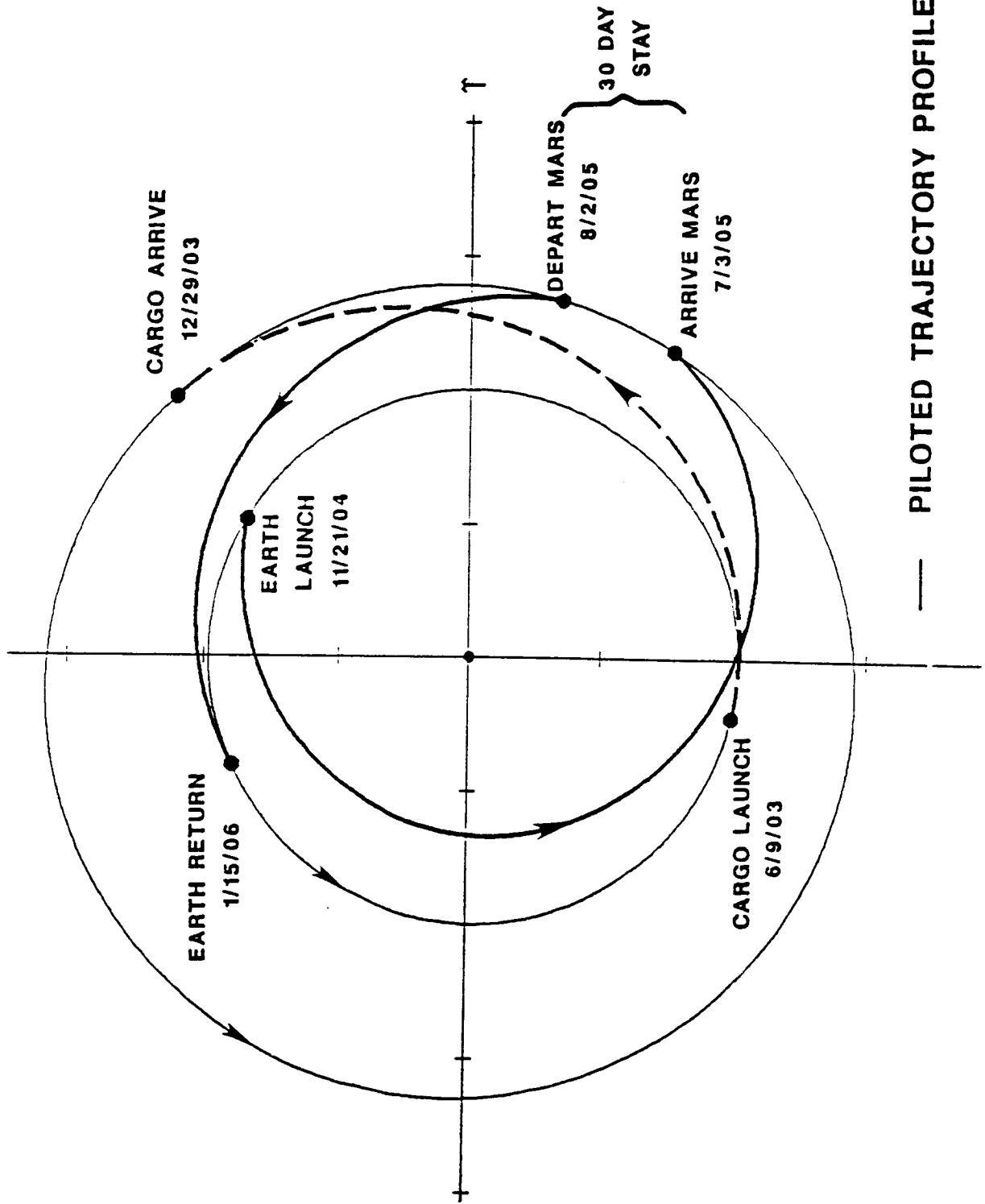
## Mars Sprint Mission Accommodation Study

# SPRINT MISSION TRAJECTORY PROFILE

The Mars Sprint Mission trajectory profile ( as provided by John Niehoff) is illustrated for the first of the three program missions. Total manned transit and stay time for each of the missions is approximately 420 days. Features of this trajectory include:

- a) Cargo vehicle delivery on a minimum energy transfer trajectory from Earth to Mars
- b) Cargo vehicle arrival at Mars well in advance of the launch of the Piloted vehicle to ensure that all of the Cargo vehicles systems are functioning properly and that the vehicle is in the correct orbit for a rendezvous with the Piloted vehicle
- c) The Piloted vehicle uses a high energy transfer trajectory in order to minimize the amount of time the crew is exposed to a low gravity environment
- d) The Piloted vehicles trajectories are tailored such that a fly-by mission abort capability is provided in case of a problem with either the Piloted vehicle or the Cargo vehicle station in orbit around Mars

Mars Sprint Mission Accommodation Study  
SPRINT MISSION TRAJECTORY PROFILE



— PILOTED TRAJECTORY PROFILE

--- CARGO VEHICLE TRAJECTORY PROFILE

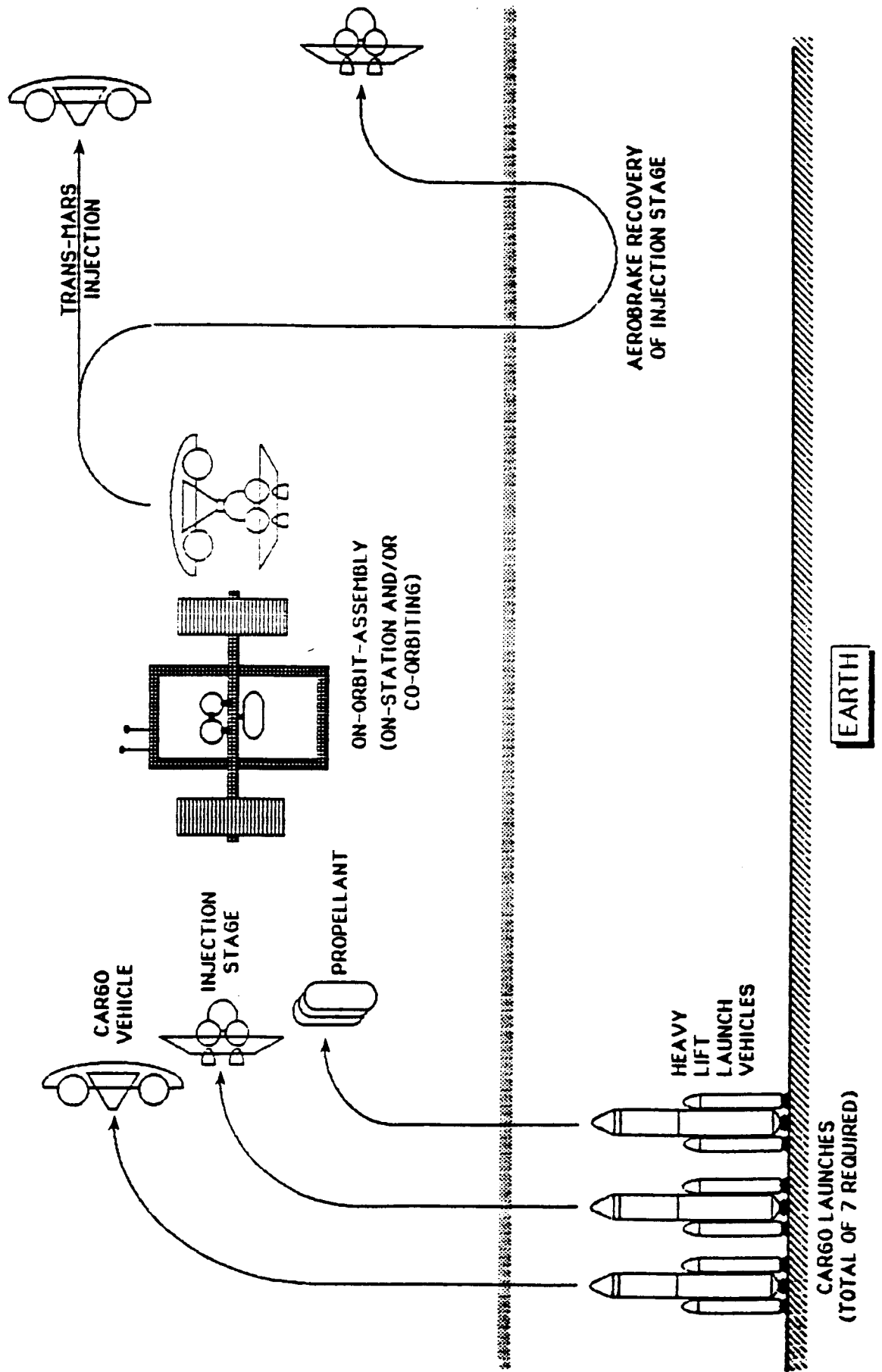


## Mars Sprint Mission Accommodation Study

### **EARTH ORBITAL CARGO FLIGHT OPERATIONS**

The Mars Sprint mission Cargo vehicle hardware and propellant is delivered to LEO via a series of eight HLLV launches. Once the hardware has arrived in LEO it is checked-out, final assembly is completed and verified, and the vehicle is fueled for Mars departure. The assembly of the Cargo vehicles may occur either on a growth version of the Space Station or on some form of a transportation depot (not pictured) designed specifically to handle large vehicle assembly.

Mars Sprint Mission Accommodation Study  
EARTH ORBITAL CARGO FLIGHT OPERATIONS



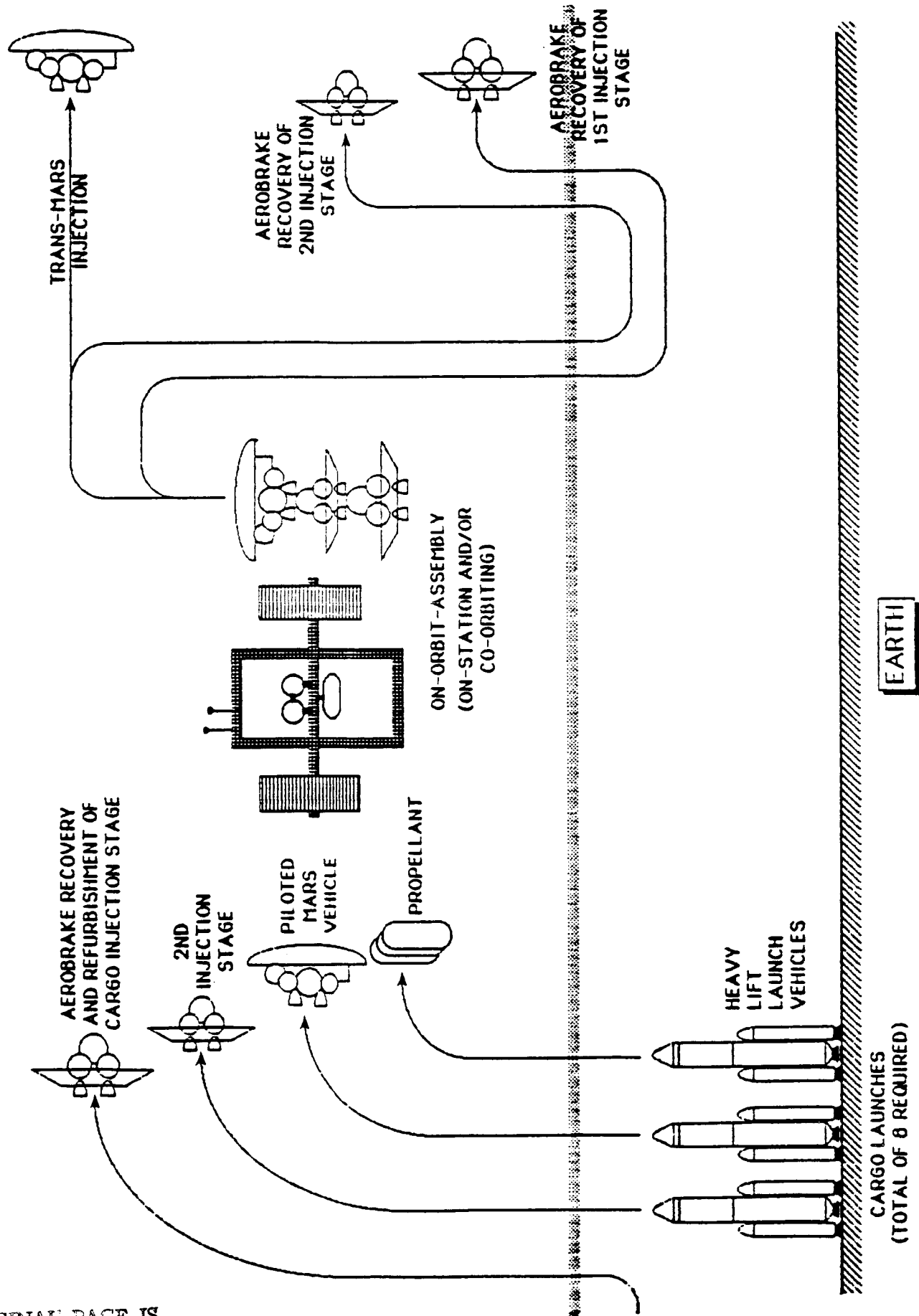
## **Mars Sprint Mission Accommodation Study**

# **EARTH ORBITAL PILOTED FLIGHT OPERATIONS**

The Mars Sprint mission Piloted Vehicle hardware and propellant is also delivered to LEO by a series of HLLV flights. The nine flights include all of the crew habitat modules, lab modules, propellant tanks, etc., that will undergo final assembly and verification while docked at the Space Station. A detailed launch manifest is provided at the end of the report.

Mars Sprint Mission Accommodation Study

EARTH ORBITAL PILOTED FLIGHT OPERATIONS



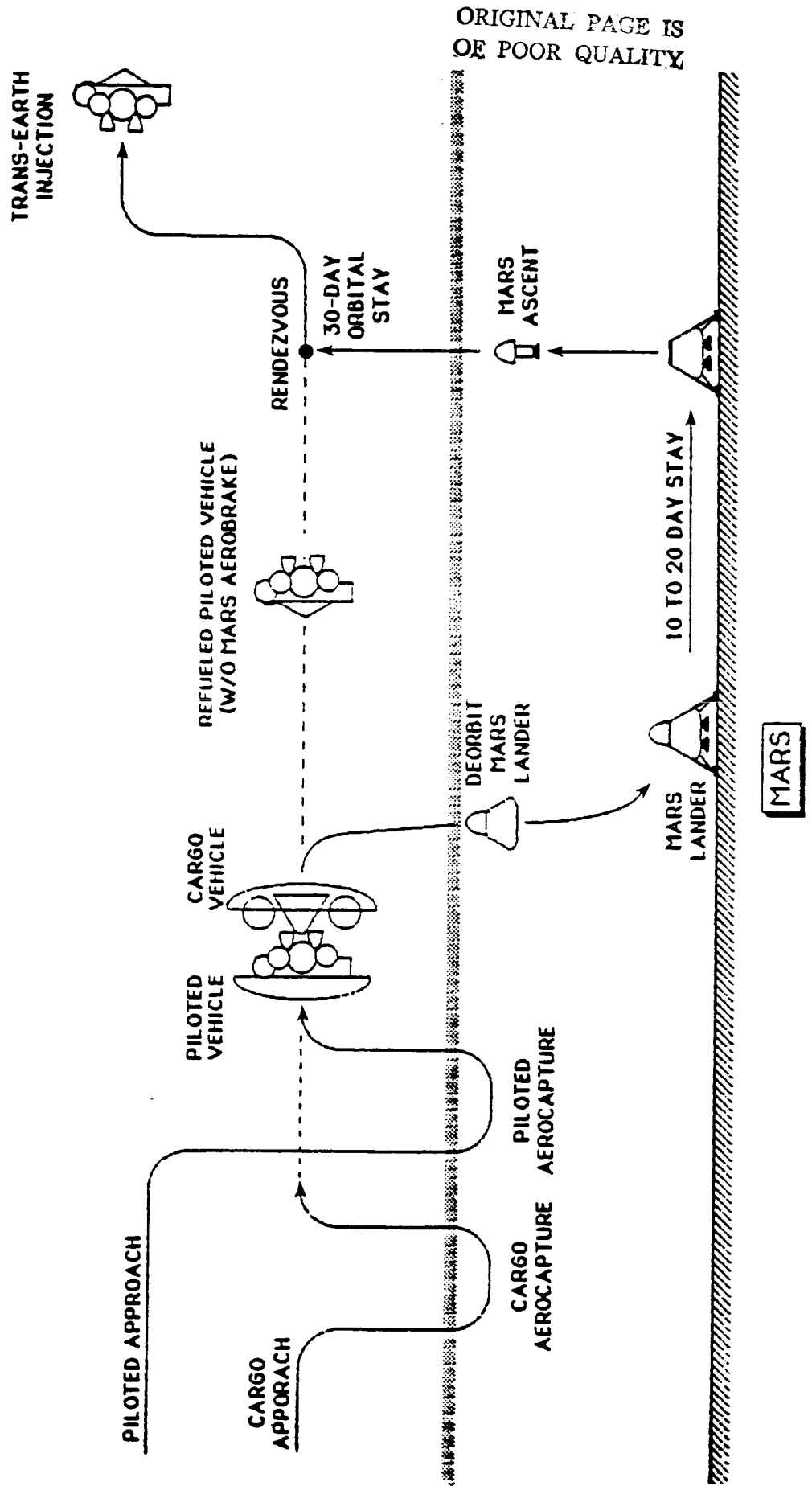
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## Mars Sprint Mission Accommodation Study

### **MARS ORBITAL/SURFACE OPERATIONS**

Once the unmanned cargo vehicle and the piloted Mars vehicle have rendezvoused in Mars orbit the six person crew will be divided to perform specific on-orbit and surface activities. Three crew members will board the Mars lander for transport to the surface where they will explore and conduct experiments for approximately twenty days. The three crew who remained on-orbit will transfer the propellant needed for return to Earth from the cargo vehicle to the piloted vehicle, and will conduct various space based experiments including the launch of experimental probes into orbit.

Mars Sprint Mission Accommodation Study  
MARS ORBITAL/SURFACE OPERATIONS



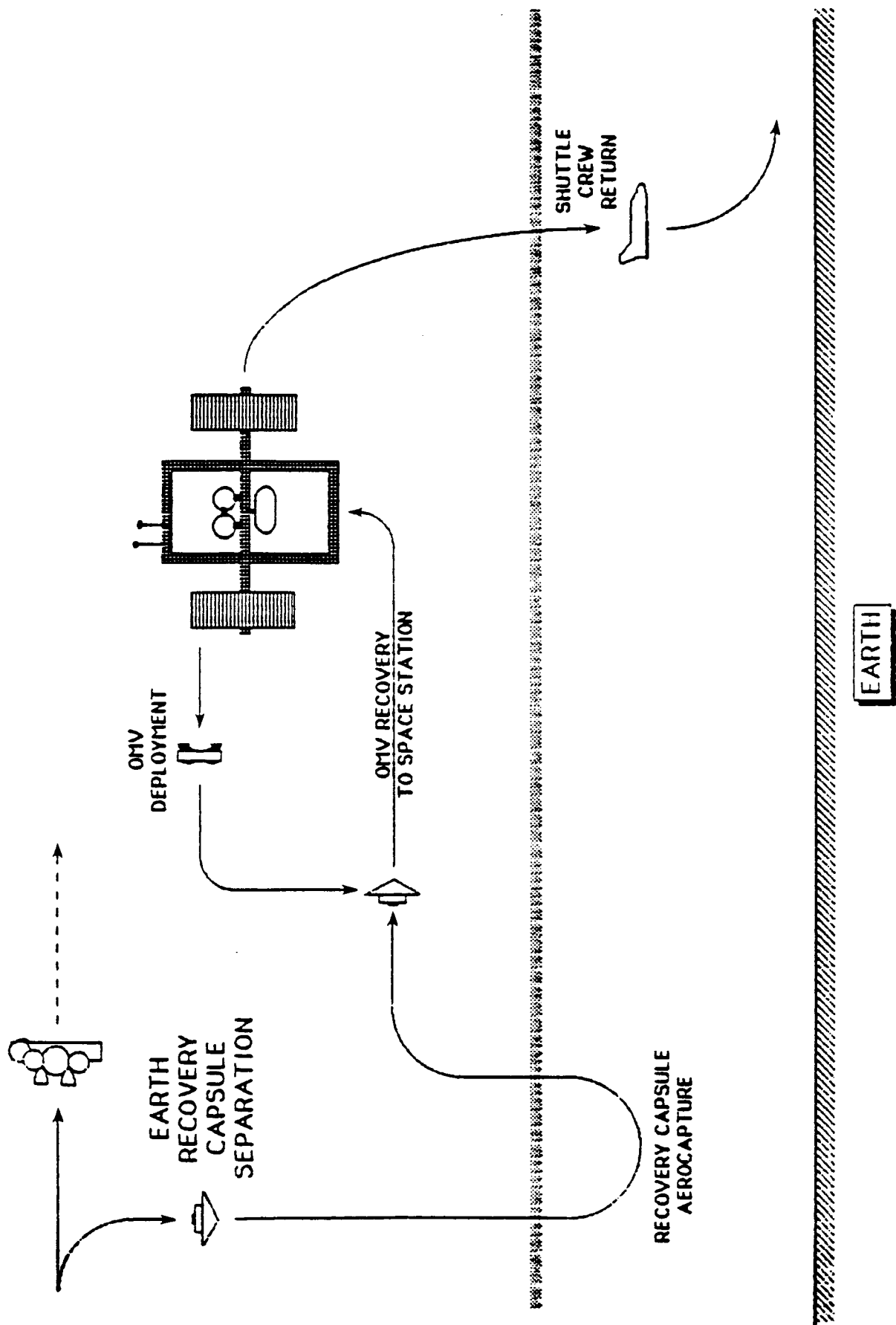
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## **Mars Sprint Mission Accommodation Study**

### **EARTH RECOVERY OPERATIONS**

The final step of the Mars Sprint mission is the recovery and return of the mission crew to the Space Station. Because of the high velocity of the returning Piloted vehicle, a crew capsule designed to carry the six crew and a small amount of samples, called the Earth Recovery Capsule (ERC), is seperated from the main structure of the returning Piloted vehicle. After the ERC performs an aerocapture maneuver, it will rendezvous with a waiting Orbital Maneuvering Vehicle (OMV) for return to the Space Station. The crew will then be returned to Earth aboard the Space Shuttle.

Mars Sprint Mission Accommodation Study  
**EARTH RECOVERY OPERATIONS**





## **Mars Sprint Mission Accommodation Study**

# **VEHICLE DESCRIPTION INTRODUCTION**

A complete Mars Sprint Mission consists of two vehicles. The first of these is the unmanned Cargo vehicle and the second, is the Piloted vehicle, which contains the mission crew. The mission is split into two different vehicles in order to reduce the total amount of propellant required, while reducing the overall crew mission time spent in low gravity. This is accomplished by transporting the Mars lander/ascent vehicle and the Piloted vehicle's Earth return propellant on the Cargo vehicle, which is traveling a low energy transfer trajectory. The second vehicle, the Piloted vehicle, contains the mission crew, with all of the habitats, laboratories, and logistics needed for the mission.

## **Mars Sprint Mission Accommodation Study**

### **VEHICLE DESCRIPTIONS**

## **Mars Sprint Mission Accommodation Study**

# **CARGO VEHICLE DESCRIPTION**

The Mars Sprint Mission Cargo vehicle stack consists of two major elements, the Cargo carrier and a reusable first propellant stage. The cargo carrier has an aeroshell for Mars orbit capture, and contains the Mars lander/ascent vehicle (fully fueled) and the Earth return propellant for the Piloted vehicle to refuel with upon rendezvous and mating. The reusable first stage has a pair of high impulse liquid hydrogen and liquid oxygen burning engines. An aeroshell is used for Earth return after the Trans Mars Injection (TMI) burn has been completed.

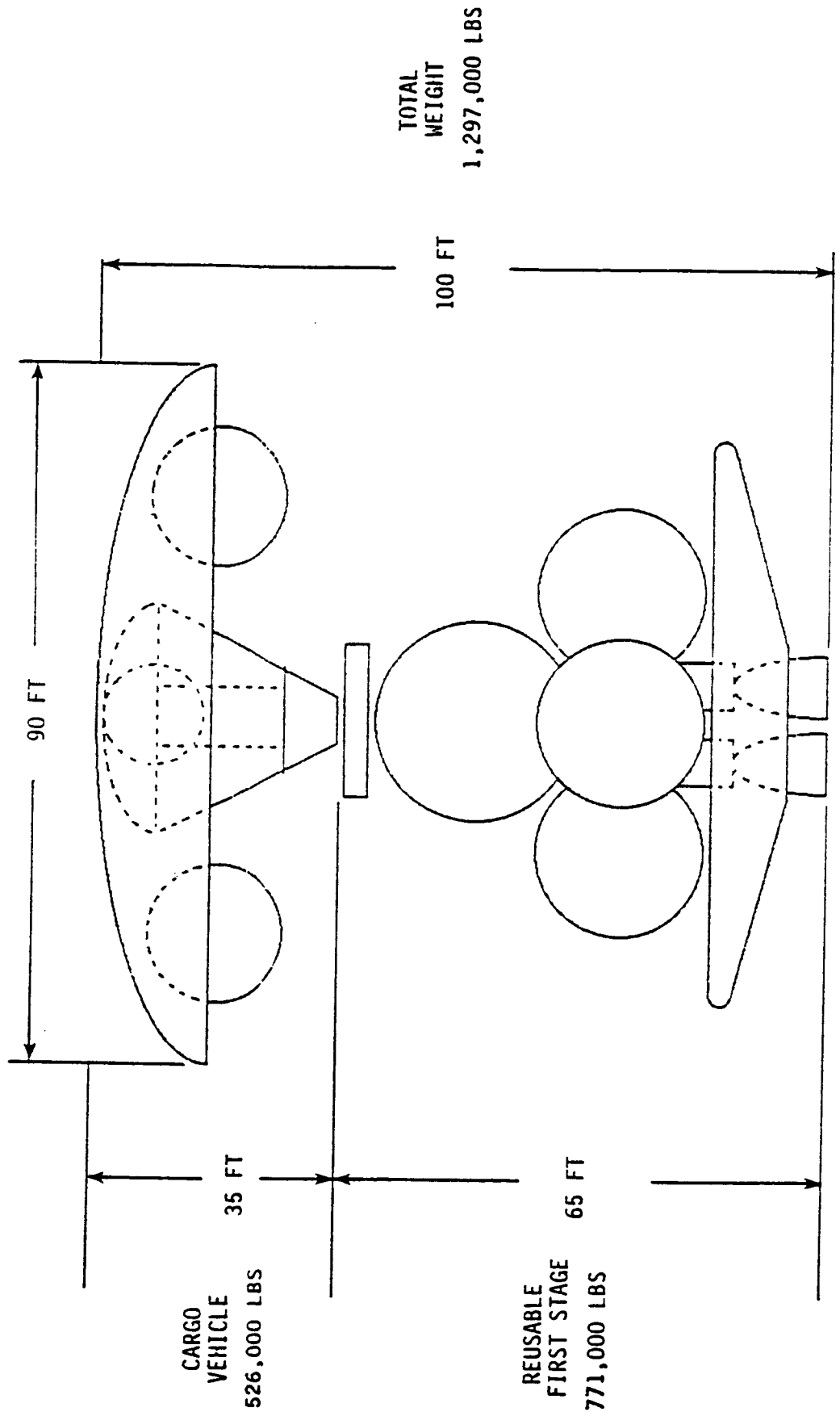
**Mars Sprint Mission Accommodation Study**  
**CARGO VEHICLE DESCRIPTION**

**THE CARGO VEHICLE STACK CONSISTS OF TWO MAIN PARTS, THE CARGO CARRIER PORTION AND THE REUSABLE 1ST STAGE**

- o CARGO CARRIER :**
  - MARS CAPTURE AEROSHELL**
  - PROPELLANT FOR PILOTED VEHICLE RETURN**
  - MARS LANDER/ASCENT VEHICLE**
  - TOTAL CARGO CARRIER WEIGHT IS 526,000 POUNDS**
  
- o REUSABLE 1ST STAGE:**
  - TWO HIGH IMPULSE LIQUID OXYGEN, LIQUID HYDROGEN ENGINES**
  - EARTH RETURN AEROSHELL**
  - TOTAL REUSABLE 1ST STAGE WEIGHT IS 771,000 POUNDS**

**TOTAL CARGO VEHICLE STACK WEIGHTS IS 1,297,000 POUNDS**

Mars Sprint Mission Accommodation Study  
**CARGO VEHICLE STACK AT LAUNCH**



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## **Mars Sprint Mission Accommodation Study**

# **PILOTED VEHICLE DESCRIPTION**

The Mars Sprint Mission Piloted vehicle stack consists of three major elements, the Piloted vehicle and two reusable propellant stages. The Piloted vehicle has an aeroshell for Mars orbit capture, and contains the necessary habitats, laboratories, logistics, power, etc. to complete the mission. The Piloted vehicle also has an Earth Recovery Capsule which the crew will use for Earth recovery at the completion of the mission or in the event that a safe haven is needed sometime during the trip for protection against unanticipated solar activity. The first reusable stage is the same first stage that was used for the Cargo mission after it has undergone refurbishment at the Space Station. The second reusable stage also uses a liquid oxygen, liquid hydrogen system and has an aeroshell assembly for Earth return.

In the event of a mission abort, the Piloted vehicle does not have to rendezvous with the Cargo vehicle to refuel, because it has enough energy in conjunction with a Mars fly-by to return to Earth.

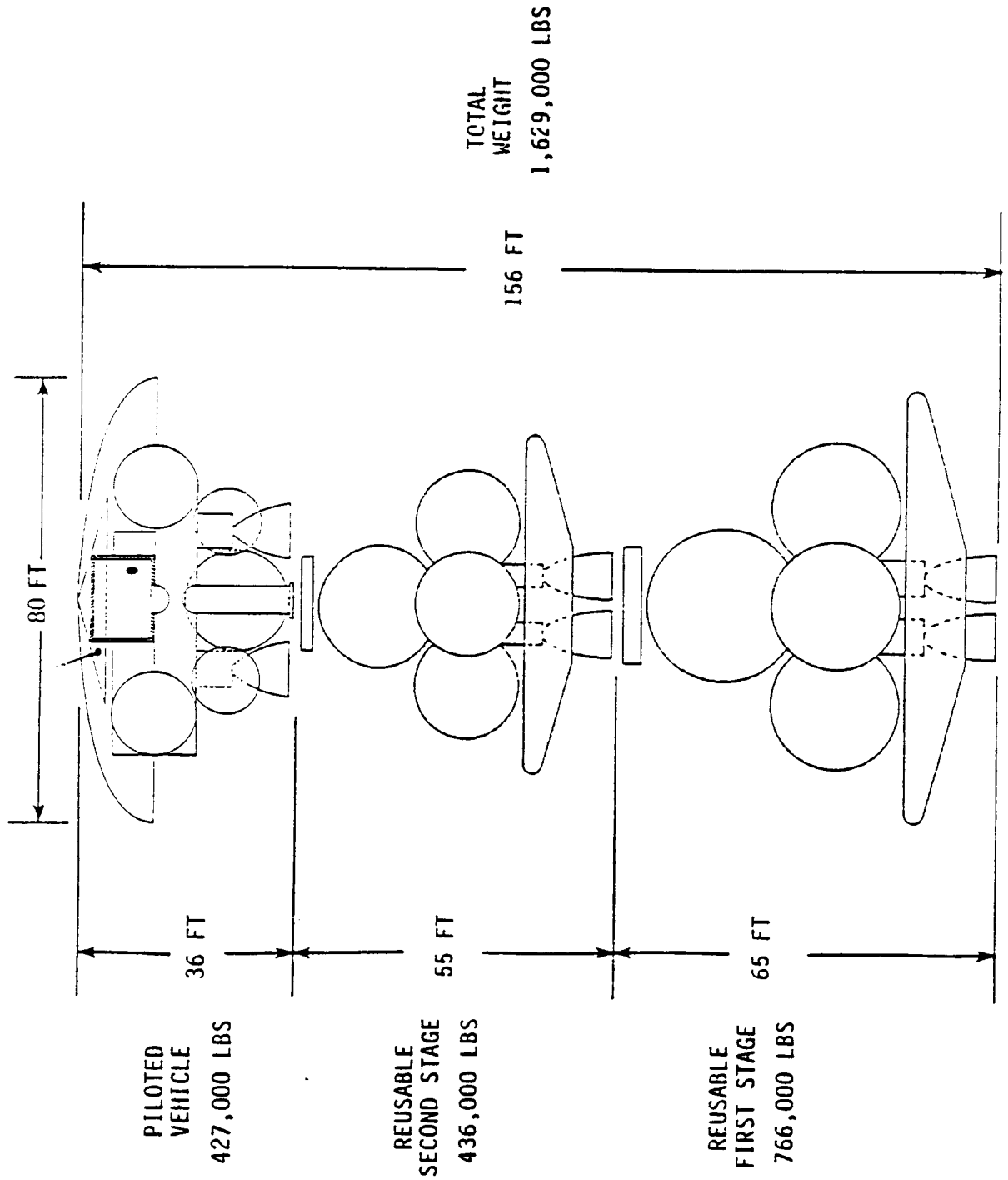
Mars Sprint Mission Accommodation Study  
**PILOTED VEHICLE DESCRIPTION**

THE PILOTED MARS VEHICLE STACK CONSISTS OF THREE MAIN PARTS, THE PILOTED VEHICLE ITSELF, AND TWO REUSABLE PROPULSION STAGES

- o PILOTED VEHICLE:
  - MARS CAPTURE AEROSHELL
  - HABITAT, LABORATORY, AND LOGISTIC MODULES
  - CREW RECOVERY CAPSULE AND STORM SHELTER
  - TOTAL PILOTED VEHICLE WEIGHT IS 427,000 POUNDS
  - EARTH RETURN PROPULSION SYSTEM
  
- o REUSABLE 1ST STAGE (REFURBISHED FROM CARGO MISSION):
  - TWO HIGH IMPULSE LIQUID OXYGEN, LIQUID HYDROGEN ENGINES
  - EARTH RETURN AEROSHELL
  - TOTAL REUSABLE 1ST STAGE WEIGHT IS 766,000 POUNDS
  
- o REUSABLE 2ND STAGE
  - TWO HIGH IMPULSE LIQUID OXYGEN, LIQUID HYDROGEN ENGINES
  - EARTH RETURN AEROSHELL
  - TOTAL REUSABLE 2ND STAGE WEIGHT IS 436,000 POUNDS

TOTAL CARGO VEHICLE STACK WEIGHTS IS 1,629,000 POUNDS

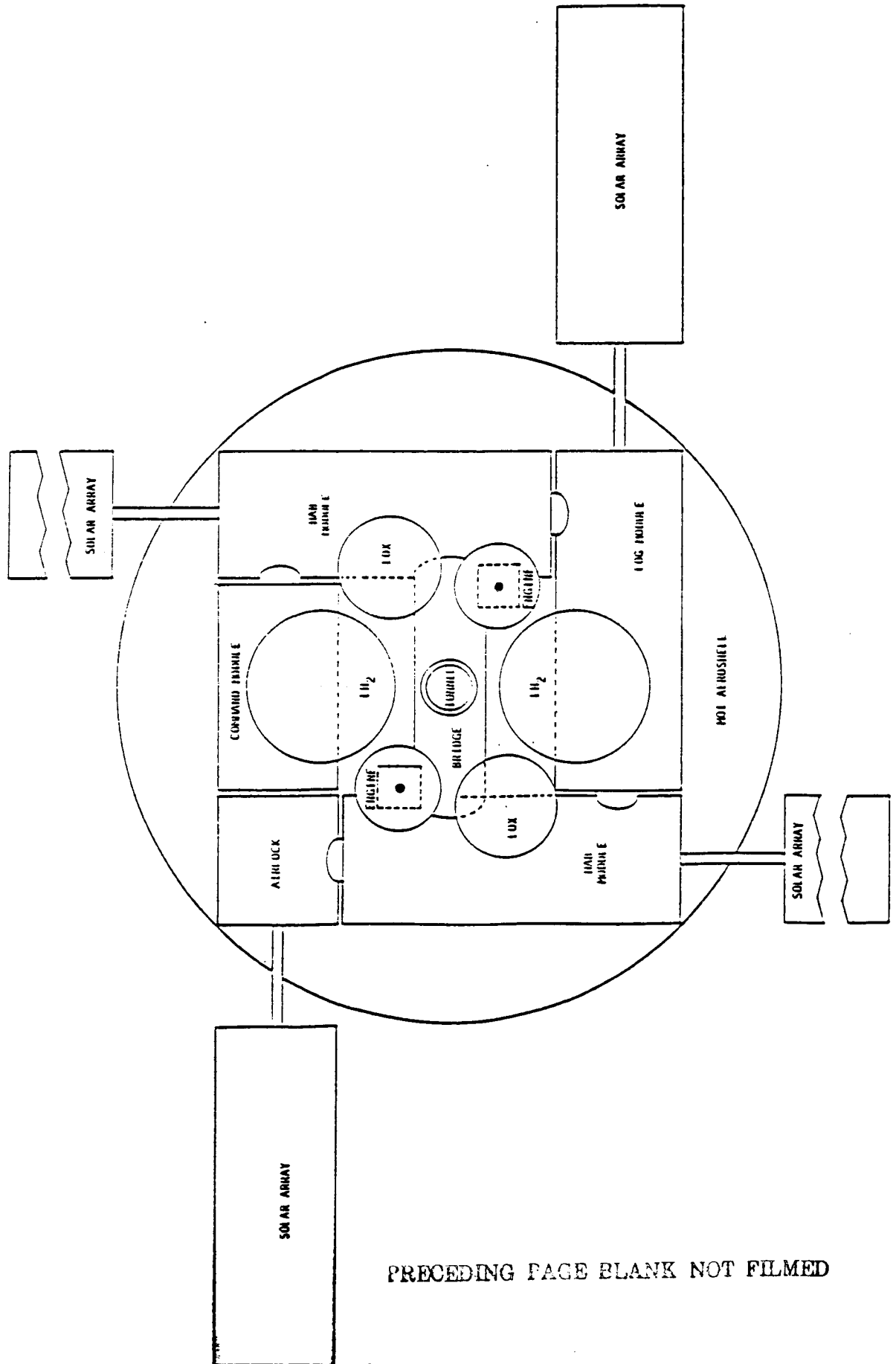
Mars Sprint Mission Accommodation Study  
PILOTED VEHICLE STACK AT LAUNCH



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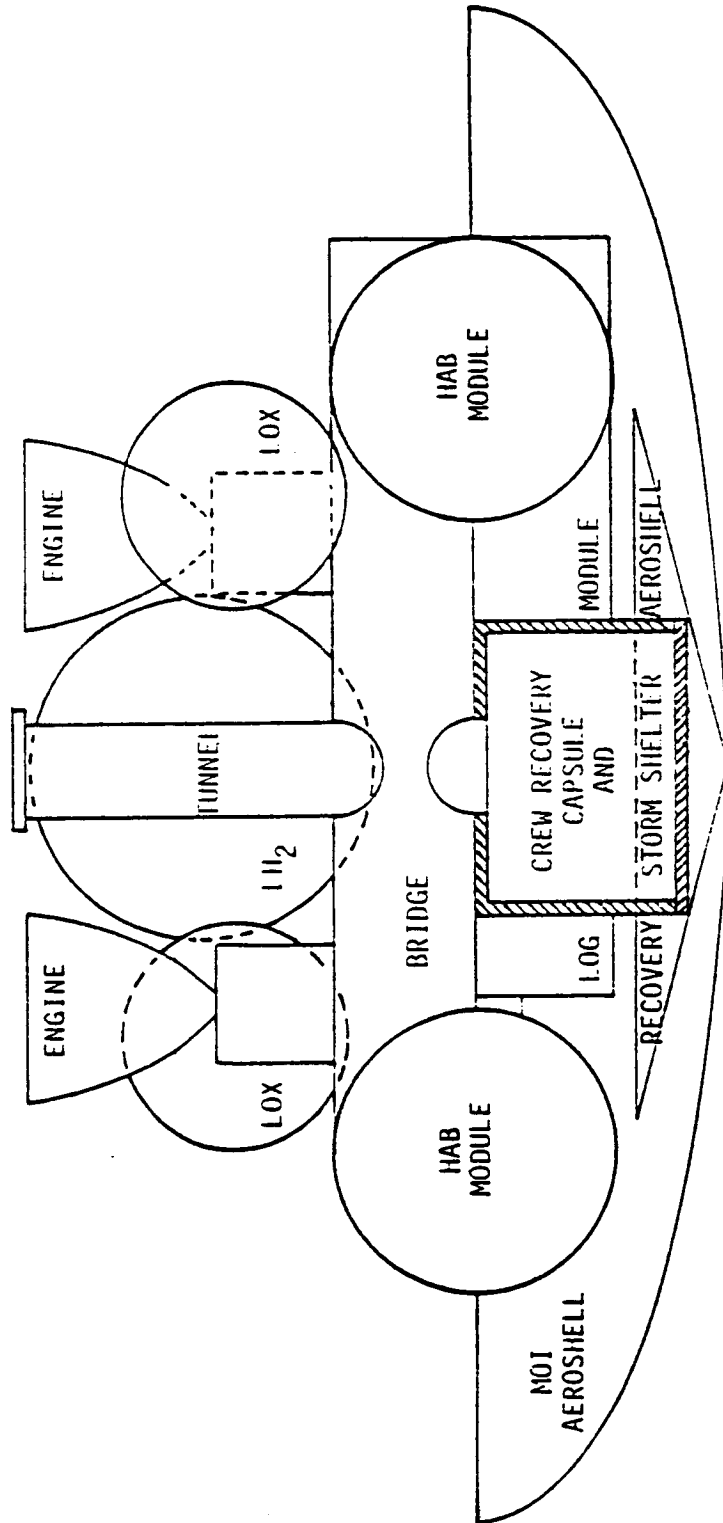


Mars Sprint Mission Accommodation Study  
PILOTED VEHICLE (TOP VIEW)



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Mars Sprint Mission Accommodation Study  
PILOTED VEHICLE (SIDE VIEW)



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**Mars Sprint Mission Accommodation Study**

**LIFE SCIENCES**

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## Mars Sprint Mission Accommodation Study

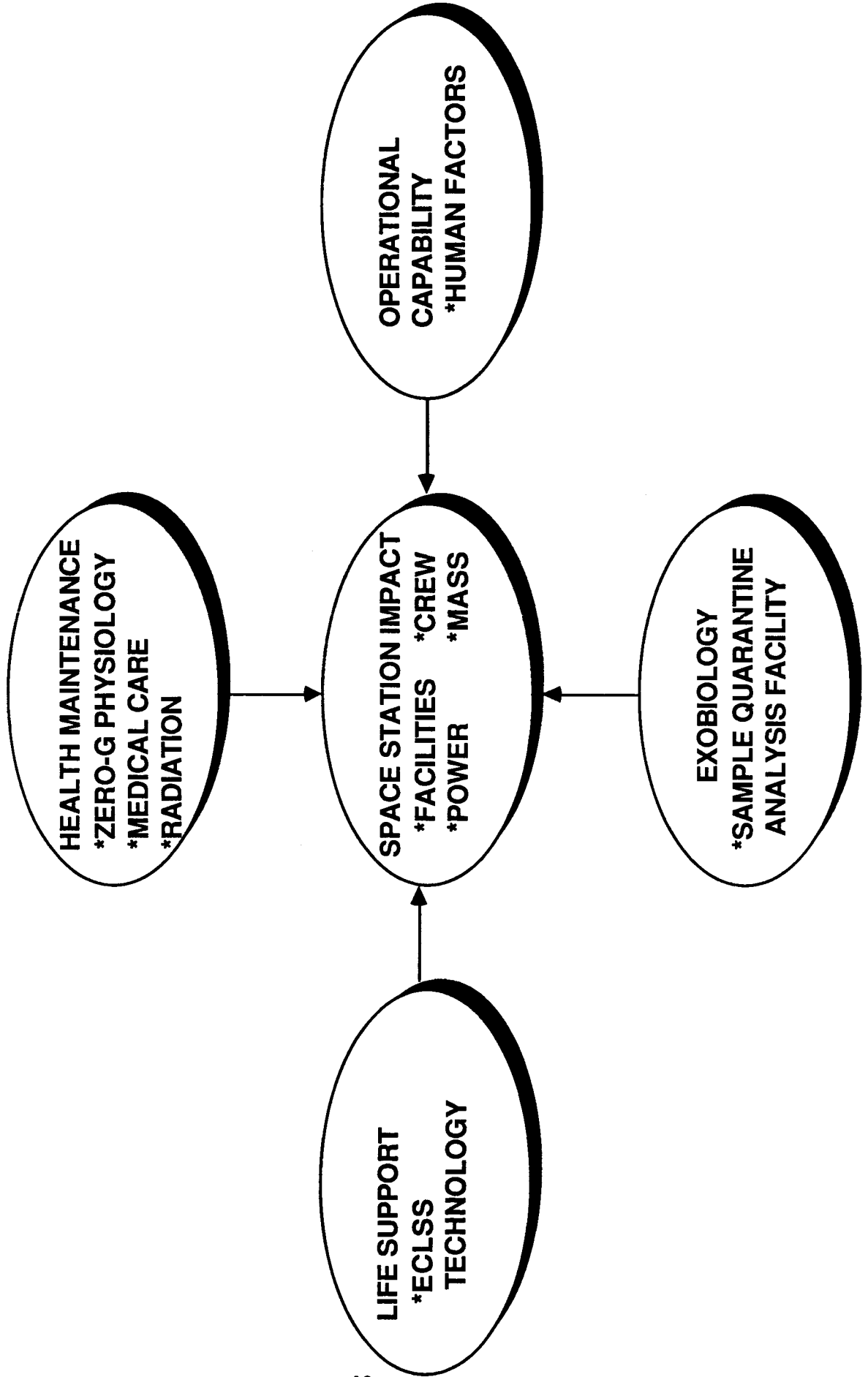
### LIFE SCIENCES AREAS OF EMPHASIS

Prerequisite to any humans to Mars mission is the need to better understand the physiological and psychological impact of long duration space flight. Of particular concern, is the area of health maintenance and the problems associated with long-term exposure to weightlessness. Bone mass loss, muscle atrophy and cardiovascular deconditioning are known to occur in zero gravity; therefore, research into the development of effective countermeasures to these adverse effects is the primary emphasis of the life science program at the Space Station. It is also necessary to provide resources at station to investigate medical issues such as wound healing, immune system responses and surgical techniques in zero gravity. There is the threat of exceeding annual and career radiation doses on the journey to Mars so it is necessary to better understand the radiation environment and how particles behave as they pass through various materials. Experiments will be conducted at station to develop improved shielding technology.

Life support system technology will be investigated at station to improve the reliability and effectiveness of water recovery, air revitalization, environmental monitoring, and waste recycling systems. Research in the field of human factors will be directed toward minimizing the adverse psychological effects of crew isolation and confinement and increasing crew productivity and performance. Space Station resources may also be required in the area of exobiology for a Sample Analysis Facility (SAF) to quarantine and analyze extraterrestrial materials. The objective is to prevent contamination of the Earth by the materials and of the materials by humans.

Mars Sprint Mission Accommodation Study

**ANALYSIS OF CRITICAL LIFE SCIENCE AREAS**



## Mars Sprint Mission Accommodation Study


# PACING MILESTONES FOR LIFE SCIENCE AND DEVELOPMENT PROGRAMS

The sprint mission scenario calls for an aggressive, two-year, zero-g countermeasure (CM) development program at the Space Station as soon as station is permanently manned (PMC). The first year is devoted to the testing of candidate CM's and then selected CM(s) are verified during a one year simulation at the station utilizing two crew members. If effective CM's are developed, a phase C/D is initiated for a zero-g piloted vehicle, if not, design and development of a variable-g research facility begins and the test/simulation phase(s) continues at the station. The sample quarantine/analysis module is assumed to be brought to station in early '98, systems operation and material handling protocols are verified and Mars samples arrive in late '99.

# MARS SPRINT MISSION ACCOMMODATION STUDY

## PACING MILESTONES FOR LIFE SCIENCE AND DEVELOPMENT PROGRAMS

| 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 |

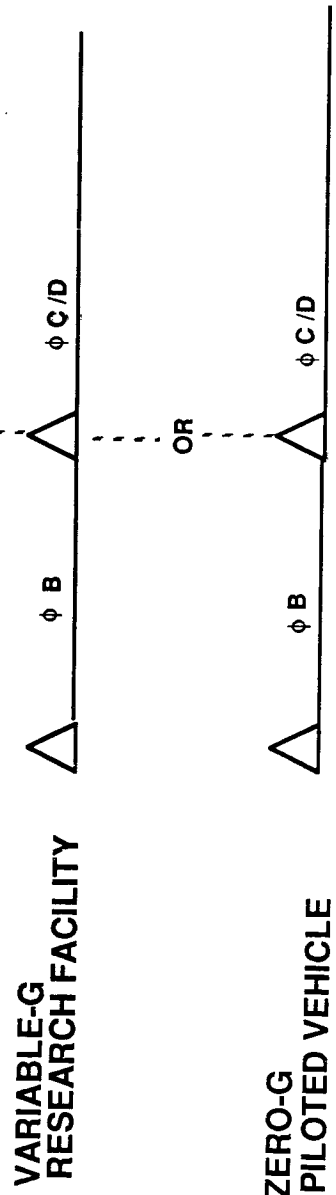
MARS SAMPLE TOSS 

QUAR. MOD. 

PMC 



New Start



## Mars Sprint Mission Accommodation Study

### AVERAGE CREW REQUIREMENT

This table presents the average Space Station crew requirements during the precursory, research and development period. One of the ground rules for the study was that the baseline station resources will be reserved for R & D missions unrelated to the Mars Sprint Mission (e.g., materials processing, astrophysics). Therefore, the baseline crew of 8, which includes 6.5 crew, set aside for "other" space science activities. The average crew requirement for life sciences varies from a nominal level of 1.5 to 2.9 during the two year zero-g, countermeasure test/simulation phase and a peak of 3.5 when an additional, dedicated crew of 2 is needed to support Mars sample quarantine and analysis. After structural additions to the station are completed in '01, assembly of the first cargo vehicle begins in '02 which requires two shifts of 3 crew each. The total crew requirement for the precursory period is adjusted to compensate for the fact that 1.5 of the life science crew is actually embedded in the baseline of 8 as defined by the Mission Requirements Data Base (MRDB).



**MARS SPRINT MISSION ACCOMMODATION STUDY**  
**MARS SPRINT MISSION AVERAGE CREW**  
**REQUIREMENTS**

	'94	'95	'96	'97	'98	'99	'00	'01	'02
BASELINE 1 CREW	8	8	8	8	8	8	8	8	8
LIFE SCIENCE	2.9	2.9	2.9	1.5	1.5	3.5	1.5	1.5	1.5
ON-ORBIT TECH. DEVELOPMENT	--	1	1	1	0.7	0.7	0.7	--	--
VEHICLE ASSEMBLY / C/O	--	--	--	--	--	--	--	3	6
TOTALS	10.9	10.9	11.9	10.5	10.5	10.2	11.3	12.5	15.5

TOTAL MSM <sup>2</sup> REQUIREMENTS CREW AFTER ADJUSTMENT FOR BASELINE LIFE SCIENCES	9.4	10.4	9	8.7	9.8	11	14
--	-----	------	---	-----	-----	----	----

1 - RESERVED FOR COEXISTING SCIENCE, COMMERCIAL AND TECHNOLOGY ACTIVITIES

2 - BASELINE CREW OF 8 INCLUDES 1.5 CREW FOR LIFE SCIENCE MISSIONS (SAAX 307, 307A, 311).

## **Mars Sprint Mission Accommodation Study**

# **SOURCES OF LIFE SCIENCE REQUIREMENTS**

A variety of sources were consulted in the process of identifying resource requirements for Space Station support of life science research. These included relevant science and application (SAAX) missions within the Mission Requirements Data Base and a summary of the Phase B, Science Lab Project produced by ORI, Inc. for Goddard Space Flight Center. In addition, communications (written and oral) with life science personnel at NASA Headquarters were utilized to derive requirements.

## MARS SPRINT MISSION ACCOMMODATION STUDY

### SOURCES OF LIFE SCIENCE REQUIREMENTS

- o SPACE STATION MRDB
  - SAAX 307 COMBINED ANIMAL, HUMAN, PLANT RESEARCH
  - SAAX 307A 1.8M CENTRIFUGE
  - SAAX 311 4.0M CENTRIFUGE
  - SAAX 303 HUMAN RESEARCH INCLUDING MEDICAL CARE TECHNOLOGY, HUMAN PERFORMANCE, RADIATION EFFECTS AND MORE
  - SAAX 304 CELSS EXPERIMENTAL SYSTEMS - IN ADDITION TO FOOD LOOP CLOSURE, ADDRESSES WASTE RECYCLING, WATER RECOVERY AND AIR REVITALIZATION TECHNOLOGY
  - SAAX 117 SAMPLE QUARANTINE / ANALYSIS MODULE
- o "SLM PROJECT SUMMARY," ORI, INC., 12/86  
(INCLUDES GSFC BREAKDOWN OF EQUIPMENT PER FUNCTION)
- o LIFE SCIENCE PRESENTATION MATERIAL
  - "ADVANCED MISSIONS WITH HUMANS IN SPACE," SULZMAN, 1/87
  - "PROJECT PACER," KELLER, 4/87
- o CONVERSATIONS WITH NASA HQS CODE EB PERSONNEL

## Mars Sprint Mission Accommodation Study

# ZERO-G COUNTERMEASURES PROGRAM TEST PHASE REQUIREMENTS

Space Station resource requirements for each life science discipline are shown. Volume is expressed in terms of dual, standard six-foot instrument racks; average electrical power is in kilowatts; launch mass is in kilograms and the crew specification is considered to be an average of a "pool" of crew resources without regard to skill mix or peak requirements (e.g., a crew of 1 is equal to 6 work days per week multiplied by a 9 hour per day work shift or 54 crewhours/week). By far, the largest percentage of resources are devoted to the zero-g physiology functions since the development of effective countermeasures is the primary thrust and drives the design of the piloted Mars vehicle.

# MARS SPRINT MISSION ACCOMMODATION STUDY

## ZERO-G COUNTERMEASURES PROGRAM TEST PHASE REQUIREMENTS

<u>DISCIPLINE</u>	<u>DOUBLE RACKS</u>	<u>AVERAGE POWER (KW.)</u>	<u>EQUIPMENT MASS (KG.)</u>	<u>AVERAGE CREW</u>
ZERO-G PHYSIOLOGY				
ANIMAL RESEARCH	6.0	1.6	1800	
HUMAN RESEARCH	10.0	1.4	2020	2.3
1.8M CENTRIFUGE	2.0	2.0	1000	
4M CENTRIFUGE	8.0	3.5	2000	
TOTALS	26.0	8.5	6820	
MEDICAL CARE TECHNOLOGY	4.0	0.8	800	
HUMAN FACTORS	0.5	0.2	100	0.5
RADIATION RESEARCH	0.5	0.2	125	
ECLSS TECHNOLOGY	1.0	0.5	250	0.1
TEST PHASE TOTALS	32.0	10.2	8095	2.9

## **Mars Sprint Mission Accommodation Study**

### **ALLOCATION OF FUNCTIONS**

**Non-life science activities are allocated to the Space Station resource nodes or the Japanese Experimental Module (JEM) to maximize volume in the U.S. lab available to human, animal and plant research. Much of the microgravity research would be conducted in the ESA module.**

**MARS SPRINT MISSION ACCOMMODATION STUDY**

**ALLOCATION OF FUNCTIONS**

	<b>USL</b>	<b>NODE</b>	<b>JEM</b>	<b>ESA</b>
<b>PLANT RESEARCH</b>	X			
<b>ANIMAL RESEARCH</b>	X			
<b>HUMAN RESEARCH</b>	X			
<b>TDMX (1)</b>			X	
<b>APM&amp;C (2)</b>			X	
<b>IVA SERVICING</b>		X		
<b>μ - GRAVITY RESEARCH</b>				X

(1) TECHNOLOGY DEVELOPMENT MISSIONS

(2) ATTACHED PAYLOAD MONITORING AND CONTROL

## Mars Sprint Mission Accommodation Study

### **LAB MODULE VOLUME ALLOCATION**

The primary constraint to life sciences at the Space Station is the internal volume available within the lab module. Of a total of 44 double racks available, 20 are assumed to be needed for subsystems and crew support. Therefore, the remaining 24 can be utilized for mission equipment.



**MARS SPRINT MISSION ACCOMMODATION STUDY**

**LAB MODULE VOLUME ALLOCATION**

- o VOLUME UNIT = DOUBLE RACK = 2 STANDARD, 6' INSTRUMENT RACKS
- o TOTAL VOLUME AVAILABLE PER MODULE = 44 DOUBLE RACKS
- o ALLOCATION
  - OVERHEAD:
  - COMMON MODULE SUBSYSTEMS      18\*
  - CREW SUPPORT                              2\*

**THEREFORE, 24 RACKS ARE AVAILABLE FOR MISSION EQUIPMENT**

\* FROM RCA/LMSC PHASE B ANALYSIS

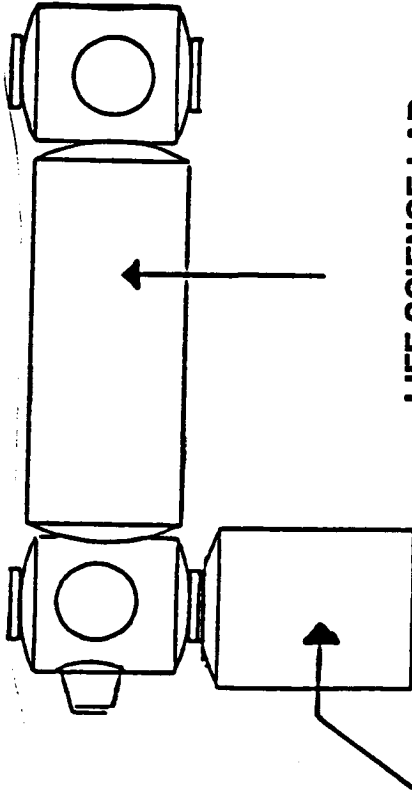
## **Mars Sprint Mission Accommodation Study**

# **TEST PHASE LAB CONFIGURATION AND FUNCTIONAL ALLOCATION**

The 4-meter centrifuge is configured within a dedicated "pocket" lab which is approximately one-half of a common module. This approach isolates potential disturbances away from the primary lab module and maintains clear egress in the module. The remaining functions consume all the available user volume in the U.S. lab which is designated as the life science lab.

# MARS SPRINT MISSION ACCOMMODATION STUDY

## TEST PHASE LAB CONFIGURATION AND FUNCTIONAL ALLOCATION



### POCKET LAB

- o 4 M CENTRIFUGE
- o 3.5 KW; 8 DOUBLE RACKS;  
2000 KG

### LIFE SCIENCE LAB

- o ZERO-G PHYSIOLOGY RESEARCH
- o MEDICAL CARE TECHNOLOGY
- o ECLSS TECHNOLOGY
- o RADIATION RESEARCH
- o HUMAN FACTORS
- o 6.7 KW; 24 DOUBLE RACKS; 6095 KG

## Mars Sprint Mission Accommodation Study

# MARS SAMPLE QUARANTINE/ANALYSIS FACILITY REQUIREMENTS

Additional resources, facilities and equipment will be needed at Space Station for the quarantine and analysis of samples returned by the Mars Rover Sample Return Mission. A half lab or pocket lab has been identified as the station facility for sample quarantine and analysis.

MARS SPRINT MISSION ACCOMMODATION STUDY

MARS SAMPLE QUARANTINE/ANALYSIS FACILITY  
REQUIREMENTS

<u>TOTAL</u> <u>VOLUME</u>	<u>POWER (KW)*</u>	<u>EQUIPMENT*</u> <u>MASS (KG)</u>	<u>CREW*</u>
0.5 LAB	5	2500	2

\* - RESOURCES ARE ESTIMATES OF MISSION  
REQUIREMENTS ONLY - NO HOUSEKEEPING

## **Mars Sprint Mission Accommodation Study**

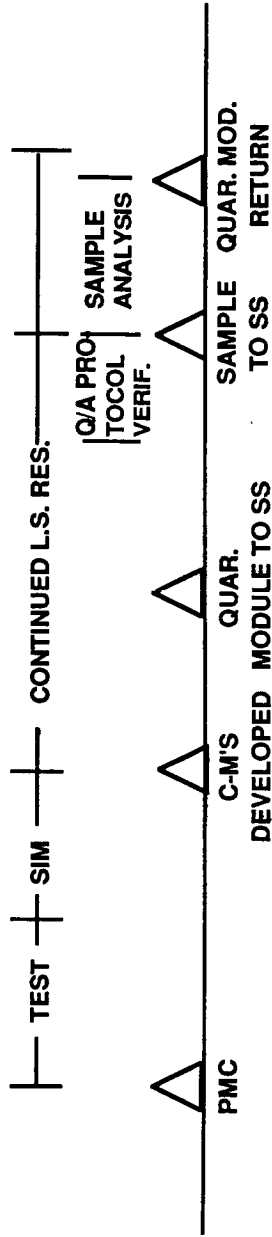
# **PHASED SPACE STATION LIFE SCIENCES**

The Life Science Program at Space Station in support of the Sprint Mission to Mars can be partitioned into four phases. The countermeasure test phase and subsequent simulation phase have identical requirements for station resources and facilities. Assuming effective CM's are produced, the third phase will consist of continued research at somewhat reduced resource levels for the purpose of further validating CM's to establish confidence in their effectiveness. The final phase includes the continued life science research plus requirements for the Mars Sample Quarantine/Analysis.

# MARS SPRINT MISSION ACCOMMODATION STUDY

## PHASED SPACE STATION LIFE SCIENCES

| 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 |



<u>TEST</u>	<u>SIM</u>	<u>CONTINUED L.S. RES.</u>	<u>L.S. RES. + SAMPLE Q/A SPT</u>
o C-M EMPHASIS	o 1 YEAR CREW	o C-M VALIDATION	o CONTINUED L.S. RESEARCH
o ALL CRITICAL L.S. AREAS ADDRESSED	o STAY WITH C-M'S CONCURRENT RESEARCH IN ALL AREAS	o MEDICAL CARE TECH.	PLUS:
- 1 L.S. LAB	o RESOURCE REQMTS. SAME AS TEST PHASE	o ECLSS TECH.	- QUAR. MODULE
- 1 POCKET LAB		o PLANT RESEARCH	- 5 KW.
- 10.2 KW.		o RADIATION RESEARCH	- 2 CREW
- 2.9 CREW		- 2/3 L.S. LAB	
		- 1 POCKET LAB	
		- 8 KW.	
		- 1.5 CREW	

**Mars Sprint Mission Accommodation Study**

**ORBITAL TECHNOLOGY DEVELOPMENT/  
DEMONSTRATION PROGRAM**

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## Mars Sprint Mission Accommodation Study

### TECHNOLOGY ISSUES - TOP LEVEL

This chart depicts the Top Level issues that are germane to manned Mars missions. The technologies listed have not been prioritized or time phased in terms of development or technology readiness, but were used as a basis to determine areas of specific emphasis for IOC Space Station focused support. For example, ECLSS, Automation & Robotics, and Structures are space station technology areas that are directly transferable to the Mars missions.

It should be pointed out here that in this study, only those technologies that required the space station for direct on-orbit support were considered in any depth. Areas such as Surface Transportation and Electrical Power, for instance, could best be done on the ground with a minimum of prototype and final flight hardware demonstration and verification being done in space.

## **TECHNOLOGY ISSUES - TOP LEVEL**

- o ADVANCED ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ECLSS)
  - AIR, WATER, WASTE MANAGEMENT, FOOD PROCESSING
- o CREW SYSTEMS
  - ADVANCED EVA SUITS
  - HABITABILITY CONSIDERATIONS
  - HEALTH CARE AND MAINTENANCE CONSIDERATIONS
- o SURFACE TRANSPORTATION
  - ROVERS (UNMANNED, MANNED)
- o AUTOMATION AND ROBOTICS
  - CARGO HANDLING
  - ASSEMBLY
  - REMOTE SITE EXPLORATION
- o STRUCTURES
  - AEROBRAKE/AEROSHELL
  - ASSEMBLY AND HANDLING
- o POWER/THERMAL
  - SOLAR
  - NUCLEAR
  - CHEMICAL
- o LONG-TERM PASSIVE STORAGE MISSION SYSTEMS/SUBSYSTEMS
  - RADIATION/TEMPERATURE EFFECTS
  - PROPELLANT STORAGE
  - MAINTENANCE/ACTIVATION

## Mars Sprint Mission Accommodation Study

# TECHNOLOGY ISSUES-STATION FOCUSED

The technology shown in this chart depict those that the study identified as needing early or accelerated emphasis on the Space Station. All of the issues listed here, with the possible exception of GN&C, COMM/TRACK, and DMS are considered as "enabling" technologies and all are dependent on the space station as a test bed for development and testing of prototype and flight hardware. While there was no major impact on space station ECLSS technologies, the program must be accelerated and the station has to accommodate a prototype Mars mission ECLSS for the long-life testing required. Automation & Robotics, while key to the Mars co-orbiting support facility,( or transportation node) assembly and build-up, is also an essential technology necessary to successfully meet the Mars vehicles servicing/refurbishment support requirements.

Cryogenic storage and transfer systems have been discussed at length in the earlier studies (Ref. 1), but these systems take on a new dimension when one considers the Mars sprint mission. The cryo systems on the Cargo Vehicle for example, have to operate for extremely long periods of time and must be highly reliable and maintenance free. Hence, quite a bit of on-orbit development will be required for the cryo storage and fuel management and recovery systems, as well as on orbit testing of these systems under actual mission conditions and durations.

GN&C and COMM/TRACK are also key issues, especially when the amount of traffic in the space station vicinity is considered. In the EVA systems area, lighter, more rugged suits, with increased mobility will be required to support the LEO and Martian surface operations. Although it is expected that Electrical Power system will rely heavily on ground-based DDT&E and limited on-orbit prototype verification, early concept definition and selection of candidate systems is paramount in meeting the schedules assumed for this study.

## Mars Sprint Mission Accommodation Study

# TECHNOLOGY ISSUES - STATION FOCUSED

### ACCELERATED EMPHASIS -

- o ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)
- o AUTOMATION AND ROBOTICS
- o SPACE PROPULSION AND AEROBRAKE SYSTEMS
- o AUTOMATED RENDEZVOUS AND DOCKING SYSTEMS
- o CRYOGENIC STORAGE AND TRANSFER SYSTEMS
- o GUIDANCE, NAVIGATION, AND CONTROL SYSTEMS
- o COMMUNICATION AND TRACKING SYSTEMS
- o EXTRA VEHICULAR ACTIVITY EQUIPMENT
- o DATA MANAGEMENT SYSTEMS
- o ELECTRICAL POWER SYSTEMS

## Mars Sprint Mission Accommodation Study

# ON-ORBIT VEHICLE PROCESSING AND OPERATIONS

The major impacts affecting the on-orbit activities resulting from the sprint mission scenario were the multiple missions and the requirement to not only assemble, but to refurbish elements of the Mars vehicles in orbit. The technology issues raised on this chart evolved from the analysis of the Mars vehicles in-space assembly and processing requirements.

A space-based diagnostics/prognostics capability is key to successfully meeting the turnaround requirement developed during this study and for establishing the high degree of confidence necessary for safe systems operations. The degree of modularity, the level of changeout and replacement, engine/tank resuability, spares inventory, etc. will be a real challenge to designers to provide serviceability/reliability to the Mars vehicles systems.

The issue of on-orbit processing of hazardous (wet) systems and the pressurized transfer of crewmen to and from the co-orbiting processing facility and the fueled manned vehicle will also require new and innovative "operational philosophies" and engineering challenges in order to provide timely and safe solutions to these problems.

Long-term passive storage of the Mars Excursion Module(MEM) and the Earth Recovery Capsule(ERC) presents additional uncertainties to the designs of these systems. During a typical mission, the MEM and the ERC will have been dormant for approximately twenty-seven and twenty months respectively! Verification and demonstration of the operability and reliability of these mission elements will require considerable in-situ testing under actual mission conditions and durations.

Mars Sprint Mission Accommodation Study

**ON ORBIT VEHICLE PROCESSING AND OPERATIONS**  
**(TECHNOLOGY ISSUES)**

- o SPACE BASED DIAGNOSTICS/PROGNOSTICS
  - ON ORBIT SYSTEMS CHECKOUT
  - ON-BOARD/IN TRANSIT DECISION MAKING FOR SAFE SYSTEMS OPERATIONS
  - SYSTEMS HEALTH PREDICTION/STATUS
- o ON ORBIT PROCESSING OF HAZARDOUS (WET) SYSTEMS
- o PRESSURIZED TRANSFER OF VEHICLE SUPPORT AND MISSION CREW TO VEHICLE ASSEMBLY/DEPARTURE SITE
- o LONG-TERM PASSIVE STORAGE OF MISSION HARDWARE AND ON ORBIT SHELF LIFE OF SPARES INVENTORY

## Mars Sprint Mission Accommodation Study

# **ORBITAL DEMONSTRATION CONSIDERATIONS TESTING AND VERIFICATION REQUIREMENTS**

The next series of charts address the orbital demonstration program considerations. The Mars vehicles systems elements are shown with the testing and verification requirements listed for each of these major hardware items. In addition to those listed, there will also be end-to-end testing and all-up mission simulations for the totally integrated Mars vehicle configurations.

For the Piloted Vehicle, the critical demonstration/verification tests will be rendezvous & docking with the Cargo Vehicle, crew transfer and activation of the MEM (Mars Excursion Module), and the fueling operations since all of these crucial mission events will be performed in the Martian orbit.

For the Cargo Vehicle, the major verification challenges will be the long-term subsystems operations and the cryogenic storage and the fuel management and recovery systems.

For the MEM, the key considerations are the activation and checkout of the vehicle, aeroshell performance, and the landing/ascent demonstrations.

For the ERC (Earth Return Capsule) in addition to solutions to the long-term passive storage issues already mentioned, the earth aerocapture tests and aeroshell performance demonstrations are the pacing items for this system.

## Mars Sprint Mission Accommodation Study

# ORBITAL DEMONSTRATION CONSIDERATIONS - TESTING AND VERIFICATION REQUIREMENTS

- o REUSABLE INJECTION STAGES
  - RENDEZVOUS & DOCKING WITH OMV
  - SEPARATION TESTS - CARGO VEHICLE, PILOTED VEHICLE, OMV
  - SERVICEABILITY/TURNAROUND OPERATIONS
  - FUELING OPERATIONS
  - AEROSHELL ASSEMBLY, PERFORMANCE, REFURBISHMENT
- o PILOTED VEHICLE (PV)
  - SUBSYSTEMS
  - COMMAND AND CONTROL INTERFACE
  - AEROBRAKE/AEROSHELL ASSEMBLY AND PERFORMANCE
  - CREW TRANSFER
  - MISSION SIMULATIONS
  - RENDEZVOUS & DOCKING WITH CARGO VEHICLE, MEM, ASCENT VEHICLE
  - FUELING OPERATIONS IN LEO, MARS ORBIT
- o CARGO VEHICLE (CV)
  - LONG-TERM SUBSYSTEMS OPERATIONS/RELIABILITY
  - COMMAND/CONTROL IN-TRANSIT, IN MARS ORBIT
  - LONG-TERM CRYOGENIC STORAGE, FUEL MANAGEMENT AND RECOVERY SYSTEMS OPERATIONS
  - AEROBRAKE/AEROSHELL ASSEMBLY AND PERFORMANCE
  - RENDEZVOUS & DOCKING WITH THE PILOTED VEHICLE



# ORBITAL DEMONSTRATION CONSIDERATIONS

## TESTING AND VERIFICATION REQUIREMENTS (CONTINUED)

- o MARS EXCURSION MODULE (MEM)
  - LONG-TERM PASSIVE STORAGE OF SYSTEMS, SUBSYSTEMS
  - SEPARATION TESTS
  - LANDING/ASCENT TESTS
  - RENDEZVOUS & DOCKING WITH THE PILOTED VEHICLE
  - CREW TRANSFER TO AND FROM THE PILOTED VEHICLE
  - MISSION SIMULATIONS
  
- o EARTH RECOVERY CAPSULE (ERC)
  - LONG-TERM PASSIVE STORAGE OF SYSTEMS, SUBSYSTEMS
  - SEPARATION TESTS
  - EARTH AEROCAPTURE TESTS AND AEROSHELL PERFORMANCE
  - RENDEZVOUS & DOCKING WITH OMV
  - SERVICEABILITY/TURNAROUND OPERATION

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**Mars Sprint Mission Accommodation Study**

**VEHICLE ACCOMMODATION**

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**Mars Sprint Mission Accommodation Study**

**VEHICLE ACCOMMODATION STUDY - OUTLINE**

The outline to be followed in this section of the report is shown.

## Mars Sprint Mission Accommodation Study

# **VEHICLE ACCOMMODATIONS - OUTLINE**

- VEHICLE PROCESSING
- APPROACH
  - OPTIONS
  - RATIONALE
  - VEHICLE ACCOMMODATION DESIGN REQUIREMENTS
- VEHICLE ACCOMMODATION CONCEPTS
  - STATION BASED WITH CO-ORBITING PROPELLANT TANK FARM (PTF)
  - PTF
  - TRANSPORTATION DEPOT
  - ANALYSIS
- SUMMARY
  - GENERAL OBSERVATIONS
  - ASSEMBLY ISSUES
  - RECOMMENDED FURTHER ANALYSIS
- CONCLUSIONS

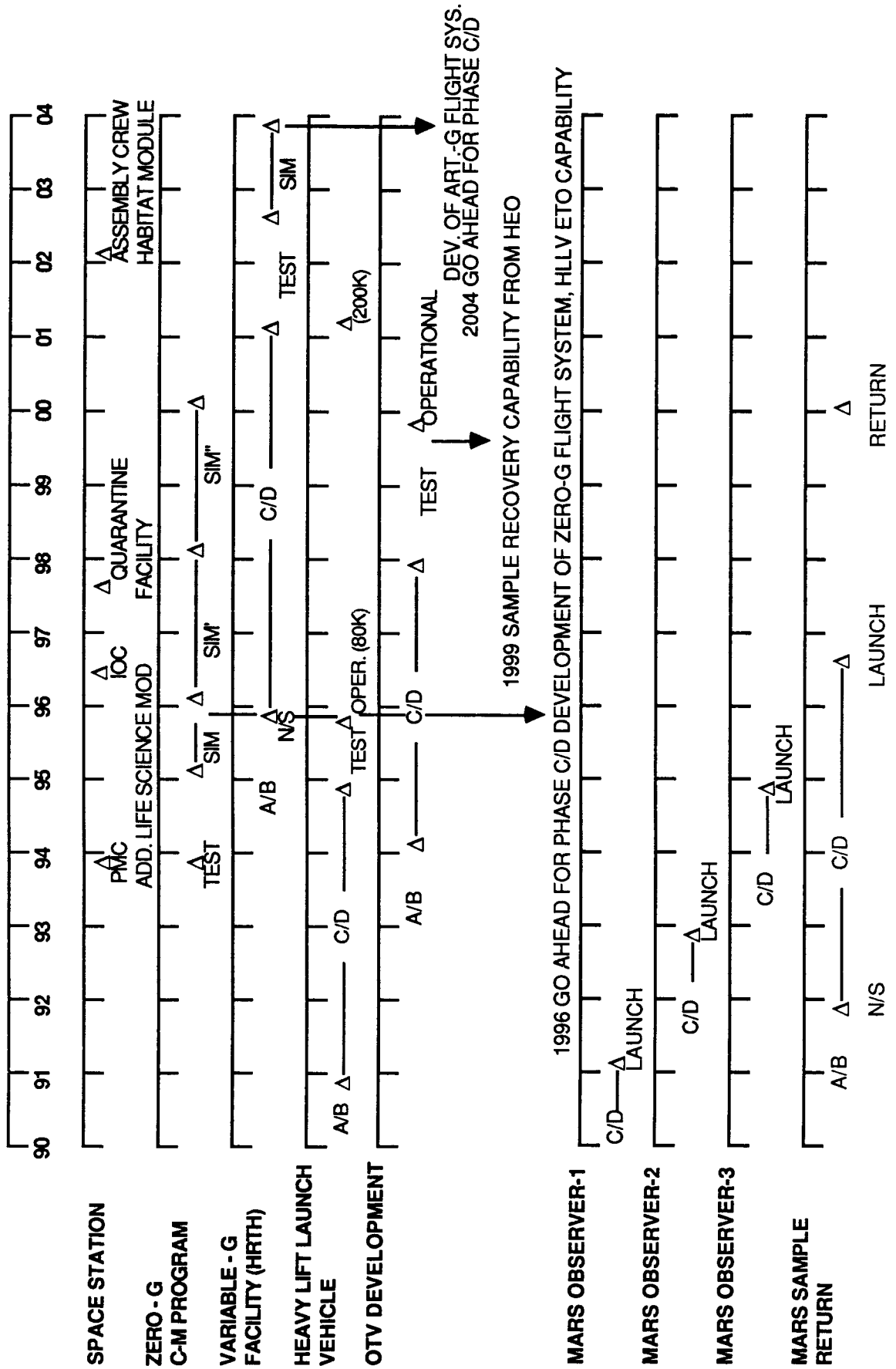
## Mars Sprint Mission Accommodation Study

# **MAJOR ACCOMMODATION MILESTONES**

The major program milestones for the development of the Mars Sprint Mission supporting infrastructure are shown. Also included, is a timeline for the development and launch of the required precursor missions.

# Mars Sprint Mission Accommodation Study

## MAJOR ACCOMMODATION MILESTONES



## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION ON-ORBIT CREW REQUIREMENTS

As mentioned earlier, the sprint mission study assumed a dual vehicle, multi-mission scenario with assembly and servicing /processing of the vehicles in space. The on-orbit processing requirements developed for the missions will be discussed in subsequent charts.

This chart shows the quarterly crew requirements needed to support the three sprint missions considered in the 2000 to 2010 time frame. In developing these data, the following assumptions were used:

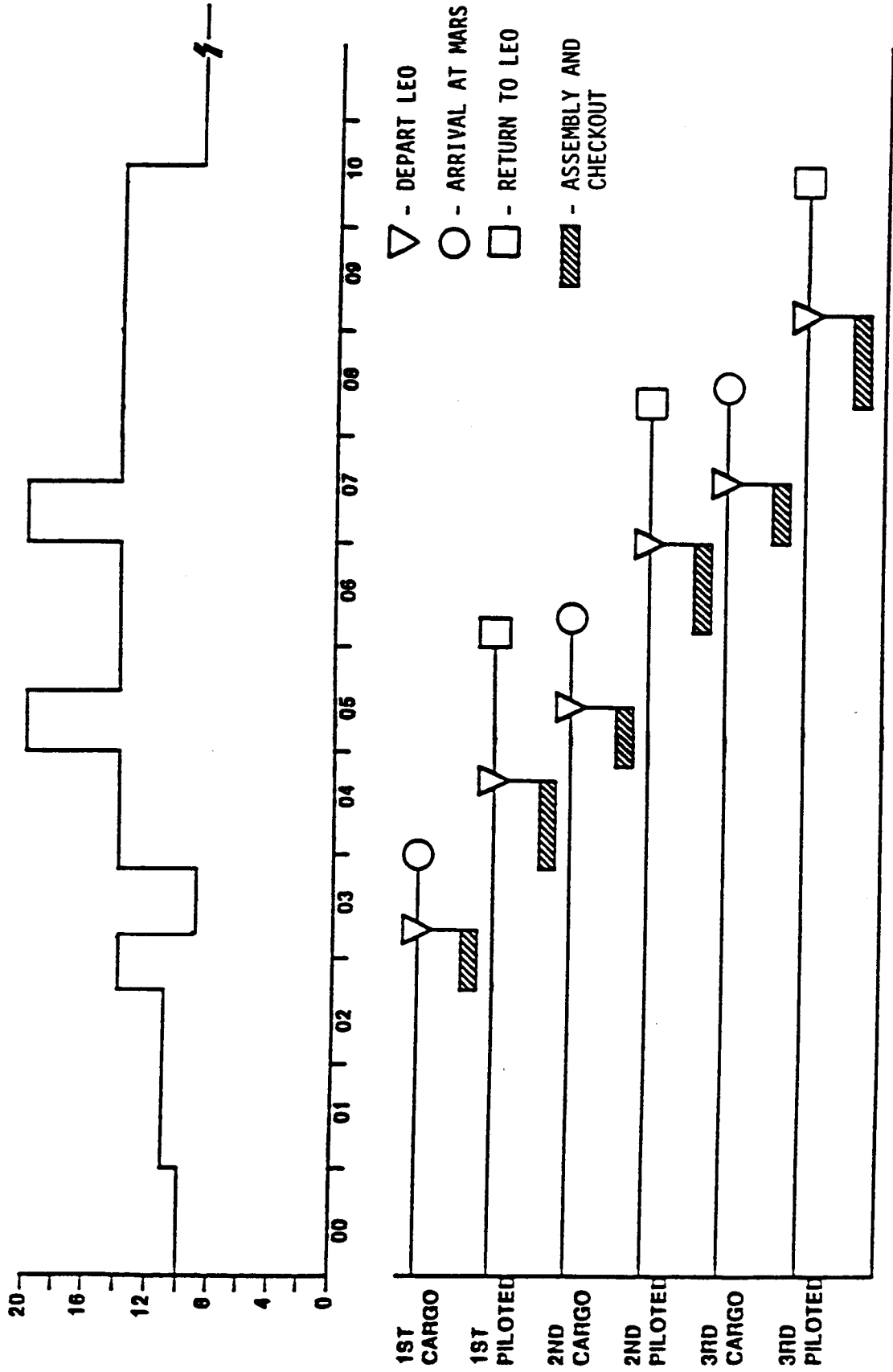
- \* on-orbit crew requirements are in quarter year increments
- \* space crew of eight
- \* life science supporting research continues through 2003
- \* six-man mission support crew is in addition to station complement and consistent with the CNDB
- \* Mars mission crew of six only on orbit for missions

The upper half of the chart shows the number of in-space crew required over the mission time frame and the lower half of the chart shows the Cargo Vehicle(CV) and the Piloted Vehicle (PV) flight schedules.

From the year 2000 to late 2002, the two to three crewmen shown over the basic space station complement of eight are needed for the life sciences research, the on-orbit technology program, and the on-orbit assembly, demonstration and verification of the facilities and flight hardware. In third quarter '02, assembly and checkout of the CV is begun, shown by the cross-hatched bar on the 1st CV schedule, at which time fourteen crewmen are on orbit. After CV departure, the on-orbit crew size is reduced to eight until 3rd quarter '03 when processing of the 1st PV begins and the crew size increases to fourteen again. In third quarter '04, the mission crew arrives and the support crew returns to earth. In early '05, the support crew for the 2nd CV arrives, the 1st piloted mission is still in progress, accounting for the twenty persons now in space. This fourteen/twenty mix continues through mid-2010 when the sprint mission is completed.

# MARS SPRINT MISSION ACCOMMODATION STUDY

## QUARTERLY ON-ORBIT CREW REQUIREMENTS





## Mars Sprint Mission Accommodation Study

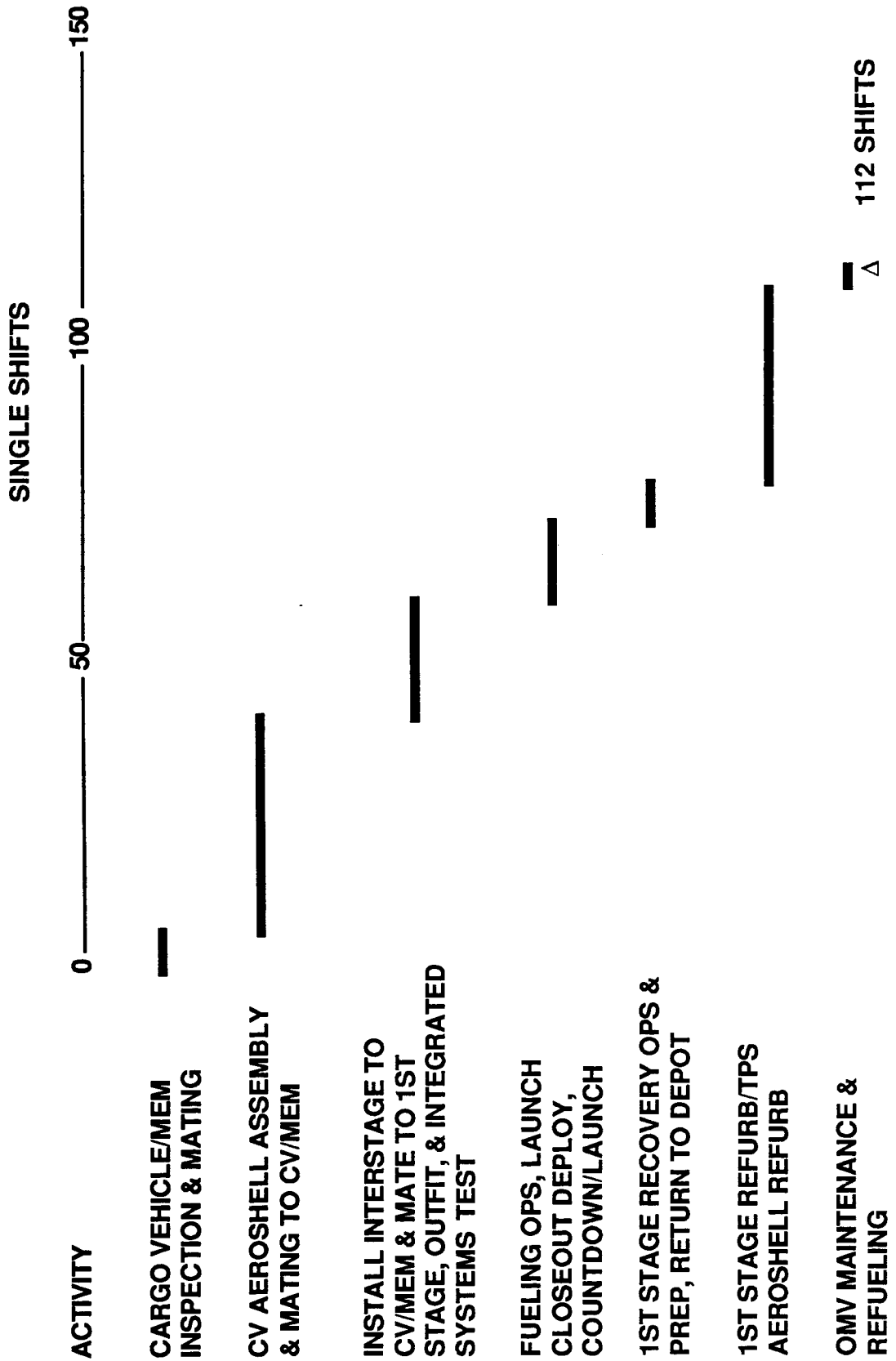
# CARGO VEHICLE ON-ORBIT PROCESSING

The following series of charts show typical processing timelines developed in this study for the Cargo Vehicles. When considering such things as the orbital facilities, equipment and crew constraints, the vehicles' physical characteristics, etc. single site serial processing proved to be the only practical on-orbit operating mode and was the basis for the following analysis.

In developing these timelines, a nine hour day, six day week per crewman was assumed for the mission support team. The man hour estimates for each of the major activities listed were based on current KSC processing practices where applicable and projected tasks requirements derived from the Space Station MRDB and relevant NASA and contractor reports. These data are shown for a single shift operation where a single shift consisted of six crewmen.

As shown on this chart, a total of 112 shifts were required to process the Cargo Vehicle.

Mars Sprint Mission Accommodation Study  
**CARGO VEHICLE ON-ORBIT PROCESSING**



## **Mars Sprint Mission Accommodation Study**

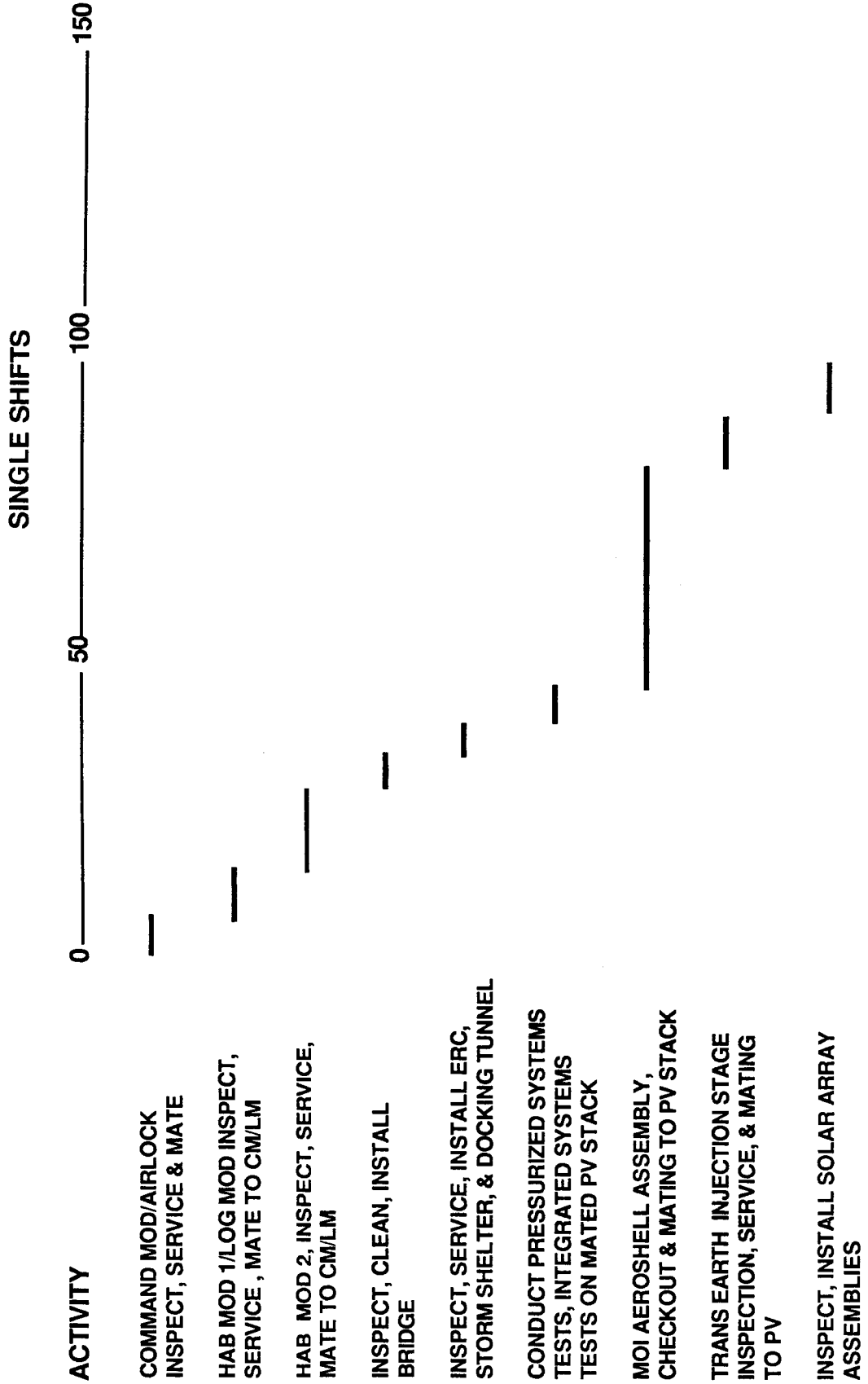
### **PILOTED VEHICLE ON-ORBIT PROCESSING**

To process the Piloted Vehicle, 240 shifts are required, or more than twice the number for the Cargo Vehicle case.

For both vehicles, the largest task requirements are aeroshell assembly and refurbishment of the reusable injection stages.

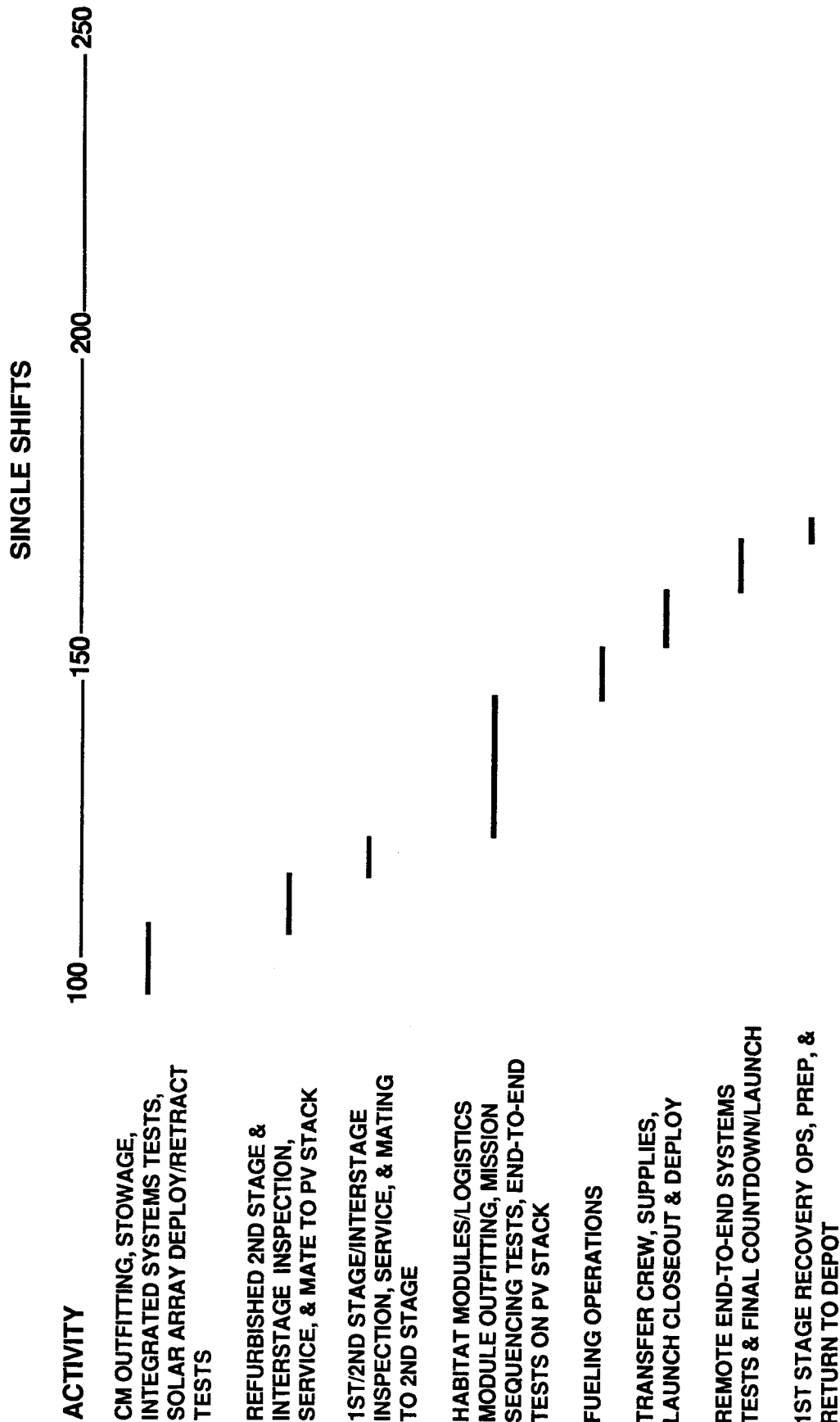
Adding a 10% contingency to these estimates results in 144 calendar days needed to process the CV and 308 calendar days to process the PV.

Mars Sprint Mission Accommodation Study  
**PILOTED VEHICLE ON-ORBIT PROCESSING**



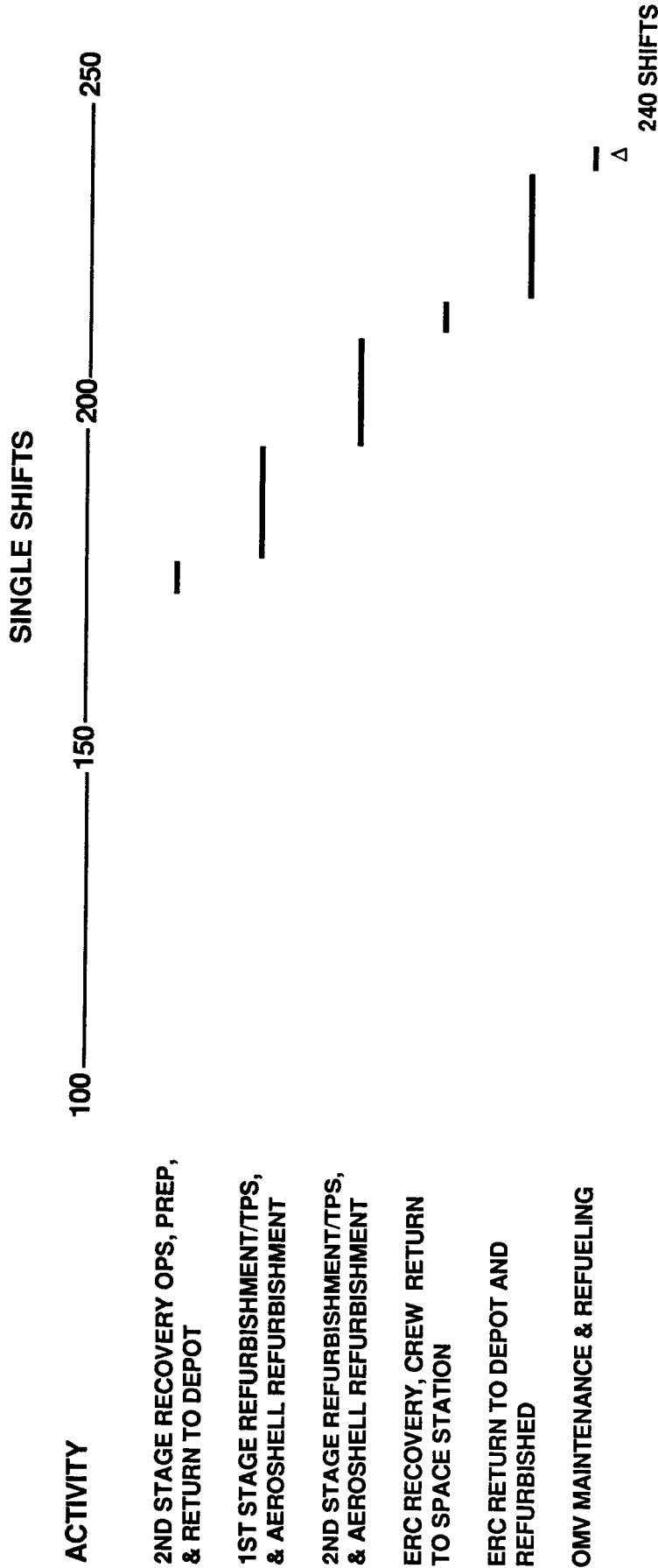
Mars Sprint Mission Accommodation Study  
**PILOTED VEHICLE ON-ORBIT PROCESSING**

(CONTINUED)



Mars Sprint Mission Accommodation Study  
**PILOTED VEHICLE ON-ORBIT PROCESSING**

(CONCLUDED)



## Mars Sprint Mission Accommodation Study

# **VEHICLE ACCOMMODATION OPTIONS**

The four basing options described represent the most likely scenarios for Mars mission support.

## Mars Sprint Mission Accommodation Study

### VEHICLE ACCOMMODATION OPTIONS

- OPTION #1: STATION BASED** - ALL VEHICLE ACCOMMODATIONS BASED ON STATION
- OPTION #2: STATION BASED w/PTF** - VEHICLE ASSEMBLY AND REFURBISHMENT FACILITY IS ON-STATION. PROPELLANT IS LOCATED ON A CO-ORBITING PROPELLANT TANK FARM (PTF)
- OPTION #3: TRANSPORTATION DEPOT (MAN TENDED)** - VEHICLE ACCOMMODATIONS ARE KEPT ON A CO-ORBITING PLATFORM, BUT CREW IS BASED ON STATION
- OPTION #4: TRANSPORTATION DEPOT (PERMANENTLY MANNED)** - A SEPARATE FACILITY IS PROVIDED FOR VEHICLE AND CREW



## **Mars Sprint Mission Accommodation Study**

### **RATIONALE**

Various studies have been performed recently which indicate that the dual keel space station is capable of accommodating the modifications needed to provide vehicle processing facilities such as those needed to support a Mars Sprint or Lunar mission. Such activities will probably adversely impact users of the station who require low micro-gravity levels or viewing angles unobstructed by large structures and propellant clouds. Furthermore, the safety problems associated with handling cryogenic propellants, while not well defined, certainly provide a good reason for separating crew and critical hardware from propellant tanks. This does not mean, though, that any final determinations have been made as to the optimum LEO infrastructure for vehicle support facilities. Studies must still be undertaken to determine the level of disturbance that would force the development of separate facilities for vehicle processing. Such a determination requires in-depth technical, cost, and operations evaluations, as well as high level prioritization of national space program goals.

For the purposes of this study, two of the previously described vehicle basing options were considered - the Station Based w/PTF option, and the Man-Tended Transportation Depot option. It was decided that by developing and analysing concepts for these two options, general results could be obtained which would provide a basis for future refinement and study.

## **Mars Sprint Mission Accommodation Study**

### **RATIONALE**

- o **STATION w/PTF (OPTION #2) AND MAN-TENDED TRANSPORTATION DEPOT (OPTION #3) WERE SELECTED FOR STUDY BECAUSE:**
  - **STATION BASED FACILITIES WILL PROBABLY ADVERSELY IMPACT SENSITIVE SCIENCE USERS (MICRO-GRAVITY, FIELD OF VIEW)**
  - **PROPELLANT BOILOFF AND SPILLAGE MAY PRODUCE RISK TO HARDWARE, CREW, AND SCIENCE**
  - **PTF REDUCES CONTAMINATION LEVELS, BUT DOES NOT APPRECIABLY ENHANCE FOV, MICRO-GRAVITY ENVELOPE, OR POINTING PARAMETERS**
  - **DEPOT SPECIFICALLY DESIGNED TO SUPPORT TRANSPORTATION NEEDS SHOULD ENHANCE MISSION EFFECTIVENESS**
- o **GOAL IS TO LAY GROUNDWORK FOR FUTURE ANALYSIS AND DESIGN OF STATION BASED AND CO-ORBITING TRANSPORTATION SUPPORT FACILITIES**
  - **DEVELOP HIGH LEVEL REQUIREMENTS**
  - **ESTABLISH GENERIC RESULTS**

## **Mars Sprint Mission Accommodation Study**

### **APPROACH**

The approach followed in study of Mars mission vehicle accommodations is shown on this chart.

## Mars Sprint Mission Accommodation Study

### APPROACH

- ESTABLISH A LIST OF FEATURES TO BE INCORPORATED IN STATION MODIFICATIONS AND DEPOT DESIGN
- DETERMINE HIGH LEVEL "PROS & CONS" FOR EACH CONCEPT
- DEVELOPE PRELIMINARY CONCEPTS FOR SPACE STATION MODIFICATIONS AND DEPOT
- FOR EACH CONCEPT, QUANTIFY:
  - MASS PROPERTIES
  - CONTROL SYSTEM SIZING
  - FLIGHT MODE ATTITUDE
- DETERMINE REQUIREMENTS FOR OPERATIONS

## **Mars Sprint Mission Accommodation Study**

### **VEHICLE ACCOMMODATION**

The first step in developing concepts for a Man-Tended Transportation Depot, or for required modifications to the station, was to create a high level list of features which such facilities would need to incorporate. This chart, and the next, show the list of design features which were used to develop the depot and station modification concepts in this study.

## **Mars Sprint Mission Accommodation Study**

### **VEHICLE ACCOMMODATION**

- o **DESIGN FEATURES FOR SPACE STATION OR DEPOT ACCOMMODATION:**
  - **SIZE AND VOLUME TO ACCOMMODATE MARS VEHICLES AND SUPPORT EQUIPMENT**
  - **PRESSURIZED "COMMAND CENTER" FOR CONTROLLING AND MONITORING EVA AND ROBOTIC ACTIVITIES**
  - **CAPABILITY FOR EXPANSION**
  - **ROBOTIC AND EVA ACCESS TO VEHICLE AND PROPELLANT TANKS**
  - **SIMPLE VEHICLE EGRESS/SEPARATION:**
    - o **VEHICLE EGRESS ALONG VELOCITY VECTOR OR NEGATIVE RADIUS VECTOR**
    - o **ROOM TO AVOID COLLISIONS WITH STRUCTURE**

## **Mars Sprint Mission Accommodation Study**

### **DESIGN FEATURES** (continued)

This chart continues the list of design features on which the concepts developed in this study were based, and includes several that pertain only to the design of the transportation depot.

## Mars Sprint Mission Accommodation Study

### VEHICLE ACCOMMODATION

- o DESIGN FEATURES (CONTINUED):
  - MICRO-METEOROID/IMPACT PROTECTION FOR VEHICLE, EVA CREW, AND PROPELLANT:
    - o ENCLOSE VEHICLE AS MUCH AS POSSIBLE
  - DEBRIS CONTAINMENT:
    - o ENCLOSE VOLUME TO CONTAIN DEBRIS PRODUCED BY VEHICLE PROCESSING OPERATIONS
  - THERMAL PROTECTION FOR EVA CREW AND PROPELLANT:
    - o ENCLOSE VOLUME IF POSSIBLE
    - o SHIELD PROPELLANT TANKS
- o DESIGN FEATURES SPECIFIC TO DEPOT :
  - DOCKING FACILITIES TO ACCOMMODATE OMV AND SHUTTLE
  - ROOM FOR PROPELLANT TANKS AND SUPPORT EQUIPMENT
  - SOLAR DYNAMIC POWER SYSTEM
  - GN&C, C&T, RCS SYSTEMS



## Mars Sprint Mission Accommodation Study

### VEHICLE ACCOMMODATION

This chart lists a few of the high level performance goals which the depot and station modification concepts must meet. Time constraints precluded analysis of structural loads, dynamic response, controls/ structure interactions, etc., but the analyses shown provide a good basis for establishing the feasibility of each concept.

## Mars Sprint Mission Accommodation Study

# VEHICLE ACCOMMODATION

- o PERFORMANCE GOALS:
  - CONTROLLABILITY OF ALL PHASES OF VEHICLE ASSEMBLY:
    - o MINIMIZE CONTROL SYSTEM SIZING AND COMPLEXITY
    - o MINIMIZE TEAs TO MAINTAIN PROTECTION ENVELOPE, EASE OF SEPARATION, AND VIEWING ANGLES
  - ORBIT DECAY OF STATION/DEPOT AND VEHICLE:
    - o DECAY RATES OF COMPLETE VEHICLE AND STATION/DEPOT MUST ALLOW SAFE SEPARATION
    - o MINIMIZE REBOOST PROPELLANT NEEDS FOR ALL PHASES OF VEHICLE ASSEMBLY

## Mars Sprint Mission Accommodation Study

### **STATION BASED WITH CO-ORBITING PTF (OPTION #2)**

Option #2, the Station Based w/PTF configuration, is described on this chart and shown on the accompanying figure. It is clear that attaching a structure large enough to enclose a complete Mars mission stack to the dual keel station will impact users. In particular, astronomical viewing from the module cluster will be totally blocked in the aft direction. Though no determination has yet been made of the dynamic effects on the micro-gravity environment, it is probable that experiments and processes with micro-g requirements will be affected as well.

## Mars Sprint Mission Accommodation Study

### **STATION BASED WITH CO-ORBITING PTF (OPTION #2)**

- o Vehicle hangar built off the back of transverse boom (see figure) :
  - Rectangular hangar completely encloses vehicle and provides robotic access
  - Command center below station modules at middle of hangar
  - Vehicle separates from station out back or top of hangar
- o Hangar size and location affects :
  - Viewing - blockage of U.S., JEM, and ESA modules
  - Orbital parameters
  - GN&C
  - Static micro-gravity envelope
- o Vehicle activities affect dynamic micro-gravity environment.
- o All propellant related operations are done at a Co-orbiting Propellant Tank Farm (PTF).

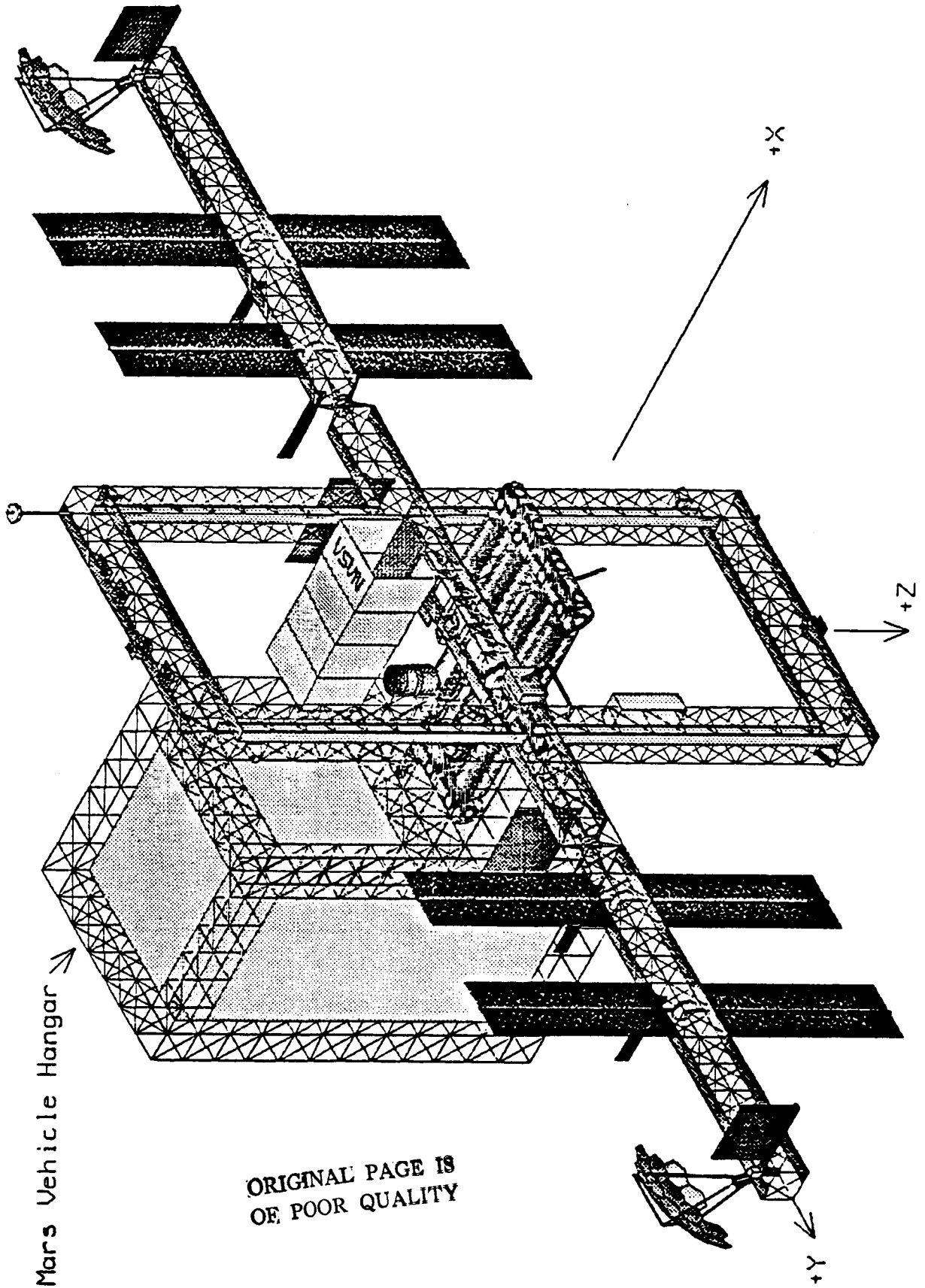
## Mars Sprint Mission Accommodation Study

### **SPACE STATION WITH CO-ORBITING PTF (OPTION #2)**

This figure shows the concept developed for a station based vehicle support facility corresponding to option #2. The coordinate system shown is the standard space station program system where the positive X-axis is along the velocity vector, the positive Y-axis is out the right side of the vehicle, and the positive Z-axis is toward earth.

Mars Sprint Mission Accommodation Study

SPACE STATION WITH HANGER



## Mars Sprint Mission Accommodation Study

### PROPELLANT TANK FARM (PTF)

The facility which accompanies the Station Based vehicle processing of option #2 is the Propellant Tank Farm (PTF) described on this chart. As stated, no concepts were developed for this facility, but it is certainly something which should be considered for future study. The advantages gained by moving propellant away from the station are considerable in terms of safety, contamination, and complexity of the station control system. One of the more perplexing problems in the space station program is how to deal with changes in the mass properties of the system when large masses are added to, or removed from, the structure. In this case, the mass of propellant for Mars, Lunar, or GEO mission vehicles would produce significant demands on the station control system since the amount of propellant fluctuates greatly with the build-up and launch of missions. By leaving that changing mass out of the station control system loop, the complexity of the system can be maintained at a lower level, and so its reliability can be enhanced. Of course the control problem would still be faced at the PTF, but problems or failures there would be less dangerous than at the station.

**Mars Sprint Mission Accommodation Study**  
**PROPELLANT TANK FARM (PTF)**

- o CO-ORBITING FACILITY DESIGNED SPECIFICALLY FOR STORAGE AND HANDLING OF PROPELLANT:
  - DOCKING FACILITIES FOR COMPLETE MARS VEHICLE STACK
  - ROBOTIC SYSTEMS FOR MANEUVERING TANKS FULL OF PROPELLANT
  - PROPELLANT DELIVERED TO ORBIT BY HLLV AND BROUGHT TO THE PTF BY AN OMV TYPE VEHICLE
  - LARGE ENOUGH TO STORE ALL NEEDED PROPELLANT
  - DESIGNED FOR MINIMUM MAINTENANCE
  - ROOM FOR GROWTH TO ACCOMMODATE OTHER MISSIONS (LUNAR, GEO, ETC.)
  - POWER, GN&C, AND DATA MANAGEMENT SYSTEMS
  
- o NO SPECIFIC CONCEPTS HAVE BEEN DEVELOPED AS PART OF THIS STUDY



## Mars Sprint Mission Accommodation Study

### MAN-TENDED TRANSPORTATION DEPOT

Three concepts for a Man-Tended Transportation Depot were developed in this study based on the design features listed previously. An attempt was made to develop concepts which differed in as many key areas as possible, yet still meet the requirements for effective vehicle support. It is clear, however, that starting with the same list of desirable design features, the concepts were sure to be similar in many respects. For example, in order to assure sufficient access to the vehicle throughout all stages of assembly, a good deal of surrounding truss structure was included in each concept; the differences lie in how much of the vehicle can be enclosed, and how close robotic arms can get to the center of the vehicle while attached to the structure. Similarly, the placement of the docking port and command center was driven by the need for sufficient clearance for the shuttle tail and wings.

The Open Box concept described on this chart is the first of the three concepts developed. It features truss sections arranged into a rectangle which completely encloses the vehicle during all stages of assembly. The rectangle is open on the front, rear, and, top faces, but blocked by a cross piece on each side and bottom. Robotic access to the vehicle is via the cross pieces, while the vehicle and associated hardware enter or leave via the front, rear, or top. It is probable that the entire box would be enclosed with impact and thermal protection, and debris containing material which could be drawn back to provide space for vehicle egress.

**Mars Sprint Mission Accommodation Study**

**MAN-TENDED TRANSPORTATION DEPOT**

C-2

- o **THREE CONCEPTS WERE DEVELOPED:**
  - **ATTEMPTED TO MAKE CONCEPTS AS DIFFERENT AS POSSIBLE, YET STILL PROVIDE NEEDED FEATURES**
- o **THE OPEN BOX CONCEPT (SEE FIGURE) :**
  - **RECTANGULAR BOX COMPLETELY ENCLOSES VEHICLE**
  - **PROPELLANT TANKS DISTRIBUTED AROUND BOTTOM OF BOX**
  - **ROBOTIC ACCESS TO VEHICLE AND TANKS VIA TRUSS AT SIDES AND BOTTOM**
  - **DOCKING PORT AND COMMAND CENTER AT TOP FRONT OF BOX**

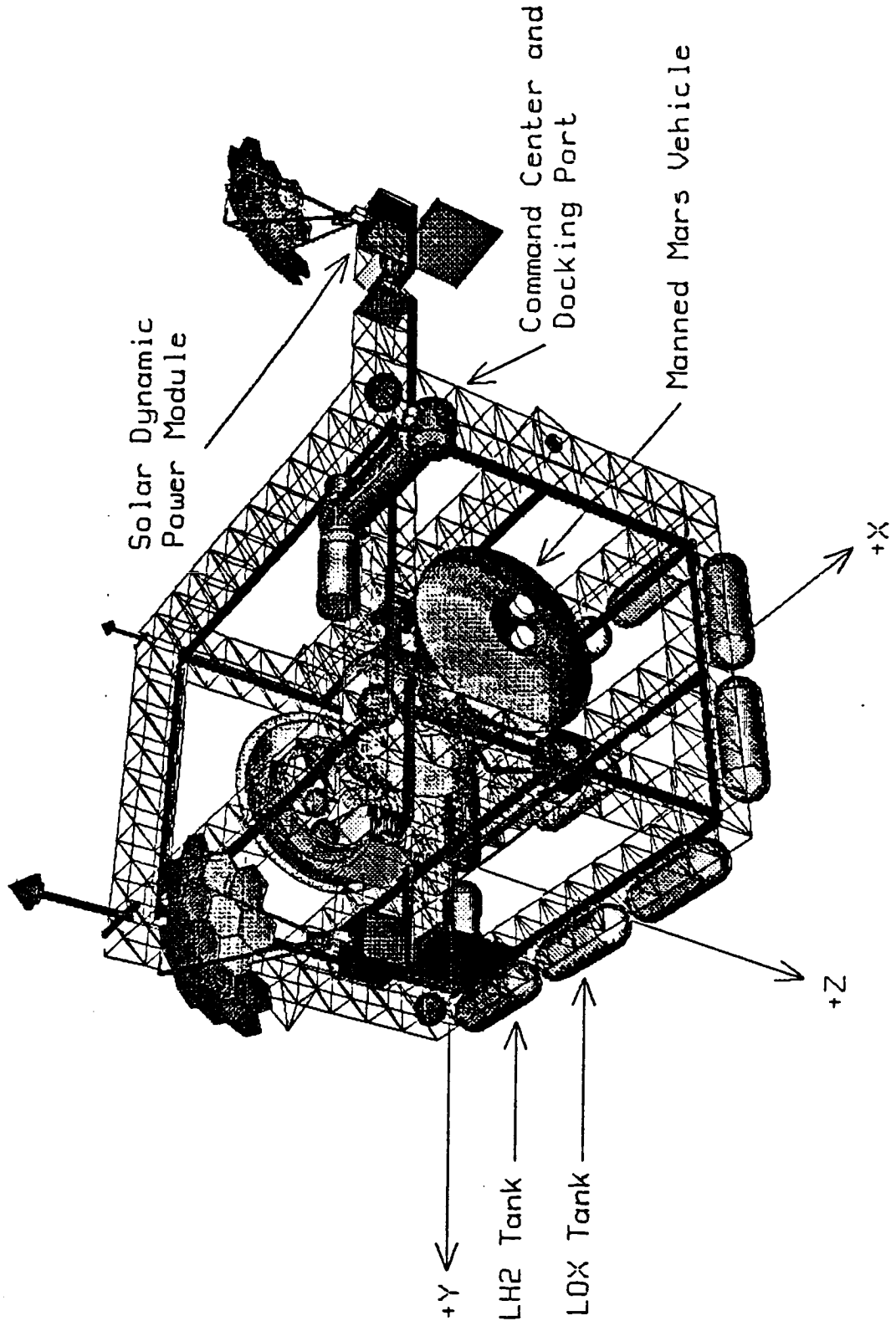
## Mars Sprint Mission Accommodation Study

### OPEN BOX CONCEPT

This figure shows the Open Box concept described on the previous chart. The coordinate system is shown, where the velocity vector is along the positive X-axis.

Mars Sprint Mission Accommodation Study

OPEN BOX CONCEPT



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## Mars Sprint Mission Accommodation Study

### PRISM & OPEN PLATFORM CONCEPTS

This chart describes the remaining two Man-Tended Transportation concepts which were developed in this study. Like the Open Box concept described previously, the Prism features truss sections which completely enclose the vehicle and can be covered with thermal and impact protection, or debris containment material. In this concept, however, the vehicle is enclosed by an equilateral triangular prism rather than a rectangle. The advantage here is that the command center is placed with a slightly better view of the vehicle and the triangular structure allows hardware to enter or leave through all five faces. A disadvantage is that the robotic arms have farther to reach to the center of the structure than on the Open Box concept.

The Open Platform concept was derived somewhat from the dual keel space station configuration, though obviously the inner transverse boom was removed and the keels were rearranged to provide access to the vehicle. In this concept the major advantage is that the command center and docking port are placed such that maximum visual access to the vehicle is obtained. The major disadvantage is that robotic access is reduced, and the vehicle cannot be completely enclosed for thermal and impact protection or debris containment.

## Mars Sprint Mission Accommodation Study

# PRISM & OPEN PLATFORM CONCEPT

- o **The Prism (see figure) :**
  - **Vehicle enclosed by large equilateral triangular prism**
  - **Propellant tanks distributed around top of Prism**
  - **Docking port and command center at lower apex of front triangle**
  - **Robotic access via truss on all sides of vehicle**
- o **The Open Platform (see figure) :**
  - **Vehicle surrounded by fore and aft keels and booms**
  - **Docking port and command center at bottom of lower boom**
  - **Robotic access via fore, aft, and lower keels**
  - **Propellant tanks attached to fore and aft keels and booms**

## **Mars Sprint Mission Accommodation Study**

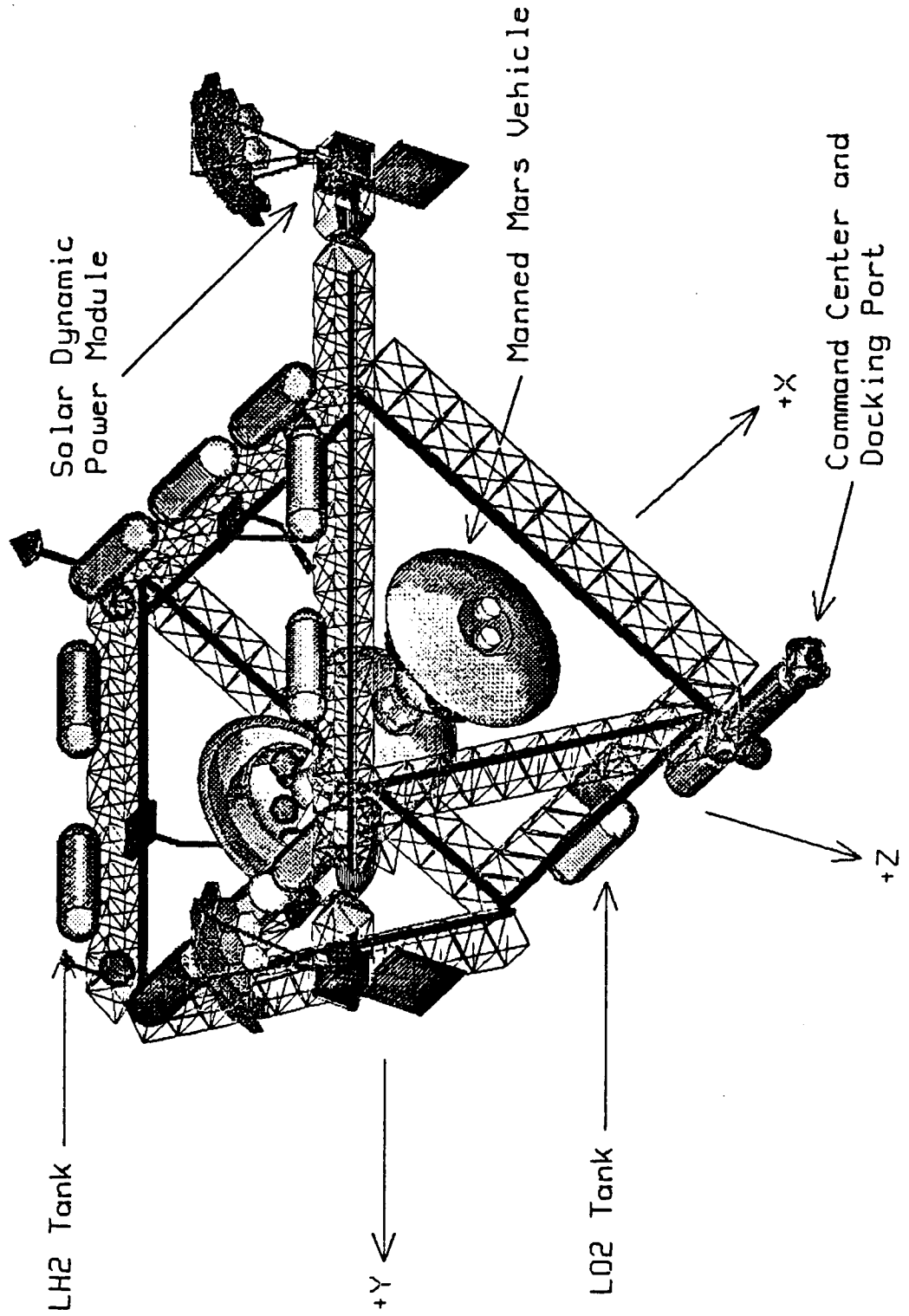
### **PRISM CONCEPT**

This figure shows the Prism concept described on the previous chart. The coordinate system is shown, where the velocity vector is along the positive X-axis.

Mars Sprint Mission Accommodation Study

MAN-TENDED TRANSPORTATION DEPOT

PRISM CONCEPT



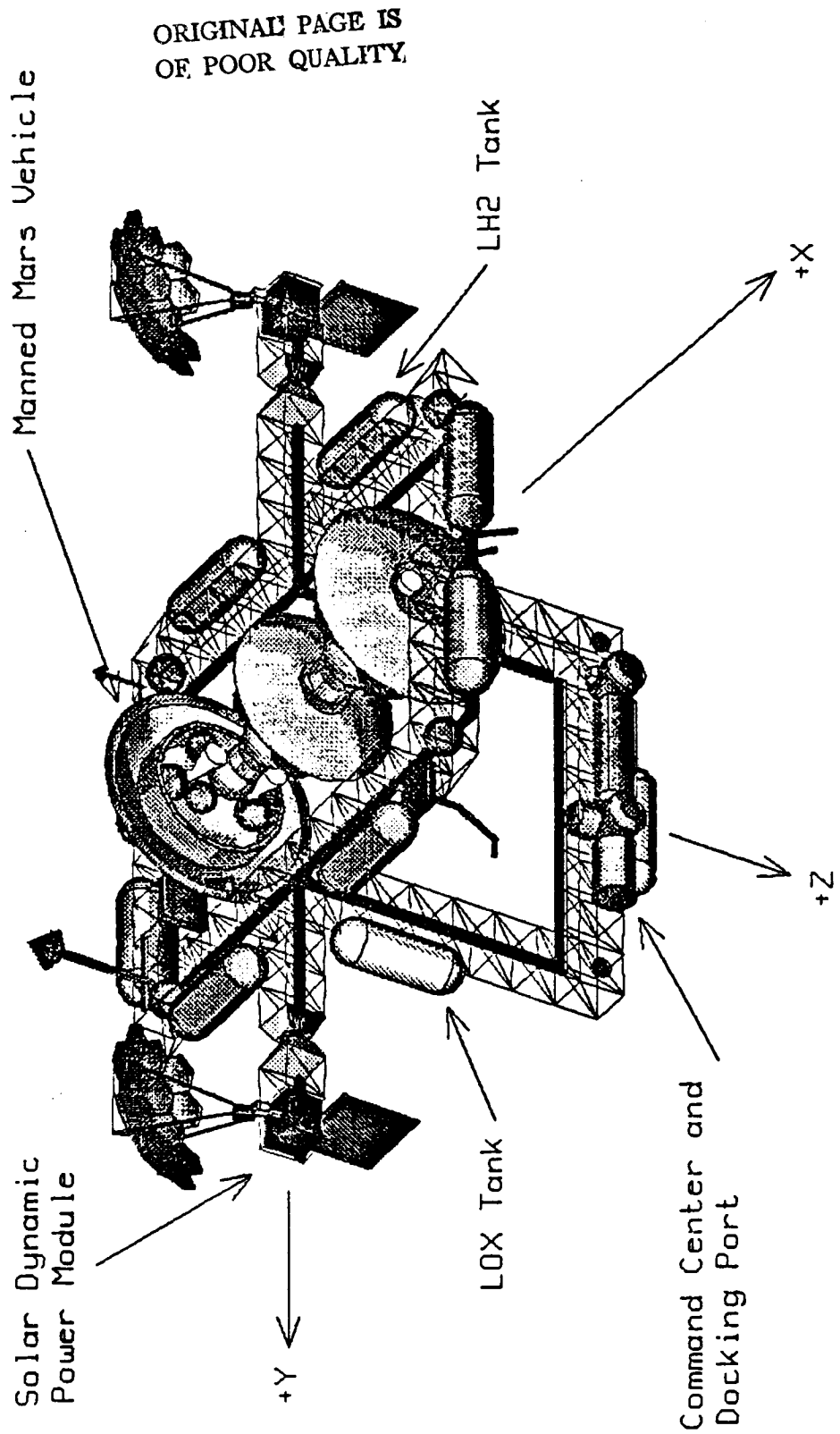


## **Mars Sprint Mission Accommodation Study**

### **OPEN PLATFORM CONCEPT**

This figure shows the Open Platform concept with the coordinate system used in this study. As before, the velocity vector is along the positive X-axis.

Mars Sprint Mission Accommodation Study  
**MAN-TENDED TRANSPORTATION DEPOT**  
**OPEN PLATFORM CONCEPT**



## Mars Sprint Mission Accommodation Study

# MAN-TENDED TRANSPORTATION DEPOT - MASS SUMMARY

This chart lists the estimated mass of each component of the three Depot concepts. The only difference in the total mass of the three Depot concepts lies in their amount of truss structure and utility trays. All other components are copies of current space station components, except in the case of the propellant tanks, where the masses were derived from previous studies of cryogenic propellant storage.

Mars Sprint Mission Accommodation Study

**Transportation Depot Mass Summary**

Component Name	Component Mass		
	Open Box	Prism	Open Platform
Airlock	2,014 Kg	2,014 Kg	2,014 Kg
Alpha Joints	1,200 Kg	1,200 Kg	1,200 Kg
CMGs	1,567 Kg	1,567 Kg	1,567 Kg
Cupola	1,455 Kg	1,455 Kg	1,455 Kg
Docking Adapters	1,000 Kg	1,000 Kg	1,000 Kg
Nodes (2)	9,091 Kg	9,091 Kg	9,091 Kg
Command Center	31,523 Kg	31,523 Kg	31,523 Kg
MSC/Transporter	4,909 Kg	4,909 Kg	4,909 Kg
RCS Clusters	1,025 Kg	1,025 Kg	1,025 Kg
RCS Prop. & Tanks	6,364 Kg	6,364 Kg	6,364 Kg
SD Power Modules(2)	14,078 Kg	14,078 Kg	14,078 Kg
TDRSS & Antenna	586 Kg	586 Kg	586 Kg
Tele. Servicer (2)	2,381 Kg	2,381 Kg	2,381 Kg
11 Prop. Tanks	68,924 Kg	68,924 Kg	68,924 Kg
Attached Hardware	12,980 Kg	12,980 Kg	12,980 Kg
2 Depot Radiators	3,670 Kg	3,670 Kg	3,670 Kg
Logistics	8,285 Kg	8,285 Kg	8,285 Kg
Truss	9,875 Kg	7,163 Kg	4,799 Kg
Utility Trays	18,008 Kg	13,062 Kg	8,750 Kg
<b>Total</b>	<b>198,900 Kg</b>	<b>191,300 Kg</b>	<b>184,600 Kg</b>

## Mars Sprint Mission Accommodation Study

# FLIGHT ATTITUDE ANALYSIS - INTRODUCTION

The scheme for maintaining momentum build-up in the current space station design involves the use of Control Moment Gyros (CMGs) as a method of storing momentum. The momentum build-up is divided into two distinct components called "Cyclic" and "Secular". Cyclic momentum results from environmental forces which grow and then dissipate through an orbit such that the net build-up is approximately zero. This type of momentum build-up is important because, even though the net value is negligible, the peak value is generally so large that it greatly affects the size of momentum storage device needed to maintain attitude. Secular momentum results from forces which vary in magnitude such that the net resulting momentum is non-zero. Values of secular momentum are generally lower than those for cyclic, but it is the secular component which must be dissipated periodically to avoid exceeding the capacity of the momentum storage system. The capacity of momentum storage device needed, then, is determined by the maximum value of momentum build-up (the maximum sum of cyclic and secular momentum) experienced in an orbit.

Along with the use of CMGs to store momentum, the space station makes use of the fact that since environmental forces are highly dependent on the flight attitude, it is generally possible to maintain an attitude which reduces their magnitude. Clearly, by determining and maintaining an attitude which minimizes the magnitude of the environmental forces, the CMGs would need to store less angular momentum and be desaturated less often. This minimum torque attitude is expressed as three ordered Euler angles, called Torque Equilibrium Angles (TEAs), which represent successive yaw, pitch, and roll rotations about the body axes. Before the rotations are executed, the body axes correspond to the Local Vertical/ Local Horizontal (LVLH) coordinate axes defined by the positive X axis along the velocity vector, positive Z toward Earth along the nadir vector, and positive Y in the orbit plane to form a right handed system.

## FLIGHT ATTITUDE ANALYSIS - INTRODUCTION

- CURRENT STATION DESIGN USES CONTROL MOMENT GYROS (CMGs) TO STORE EXCESS ANGULAR MOMENTUM BUILD-UP
- TORQUE EQUILIBRIUM ANGLES (TEAs) EXPRESS VEHICLE ATTITUDE WHICH MINIMIZES TOTAL ANGULAR MOMENTUM BUILD-UP:
  - " SECULAR " MOMENTUM MUST BE DISSIPATED PERIODICALLY TO KEEP THE CMGs WITHIN THEIR CAPACITY
  - " CYCLIC " MOMENTUM HAS NET BUILD-UP OF ZERO, BUT HAS HIGH PEAKS WHICH MUST BE COUNTERED BY CMGs
- SIZING OF CMGs DEPENDS ON GREATEST SUM OF SECULAR AND CYCLIC PEAKS IN A SINGLE ORBIT - MAGNITUDE OF RESULTANT TOTAL ANGULAR MOMENTUM VECTOR

## Mars Sprint Mission Accommodation Study

### **FLIGHT ATTITUDE ANALYSIS - APPROACH**

The flight attitude analysis consisted of calculating TEAs and corresponding momentum build-ups for three different configurations of each depot concept and two for the Station Based concept (eleven configurations in all) where each configuration represents a different operational state. The first depot configuration was simply the depot without any propellant, tanks, or vehicle on board. Tanks and propellant were added for the second, and finally a complete vehicle was included. In this way, it was possible to evaluate the effects of increasing and repositioning the total mass of the three depot concepts. The Station Based concept was analyzed both with and without a vehicle.

## Mars Sprint Mission Accommodation Study

# FLIGHT ATTITUDE ANALYSIS - APPROACH

- o Calculate Torque Equilibrium Angles (TEAs) for several operational configurations of each concept :
- Depot concepts :
  - o Depot without tanks, propellant or vehicle
  - o Depot with tanks and propellant, without vehicle
  - o Depot with tanks, propellant, and vehicle
- Station Based concept :
  - o Without vehicle
  - o With vehicle in hangar
- o Calculate momentum built up by each configuration in a single orbit.



## Mars Sprint Mission Accommodation Study

### MASS PROPERTIES

Solid models of each configuration were developed using the GEOMOD program developed by Structural Dynamics Research Corp. (SDRC), and the geometry and mass properties were then passed to the Articulated Rigid Body Dynamics (ARCD) program. The ARCD program computes forces and moments needed to maintain a given attitude and calculates the momentum build-up about each axis in a single orbit. The calculations in ARCD include environmental effects as well as the effects due to articulating mechanisms such as solar dynamic reflectors. The two software packages, GEOMOD and ARCD, are integrated under a single operating environment at NASA Langley called IDEAS\*\*2, which also includes other SDRC and NASA developed software for structural, thermal, and controls analysis.

The following two charts show the mass properties derived from the analytical models of the Depot and Station Based concepts. It should be noted that the Center of Mass locations are expressed as distances away from the origin of a body fixed right handed coordinate system. The origins for the Phase II station and the Station Based concept are located at the center of the middle truss bay on the transverse boom. The origin for the Open Box is at the center of the starboard face.

# Mars Sprint Mission Accommodation Study

## MASS PROPERTIES

Configuration ( Total Mass )	Center of Mass ( M )			Inertias ( Kg-M**2 X 10**7 )					
	X	Y	Z	IXX	IYY	IZZ	IXY	IXZ	IYZ
Phase II Dual Keel Space Station ( 267,000 Kg )	-3.5	-0.9	3.2	31.0	9.1	25.6	1.76	-1.54	-1.87
Station Based w/PTF ( 326,000 Kg )	-3.6	2.1	2.9	33.1	13.2	28.6	0.74	0.08	0.21
Station Based w/PTF w/Vehicle ( 493,000 Kg )	-17.6	1.4	3.0	37.3	36.9	48.7	1.74	-0.7	0.2
Open Box ( 118,000 Kg )	-3.1	-19.5	-12.2	8.0	8.8	9.7	0.02	-2.9	-0.08
Open Box w/prop. ( 1,030,000 Kg )	-22.5	-20.0	20.7	46.4	39.5	49.7	0.33	-11.3	-0.32
Open Box w/Vehicle ( 1,190,000 Kg )	-22.7	-20.0	17.9	53.1	49.9	53.9	0.33	-10.9	-0.32

## **Mars Sprint Mission Accommodation Study**

# **MASS PROPERTIES** (Concluded)

This chart shows the remaining mass properties of the depot concepts.

The origin of the body fixed coordinate system of the Prism is in the center of the volume enclosed by the equilateral triangular prism. For the Open Platform the origin is located in the center of the rectangle which surrounds the vehicle.

# Mars Sprint Mission Accommodation Study

## MASS PROPERTIES

(Concluded)

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Configuration ( Total Mass )	Center of Mass ( M )			Inertias ( Kg-M**2 X 10**7 )					
	X	Y	Z	IXX	IYY	IZZ	IXY	IXZ	IYZ
Prism ( 107,000 Kg )	-1.0	0.6	-61.1	22.3	18.6	9.1	0.1	0.78	-0.65
Prism w/prop. ( 1,020,000 Kg )	-7.0	1.6	-26.4	143.2	102.8	70.1	0.8	-13.2	-2.1
Prism w/Vehicle ( 1,180,000 Kg )	-6.3	1.4	-25.0	145.4	108.9	74.8	0.69	-12.5	-2.4
Open Platform ( 99,900 Kg )	0.5	-1.8	20.8	7.9	3.9	6.5	-0.06	0.38	-2.2
Open Plat. w/prop. ( 1,010,000 Kg )	-1.7	-0.26	17.6	65.2	36.6	56.4	-0.37	-0.50	-0.12
Open Plat. w/Veh. ( 1,180,000 Kg )	-1.1	-0.2	15.1	70.2	45.5	60.9	-0.39	-1.6	-0.25

## Mars Sprint Mission Accommodation Study

# ATTITUDE ANGLES AND CORRESPONDING MOMENTUM BUILDUP

The next two charts contain the basic results of the flight attitude analysis of the station based and depot concepts in each of the configurations described above. The first three entries on the chart are the attitude angles for each configuration which minimize the amount of momentum built up in an orbit. These are the TEAs described above, where positive values for the angles Phi, Theta, and Psi represent positive rotations about the X, Y, and Z axes respectively. Thus, if one were looking along the flight path, a positive Phi would be characterized by a clockwise roll, Theta by an upward pitch, and Psi by a left-to-right yaw.

The fourth entry on each chart is the resultant magnitude of the X, Y, and Z axis secular momentum build-ups which correspond to the given TEAs. The fifth is the value of momentum build up for the given attitude which represents the greatest resultant of the cyclic and secular components in a single orbit. These two values are given because it is the secular component which needs to be dissipated periodically, while the maximum value provides a good measure of the size of momentum storage device needed. In a broader sense, then, the maximum value expresses the overall difficulty of maintaining the given attitude, and thus is a convenient means for comparing concepts.

**Mars Sprint Mission Accommodation Study**  
**ATTITUDE ANGLES AND CORRESPONDING**  
**MOMENTUM BUILD-UP**

Configuration	Torque Equil. Angles ( Degrees )			Momentum Build-up ( Nt-M-Sec )	
	Phi ( X )	Theta ( Y )	Psi ( Z )	Secular	Maximum
Phase II Dual Keel Space Station	0.2	3.0	0.6	1,500	3,050
Station Based w/PTF	-0.4	4.2	4.5	8,790	8,790
Station Based w/PTF w/Vehicle	-2.1	-4.5	21.4	5,470	13,000
Open Box	1.3	-36.6	-2.6	467	5,800
Open Box w/prop.	0.1	-41.4	-9.2	2,442	8,400
Open Box w/Vehicle	0.0	-44.4	-4.4	2,335	3,270

## Mars Sprint Mission Accommodation Study

# ATTITUDE ANGLES AND CORRESPONDING MOMENTUM BUILDUP

(Concluded)

The dominant secular momentum value generally occurs about the pitch axis, but in many cases the value about the roll or yaw axis is larger. This is why the resultant magnitude is given, with the implication that it is necessary to provide significant momentum storage and dissipation along all three axes. The momentum values given are very sensitive to small changes in attitude. For example, the maximum resultant build up for the Open Box and the Prism increases by two orders of magnitude with only a 5 degree change in Theta. This implies that to provide margin for maneuvering and reboosting, a somewhat larger storage device would be needed. For example, when specifying a CMG design, a contingency factor (usually 1.5-2.0) is usually applied to the maximum value shown. The Open Platform is slightly less sensitive than the Open Box and Prism, but still would require a greater capacity than indicated by the maximum value shown. Also shown on the chart are results for the current dual keel space station design. These values are subject to the same argument, but since the station will not experience the same degree of mass property changes, it will not need to change its attitude as drastically or as often as the depot.

**Mars Sprint Mission Accommodation Study**  
**ATTITUDE ANGLES AND CORRESPONDING**  
**MOMENTUM BUILD-UP**

(Concluded)

Configuration	Torque Equil. Angles ( Degrees )			Momentum Build-up ( Nt-M-Sec )	
	Phi ( X )	Theta ( Y )	Psi ( Z )	Secular	Maximum
Prism	-4.0	-6.4	-4.0	3,441	10,870
Prism w/prop.	-3.8	10.1	0.1	1,440	3,360
Prism w/Vehicle	-3.9	9.9	0.0	1,075	2,870
Open Platform	5.0	-0.4	-1.0	1,750	6,470
Open Plat. w/prop.	0.3	4.0	-0.7	442	2,880
Open Plat. w/Veh.	0.6	10.9	-0.7	616	5,380



## Mars Sprint Mission Accommodation Study

### FLIGHT ATTITUDE ANALYSIS - SUMMARY

It is immediately clear from the previous charts that of the depot concepts, the Hanger, Prism and the Open Platform concepts exhibit much more favorable TEAs than the Open Box, while the momentum values are comparable. Of course, the TEA values are less important for the depot concepts than for the Space Station based concept since the Depot attitude is not restricted by +/- 5 degrees field of view requirements. Thus, the high pitch angle of the Open Box is less of a concern than the Station based concept angles which approach or exceed +/- 5 degrees.

The above analyses, while incomplete, nonetheless increases the feeling that this type of facility is feasible. By showing that the controllability requirements of a few very different configurations are comparable to those of the current station design, some confidence is gained that future designs will avoid significant difficulty.

## Mars Sprint Mission Accommodation Study

### FLIGHT ATTITUDE ANALYSIS - SUMMARY

- o All concepts maintain reasonable momentum build-up :
  - Secular momentum build-up well within current desaturation capabilities
  - Maximum build-up within momentum storage capabilities
- o Prism, Open Platform, and Station Based concepts maintain moderate to low pitch TEAs :
  - Maintain viewing angles
  - Maintain pointing for payloads, communications, etc.
  - Maintain envelope for using aeroshells for protection
- o Open Box has high pitch TEAs.
- o All concepts are sensitive to small TEA changes :
  - Prism and Open Box momentum build-ups increase by two orders of magnitude with only 5 degrees angle change.
  - Open Platform and Station Based concepts are less sensitive, but still increase significantly

## **Mars Sprint Mission Accommodation Study**

### **FURTHER ANALYSIS**

This chart summarizes the analyses which have been identified as necessary or desirable for refinement of vehicle support facility concepts.

## Mars Sprint Mission Accommodation Study

### FURTHER ANALYSIS

- o Refine hangar and depot concepts :
  - Analysis for various stages of vehicle assembly and various amounts of stored propellant
  - Reaction to dynamic disturbances ( modes excitation, structural loads, etc.)
  - Develop assembly timelines
  - Launch manifest for hangar/depot hardware
  - Resource requirements
- o Develop growth scenarios for hangar/depot concepts :
  - GEO missions
  - Lunar missions
- o Perform similar studies for other possible co-orbiting facilities :
  - Science Platforms
  - Propellant Tank Farm
  - Variable/Artificial Gravity Facilities

## **Mars Sprint Mission Accommodation Study**

### **ASSEMBLY ISSUES**

The process of assembling a large structure such as the hangar or depot is aided considerably by the presence of a functioning dual keel space station. In particular, the process can be based at the station and, thus, remove dependency on the shuttle. Also, the assembly and checkout processes will use hardware, software, and assembly techniques already proven during construction of the station.

## **Mars Sprint Mission Accommodation Study**

### **ASSEMBLY ISSUES**

- o **Assembly and checkout of hangar or depot must be complete by early 2002.**
- o **Crew needed to assemble depot can be based on station and transferred to assembly area via enhanced OMVs.**
- o **Experience gained on station is directly applicable hangar and depot assembly :**
  - **Assembly of truss (techniques, timelines, etc.)**
  - **Integration of power modules and utilities**
  - **GN&C, C&T**
  - **Robotic support**
  - **EVA/IVA procedures**
  - **Maintenance, failure prediction**
  - **Transfer and mating of payloads**

## Mars Sprint Mission Accommodation Study

# CONCLUDING REMARKS AND OBSERVATIONS

The present Space Station configuration, with the addition of more power, a servicing hanger, and a large propellant depot is capable of accommodating the Mars Sprint Mission.

Other key conclusions/observations drawn from this report are:

The large quantities of propellant that are required for the Mars Sprint Mission dictate the need for a Heavy Lift Launch Vehicle with a payload capability of approximately 200,000 pounds.

For the sprint missions, a trade study should be initiated to examine a chemical/aerobrake earth capture system for the Piloted Vehicle. Although there will be some mass in LEO penalties, the ability to recover and subsequently reuse this piece of flight hardware rather than just the Earth Recovery Capsule may well be worth the expenditure.

From the documentation available to the study, the OMV's being considered in the IOC Space Station time frame do not appear adequate to fully support the orbital activities required by the sprint missions. Studies are needed to define the requirements for an OMV-type vehicle that is specifically tailored to satisfy the broad range of tasks necessary to support this mission.

The success of the Mars sprint mission depends primarily on the capability to refuel the Piloted Vehicle in the Martian orbit. The DDT&E and subsequent demonstration and verification of long-term storage of the cryogenics, and the development of the cryogenic management and recovery systems necessary to guarantee high reliability and safe operations of these systems is crucial to this program.

In addition to the cryogenic management and recovery systems, on-orbit servicing/refurbishment, automation & robotics, ECLSS, and automatic rendezvous and docking technology programs must be enhanced and accelerated.

## Mars Sprint Mission Accommodation Study

### CONCLUDING REMARKS AND OBSERVATIONS

- ENHANCED CETF SPACE STATION CAN ACCOMMODATE A MANNED MARS SPRINT MISSION
- HLLV WITH APPROXIMATE PAYLOAD CAPABILITY OF 200,000 LBS NEEDED TO SUPPORT MISSION
- SHOULD CONSIDER A CHEMICAL RETROPROPULSION/AEROBRAKE SYSTEM FOR EARTH ORBIT CAPTURE OF THE PILOTED VEHICLE
- NEED FOR AN OMV-TYPE VEHICLE CAPABLE OF HANDLING MASSES IN EXCESS OF 250,000 POUNDS
- ON-ORBIT SERVICING/REFURBISHMENT, SPACE STORABLE CRYOGENICS, A&R, ECLSS, AND AUTOMATED RENDEZVOUS AND DOCKING TECHNOLOGY PROGRAMS MUST BE ENHANCED AND ACCELERATED



## **Mars Sprint Mission Accommodation Study**

# **CONCLUDING REMARKS AND OBSERVATIONS** (CONCLUDED)

This chart lists several of the generalizations drawn from the analysis of the vehicle support facility concepts. As could be expected, not all the desirable design features listed previously are compatible. For example, the advantages gained by fully or partially enclosing the vehicle make separating the vehicle from the depot or station a considerably more complicated process. Similarly, distributing the propellant around the depot structure will help maintain the controllability of the system, but will also complicate the propellant transfer process. These issues will be at the heart of future studies to refine the designs of this type of facility.

## **CONCLUDING REMARKS AND OBSERVATIONS**

- o Large enclosed volumes :
  - Better thermal/radiation/impact protection
  - Better debris containment
  - Better robotic and EVA access
  - Must not block viewing from command center
  - More complex separation of vehicle from depot
- o Command center location :
  - Should be near middle of vehicle to avoid blockage from aeroshells
  - Should be inside enclosed volume to take advantage of thermal/radiation/impact protection and provide better viewing
- o Propellant tanks (on depot) :
  - Location and mass greatly affects TEAs, demands on control system
  - Propellant should be distributed to avoid C.M. travel and minimize danger from spillage
  - Pumping propellant over great distances may increase danger of spillage

**Mars Sprint Mission Accommodation Study**

**APPENDIX A: MANIFESTING**

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## **Mars Sprint Mission Accommodation Study**

### **MANIFESTING**

**This chart summarizes the key features and issues in the manifesting of hardware and propellant for launch on HLVs to support the baseline mission.**

## Mars Sprint Mission Accommodation Study

### MANIFESTING

- o 2 HLLV LAUNCHES ARE REQUIRED FOR DELIVERY OF ADDITIONAL SPACE STATION HARDWARE:
  - LIFE SCIENCE, CENTRIFUGE, HABITATION, AND ISOLATION MODULES
  - 2 OMVs WITH CREW CABS
  - Telerobotic Servicer
  
- o 8 HLLV LAUNCHES ARE REQUIRED TO DELIVER HARDWARE AND PROPELLANT FOR EACH CARGO MISSION ( 2 HARDWARE, 6 PROPELLANT)
  
- o 9 HLLV LAUNCHES ARE REQUIRED TO DELIVER HARDWARE AND PROPELLANT FOR EACH PILOTED MISSION ( 2 HARDWARE, 7 PROPELLANT)
  
- o 45 DAY LAUNCH RATE OF HLLVs FORCES OVERLAP OF CONSECUTIVE MISSIONS (SEE MISSION TIMELINE)
  
- o MISSION TIMELINE WAS NOT ALTERED TO ELIMINATE OVERLAP. INSTEAD, PROPELLANT IS LAUNCHED DURING OVERLAP TIMES TO AVOID HAVING HARDWARE FOR TWO MISSIONS IN LEO AT THE SAME TIME

**Mars Sprint Mission Accommodation Study**

**MASS OF EQUIPMENT TO BE ACCOMMODATED  
IN LEO (WORST CASE)**

This chart describes the point in the baseline mission scenario where the maximum mass in LEO is reached.

**MASS OF EQUIPMENT TO BE ACCOMMODATED  
IN LEO (WORST CASE)**

- o MAXIMUM MASS NEEDED IN LEO FOR MARS MISSION SUPPORT OCCURS BEFORE LAUNCH OF 2nd PILOTED MISSION (1st QUARTER 2007)
- o TO MAINTAIN 45 DAY LAUNCH CENTERS FOR HLLVs, IT IS NECESSARY TO DELIVER NEARLY 3/4th OF THE PROPELLANT FOR THE 3rd CARGO MISSION BEFORE LAUNCH OF THE 2nd PILOTED MISSION

ZERO-G PILOTED VEHICLE STACK (DRY)	167,400 Kg.
LH2/LO2 PROPELLANT FOR PILOTED STACK	489,400 Kg.
REFURBISHMENT UNITS	17,800 Kg.
SPACE STATION HARDWARE ( MODULES, ETC. )	147,800 Kg.
	<hr/>
LH2/LO2 PROPELLANT FOR 3rd CARGO MISSION	822,400 Kg.
	(1,809,300 Lbm)
	290,400 Kg.
	(638,900 Lbm)
	<hr/>
TOTAL	1,112,800 Kg.
	(2,448,200 Lbm)

- o ABOVE VALUE DOES NOT INCLUDE MASS OF TRUSS, PROPELLANT TANKS, UTILITIES, POWER MODULES, ETC. ASSOCIATED WITH SPACE STATION MODIFICATIONS, PROPELLANT TANK FARM (PTF), OR DEPOT

**Mars Sprint Mission Accommodation Study**

**PROPELLANT SUMMARY**

**This chart summarizes some of the characteristics of propellant storage requirements for a Mars Sprint Mission.**



## Mars Sprint Mission Accommodation Study

# PROPELLANT SUMMARY

- o PROPELLANT MASS IS BY FAR THE MOST SIGNIFICANT ADDITION TO TOTAL MASS IN LEO.
- o MAXIMUM PROPELLANT IN LEO IS 779,800 Kg. (SEE CHART) - THIS DOES NOT INCLUDE CONTINGENCY FOR SPILLAGE OR BOILOFF
- o AFTER 1st AND 3rd CARGO MISSIONS THE PROPELLANT MASS IN LEO IS ZERO (SEE CHART)
- o MIXTURE RATIO IS 6:1 (L02 TO LH2)
- o PROPELLANT TANKS : DIAMETER = 5 m  
LENGTH = 15 m  
MASS = 19,300 Kg. (INCLUDES ULLAGE)  
MASS OF L02/TANK = 222,200 Kg.  
MASS OF LH2/TANK = 19,000 Kg.
- o OTHER STUDIES HAVE IDENTIFIED TECHNOLOGIES WHICH PROMISE TO PROVIDE STORAGE OF UP TO 1 YEAR WITH MINIMAL LOSS
  - THERMAL SHIELDING AND ACTIVE COOLING TO MINIMIZE BOILOFF
  - QUICK RELEASE VALVES TO MINIMIZE SPILLAGE
  - ACTIVE AND PASSIVE CAPTURE OF SPILLAGE AND BOILOFF
  - RE-LIQUIDIFICATION OF CAPTURED PROPELLANT

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

The seven charts that follow show a condensed version of the launch manifest for support of the three Mars Sprint missions described previously. The development of these lists assumed that a Heavy Lift Vehicle (HLV) with capacity to deliver 200,000 Lbm to orbit was available for launch every 45 days. Also, it should be noted that the list of hardware included on each HLV launch was determined by considering the mass of each hardware component and when it is needed on-orbit. The mass of each component was obtained from the Civil Needs Data Base (CNDB), and though the volume of each component was also available, it was not specifically considered.

This chart shows the launch of hardware which is to be located at the station. Included are those hardware elements which are necessary for precursor life science activities, LEO transportation, and crew habitation.

Mars Sprint Mission Accommodation Study

**MARS SPRINT MISSION EARTH TO LEO MANIFEST**

HLV-1	Space Station Hardware		
-----			
	2 OMVs	11,705 Kg	25,800 Lbm
	OMV Crew Cab (2)	5,445 Kg	12,000 Lbm
	OMV Prop./Tanks	4,900 Kg	10,800 Lbm
	Habitat Modules (2)	27,407 Kg	60,406 Lbm
	Module Outfitting	27,223 Kg	60,000 Lbm
		-----	-----
		76,680 Kg	169,006 Lbm
HLV-2	Space Station Hardware		
-----			
	Life Sci. Module	14,688 Kg	32,373 Lbm
	Module Outfitting	16,777 Kg	36,976 Lbm
	Centrifuge Mod.	15,733 Kg	34,675 Lbm
	Isolation Module	15,733 Kg	34,675 Lbm
	Telerobotic Serv.	454 Kg	1,000 Lbm
	2 GEO Relays	7,713 Kg	17,000 Lbm
		-----	-----
		71,098 Kg	156,699 Lbm

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

The third and fourth HLV launches contain hardware for the build-up of the first cargo mission. Included is the entire cargo vehicle and payloads, as well as the first injection stage. Launches five through ten contain LO2/H2 propellant for the trip to Mars orbit, and the propellant needed for the manned mission to return to LEO.

Mars Sprint Mission Accommodation Study

**MARS SPRINT MISSION EARTH TO LEO MANIFEST**

(Continued)

HLV-3 -----	1st cargo mission vehicle build-up, 1st Quarter 2002		
	MOI Aerobrake	35,062 Kg	77,276 Lbm
	Robotic Payloads	14,973 Kg	33,000 Lbm
	Interstage	4,764 Kg	10,500 Lbm
	1st Stage (dry)	21,552 Kg	47,500 Lbm
	1st Stage Aerobrake	4,001 Kg	8,820 Lbm
		-----	-----
		80,352 Kg	177,096 Lbm
HLV-4 -----	1st cargo mission vehicle build-up, 2nd Quarter 2002		
	Mars Descent Stage	29,946 Kg	66,000 Lbm
	Mars Ascent Stage	29,946 Kg	66,000 Lbm
	Storage Tanker	17,332 Kg	38,200 Lbm
		-----	-----
		77,224 Kg	170,200 Lbm
HLV-5 thru HLV-10 -----	1st cargo mission propellant launches		

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

The eleventh and twelfth HLV launches contain hardware for the build-up of the first manned mission. Included is the entire manned vehicle, and the second injection stage. Launches thirteen through twenty two contain LO2/H2 propellant for the manned trip to Mars orbit, as well as propellant needed for the second cargo mission. Propellant for the second cargo mission is launched from earth and stored on-orbit before the first manned mission leaves LEO in order to maintain the 45 day HLV launch schedule and at the same time avoid having hardware for manned and cargo missions in LEO simultaneously. It may well turn out after further study that it is more difficult to accommodate extra propellant than to store extra hardware; in that case the launch of second cargo mission hardware could be accelerated and propellant launches could be delayed.

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

<p>HLV-11 -----</p>	<p>1st manned mission vehicle build-up, 2nd quarter 2003</p>	<p>MOI Aerobrake Return Capsule Airlock Command Module Habitat Module #1 Habitat Module #2 Bridge Docking Tunnel Power Subsystem Escape Stage 1st Stage Refurb.</p>	<p>16,107 Kg 6,765 Kg 3,212 Kg 8,493 Kg 15,499 Kg 15,499 Kg 1,606 Kg 789 Kg 3,892 Kg 6,034 Kg 6,157 Kg</p> <hr style="width: 100%;"/> <p>84,053 Kg</p>	<p>35,500 Lbm 14,883 Lbm 7,080 Lbm 18,720 Lbm 34,160 Lbm 34,160 Lbm 3,540 Lbm 1,740 Lbm 8,580 Lbm 13,300 Lbm 13,570 Lbm</p> <hr style="width: 100%;"/> <p>185,233 Lbm</p>
<p>HLV-12 -----</p>	<p>1st manned mission vehicle build-up, 2nd quarter 2003</p>	<p>Logistics Module Storm Shelter Interstage 2nd Stage 2nd Stage Aerobrake 1st/2nd Interstage Consummables 1st Stage Vernier Prop. 2nd Stage Vernier Prop. Flight Control (wet)</p>	<p>10,825 Kg 6,103 Kg 3,879 Kg 12,794 Kg 2,377 Kg 7,078 Kg 6,125 Kg 1,411 Kg 839 Kg 12,364 Kg</p> <hr style="width: 100%;"/> <p>63,795 Kg</p>	<p>23,860 Lbm 13,450 Lbm 8,550 Lbm 28,200 Lbm 5,240 Lbm 15,600 Lbm 13,500 Lbm 3,110 Lbm 1,850 Lbm 27,250 Lbm</p> <hr style="width: 100%;"/> <p>140,610 Lbm</p>

HLV-13 thru HLV-22 -----  
1st manned mission and 2nd cargo mission propellant launches

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

This chart shows the hardware and propellant for the second cargo mission and propellant for the second manned mission. As before, to maintain the 45 day HLV launch schedule, propellant is launched to cover the overlap and prevent having hardware for two missions in LEO at the same time. Note also that since the first injection stage is reusable it does not need to appear here as it did for build-up of the first cargo mission.



Mars Sprint Mission Accommodation Study

**MARS SPRINT MISSION EARTH TO LEO MANIFEST**  
(Continued)

HLV-23 -----	2nd cargo mission vehicle build-up, 4th quarter 2004		
	MOI Aerobrane	35,062 Kg	77,276 Lbm
	Robotic Payloads	14,973 Kg	33,000 Lbm
	Interstage	4,764 Kg	10,500 Lbm
		<u>54,799 Kg</u>	<u>120,776 Lbm</u>
HLV-24 -----	2nd cargo mission vehicle build-up, 4th quarter 2004		
	Mars Descent Stage	29,946 Kg	66,000 Lbm
	Mars Ascent Stage	29,946 Kg	66,000 Lbm
		<u>59,892 Kg</u>	<u>132,000 Lbm</u>
HLV-25 thru HLV-28 -----	2nd cargo mission and 2nd manned mission propellant launches		

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

This chart shows the hardware and propellant for the second manned mission and propellant for the third cargo mission. Since the second injection stage is also reusable, it does not appear here as it did for build-up of the first manned mission.

**Mars Sprint Mission Accommodation Study**  
**MARS SPRINT MISSION EARTH TO LEO MANIFEST**  
**(Continued)**

HLV-29 -----	2nd manned mission vehicle build-up, 3rd quarter 2005	Ret. Cap. Refurb. MOI Aerobrake Command Module Habitat Module #1 Habitat Module #2 1st Stage Refurb.	1,802 Kg 16,107 Kg 8,493 Kg 15,499 Kg 15,499 Kg 6,157 Kg	3,971 Lbm 35,500 Lbm 18,720 Lbm 34,160 Lbm 34,160 Lbm 13,570 Lbm	<hr/> 140,081 Lbm
HLV-30 -----	2nd manned mission vehicle build-up, 3rd quarter 2005	Airlock Bridge Docking Tunnel Power Subsystem Escape Stage Logistics Module Storm Shelter Interstage 1st/2nd Interstage Consummables 1st Stage Vernier Prop. 2nd Stage Vernier Prop. Flight Control (wet)	3,212 Kg 1,606 Kg 789 Kg 3,892 Kg 6,034 Kg 10,825 Kg 6,103 Kg 3,879 Kg 7,078 Kg 6,125 Kg 1,411 Kg 839 Kg 12,364 Kg	7,080 Lbm 3,540 Lbm 1,740 Lbm 8,580 Lbm 13,300 Lbm 23,860 Lbm 13,450 Lbm 8,550 Lbm 15,600 Lbm 13,500 Lbm 3,110 Lbm 1,850 Lbm 27,250 Lbm	<hr/> 141,410 Lbm
HLV-31 thru HLV-40 -----	2nd manned mission and 3rd cargo mission propellant launches		<hr/> 64,157 Kg		

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

This chart shows the hardware and propellant for the third cargo mission. In this case, it is not necessary to launch propellant for the third manned mission because so much propellant was stored in LEO prior to launch of the second manned mission. Here, once the cargo mission leaves LEO, only the reusable hardware is present until the next set of HLV launches begins.

Mars Sprint Mission Accommodation Study

**MARS SPRINT MISSION EARTH TO LEO MANIFEST**  
(Continued)

HLV-41	3rd cargo mission vehicle build-up, 1st quarter 2007		
-----			
	MOI Aerobrake	35,062 Kg	77,276 Lbm
	Robotic Payloads	14,973 Kg	33,000 Lbm
	Interstage	4,764 Kg	10,500 Lbm
		<u>54,799 Kg</u>	<u>120,776 Lbm</u>
HLV-42	3rd cargo mission vehicle build-up, 1st quarter 2007		
-----			
	Mars Descent Stage	29,946 Kg	66,000 Lbm
	Mars Ascent Stage	29,946 Kg	66,000 Lbm
		<u>59,892 Kg</u>	<u>132,000 Lbm</u>
HLV-43	3rd cargo mission propellant launches		
and			
HLV-44			
-----			

## Mars Sprint Mission Accommodation Study

# MARS SPRINT MISSION EARTH TO LEO MANIFEST

This chart shows the hardware and propellant for the third manned mission. This completes the current three Sprint mission scenario.

**Mars Sprint Mission Accommodation Study**  
**MARS SPRINT MISSION EARTH TO LEO MANIFEST**  
**(Concluded)**

HLV-45 -----	3rd manned mission vehicle build-up, 4th quarter 2007		
	Ret. Cap. Refurb.	1,802 Kg	3,971 Lbm
	MOI Aerobrake	16,107 Kg	35,500 Lbm
	Airlock	3,212 Kg	7,080 Lbm
	Command Module	8,493 Kg	18,720 Lbm
	Habitat Module #1	15,499 Kg	34,160 Lbm
	Habitat Module #2	15,499 Kg	34,160 Lbm
	Bridge	1,606 Kg	3,540 Lbm
	Docking Tunnel	789 Kg	1,740 Lbm
	Power Subsystem	3,892 Kg	8,580 Lbm
	Escape Stage	6,034 Kg	13,300 Lbm
	1st Stage Refurb.	6,157 Kg	13,570 Lbm
		<u>79,090 Kg</u>	<u>174,321 Lbm</u>

HLV-46 -----	3rd manned mission vehicle build-up, 1st quarter 2008		
	Logistics Module	10,825 Kg	23,860 Lbm
	Storm Shelter	6,103 Kg	13,450 Lbm
	Interstage	3,879 Kg	8,550 Lbm
	1st/2nd Interstage	7,078 Kg	15,600 Lbm
	Consummables	6,125 Kg	13,500 Lbm
	1st Stage Vernier Prop.	1,411 Kg	3,110 Lbm
	2nd Stage Vernier Prop.	839 Kg	1,850 Lbm
	Flight Control (wet)	12,364 Kg	27,250 Lbm
		<u>48,624 Kg</u>	<u>107,170 Lbm</u>

HLV-47  
 thru  
 HLV-53  
 -----  
 3rd manned mission propellant launches

**Mars Sprint Mission Accommodation Study**

**APPENDIX B: CONCEPT RATINGS**

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## Mars Sprint Mission Accommodation Study

# ANALYSIS OF VEHICLE ACCOMMODATION CONCEPTS

This chart and the one that follows are an attempt to assign a level of importance to the various requirements for vehicle support facilities, and evaluate each concept accordingly. The aim, of course, is to establish a few generalizations about the advantages and disadvantages of each concept and express them in a concise format. The numerical rankings that appear on these charts were prepared by a very high level, and somewhat subjective analysis, and should be viewed with that in mind.

The Open Box command center will be blocked somewhat by aeroshells, while the Prism and Open Platform command centers are in better locations. Each concept has room for expansion, but the Open Box is capable of expanding in every direction. The Prism can expand in each direction as well, but the added volume may be less useful due to the skewed nature of the triangular shape.

Robots have farther to reach on the Prism than on the Open Box and the Hangar, and they may have difficulty reaching around the vehicle on the Open Platform. All depot concepts have adequate robotic access to propellant, but the Open Box and the Prism allow EVA access from inside the enclosed volume.

Mars Sprint Mission Accommodation Study

**ANALYSIS OF VEHICLE ACCOMMODATION CONCEPTS**

Weight : 5 = very important  
1 = not important

Rank : 5 = very good  
1 = poor

Score = Weight X Rank

	Weight	Hangar		Open Box		Prism		Open Plat.	
		Rank	Score	Rank	Score	Rank	Score	Rank	Score
Effectiveness of docking port/command center : o Viewing around aero-shells	4	4	16	2	8	3	12	4	16
Capability for expansion : o Additional power o Additional volume	3	4	12	5	15	4	12	3	9
Access to vehicle : o Robotic and EVA o All assembly phases	5	4	20	5	25	4	20	3	15
Access to propellant : o Robotic and EVA	4	3	12	4	16	4	16	3	12

## Mars Sprint Mission Accommodation Study

# ANALYSIS OF VEHICLE ACCOMMODATION CONCEPTS

This chart continues the rankings of each concept with respect to the requirements for vehicle support.

To maintain mass balance, the propellant tanks must be distributed around the depot structure. All depot concepts have tanks near the vehicle to avoid pumping propellant over great distances. Obviously, the station based hangar concept avoids propellant problems by moving all cryogenics to the PTF.

By definition, the three depot concepts have little or no impact on station science while, as described previously, the hangar concept will block astronomical viewing, and change the station micro-gravity environment.

The Open Platform offers much simpler separation of vehicle from depot because so little of the vehicle is surrounded by truss.

Mars Sprint Mission Accommodation Study

# ANALYSIS OF VEHICLE ACCOMMODATION CONCEPTS

(Concluded)

	Weight	Hangar		Open Box		Prism		Open Plat.	
		Rank	Score	Rank	Score	Rank	Score	Rank	Score
Safety of propellant tank location :	5	5	25	4	20	3	15	3	15
o Proximity to command center and EVA crew									
Impact on station science	5	2	10	5	25	5	25	5	25
Impact protection :									
o Vehicle and crew	4	5	20	5	20	5	20	3	12
Debris containment	4	5	20	5	20	5	20	2	8
Thermal/rad. protection :									
o Vehicle and crew	3	5	15	5	15	5	15	3	9
Ease of vehicle separation	5	3	15	3	15	3	15	4	20
Tot. Score		165		179		170		141	



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16. Abstract This report documents the results of a study conducted at the NASA-LaRC to assess the impacts on the Phase II Space Station of Accommodating a Manned Mission to Mars. In addition, several candidate transportation node configurations are presented to accommodate the assembly and verification of the Mars Mission vehicles. This study includes an identification of a life science research program that would need to be completed, on-orbit, prior to mission departure and an assessment of the necessary orbital technology development and demonstration program needed to accomplish the mission. Also included is an analysis of the configuration mass properties (mass, volume, etc.) and a preliminary analysis of the Space Station control system sizing that would be required to control the station.  Results of the study indicate the Phase II Space Station can support a manned mission to Mars with the addition of a supporting infrastructure that includes a propellant depot, assembly hanger and a heavy lift launch vehicle to support the large launch requirements.					
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