PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Space Stations and their Potential Uses [and Discussion]

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Space stations and their potential uses

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This paper discusses the status of N.A.S.A's efforts to define the scope of a space station programme. It presents N.A.S.A's rationale for a space station, architectural, technological and operational concepts that would enhance its capabilities, status of planning, how it would be used, opportunities for commercialization, and the potential for international participation in the programme.

1. Introduction

A process is under way in the United States to decide on a course of action regarding the next major step for the United States Manned Space Programme; that is, should the National Aeronautics and Space Administration (N.A.S.A.) undertake the development and deployment of a permanently manned space station. A positive decision will set the course for space activities for the next two decades not only for the United States, but also for other countries and organizations that could become involved in the programme.

N.A.S.A. has received continued encouragement and support from the U.S. President for a strong, national space programme. The following excerpts of remarks President Reagan made on 19 October 1983 at N.A.S.A's 25th Anniversary Celebration in Washington, D.C., illustrate his strong commitment to space activities.

> 'Right now we're putting together a national space strategy that will establish our priorities and guide and inspire our efforts in space for the next 25 years and beyond. It will embrace all three sections of our space program – civil, commercial, and national security. The strategy should flow from the national space policy I announced on July 4 last year.
>
> We're not just concerned about the next logical step in space. We're planning an entire road, a 'high road' if you will, that will provide us a vision of limitless hope and opportunity, that will spotlight the incredible potential waiting to be used for the betterment of humankind...'
>
> '...Let us demonstrate to friends and adversaries alike that America's mission in space will be a quest for mankind's highest aspirations: opportunity for individuals, cooperation among nations and peace on Earth.'

This presentation to The Royal Society will allow N.A.S.A. to inform its friends in the United Kingdom its plans for its next major programme: the Space Station.

2. Background

Even before the Apollo programme had successfully landed a man on the moon and returned him safely to Earth, N.A.S.A. engineers and scientists were considering the next step of the space age. That next step was defined to be the simultaneous development of two comple-

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

mentary capabilities. One was a safe, reliable transportation system that could provide routine access to space. The other was an orbital space station, where humans could work and live in space, and which could be the base camp from which other, more advanced 'next steps' could be initiated. This thinking set the stage for two of the most significant activities conducted by N.A.S.A. in the 1970s and 1980s; that is, Skylab and the Space Shuttle.

On 14 May 1973, the United States launched its first space station, Skylab, aboard a Saturn V booster. Skylab demonstrated that humans could function in space for periods up to 12 weeks and, with proper exercise, could return to Earth with no ill effects. In particular, the flight of Skylab proved that man could operate very effectively in the weightless environment and that it was not necessary to provide artificial gravity to live and work in space. Skylab crews accomplished a wide range of emergency repairs on station equipment, which included freeing a stuck solar array panel, replacing rate gyros, and repairing a malfunctioning antenna. The crews twice installed portable sun shields to replace one lost during Skylab's launch. These activities clearly demonstrated the utility of man in space.

Another product of the Skylab programme was N.A.S.A's realization that extravehicular activity (e.v.a.) could be considered normal and routine. Skylab amassed more than 82 h of e.v.a. Skylab also demonstrated the effectiveness of a scientific laboratory orbiting the Earth. Skylab's eight different solar telescopes provided a quantum step in our understanding of the Sun. Materials-processing experiments done aboard Skylab produced unusually high quality crystals of key microelectronic materials. Skylab-generated, Earth resources photography demonstrated the practicality of using space to observe the Earth with sensors tuned to visible, infrared, and microwave regions of the spectrum. Skylab allowed a comprehensive series of life sciences experiments that provided the basic data needed to design equipment and procedures for long-term living and working in space. In short, the Skylab programme was a resounding success and established a baseline of U.S. experience in the operational use of a space station.

Unfortunately, Skylab was not designed for permanent presence in space. It was not intended to be serviced on orbit, although the Skylab crews were able to make certain repairs. It was not equipped to maintain its own orbit, which eventually caused its fiery demise. It was not designed for evolutionary growth and, hence, was subject to rapid technological obsolescence. These shortcomings, as we shall see, are carefully accounted for in the current N.A.S.A. planning for a permanent space station.

While the U.S. was conducting the Skylab programme, the Soviets were embarking on a more ambitious endeavour. The Soviet Union launched its first space station, Salyut 1, in April 1971. In the twelve years since that launch, additional Salyut stations have been placed in orbit. Their programme is an aggressive and expanding national, manned space flight programme combining Soviet military and civilian missions. The two most recent Salyuts, Salyut 6 and 7, represent a second-generation version of the space station. Salyut 6 demonstrated the ability to refuel the station by using the Progress logistics craft. Salyut 6 cosmonaut crews completed missions lasting 96, 140, 175 and 185 days in space. Ten international crews were hosted, representing the nations of Czechoslovakia, Poland, East Germany, Bulgaria, Hungary, Vietnam, Cuba, Mongolia, Romania and France.

Clearly, the Salyut space programme represents a long-term, methodical development of space capabilities that the Soviet Government considers worthwhile and in their national interest. Their programme is obviously well financed and has involved dozens of high energy launches. In the next few years, U.S. space experts expect to see the flight tests of a Soviet Space

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Shuttle, the test of an extremely powerful Soviet space booster, and the appearance of a small, highly manoeuvrable space plane capable of re-entry through the Earth's atmosphere. The challenge of the Soviet space programme in general and of the Salyut programme in particular is unmistakable.

In the early 1970s, the United States embarked on the development of a reusable launch vehicle, the Space Shuttle. The Shuttle has completed its orbital flight tests and was declared operational on 4 July 1982. Since then, the Orbiter Columbia and its sistership, the Challenger, have completed four operational flights. The third Orbiter, Discover, has been delivered to the Kennedy Space Center and is being readied for its maiden flight. The fifth operational flight, STS-9, is in space as this paper is being written. The STS-9 flight includes the Spacelab mission that is designed and built by the European Space Agency and marks Europe's first major entry into a manned space programme. The crew on the STS-9 includes a West German scientist, Dr Ulf Merbold. A key element of the Spacelab is the instrument pallet, which was designed and built by the British Aerospace Corporation. The pallet carries experiments and equipment built by other United Kingdom firms.

With the Shuttle Transportation System operational, it is N.A.S.A's belief that the development of a space station should now be initiated as the next logical step for a major N.A.S.A. technological initiative.

3. Why a space station now?

A space station is essential to ensure civil leadership in space for the United States during the 1990s. A permanent, U.S. manned space station is needed to maintain the continuity and focus of the U.S. space programme and to present a continuing challenge to industry and government.

Table 1. Functions of a space station

on-orbit laboratory	communications and data processing node
science and applications	permanent observatory
technology and advanced development	transportation node
servicing facility	manufacturing facility
free flyers	assembly facility
platforms	storage depot

The functions of a space station, which is a multi-purpose facility, are listed in table 1. The basic need for a space station is associated with providing a permanent facility in orbit that is rich in power, has ample astronaut, scientist, and technician man-hours available, and provides large facilities to assemble, deploy, and operate very large spacecraft that are too large to be carried in the Orbiter payload bay.

A prime purpose of a space station will be the establishment of a laboratory in orbit to capitalize on the unique environment of space, one of the properties of which is weightlessness (sometimes referred to as microgravity). The space station will be a base for upper stage and spacecraft deployment, servicing, and retrieval, which allows the concept of reusable upper stages and spacecraft to reduce costs just as the reusable Orbiter has reduced launch costs. In the future, the space station could allow the creation of immense spacecraft assembled in orbit from subassemblies or pieces brought up by Orbiters, extremely large antennas, power generation equipment, large spacecraft for Earth departure expeditions, and large manufacturing plants.

MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES
THE ROYAL SOCIETY A
PHILOSOPHICAL TRANSACTIONS OF

A space station would extend and enhance the effectiveness of our national security space assets. At present, the U.S. and other countries use space as an arena in which essential national security activities are conducted. The United States employs spacecraft for a variety of defence missions including early warning, communications, navigation, and surveillance. Late in the 1990s, it might be appropriate to deploy a space station in polar orbit belonging to the Department of Defense. Such a space station could build upon the lessons learned from the initial civilian space station and could be designed to satisfy national security requirements of that period.

The space station programme will present challenges that will create technological advances in many disciplines, which will lead to benefits in sectors of our society far removed from the space programme. Early studies of the needs and mission requirements of a manned space station in the 1990s indicate that we will require advances in such key areas as space suit capability, data management and processing, electrical power generation, storage and distribution, and thermal control systems design. The same contractors who will develop and supply these technologically advanced capabilities for a space station will soon be using those same advances in the development of consumer goods. We saw dramatic examples of technology spin-off as a result of the Apollo and Space Shuttle programmes. This can be expected to be repeated for the space station.

4. Architecture

A space station concept includes a system of permanent, manned and unmanned elements in orbit, which communicate with ground support facilities. The concept also includes one or more unmanned, free-flying platforms, dedicated to commercial or scientific activities, orbiting near a manned base that would serve as a human habitat, utility core, laboratory, and orbital service station. The Shuttle Orbiter would carry the various station elements to orbit, help assemble the space station in orbit, and periodically return to the space station's manned element to bring supplies, fresh crews, and equipment. Transportation between the manned element and the free-flying platforms would be by a co-orbiting, unmanned space tug called an Orbital Manoeuvring Vehicle (OMV) based at the manned element. Eventually, the manned element would be the operations base for an Orbital Transfer Vehicle (OTV), a high energy, propulsive stage for transporting payloads to higher Earth orbits or into the solar system. This concept is shown in figure 1.

It is not yet certain what this space station system will look like because no space station design currently exists. However, N.A.S.A. is currently establishing the criteria for it. N.A.S.A would be very likely to adopt an evolutionary approach; that is, a space station capable of growing and changing to fit developing needs. N.A.S.A. would start with the design, development, test, and deployment of a small but useful space station capable of supporting a crew of six to eight in a low altitude, low inclination orbit. Figure 2 illustrates a few examples of possible configurations for a 1991 space station. Certain common architectural features can be noted. The laboratory modules, habitats, servicing bases, and other elements are all modules similar to the European Spacelab, the size of which is determined by the dimensions of the Orbiter payload bay. The Shuttle is the basic assembly and logistics vehicle.

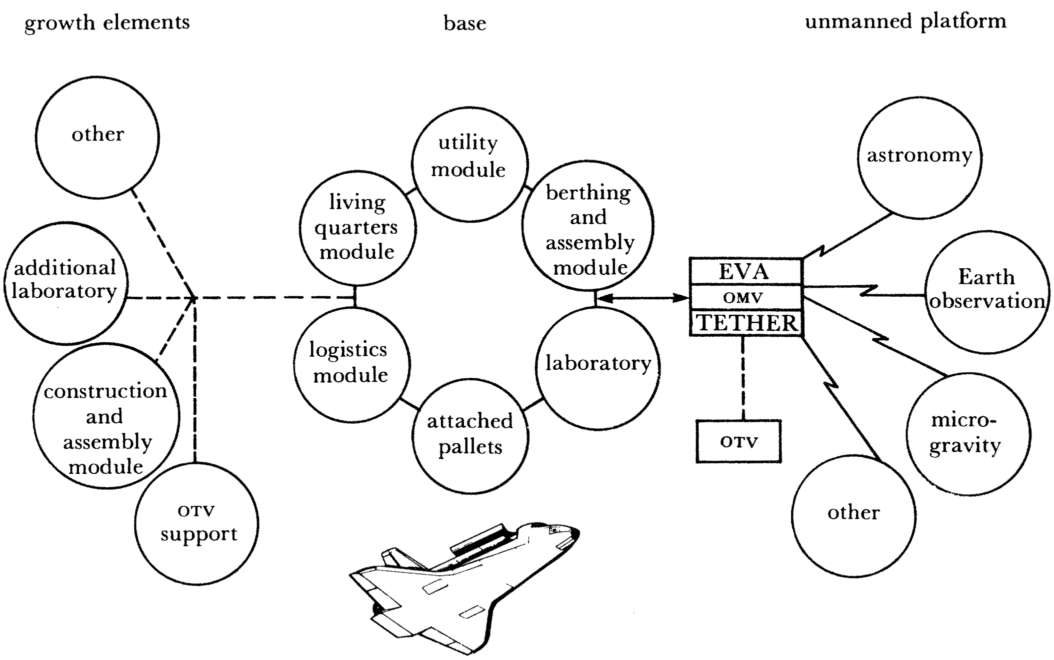

FIGURE 1. A space station architecture: cluster concept.

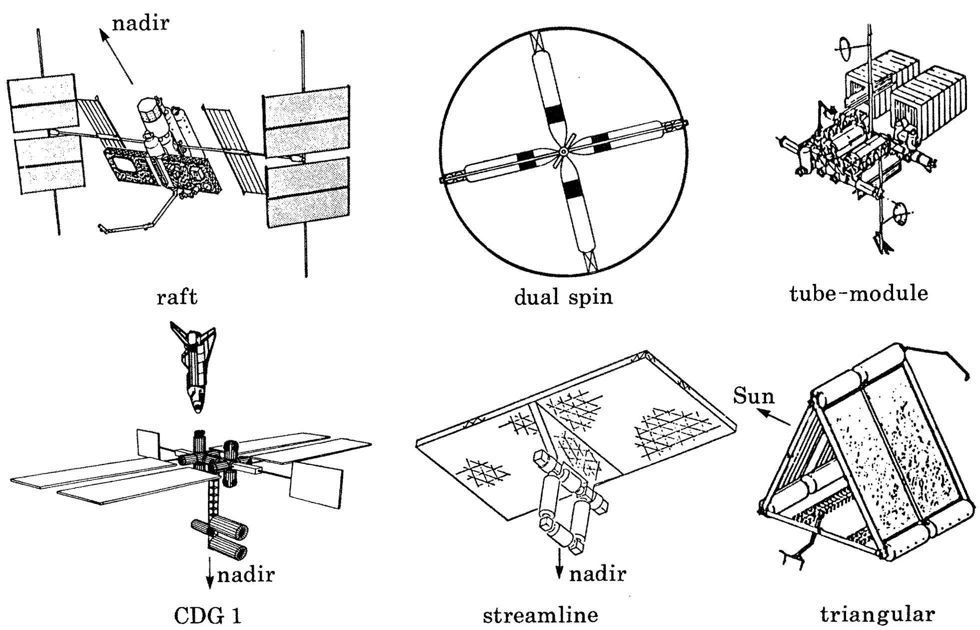

FIGURE 2. Possible space station geometries.

5. Technology and operational needs for a space station

The space station development concept is based upon two radical approaches for spacecraft. One is that of evolving technology where systems can be replaced with advanced equipment as new technologies emerge. The second is the design for ease of maintenance and refurbishment.

These concepts should reduce developmental and operational costs, greatly enhance reliability, and obviate obsolescence.

N.A.S.A. is carefully assessing the technology requirements for a space station. Technology disciplines include data management, power, thermal, propulsion, and human capabilities. N.A.S.A. is developing a plan to move technology from its current level to that required by an evolving space station that will allow upgrading as technology matures.

Through these planning processes, numerous technological issues have been identified. The challenge will be to optimize the space station design so that the right level of autonomy in space operations and the proper level of maintainability is achieved, while still providing for evolving technology. The proper use and balance of automation and human capabilities will assure that the utility of the space station is brought to a level that can serve all user needs. The design, construction, and evolution of the space station must also assure low life cycle costs.

The use of dedicated systems such as Apollo can no longer serve our future purposes. Our planning must embrace the principles of reusability and maintainability yet provide technical flexibility to accommodate future requirements.

6. Status of U.S. planning for a space station

N.A.S.A's space station planning effort has been under way for almost two years. Many long-standing international partners have participated in these planning activities. This planning is consistent with President Reagan's policy 'to continue to explore requirements, operational concepts, and technology associated with permanent space facilities'. The planning guidelines are divided into management and engineering-related categories, as shown in table 2.

Table 2. Space station planning guidelines

management related	engineering related
three year extensive definition (5–10% of programme cost)	continuously habitable dependent on the shuttle
planning throughout N.A.S.A.	
development funding in the fiscal year 1987	manned and unmanned elements
i.o.c. in 1991	evolutionary
cost of initial capability: $8 billion	maintainable
users involved in planning science and applications industry Department of Defense commercial	operationally autonomous user friendly
possible international participation	hardware can be upgraded as technology matures

The management-related guidelines include a comprehensive definition effort of approximately three years with an investment of 5–10% of the total programme costs. The mission roles and responsibilities of the various N.A.S.A. centers will be determined early next year. N.A.S.A. is also conducting the necessary preparation and planning to support definition studies with industry in 1984. It is expected that several contracts will be let for different elements of the space station. Two or more contractors will conduct definition studies on the same element tasks. The programme is also being planned so that significant design and development funding would start in the fiscal year 1987 with a planned initial operational capability (i.o.c.) in orbit in the early 1990s. The cost of the initial capability is estimated to be about $\$8 \times 10^9$.

The engineering guidelines include provisions for continuous habitation, Shuttle support for initial launch, resupply and crew rotation, evolutionary growth through maintainable and restorable systems, manned and unmanned elements, and autonomous operation with the ability to upgrade systems as new technology becomes available. The entire system would be designed with emphasis on specific user needs.

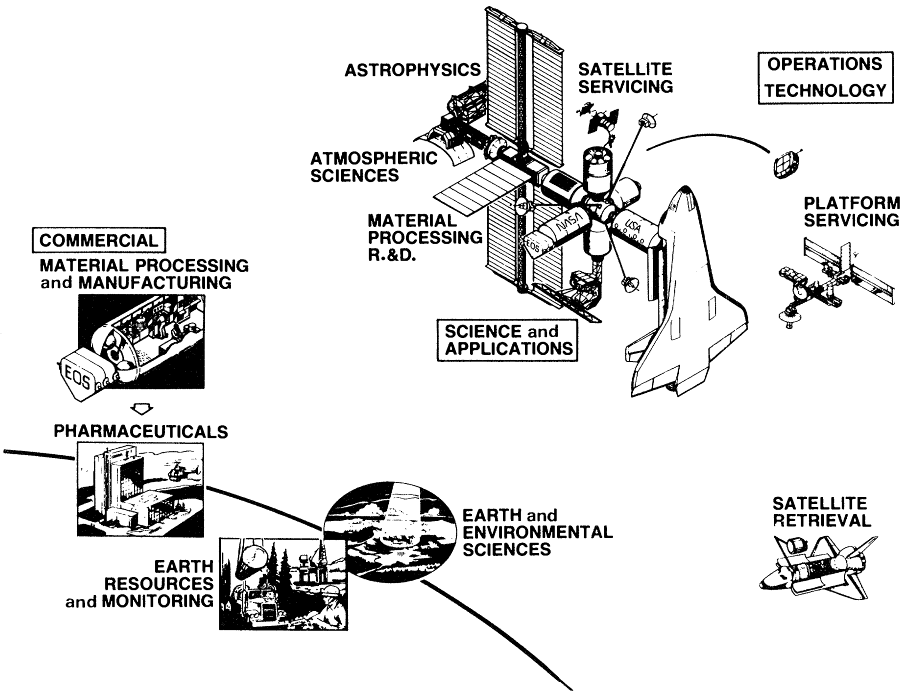

FIGURE 3. Initial concept for a space station.

An initial space station concept is shown in figure 3. It would satisfy initial user requirements by providing utilitarian laboratories for science and applications including commerical and defence applications complete with servicing, logistics, and operations support. It may also include special payload platforms and the capability to service them.

The initial capability is planned to evolve with emerging technology and advanced developments into the space station of the 2000s and beyond. A futuristic concept is shown in figure 4. It illustrates added capabilities to take payloads into higher orbits, service and repair satellites, retrieve various payloads, refuel vehicles, and many other capabilities to satisfy scientific, commercial, and security needs.

The planning schedule for the space station is shown in figure 5. All planning activities are geared toward initial operation in the early 1990s. The schedule includes planning activities to support the evolutionary process developing from the initial operational capability (i.o.c.) and leading up to the final operational capability (f.o.c.) in the year 2000.

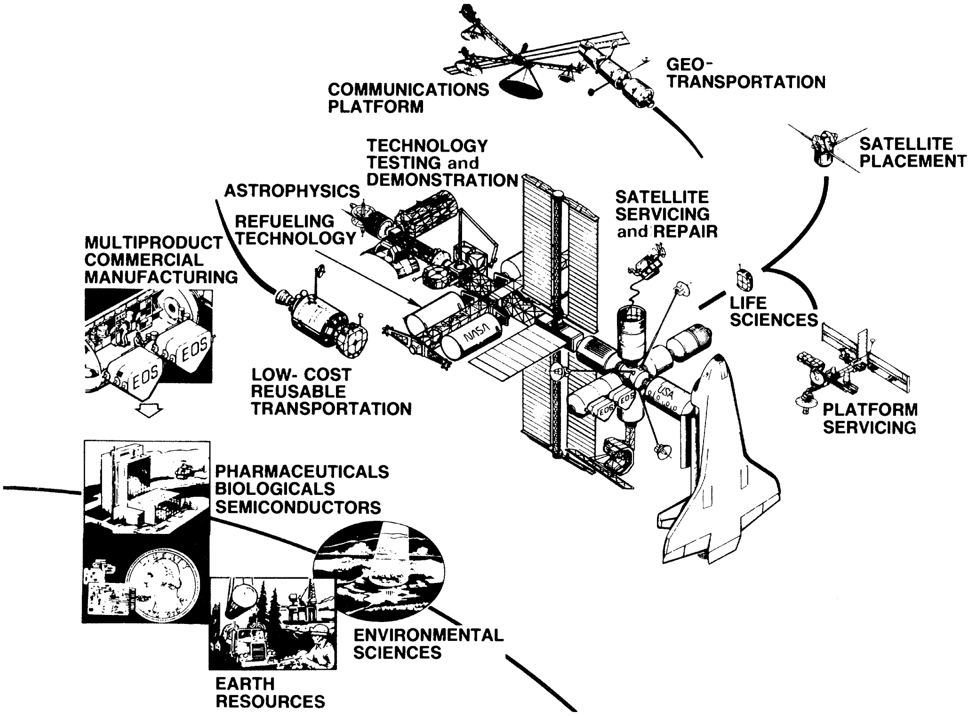

FIGURE 4. Future concept for a space station.

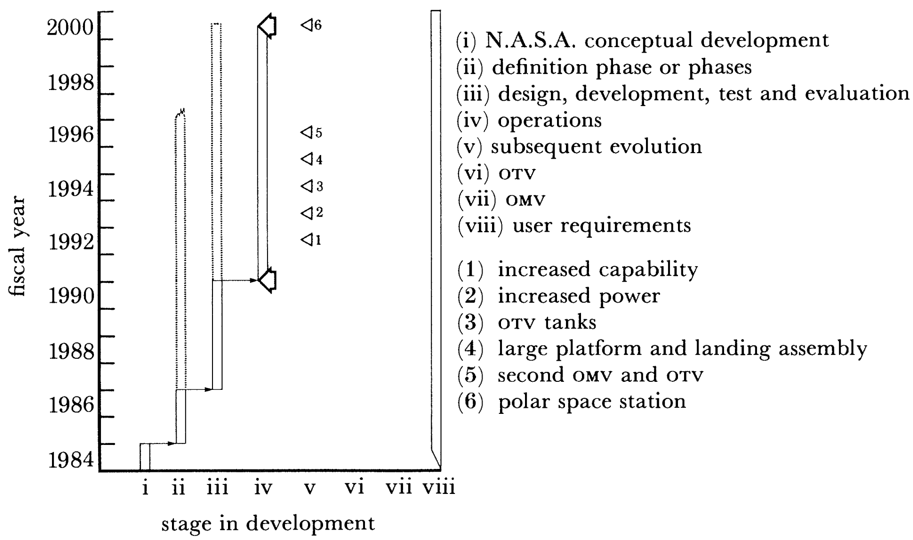

FIGURE 5. Space station planning schedule.

7. THE USE OF A SPACE STATION

User requirements, which translate into functional capabilities, provide the foundation for the development of the space station architecture. The space station has focused on studies that emphasize user requirements for three groups: (i) science and applications; (ii) commerce; and (iii) technology development. Study contracts recently conducted by eight U.S. aerospace contractors assessed these requirements. The results of the study contracts were integrated into a single, time-phased mission set for a total of 107 missions. These are illustrated by discipline

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

in table 3. On the basis of this mission set and the associated functional capabilities required of the space station system, the estimation of space station capabilities has been developed and is shown in table 4. These capabilities satisfy all initial requirements with the inclusion of two unmanned platforms, one co-orbiting with the manned space station and one in a near polar orbit. It should be noted that the future system requires 160 kW of power to the user as well as the space-based OTV for the transportation node function. As in the initial space station, materials processing facilities are the power drivers.

Table 3. Preliminary data base for definition of space station missions (1991–2000)

science and applications	
astrophysics	22
Earth science and applications	5
Solar System exploration	10
life sciences	6
materials science	4
communications	1
subtotal	48
commercial	
materials processing in space	11
Earth and ocean observations	3
communications	14
subtotal	28
technology development	
materials and structures	5
energy conversion	3
computer science and electronics	4
propulsion	2
controls and human factors	5
space station systems and operations	8
fluid and thermal physics	4
subtotal	31
total	107

Table 4. Estimation of capabilities

	initial	future
base at 28.5°		
crew	6–8	12–18
power	75 kW	160 kW
attached payloads	some	more
servicing capability	initial (near)	better
orbital manoeuvring vehicle	available	available
data system	300 Mbit s^{-1}	300 Mbit s^{-1}
utility module	one	more
laboratory module	one	more
logistics module	two	more
living quarters module	one	more
multiple berthing adapter	one	under study
platforms		
base at 28.5°; 15 kW	one	several
polar; 15 kW	one	one
space-based OTV	no	yes
manned polar station	no	under study

8. Commercialization of space

The space station concept of today encompasses many new and broader spacecraft capabilities than were possible a decade ago. In addition to the science and applications laboratory functions, today's concept includes promising commercial opportunities. Commercial opportunities in space are defined as those products, processes, and services that demonstrate technical, economic, and institutional viability sufficient to achieve private sector investment in, ownership of, and operation of the activity as a profit-making venture.

The first 25 years of the space age has seen very significant programmes of commercial use of space systems for profitable enterprise. The dramatic achievements of the communications industry's exploration of geostationary satellites are well known. In the 1960s, N.A.S.A. undertook the development of the first communications satellites. Since that time, a vast, multinational business has emerged based on the idea of providing long distance communications services on Earth through exploitation of the global capabilities of communications satellites in synchronous equatorial Earth orbits. The tax revenues collected by the U.S. government each year from the corporations involved in this very profitable, space-based business exceed the total early N.A.S.A. investment in communications satellites. A similar success story can be told for the N.A.S.A. investment in meteorological satellites from which daily space-based photography has become a part of the nightly television weather report. The U.S. Navy's Transit navigation satellite is also a great commercial success with shipboard systems installed on over 4000 ships flying the flags of fifty nations. Even more significant is that these shipboard systems are manufactured by about fifteen nations. Similar steps are beginning for the commercialization of Earth observation systems such as the U.S. Landsat, the French Spot system, and the German MOMS equipment.

Likewise, the provision of launch services, initially government subsidized, is moving into commercialized operations with upper stages, launch boosters, and spacecraft being furnished by private industry.

N.A.S.A. has met with receptive firms in various industries to introduce the attributes of space and to start dialogues. These discussions have stimulated forward-looking industry managers, planners, and research leaders to conceive activities that can lead to profitable ventures in space. N.A.S.A. would then provide assistance and access to space technology with a view toward early proof of concepts, typically in N.A.S.A. low-gravity facilities such as drop tubes and towers, KC-135 flights and, in some cases, Shuttle flights. This programme has begun to stimulate innovative thinking in firms in a number of fields (for example, crystal growth, biological separations, containerless processing of alloys and other materials, and production of optical glass). The focus is on processes that gain a special advantage from the space environment and on products with high market value.

Two examples of commercial ventures are the McDonnell Douglas–Johnson and Johnson venture and the Microgravity Research Associates venture. McDonnell Douglas, using its own risk capital, is experimenting with a continuous-flow electrophoresis system in space, which is capable of yielding 700 times the quantity of certain kinds of pharmaceuticals with five times the purity of that available on Earth. Their market potential is enormous.

Microgravity Research Associates (M.R.A.) is a small, risk capital firm that will use its own funds to design and build an electroepitaxial furnace to produce gallium arsenide crystals that are virtually free of defects and are of very high purity for use in electronics and computer applications. M.R.A. believes that this kind of gallium arsenide crystal can be produced only in the microgravity of space. This material could potentially replace silicon as the microelectronic chip material of the future.

A space station, as N.A.S.A. now contemplates, will, on a long-term basis, accommodate many of the commercial processes and product applications now being studied by industry. It fosters further activity by enabling the development of space technology and operational techniques in fields such as space construction, Earth and space observation and monitoring, satellite servicing, testing, transportation node operation, and human endurance studies.

The commercialization of space in all its forms will have increasing implications for the U.S. economy, security, and world leadership and prestige. We have observed the value to Japan's economy gained through government and industry partnerships. Space offers one of several opportunities for government to demonstrate leadership and support to industry. There is a challenge to both sectors to use vision, creativity, and perseverance to make such a partnership work.

9. Potential for international participation

N.A.S.A. has seen a tremendous interest in its space station planning activities by many of its long-standing, international cooperative partners. While N.A.S.A. and the international space community recognize that the potential exists for international cooperation, all parties clearly understand that the space station programme has not been approved and that N.A.S.A. cannot and has not made any commitments at this time. Still, the growing space ambitions of the European Space Agency (E.S.A.), Canada, Japan, France, Germany, and Italy have prompted these countries to conduct parallel mission analysis studies at their own initiative and expense. Results of some of these studies compared with United States requirements are shown in table 5.

Table 5. Summary of international use of space

mission area	U.S.	E.S.A.	Japan	Canada
material science and space processing				
manned R.&D. lab	×	×	×	×
attached processing facility	×			
co-orbiting processing facility	×	×	×	×
life science				
manned R.&D. lab	×	×	×	×
co-orbiting research facility				
space sciences and applications				
Earth observation				
high inclination free flyers and platforms	×	×		×
attached research facility	×			
manned high inclination platforms			×	
astronomical observation				
attached observatory	×			
low inclination free flyers and platforms	×	×	×	×
high inclination free flyer and platforms	×	×	×	×
technology and operations				
large structures	×	×	×	×
energetics	×	×	×	×
sensor development	×			×
maintenance, service and repair	×	×	×	×
OTV	×	×		×

Periodic meetings have been held to exchange study results. In addition, these countries are examining potential contributions to a space station if the opportunity to cooperate arises.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

These early discussions are important for N.A.S.A. and its potential partners. Since the space station is viewed as a working orbital facility, N.A.S.A. is gaining information on potential world wide space station use patterns. Given the scope and complexity of a space station, this early involvement has given N.A.S.A. and the international community time to carefully evaluate cooperative possibilities should the decision be made to proceed.

N.A.S.A. has a long, successful history of cooperative activities. It has undertaken numerous activities with the E.S.A. and with individual European countries. For example, N.A.S.A. and British government agencies have participated in the Ariel satellite programme. Five satellites were launched from 1962 to 1974 to investigate a broad spectrum of scientific questions in the radio sciences, particles and fields, and high energy astronomy areas. Other cooperative activities include British hardware contributions to U.S. meteorological satellites, the N.A.S.A. International Ultraviolet Explorer, and the Solar Maximum Mission. More recently, the United Kingdom and the Netherlands participated in the Infrared Astronomical Satellite (I.R.A.S.), by providing the ground operations systems and an experimental instruments on the spacecraft. As we have all recently heard, I.R.A.S. has made some outstanding discoveries that astronomers will be studying for years. Finally, the United Kingdom is participating in the International Satellite-aided Search and Rescue Programme which has already demonstrated its ability to save lives.

In the field of space commercialization, several United Kingdom contractors have made successful, profitable arrangements with international industrial partners in the fields of communications satellites.

Additionally, Europe became a partner with N.A.S.A. in its Shuttle programme by building Spacelab. The recent launch of Spacelab aboard STS-9 marked the culmination of many years of hard work and excellent cooperation and is only the beginning of the possibilities that Spacelab provides. Spacelab offers numerous opportunities in several commercial areas and for science and applications, materials processing, and communications.

These joint activities have benefited all of us because we have been able to share the costs of these undertakings, thus allowing us to do more work. Very importantly, the scientific results from these activities have been shared among us.

It is our observation that large, peaceful, joint high-technology programmes among Western nations hold the hope of vitalizing high-technology industry on both sides of the ocean and strengthens our business and political ties. The only such programme in sight now and for the immediate future is the space station programme.

N.A.S.A's space station planning envisages a continuation of these policies of cooperation on space station development and use. There remains, however, the necessity of gaining a full understanding of cooperative and competitive activities and where one ends and the other begins. We enjoin all concerned to study the problem with us to ensure that we develop the right approach and a complete understanding on both sides.

10. Conclusion

The United States must continue space research, development, and applications to reap benefits for society and maintain space leadership. This continued involvement, shared with other nations and in cooperation with commercial companies, will expand the world's space activities into new realms. Just as we have shifted from pure space research and exploration in the 1960s toward applications in the 1970s and routine operations in the 1980s, space activities in the 1990s and into the next millennium will take on new meaning to mankind.

Just as N.A.S.A. had no idea that the Apollo programme would have so many benefits for society in the 1980s, N.A.S.A. cannot fully predict the impact and benefits of the space station in the year 2000. What is known is that the U.S.A. and many countries now have both a taste for space-borne knowledge and the institutional mechanisms for using new knowledge and rapidly converting it to new applications that come in many forms.

The 'high road' to space will soon be travelled by the common man, not just by those who possess 'the right stuff'. When the space station passes from the esoteric concepts of 1983 to the mundane activities of 2001, with factories in orbit, with permanent laboratories routinely yielding new knowledge, and with payload launches from the space station to the Moon, Mars, and other orbits in between and beyond, mankind will have found his place in the universe and will no longer be restricted to the world under his feet. We will then have the start of 'a city in space'.

Discussion

I. Crawford (*University of Newcastle, U.K.*). What thought has been given to international financing of space stations?

R. F. Freitag. N.A.S.A. has a long history of successful international cooperation in space activities. For space station studies conducted in 1982–1983, interest in potential cooperation has been expressed by E.S.A. and the Governments of Canada, France, West Germany, Italy and Japan. N.A.S.A. has welcomed their study participation but no commitments on co-operation have been made.

One groundrule that has been consistently followed in international cooperative projects is no exchange of funds. That is, each country funds its part of the mission. A good example in the space transportation system is the funding of the development of Spacelab by E.S.A. In the space station programme, we plan to follow the same policy.

Note added in proof (26 *March* 1984). President Reagan directed N.A.S.A. in his State of the Union message on 25 January 1984 to develop a permanently manned Space Station and to do it within a decade.