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# SPACE STATION UTILIZATION AND COMMONALITY

John Butler
Marshall Space Flight Center/NASA
Marshall Space Flight Center, Alabama

ABSTRACT

This paper identifies and discusses several potential ways of utilizing the Space Station (SS), including utilization of learning experiences (such as operations) utilization of specific elements of hardware which can be largely common between the SS and Mars programs, and utilization of the on-orbit SS for transportation node functions. The probablility of using the SS in all of these areas seems very good.

Three different ways are discussed of utilizing the then existing Low Earth Orbit (LEO) SS for operational support during assembly and check-out of the Mars Space Vehicle (SV) : (1) attaching the SV to the SS, (2) allowing the SV to co-orbit near the SS, and (3) a hybrid of the first 2 ways. Discussion of each of these approaches is provided, and the conclusion is reached that either the co-orbiting or hybrid approach might be preferable. Artists' concepts of the modes are provided, and sketches of an assembly system concept (truss structure and subsystems derivable from the SS) which could be used for co-orbiting on-orbit assembly support are provided.

## SS CONCEPT

The initial Space Station (SS) is currently planned to be operational in the early 1990's. The timing for a growth version of the SS has not been established, but it certainly can occur in the time frame appropriate for support to Mars missions. The nature and capabilities of the growth SS will partially determine the ability of the manned Mars program to benefit from the SS program. This definition of the growth SS is in progress at this time.

There are several possible scenarios for the evolution of the SS, including phased growth; one growth mode might be replication. Exchange of new-technology equipment for old-technology equipment is a form of evolution, but this will occur as a part of any of the scenarios mentioned. If replication is the path chosen for growth, there would be in existence two or more smaller stations of somewhat limited size and capability. These might have a high degree of basic commonality among them, and yet might be dedicated to different functional purposes, e.g., one might be a more science-oriented SS and another might have a more operations-oriented capability--or, the stations might have identical capabilities and have all types of work evenly divided among them. If there are multiple stations, these might all be at the same orbit, or they could be at different orbits. If the growth path taken by the SS is an increase in the size of the IOC SS, this one would have responsibility for supporting a wide variety of science and operations activities. Such a SS would have larger dimensions, greater resources, and more functions than the initial SS. Each of these considerations would have some bearing on the potential usability of the SS for the manned Mars program.

An early concept of the growth SS was defined in reference 1 and is shown on Figure 1. Dimensions are shown on the figure; weights will be between 500K and 1M lbs. Solar dynamic and photovoltaic power systems are candidates for both the IOC and growth SS. A solar dynamic concept is shown in Figure 1, for reference. The Orbiter (not shown) would berth to one of the Habitability Modules during resupply missions. Some of the user accommodation equipment (experiment, servicing equipment, etc.) has been omitted from Figure 1 for simplification of the drawing. Figure 2 shows such equipment as it is envisioned for the IOC SS; the growth SS would have an increased complement of such equipment. The IOC SS weight is estimated to be slightly less than 500K lbs.

The flight orientation of the SS, as shown in Figure 3, is with the keel along the nadir - zenith line and with modules earthward; the transverse boom is kept perpendicular to the orbit plane.

SS UTILIZATION/COMMONALITY WITH MARS PROGRAM

There are several ways in which the manned Mars program can benefit greatly from the SS program. Some of the key benefits and impacts are listed in Table 1. The two general categories into which these applications fall are: (1) use of SS heritage including experience and use of SS technology, concepts, and/or specific hardware/software designs, and (2) use of the existing on-orbit SS.

As shown in Table 1, there are many areas in the first category where the manned Mars program could benefit greatly from the SS program. It is not apparent at the level of investigation done thus far that there

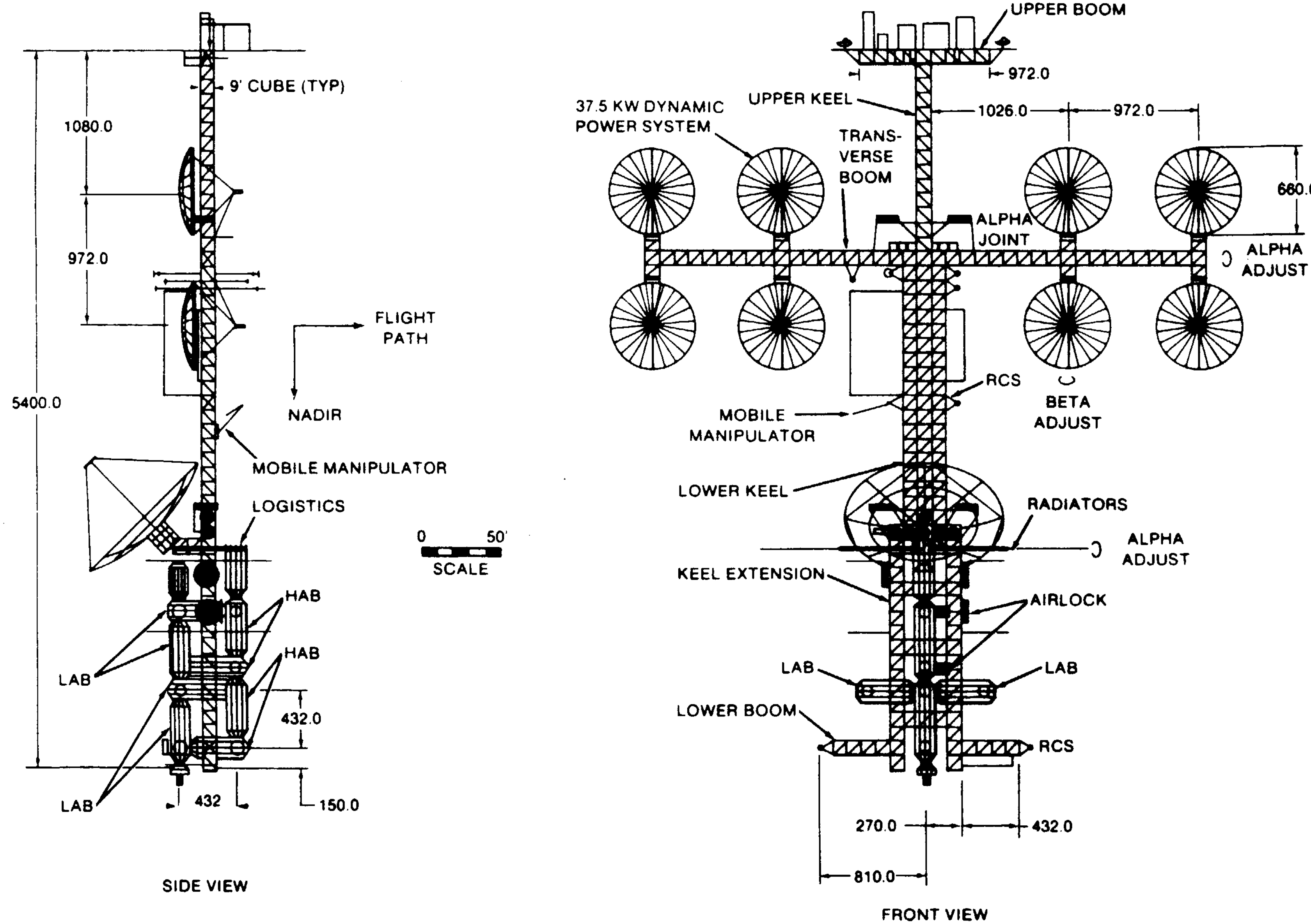


FIGURE 1. – SPACE STATION REFERENCE GROWTH CONFIGURATION

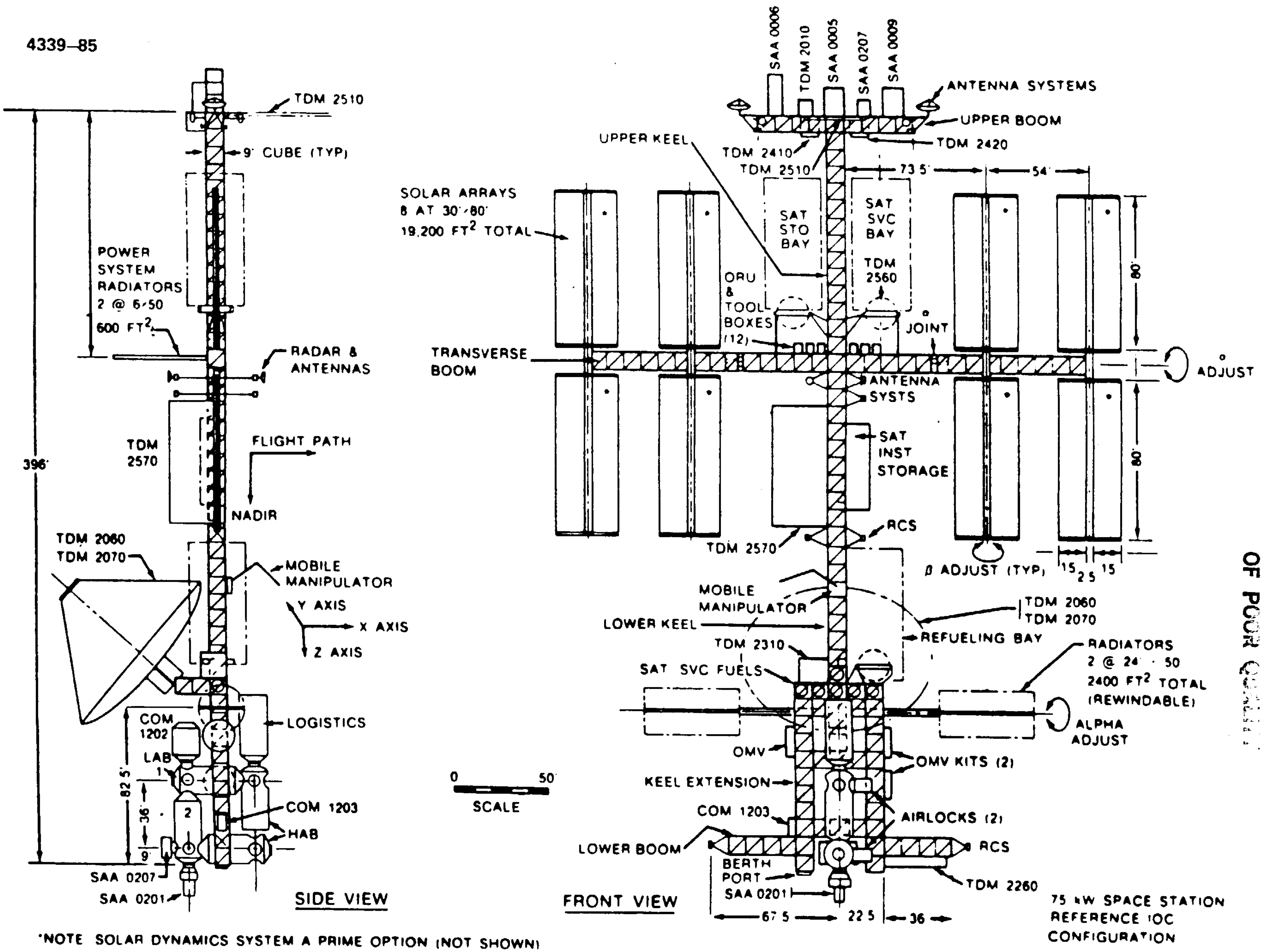


FIGURE 2. – USER ACCOMMODATIONS (IOC SPACE STATION)

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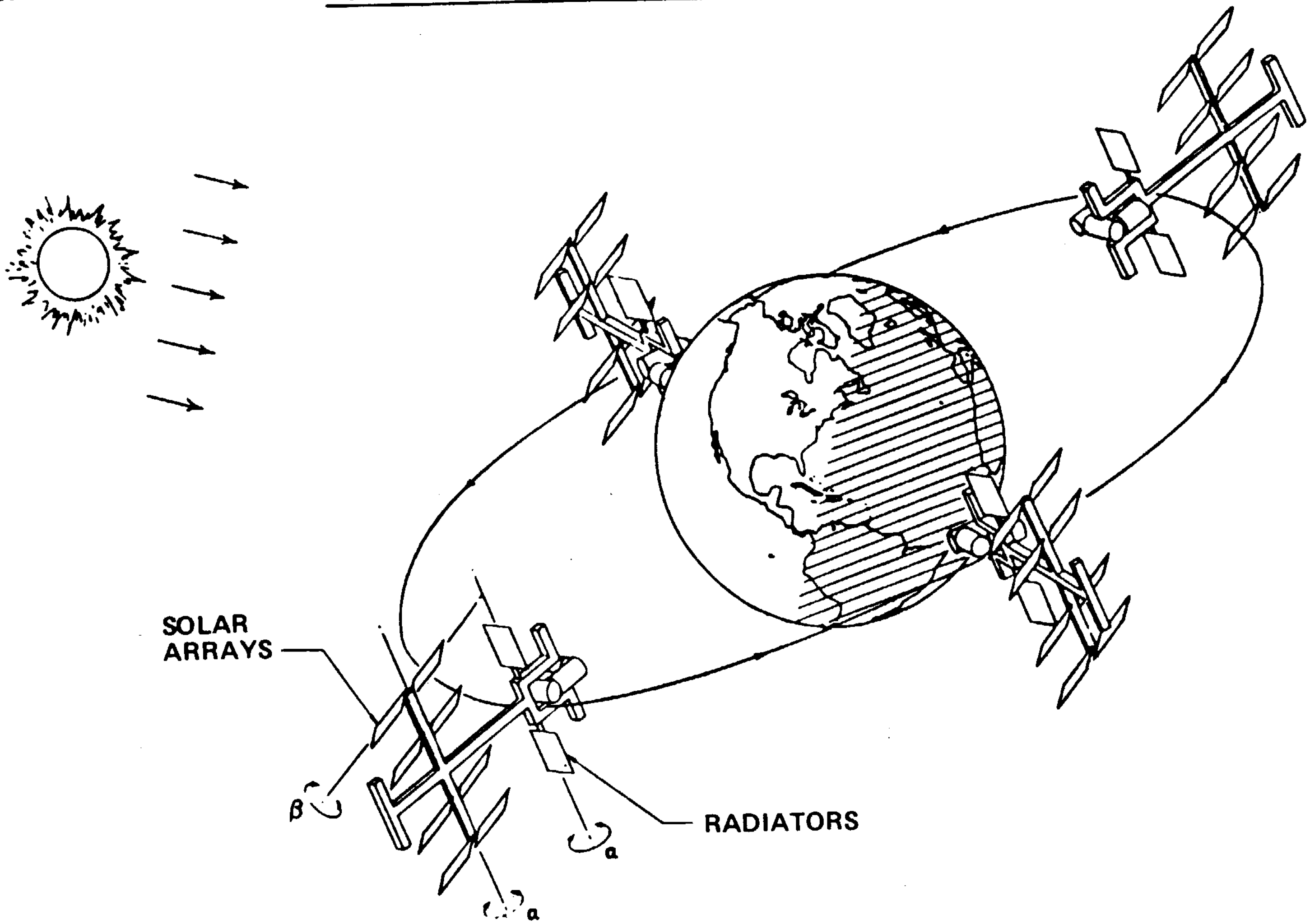
FIGURE 3. SPACE STATION ORIENTATION



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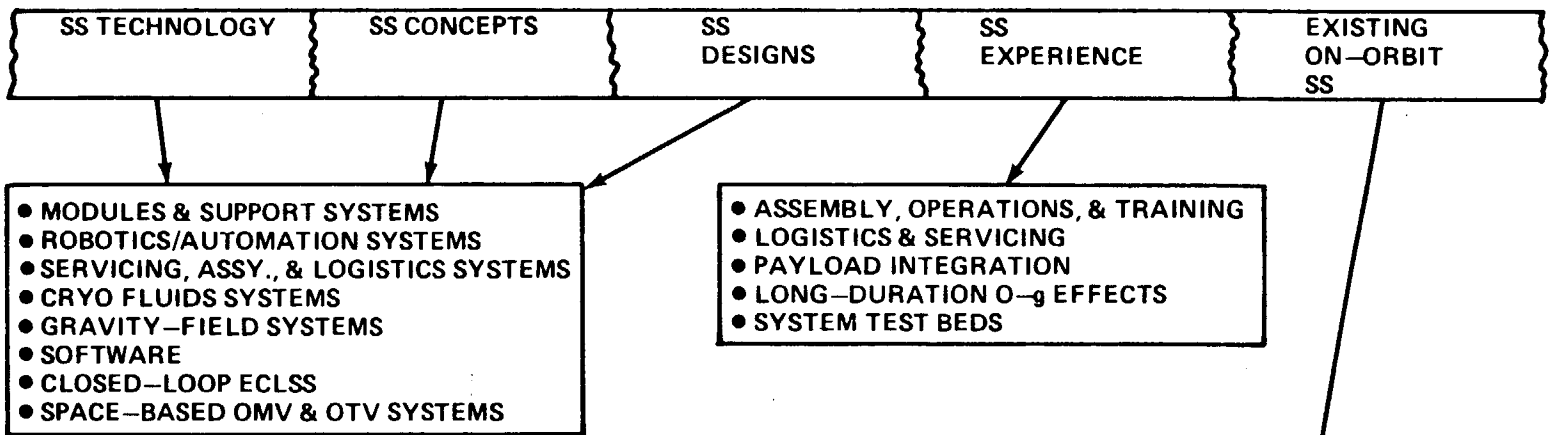
# TABLE 1.
# SPACE STATION IMPLICATIONS




| | MARS VEHICLE ASSEMBLY OPS | | MARS SPACECRAFT RETURN OPS |
|---|---|---|---|
| CONSIDERATION | ATTACHED | CO–ORBITING | |
| ● MINIMUM DISRUPTION OF SS | | √ | |
| ● MINIMUM REAL ESTATE REQ'D. ON SS | | √ | |
| ● MINIMUM QUARANTINE (FWD OR REV.) IMPACTS ON SS | √ | √ | √ |
| ● USE OF SS OTV & OMV | √ | √ | √ (RETRIEVAL) |
| ● SHARED STS FLIGHTS | √ | √ | |
| ● MINIMUM OVERALL ORBITKEEPING PENALTY | √ | | |
| ● MINIMUM OVERALL COST | √ | | |

SOME HYBRID MODE OPTIMUM?

would be any impact to the SS for the Mars program to benefit from use of items shown in this category. Some modification of the designs might be necessary as part of the Mars program due to the requirements for longer mission duration, higher reliability, differences in environments, weight and volume criticality, etc., but costs of incorporating such changes should be far less than those which would be incurred for development of a totally new system. Of course, the greater the similarity between the SS and Mars designs, the more usable will be the "experience" (logistics, servicing, etc.) listed in the first category in Table 1.

As shown by the items listed in the second category of Table 1, the existing SS should be highly useful as a development and qualification test bed for the Mars program systems, elements, operations activity and crew. "Qualification" of the crew will include verfication of methods of reducing or eliminating deleterious physiological effects of long-duration exposure to zero-gravity environments.

Utilization of the SS as a transportation node for the Mars program will potentially require support in the areas listed under that heading in Table 1. There are basically two modes of operation: (1) attaching the SV to the SS, and (2) allowing the SV to co-orbit with the SS. A modified version ofthe second mode would be to allow the SV to free-fly, but would not constrain it to co-orbit with the SS. However, this would essentially amount to not utilizing the SS as a transportation node. Implications of using the attached and co-orbiting modes are discussed in succeeding paragraphs.

<u>ASSEMBLY OF SV WHILE ATTACHED TO SS</u>

Figure 4 shows an artist's concept of the SS with a manned Mars SV attached; on-orbit assembly of the Mars vehicle is being completed here. The SS and SV appear at roughly their relative sizes here, so it can be seen that the SV is a very sizable vehicle in comparison to the SS. This concept of the growth SS is greater than 450 ft. long, and would weigh between 500K and 1M lbs. This concept of the SV is about 246 ft. long and would weigh about 1.6M lbs. fully loaded, of which about 1.2M is propellant. The large aeroshells shown near one end of the SV are about 80 ft. in diameter.

Attaching the SV to the SS could result in significant impacts to the SS, due to the large size, weight, and types of activities associated

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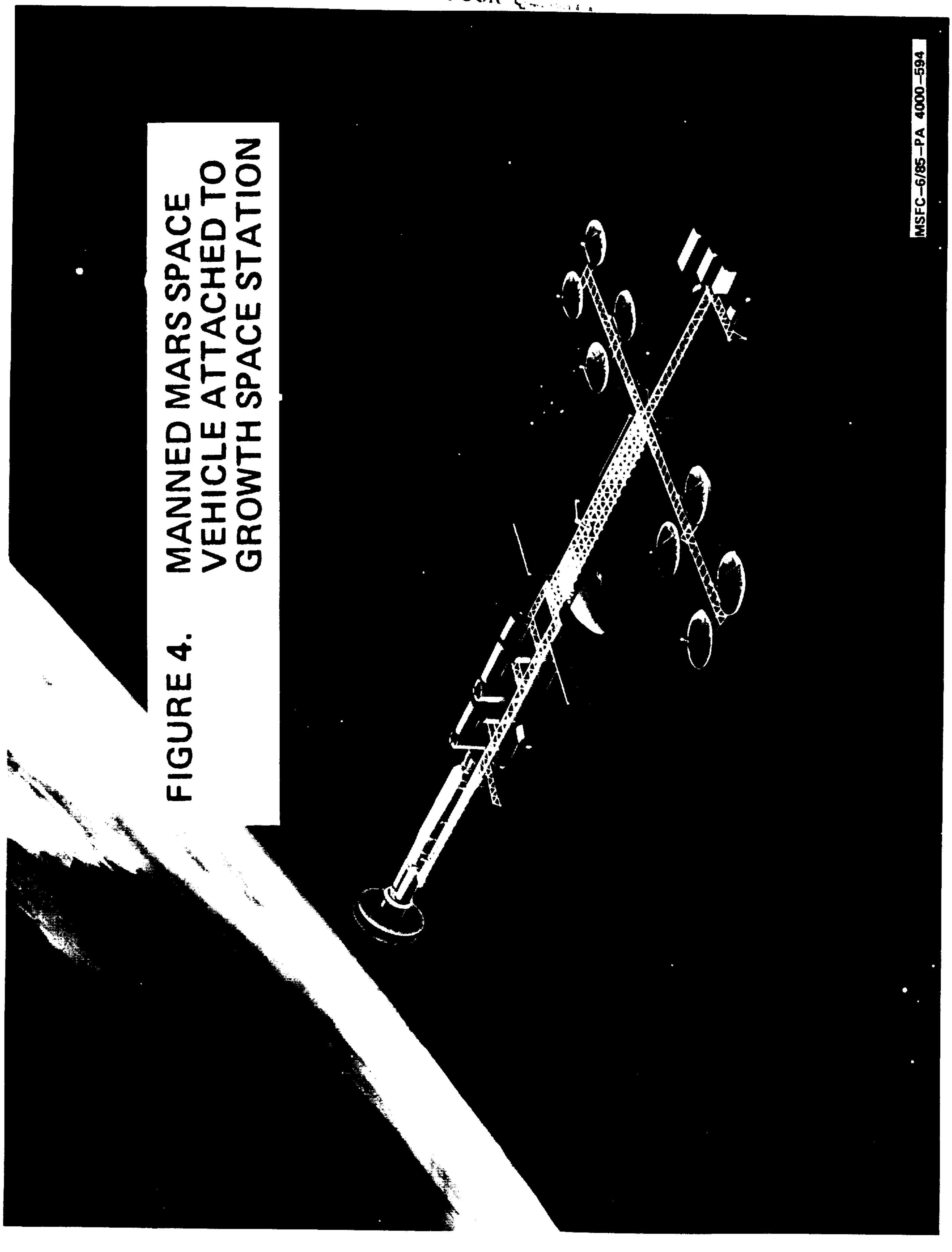


FIGURE 4. MANNED MARS SPACE VEHICLE ATTACHED TO GROWTH SPACE STATION

with the SV. Some of the potential difficulties associated with this mode of operation are discussed below. There will be a number of elements and activities associated with the SS which are not shown in Figure 4. For example, an OTV and spacecraft propellant storage and refueling area will probably be located in the lower central part of the keel. Also in this vicinity will be the berthing and servicing locations for two or more OMV's. In the SS reference concept, at least one face of the keel must be kept free of attached elements to allow for traverse of the MRMS up and down the SS. Payload servicing stations are located along both sides of the upper keel, and Earth-viewing payloads (not shown) will be attached to the lower boom. The payloads mounted on the upper boom need an entire hemisphere of unobstructed viewing in the zenith direction, and those mounted on the lower boom need an entire hemisphere of unobstructed viewing in the nadir direction. For these reasons, it is very difficult to find a location on the SS large enough to attach the SV without incurring some physical or field-of-view obstruction.

Any change in SS mass which would shift the center of gravity (c.g.) out of the orbit plane could quickly become a problem for the SS momentum exchange system, since controllability is fairly sensitive to such shifts. Consequently, the SV should not be attached to the side of the keel. Any SS c.g. shift within the orbit plane is much easier to handle from a momentum-exchange standpoint, and hence, if the SV were attached to the front or back surface of the keel, or to the bottom of the keel, controllability might be acceptable.

As previously mentioned, however, the central part of the keel will be congested, so the lesser of the evils might be to provide a keel extension on the lower end for attachment of the SV (see Figure 4). This would probably interfere with some of the Earth-viewing experiments, so some of them might have to be inoperable during this period. Design of such a keel extension would have to be done so as to ensure that STS berthing to the SS modules would not be impacted. Care would also have to be taken to ensure that the longitudinal c.g. shift did not exceed the bounds allowed by the RCS thruster arrangement, and that the center of pressure (c.p.)-to-c.g. shift did not overburden the momentum exchange system. On-orbit loading of SV propellants and other fluids in the vicinity of the Earth-viewing payloads might be very undesirable from a contamination point of view (depending on the types of propellants used). The SV assembly operations might cause disturbances to any materials science or other payloads desiring a low-g environment. Orbit decay and reboost of the SS may be affected; this might be improved or worsened, depending on the change in ballistic coefficient.

Quarantine constraints on the SV on either the outbound or inbound trip could cause impacts to the SS. In fact, this consideration alone might restrict the SV to a location isolated from the SS.

In spite of the potential difficulties mentioned above, attachment of the SV to the SS could no doubt be made to work if further study indicates that this mode is preferred. Some mitigating factors and steps which could be taken to minimize impacts are listed below:

- Since the reference SS is Earth-oriented, addition of a large payload to either end would minimize controllability impacts.
- In the early buildup phases of the SV, its physical dimensions and mass are smaller, hence impacts to the SS would be less than in later phases; the addition of the dry SV transportation elements represent the largest incremental increase in physical size, and propellant loading of the SV represents the largest incremental increase in mass (75% of total SV weight is propellant). Propellant loading and/or mating of the Mars habitable elements with the transportation elements could be done after separation from the SS.
- Propellant loading of the Mars SV should be accomplished by loading directly from Earth-to-orbit (ETO) tankers to the SV or from an on-orbit propellant depot to the SV, rather than requiring propellants to be stored on or pumped through the SS.
- The existence of a heavy-lift ETO system would allow delivery of larger pieces of the SV than if the STS must be utilized alone, thus reducing the on-orbit assembly and integration effort, skills, and time required at the SS.
- If the SS evolution has proceeded to the point where "branching" has occured (i.e., The SS has been replicated and functions have been re-aligned to provide a science SS and an operations

SS), the disturbances to pointing and low-g payloads due to SV assembly operations would be eliminated.

The SS Orbital Transfer Vehicle (OTV) can be used to circularize the orbit of the SV after return to Earth at end of the mission. This will eliminate having to round-trip a propulsive element for circularization, and will allow significant weight savings. The SS OMV can be used to ferry equipment back and forth and provide other assistance during the assembly period. A duplicate or derivative OTV will be usable as part of the SV propulsion system and possibly as an OTV in the Mars vincinity.

If the SS is in great demand for on-orbit operations or science activities as part of its normal course of business (particularly if commercial or international payloads are involved, any requirement to support the SV, particularly if it extended out to a several-month activity, would be a disruptive occurrence and would interfere with other potential activities. On the other hand, if the Mars activity is a national or international priority item, other workarounds (platforms, etc.) might be provided for the normal SS customers during the occasional periods of Mars mission involvement or a replicated SS could be devoted to support of Mars activities during the time needed.

There are several modes in which the attached SV modules and systems could be supported by the SS (see Table 2): (1) the SV provides most of the crew time for assembly, but the SV modules and systems remain dormant, with the SS providing all habitability (housing, food, etc.) for the SV crew, all resources (power, communications, heat rejection, etc.) and some of the crew time for assembly of the SV, (2) the SV provides habitability and most of the crew time, but the SS provides resources to operate the SV modules and systems and some of the crew time, and (3) the SV provides habitability, resources, and most of the crew time, and the SS provides some crew time. If the SS must provide all the resources to the SV, this could pose a significant problem to the SS, especially if all the other attached payloads continued to be operated using SS resources. Also, providing housing and food for the SV assembly crew would be a problem for the SS, since the SS would not normally be able to accommodate that many additional people. If the SV has to provide its own resources, that could necessitate the deployment of SV solar-energy-



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## TABLE 2. POTENTIAL SS SUPPORT OF SV IN ATTACHED MODE

| OPTION | PROVISION | FURNISHED BY | | REMARKS *** |
|---|---|---|---|---|
| | | SV | SS | |
| 1 | • CREW TIME<br>• HABITABILITY *<br>• RESOURCES ** | √ (MOST) | √ (SOME)<br>√<br>√ | MAJOR IMPACTS TO THE SS HAB & RESOURCES CAPABILITY |
| 2 | • CREW TIME<br>• HABITABILITY *<br>• RESOURCES ** | √ (MOST)<br>√ | √ (SOME)<br><br>√ | SIGNIFICANT IMPACTS TO THE SS RESOURCES |
| 3 | • CREW TIME<br>• HABITABILITY *<br>• RESOURCES ** | √ (MOST)<br>√<br>√ | √ (SOME) | POTENTIAL IMPACTS TO PHYSICAL CLEARANCES & FIELDS OF VIEW |

* INCLUDES HABITABILITY VOLUME, ECLSS, FOOD, ETC.
** INCLUDES POWER, COMMUNICATIONS, HEAT REJECTION, ETC.
*** CONTROLLABILITY NOT ASSESSED HERE – PROBABLY A MAJOR IMPACT

collecting devices, radiators, antennas, etc., which could quickly exacerbate the "real estate" and field-of-view situation.

ASSEMBLY OF SV WHILE CO-ORBITING WITH SS

Allowing the SV to co-orbit in the vicinity of the SS (see Figure 5), appears to offer significant potential advantages. Here, there is sufficient isolation and independence between the SV and SS to minimize interference with the SS, yet the SV could benefit from using some of the SS resources or equipment as part of the normal mode of operation (see Table 1). In an emergency, the proximity of the SS to the SV would allow use of the SS (or vice versa) for backup in a number of areas, such as those listed in Table 1.

The only significant impact to the SV to operate in the vicinity of the SS would be the propellant required to maintain proper orbit phasing. The quantity of propellant required for this activity has not been assessed, but would be a function of the degree of tolerance allowed in the orbit separations. For close tolerances, this might get to be a sizable quantity. The SS might provide part of the delta velocity required to maintain phasing, if this is cost-effective.

If the SV is assembled while in an orbit in the proximity of the SS (but not attached to the SS), an assembly system (structure and other subsystems) may be required. If it is required to have such a system, the central portion of the SS upper transverse boom (the portion between the two rotating alpha joints) and part of the keel, if necessary,could serve as the basis for such an element (see Figure 6). This structure is an open truss framework, expandable or erectable on orbit. The transverse boom contains the attitude control sensors, control moment gyros (CMG's), communications equipment, power conversion and conditioning equipment, and deployable radiators for heat rejection. This piece of equipment is an integrated free-flying element capable of providing its own stabilization, control, and resources, and provides resources to the user. If needed, the two gimbal joints and the solar dynamic (or solar array) energy collection elements can be included as part of the assembly. This total complement of equipment is used (together with the experiment accommodation portion of the SS truss) as the basis for some concepts of the SS unmanned platforms in the SS program. The SS Mobile Remote Manipulator System (MRMS) is designed to

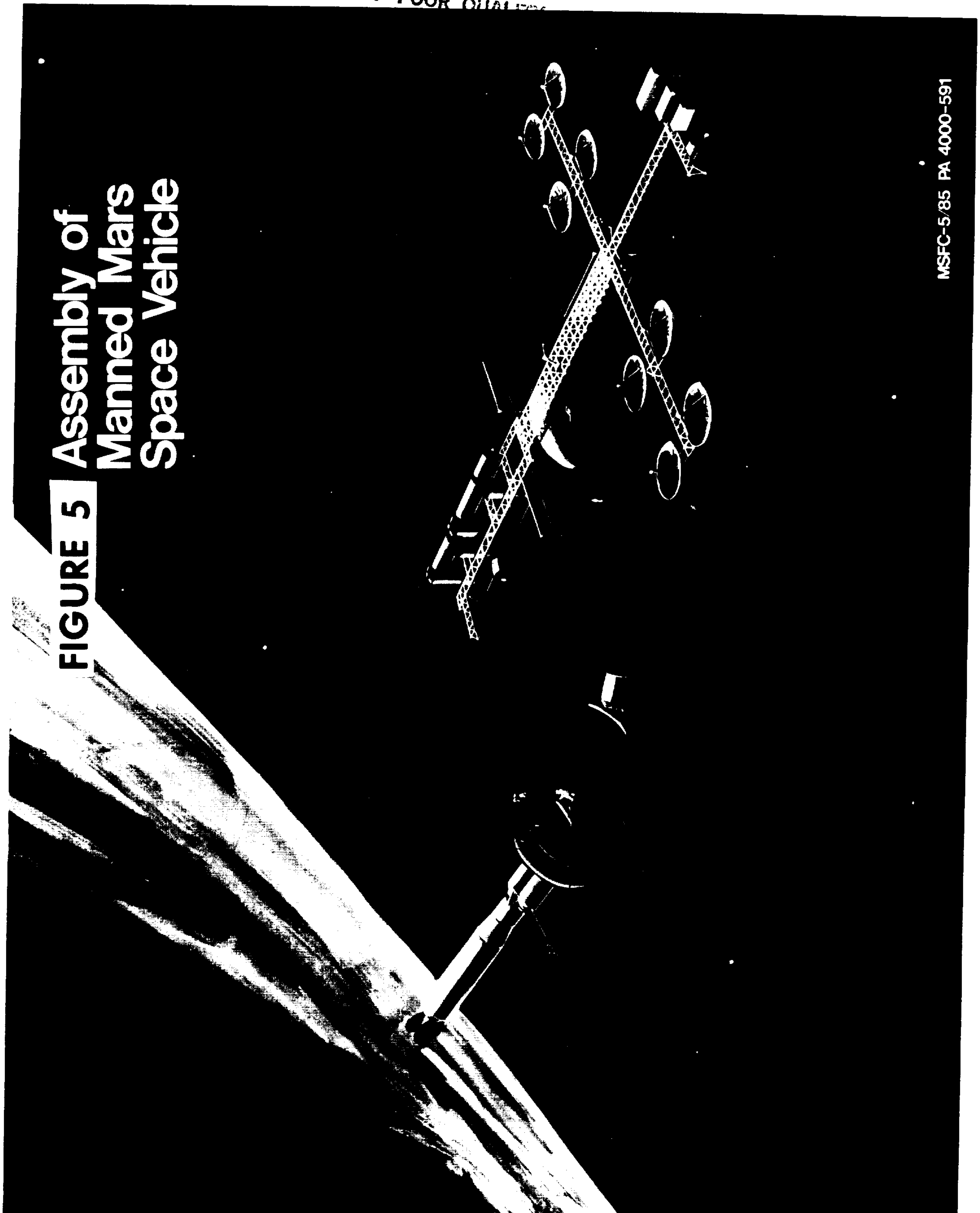
FIGURE 5
Assembly of
Manned Mars
Space Vehicle
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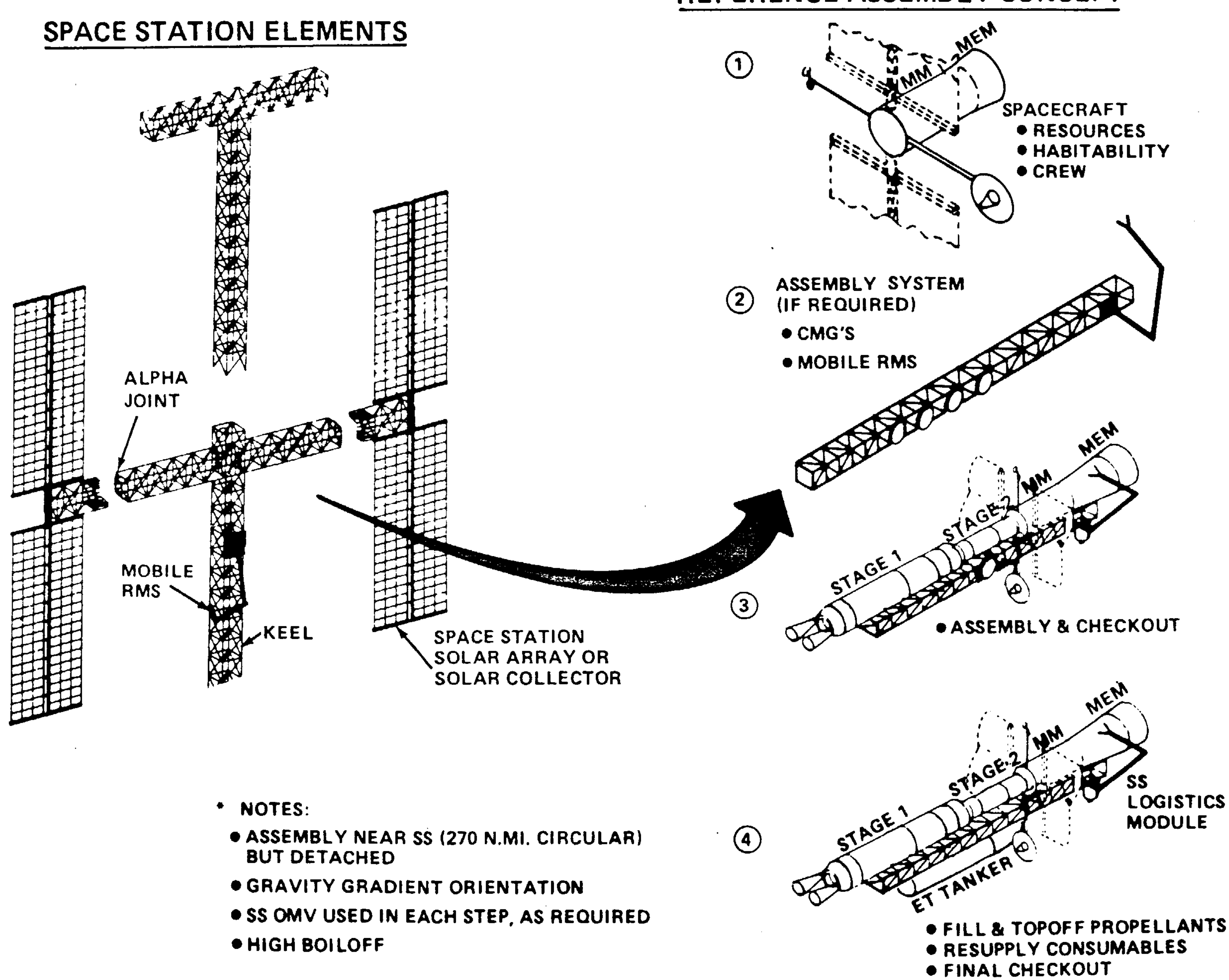
# FIGURE 6. LOW EARTH ORBIT ASSEMBLY CONCEPT



traverse along the truss members, and can be used to aid in assembly of the SV.

If the on-orbit assembly time of the SV can be kept fairly short (a few weeks or months), the SV modules and systems might be used for habitability, power, communications, etc. during assembly. This would allow some burn-in time on these systems, and would allow the assembly system (if used) to be less complex and costly. If the assembly time is long, however, too much of the SV systems' lifetime might be expended, and the assembly system instead would need to provide the necessary habitability and resources during the assembly phase. It was assumed in this limited study that the assembly system would be kept simple and that the SV systems would be used during the assembly phase. The assembly system would be left on LEO after departure of the SV. An augmented co-orbiting platform might even serve as an assembly system.

The OTV and OMV would be useful in the co-orbiting mode of SV assembly for the same functions identified in the discussion on the attached assembly mode.

HYBRID MODE

Each of the other modes has advantages and disadvantages. The attached mode is more convenient, but disruptive. The co-orbit mode is less disruptive, but adds the expense of a separate assembly system and the mass of station-keeping propellant.

In the early years of a Mars program, with flight rates of about one per 2 years, a separate assembly system might not be very cost-effective, since it would be dormant for long periods. In later years this should change somewhat (although a Mars program will always tend to have greater functuations in activity levels from year to year than most other programs, due to the scarcity of flight opportunities). Program maturity thus might be a factor in determining the mode of assembly.

A hydrib mode in which the SV would be attached to the SS during early phases of SV assembly, then would be separated and co-orbit with the SS during later phases, might be an optimum mode and should be investigated further.

Futher study must be done to determine the most effective mode of utilizing the SS, but it appears that a high degree of usability should be possible.

REFERENCE

1. JSC-19989, Space Station Reference Configuration Description, August 1984.