A NASA CAPABILITIES EVALUATION DOCUMENT

June 24, 1983

Approved For Release 2008/07/07 : CIA-RDP85M00363R000400960023-2

SIG DOCUMENT

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1.0 INTRODUCTION

This document has been prepared by NASA to provide a set of scenarios that bound the options available to fulfill the nations civil space goals for the time period 1991-2000. The document is a result of one year of developing mission requirements, two months of evaluating architectural options to fulfill those mission requirements, and one month of developing the cost data for a Space Station concept and its operations.

This assessment process required a set of missions which represent the civil space requirements, a group of scenarios of capabilities to fulfill those options, and the developmental cost of each of the scenarios.

The approach used is to increase capabilities incrementally from one scenario to the next. The scenarios begin with the "baseline" of today's STS capability augmented by a Teleoperated Maneuvering System (TMS) and progress through options of varying capabilities to a manned Space Station scenario. The scenarios are shown in Table 3.1 and a description of each element of the scenarios is presented in Appendix B.

It is necessary to point out that the scenarios' capabilities and/or their limitations do not lend themselves to a classical capture analysis where a value, or figure of merit, can be placed on the increased capabilities. In a classical capture analysis, the added capabilities, their development costs and their life cycle cost would be used to determine the benefit of the added capability. To determine the value or benefit of each capability, a normalization of scenario to scenario of long duration missions (years) would require an exorbitant number STS launches. The cost of these additional launches (at $122 M average for Eastern Test Range or Western Test Range launch) causes the life cycle costs of the scenarios without long duration mission capability to be very unrealistic.

Therefore, a qualitative evaluation of the capability of each scenario is presented in Section 3.0 and the conclusions drawn from this evaluation are presented in the Summary Section 4.0.

The mission model is the result of a one year NASA effort of planning mission sets that represent the Agency's plans for the period 1991-2000 and are within the Agency's forecast budget. The study was conducted within the frame work of exploiting the capabilities of a long term on-orbit facility with the added capability of manned interaction. The coupling of these two unique aspects, the long duration in space and the permanent presence of man, is the key element of these missions sets. Upon examination, many mission requirements can be at least partially met with existing facilities, e.g., a free flying satellite allows long mission duration and STS sortie missions allow manned interaction, but only the Space Station provides both long duration missions and manned interaction.

Following the mission analysis study and the architectural options survey, the costs data for the Design, Development, Test, and Evaluation (DDT&E) were developed for the scenario elements that were incrementally added to the present STS baseline. Although the establishment of a figure of merit was not possible, the DDT&E cost offers additional understanding to evaluate the added capabilities.

Finally, Section 3.0 develops an evaluation of each scenario to determine if the scenario accommodates the mission set and provides the cost for added capability.

This document is based on a first iteration of a set of space missions and a Space Station concept that will continue to be refined in the next few months.

2.0 METHODOLOGY

2.1 MISSION MODEL

2.1.1 Mission Model Development

The mission model was developed by merging the "STS Mission Model 1983-2000 — Nominal Version" (Advanced Planning Division, NASA Headquarters, December 20, 1982) and the results of the Space Station Mission Requirements Workshop which was the culmination of one year of NASA and private industry study of missions for the Space Station era. The study and the Workshop were necessary because previous mission planning had generally considered only STS, Spacelab, and Free Flyers and did not include the availability of a Space Station System. The Mission Requirements Workshop utilized advocacy groups in three major areas: Science and Applications, Commercial, and Technology as a means to merge the results of the industry Mission Analysis Study results of the past year with NASA's space mission plans. This activity can be perceived as one of refocusing NASA mission plans to include a capability in excess of the present STS in terms of orbit stay time. This need has been recognized for many years, but mission planning has been constrained by the lack of long-term, manned on-orbit capability.

The term "mission" is used very broadly in this model. In some cases, the term refers to (1) a single instrument (e.g., a telescope), or (2) a single launch of a spacecraft, or (3) a series of experiments.

2.1.2 Mission Categories

The model includes missions in the following categories:

2.1.2.1 Astrophysics. The astrophysics missions use telescopes or other detectors that are flown as missions requiring one to ten years on-orbit to complete their mission objectives. The long duration is required because the observation of just one object can require integration of photons over a period of hours or days and many objects must be surveyed and compared; simultaneous observations at several different wavelengths are often required for each object; and detection of changes over periods of years are often important. In addition, several missions desire ready manned intervention for adjustment and servicing of instruments.

2.1.2.2 Earth Science And Applications. Earth Science and Applications missions are generally flown in high inclination orbits. Long duration missions are essential for the observations of the slowly varying changes on the earth's surface.

2.1.2.3 Solar System Exploration. The Solar System Exploration missions utilize either expendable upper stages or Orbital Transfer Vehicles (OTV's) for insertion into the proper trajectory.

2.1.2.4 Life Sciences. The life sciences missions require extended, uninterrupted time on-orbit with extensive crew involvement. The major objective of these missions is to understand, and develop countermeasures for, the effects of lack of gravity on humans.

2.1.2.5 Communication Satellites. The communications satellites require launch capability to geosynchronous orbit.

2.1.2.6 Materials Processing. Effective development of Materials Processing in Space (MPS) requires a research and development facility that affords long duration, uninterrupted time on orbit with extensive manned interaction. This facility would allow realization of the potential of MPS research to yield new commercial enterprises and technology advances.

2.1.2.7 Satellite Servicing. On-orbit satellite servicing in low earth orbit is expected to become a routine procedure in the 1990s. Satellite servicing includes routine and contingency maintenance of free flyers and platforms, resupply of propellants, adjustment or change-out of scientific instruments, and, in some cases, on-orbit assembly and deployment of satellites. Servicing satellites at geosynchronous orbit is also proposed.

2.1.2.8 Technology Development. The Technology Development missions that are listed in this model were designed specifically to take advantage of long duration in space with interaction by man. Most of these missions are designed to provide verification of Space Station technology for the enhancement of Space Station evolution. Some of the missions provide significant technology development for areas such as large antenna development for commercial communication.

2.2 COST ESTIMATING

The cost estimates used for the Space Station System were derived from a cost model developed by NASA. This model is based on a historical manned spacecraft (Gemini, Apollo, Skylab, Spacelab, STS orbiter) and unmanned spacecraft (Landsat, HEAO, ATS, and others) data base. This model uses cost estimating relationships (CER's) to determine the subsystem and system level costs. The CER's in the cost model were developed from a normalized historical data base by parametric costing and similarity between present and past programs.

The cost estimates are for Design, Development, Test, and Evaluation (DDT&E) and are based on 1984 dollars.

2.2.1 DDT&E Costs

When new elements (i.e., PEP, Platform, Space Station, see Appendix B for details) are required to support a scenario, a DDT&E cost for the element is factored into the total cost. The cost includes design and development of such items as structures, thermal control, electrical power, communications, data handling, attitude control, and environmental control and life support subsystems. It also includes the systems test hardware, integration, assembly, checkout, ground support equipment, and program management cost estimates. The initial DDT&E cost includes the cost of the first unit. If additional elements (second buy's) are required, these elements are procured at a significantly lower price since the initial units include the design and development cost.

Examples of second unit cost can be seen by reviewing DDT&E cost for Scenario II. The cost of the 28.5° Space Platform is \$650 M. The cost for the 90° Space Platform (a second unit) is \$305 M.

Another example of reduction in cost for like elements can be seen in Scenario IIIc. The cost for the first 28.5° Space Platform is \$550 MIL less than in Scenario II since some development cost is covered by the Space Station development. The second Space Platform (90°) for this Scenario is also less (\$260 MIL).

The cost for instruments or mission/payload equipment are not included in any scenario cost.

Operations/Life Cycle Costs

An operations/life cycle cost was developed for the element within each scenario from 1991 through 2000. The life cycle cost utilized for the STS was based on STS historical data which includes the ground processing and flight operations costs for each flight. However, as stated in the introduction, this operational life cycle cost was not used.

3.0 SCENARIOS

The elements of each scenario are outlined in Table 3.1. The further detail description of the elements is contained in Appendix B.

An extended orbitor capability, in the form of a power extension package, has been added to some of the scenarios to evaluate its ability to fulfill the mission model requirements

TABLE 3.1

I	Ia	II	IIa	IIb	IIIa	IIIb	IIIc	IV
STS	STS	STS	STS	STS	STS	STS	STS	STS
S/L	S/L	S/L	S/L	S/L	S/L	S/L	S/L	S/L
U/S	U/S	U/S	U/S	U/S	U/S	U/S	U/S	U/S
F/F	F/F	F/F	F/F	F/F	F/F	F/F	F/F	F/F
TMS	TMS	TMS	TMS	TMS	TMS	TMS	TMS	TMS
	PEP	SP28.5°	PEP	SP90°	SS28.5°	SS28.5°	SS28.5°	SS28.5°
		SP90°	SBOTV	SP28.5°	PEP	SP90°	SP90°	SP90°
		PEP	OTV/SS	SBOTV			OTV @SS	SP 28.5°
				OTV/SS			SP 28.5°	SS90°
								OTV @ SS

LEGEND:

STS - SPACE TRANSPORTATION SYSTEM
S/L - SPACELAB - SORTIES
U/S - UPPER STAGES
FF - FREE FLYERS
TMS - TELEOPERATOR MANEUVERING SYSTEM
PEP - POWER EXTENSION PACKAGE (PEP)
SP - UNMANNED SPACE PLATFORM
OTV/SS - OTV SPACE STATION
SS - SPACE STATION
SBOVT - SPACE BASED ORBITER TRANSFER VEHICLE
MPS - MATERIALS PROCESSING IN SPACE
L/S - LIFE SCIENCE
OTV @ SS - OTV CAPABILITY ADDED TO EXISTING SPACE STATION

3.1 SCENARIO I

3.1.1 Description

Scenario I utilizes the present STS system augmented with an STS-based Teleoperator Maneuvering System (TMS) to enhance capabilities for deployment, retravial, service, and on-orbit maintenance of free flying satellites. Other elements in the scenario are free flying satellites, and expendable upper stages (PAM-A, PAM-D, IUS, and Centaur) that are used to lift payloads from the shuttle orbit to geosynchronous and other high energy orbits.

3.1.2 Capabilities

The Materials Processing missions preferred mode of accommodation is the Space Station. These missions require long duration, uninterrupted time on-orbit with extensive manned interaction. These missions cannot be accommodated by the capabilities of this scenario. A limited amount of research can be accomplished by STS sortie flights. These limited R&D missions could provide early precurser equipment development leading to the eventual product capability, but the potential of materials processing in space cannot be fully developed with intermittent missions that cause much lost time and require the expense of re-integrating and relaunching the instruments for only a week's experimentation.

The astrophysics missions require long time on-orbit (one to ten years) and many of these missions also desire manned involvement for servicing and adjustment of instruments. The total mission set cannot be accommodated within the capabilities of Scenario I. Some of the missions will be flown as free-flying satellites. The remaining missions will be placed on STS sortie flights, where they do receive the benefit of manned involvement; but in this case, the attainment of mission objectives is severely limited because of the short duration of the STS flights. For example, experiments such as Starlab and Solar Optical Telescope that need three to four years of on-orbit observation time are limited to one or more STS missions of approximately seven days each. Since several days of outgassing time are required before good observations can be performed with these instruments, the amount of good quality data obtained is questionable.

Life science missions require extended, uninterrupted time on-orbit with extensive crew involvement. These missions cannot be fulfilled in this scenario. Only precursor experiments can be accomplished in this scenario (flying these experiments as sortie missions on the STS). The long term objectives of these missions can only be accomplished with a permanent manned orbiting faciilty.

The earth science and application missions in general require high inclination orbits and a few missions require man involvement. The high inclination missions will be flown on free flyers in this scenario. Those missions requiring man intervention because of the complexity of the experiments, will be flown as STS sortie missions, but again the short duration on orbit severely limits the attainment of mission goals.

Satellite servicing missions preferred accommodation modes are, satellite return to the on-orbit servicing facility, or remote servicing at the satellite location. These missions can be accomplished with the STS, TMS, and expendable launch vehicles. However, the servicing equipment must be brought to orbit on planned STS flights for each mission.

Communications satellites which require geosynchronous orbit will be launched via the STS with an expendable upper stage (PAM-A, PAM-D, IUS, or Centaur).

Since the technology development missions in this model were designed specifically as Space Station missions, most of the objectives cannot be accomplished in this scenario. However, different versions of many of these missions could be done on the STS. Additionally, the STS can be used to enhance the technology required to build the initial Space Station.

The STS can be utilized for the development of some techniques and equipment for eventual use by the Space Station in fulfilling some of its mission objectives (e.g., satellite servicing).

In Scenario I, the solar system exploration missions will be accomplished with expendable upper stages (IUS or Centaur) launched from the STS.

3.1.3 Cost

The following are the cost associated with Scenario I:

DDT&E Cost		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$ 232 MIL
*Free Flyers	(26 FF x $200)	$5200 MIL
	Total Cost	$ 5432 MIL

* The Free Flyers cost is for the bus only, not instruments.

3.2 SCENARIO IA

3.2.1 Description

This scenario utilizes the present STS system augmented with (1) a power extension package (PEP) which extends the shuttle on-orbit stay time from a maximum of 7 to 20 days and (2) a STS-based teleoperator maneuvering system (TMS) to enhance capabilities for deployment, retrieval, service, and on-orbit maintenance of free flying satellites. Other elements in the scenario are free flying satellites and expendable upper stages (PAM-A, PAM-D, IUS, and Centaur) that are used to lift payloads from the shuttle orbit to geosynchronous and other high energy orbits.

3.2.2 Capabilities

The major change in capabilities to this scenario from Scenario I, is the addition of the PEP (Power Extension Package). This addition has a small impact on the fulfilling of the mission model. The significant impact is in the increased orbitor stay time for the Spacelab/sortie missions. Most sortie missions benefit is an increase in the on-orbit staytime, but still fail to accomplish a significant fraction of the mission objectives.

3.2.3 Cost

DDT&E		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$232 MIL
*Free Flyers	(27 x $200 To Support The Scenario)	5400 MIL
PEP		150 MIL
RMS		$ 25 MIL
	Total Cost	$ 5807 MIL

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

3.3 SCENARIO II

3.3.1 Description

Scenario II utilizes the present STS system augmented with a power extension package (PEP) which extends the Shuttle on-orbit stay time from 7 to a maximum of 20 days and a STS-based Teleoperator Maneuvering System (TMS) to enhance capabilities for deployment, retrieval, service, and on-orbit maintenance of free flying satellites. Other elements in the scenario are free flying satellites and expendable upper stages (PAM-A, PAM-D, IUS, and Centaur) that are used to lift payloads from the shuttle orbit to geosynchronous and other high energy orbits.

The major elements added to this scenario over previous scenarios are space platforms located at 28.5° and 90° inclinations.

3.3.2 Capabilities

In Scenario II, the long duration astrophysics missions are accommodated on the platforms. They provide indefinite on-orbit stay time; however, there is a small percentage of time that manned interaction is available. Man is present only during periodic STS servicing/supply missions -- probably twice a year. The addition of PEP to the STS in this scenario does not increase the mission accommodation capability, but does provide longer servicing periods. Another consideration for the astrophysics missions in this scenario is that the platforms are cost-effective because the instruments are placed on a common bus, thus saving design, development, and production costs.

The long duration earth science and applications missions are accommodated on the platforms with the same advantages and restrictions as for the astrophysics missions.

The solar system exploration and geosynchronous satellite missions are launched from the STS with expendable upper stages as in the previous scenarios.

The same limitations identified in Scenario Ia apply to life science missions in this scenario.

The accommodation of Materials Processing Research is also inhibited as in Scenario Ia, because of the short duration orbit time of the Shuttle.

Satellite servicing in this scenario will be performed from the STS as in the Scenario Ia. The servicing of instruments grouped or mounted on the platforms will be more efficient because servicing can be done in tandem with the platform resupply missions.

The accommodation of Technology Development missions in this scenario is similar to that of Scenarios I and Ia.

The Free Flyers that are included in this scenario are those that were on-orbit before the Space Platform, those that require unusual orbits or have other unusual characteristics incompatible with the Space Station orbit, and those that have been launched beyond low earth orbit for solar system exploration or geosynchronous missions.

3.3.3 Cost

The following are costs associated with this scenario:

DDT&E		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$ 232 MIL
*Free Flyers	(20 x $$200)	4000 MIL
Platforms	28.5°	650 MIL
	90°	305 MIL
PEP		150 MIL
RMS		25 MIL
	Total Cost	$5362 MIL

* The Free Flyers cost is for the bus only, not instruments.

3.4 SCENARIO IIa

3.4.1 Description

Scenario IIa utilizes the present space transportation system (STS) augmented with a power extension package (PEP) which extends the Shuttle on-orbit stay time. Other elements required in the scenario are (1) free flying satellites for 1991, (2) expendable upper stages for 1991, and (3) an STS-based Teleoperator Maneuvering System (TMS).

This scenario contains a space-based OTV capability in 1992. The OTV is launched from a manned OTV servicing station. The TMS will also be space-based at that time.

3.4.2 Capabilities

Scenarios IIa adds to the capabilities of scenario Ia the capability to service and launch space-based OTV's and to mate payloads to OTV's on-orbit. The on-orbit OTV payload mating capability allows greater flexibility in STS payload manifesting, thus potentially increasing the STS load factor. Greater flexibility in satellite design is allowed because the payload can be assembled on-orbit prior to mating to the OTV. The number of STS flights will also be reduced because flights to bring the expendable launch vehicles to orbit are no longer required. Geosynchronous satellite servicing is included in this scenario because the space-based OTV provides round-trip transportation to geosynchronous orbit for the TMS or other servicing equipment.

This station has no capability to provide for attached payloads or laboratory modules. The accommodation of missions that do not use the OTV are the same as in Scenario Ia.

The advantages of the PEP in this scenario are the same as in Scenario Ia.

3.4.3 Cost

DDT&E		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$ 232 MIL
*Free Flyers	(27 FF x $200 To Support this Scenario)	5400 MIL
RMS		25 MIL
PEP		150 MIL
OTV Servicing Station		6808 MIL
OTV		1600 MIL
	Total Cost	$14215 MIL

* The Free Flyers cost is for the bus only, not instruments.

3.5 SCENARIO IIb

3.5.1 Description

Scenario IIb utilizes the present space transportation system (STS). Other elements required in the scenario are (1) free flying satellites, (2) expendable upper stages (phased out in 1992), and (3) an shuttle-based Teleoperator Maneuvering System (TMS).

This scenario adds two unmanned space platform with operational capability beginning in 1991 and a space-based OTV capability in 1992. The OTV is launched from a manned OTV servicing station. The TMS will also be space-based at that time.

3.5.2 Capabilities

The capabilities of Scenario IIB are the sum of the capabilities of Scenarios II and IIa. As in Scenario II the long duration missions are accommodated on platforms. As in Scenario IIa the OTV servicing station provides capability for servicing and launching of OTV's, on-orbit mating of payloads to OTV's, assembly of payloads on-orbit, and servicing of satellites at geosynchronous orbit.

3.5.3 Cost

DDT&E		Cost
STS	(Developed)	0
Spacelab	(Developed)	0
Upper Stages	(Developed)	0
TMS		$ 232 MIL
*Free Flyers	(22 FF x $200)	4400 MIL
Manned OTV	Servicing Station	6808 MIL
OTV		1600 MIL
Platforms	28.5°	550 MIL
	90°	260 MIL
	Total Cost	$13850 MIL

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

3.6 SCENARIO IIIa

3.6.1 Description

Scenario IIIa utilizes the 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) that are used to launch payloads from the STS orbit to geosynchronous and other high energy orbits.

This scenario adds a manned Space Station that is operational in 1991 and grows to support mission requirements. When the station is activated the TMS will be moved from shuttle-based to space-based.

3.6.2 Capabilities

In Scenario IIIa most astrophysics missions are accommodated on the Space Station at 28.5°; in this mode they receive the benefits of both long on-orbit stay-time and ready manned intervention. The missions that are free-flyers in this scenario are those that were on-orbit before the Space Station became operational or those that have unique requirements such as orbits that are not compatible with the Space Station.

Most of the earth science and applications missions must be accommodated on high inclination orbiting free-flyers in this scenario.

The Space Station defined in this scenario has no reusable OTV capability, therefore, the geosynchronous satellites and planetary missions will utilize expendable upper stages as in Scenarios I, Ia, and II.

This scenario accommodates life sciences research. It provides laboratory research facilities and meets the requirements for extended time on orbit with manned interaction.

This scenario also fully enables Materials Processing in Space (MPS) research and development. A man-tended laboratory on the Station will be utilized to develop these MPS capabilities which have the potential to produce both commercial enterprises and technology advances.

Free flying near 28.5° inclination will be serviced from the Space Station. In this scenario the servicing facility is an integral part of the Space Station, therefore, additional STS launches to bring up servicing equipment are not required for servicing of satellites near the station's orbit.

The Space Station will be used to develop technology that will enhance capabilities for Space Station growth, science mission execution, communications, and other areas. One of the major areas to be developed, is the capability to construct large structures on orbit. This technology is required for large antennas, telescopes, and communications satellites. Technology will also be developed for science missions including optics assembly techniques and earth observation instrument development.

The high energy missions are accomplished by a space-based OTV as described in Scenario IIa.

The addition of PEP to the STS in this scenario does not increase the mission capability since the long duration missions are accommodated by the Space Station and space based TMS.

The Free Flyers that are included in this scenario are those that were on-orbit before the Space Station, those that require unusual orbits or have unusual characteristics incompatible with the Space Station orbit, and those that have been launched beyond low earth orbit for solar system exploration or geosynchronous missions.

3.6.3 Cost

DDT&E

			Cost
STS	(Developed)		0
Spacelab	(Developed)		0
Upper Stages	(Developed)		0
TMS			$ 232 MIL
*Free Flyers	(27 FF x $200)		5400 MIL
Manned Space Station at 28.5°		Initial	7520 MIL
		Growth	4745 MIL
PEP			150 MIL
RMS			$ 25 MIL
	Total Cost		$18072 MIL

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

3.7 SCENARIO IIIb

3.7.1 Description

Scenario IIIb 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) that are used to lift payloads from shuttle orbit to geosynchronous and other high energy orbits.

This scenario adds a manned space station beginning in 1991 with growth to support mission requirements, and a space platform at 90°. When the station is activated the TMS will be moved from orbiter based to space-based.

3.7.2 Capabilities

With the capability of the Space Station at 28.5° and the space platform at 90° the mission requirements of astrophysics, material processing, and life sciences are all fulfilled.

With the basic capabilities of the STS and the expendable launch vehicles for satellite servicing, the mission requirements for solar system exploration, and commercial communication are accomplished.

3.7.3 Cost

DDT&E			Cost
STS	(Developed)		0
Spacelab	(Developed)		0
Upper Stages	(Developed)		0
TMS			$ 232 MIL
*Free Flyers	(22 FF x $200 To		4400 MIL
Manned Space Station at 28.5°			
		Initial	7520 MIL
		Growth	4745 MIL
Platform		90°	550 MIL
		Total Cost	$17447 MIL

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

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.

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.

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 integra-tion 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 trans-fer 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-or-bital 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, aero-braked 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.

- Service, refuel, replenish consumables, change experiments and/or payloads, and repair failed subsystems of free-flying satellites at the Space Station.
- 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:

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