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CONCEPTUAL DESIGN STUDIES FOR SURFACE INFRASTRUCTURE

Ann L. Bufkin
William R. Jones II
NASA, Johnson Space Center
Houston, Texas

ABSTRACT

The ultimate design of a manned Mars base will be the result of considerable engineering analysis and many trade studies to optimize the configuration. Many options and scenarios are available and all need to be considered at this time. Initial base elements, two base configuration concepts, internal space architectural concerns, and two base set-up scenarios are discussed in this paper. There are many variables as well as many unknowns to be reckoned with before people set foot on the red planet.

INTRODUCTION

The design process begins with some initial requirements. These requirements will inevitably change and increase in number and scope as various concepts are generated, evaluated and refined. This cycle of design and refinement continues until acceptable conceptual designs are defined and detailed design can begin. We are now in the first iteration of this process on the manned Mars mission.

REQUIREMENTS

The requirements we are now considering for the surface infrastructure on Mars are as follows:

Overall

(1) Use proposed and existing equipment to keep down cost--Space Shuttle and Space Station modules, and (2) Provide adequate radiation protection--daily and solar events, in transit and on surface.

Base Elements

(1) Provide habitat(s) for four people initially with future add-on capability, (2) Provide laboratory, both stationary and mobile, (3) Provide means of surface transportation, EVA (extra vehicular activity), and shirtsleeve, (4) Provide vehicle capable of moving modules on the surface, (5) Provide capability to move Martian soil, to clear landing fields, and bury modules if required, and (6) Set up for habitability in minimum number of missions.

Base Elements

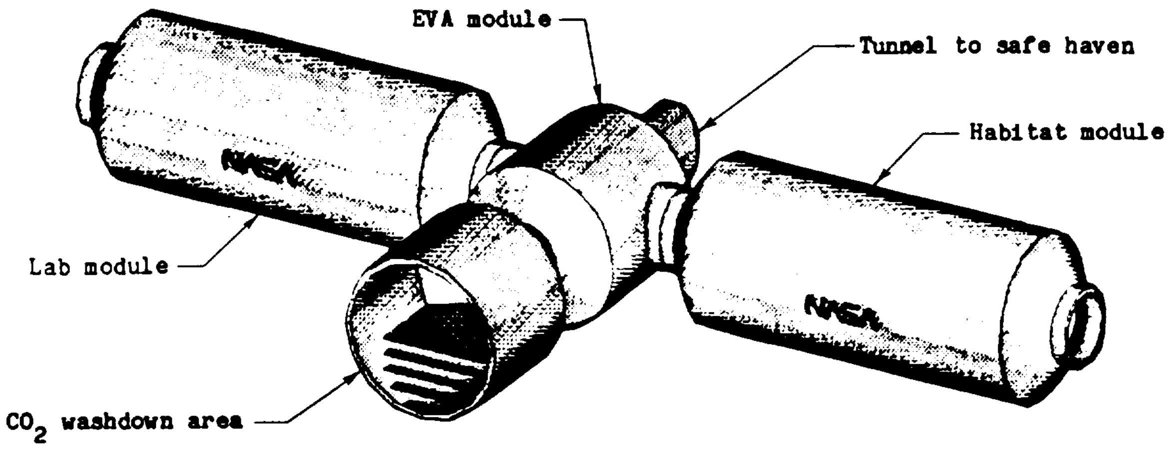
Two basic configurations are being studied for feasibility at this time. They are the "T" configuration and the "little b" configuration, both named for their shape (see figures 1 and 2). These configurations are considered to have the bare necessities for an operational base. It will take perhaps two-three missions to achieve the operational phase with two landers per mission. These configurations are similar in that they both use the same basic elements and are open to the same options, which will be discussed later.

Both the "T" and "little b" configurations contain the following elements: (1) One self-sufficient habitation module: contains bunks, ECLSS, galley, etc., (2) One laboratory module: contains various experiments in materials processing, geology, etc., (3) One EVA module: contains EVA suits, tools, and other equipment for EVA; can be used as emergency pressure chamber, (4) One CO_2 wash down area: pressurized Mars atmosphere is used to remove most of the dust from the EVA suits, (5) One tunnel to base safe-haven (radiation): constructed using shaped charges or other method, and (6) One or more vehicles for moving modules, towing the lab to a new study area, moving soil, or just moving people around the planet.

The habitation and lab modules could be modified Space Station modules. The interior configuration concepts are based on designs to be used on Space Station, modified for 0.4-g. The first iteration of a Mars habitat is shown in figure 3. These designs and architectural concerns are discussed in the "Infrastructure- Interior Space" section below. The lab interior has not been studied yet. These designs are being driven by requirements developed by Fairchild (Ref. 2).

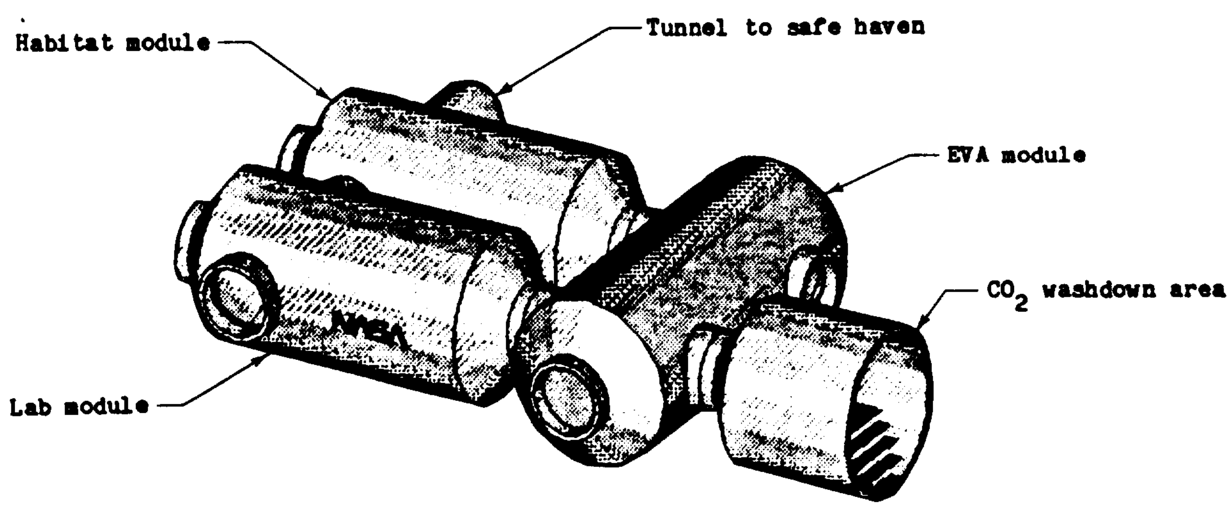
The exteriors will include hatches and docking equipment for mating to other modules. Leveling equipment with some lateral adjustment will be necessary for all of the modules.

The EVA module of the "T" configuration is smaller than a habitat or lab module. It can be sent with either the lab or habitat module to LEO in the cargo bay of the Space Shuttle. The EVA module of the "little b" configuration may also use a modified Space Station module. This allows for docking of two modules to either side of it. The larger EVA module allows the crew more room for suiting up, maintenance of suits, and



The "T" Configuration

Figure 1



The "Little b" Configuration

Figure 2

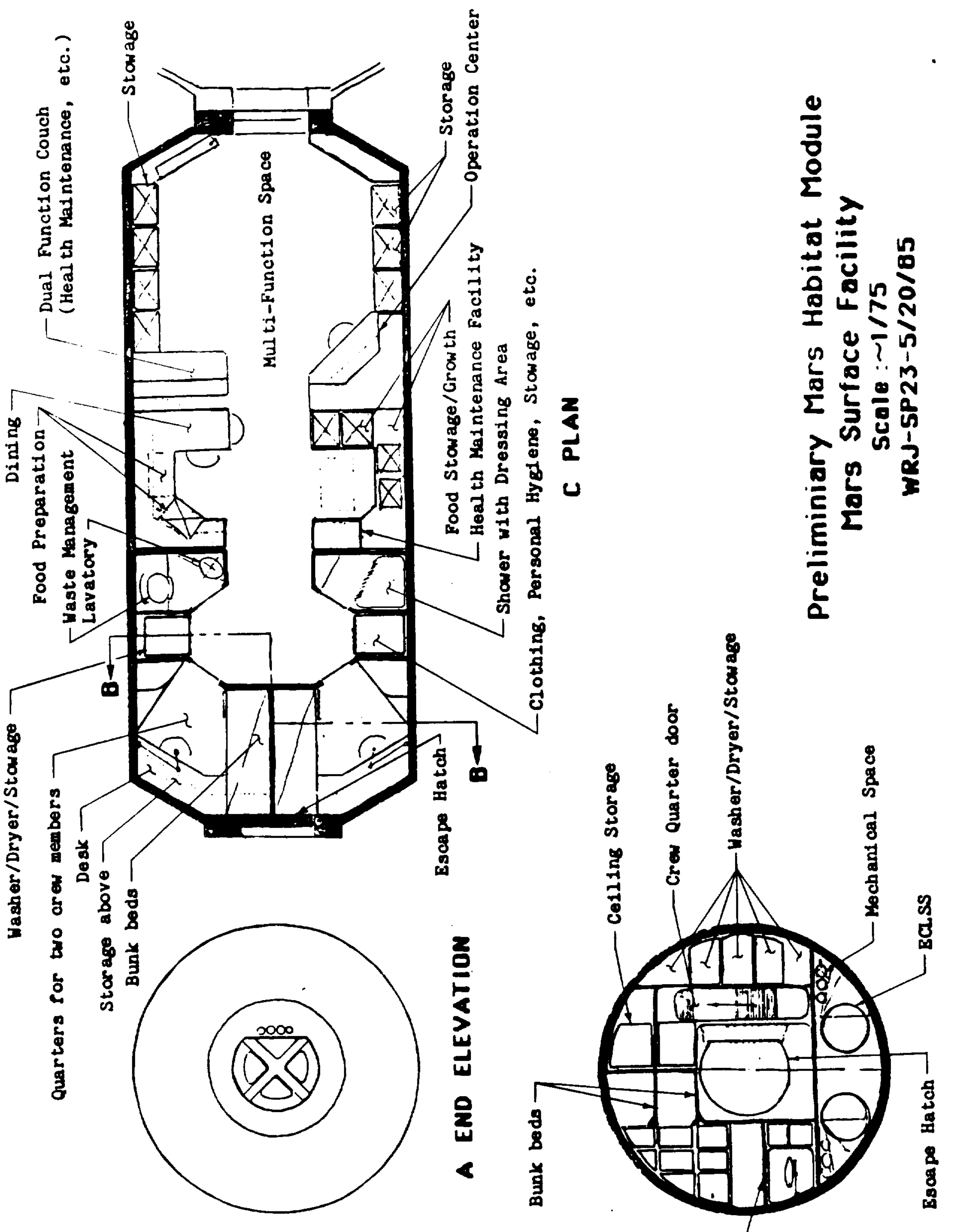

Stowage
Dual Function Couch
(Health Maintenance, etc.)
Multi-Function Space
Dining
Food Preparation
Waste Management
Lavatory
Washer/Dryer/Stowage
Quarters for two crew members
Desk
Storage above
Bunk beds
Escape Hatch
B
B
Storage
Operation Center
Food Stowage/Growth
Health Maintenance Facility
Shower with Dressing Area
Clothing, Personal Hygiene, Stowage, etc.
C PLAN
A END ELEVATION
Bunk beds
Ceiling Storage
Crew Quarter door
Washer/Dryer/Stowage
Mechanical Space
ECLSS
Escape Hatch
Desk
B SECTION
Preliminiary Mars Habitat Module
Mars Surface Facility
Scale :~1/75
WRJ-SP23-5/20/85

Figure 3

stowage. This module also provides a second path between habitat and lab modules.

The wash down area will have grated stairs leading to a grated platform raised above the surface. On the walls of this area, shower heads will be mounted for spraying suited crew members. Also, a flexible shower head may be desirable.

A solar event radiation safe-haven could be located through the tunnel shown. The safe-haven could be constructed using an inflatable structure installed in the side of a mountain or buried. The hole in the mountain as well as the burying system could use shaped explosive charges to remove or move dirt. Los Alamos National Laboratories (Ref. 5) is working out the explosive techniques that could be used. Solar events can last several days, so the safe-haven will have to provide ECLSS and contain water and food rations for this time period.

Several vehicles will be necessary on the surface for many different tasks. One vehicle could be developed for most or all of the tasks. But, assuming long treks out of the walking range for a suited crew person, at least one other vehicle will be needed for rescue purposes or as backup for most tasks.

INFRASTRUCTURE-INTERIOR SPACE ARCHITECTURAL CONCERNS

Architecture and Habitability as it Relates to Micro-G and 0.4-G

There has been and is considerable effort in developing habitability requirements such as the current effort of developing these requirements for a Space Station in low Earth orbit with a micro-gravity environment. Such an environment offers unique opportunities in the architectural utilization of space by re-examining the anthropometric requirements for the human body in the neutral body position. The lessons learned with relation to long duration in total man-made environments will be invaluable; however, the derived architectural solutions will not be applicable to the 0.4-gravity environment found on Mars. In general, the architectural environment will be more Earth-like in terms of orientation, proportion, and anthropometric criteria allowing more accurate verification of potential configurations than is possible with the Space Station.

General Concerns

(1) Circulation spaces will possibly have to be designed with slightly higher ceilings than past vehicle designs to accommodate added spring in walk, (2) Openings (i.e., doors and hatches) will be more Earth-like to allow for a more erect posture when passing through them, and (3) In flight optimum man-machine interfaces will differ from those on the surface due to differences in the micro-gravity neutral body position and a full stature standing position.

Possible Solutions for this

(1) To provide totally separate and different architecturally configured transportation modules and surface facility modules, (2) To provide equipment that can be adjusted and/or reconfigured (i.e., adjustable work station heights, movable walls and ceilings). The ability to move heavier objects would help to support this approach, and (3) The ability to move heavier objects, on the surface of Mars, than we are accustomed to on Earth will require equipment to have hold-down mechanisms to prevent inadvertent movement.

Structure

In considering the integration of all the various systems, subsystems, and components, there would be advantages in having these components interchangeable from place to place and from module to module. This can be done by developing a range of standard volumes with similar attachment mechanisms and common system interface connections (i.e., universal power connectors). The advantages of developing this modular infrastructure are: (1) Conversion of stowage space (supplies required for the flight to Mars) into habitable and/or work space, (2) Addition of new equipment without the need to increase the existing facility volume by removing nonessential or inoperative equipment as mission goals change and technology advances, (3) Ability to redefine space use as the facility evolves (i.e., crew quarters could be added near existing ones) thus ensuring controlled growth, and (4) Forces commonality so that equipment components might be usable from one device to the next (i.e., cannibalizing equipment for repairs, etc.).

Functional Layout

As indicated previously, the presence of gravity on Mars drives the character of the environment closer to that of Earth. Therefore, models of existing buildings will provide the support needed to define the optimum configuration for a Mars surface facility.

General Concerns

(1) Minimize the presence of support systems by placing them in remote locations and/or under visual concealment and sound insulation. At all times, this equipment should be accessible without moving unrelated equipment or furnishings. A prime location for this common module equipment will be in the floor cavity under the circulation space.

(2) Separate and dedicate space for significantly different tasks. Although volume can be saved by allowing a space to serve dual purposes (i.e., the galley table doubling as a worktable), the penalties that arise from scheduling to prevent task interference and the inability of designing an object to serve two purposes well outweigh these savings.

(3) In general, if the volume to be inhabited is to be a long cylindrical object, then the functional organization of the space should be as follows: (a) The initial entry from EVA or lab module should be located at one end to act as a buffer between work areas and private areas, (b) The next area should be the galley and dining facilities. Again, acting as a buffer from the working environment to a private environment, (c) The crew quarters should be placed in the furthest and most removed area from daily activities, providing the privacy required for crew quarter activities, (d) The personal hygiene facilities are best located between crew quarters and the public spaces to reduce interference when in use by either group, and (e) Equipment and stowage should be located around the perimeter of the volume so that the operational space required by a user can be shared, with general circulation free space creating a perceived larger overall volume and to take advantage of any additional radiation shielding the equipment may provide.

BASE SET-UP SCENARIOS (OPTIONS)

When the landers reach the surface, there is no doubt they will not be very close together or close to the desired base location. Therefore, the need for vehicle(s) to move the modules is apparent. Also, the modules may need to be buried to provide radiation protection. At this time, it is believed that this will not be necessary, but soil will have to be moved to create landing areas and level the ground to place the modules in an assembled configuration.

Two options are now being considered: (1) Bulldozer type vehicle with hitch for pulling a module (figure 4), and (2) Crane with a drag bucket and hitch (figure 5).

In both cases, the modules must be moved to the base location. This could be accomplished by putting wheels on all the modules and towing them. Another solution would be to use one trailer to move all the modules. The landers could have leveling and lateral adjustment equipment built in, with detachable descent engines and tanks. Once the engines and tanks are detached and dragged away, the trailer is positioned under the lander stand. Using the leveling equipment or jacks on the trailer, the module and stand are supported by the trailer and moved to the base. The modules could be located and docked to one another, one by one.

The need for a mobile lab could be satisfied by this same method. The lab located at the base could be undocked and towed to a new study area as described in the next paragraph. Another option being considered is a separate mobile lab.

The bulldozer type vehicle (BTV) will carry its own ECLSS on board, capable of supporting the lab module. In this situation, the habitat module would have its own ECLSS also capable of supporting the lab when in hard docked mode at the base. When in transit to a new study location, the lab would be secured to the BTV with a trailer hitch and be docked through a flexible duct. When the new study location is reached, the lab and BTV perform a hard dock, providing a shirt sleeve environment. If EVA's are necessary, the hatch between the two could be sealed off and the BTV depressurized. Having a bulldozer attachment in the front of this vehicle will enable it to get past objects that may cause the crane to go the long way.

The crane will probably be an EVA operated vehicle and have no ECLSS capability. This vehicle may be easier to use for putting the modules on a trailer, without the lander stand or special jackup equipment becoming factors. If this is the vehicle for moving soil as well, a drag bucket would be included. This method of clearing and leveling the land may be a more tedious process than with the BTV.

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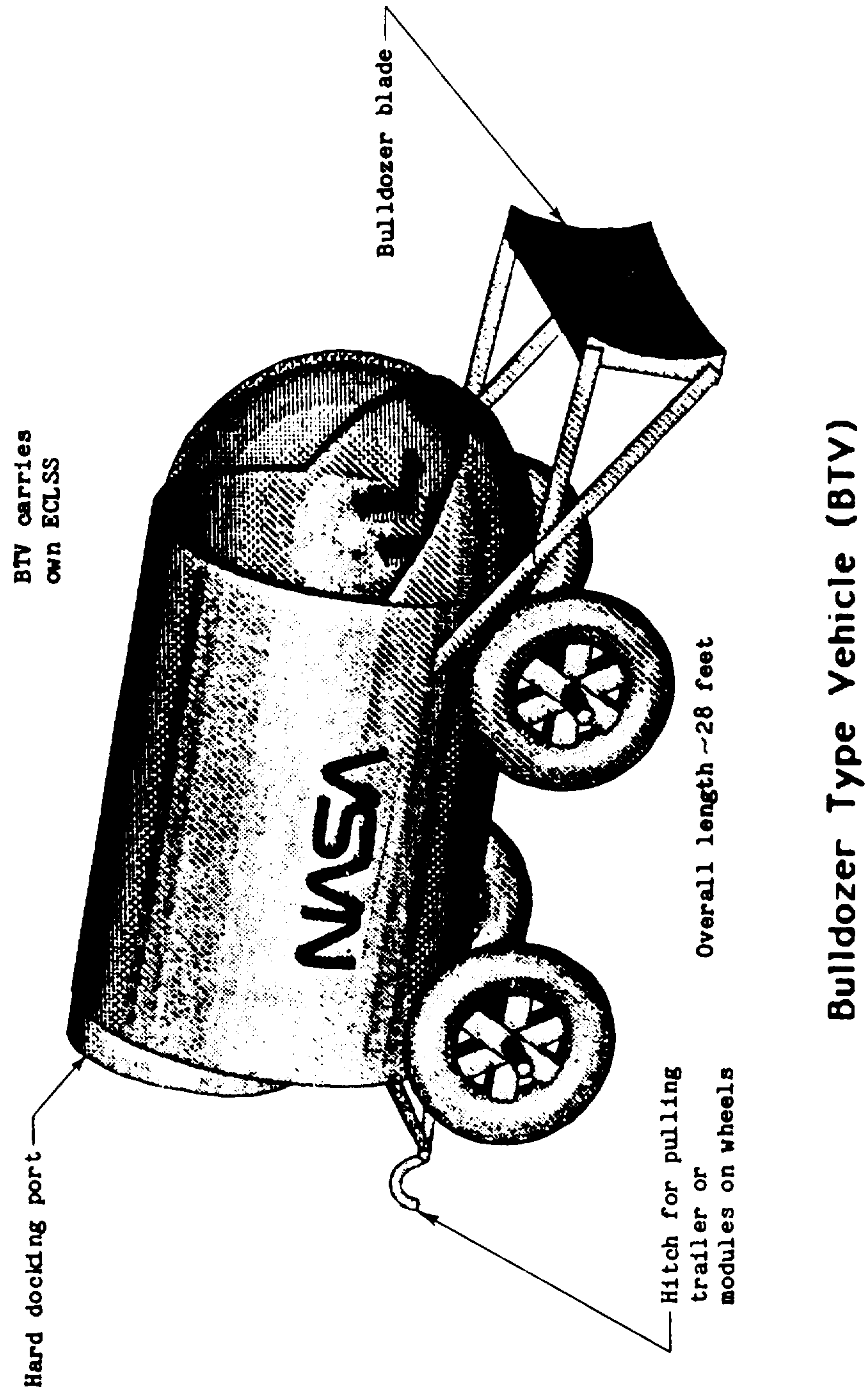

Figure 4

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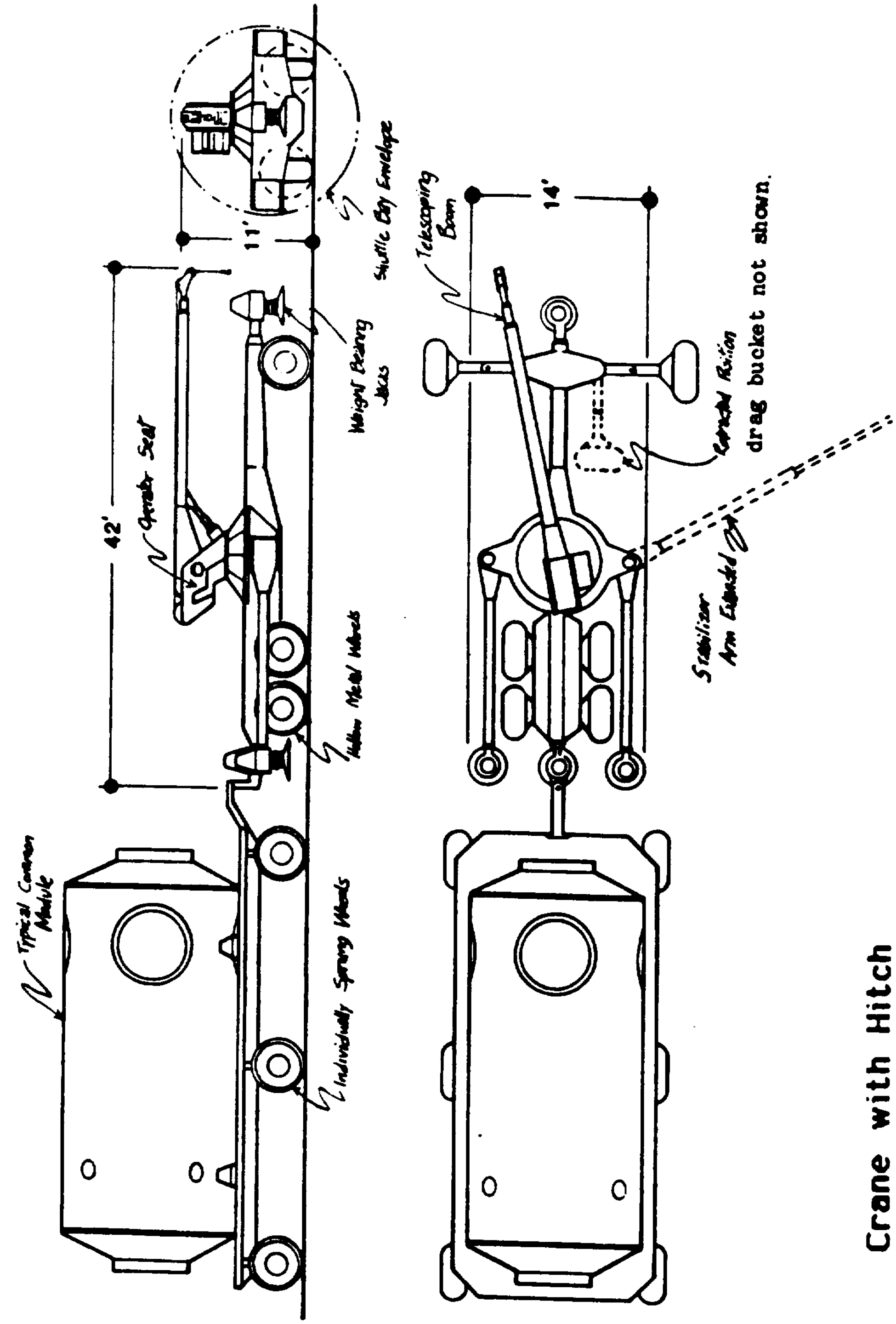

Crane with Hitch
(Illustration copied from page 12 of reference 4)

Figure 5

CONCLUSIONS AND RECOMMENDATIONS

(1) The "little b" configuration appears to be more attractive for the addition of future modules because of its compact size, i.e., less land to clear and level, (2) Both the BTV and the crane could be made to work for all the tasks necessary, but perhaps a crane with a bulldozer attachment is preferable and (3) As far as power is concerned, batteries could be used to run the surface vehicles, but some other propulsion form should be developed, perhaps an engine that runs on super oxides or regenerating fuel cells. Power for the station itself could be nuclear (SP-100), solar, etc. This will be the subject of further study.

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