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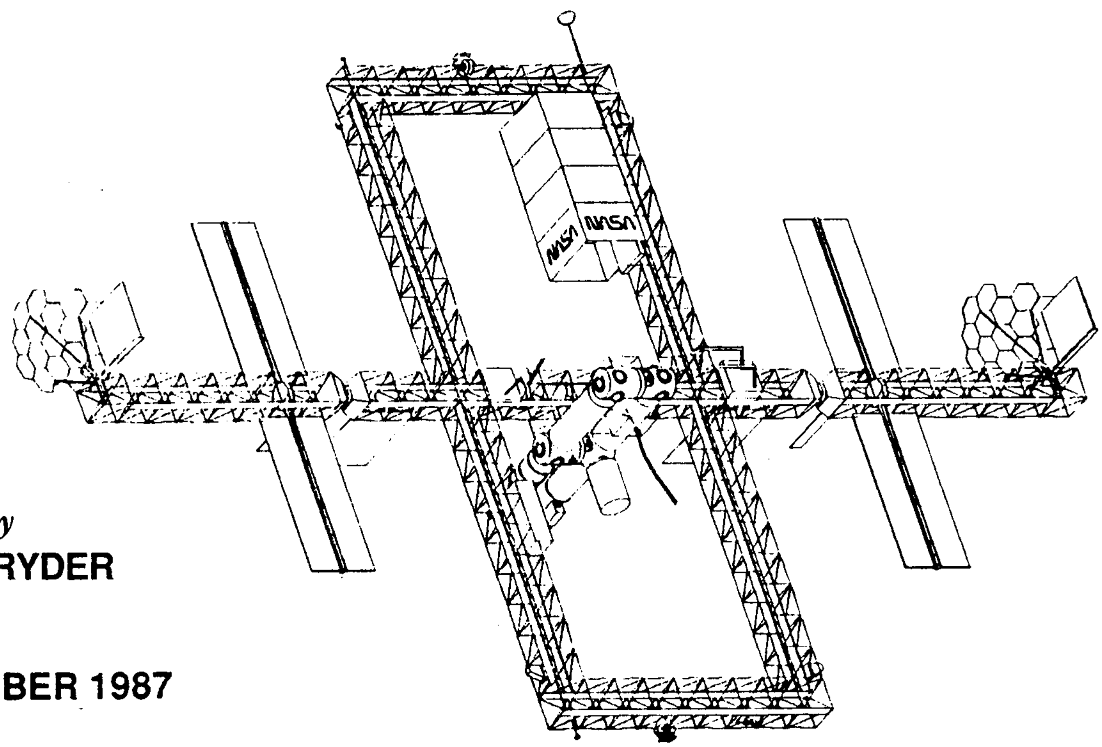
ASSESSMENT OF MIXED FLEET POTENTIAL FOR SPACE STATION LAUNCH AND ASSEMBLY



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1.0 INTRODUCTION AND TEAM MEMBERSHIP

SPACE STATION PROGRAM

When originally conceived in the 1960s and early 1970s, the Space Shuttle and Space Station were envisioned as two elements of a Space System infrastructure. This close relationship is embodied in the Space Station Program goal of permanent manned presence in space which requires a robust STS Program to support salient Space Station program attributes such as on-orbit assembly, an uninterrupted long operational life, and evolutionary growth.

As the only available way to deliver astronauts to orbit, to assemble the Station, and later to rotate crew members back and forth to Earth, the Space Shuttle is an essential element of the program. Furthermore, the Shuttle is the only available vehicle for returning laboratory products, failed equipment, and refuse to the ground.

SPACE STATION PROGRAM

- PREDICATED ON SPACE SHUTTLE AVAILABILITY
  - REQUIRED FOR MANNED ASSEMBLY
  - MAJOR CONSTRAINT BECAUSE THERE IS NO OTHER MANNED TRANSPORTATION SYSTEM
  - ONLY AVAILABLE DOWN CARGO CARRIER

OBJECTIVE

As a result of the 51-L accident in 1986, both STS flight frequency and weight capacity are projected to be lower than when initial Station Phase B design definition and program planning was done. In addition, Station assembly and science/laboratory payloads must now compete for flight opportunities with a large backlog of other shuttle customers, especially national security payloads. As a result, this study examines the possible benefits of using existing ELV systems to increase the rate at which material can be placed in orbit.

In addition to existing ELVs, newly developed vehicles with larger lift capabilities could be used to support Station assembly. One option generating a lot of interest is the Shuttle-Derived Vehicle (SDV), which in concept is based largely on existing STS components. The major attraction of a SDV is that this type of Heavy Lift Launch Vehicle (HLLV) could be developed faster and at lower cost than an entirely new design. This study considers use of a representative heavy lift SDV concept as well as existing ELVs.

Policy guidance indicates that the number of STS flights per year dedicated to the Station may drop from 8 to 6, or even to 4, per year. This study will examine if use of ELVs or SDVs can compensate for this reduction. There may be impacts of STS flight rate reduction beyond weight-to-orbit deficiencies, particularly with relation to crew rotation, and this study will consider these as well.

OBJECTIVE

- IDENTIFY ASSEMBLY PHASE FLIGHTS THAT CAN BE LAUNCHED ON ELV'S

  - SPACE SHUTTLE + EXISTING ELV'S

  - SPACE SHUTTLE + EXISTING ELV'S + SDV

- ASSESS IMPACT OF REDUCING FLIGHT FREQUENCY FROM 8 TO 4 OR 6 SPACE SHUTTLE FLIGHTS PER YEAR FOR SPACE STATION

ASSES.OBJ2

STUDY PARTICIPANTS

The study team was composed of participants from LaRC, LeRC, and MSFC. Because of its tight schedule, however, it relied heavily on LaRC personnel and was not able to include members from JSC or KSC.

STUDY PARTICIPANTS

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GROUND RULES

A number of ground rules to constrain the study were laid down at the outset. First, the detailed Station program for alternative launch vehicle evaluation was to be that defined by the Critical Evaluation Task Force (CETF), and CETF objectives were to be met. The principal CETF objectives were:

- retain system and element weight allocations as defined in Phase B;
- maintain configuration definitions for man tended capability (MTC), Permanently Manned Capability (PMC), international participation, and Initial Operational Capability (IOC);
- assembly sequence would provide early scientific utilization of the station;
- minimize dependence on Extra Vehicular Activity (EVA) for assembly and maintenance;
- each assembly sequence launch vehicle flight provides a fully functional spacecraft
- a maximum 90 day crew stay time for permanent habitation of the Space Station.

The study was chartered to consider benefits to be realized from using expendable launch vehicles (ELVs), including heavy lift expendable Shuttle Derived Vehicles (SDV), to augment Space Shuttle launch schedule planning through the 1995 time period to provide NASA with a mixed fleet STS capability. Any schedule, cost, or risk savings from using ELVs should be identified during the study. In addition, some foreign launch systems should also be examined for usefulness later in the program. In order to be able to retrieve and manipulate ELV- or SDV-borne Station payloads, the early availability of the Orbital Maneuvering Vehicle (OMV) had to be assumed.

Although the Crew Escape and Rescue Vehicle (CERV) had been considered by CETF, it was not to be considered in the study but was left for later study as alternative launch scenarios matured.

GROUND RULES

- ACCOMPLISH ALL CETF OBJECTIVES
- NO CHANGE IN CETF SPACE STATION CONFIGURATION
- CONSIDER USE OF SDV IN ADDITION TO EXISTING ELV'S (TITAN 4, TITAN 34D, ATLAS/CENTAUR, DELTA, H-2, AND ARIANE)
- SPACE BASED OMV AVAILABLE AT FIRST ELV
- NO CERV

ASSES.GRRULES

KEY CETF MISSION GOALS LEADING TO IOC

The CETF defined a specific Station build-up sequence to meet its objectives. Major milestones are the initiation of user operations with attached payload capability after Flight #3, man-tended capability on Flight #5, permanently manned capability on Flight #11, addition of solar dynamic power system modules on Flight #12 to upgrade to a 75 kilowatt operational capability, and incorporation of the Japanese and European Space Agency (ESA) laboratory modules at Flight #16. In CETF, the full servicing capability is achieved only after a series of steps beginning with Flight #18. The servicing capability includes the Mobile Servicing Center (MSC), which is a major component of Canadian participation in the Space Station program.

Additionally, the Space Station program includes in its space system infrastructure definition two unmanned science platforms. With the launch of the co-orbiting platform on Flight #32, the Space Station Program achieves its defined Initial Operating Capability (IOC).

KEY CETF MISSION GOALS LEADING TO IOC

- FUNCTIONAL SPACECRAFT ON FLT #1 & #2
- EARLY USER INVOLVEMENT
  - ATTACHED PAYLOAD CAPABILITY ON FLT #3
  - MAN TENDED CAPABILITY (MTC) ON FLT #5
    - LABORATORY SCIENCE EXPERIMENTS
- PERMANENTLY MANNED CAPABILITY ON FLT #11
- SOLAR DYNAMIC POWER TO 75 KW ON FLT #12
- INTERNATIONAL LABORATORIES ESTABLISHED AT FLT #16
- EARLY SERVICING CAPABILITY BY FLT #18
  - MOBILE SERVICING (MSC) UPPER/LOWER BOOM P/L BY FLT #28
  - PHASED SERVICING BUILD-UP COMPLETE BY FLT #30
- CO-ORBITING PLATFORM ON FLT #32

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EXTERNALLY IMPOSED CONSTRAINTS

There are several specifically crew-oriented constraints on any approach to Station build-up and operations. Medical studies of the effects of weightlessness conducted on SKYLAB and Soviet manned platforms were the basis for baselining, for the Space Station Program, a maximum crew stay time of no more than 90 days. In addition, because of the limited crew capacity of the Orbiter and the need for a complement of three to fly it, the number of Station astronauts that can be exchanged in a given Orbiter visit is constrained to no more than four. Astronaut Extra Vehicular Activity (EVA) from the Orbiter is also limited during its nominal 7 day on-orbit stay. Nominally 48 hours of EVA can be provided by current Orbiter system capabilities. However, because crew safety and contingency planning is of key importance, 24 EVA hours per flight have been established as the operational baseline for Shuttle flights supporting Space Station assembly.

EXTERNALLY IMPOSED CONSTRAINTS

- 90 DAY - MAXIMUM CREW STAY TIME
- CREW CHANGE OUT LIMITED TO 4 OR 5 PEOPLE PER SPACE SHUTTLE FLIGHT
- 24 EVA HOURS LIMIT ON ALL SPACE SHUTTLE FLIGHTS PRIOR TO PMC

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CETF CREW ROTATION REQUIREMENT

The CETF concept calls for a Space Station crew complement of four beginning at PMC, with the first rotation limited to 60 days. This first rotation may actually be reduced further to 45 days to match STS flight schedules. Subsequent crew stays are all 90 days, and the crew size will grow to eight once the crew Habitation Module is completely outfitted and JEM and ESA modules are added to the module pattern.

CETF CREW ROTATION REQUIREMENT

- 4 MAN CREW PMC
  - 60 DAY ROTATION 1ST TIME
  - 90 DAY ROTATION THEREAFTER
- 8 MAN CREW AT COMPLETION OF MODULE PATTERN
  - 90 DAY ROTATION THEREAFTER

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2.0 REVIEW OF CETF LAUNCH AND ASSEMBLY SEQUENCE

CETF FLIGHT SEQUENCE OVERVIEW

The current Space Station Program Definition requires 32 STS flights to support Station assembly, operations,and platform deployment. In addition to the STS flight number, a special code is used to designate the type and number of each STS flight, whether Manned Base (MB) assembly flight, platform (P), module outfitting (OF), logistics (L), or platform refurbishment (PR). Outfitting refers to equipment to be installed inside a pressurized module, whereas logistics refers to resupply of spares and consumables. The first four flights (MB-1,2,3,4) all carry components of the manned base, including parts of the photovoltaic (PV) power system, thermal control system (TCS), the Space Station remote manipulator system (SSRMS), and the first user payloads (P/Ls). After the first platform launch (P-1) from the western test range (WTR), build-up of the Manned Base continues with the laboratory module (MB-5) and habitability module (MB-6). The lab module outfitting flight (OF-1) is needed because the fully equipped laboratory module is too heavy for a single Shuttle launch, so part of its subsystems and user equipment must be off-loaded before launch and sent up and installed later.

Once the Station achieves permanently manned capability (PMC) on MB-8, the logistics flights occur at regular intervals (L-1, L-2, etc.). Additional power is provided by launch and installation of the solar dynamic (SD) power subsystems on MB-9. International modules are added to the basic configuration beginning with the Japanese Experiment Module (JEM) and exposed facility (EF) on MB-10 and the European (ESA) module on MB-11. Resupply and/or outfitting of the JEM is provided separately on MB-14 by the Experiment Logistics Module (ELM). Important components of the Station servicing equipment are sent up on a series of flights (MB-12, 13, 15, and 17), with completion of this build-up and over-all Station initial operational capability (IOC) occurring on MB-17. Launch of the co-orbiting platform completes the Space Station program IOC, which consists of the dual keel Space Station configuration, a polar orbiting platform and a co-orbiting platform.

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FLIGHT SEQUENCE OVERVIEW
OPTION 3

FLIGHT			
1	(MB-1)	1/2 PV, NODE, TRUSS	
2	(MB-2)	1/2 PV, NODE, TRUSS	
3	(MB-3)	TCS, AIRLOCK, P/L, SSRMS	
4	(MB-4)	AIRLOCK	
5	(PI)	U.S. POLAR PLATFORM (WTR)	
6	(MB-5)	U.S. LAB MODULE	← MAN-TENDED
7	(OF-1)	LAB MODULE OUTFITTING	
8	(MB-6)	U.S. HAB MODULE	
9	(P-2)	ESA POLAR PLATFORM (WTR)	
10	(MB-7)	NODES, CUPOLAS	
11	(MB-8)	CREW (4), LOGISTICS	← PMC
12	(MB-9)	SD POWER	← SD
13	(L-1)	LOGISTICS	
14	(MB-10)	JEM, EF #1	
15	(L-2)	LOGISTICS	
16	(MB-11)	ESA MODULE	
17	(L-3)	LOGISTICS	
18	(MB-12)	SERV. FAC., PAYLOADS	← PHASE 1 SERVICE
19	(L-4)	LOGISTICS	
20	(MB-13)	SERV. FAC., OUTFITT.	← PHASE 2 SERVICE
21	(L-5)	LOGISTICS	
22	(MB-14)	JEM EF #2, ELM	
23	(L-6)	LOGISTICS	
24	(MB-15)	MSC/TRANSPORTER	
25	(L-7)	LOGISTICS	
26	(PR-1)	PLATFORM SERV. (WTR)	
27	(L-8)	LOGISTICS	
28	(MB-16)	UPPER & LOWER BOOMS	
29	(L-9)	LOGISTICS	
30	(MB-17)	FAC. PAYLOADS	← PHASE 3 SERVICE IOC
31	(L-10)	LOGISTICS	
32	(P-3)	CO-ORBITING PLATFORM (ETR)	

ASSEMBLY FLIGHT 1 - MANIFEST

MB-1 includes the elements needed to construct a functional, free flying spacecraft that is a powered and dynamically stable subset of the ultimate Station configuration. These elements include power generation and distribution, attitude sensing and control, data handling, communications, and structural components which are grouped for transport to orbit in the Shuttle cargo bay into three major packages.

The first package contains the "alpha joint" (the main articulation for the solar panels), the reaction control system (RCS), an antenna, and guidance, navigation, and control (GN&C) sensors and controls. The second package is one of the CETF nodes; it contains elements of the thermal control system (TCS), the attitude control system (ACS), the electric power system (EPS), and the data management system (DMS). It contains the RCS electrolysis system to create hydrogen and oxygen from water, and some subsystems relocated by CETF into the nodes from unpressurized areas. These relocated systems include communications and tracking (C&T), DMS, fluid management and distribution (FMAD), GN&C, electronics, heat rejection and transfer (HR&T), and electrical power system (EPS). A third package contains the photovoltaic power module, truss components, utility tray containing cabling, and the erector jig. The erector jig is a device to help assemble the truss; weighing 2000 lbs., it later becomes part of the mobile servicing center (MSC).

The flight support equipment (FSE) and attach fittings hold manifested station elements within the Orbiter bay during launch and are returned to the ground on completion of the Shuttle mission. FSE refers to equipment which supports a Station element during launch. Attach fittings interface between Station elements, including their FSE, and the Orbiter cargo bay.

All assembly is performed by Orbiter EVA, since there is no Station crew yet.

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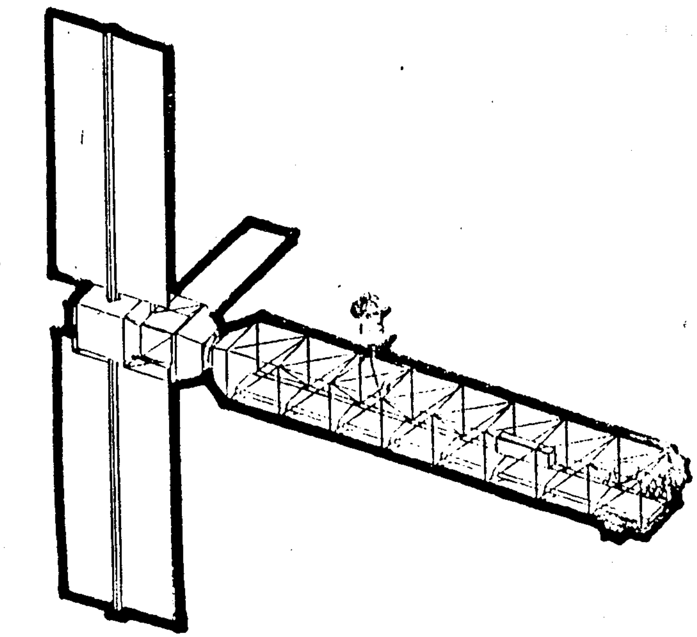
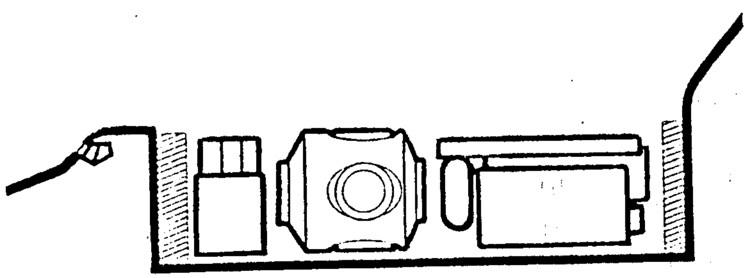
ASSEMBLY FLIGHT NO. 1





EVA : 24.4 MH

SS CREW : 0

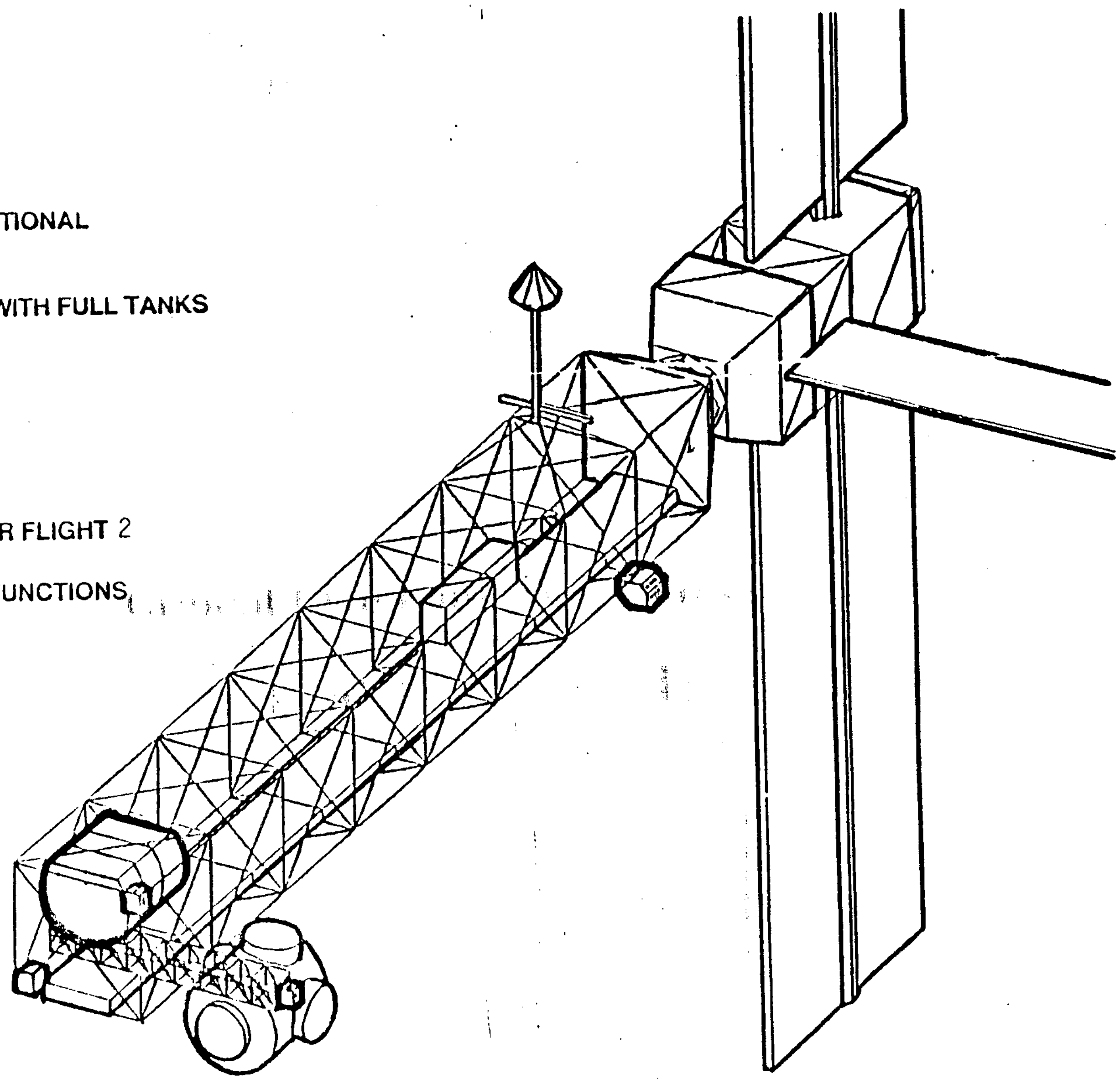
MANIFEST	MASS (LBS)
PACKAGE	8,260
- α JOINT	
- RCS PACKAGE	
- ANTENNA	
- GN&C SENSORS & CTRLS	
AFT NODE #1	12,015
- SUBSYSTEMS	
- TCS, ACS, EPS, DMS	
- RCS ELECTROLYSIS	
- OUTSIDE TO INSIDE EQP	
- C&T, DMS, FMAD, GN&C ELECTRONICS, HRT&T & EPS	
TRUSS/ASSEMBLY	19,222
- POWER MODULE	
- TRUSS	
- UTILITIES	
- ERECTOR JIG	
FSE	2,410
ATTACH FITTINGS	3,700
TOTAL	45,607

ASSEMBLY FLIGHT 1 - STATION CONFIGURATION

At the completion of Flight 1, the partial Station is capable of reboost and attitude control, with one-half (18.75 kw) of the photovoltaic (PV) solar arrays deployed. The orbital attitude orientation is described as an "arrow mode." This flight mode was conceived because the aerodynamic effects on the large PV panels required that the direction of flight be along the long truss axis with the panels in a low drag profile. Note the small truss section called the "stinger" to which the subsystem resource node is attached. Utility trays run along the truss between the alpha joint and the critical Space Station subsystems housed in the stinger/node assembly.

ASSEMBLY FLIGHT 1

- SPACECRAFT IS FULLY FUNCTIONAL
  - 18.75 KW ARRAYS
  - REBOOST AND RCS WITH FULL TANKS
  - SUBSYSTEMS
- GROUND VERIFIED
- FLIES IN ARROW MODE
- ERECTION FIXTURE LEFT FOR FLIGHT 2
- NODE CONTAINS CRITICAL FUNCTIONS



ASSEMBLY FLIGHT 1 - OPERATIONS SCENARIO

Because Orbiter EVA time is so limited, the duration of planned assembly activities proposed for each flight must be carefully evaluated for feasibility. In this chart, the EVA steps required for flight 1 sum (with a 20% overhead allocation) to 24.4 man-hours. All EVA is carried out in 2-person teams nominally planned at six hours per EVA session.

"Bays" refer to Station truss structure. Each bay is a single, cubic, boxlike segment of the truss. The stinger is a deployable truss structure, narrower than the main truss and attached perpendicular to it, that serves both to locate the resistojet orbit maintenance (reboost) system and to support the node.

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OPERATIONS SCENARIO
ASSEMBLY FLIGHT NO. 1

ACTIVITY		EVA TIME
WORKSITE PREP (2)		30
ERECT THE ERECTOR		60
INSTALL THE PV MODULE		30
BUILD TWO BAYS		44*
INSTALL HEAT PIPES		60
INSTALL ALPHA JOINT		60
BUILD TWO BAYS		44*
INSTALL CONTROL PKG. (RCS MODULE, ANTENNA UNIT)		30
BUILD FOUR BAYS		88*
INSTALL STINGER (W/ RESISTO JET, TANK FARM AND ACA & GNC)		30
INSTALL AFT STBD NODE		60
COMPLETE THE REST OF TEN BAYS		44*
DEPLOY STATION W/ ERECTOR ON THE END		
PLB CLEAN-UP (2)		30
		610
	+20% OVERHEAD	122
		732 MIN
	OR	12.2 HRS
	OR	24.4 M-HRS

EVA ALLOCATION

24 MAN-HRS PLANNED
12 MAN-HRS TASK GROWTH
12 MAN-HRS STATION OPS CONTINGENCY

*22 MIN. CLOCK TIME FOR BAY ASSEMBLY BASED ON ERECTABLE TRUSS AND DEPLOYABLE UTILITIES

ASSEMBLY FLIGHT 2 - MANIFEST

The second flight carries up, constructs, and installs the opposite half of the basic truss structure. After EVA completion, the structure is basically symmetrical, with the second set of PV panels deployed at the opposite end of the truss. The second node is installed, and an Orbiter docking adapter is installed on the truss structure for use during the assembly process.

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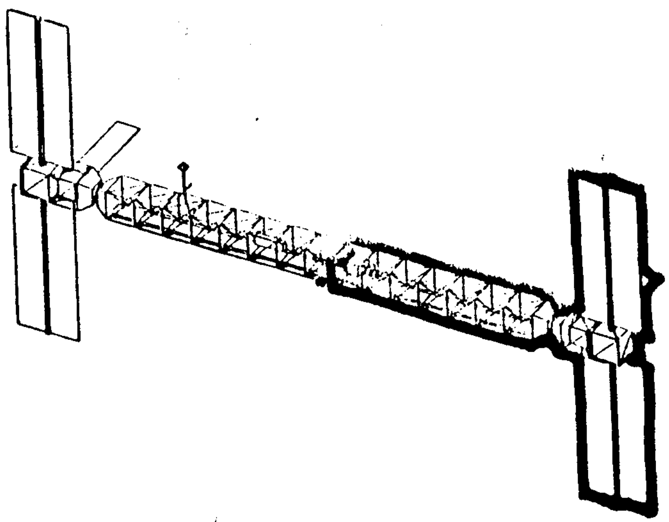
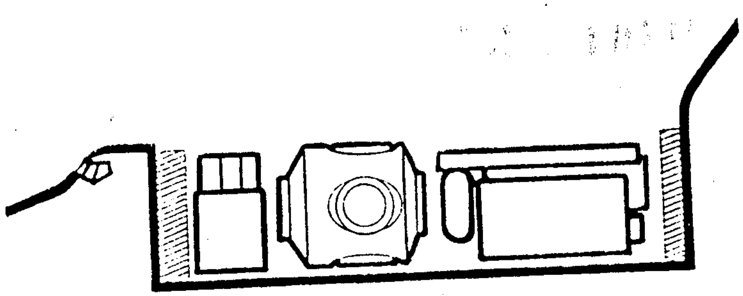
ASSEMBLY FLIGHT NO. 2





EVA : 21.3 MH
SS CREW : 0

MANIFEST	MASS (LBS)
AFT NODE # 2	10,525
- SUBSYSTEMS	
- TCS, ACS, EPS, DMS	
- OUTSIDE TO INSIDE EQP.	
- C&T, DMS, FMAD, GN&C ELECTRONICS, HR&T & EPS TRUSS DOCKING ADAPT	
PACKAGE	5,615
- α JOINT	
- RCS MODULE	
- CMG'S	
TRUSS/ASSEMBLY	15,945
- POWER MODULE	
- TRUSS	
- UTILITIES	
FSE	2,130
ATTACH FITTINGS	4,625
TOTAL	38,840

ASSEMBLY FLIGHT 2 - STATION CONFIGURATION

After EVA completion, both solar arrays are deployed in the final 37.5 kw configuration. The GN&C system is fully operational, including control moment gyros (CMGs). The electrical cabling and fluid plumbing running along the utility trays are connected in orbit. Because the whole structure is now aerodynamically symmetrical, it is now flown in its normal attitude, with the velocity perpendicular to the long dimension of the truss.

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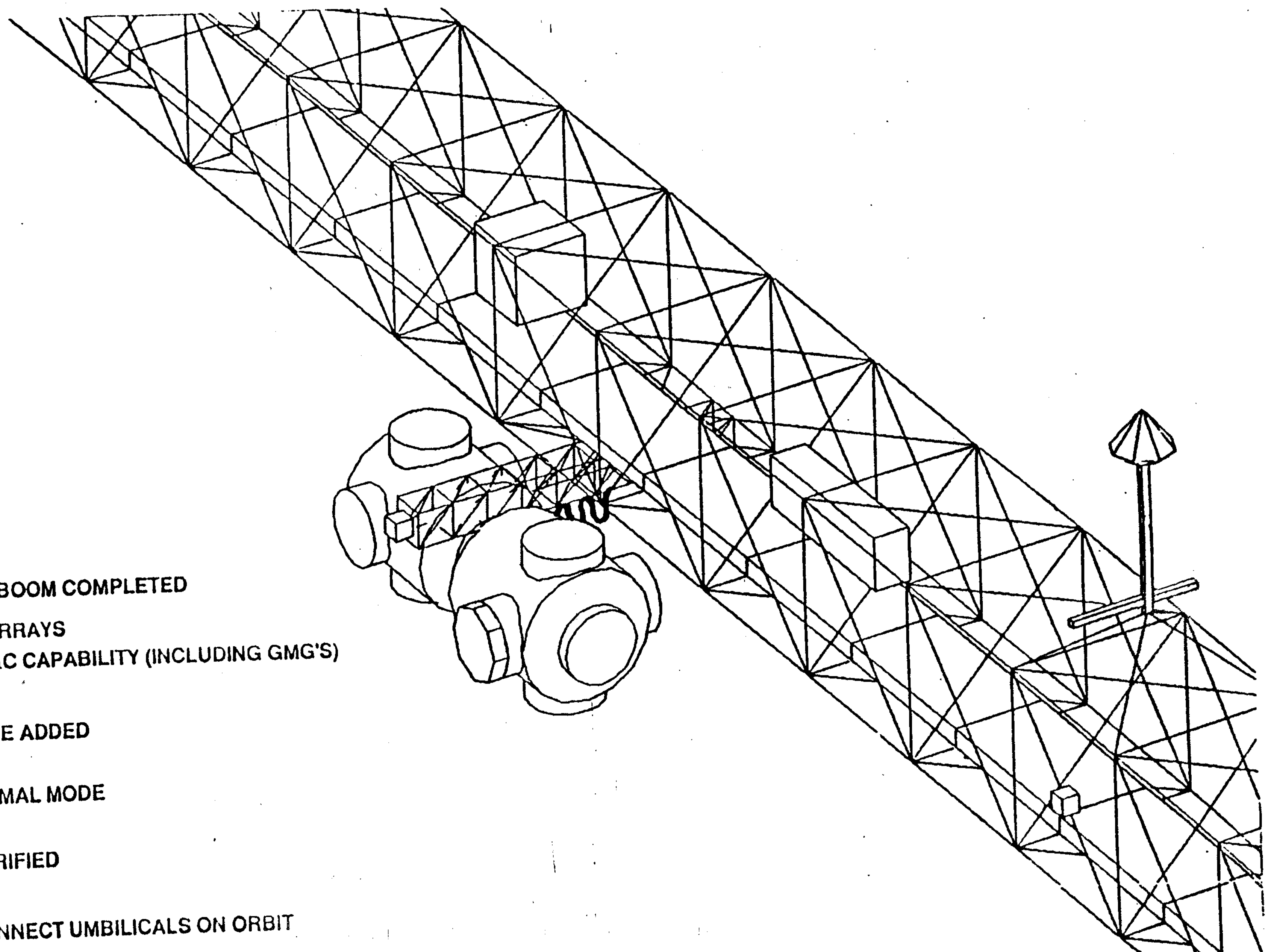
ASSEMBLY FLIGHT NO. 2



- HORIZONTAL BOOM COMPLETED
  - 37.5 KW ARRAYS
  - FULL GN&C CAPABILITY (INCLUDING GMG'S)
- SECOND NODE ADDED
- FLIES IN NORMAL MODE
- GROUND VERIFIED
- NEED TO CONNECT UMBILICALS ON ORBIT

ASSEMBLY FLIGHT 2 - OPERATIONS SCENARIO

The sequence of activities carried out during this flight is very similar to flight 1. The major difference is installation of the truss docking adapter, berthing the Orbiter to the Station for the first time on this adapter, and reinstallation of the erector jig on the truss for future reconfiguration with the MSC transporter on assembly flight MB-4.

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OPERATIONS SCENARIO
ASSEMBLY FLIGHT 2

ACTIVITY	EVA TIME
RENDEZVOUS W/ STATION	
GRAPPLE STATION AT ERECTOR SET AND BERTH IN P/L BAY	30
WORKSITE PREP (2)	10
INSTALL CMG'S IN ACA & GNC UNIT	44*
BUILD TWO BAYS	60
INSTALL AFT PORT NODE (CAPTURE LATCHES ONLY)	66*
BUILD THREE BAYS	30
INSTALL A RCS MODULE AND ANTENNA STRUCTURE	44*
BUILD TWO BAYS	10
INSTALL TRUSS DOCKING ADAPTER	60
INSTALL ALPHA JOINT	44*
BUILD TWO BAYS	30
INSTALL PV MODULE	60
INSTALL RAD ASSY	30
PLB CLEAN-UP (2)	
DEPLOY SS	
BERTH ORBITER TO STATION AT PORT TRUSS DOCKING ADAPTER	
INSTALL ERECTOR ON TRUSS	
	533
+20% OVERHEAD	107
OR	10.7 HRS
OR	21.3 M-HRS

*22 MIN. CLOCK TIME FOR BAY ASSEMBLY BASED ON ERECTABLE TRUSS AND DEPLOYABLE UTILITIES

ASSEMBLY FLIGHT 3 - MANIFEST

Four main packages are launched on this flight. Thermal radiators for the TCS are manifested; however, due to EVA limitations only the port radiator is installed on Flight 3 (the starboard radiator is installed on assembly Flight 4). The Space Station remote manipulator system (SSRMS) is installed and will be utilized later to assist in assembly tasks. The erector jig installed on Flight 2 will be converted to a transporter unit for the SSRMS on assembly Flight 4, making it a mobile system. The equipment to effect this conversion is manifested on Flight 3.

RCS tankage, fully charged with an initial load of hydrogen and oxygen fuel, is installed. The first complement of user payloads, to be attached to the truss, is also manifested on this flight.

The first station airlock, to permit later Station based EVA, is manifested and installed. The pressurized node docking adapters are also manifested, which will permit later astronaut egress from the Orbiter aft deck to the Space Station pressurized modules in a shirt sleeve environment.

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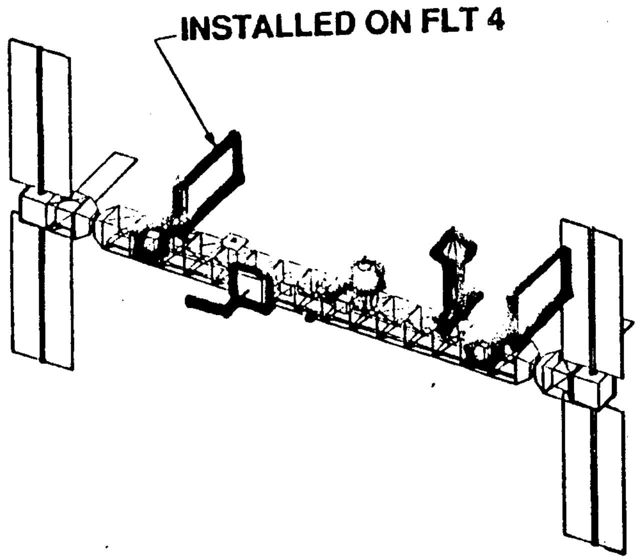
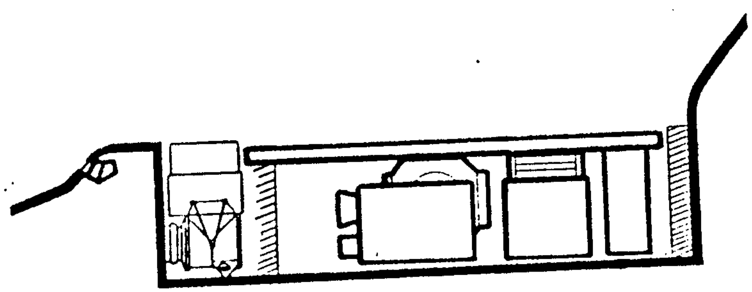
ASSEMBLY FLIGHT NO. 3





EVA : 21.2 MH
SS CREW : 0

MANIFEST		MASS (LBS)
#1	- RADIATORS - SSRMS & TRANSPORTER UPGRADE	11,140
#2	- DOCKING ADAPTERS - AIRLOCK - ANTENNA	7,670
#3	ATTACHED PAYLOADS	5,240
#4	RCS TANKAGE	4,700
	FSE	2,330
	ATTACH FITTINGS	5,550
	TOTAL	36,630

ASSEMBLY FLIGHT 3 - STATION CONFIGURATION

Looking over the port radiator, this view shows the two aft nodes attached to the stinger. The large cylindrical object on the top of the aft port node is the first of two Space Station airlocks. The SSRMS arm can be seen extending out of the right side of the figure from the fore side of the truss.

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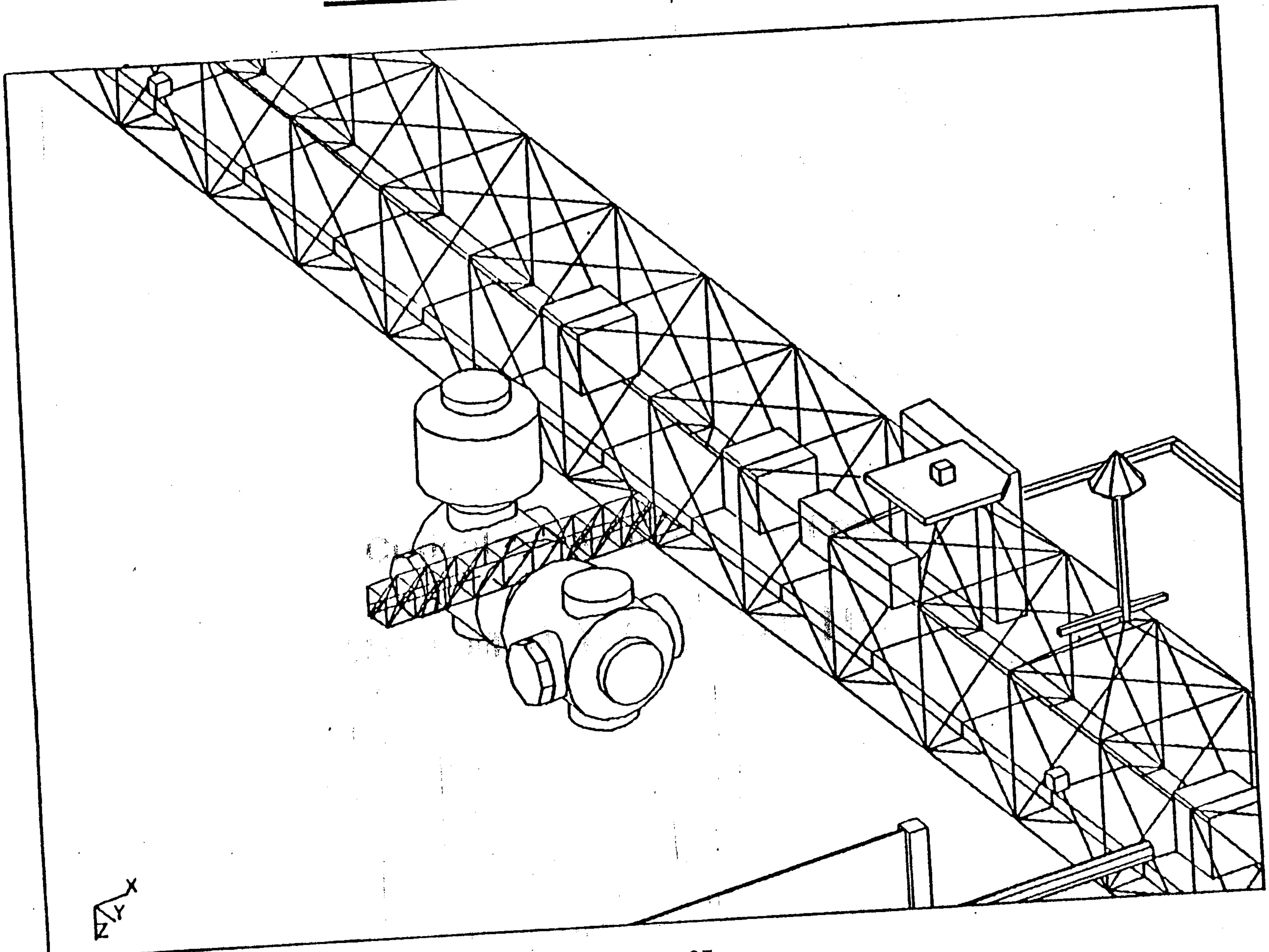
ASSEMBLY FLIGHT NO. 3



ASSEMBLY FLIGHT 3 - OPERATION SCENARIO

A complex series of Orbiter rendezvous and reberthing maneuvers is carried out on this flight. First, the Orbiter berths to the adapter on the port boom and EVA crew install the port radiator. Then, the Orbiter unberths (but continues to hold the truss with its RMS) while EVA crew remove the truss docking adapter and stow it in the Orbiter payload bay (PLB). The node pressurized docking adapter is installed on the aft port node, after which the Orbiter moves to the aft port node and berths to it. At this point, the airlock is installed on the neighboring, aft starboard node. The SSRMS is attached to the top of the truss, and the starboard radiator assembly is stowed on the truss -- it will be installed on the next flight. EVA crew now install the antenna package, the RCS tanks, and the Station interface adapters (SIAs) and the first user payloads. The SIA attaches directly to the truss and is the standard interface between the truss and each payload's payload interface adapter (PIA). Finally, the truss docking adapter is removed from the Orbiter payload bay and installed in position ready for use in installing the lab module on flight 5.

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OPERATIONS SCENARIO ASSEMBLY FLIGHT NO. 3

ACTIVITY	EVA TIME
RENDEZVOUS W/STATION	
BERTH TO TRUSS DOCKING ADAPTER ON THE PORT BOOM	30
WORKSITE PREP (2)	120
BUILD AND INSTALL PORT RADIATOR ASSEMBLY	
UNBERTH FROM TRUSS DOCKING ADAPTER (REMAIN GRAPPLED TO TRUSS)	30
REMOVE AND STOW TRUSS DOCKING ADAPTER IN THE PLB	15
INSTALL NODE DOCKING ADAPTER ON ORBITER DOCKING MODULE	
ORBITER TRANSLATE TO AFT PORT NODE AND	30
BERTH TO AFT PORT NODE	30
BERTH AND INSTALL AIRLOCK TO AFT PART OF AFT STBD NODE	15
INSTALL SSRMS ON TOP OF TRUSS AND STOW EQUIPMENT	20
TRANSFER STBD RADIATOR ASSEMBLY TO TRUSS AND TIE DOWN	30
INSTALL ANTENNA PKG.	30
INSTALL RCS TANKAGE	90
INSTALL SIA AND P/L	60
INSTALL TRUSS DOCKING ADAPTER IN POSITION FOR LAB	30
PLB CLEAN-UP (2)	530
+20% OVERHEAD	106
	636 MIN

OR 10.6 HRS
OR 21.2 M-HRS

ASSEMBLY FLIGHT 4 - MANIFEST

Additional RCS tankage is manifested on this flight, as well as a second Space Station airlock which contains a hyperbaric chamber, the stationary RMS (SRMS), and structure to support the SRMS. Additional user payloads are also manifested on this flight.

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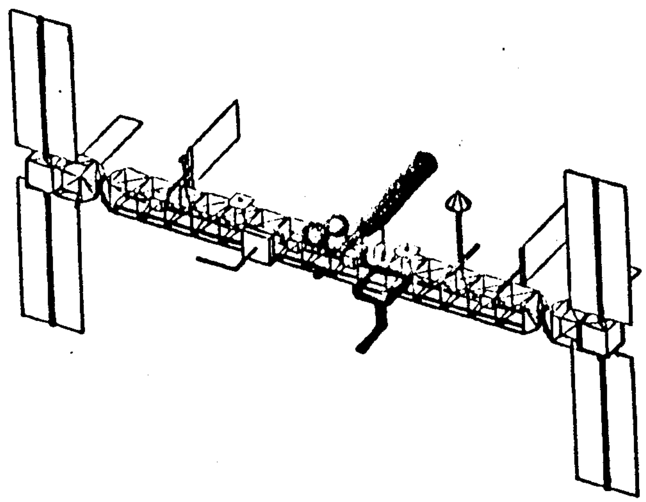
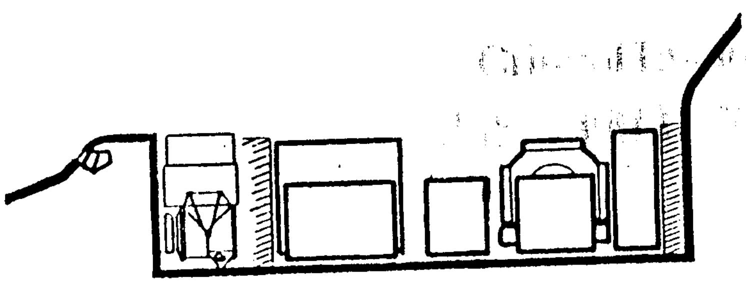
ASSEMBLY FLIGHT NO. 4





MANIFEST	MASS (LBS)
RCS TANKAGE	4,700
- AIRLOCK, HB - STRUCTURE FOR SRMS & SRMS	8,760
PAYLOADS	6,000
ATTACHED PAYLOADS	12,000
FSE	1,330
ATTACH FITTINGS	3,700
TOTAL	36,630

EVA: 16

ASSEMBLY FLIGHT 4 - OPERATIONS SCENARIO

After the Orbiter berths to the pressurized docking adapter on the aft port node, the (still fixed) SSRMS moves the existing airlock to the starboard side of the aft starboard node. The second (hyperbaric) airlock is then installed on the top of the aft port node, and the new RCS tankage is installed. The new stationary RMS (SRMS) and its support structure are stowed on the truss for later installation. The conversion equipment brought up on Flight 3 is now used to combine the erector jig with the MSC transporter to provide a mobile remote manipulator system capability. Note that the second RMS, the SRMS, can later be plugged into the transporter if desired. Finally, the starboard radiator assembly brought up on flight 3 is installed.

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OPERATIONS SCENARIO
ASSEMBLY FLIGHT NO. 4

ACTIVITY	EVA TIME
RENDEZVOUS W/STATION AND BERTH TO THE DOCKING ADAPTER ON THE AFT PORT NODE	
SSRMS MOVE AIRLOCK TO THE STBD SIDE OF THE AFT STBD NODE	30
WORKSITE PREP (2)	30
INSTALL SECOND AIRLOCK ON THE TOP OF THE AFT PORT NODE	30
INSTALL RCS TANKAGE	30
TIE DOWN STATIONARY SSRMS (ARM #2) AND SUPPORT STRUCTURE ON TRUSS	20
CONVERT ERECTOR INTO TRANSPORTER	120
INSTALL STBD RADIATOR	120
PLB CLEAN-UP (2)	30
	410
+20% OVERHEAD	82
	492 MIN
OR	8.2 HRS
OR	16.4 M-HRS

ASSEMBLY FLIGHT 5 (MTC) - MANIFEST

On this flight, the Station achieves man-tended capability (MTC). The entire Shuttle cargo bearing capability is devoted to bringing up the U.S. Laboratory Module (lab), which has had a portion of its internal subsystems and payloads de-integrated and removed prior to launch to be compatible with Shuttle mass-to-orbit performance. Note that no FSE is required and the module attaches directly to the attach fittings in the Orbiter bay.

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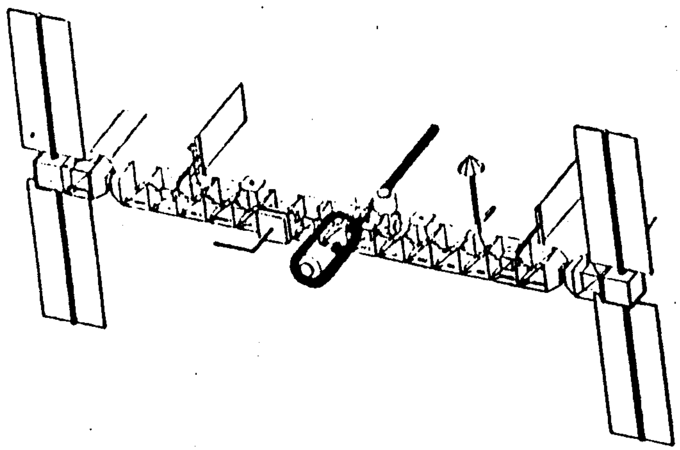
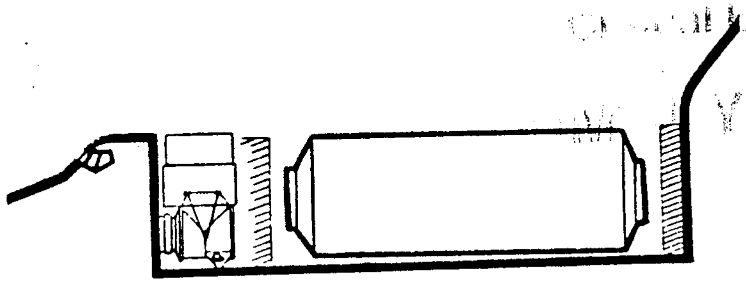
ASSEMBLY FLIGHT NO. 5 (MTC)



	MANIFEST	MASS (LBS)
#1	U.S. LAB MODULE	34,230
	FSE	0
	ATTACH FITTINGS	1,100
	TOTAL	35,330



EVA : 16 MH
SS CREW : 0

ASSEMBLY FLIGHT 5 - STATION CONFIGURATION

At the completion of this mission, the lab module is fully functional and includes 4 double racks of user equipment. This figure shows the lab module connected to the aft starboard node in a location under the truss structure. Also, the two airlocks are shown with one attached to each aft node.

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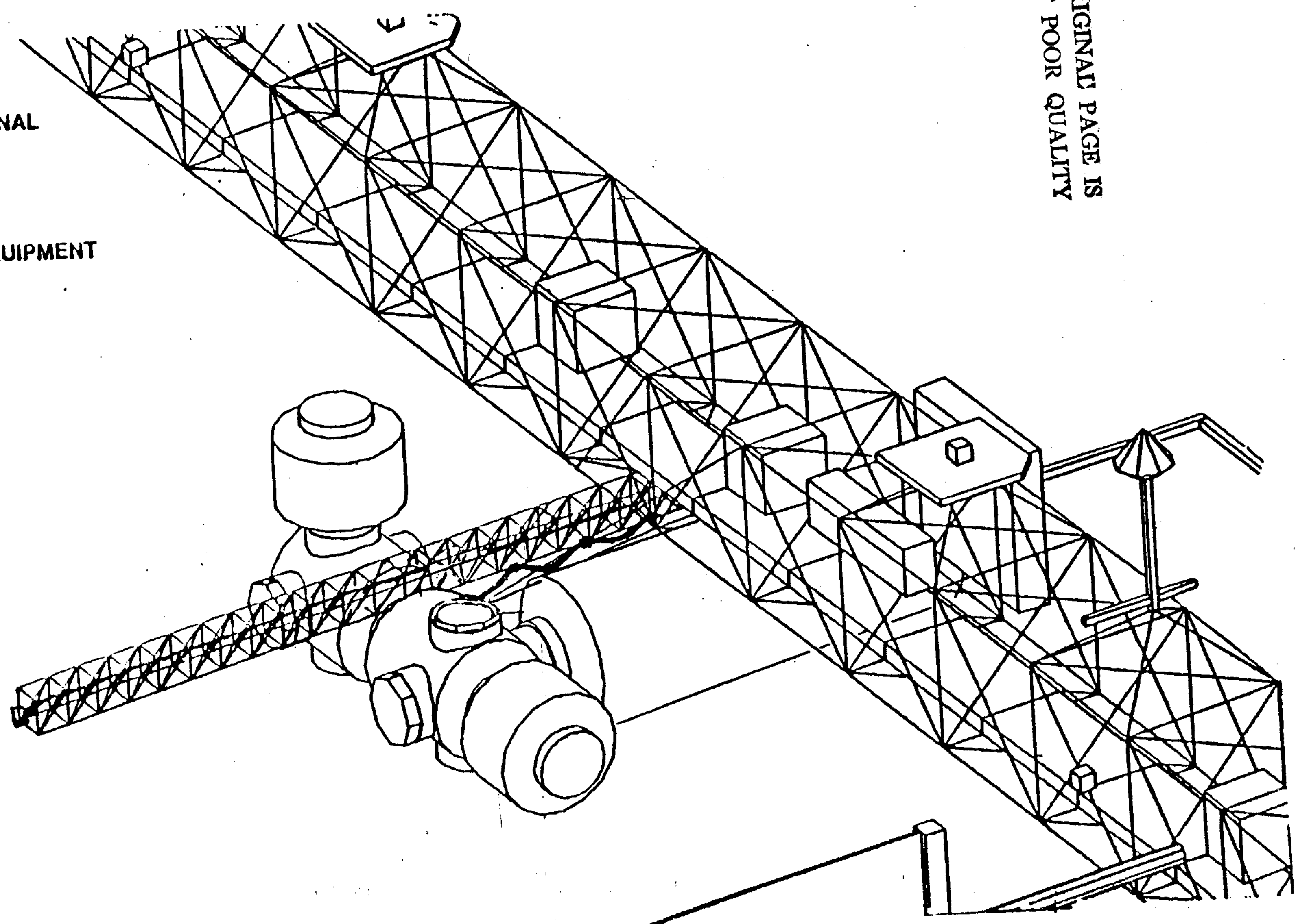
ASSEMBLY FLIGHT NO. 5

- US LAB MODULE FUNCTIONAL
  - ALL UTILITIES
  - 4 RACKS OF USER EQUIPMENT



ASSEMBLY FLIGHT 5 - OPERATIONS SCENARIO

After the Orbiter berths to the truss structure docking adapter where it had been installed on assembly Flight 4, the lab module is installed on the starboard aft node. The docking adapter on the aft port node is removed and reinstalled on the lab module for later use. A two-hour, 2-man EVA is devoted to the detailed completion of the installation of the lab module, including mechanical attachment and connection of all utility services. When this is complete, the Orbiter leaves the truss docking adapter, berths to the lab, and repositions the truss docking adapter for later use in installing the U.S. Habitation Module. Astronauts enter the lab for the first time on orbit and activate and verify correct functioning of the Station environmental control and life support system (ECLSS).

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OPERATIONS SCENARIO
ASSEMBLY FLIGHT NO. 5

ACTIVITY

RENDEZVOUS W/ STATION AND BERTH TO
TRUSS DOCKING ADAPTER (D/A)

WORKSITE PREP (2)

BERTH LAB

MOVE D/A FROM AFT PORT NODE TO THE ORBITER
SIDE OF LAB

INSTALL D/A TO LAB (INCLUDING BOLTING)

UNBERTH FROM TRUSS D/A AND BERTH TO LAB

MOVE TRUSS D/A INTO POSITION FOR HAB

PLB CLEAN-UP (2)

INGRESS LAB

EVA TIME

30

120

30

120

60

30

		390
+20% OVERHEAD		78
		468 MIN
	OR	7.8 HRS
	OR	15.6 M-HRS
+ SSEMU FLT VERIFICATION		4.2 HRS
	OR	8.4 M-HRS

TOTAL TIME = 24 M-HRS

ASSEMBLY FLIGHT 6 - INSTALLATION OF HAB MODULE

In this view from the forward starboard side of the Station, the STS RMS positions the habitation (hab) module for installation under the truss.

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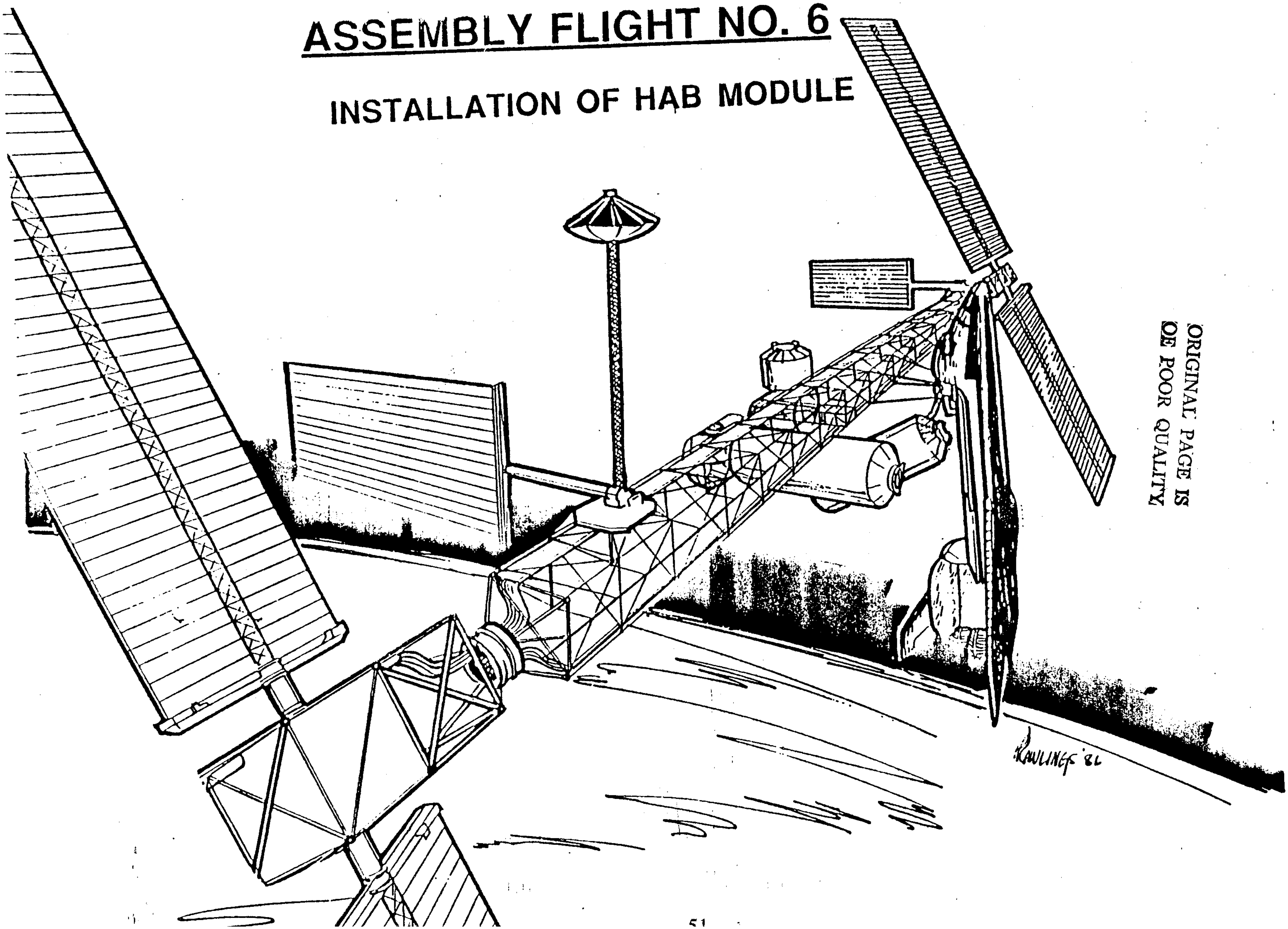
ASSEMBLY FLIGHT NO. 6

INSTALLATION OF HAB MODULE



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ASSEMBLY FLIGHT 6 - MANIFEST

This flight is entirely devoted to manifesting the crew habitation (hab) module, which occupies the entire Orbiter bay. As was the case with the lab module on assembly Flight 5, the hab module requires offloading of equipment racks because of Shuttle launch capability. This equipment will be reintegrated into the hab module on subsequent module outfitting and logistics Shuttle flights.

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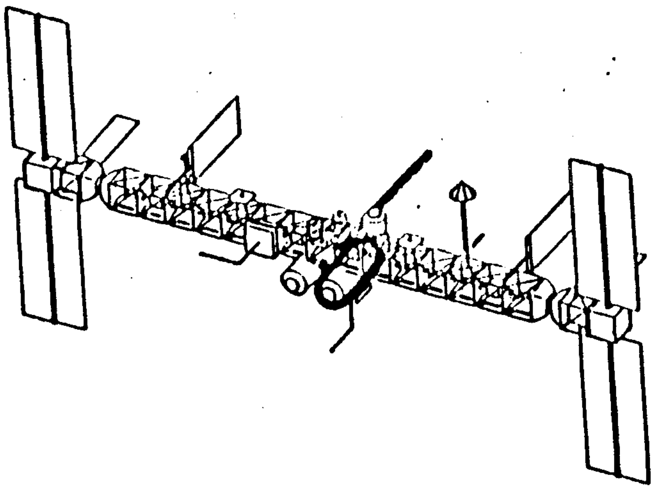
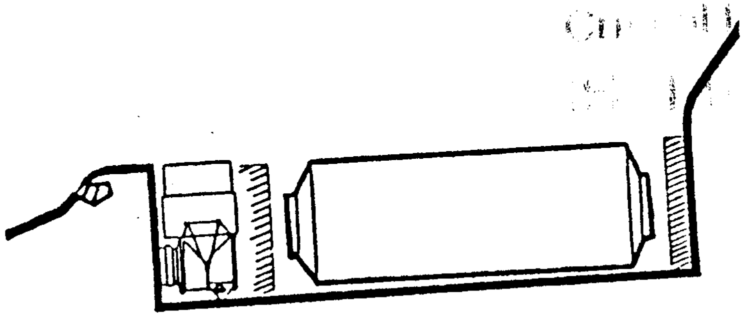
ASSEMBLY FLIGHT NO. 6



MANIFEST	MASS (LBS)
HAB MODULE	34,230
FSE	0
ATTACH FITTINGS	1,100
TOTAL	35,330
MARGIN	0



ASSEMBLY FLIGHT 6 - OPERATIONS SCENARIO

The Orbiter initially berths to the truss structure docking adapter where it was installed on the previous flight. The hab module is installed on the port aft node, and a long EVA is devoted to reinstalling the pressurized lab docking adapter to the hab module. After completion of the lab module installation, the Orbiter leaves the truss docking adapter and berths to this newly reinstalled pressurized hab module docking adapter. The truss bay to support the stationary SRMS is built and the SRMS is installed on it. The truss docking adapter is removed from its location at the beginning of the flight, and repositioned for use in future installation of the forward nodes.

Astronauts enter the hab module through the pressurized docking adapter and confirm that all systems are functional.

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ASSEMBLY FLIGHT NO. 6

	EVA TIME
RENDEZVOUS W/ STATION AND BERTH TO TRUSS D/A	
WORKSITE PREP (2)	30
BERTH HAB	120
MOVE LAB D/A TO HAB	240
UNBERTH FROM TRUSS D/A AND BERTH TO HAB	30
ASSEMBLE SSRMS TRUSS BAY AROUND HAB	20
INSTALL STATIONARY SSRMS	15
MOVE TRUSS D/A INTO POSITION FOR NODES	60
PLB CLEAN-UP (2)	30
INGRESS HAB	
	545
+20% OVERHEAD	109
	654 MIN
OR	10.9 HRS
OR	21.8 M-HRS

ASSEMBLY FLIGHT 7 - MANIFEST

The IOC pressurized volume configuration resembles a rectangular "race track" configuration, where the longer lab and hab modules are joined at each end by a pair of shorter, connected nodes. This flight delivers the two forward nodes to complete this configuration. Also on Flight 7 are two cupolas, which are large node viewports for proximity operations observation. A substantial amount of subsystem and user equipment offloaded from the modules before launch for weight reasons is manifested inside the nodes for installation in the hab and lab modules. Equipment to support Station crew EVA is also brought up for future use.

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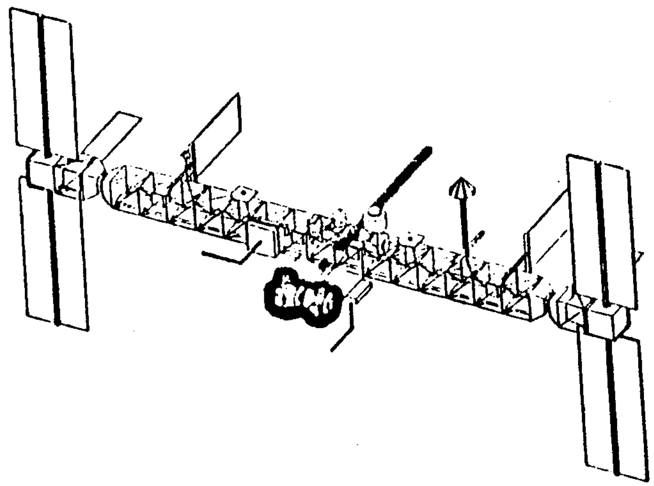
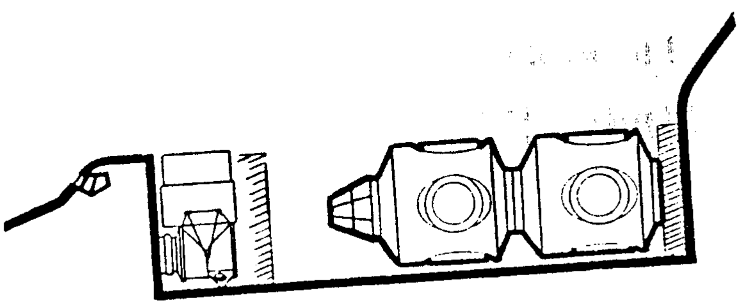
ASSEMBLY FLIGHT NO. 7



MANIFEST	MASS (LBS)
• FWD NODE, STARBOARD	9,540
• FWD NODE, PORT	9,040
• MODULE OFFLOADS	3,200
• CUPOLAS (2)	3,200
• EVA SUPPORT EQUIP.	800
FSE	300
ATTACH FITTINGS	1,850
TOTAL	27,930



EVA : 21.6 MH
SS CREW : 0

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ASSEMBLY FLIGHT 7 - OPERATIONS SCENARIO

The Orbiter berths to the truss docking adapter where it was left near the hab module and the pressurized hab docking adapter is removed in preparation for installing the forward nodes. The Space Station stationary SRMS is used to assist in the installation of the two forward nodes. The SRMS receives the starboard node from the STS RMS and berths it to the lab module. Before installation of the second node, the pressurized docking adapter is installed on it. The STS RMS hand-off procedure to the Station SRMS is repeated to berth the second node to the hab module. The cupolas are then installed on the forward nodes. Finally, the Orbiter berths to the pressurized docking adapter and an Intra-Vehicular Activity (IVA) to complete internal connections is carried out.

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OPERATIONS SCENARIO ASSEMBLY FLIGHT 7

ACTIVITY	EVA TIME
RENDEZVOUS W/STATION AND BERTH TO THE TRUSS D/A	30
WORKSITE PREP (2)	120
REMOVE THE HAB D/A	30
GRAPPLE THE STBD NODE W/RMS AND ATTACH BELLOWS	
HAND-OFF TO SSRMS	30
BERTH NODE TO LAB W/SSRMS	120
GRAPPLE PORT NODE W/RMS AND INSTALL D/A	
HAND-OFF TO SSRMS	120
BERTH NODE TO HAB AND NODE AND ADJUST BELLOWS	60
INSTALL CUPOLAS (2)	30
PLB CLEAN-UP (2)	
BERTH TO NODE AND BOLT IT ALL TOGETHER IVA	
	540
+20% OVERHEAD	108
	648 MIN
OR	10.8 HRS
OR	21.6 M-HRS

ASSEMBLY FLIGHT 8 - STATION CONFIGURATION (PMC)

With this flight, the Station receives logistics for its first crew of four and achieves permanently manned capability (PMC) status. A nominal crew stay time of no more than 60 days is planned; however, contingency logistics for 6 months is manifested within the logistics carrier module.

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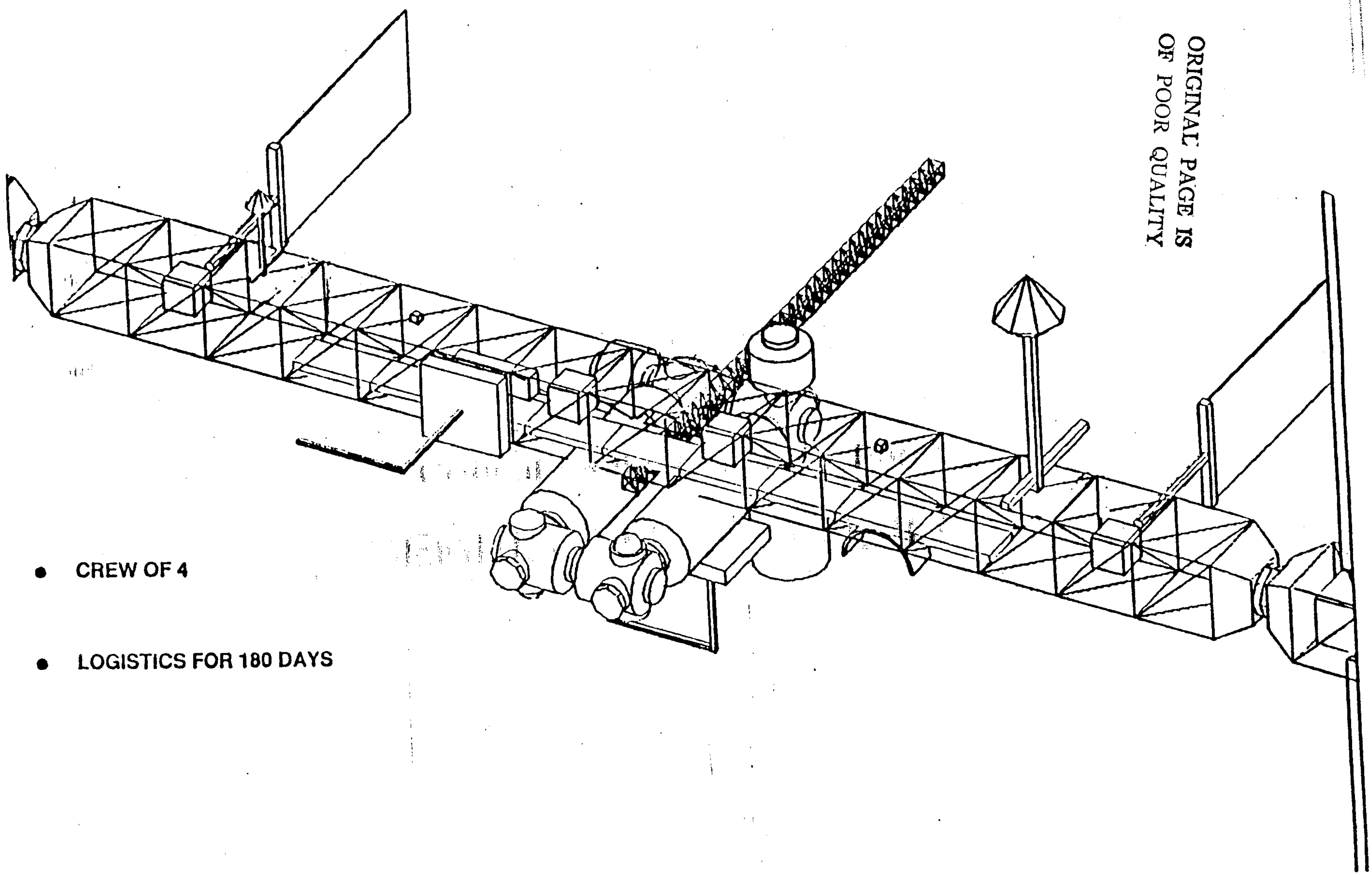
ASSEMBLY FLIGHT NO. 8 (PMC)



- CREW OF 4
- LOGISTICS FOR 180 DAYS

ASSEMBLY FLIGHT 9 - STATION CONFIGURATION (SOLAR DYNAMIC)

A major Station capability is the availability of adequate electrical power to support all desired operations, particularly some of the more demanding user payloads. On this flight, a pair of solar dynamic power generation systems are installed, increasing total available power by 50 kw to 87.5 kw.

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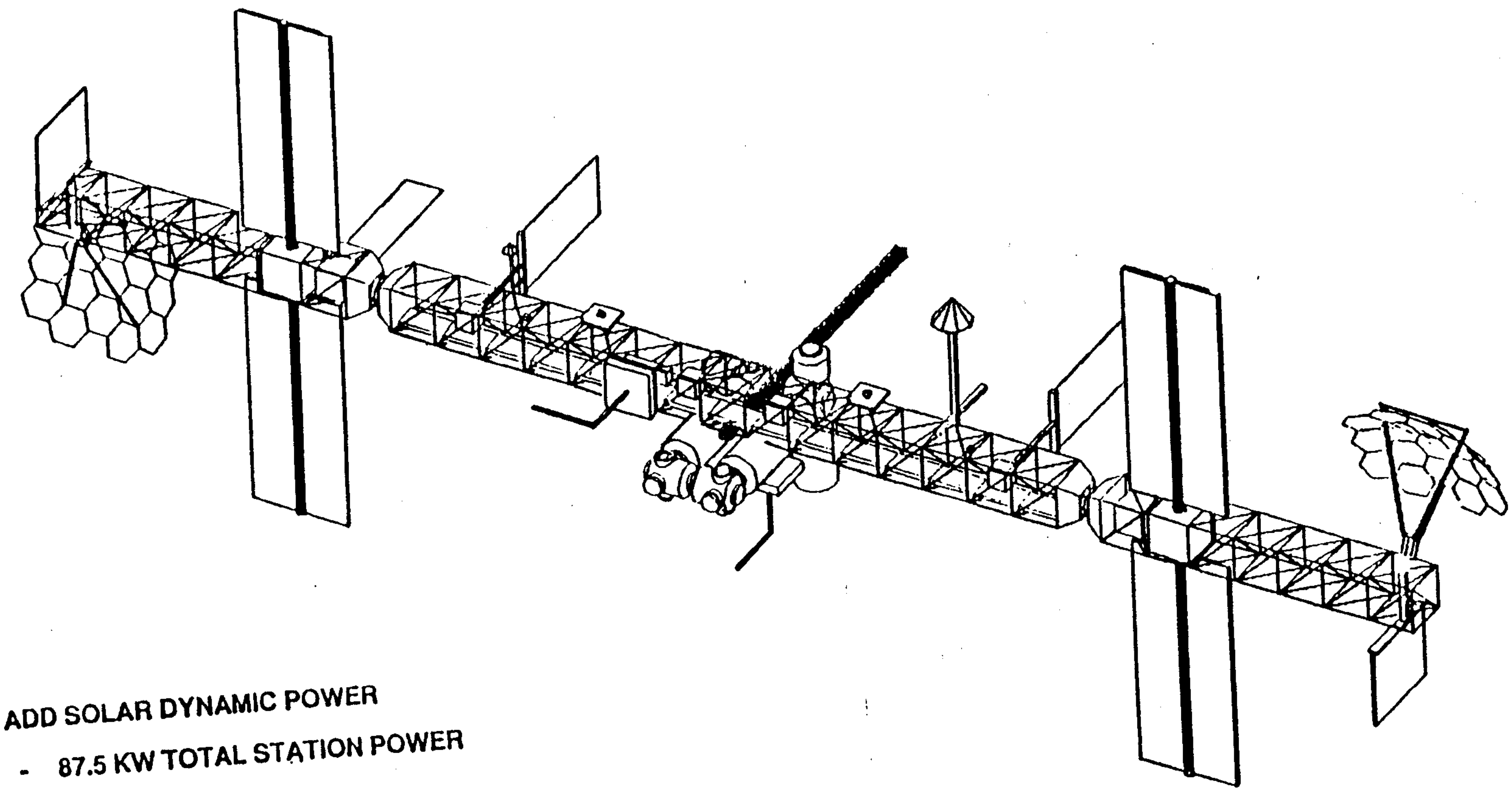
ASSEMBLY FLIGHT NO. 9 (SOLAR DYNAMIC)



- ADD SOLAR DYNAMIC POWER
  - 87.5 KW TOTAL STATION POWER

- CAPABILITY TO OPERATE ALL SCHEDULED PAYLOAD EQUIPMENT

ASSEMBLY FLIGHTS 10 & 11 - STATION CONFIGURATION (INTERNATIONALS)

The Japanese Experiment Module (JEM) and the ESA module are installed on Flights 10 and 11. This completes the planned IOC configuration of laboratory pressurized volume and crew habitation pressurized volume.

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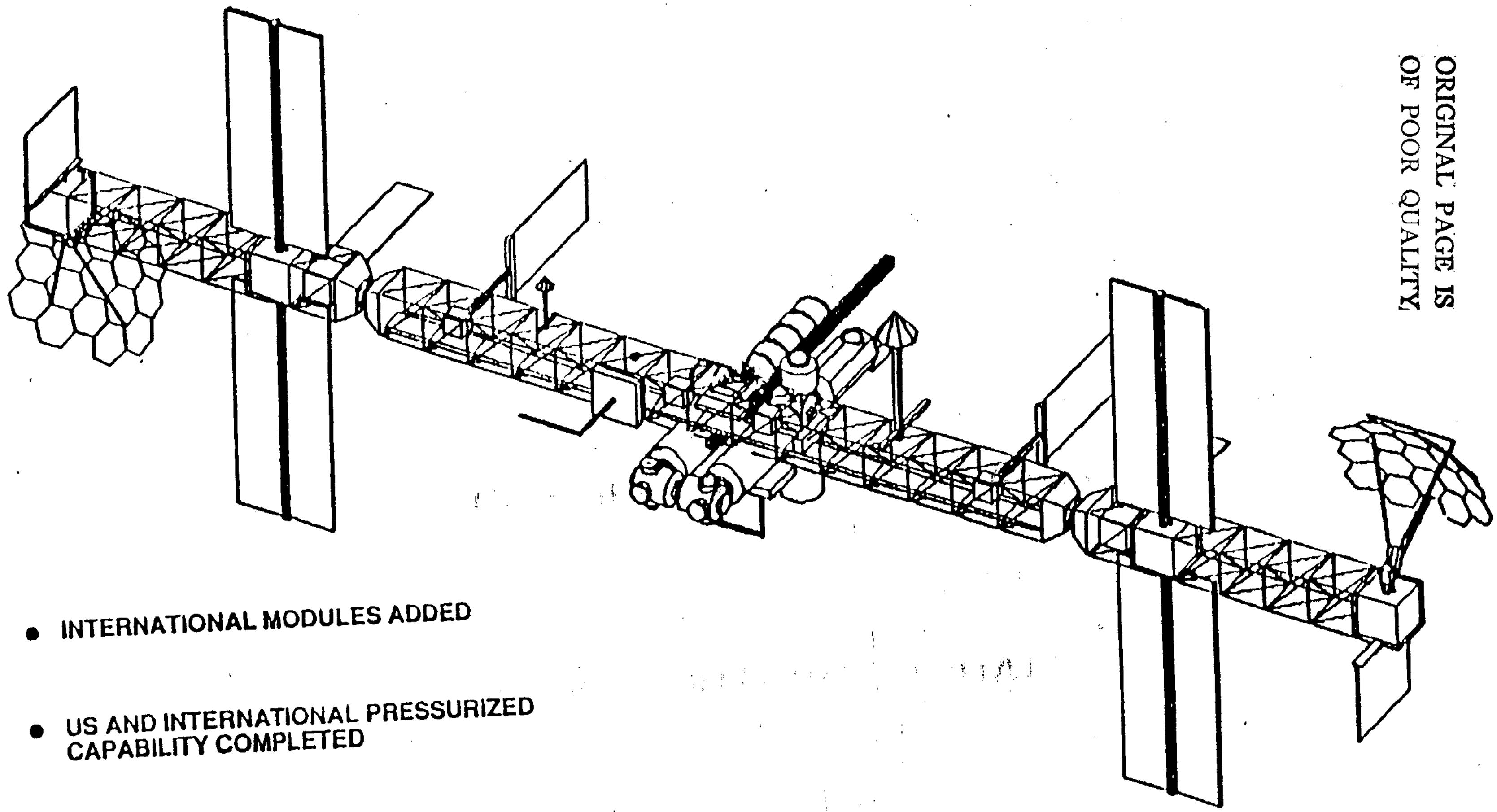
ASSEMBLY FLIGHT NO. 10 & 11

(PMC & INTERNATIONALS)



- INTERNATIONAL MODULES ADDED
- US AND INTERNATIONAL PRESSURIZED CAPABILITY COMPLETED
- LIFE SCIENCES CAPABILITY

ASSEMBLY FLIGHT 13 - STATION CONFIGURATION (SIGNIFICANT SERVICING)

In the CETF build-up sequence, the evolution of Station servicing capability spans a number of flights. With Flight 13, the first Phase of the Space Station servicing bay is in place and available for servicing the OMV, free flyer platforms, and payloads attached to the Station truss.

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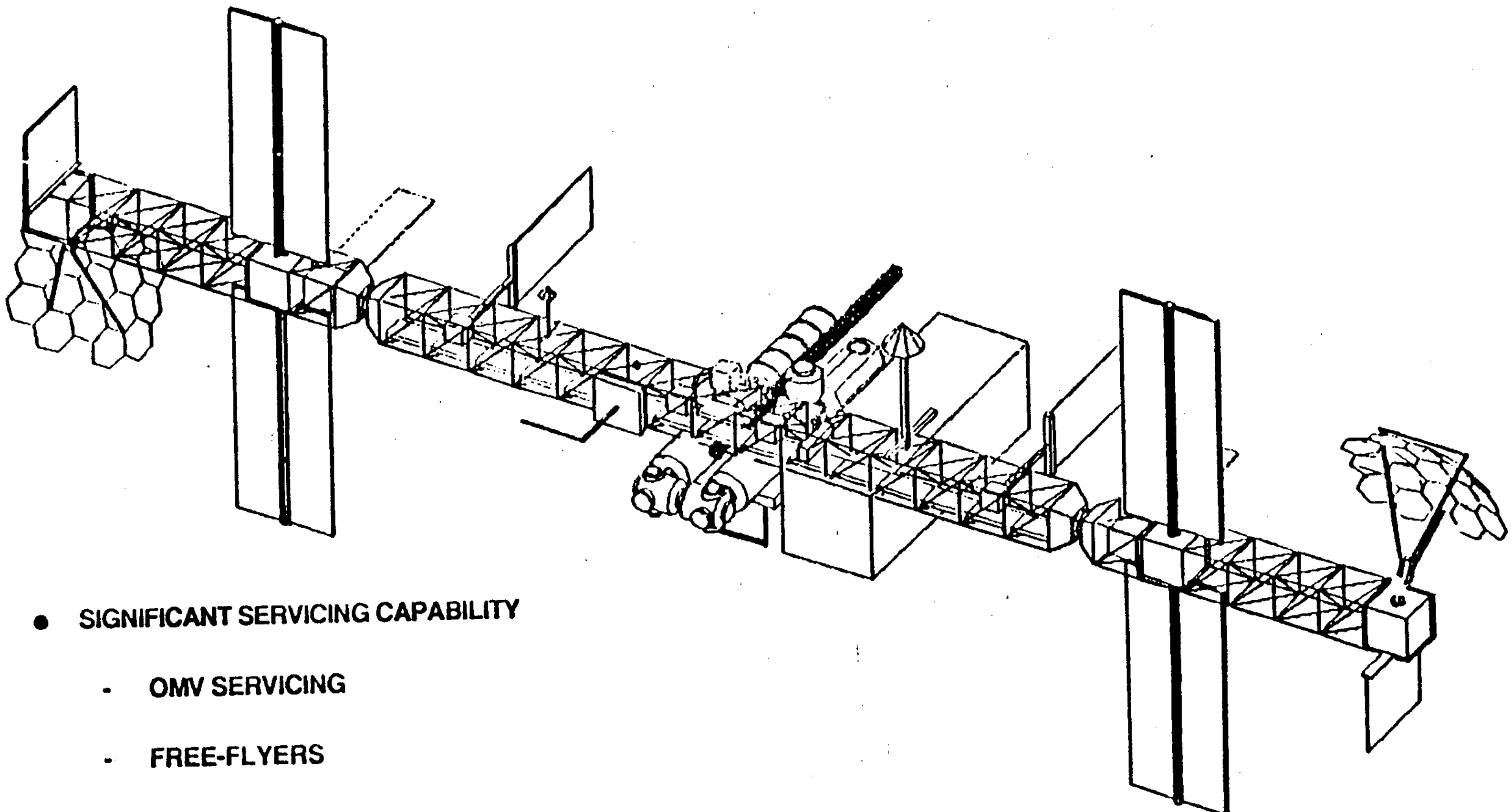
ASSEMBLY FLIGHT NO. 13

(SIGNIFICANT SERVICING)



- SIGNIFICANT SERVICING CAPABILITY
  - OMV SERVICING
  - FREE-FLYERS
  - ATTACHED PAYLOADS

ASSEMBLY FLIGHT 17 - STATION CONFIGURATION (IOC)

Flight 17 marks the achievement of initial operational capability (IOC). The upper and lower trusses of the full rectangular configuration are in place, utilities are installed, and the entire structure is available for placement of user equipment or other uses. The final phase of Space Station servicing capability is completed, including the mobile robotic servicing capability (MSC). The MSC was manifested on assembly Flight 15 and the Mobile Maintenance Depot (MMD), for stowage and maintenance of the MSC, is manifested in Flight 17.

This concludes a description of the Space Station Program assembly sequence developed and adopted by NASA from the CETF guidelines, ground rules, objectives and study results. It is the baseline assembly sequence upon which this Space Station Mixed Fleet Study is founded.

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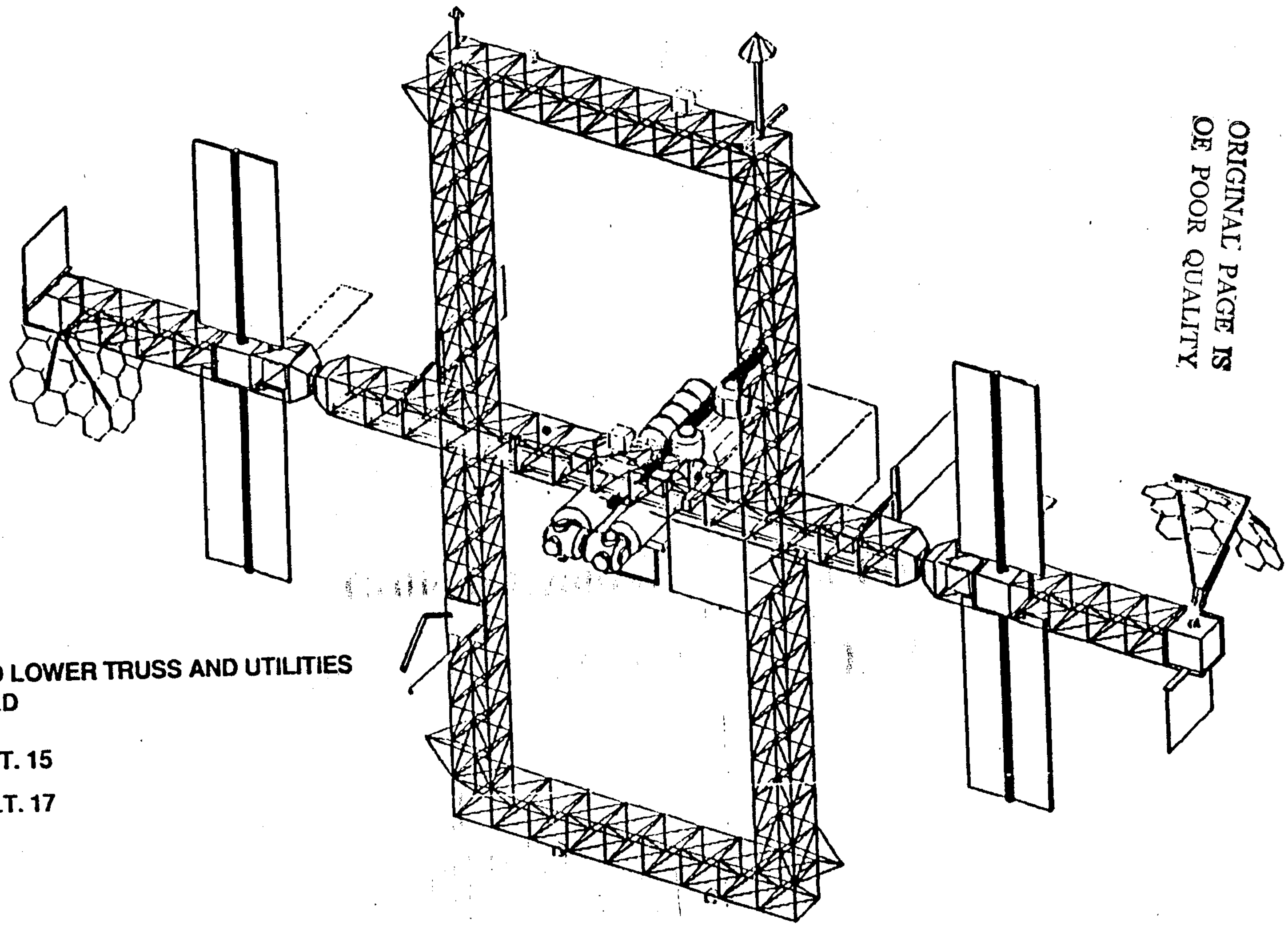
ASSEMBLY FLIGHT NO. 17 (IOC)



- UPPER AND LOWER TRUSS AND UTILITIES COMPLETED
- MSC ON FLT. 15
- MMD ON FLT. 17

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3.0 EXPENDABLE LAUNCH VEHICLE (ELV) CHARACTERISTICS

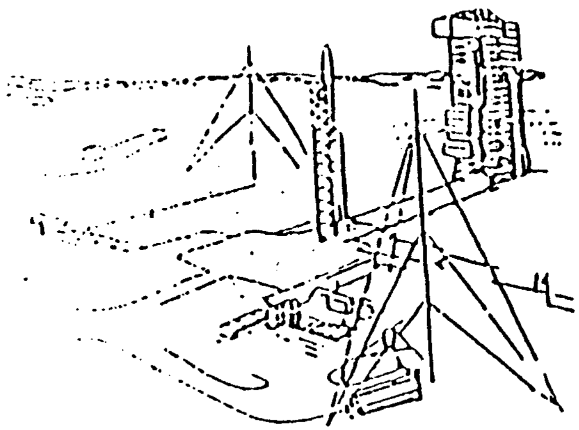
TITAN LAUNCH CAPABILITY - ACTIVE LAUNCH COMPLEXES

Of available ELVs, the TITAN 34D/TITAN 4 systems offer the greatest lift capacity, approximately 35,000 lbs. to a 190 nm. orbit. They may also be launched from either the Western Test Range (WTR) at Vandenberg Air Force Base to polar orbit, or from the Eastern Test Range (ETR) at Cape Canaveral to a 28.5 degree inclination "equatorial" orbit. Both the WTR and ETR have two active launch complexes, normally supporting up to four launches per year and six launches per year, respectively.

Titan Launch Capability

FOUR ACTIVE LAUNCH COMPLEXES DEDICATED TO TITAN OPERATIONS

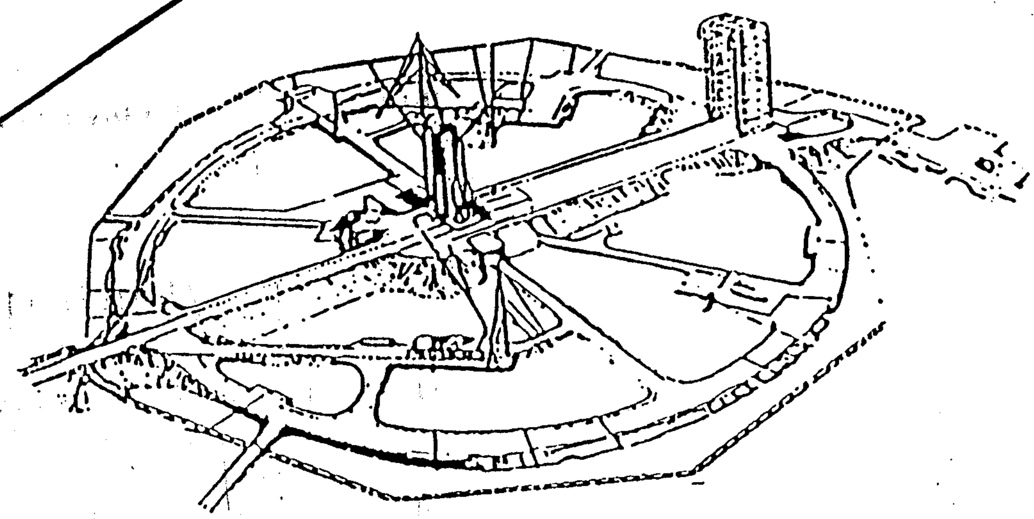
LAUNCH COMPLEX	VEHICLE	NOMINAL RATE
4 EAST	TITAN 34D * TITAN IV	4/YR
4 WEST	TITAN 34B * TITAN II	4/YR



TRANSITIONS IN 1987

WEST COAST

LAUNCH COMPLEX	VEHICLE	NOMINAL RATE
40	TITAN 34D TITAN II	6/YR
41	TITAN IV	6/YR



EAST COAST

TITAN 4 LAUNCH CAPABILITY

If 7-day-a-week, around-the-clock operations are established at the ETR, up to 12 TITANs can be launched per year from a single one of its two launch complexes.

TITAN IV LAUNCH CAPABILITY

- HIGHER LAUNCH RATES CAN BE ACHIEVED AT ETR

  10 TO 12 LAUNCHES PER YEAR FROM LAUNCH COMPLEX 41 CAN BE ACHIEVED BY A THREE SHIFT, SEVEN DAY A WEEK SCHEDULE

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4.0 SHUTTLE-DERIVED VEHICLE (SDV) CHARACTERISTICS

SHUTTLE DERIVED VEHICLES - SIDEMOUNT

The shuttle derived vehicle (SDV) concept has been developed to speed development of an unmanned heavy lift launch vehicle that takes maximum advantage of the engineering investment in the present STS. Many configurations have been studied; variables include the number of liquid fuel Space Shuttle main engines (SSMEs) installed, whether or not the SSMEs are recovered and reused, the physical geometry of the payload fairing, and whether the cargo carrier is side-mounted similar to the Shuttle or inline in a manner similar to the existing ELVs. A two-engine SSME design has less lift capability than a three-engine configuration, and recoverability of the SSMEs exacts a further performance and cost overhead. Although a SDV could be launched from either the WTR or the ETR, the performance curve of payload delivered to orbit shown in the figure refers to ETR launches to an equatorial-type orbit which is representative of Space Station assembly orbit geometry. The estimated lift to 220 nm. for a two-engine, expendable system is 105,000 lbs., well over twice the STS planning guidance provided by the NASA Office of Space Flight in December, 1986.

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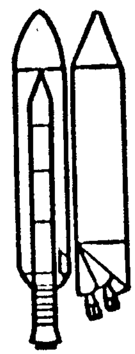
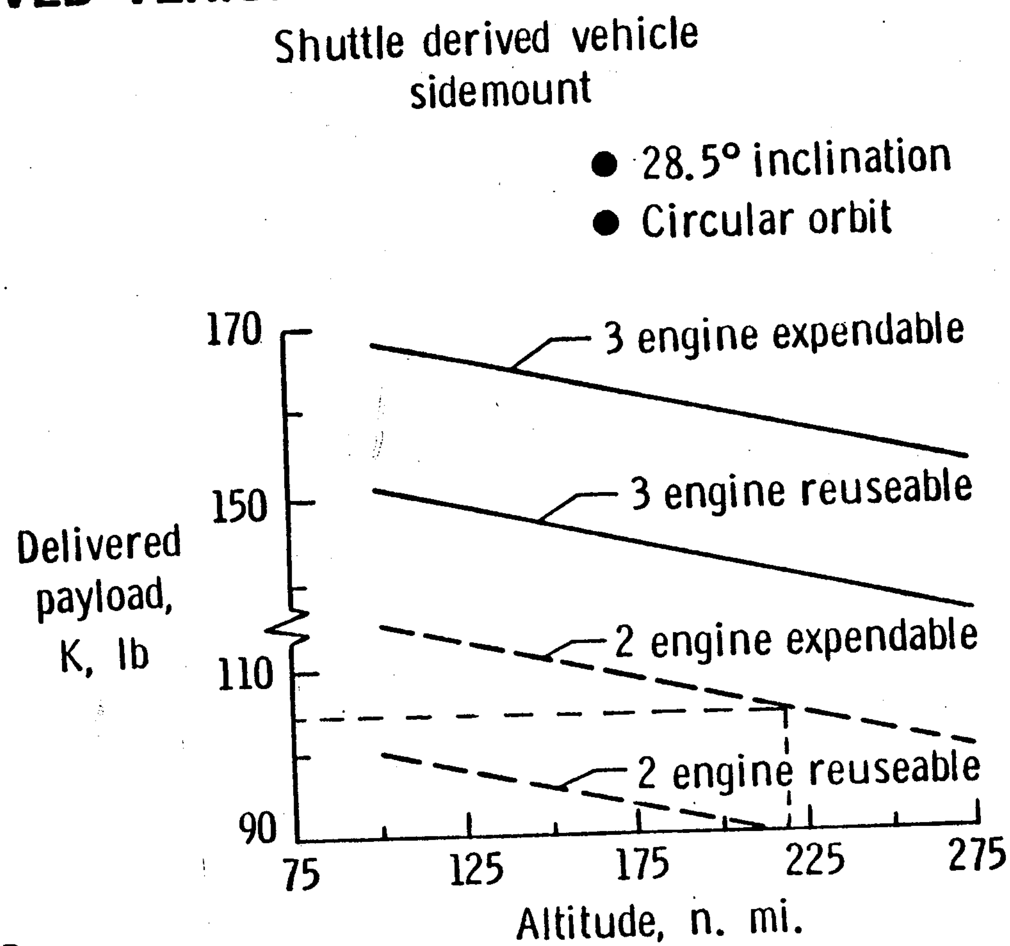
SHUTTLE DERIVED VEHICLES SIDEMOUNT



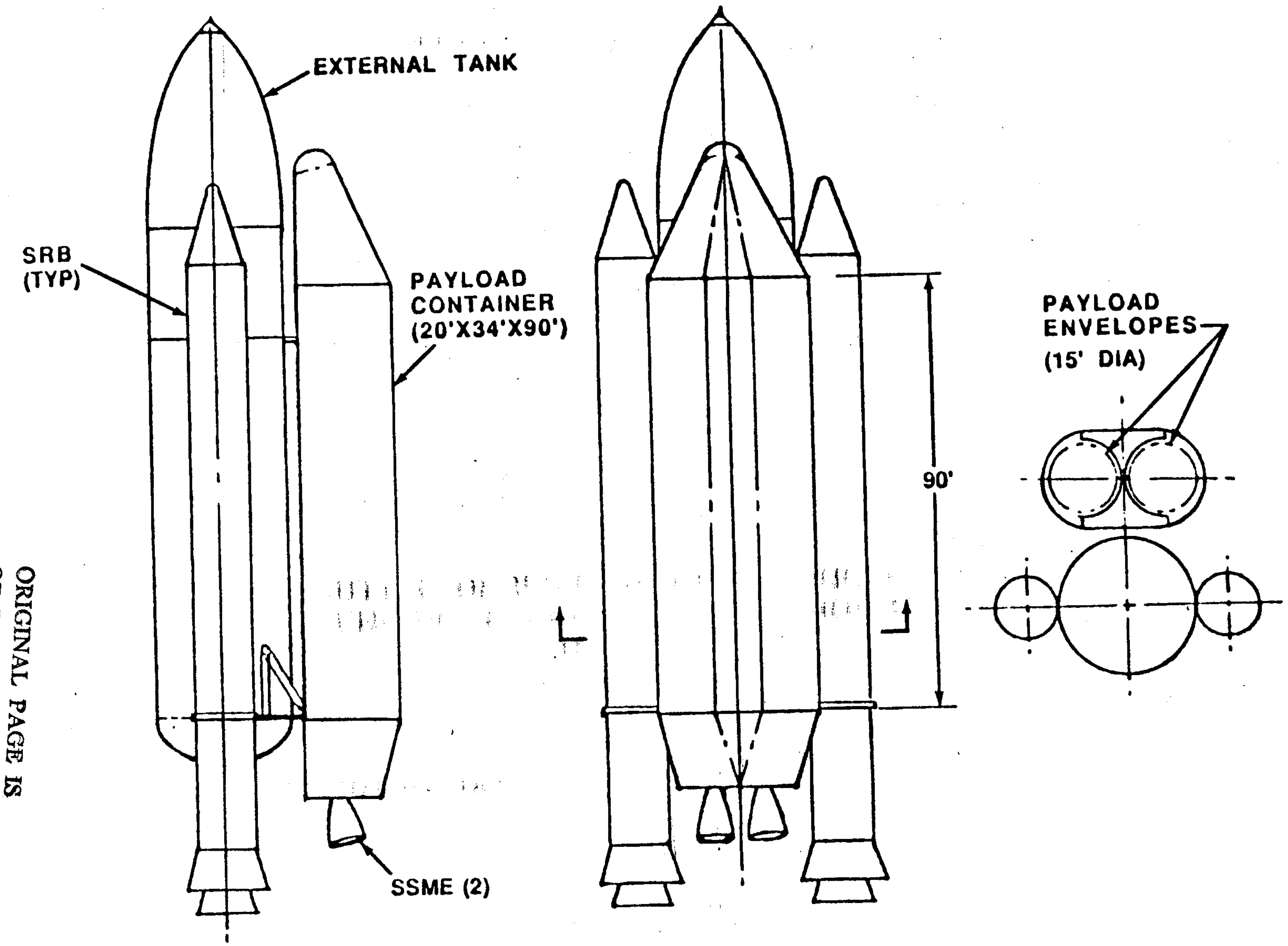


Manufacturer	TBD
Payload fairing	25 × 90
Launch site	KSC, VAFB
IOC date	6 years after ATP

<u>SHUTTLE DERIVED VEHICLE CONCEPT</u>
(2 Engine, Expendable, Sidemount)

This figure illustrates an expendable SDV vehicle concept with a two engine sidemount configuration. The payload fairing is a flattened cylinder containing two parallel 15 ft. diameter bays. These bays, which are each compatible with a single Orbiter bay but are 30 feet longer, allow payloads or cargo packaging of a single design to be flown on either vehicle, interchangeably. The STS external tank (ET) and solid rocket boosters (SRBs) are the same as on the manned STS.

SHUTTLE DERIVED VEHICLE CONCEPT
2 ENGINE, EXPENDABLE, SIDEMOUNT
SDV-2ES



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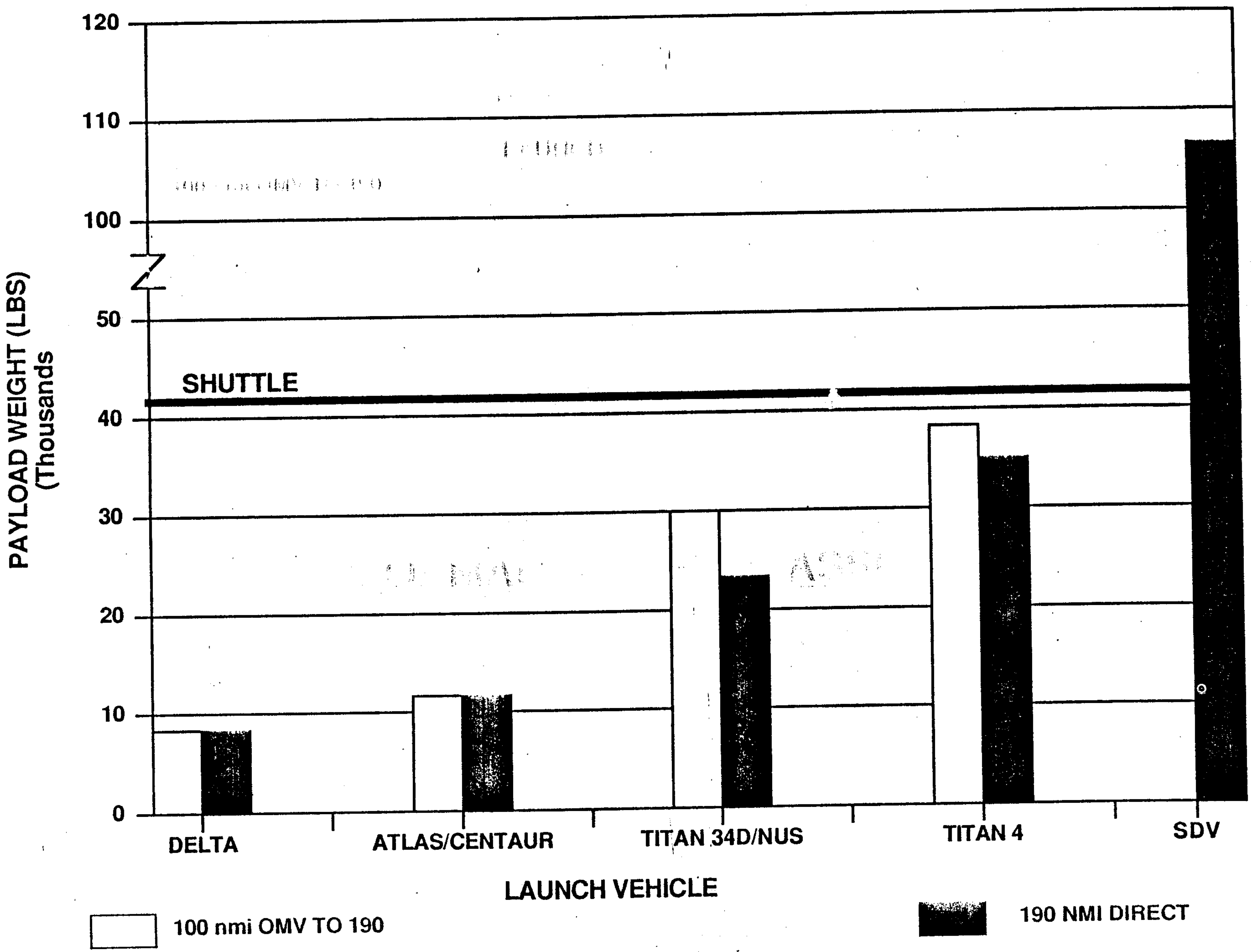
5.0 ELV-SDV COMPARISONS

ELV PERFORMANCE FOR SS ASSEMBLY

An orbital altitude of 190 nm. is chosen to compare representative ELV performance. This altitude represents the Space Station nominal assembly and logistics resupply altitude as dictated by Shuttle performance and Station program requirements and objectives. Two options are shown. The first option shows the greater capability provided by targeting to a lower 100 nm. orbit altitude with utilization of the orbital maneuvering vehicle (OMV) to raise the payload to a Station compatible altitude of 190 nm. or above. The TITAN launch vehicle systems provide higher payload performance for this option than for an alternate second option of targeting ELVs directly to a Station-compatible 190 nm. altitude.

A SDV performance of 105,000 lbs. provides a greater cargo carrying capability than the TITAN systems and requires no OMV augmentation to achieve Station-compatible altitude. However, OMV utilization will be necessary for rendezvous and berthing of Station assembly elements.

ELV PERFORMANCE FOR SS ASSEMBLY



SPACE STATION BUILD-UP AND LOGISTICS SDV UTILIZATION

There are advantages to using ELV vehicles of the TITAN 4 class to augment the STS Station assembly sequence and reduce the total number of Shuttle flights required to achieve IOC. There is a basic appeal of using the greatly enhanced lift capacity of SDVs to reduce both the number of Station-dedicated STS and/or TITAN 4 flights needed for Station assembly. However, until after PMC when crew time is available without Shuttle flights to provide EVA for Station assembly, the lift performance of the SDV cannot be effectively utilized. Even if a SDV launch for initial pre-PMC Station assembly were performed concurrently with an EVA-bearing Shuttle launch, the SDV launch manifest would greatly exceed the 24 hour EVA time capability available with the companion Shuttle flight. This would result in an accumulation of Station elements to be stored in orbit until Shuttle flights could be made available to provide EVA assembly. Therefore, there is no advantage in using SDV launches to replace or save Shuttle flights until after the Station has achieved a permanent manned capability and Station-based EVA can be utilized for assembly tasks.

SPACE STATION BUILD-UP AND LOGISTICS
SDV UTILIZATION

- REDUCE SHUTTLE FLIGHTS BY USE OF SDV'S AND TITAN 4'S

- SDV'S NOT USED PRE PMC DUE TO EVA CONSTRAINTS

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6.0 ASSEMBLY OPTIONS USING BOTH THE STS AND ELVs

SPACE SHUTTLE AND EXISTING ELVs

Two options for ELV utilization were considered. For option 1, no modules are to be carried by the ELV because there is no significant module outfitting advantage over the Shuttle module lift capability of 34,000 pounds. For the operational complexity and added cost of utilizing an OMV for altitude augmentation to 190 nm. there is no significant advantage for the small amount (approx. 4,000 lbs.) of module outfitting improvement.

For option 2, one post-PMC module will be launched on an ELV for purposes of evaluating the OMV utilization option.

In both options 1 and 2, ELVs are considered for launching Station elements such as the solar dynamic (SD) systems, servicing equipment, and user payloads.

SPACE SHUTTLE AND EXISTING ELV'S

- OPTION 1
  - NO MODULES CARRIED ON ELV'S
- OPTION 2
  - ONE POST PMC MODULE ON ELV

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OPTION 1 & 2 APPROACH PRE-PMC

Prior to PMC, both option 1 and option 2 utilize ELVs to launch the forward nodes and cupolas to the Station. The two nodes can be pre-integrated together prior to launch to minimize EVA. This launch would occur concurrently with a baselined Shuttle flight so that the total STS EVA requirement for both the ELV launch and the Shuttle launch does not require more than a total of 24 hours for assembly tasks. This eliminates the need for one Station assembly STS flight prior to PMC.

The OMV is used to carry the manifested Station elements to rendezvous with the Station, assuming that the ELV launch was targeted for 190 nm. altitude.

Both the U.S. polar platform and the ESA polar platform are launched with ELVs from WTR, eliminating two more Shuttle flights prior to PMC.

OPTION 1 & 2 APPROACH PRE PMC

ETR

- NODES #3 & #4, OMV, CUPOLAS & FSE

WTR

- U.S. POLAR PLATFORM
- ESA POLAR PLATFORM

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PRE-PMC FLIGHT SEQUENCE

This is a model Station build-up flight sequence utilizing three TITAN 4 ELV flights prior to PMC. Two ELV flights are utilized to launch the U.S. and ESA polar platforms. The third TITAN 4 launch is utilized to launch the forward nodes (#3 and 4), the OMV, and cupolas concurrently with Shuttle Orbiter Flight #7 (SO-7), which is the first Station outfitting flight (OF-1). The concurrent payloads for both the T4-3 and SO-7 launches do not exceed 24 EVA hours for Station assembly.

This option achieves Station PMC on Flight 11 (assembly Flight MB-8) with three less Shuttle flights.

	FLIGHT	LV	
1	MB-1	SO-1	1/2 PV, TRUSS, NODE : TANKAGE , 2 RCS
2	MB-2	SO-2	1/2 PV, TRUSS, NODE, ACA, DOCKING ADAPTER, 1 RCS
3	MB-3	SO-3	RADIATORS, TANKAGE ATTACH PAYLOADS, AIRLOCK
4	MB-4	SO-4	AIRLOCK, TANKAGE, SS RMS, SSEMU, ATTACH PAYLOADS
5	P-1	T4-1	US POLAR PLATFORM
6	MB-5	SO-5	LAB MODULE
7	MB-6	SO-6	HAB MODULE
8	P-2	T4-2	ESA POLAR PLATFORM
9	MB-7	T4-3	NODES, OMV, CUPOLAS
10	OF-1	SO-7	MODULE OFFLOADS
11	MB-8	SO-8	LOGISTICS, EMU'S, CREW

OPTION 1 APPROACH POST PMC

Post-PMC option 1 considerations utilize both Atlas-Centaur and TITAN 4 vehicles for non-module payloads to reduce STS flights. TITAN 4 performance capability permits manifesting two launch packages for Station assembly. The first launch package manifests both solar dynamic power units. The second TITAN 4 flight manifests the combined phase 1 and phase 2 servicing facilities in a single launch, which provides an opportunity for a higher degree of pre-launch integration thereby minimizing EVA and in-flight verification requirements. A third TITAN 4 flight is utilized to launch the U.S. co-orbiting platform from ETR.

Three Atlas/Centaur vehicles may be used to launch three Station element packages manifested as (1) JEM Exposed Facility #1 with its associated science/mission payload, (2) JEM Exposed Facility #2 with its associated payload and (3) the MSC Maintenance Facility (MMD).

The two TITAN launches and the three Atlas/Centaur launches that manifest Station assembly elements do not have to be launched concurrently with a STS launch because after PMC all EVA is Station-based.

OPTION 1 APPROACH POST PMC

- TITAN 4 LAUNCHES
  - SD MODULES
  - SERVICE FACILITY (PHASE 1 & 2), ATTACHED PAYLOADS
  - U.S. COORBITING PLATFORM
- ATLAS/CENTAUR
  - EXPOSED FACILITY #1 & P/L #1
  - EXPOSED FACILITY #2 & P/L #2
  - MSC MAINTENANCE FACILITY

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OPTION 1 POST PMC

The post-PMC flight assembly sequence for option 1 utilizing six ELV launches, three TITAN 4 (T4-4, T4-5, T4-6) and three Atlas/Centaur launches (A/C-1, A/C-2, A/C-3), results in the reduction of Shuttle Orbiter (SO) flights from 21 to 14. The flight assembly sequence follows the CETF baseline Station build-up sequence and Station-based EVA task schedule except for Flight 19, assembly Flight MB-12, which manifests the first two phases of the servicing facility on one launch and which results in the elimination of one flight from the overall assembly sequence. In the CETF baseline flight sequence the servicing facility, attached payloads, and module outfitting were functionally allocated to share shuttle cargo resources on each flight. A dedicated servicing facility ELV flight for option 1 results in the elimination of one assembly flight, which reduces the total number of flights needed by the Space Station Program from 32 to 31.

The major advantage of ELV utilization, however, for option 1 is that it maintains current Space Station Program and Shuttle system compatibility per the CETF objectives with a 31% reduction in the total number of Shuttle flights required. For option 1, both pre-PMC and post-PMC objectives can be achieved with 22 Shuttle Orbiter flights compared to 32 flights to accomplish the CETF baseline. The 22 Option 1 Shuttle flights in this case would be augmented by nine ELV flights.

OPTION 1 POST PMC

	FLIGHT	LV	
12	MB-9	T4-4	SD MODULES
13	MB-10	A/C-1	EXPOSED FACILITY #1 AND P/L
14	L-1	SO-9	LOGISTICS, CREW
15	MB-10	SO-10	JEM MODULE
16	L-2	SO-11	LOGISTICS, CREW
17	MB-11	SO-12	ESA MODULE
18	L-3	SO-13	LOGISTICS, CREW
19	MB-12	T4-5	SERVICE FACILITY (PHASE 1 &2), ATTACHED PAYLOADS
20	MB-13	SO-14	ELM + LOGISTICS, MODULE OFFLOADS
21	L-4	SO-15	LOGISTICS, CREW
22	MB-13	SO-16	MODULE OFFLOADS
23	L-5	SO-17	LOGISTICS, CREW
24	MB-15	A/C-2	EXPOSED FACILITY #2 + P/L
25	L-6	SO-18	CREW SERVICE FACILITY (PHASE 3), EXPOSED FOR #2 P/L MSC, MSC TRANSPORTER, ATTACHED P/L
26	MB-17	A/C-3	MSC MAINTENANCE FACILITY
27	L-7	S0-19	LOGISTICS, CREW
28	MB-18	SO-20	TRUSS, CREW
29	P-3	T4-6	US CO-ORBITING PLATFORM
30	L-8	S0-21	LOGISTICS, CREW
31	PR-1	SO-22	PLATFORM SERVICING (WTR)

FLIGHT26-32

OPTION 2 POST PMC

This option 2 post-PMC flight assembly sequence differs from option 1 for Flight 15, assembly Flight MB-11, where a TITAN 4 ELV is utilized to launch the JEM module, and on Flight 21, assembly Flight MB-14, to launch the JEM ELM. The JEM module is considered for this option because of its smaller length, 31 feet compared to 45 feet for the U.S. and ESA modules. Also, the JEM module requires 36% less off-loading than the ESA module for this post-PMC option to meet the TITAN 4 lift performance capability (the completely outfitted JEM weight is 45,900 lbs. compared to the ESA Module weight of 51,400 pounds). This suggests an in-flight module integration advantage for ELV utilization for launching Space Station modules. Also, with regards to demonstrating the effect on Shuttle flight reduction, utilization of an ELV for this MB-11 flight also eliminates the need for the subsequent logistics flight when compared to the CETF Flight sequence. In this Option 2 post-PMC scenario, Flights 15 and 16 are back-to-back assembly flights with no need for an intermediate logistics/crew rotation flight. In this flight sequence, ELV utilization has the effect of substituting one ELV flight for two Shuttle Orbiter flights and eliminating altogether the need for the second Shuttle Orbiter logistics flight. By utilizing an ELV launch for Flight 21, it is possible to sequence four assembly flights in succession without the need for intervening logistics flights. Two more Shuttle flights therefore can be eliminated from the overall assembly sequence.

Comparing Option 2 to the CETF baseline assembly sequence it can be seen that ELV utilization has the potential to eliminate three launches from the flight sequence altogether, reducing the total number of flights required by the Space Station Program from 32 to 29. ELV utilization can reduce the total number of Shuttle flights by 44%, from 32 flights to 18 flights, by utilizing 11 ELV launches.

OPTION 2 POST PMC

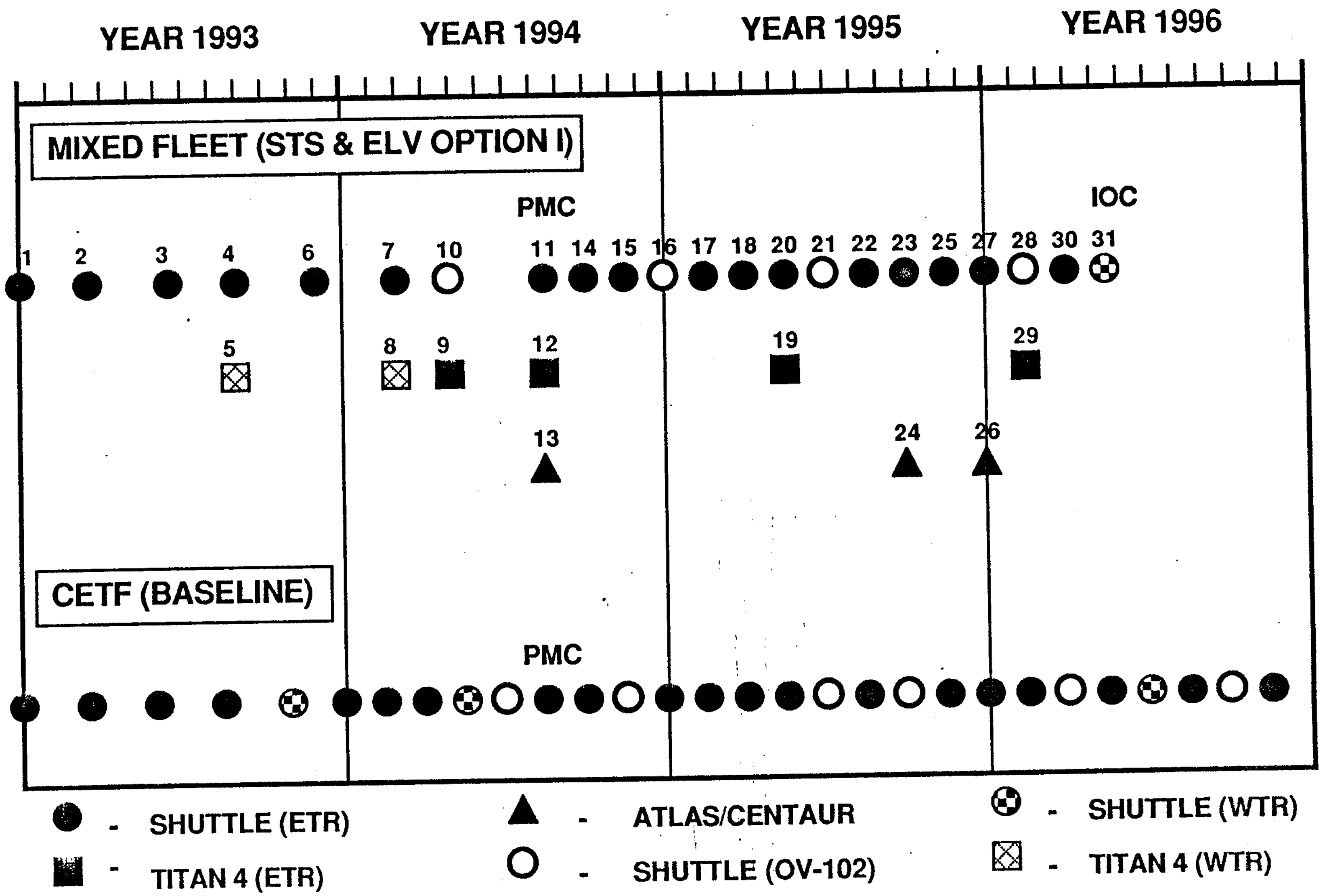
STS + EXISTING		ELV	
12	MB-9	T4-4	SD MODULE
13	MB-10	A/C-1	EX FAC #1 + P/L
14	L-1	SO-9	LOGISTICS, CREW
15	MB-11	T4-5	JEM MODULE
16	MB-12	SO-10	ESA MODULE
17	L-2	SO-11	LOGISTICS, CREW
18	MB-13	T4-6	SERVICE FAC (PH 1 & 2), ATTACHED P/L
19		SO-12	MODULE OFFLOADS,
20	L-3	SO-13	LOGISTICS, CREW
21		T4-7	ELM + LOGISTICS, MODULE OFFLOADS
22		A/C-2	EX FAC #2 + P/L
23		SO-14	SERVICE FAC (PH 3), EX FAC #2 P/L, MSC MSC TRANSPORTER, ATTACHED P/L
24		A/C-3	MSC MAINTENANCE DEPOT
25	L-4	SO-15	LOGISTICS, CREW
26	P-3	T4-8	US CO-ORBITING PLATFORM
27		SO-16	TRUSS
28	L-5	SO-17	LOGISTICS, CREW
29	PR-1	SO-18	PLATFORM SERVICING (WTR)

SPACE STATION ASSEMBLY SCENARIO COMPARISON
STS & ELV OPTION 1

For the purpose of comparing assembly scenarios, the PMC date of September 1994 will be held constant. For CETF, shown along the bottom of the chart, Space Station assembly completion occurs at Flight 30 in 1997, and is not shown. Three STS flights operate from the WTR for polar orbit launches, and flight of the lower performance STS OV-102 vehicle is indicated by open circles.

For mixed fleet option 1, Space Station assembly completion occurs on Flight 28 (Flight 30 is a logistics flight and Flight 31 is a polar platform resupply mission from the WTR), instead of Flight 30 (CETF). Six of the post-PMC flights are ELV flights. A total of nine option 1 flights are ELV flights. By maintaining basically the same STS flight rate, the mixed fleet option is able to achieve IOC approximately 1 year earlier than CETF.

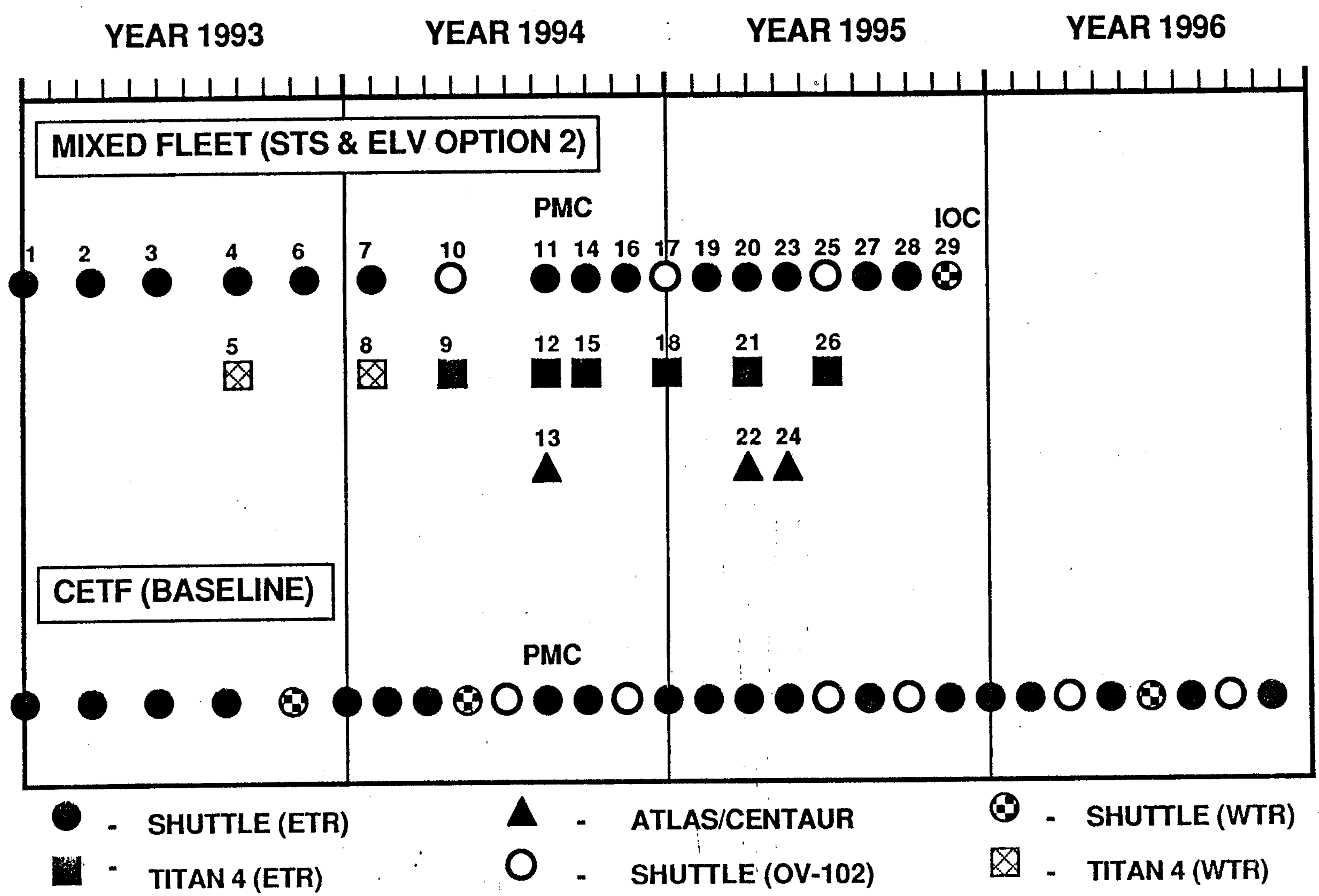
SPACE STATION ASSEMBLY SCENARIO COMPARISON



SPACE STATION ASSEMBLY SCENARIO COMPARISON
STS & ELV OPTION 2

This mixed fleet option uses more ELV launches than option 1 (8 post-PMC instead of six, 11 total instead of nine), with the result that there is a further decrease in the total number of launches required to reach IOC (27 versus 29). Flight 28 is a logistics flight, and Flight 29 is a WTR platform refurbishment STS flight. Since 11 of these are ELV flights, the number of STS flights for mixed fleet option 2 is 18, versus 32 for CETF. The net schedule improvement to IOC compared to CETF is approximately a year and a half.

SPACE STATION ASSEMBLY SCENARIO COMPARISON



OPTION 1 & 2 FLIGHT SUMMARY

An assessment of the differences between CETF and mixed fleet options 1 and 2 indicates that although the total number of launches required for the Space Station Program does not differ greatly, a potential reduction of nearly 50% in STS flights can be achieved.

OPTION 1 & 2 FLIGHT SUMMARY

	SPACE SHUTTLE	TITAN 4	ATLAS/CENTAUR	TOTAL
CETF BASELINE	32	---	---	32
OPTION 1	22	6	3	31
OPTION 2	18	8	3	29

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OFFICE OF SPACE FLIGHT - CHALLENGE

Mixed fleet Option 2 is the more efficient ELV option in terms of minimizing STS flights, with between five and seven STS flights per year. A major difficulty of this reduced STS rate, however, is accommodating a 90 day rotation schedule for a crew of eight. The minimum STS flight rate to support this crew rotation is eight per year because the Space Shuttle can only carry a maximum of four Space Station crew on any one flight.

It is currently possible to achieve the post-PMC goals of the Space Station program at a level of five to seven STS flights per year with or without the utilization of ELVs. Permanently manned Space Station operation within the current Office of Space Flight guidelines for available Shuttle seats and on-orbit crew stay time is incompatible with anything less than eight STS flights per year. A formidable design redefinition challenge needs to be addressed by the Office of Space Flight to reduce the issue.

OFFICE OF SPACE FLIGHT- CHALLENGE

ACCOMMODATE THE 90 DAY 8 PERSON CREW ROTATION IN LESS THAN 8 SPACE SHUTTLE FLIGHTS PER YEAR

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7.0 OPTIONS INCLUDING THE SDV

POST-PMC SDV OPTION FLIGHT SEQUENCE

After PMC, when more on-orbit crew time is available to take advantage of the large capacity of heavy lift launch vehicles, utilization of SDVs can further reduce the total number of Space Station assembly sequence flights. In this scenario, both SDV-1 and SDV-2 carry up fully outfitted and pre-integrated JEM and ESA modules and substantial amounts of other equipment, not possible with the Shuttle lift capacity. SDV-3 manifests not only the Japanese Experiment Logistics Module (ELM), but also all necessary servicing facility equipment, and eliminates the phased build-up required by the CETF assembly sequence. In this scenario, only one post-PMC non-SDV ELV is used, which is utilized for launching the coorbiting platform on a TITAN 4 from the ETR.

This approach to SDV utilization illustrates how early post-PMC use of the Orbiter as a logistics supply, crew rotation and down cargo carrier realizes the high productivity of the Space Station/Shuttle Orbiter infrastructure in this phase of the assembly sequence. The crew rotation scenario shown exchanges the initial PMC crew within 60 days on Flight 12 and the second crew of four within 60 days on Flight 14. CETF requirements established 60 day rotations for the first two Station crews. Flight 16 increases total crew to eight. Subsequent logistics flights rotate four crew every 45 days, assuring that no crew member stays on orbit more than 90 days.

This utilization of SDVs reduces the total number of assembly and outfitting flights required from 18 for CETF to only 12. The elimination of six interleaving logistics flights reduces the total number of flights by 12. However, the total number of Shuttle flights is reduced by 60% from 32 to 13 by utilizing one ELV and three SDV launches. This SDV scenario can accommodate a Shuttle flight rate of less than eight per year until the crew level on the Station reaches a level of eight. After that, because of the 90 day stay time constraint and the Shuttle crew carrying limit of four per flight for crew rotation, a Shuttle flight rate of eight per year is required.

POST PMC SDV OPTION FLIGHT SEQUENCE

FLT	TYPE	LV -	FLIGHT MANIFEST DESCRIPTION
12	L-1	SO-9	LOGISTICS (4↑,4↓,4 CREW)
13	MB-9	SDV-1	SD POWER, ESA, ATTACH, P/L
14	L-2	SO-10	LOGISTICS (4↑, 4↓, 4 CREW)
15	MB-10	SDV-2	• JEM + EF1 + P/L • MSC + X PORTER + MAINT. DEPOT • UPPER/LOWRE KEELS & BOOMS
16	L-3	SO-11	LOGISTICS (4↑, 0↓, 8 CREW)
17	MB-11	SDV-3	• SERVICING FACILITY • JEM EF2 + ELM + ELM P/L • MODULE OUTFIT & OFFLOAD MAKEUP
18	L-4	SO-12	LOGISTICS (4↑, 4↓, 8 CREW)
19	P-3	T4-4	CO-ORBITTING PLATFORM (ETR)
20	PR	SO-13	POLAR PLATFORM SERVICING (WTR)
21	L-6	SO-14	LOGISTICS (4↑, 4↓, 8 CREW)
22	PR	SO-15	POLAR PLATFORM SERVICING (WTR)

CETF ASSEMBLY FLIGHT NO. 13
(Significant Servicing)

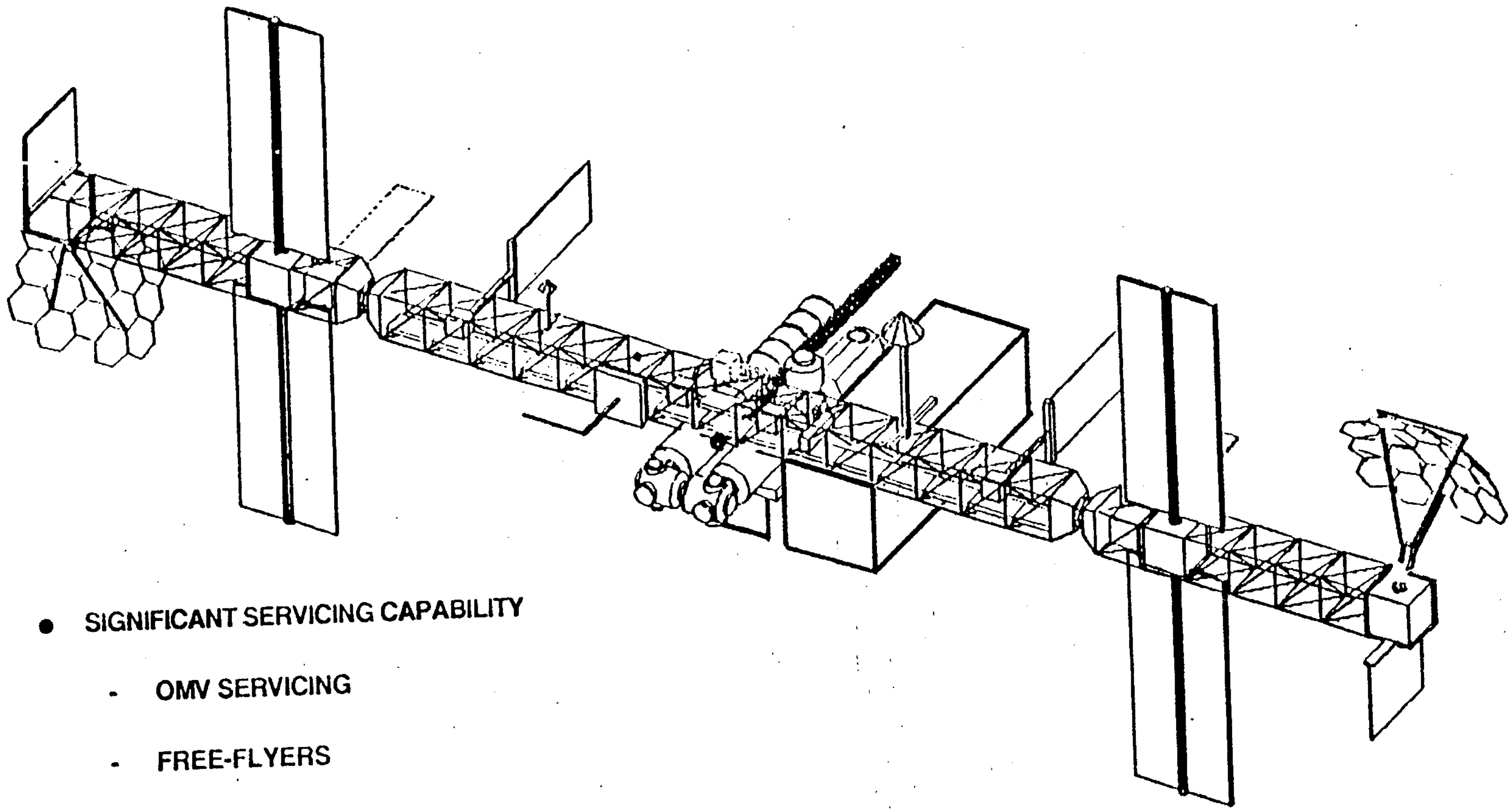
In the CETF sequence, significant but limited servicing capabilities are established on assembly Flight 13, which is actually Flight 20 (including all platform and logistics flights). Nearly 3 years are required after the first Station flight to achieve this capability, which is able to meet the servicing requirements of the OMV, free flyers, and attached payloads.

The increased mass and volume resource availability per SDV launch admits the possibility of combining several Space Station elements within a single launch, which is not possible within the Shuttle Orbiter performance constraints. This significantly reduces the total number of flights required to complete Space Station assembly. For example, the CETF phased build up of the servicing facility required several Shuttle flights to accomplish the final objective. The post-PMC SDV assembly sequence previously described permits the complete servicing facility to be placed in orbit with a single launch.

Critical Evaluation Task Force

ASSEMBLY FLIGHT NO. 13

(SIGNIFICANT SERVICING)



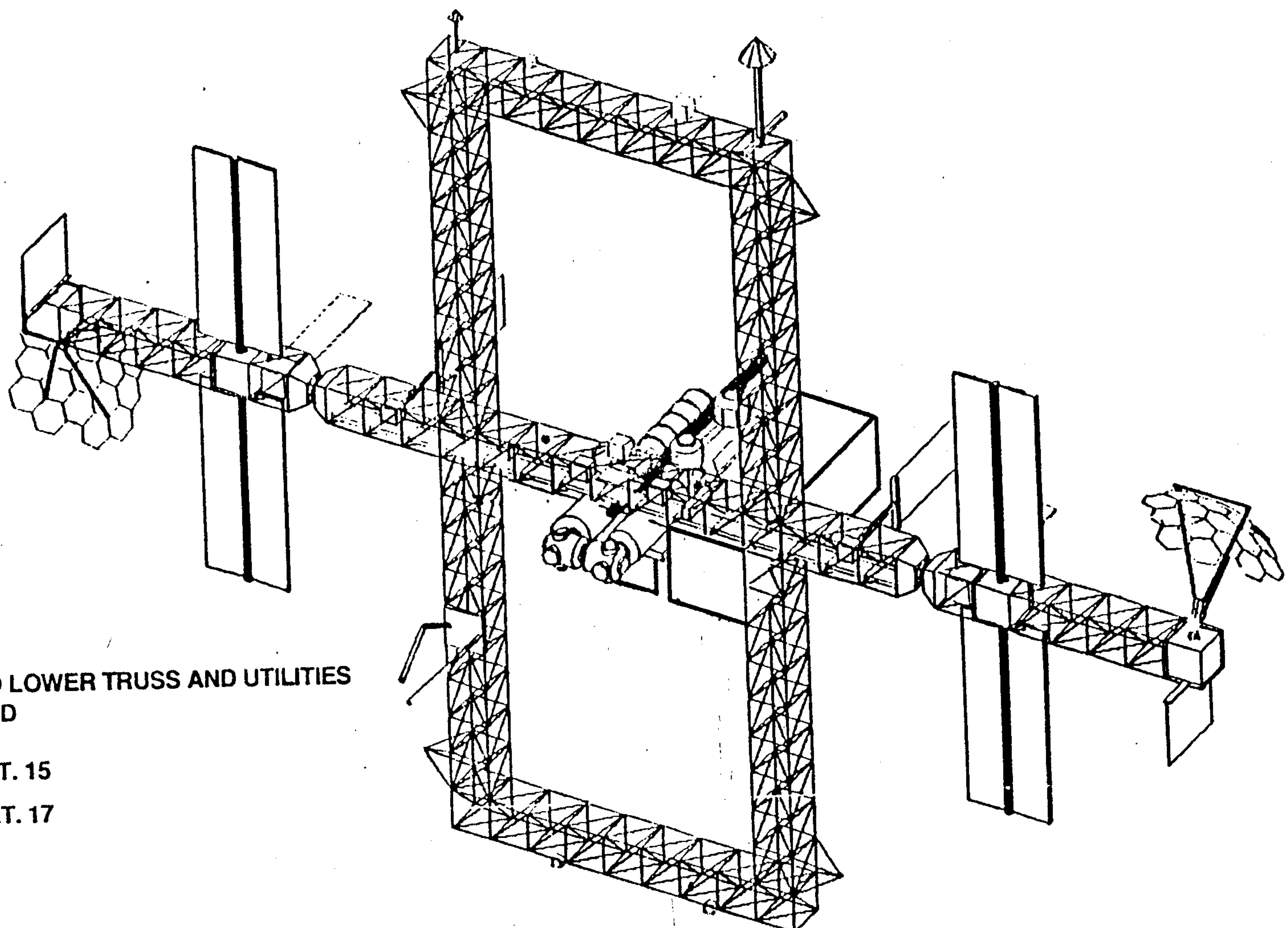
- SIGNIFICANT SERVICING CAPABILITY
  - OMV SERVICING
  - FREE-FLYERS
  - ATTACHED PAYLOADS

CETF ASSEMBLY FLIGHT NO. 17 (IOC)

CETF Station assembly is completed on assembly flight 17, which is flight 30 counting the non-assembly flights. The Station configuration at IOC includes the completed upper and lower booms, as well as the MSC and Mobile Maintenance Depot (MMD). This full servicing capability is reached approximately 4 years after the first Station launch.

Critical Evaluation Task Force

ASSEMBLY FLIGHT NO. 17 (IOC)

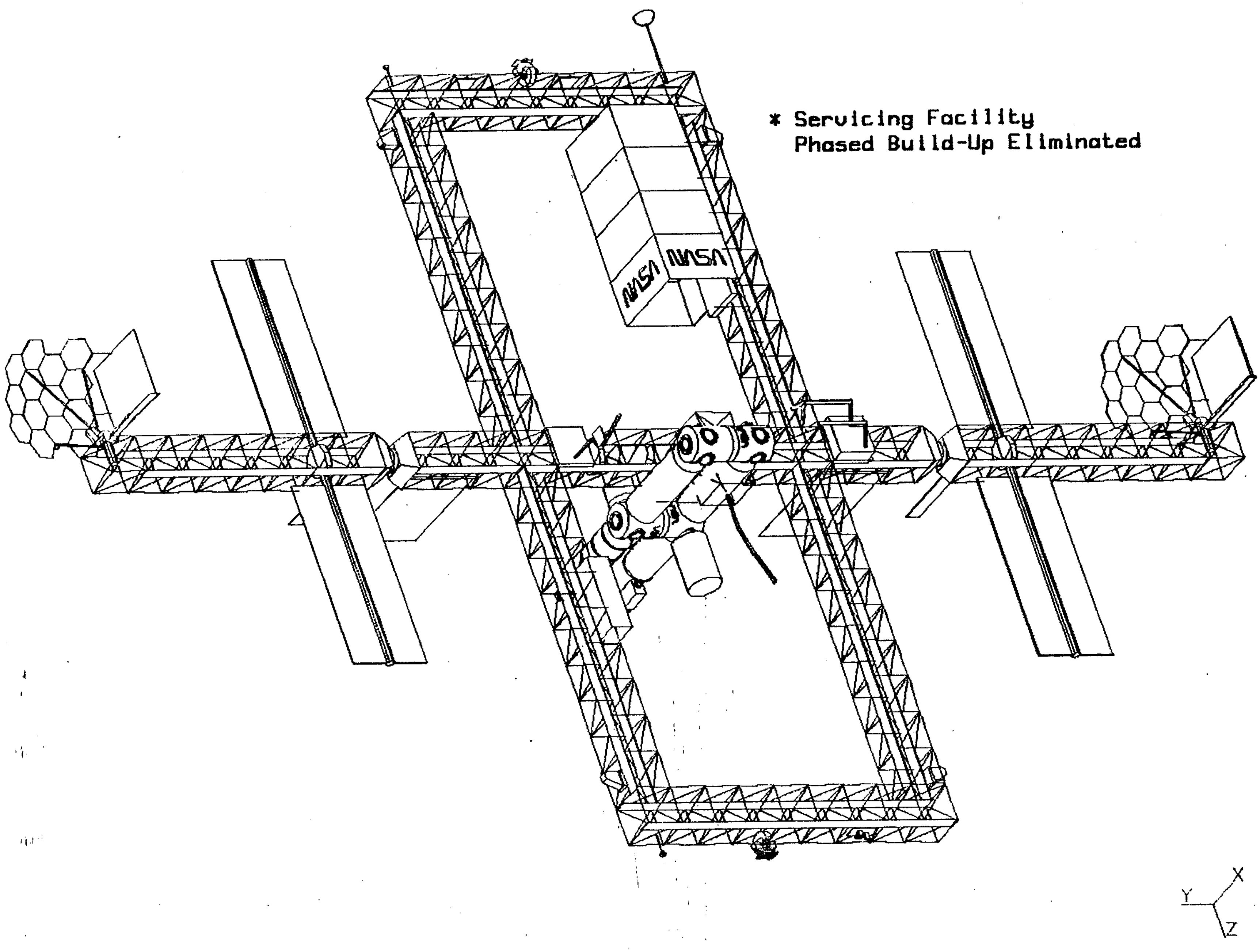


- UPPER AND LOWER TRUSS AND UTILITIES COMPLETED
- MSC ON FLT. 15
- MMD ON FLT. 17

SHUTTLE DERIVED LAUNCH VEHICLE OPTION
SPACE STATION IOC

Utilization of SDVs enables full servicing capability to be achieved at once, with Flight MB-11 (Flight 17 from first Station launch). No phased build-up of servicing is required in this scenario, and the full capability is attained about 2 years after the first Station flight.

SHUTTLE DERIVED LAUNCH VEHICLE OPTION
SPACE STATION IOC



ASSEMBLY SCENARIO COMPARISON

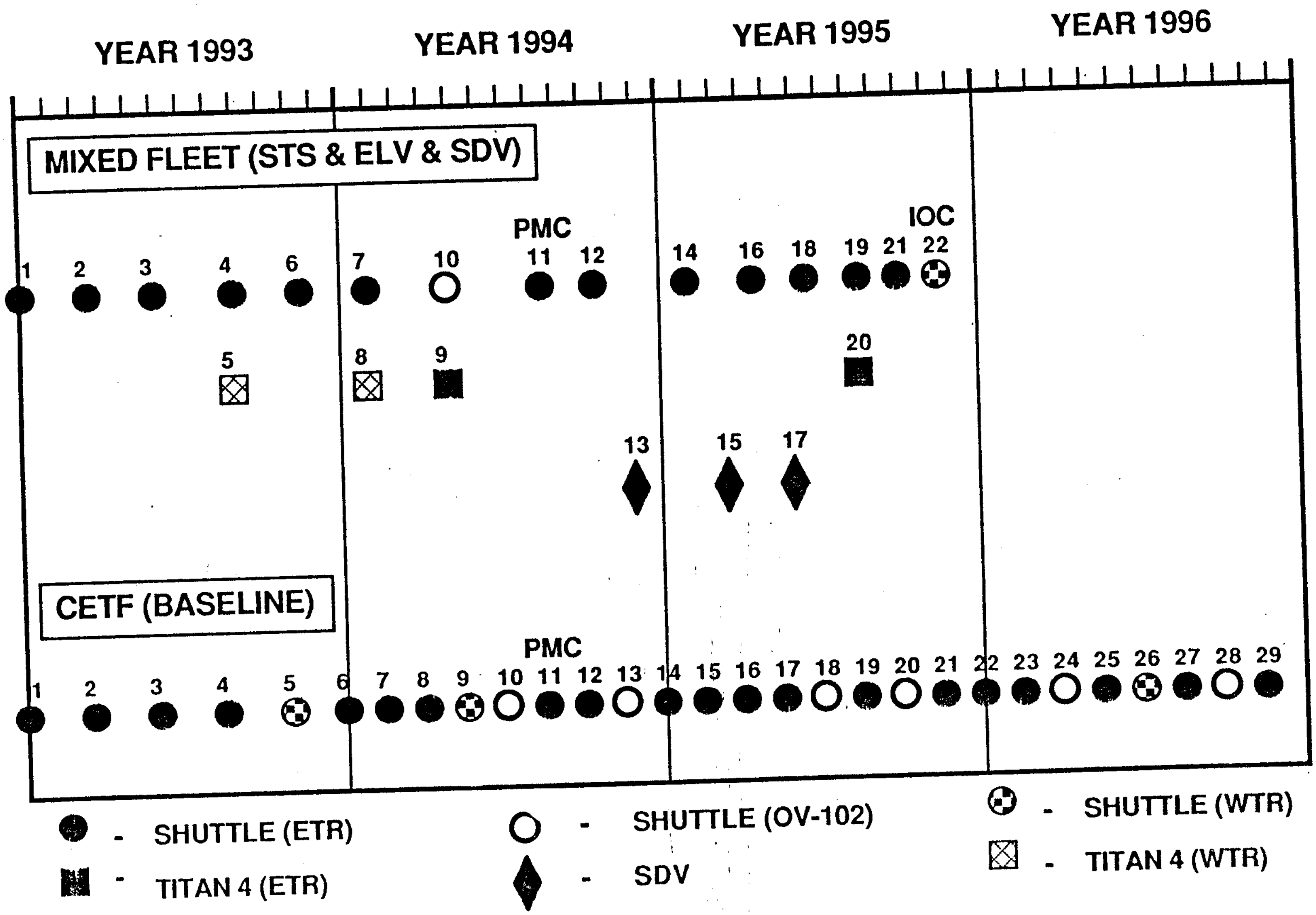
In the CETF flight sequence, approximately 4 years are required to reach IOC. Using SDVs to speed the post-PMC assembly phases, the elapsed time from the first Station flight to IOC is about 2 years.

The lower panel shows the corresponding build-up sequence in the SDV option. Up to PMC, only STS and Titan 4 flights are used. Thereafter, flights 9, 10, and 11 (circled symbols) are SDV flights SDV-1, -2, and -3. IOC effectively occurs with flight 11 (MB-11). The six logistics flights (triangle symbols) are all Orbiter flights, SO-9 through SO-14. The last two platform flights, numbers 3 and 4 (diamond symbols), are a Titan 4 launch from the ETR and a STS launch from the WTR respectively. A total of 22 flights of all kinds are required to get to the polar platform servicing missions included in the other options.

However, it must be noted that the commitment to complete Station assembly earlier requires earlier commitment to eight Shuttle flights per year to sustain a permanent crew of eight at the Station.

SPACE STATION ASSEMBLY SCENARIO COMPARISON

SHUTTLE DERIVED VEHICLE (SDV) AUGMENTATION



SDV SUMMARY

Expendable launch vehicles with TITAN 4 and SDV performance capabilities can effectively be combined in a mixed fleet scenario with Shuttle launches to reduce the total number of flights required to complete assembly of the Space Station. Substantially fewer Shuttle launches are required, which is the main objective of utilizing ELVs. The calendar time saving to IOC is between 1-1/2 and 2 years, with the benefit of a mature servicing capability achieved without the need for a phased approach.

SDV SUMMARY

- ELV'S (SDV + TITAN 4) EFFECTIVELY UTILIZED TO REDUCE STS FLIGHTS POST PMC

- FLIGHT SEQUENCE AND CALENDAR TIME REDUCED TO IOC BY UTILIZING SDV'S AND TITAN 4'S
- EARLY UPPER/LOWER BOOM ATTACHED PAYLOADS

	TOTAL FLTS TO IOC	
VEHICLES	CETF	SDV/T4 ALTERNATE
SHUTTLE	32	15
TITAN 4	--	4
SDV-2E (S)	--	3
TOTAL	32	22
CALENDAR	1ST QTR 5TH YEAR	3RD QTR 3RD YEAR

AS.SUM

LARGE SDV LIFT CAPACITY ELIMINATES NEED FOR PHASED APPROACH TO SERVICE FACILITY (2 STS FLTS)

IMPACT OF REDUCED SHUTTLE LAUNCHS FOR SPACE STATION PROGRAM

Aside from the positive benefits to the Station program of using ELVs augmented with SDVs for assembly and platform deployment, contention with other user communities for Shuttle flight opportunities may require Station Shuttle flight rates to be reduced anyway. Without a mixed fleet approach, such a shortage of STS flights would cause a substantial slip in IOC and could impose a serious limitation on crew size and availability, one of the scarcest resources on the Station.

CETF studies showed that a minimum crew level of eight is needed to perform the tasks necessary to effectively utilize the current Station concept. To effectively utilize the Station with less than eight STS flights per year for crew rotation will require a serious study to determine the appropriate acceptable crew stay time permissible beyond 90 days with respect to the number of available STS flights, or an increase beyond seven of the number of crew that may be carried per STS flight.

IMPACT OF REDUCED SHUTTLE LAUNCHES FOR SPACE STATION PROGRAM

4 FLTS/YR

- STATION IOC EXTENDED BY ~2-1/2 YEARS
- CREW CHANGED OUT COMPLETELY EVERY 90 DAYS
- CREW LIMITED TO 4-5 PEOPLE
- SCIENCE DRASTICALLY CURTAILED

6 FLTS/YR

- STATION IOC EXTENDED BY ~2 YEARS
- CREW CHANGED OUT COMPLETELY EVERY 90 DAYS
- CREW LIMIT TO 4-5 PEOPLE
- SCIENCE DRASTICALLY CURTAILED

NOTE:

- MEDICAL LIMIT OF 90 DAY STAY TIME FOR CREW
- CREW TIME MOST LIMITED RESOURCE ON STATION

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8.0 SURVEY OF INTERNATIONAL VEHICLES

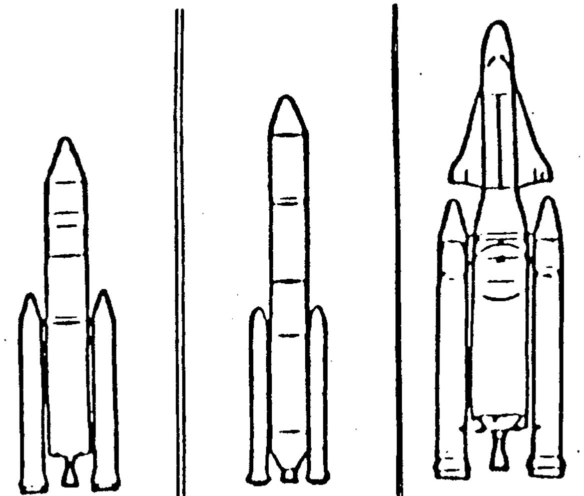
INTERNATIONAL LAUNCH VEHICLES

Although not available today, several planned foreign launch vehicles with applicable advertised capabilities can be identified for consideration for utilization within the Station assembly time frame. The Japanese H-2, though offering only 13,000 lbs. lift to a 28.5° inclination, 220 nm. orbit, should be available in 1992. The more capable Ariane 5 may be operational in 1995. The ESA manned Hermes vehicle, although offering modest pressurized payload launch weight and volume, could contribute to rotation of the crew after 1995.

INTERNATIONAL LAUNCH VEHICLES

- **PERFORMANCE**

  28.5 °, 220 N.MI.



	ARIANE 5	H-2	HERMES
Manufacturer	Aerospatiale	MITSUBISHI	ESA
Payload fairing	18.1 X 98	4M DIA	10' x 16'
Performance Cap.	30-32,000	13,000	10,000
Launch site	KOUROU	Tanegashima	KOUROU
IOC Date	1995	1992	1995
No. In Inventory	N/A	N/A	2(late 1995)
Launch cost		$66M	unknown
Concept sponsor	ESA/CNES	NASDA	ESA/CNES
Development cost	$2B	$900M	
Production Cap			
Launch rate Cap.	3-4 /YR	2 /YR	3-4 /YR
No. of passengers	N/A	N/A	4

INTERNATIONAL LAUNCH VEHICLES

In addition to reducing flight rate requirements on the U.S. fleet, foreign launch participation could reduce their cost sharing obligations for these operations. Platforms are key candidates for launch by international ELVs. Modules lofted by any of the international vehicles would need to be flown without major portions of their outfitting and interior user gear, however, because of the lower weight capacity of these vehicles.

Hermes offers the attractive capability of augmenting the Shuttle as an up and down crew carrier.

INTERNATIONAL LAUNCH VEHICLES

- CAN BE USED TO PARTIALLY OFFSET INTERNATIONAL PARTNER SHARE OF OPERATIONS COST
- ARIANE 5 AND H-2 MAY BE AVAILABLE, HERMES IS POST IOC PERIOD
- COULD LAUNCH INTERNATIONAL MODULES (OFF LOADED) - CETF FLIGHTS 14, 16, 22
- COULD LAUNCH PLATFORMS - CETF FLIGHTS 5, 9, 32
- COULD REPLACE ALL OR PART OF TITAN IV LAUNCHES TO REDUCE LAUNCH RATE AT ETR AND/OR WTR (EG. 5 TITAN IV'S AND 4 ARIANE V'S FOR THE SHUTTLE + ELV OPTION)
- HERMES COULD BE USED TO REDUCE STS FLIGHTS FOR CREW ROTATION POST IOC

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9.0 OBSERVATIONS AND CONCLUSIONS

POST 1995 CONSIDERATIONS

In addition to issues related to ELV, SDV, and international launches availability, several other new space systems under consideration can have major impacts on Station operations and evolution. The Shuttle II concept, if realized, could augment the capabilities of the present STS manned system. The ELV logistics return capsule could help return mass from orbit, presently a very serious concern because of the low return mass capability of the Orbiter (24,000 lbs.). It is possible that the crew escape and reentry vehicle (CERV), beyond performing an important safety function, could be designed to perform some mass return functions.

POST 1995 CONSIDERATIONS

- ELV FLEET MIX AND AVAILABILITY
- SHUTTLE II CAPABILITY AND AVAILABILITY
- EVOLUTION TO 18 MAN CREW ROTATION
- ELV LOGISTICS RETURN CAPSULE
- CERV
- INTERNATIONAL LAUNCH VEHICLES AVAILABILITY INCLUDING HERMES

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SPACE STATION PROGRAM IMPACT CONSIDERATIONS

In addition to payload launch manifesting, the use of ELVs and SDVs does have other significant impacts on the Space Station Program. A space based OMV will be required early in the program to retrieve payloads delivered by unmanned vehicles to the Station. The use of multiple launch systems, especially existing ELVs not designed to be closely compatible with the Orbiter bay, complicates interface and integration equipment and procedures. It will be necessary for the Orbiter and ELVs to perform three-body rendezvous with Station under strict flight operations time constraints. When large or multiple payloads are delivered to orbit, the contents must be suitably stowed until they are used, presenting a storage space and crew resource impact not currently considered. As advantages, however, IOC and servicing capability are achieved much sooner, and the upper and lower booms are available sooner for attached science payloads.

SPACE STATION PROGRAM IMPACT CONSIDERATIONS

- SPACE BASED OMV REQUIRED
- MULTIPLE LAUNCH VEHICLES TYPE
  - INTERFACES/INTEGRATION
  - ENVIRONMENT
- 3 BODY RENDEZVOUS
  - TIME PHASED LAUNCH CONSTRAINT (FLT 9 & 10)
- POTENTIAL ON-ORBIT STORAGE PROBLEM
  - LARGE SDV CARGO CARRIER
  - PACKAGES FROM MULTIPLE LAUNCH VEHICLES
- REACH IOC SOONER AND REDUCE TOTAL NUMBER OF SHUTTLE FLIGHTS TO IOC
- INTEGRATED SERVICING FACILITY LAUNCHED ON SDV
- EARLIER UPPER/LOWER BOOM ATTACHED PAYLOADS

ASSES.IMPACT

SUMMARY

A comparison of the three mixed fleet options previously described shows the strong relationship of available mass- and volume-to-orbit provided by each option. The Shuttle must provide EVA resources for assembly, which can limit the amount of mass that can usefully be launched prior to PMC. However, the availability of Station-based EVA post-PMC provides the opportunities for higher performance ELVs, such as the SDV, to be effectively utilized. Option 3, which utilizes the SDV post-PMC, dramatically demonstrates this point.

SUMMARY

	SPACE SHUTTLE	TITAN 4	ATLAS/CENTAUR	SDV-2E	TOTAL
CETF BASELINE	32	---	---	--	32
OPTION 1	22	6	3	--	31
OPTION 2	18	8	3	--	29
OPTION 3	15	4	--	3	22

ASSES.FLSUM

CONCLUSIONS

The major conclusions of the study show that while use of ELV and SDV systems can significantly reduce the number of STS flights for transferring material to orbit, any reduction of STS flight rates below eight per year will decrease the permanent crew size and diminish science returns from the program unless alternative means of crew rotation are identified or crew stay time is increased.

CONCLUSIONS

- SPACE STATION PROGRAM REQUIREMENT FOR A CREW OF 8 DICTATES 8 SHUTTLE FLIGHTS/YEAR UNDER CURRENT CONSTRAINTS. WTR PLATFORM LAUNCHES/SERVICING ARE IN ADDITION

- ELV'S CAN BE EFFECTIVELY USED TO REDUCE THE TOTAL NUMBER OF SHUTTLE FLIGHTS FROM FIRST LAUNCH TO IOC CONFIGURATION TO 22 (EXISTING ELV'S) OR 15 (EXISTING ELV'S + SDV)

- IMPACT OF REDUCING NUMBER OF SHUTTLE FLIGHTS/YEAR TO THE MANNED BASE TO FOUR OR SIX IS TO REDUCE THE MAXIMUM SPACE STATION CREW SIZE TO 5 UNDER CURRENT CONSTRAINTS AND DRASTICALLY CURTAIL SCIENCE

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16. Abstract

Reductions in expected Space Transportation System (STS) flight rates of the Space Shuttle since the 51-L accident raise concerns about the ability of available launch capacity to meet both payload-to-orbit and crew rotation requirements for the Space Station. In addition, it is believed that some phases of Station build-up could be expedited by using unmanned launch systems with significantly greater lift capacity than the STS. This study examines the potential use of expendable launch vehicles (ELVs), yet-to-be-developed unmanned shuttle-derived vehicles (SDVs), and international launch vehicles for meeting over-all launch requirements to meet Space Station Program objectives as defined by the 1986 Critical Evaluation Task Force (CETF). The study concludes that use of non-STS transportation can help meet several important program objectives as well as reduce the total number of STS flights. It also finds, however, that reduction of Space Station-dedicated STS flights below 8 per year forces a reduction in Station crew size assuming the CETF 90 day crew stay time baseline and seriously impairs scientific utilization of the Station.

This study is the Space Station Program's contribution to a NASA agency-wide study of mixed fleet concepts.

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