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Manned Mars Mission
On-Orbit Operations
FTS Capabilities Assessment

Final Report

Prepared for:

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Greenbelt Md., 20771

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This document presents an overview of the characteristics and capabilities of the Flight Telerobotic Servicer (FTS), under development at GSFC at the time the report was prepared. (The project has since been cancelled.) The assessment was directed toward developing the FTS to enable assembly and servicing of the Mars vehicle at the Space Station; facilitate rendevous, docking, and fluid-transfer operations involving the Mars vehicle fuel tank; to perform strip-mining operations on the lunar/martian surfaces; and to construct a 3-story shelter on the martian surface. The report considers the FTS' mechanical, electrical, thermal, and operational subsystems, as well as its proposed manipulator capabilities.

14. SUBJECT TERMS

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Manned Mars Mission
On-Orbit Operations
FTS Capabilities Assessment

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STATEMENT OF WORK

Assess the ability of the FTS, with and without modifications, to perform the following tasks:

1) Assembly and Servicing of the mars vehicle at space station
2) Rendevous, docking, and fluid transfer operations involving mars vehicle fuel tanks
3) Strip mining on the Lunar/Martian surface
4) Construction of a 3 story shelter on the martian surface

TABLE 1: Describes the applicability of the FTS requirement/capability to the following tasks:

MVA = MARS Vehicle Assembly
FTRD = Fuel Tank Rendezvous and Docking
SML = Strip Mining on Lunar Surface
SMM = Strip Mining on Martian Surface
SCM = Shelter, Construction on Martian Surface

X = Operation can be used as is for this task

FTS REQUIREMENTS: OPERATION, SYSTEM, MECHANICAL, AND ELECTRICAL

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
OVERVIEW: Crew can override automatic telebotic safing function from work station or by EVA	X	X	X	X	X	
Capable of teloperation by one person at the work station	X	X				
Telerobot manipulators, indivually controllable	X	X				
Fixed based independent operation wireless communication	X	X	X	X	X	

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TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
OVERVIEW:						
Ground storage life of six years	X	X	X	X	X	
FTS can be transfered by the OMV using a special kit	X	X				
Supervized, autonomous	X		X	X	X	
THERMAL:						
Independent of the space station and STS	X	X	X	X	X	
Margin of 10 °C between design extremeties and unit qual temperature limits + 5 °C from unit acceptance temperature levels	X	X	X	X	X	
No interference of the manipulators by the radiators	X	X	X	X	X	

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
CONTROL ALGORITHMS: Support SSFTS telerobot operations; teleoperated and autonomous modes	X	X				Control algorithms must be different for Lunar and Mars operation
Control and control inputs	X	X				
Bilateral force reflection control - higher gains allow for a better "feel" to the operator in low force, dexterous operation	X	X	X			Autonomous operation on Mars may be better
Backup methods	X	X	X	X	X	
Selection and defining coordinate reference	X	X	X	X	X	
Control each manipulator joining independently or in conjunction with other joints	X	X				This type of operation on the Martian and Lunar surface might produce longer response times
Control cameras	X	X				
Dual-arm coordinated control	X	X				
Adjustable force and torque limits for manipulation of objects	X	X	X	X	X	

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
ELECTRICAL:						
Flight wiring and harness for inter-connection of SSFTS subsystems and components in the telerobot and the work station	X	X	X			Telerobotic operation would be different for remote Mars operation
Provide cables, umbilical, and connector required for telerobot and work station connection to STS inter-face and SS	X	X	X			
Power: Peak 2000 watts AU Power < 1000 watts Standby 350 watts	X	X	X	X	X	
POWER SUBSYSTEM:						
Rechargable battery power source + Operator for two hours fixed-base + One year battery placement + Telerobotic stand-by state (3 years)	X	X	X			Better battery life is required for the trip to Mars
Electrical power Acquisition from: SS 208 VAC at 20 KHZ STS 28 + A VDC OMV Accommodation Kit	X	X	X			
VISION SUBSYSTEM:						
Three viewing modes + Global view + Task overview + Close-up view for detailed operation and inspection	X	X	X	X	X	

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
VISION SUBSYSTEM:						
Four Video Cameras + One on or near the wrist of each manipulator + Two positionable cameras for task specific worksite viewing	X	X	X	X	X	
Color CCD technology	X	X	X	X	X	
Optional black and white operation	X	X	X	X	X	
Can evolve to stereo operation	X	X	X	X	X	
Provide lighting for ACC operations	X	X	X	X	X	
Wireless or hard-wired transmission of video signals	X	X	X	X	X	
MANIPULATORS:						
Seven degrees of freedom	X	X	X	X	X	
Repeatability of less than 0.005 inch in position and +/- 0.05 degree in orientation	X	X	X	X	X	
Accuracy of less than 1.0 inch in position and +/- 3.0 degrees in orientation	X	X	X	X	X	
Tip force of 20 lbs.	X	X				Need stiffer arm on Mars and the moon
Tip torque of 20 ft-lbs.	X	X				Need stiffer arm on Mars and the moon

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
MANIPULATORS:						
Incremental motion of less than 0.001" and less than 0.01 degree at the center of the tool plate	X	X	X	X	X	
Sensors at each joint that measure torque, position, and rate required for telerobot control	X	X	X	X	X	
Joint braking system capable of over-riding the joint torque	X	X	X	X	X	
Backdriveable system	X	X	X	X	X	
Tool plate attached to the manipulator and tool change out	X	X	X	X	X	
Work Envelope: Robot Stretched Out - 162" horz. 181" vert.	X	X	X	X	X	
Dexterious Reach - 138"	X	X	X	X	X	
ON-ORBIT STORAGE:						
Storage of FTS and associated equipment; tools, and efflitors, spare parts, and ORV's	X	X	X	X	X	
Additional material weight not to exceed 450 lbs.	X	X				Once arms are stiffer, weight may increase
Stowed configuration - 84" x 42" x 36" volume	X	X	X	X	X	

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
TWO MAIN ARMS:						
Wrist Role - 24 ft-lbs +180°	X	X				Upgrade for surface operations
Wrist Yaw - 24 ft-lbs. + 180°	X	X				Upgrade for surface operations.
Wrist Pitch - 24 ft-lbs. + 90°	X	X				Upgrade for surface operations
Elbow Pitch - 58 ft-lbs. - +0°, -180°	X	X				Upgrade for surface operations
Shoulder Pitch - 99 ft-lbs. +120°, -90°	X	X				Upgrade for surface operations
Shoulder Rub - 20 ft-lbs. +0°, -90°	X	X				Upgrade for surface operations
Shoulder Yaw - 99 ft-lbs. +90°, -225°	X	X				Upgrade for surface operations
Weight 117 lbs.	X	X				Upgrade for surface operations
Wrist Length 14 inches	X	X	X	X	X	
Forearm Length 18 inches	X	X	X	X	X	
Upperarm Length 18 inches	X	X	X	X	X	
Shoulder Length 9 inches	X	X	X	X	X	
TOTAL Length w/ joint and end effector 72.15 inches	X	X				Weight increase due to increase in arm stiffness for Mars

TABLE 1 CONTINUED

REQUIREMENTS	MVA	FTRD	SML	SMM	SCM	COMMENTS
SSPS: (LEG)						
Wrist Roll + 180°	X	X	X	X	X	
Wrist Pitch + 90°	X	X	X	X	X	
Elbow Pitch + 180°- 0°	X	X	X	X	X	
Shoulder Pitch + 90°	X	X	X	X	X	
Roll + 135°	X	X	X	X	X	
Weight 90.75 lbs.	X	X				Increase in weight for Mars and Lunar operation
Wrist Length 9.35 inches	X	X	X	X	X	
Forearm Length 18 inches	X	X	X	X	X	
Upperarm 18 inches	X	X	X	X	X	
Total Length 61.45 inches	X	X	X	X	X	
FTS Body Length 64 inches	X	X	X	X	X	

ASSEMBLY OF THE MARS VEHICLE

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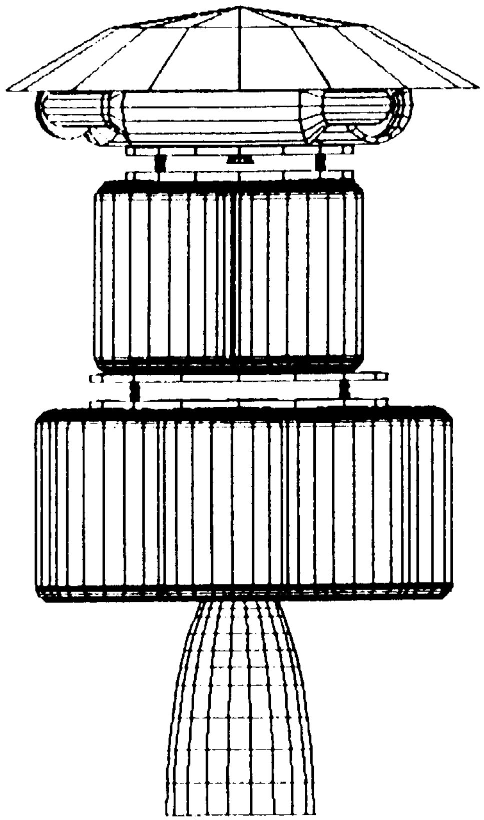

GIVEN:

0 SPACE CRAFT DESIGN IS AS SHOWN ABOVE

ASSUMPTIONS:

0 MARS SPACECRAFT WILL BE ASSEMBLED ON-ORBIT EITHER AT THE SS FREEDOM OR AT A SPECIAL CO-ORBIT HANGAR.
0 ALL COMPONENTS OF THE SPACE CRAFT ARE MODULARIZED FOR ROBOTIC ASSEMBLY
0 FTS WILL BE USED IN THE TELEOPERATED MODE FOR ALL ASSEMBLY OPERATIONS
0 THE HANGAR IS NOT PRESSURIZED
0 ALL COMPONENTS ARE STAGGED IN A STORAGE AREA IN THE HANGAR
0 ADEQUATE LIGHTING IS PROVIDED AS PART OF THE HANGAR DESIGN FOR ALL ASSEMBLY ACTIVITIES
0 UTILITY ATTACHMENT POINTS ARE PROVIDED IN THE HANGAR FOR FTS
0 ALL SPACE CRAFT COMPONENTS WHICH NEED TO BE ASSEMBLED ON-ORBIT ARE PROVIDED WITH INTERFACES WHICH ARE COMPATIBLE WITH ROBOTIC OPERATIONS
0THE CREW SHIP WILL CONSIST OF STANDARD SS MODULES
0THE PROPULSION SYSTEM IS DESIGNED SO THAT THE ONLY ASSEMBLY REQUIRED IS THE COUPLING OF THE FUEL TANKS THROUGH QUICK CONNECT COUPLINGS
0 THE INTERNAL DIMENSIONS OF THE HANGAR ARE COMPATABLE WITH THE DIMENSIONS OF THE SPACE CRAFT

REQUIREMENTS:

0 A RIGID TRANSPORT SYSTEM WHICH IS CAPABLE OF POSITIONING FTS AT ANYPOINT WITHIN THE HANGAR IS REQUIRED FOR ASSEMBLY
0 ATTACHMENT POINTS TO SUPPORT COMPONENTS IN PLACE WITHIN THE HANGAR IS REQUIRED
0 A CCTV SYSTEM FOR VIEWING ALL OPERATION IS REQUIRED AS FOLLOWS:
- OVERVIEW CAMERA SYSTEM WITH PTZ
- CLOSE UP CAMERA SYSTEM WITH PTZ

TABLE 1 OVERVIEW OF ASSEMBLY ACTIVITIES FOR THE MARS VEHICLE

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COMPONENT	QTY	NO. OF PARTS	SIZE	MASS (LBS)	METHOD OF * JOINING	REQ'TS F0R ASSEM	GENERAL COMMENTS
A) AEROBRAKE	1	4/15/80 FUNCTION OF LUANCH VEHICLE USED	92 ' DIA	53000	BOLTED OR PINNED/BOLT	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	BOLTS MUST BE DESIGNED TO BE CAPTIVE AND MATING INTERFACES TAPPERED AT THE LEAD-IN EDGE
B) CREW SHIP							
0 HABITAL MODULES	3	1 EACH	15' DIA X 60' LG	30000 EA	STANDARD SS INTERFACE 0 CLAMPING 0 BOLTING FOR ALL COMPONENTS	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	THE STANDARD SS MODULE INTERFACE HAS THE LEAD-IN CAPABILITY TO ACCEPT FTS POSTIONING INACCURACIES AND THE SOFT DOCK FOR REMOTE OPERATIONS
0 DISK MODULE /DOCK PORT	1	1	25' DIA X 15' H	21000			
0 AIR LOCKS	3	1 EACH	12' DIA	4000			
0 SOLAR OBSERVATORY	1	1	10' DIA	4000			
0 ACCESS TUNNELS	3	1 EACH	6' DIA	1000			
0 EARTH CREW CAPTURED VEHICLE (ECCV)	1	1		15700			
0 STRUCTURAL RING	1	3	48' DIA	900	PINNED AND BOLTED	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	BOLTS MUST BE CAPTIVE AND PINS PROVIDED WITH TAPPERS AT THE LEAD-IN EDGE TO ACCEPT POSITIONING ACCURACY OF FTS
C) STRUCTURE							
0 TRANS MARS INJECTION STAGE (TMIS) TANKS	3	1 EACH	25' DIA X 36 5' L	21000 EA	ASSUMED A SIMULAR METHOD AS FOR THE SS MODULES	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	THIS INTERFACE HAS THE LEAD-IN CAPABILITY TO ACCEPT FTS POSTIONING INACCURACIES AND THE SOFT DOCK FOR REMOTE OPERATIONS

TABLE 1 OVERVIEW OF ASSEMBLY ACTIVITIES FOR THE MARS VEHICLE (CONTINUED)

0 UPPER STRUCTURAL RING	1	3	48' DIA	900	PINNED AND BOLTED	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	BOLTS MUST BE CAPTIVE AND PINS PROVIDED WITH TAPPERS AT THE LEAD-IN EDGE TO ACCEPT POSITIONING ACCURACY OF FTS
0 LOWER STRUCTURAL RING	1	4	70' DIA	1100	PINNED AND BOLTED	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	BOLTS MUST BE CAPTIVE AND PINS PROVIDED WITH TAPPERS AT THE LEAD-IN EDGE TO ACCEPT POSITIONING ACCURACY OF FTS
0 PROPULSION SYSTEMS - CAPTURE SYSTEM - MARS ORBIT							ASSUMED PROPULSION SYSTEMS ARE AN INTEGRAL PART OF THE APPROPRIATE STRUCTURE AND THE ONLY OPERATION IS THE MATING OF THE INTERFACES
D) MAIN PROPULSION SYSTEM							
0 STRUCTURAL RING	1	4	70' DIA	1100	PINNED AND BOLTED	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	BOLTS MUST BE CAPTIVE AND PINS PROVIDED WITH TAPPERS AT THE LEAD-IN EDGE TO ACCEPT POSITIONING ACCURACY OF FTS
0 MAIN ENGINE	1	1	17' X 20' OVAL	6360	SAME MOUNT AS TMIS TANKS		
0 TMIS TANKS	7	1 EACH	25' DIA X 36 5' L	21000 EA	ASSUMED A SIMULAR METHOD AS FOR THE SS MODULES	0 POSITIONING ACCURACY 0 TORQUE CAPABILITY	THE STANDARD SS MODULE INTERFACE HAS THE LEAD-IN CAPABILITY TO ACCEPT FTS POSTIONING INACCURACIES AND THE SOFT DOCK FOR REMOTE OPERATIONS

* ALL STRUCTUAL JOINTS CAN ALSO BE WELDED USING FTS. EARTH BASED TECHNOLOGY EXIST FOR THIS APPLICATION AND CAN BE CONVERTED FOR SPACE APPLICATION

FIGURE 1 - OVERALL ASSEMBLY OF THE MARS SPACE CRAFT

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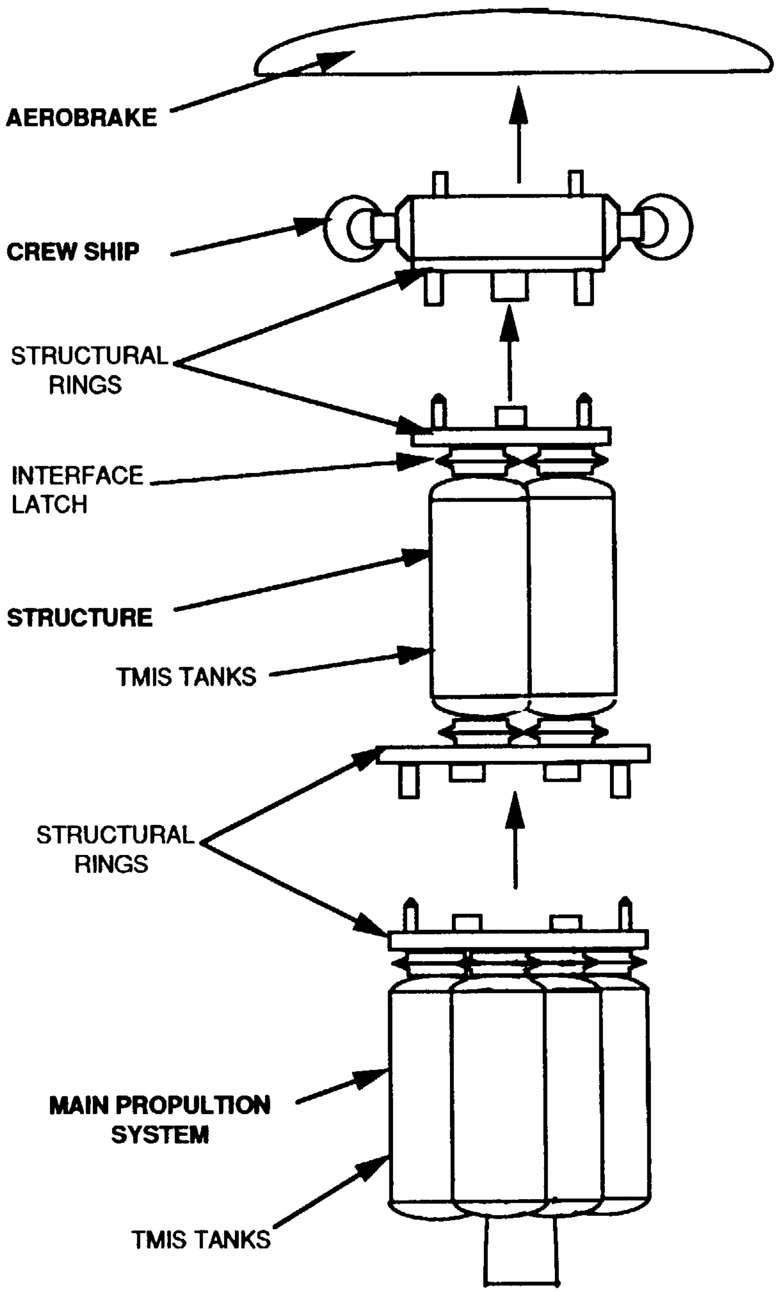

ASSEMBLY SEQUENCE

1) AEROBRAKE

- USING THE FTS REMOVE THE FIRST AEROBRAKE SHIELD SEGMENT FROM THE STAGGING AREA AND SECURE IT IN POSITION IN THE ASSEMBLY AREA
- POSITION THE NEXT AEROBRAKE PANEL SO THAT IT ENGAGES THE FIRST PANEL AND FASTEN TOGETHER. REFER TO FIGURE 2 FOR ACCEPTABLE METHODS FOR FASTENING THE PANEL WHICH ARE COMPATABLE WITH FTS
- REPEAT THE ABOVE STEP FOR ALL AEROBRAKE PANELS

2) CREW SHIP

- ASSEMBLE THE CREW SHIP AS SHOWN IN FIGURES 3 AND 4
- ONCE ASEMBLED POSITION THE CREW SHIP ONTO THE AEROBRAKE SHIELD AND SECURE IT IN PLACE
- ASSEMBLE THE 48' DIAMETER STRUCTURAL RING, FIGURE 5A
- MOVE RING INTO POSITION AND SECURE TO THE CREW SHIP

3) STRUCTURE

- ASSEMBLE THE SECOND 48' DIAMETER RING (FIGURE 5A) AND SECURE IN POSITION IN THE HANGAR
- IN SEQUENCE, POSITION EACH OFTHE THREE TMIS TANKS ONTO THE STRUCTURAL RING AND SECURE IN PLACE THROUGH THE INTERFACE LATCH (FIGURE 6)
- ASSEMBLE THE 70' DIAMETER STRUCTURAL RING (FIGURE 5B)
- POSITION THE 70' DIAMETER RING AND SECURE IT TO THE THREE TMIS TANKS (FIGURE 6)
- ONCE ASSEMBLED POSITION THE STRUCTURE ONTO THE CREW SHIP INTERFACE STRUCTURAL RING AND SECURE IT IN PLACE

4) MAIN PROPULSION SYSTEM

- ASSEMBLE THE 70' DIAMETER STRUCTURAL RING (FIGURE 5B) AND SECURE IT IN PLACE IN THE HANGAR
- IN SEQUENCE POSITION THE MAIN ENGINE AND THE SEVEN TMIS TANKS ONTO THE STRUCTURAL RING AND SECURE IN PLACE THROUGH THE INTERFACE LATCH (FIGURE 6)
- ONCE ASSEMBLED POSITION THE MAIN PROPUSION SYSTEM ONTO THE STRUCTURE SECTION OF THE SPACE CRAFT AND SECURE IN PLACE

FIGURE 2 - ASSEMBLY METHODS FOR THE AEROBRAKE SHIELD

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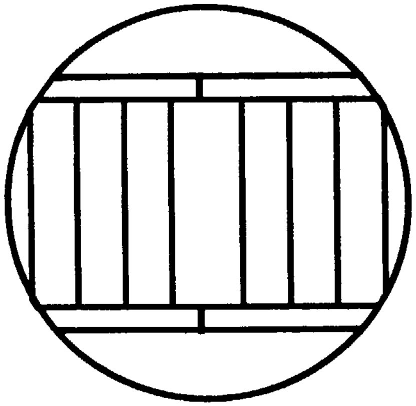
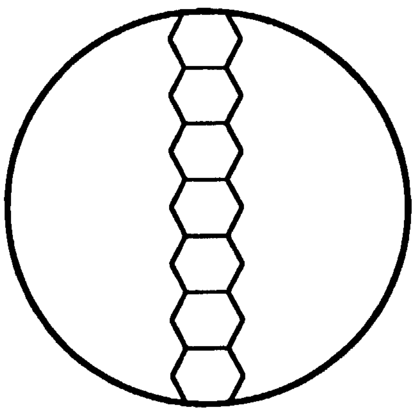
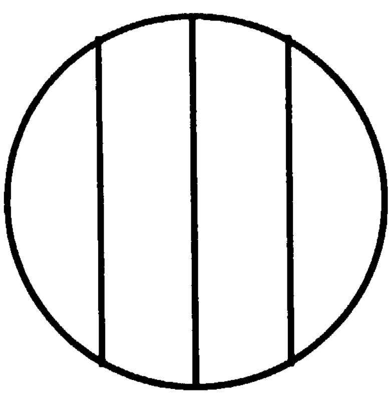
CONSTRUCTION OPTIONS



- TRANSPORTED USING THE NATIONAL SPACE TRANSPORTATION SYSTEM ORBITER
- DIVIDED INTO 15 PARTS
- REQUIRES TW0 (2) LAUNCHES
- MINIMIZES THE NUMBER OF PARTS THE AEROBRAKE SHIELD NEEDS TO BE DIVIDED INTO FOR TRANSPORT ON THE SHUTTLE

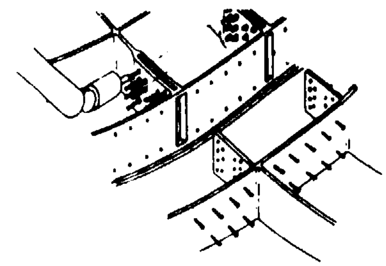


- TRANSPORTED USING THE NATIONAL SPACE TRANSPORTATION SYSTEM ORBITER
- DIVIDED INTO APPROXIMATELY 80 PARTS
- REQUIRES TWO (2) LAUNCHES
- PROVIDES A STANDARD SET OF PARTS FOR ASSEMBLY OF THE AEROBRAKE SHIELD, REDUCING THE POTENTIAL FOR ERROR DURING ASSEMBLY OPERATIONS
- MANIFEST NICELY IN THE SHUTTLE CARGO BAY
- PROVIDES THE FLEXABILITY TO EASILY CHANGE THE SIZE OF THE AEROBRAKE SHIELD



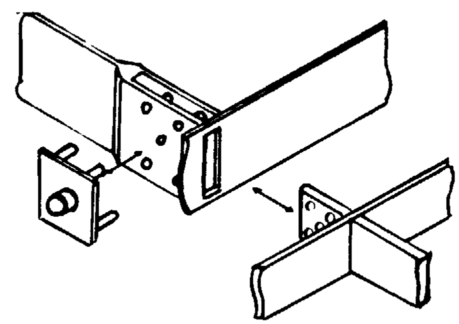
- TRANSPORTED USING AN EXPENDABLE LAUNCH VEHICLE
- DIVIDED INTO 4 PARTS
- REQUIRES ONE (1) LAUNCH
- MINIMIZES THE NUMBER OF PARTS WHICH NEEDS TO BE ASSEMBLED, THUS MINIMIZING OPERATIONS
- REQUIRES THE AEROBRAKE SHIELD PARTS TO BE RETRIEVED FROM ORBIT
- COMPLEXITY OF ASSEMBLY OPERATIONS ARE GREATER DUE TO THE LARGE SEGMENTS WHICH NEEDS TO BE HANDLED AND POSITIONED

METHODS OF ASSEMBLY COMPATABLE WITH FTS



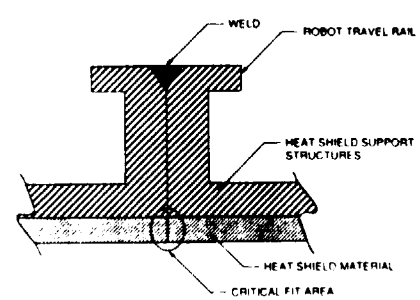
BOLTED

- CAPTIVE FASTENERS ARE REQUIRED FOR THIS METHOD
- REQUIRES NUMEROUS OPERATIONS
- BOLTS ARE PLACED IN SHEAR
- WILL WORK BUT NOT RECOMENDED AS THE PRIMARY METHOD



PINNED/BOLTED

- LARGE DIAMETER PINS REACT ALL LOADS
- MINIMIZES NUMBER OF BOLTING OPERATIONS SIMPLIFYING OVERALL ASSEMBLY TASKS
- ALL BOLTS ARE IN TENSION RESULTING IN MINIMUM LOADING
- PROVIDES A STRONG, RUGGED JOINT



WELDED

- PROVIDES A STRONG RIGID JOINT FOR THE AEROBRAKE SHIELD
- REQUIRES SPECIAL CONSIDERATIONS FOR WELDING SUCH AS
  - SEAM TRACKER OR
  - GUIDE RAIL SYSTEM
- DIRTY OPERATION COMPARED TO MECHANICAL SYSTEMS

FIGURE 3 - ASSEMBLY METHOD FOR CREW SHIP

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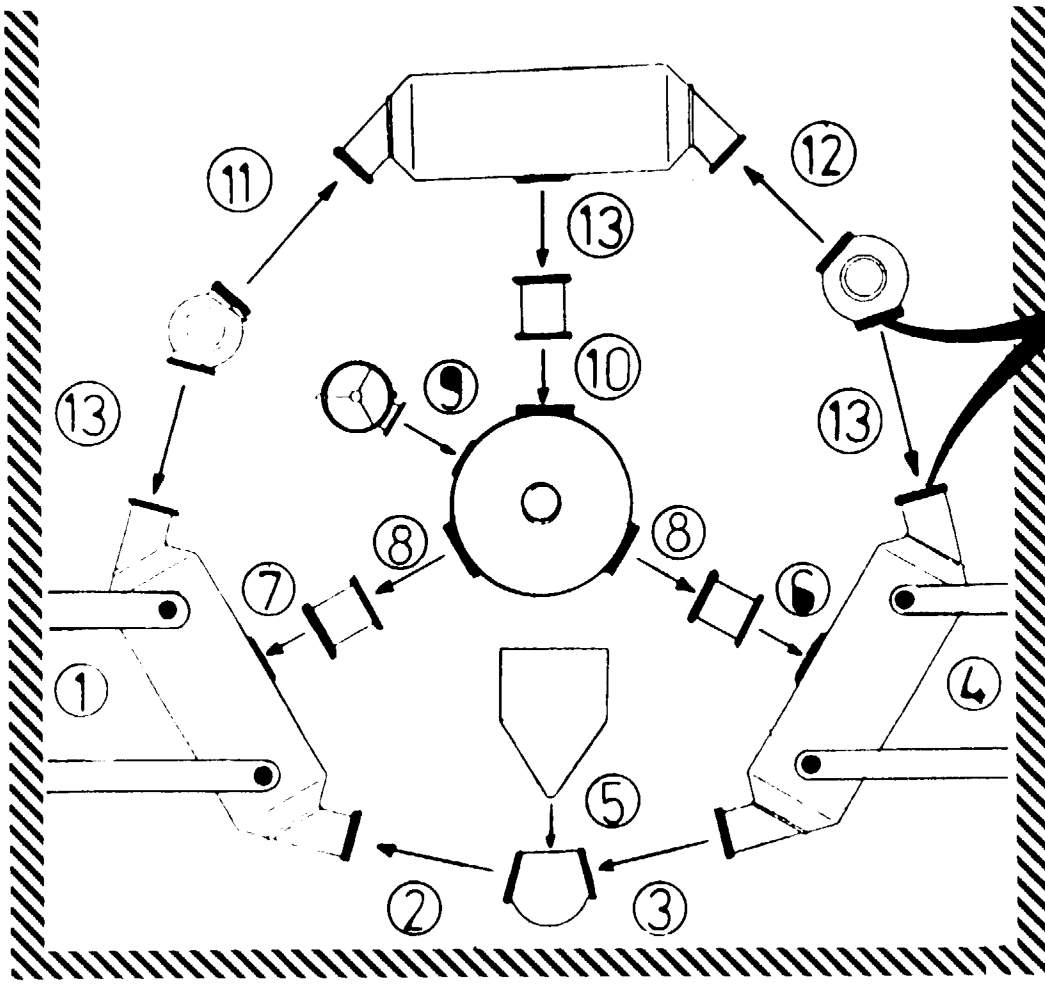

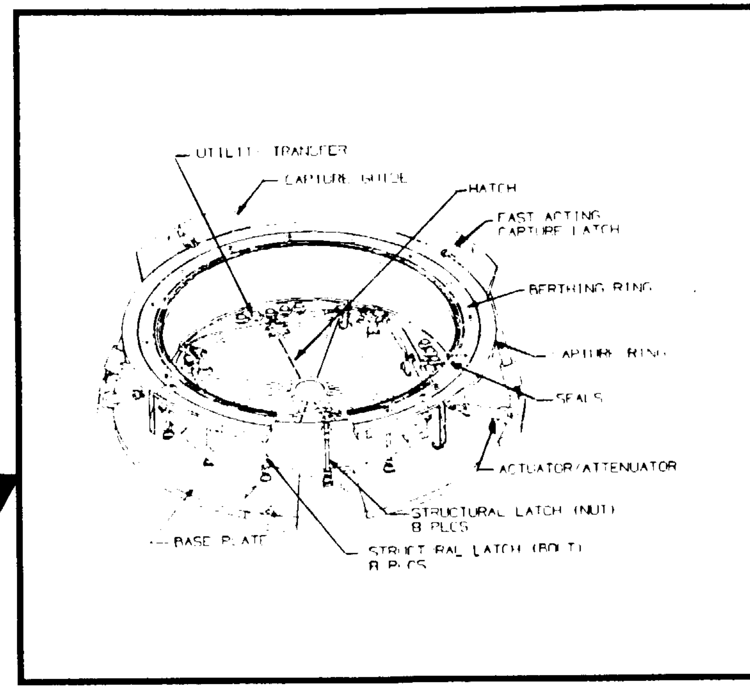

STANDARD SS MODULE INTERFACE

ISSUES:

- INITIAL LATCHING OPERATION FOR THE MODULE INTERFACE IS COMPATABLE WITH FTS
- TWO DESIGNS ARE BEING CONSIDERED FOR THE FINAL STRUCTURAL LATCH OF THE MODULE INTERFACE
  - THE FIRST DESIGN IS ACCESSABLE FROM THE OUTSIDE OF THE MODULE AND APPEARS TO BE COMPATABLE WITH FTS OPERATIONS
  - THE SECOND DESIGN REQUIRES THE STRUCTURAL LATCHES TO BE ACCESSED FROM INSIDE THE MODULE AND IS NOT COMPATABLE WITH FTS OPERATIONS
- DEPENDING ON THE DESIGN SELECTED, THE MODULE INTERFACE MAY NEED TO BE MODIFIED FOR THIS APPLICATION
- TOLERANCE BUILD-UP IN THE CONSTRUCTION OF THE CREW SHIP IS A CONCERN. THIS CAN BE ACCOMODATED BY:
  - PERFORMING A FIT CHECK ON EARTH AND PROVIDING SPECIAL ADAPTERS AS REQUIRED
  - DESIGN THE MODULE INTERFACE TO ACCOMODATE THE TOLERANCE BUILD-UP

FIGURE 4 - ASSEMBLY SEQUENCE FOR THE CREW SHIP

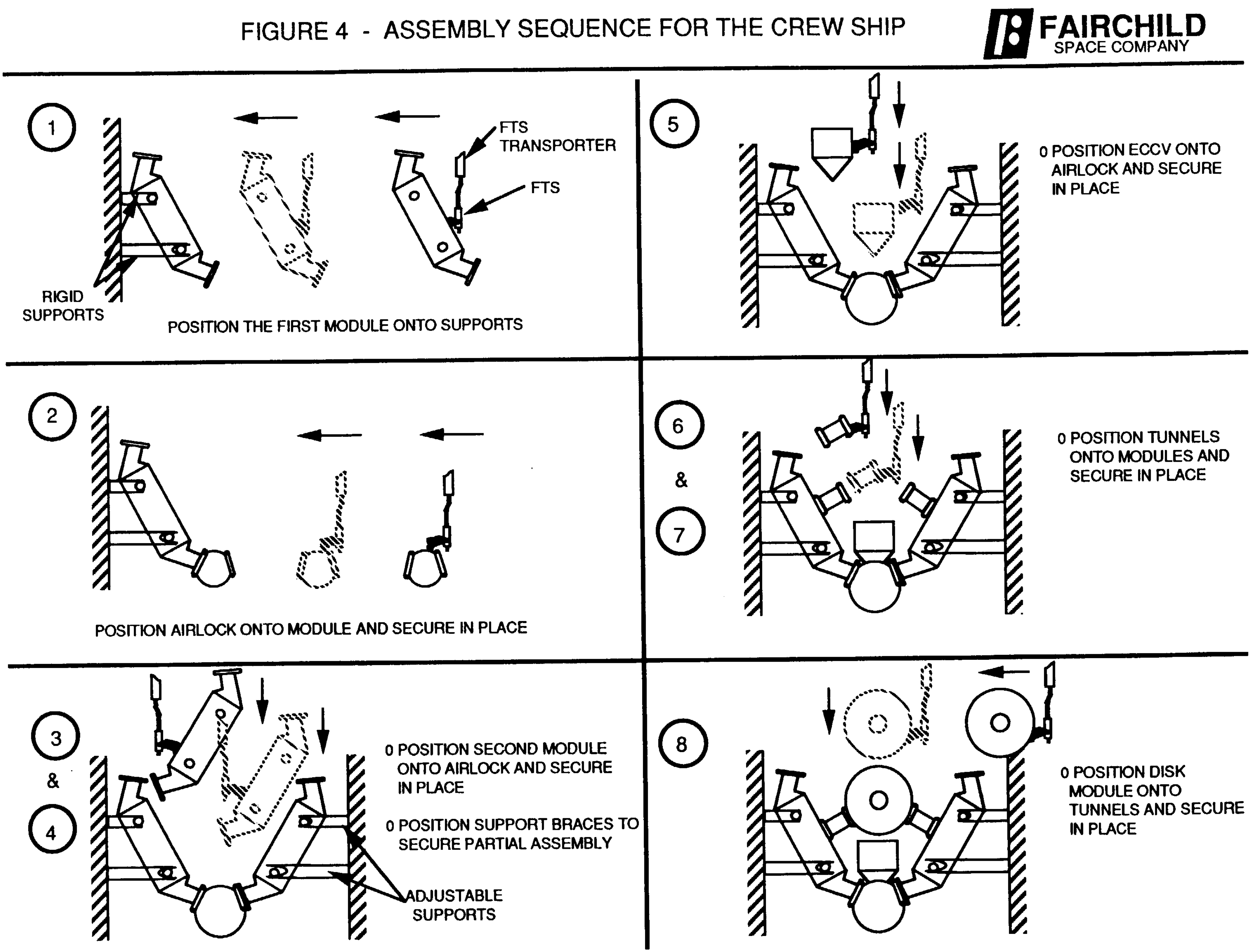

FIGURE 4 - ASSEMBLY SEQUENCE FOR THE CREW SHIP (CONTINUED)

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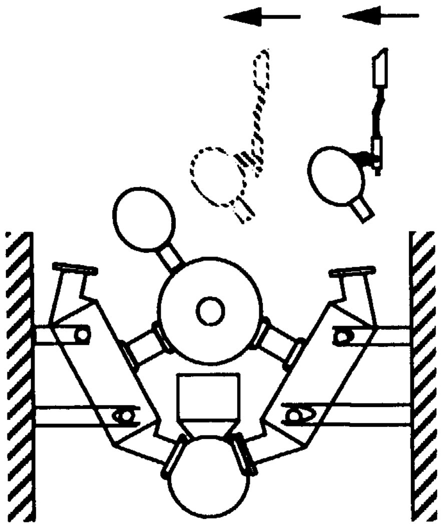
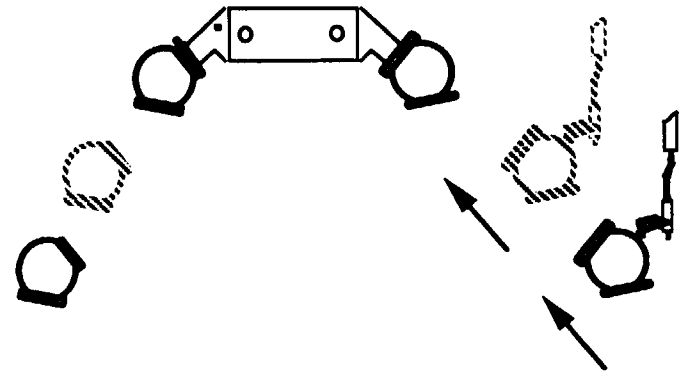


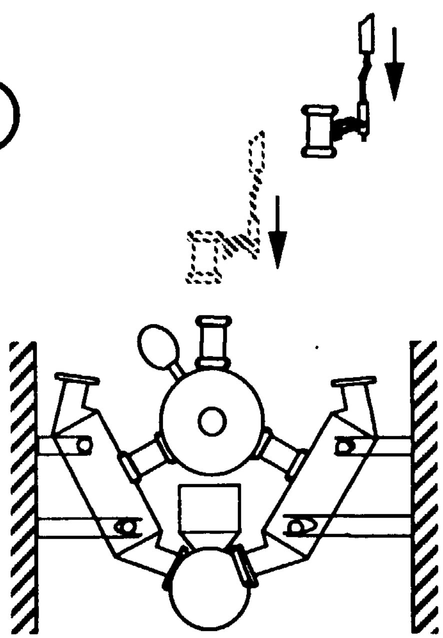
POSITION SOLAR OBSERVATORY ONTO DISK MODULE AND SECURE IN PLACE

11 & 12



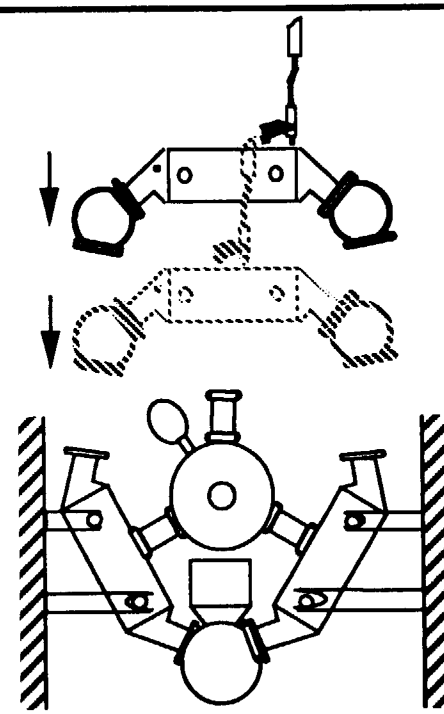
POSITION AIRLOCKS ONTO EACH END OF THE LAST MODULE AND SECURE IN PLACE

10



POSITION THIRD TUNNEL ONTO DISK MODULE AND SECURE IN PLACE

13



PLACE THE REMAINING MODULE INTO POSITION ON THE CREW SHIP AND SECURE IN PLACE

FIGURE 5 - ASSEMBLY METHOD FOR THE STRUCTURAL RINGS

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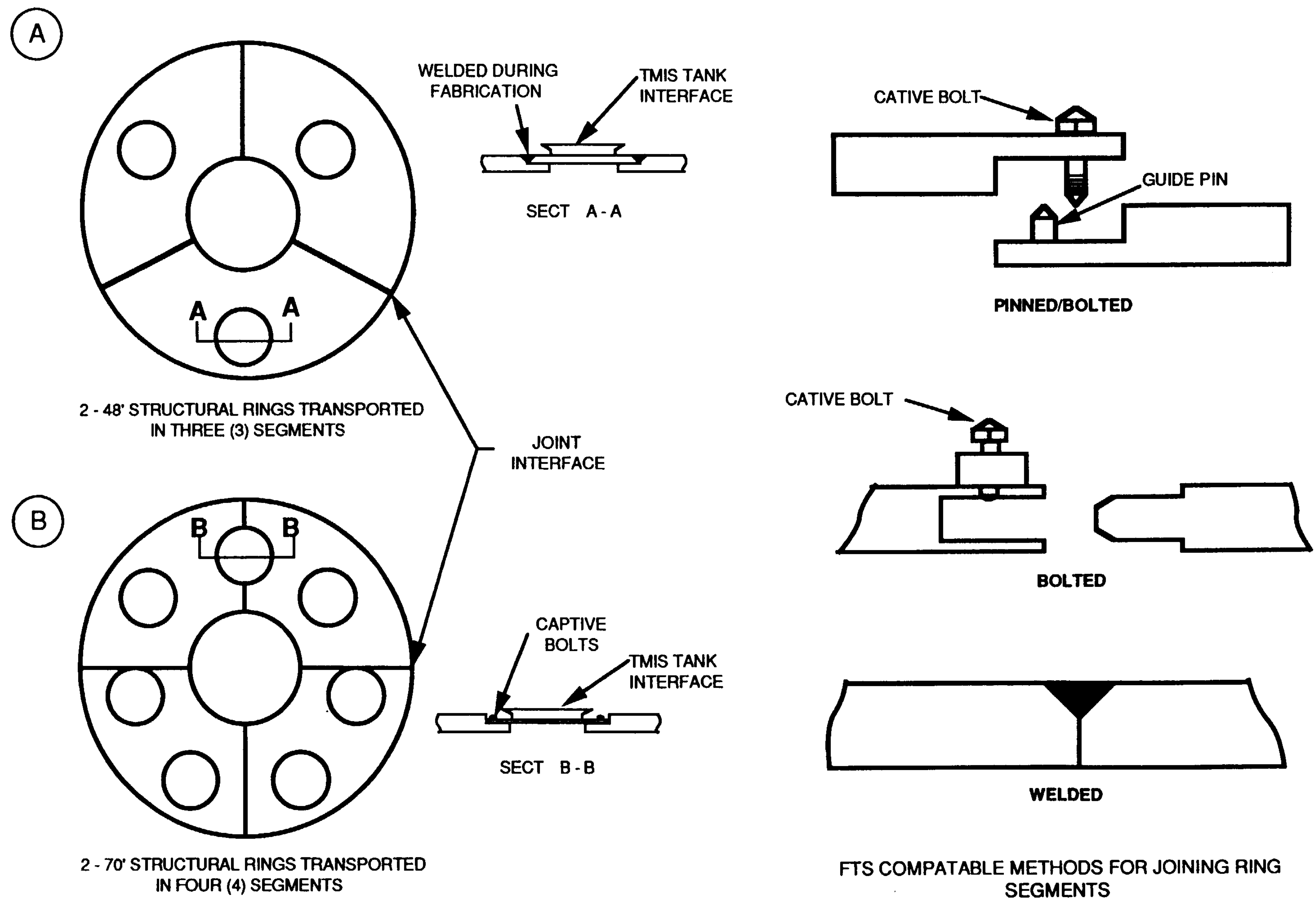
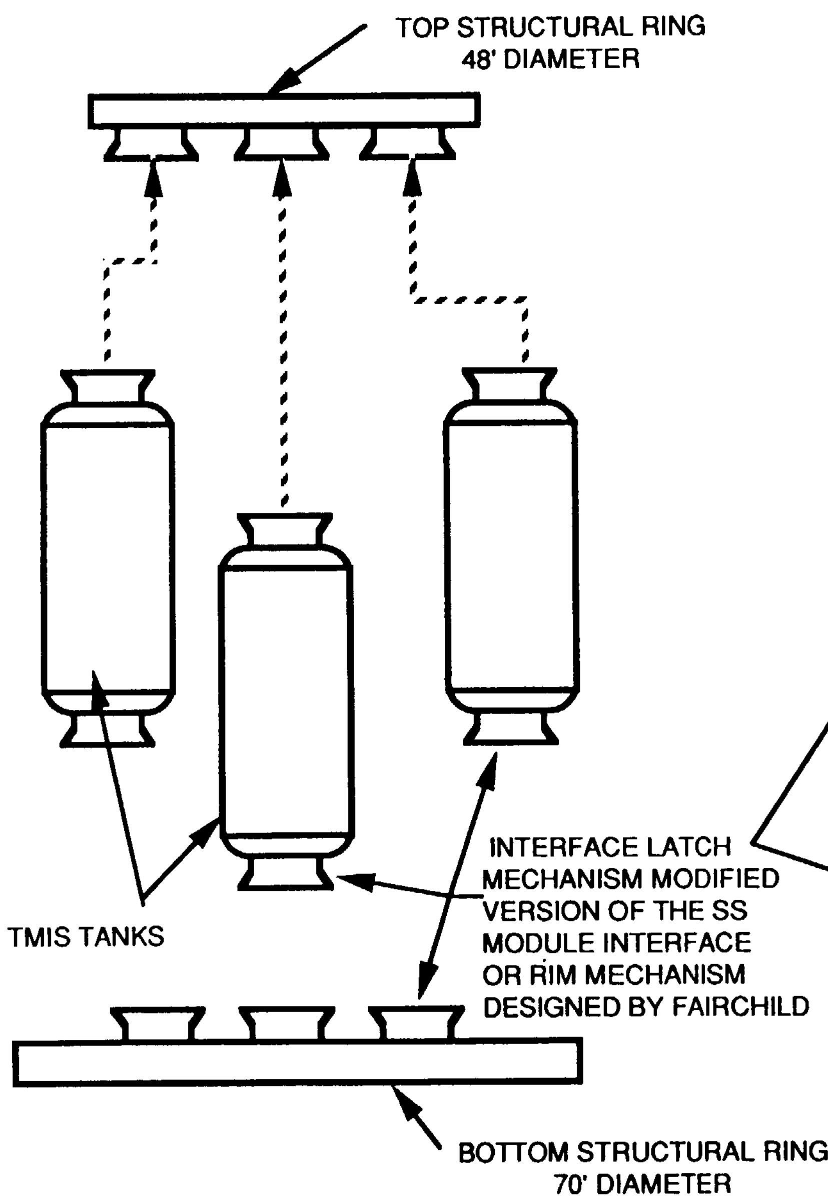
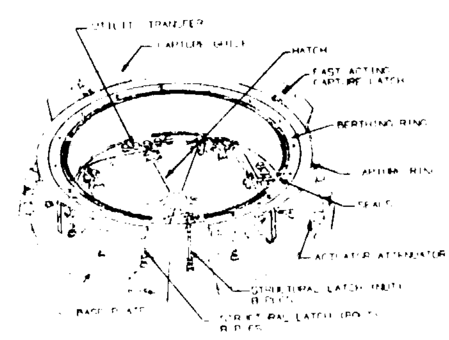


FIGURE 6 - ASSEMBLY METHOD FOR ALL TANKS

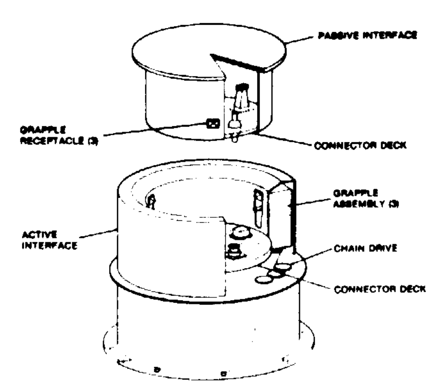
FAIRCHILD SPACE COMPANY





SS MODULE INTERFACE

- ACCESS HATCH IS NOT NEEDED FOR THIS APPLICATION
- STRUCTURAL LATCHES MUST BE ACCESSABLE FROM OUTSIDE OF THE TANKS
- DESIGN REQUIRES THE ACTUATION OF MULTIPLE LATCHING MECHANISMS FOR MATING/DEMATING OPERATIONS
- SIZE & WEIGHT CAN BE REDUCED FROM PRESENT CONCEPT
- MAY NEED TO BE MODIFIED TO ACCOMODATE STRUCTURAL AND THERMAL LOADS
- DESIGN UTILIZES OFF-THE-SHELF QUALIFIED CONNECTORS



RESUPPLY INTERFACE MECHANISM

- RIM IS DESIGNED TO BE COMPATABLE WITH ROBOTIC OPERATIONS
- PROVIDES THE STRUCTURAL INTEGRITY FOR THIS APPLICATION
- MATING/DEMATING IS ACCOMPLISHED BY OPERATING A SINGLE MECHANICAL ACTUATOR USING A POWER RATCHET END-EFFECTOR TOOL
- MAY NEED SOME DESIGN CHANGES TO ACCOMODATE TERMAL CONSIDERATIONS
- UTILIZES OFF-THE-SHELF QUALIFIED CONNECTERS

ON-ORBIT ASSEMBLY OF MARS VEHICLE - CONCLUSIONS

FAIRCHILD SPACE COMPANY

- FTS CAN BE USED, AS PRESENTLY CONFIGURED, TO PERFORM ON-ORBIT ASSEMBLY OPERATIONS FOR THE MARS VEHICLE
- A RIGID TRANSPORT VEHICLE, SUCH AS A TELESCOPING TUBE BRIDGE CRANE WITH X,Y,&Z POSITIONING CAPABILITIES IS REQUIRED FOR MANEUVERING FTS WITHIN THE HANGAR FOR ASSEMBLY OPERATIONS
- RIGID SUPPORTS ARE REQUIRED TO SECURE THE SPACECRAFT COMPONENTS IN POSITION DURING ASSEMBLY OPERATIONS
- THE SPACECRAFT COMPONENTS MUST BE MODULARIZED AND THE DESIGNS STANDARDIZED TO THE GREATEST EXTENT POSSIBLE
- THE SPACECRAFT COMPONENT INTERFACES NEED TO BE DESIGNED SO THAT THEY ARE COMPATABLE WITH TELEOPERATED ROBOTIC OPERATIONS
- ALL COMPONENTS WHICH NEED TO BE HANDLED BY FTS MUST BE PROVIDED WITH APPROPRIATE HANDLING FIXTURES
- A CCTV SYSTEM MUST BE PROVIDED IN THE HANGAR. THIS SYSTEM WILL NEED TO CONSIST OF AS A MINIMUM A CLOSE-UP CAMERA SYSTEM AND AN OVERVIEW SYSTEM
- A THOROUGH CHECKOUT OF ALL MATING INTERFACES MUST BE PERFORMED ON EARTH AS PART OF THE ACCEPTANCE TESTING
- IF WELDING IS SELECTED AS THE PRIMARY METHOD FOR FASTENING ALL JOINTS, THE JOINT WILL EITHER NEED TO BE DESIGNED TO PROVIDE THE NECESSARY GUIDANCE FOR THE WELD HEAD OR A SEAM TRACKER WILL NEED TO BE USED

RENDEVOUS, DOCKING, AND FLUID TRANSFER OPERATIONS INVOLVING MARS VEHICLE FUEL TANKS

MARS VEHICLE FUEL TANKS RENDEZVOUS AND DOCKING

ASSUMPTION:

- FUEL TANKS ARE PLACED IN THE SAME ORBIT AS STS OR SPACE STATION (SS)
  - MINIMIZE OMV FUEL REQUIREMENT TO RETRIEVE FUEL TANKS
  - ALLOWS EASY RENDEZVOUS WITH TANK STORAGE

MARS VEHICLE FUEL TANKS RENDEZVOUS AND DOCKING

APPROACH:

- RENDEZVOUS AND DOCKING WITH THE MARS VEHICLE FUEL TANKS USING THE FTS ATTACHED TO THE OMV
- USE STANDARD OMV RENDEZVOUS AND DOCKING PROCEDURE
- FTS GRAPPLE PORTS DESIGNED INTO THE FUEL TANK HOUSING
- FTS USES SPECIAL END EFFECTOR TO GRAPPLE AND PULL THE TANK INTO THE DOCKING PORT

MARS VEHICLE FUEL TANKS RENDEZVOUS AND DOCKING

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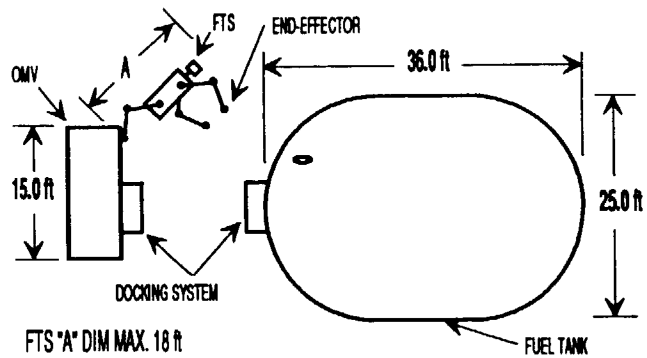
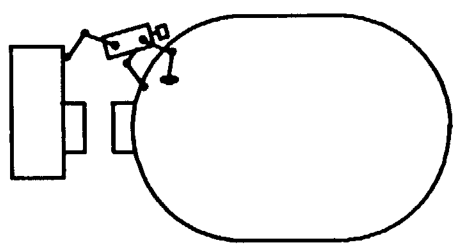
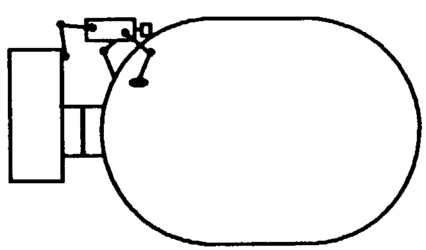


RENDEZVOUS



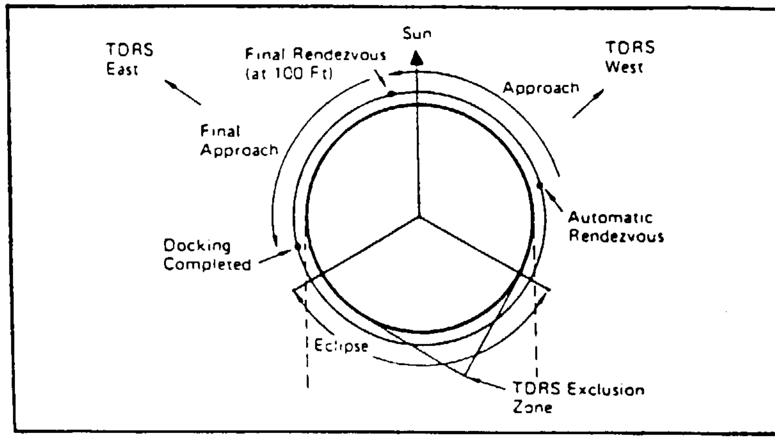
FTS GRAPPLED FUEL TANK



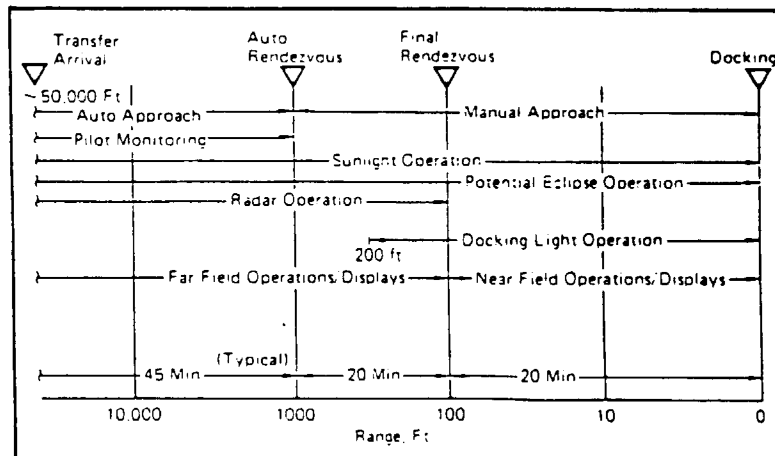
FUEL TANK DOCKED WITH THE OMV

WEIGHTS:

OMV= 20,873 LBS (FULL)
FTS < 1,500 LBS
TANK= 21,000 LBS



ORBIT GEOMETRY
FOR APPROACH AND DOCKING



OPERATING RANGES
FOR APPROACH AND DOCKING

MARS VEHICLE FUEL TANKS RENDEZVOUS AND DOCKING

ADVANTAGES:

WHY USE THE OMV AND FTS FOR RENDEZVOUS AND DOCKING OF THE MARS VEHICLE FUEL TANKS:

- REMOTE DEXTEROUS OPERATIONS CAN BE PERFORMED WITH OMV/FTS
- NON-SCHEDULED SERVICING OF THE TANKS CAN BE FACILITATED WITH OMV/FTS
- SAME FTS CONTROL METHODOLOGY AS SS
- OMV AND FTS WILL BE AVAILABLE
- MONEY AND TIME REQUIRED TO DESIIGN A SPECIALIZED RENDEZVOUS AND DOCKING SYSTEM WOULD NOT BE NECESSARY
- THE FTS WILL PROVIDE AN INCREASE IN THE DOCKING CONTROL

MARS VEHICLE FUEL TANKS RENDEZVOUS AND DOCKING

DISADVANTAGES:

- FTS ARM LINKS AND JOINTS MAY REQUIRE STIFFENING
- SPECIAL UTILITY CONNECTOR BETWEEN THE OMV AND FTS WOULD BE REQUIRED
- EXTENDED FTS BATTERY LIFE WOULD BE REQUIRED
- SPECIAL GRAPPLING END-EFFECTOR WOULD BE REQUIRED

SUMMARY

MARS VEHICLE FUEL TANK RENDEZVOUS AND DOCKING

FTS CAN BE USED FOR MARS VEHICLE FUEL TANK RENDEZVOUS AND DOCKING WITH THE FOLLOWING CONCERNS:

- THE FTS ARM LINKS AND JOINTS MUST BE STIFFNED TO ACCOMPLISH THE FUEL TANK DOCKING WITHIN THE FTS STRUCTUAL MARGIN OF SAFETY.
- SOME OF FTS SYSTEMS THAT ARE SENSITIVE TO REMOTE AND EXTENDED OPERATION MUST BE UPDATED.
- OMV ATITUDE CONTROL SYSTEM MUST BE CAPABLE OF ACCOMMODATING THE FORCES PRODUCED IN THE GRAPPLING AND FUEL TANK DOCKING.
- A TOOL KIT SHOULD BE SUPPLIED TO FACILITATE FTS DEXTEROUS SERVICING OPERATION.
- THE OMV MUST SUPPLY A SPECIAL FOOT RETRAINT FOR THE FTS.
- THE FTS MOUNTING CONFIGURATION MUST ACCOMMODATE THE OMV ATITUDE CONTROL SYSTEM.

STRIP MINING ON LUNAR/MARTIAN SURFACE

WHAT IS THE PURPOSE OF MINING?

- GEOLOGICAL ASSAY OF THE LUNAR OR MARTIAN SUFACE
- OBTAINING SOIL AND ORE TO PROCESS OXYGEN
- PRODUCE SAND BAGS FOR SHIELDING THE SHELTER
- EXCAVATION FOR INSTALLING PRESSURIZED HABITATION MODULES

WHY STRIP MINING?

- AUTONOMOUS FEASIBLE
- ECONOMICAL PRACTICALITY
- BEST MINING METHOD FOR FLAT SURFACE OPERATION
- LIMITATION IN THE TYPE OF EQUIPMENT REQUIRED
- EASIEST TYPE OF MINING TO PERFORM

"BASELINE SCENARIO"

PROCEDURE TO ESTABLISH MINING SYSTEM

- **MINING PLANNING**
  - MINING EXPLORATION, REQUIRED TO DETERMINE MINERAL RICHNESS OF THE PROPOSED MINING SITE
    - GEOLOGIC INFORMATION STORAGE
    - DATA REDUCTION/ANALYSIS OF CORE SAMPLES
    - RESERVE ESTIMATION AND ANALYSIS
    - PROJECT EVALUATION
  - ESTABLISH MINING SITE

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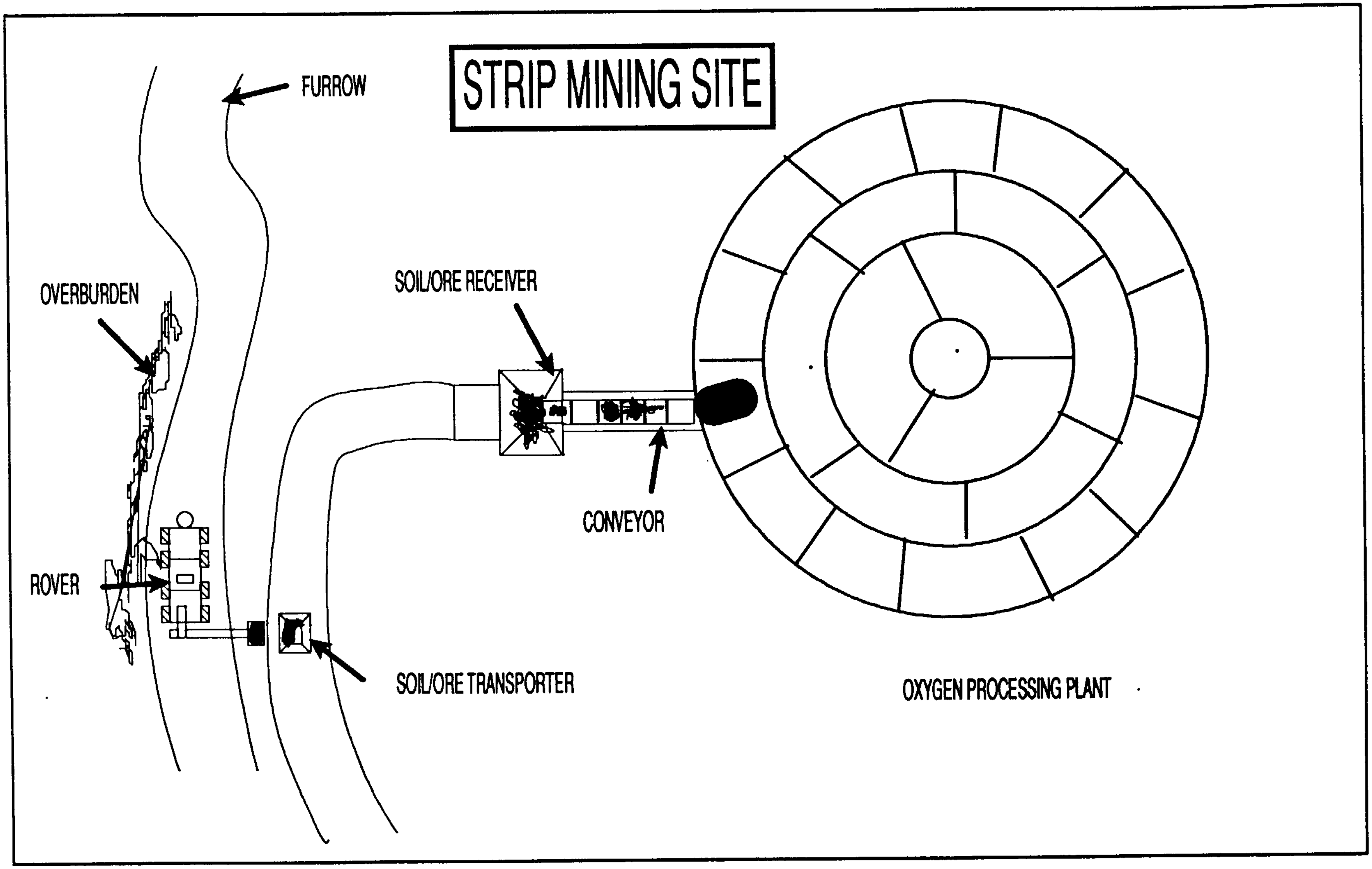
"BASELINE SCENARIO"



"BASELINE SCENARIO"

PROCEDURE TO ESTABLISH MINING SYSTEM CONT'D

- **MINING PROCESS**
  - REMOVAL OF OVERBURDEN (SOIL)
  - BRAKE-UP OF THE ORE
  - REMOVAL OF THE SOIL AND ORE FROM THE FURROW
  - TRANSPORTATION OF THE SOIL/ORE TO THE PROCESSOR PLANT
  - PROCESS OF THE SOIL/ORE
- **MAINTENANCE AND INVENTORY CONTROL**

"BASELINE SCENARIO"

PROCEDURE TO ESTABLISH MINING SYSTEM CONT'D

- **EQUIPMENT SETUP**
  - SHOVEL - TO REMOVE SOIL AND ORE SAMPLES
  - DRILL - FOR CORE SAMPLING
  - HAMMER - TO BRAKE-UP ORE
  - SOIL/ORE STORAGE CONTAINMENT
  - SOIL/ORE TRANSPORTOR
    - WAGON
    - CONVEYOR
  - SOIL/ORE PROCESSOR

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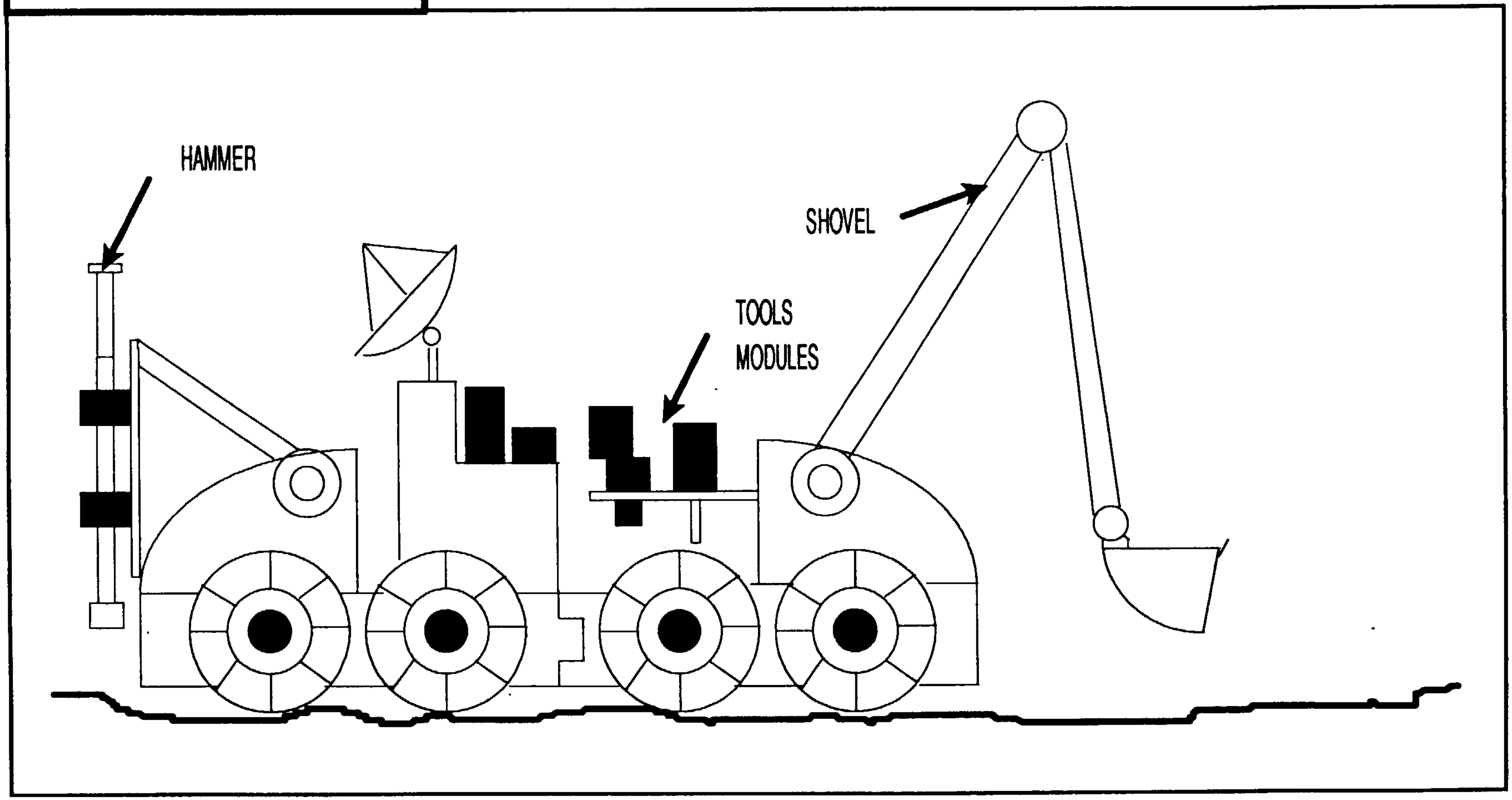
"BASELINE SCENARIO"

ROVER



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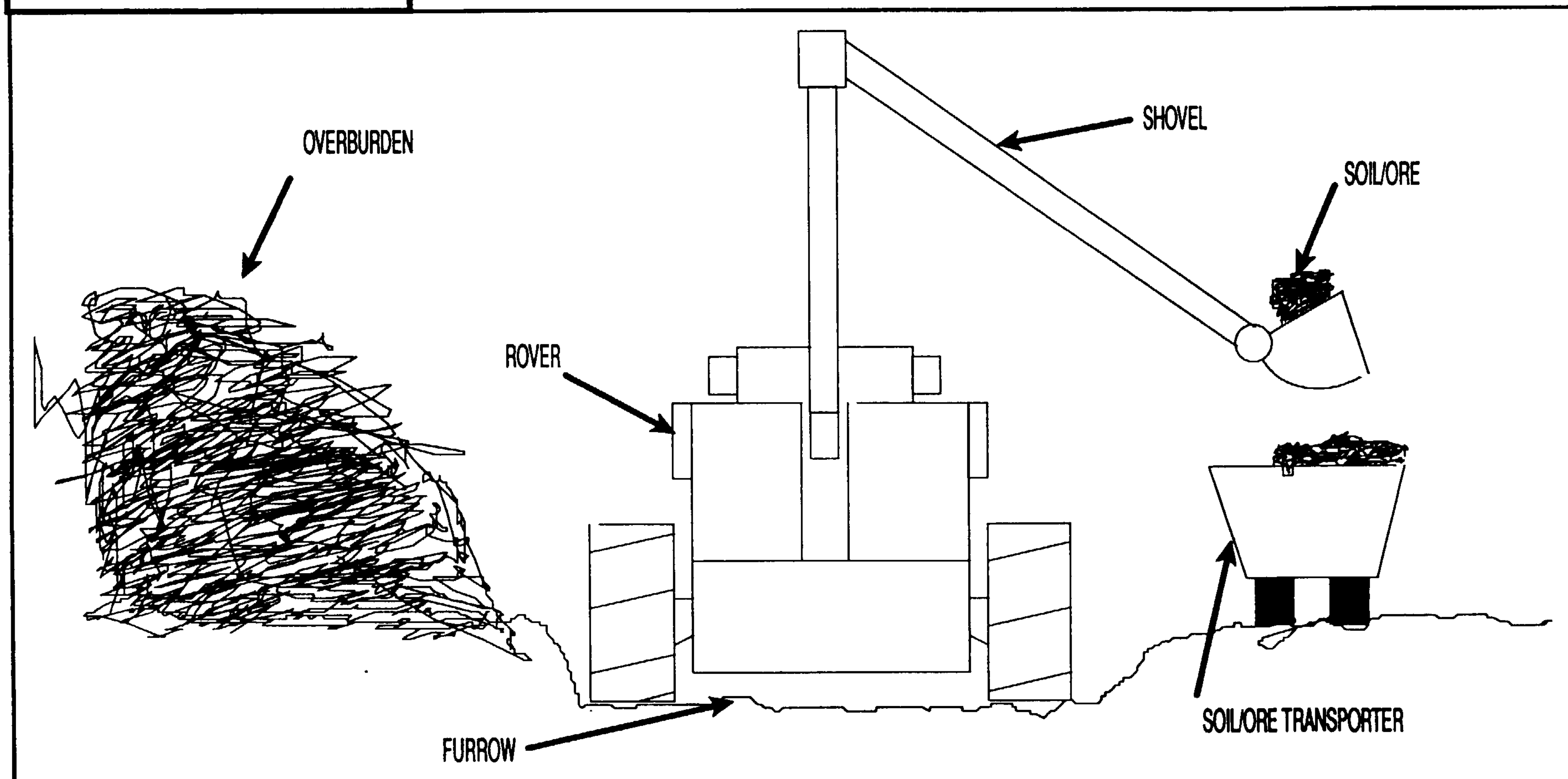
"BASELINE SCENARIO"

STRIP MINING



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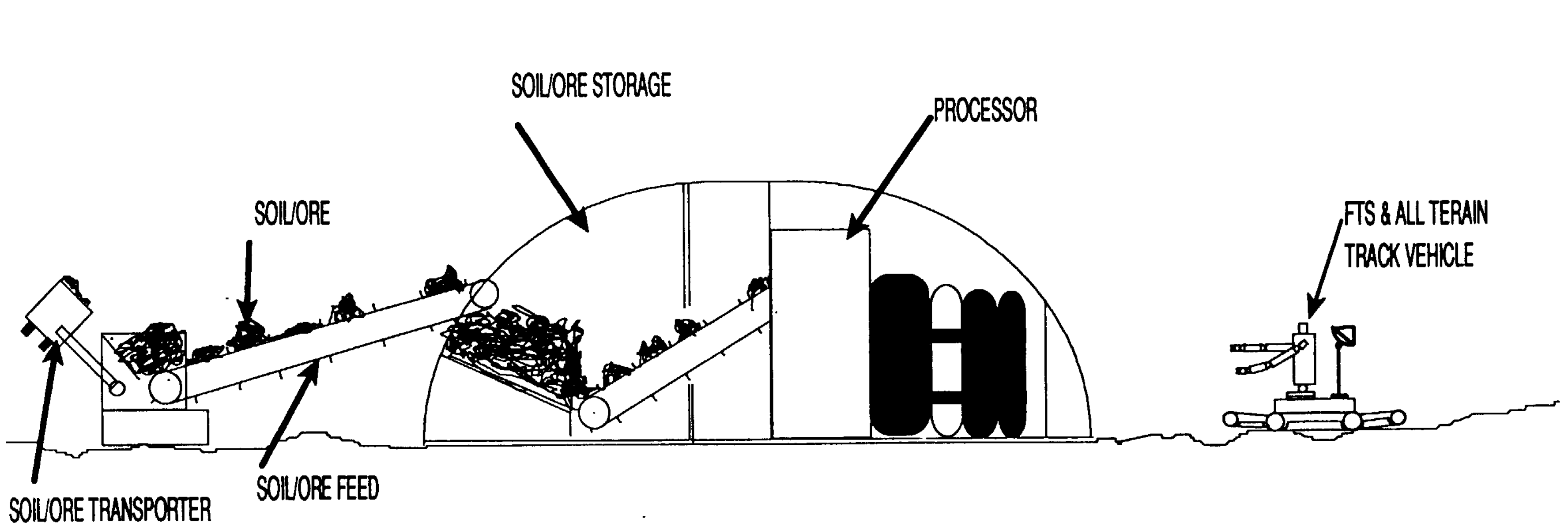
"BASELINE SCENARIO"

OXYGEN PROCESSING PLANT



CONCEPTS OF MOBILE TRANSPORT SYSTEMS FOR FTS

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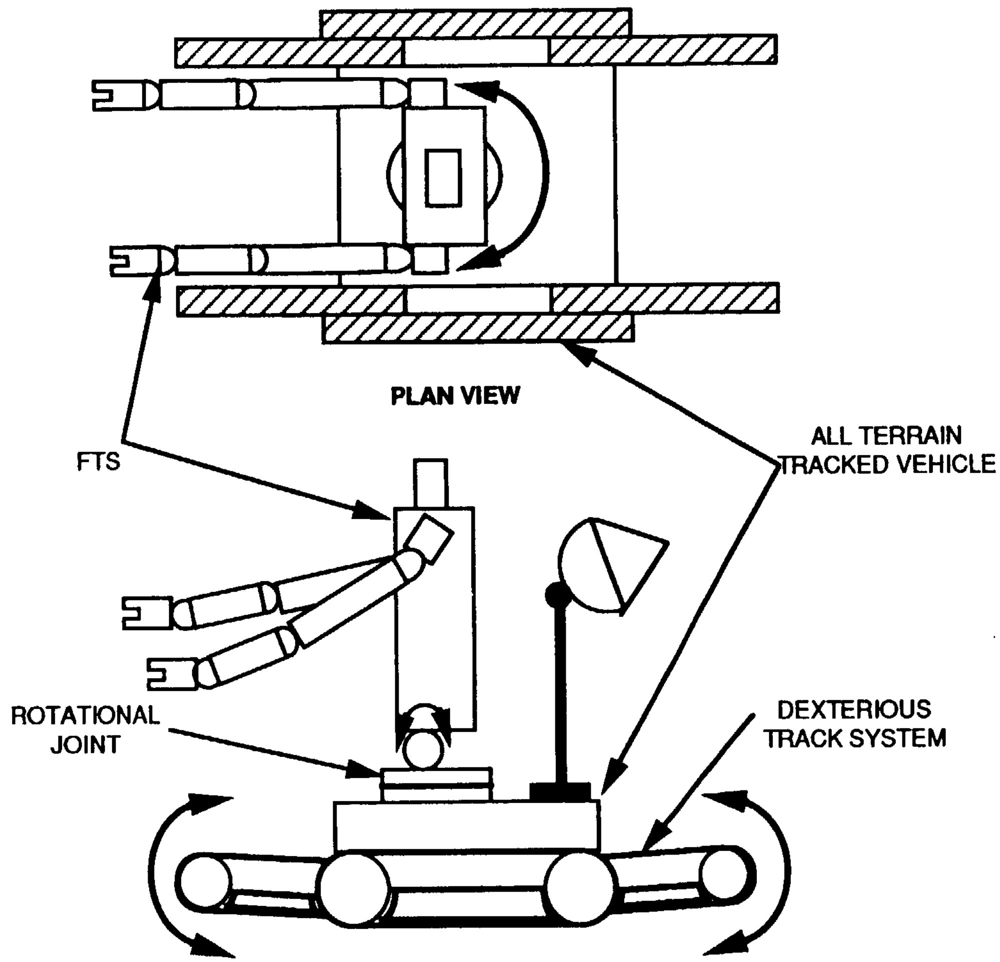
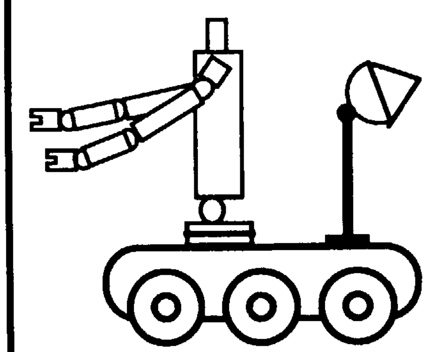


ALL TERRAIN TRACK VEHICLE (ATTV)

NOTE: Vehicle concept based on ground robotic technology



ALTERNATE CONCEPT
ALL TERRAIN WHEEL
VEHICLE (ATWV)

COMPARISION OF VEHICLES

ATTV	ATWV
- VERY STABLE VEHICLE - TRACKS ARE EXCELLENT WAY OF MANEUVERING IN ROUGH TARRAIN - ABLE TO CRAWL OVER LARGE OBSTACLES - HAS A LARGE FOOT PRINT TO MANEUVER IN LOOSE SOIL - TRACKS WILL BE DIFFICULT TO REPLACE IF NEEDED - DEXTERIOUS TRACK SYSTEM ENABLES MANEUVERING IN TIGHT AREAS	- WHEELS ARE EASY TO MAINTAIN - SOFT TIRES ARE A GOOD WAY OF MANEUVERING IN ROUGH TERRAIN - NOT AS STABLE AS TRACKED VEHICLE - NOT CAPABLE OF CRAWLING OVER LARGE OBSTACLES - NOT AS MANEUVERABLE AS TRACKED VEHICLE
- TRACKED VEHICLE IS PERFERRED CONCEPT - WALKERS SHOULD NOT BE CONSIDERED FOR THIS APPLICATION	

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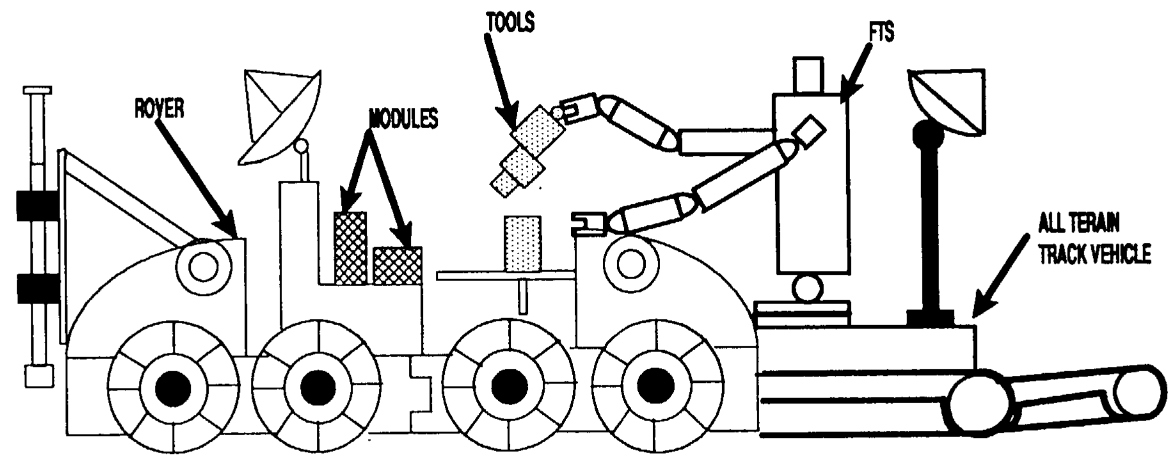
FTS MINING TASK



FTS EXCHANGING TOOLS ON THE ALL PURPOSE ROVER

FTS AND ALL TERAIN TRACK VEHICLE

- FTS IS MOUNTED ON AN ALL TERAIN VEHICLE (ATTV)
- ROTATIONAL BASE DRIVE CAN BE:
  + A LINKAGE
  + SWIVAL JOINT
- SELF SERVICING
  + FTS IS INDEPENDENT OF THE ATTV
  + FTS CAN EXCHANGE ATTV MODULES

FTS MINING EQUIPMENT SERVICING

- ROVER SERVICED BY EXCHANGING MODULES
  + BATTERY
  + TOOLS
  + ROVER WHEELS
  + CORE BOX
  + ETC.
- SERVICING OF THE SOIL/ORE TRANSPORTER
- PROCESSING PLANT SERVICING

FTS MINING SUMMARY

- A MODIFIED FTS MIGHT SERVE AS CARETAKER OF THE MINING SITE.
- IN ORDER TO PERFORM SERVICING VIA FTS ALL MINING EQUIPMENT SHOULD BE MODULIZED.
- MINING EQUIPMENT MODULES AND FTS SHOULD BE DESIGNED TO BE COMPATIBLE IN THE FOLLOWING AREAS
  - WEIGHT
  - SIZE
  - INTERFACE
  - SERVICING OPERATIONS
- ALL MINING EQUIPMENT SHOULD BE DESIGNED WITH THEIR MODULES ACCESSIBLE TO FTS.
- MOBLITY OF THE FTS WITHIN THE MINING SITE IS SIGNIFICANT TO SERVICE THE MINING EQUIPMENT. THE FTS WILL REQUIE A MOBILE TRANSPORTER SUCH AS AN ALL TERAIN TRACK VEHICLE (ATTV).
- FTS MUST BE CAPABLE OF SERVICING THE ATTV AND SELF MAINTANCE.
- OTHER MINING VEHICLES SUCH AS THE ROVER, DO NOT NEED ALL TERRAIN CAPABILITY BECAUSE THESE VEHICLES ARE NOT EXPECTED TO BE OPERARTING IN ROUGH TERAIN.
- THE SUCCESS OF USING FTS AS THE CARETAKER OF THE MINING SITE DEPENDS ON:
  - SITE SIZE
  - HAZARDOUS TERAIN
  - COMPLEXITY OF OPERATING AND SERVICING THE MINING EQUIPMENT.
- THE FTS ARM LINKS AND JOINTS MUST BE STIFFNED TO PERFORM AUTONOMOUS SERVICING ON THE MARTIAN AND LUNAR SURFACE.

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CONSTRUCTION OF THE MARS SHELTER

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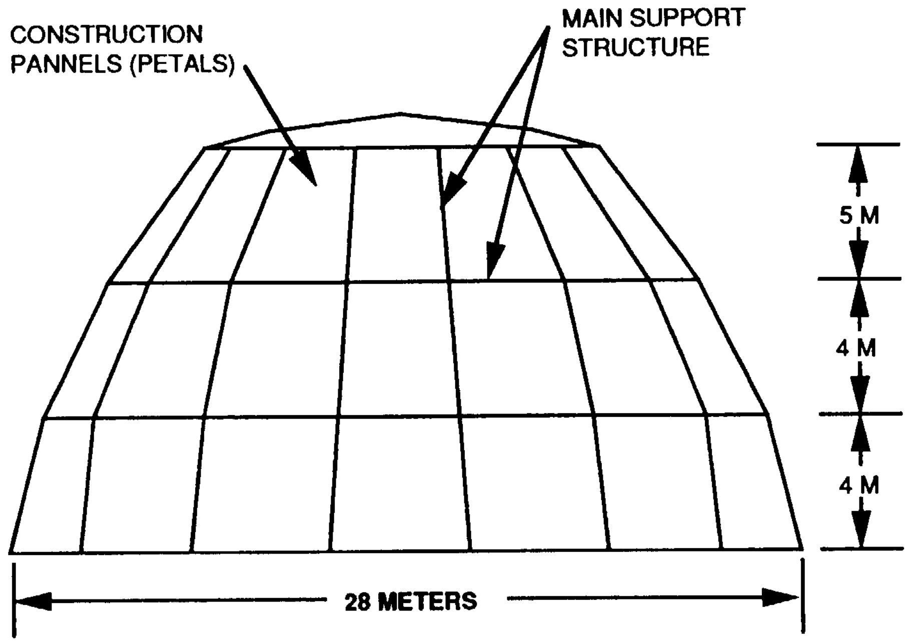

GIVEN:

0 THE BUILDING IS A THREE (3) STORY STRUCTURE
0 THE BUILDING IS NOT PRESSURIZED
0 THE BUILDING DIMENSIONS ARE AS DEFINED ABOVE

ASSUMPTIONS (REFER TO FIGURES 1 AND 2)

0 ALL ASSEMBLY TASKS WILL BE PERFORMED IN EITHER THE TELEOPERATED OR SUPERVISED AUTONOMOUS MODE OF OPERATION
0 THE MAIN SUPPORT STRUCTURE CONSISTS OF A TRUSS TYPE STRUCTURE.
0 THE BUILDING COMPONENTS ARE MODULARIZED AND PROVIDED WITH THE PROPER INTERFACES FOR ROBOTIC ASSEMBLY
0 THE BUILDING CONSISTS OF LIGHT WEIGHT STRUCTURAL SKELTON ON WHICH LIGHT WEIGHT RIGID PANNELS ARE MOUNTED
0 THE BUILDING PANELS ARE DESIGNED TO INTERLOCK WITH ONE ANOTHER
0 THE SPAN BETWEEN STRUCTURAL MEMBERS IS 6.8 METERS
0 THE FLOORING CONSISTS OF LIGHT WEIGHT PANELS WHICH INTERLOCK WITH ONE ANOTHER
0 A METHOD OF ESTABLISHING THE INITIAL POSITION OF THE SUPPORT COLUMNS IS PROVIDED. (i.e. TEMPLATE, etc.)
0 ALL PARTS ARE STAGED ON THE MARTIAN SURFACE
0 THE BUILDING IS NOT DESIGNED TO ACCOMODATE LARGE FLOORING LOADS (FLOORING LOADS ARE EQUIVALENT TO THOSE SPECIFIED FOR STANDARD HOMES ON EARTH)
0 ALL UTILITIES ARE DESIGNED AS PART OF THE TRUSS STRUCTURE AND ONLY NEED TO BE CONNECTED THROUGH A QUICK CONNECT COUPLING SYSTEM WHICH IS COMPATABLE WITH FTS
0 CREW LIVING QUARTERS WILL CONSIST OF SEPERATE PRESSURIZED CYLINDERS SIMULAR TO SS MODULES

REQUIREMENTS

0 THE FTS DESIGN MUST BE UPDATED TO OPERATE IN THE GRAVITY FIELD ON MARS
0 FTS MUST BE PROVIDED WITH A MOBILE TRANSPORT SYSTEM (FIGURE 3
0 HEAVY LIFT EQUIPMENT WILL BE REQUIRED FOR SOME OPERATIONS
- LIFT THE CENTER SUPPORT IN TO PLACE
- LIFT FTS UP TO THE DIFFERENT LEVELS TO COMPLETE ASSEMBLY
- LIFT CREW LIVING QUARTERS INTO POSITION
0 FTS MUST BE PROVIDED WITH PROTECTIVE COVERS OVER ALL JOINTS TO REDUCE THE CHANCE OF CONTAIMATION FROM THE ENVIRONMENT.
0 FTS MUST BE PROVIDED WITH A RECHARGEABLE PORTABLE POWER SYSTEM

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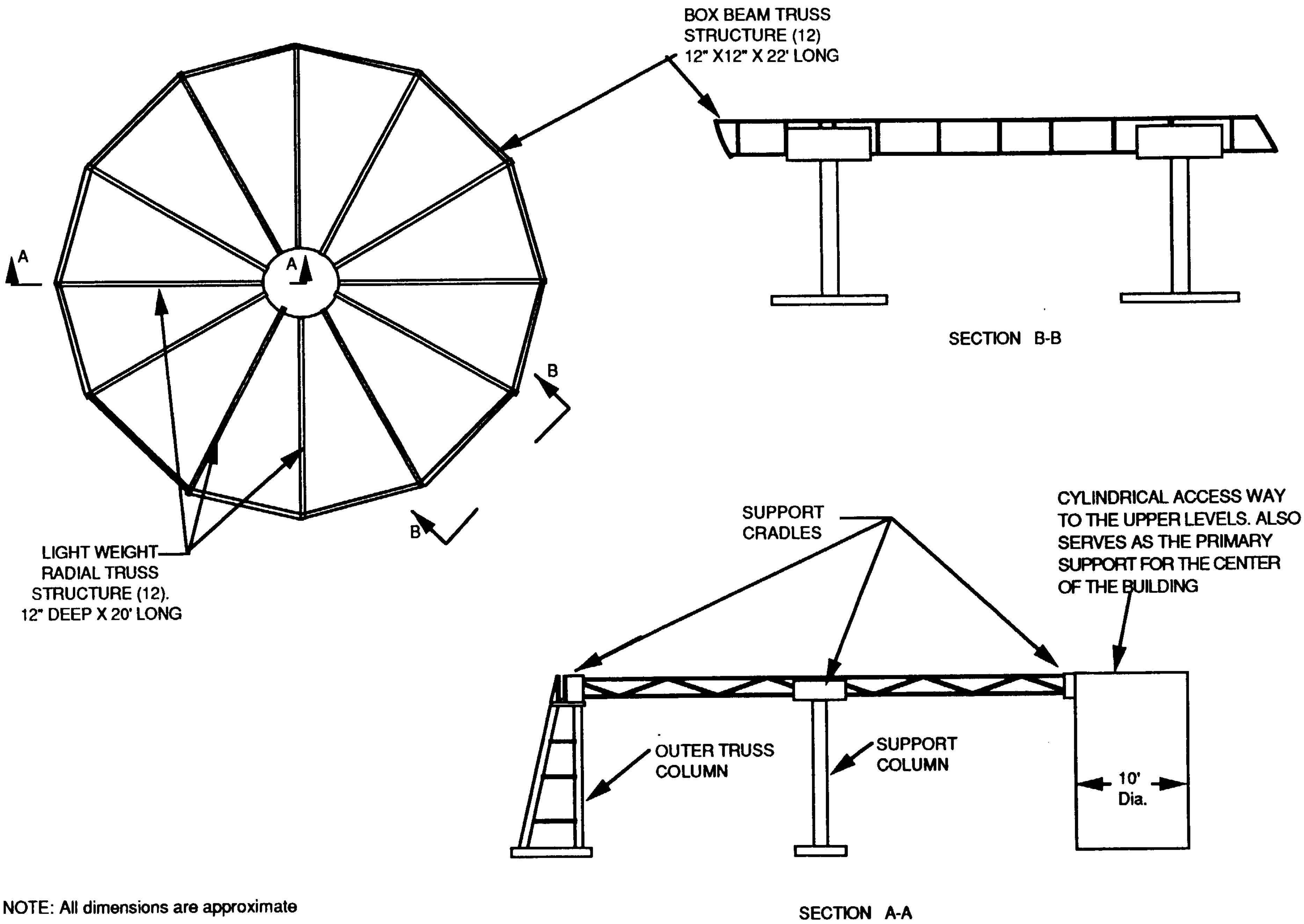
FIGURE 1 - PLAN VIEW OF THE MARS SHELTER



NOTE: All dimensions are approximate

FIGURE 2 - ELEVATION VIEW OF THE MARS SHELTER

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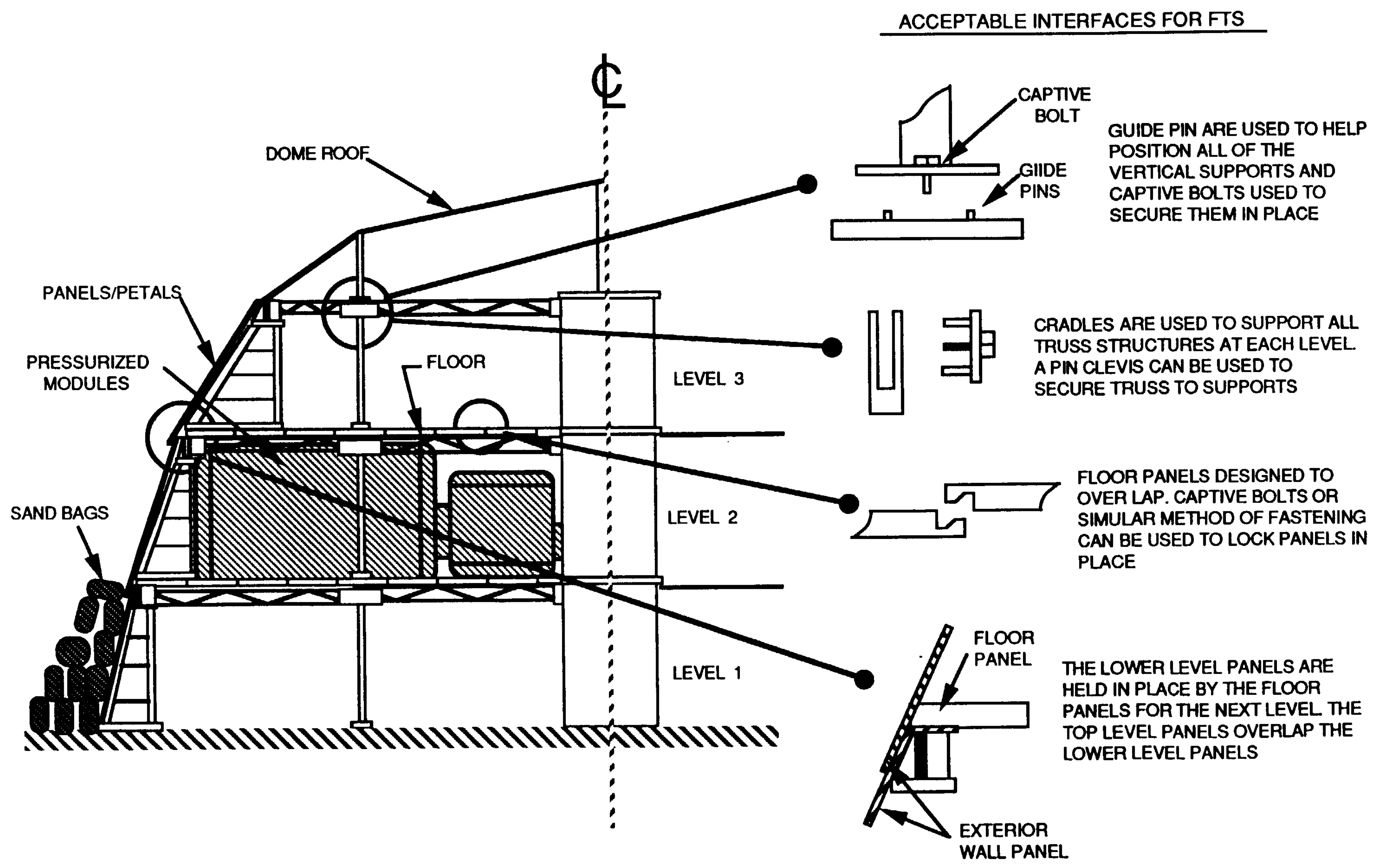
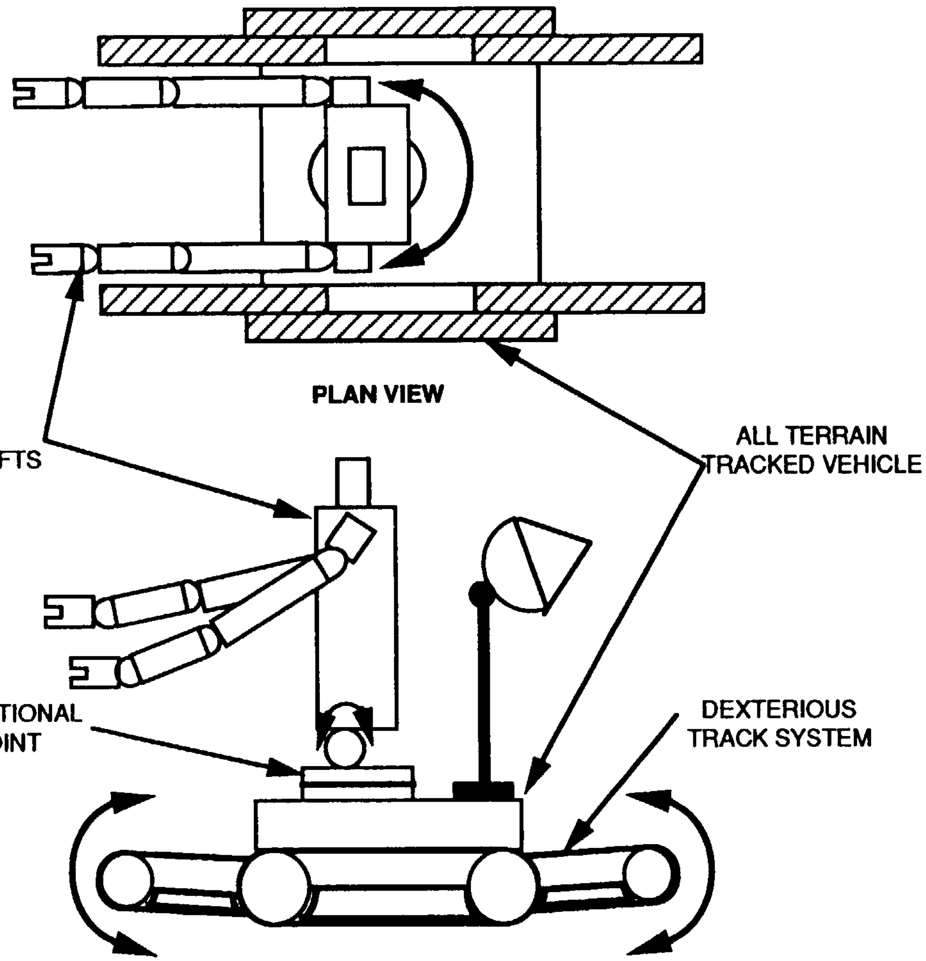
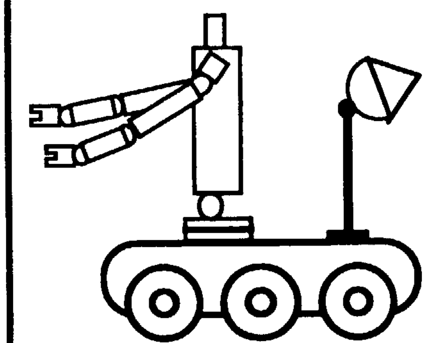


FIGURE 3 - CONCEPTS OF MOBILE TRANSPORT SYSTEMS FOR FTS



ALL TERRAIN TRACK VEHICLE (ATTV)

NOTE: Vehicle concept based on ground robotic technology



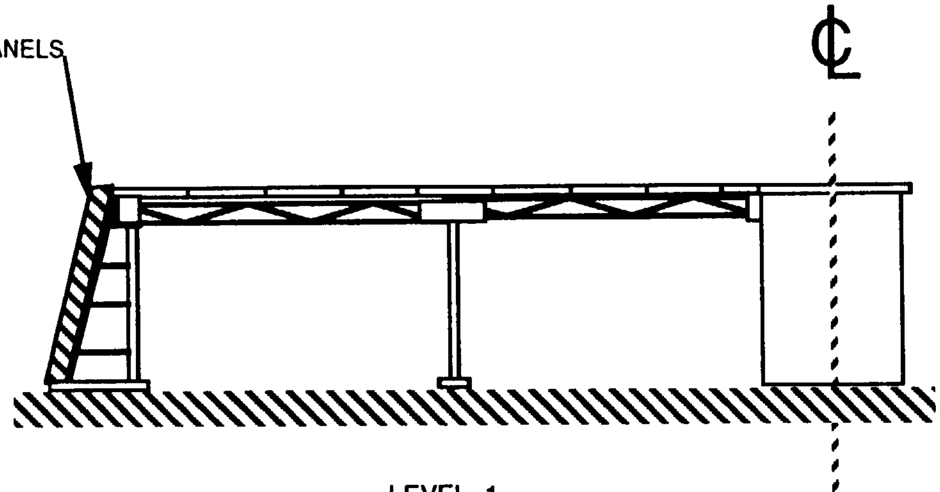
ALTERNATE CONCEPT
ALL TERRAIN WHEEL VEHICLE (ATWV)

COMPARISION OF VEHICLES

ATTV	ATWV
- VERY STABLE VEHICLE - TRACKS ARE EXCELLENT WAY OF MANEUVERING IN ROUGH TARRAIN - ABLE TO CRAWL OVER LARGE OBSTACLES - HAS A LARGE FOOT PRINT TO MANEUVER IN LOOSE SOIL - TRACKS WILL BE DIFFICULT TO REPLACE IF NEEDED - DEXTERIOUS TRACK SYSTEM ENABLES MANEUVERING IN TIGHT AREAS	- WHEELS ARE EASY TO MAINTAIN - SOFT TIRES ARE A GOOD WAY OF MANEUVERING IN ROUGH TERRAIN - NOT AS STABLE AS TRACKED VEHICLE - NOT CAPABLE OF CRAWLING OVER LARGE OBSTACLES - NOT AS MANEUVERABLE AS TRACKED VEHICLE
- TRACKED VEHICLE IS PERFERRED CONCEPT - WALKERS SHOULD NOT BE CONSIDERED FOR THIS APPLICATION	

FIGURE 4 - ASSEMBLY SEQUENCE FOR THE FIRST LEVEL OF THE SHELTER

FAIRCHILD SPACE COMPANY



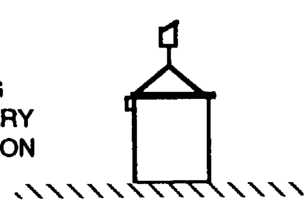
LEVEL 1

NOTE: ALL CONSTRUCTION JOINTS PROVIDED WITH GUIDE PINS AND CAPTIVE BOLTS FOR SECURING STRUCTURE. THIS METHOD OF ASSEMBLY WILL BE COMPATIBLE WITH FTS

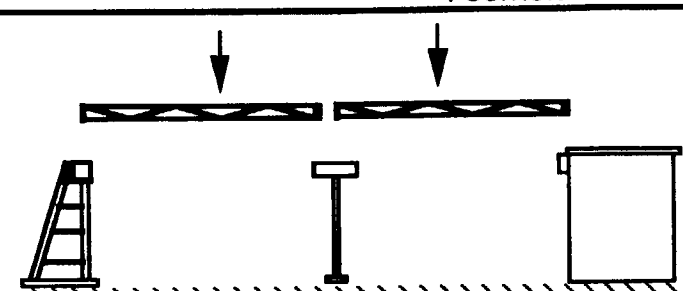
ASSEMBLY SEQUENCE

1. PREPARE TERRAIN WITH HEAVY MINING EQUIPMENT

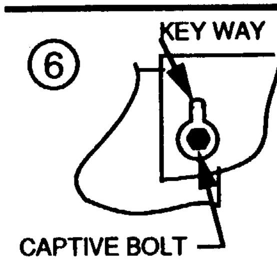
2. USING HEAVY LIFT MINING EQUIPMENT SET THE PRIMARY CENTER SUPPORT IN POSITION



3.  USING FTS/ATTV SET THE SUPPORT COLUMN AND OUTER TRUSS COLUMN IN POSITION

4.  ONCE THE SUPPORT COLUMNS AND CENTER SUPPORT ARE SETUP FTS/ATTV IS USED TO LIFT AND LOWER THE TRUSSES INTO THE CRADLES

5. STEPS 3 AND 4 ARE REPEATED FOR EACH OF THE TWELVE (12) RADIAL TRUSS STRUCTURES. THE BOX BEAM TRUSS WILL BE SET IN PLACE BY FTS/ATTV IN SEQUENCE WITH THE RADIAL TRUSSES

6. 

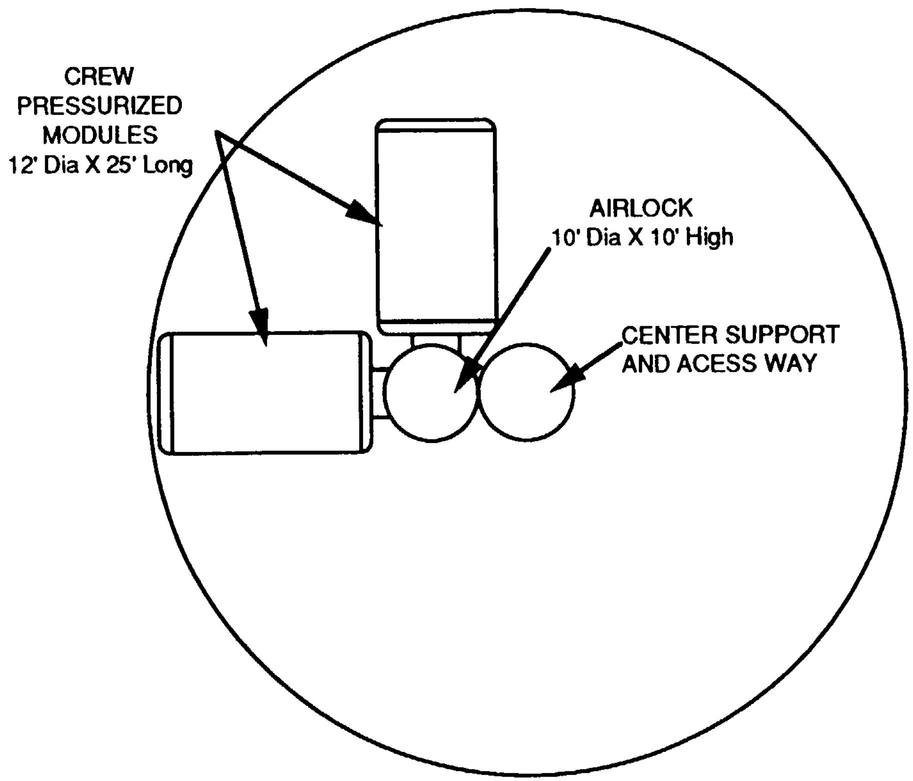
ONCE ALL OF THE MAIN STRUCTURE IS ASSEMBLED INSTALL OUTSIDE PANELS , USING FTS/ATTV, BY POSITIONING PANEL OVER PREVIOULY INSTALLED PANEL SO THAT KEY WAY ALIGNS WITH CAPTIVE BOLT. DROP PANEL DOWN INTO POSITION AND SECURE BOLT

7. USING FTS/ATTV SET THE FLOOR INTO POSITION ON THE TRUSS STRUCTURES. ONCE IN POSITION SECURE IN PLACE.

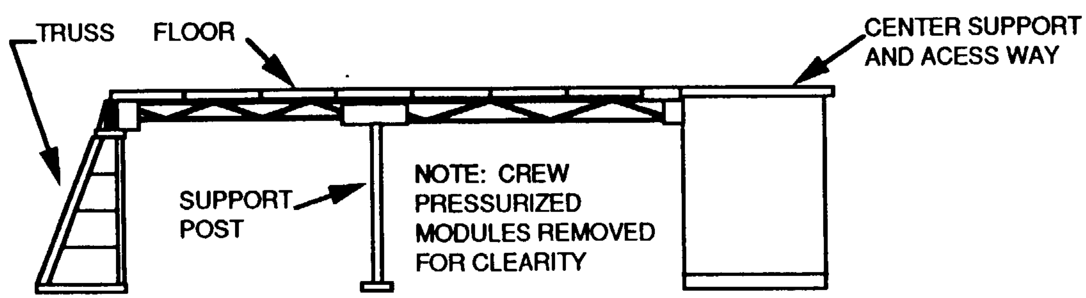
8. USING FTS/ATTV POSITION SAND BAGS ALONG OUTER WALL OF THE FIRST LEVEL OF THE STRUCTURE PRIOR TO CONTINUING TO THE NEXT LEVEL. SAND BAGS WILL BE STACKED TO FORM A 3 METER THICK PROTECTIVE LAYER

FIGURE 5 - ASSEMBLY SEQUENCE FOR THE SECOND LEVEL OF THE SHELTER

FAIRCHILD SPACE COMPANY



PLAN VIEW



ELEVATION

ASSEMBLY SEQUENCE

- THE SECOND LEVEL SUPPORT STRUCTURE, FLOOR, OUTSIDE PANELS, AND VERTICAL SUPPORTS ARE ASSEMBLED BY THE SAME METHOD AS DEFINED FOR THE FIRST LEVEL. ALL CONSTRUCTION JOINTS ARE SUPPLIED WITH GUIDE PINS FOR POSITIONING OF COMPONENTS AND CAPTIVE BOLTS TO SECURE COMPONENTS IN PLACE. EACH IS COMPATABLE WITH FTS

- THE CREW PRESSURIZED MODULES WILL BE PLACED INTO POSITION BY HEAVY LIFT EQUIPMENT. ONCE IN POSITION THE MODULES CAN BE SECURED IN PLACE USING FTS/ATTV. COUPLING OF THE MODULES TO THE AIRLOCK WILL BE ACCOMPLISHED IN THE SAME MANNER AS FOR THE SPACECRAFT MODULES

- COMPLETE ASSEMBLY BY POSITIONING SAND BAGS ALONG THE OUTER WALL TO A THICKNESS OF 3 METERS

FIGURE 6 - ASSEMBLY SEQUENCE FOR THE THIRD LEVEL OF THE SHELTER

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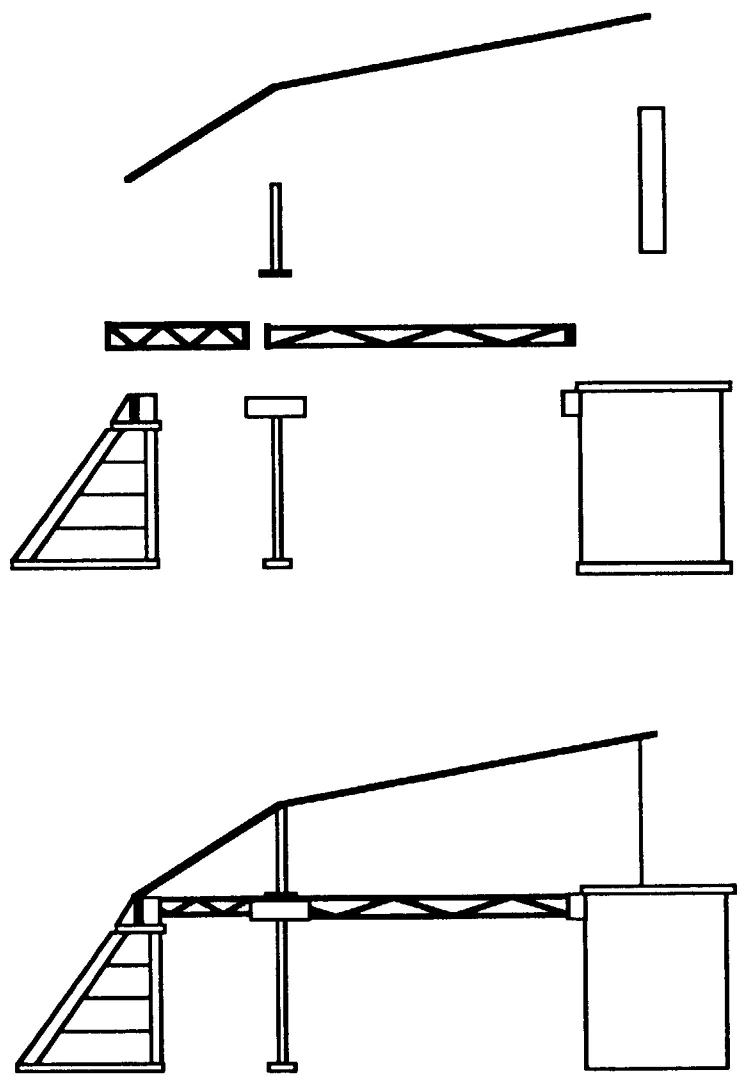

ELEVATION VIEW

ASSEMBLY SEQUENCE

- THE THIRD LEVEL SUPPORT STRUCTURE, ROOF, OUTSIDE PANELS, AND VERTICAL SUPPORTS ARE ASSEMBLED BY THE SAME METHOD AS DEFINED FOR THE OTHER LEVELS. ALL CONSTRUCTION JOINTS ARE SUPPLIED WITH GUIDE PINS FOR POSITIONING OF COMPONENTS AND CAPTIVE BOLTS TO SECURE COMPONENTS IN PLACE. EACH IS COMPATABLE WITH FTS

- COMPLETE ASSEMBLY BY POSITIONING SAND BAGS ALONG THE OUTER WALL TO THICKNESS OF 3 METERS

CONSTRUCTION OF THE MARS SHELTER - CONCLUSIONS

FAIRCHILD SPACE COMPANY

- FTS DESIGN MUST BE MODIFIED TO PERFORM CONSTRUCTION OPERATIONS ON THE MARTIAN SURFACE
  - JOINTS AND LINKS NEED TO BE STRENGTHENED FOR THE GRAVITATIONAL FIELD OF MARS
  - FTS NEEDS TO BE MOUNTED ONTO A MOBILE TRANSPORT SYSTEM SUCH AS THE ALL TERRAIN TRACK VEHICLE (ATTV), REFER TO FIGURE 3
  - THE FTS/ATTV SYSTEM NEEDS TO BE PROVIDED WITH SEALS AND PROTECTIVE COVERS TO PROTECT ALL OPERATING SYSTEM FROM THE ENVIRONMENT
  - FTS/ATTV NEEDS TO BE DESIGNED FOR AUTONOMOUS OPERATIONS/SUPERVISED AUTONOMOUS OPERATIONS

- THE ENTIRE VOLUME OF THE MARS SHELTER, AS PRESENTLY CONFIGURED, CAN NOT BE PRESSURIZED. ALTERNATE CONCEPTS FOR PRESSURIZED SHELTERS ARE PROVIDED IN FIGURE 7

- FTS SHOULD BE MODIFIED TO PERFORM LIGHT DUTY, DEXTERIOUS, TASKS. A SECOND SYSTEM AND/OR THE MINING EQUIPMENT SHOULD BE DESIGNED TO HANDLE THE HEAVIER CONSTRUCTION TASKS

- THE BUILDING COMPONENTS NEED TO BE MODULARIZED AND THE DESIGN STANDARDIZED TO THE GREATEST EXTENT POSSIBLE

- THE COMPONENT INTERFACES NEED TO BE DESIGNED SO THAT THEY ARE COMPATABLE WITH AUTONOMOUS AND/OR SUPERVISED AUTONOMOUS ROBOTIC OPERATIONS

- ALL COMPONENTS WHICH WILL NEED TO BE HANDLED BY FTS MUST BE PROVIDED WITH THE APPROPRIATE HANDLING FIXTURES

- A THROUGH CHECK-OUT OF ALL MATING INTERFACES MUST BE PERFORMED ON EARTH AS PART OF THE ACCEPTANCE TESTING

FIGURE 7 - ALTERNATE CONCEPTS FOR A PRESSURIZED SHELTER

FAIRCHILD SPACE COMPANY