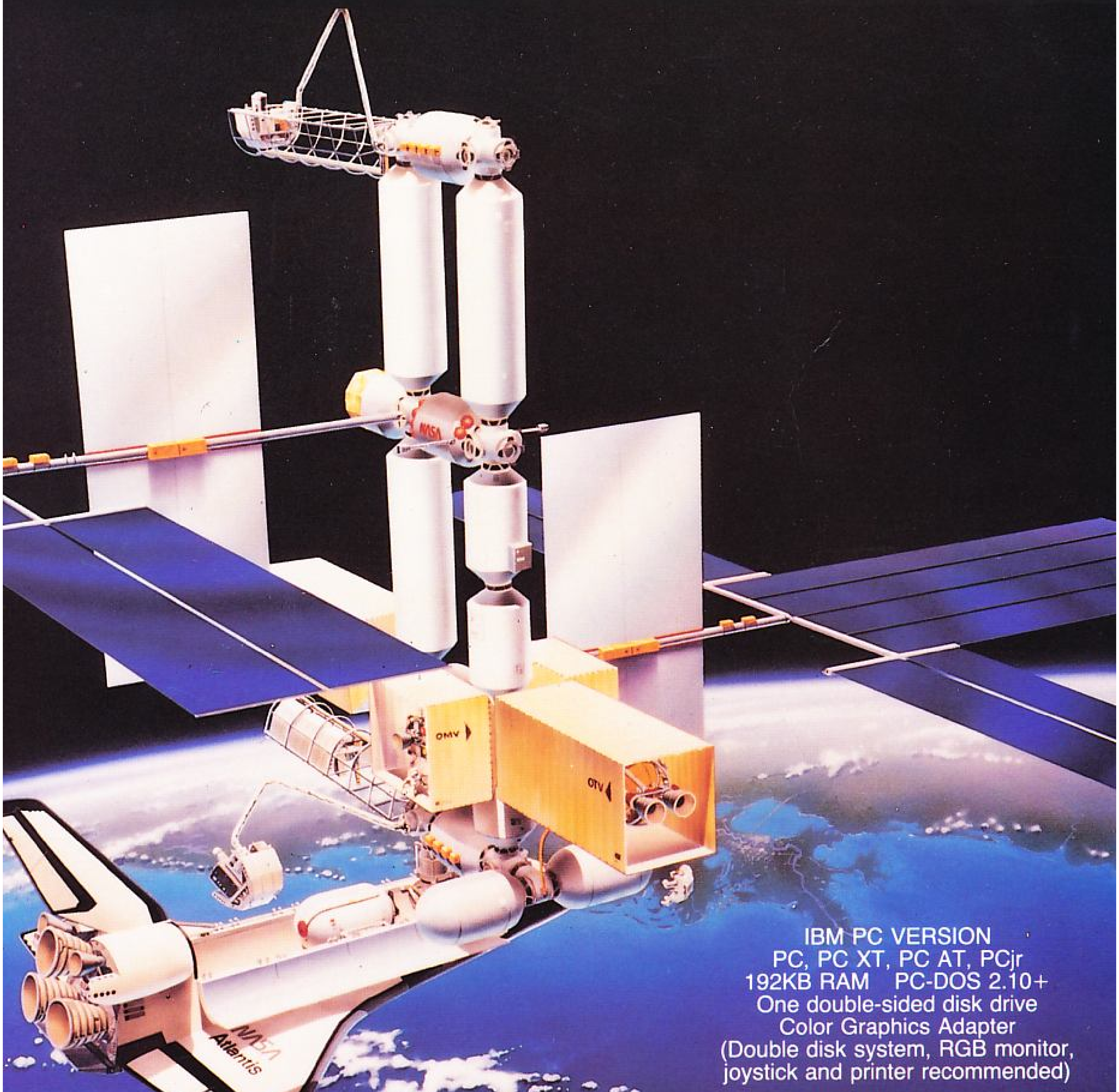
SPACE M•A•X™

SPACE STATION CONSTRUCTION SIMULATOR

T.L. Keller



IBM PC VERSION
PC, PC XT, PC AT, PCjr
192KB RAM PC-DOS 2.10+
One double-sided disk drive
Color Graphics Adapter
(Double disk system, RGB monitor, joystick and printer recommended)

2FS FINAL FRONTIER SOFTWARE®

CAUTION

THE **SPACE M+A+X** SIMULATOR SHOULD BE OPERATED ONLY AFTER A COMPLETE REVIEW OF THIS MANUAL. THE SAFETY OF CREW MEMBERS AND THE SECURITY OF HIGH-VALUE RESOURCES WILL DEPEND ON YOUR THOROUGH UNDERSTANDING OF THE MATERIAL IN THIS DOCUMENT.

SPACE M+A+X ENTERPRISES, INC.

DOCUMENT CONTROL NO. 103770

System Requirements

IBM PC, PC XT, PC AT, PCjr

IBM PC-DOS Version 2.10 (or higher); 3.00 (or higher) for PC AT

192-KB RAM (or more); 640-KB RAM for PCjr

One double-sided disk drive

Color graphics adapter (100% IBM-compatible)

Recommended System Options

Double disk system (two floppy or floppy/hard disk drives)

IBM Enhanced Color Display (requires EGA) or high-resolution RGB

Joystick (requires game adapter)

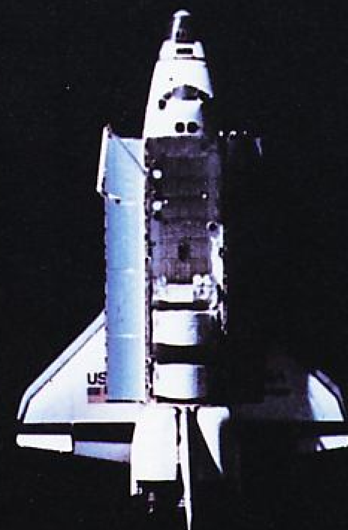
Printer (dot matrix or daisywheel)

IMPORTANT

THE RED AND BLUE DISKETTES HAVE A WRITE-PROTECT NOTCH SO THAT DATA CAN BE SAVED. DO NOT COVER THE WRITE-PROTECT NOTCHES.


USA
NASA
Challenger

SPACE M·A·X



OPERATOR'S MANUAL

Space Station Construction Simulator

T.L. Keller

2FS
Final Frontier Software

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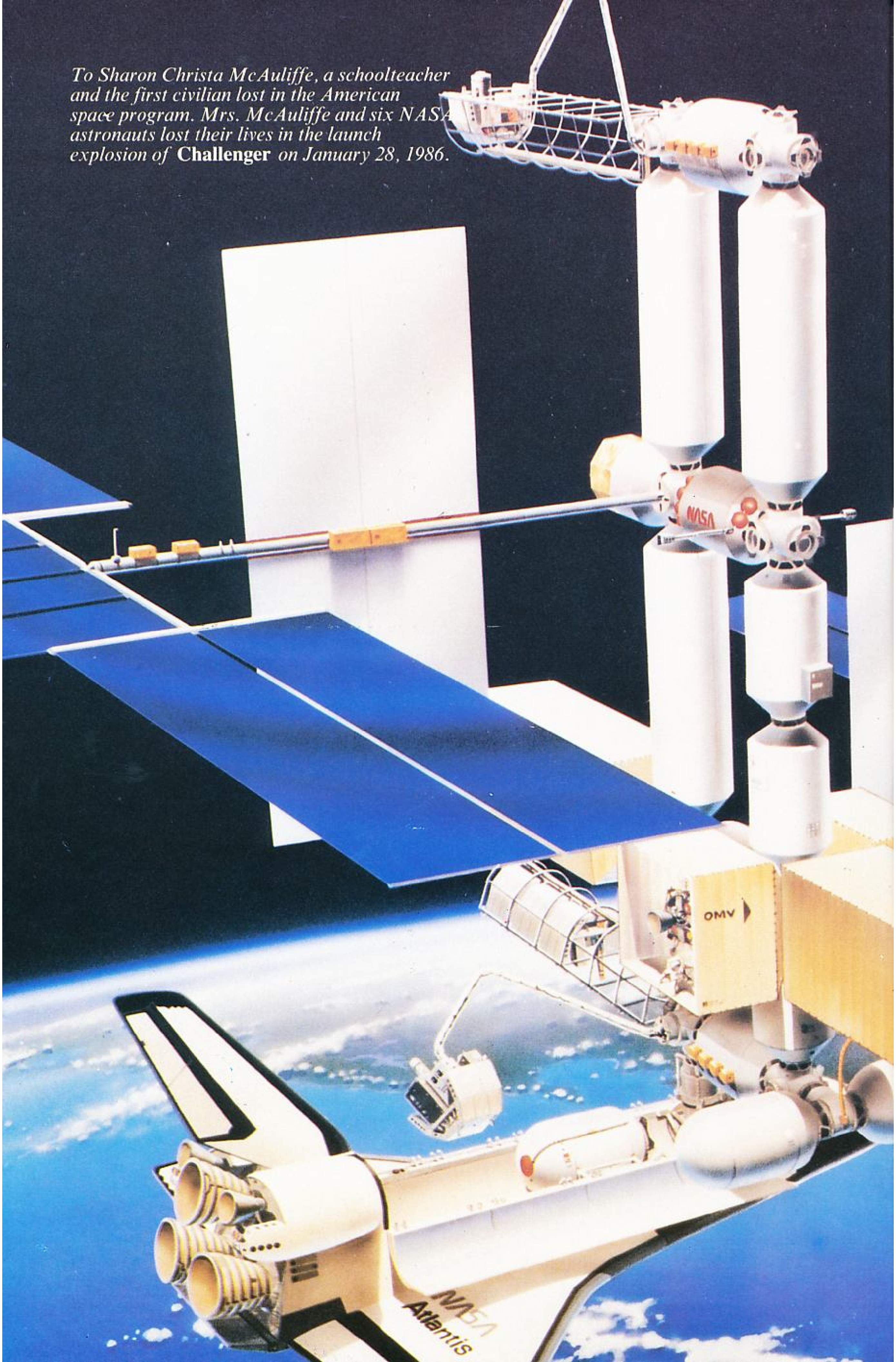
To Sharon Christa McAuliffe, a schoolteacher and the first civilian lost in the American space program. Mrs. McAuliffe and six NASA astronauts lost their lives in the launch explosion of **Challenger** *on January 28, 1986.*



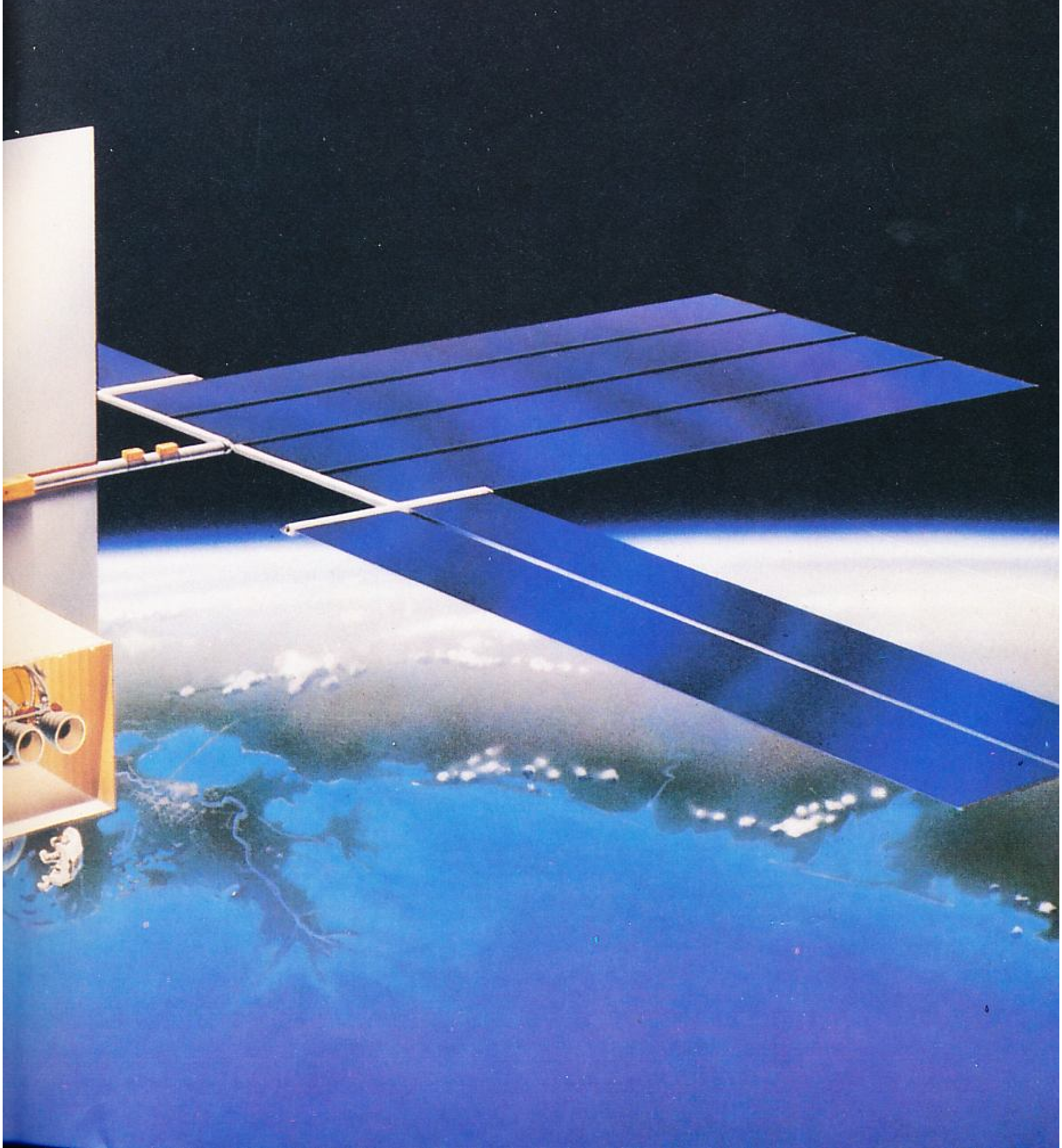
"For I dipt into the future,
far as human eye could see,

Saw the Vision of the world,
and all the wonder that would be;

Saw the heavens fill with commerce,
argosies of magic sails,

Pilots of the purple twilight,
dropping down with costly bales."

Alfred, Lord Tennyson
English Poet Laureate
(1809-1892)



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1.0 Simulation Scenario

America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanent manned space station, and to do it within a decade.

President Ronald Reagan
January 25, 1984

1.1 Historical Perspective

In 1986 the Soviet Union launched the first permanently-manned space station known as *Mir* (for *peace*). The reaction in the United States was to accelerate its own Space Station Program. In 1992, five hundred years after Columbus explored the New World, the first American space station was constructed in low orbit above Earth. After the Space Shuttle, development of a space station was the next logical step in the history of manned spaceflight. It was a development which promised major advances in fields ranging from fiber optics to pharmaceuticals. Planned and managed by the National Aeronautics and Space Administration (NASA), it was to be the prototype of future factories and laboratories in space.

It is now five years later...

The original NASA space station is half-way through its expected lifetime (10 years). It has successfully proven to the world that manufacturing and research in space are viable activities worthy of further development and exploitation. It has shown that medicines of unusual qualities can be produced in space. It proved that certain metals which could not be mixed in the full gravity of Earth, could be mixed in the near-weightlessness of space. It demonstrated that glass and alloys of unusual purity could be similarly manufactured. It also proved that there was an enormous market demand for all of those exotic space materials. In 1996, the market for space-processed materials exceeded $55 billion.

The NASA space station is also small, out-dated and inefficient. The commercial companies originally participating in the space station have realized for some time that a new, more efficient, commercial space station was needed. Space M+A+X Enterprises, Inc. (SME) was formed to meet the demand of these companies and the companies of the future to design and develop the world's first privately-funded, commercial space station.

The result is Space M+A+X-the first, purpose-built, civilian Space Station. *M+A+X* is an acronym of *M*aterials processing, *A*strophysics and e*X*perimental-the primary activities involved in the Space Station's operation.

1.2 Assignment: Space Station Project Management

As the Simulator Operator, your assignment is to direct the construction and pilot operation of the Space Station. Your responsibility will involve the planning of all payloads to be launched into orbit, the sequencing and assembly of all Space Station components, pilot production of laboratories and manufacturing, and the loading of all payloads to be deorbited and landed. You will have full authority and responsibility for the project budgeting and scheduling until it is completed, operating and accepted by the management of Space M + A + X Enterprises, Inc.

You will be well compensated for your successful efforts in the form of a generous salary, completion bonus and profit sharing scheme. Your total earnings will be in direct proportion to your degree of success in managing the space station project.

1.3 Major Constraints

- Total Project Days

  The Space Station must be assembled and operating within the *total number of days* scheduled and authorized by the Board of Directors of Space M + A + X Enterprises Inc. The Board, in their ultimate wisdom, have already contractually agreed that the M + A + X modules will be fully operational by the end of the scheduled number of days (*total project days*). The Company will suffer severe financial penalties if the Space Station is not operational in its *minimum configuration* at the end of that period of time.

- Total Project Budget

  You will be given sufficient funding to meet the capital costs and operating expenses over that period of time. This will be the *total project budget*. The funds may be expended in any manner you deem appropriate. If you are within the total project budget at the completion of the project, you will receive additional incentive payments for spending less than the amount budgeted. You may also exceed the total project budget if necessary. However, *the budget must not be exceeded by more than 10 per cent* . Clearly, the Board of Directors have placed the total project budget in second priority compared to the scheduled total project days (see the letter from the Chairman of the Board, figure 1).

- Limited Physical Resources

  You are also constrained by other limited resources which, at this time, cannot be changed due to production problems with our suppliers and contractual agreements with NASA on the use of their crews, facilities and equipment.

Figure 1 Chairman of the Board Letter →

S P A C E
M+A+X
Enterprises

1100 Milam
Houston, TX 77002

January 2, 1997

To: Client Companies

RE: COMPLETION OF CONTRACT

At our recent meeting in Boca Raton, we tentatively agreed that the Space M+A+X Space Station would be completed and operational within the period referred to as the "total project days". As you will recall, I could, at that time, give only a tentative assurance on that aspect of our contractual agreement since the selection of the project manager had not been made at that time.

I have the pleasure to announce that our project manager has been selected and that I can now confirm that the project will be completed within the period agreed to be the total project days.

By this letter, I reconfirm and acknowledge our previous contractual agreements that Space M+A+X Enterprises, Inc. will guarantee completion based upon this time frame. In the event that the project is not completed to at least the "minimum configuration" by that time and accepted by yourselves, Space M+A+X Enterprises, Inc. will then be in default of its contractual obligations. As you are aware, under the terms of our contract, the liquidated damages that will then be paid to you will be $4,550,000 per day for every day that the Space Station is not completed beginning the first day after the total project days.

We at Space M+A+X Enterprises, Inc. have every confidence in our newly-selected project manager and our team of highly trained space construction technicians. We are confident that the years ahead will be bountiful ones for us all and that our customers will benefit from our mutual efforts and far-sighted vision of the future.

Very truly yours,

R.A. Wagner

Rayleigh A. Wagner, Jr.
Chairman of the Board

RAW/vj

For example, NASA has agreed (through a lease contract) to provide four Space Shuttle Orbiters to the Company for the period of the *total project days*. Thereafter, the four Orbiters will no longer be available on a continuous basis. The more advanced "Super Shuttles" developed in the mid-1990's are already scheduled by NASA for their own projects and are not available at any time.

In general, project resources are provided as follows:

Organization	Crew/Facilities/Services Provided
NASA	Flight Crews Orbiters Solid Rocket Boosters Ground Support Equipment Ground Facilities Shuttle Carrier Aircraft
SME	Assemblers Operating Crew Flight Surgeons External Tanks Heavy-Lift Launch Vehicles Space Station Modules Consumables

1.4 Minimum Configuration

The Chairman of the Board has agreed with our client companies that there will be *at least* a minimum Space Station configuration in orbit and operational at the end of the total project days. The minimum configuration consists of all the major Space Station elements (modules) and operating crews. Sufficient consumable goods should be provided in order to remain in orbit for 90 days without the presence and support of a Space Shuttle Orbiter. This minimum configuration will then be self-sufficient in the generation of power and rejection of waste heat, provide suitable and comfortable living quarters for its operating crew and provide sufficient air, food, water, and medical and recreational facilities. It will contain at least one module for each of its major laboratory and manufacturing disciplines. In essence, it will be a small, self-supporting commercial community in space. The minimum configuration is shown in figure 2.

1.5 Module Characteristics and Functions

The characteristics and functions of the sixteen different module types appear in figure 3.

Minimum Configuration

Modules (activated)

1 Astrophysics Laboratory
1 Command
1 Experimental Laboratory
3 Habitation
1 Heat Radiator
3 Adapter
1 Materials Processing: Biological
1 Materials Processing: Electronics
1 Materials Processing: Metals-Glasses-Plastics
1 Medical
1 Pallet Rack
4 Thruster
1 Recreation
1 Remote Manipulator Arm
1 Solar Array
2 Logistics

Crew (working)

11 Operating Crew
1 Flight Surgeon

Ideally, the following 90-day supply of consumables would be stored in the Logistics, Habitation, Medical, Thruster and M + A + X Modules:

Consumables (weight in pounds)

6000	Oxygen/Nitrogen/Lithium Hydroxide ($O_2/N_2/LiOH$)
2200	Food
9000	Water (potable, hygiene, wash) and Beverages
550	Medical Supplies
4500	Liquid Hydrogen (LH)/Liquid Oxygen (LOX)
4300	Spare Parts
1350	Astrophysics Laboratory Supplies
2250	Experimental Laboratory Supplies
1300	Materials Processing: Biological raw materials
1200	Materials Processing: Electronics raw materials
33600	Materials Processing: Metals-Glasses-Plastics raw materials
2550	Emergency Supplies (personal oxygen systems, fire fighting equipment, personal rescue enclosures, emergency water, food/beverage rations)

Figure 2 Minimum Configuration

Module Characteristics and Functions

Module	Min Config	Net Weight (Lbs)	Crew Per Module	Power Consump (KW)	Heat Gener (KW)	Function
Astrophysics	1	39,500	1	8	10	Astrophysics laboratory
Command	1	42,900	1	12	16	Command, control and communication (C^3)
Experimental	1	33,600	1	8	10	Experimental laboratory
Habitation	3	31,300	–	3	3	Living quarters (four-man)
Heat Radiator	1	7,200	–	–	–175	Waste heat rejection
Adapter	3	18,500	–	3	3	Utility linkage/EVA/equipment storage
Matl Pro-BIO	1	59,900	2	19	23	MPS biological processing
Matl Pro-ELC	1	55,300	2	53	62	MPS furnace processing (electronics)
Matl Pro-MGP	1	61,800	2	11	15	MPS containerless processing (metals-glasses-plastics)
Medical	1	32,700	1*	1	3	Sick bay (* = Flight Surgeon)
Pallet Rack	1	17,300	–	5	–	External experiment storage
Thruster	4	7,000	–	–	–	Propulsion (altitude/inclination adjustment)
Recreation	1	28,100	–	1	3	Health and morale maintenance/entertainment
Rem Manip Arm	1	1,300	–	1	–	Assembly crane
Solar Array	1	20,400	–	–150	–	Electricity generation
Logistics	2	20,000	1	2	3	Consumables, waste and processed materials storage/transport

Figure 3 Module Characteristics and Functions

1.6 Client Companies

Space M + A + X Enterprises, Inc. is presently contracted with eight American and multinational companies, the European Space Agency (ESA), the National Space Development Agency (NASDA) of Japan and the National Research Council of Canada (NRCC). We are fortunate to have an international clientele on whose behalf we will be operating facilities for or who will be operating leased facilities of their own. The following is a synopsis of those organizations from which we have contracted work and their major areas of technical involvement:

COMPANY	MATERIAL	APPLICATION
Battelle Columbus of Laboratories	Collagen fiber	Repair and replacement human connective tissues
McDonnell Douglas Astronautics	Interferon	Anti-cancer drug
Johnson & Johnson McDonnell Douglas and Astronautics	Urokinase	Enzyme that dissolves blood clots in stroke phlebitis victims
3M Company	HgCdTe crytals	Computer microchips (mercury-cadmium-tellurium)
3M Company Microgravity Research Associates (MRA)	GaAs crystals	Computer microchips, solar power panels, lasers, high frequency antennas, high-conductivity applications (gallium arsenide)
TRW	Optical fiber	High-purity fiber optics for communications
Union Carbide Grumman Aerospace	Ultra-pure alloys	Turbine blades, magnetic materials, nuclear fuel rods, defence applications
General Electric Particle Technology	Latex beads	Counting blood cells, measuring particulate pollution, chemicals, paint pigments, calibration of electron microscopes

1.7 Compensation

You will be compensated in relation to your experience level and your success in completing the Space Station within the specified *total project days*. Specifically, your total earnings will be based upon the following variables:

- Salary

  You will be paid a generous base salary for each calendar day of the project.

- Completion Bonus

  Upon the successful completion of the project, you will receive a generous bonus for completing the project within the period of the *total project days*. The bonus will be based on the number of days the project actually took to complete. For every day ahead of schedule, you will receive a per diem bonus.

- Savings Bonus

  You will receive a percentage of any net savings which you may be able to achieve by the prudent expenditure of funds from the *total project budget*. For every million dollars that are not expended you will receive a fixed percentage of those savings.

- Profit Sharing

  You will receive a fixed percentage share of the profits made by Space M + A + X Enterprises, Inc. during the construction and pilot production phase of the project. This is inclusive of any profits made from the revenues generated from the leased modules and any revenues from the materials processing modules. Therefore, it is in your financial best interest to begin operating the materials processing and leased modules as early in the project as possible.

[Note: This is not a prospectus. You will be issued with a Salary and Bonus Plan which will advise you of the full details of this compensation package.]

2.0 Space Transportation System and Space Station

The Space Station is to be launched by means of the *Space Transportation System* (STS) provided under contract by the National Aeronautics and Space Administration (NASA). The STS can be configured in one of two ways depending on the vehicle to be launched. Manned missions are launched using *Orbiters*. Unmanned missions are launched using *Heavy-Lift Launch Vehicles* (see figures 4a and 4b). Heavy-Lift Launch Vehicles (HLLV) are unmanned cargo-launch vehicles and do not carry any crew. The STS consists of three primary components: Orbiter (or HLLV), External Tank and Solid Rocket Boosters.

2.1 Space Transportation System

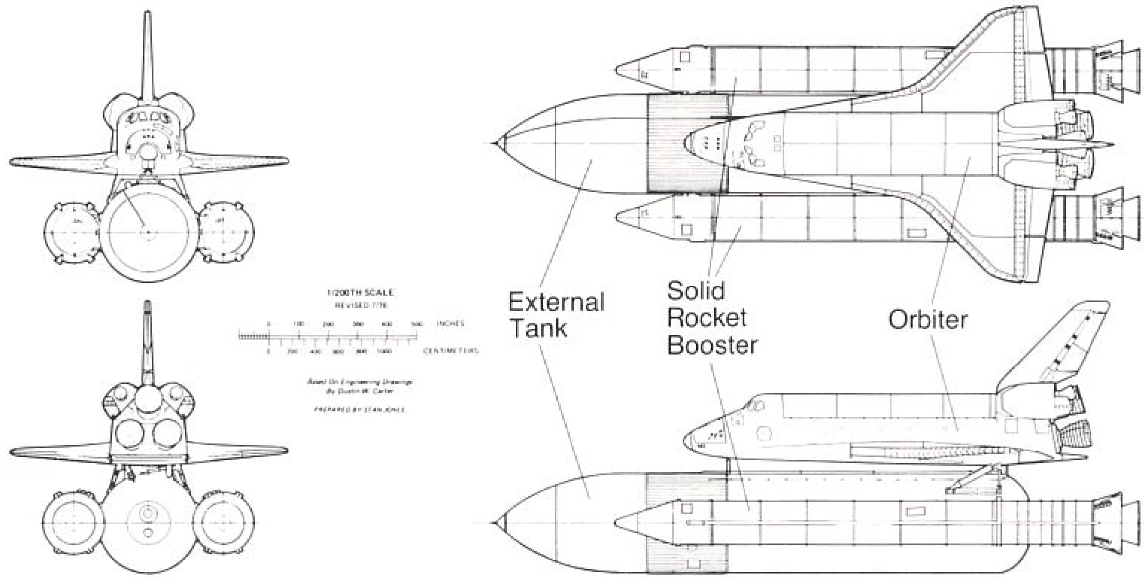
Orbiters

The Orbiter (commonly referred to as the "Space Shuttle") is the manned, payload-carrying element of the STS (figure 4a). Its mission is to transport a payload of up to 65,000 pounds into a low Earth orbit between 100 and 600 nautical miles in altitude and to return to Earth a maximum of 32,000 pounds of payload. The basic mission requirement is to carry a Flight Crew of three (Commander, Pilot and Mission Specialist) and up to four passengers into orbit for a maximum period of 30 days. The Orbiter is 122 feet in length and has a wingspan of 78 feet.

There are a total of four Orbiters provided to SME under contract by NASA. **Columbia**, **Discovery** and **Atlantis** are three of the four original Orbiters and were made operational in 1981, 1983, and 1984, respectively. **Columbia** is named after the first American ship to circumnavigate the Earth. **Discovery** is named after Captain Henry Hudson's ship which searched for the Northwest Passage. **Atlantis** is named after a research ship operated by the Woods Hole Oceanographic Institute from 1930 to 1966. The **Endeavour** was built to replace the **Challenger**, the last of the original Orbiters, which was destroyed in a launch explosion in 1986. **Endeavour** is named after the ship captained by James Cook in the discovery of Australia. The **Endeavour** was made operational in 1989. The Orbiters were built by Rockwell International Corporation in Palmdale, California.

Each Orbiter has a cargo bay sixty (60) feet in length and fifteen (15) feet in width and can accomodate payloads up to these dimensions. The cargo bay is large enough to accomodate a large tour bus. It is equipped with a Remote Manipulator System (RMS) which is used to unload payloads for placement into orbit and to load payloads to be returned to Earth. The RMS consists of a fifty (50)-foot mechanical arm with three joints. The three joints allow six degrees of freedom, similar to the human arm. The RMS has a shoulder joint, an elbow joint and a wrist joint called an *end effector*. The RMS is operated by a crew member inside the Orbiter cabin using a joystick-like hand controller. The RMS is built by Spar Aerospace in Canada under license by the National Research Council of Canada (NRCC).

2 STS and Space Station

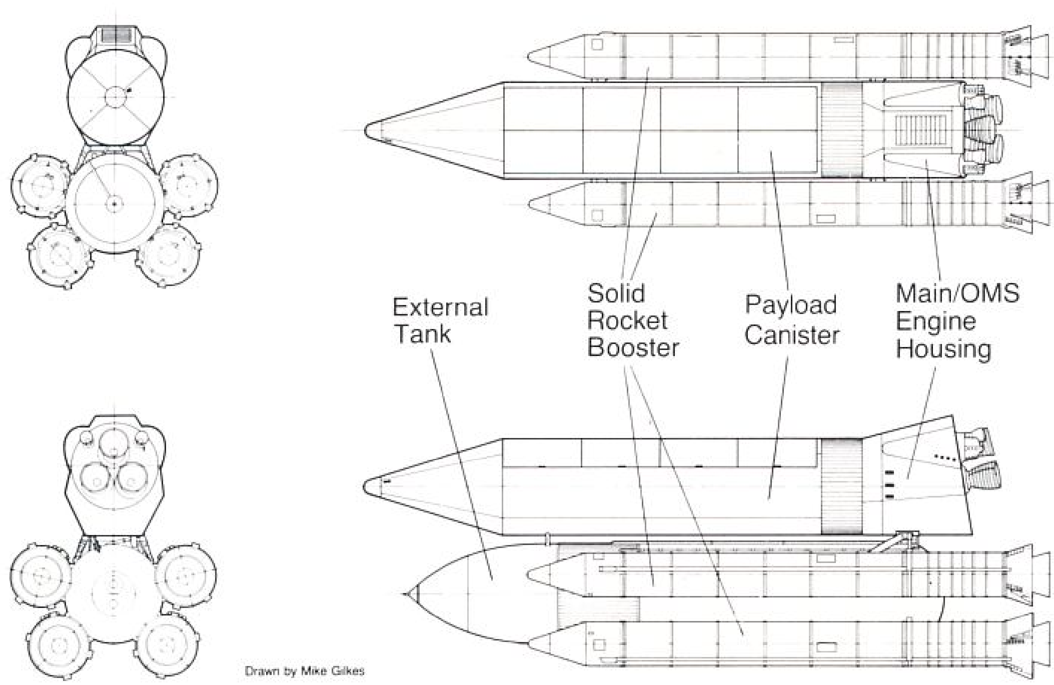


Rockwell International

North American Space Operations

Figure 4a

Space Transportation System
Orbiter Configuration



SPACE MAX
Enterprises

Figure 4b

Space Transportation System
Heavy-Lift Launch Vehicle

The Orbiter carries three main rocket engines and two orbit maneuvering system (OMS) engines. The three Space Shuttle main engines join forces with two Solid Rocket Booster engines to propel the Orbiter into near-orbital flight. The three main engines are the most advanced and powerful liquid-fuelled rocket engines in the world (375,000 pounds of thrust each). The two OMS engines are used after the Solid Rocket Boosters have separated from the Orbiter during four separate "burns" for orbital insertion and to maneuver into the approximate position for payload operations. Precise positioning is accomplished by means of the Reaction Control System (RCS), a series of smaller positioning engines. The OMS engines are used again during the deorbit stage.

External Tank

The Orbiter is mounted onto a large propellant tank called the External Tank. The External Tank (ET) is used to store the liquid hydrogen (LH) and liquid oxygen (LOX) propellants which are used by the Orbiter's main engines during liftoff (see figure 5). The External Tank also forms the structural backbone of the STS and is not reused. Once the propellants inside the External Tank have been expended, it is jettisoned and then disintegrates and burns up upon re-entry into the Earth's atmosphere. The ET is 154 feet long and 27.5 feet in diameter. It is built by the Martin Marietta Corporation in New Orleans, Louisiana. The External Tank is itself mounted onto the two Solid Rocket Booster engines.

Solid Rocket Boosters

The Solid Rocket Boosters (SRBs) are rocket engines containing solid propellants and are used to propel the Orbiter and External Tank into near-orbit during the launch phase. The solid propellant is a mixture of ammonium perchlorate (an oxidizer) and aluminum powder (the fuel). An epoxy adhesive is used to bind the oxidizer and fuel together. Each SRB is built up from four barrel-like segments held together by fasteners. Both Solid Rocket Boosters are reusable. Once the solid propellants are expended, the boosters are jettisoned and then fall back to Earth by parachute. They are then recovered at sea, reconditioned and reused in a subsequent launch. The SRBs are the world's first reusable solid propellant engines and are also the world's most powerful rocket engines (2.9 million pounds of thrust each). The SRBs are 149 feet long and 12 feet in diameter. The two SRBs support the entire weight of the Orbiter and External Tank on the launch pad.

Heavy-Lift Launch Vehicles

In the late 1980's, the increasing costs and the inherent risks of manned missions led to a requirement for a stripped-down, *unmanned* cargo lifter (figure 4b). In order to launch maximum payload weights at minimum cost, these vehicles were produced to take advantage of existing Space Shuttle technology. The objective was to minimize development cost, time and risk by using proven Space Shuttle hardware (main rocket engines, SRBs and External Tanks). The HLLV is composed of a large cargo-carrying canister equipped with rocket engines and is launched by the STS in place of the Orbiter. The HLLV engines are the same liquid-fuelled main rocket engines and on-orbit maneuvering (OMS) engines used in the Orbiter. The engines are controlled by avionics (electronic flight control equipment) carried inside the canister. The HLLV canister is mounted on an External Tank in a manner similar to the Orbiter. The HLLV is used to launch cargo payloads of up to 150,000 pounds. It is unpressurized and cannot carry passengers. The payload canister and engine housing have a total length of 187 feet and a diameter of 27.5 feet. The cargo stowage bay is 90 feet in length and 25 feet in width. A volume equivalent to two large tour buses could be accomodated inside an HLLV cargo canister.

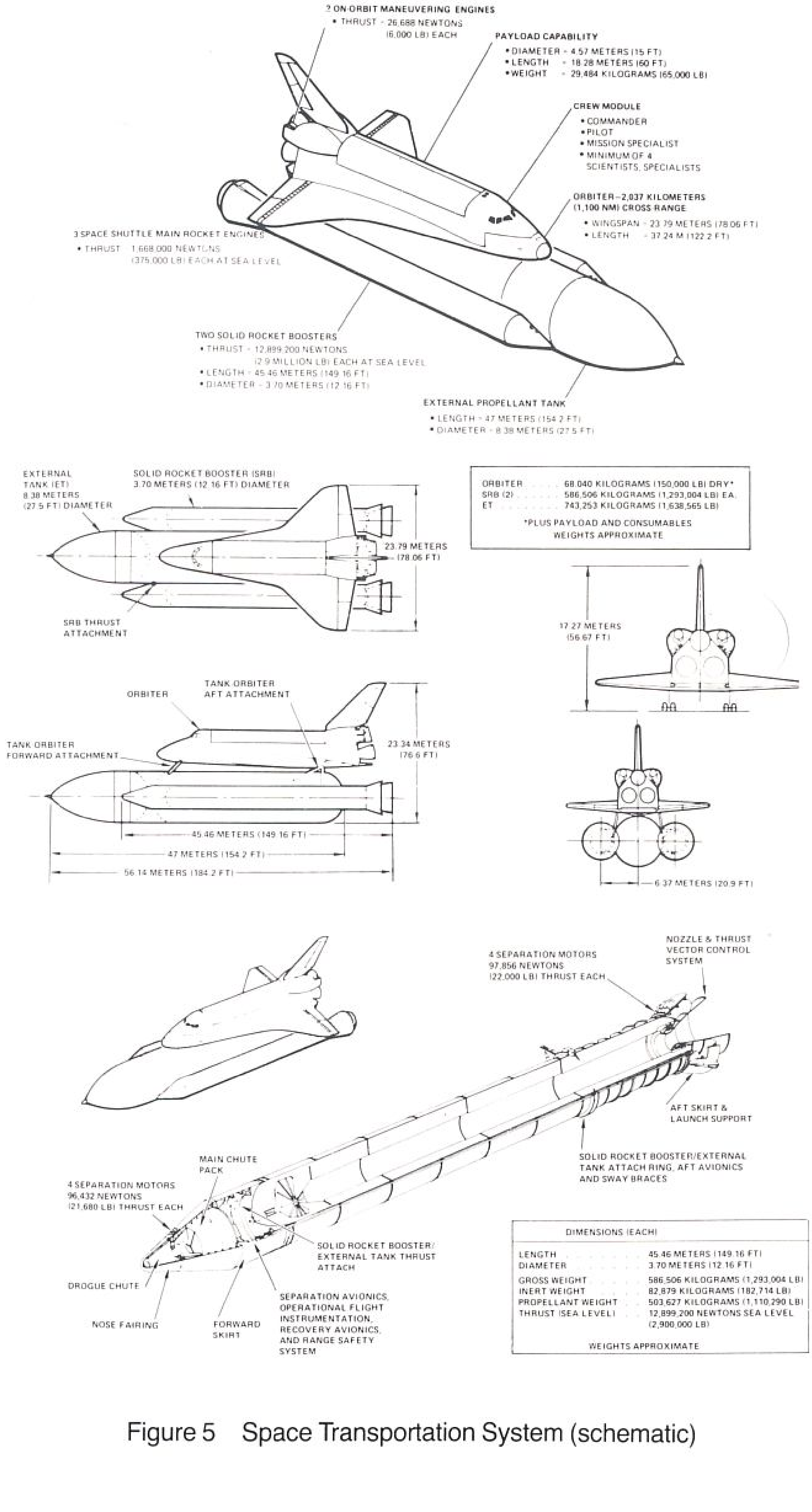


Figure 5 Space Transportation System (schematic)

Four SRB engines and an External Tank are required to launch an HLLV. Once in orbit, the HLLV canister and engines can be dismantled, salvaged and returned to Earth. The salvaged HLLV is returned to the original manufacturer and refurbished in the same manner as the SRBs. The HLLV is then shipped back to Kennedy Space Center and used on a later launch. In an HLLV launch, the four SRB engines are recovered as in a normal Orbiter launch and are provided by NASA under contract. As in an Orbiter launch, the External Tank is not recovered. The HLLV design has proven to be the more cost-effective launch vehicle in terms of cost per unit weight of payload. As a result, the Board of Directors have purchased HLLV canisters and these are now capital assets owned by the Company instead of leased from NASA. Since the External Tanks are expended, these are also Company-owned and are purchased directly from the manufacturer.

Shuttle Carrier Aircraft

The Shuttle Carrier Aircraft (SCA) are converted Boeing 747-100 airliners (see figure 6). An SCA is used to ferry the Orbiter from one location to another. The SCA is primarily used when an Orbiter has landed at Edwards Air Force Base and must be transported back to Kennedy Space Center for reconditioning and preparation for another launch. Two SCAs are owned and operated by NASA under contract to SME. The original SCA was first used in 1977. The second SCA was made operational in 1990.

Ground-Based Facilities

The Space Transportation System comprises a network of world-wide ground facilities. These include the Mission Control Center (MCC) in Houston, Texas, the Kennedy Space Center (KSC) at Cape Canaveral, Florida, three emergency landing sites, the Spaceflight Tracking and Data Network and a variety of training and support centers. The Mission Control Center at Johnson Space Center in Houston is the main mission operations center. Kennedy Space Center is the launch site and primary Orbiter landing site. See **2.20, Ground-Based Facilities**, for a more detailed discussion of all ground support centers.

Figure 6 Shuttle Carrier Aircraft

2.2 Orbiter Flight Profile

The following describes the flight profile of a typical Orbiter launch from lift-off to landing (see figure 7).

A Launch

Lift-off from Launch Complex 39 at Kennedy Space Center (KSC), Cape Canaveral, Florida

B Solid Rocket Booster (SRB) Separation

The two Solid Rocket Boosters separate from the External Tank after their solid propellant is burned. Altitude: 30.88 miles; down-range distance: 30 miles; speed: 2,875 mph. The three main parachutes of the SRBs deploy at an altitude of 2,200 feet and the SRBs are recovered at sea approximately 160 miles down range from KSC.

C Main Engine Cutoff

The three liquid-fuelled engines aboard the Orbiter are shut off under computer control at an altitude of 73.65 miles. Down-range distance is 847 miles and speed is 16,600 mph.

D External Tank Separation

After the liquid oxygen (LOX) and liquid hydrogen (LH) inside the External Tank (ET) have been burned, the ET is separated from the Orbiter. The ET re-enters the atmosphere and burns up over the Indian Ocean approximately 12,100 miles down-range from KSC.

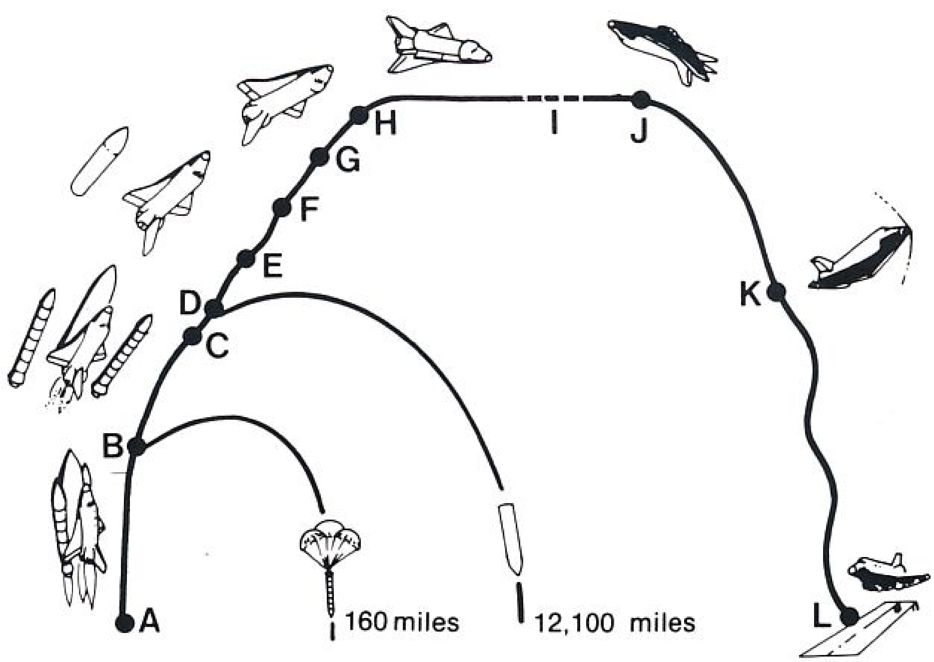


Figure 7 Flight Profile (Orbiter)

E Orbit Maneuvering System First Burn

This is the first of four *burns* of the OMS engines required for orbital insertion. The fourth burn will place the Orbiter in near proximity to the Space Station.

F Orbit Maneuvering System Second Burn

G Orbit Maneuvering System Third Burn

H Orbit Maneuvering System Fourth Burn

I Assembly of Modular Space Station

Assembly takes place at an altitude of 270 nautical miles. The payload is unloaded from the Orbiter cargo bay. The Space Station modules are assembled and activated as appropriate. See **2.5, Assembling a Modular Space Station**.

J Deorbit

The Orbiter is prepared for its return to Kennedy Space Center. The Orbit Maneuvering System (OMS) engines of the Orbiter are retro-fired. This decreases the orbital velocity of the Orbiter so that it can re-enter the atmosphere. Altitude: 270 nautical miles.

K Re-entry

The Orbiter encounters the upper atmosphere and begins the re-entry heating phase. Friction with the air of the upper atmosphere will make parts of the Orbiter glow during the critical re-entry period. The nose and leading edges of the wings are exposed to temperatures on the order of 1,260° C. Altitude: 66 nautical miles; speed: 16,465 mph.

L Landing

Touch-down at Edwards Air Force Base (primary landing site) or Kennedy Space Center (secondary landing site). Speed: 215 mph.

HLLV Flight Profile

The launch sequence of an Heavy-Lift Launch Vehicle (HLLV) is identical to that of an Orbiter with the exception that *four* SRBs are used instead of the two for an Orbiter. Stages A to H are otherwise the same as for an Orbiter. Once the HLLV is in orbit (Stage I), its payload is unloaded by Assemblers (assembly crew members) already in orbit. The HLLV canister/engines are then dismantled (salvaged), loaded into the next Orbiter returning to Earth and then landed at Edwards Air Force Base (EAF). The HLLV salvage is returned to its manufacturer to be refurbished for another launch. The only component of the STS that is not recovered for later use is the External Tank.

2.3 Shuttle System Ground Flow

Landing

The sequence of ground operations begins with the landing of an Orbiter at Kennedy Space Center (see figure 8).

Safing

As soon as the Orbiter completes its landing, the ground crew, wearing special protective suits, check the Orbiter for leaking fuel or gases. A wind-machine is used to blow away explosive vapors if any are detected. The Orbiter's skin is still quite hot at this stage. An air-conditioning unit is attached to circulate cool air through the hotter sections of the airframe. A second unit is attached to cool the crew compartment and the electronics bays. The flight crew then leaves and the Orbiter is towed to the Orbiter Processing Facility within one hour of landing. Here the Orbiter is drained of any remaining propellants and gases and all of the explosive connectors are disarmed. This process is called *safing*.

Maintenance and Checking

The Orbiter is then thoroughly checked and overhauled as necessary in the Orbiter Processing Facility (OPF). The payload from the last flight (processed materials, waste materials and salvaged materials) is removed and sent to the Payload Operation Control Center (POCC). The OMS engines are removed, refitted and reinstalled. Note: if the Orbiter had been diverted to an emergency landing site, the Orbiter would be mounted onto the Shuttle Carrier Aircraft (SCA). This is a Boeing 747 airliner specially converted for transporting an Orbiter from emergency landing sites to KSC. Typically, this additional stage would add approximately six (6) days to the Orbiter turnaround time (the time from landing to the Orbiter's readiness for its next launch).

Payload Operations

The payload for the next flight (new modules and consumables) are then loaded into the payload bay. At this stage approximately eight and one-half days have elapsed since the Orbiter landed. This phase comprises approximately 60 percent of the total turnaround time of 14 days.

SRB Recyling

Immediately after launch, the two SRB casings and the specially- designed parachutes are recovered in the Atlantic Ocean by two retrieval ships. Depending on the weather conditions, it can take from two to five days to tow the casings back over the 160 miles to Port Canaveral. Each casing is washed out, broken down into its four segments, loaded onto trailers and transported to Morton Thiokol Inc. in Utah. This requires approximately five days. The casings are then cleaned again and refilled with solid propellants. The SRBs are then loaded onto flatbed rail cars and shipped back to KSC. This portion of the cycle requires ten days since the SRBs are only transported under guard during the daylight hours to prevent sabotage or terrorism. The total SRB turnaround time is approximately 25 days.

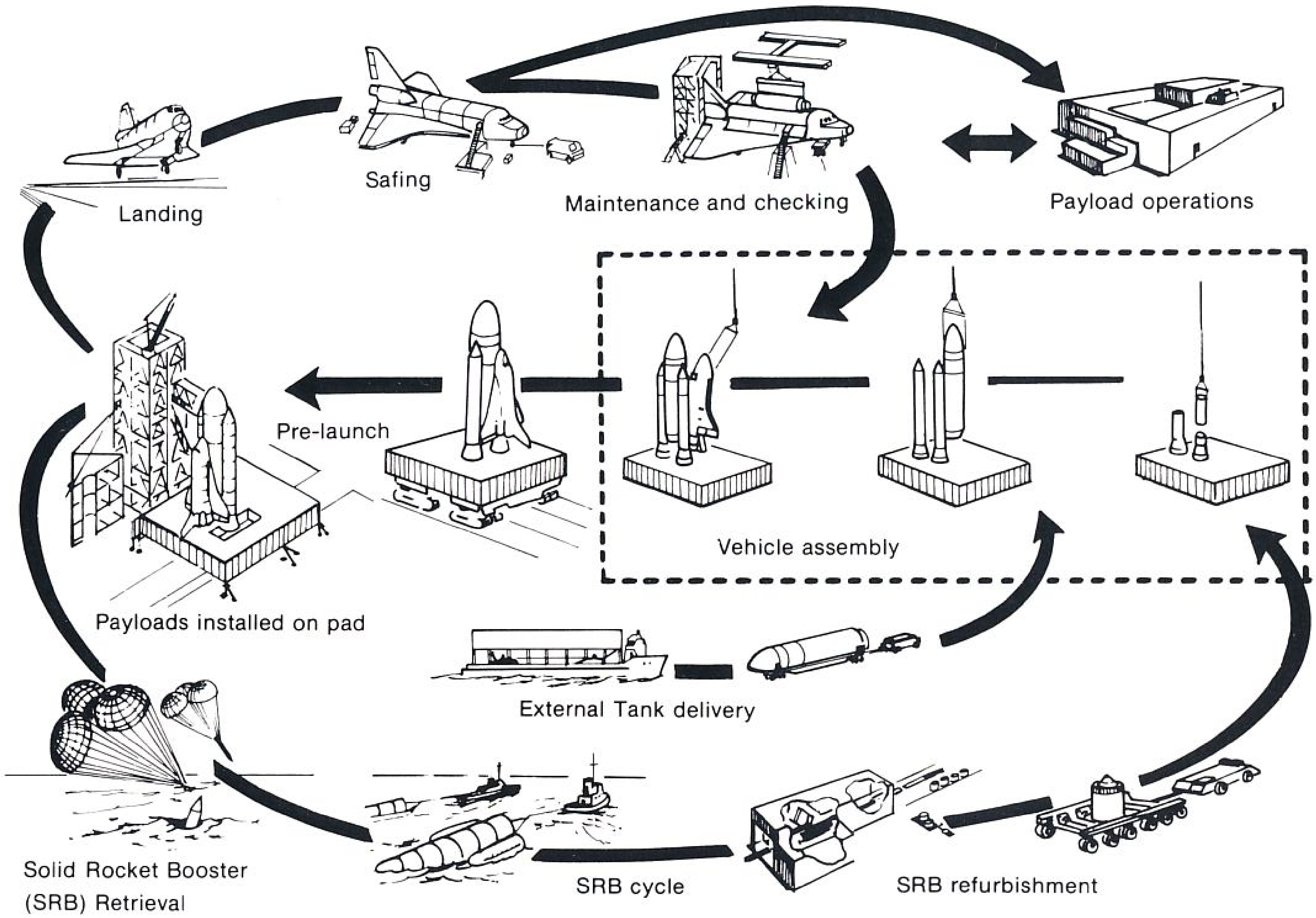


Figure 8 Shuttle System Ground Flow

Vehicle Assembly

An ET has been delivered by ship, and the SRBs have arrived by flatbed rail car from the propellant manufacturer. The Orbiter is towed from the OPF to the Vehicle Assembly Building at KSC. The Vehicle Assembly Building (VAB) is a 525-foot high assembly facility which was originally built to assemble the Saturn V for the Apollo Program. Here, the SRBs were first erected into place on a Mobile Launch Platform while the Orbiter was in maintenance in the OPF (Orbiter Processing Facility). The External Tank (ET) has also been mated to the SRBs. The Orbiter is then lifted into place and mounted onto the ET. The VAB portion of the process is scheduled to take approximately three and one-half days. Once the Orbiter has been mounted, the explosive connectors are armed. When the STS assembly is complete, the Mobile Launch Platform can then be moved.

Pre-launch

With the STS aboard the Mobile Launch Platform, it is then moved to the launch complex by the Crawler-Transporter. The Crawler-Transporter is a self-propelled vehicle used to move the STS from the VAB to the Launch Complex. Approximately two days are scheduled for this portion of the operation.

Launch

Two hours are allocated to this portion of the STS schedule (assuming a perfect launch countdown). From landing to launch, a total turnaround time of 14 days can be anticipated provided that the Orbiter landed at KSC rather than Edwards Air Force Base (the primary landing site) or one of the other emergency landing sites. Normally the Orbiter would land at Edwards Air Force Base. It would then be loaded onto a Shuttle Carrier Aircraft and transported back to Kennedy Space Center. This would add another six days, making a total turnaround time of 20 days. If the Orbiter landed at Northrop Strip or Dakar Air Base, the delays would be longer (eight to 12 days).

2.4 Crew

The crew assignments involved in the construction and operation of the Space Station are as follows. The Flight Crew operate the Orbiter and are NASA employees. All other crews of the Space Station are Company employees.

Flight Crew (Orbiter)

Commander

Has overall responsibility for Orbiter flight execution and crew safety.

Pilot

Second in command, the Pilot assists the Commander.

Mission Specialist

Coordinates payload operations and assists Operating Crew during payload unload/load operations. The Mission Specialist is not involved with the construction of the Space Station.

Flight Surgeon

A fully-trained physician/surgeon assigned to the Space Station in orbit. The Flight Surgeon is responsible for the operation of the Medical Module(s). The Flight Surgeon performs sick bay duties, attends all emergency trauma cases, prepares patients for transport back to Earth if necessary, and performs emergency surgical procedures as may be required. The Flight Surgeon is responsible for monitoring the physical and mental health of the Space Station crew.

Assemblers

These are crew members qualified to construct the Space Station. Each Assembler has been trained to perform all assembly procedures involved in the contruction project. Assemblers are not qualified to operate the Space Station. They have been trained in emergency first aid procedures only.

Operating Crew

These are crew members qualified to operate the Space Station once it has been assembled and activated. Each Operating Crew member has been trained to perform all operating procedures and are fully qualified to operate all modules except for the Medical Modules. They are not qualified to assemble the Space Station. They have been trained in first aid procedures only.

2.5 Assembling a Modular Space Station

The Space Station is assembled using a *modular* or building block principle. On the first launch of an Orbiter, the first module (or modules) will be placed into orbit (see figure 9). Using the Remote Manipulator System (RMS) of the Orbiter, the module will be unloaded and inserted into orbit. If the Orbiter is carrying more than one module, the second module will be placed adjacent to the first module. They are then docked (joined) together by Assemblers using the RMS with an attached Manned Remote Work Station (MRWS) and Manned Maneuvering Units (MMU). See figure 10. The first Orbiter will deorbit and land with the Assemblers aboard (since there are no habitable living quarters in orbit at that stage).

A second Orbiter is then launched. The second Orbiter will rendezvous with the orbiting modules. Using the MMUs, RMS and MRWS of the Orbiter, the payload is unloaded and the modules docked to those already in orbit. This modular *buildup* method is repeated until habitable living quarters can be activated. The Assemblers can then remain in orbit and continue assembly work.

Additional Orbiter or HLLV launches continue to ferry more modules into orbit. Additional Assemblers are orbited as more living space becomes available. Operating Crew members will be brought up as the various modules become functionally operational. Some modules could be fully operational even before the Space Station is completed.

A *possible*, but not the only or even an optimal, assembly sequence for the first three launches might be as follows:

First Launch

Solar Array Module
Heat Radiator Module
Adapter Module

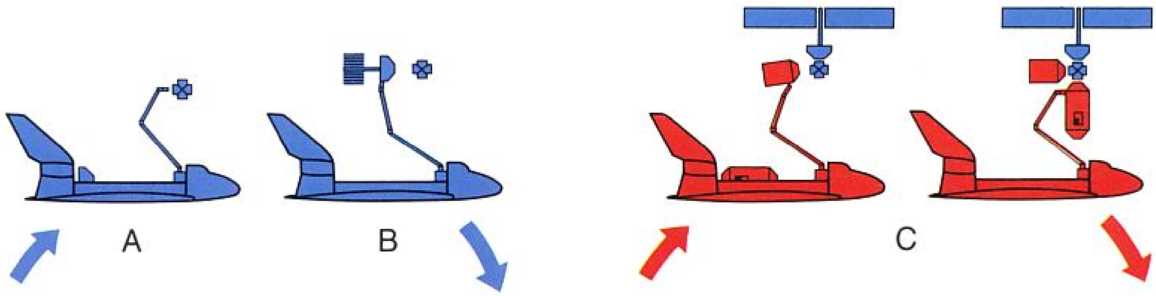
Second Launch

Command Module
Remote Manipulator Arm
Logistics Module

Third Launch

Habitation Module
Logistics Module

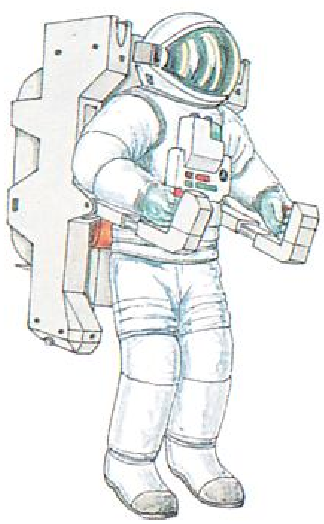
There are many other possible sequences involving various combinations of Orbiters, HLLVs and modules. The actual sequence that is used in the simulation is the responsibility of the Simulator Operator (you).



The cargo bay of an Orbiter is big enough to accommodate cylindrical modules of the Space Station for assembly on the "building block" principle. This illustrates one possible sequence of the initial Space Station buildup.

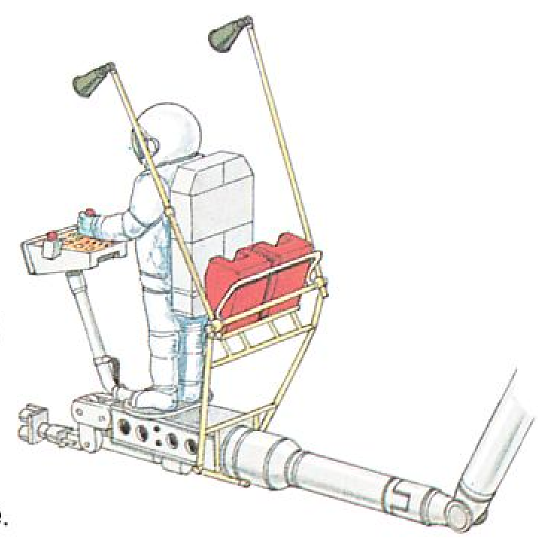
A. First module is deployed by Remote Manipulator System (RMS) of the Orbiter.
B. Second module is unloaded and docked to first module. Orbiter then returns to KSC.
C. A second Orbiter is launched and it docks two additional modules.

Figure 9 Assembling a Modular Space Station



Manned Maneuvering Unit (MMU)
Self-contained life-support backpack with small thrusters allows astronaut to maneuver in space for construction, maintenance and repair tasks.

The back cover illustration shows Astronaut Bruce McCandless during the first Spacewalk using an MMU.



Manned Remote Work Station (MRWS)
"Open cherry picker" mounted on end of a 50-foot Remote Manipulator System (RMS) or Remote Manipulator Arm (RMA). It has lights for general and point illumination, a swing-away control panel and handy tool and parts bin. A three degree-of-freedom stabiliser bar anchors the unit to the work site.

Figure 10 Manned Maneuvering Unit and Manned Remote Work Station

2.6 Activating a Modular Space Station

The Space Station is *activated* as soon as the *core* modules are assembled together. The *core* modules are those that are critical to life support and the basic utility and control functions such as electricity generation, waste heat rejection, command, control and communication. *Activation* is the condition when several modules can function together as a unit. Additional modules necessary for providing permanent living quarters can then be added so that assembly crews can be maintained in orbit without the presence of an Orbiter. Once the *living quarters* are assembled and activated, the Space Station can be manned on a full-time basis. Other modules necessary for a community in space are then added as additional Orbiters or HLLVs can ferry up the *service* modules, additional consumables and operating crews.

The *core* modules are those modules that provide the following utility, storage and control functions:

electricity generation
waste heat rejection
utility linkage and equipment storage
command, control and communication
consumables and materials storage

The *living quarters* modules provide:

sleep compartments
hygiene stations
wardroom and personal storage
galley

The *service* modules provide:

assembly crane
propulsion
sick bay
recreation and health maintenance
materials processing
astrophysics laboratory
experimental laboratory
experiment storage racks

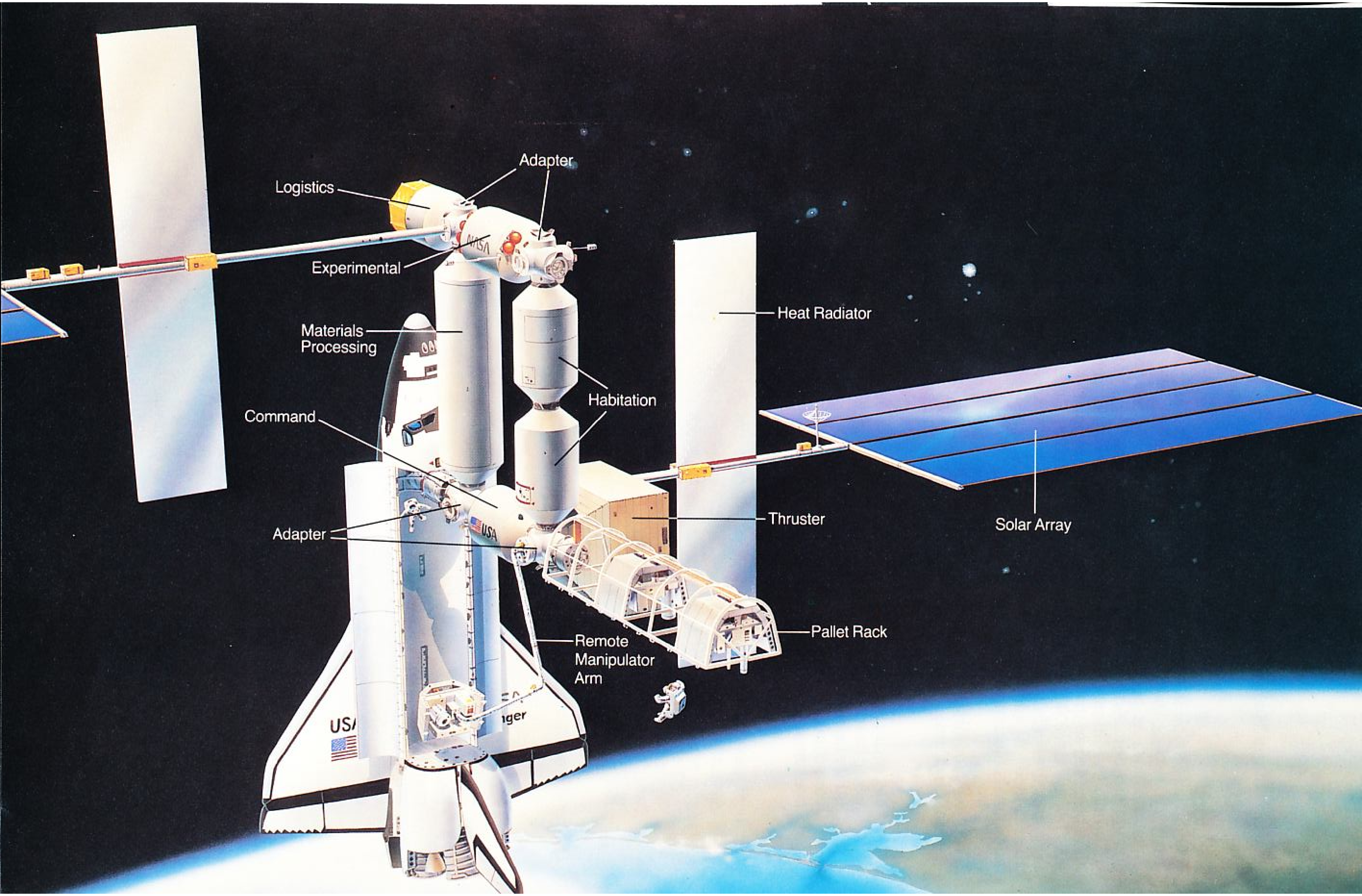

Logistics
Adapter
Experimental
Materials
Processing
Habitation
Command
Heat Radiator
Adapter
Thruster
Solar Array
Pallet Rack
Remote
Manipulator
Arm

Figure 11 is an artist's conception of an activated modular Space Station. An Orbiter has docked and two Assemblers are unloading an experiment *pallet* from the Orbiter's cargo bay. The Assemblers are using the Remote Manipulator Arm (RMA) of the Space Station in the unloading operation. The illustration shows nine modules assembled in what is called a "racetrack" configuration. This configuration, a rectangular-shaped arrangement, allows the Operating Crew easier movement from one module to another without traffic having to flow through a series of other modules.

In figure 11 the racetrack arrangement has been assembled using four Adapter Modules (one at each corner of the racetrack), one Materials Processing Module, one Command Module and one Experimental Module. The other two modules comprising the racetrack are Habitation Modules. Two Habitation Modules have been connected together to maintain a *quiet zone* within the Space Station. The pallet being unloaded from the cargo bay is being loaded into the Pallet Rack Module. A Logistics Module has been attached outside of the racetrack. Note that the Logistics Module is connected on one end to the Space Station and is free on the opposite end. This allows the Logistics Module to be removed at a later time and loaded into an Orbiter for return to Earth. Several modules are connected to Multiple Berthing Adapters including the Solar Array, Heat Radiator, Remote Manipulator Arm and Thruster. A Thruster Module is partially shown to the right of the Experimental Module.

The Space Station shown has been *activated* since it contains all of the *core* modules required to operate as a unit, namely:

Solar Array Module
Heat Radiator Module
Multiple Berthing Adapters
Command Module
Logistics Module

It also is equipped with two *living quarters* modules:

Habitation Modules

and it has five *service* modules:

Remote Manipulator Arm
Thruster Module
Materials Processing Module
Experimental Module
Pallet Rack Module

[Technical Note: This NASA drawing shows the Command Module as a 22-foot module. The simulator version shows it as a 33-foot module.]

← Figure 11 Space Station Buildup

2.7 Module Descriptions

Core Modules

Solar Array Module (electricity generation)

Electricity is generated by one or more arrays of photovoltaic cells, commonly called solar panels or solar arrays. The arrays collect sunlight and convert it to electrical energy. The utility module which generates electricity is known as a Solar Array Module. The number of Solar Array Modules would depend on the number of modules operating in the Space Station. As more modules are added, additional Solar Arrays are required. One Solar Array Module is required to operate the minimum configuration Space Station. One Solar Array Module generates 150 kilowatts of electrical power. In order to assemble a Solar Array, an Adapter Module (see below) must first be assembled and then the Solar Array docked (joined) to it. All *utility* modules must be docked to an Adapter Module. See figures 12 and 18.

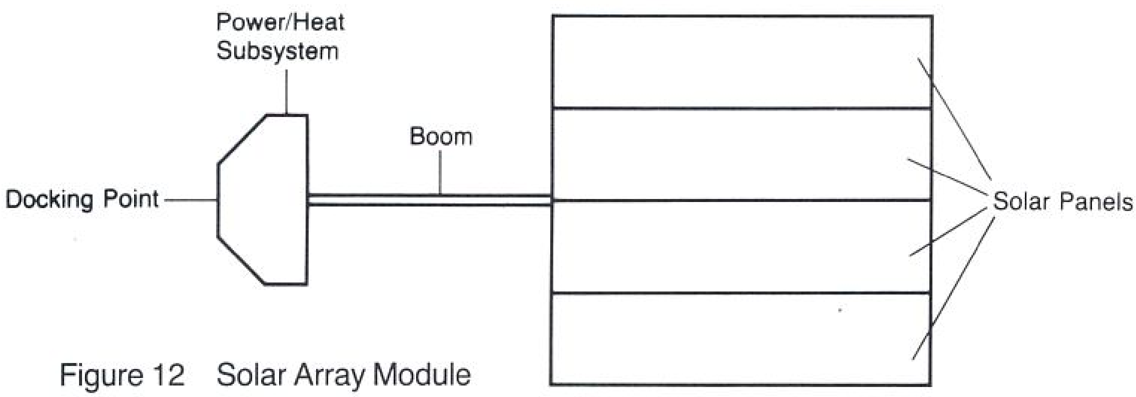


Figure 12 Solar Array Module

Heat Radiator Module (waste heat rejection)

The second type of utility module is the Heat Radiator Module. This type of module provides for the rejection of excess thermal energy (heat). This module is part of the Environmental Control and Life Support System (ECLSS) which controls temperature and humidity and allows a "shirt sleeve" working environment within the Space Station. Each Heat Radiator is capable of dissipating at least the amount of heat generated by each Solar Array plus the body heat of the crew and any solar heat transferred from the outer skin of the modules to the interiors. The Heat Radiator Modules must also be docked to an Adapter Module in order to be activated. See figure 13.

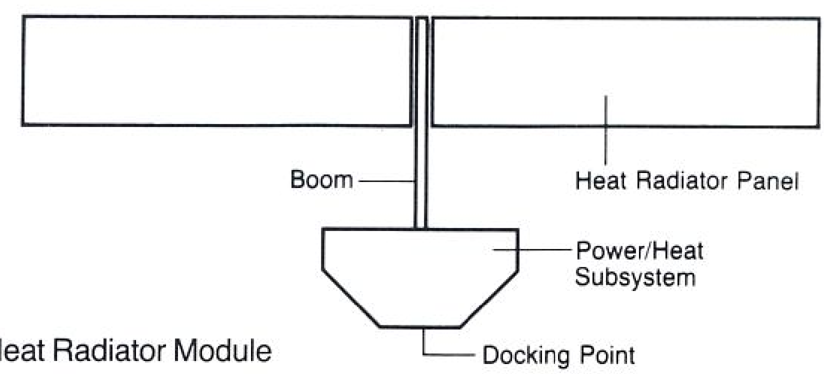


Figure 13 Heat Radiator Module

Adapter Module (utility linkage and equipment storage)

The module that all utility modules must be docked to is the Multiple Berthing Adapter (called an *MBA* or simply *Adapter*). This module has four roles. Its principle role is to connect the Heat Radiator, the Solar Array, the Remote Manipulator Arm, or the Thruster Modules to the other modules. The Adapter Module provides the electro-mechanical connectors and heat transmission equipment required to interface the main modules to the utility modules. The Adapter also contains a control panel and view port for operating the Remote Manipulator Arm (see below). Its second role is to provide a port for extravehicular activity (EVA). In this context, it is also used as an equipment storage facility for space suits. The fourth role of the Adapter Module is to serve as a *corner* module. This allows flexibility in assembling the Station, since its four docking ports are set at right angles to each other. This allows the Operator to "turn a corner" when docking one module to another (see figures 11, 14 and 18. As can be seen in figure 11, Adapter Modules are placed at the four corners of the racetrack and allow right-angle module configurations.

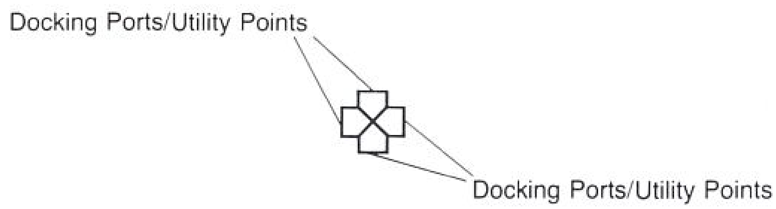


Figure 14 Adapter Module

Command Module (command, control and communication)

As its name implies, the Command Module serves as a command base, computer operations area and telecommunications center. Most of activities of the Space Station are controlled from this module. Under normal circumstances it is manned by one full-time Operating Crew member and at other times by three operators (the two Operating Crew members normally assigned to the Logistics Modules (see below). Only one Command Module is required in the Space Station. The Command Module is approximately 33 feet in length and 15 feet in diameter. See figure 15.

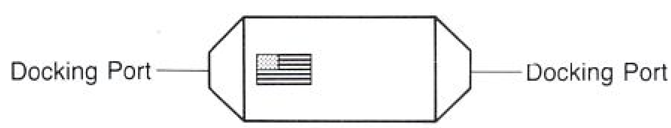


Figure 15 Command Module

Logistics Module (consumables and materials storage)

The Logistics Module is used for bulk storage of consumables, and raw, waste and processed materials. It is also used as a shipping container for transporting materials during both the launch and deorbit phases. Most of the oxygen, food, beverages, water and other fluids, spare parts, raw materials and emergency supplies are stored on or within one or more Logistics Modules. The Logistics Module is therefore a critical module in the operation of the Station and the well-being of the crew. The number of Logistics Modules required will be determined by the number of crew members, the quantity of consumables stored, and the number of modules in orbit. See **2.16, Resupply**, figures 16 and 18.The Orbiter-access end of the Logistics Modules cannot be used to dock other modules. The Orbiter-access end must be left free for the loading and unloading of consumables and materials by the Orbiters.

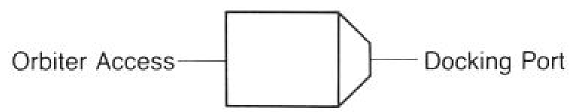


Figure 16 Logistics Module

Living Quarters

Habitation Module

A Habitation Module is the living quarters for up to four (4) Assemblers or Operating Crew members. It contains a private sleeping compartment for each person, a wardroom, storage lockers for personal effects, a shower, a waste management system, a hand wash and a galley. The galley contains a refrigerator and freezer, microwave and thermal ovens and washing facilities. The Habitation Module also is equipped with clothes washing and drying equipment. The number of required Habitation Modules depends on the total number of crew and Orbiters in orbit. An Orbiter can be used as living quarters for up to seven (7) crew (including the Flight Crew). Between the Orbiters and activated Habitation Modules in orbit, there must be sufficient numbers of sleep stations for all crew members. A Habitation Module is approximately 22 feet long and 15 feet in diameter. See **2.15, Living Quarters**, figures 17 and 18.

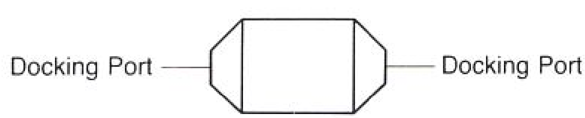


Figure 17 Habitation Module

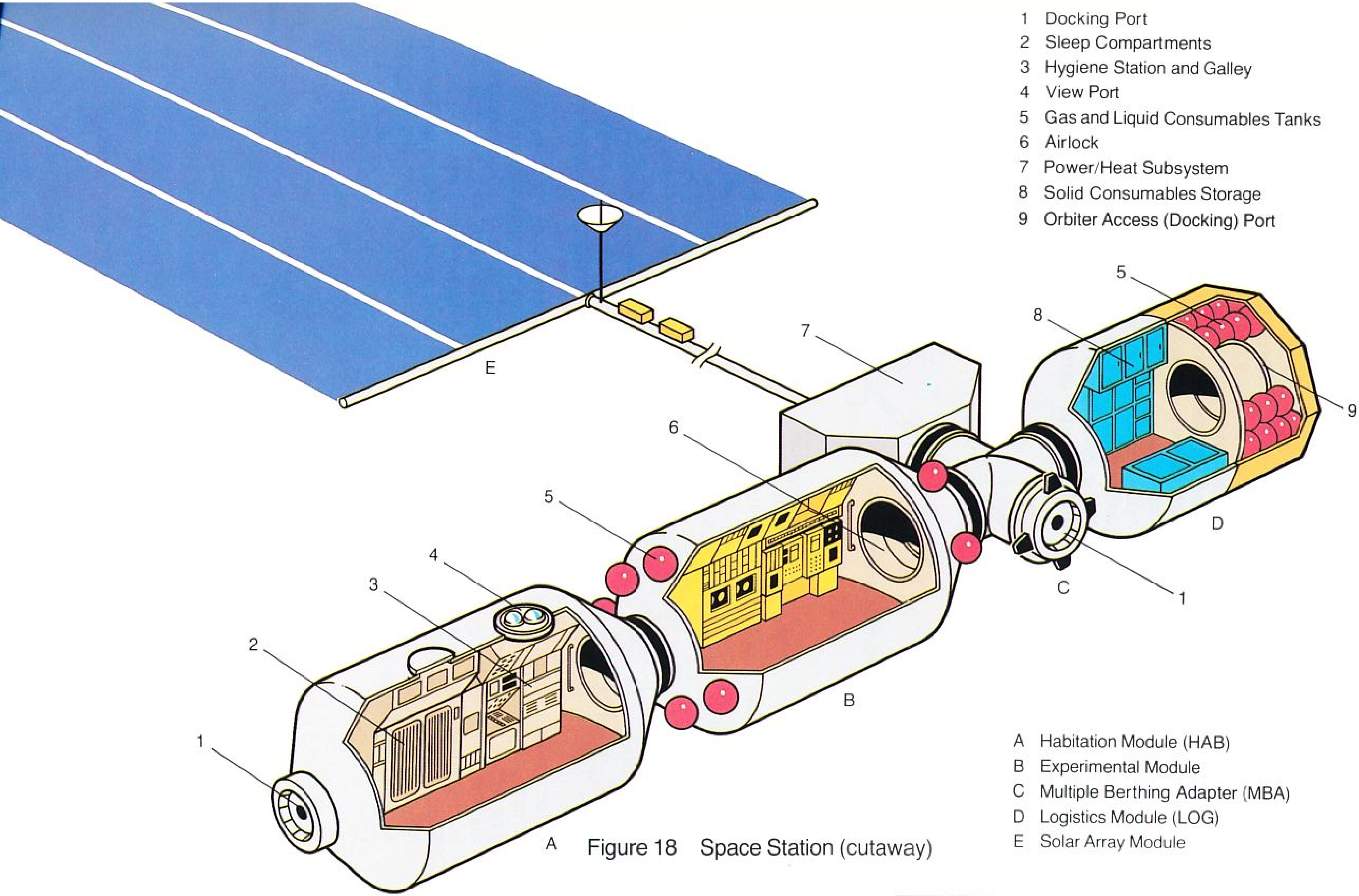


Figure 18 Space Station (cutaway)

1 Docking Port
2 Sleep Compartments
3 Hygiene Station and Galley
4 View Port
5 Gas and Liquid Consumables Tanks
6 Airlock
7 Power/Heat Subsystem
8 Solid Consumables Storage
9 Orbiter Access (Docking) Port

A Habitation Module (HAB)
B Experimental Module
C Multiple Berthing Adapter (MBA)
D Logistics Module (LOG)
E Solar Array Module

Service Modules

Remote Manipulator Arm (assembly crane)

The Canadian-built Remote Manipulator Arm (RMA) is a mechanical crane used in the assembly of modules and the positioning and removal of the Logistics Modules. It is nearly identical to the Remote Manipulator System (RMS) of the Orbiters in design, and it is also equipped with a Manned Remote Work Station (MRWS). See figures 11 and 19. In the absence of an Orbiter with an RMS, the Remote Manipulator Arm is necessary in order to assemble other modules. The only constraint is that it must be docked to an Adapter Module in order to be operated. The Multiple Berthing Adapter is the only module capable of connecting the RMA to the main modules. The RMA is operated from a control panel located in the Adapter Module to which it is docked ("fly by wire"). The RMA is 50 feet in length and approximately one foot in diameter.

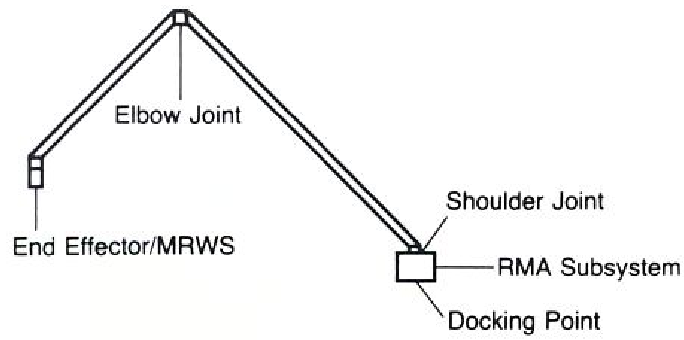


Figure 19 Remote Manipulator Arm (RMA)

Thruster Module (propulsion)

The Thruster Module is a utility module consisting of a small rocket engine which is used to increase or decrease the altitude of the Space Station or to adjust the inclination of the Station in orbit. Increasing the altitude is called *reboosting*. Decreasing the altitude is called *deboosting*. The Thruster operates as a result of the combustion of liquid hydrogen (LH_2) and liquid oxygen (LOX). Four Thrusters are required in the minimum configuration-one for reboost directed "vertically downward" (with respect to the monitor screen), one for deboost directed "vertically upward" (with respect to the screen), and two directed "laterally" in opposite directions for inclination adjustment. The Space Station must be kept within certain ranges of altitude and inclination for maximum efficiency. Typically, the altitude or inclination or both must be adjusted at least every 90 days. The Thruster must be docked to an Adapter Module to be activated. Each Thruster Module has two propellant storage tanks (LH_2/LOX). The Thruster Module is launched with empty storage tanks and is refueled from the Logistics Module. See figure 20.

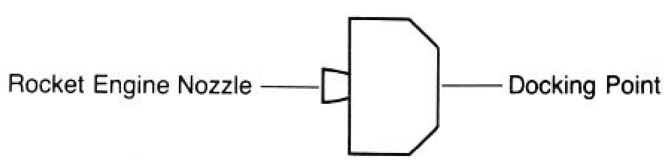


Figure 20 Thruster Module

Medical Module (sick bay)

The Medical Module contains the Space Station sick bay and emergency operating facility. Each Medical Module has two sleep stations for injured or recuperating crew members. The Medical Module is equipped with pharmaceutical storage facilities, standard physician's and surgeon's operating instruments and equipment and an emergency operating area. The operating area is used for emergency trauma (injury) care and surgery when the injured crew member cannot be immediately returned to Earth. In the event of a power (or heat rejection) failure, the Medical Module is equipped with an emergency power/heat rejection system. The Medical Modules are operated by one (or more) Flight Surgeons who are fully-trained physician/surgeons. The Medical Module is approximately 22 feet long and 15 feet in diameter. See figure 21.

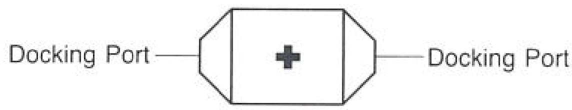


Figure 21 Medical Module

Recreation Module (recreation and health maintenance)

The Recreation Module contains all of the equipment for health maintenance and entertainment for the crew. It provides television and video equipment, stereo systems, traditional and computer games and exercise equipment. There is a "telephone booth" where crew can place and receive calls to friends and family and receive recorded messages. Four viewing ports, one with a small astronomical telescope, are also provided. There are no recreational facilities provided in any other modules including the Habitation Modules (except TV/stereo with headphones). This has been done by design to maintain a quiet zone within the Habitation Modules for undisturbed sleep and privacy. This is considered by the Chief Flight Surgeon to be critical for morale and the mental health of the crew. The Recreation Module is approximately 22 feet long and 15 feet in diameter. See figure 22.

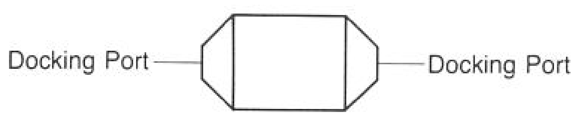


Figure 22 Recreation Module

Materials Processing (biological, furnace, and containerless)

There are three types of processes performed in the Materials Processing Modules. Biological processing involves the separation of biological materials. This type of processing is performed in a *Materials Processing-Biological* Module. Furnace processing is a type of process used to manufacture semiconductor materials for electronic equipment and is performed in a *Materials Processing-Electronics* Module. Containerless processing is a type of process where the material is suspended without coming into contact with the wall of a container. Metals, glasses and plastics are manufactured using containerless processing techniques in a *Materials Processing-MGP* (metals, glasses and plastics) Module. Each of the three module types is designed for the specialized processing operations required to manufacture the materials which are sold to our client companies. See **1.6, Client Companies**, **2.11, Materials Processing in Space** and figure 23. Each module requires two full-time Operating Crew members for maximum efficiency. All three module types require substantial amounts of electrical energy, particularly the Electronics Module in which furnace processing is conducted. The Materials Processing Modules are all approximately 44 feet long and 15 feet in diameter.

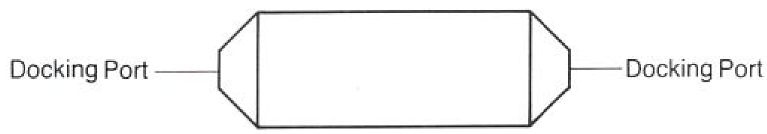


Figure 23 Materials Processing Module

Astrophysics Module (astrophysics laboratory)

The Astrophysics Module provides a pressurized, shirt-sleeve environment for the study of astrophysics (study of the Universe and the Sun as a star). The Astrophysics Module contains a variety of mannned and unmanned research equipment which is provided and owned by the lessee. See **2.12, Astrophysics** and figure 24. One full-time Operating Crew member is required either to attend the research equipment or serve as an observer. The Astrophysics Module is approximately 22 feet long and 15 feet in diameter.

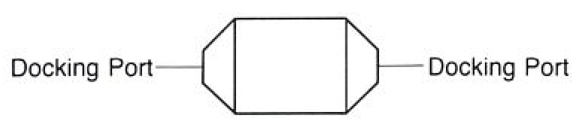


Figure 24 Astrophysics Module

Experimental Module (experimental laboratory)

The Experimental Module provides a pressurized environment similar to the Astrophysics Module for a variety of experiments conducted by or on the behalf of the scientific community by the lessee. One full-time Operating Crew member is required either to attend the experimental equipment or to serve as an observer. See **2.13, Experimental Research**. The Experimental Module is equipped with externally-mounted, storage tanks containing gases and liquids used in experimental research. The Experimental Module is also supported by the Pallet Rack Module which is used to store any experimental apparatus which must be exposed directly to space. The Experimental Laboratory Modules are approximately 22 feet long and 15 feet in diameter. See figures 18, 25 and 28.

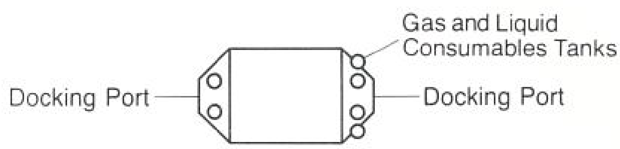


Figure 25 Experimental Module

Pallet Rack Module (experiment storage racks)

The Pallet Rack is a storage module for experimental apparatus and equipment which must be exposed directly to sunlight, cosmic rays, x-rays, the solar wind, a vacuum, or other space conditions. The experimental equipment which was originally loaded onto a *pallet* at KSC is simply placed into the rack and then activated. A *pallet* is a U-shaped, metal-frame carrier platform and has no direct involvement with the experiment. The Pallet Rack Modules are not pressurized and are approximately 33 feet long and 15 feet in diameter. The pallets are manufactured by British Aerospace in the United Kingdom. See figures 26 and 28.

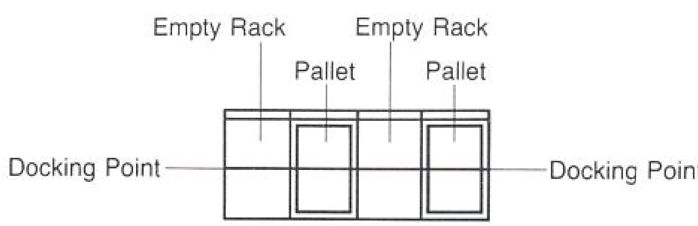


Figure 26 Pallet Rack Module

2.8 Operating a Modular Space Station

The Space Station can be *operated* as soon as the core modules are activated and the Space Station has sufficient Operating Crew, consumables and raw materials to begin work. *Operation* is the start of pilot production of the materials processing modules and laboratories and marks the beginning of on-orbit revenue generation. *Activation* and *operation* are *not* the same. *Activation* means that at least all core modules have been assembled so that they *could* be operated if materials and crew were available to do so. *Operation* means that sufficient crew and materials are in orbit and the Space Station is in pilot production.

The Space Station can operate only if the following resources are provided in orbit:

electrical power
waste heat rejection
operating crew
consumables and raw materials
habitable living and working conditions

Clearly, the Space Station can operate at *peak efficiency* only with sufficient quantities of all of the resources that are required to operate a Space Station. For example, a crew of five may be required to operate a given number of modules. But if one is ill, only four Operating Crew would be working. The Operating Crew available is then only 80% (4/5) of what it should be. Therefore, the crew could only work at an 80% level of efficiency. In such a case some of the work that one would expect to be accomplished under normal conditions would not be done. In a Materials Processing Module, for example, only 80% of the expected production of a material would actually be produced. Shortages in electrical power, heat rejection and raw materials cause similar reductions in efficiency. The operating efficiency of the Space Station is directly related to these factors. Maximum production can be achieved only when the operating efficiency is 100%. See **3.12, Daily Status Report**.

[Technical Note: under certain conditions one or more Orbiters in orbit can provide temporary, critical support services in order to *activate* and *operate* the Space Station. These services are discussed elsewhere.]

2.9 Center of Mass and Traffic

Center of Mass

Materials processing in space (MPS) is made possible by the very low acceleration due to gravity (0.0001g or less) experienced in orbit. This low gravitational force allows very high purities of processed materials to be attained (see **2.11, Materials Processing in Space**). All matter has mass, and two sufficiently massive bodies exert a gravitational force on each other. For example, the Moon exerts a gravitational force on the Earth and vice versa. Sir Isaac Newton discovered that the force of attraction of two such bodies was proportional to the product of their masses and inversely proportional to the square of their distance (Newton's Law of Universal Gravitation).

The Space Station modules also have mass, and they each exert a small gravitational force on the other modules. In constructing the Space Station, it is important to take into consideration the effect of the combined gravitational forces exerted by the module complex on the materials processing operations. The gravitational forces might be well in excess of 0.0001g in some cases. If the Materials Processing Modules are assembled under such conditions, the gravitational forces exerted by the Space Station on those operations will cause the processed materials to be of lower quality. Clearly, lower quality processed materials will command relatively lower market prices (revenues). Therefore, the Materials Processing Modules should be assembled *as close to the center of mass of the Space Station complex as possible* in order to minimize the effect of these gravitational forces. If the materials processing operations were centered exactly at the center of mass of the Space Station, all such forces would cancel out, and the processed materials would be of the highest quality.

During the assembly sequence, the Operator (you) will be advised as to the location of the center of mass of the Space Station modules as they are assembled. The final location of the center of mass will, of course, depend on the final configuration of the Space Station as assembled under the direction of the Operator.

Traffic

Traffic is the movement of crew and materials throughout the Space Station once it is activated and operational. The operating efficiency of the Space Station will depend on how well (or poorly) the modules are assembled with respect to each other. The location of one module with respect to an adjacent module is important since the activity in one may affect the activity in the other. In general, it is better to place modules of the same or similar type together rather than randomly. For example, a Habitation Module should be connected to another Habitation Module rather than a Logistics Module.

Habitation Modules are quiet zones that should not be exposed to high traffic, congestion and noise. If a Habitation Module were connected to a Logistics Module, it would be exposed to the effects of continual traffic and the loading and unloading of supplies. Likewise, it is better to connect two Astrophysics Modules together than to locate them at opposite corners of the Space Station complex. The latter arrangement could cause unnecessary traffic between the two and disturb the activities within all modules along the flow of traffic.

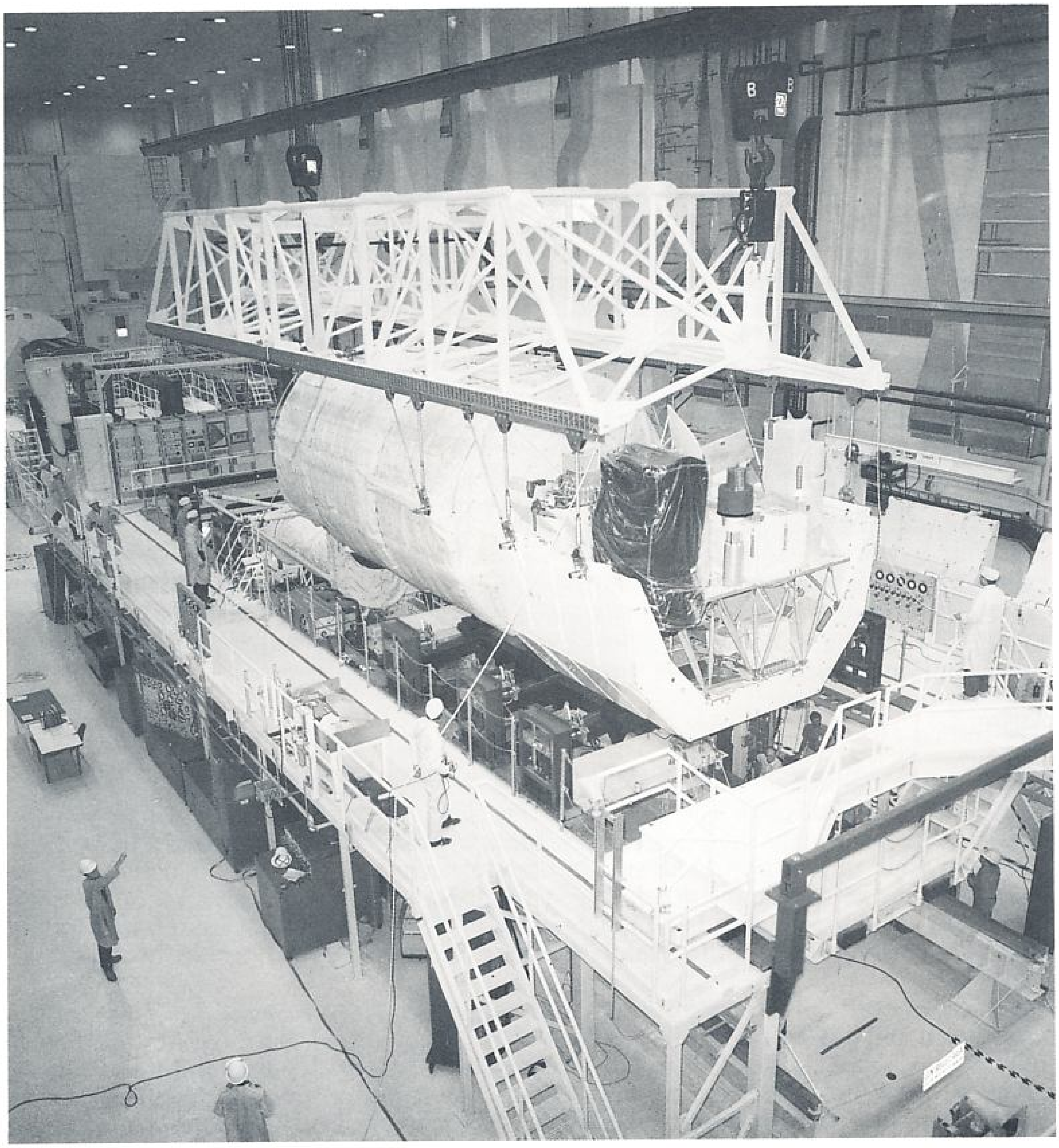


Figure 27   Space Station Module During Final Checkout

2.10 Altitude and Inclination

The Space Station is designed to operate in a circular orbit at an altitude of approximately 270 nautical miles (one nautical mile is equal to 6,076 feet or 1.15 statute miles). The Space Station is also intended to operate at an angle of 28.5 degrees from the equatorial plane. That angle is called the *inclination*.

Altitude

270 nautical miles has been selected as the nominal altitude for a low Earth orbit (LEO) space station.[1] A low Earth orbit (as opposed to a high Earth orbit or a geosynchronous orbit) is necessary since the Orbiters cannot attain an altitude of much more that a few hundred nautical miles (see **figure 34, Helpful Statistics**).

While an object is in low Earth orbit its altitude will continually decline. Orbital decay is caused by the atmospheric drag placed on the Space Station due to the very thin atmosphere at that altitude. The atmospheric drag is particularly affected by the presence of the Solar Array and Heat Radiator Modules (due to a *sail* effect). As a result a reboost will be required at least every 90 days. Reboosting can be carried out on a periodic basis (approximately every 90 days) or on a continuous basis (daily).

Inclination

The 28.5 degree inclination (28.5 degrees from the plane of the equator) has been chosen for equally good reasons. It is due to two factors. The maximum payload deliverable by the Orbiters is achieved at the 28.5 degree inclination. At other inclinations the maximum payload delivered into orbit will be less. When the Orbiter is launched from KSC in an easterly direction, full advantage of Earth's eastward rotation can be used as a "springboard". This is in sharp contrast to military launches from Vandenburg Air Force Base in California. For these launches, near-polar orbits (north-south) are required. Polar orbit launches cannot take advantage of any springboard effect. As a result the maximum payloads achievable are on the order of 40,000 pounds (40% less than eastward launches from Kennedy Space Center). Secondly, all of the materials processing, astrophysics and experimental research to be conducted at the Space Station can be performed at the 28.5 degree inclination.[2]

Although every effort is made to launch the Space Station in a perfectly circular orbit and at a 28.5 degree inclination, certain orbital irregularities can occur. These orbital eccentricities can cause the Space Station to deviate from the 28.5 degree inclination. In this event an adjustment in inclination may be required.

Altitude or Inclination Adjustment

Adjustments to the operating altitude are required at regular intervals and may be required at irregular intervals for both altitude and inclination. The altitude may be increased by the firing of a Thruster Module in the "downward" direction (relative to the

1. *The Space Station: An Idea Whose Time Has Come*, Theodore R. Simpson, IEEE Press, p. 149.
2. *Space Station Program: Description, Applications, and Opportunities*, National Aeronautics and Space Administration, Noyes Publications, p. 35.

monitor screen). This is known as *reboosting*. The altitude may also be decreased by firing a Thruster Module in the "upward" direction (*deboosting*). Inclination adjustments are made by firing additional Thrusters to either side of the Space Station ("left" or "right" relative to the monitor screen) to adjust the inclination to the 28.5 degree point. Two Thruster Modules are required to perform the altitude adjustment (one in each direction) and two additional Thruster Modules are required to perform the inclination adjustment (one in each direction). Therefore, full attitude control of the Space Station requires the presence of four Thruster Modules each pointed in its respective direction.

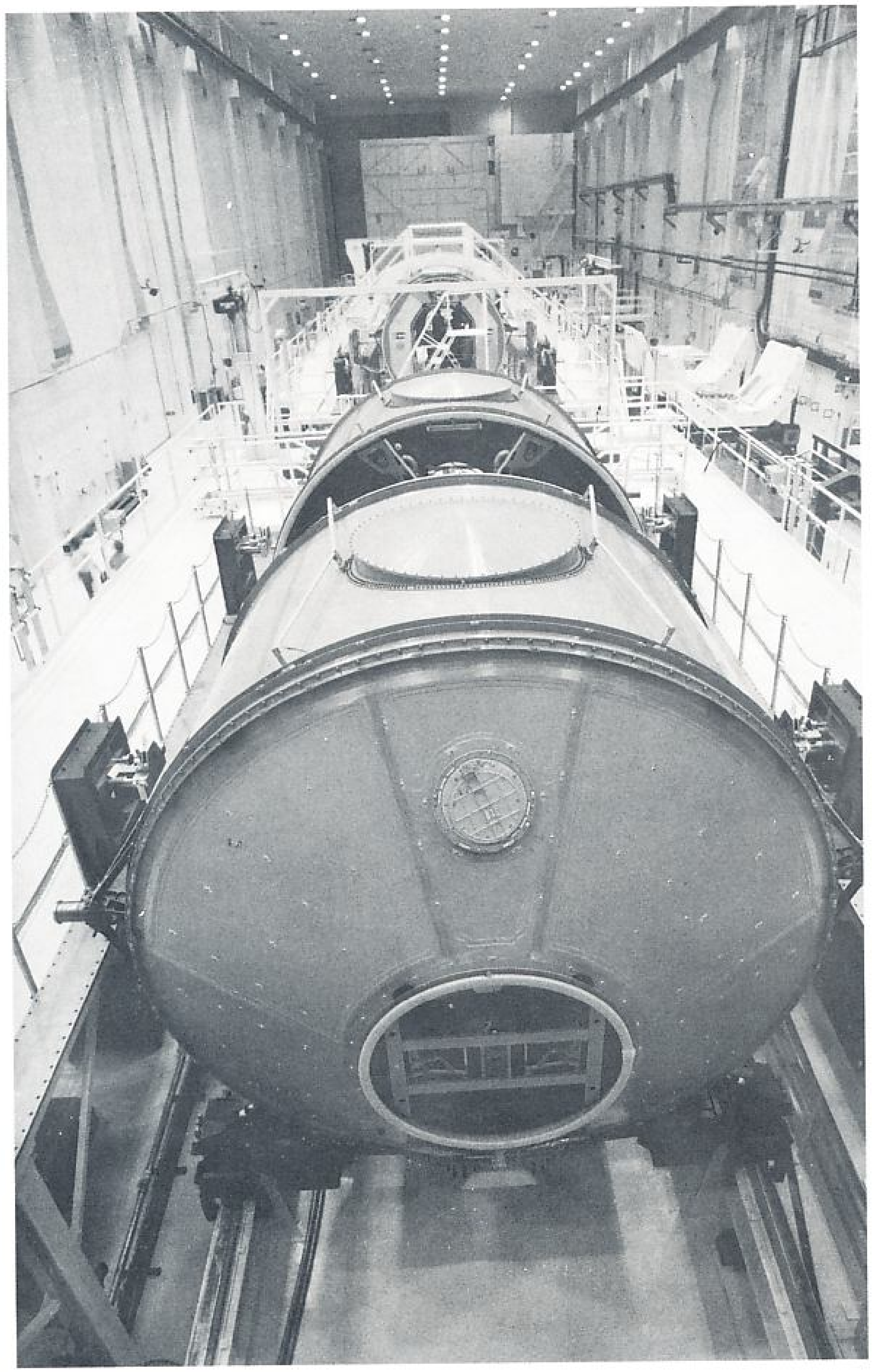


Figure 28 Experimental Module and Pallets

2.11 Materials Processing in Space

Materials processing in space (MPS) is the process of converting relatively low-value raw materials into high-value materials in the low gravity and atmospheric pressure of space. This low gravity (0.0001g) is known as *microgravity*. MPS makes use of microgravity to produce certain materials that could not otherwise be manufactured on Earth. MPS takes advantage of the *microatmosphere* in space by manufacturing in the absence of gases that cause contamination. MPS has applications in the manufacturing of drugs and other biological products, metals, crystals, ceramics, glasses, plastics, electronic components and others. There are three basic types of MPS processes: biological processing, furnace processing and containerless processing.

Biological Processing

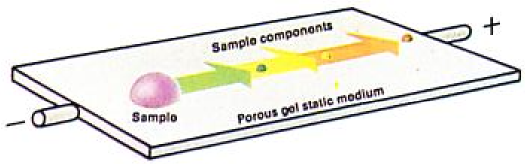
Biological processing, also known as bioprocessing, is the separation of ordinary biological materials into high-value pharmaeceuticals and chemicals. Bioprocessing typically requires the separation of specific cells, hormones, antigens, and proteins from a biological medium. In the absence of gravity, these separation processes produce drugs and chemicals of much greater purity than is achievable on the ground.

Electrophoresis is a typical separation technique where the material to be processed is exposed to an electrical charge. In electrophoresis small amounts of the material (e.g. blood cells) are separated by differences in the net electrical charges. Positive and negative potentials are applied to the material. When the electrical potential is applied, the material separates and moves toward the attracting potential. A technician then collects the separated material. This process is known as *continuous flow electrophoresis* (CFE). See figure 29. On Earth, the effectiveness of the electrophoresis technique is limited by the presence of gravity. As the material moves toward the attracting potential, it is remixed due to convection caused by gravity. In space, complete separation is achieved due to the near absence of gravity and, consequently, convective flows are virtually eliminated. MPS allows large volumes of extremely pure biological materials to be manufactured. As a result, what was previously a low-volume, high-cost material can be produced in large volumes on a much more economical basis.

Johnson & Johnson and McDonnell Douglas Astronautics are involved in the bioprocessing of interferon and urokinase. Interferon is a cancer drug, and urokinase is an enzyme that dissolves blood clots in stroke and phlebitis victims. Battelle Columbus Laboratories is involved in the manufacturing of collagen fiber, a material used in the repair and replacement of human connective tissues.

Furnace Processing

Furnace processing is used to manufacture semiconductor crystals. The raw materials are heated in an electrical furnace and are then crystalized from the melt. This process is called directional solidification. In a similar process, material is heated and vaporized and the crystals are grown from the vapor. This is called the vapor crystal growth process. Gallium arsenide (GaAs) is manufactured by furnace processing and is used in the production of computer microchips, solar power panels, lasers, and high frequency antennas. Mercury-cadmium-tellurium (HgCdTe) crystals are also manufactured using furnace processing and used in computer microchips. Furnace processing requires large amounts of electrical energy.



Electrophoresis is the movement of charged particles in solution under the influence of an electrical field.
Particles of different charges and sizes move at different rates towards an oppositely-charged electrode; it is thus especially useful for separating the different components of a mixture. Electrophoresis can be performed on a static medium on Earth (**left**), but only a small amount of sample can be treated at one time (c0·01ml). A more productive method is called continuous-flow electrophoresis (**right**). Here a sample is continuously injected into a flowing buffer solution that transports it up a rectangular chamber. An electrical field is applied across the flow, causing the sample to split into separate particle streams that exit through separate collection outlets at the top. CFES is particularly suited to the space environment because there the disturbing effects of gravity experienced on Earth, such as convection currents, bandspreading (the widening of individual streams as they flow), and the collapse of too concentrated a sample around the inlet port, are eliminated. Yields are therefore higher (by a factor of 500 in the first EOS test on STS-4) and the product purity greater.

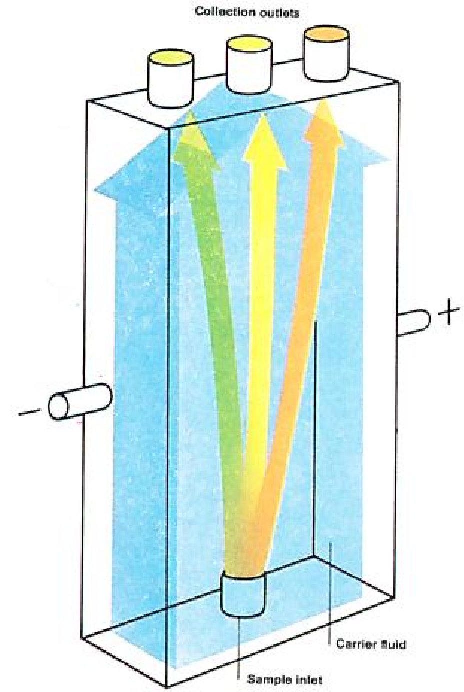
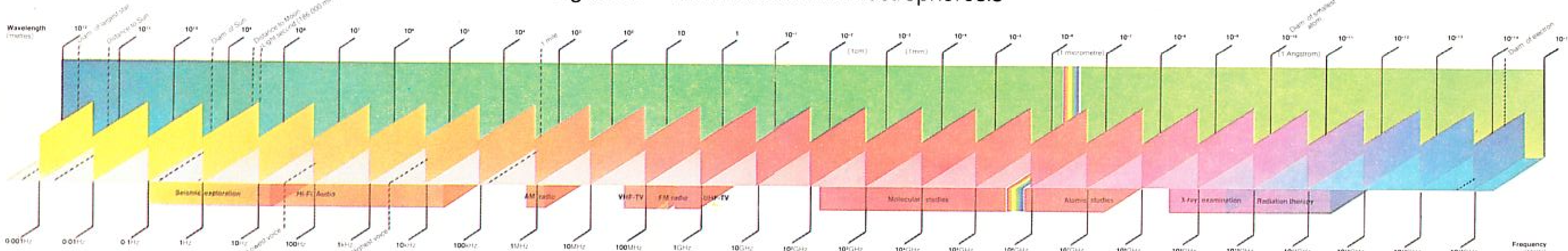


Figure 29 Continuous Flow Electrophoresis



The Electromagnetic Spectrum
Early man registered the Universe only through the visible spectrum. Science has taught us that this optical band is but a narrow slot in the total range of electromagnetic radiation. Beyond the violet end of the visible spectrum is light with waves too short for our eyes to register. We call it ultra violet light. Beyond the red end of the spectrum is a region we cannot see because its waves are too long. We call it infra red. When we switch on an electric fire and feel its heat before the element starts to glow, we are registering the effect in infra red. To see these radiations we must invent new 'eyes' (or sensors) tuned to the band of radiation we wish to examine. For example, the 'eyes' we use to detect infra red radiation, measuring an object's low heat value or the amount of thermal radiation it reflects, are called infra red radiometers. We use them in weather satellites to observe the Earth's cloud cover at night, and in interplanetary spacecraft to find 'hot spots' in planetary atmospheres. In deep space, astronomical objects (eg. stars, nebulae, galaxies) emit radiation over a wide range of wavelengths and frequencies, mostly invisible to us. (Wavelength and frequency are the units of measurement in the spectrum. Wavelength is the distance from wave peak to wave peak; frequency is the number of waves, or cycles, passing a fixed point in a given time.) Stars of different age and type emit several kinds of radiation. We can investigate these emissions only with instruments tuned to specific wavelengths. The 'eyes' which detect radio waves from the Universe are radio telescopes. But only the narrow band of the visible spectrum and some of the longer wavelengths penetrate Earth's atmosphere; to study others, we must make observations from space. This chart covers the breadth of the electromagnetic spectrum from very short, high frequency gamma and cosmic rays to very long waves of low frequency. Each major division represents a factor of ten, also known as an order of magnitude. The 28 orders of magnitude in wavelength extend from the size of the electron to beyond the distance between the Sun and Earth, called the Astronomical Unit. This dimension is small in astronomical terms. The next unit, the light year, would extend the scale five more orders of magnitude.

Figure 30 The Electromagnetic Spectrum

3M Company is involved with the production of mercury-cadmium- tellurium crystals. Microgravity Research Associates (MRA) is involved in the production of gallium arsenide crystals.

Containerless Processing

Containerless processing involves the heating, melting, cooling and solidifying of materials without the materials touching the container. The advantage of containerless processing is that, due to microgravity, the material can be suspended without coming into contact with the wall of a container. The materials are separated from the container walls by acoustic or electromagnetic forces. This eliminates any contamination that may otherwise result from such contact. It prevents premature crystallization, internal stresses, and fractures of crystals due to their own weight. Vibrations transmitted by the container walls are also eliminated. Containerless processing allows the mixture and solidification of metals, ceramics, glasses and plastics in forms and levels of purity unobtainable on Earth.

Optical fibers are replacing metal cables used for communications because thousands of telephone messages can be transmitted using just one optical fiber. Present methods of fiber optic production introduce metal and water contaminants which limit the transmission qualities of the optical fibers produced on Earth. Contaminants on the order of a few parts per billion reduce the laser light being transmitted through the glass fibers. The ultra-pure fibers produced in microgravity virtually eliminate such contaminants. As a result, optical fibers manufactured in space will be highly competitive with fibers produced on Earth and will be made in ton quantity lots. TRW is involved in the manufacture of ultra-pure optical fibers.

Containerless processing is used in the manufacture of monodisperse (i.e., all the same size) latex beads. These are extremely small and uniform latex spheres and are produced by the polymerization of latex in a solution. In normal gravity (1 g), the size of these spheres is limited due to convection flows which cause sedimentation. The beads are used in calibrating electron microscopes, particle counters and aerosol monitoring equipment. General Electric and Particle Technology, Inc. are involved in the manufacture of monodisperse latex beads.

2.12 Astrophysics

Astrophysics is the study of the Universe and the Sun as a star. The targets of study range from the Sun and the immediate environment of the Sun to the furthest quasars at the very edge of the observable Universe. The objective of astrophysics is to understand the physical laws which control the Universe. Astrophysics is concerned with every aspect of the cosmos from the smallest dead star (including black holes) to the Universe as a whole.

Visible light, x-rays and radio waves are examples of electromagnetic radiation. Astrophysics is primarily involved with the examination of specific parts of the electromagnetic spectrum (see figure 30). Stars of different types emit different types of electromagnetic radiation. By studying the radiation that is emitted, scientists can understand the nature of the star and the conditions under which the radiation is emitted. In a similar manner, electromagnetic radiation passing through interstellar or intergalactic dust or gas is either transmitted or absorbed by that medium. By studying the wavelengths that are transmitted and absorbed, an analysis of the composition of the dust or gas can be made. Astrophysics research is centered upon the study of visible, ultraviolet and infrared light, x-rays, gamma rays and cosmic rays.

Since most of the astrophysical data is received in the form of electromagnetic radiation (which reaches the Earth at most latitudes equally well), the inclination of the Space Station is normally not important. The most significant factor is that the astrophysical laboratory be located above the Earth's atmosphere which obscures most of the incoming radiation from space. Even when radiation can penetrate the atmosphere to Earth-based observatories, the atmosphere acts as a glowing background against which scientists often cannot perform their work effectively.

The Astrophysics laboratories operating in the Space Station are concerned with the following areas of opportunity.

Optical and Ultraviolet Astronomy

Optical (visible light) and ultraviolet (UV) astronomy is the observation of light from the stars after it passes through the dust and gases in interstellar and intergalactic space. By studying the visible and UV spectrum, scientists can determine the physical conditions present at the source of the light (the star) and at the point of interception of that light with the dust and gases. Quasars and pulsars both emit visible and UV light.

Infrared and Radio Astronomy

Infrared and radio astronomy involve the study of the infrared and radio (high frequency) parts of the electromagnetic spectrum. This area of study is primarily concerned with the birth of the Universe when dust and gases combined together to form stars and nebulae ("Big Bang"). Infrared astronomy is extremely limited on Earth due to the interference of the atmosphere. Radio astronomy, although virtually unlimited by the interference of the Earth's atmosphere, can be greatly enhanced in space. By having a radio telescope in space, Earth-based radio telescopes can be linked together in a large radio astronomy network. The effect is to make one massive radio telescope effectively as large as the separation of the various stations.

X-ray Astronomy

This branch of astrophysics involves the study of high-energy processes of stellar systems. Black holes and neutron stars have the mass of an entire star concentrated into a radius of only a few miles, resulting in high gravitational fields. X-rays are emitted as large amounts of matter are transferred and accelerated within these very high gravitational fields. Periodic changes in the intensity of the x-ray emissions are a source of data for analyzing the physical properties of these x-ray sources.

Gamma-ray Astronomy

Gamma-ray astronomy is the study of electromagetic radiation with a wavelength of the size of the nucleus of an atom or smaller. Typically, gamma rays have very high energies (on the order on 100 million electron volts). When gamma rays encounter the nucleus of an atom, this energy is converted into an electron and an anti-electron (anti-matter) pair. This pair then move at nearly the speed of light and in the same direction as the incoming gamma ray. Since gamma-rays can be observed from above the atmosphere only, this phenomena can be thoroughly investigated and understood.

Cosmic-ray Astrophysics

Cosmic-ray astrophysics involves the study of the origin and nature of massive electrically-charged particles which move at a velocity near the speed of light. Cosmic rays are the nuclei of atoms that have been stripped of their electrons. The purpose of studying cosmic rays is to learn how they achieve near-light (approaching 186,000 miles per second) velocities. This research will reveal the source of cosmic rays, how they were accelerated to such high velocities, and what mediums they passed through on their journey to Earth.

Solar Physics

Solar physics investigates the movement of gases on the surface and in the atmosphere of the Sun. By studying sunspots, the solar corona and flares, solar activity can be predicted.

2.13 Experimental Research

The Experimental (laboratory) Modules are leased to scientific and commercial institutions for the purpose of basic and applied research in space. Some of the research work to be performed in these modules relates to studies of plants, humans and animals in the space environment.

Life Support Systems Research

The Space M+A+X Space Station will use far more consumables than would be desirable in future, larger-scale space stations. The objective of life support systems research is to study biological systems (plants) which could be used to regenerate supplies that must presently be brought from Earth. The controlled environment life support system (CELSS) studies will investigate regenerative methods to support human crews in orbit using only plants and solar energy. CELSS will study the production of food, water, oxygen and other life-critical consumables. The results of these studies will also be used for manned explorations to the planets and asteroids, where resupply of such critical materials would otherwise be extremely difficult and expensive.

Biomedical Research

During the Mercury, Gemini, Apollo, Skylab and NASA Space Shuttle programs, various physiological changes occurred during exposure to a space environment. Astronauts experienced loss of skeletal mass, loss of bone calcium, decreased red blood cells, increased white blood cells, redistribution of body fluids, loss of muscle mass and a variety of other effects. Under a long-term exposure (e.g. in a manned planetary expedition), these physiological effects could be detrimental to the crews' health and safety. Biomedical research must be conducted on human subjects to understand these and other effects. Means must also be found to avoid or eliminate any effects which are found to be detrimental.

Gravitational Biology Research

Life as we know it has developed under the influence of a stable, protective atmosphere, constant gravity and uniform source of energy (the Sun). In order for man to live and work in space, the effect of an artificial atmosphere, microgravity and man-made energy sources must be studied and understood. Gravitational biology is the study of the life sciences in space. Biomedical research involving animal subjects will result in an understanding of bone demineralization, muscle tone loss, metabolism, cardiovascular deconditioning and other areas of biomedical studies.

2.14 Environmental Control and Life Support

Space is probably the most inhospitable environment Man has yet encountered. The human body exposed to the vacuum of space would fall victim to it in a matter of seconds. Air in the lungs of a crew member would be drained in one quick exhalation. Oxygen in the blood would likewise be lost. The hypoxia (lack of oxygen) would make the crew member giddy, his eyes would lose focus, skin would blister and blood vessels would rupture causing bruises. His brain would be dead in a matter of seconds. Contrary to popular belief, the body would not explode, but body fluids would evaporate. A crew member equipped with an extravehicular activity (EVA) space suit would not be without risk. A tear in the space suit fabric would cause loss of the protective gases and the hypoxia would be experienced.

Exposure to large doses of radiation from the Sun would likewise be lethal. A large solar flare would create sufficient radiation to cause vomiting, diarrhea and death within six days. Even lower doses of radiation could cause dehydration, emaciation and severe blood disorders.

Security from the risks of this hostile environment is not even guaranteed within the Space Station. Equipment malfunctions could create a host of life-threatening situations. A failure in the heating system could cause hypothermia, the lowering of body temperature. A malfunction in the air revitalization and carbon dioxide removal systems would mean death due to carbon dioxide poisoning. A three percent level of carbon dioxide will cause a doubling of the breathing rate and at higher levels, headaches, dizziness and nausea would be experienced. At six percent crew members would be mentally confused and disoriented. At eight percent carbon dioxide levels, convulsions would set in and at 10 percent, consciousness would be lost. [3]

Space Station life support is provided by the Environmental Control and Life Support System (ECLSS). Each pressurized module contains various elements of the ECLSS. The ECLSS provides for the recovery of water, oxygen revitalization, carbon dioxide removal and effective environmental protection during EVAs.

Water Recovery

The water supply initially launched into orbit will provide the potable, hygiene and wash water required by the Space Station for an indefinite period. All recovered water is recycled. The only water not recovered is the water vapor that is lost due to leakage into space and due to the use of airlocks during EVA. Therefore, resupply missions need carry only replacement water.

The ECLSS contained within all pressurized modules is designed to condense water vapor from the cabin atmosphere. The condensed water is then iodized and is used as wash water without further treatment. Used wash water, which contains solutions of low concentration (soap, detergents, etc.) is subjected to ultrafiltration and a reverse osmosis process and is then reused as potable water. Urine, a high-concentration solution, is processed using two low-pressure distillation techniques (vapor compression

3. *Pioneering Space: Living on the Next Frontier*, James and Alcestis Oberg, McGraw-Hill, 1986.

distillation and thermoelectric integrated membrane evaporation). The recovered water is returned to the potable water system. The by-product of the distillation is a concentrated brine that is stored in the Logistics Module and returned to Earth. Water is also recovered from fecal material using a supercritical water system in which the waste water is raised above its critical point and oxygen is injected to oxidize the dissolved organic material. The by-product is a slurry which is also returned to Earth in the Logistics Module. Liquid and solid waste materials are never vented or dumped into space except during emergencies.

Air Revitalization

Oxygen (O_2) is lost due to atmospheric leakage and during EVA activities. It is also metabolized into carbon dioxide by the crew. The Space Station is equipped with water electrolysis cells which convert recovered water vapor into oxygen and hydrogen. The cells are approximately 90 percent efficient thereby requiring replacement oxygen for only the remaining 10 percent. Replacement nitrogen (N_2) is provided by using gaseous nitrogen tanks carried in the Logistics Module.

Carbon Dioxide Removal

Two methods of removing carbon dioxide (CO_2) from the cabin atmosphere and EVA equipment are used. One process uses solid amine granules which absorb the carbon dioxide. Periodically, the granules are sprayed with steam which drives the carbon dioxide ahead of it and both are vented into space. The ECLSS also uses the standard method of exposure of the carbon dioxide to lithium hydroxide (LiOH). The lithium hydroxide removes the carbon in a chemical reaction and produces free oxygen (O_2). The lithium hydroxide method is used in the EVA equipment and as a supplementary process in the pressurized modules. The lithium hydroxide canisters must be periodically replaced by resupply missions from Earth.

Extravehicular Activity (EVA)

EVA is accomplished using a new high-pressure space suit developed by NASA in recent years. The new suit uses an oxygen/nitrogen atmosphere and is more comfortable and reliable than earlier versions. The new suit does not require pre-breathing of pure oxygen to purge the nitrogen from the wearer's body as in the old- style low-pressure, pure-oxygen suit. Lithium hydroxide is used to remove the carbon dioxide from the atmosphere.

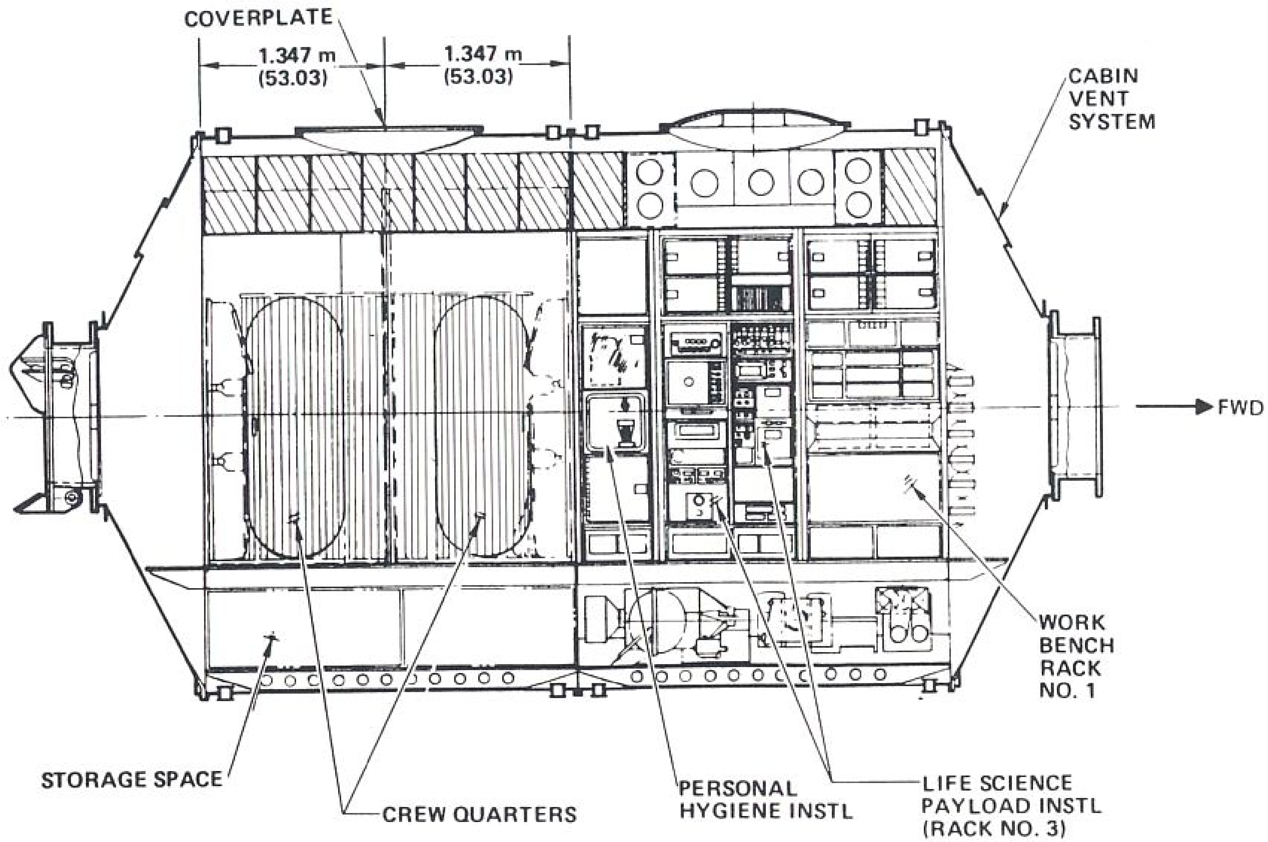
2.15 Living Quarters

Living quarters provide a comfortable environment for off-duty crew members. Whereas an Orbiter, a Logistics Module or a Command Module can provide a heated and pressurized shelter in the event of an emergency, the living quarters provide a long-term, environment and personal comfort for off-duty rest and relaxation. Each Habitation Module can provide the living quarters for up to four crew members (see figure 31). Each Habitation Module provides four sleeping compartments, a hygiene station, shower, galley and laundry facilities.

Each crew member has a private sleep compartment. The sleep compartment is equipped with a sleep restraint, heating and air conditioning, and personal stowage. The sleep compartments contain: a bulletin board, writing and reading facilities, lighting, and its own TV/stereo system for entertainment and training with earphones to minimize disturbance to other crew members. A remote communication unit is provided in each compartment for communication to other crew members throughout the Space Station. It also has facilities for shaving, tooth brushing, urinating and simple cleaning. There is a soundproof bulkhead separating the sleep compartments from other areas of the module. All other recreational facilities are provided in the Recreation Module. For example, exercise equipment, games, and other recreational facilies are provided in the Recreation Module.

There is a galley equipped with a refrigerator, freezer, thermal and microwave oven in each Habitation Module. The dining area/wardroom seats up to six crew members. There is a clothes washer and dryer. Each Habitation Module is equipped with a hygiene station, hand washer and shower. The hygiene station is the standard Orbiter-type waste management system for fecal and urinary waste. One shower and one hand washer are provided in each module.

The Habitation Module is also a *safe haven*. Emergency food, beverages, oxygen and space suits are stored within the Habitation Module. This module may be used as an emergency shelter in the event of a catastrophic event when all crew members must take refuge.



Source: McDonnell Douglas Astronautics Company

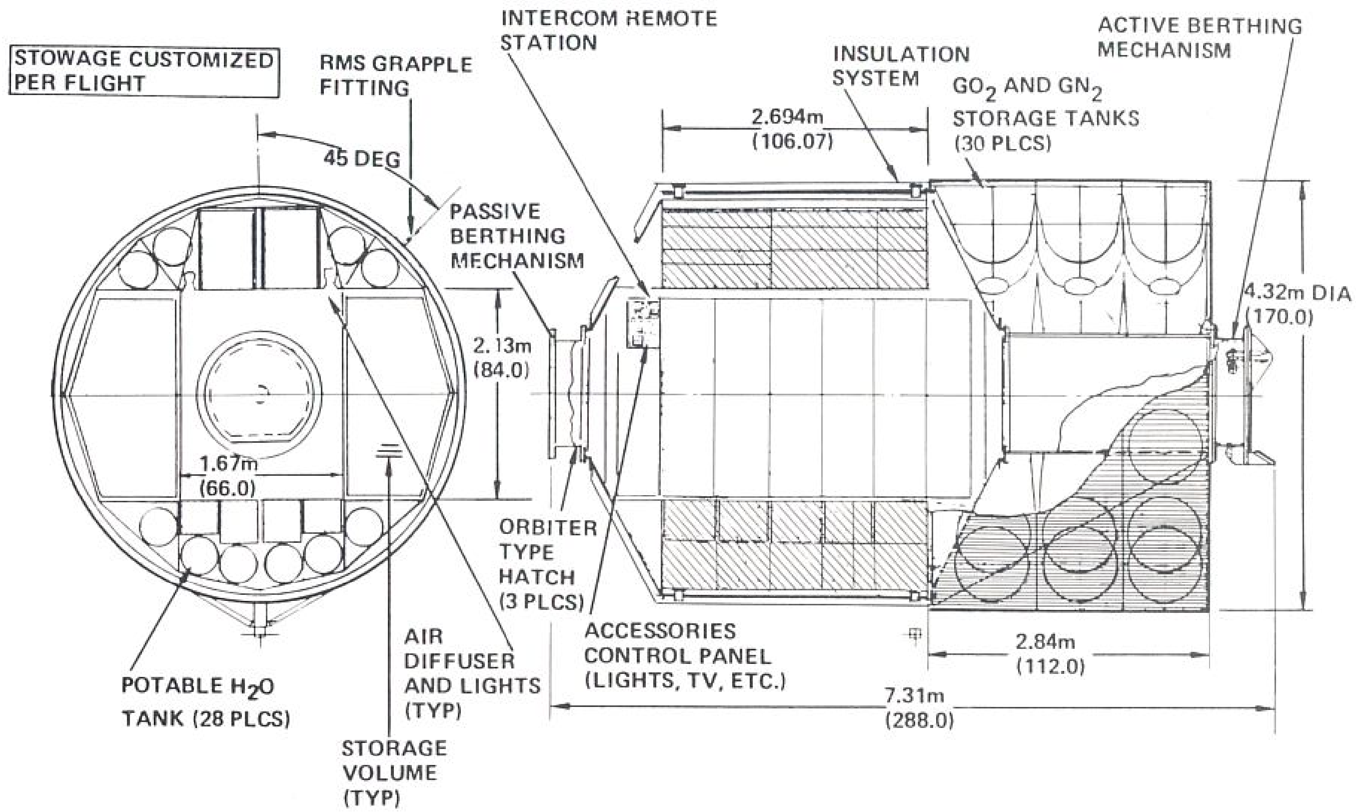
Figure 31 Habitation Module (inboard profile)

2.16 Resupply

Resupply of the Space Station is accomplished by use of the STS and one or more Logistics Modules. The Logistics Module is the shipping container used to *stow* consumables during either a launch or deorbit mission (see figure 32). Either an Orbiter or an HLLV can carry a Logistics Module. Once the Logistics Module docks to the Space Station and is activated, it then serves as a storage container for the Space Station: for consumables, processed materials and waste materials while in orbit. It can also be used as a *safe haven* during emergencies (see **2.18, Emergency and Rescue Operations**).

The Logistics Module is used in the supply of short-term and long-term consumables. Short-term consumables include oxygen, nitrogen and lithium hydroxide canisters, Thruster propellants (LH/LOX), personal equipment, sundries, and miscellaneous items. Long-term consumables include new instruments, Space Station or customer spare parts, raw materials, laboratory supplies and emergency equipment. This module is also used to return obsolete or defective equipment, waste and processed materials to Earth. For this reason the amount of materials to be delivered to orbit or returned to Earth is dependent on the carrying capacity of the Logistics Module, the carrying capacity of the Orbiter/HLLV and the number of Logistics Modules that are available for use at any given time. Each Logistics Module has a maximum payload capacity of appproximately 13,000 pounds. Resupply is required at least every 90 days.

It is Company safety policy that at least one Logistics Module be docked and activated if the Space Station is not to be Orbiter-tended (Note: *Orbiter-tended* means simply having one or more Orbiters docked or in near proximity to the Space Station in the event of an emergency).



Source:. McDonnell Douglas Astronautics Company

Figure 32 Logistics Module (inboard profile)

2.17 Habitability, Health and Safety

Habitability

Habitability, like health and safety, contributes to the physical, mental and emotional well-being of the Space Station crew. This discipline is concerned with comfort, ease of use, and avoidance of distractions and nuisances. Unlike health and safety, it is not concerned with survival. The following habitability requirements deal with the morale, physiological and psychological well-being of the Space Station crew. The requirements, although primarily concerned with the Habitation and Recreation Modules, are generally applicable to all manned areas of the Space Station:

- Habitation Module(s) shall be activated as soon as possible in order to provide proper living quarters for the crew. The use of an Orbiter as living quarters should be minimized. An Orbiter provides only survival- level living conditions and is not considered by the Chief Flight Surgeon to be acceptable accomodation over extended periods.

- Recreation Module(s) shall be activated within a reasonable period of time to provide proper entertainment and health maintenance facilities for the crew. Recreational devices such as books, computer games, TV, stereo, motion picture films, and exercise equipment shall be provided.

- A separate wardroom for crew dining and for lounging/meetings shall be provided. Interior coloring, appointments, decoration and furniture arrangements shall provide stowage, a sense of visual space, stimulation, and a soothing environment.

- Each crew member shall have a private sleeping compartment. The sleeping compartment shall be equipped with a sleep station, writing desk, bulletin board, personal stowage space, lighting, heating and sufficient space for dressing/undressing. A stereo and TV operated with earphones shall be provided.

- Private facilities for personal waste management shall be provided (urine, fecal matter and vomitus). Personal washing, showering and shaving facilities shall be provided.

- Person-to-person communication, within the Space Station and to Earth for family and friends, shall be provided (video and voice).

- Every effort shall be made to optimize the crew number and mix and to allow for both male and female crew members. Each crew member shall receive group dynamics training on Earth. An adequate command and authority structure shall be provided.

- Families of crew members shall receive training to allow them to provide a support network to the crew before, during and after their orbital duties.

- Nourishing hot and cold meals, beverages and snacks shall be provided in an appetizing and tasteful manner.

Health

- The Medical Module(s) shall be activated within a reasonable length of time after the core modules have been activated.
- At least one Flight Surgeon shall be assigned to the Medical Module (or one of the Medical Modules).
- Emergency first aid equipment and supplies shall be stored in critical areas of the Space Station.
- Sufficient medical supplies shall be maintained for emergency treatment and trauma (injury) care.
- Health maintenance facilities shall be provided in a Recreation Module to maintain a healthy and well-conditioned crew. The Chief Flight Surgeon recommends that the Recreation Module be activated as soon as possible so that the crew can maintain good muscle tone and physical conditioning. As a result of the studies conducted aboard Skylab, it is well known that bone calcium, muscle mass and blood counts deteriorate even with regular physical exercise. Any lengthy period of physical inactivity will have detrimental effects on the physical conditioning of the crew.
- All crew members shall be thoroughly screened for general physical and mental health prior to orbital assignment.
- Automated environmental hygiene monitoring equipment shall be provided and operated.
- Crews shall be returned to Earth at least every 90 days to maintain good mental and physical health. Crew members who have undergone abnormal illness or emotional disturbance shall be returned to Earth on the next deorbit mission.

Safety

- The Space Station shall be Orbiter-tended until at least one Logistics Module and one Command Module (in addition to any Habitation Module) have been activated. This is consistent with the *safe haven* policy. *Orbiter-tended* is defined as at least one Orbiter in the near proximity to the Space Station or docked at the Space Station.
- Sufficient emergency air breathing equipment, fire fighting equipment, and toxic gas detection equipment shall be provided. Each crew member shall be provided with one personal oxygen system (POS) and one personal rescue enclosure ("rescue ball").
- Procedures shall be instituted for the monitoring of Space Station attitude controls to assure proper altitude, inclination and stability.
- Provision shall be made to monitor the level of consumables and the rates of depletion of consumables. Provisions for the timely resupply of consumables shall be made.
- Procedures shall be instituted to prepare for unexpected emergencies and subsequent rescue operations.

→

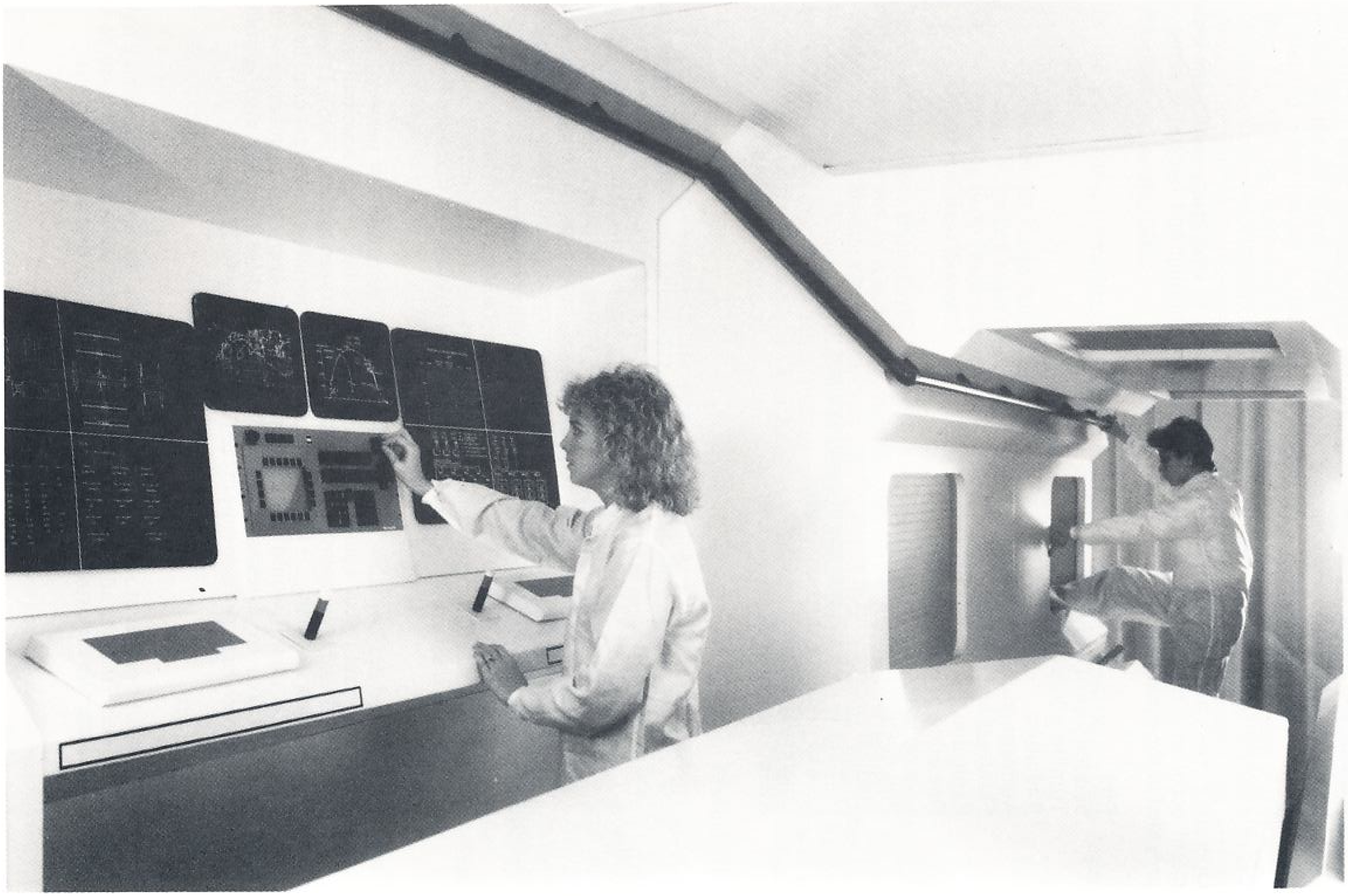


Figure 33 Habitation Module (interior)

2.18 Emergency and Rescue Operations

Operational Emergencies

Operating crews are capable of handling various types of emergency conditions which might occur in a manned space station. Emergency training and backup systems are provided in the event of: [4]

Fire
Sudden loss of cabin pressure
Tumbling/loss of control
Radiation
Atmospheric contamination
Fluid/gas leakage
Explosion
Depletion of consumables
Loss of access to any hatch
Low/high oxygen concentration
Medical emergencies
Damage to external equipment or subsystems
Loss of power or thermal control
Emergency collision avoidance
Abandonment of Space Station

Safe Havens

The Space Station is designed to provide the capablility for onboard repair and reactivation in the event of a catastrophic event such as fire, meteoroid impact or collision. In the event of such an incident, retreat positions have been provided. These *safe havens* provide a temporary refuge for the crew during such a catastrophe. The safe havens are modules specially designed to provide food, beverages, clothing, oxygen and emergency medical supplies during and after the emergency until repair work can be accomplished. The following modules provide safe haven facilities:

Command
Habitation
Logistics

Each of these modules contains two emergency space suits and ten personal rescue enclosures. A personal rescue enclosure is a 30-inch fabric ball. The rescue ball is large enough to contain one crew member and his personal oxygen system (POS). During a rescue or a situation involving air contamination, a crew member would get into the ball with his POS, and then it would be zipped closed by another crew member. The ball could then be taken to a rescue spacecraft. Each of these modules also contains sufficient consumables to provide support to the crew for up to 22 days. [5]

Rescue Operations

In the event of unforeseen or multiple catastrophic events, the Space Station may have to be abandoned. In such an event, an emergency rescue mission would have to be mounted to rescue the surviving crew. The best case would be that an Orbiter was

4. National Aeronautics and Space Administration, *op. cit.*, p. 534.
5. *Ibid*, p. 640.

currently in orbit, in which case immediate transfer to the Orbiter could take place and rescue would be direct. The worst case is that an Orbiter would be already prepared ("stacked") and loaded in the Vertical Assembly Building at KSC. That Orbiter would then have to be destacked and rolled back to the Orbiter Processing Facility. That Orbiter (or another Orbiter) would then have to be configured for a rescue mission, stacked in the VAB, processed through the integration check, rolled out and then launched. This would take 22 days. [6]

Emergency Landing Sites

In the event of an emergency deorbit, emergency landing sites have been located as follows:

Edwards Air Force Base (California)
Kennedy Space Center (Florida)
Northrop Strip (New Mexico)
Dakar Air Base (Senegal, West Africa)

Edwards Air Force Base (EAF) is considered to be the safest landing site. The Edwards Air Force Base runway is a dry lake bed (Rogers Dry Lake) with virtually no landing restrictions. The Shuttle Carrier Aircraft (SCA) would then transport the Orbiter back to Kennedy Space Center. In the event of unfavorable conditions at EAF, the Orbiter is to be diverted to one of the other sites as appropriate. Kennedy Space Center is the preferred secondary landing site. The KSC runway was extended and widened as a result of the **Challenger** disaster.

In the event of a main engine failure during the first four minutes and 20 seconds after launch, the Orbiter will return to Kennedy Space Center. This is known as a Return to Launch Site (RTLS). If the failure condition occurs after that point in the launch profile but before the Orbiter can attain suborbital flight the Orbiter will land at Dakar Air Base in Senegal. This is called a Trans-Atlantic Abort Landing (TAL). If suborbital flight can be attained, the Commander will Abort Once Around (AOA), meaning to fire the OMS and RCS engines after main engine cut-off and complete one flight around the Earth landing at Northrop Strip in New Mexico. If a main engine malfunctions late in the ascent stage, the Commander may elect to Abort To Orbit (ATO). Under these conditions the remaining main engines will be fired longer than usual and a lower-than-expected orbit will be attained. Deorbit, reentry and landing would then be accomplished as usual.

6. National Aeronautics and Space Administration, *op. cit.*, p. 598.

2.19 Weather

Weather plays a central role in scheduling the launches of the Space Transportation System and landings of the Orbiters. It also affects the movement of the Shuttle Carrier Aircraft on flights to Kennedy Space Center. Kennedy Space Center is located on the east coast of the Florida peninsula and is affected by the subtropical climate of the Carribean region. Rain and thunderstorms, gale force winds and occasional hurricanes have frequently delayed Space Shuttle launches.

The Thermal Protection System (TPS) of the Orbiters is subject to serious damage during rainstorms or other unfavorable weather conditions. The TPS is composed of high-temperature insulation tiles which cover those surfaces exposed to re-entry heating. The TPS tiles weaken and can be damaged due to the impact of rain at launch velocities. Weather at Cape Canaveral can also be unseasonably cold. Icing conditions (with temperatures as low as 24° F) have been experienced during launch countdowns. Icicles have been known to form on the launch pad gantry and on the STS itself. It is possible that damage could be done to the tiles (or even the External Tank) during launch due to icicles breaking off from the Orbiter and striking the vertical stabilizer or engine housing. The manufacturers of the SRB (Morton Thiokol, Inc.) recommend that propellants be ignited only between 40° F and 90° F and that the fuel's temperature never fall below freezing. Freeze-thaw cycles could damage the internal seals and the fuel adhesives of the SRB propellants.

Winds on the order of 35 mph and more (low gale force) have been experienced at Kennedy Space Center during launch countdowns. For safety reasons high winds have postponed numerous launches due to the standard safety procedures practiced by NASA. In the event of an RTLS (Return to Launch Site) emergency condition, the Orbiter would be forced to land at the KSC runway. Even crosswinds as low as 35 mph could cause a crash landing. During a landing, the Orbiter is unpowered and is, effectively, a very heavy glider. For these reasons, launches, landings and SCA flights should not be made during unfavorable weather conditions. The primary landing site of the Orbiters is Edwards Air Force Base (EAF) due to its more predictable weather (and unobstructed landing conditions). If the weather at EAF is unfavorable, the Orbiter should be diverted to another landing site.

The emergency landing sites at Kennedy Space Center, Northrop Strip and Dakar Air Base, Senegal (West Africa) are also subject to occasional inclement weather. Senegal is the emergency landing site if the main engines fail on a launch from KSC and the Orbiter is unable to RTLS or AOA (Abort Once Around the Earth and return to Northrop Strip). Launches are typically postponed if weather conditons in Spain or northwest Africa are unacceptable. Dust storms in Senegal have caused postponements of STS launches. Likewise, landings cannot be made at Northrop Strip or Edwards Air Force Base during stormy weather. Even though these landing strips are in a desert climate, they are both subject to heavy rain on occasion. The landing strip at Edwards Air Force Base is a dry lake bed and is likely to become muddy after a rainstorm.

2.20 Ground-Based Facilities

With the exception of the Payload Operation Control Center (POCC), the One-g Trainer, and the Space Station System Trainer (SSST), all of the ground-based facilities in direct support of the Space Station are provided by NASA under contract to the Company. The following is a summary of all major ground-based facilities supporting the Space Station project.

Mission Control Center (MCC)

The Mission Control Center is the primary point of communication and control with the Orbiters and the Space Station. The MCC maintains overall control of launches, operations, and landings. The MCC is located at the Johnson Space Center in Houston, Texas.

Payload Operation Control Center (POCC)

The POCC is a Company facility owned and operated by SME. The purpose of the POCC is to control the payloads being prepared for launch, to control landed payloads and to receive and process proprietary Company communications and data transmitted to and from the Space Station. This facility is equipped with communications equipment to ensure that Company confidental data is kept secure. The POCC is located at Kennedy Space Center, Florida.

Space Station System Integration Facility

This NASA facility is used to process and integrate Space Station modules. The facility provides environmental control for cleanliness, storage of flight hardware, and checkout equipment. Once the modules are checked and integrated, they are sent to the Orbiter Processing Facility. See figure 27.

Orbiter Processing Facility (OPF)

The Orbiter Processing Facility, located at Kennedy Space Center, is the primary facility for unloading the payload of a landed Orbiter and loading new payloads for the next launch of an Orbiter or HLLV. In the mid-1980s the OPF had two working bays each supporting one Orbiter during processing. In the early 1990s two additional bays were added, allowing four vehicles (Orbiters or HLLVs) to be processed at the same time. Refer to **2.3, Shuttle System Ground Flow** for more details.

Vehicle Assembly Building (VAB)

The VAB is the facility in which the Orbiter is mounted onto the External Tank and Solid Rocket Boosters just prior to launch. It is within this facility that the horizontally-loaded Orbiter (or HLLV) is rotated to the vertical and mounted to the STS. The entire STS is assembled on a Mobile Launch Platform within the VAB. In the mid-1980s there were two high-bay assembly stations in the VAB. In the early 1990s two more stations were added allowing four vehicles (Orbiters or HLLVs) to be assembled at the same time. Adjacent to the VAB is the Launch Control Center (LCC). The Launch Control Center contains four separate firing rooms each dedicated to one of the four vehicles being processed.

Crawler-Transporter

The Crawler-Transporter is a self-propelled, tracked vehicle which is used to move the Mobile Launch Platform and the STS from the VAB to the launch pad. The Crawler-Transporter has two diesel engines driving eight tracks. The Crawler-Transporter moves at a maximum speed of two mph and is the world's largest land vehicle. In the mid-1980s there were two Crawler-Transporters and in the early 1990s two more were placed in service.

Launch Complex 39

The launch pad provides support to the STS and payloads prior to and during launch. The launch pad consists of two primary parts: the fixed service structure and a rotating service structure. The rotating service structure can roll into place to surround the Orbiter or HLLV. Around the pad are liquid hydrogen and liquid oxygen tanks which are used to fill the External Tank. In the mid-1980s there were two Space Shuttle launch pads, 39A and 39B. In the early 1990s 39C and 39D were put into service, allowing four separate vehicles to be processed at the same time.

Logistics Module Facility

The Logistics Modules will resupply the Space Station at least every 90 days. This facility provides for module repair and refurbishment, maintenance and preparation for the next resupply mission. The facility is also a warehouse where sufficient quantities of all of the consumables (except hazardous materials) carried in the Logistics Modules are stored.

Hazardous Materiel Facility

Space Station payloads and components considered as hazardous will be processed in this facility before or after flight. Liquid hydrogen (LH) and liquid oxygen (LOX) would typically be processed here and delivered to the launch complex to be installed in the Logistics Modules carried in the Orbiter or HLLV.

One-g Trainer

This is a full-scale, training mockup of each manned module. Each module is equipped with operational lighting, sleep compartments, EVA stations, waste management, and support equipment. It is owned and operated by the module manufacturer and is located at their main manufacturing facility in California. All crew members are trained at this facility prior to orbital assignment.

Space Station System Trainer (SSST)

This is a Space Station module simulator equipped with flight-type hardware and software. All communications, computer and support equipment have been incorporated into the simulator. The module interior geometry is closely approximated within the simulator although it is not a full-scale module mockup. This facility is also owned and operated by the module manufacturer.

Weightless Training Facilities

These NASA facilities provide a weightless environment training facility and a neutral bouyancy simulator. Access to the NASA KC-135 is available. The KC-135 is a research aircraft (B-707 type) which flies in a parabolic trajectory and thus achieves weightlessness for its passengers for approximately 30 seconds.

Altitude Chambers

These NASA facilites provide a high-altitude simulation for training crew in EVA activities. The very low pressures simulate the space environment.

Spaceflight Tracking and Data Network (STDN)

The STDN is an international network of 15 ground-based stations. Twelve of the stations track manned Earth-orbital missions. Three special-purpose stations (including the NASA tracking facility at Goldstone in the Mojave Desert, California) are used to track NASA Space Shuttles and Space Stations . The STDN combined with the Tracking and Data Relay Satellite System (TDRSS) provide virtually full-time communications coverage for the Space Station.

Emergency Landing Sites

Several runways have been designated as Orbiter landing sites. During a launch emergency one of two landing sites are to be used: Kennedy Space Center for a Return to Launch Site (RTLS) and Dakar, Senegal (western Africa) in the case of a trans-Atlantic abort. In the event of an emergency deorbit, Edwards Air Force Base in the Mojave Desert, California and Northrop Strip at White Sands, New Mexico may also be used. Vandenburg Air Force Base (California) is not to be used due to security restrictions. (Vandenburg Air Force Base is used only for military Space Shuttle missions).

Helpful Statistics

ALTITUDE	Nominal altitude of Space Station: Maximum altitude of Orbiters: Atmospheric reentry:	270 nautical miles 600 nautical miles 66 nautical miles
INCLINATION	28.5 degrees	
CREW PROFILE	Commander, Pilot, Mission Specialist and four passengers	
ORBITERS	Number of Orbiters: 4	
	Orbiters:	**Atlantis** **Columbia** **Discovery** **Endeavour**
PAYLOADS	Maximum launch payload – Orbiter: 65,000 pounds Maximum landing payload – Orbiter: 32,000 pounds Maximum launch payload – HLLV: 150,000 pounds Maximum Logistics Module payload – 13,000 pounds	

EXTERNAL TANKS (ET):	Required per launch: 1 (Orbiter or HLLV; expendable)
SOLID ROCKET BOOSTERS (SRB):	Required per launch (Orbiter): 2 Required per launch (HLLV): 4 (reusable)
LAUNCH SITE:	Kennedy Space Center (Florida)
PRIMARY LANDING SITE:	Edwards Air Force Base (California)
EMERGENCY LANDING SITES:	Kennedy Space Center (Florida) Northrop Strip (New Mexico) Dakar (Senegal, western Africa)
SHUTTLE CARRIER AIRCRAFT	Number of SCAs: 2

CONSUMABLES: (90 days)	Oxygen/nitrogen/lithium hydroxide	
	O_2/N_2/LiOH required per crewman:	500 pounds
	Water/Beverages	
	Potable, hygiene and wash water required per crewman: Beverages per crewman:	600 pounds 150 pounds
	Food per crewman: (frozen/dehydrated/dry)	180 pounds

Figure 34 Helpful Statistics

3.0 Operating Instructions

It is strongly recommended that the following chapter be read thoroughly. The lives of crew members and the security of valuable resources depend on your knowledge and understanding of the Space Station assembly and operation procedures.

3.1 Project Management

Your assignment, as Simulator Operator, is to manage the resources of the Company so that the Space Station is assembled, activated and operating within the *total project days* and *total project budget*. The Space Station must attain at least the minimum configuration within that number of days. This may be accomplished using many different approaches. There may be several *optimal* solutions or there may be only one. The optimal solution will be that solution which maximizes your earnings and the profits of the Company yet has no detrimental social effects on the Company employees or the NASA Flight Crews.

As Operator, your best initial strategy might be as follows:

- Total Project Budget

When you arrive at the Mission Control Center, request the report called Project Cost Profile. This report will display the total project budget (in millions of dollars). This is the total amount of funds available to you. As the project progresses, costs will be incurred, and the funds remaining will be reduced accordingly.

- Total Project Days

The Project Cost Profile also displays the total project days. This is the total number of days that you have to complete the project.

Time (*days*) progresses by one of two ways: (a) by assembling Space Station modules or (b) by entering *Wait* status. Wait status is used when the Operator requires time to pass without having to assemble additional modules (see **3.9, Orbital Operations**).

- Project Schedule and Strategy

Given the total time available for the project, plan a project strategy. You should develop a project schedule to do this. To develop such a schedule you will need to know the number of man-days required to assemble each of the Space Station modules. This data is shown on the Sequence and Assembly display (see **3.10, Sequence and Assembly**). You will also need to know the number of Assemblers that are available to you as a resource. The number of Assemblers (as well as all other resources) available to the project are shown on the Launch Readiness Profile.

If you are uncertain as to how the STS is used, the purpose of each of the modules or the assignments of each of the crew members, it is suggested that you review the STS and Space Station chapter of the Operator's Manual before proceeding. Begin the simulation by using the startup procedure (see next page).

3.2 Simulator Startup Procedure/Installation

Diskettes — The simulator diskettes are color-coded and labelled as follows:

Red — This diskette contains all **STARTUP** commands (except for DOS) and is used to store **DATA** for work in progress (Continue Assembly). For Drive A only.

Blue — This diskette contains **GROUND OPERATIONS** (Drive A).

Black — This diskette contains **ORBITAL OPERATIONS** (Drive B).

Installation — If you purchased a version of Space M+A+X which can be copied, you may copy the diskettes for backup purposes onto floppies or to a hard disk for hard disk operation. See Section 3.15 to "uninstall".

- **Floppy Diskettes**

1. Insert the **red** diskette into Drive A and a formatted diskette into Drive B.
2. At the A> prompt, type **INSTALL** and then press [Enter] or [Return]. Follow the instructions on your screen to install **MAX.EXE**. **MAX.COM** will also be automatically installed. You will see a message that installation was successful (if not, you have a copy-protected version).
3. At the next A>, type **DIR** and get a list of the files resident on the **red** disk. Except for **MAX.EXE** and **MAX.COM**, you must copy all of the remaining files *one by one* using the DOS **COPY** command. Do *not* use "*.*" commands on the **red** disk.
4. The **blue** and **black** diskettes are *not* copy-protected. Use the DOS **COPY** command to copy the blue and black diskettes.

- **Hard Disk**

1. Following startup and obtaining the C>, type **MD\SPACEMAX** and then press [Enter] or [Return].
2. At the next C>, type **CD\SPACEMAX** and then press [Enter].
3. At the next C>, type **A:**
4. Insert the **red** diskette into Drive A.
5. Follow the instructions 2 – 4 above for making floppy copies. The files will automatically install to a subdirectory of the directory named **SPACEMAX**.

Startup

- Insert your IBM PC-DOS Version 2.10 (or higher) diskette into Drive A (default drive; left side). Turn on the *printer* (if you wish to select the printer as an option) and plug in the *joystick* (if you wish to use a joystick as an option). Switch on your computer. Enter the date and time. Turn off the *Num Lock* (number lock) key and switch on the cursor pad key (if any).
- When the A> prompt is displayed, remove the DOS diskette and insert the **red** diskette (Startup/Data Save) into Drive **A**. Type **MAX** and press [Enter].
- When the main Space M+A+X title and credits have been shown, the Space M+A+X option selection will be displayed. If this simulation is being started for the first time, select *New Project*.
- If this simulation is a continuation of a previous simulation, then select *Continue Assembly* and be very patient as it will take some time for the previous project data to be loaded from the red diskette (approximately 30 seconds). Get yourself a snack or drink. After the data is received, you will be prompted to remove the red diskette and insert the blue diskette. You will then be transferred back to the Mission Control Center where you can then continue with the Space Station Construction Simulation. If you originally selected the printer option, be sure to switch on the *printer*.
- When you are prompted to change diskettes, remove the **red** diskette and insert the **blue** diskette into Drive **A** (left) and the **black** diskette into Drive **B** (right). If you only have one disk drive, insert the **blue** diskette and exchange the **blue** and **black** diskettes when instructed on the monitor.

3.3 Keyboard

The Space Station Construction Simulation is interactive and requires responses from the Operator (you) as to the next desired command. The key responses are simple, logical and well-edited. Some keys have more than one function. The following is a comprehensive list of keys and their functions:

Key(s)	Command or Response
[A]	Assemble
[A][T]	**Atlantis** (Orbiter)
[B]	Boost
[C]	Cost Detail Report; Continue Assembly
[C][O]	**Columbia** (Orbiter)
[D]	Decrease; Deboost; Deorbit Cost Report
[D][A][K]	Dakar (Senegal)
[D][I]	**Discovery** (Orbiter)
[E]	Earnings-to-Date Report
[E][A][F]	Edwards Air Force Base
[E][N]	**Endeavour** (Orbiter)
[Enter]	Enter Data; Continue
[F1]	Project Cost Profile
[F2]	Orbital Operations/Revenue Profile
[F3]	Launch Readiness Profile
[F4]	Load for Launch
[F5]	Launch
[F6]	Load for Deorbit
[F7]	Deorbit
[F8]	Financial Reports
[F9]	Save/Exit
[F10]	Return to Mission Control
[H]	Highest Previous Earnings
[I]	Inclination Adjustment; Increase
[K][S][C]	Kennedy Space Center
[L]	Launch Cost Report
[M]	Monitor Only
[N]	No
[N][O][R]	Northrop Strip
[O]	Orbital Operations Daily Report
[P]	P & L Report; Printer and Monitor
[R]	Revenue Detail Report; Reassemble
[Return]	Enter Data; Continue
[S]	Salary and Bonus Plan
[V]	View
[W]	Wait
[Y]	Yes
[+]	rough adjustment (cursor control)
[−]	fine adjustment (cursor control)
[←]	left direction (cursor control)
[→]	right direction (cursor control)
[↑]	upward direction (cursor control)
[↓]	downward direction (cursor control)

The computer will *beep* with a rude sound if your response is not to its liking. If you are using an IBM PCjr, follow the instructions in the IBM PCjr Guide to Operations manual (Keyboard Difference Chart) regarding the emulation of an 83-key IBM PC keyboard.

3.4 Option Selection

Several simulation options are offered and can be selected when the simulation begins.

Floppy Disk/Hard Disk System

If your computer has one or two floppy disk drives, press "F" at the start of the simulation (when prompted). If your computer is equipped with a hard disk drive and you have installed all of the files to the hard disk, then press "H". If you are running a hard disk system and there is a computer interrupt, you have not correctly installed all of the files to the hard disk. Use your DOS *DIR* command to find out which of the files are not on your hard disk drive.

New Project/Continue Assembly

If you wish to start a new simulation, select *New Project*. If you wish to continue a simulation and you saved your data, select *Continue Assembly*.

Experience Level

Five levels of difficulty are available. Level *1* (Management Trainee) is the lowest. If you are starting for the first time, Level *1* is recommended. Levels *4* and *5* closely simulate a variety of real-life scenarios and are only for experienced Operators. Level *5* is designed solely for those who can accept a degree of risk which may otherwise be unacceptable to many individuals. Caution: read the Chief Flight Surgeon's warning before selecting Level *5*.

CHIEF FLIGHT SURGEON'S WARNING: Used At The Highest Level Of Difficulty, This Software May Be Too Intense And Could Damage Your Mental Health.

Space Insurance

If you are the cautious type, you may wish to take out space insurance underwritten by Lloyd's of London. Space insurance provides coverage against loss due to accidents and launch or deorbit failures (such as launch explosions, human error, equipment malfunctions, crash landings, etc.) associated with Orbiters, HLLVs, External Tanks, modules, launch facilities, ground support equipment, Shuttle Carrier Aircraft, and SRBs leased and operated by NASA. Space insurance does not cover riots, acts of war, or acts of God (such as solar radiation or lightning). Space insurance will cover the capital costs associated with any modules, External Tanks or HLLVs lost due to the above occurances and life insurance for any crew member who may be lost in such catastrophes. The premium will vary according to the experience level of the Operator. It is based on a percentage of the capital cost of the Space Station modules, HLLVs, and External Tanks used in the project and will be prorated on a daily basis over the length of the project.

Cursor Option

The assembly of the modules can be accomplished by using either the keyboard cursor keys or a joystick. The cursor keys provide a slower, more precise movement and the joystick provides a more rapid movement of the modules. The end result is the same. Use of the joystick can cause a temporary loss of module image if used incautiously.

Command Keys

The abbreviated commands of the function keys can appear on the bottom of the screen as a reminder if you wish. If you want to have the command key titles displayed, select the *command keys*. Otherwise, the bottom row of the screen will be blank.

Display Option

The Daily Status Report (see figure 42) can be printed automatically on your printer if you wish. The report displays the number of Assemblers and Operating Crew *on-orbit* (in orbit), the daily production of processed materials, the number of activated leased modules and the operating efficiency. You will find this report very useful to keep abreast of changes in Space Station operating status as assembly progresses on any given module. If you would like to have a printed copy of any other report (except the Sequence and Assembly display), just press [SHIFT][PRT SC] at the same time, and if you have a printer, the report will be printed. You will find a printed report of some of the displays useful, particularly during the module assembly phase. The Daily Status Report is highly recommended.

Music, Musical Prompts and Sound Effects

Several masterpieces in classical and contemporary style are available for your musical enjoyment. If you don't like computer music, you should decline this option. No offense will be taken by the composer. Your musical preferences have no influence on the outcome of the simulation. All sound effects and the musical prompts will also be silenced.

"*The business of flying in space is bold business.*
We cannot print enough money to make it totally risk-free."

Rear Admiral Richard H. Truly
Commander, STS-8 (**Challenger**)
Director, NASA Space Shuttle Program

3.5 Mission Control Center

The major activities of the Space Station construction are initiated through the Mission Control Center. Mission Control Center (see figure 35) is the main *menu* and all major activities and data profiles are entered from Mission Control. Pressing any function key at the Mission Control Center display will activate the following command(s):

Function Key	Command	Command used for:
[F1]	COST	Display of the Project Cost Profile (figure 36);a listing of all relevant unit costs
[F2]	OPS/RV	Display of Orbital Operations and Project Revenue Profile (figure 37); current operations data for orbiting modules and all unit revenues
[F3]	LD LCH	Load an Orbiter or HLLV for launch into orbit
[F4]	LAUNCH	Begin launch countdown and launch vehicle
[F5]	LD DOR	Load an Orbiter for deorbit, re-entry and landing
[F6]	DEORBIT	Begin countdown, deorbit, re-entry, and landing
[F7]	OPS	Orbital Operations. These will call for the Sequence and Assembly display (figure 40); assemble modules; view Space M+A+X; boost; reassemble modules, enter *Wait* status
[F8]	REPORT	Call for one or more financial reports: Salary & Bonus Plan (figure 45), Highest Previous Earnings (figure 46), Earnings-to-Date (figure 47), Launch Cost Detail Backup (figure 48), Orbital Operations -Daily Detail Backup (figure 49), Deorbit and Landing Cost Detail (figure 50), Revenue Detail (figure 51), Profit & Loss Report (figure 52)
[F9]	SAVE	Saves all of the current data so that you can continue the simulation at a later time.
[F10]	MCC	Return to Mission Control (from another activity or display)

3 Operating Instructions

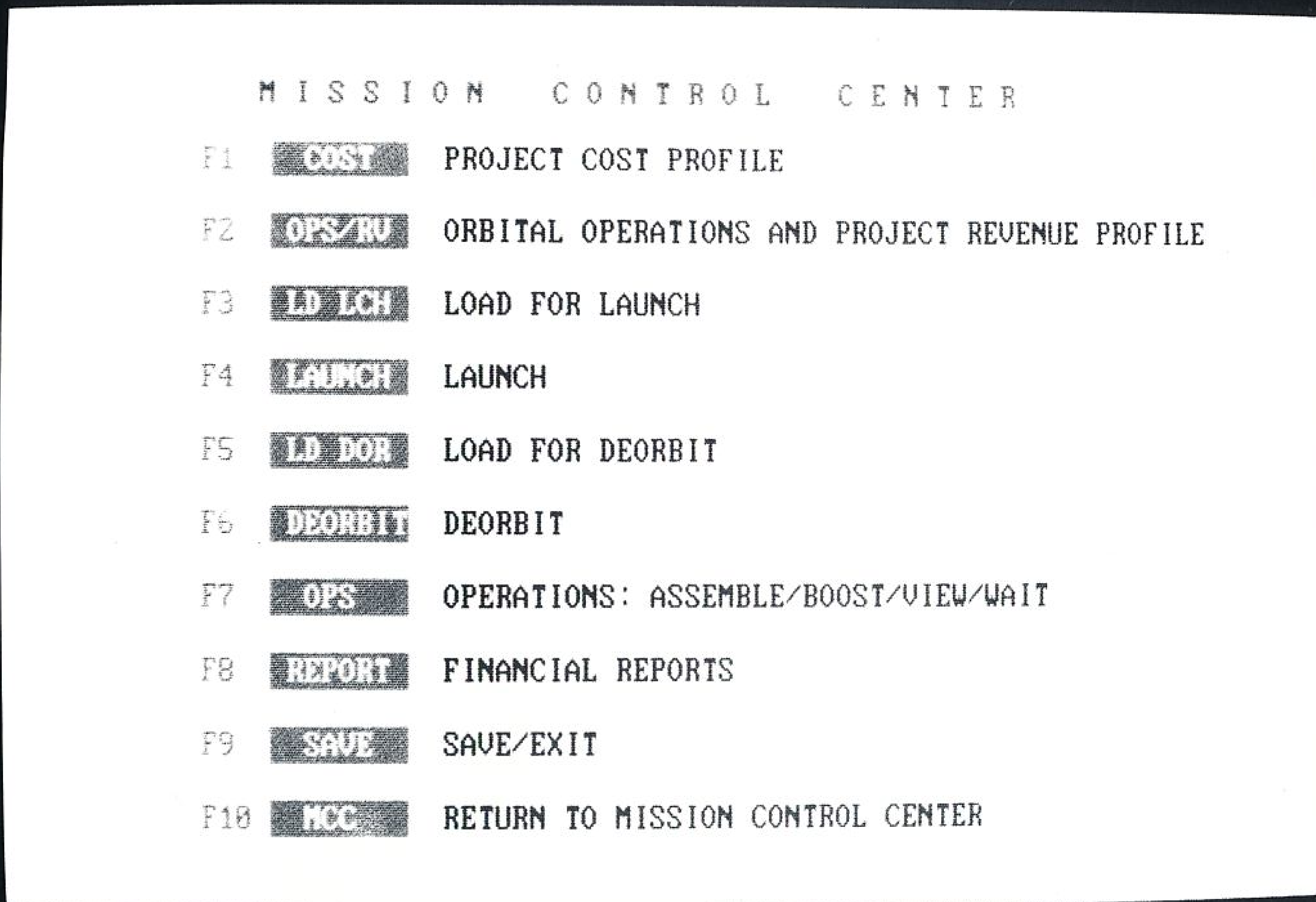


Figure 35 Mission Control Center

3.6 Project Cost Profile

The Project Cost Profile (see figure 36) is a display of all *unit* costs (for example, cost *per* day, cost *per* flight or salary *per* crew member) for the project simulation. Data displayed are:

STS COST PER FLIGHT (blue area)

CAPITAL COSTS – cost of purchasing assets such as the External Tanks and Heavy-Lift Launch Vehicles (HLLV). Costs are shown in millions of dollars ($000000).

LEASE EXPENSES – costs of leasing the Space Transportation System (STS) from NASA. Costs of leasing the Orbiters per launch and on a *daily* basis while on-orbit. Costs of leasing Solid Rocket Boosters (SRB) for an Orbiter launch (two required) and for an HLLV launch (four required). Costs of leasing the Shuttle Carrier Aircraft (SCA) per flight between the emergency landing sites and KSC.

CREW (brown area)

COST PER DAY ON-ORBIT – cost in dollars per day for each crew member of a given category. Displays Flight Crew charges for NASA employees (Commander, Pilot, Mission Specialist) and the salaries paid to SME employees (Flight Surgeons, Assemblers, Operating Crew).

LAUNCH/LANDING SITES (purple area)

LAUNCH – cost in millions of dollars per launch for the lease of ground facilities (Launch Complex, Crawler-Transporter, Mission Control Center, Vertical Assembly Building, tracking stations etc.).

LANDING – cost in millions of dollars per landing at KSC or at any of the three emergency landing sites and for leasing the ground facilities (landing fees, Mission Control Center, ground crews and equipment, hangar, etc).

INTEREST RATE (white area) – current rate of interest charged yearly to the project on capital costs financed by long-term loans made by financial institutions such as banks.

INSURANCE (white area) – the cost of the insurance policy (a percentage of the project's total capital costs) charged to the project by Lloyd's of London (if you chose space insurance at the Option Selection).

COST PER MODULE (blue area) – the capital cost (CAPITAL) of each module type in millions of dollars and the operating expenses (OPR EXP) in dollars per day for each type of module.

BUDGET & SCHEDULE (white area) – the total budget, funds expended and any remaining funds (in millions of dollars) are displayed. The total number of project days, days elapsed, and any days remaining in the project are also shown.

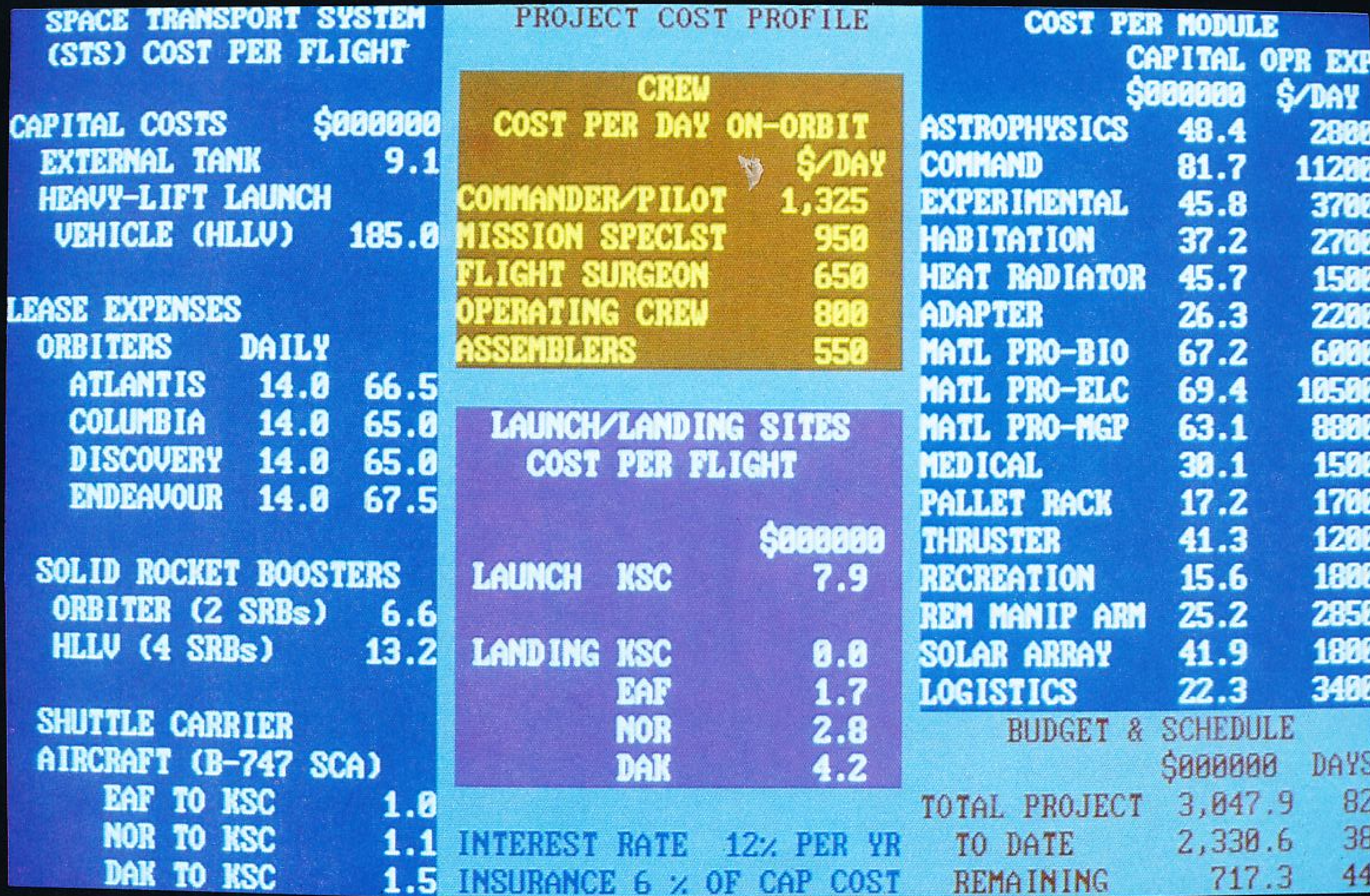


Figure 36 Project Cost Profile

3.7 Orbital Operations and Project Revenue Profile

The revenue section of the Orbital Operations and Project Revenue Profile (see figure 37) is a display of the *unit* revenues for the project simulation. Data displayed are:

REVENUES (green area)

LEASED MODULES – revenues per day in thousands of dollars per module (Astrophysics and Experimental).

PROCESSED MATERIALS – revenues per ounce (in hundreds of dollars per ounce) of processed material for the eight materials manufactured in the Materials Processing modules. The rate of manufacture is in ounces per day.

SALVAGE MATERIALS – revenues from the salvage of HLLVs or damaged modules in orbit. Revenues are based on a percentage of the HLLV or module capital cost.

The Orbital Operations and Project Revenue Profile also displays the current status of operations on-orbit.

CREW STATUS (brown area)

Number of each crew type on-orbit including the number of Assemblers and Operating Crew members. Assembler and Operating Crew data is presented in five status groups:

JOURNEYMEN – Assemblers or Operating Crew who have been on-orbit for less than 45 days. After 45 days on-orbit, they become *Experienced* crew members.

EXPERIENCED – Assemblers or Operating Crew on-orbit for more than 45 days and less than 90 days.

AT RISK – Assemblers or Operating Crew on-orbit for more than 90 days, Assemblers or Operating Crew released from sick bay or returning from strike.

SICK/ON STRIKE – Assemblers or Operating Crew on-orbit but not working. These crew members are in sick bay or on strike.

LOSSES – Assemblers or Operating Crew that have died while on-orbit.

OPERATING EFFICIENCY – this shows the percentage efficiency of current orbital operations. See **3.12, Daily Status Report**.

CONSUMABLES INVENTORY (red area)

Current inventory of all Space Station consumables on-orbit is shown in pounds. This does *not* include Orbiter consumables which can support the *Flight Crew* for up to 30 days.

O2/N2/LiOH – total weight in pounds of compressed O_2 (oxygen), compressed N_2 (nitrogen), and lithium hydroxide (LiOH) absorber. O_2 and N_2 are mixed by the ECLSS to produce breathable air. LiOH is a chemical which absorbs CO_2 (carbon dioxide) from the air and allows the air to be recycled.

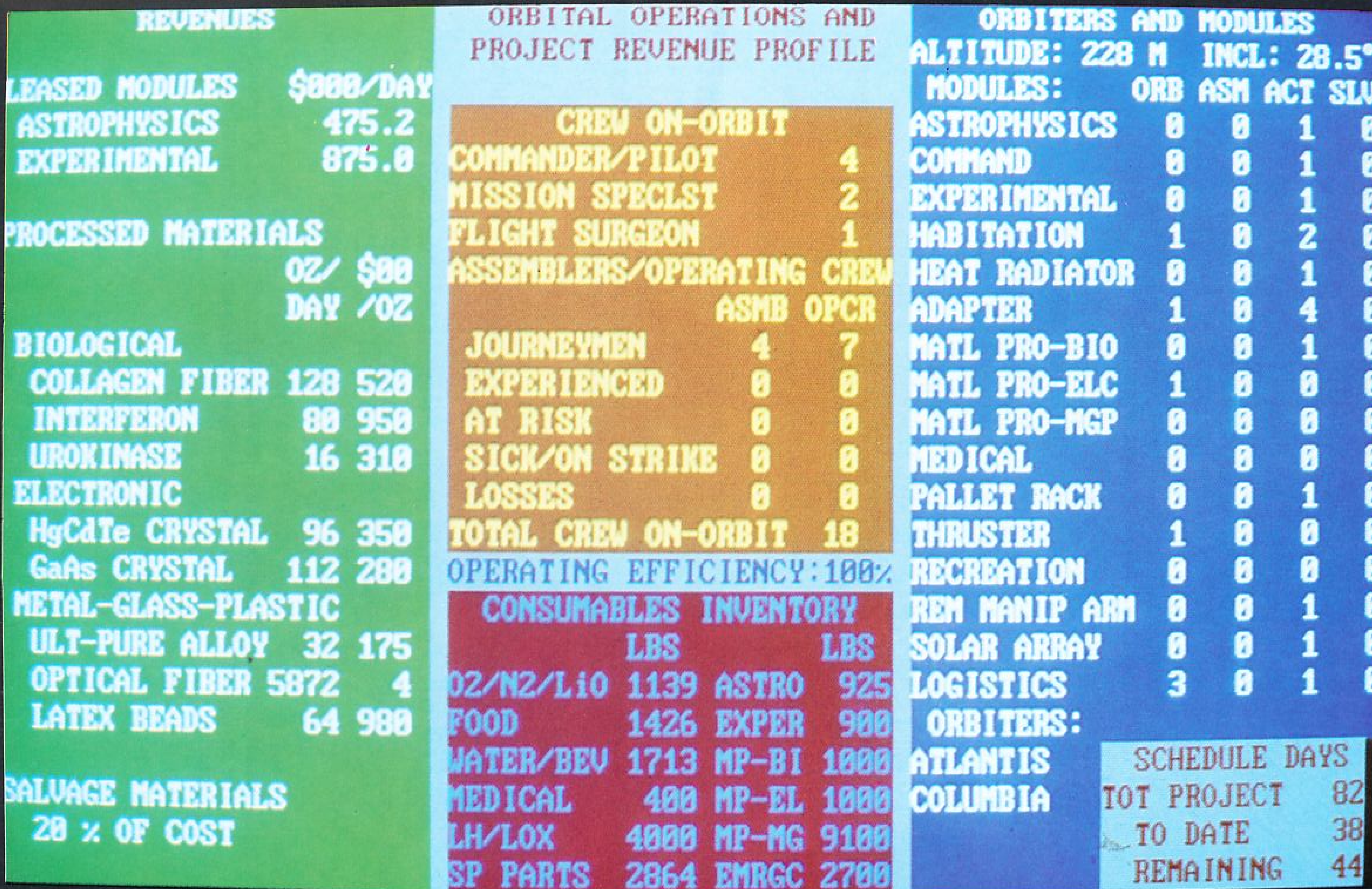


Figure 37 Orbital Operations and Project Revenue Profile

FOOD – total weight of all food (rehydratable or whole).

WATER/BEV – this is the weight of all potable, hygiene, and wash water plus all beverages.

MEDICAL – total weight of all medical supplies, bandages, pharmaceuticals, and all other medical consumables.

LH_2/LOX – shows total weight in pounds of LOX (liquid oxygen) and LH_2 (liquid hydrogen) used as propellants in the Thruster Module engines used for altitude and inclination adjustment.

SP PARTS – total weight in pounds of all spare parts for electronic/ mechanical equipment aboard the Space Station.

ASTRO – this gives the total weight in consumable materials used in the Astrophysics (laboratory) Modules.

EXPERL – this shows the total weight in consumable materials used in the Experimental (laboratory) Modules.

MP-BIO – total weight in raw materials for the bioprocessing operations in the Materials Processing Modules is given.

MP-ELC – this indicates the total weight of raw materials used in the electronics manufacturing in the Materials Processing Modules.

MP-MGP – total weight in raw materials used in the metals-glass-plastics processing for the Materials Processing Modules is indicated.

EMRGCY – total weight of emergency consumables such as personal oxygen systems, fire fighting equipment, rescue balls, emergency space suits, food rations, water, first aid kits, etc. is shown.

ORBITERS AND MODULES (blue area)

ALTITUDE/INCL – displays the Space Station's current altitude in nautical miles and inclination in degrees.

MODULES – displays the numbers of unassembled modules (ORB), the assembled modules (ASM), the activated modules (ACT), and the number of salvagable modules (SLV) on-orbit.

ORBITERS – this displays the names of each Orbiter currently on-orbit with the Space Station.

SCHEDULE DAYS (white area) – displays the total number of scheduled days in the project, the number of days expended so far, and the number of days remaining.

3.8 Launch Readiness Profile

The Launch Readiness Profile (see figure 38) is a display of the *current* status of the STS, crew, launch and landing sites, and weather forecasts. The Launch Readiness Profile is also used to *load* Orbiters or HLLVs for *launch*.

STS STATUS (blue area)

ORBITERS – name of each Orbiter and its current status.

- LAUNCH – means this Orbiter is ready for launch
- ON-ORBIT – means Orbiter is currently on-orbit
- MAINTENANCE – Orbiter being prepared for launch
- IN TRANS – Orbiter being transferred by Shuttle Carrier Aircraft from landing site (EAF, NOR, or DAK) to KSC

SR BOOSTERS – shows number of SRBs in the inventory which are ready for launch

EXTERNAL TANKS – displays number of ETs in the inventory ready to be launched

HLL VEHICLES – number of HLLVs in the inventory which are ready for launch

CONSUMABLE PAYLOAD PLAN (cyan area) – displays the weight in pounds of each consumable to be loaded into the Orbiter or HLLV. See **3.7, Orbital Operations and Project Revenue** for details of the consumables.

CREW STATUS (brown area) – displays the crew job title, current status, and number boarded into the Orbiter.

LCH – shows the number of crew members ready for launch

ORB – this is number of crew members on-orbit

T/I – number of crew members in training or on inactive status (R & R) is shown

LOAD – number of crew members who have boarded the Orbiter.

LAUNCH AND LANDING SITES (purple area) – displays the current launch readiness at KSC and the weather *forecast* for the day; displays the current landing readiness at KSC and at the three emergency landing sites (EAF, NOR, DAK), and the weather conditions at each site.

ORBITER/HLLV PAYLOAD PLAN (cyan area) – displays, for each module type, the number of modules in inventory, the weight of the module in pounds, and the number of modules loaded into the Orbiter or HLLV.

INVEN QTY – number of modules, for each module type, in inventory and ready for launch (i.e., the Operator cannot launch more modules than there are available in inventory).

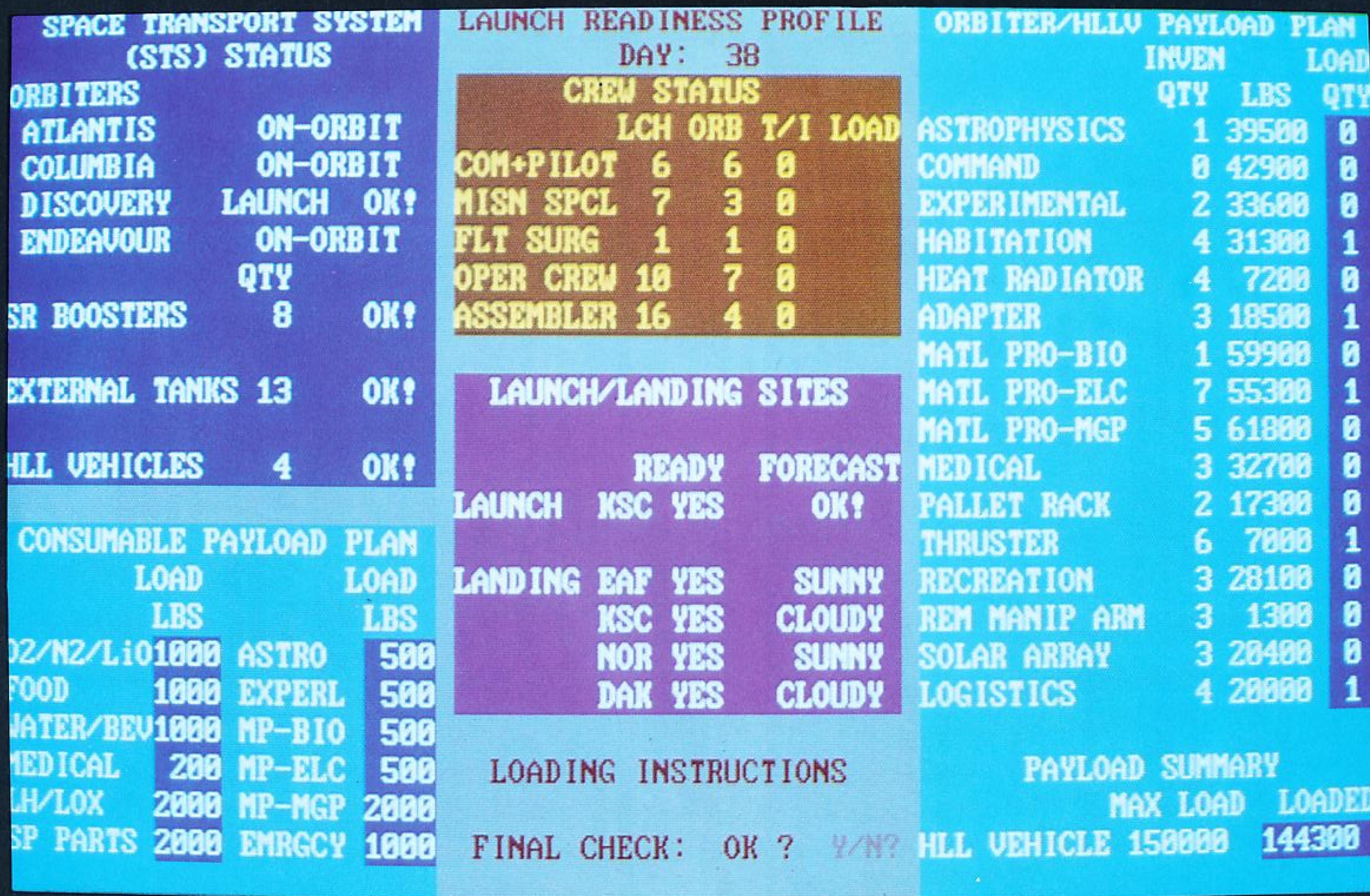


Figure 38 Launch Readiness Profile

LBS. - this gives the weight of each module in pounds.

LOAD QTY - the number of modules of each type loaded into Orbiter or HLLV is displayed.

PAYLOAD SUMMARY (cyan) - displays the name of the Orbiter or HLLV being prepared for launch, the maximum launch payload of that Orbiter (or HLLV) and the total weight loaded into the Orbiter or HLLV. Note: the maximum payload of an Orbiter (or HLLV) depends on the Orbiter or HLLV and the current *inclination*. If the maximum payload displayed is less than normal, the inclination may need adjustment. The maximum payload is acheived at a Space Station inclination of 28.5 degrees. By increasing or decreasing your present inclination to 28.5 degrees you will be able to maximize your launch payloads. See **2.10, Altitude and Inclination** for further details.

LOADING INSTRUCTIONS (white area) – this area is interactive

- You will be asked if you are ready to load an Orbiter or HLLV. If the weather forecast is unacceptable and you do not launch, you will lose one (1) day. A "GO TO WAIT" message will be displayed. You will have to press [F7] for Orbital Operations and then [W].
- If so, you will be asked if you want to load an HLLV.
- If not, you will be asked which Orbiter you wish to load. Possible responses are:

  [A][T] – **Atlantis**
  [C][O] – **Columbia**
  [D][I] – **Discovery**
  [E][N] – **Endeavour**
- Once you have specified the Orbiter or HLLV to be loaded, you will be asked to specify the numbers of crew members to be boarded, the numbers of modules to load, and the weight of any consumables to load.
- *Bon voyage!*

3.9 Orbital Operations

The Orbital Operations menu (see figure 39) is used to initiate all assembly activities on-orbit. This menu is also used to begin five other operations relating to orbital activities. You obtain this menu via function key [F7] of the main menu. The six separate operations included with the Orbital Operations menu are:

[A]	ASSEMBLE	Select and assemble the modules currently on-orbit. View the Sequence and Assembly display.
[B]	BOOST	Increase (reboost) or decrease (deboost) the altitude of the Space Station using a reboost or deboost Thruster Module.
[I]	INCLINATION ADJUSTMENT	Increase or decrease the orbital inclination using an inclination adjustment Thruster Module.
[R]	REASSEMBLE	Disconnect the existing assembled modules so that they may be reassembled into a different configuration. Note: repositioning of the modules using this procedure requires a complete dissassembly of the Space Station. The time required to reassemble the modules will be substantially the same as the time required to assemble the modules in the first place.
[V]	VIEW	Observe the present assembled and activated modules of the Space Station.
[W]	WAIT	Advance the project by one (1) day. This will effectively allow one work day to pass without any assembly work being accomplished. Any activated modules will operate during that day. All time-related activities will progress by one day (weather conditions can change, renovated SRBs will be placed into service, Orbiters will be readied for launch).
[F10]	RETURN TO MISSION CONTROL	Return to the Mission Control Center (main menu). Note: [F1], [F2], and [F8] are also operational.

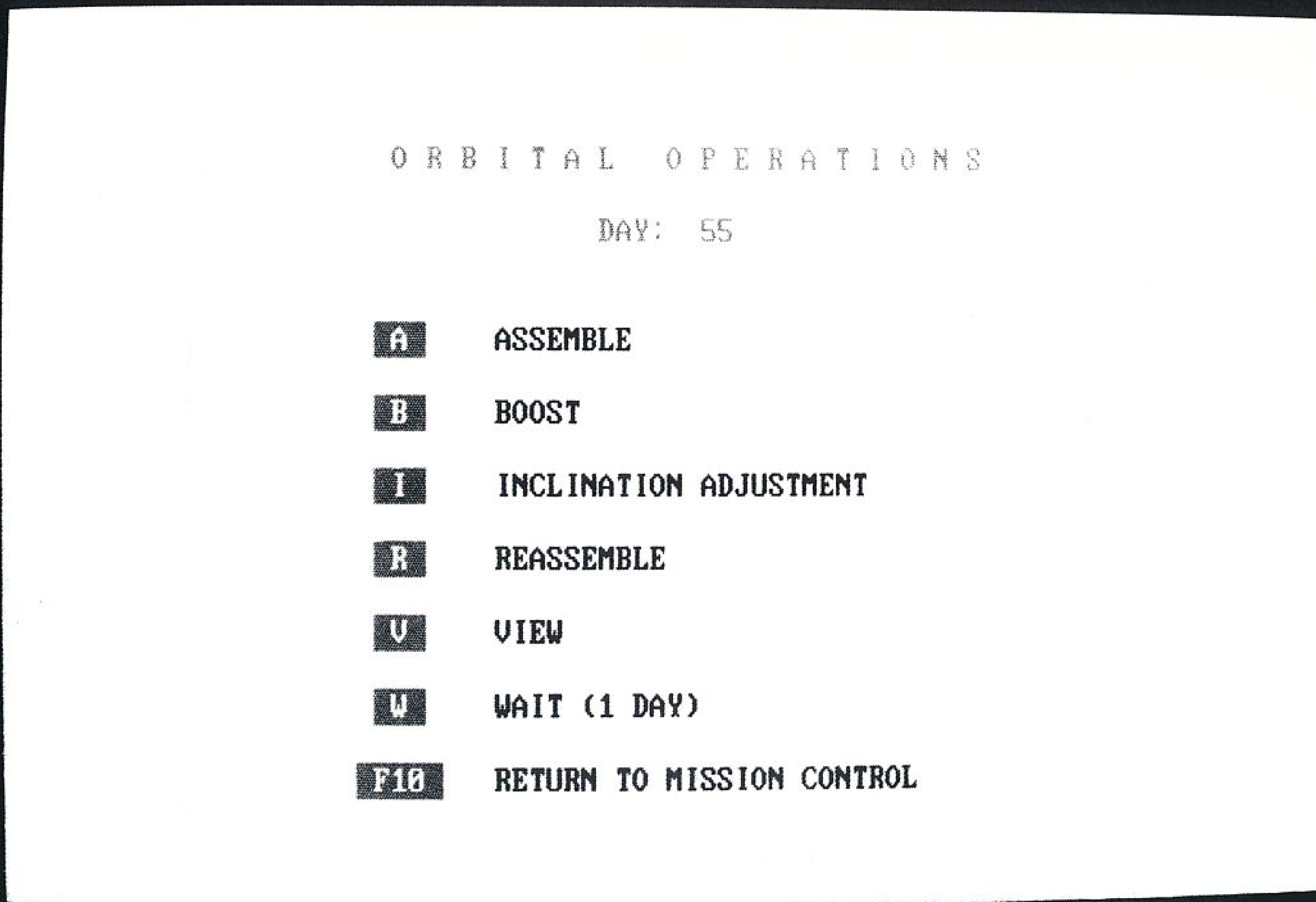


Figure 39 Orbital Operations

3.10 Sequence and Assembly

The Sequence and Assembly Display (see figure 40) aids in the development of an assembly sequence strategy and acts as a table of assembly choices in which you can select modules for assembly. The Sequence and Assembly Display, as the title implies, is split into two parts: a module sequence network (red area) and a module assembly table (blue area). Working crew status (brown area) is also shown as an help.

SUGGESTED MODULE ASSEMBLY SEQUENCE (red area)

Assembly Sequence

This part of the display shows *one possible* assembly sequence, but does *not* represent the only, or even the *optimal* (best possible), assembly sequence. It is a guide only. There are dozens of other sequences possible, and the astute Operator will undoubtedly select another sequence. The display shows all of the module *types* required to complete the minimum configuration for a space station. The red section shows a *sequence network* in which certain modules must be assembled before any given module can be *activated*. This is to say that there are certain *activation prerequisites* before any module can be activated. The Operator must bear in mind that he or she can assemble most modules in any sequence so desired. (The exceptions: the Solar Array Module, the Heat Radiator Module, the Thruster Module, and the Remote Manipulator Arm). However, the Operator cannot place an *assembled* module into *activated* status until other prerequisite modules have also been *assembled*. Common logic follows: "You can't turn on a light bulb without any electricity." Likewise, for Space M+A+X: "You can't operate the ECLSS until the Solar Array is activated."

For example, the Pallet Rack module, the Logistics Module and the Habitation Module must all be activated before an Experimental Module can be activated. This is shown in figure 40 as two arrows going into the *EXPERL* block on the network diagram. One arrow comes from the *PALLET* block and the other arrow comes from the *HAB* and *LOG* blocks. Therefore, you must *assemble* the Pallet Rack Module, a Habitation Module and a Logistics Module before you can activate an Experimental Module.

[Technical Note: this is the basis of what is called the *critical path method* (CPM) used in the planning of any large construction or aerospace project. Clearly, a space station is both a large construction and a large aerospace project. Network planning is an essential tool in planning any project of this magnitude.]

Assembly Man-days

The elasped time to assemble any given module is critical in planning the assembly sequence and developing a project schedule. The number of man-days required to assemble each module is shown in brackets [ ] below each module block. For example, if *15 man-days* are shown and there are three Assemblers on-orbit and working, then they will require five days to assemble the module (15 man-days divided by 3 Assemblers = 5 days). (Note: the seventh day of every week is not a work day. Union rules allow for six work days per week with one day of rest, emergencies excepted.)

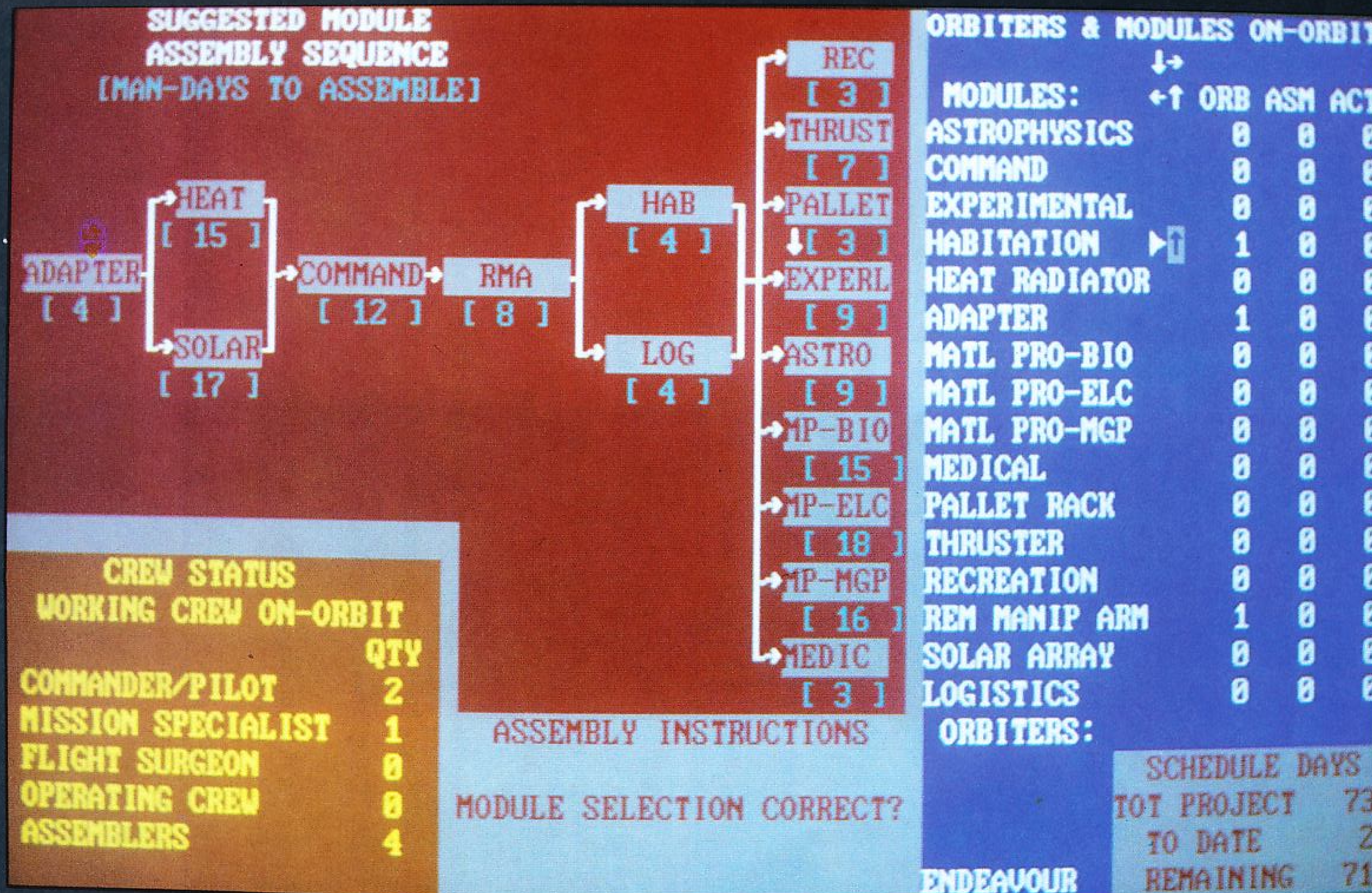


Figure 40 Sequence and Assembly Display

MODULE SELECTION TABLE (blue area)

ORBITERS AND MODULES ON-ORBIT – this shows each module type, the selected *orientation* of the module (with respect to the adjoining module), the number of modules on-orbit, the number of modules assembled, and the number of modules activated.

↓→ ←↑ selected *orientation* of the module to be assembled. When in the interactive mode, you will be asked to select the next module to assemble. A cursor will be displayed in turn next to each unassembled module. One of the following responses are then expected from you depending upon whether you wish to select that module for assembly or pass to the next module:

[←] select this module for assembly; orient this module in the left direction

[→] select this module for assembly; orient this module in the right direction

[↑] select this module for assembly; orient this module in the upward direction (away from Earth)

[↓] select this module for assembly; orient this module in the downward direction (toward Earth)

[ENTER] – no selection; pass to next module

As you can see, the cursor control keys are used *both* to select the *module* to be assembled and to select its *direction* with respect to the module it is being docked. This may take a little getting used to since each key does two things simultaneously.

ORB – shows the number of unassembled modules on-orbit

ASM – displays the number of assembled modules on-orbit

ACT – indicates the number of activated modules on-orbit

CREW STATUS (brown area) – this shows the number of crew on-orbit and *working* (crew members in sick bay or on strike are obviously not working, so do not contribute to any work). For example, if there are four Assemblers on-orbit and one is in sick bay, *3* will be displayed for *ASSEMBLERS*. Therefore, only three Assemblers will contibute to the assembly of the next module. The elapsed time will reflect that number of workers. This is a planning aid only.

ASSEMBLY INTRUCTIONS (white area) -this area is interactive

- You will be asked to select the next module for assembly.
- A cursor will appear in turn next to each module type that is unassembled (ORB).
- If the cursor is opposite the module type that you wish to assemble next, then press the appropriate cursor key depending upon how you wish to dock this module to another module already assembled. For example, if you wish to dock the module on the left side of an assembled module, then select the ← direction.

  [←] = left direction
  [→] = right direction
  [↑] = upward direction
  [↓] = downward direction

  If you press a cursor direction key and nothing happens, you forgot to switch on the cursor pad of your keyboard! You may do so now.
- If the cursor is opposite a module type that you wish to skip, press [ENTER] and the cursor will move to the next module.
- If you wish to exit from the selection table, continue to press [ENTER] until you are returned to the *Orbital Operations* menu.

[Technical Note: The NASA Space Station will require an elapsed time of approximately 18 to 24 months to complete the initial buildup. It is currently scheduled to begin in 1992 and is planned to be operational in 1994. For the purposes of this simulation, the time scale has been compressed. Actual assembly elasped time will be longer than that shown in the simulation.]

3.11 Module Assembly

The physical assembly of a module begins after you have selected the module and set the orientation on the Sequence and Assembly Display. The screen will change to an interactive mode. You must then use either the cursor keys or the joystick (depending on which option you initially selected) to position the module.

Cursor Keys

- The module selected will appear in the upper left-hand corner of the screen.
- You will be instructed to use the controls (cursor keys) to position the module.
- Using the cursor keys, move the module into the *approximate* position where the module is to be assembled. This requires a degree of advance planning since all modules of the Space Station must ultimately be displayed on the screen at the same time (modules cannot be assembled off-screen).
- When the module is approximately in position, press the [–] button of the numeric keypad to set the fine adjustment mode. The module may now be moved into the position required. To place the cursor keys into the rough positioning mode again, press the [+] key of the numeric keypad.
- You will be asked to press [ENTER] when you are ready. If the module is in the *exact* postion desired, press [ENTER]. If the module selected is incorrect or the module orientation is incorrect, you should also press [ENTER].
- You will be asked if the position shown is correct. If it is, press [Y]. The assembly of the chosen module will then proceed. If it is incorrect, press [N]. You will be advised to *Change Module, Position or Direction* and you will be returned to the Sequence and Assembly Display where you can select a different orientation or a different module.

Joystick

- A red cross hair will be displayed on the screen. You will be asked to move the cross hair using the joystick toward the module in the upper left-hand corner.
- As you do, the module will be *captured* by the cross hair and you will be able to move the module very rapidly to the *approximate* position of placement.
- When you want to place the module in an *exact* position, press the fine adjustment button (button B) of the joystick. Then position the module and when ready, press the *fire* button (button A).
- IMPORTANT: Once the fire button is pressed, move the joystick so that the cross hair is out of the module assembly area (for example, the lower-left hand or upper right-hand corner of the monitor screen).

- The initial position of the joystick does make a difference! If the initial position of the joystick (and therefore the cross hair) happens to be in the same position as an assembled module, the cross hair image will overlay the module image. This will cause part of the module image to be lost temporarily. To avoid this completely, simply position the joystick in the lower left-hand corner or upper right-hand corner *before* the cross hair appears. In any case don't worry, the image will be redrawn completely after the assembly.

Notes on Module Positioning

- The modules must be positioned very carefully and thoughtfully with respect to other modules in the Space Station. As you would expect the centerline of the module being positioned must be *aligned* with the centerline of the adjacent module. If you misalign the modules, the assembly will fail. Figure 41 shows a properly aligned docking position.

- The module cannot be too far away from the module that it is being docked to. You must set the module exactly *ONE PIXEL* in distance from the module to which it is being docked. This means that one black *dot* (pixel) can be placed between the new module and the adjacent module. Figure 41 shows an actual screen display with the one pixel docking position. Notice that a pixel is taller than it is wide.

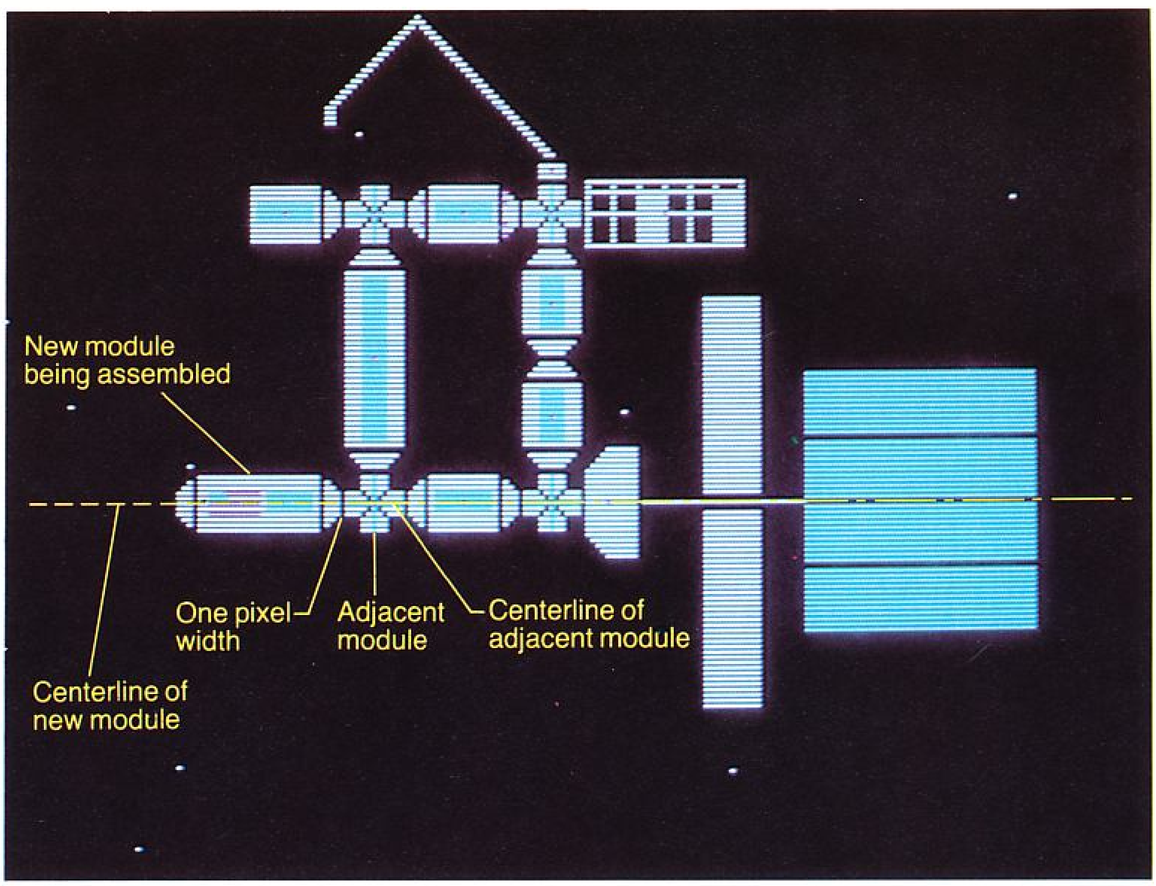


Figure 41 Module Assembly Screen Display

- The module cannot be too close to the adjacent module either. *Too close* means that one module has collided with the other module during assembly. For the same reason, modules must be positioned exactly. If *ONE PIXEL* separates the modules, then the assembly is correct. If there are more or fewer pixels, the assembly will fail.

- Hint: to make sure that the modules are neither too close (collision) nor too far away (poor contact causes loss of airtightness), move the new module until it just touches the adjacent module. Then, move it away by just *ONE PIXEL* so that a black line of *dots* one pixel in width can be seen between the two modules. Then press [ENTER]. After a little practice this will get easier. Think of the black dots as a dark-colored airlock seal between the two modules and positioning should be easier.

- The cursor key method is slower, but positioning the module is more exact. In the fine adjustment mode the module moves one position (pixel) for each time you press the cursor key. You can also go from the fine adjustment mode to the rough adjustment mode and back.

- The joystick method is faster, but the module positioning takes a bit of practice to get right the first time. Once you go to the fine adjustment mode, you'd better be pretty close to the final position. There is no reversing mechanism to take you back to the rough adjustment mode. Don't go to the fine adjustment mode too early or you'll have to *change module position* and then it will take longer. If you're a management trainee, it is recommended that the modules be placed by cursor keys (slow but sure) and not with the joystick. Clearly, the joystick has the advantage of speed and the feel of a Remote Manipulator Arm joystick control.

- Where are the unassembled modules located? Obviously, if all of the unassembled modules were displayed on the screen, there would be a big jumble of unassembled and assembled modules floating around. It would be a big mess, to say the least. Think of the unassembled modules as being placed in a marshalling area off-screen when they are first unloaded from an Orbiter or HLLV. Then, when you select the next module for assembly, that module is brought to the *upper left corner* of the assembly area (the screen).

Assembly Interrupt

Module assembly can be stopped. By pressing the [F10] key after the "ASSEMBLY IN PROGRESS" message is displayed, assembly of the current module will be stopped after work is completed for that day and you will be returned to Mission Control Center. If you elect to return to Mission Control, any progress towards assembling the current module is lost.

3.12 Daily Status Report

If you requested printed output during the option selection, the Daily Status Report (see figure 42) will print on your printer. The Daily Status Report will aid considerably in controlling the project and is highly recommended.

The Daily Status Report displays, for each working day: crew status, materials processed, activated leased modules and operating efficiency.

DAY –	shows the day number
CREW STATUS –	indicates the number of assemblers and operating crew members in sick bay (SICK), on strike (STK) and working (WORK).
MATERIALS PROCESSED –	this displays the number of ounces of each material processed on that day. The abbreviated titles are: CF – collagen fiber INT – interferon URO – urokinase HCT – mercury-cadmium-tellurium GaAs – gallium arsenide crystals UA – ultra-pure alloy OF – optical fiber LB – latex beads
LEASES –	indicates the number of leased modules currently in activated status. ASTRO – Astrophysics Module EXPR – Experimental Module

OPERATING EFFICIENCY – this is a measure of the effectiveness of the operation of the Space Station. If the efficiency is 100%, then there are sufficient raw materials, power, heat rejection, consumables, and Operating Crew members to assure maximum output. If there is less than 100% efficiency, there are one or more shortages of these resources. In this event an investigation should be conducted to determine the nature of the problem and to correct it. Otherwise, the efficiency will continue to decline and output will suffer. An operating efficiency of 0% indicates that the Space Station is not currently operational. Operating efficiency is also displayed on the Orbital Operations and Project Revenue Profile.

The Daily Status Report is printed after each working day and details the assembly status of crew and operating status of the modules. It can be used to predict quantities of processed materials in inventory ready for deorbit and module lease revenues to date. It also can be used as an *exception* report showing when modules are *not* processing materials.

```
DAY  -------CREW STATUS------  -----MATERIALS PROCESSED (OUNCES)---- --LEASES--
                SICK STRK WORK  -----BIO---- ---ELC--- -----MGP------ ASTRO EXPR
                                 CF  INT  URO HCT  GaAs   UA   OF   LB

 60  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   96   60   12   72   84 1812 4404   48    0    0
     OPERATING EFFICIENCY =  75 %
 61  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   96   60   12   72   84 1812 4404   48    0    0
     OPERATING EFFICIENCY =  75 %
 62  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   96   60   12   72   84 1812 4404   48    0    0
     OPERATING EFFICIENCY =  75 %
 64  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   96   60   12   72   84 1812 4404   48    0    0
     OPERATING EFFICIENCY =  75 %
 65  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   85   53   11   64   75 1611 3915   43    1    0
     OPERATING EFFICIENCY =  67 %
 66  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   85   53   11   64   75 1611 3915   43    1    0
     OPERATING EFFICIENCY =  67 %
 67  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   85   53   11   64   75 1611 3915   43    1    0
     OPERATING EFFICIENCY =  67 %
 68  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   77   48   10   58   67 1450 3523   38    1    1
     OPERATING EFFICIENCY =  60 %
 69  ASSEMBLER    0    0    9
     OPER CREW    0    0    6   77   48   10   58   67 1450 3523   38    1    1
     OPERATING EFFICIENCY =  60 %
```

Figure 42 Daily Status Report

3.13 Module Assembly Quality and Damage Control

The Module Assembly Quality and Damage Control (see figure 43) displays a multitude of assembly-related information. It is a performance report which evaluates the current status of the Space Station assembly. It ranks the Operator's (your) performance on the assembly of the most recent module and the Space Station as a whole. If the Operator has planned and executed the assembly well, the performance report will reflect that and vice versa. The end result of the report is the Operator's overall performance rating. The report is segmented into six sections:

MODULE ASSEMBLY (blue area) – shows the status of several critical variables:

ALT/INCL –	current altitude of the Space Station in nautical miles and the inclination in degrees. See **figure 34, Helpful Statistics**.
INTEGRATION –	displays a *pass or fail* grading as to the quality of the physical placement of the module
CENTER OF MASS –	gives an *excellent* to *poor* grade on the location of the Materials Processing Modules with respect to the the center of mass of the Station.
TRAFFIC –	gives an *excellent* to *poor* grade on the location of Habitation, Logistics, and Medical Modules with respect to other modules.
SOLAR POWER –	shows the power output in kilowatts, the power currently required and any surplus power.
HEAT RADIATION –	shows the heat radiation capacity and the capacity required and any heat radiation surplus capacity.

CONSUMABLES (purple area) – shows the current weight in pounds of all critical consumables. See **3.7, Orbital Operations and Project Revenue Profile** for a detailed description of all consumables.

CREW SAFETY & HEALTH (brown area) – displays the number of crew who directly affect the safety and health of the Space Station complement. It shows the number of Flight Surgeons in orbit, the number of crew in sick bay and on strike and the number of lost crew. The total crew in orbit is displayed. Also displayed are other relevant data measuring health and safety:

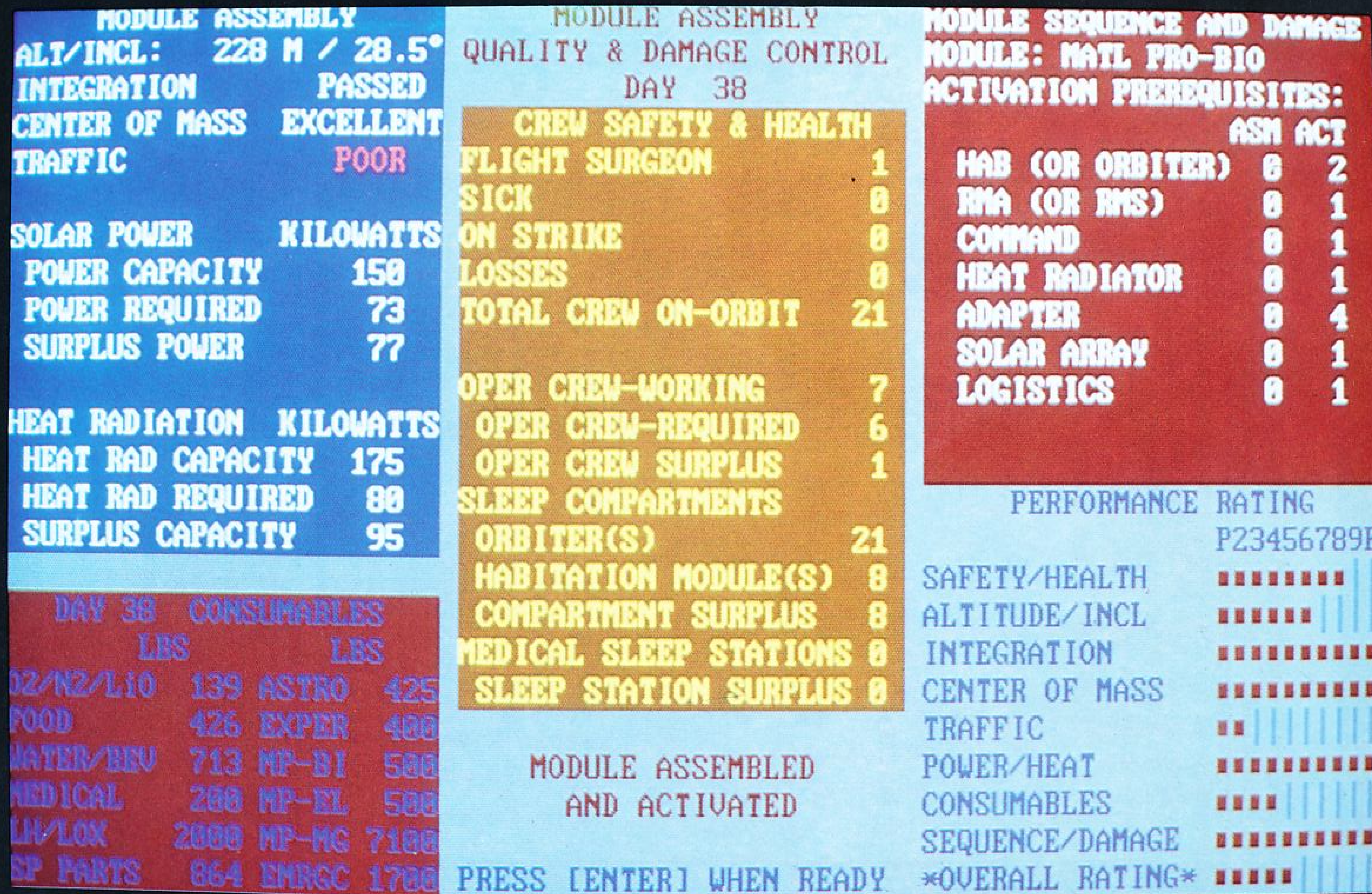


Figure 43 Module Assembly Quality and Damage Control

SLEEP COMPARTMENTS – shows the total number of sleep compartments available including those in all Orbiters in orbit and those in activated Habitation Modules.

ORBITER(S) – total number of sleep stations in orbiting Orbiters (7 per Orbiter)

HABITATION MODULE(S) – total number of sleep compartments in all activated Habitation Modules

COMPARTMENT SURPLUS – different between the total compartments available and total crew in orbit (excluding crew in sick bay and losses).

MEDICAL MODULE SLEEP STATIONS – gives the total number of Medical Module sleep stations available (two stations per module).

SLEEP STATION SURPLUS – is the difference between the total number of medical sleep stations and the number of crew in sick bay.

MODULE SEQUENCE AND DAMAGE (red area) – displays the name of the module being assembled. It lists the other modules that are prerequisites to the activation of the module being assembled. It shows the status of module if damaged during assembly.

ACTIVATION PREREQUISITES: – list of all modules (or Orbiters) that must be assembled (or on-orbit in the case of Orbiters) in order for the current module to become activated.

ASM – number of modules already assembled

ACT – number of modules (or Orbiters) activated (or on-orbit)

[Note: in the absence of an activated Habitation Module, an Orbiter on-orbit can obviously function as a living quarters for Assemblers. In the absence of an activated RMA (Remote Manipulator Arm), the RMS of an Orbiter can be used instead. These are both temporary methods of assembling and operating modules; however, the Space Station is not completed until at least three Habitation Modules and one Remote Manipulator Arm are activated.]

PERFORMANCE RATING (white area) – shows the rating (on a scale of *1 to 10*, *10* being best) of the performance of the Operator in eight critical areas of assembly performance and general management. It shows an overall weighted rating of performance from Day 1 to the present.

Instruction Section (white area) – this area is interactive

This section (lower central area) displays the status of the module that has been in assembly. If the module was assembled correctly, *MODULE ASSEMBLED* will be shown. If the module was assembled correctly and is also now activated, *MODULE ASSEMBLED AND ACTIVATED* will appear. If the module was incorrectly assembled, one of the following error messages will be displayed:

MODULE SALVAGED
LOSS OF AIRTIGHTNESS
MODULE MUST DOCK ADAPTER
INSUFFICIENT NUMBER OF ADAPTER MODULES
MODULE MISALIGNED OR ADAPTER MODULE REQUIRED
THRUSTER BLAST ZONE
ORBITER ACCESS: LOGISTICS

See **5.1, Error and Status Messages** in the **Appendices** for a full a list and descripton of all error and status messages.

Keyboard Responses

- When the *PRESS [ENTER] WHEN READY* message is displayed you may either review the performance report or continue with the simulation.

  [ENTER] – continue with simulation

- You will then be given an opportunity to continue assembly or else return to the Orbital Operations menu.

  [Y] – continue assembly
  [N] – return to Orbital Operations

3.14 Deorbit Readiness Profile

The Deorbit Readiness Profile (see figure 44) displays the *current status* of the STS, crew landing sites, and weather forecasts in preparation for deorbit and landing. The Deorbit Readiness Profile is also used to *load* Orbiters for *deorbit*.

STS STATUS (blue area)

ORBITERS – name of each Orbiter and its current status.

ON-ORBIT –	ready for deorbit (only Orbiters in this status can be deorbited and landed).
LAUNCH –	ready for launch (lift-off)
MAINTENANCE –	Orbiter being prepared for launch
IN TRANS –	Orbiter being transferred by Shuttle Carrier Aircraft from its landing site (EAF, NOR, or DAK) to KSC

SHUTTLE CARRIER AIRCRAFT

CONDITION – if *OK* is displayed, there is at least one SCA available. If not, you must wait for one to be free.

LOCATION – shows the location of the SCA that is currently available.

SEND TO – this is the destination of the SCA; namely, whichever landing site the Operator selects, if not EAF.

RETURN TO – this will be *Kennedy SC* since all launches take place at KSC.

TRANSIT TIME – this is the time in days required for the SCA to travel from its present location to the landing site, pick up the Orbiter and its payload and transport it back to KSC. If the Orbiter lands at KSC, the transit time is *0* days since no transfer is necessary.

LANDING SITES (purple area) – shows the readiness condition of EAF and the three emergency landing sites to receive a landing Orbiter. Also shown is the weather *forecast* for each site. If the weather conditions are considered to be risky, *NO* will be displayed in the *READY* column.

CREW STATUS (brown area) – shows the crew type, the number of crew members, and the number to be boarded into the Orbiter.

PAYLOAD PLAN (cyan area) – shows the name of each processed material, the weight of that material that is processed (in pounds) and ready for deorbit, and the weight loaded by the Operator into the Orbiter. Note: when the Logistics Module is loaded into the Orbiter, the *full weight* of the storage module must be loaded (a Logistics Module cannot be broken down into pieces, it must be loaded as a unit). If there are any HLLVs or damaged modules in orbit that are

3 Operating Instructions

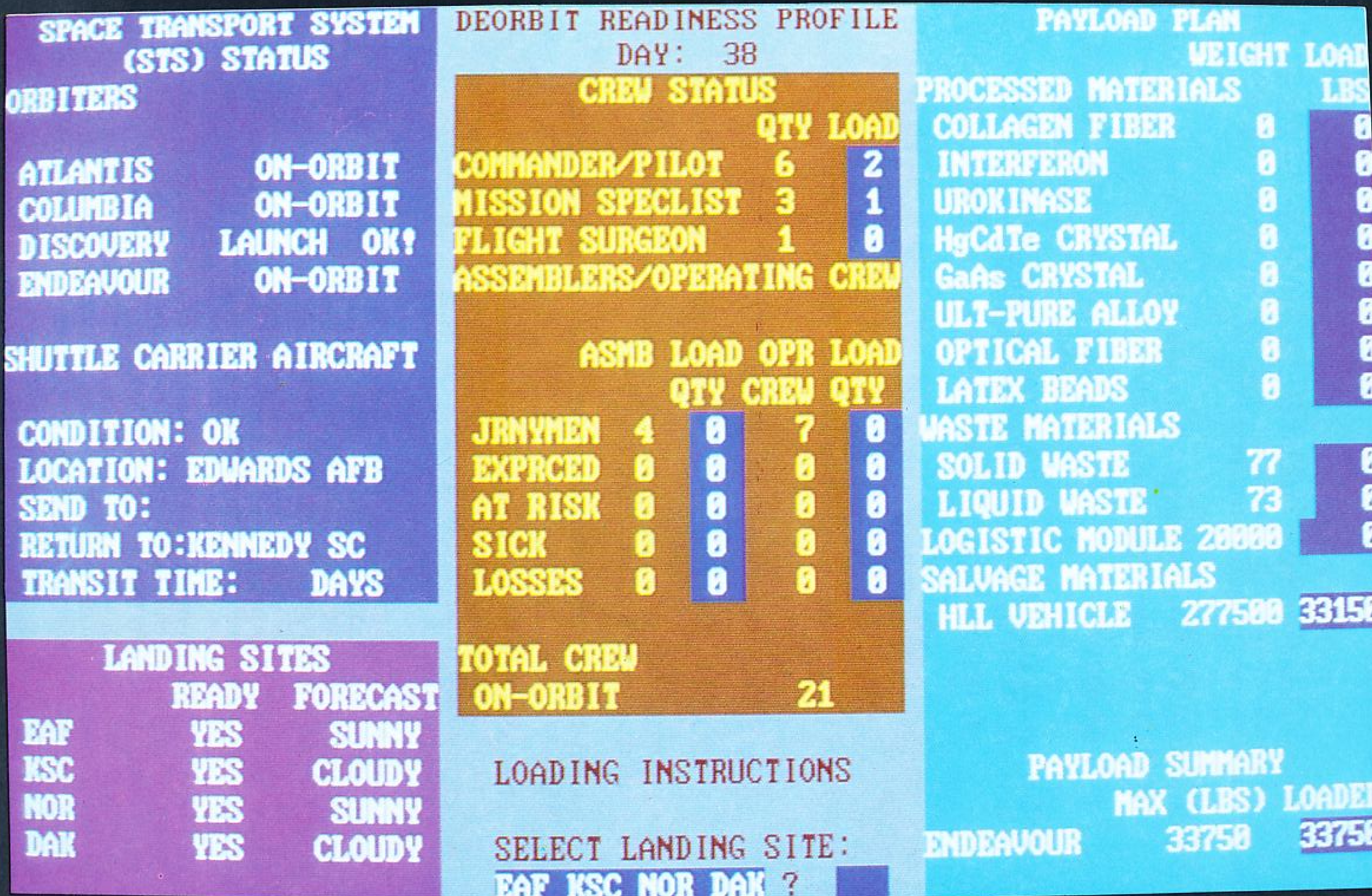


Figure 44 Deorbit Readiness Profile

salvagable, the name of the module and the salvagable weight will be displayed under *SALVAGE MATERIALS*. Salvage materials can be broken up into any convenient size or weight in order to be loaded into an Orbiter to be deorbited and ultimately recovered. If the total weight of the salvage can be loaded, then do so. If not, load as much of the salvage as the Orbiter can take. Remember, the Orbiters cannot *land* the same weight that they can carry into orbit. See **figure 34, Helpful Statistics**.

Note: to load a Logistics Module for a *deorbit* mission, the Logistics Module must first have been *activated*. A Logistics Module which has only been orbited cannot be used since it must be activated first and then loaded for deorbit while docked to the Space Station.

PAYLOAD SUMMARY (cyan area) – shows the Orbiter being loaded, the maximum payload weight in pounds, and the total weight loaded into the Orbiter.

LOADING INSTRUCTIONS (white area) – this area is interactive.

- You will be asked if you are ready to load an Orbiter for deorbit and landing.
- If so, you will be asked which Orbiter you wish to load.

  [A][T] – **Atlantis**
  [C][O] – **Columbia**
  [D][I] – **Discovery**
  [E][N] – **Endeavour**

- Once you have specified the vehicle to be loaded, you will be asked to specify the numbers of crew members to board, the weight of waste and processed materials to load (if desired), the weight of the Logistics Module (if any), and the weight of salvage materials to load (if desired).
- Lastly, you will be asked which landing site you wish to use, using the following landing site codes:

  [K][S][C] – Kennedy Space Center
  [E][A][F] – Edwards Air Force Base
  [N][O][R] – Northrop Strip
  [D][A][K] – Dakar

- Happy landings!

3.15 Simulator Shutdown Procedure/Uninstall

Shutdown

- If you do not want to save your data to continue assembly at a later time, simply switch off the computer, place the diskettes in their protective covers, and store them in a cool, dry place (such as the diskette pocket) where you won't spill drinks on them.

- To save your project data for a later session, return to Mission Control Center [F10].

- If you want to save this simulation on the red diskette, press function key [F9] (SAVE) and you will be prompted when to remove the **blue** diskette and insert the **red** diskette into drive **A**. You will be advised when the data is being stored. Wait until you receive a Mission Control Advisory. Be patient. It takes a long time (approximately 30 seconds) for the data to be saved. When the Advisory is displayed, switch off the computer and do whatever you want. If you have only one disk drive, follow the instructions displayed on your monitor.

Uninstall

- If you purchased a version of Space M + A + X which can be copied, you may "un-install" the copy-protected software so that it can be **transferred** back to the original red diskette. When the **A>** prompt is displayed, insert the **red** diskette (copy-protected) into drive **A** and type **INSTALL /U**. Then press [Enter] or [Return]. Follow the instructions displayed on your screen to make a transfer. The **blue** and **black** diskettes are *not* copy-protected. Use your DOS **COPY** command to copy the **blue** and **black** diskettes.

4.0 Financial Reports

There are a variety of financial reports which detail all relevant costs incurred and revenues associated with the Space M + A + X construction and pilot operation.

Budget and Schedule	4.1
Salary and Bonus Plan	4.2
Highest Previous Earnings	4.3
Earnings-to-Date	4.4
Launch Costs	4.5
Orbital Operations-Daily Detail	4.6
Deorbit and Landing Costs	4.7
Revenues	4.8
Profit and Loss	4.9

4.1 Budget and Schedule

The frequent monitoring of project expenditures (drawn from the *total project budget*) and the project schedule (which is based on *total project days*) is critical to successful project management. For this reason the *total project budget*, project expenditures to date and remaining funds are incorporated into the *Project Cost Profile* (which is displayed by pressing [F1] when at Mission Control Center) for easy reference.

Likewise, the *total project days*, project days elapsed and project days remaining are also displayed on the Project Cost Profile.

In addition, it is recommended that you develop an overall project strategy and a project schedule before beginning any actual launches of crews and materials. Remember that you are dealing with the lives of crew members and with extremely valuable and limited resources. The simulation should not be approached in a haphazard manner. Plans and strategies should be developed first before launching any of your resources into orbit.

There is no separate budget summary and any detailed schedule must be prepared by the Operator (you again!) based upon the total project days and the man-days of assembly time displayed on the Sequence and Assembly Display (see **3.10, Sequence and Assembly**).

4.2 Salary and Bonus Plan

The Salary and Bonus Plan displays the detailed Operator's compensation package as outlined in the simulation scenario. Figure 45 shows a sample Salary and Bonus Plan report (the actual compensation will depend on the level of experience you selected.) The Plan shows the base salary of the Operator and the per unit rates of bonuses, surcharges and profit sharing applicable over the project life.

BASE SALARY PER DAY – this is the base salary in dollars per calendar day paid to the Operator.

PERFORMANCE PLAN – these are the per unit surcharges which are deducted from the total earnings of the Operator for each crewman involved in an accident or strike action.

PER CREWMAN ON STRIKE – is the surcharge deducted for every crewman involved in a strike action.

PER CREWMAN HOSPITALIZED – is the surcharge deducted for every crewman hospitalized in sick bay.

PER CREWMAN LOST- is the surcharge deducted for every crewman dying during active service.

COMPLETION BONUS – this displays the bonus paid to the Operator for every day that the project is ahead of schedule (total project days) upon successful completion of the project.

SAVINGS BONUS – this shows the bonus paid for every $1 million under budget (total project budget) upon successful completion of the project.

PROFIT SHARING – this shows the percentage of the net Company profits paid as part of the profit sharing scheme upon successful completion of the project.

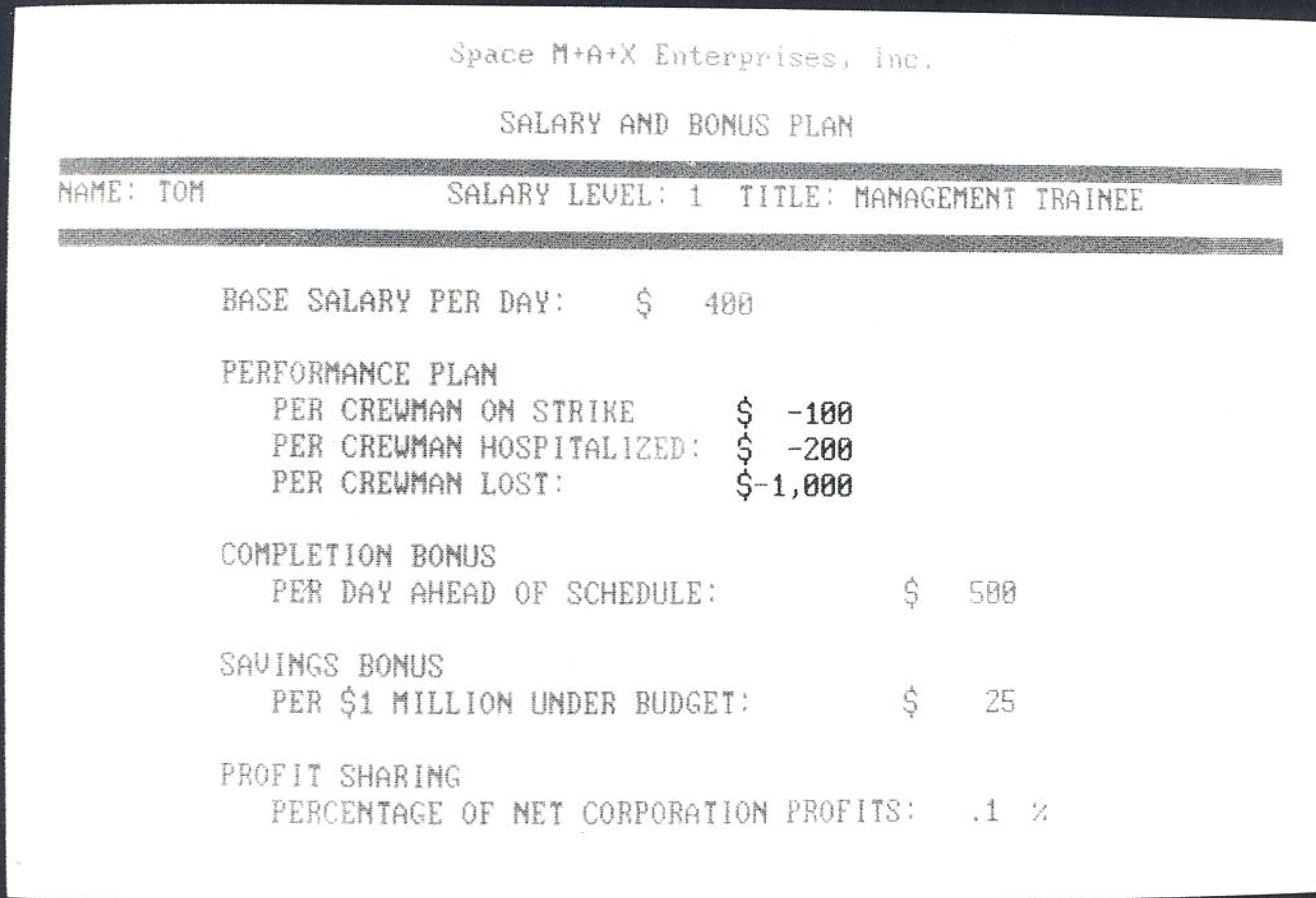


Figure 45 Salary and Bonus Plan

4.3 Highest Previous Earnings

The Highest Previous Earnings report (see figure 46) displays the Operator's highest earnings on previous simulations. Only those simulations in which the project was completed or stopped due to a shortage of time or funding are displayed. Simulations in which the Operator voluntarily resigned are not displayed. The simulation in which the Operator received his or her all-time highest earnings is shown on the first detail line followed by the number of days in that simulation. The third figure is a calculated value determined by taking the total earnings (including bonuses and profit sharing, if any) and dividing the earnings by the number of days required in that simulation. Lastly, the salary level of the Operator at the time the earnings were made is displayed. The last figure should be useful in comparing the degree of risk with the rewards.

EARNINGS –	this shows the Operator's total earnings for a given simulation (including base salary, bonuses and profit sharing) for the number of days involved to the end of the simulation.
DAYS –	this indicates the number of days required in the simulation to either complete the project, run out of time or run out of funds.
EARNINGS/DAY –	this gives the average earnings per day for that simulation. Note: the highest earnings per day are not necessarily achieved on the simulation with the highest overall earnings, since the number of days is critical.
SALARY LEVEL –	this is the salary level of the Operator when the earnings were achieved.

Space M+A+X Enterprises, Inc.

HIGHEST PREVIOUS EARNINGS

NAME: TOM SALARY LEVEL: 1 TITLE: MANAGEMENT TRAINEE

EARNINGS	DAYS	EARNINGS/DAY	SALARY LEVEL
$ 48,808	59	$ 827	1
$ 35,882	76	$ 472	1
$ 35,320	74	$ 477	1
$ 31,600	79	$ 400	1

Figure 46 Highest Previous Earnings

4.4 Earnings-to-Date

The Earnings-To-Date report (see figure 47) displays the Operator's earnings from the start of the project to the present day. It represents the detailed earnings of the Operator based upon his or her level of experience and success in project management. The earnings-to-date are a representation of financial success and do not reflect the Operator's social awareness or other intangible measures of personal success and worth.

TOTAL SALARY TO DATE –	this is the product of daily salary and the number of calendar days from the start of the project to date.
PERFORMANCE PLAN –	this section details the number of crew on strike, hospitalized or lost since the start of the project. It also shows the surcharges made for each category against the total earnings.
COMPLETION BONUS –	if the project is completed, the number of days ahead of schedule will be displayed and the total completion bonus will be awarded.
SAVINGS BONUS –	if the project is completed, the savings bonus or surcharge will be displayed.
PROFIT SHARING –	if the project is completed, the Operator's share of the profits to date will be displayed.
TOTAL EARNINGS-TO-DATE –	this sums the salary to date, performance plan, completion bonus, savings bonus, and profit sharing. A measure of the Operator's success in managing the project from its inception to the present.

Space M+A+X Enterprises, Inc.

EARNINGS-TO-DATE

NAME: TOM   TITLE: MANAGEMENT TRAINEE

DAY: 55   SALARY LEVEL: 1   HIGHEST PREVIOUS EARNINGS: $ 48,808

TOTAL SALARY-TO-DATE:		$ 22,000
PERFORMANCE PLAN		
CREWMEN ON STRIKE:	0	
CREWMEN HOSPITALIZED:	0	
CREWMEN LOST:	0	
COMPLETION & SAVINGS BONUS		
PROFIT SHARING		$ 0
TOTAL EARNINGS-TO-DATE:		$ 22,000

Figure 47 Earnings-to-Date

4.5 Launch Cost Detail Backup

This financial management report itemizes the direct costs (both lease expenses and capital costs) of the most recent launch (see figure 48). This managerial cost report displays direct launch costs only (it is not a financial accounting analysis). Interest, insurance premiums, depreciation and other overhead costs do not appear (see **4.9, Profit and Loss Report**).

FLIGHT CREW COST –	shows the charges paid to NASA for the Flight Crew (Commander, Pilot and Mission Specialist)
	(Note: Assemblers and Operating Crew costs are charged to the project beginning on the first day of work in orbit. Therefore, their costs are not displayed on this report and these costs will only be shown on the Orbital Operations-Daily Detail Backup Report. The actual costs for Assemblers and Operating Crew on launch and deorbit days are charged to Company overhead and do not show up as a direct charge to the project budget).
LEASE EXPENSES –	shows the lease expenses paid to NASA for an Orbiter (if used),the Solid Rocket Boosters, and the use of Launch Complex 39.
	(Note: if an Orbiter was not used in the launch, an Orbiter lease expense was not incurred and therefore will not be shown. In this event, an HLLV will have been launched instead and the capital cost for an HLLV will be displayed in the *Capital Costs* section of the report).
CAPITAL COSTS –	shows the asset cost for an External Tank and the asset cost for an HLLV if used. Additionally, the name of each module launched and the asset cost of that module will be displayed.
TOTAL LAUNCH COST-	total lease expenses and capital costs incurred for the most recent launch.

Space M+A+X Enterprises, Inc.

MISSION NO: 12
DAY: 48

LAUNCH COST DETAIL BACKUP

		QUANTITY	COST
FLIGHT CREW COST:	COMMANDER + PILOT	2	$ 2,650
	MISSION SPECIALIST	0	$ 0
LEASE EXPENSES:	ORBITER (DISCOVERY)		$ 65,000,000
	SOLID ROCKET BOOSTERS	2	$ 6,600,000
	KSC LAUNCH COMPLEX		$ 7,900,000
CAPITAL COSTS:	EXTERNAL TANK	1	$ 9,100,000
	ADAPTER	2	$ 52,600,000
	THRUSTER	3	$123,899,992
TOTAL LAUNCH COST:			$265,102,642

Figure 48 Launch Cost Detail Backup

4.6 Orbital Operations-Daily Detail Backup

This is a report detailing the daily expenses, revenues and value of materials processed on any given day. The day number is shown in the upper left-hand corner (see figure 49). The *values* of materials processed are shown as *expected* realizations (revenues) after the materials are actually deorbited and landed. That is to say the revenues from the sale of processed materials are only realized when the materials have been landed and not simply after they have been processed. Therefore, revenues from processed materials will not be realized until they have been landed and consequently are only reflected in the Profit and Loss Report after landing. This is in sharp contrast to lease revenues. These revenues are credited daily since the Client Companies are paying for the leases as the modules are used. The message for the astute Operator is, "Don't keep large inventories of processed materials!"

The Orbital Operations-Daily Detail Backup does not include indirect costs such as insurance, interest and depreciation. The costs displayed are direct costs incurred as a result of orbital operations only. All daily costs, both direct and indirect, are displayed on the Profit and Loss Report (see **4.9, Profit and Loss Report**).

VALUE OF MATERIALS PROCESSED – displays the number of each Materials Processing Module in operation and the expected value of the materials when landed. These are *not* revenues since revenues for processed materials are only credited when the processed materials have been deorbited, landed and received at the POCC.

LEASE REVENUES – shows the number of operational leased modules and the daily revenue realized. These revenues are credited daily if Astrophysics and/or Experimental Modules are activated and operational.

OPERATING EXPENSES – displays the number of members of each CREW crew type in orbit and the total crew costs.

MODULE OPERATING EXPENSES – shows the total operating expenses of all currently operating modules excluding labor costs. Costs include raw materials, spare parts, telecommunications, laboratory supplies and sundries, fuels and other consumables.

Space M+A+X Enterprises, Inc.

DAY 55 ORBITAL OPERATIONS–DAILY DETAIL BACKUP

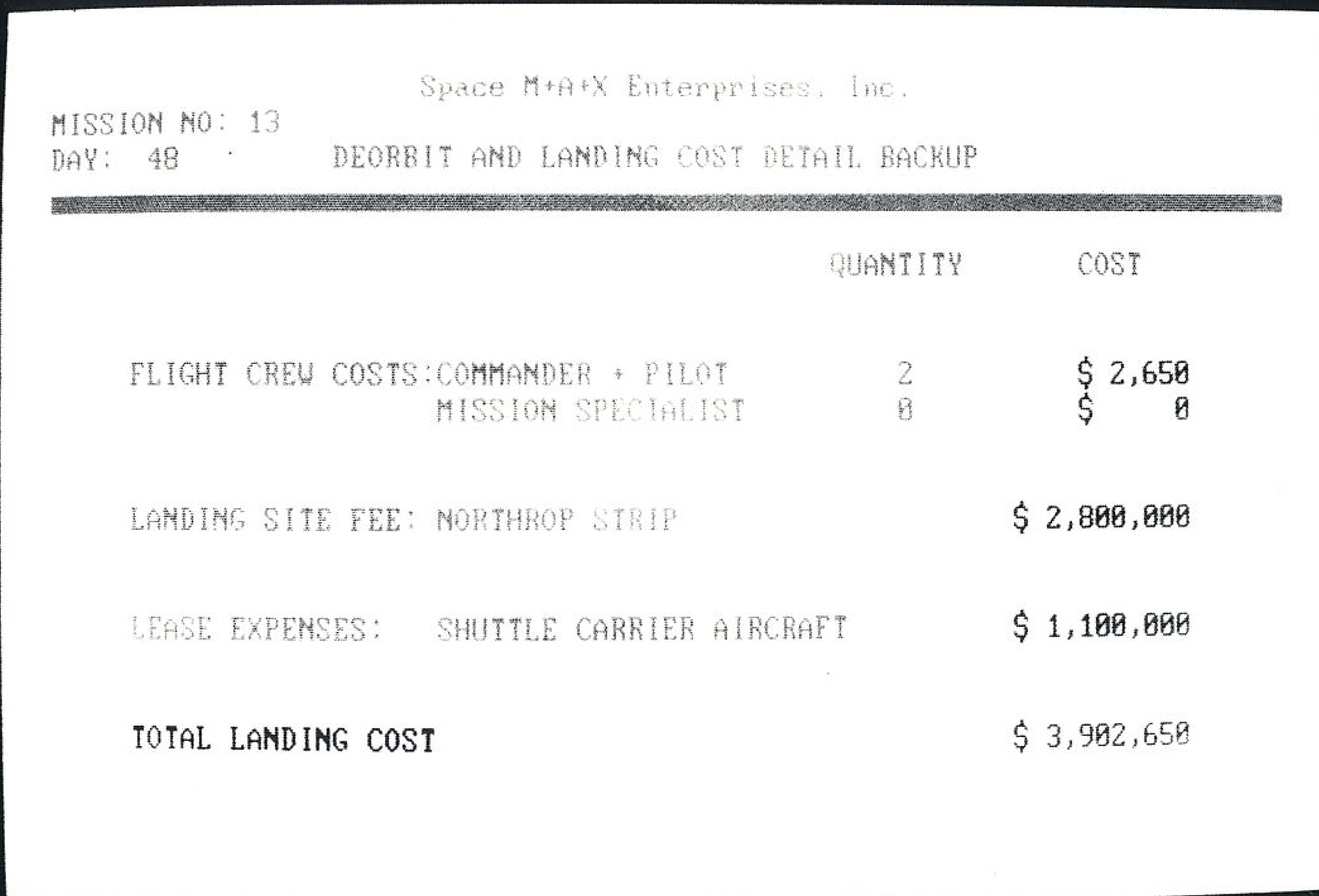
VALUE OF MATERIALS PROCESSED	MODULES	VALUE/EXPENSES
BIOPROCESSING	1	$ 11,801,600
ELECTRONIC	1	$ 5,196,800
METAL-GLASS-PLASTIC	1	$ 7,344,640
LEASE REVENUES	MODULES	
ASTROPHYSICS	1	$ 475,200
EXPERIMENTAL	1	$ 875,000
OPERATING EXPENSES	QUANTITY	
CREW: COMMANDER/PILOT(S)	0	$ 0
MISSION SPECIALIST(S	0	$ 0
FLIGHT SURGEON(S)	1	$ 650
OPERATING CREW	11	$ 8,800
ASSEMBLERS	5	$ 2,750
DAILY ORBITER CHARGES	0	$ 0
MODULE OPERATING EXPENSES		$ 106,814

Figure 49 Orbital Operations – Daily Detail Backup

4.7 Deorbit and Landing Cost Detail Backup

The Deorbit and Landing Cost Detail Backup reports the cost of the Flight Crew, the landing site fees, and the cost of the Shuttle Carrier Aircraft (if any) to transport the Orbiter to KSC (see figure 50). For the reasons specified in the Launch Detail Backup, the crew cost for Assemblers and Operating Crew aboard the landed Orbiter are not included in this report.

FLIGHT CREW COSTS –	shows the cost of the NASA Flight Crew to land the Orbiter
LANDING SITE FEE –	lists the cost of landing the Orbiter at the selected landing site.
LEASE EXPENSES –	the cost of leasing the Shuttle Carrier Aircraft (if it was required) to transport the Orbiter back to KSC is displayed.
TOTAL LANDING COST –	sums all of the above expenses.



Space M+A+X Enterprises, Inc.

MISSION NO: 13
DAY: 48

DEORBIT AND LANDING COST DETAIL BACKUP

		QUANTITY	COST
FLIGHT CREW COSTS:	COMMANDER + PILOT	2	$ 2,650
	MISSION SPECIALIST	0	$ 0
LANDING SITE FEE:	NORTHROP STRIP		$ 2,800,000
LEASE EXPENSES:	SHUTTLE CARRIER AIRCRAFT		$ 1,100,000
TOTAL LANDING COST			$ 3,902,650

Figure 50 Deorbit and Landing Cost Detail Backup

4.8 Revenue Detail Backup

This is a report detailing the revenue realized as a result of the most recent Orbiter landing (see figure 51). The report specifies each processed material landed, its weight, and the revenue realized. Damaged modules returned for salvage operations are also displayed along with the salvage revenues gained.

All revenues displayed on this report are also reflected on the Profit and Loss Report.

PROCESSED MATERIALS – this displays, for each processed material landed, the weight in pounds and the revenue realized.

SALVAGE MATERIALS – displays the name of each damaged module returned in the Orbiter and the salvage revenues.

TOTAL REVENUE – total revenue produced as a result of the most recent landing is shown.

MISSION NO: 13

Space M+A+X Enterprises, Inc.

REVENUE DETAIL BACKUP

PROCESSED MATERIALS	WEIGHT (LBS)		REVENUE
COLLAGEN FIBER	0	$	0
INTERFERON	0	$	0
UROKINASE	0	$	0
HgCdTe CRYSTAL	0	$	0
GaAs CRYSTAL	0	$	0
ULT-PURE ALLOY	0	$	0
OPTICAL FIBER	0	$	0
LATEX BEADS	0	$	0
	SUBTOTAL	$	0
SALVAGE MATERIALS			
HLL VEHICLE	32100	$	9,022,703
	SUBTOTAL	$	9,022,703
TOTAL REVENUE		$	9,022,703

Figure 51 Revenue Detail Backup

4.9 Profit and Loss Report

The Profit and Loss Report (see figure 52) is a financial accounting statement of the Company's profit and loss to date for the project, excluding certain overhead and indirect costs charged to the corporate account and not to the project account. This report incorporates all revenues to date, excluding any processed materials in orbit and not as yet landed, all expenses including interest expense and insurance (if the latter was taken out by the Operator), depreciation against capital costs, and local, state and U.S. taxes.

The Profit and Loss Report is not directly related to the Launch Cost, Orbital Operations and Deorbit and Landing Cost reports for all cost elements. Interest and insurance costs are not reflected on the Launch, Operations and Deorbit reports. Depreciation is an amortization (the gradual writing-off of the capital costs) of module capital costs over a ten-year period and HLLV and ET capital costs over a two-year period.

Note: profits and losses are shown in thousands of dollars ($000).

REVENUES

MODULE LEASES – this displays the number of leased modules currently operational, the revenues for the current day, and the total revenues to date.

PROCESSED MATL- this shows the number of Materials Processing Modules for each type in orbit and operating, the revenues for the current day and the total revenues to date.

SALVAGE MATERIALS – displays the revenues received on the current day from salvage materials and the total revenue to date.

COSTS

CREW COSTS – this displays the total crew costs for the day and the total crew cost to date.

OPER EXPENSES – the total operating expenses for operational modules in orbit for the current day and to date appears.

INTEREST – interest expense for institutional loans on capital costs for the current date and to date is shown.

INSURANCE – insurance expense (if any) on capital assets for the current date and to date.

Space M+A+X Enterprises, Inc.

$ 000 PROFIT AND LOSS REPORT

REVENUES		MODULES		DAY 55		TOTAL TO DATE
MODULE LEASES	:ASTROPHYSICS	1	$	475	$	3,707
	EXPERIMENTAL	1	$	875	$	10,228
PROCESSED MATL	:BIOPROCESSING	1	$	0	$	0
	ELECTRONIC	1	$	0	$	0
	METAL-GLASS-PLASTIC	1	$	0	$	0
SALVAGE MATERIALS			$	9,823	$	36,864
COSTS						
CREW COSTS	:		$	12	$	365
OPER EXPENSES	:		$	107	$	2,214
INTEREST	:		$	1,830	$	47,865
INSURANCE	:		$	0	$	0
LEASE EXPENSES	:ORBITERS/SRBS		$	0	$	627,100
	FACILITY FEE/SHUTTLE CARRIER		$	0	$	72,500
DEPRECIATION	:HLLV/EXTERNAL TANKS		$	3,997	$	92,826
	MODULES (ORBITAL)		$	1,353	$	33,963
GROSS PROFIT (LOSS)			$	3,874	$	-826,035
NET PROFIT (LOSS) AFTER TAXES			$	6,364	$	-699,246

Figure 52 Profit and Loss Report

LEASE EXPENSE ORBITERS/SRBS –	lease expenses paid to NASA for the use of Orbiters and SRBs for the current day and to date appears here.
LEASE EXPENSE FACILITY FEE/ SHUTTLE CARRIER –	lease expenses paid to NASA for the use of launch and landing facilities and Shuttle Carrier Aircraft are displayed.
DEPRECIATION –	the depreciation expense for Heavy-Lift Launch Vehicles and External Tanks assuming a two-year life and straight-line depreciation method is displayed.
DEPRECIATION MODULES (ORBITAL) –	the depreciation expense for all orbital modules (activated or not) assuming a 10-year life and straight-line depreciation method is displayed.

GROSS PROFIT (LOSS) – this indicates the difference between revenues and costs, not including taxes.

NET PROFIT (LOSS) – this figure represents gross profit with local, state and federal taxes subtracted from it. Some of these taxes will be used by the National Aeronautics and Space Administration (NASA) to finance further space research and development, a Moon base and the exploration of the planets and asteroids by men and interplanetary robots. The Company's net profit is a measure of the Operator's success in project management as well as the chief executive's success in corporate management. A profit does not necessarily mean that it is solely a result of the Operator's project management success. If there is a profit, congratulations!

5.0 Appendices

5.1 Error and Status Messages

Message	Description
Abort: Systems Malfunction	The launch has been "scrubbed" (aborted). One or more malfunctions in the Orbiter/launch pad systems have occurred. The launch will be postponed for at least one day (may-be more).
All Sick / On Strike	All of the Assemblers presently in orbit are either in sick bay or are on strike. Assembly work is not being accomplished. The net effect is that the Operator is *waiting* for Assemblers to be released from sick bay or to come off strike.
Altitude Too High	The Space Station has been reboosted to an altitude which is higher than the maximum altitude of the Orbiters. The Space Station must be deboosted to a lower orbit so that it can be serviced by the Orbiters.
Assembly Impossible: No RMS or Activated RMA	The Operator attempted to assemble a module without the presence of an Orbiter with an RMS or an activated RMA on the Space Station. You will need an RMA or RMS to do so.
Assembly In Progress	A module is being assembled by Assemblers working in orbit.
(Beep)	(audio signal) The Operator entered data which Mission Control cannot understand or otherwise finds unacceptable. Better check your input against the displayed data or refer to the Operator's Manual.
Change Module, Position or Direction	The Operator input an *N* to signal that the module position was not correct. You may now either change the module direction, position and/or type by returning to the Assembly Sequence.
Crew Shortage	The Operator has attempted to load more crew members than are available for launch. Do not attempt to load more crew than are listed under *LCH* (meaning ready-to-launch).

Data Transmission in Progress-Please Stand By	The Operator has requested that assembly of an existing project be continued. Data relating to the existing space station project is being transmitted to Mission Control. Be patient. Transmission of stored data requires approximately 30 seconds.
Deorbit Countdown in Progress	The Orbiter is in the final countdown sequence prior to deorbit, re-entry and landing. All computer, propulsion, electromechanical and guidance systems are being checked for the deorbit sequence. Landing in stormy conditions (including rainstorms) is risky. Keep cool. Countdown can be very time-consuming but is necessary to verify that all systems are nominal (functional).
Device Fault	The computer expects your printer to be switched on since you elected to have printed reports. The "switch printer on" message was displayed, but you didn't respond soon enough. A system fault was therefore detected. You now have to start from scratch.
Device Timeout	Your printer and CPU are not talking to each other! The CPU expected a response from your printer and it didn't get it. As IBM says in its manual, "Retry the operation." Sorry about that!
Final Earnings	The simulation is over. Your final project earnings, based upon the degree of completion of the project, are displayed.
Go To Wait	This instruction simply means that the Operator must wait at least one day before ground-based conditions can change. One or more days must pass so that time-related events (such as a change in weather) can take place. The Operator is required to *either assemble* additional modules *or* use the *Wait* status option (Orbital Operations menu). By pressing [F7] and then [W], one (1) day will pass and various time-related events will take place. This simulated the real-life situation of having to wait for conditions to change before action can be taken.
Insufficient Number of Adapter Modules	The Operator has attempted to dock more utility modules to Adapter Modules than can be permitted. The solution is to dock another Adapter Module so that assembly can continue.
Logistics Module Required	Processed materials or waste materials can be loaded into an Orbiter only if a Logistics Module is also loaded. The purpose of any Logistics Module is as a storage module for materials in transit.
Logistics Module Overload	The Operator attempted to load more consumables than the Logistics Module(s) is (are) capable of carrying. Reload again. One Logistics Module has a maximum payload of approximately 13,000 lbs.

Launch Countdown in Progress	The Orbiter or HLLV is now in final launch countdown. All computer, electromechanical, guidance and propulsion systems are being checked for the final launch and lift-off sequence. Launch is dependent on numerous variables including weather conditions. Launches are very risky in stormy conditions (including rainstorms). Keep cool. Countdowns are very time-consuming, but are critical to the verification that all systems are nominal (functional).
Loss of Airtightness	The module was assembled improperly. There was a gap between the module and the space station which caused a loss of cabin pressure. This results if you allowed more than one pixel between the module and the one being connected to on the space station. There must be only one pixel's distance between the two modules that are being connected. This means that the separation between the two must be one (black) pixel only. No damage to either module was done, but valuable resources were lost. You had better reread the Operator's Manual **3.11, Module Assembly**.
Module Assembled	The module was positioned and assembled correctly. It has not been activated as yet since there are other modules required for its activation. See *Activation Prerequisites* on the Module Assembly Quality & Damage Control display.
Module Assembled and Activated	Same as above except that the module is also activated. If you have Operating Crew and sufficient consumables aboard, it is also operational.
Module Assembly Defective	The assembly is incomplete and must be redone. There are several possible sources of problems, including damage to the module. See the *Instruction* section in the bottom center of the Assembly Quality & Damage Control report for more details.
Module Misaligned or Adapter Module Required	This error message results from one of two causes: (a) The module was misaligned with respect to the module it was being connected to. The alignment must be perfect with the centerline of the module aligned with the centerline of the connecting module. (b) An Adapter Module is required if you are assembling a Solar Array, Heat Radiator, Thruster, or RMA. Do not attempt to dock any of these directly to any module except and Adapter Module.
Module Must Dock Adapter	All utility modules (Solar Array, Heat Radiator, Thruster, or RMA) must be docked to an Adapter Module. An Adapter Module is required before a Solar Array, Heat Radiator, Thruster, or RMA can be assembled. Do not attempt to dock any of these directly to any module except an Adapter Module.

Module Salvaged	The module was damaged on assembly and can be salvaged. It has been placed into the *salvaged modules* marshalling area for return to Earth for repair and refurbishment.
Module Shortage	The Operator attempted to load more modules than are available to be launched. The column called *INVEN* showns the number of modules of a given type in inventory and available for launch. Reload again.
No Boost Thruster: Boost Impossible	The Operator attempted to boost the Space Station without the presence of an activated Thruster Module. Even if a booster Thruster is assembled, it must be activated in order to operate.
No Modules to Assemble	The Operator directed the Assemblers to assemble another module, but there are none in orbit left to assemble. Suggest that you schedule another launch.
No LOG Module Loaded	The Operator attempted to load consumables without a Logistics Module loaded. Consumables can only be carried using a Logistics Module. Suggest that you complete the loading procedure and then key in *N* when asked for a *Final Check?*. This will restart the loading procedure.
No Orbiters On-Orbit	The Operator attempted to load an Orbiter for deorbit when there were no Orbiters in orbit.
No Orbiters to Launch	The Operator attempted to launch an Orbiter when there were no Orbiters ready to launch.
No Thruster: Adjustment Not Possible	There are no Thruster Modules in orbit that can be that can be used to adjust the inclination. You must activate an additional Thruster Module to increase or decrease the inclination. Even if there are assembled Thrusters in orbit, the Thruster must be activated in order to operate.
No Working Assemblers	There are no working Assemblers in orbit. If there are Assemblers in orbit, they may be sick or on strike.
Orbiter Access:Logistics	The Operator attempted to assemble a module at the Orbiter-access end of a Logistics Module. Modules cannot be connected to the Orbiter-access end of a Logistics Module (see the diagram of Logistics Module, page 28).
Overloaded	The Operator attempted to load more cargo into an Orbiter or HLLV than it can carry as a payload. The maximum payload of the vehicle is shown in the lower right-hand corner of the Launch Readiness Profile. Note: Orbiters will load up to their maximum payload in modules less the weight of the minimum Flight Crew (i.e. there must be at least sufficient payload capacity to carry the Flight Crew after the module payload is loaded).

Pilot Shortage	A Pilot and a Commander are required to launch an Orbiter. At present, there is a shortage of one or both. Go to Wait.
Press [ENTER] When Ready	This is a prompt reminding the Operator that the simulation will continue when the [ENTER] key (sometimes called the *Return* key) is pressed.
Press [DEORBIT] When Ready	The Operator has loaded the Orbiter and the payload Integration Checklist has been verified. Countdown will begin when the [DEORBIT] key [F6] is pressed.
Press [LAUNCH] When Ready	The Operator has loaded the Orbiter or HLLV and the Payload Integration Checklist has been verified. Countdown will begin when the [LAUNCH] key [F4] is pressed.
Project Completed	The simulation is finished. The minimum configuration was achieved. Well done.
Project Stopped: Out of Money Total	The simulation is finished. The project was not completed because the Project Budget was exceeded by more than 10%. Try again.
Project Stopped: Out of Time	The simulation is finished. The project was not completed because the Total Project Days were exceeded (out of time). Try again.
Red Cross Hairs Locate Center of Mass	The center of mass of the Space Station is critical to the operation of the Materials Processing Modules. The red cross hairs displayed on the monitor locate the center of mass of the entire Space Station. The closer the Materials Processing Modules are to the center of mass, the better the results of the microgravity processing operations. Likewise, the further away these modules are from the center of mass, the poorer will be the processed materials. This is because the mass of the Space Station modules has a gravitational effect on the processing operations. If the center of mass is located where the processing operations take place, there is then no detrimental effect on the processing operations due to the mass of the Space Station.
Rescue	The Space Station must be abandoned. A rescue mission must be organized to deorbit all crew members. You have a maximum of 22 days to return the crew to Earth. Crew members are now confined to the safe havens. See **2.18, Emergency and Rescue Operations**.
Rest and Recreation	This is the seventh day of the week and by union agreement only emergency work is performed on this day. The seventh day is a day of rest and recreation.

Shortage of ET Tanks	The Operator attempted to launch an Orbiter or HLLV when the inventory of External Tanks was fully depleted. This is the equivalent of a project stoppage because the External Tanks are not recoverable and our suppliers cannot provide additional ETs in time. Try again.
Shortage of HLL Vehicles	The Operator attempted to launch an HLLV when the inventory of HLLVs was fully depleted. Launches can only be made using available Orbiters at this stage.
Shortage of SR Boosters	The Operator attempted to launch an Orbiter or HLLV when the inventory of flight-ready SRBs was depleted. SRBs are recoverable and those that were launched are presently being refurbished. The Operator will have to go onto *Wait* Status until the SRBs arrive from the manufacturer (Morton Thiokol, Inc., Brigham City, Utah).
Stand By – Data Transmission in Progress	The Operator has requested that the project be stopped temporarily by pressing the [SAVE/EXIT] key [F9]. This will allow all current data to be stored so that the simulation may be stopped and started at a later time. Be patient. This process takes approximately 30 seconds.
Strike Called Off	The labor strike called by the Assemblers and/or Operating Crew in orbit has been called off. All working crew members have returned to their duties.
String Space Corrupt	Bad luck! This is a non-recoverable error condition. According to IBM, this can be caused by the use of a *non*-IBM memory expansion or "multi-function" board. It is intermittent in nature and occurs infrequently. Short of removing the memory expansion board from your computer, the only way of avoiding a complete restart is to occasionally save your data (function key [F9]) and continue from that point.
Switch On Printer	When starting a "Continue Assembly" simulation, you forgot to turn on the printer. Switch on the printer and then press [Enter].
Thruster Blast Area	The Operator attempted to connect a module to the end of a Thruster Module rocket nozzle. Modules cannot be connected to the rocket engine as this is in the engine blast zone.
Thruster Burnout: Fuel Exhausted	The liquid oxygen and liquid hydrogen used to used to oxidize and fuel the Thrusters has been fully consumed. Suggest that you resupply the Space Station.
Too Many Crewmen	The Operator attempted to load more crew members into an Orbiter than it can accomodate. The maximum crew capacity is seven.

Too Many Flight Crewmen — The Operator attempted to load more Flight Crew members into an Orbiter than it can accomodate. The Orbiter can carry a maximum of three Flight Crew members.

5.2 Glossary

Abort	to end a mission prematurely due to a malfunction or emergency.
Adapter	a type of module used to link utility and service modules to other modules, to connect one module with another module at a right angle, to store and repair space suits and as a port for EVA; a *Multple Berthing Adapter*.
Astrophysics	a type of module used for the study of the Universe and the Sun as a star.
Attitude adjustment	to change the inclination or orientation of the Space Station.
Airlock	a chamber used to adjust pressure between the Space Station interior and space prior to or after an EVA.
At risk	category of crew members in orbit for over 90 days, previously ill or previously on strike.
Avionics	electronic equipment carried aboard a spacecraft and used for guidance and control.
Biological processing	the manufacture of biological products in space.
Bioprocessing	same as biological processing.
Boost	to change the altitude of the Space Station using a Thruster Module.
Burn	the firing of a rocket engine.
Capital	tangible assets of a business used to produce revenue; an accounting term.
Center of mass	the point within a body about which the sum of the moments of mass of the body is zero.
Collagen Fiber	a bioprocessed fiber which is used as a surgical material in the repair and replacement of human connective tissues.
Command	that module which is used as a command, control and communications center.
Company	Space M + A + X Enterprises, Inc.
Consumables	a variety of expendable goods (such as oxygen, food) which are used by the crew during the normal operation of the Space Station.

Containerless processing	manufacturing a product without the use of a container.
Crawler-Transporter	a mobile, tracked platform used to transfer the STS from the VAB to the launch pad.
Deboost	use of a Thruster Module to lower the altitude of the Space Station.
Depreciation	an expense which accounts for a loss in value due to wear and tear; an accounting term.
Dock	to join two spacecraft together in orbit.
Expense	a cost incurred; an accounting term.
Experienced	a category of crew members in orbit for more than 45 days and less than 90 days.
Experimental	a type of module leased by corporations to perform research and development work.
External Tank	the expendable portion of the Space Shuttle which holds the liquid propellants during the launch stage of each mission.
Extravehicular activity (EVA)	the movement of a space-suited crew member outside the pressurized areas of spacecraft.
Fuel cell	a device which converts stored oxygen (O_2) and hydrogen (H_2) into water (H_2O) and electricity.
Furnace processing	manufacturing electronic materials with the use of a high-temperature furnace.
g	the symbol used to represent the force equivalent to the acceleration of Earth's gravity.
Gallium Arsenide	a chemical compound of gallium and arsenic (chemical formula: GaAs). GaAs crystals conduct electrons ten times faster than silicon. GaAs crystals are particularly resistant to heat and radiation and their high conducti- vity yields more work per unit of weight. See page 7.
Geosynchronous	a type of orbit where a spacecraft remains over exactly the same point on Earth at all times; an orbit at the altitude of 22,300 miles above the equator (sometimes called "Clarke" or geostationary orbit).
Habitation	a type of module used by crew members as living quarters while not on active duty; it contains bathing, sanitation facilities, sleeping quarters.
HLLV	an unmanned launch vehicle used to lift heavy payloads (150,000 lbs.) into orbit; Heavy-Lift Launch Vehicle.

Heat Radiator	a type of utility module used to transfer waste (excess) heat from the Space Station into space.
Inclination	the angle between the Space Station orbit and the plane of the equator.
Inclination adjustment	to change the Space Station inclination by the use of a Thruster Module.
Integration	the process of loading modules together for launch or the assembly of modules together in orbit.
Interactive mode	status of simulation when the Operator must provide responses to computer-generated queries and conditions.
Interferon	a bioprocessed material used as an anti- cancer drug; a cellular protein which acts to prevent the replication of a virus in an infected cell.
Intravehicular activity	movement of a crew member inside the pressurized areas of a spacecraft.
Journeyman	category of crew members in orbit for 45 days or less.
Kilowatt	one-thousand watts: a unit of power used to measure the amount of power generation by the Solar Arrays or the amount of heat rejection by the Heat Radiators.
Latex Beads	small and very uniform latex spheres used in calibrating electron microscopes, particle counters, paint pigments, and aerosol monitoring equipment.
Lithium hydroxide	a chemical compound used to remove carbon dioxide from the cabin atmosphere (air containing metabolized oxygen).
Materials Processing	a type of module used for materials manufacturing; there are three subtypes of materials processing modules: biological, electronics, metals-glasses-plastics.
Medical	a type of module staffed by a Flight Surgeon containing the Space Station sick bay, an emergency operating facility and medical supplies.
Mercury-Cadmium-Tellurium	a type of crystal which is used in computer microchips (HgCdTe).
Meteoroid	meteoric particles moving through space at very high velocity.
Microgravity	a term used to mean a near weightless condition; the presence of a small gravitational force considerably less than one "g" (0.0001g or less).

Minimum configuration	the least number of modules and crew members making up a completed Space Station project.
Module	a functional element of a Space Station.
Nautical mile	a unit of distance used in naval and aerospace applications; 6,076 feet or 1.15 statute miles.
On-orbit	aerospace jargon meaning *in orbit*.
Operator	the person using the Space Station Construction Simulator (you).
One-g	the full force of Earth's gravity.
Optical fiber	an ultra-pure glass fiber capable of transmitting light with very low distortion and loss. Used for communications and defense.
Orbit	the path of the Space Station, which is created by the balance between its inertia (its tendency to continue in straight-line motion) and the attraction of Earth's gravity which bends the path into a circle.
Orbiter	the spacecraft portion of the Space Shuttle used to carry passengers and cargo.
Orbiter-tended	condition where an Orbiter is docked to or in close proximity to the Space Station.
Pallet Rack	a type of module used to store scientific and commercial experiments which require exposure to space; the experiments are loaded into a pallet and stored within this unpressurized module.
Payload	passengers and cargo loaded into an Orbiter or cargo loaded into a HLLV.
Payload integration checklist	final verification of the payload and launch vehicle prior to lift-off.
Personal Rescue Enclosure	a 30-inch-diameter fabric sphere used to hold a crew member during a rescue in space.
Project management	the effective use of resources in the execution of a project.
Reboost	to increase the altitude of the Space Station orbit by firing the Thruster Module; typically, reboosting is required at least every 90 days.
Recreation	a type of module used by the crew members for exercise and entertainment; TV, library, stereo, exercise equipment.

Remote Manipulator	a type of module consisting of a mechanical arm used to move large loads during the construction of the Space Station; similar to the Remote Manipulator System (RMS) of the Orbiter.
Resources	budget (money), crew, consumables, modules, launch vehicles, and ground support equipment
Retro-fire	to fire the engines in the direction of motion to reduce the forward velocity; this results in loss of altitude due to the influence of gravity.
Rocket engine	an engine which carries its own oxidizer and fuel for combustion; it does not require an external air supply.
Safe haven	any one of several locations in a Space Station with a pressurized and heated life support system that can be used during emergencies; the Habitation, Command and Logistics Modules are safe haven modules.
Salary level	salary pay scale ranging from *1* (management trainee) to *5* (senior project director).
Shuttle Carrier Aircraft	a type of aircraft designed to transport the Orbiter from a landing site to KSC
Software	computer programs.
Solar Array	a type of utility module which generates electricity from solar energy.
Solar panel	an array of semiconductors which convert sunlight into electricity; same as solar array.
Solid Rocket Booster	a reusable rocket engine used in the lift-off stage to launch an Orbiter or HLLV; the engine burns solid propellents.
Space Transportation System	the Orbiters, HLLVs, Solid Rocket Boosters, External Tanks, Shuttle Carrier Aircraft, launch complex and tracking stations which comprise the total Space Shuttle system.
Thrust	the propellant force generated by a rocket engine.
Thruster	a type of module used to increase or decrease the altitude or to make an inclination adjustment of the Space Station.
Traffic	the internal passage of crew members, equipment and cargo between modules.
Trainer	any one of several types of devices or systems used to train Space Station crews; these typically simulate some particular aspect of the space environment (e.g. weightlessness, high altitude); the Space M+A+X Project Simulator is a trainer.

Ultra-Pure Alloys	a mixture of two or more metals with very few impurities. Used in the manufacture of magnetic materials, nuclear fuel rods, turbine blades and for defense applications.
Urokinase	a bioprocessed material; an enzyme which dissolves blood clots in stroke and phlebitis victims (blood-clotting disorders kill over 200,000 people every year).
Wait status	the condition when the Operator chooses wait for the passage of time so that weather conditions may improve or so that time- dependent resources can become available again (e.g. the arrival of refurbished SRBs); Wait status is entered via Orbital Operations and by pressing [W].
Weightlessness	absence of gravity and therefore the apparent absence of weight; see **Microgravity**.

5.3 Acronyms and Abbreviations

ACT	Activated
ALT	Altitude
ALT/INCL	Altitude/Inclination
AOA	Abort Once Around
ASM	Assembled
ASMB	Assemblers
ASTRO	Astrophysics
AT	**Atlantis** (Orbiter)
B-707	Boeing 707
B-747	Boeing 747
BEV	Beverages
BIO	Biological
C	Centigrade
CAP	Capital
CELSS	Controlled Environment Life Support System
CF	Collagen Fiber
CFE	Continuous Flow Electrophoresis
cm	Centimeters
CO	**Columbia** (Orbiter)
COM + PILOT	Commander Plus Pilot
CONFIG	Configuration
CO_2	Carbon Dioxide
CPM	Critical Path Method
CPU	Central Processing Unit
C^3	Command, Control and Communication
DAK	Dakar Air Base (Senegal, West Africa)
DI	**Discovery** (Orbiter)

DIA	Diameter
DEG	Degrees
DOR	Deorbit
DOS	Disk Operating System
E	Excellent
EAF	Edwards Air Force Base (California)
ECLSS	Environmental Control and Life Support System
EGA	Enhanced Graphics Adapter
ELC	Electronics
EN	**Endeavour** (Orbiter)
EOS	Electrophoresis Operations in Space
ESA	European Space Agency
ET	External Tank
EMRGCY	Emergency
EVA	Extravehicular Activity
EXP	Expense
EXPR	Experimental
EXPERL	Experimental
EXPRCED	Experienced
F1	Function Key 1 (Project Cost Profile)
F2	Function Key 2 (Orbital Operations and Project Revenue Profile)
F3	Function Key 3 (Load for Launch)
F4	Function Key 4 (Launch)
F5	Function Key 5 (Load for Deorbit)
F6	Function Key 6 (Deorbit)
F7	Function Key 7 (Orbital Operations)
F8	Function Key 8 (Report)
F9	Function Key 9 (Save/Exit)

F10	Function Key 10 (Mission Control Center)
FLT SURG	Flight Surgeon
g	Acceleration Due To Earth's Gravity
GaAs	Gallium Arsenide
GHz	Gigahertz (frequency)
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
GSE	Ground Support Equipment
HAB	Habitation
HCT	Mercury-Cadmium-Tellurium
HgCdTe	Mercury-Cadmium-Tellurium
HLL	Heavy-Lift Launch
HLLV	Heavy-Lift Launch Vehicle
Hz	Hertz (frequency)
H_2	Hydrogen
H_2O	Water
IBM	International Business Machines Corporation
INC	Incorporated
INCL	Inclination
INT	Interferon
INVEN	Inventory
IVA	Intravehicular Activity
JPL	Jet Propulsion Laboratory (NASA)
JRYMEN	Journeymen
JSC	Johnson Space Center (Texas)
KB	Kilobytes
KHz	Kilohertz (frequency)
KSC	Kennedy Space Center (Florida)
KW	Kilowatts

LB	Latex Beads
LBS	Pounds
LD DEO	Load For Deorbit
LD LCH	Load For Launch
LEO	Low Earth Orbit
LiOH	Lithium Hydroxide
LH2	Liquid Hydrogen
LH_2	Liquid Hydrogen
LOG	Logistics
LOX	Liquid Oxygen
m	Meters
M	Miles (Nautical)
MANIP	Manipulator (Remote Manipulator Arm)
MATL	Materials
MATL PRO-BIO	Materials Processing: Biological
MATL PRO-ELC	Materials Processing: Electronics
MATL PRO-MGP	Materials Processing: Metals-Glasses-Plastics
MAX	Maximum
M + A + X	Materials Processing-Astrophysics-Experimental
MBA	Multiple Berthing Adapter
MEDIC	Medical
MIN	Minimum
MISN SPCL	Mission Specialist
MCC	Mission Control Center
MGP	Metals-Glasses-Plastics
MHz	Megahertz (frequency)
mm	Millimeters
MMU	Manned Maneuvering Unit

MPS	Materials Processing in Space
MP-BIO	Materials Processing: Biological
MP-ELC	Materials Processing: Electronics
MP-MGP	Materials Processing: Metals-Glasses-Plastics
MPH	Miles Per Hour
MRA	Microgravity Research Associates
MRWS	Manned Remote Work Station
N2	Nitrogen
N_2	Nitrogen
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency (Japan)
NOR	Northrop Strip (New Mexico)
NRCC	National Research Council of Canada
O2	Oxygen
O_2	Oxygen
OF	Optical Fiber
OMS	Orbit Maneuvering System
OPCR	Operating Crew
OPER	Operating
OPF	Orbiter Processing Facility
OPR	Operational
OPS	Operations
ORB	Orbital
OZ	Ounces
OZ/DAY	Ounces Per Day
P	Poor
PC	Personal Computer
POCC	Payload Operation Control Center
P & L	Profit and Loss

QTY	Quantity
RAD	Radiation
RCS	Reaction Control System
REC	Recreation
REM	Remote (Remote Manipulator Arm)
RGB	Red-Green-Blue (Monitor)
RMA	Remote Manipulator Arm (Space Station)
RMS	Remote Manipulator System (Orbiter)
RTLS	Return To Launch Site
RV	Revenue
R & R	Rest and Recreation
SCA	Shuttle Carrier Aircraft
SLV	Salvaged
SME	Space M + A + X Enterprises
SP	Spare
SR	Solid Rocket
SRB	Solid Rocket Booster
SSST	Space Station System Trainer
STRK	Strike (Industrial Dispute)
STS	Space Transportation System
STDN	Spaceflight Tracking and Data Network (NASA)
TAL	Trans-Atlantic Abort Landing
TDRSS	Tracking and Data Relay Satillite System (NASA)
TRANS	Transit
3M	Minnesota Mining and Manufacturing Company
T/I	Training/Inactive
THRUST	Thruster
TRW	TRW, Inc.
TV	Television

TYP	Typical
UA	Ultra-Pure Alloy
ULT-PURE	Ultra-Pure
URO	Urokinase
UV	Ultraviolet
YR	Year
Y/N	Yes or No
VAB	Vehicle Assembly Building
$/DAY	Dollars Per Day
$00/OZ	Hundreds of dollars Per Ounce
$00	Hundreds of dollars
$000	Thousands of Dollars
$000000	Millions of Dollars
°	Degrees (Inclination)
°C	Degrees Centigrade
°F	Degrees Fahrenheit
←	Left Direction
→	Right Direction
↑	Upward Direction
↓	Downward Direction

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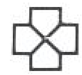

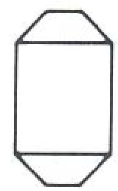

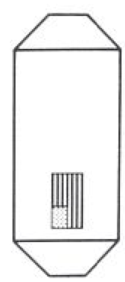

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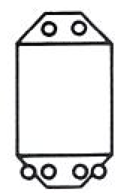

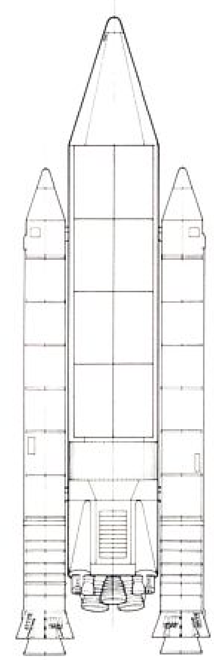

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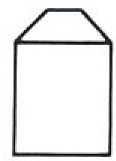

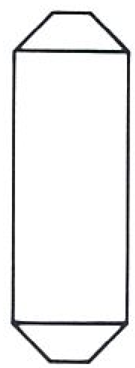

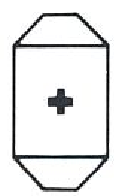

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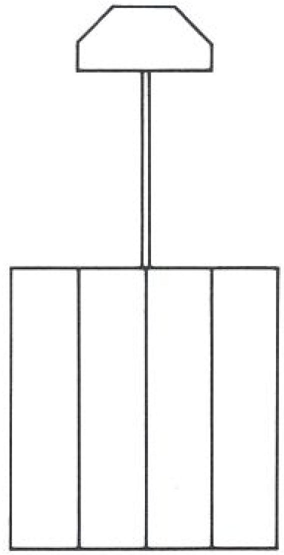

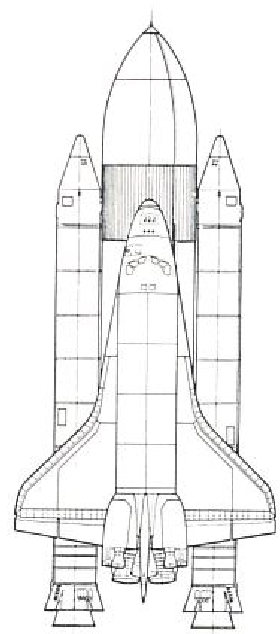

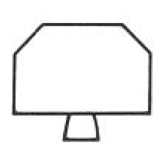

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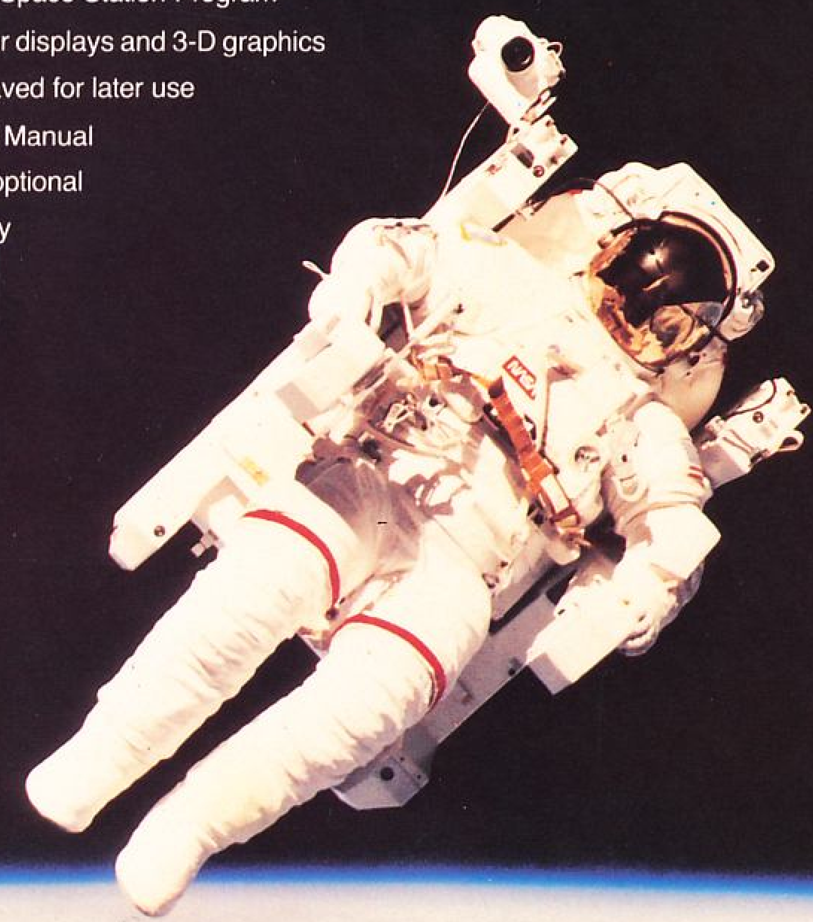

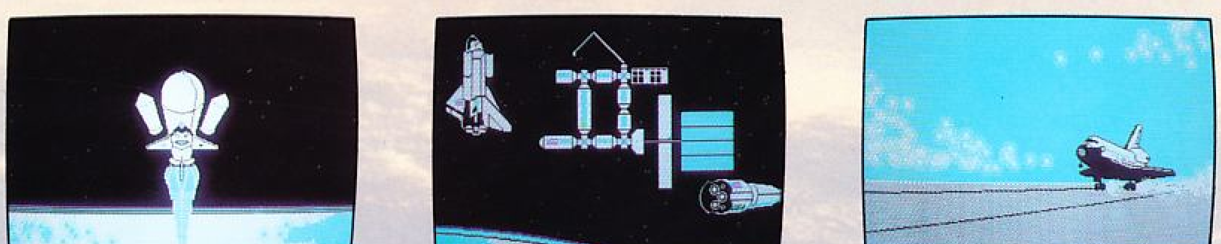

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