3.8 SCENARIO IIIc

3.8.1 Description

Scenario IIIc uses the present Space Transportation System (STS). Other elements in the scenario are (1) free flying satellites and (2) expendable upper stages (PAM A, PAM D, IUS, and Centaur) until 1995.

This scenario contains a manned Space Station beginning in 1991 with growth to support mission requirements. When the station is activated, the TMS will be moved from shuttle-based to space-based. OTV space-based operations will commence in 1994.

In addition, two space platforms, one at 28.5° and one at 90°, are added to this scenario.

3.8.2 Capabilities

Scenario IIIc adds a 28.5° platform and space-based OTV to the capabilities of Scenarios IIIa and IIIb. The OTV capability of this scenario is functionally the same as that of scenarios IIa and IIb, but physically it is different because this facility is attached to an existing station rather than being a unique facility.

The astrophysics instruments that are on-orbit at 28.5° will be the same as those in Scenario IIIa, but telescopes and other instruments that do not require frequent manned interaction will be placed on the Space Platform at 28.5°. The orbit of the Platform will be compatible with that of the Space Station. In addition to allowing the total required mission duration, this scenario offers the astrophysics missions a choice between a manned station (for the benefits of readily available manned intervention) and an unmanned platform (for the benefits of very low disturbance levels combined with the periodic availability of manned intervention via servicing from the station).

In this scenario the OTV capability is fully operational in 1995. Prior to this time the geosynchronous satellites and planetary exploration missions will be launched with expendable upper stages. After 1995, these missions will be accomplished with the OTV, and include satellite servicing at both low earth and geosynchronous orbit.

The life sciences and Materials Processing in Space accommodations in for this Scenario are the same as described in Scenarios IIIa and IIIb.

The technology development missions accommodate in this scenario will be the same as those of IIIa and IIIb.

3.8.3 Cost

DDT&E			Cost
STS	(Developed)		0
Spacelab	(Developed)		0
Upper Stages	(Developed)		0
TMS			$232 MIL
*Free Flyers	(20 FF x $200 MIL)		4000 MIL
Manned Space Station at 28.5°			
		Initial	7520
		Growth	4745
		OTV Ser.	1400
OTV			1600
Platforms		28.5°	550
		90°	260
		Total Cost	$20,307 MIL

* The free flyers cost is for bus only, not instructions.

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3.9 SCENARIO IV

3.9.1 Description

Scenario IV utilizes the present Space Transportation System (STS). Other elements in the scenario are (1) free flying satellites and (2) expendable upper stages (PAM A, PAM D, IUS, and Centaur) until 1995.

This scenario contains a manned Space Station beginning in 1991 with growth to support mission requirements. When the station is activated, the TMS will move from orbiter-based to space-based. OTV space-based operations will commence in 1994 and phase out the use of expendable upper stages. There will be two platforms (one at 28.5° and one at 90°.

In addition a manned polar station has been included beginning in 1998.

3.9.2 Capabilities

Scenario IV adds a manned Space Station at polar orbit to the capabilities of Scenario IIIc. The mission model used in support this exercise does not presently include any missions that require a manned station at polar orbit.

3.9.3 Cost

DDT&E		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$232 MIL
*Free Flyers	(20 FF x $200)	4000 MIL
Manned Space Station at 28.5°		
	Initial	7520 MIL
	Growth	4745 MIL
	OTV Ser.	1400 MIL
OTV		1600 MIL
Platforms	28.5°	550 MIL
	90°	260 MIL
Manned Space Station at 90°		$5000 MIL
	Total Cost	$25307 MIL

*The free flyers cost is for bus only, not instruments.

4.0 SUMMARY

The ability to accomplish the nation's civil space goals have been evaluated by comparing the capabilities of a number of scenarios beginning with the present STS capability and progressing to a manned Space Station. A qualitative survey of the scenario yields several conclusions:

1) A manned Space Station offers the unique coupling of long mission duration in space with continuous manned interaction.

2) This coupling of long duration and manned interaction is required for materials processing in space research and development, as well as life sciences research and many missions in other areas.

3) The extended orbiter capability provided by the Power Extension Package offers longer on-orbit stay time that benefits satellite servicing missions and sortie science and applications missions; however, it cannot provide the mission duration required to meet all of the objectives of materials processing, life sciences, and the majority of astrophysics missions.

4) The Space Platform scenarios meet the long duration requirements, but extensive manned interaction required for specific missions is not provided.

5) Both the Space Station and Space Platform offer an cost avoidance through the grouping of payloads on a common bus.

6) Both the Space Station and Space Platform provide a unique capability for ready access to multiple payloads for servicing and/or payload change-out.

7) The Space Station enables a reusable space-based OTV that has the potential of increase in the STS load factor. This is accomplished by manifesting more individual payloads per launch, since the expendable stages are not required. As such, the Space Station as a transportation node can offer some cost avoidance.

8) The Space Station as a satellite servicing facility can offer efficient, readily available service to satellites and platforms near the Space Station orbital inclination.

9) The Space Station program could provide a unique capability for technology advancement due to the development of technology for the initial and evolutionary stations as well as the technology resulting from the use of the station as a space oriented technology development laboratory.

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APPENDIX A

MISSION MODEL

Table A-1 is a listing of the various missions and the flight duration.

TABLE A-1 MISSION MODEL

Mission Name	Mission Duration
Missions From Langley Model	
o **Astrophysics**	
Spectra of Cosmic Ray Nuclei	('91-1 Yr)
Starlab	('92-'95)
Solar Optical Telescope	('91-195)
Pinhole Occulter Facility	('97-'98)
Advanced Solar Observatory	('99-2000)
Shuttle IR Telescope Facility	('93-1 Yr)
Transition Radiation & Ion Calorimeter	('94-'95)
High Throughput Mission	('96-'99)
High Energy Isotope	('97-2000)
Space Telescope	('91-2000)
Gamma Ray Observatory	('91-'93)
X-Ray Timing Experiment	('91-'92)
Far UV Spectroscopy Exp.	('93-'94)
Solar Corona Diagnostic Exp.	('99-2000)
Solar Max Mission	('91-'93)
Adv. X-Ray Astrophysics Facility	('93-2000)
Very Long Baseline Interferometer	('95-'97)
Large Deployable Reflector	('98-'2000)
Shuttle IR Telescope Facility/Sunsynch	('98-2000)
Solar Dynamics Observatory	('91 Launch)
o **Earth Science & Applications**	
LIDAR Facility	('92-1 Yr)
Earth Science Research (Includes SAR, IS, LAMMR other)	('91-2000)
Ocean Topography Experiment	('91-'94)
Geopotential Research Mission	('91-1 Yr)
Space Plasma Physics	('92-'93)
Origin of Plasma in Earth's Neighborhood	(92'-95)
o **Solar System Exploration**	
Mars Geochem/Climatol Orbiter	('91 Launch)
Lunar Geochem Orbiter	('91 Launch)
Comet Rendezvous	('91 Launch)
Venus Atmosphere Probe	('94 Launch)
Titan Probe	('93 Launch)

Table A-1 (Continued)

Mission Name	Flight Dates
Saturn Probe	('94 Launch)
Main Belt Asteroid Rendezvous	(2-'97 Launches)
Saturn Orbiter	('93 Launch)
Near Earth Asteroid Rendezvous	('97 Launch)
Mars Sample Return	('99 Launch)
o Life Sciences	
Health Maintenance Clinical Research	('91-2000)
Animal/Plant Vivarium and Lba	('91-2000)
Human Research Lab	('91-2000)
Closed Environmental Life Support Exp. Sys.	('92-2000)
Closed Environmental Life Support Exp. Pallet	('93-'98)
Dedicated Closed Env. Life Support Module	('99-2000)
o Pilot MPS Processes	
Pilot Biological Processes	('93-'95)
Pilot Containerless Processing	('94-'96)
Pilot Furnace Processes	('94-'96)
o Communications*	
Experimental Geo. Platform	('94 Launch)
Communications Test Lab	('93-2000)
PAM-D Class Satellite Deployment	('96(3), '97(5), '98(4), '99(4), 2000(4))
PAM-A Class Satellite Deployment	('96(3), '97(3), '98(3), '99(2), 2000(2))
IUS Class Satellite Deployment	('96(6), '97(6), '98(6), '99(7), '2000(7))
Centaur Class Satellites	('96(1), '97(1), '98(2), '99(2), 2000(2))
PAM-D Class Satellite Servicing at GEO	('99(1))
PAM-A Class Satellite Servicing at GEO	('98(1), '99(1) 2000(2))
IUS Class Satellite Servicing at GEO	('96(1), '97(1), '98(1), '99(2), 2000(3))
Centaur Class Satellite Serv. at GEO	('95(1), '96(1), '97(1), '98(1), '99(1), 2000(2))
Exchange Reconfigured Satellite Spares On-orbit	('95(2), '96(2), '97(3), '98(3), '99(3), 2000(3))

* Geosynchronous launches from 1991-1995 are listed in the STS model section.

Table A-1 (Continued)

Mission Name	Flight Dates
o Materials Processing (Commercial Development)	
Materials Processing in Space Lab #1	('91-2000)
Materials Processing in Space Lab #2	('94-2000)
Electrophoretic Separation Production	('91-2000)
Galium Arsenide Production Unit	('91-2000)
Isoelectric Focusing Production	('94-2000)
HgCdTe Crystal Production	('96-2000)
Optical Fiber Production	('93-2000)
Solution Crystal Growth Production	('97-2000)
Iridium Crucible Production	('93-2000)
Biological Processes	('94-2000)
Merged Technology/Catalyst Prod.	('93-2000)
o Earth and Ocean Observations (Commercial)	
Remote Sensing Test/Develop. Facility	('97-6mo.)
Stereo Multi-Linear Array	('91-2000)
Stereo SAR/MLA/CZCS Instruments	('99-2000)
o Technology Development Missions	
Materials Performance Technology	('91-2000)
Materials Processing Technology	('91-'94)
Deployment/Assembly/Construction	('92'94)
Structural Dynamics	('92-'94)
Design Verification Technology	('92-18mo.)
Waste Heat Rejection Technology	('95-'96)
Large Solar Concentrator Technology	('96-'97)
Laser Power Transmission/Conversion	('97-'98)
Attitude Control Technology	('92-'93)
Figure Control Technology	('92-'93)
Telepresence and EVA Technology	('93-'94)
Interactive Human Factors	('93-'94)
Advanced Control Device Technology	('94-1yr & '99-1yr)
Satellite Servicing Technology	('91-'92)
OTV Servicing Technology	('91-'93)
Habitation Technology	('91-'94)
Environmental Effects Technology	('91-18mo, '96-18mo)
Medical Technology	('91-'94)
Power System Technology Experiments	('96-1yr)
On-Board Operations Technology	('92-'97)

Table A-1 (Continued)

Mission Name	Flight Dates
Planetary Automated Orbit Ops.	('98-'99)
Large Space Antenna Technology	('93-'94)
Earth Observation Instrument Tech.	('92-'96)
Telecommunications System Tech.	('96-1yr)
Space Interferometer System Tech.	('95-1yr)
Fluid Management Technology	('91-'92)
Low Thrust Propulsion	('94-1yr, '97-1yr)
Fluid Dynamics Experiments	('94-'95)
Cryogenic Physics Experiments	('95-'96)
Space Polymer Chemistry Experiments	('95-'96)
General Relativity Experiments	('99-1yr)
Missions from STS Model	
Materials Experiment Assembly	(Sortie missions in '91, '92, '93, '94, '95, '96, '97 & '2000)
EURECA (European free flyer)	('91, '93, '96, '99)
Materials Processing in Space Processes	(Sortie missions in '92, '94, '95, '96, '97, '98, '99, '2000)
Tethered Satellite System	(Sortie missions in '92, '94, '95, '97, '98, 2000)
OSTA Materials Experiments	(Sortie missions in '91, '92, '93, '95)
Radar Research Mission	(Sortie in '91)
Intelsat	('91(3), '94(3), '94(3), '95(2) Launches)
Telesat	(Canadian - '91 Launch)
Satcol	(Columbian - '91 Launch)
Tropical Earth Resources Satellite	(Indonesia - '91, '93 Launches)
Geosynchronous Earth Obs. Sys.	('92, '95 Launches)
NOAA TIROS	('92, '93, '94, '96, '98, '99 Launches)
Advanced Earth Resources Satellite	('92, '94, '96, '98, '99, Launches)
Satcom	(RCA - '92(2), '93(2), '94(3) Launches)
Galaxy Satellite	(Hughes - '92, '93, '95 Launches)
Direct Broadcast Satellite	('92(2), '93(3), '95(3) Launches)

APPENDIX B

CAPABILITIES OF SUPPORTING ELEMENTS

The SIG scenarios involve the incorporation of various specific hardware elements to accomplish mission goals. This appendix describes each of these elements and presents general performance capabilities of the elements. The supporting elements discussed herein are:

1. Space Transportation Systems (STS)
2. Power Extension Package (PEP)
3. Teleoperator Maneuvering System (TMS)
4. Free-Flying Spacecraft
5. Unmanned Space Platforms
6. Spacelab
7. Orbital Transfer Vehicles (Ground and Space-Based, Reusable and Expendable).
8. OTV Servicing Facility
9. Space Station

1. SPACE TRANSPORTATION SYSTEM (STS)

STS is used as an integral part of each scenario and will be used to place all elements in low-earth orbit (LEO).

The Orbiter on-orbit stay time is limited by the amount of consumables and their rate of consumption. Power is one of several consumables that limit the STS stay time. A nominal power level of 18-20 kW, limits the on-orbit stay time to 7-10 days depending on the number of cryogenic tank sets installed.

2. POWER EXTENSION PACKAGE (PEP)

The PEP is a 2000-pound solar array kit which provides most of the required Orbiter/payload electrical power during light-side orbit periods. This relieves the baseline Orbiter cryogenic oxygen and hydrogen storage limitations on mission duration and increases power available to payloads. Note that to increase the stay time of the STS, systems other than just the power system must be modified.

The PEP solar array is held in the desired attitude and location by the RMS with the PEP providing two-axis sun tracking. More than one RMS position can be used for any Orbiter orientation. This flexibility allows minimal interference with payload viewing.

PEP operates with the regulated solar power in parallel with the Orbiter fuel cells. When in sunlight, the Orbiter fuel cells are off-loaded to conserve fuel cell reactants (and may, indeed, actually be enhanced by electrolysis).

3. TELEOPERATOR MANEUVERING SYSTEM (TMS)

There will be two distinctly different TMS systems. TMS-1 will be available for all scenarios and will be limited to the capability of deploying and/or retrieving free-flying spacecraft to/from the proximity of the Orbiter or to/from the Space Station. TMS1 will not have the capability of performing payload servicing remotely from the Orbiter or Space Station.

TMS-2 will be available for all scenarios. TMS2 will be a general-purpose, remotely-controlled, free-flying vehicle capable of performing a wide range of payload service remotely from the STS or Space Station. The system will provide spacecraft placement services, planned or contingency payload retrieval functions, assembly/servicing support for large space systems, dextrous manipulator operation for planned or contingency satellite servicing, satellite viewing and science support as a free-flying subsatellite operating in the vicinity of the STS or Space Station, resupply, change-out, etc.

For Scenarios IIa, IIb, IIIc and IV, TMS can be space-based. The TMS will receive routine service and repair in orbit. For major repairs or major refurbishment the TMS will be retrieved and returned to earth by the Orbiter. When the TMS is Orbiter-based, it will be returned to earth in the Orbiter payload bay at the completion of each servicing mission. The TMS for Scenarios IIIa, IIIb, IIIc and IIId will be space-based at the Space Station where it will be harbored, serviced, and maintained.

4. FREE-FLYING SPACECRAFT

Free-flying spacecraft include all dedicated-mission satellites that cannot be accommodated in Space Platforms or attached to a Space Station because of unique orbit location or unique instrument environmental requirements. For Scenarios I, IA, and IIA this class of satellites includes all missions that are not accommodated in the Orbiter crew area or in the Spacelab.

5. UNMANNED SPACE PLATFORMS

The unmanned space platform is a spacecraft bus that provides the key resources of power, thermal control, data transmission, and attitude control. Multiple payloads are attached to this bus and operated simultaneously. The payloads may all be of the same discipline, e.g., astronomy, or a platform may accommodate a set of multi-disciplinary payloads. The platform design allows payloads to be removed and replaced with new ones on-orbit when the mission is complete or improved instruments are available.

Significant savings in the design and development costs for multiple platforms will be realized by utilizing a common design for all platforms (high or low inclination). The design will be modular to allow for appropriate scaling and on-orbit expansion of the electrical, thermal and other capabilities of the platforms. Initially each platform will provide approximately 12 kW of electrical power and heat rejection capability. The modular design will allow on-orbit "growth" (e.g., by the addition of more solar array panels) if additional resources are required in the future.

6. SPACELAB/SORTIE

Under international agreement, the European community has provided to the U.S. Space Program a system of Orbiter cargo bay experiment mounting facilities. The system includes two types of manned laboratories, i.e., short and long modules. Also included are several three-meter length pallets and environmentally controlled subsystems in an "igloo" unit. All integration and reconfiguration costs of the above hardware are the responsibility of the U.S. Space Program. Sortie missions are those flying in the Spacelab module or on a Spacelab pallet.

7. ORBITAL TRANSFER VEHICLES (OTV'S)

a. Ground-based Upper Stages (STS-Compatible)

The initial STS will make use of a family of upper stages to transport payloads beyond LEO. Included is a class of expendable solid rockets, the largest being the IUS, capable of transporting 5,000 pounds from LEO to GEO. Another ground-based OTV currently under development is the ground-based, Shuttle-deployed, Centaur vehicle. The Centaur's performance permits transfer to GEO for payloads of up to 13,500 pounds. They are all expendable vehicles, adaptable to mating either on the ground or in space, and not optimized for space-based use.

b. Reusable, Space-Based OTV's

Scenarios IIa, IIb, IIIc and IV assume the development of a reusable, space-based OTV for transporting payloads from LEO to their final earth-orbital destination. These vehicles will be transported to the LEO Space Station or OTV servicing facility by the STS and will be maintained and serviced at the Space Station.

The reusable space-based OTV has been assumed to be a cryogenic, aerobraked stage with geosynchronous orbit capability equal at least to that of the Shuttle-based Centaur, i.e., 13,500 pounds. The capability to service GEO-based payloads with an OTV/TMS combination would be available at the inception of Space Station/OTV service facility operation. The OTV would be of modular space-based design to allow maintenance, servicing and mission modifications on-orbit.

8. OTV SERVICING FACILITY

The permanent OTV servicing facility will consist of the following elements:

a. An unpressurized enclosure with the necessary equipment to service, maintain, and protect the OTV from meteoroids and space debris during servicing and storage. A high level of automation will be employed to perform servicing and checkout functions. The crew will repair, maintain and provide backup for the automated equipment through EVA.

b. A similar unpressurized protective enclosure for service, maintenance and checkout, will be utilized for OTV payloads. A common remote manipulator system (RMS) on tracks will provide a means of receipt, deployment, mate/demate and transfer for both the OTV and the OTV payloads.

c. A pressurized module to provide accommodations to support a crew of approximately four for up to 30 days, plus contingency time, will be provided.

d. An unpressurized utility element to provide electrical power (30 KW avg) for all facility elements (including propellant reliquefaction). The attitude control and reboost system will be contained in this module.

e. A central core element with external viewing ports will house the OTV and RMS control stations. Air locks and berthing ports will provide ingress/egress and allow Orbiter docking.

f. A logistics module of sufficient volume to house consumables for the crew for the allotted stay time, the waste management system, and for OTV spares.

9. SPACE STATION

The permanent facility in space which is manned is termed the "Space Station." However, the characteristics and capabilities of the Space Station vary with the different scenarios. These characteristics and capabilities are delineated into two general types of Space Stations: (a) initial and (b) growth.

a. Initial

This manned Space Station will support technological, commercial, and scientific research and development laboratories. It will also support a satellite servicing capability.

The capabilities of this Space Station are described as follows:

- Provide laboratory facilities (including power, environment control, data management, etc.) as well as permanent-manned-presence in order to conduct research and development in technological, commercial, and scientific disciplines.

- Accommodate attached, unpressurized payload pallets with accurate pointing and environmental control in addition to pressurized laboratory modules for research and development pursuits.

- Retrieve free-flying satellites to the Space Station by means of the Teleoperator Maneuvering System (TMS) for servicing by EVA and/or place free-flying satellites into their operational orbits with the TMS.

- o Service, refuel, replenish consumables, change experiments and/or payloads, and repair failed subsystems of free-flying satellites at the Space Station.
- o Store propellants for the TMS, satellite refueling, and Space Station orbit maintenance at the Space Station.

b. Growth

The growth station includes (1) a phased increase of laboratory capability and (2) support for a space-based reuseable orbital transfer vehicle (OTV).

The space-based, reuseable Orbital Transfer Vehicle (OTV) will provide access to geosynchronous orbit and beyond. The manned Space Station at which the OTV is based will become a transportation mode to serve all user communities. This station will have the capability to:

- o Provide structure for OTV docking, servicing, refueling, and payload mating.
- o Coordinate OTV servicing, launch, and retrieval.
- o Provide facilities for OTV propellant storage and handling.