THE SPACE SHUTTLE — A FUTURE SPACE TRANSPORTATION SYSTEM

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Abstract

The objective of the Space Shuttle Program is to achieve an economical space transportation system. This paper provides an introductory review of the considerations which led to the Government decisions to develop the Space Shuttle. The role of a space transportation system is then considered within the context of historical developments in the general field of transportation, followed by a review of the Shuttle system, mission profile, payload categories, and payload accommodations which the Shuttle system will provide, and concludes with a forecast of the systems utilization for space science research and payload planning activity.

Introduction

In 1979, only two decades after the successful launch of the 14-kilogram (31 pound) Explorer I satellite, the United States is scheduled to begin orbital flight of the Space Shuttle system (Fig. 1). This system is being designed to routinely carry payloads of up to 29 510 kilograms (65 000 pounds) into Earth orbit. Large general-purpose payload capacity is an important feature of the Shuttle system design; however, an equally important aspect of the Space Shuttle is the reusability of most of its major hardware elements. It is this "reusability" feature that will enable the Shuttle system to overcome the major obstacle to exploitation of space — the high cost of space flight operations.(1) Since the launch of that first American Earth-orbiting satellite on January 31, 1958, U.S. unmanned satellites have probed the near and distant reaches of space. Manned missions have progressed from 15-minute flights covering a few hundred kilometers to extended orbital flights and the successful completion of six 925 000-kilometer (500 000 mile) round-trip lunar exploration missions. From 1958 until 1973, the United States had successfully launched over 600 payloads with a total expenditure estimated at over $60 billion.(2) The cost of delivering the early satellites to orbit was approximately $2.2 million per kilogram ($1 million per pound) compared to current delivery costs of $1980 per kilogram ($900 per pound). These significant cost reductions were due principally to economies realized by increased production rates, improved launch vehicle performance, use of standard launch vehicle systems for U.S. Department of Defense/NASA payloads, and the overall increasing level of space activity. But today, as in the 1950's, every launch vehicle is expended after its initial use and, equally significant, its payload as well. Once payloads are placed into space, they can no longer be repaired, modified, or reused. As a result, designers have been driven to develop payloads of "minimum weight and volume" and "maximum performance." Every component has been designed to the limit, with low margins and low tolerances. The low design tolerances require extensive testing and enormous amounts of personal attention and control to assure success. Most systems are tailormade for one purpose and can be used only for that purpose. The technology of microminiaturization of electronic circuitry was stimulated by the need to conserve payload weight and volume because of the overridingly important relationship of weight to costs in launch vehicle performance tradeoffs. All this is changing as we approach the Shuttle era in space flight operations where weight and volume constraints can be relaxed. The payload designer can now optimize his payload for "low cost" and "high reliability."

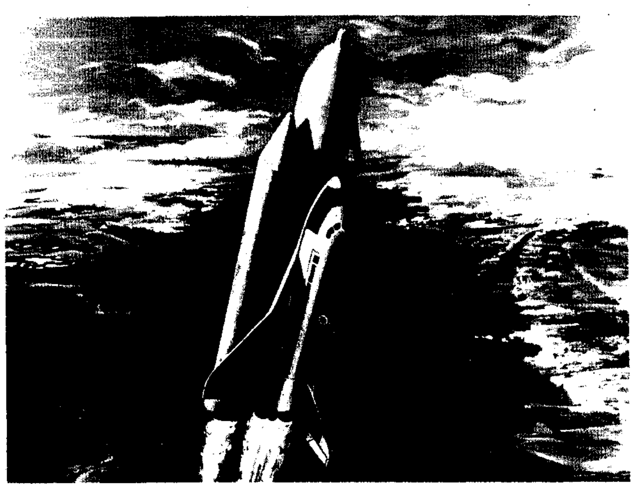


Fig. 1 Space Shuttle.

The cost-effective development of the Space Shuttle system and the resultant impact on payload design will satisfy three critical factors which should guide the development of new systems for space operations advanced by the Space Task Group in its report to the President in September 1969.(3) These factors are as follows.

1. Commonality - The use of a few major systems for a wide variety of missions

2. Reusability - The use of the same system over a long period for a number of missions

3. Economy - The reduction in the number of throwaway elements in any mission; the reduction in the number of new developments required, the development of new program principles that capitalize on such capabilities as man-tending of space facilities; and the commitment to simplification of space hardware

A National Space Objective

In September 1969, the Space Task Group appointed by the President to recommend a coordinated post-Apollo Space Program for the United States made the following recommendation.

"That this nation accept the basic goal of a balanced manned and unmanned space program conducted for the benefit of all mankind. To achieve this goal, the United States should emphasize the following program objectives:

". . . develop new systems of technology for space operations . . . . through a program directed initially toward development of a new space transportation capability . . . ."

Authority to Proceed

On January 5, 1972, after several years of intensive study by NASA and the U.S. Air Force of the principal contending vehicle configurations and cost estimates for a space transportation system, the President proposed and the Congress subsequently approved NASA's plan for the Space Shuttle system.

The President said, "This system will center on a space vehicle that can shuttle repeatedly from Earth to orbit and back. It will revolutionize transportation into near space, by routinizing it. It will take the astronomical costs out of astronautics. In short, it will go a long way toward delivering the rich benefits of practical space utilization and the valuable spinoffs from space efforts into the daily lives of Americans and all people . . . This is why commitment to the Space Shuttle Program is the right next step for America to take . . . ."

In the Congress, the Shuttle Program has received continuing substantial support in both branches, and this has enabled NASA to proceed effectively with the development phase of the program.

Transition and Commitment to the Future

In 1972, having completed a transition from the manned exploration and operational experimentation programs which began in the 1960's, NASA moved toward space activities which focus on direct practical down-to-Earth applications of space technology. Some of the most promising of the new applications of space are the Earth observation missions for such tasks as weather forecasting, air and sea navigation and control, Earth resources, land use management, and many other Earth-related functions.

The Space Shuttle system will provide a capability for exploiting the near-Earth space environment on a larger scale with greater results while reducing costs in dollars and preparation time for launch systems, experiments, payloads, and operations. The use of this general-purpose launch system in the 1980's (Fig. 2) and beyond will result in an era of integrated manned and

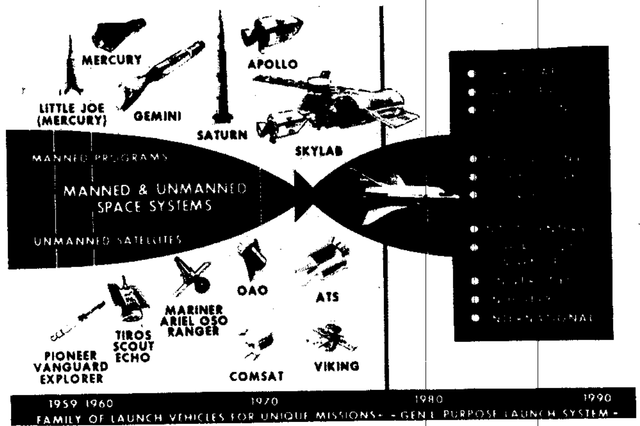


Fig. 2 Space Shuttle era.

unmanned space flight, with science, technology and applications missions in support of research, commercial activities, national defense, and in international cooperation.

Development of the Space Transportation System

The Space Shuttle has been described as the key element of a transportation system for space operations which will combine the advantages of airplanes and spacecraft to give us an ability to fly repeatedly into space and back to Earth on a cost-effective basis. The other major elements of the space transportation system will include the Spacelab (a Shuttle-borne space station) and the Tug, which will be an advanced propulsion stage for payloads requiring on-orbit launch. These elements are further described in subsequent sections. The U.S. Department of Defense has participated with the NASA for many years in programs to achieve standardization of launch vehicles. Because the Department of Defense will be a principal user of the operational space transportation system, its personnel are actively participating in the development of the Space Shuttle system.

The NASA is currently well into the developmental phase of the Space Shuttle system of the space transportation system (Fig. 3). Test flights are to begin in 1977, with manned orbital test flights in 1979, and the Shuttle system is to be operational in 1980.

Dr. James C. Fletcher, the NASA Administrator, recently announced: ". . . We can and must look upon the Space Shuttle as a major investment in America's future; as the key to American power and productivity in space for the rest of this century."[4] Consequently, the NASA is devoting a major portion of its resources to Shuttle and has followed a careful deliberate path of study and analyses leading to the selection of the current baseline system which promises the least technical risk while providing maximum confidence in both developmental and operational cost estimates.

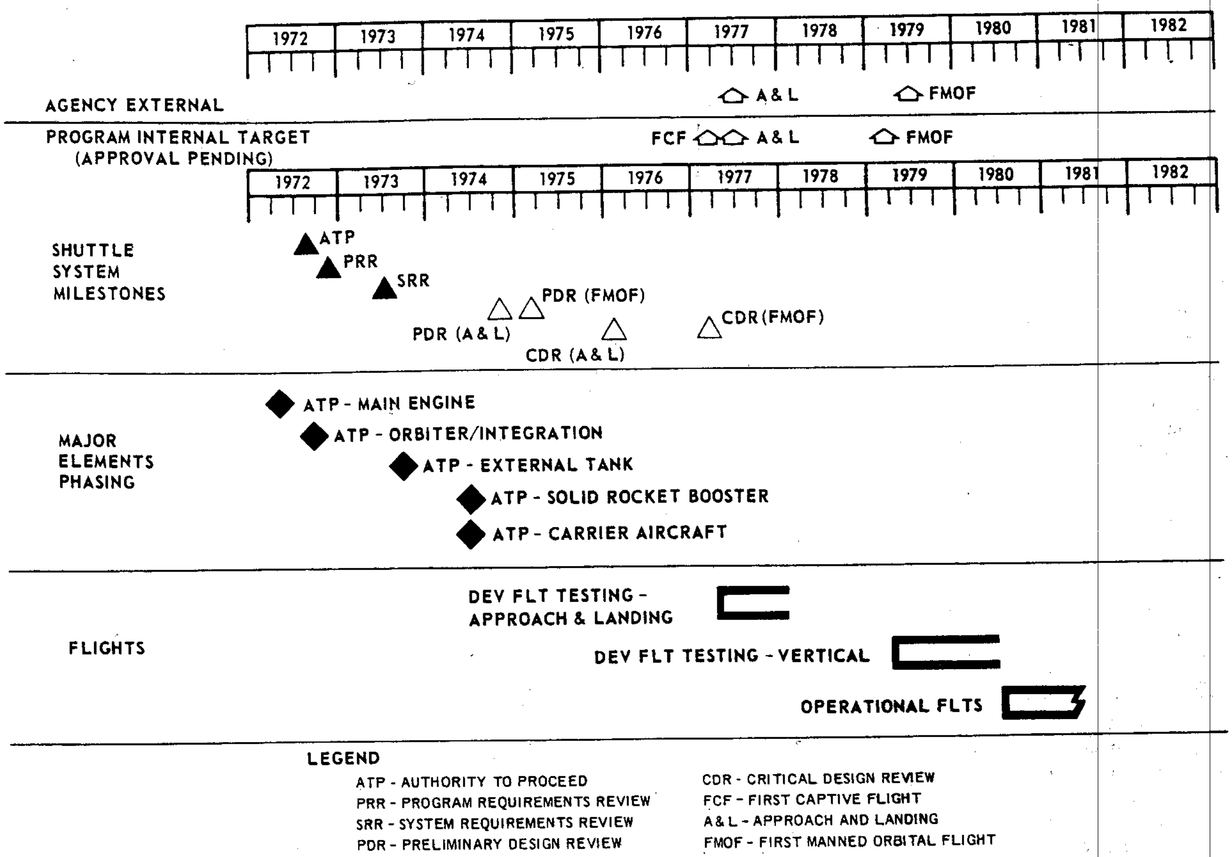


Fig. 3 Program target schedule.

Mobility and Progress

Students of history are well aware of the role which transportation developments have played in the progress of civilization. Transport — the ability to move people and things over natural obstacles — has been a key to world progress since the invention of the wheel, which is thought to have occurred about 4000 years ago. This connection between the advancement of transportation systems in speed, flexibility, and utility and the overall advancement of society is borne out by many historians. One authority maintains that ". . . Transport has special significance because of the pervasive role of 'Mobility' in facilitating other objectives. Transport is a necessary ingredient of nearly every aspect of economic and social development." *Mobility* then is a dynamic description of transportability. The Space Shuttle will build upon the achievements of past transportation systems blending particularly the aircraft and spacecraft technologies and challenging the engineering and scientific talents of these industries to produce a new mobility for space research and applications. This new mobility will enable man to overcome modern-day obstacles to progress and will open the path for countless applications of spaceborne systems.

Throughout the history of the development of transportation technology, examples of a technological advance are found followed by experimentation and eventually by applications for progress in many other fields. In most cases, the applications were not anticipated during the research and experimentation phases except by visionaries, but each series of improvements in transportation technology moved man to a new plateau of economic and social improvement. For example, the building of canals in early American history reveals initial efforts aimed at overcoming the obstacles of the East Coast forests and mountain ranges. The canals involved what was considered heavy subsidization by public funds in those days, but the principal example, the Erie Canal, drastically reduced the cost of moving goods from the Eastern seaboard inland and paid for itself in a few years.[5] Of greater significance, it directed the movement of entire populations, fixed the destinies of countless cities and states, and made the first effective use of the great interior of America, in the establishment of a national market, on which industrial development could be based.[6] For all its benefits, the canal concept had serious shortcomings, not the least of which were a lack of flexibility and inherent climatic weaknesses; and, before the canal era ended, another more mobile and versatile transportation form appeared. The new technology of the railroads, with increased speed, made the concept of canals obsolete until their most productive applications were realized in projects such as the Suez and Panama Canals, which were completed in 1869 and 1914, respectively.

The railroads also required heavy expenditures of public funds, but they further reduced the cost of transportation because of their speed and capacity, providing efficient transportation services to a vast and largely unsettled continent. According to one prominent economist, the railroads played a leading role in the crucial "take-off" stage of economic development in the United States.[7] However, the railroads were limited in flexibility and speed and thus were soon to be challenged by a revolutionary concept of transportation.

The evolution of economical air transportation systems is an especially relevant story from which reasonable conclusions can be postulated about the role which the Shuttle can be expected to play in future economic growth. Although the first aircraft was successfully flown by the Wright brothers at Kitty Hawk in 1903, the significance of the speed and great flexibility of the aircraft was not fully recognized for several decades. Eventually, it became apparent that aircraft speed could influence the time-distance equation to the point where virtually any spot on the globe was accessible in hours.

It was approximately 30 years later, with the introduction of the Douglas DC-3 and similar aircraft, that air transport began to compete economically with the railroads. As one authority has noted, "Modern commercial aviation got off the ground with the production of all-metal, twin-engine airliners — particularly the DC-3." For years, the DC-3 was the workhorse of air transport, providing the foundation for the transportation of people and goods as opposed to mail, which was the predominant payload of airplanes prior to 1935.[8]

After World War II, research with rocket aircraft and jet engines produced aircraft with speeds which further assaulted the time-distance barrier, ushering in the jet age. In 1972, scheduled airlines carried 450 million passengers (30 million of these on transoceanic flights). Daily intercontinental travel by thousands of passengers is now a routine event that was undreamed of just a half century ago. In that year, the air cargo industry flew $13\ 400 \times 10^9$ kilogram-kilometers (8 billion ton-miles) of cargo. By 1985, this growth industry is expected to produce revenues on the order of $14 billion per year. Transport aircraft technology has now reached the point where a Boeing 747 jet, which can carry 366 passengers and 3178 kilograms (7000 pounds) of cargo 8325 kilometers (4500 miles), can pay for itself even with all seats empty, provided 85 percent of its huge cargo space is full.[9]

With the launching of the Russian Sputnik in 1957, we had reached a new plateau in the history of man's quest for mobility, when the obstacle of Earth gravity was overcome. The past 15 years have witnessed the application of this new capability in many different ways: the development of ballistic missile systems for national defense; the placement of sophisticated equipment in Earth orbit for the purposes of experimentation, research, and commerce; the launch of exploratory manned and unmanned payloads to the Moon; and unmanned payloads to other planets in our solar system.

The combined results of decades of aeronautical and space research, including the X-series rocket airplanes and the Mercury, Gemini, Apollo, and Skylab manned space flight programs, have supplied the technology for the emergence of the Space Shuttle, the first economically feasible space transportation system. Like the DC-3, the Shuttle offers a new and unique form of mobility — routine space flight beyond the constraining envelope of Earth's atmosphere and gravity.

"Initiative and innovation," one authority has noted, "are successful when the time and place for introducing a new system are correctly judged. Once the initial risk has been accepted and the new means demonstrated, exploitation is not usually very difficult."[10] The initiative for introduction of this new system has been provided. The Government-industry team working on the Shuttle Program is now demonstrating the innovative ability needed to develop this effective system at a price which the economy can afford. Exploitation will surely follow, as it has in every previous chapter in the history of transportation technology.

Space Shuttle System and Payload Operations

The Shuttle flight system is composed of the orbiter, an external tank containing the ascent propellant to be used by the orbiter main engines, and two solid-rocket boosters. The general system specifications are shown in Figure 4. The Space Shuttle mission begins with the installation of the mission payloads into the orbiter payload bay (Fig. 5). The payload will be checked and serviced before installation and will be activated on orbit. Flight safety items for some payloads will be monitored by a caution and warning system.

The solid-rocket boosters and the orbiter main engine will fire in parallel at lift-off. The two solid rockets are jettisoned after burnout and are recovered for reuse by means of a parachute system. The large hydrogen and oxygen tank is jettisoned before placing the Space Shuttle orbiter into orbit. The orbital maneuvering system of the orbiter is used to attain the desired orbit and to make any subsequent maneuvers that may be required during the mission.

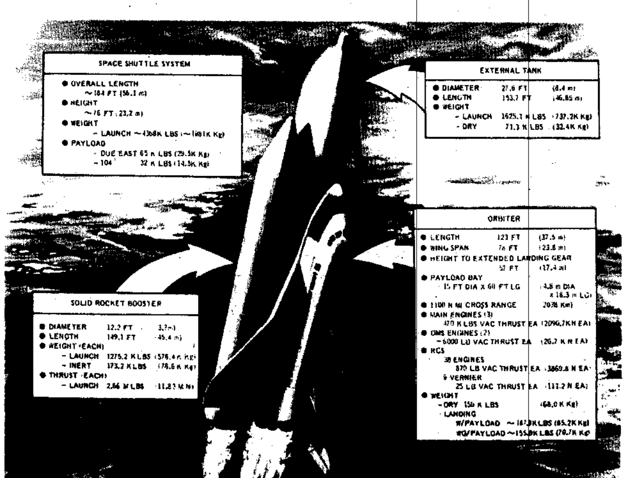


Fig. 4 Space Shuttle system.

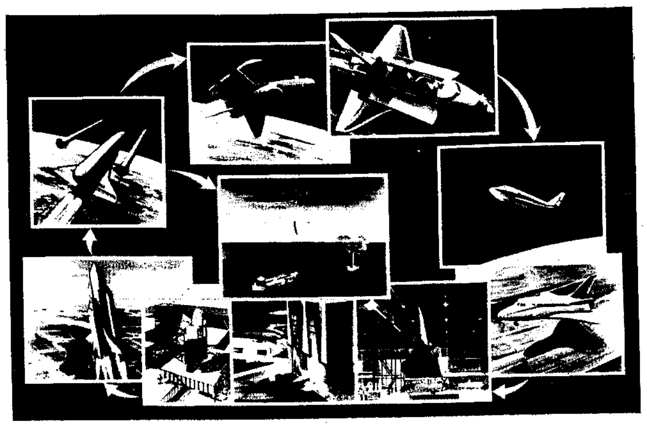


Fig. 5 Space Shuttle mission profile.

When the payload-bay doors located in the top of the orbiter fuselage open to expose the payload, the crewmen are ready to begin payload operations. Payloads weighing 29 500 kilograms (65 000 pounds) can be carried to low Earth orbit. The duration of the initial missions will nominally extend to as many as 7 days. By adding consumables in mission kits, the mission duration can be extended to as long as 30 days.

On completion of orbital operations, deorbiting maneuvers are initiated. Entry is made into the Earth atmosphere at a high angle of attack. At low altitude, horizontal flight attitude is assumed for approach and execution of a high-performance aircraft-type landing.

A 2-week ground turnaround is the goal for reuse of the Space Shuttle orbiter.

On-orbit Service of Satellites

The NASA is studying a family of application satellites to be placed in orbits of various inclinations and altitudes. Low-cost standard hardware is expected to comprise much of each satellite. Among other features, the design of this hardware will provide for on-orbit servicing (Fig. 6) by changeout of supporting subsystem assemblies and applications sensors. These system features, in association with the Shuttle-based equipment and Shuttle operational techniques, will permit on-orbit maintenance and updating of this family of satellites.

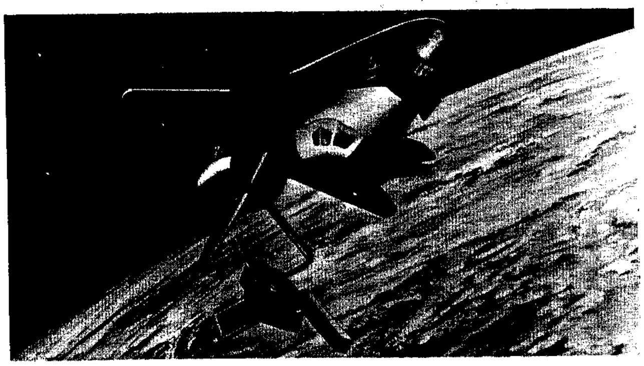


Fig. 6 On-orbit satellite servicing.

Placement of Laboratories in Space

Free-flying space telescopes (Fig. 7) represent a type of international facility for on-orbit space research controlled by the investigating scientists on Earth. Design studies of these future payloads are currently underway. The Space Shuttle will deliver the telescope to orbit, and the crewmen will assist in preparing the facility for operation. During scheduled revisits to the facility, the Space Shuttle crewmen will service supporting subsystems, exchange scientific hardware, and, several years later, return the facility to Earth at the end of its mission.

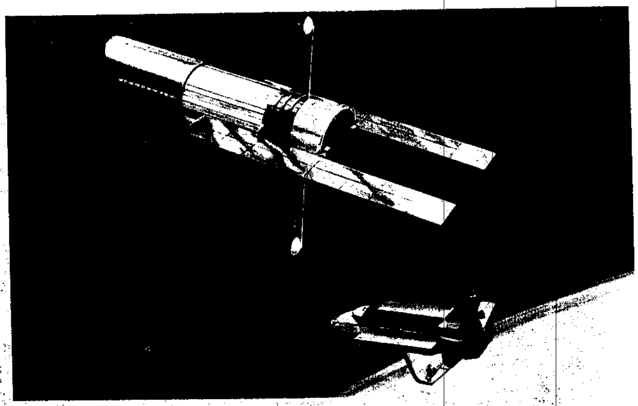


Fig. 7 Large space telescope.

International Cooperation in Space

The large pressurized Spacelab module with an external equipment pallet will be a frequent payload carrier during the Space Shuttle era (Fig. 8). Nine member nations of the European space community have agreed to commit approximately $400 million to design and deliver one set of flight hardware plus the necessary supporting equipment to the United States. Agreements provide for purchase of additional Spacelab units by the United States. Many types of scientific, technological, medical, and applications investigations can be accomplished with this flight hardware. Each Spacelab may be flown as many as 50 times over a 10-year period.

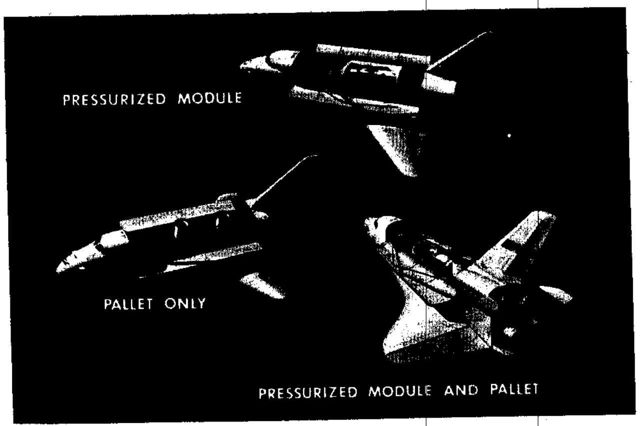


Fig. 8 Alternate Spacelab/pallet configurations.

Use of Propulsion Stages

Major activity is forecast for geosynchronous orbits, deep-space missions, elliptical orbits, and higher circular orbits. Payloads with such destinations will require a propulsion stage in addition to the Shuttle. The Space Shuttle will deliver the payload with a propulsion stage to low Earth orbit and will stand by until a successful on-orbit launch is effected. In an initial cooperative effort, the Department of Defense is planning to adapt an existing propulsion stage to be an interim upper stage for use with the Shuttle. For later applications, an advanced reusable propulsion stage called the Space Tug (Fig. 9) is being studied for inclusion in the space transportation system.

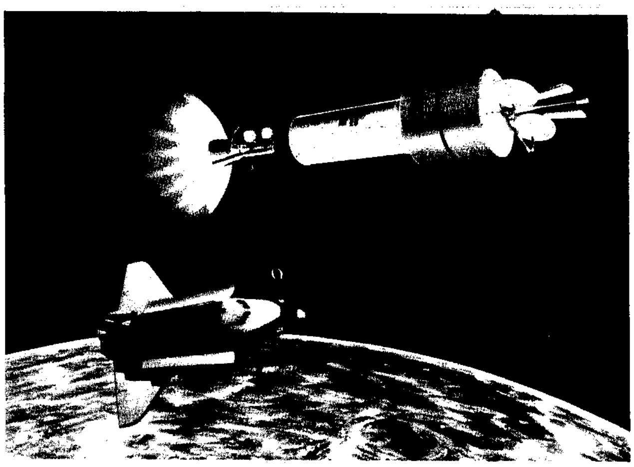


Fig. 9 Space Tug concept.

Reduced Launch and Entry Accelerations

Crewmembers, who will include scientists and payload specialists, will experience a design maximum gravity load of only 3g during launch (Fig. 10) and less than 1.5g during a typical entry (Fig. 11). These accelerations are about one-third the levels experienced on previous manned flights. Many other features of the Space Shuttle, such as a standard sea-level atmosphere, will welcome the nonastronaut space worker of the future.

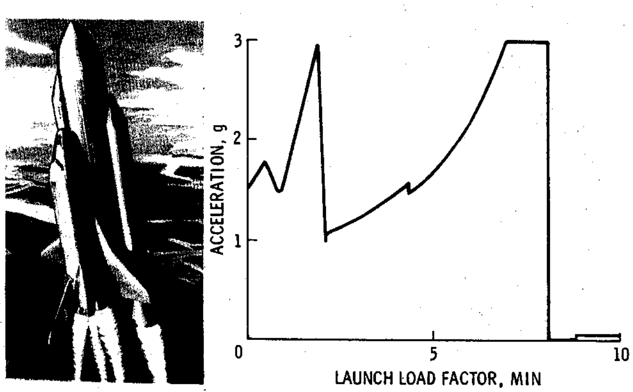


Fig. 10 Launch load factor.

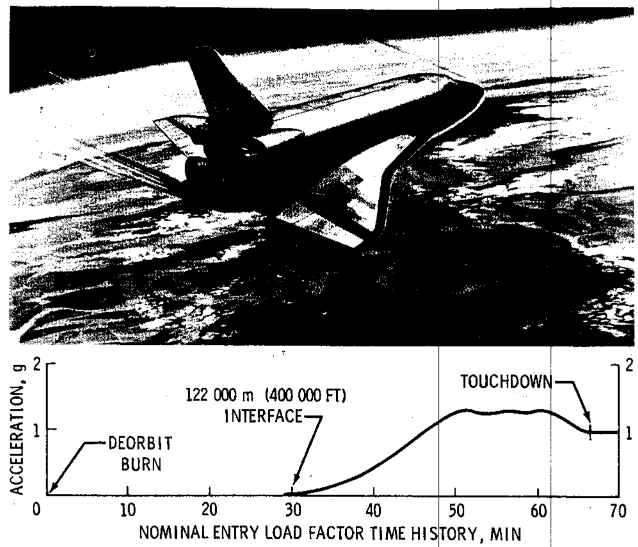


Fig. 11 Entry load factor.

Crew Cabin

The orbiter crew cabin (Fig. 12) has a flight deck from which the mission is flown. The flight deck seats as many as four crewmen. In the midsection area, eating, sleeping, and housekeeping functions are accommodated. Depending on the mission requirements, an additional six seats can be placed in this area.

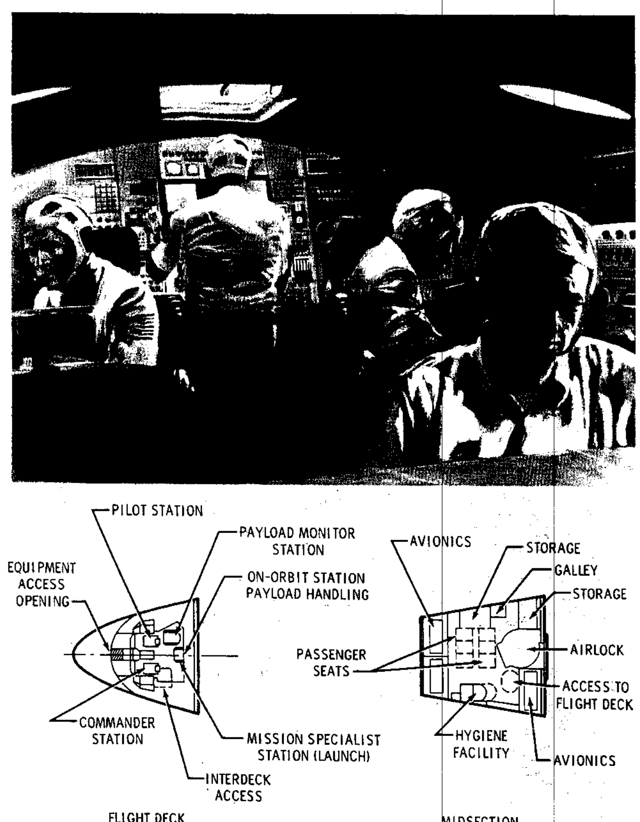


Fig. 12 Crew cabin layout.

Payload Accommodations

The orbiter systems (Fig. 13) are being designed to handle various payloads and to support a variety of payload functions. The payload and mission specialist stations on the flight deck provide command and control facilities for payload operations required by the cognizant scientist (the user). Remote-control techniques can be employed from the ground when desirable. The Spacelab payload provides additional command and data management capability plus a pressurized work area in the payload bay for the payload specialists.

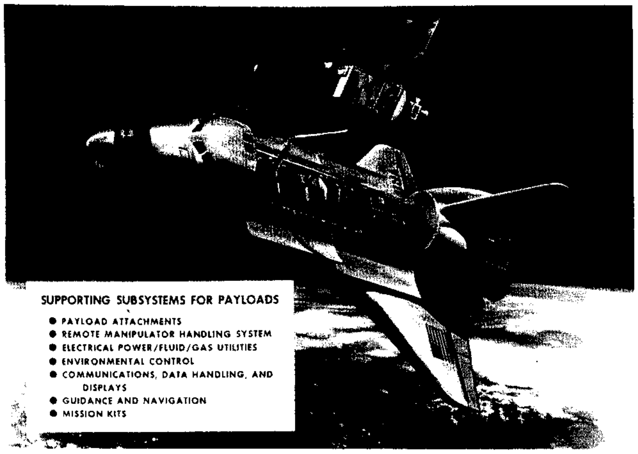


Fig. 13 Payload support.

Payload Attachments

Multiple attachment points along the sides and bottom of the 18.2-meter (60-foot) payload bay provide places for the many different payloads to be accommodated (Fig. 14). Thirteen primary

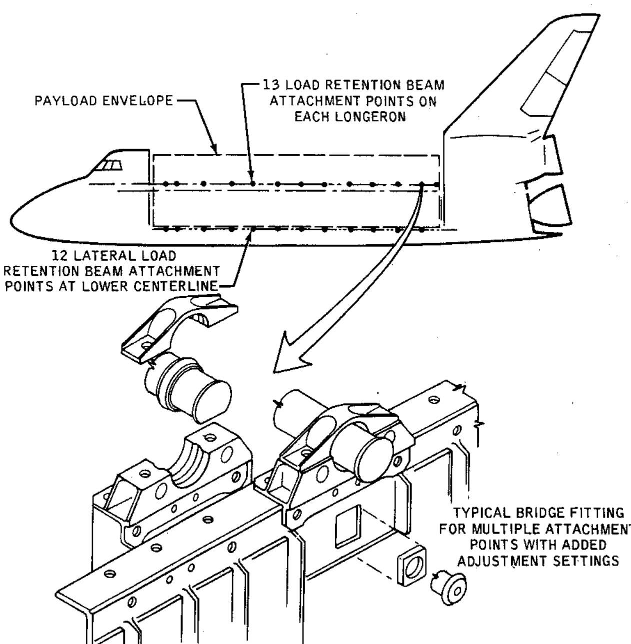


Fig. 14 Attachment design concept.

attachment points along the sides accept longitudinal and vertical loads. There are twelve positions along the keel that take lateral loads. The proposed design of the standard attachment fitting will also have some adjustment capability to adapt to specific payload weight distributions in the bay.

Payload Handling During On-Orbit Operation

Many payloads to be transported to orbit will require complete deployment and separation (and some retrieval) or some handling of equipment within the payload bay (Fig. 15). A remote manipulator arm that can use various end effectors is being tested to be operated from the Space Shuttle flight deck. Windows are located in such a way to permit direct viewing of the operation. One television camera on the manipulator arm and two cameras within the payload bay also assist the operator. Rapid deployment and retrieval procedures of large payloads are being evaluated together with the delicate handling techniques for sensitive equipment.

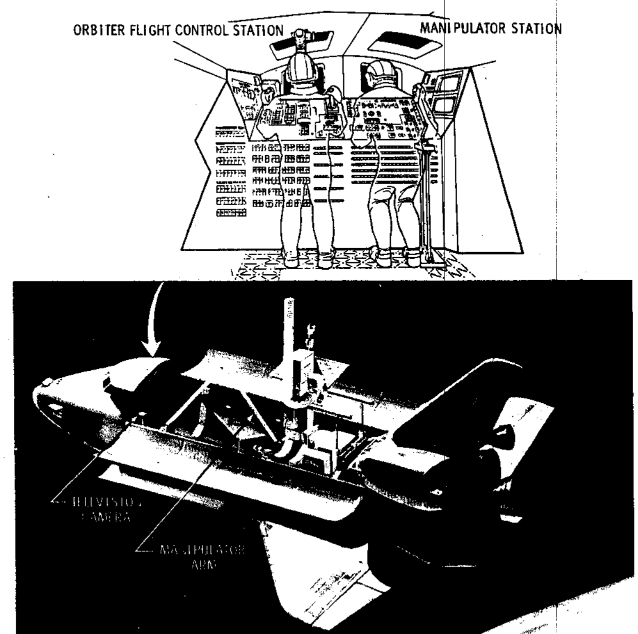


Fig. 15 Payload deployment.

Electrical Power Service

The operational use of hydrogen-oxygen fuel-cell powerplants for manned space flight evolved during the Gemini and Apollo Programs. The Space Shuttle fuel cells (Fig. 16) will be serviced between flights and reflown until each one has accumulated 5000 hours of online service. The electrical power requirements of the payloads will vary throughout the mission. During the 10-minute launch-to-orbit phase and the 30-minute deorbit-to-landing phase when most of the experiment hardware is in a standby mode or completely turned off, 1000 watts (average) to 1500 watts (peak) are available from the orbiter. During payload equipment operation on orbit, the capability exists to provide as much as 7000 watts (average) to 12 000 watts (peak) for major energy-consuming payloads. There are three fuel cells on board the Space Shuttle; one is dedicated to payloads with switching capability to the other two. For the 7-day mission payload, 50 kilowatt-hours of electrical energy are available. Mission kits containing consumables for 840 kilowatt-hours each are available to be carried if required by the mission plan.

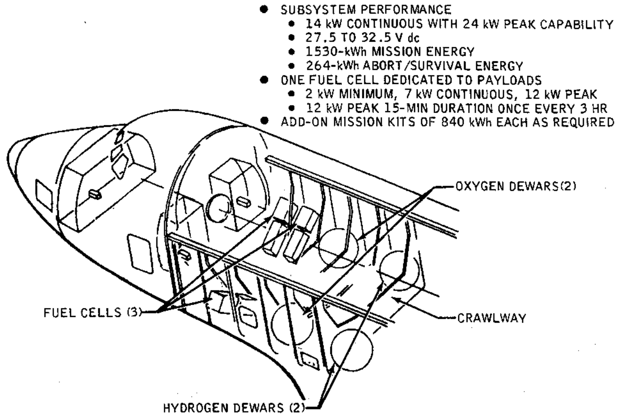
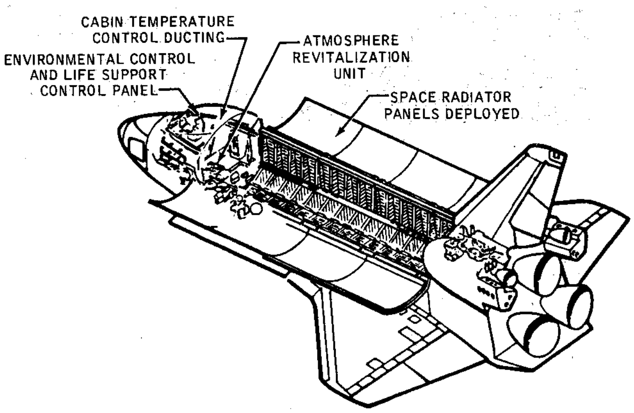


Fig. 16 Orbiter electrical power subsystem.

Cooling

Cooling services (Fig. 17) are provided to payloads by the Space Shuttle. Ground support equipment provides a selectable temperature range during prelaunch activities. After landing, ground support equipment similar to airline support hardware will be connected to the orbiter cabin and the payload bay to control temperature levels. The radiator system located inside the payload-bay doors will be the primary on-orbit heat-rejection system.

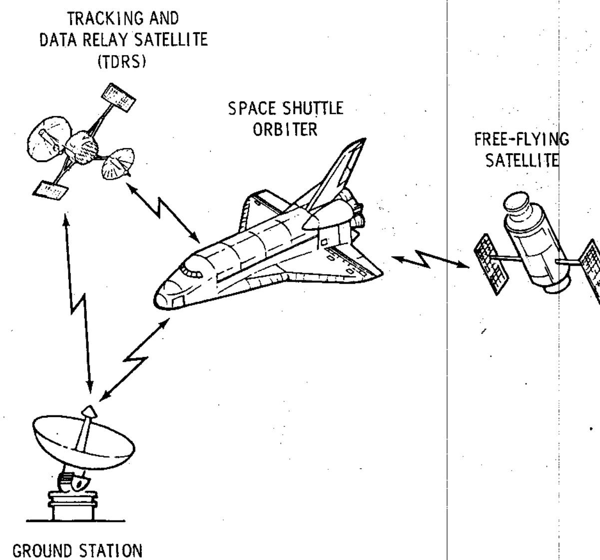


FLIGHT PHASE	COOLING SUPPORT
PRELAUNCH	SELECTABLE RANGE USING GROUND SUPPORT EQUIPMENT
LAUNCH	1.5 kW THERMAL
ON ORBIT	6.3 kW THERMAL 8.5 kW THERMAL WITH MISSION KIT
ENTRY	1.5 kW THERMAL
POSTLANDING	COOLING SUPPLIED FROM GROUND SUPPORT EQUIPMENT

Fig. 17 Orbiter environmental control subsystem.

Communications, Tracking, and Data Management

The orbiter systems are being designed to handle various payloads and to support a variety of payload functions. Voice, television, and data-handling capabilities (Fig. 18) support on-board control or remote control from Earth when desirable. The payload communications and data support capabilities are being combined into a standard on-orbit and ground-station handling system that will support all major classes of payloads to be flown.



FUNCTION	GROUND TO ORBITER	ORBITER TO GROUND	GROUND TO ORBITER VIA TDRS	ORBITER TO GROUND VIA TDRS	ORBITER TO SATELLITE (PRIME OR RELAY)	SATELLITE TO GROUND VIA ORBITER
VOICE	X	X	X	X		
TELEVISION		X		X		
TRACKING DATA	X	X	X	X	X	X
COMMANDS	X		X		X	
OPERATIONAL DATA		X		X		X
PAYLOAD WIDE-BAND DATA		X		X		

Fig. 18 Orbiter communications subsystem.

Payload Pointing and Stabilization Support

The orbiter is capable of achieving and maintaining any desired attitude (Fig. 19). This capability permits the pointing of payload sensors mounted in the payload bay at any selected celestial or Earth object with an accuracy of ±0.5°. The greatest pointing accuracy using the orbiter control system is achieved when a payload-pointing sensor is operated in a closed loop with the orbiter guidance, navigation, and control system. In this mode, pointing accuracies approaching ±0.1 deg/axis are possible. The orbiter can be stabilized at a rate as low as ±0.01 deg/sec within a deadband of ±0.1 deg/axis. Payloads that require more stringent pointing requirements must provide their own added stabilization hardware for that particular experiment.

Mission Kits

A group of mission kits to provide special or extended services for payloads is being studied. These kits will be added only when required

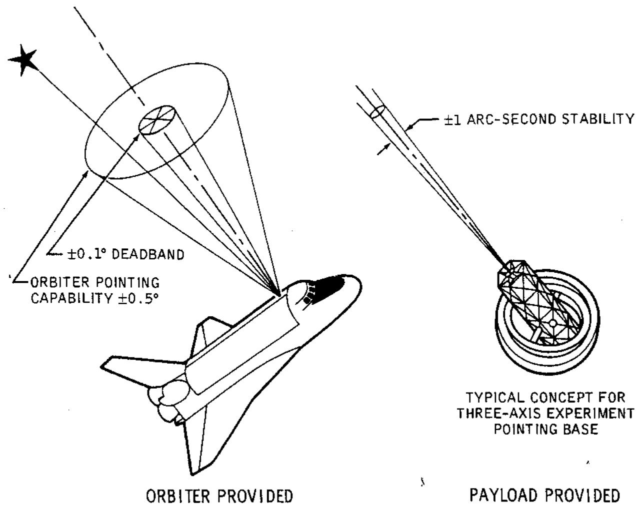


Fig. 19 Orbiter attitude control subsystem.

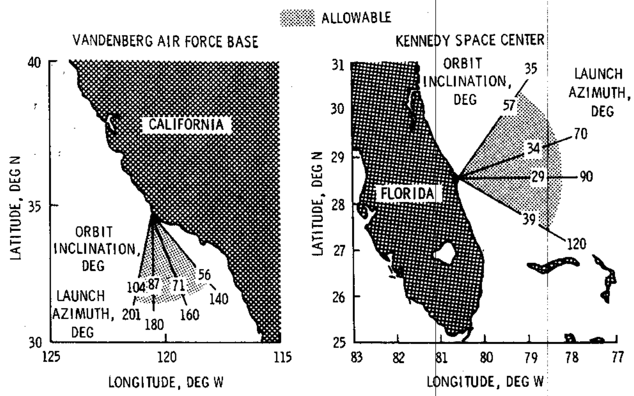


Fig. 20 Orbital inclinations and launch azimuths from VAFB and KSC.

and are designed to be quickly installed and easily removed. The major mission kits are as follows.

1. Oxygen and hydrogen for fuel-cell usage to generate electrical energy

2. Life support for extended missions

3. Added propellant tanks for special on-orbit mission maneuvers

4. Extra or specialized attachment fittings

5. Transfer tunnels and docking modules

6. A second remote manipulator arm and extra antennas

Launch Sites, Dates, and Inclination Limits

Space Shuttle flights will be launched from two locations — the NASA John F. Kennedy Space Center (KSC) in Florida and the Vandenberg Air Force Base (VAFB) in California. Present program planning calls for a gradual buildup of 40 to 60 total flights per year into many varying orbits and inclinations. The expected crew complement is four to seven, and the expected flight duration is up to 7 days on orbit with growth to 30 days.

To attain operational status by 1980, Space Shuttle orbital test flights are scheduled to begin from KSC during 1979; the second launch site at VAFB is planned to be available in the early 1980's. The various orbital inclinations and their related launch azimuths are illustrated for each site in Figure 20. Together, these capabilities satisfy all known requirements. Payloads as large as 29 500 kilograms (65 000 pounds) can be launched due east from KSC into an orbit of 28.5° inclination. From VAFB, 14 500-kilogram (32 000 pound) payloads can be launched into the highest inclination orbit of 104°. Polar-orbiting capabilities up to 18 000 kilograms (40 000 pounds) can be achieved from VAFB.

System Utilization

In the summer of 1973, a prestigious group of 50 scientists from the United States and 11 scientists from other nations conducted a summer study at Woods Hole, Massachusetts. This group represented a wide variety of scientific disciplines. They were supported by specialists from NASA and the European Space Research Organization. A final report on the study was published by the National Academy of Sciences in June 1974, after a thorough review by an independent committee of the National Research Council. Dr. Findlay, who chaired the study group, characterized the group as members of the "scientific space club" in hearings before the Senate in October 1973. However, the scientific objectives, tasks, and research work identified in the study do provide a significant projection of the research workload that can be expected to be translated into discrete experiments, experiment packages, payload groupings, and, finally, flight requirements which make up the mission model.

Specific disciplines covered by the study included atmospheric and space physics, high-energy astrophysics, infrared and radio astronomy, optical and ultraviolet astronomy, solar physics, life sciences, and lunar and planetary exploration.

The summary of the findings was as follows.

1. Shuttle can be an important asset to scientific research in and beyond the 1980's.

2. An important aspect of the Shuttle system for science will be its ability to carry many large and heavy payloads into orbit with potentially substantial economy.

3. Many of the potential advantages of the Shuttle depend on the development of efficient and flexible procedures for flying multipurpose missions and combined payloads.

4. The ability of the Shuttle system to recover or service payloads in orbit will be of special value for large and expensive systems, such as large observatories; for some less expensive payloads, the economic advantages of recovering and servicing are not obvious.

5. Most planetary missions can be launched with a Shuttle/Centaur system. Some missions

identified for the 1980's require additional capabilities such as might be provided by tug, solar electric, or another advanced propulsion system.

6. For biomedical research in space, the study identified a clear and essential requirement for the use of the manned pressurized space laboratory.

7. Many disciplines require rapid interaction between man and payload. This function appears to be adequately fulfilled in many cases by the payload specialist and his console. However, for some experiments in atmospheric or space physics in which continuous involvement of man is required, the pressurized space laboratory is highly desirable.

8. The ability to operate instruments mounted in the Shuttle bay in the pallet mode with or without a pressurized laboratory is an important feature for all disciplines except the life sciences.

9. Payloads carried into orbit by the Shuttle and then released as free flyers are major elements in most discipline programs.

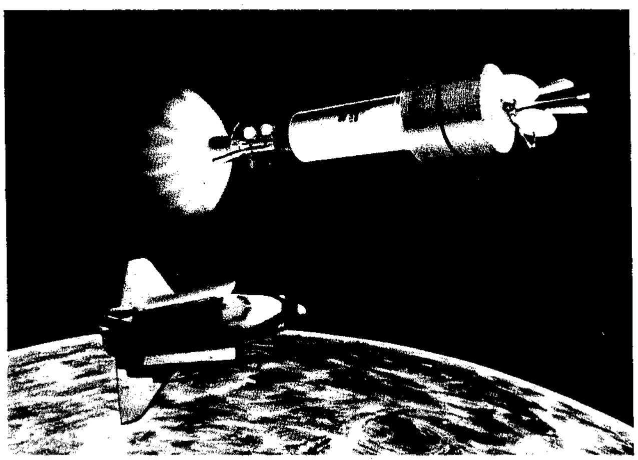
10. For most discipline groups, the 28-day (or longer) sortie mission duration is judged to be very valuable.

This summary forecasts an intention by at least one segment of the scientific sector to use the space transportation system extensively in its research. The Shuttle system and the Spacelab have many potential users in other segments of the scientific and technological communities.

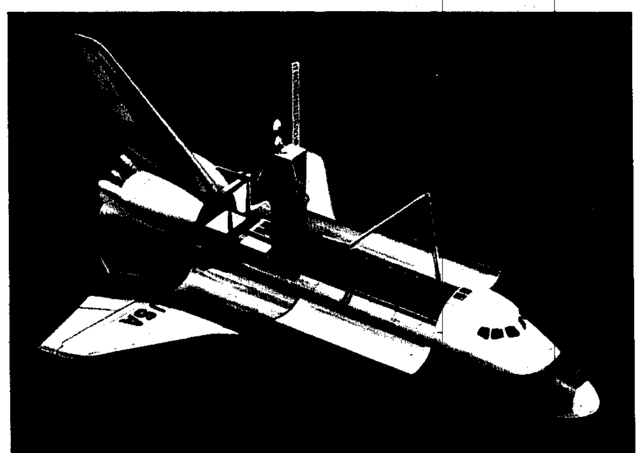
Payload Planning Activity

To interface effectively with such a large number of potential payload users and developers, NASA Headquarters has established a Mission Payloads Integration Organization in Washington. This organization represents the potential payload users to ensure the continual consideration of overall payload requirements in the development of the space transportation system and the Spacelab. The Space Shuttle Program Office at the Lyndon B. Johnson Space Center also maintains a payloads coordination office that serves as a point of information concerning the Shuttle system baseline capabilities, specifications, and payload accommodations.

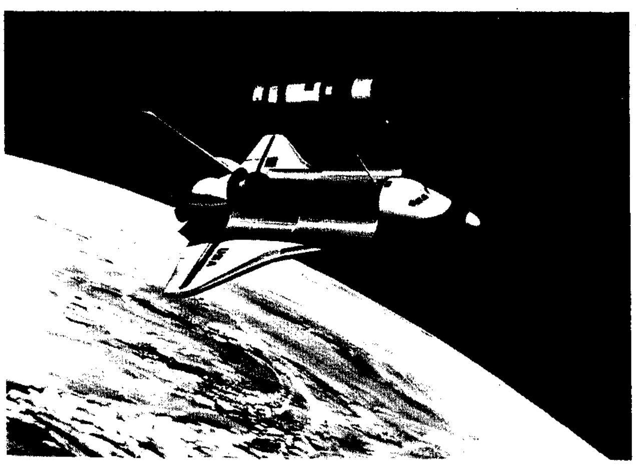
The payload planning of the various governmental, industrial, and academic groups and various international organizations is incorporated into NASA planning to determine short- and long-term mission models. In general, the planning for the early years is more accurate; however, there is a potentially large usage indicated in



DELIVERY



SERVICING



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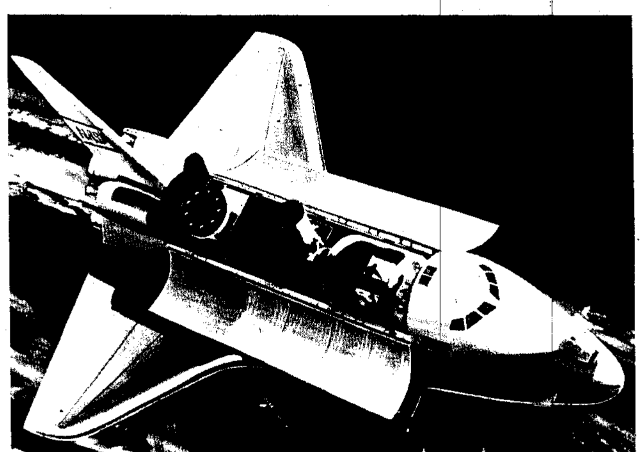

SHORT-DURATION SORTIE

Fig. 21 Space transportation system operating modes.

the projected mission models for the space transportation system of the 1980's.

As previously described, the space transportation system will consist of a group of vehicles which will be used in various types of operations and in various modes. These various operational categories include delivery, servicing, retrieval, and short-duration sorties (Fig. 21).

These basic capabilities of the system serve as the initial frame of reference for the development of the NASA mission model, which, naturally, contains many permutations and combinations of these categories.

Mission model development is characterized as a complex and iterative process of receiving inputs from the users; identifying the specific experiments, instrumentation, and payloads; and packaging these data through a traffic-schedule activity to arrive at the number of space transportation system flights anticipated in a given year (Fig. 22).

Mission model planning (Fig. 23) is critically essential to the economical use of the Shuttle system, and the NASA will continue to place high priority on this management function. The next three products of mission model planning from 1973 data (Figs. 24 and 25) for the period between 1980 and 1990 (Fig. 26) provide an interesting analysis of the makeup of the model by user, operating mode, weight, delivery mode, et cetera.

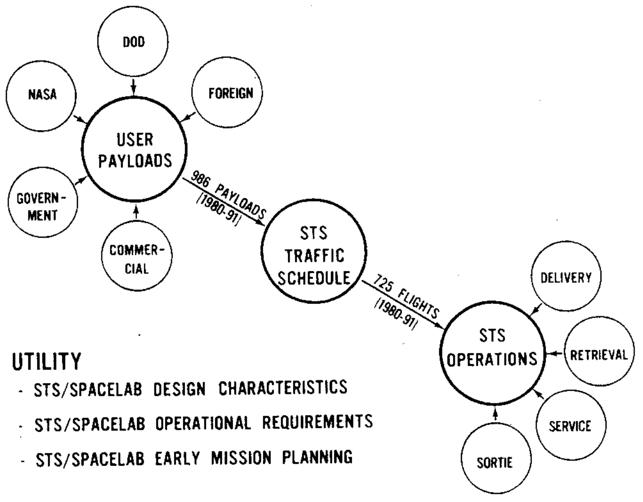

Fig. 22 Characterization of mission model development.

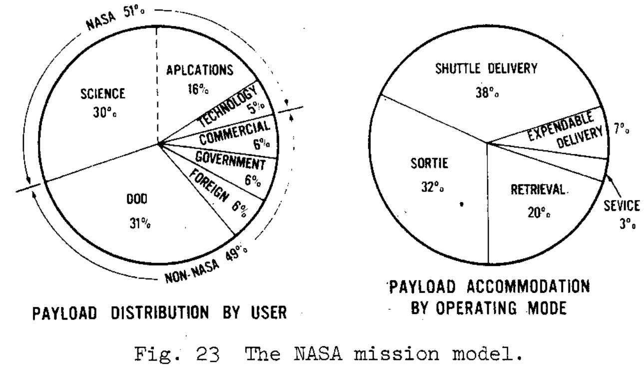

Fig. 23 The NASA mission model.

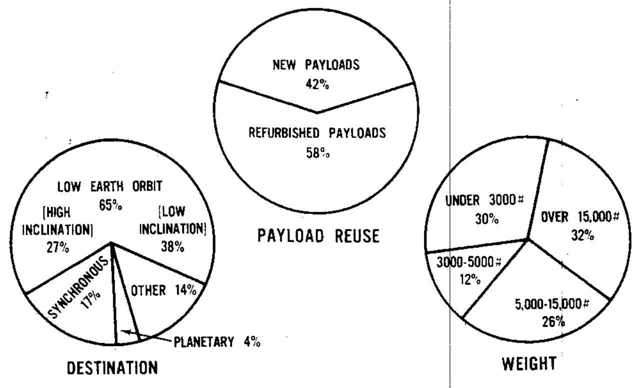

Fig. 24 1973 payload summary (986 payloads).

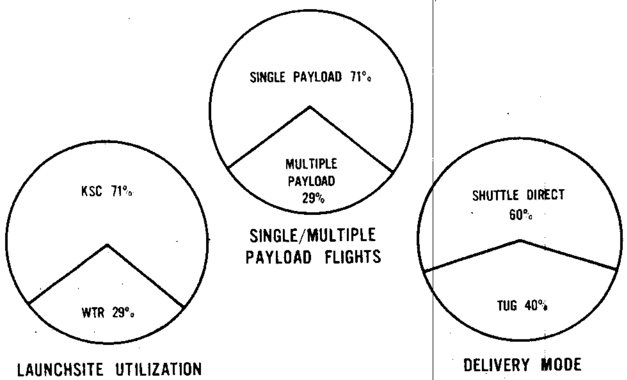

Fig. 25 1973 traffic summary (728 flights).

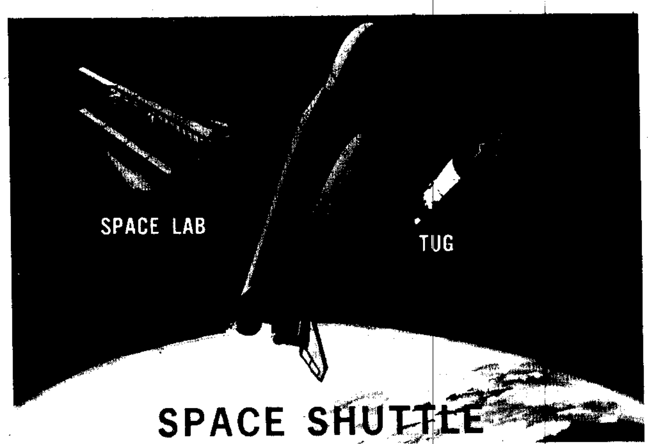

Fig. 26 Space operations: 1980 to 1990.

One of the goals of payload planning is to increase the load factor to maximize the economic value of the space transportation system by increasing the number of multiple payload flights; however, it is logical that planning allow some flexibility between mix and loading (e.g., planning a full load long before the flight date would reduce the flexibility for adding priority payloads on short notice).

In summary, activities leading to the development of the Shuttle, Spacelab, and Tug are all progressing in an orderly and deliberate manner.

Close cooperation and interdependence have been effected with the European Space Research Organization and with the Department of Defense. NASA design, development, test, and evaluation and operational cost estimates are within the current commitment estimates to the Congress and the Office of Management and Budget; and no serious technical problems have been encountered in the design and development of the Space Shuttle system. Provided with the necessary annual and total resources requested in the cost commitment, NASA managers are confident that the space transportation system will be available to the scientists and technologists of the world as a powerful tool for mankind.

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