A Publication of the British Interplanetary Society March 1993 Vol. 35 No.3 US$3.50 £1.70

Spaceflight

The International Magazine of Space and Astronautics

Into Orbit WITH Reusable Spacecraft

Radar Observation of Earth: Zones of Planets: What is the Problem? By *Dr William I. McLaughlin*

- ENDEAVOUR'S THIRD MISSION : STS-54
- STS-53 MISSION WITH CLASSIFIED PAYLOAD
- HUNTSVILLE OPERATIONS CONTROL CENTER
- WORLDWIDE SPACE NEWS & LAUNCH REPORTS

ISSN 0038-6340
03
9 770038 634010

Spaceflight Office:
27/29 South Lambeth Road,
London, SW8 1SZ, England.

Tel: 071-735 3160
Fax: 071-820 1504

DISTRIBUTION DETAILS

Spaceflight may be received worldwide by mail through membership of the British Interplanetary Society. Details from the above address. Library subscription details are also available on request.

* * *

Spaceflight is distributed in the UK and overseas through newsagents by COMAG Specialist Division, Mercury Centre, Central Way, Feltham, Middlesex TW14 ORX Tel 081-844 1000 Fax 081 751 266

* * *

Opinions in signed articles are those of the contributors and do not necessarily reflect the views of the Editor or the Council of the British Interplanetary Society.

* * *

Back issues of ***Spaceflight*** are supplied at £3.00 (US$6.00) each, inclusive of surface mail delivery. ***Spaceflight*** binders (holding 12 issues) are available at £7.50 (US$15.00), inclusive of surface mail delivery.

* * *

Published monthly by the **British Interplanetary Society Ltd.**, 27/29 South Lambeth Road, London, SW8 1SZ, England. Printed by JWL Ltd, Aylesbury, Buckinghamshire, England.

* * *

Spaceflight

The International Magazine of Space and Astronautics

Published By The British Interplanetary Society

Vol. 35 No. 3 **MARCH 1993**

Front Cover: Latest configuraton of National Aerospaceplane. *NASA*

Spaceplanes - Back to

The Question of Money Seems Likely To Delay

An aeroplane is a powered, heavier than air vehicle which takes off from a runway and uses aerodynamic lift to keep it airborne. Its destination is another or the same runway. For the purposes of this article a spaceplane is a vehicle which takes off and lands like an ordinary aircraft but is also able to enter space.

Many are familiar with recent spaceplane programmes such as the UK's HOTOL, Germany's SÄNGER and the USA's NASP (National Aerospaceplane). Each is a different concept to launch a winged reusable orbiter into space. All are still in the early stages of research and it is unlikely that we shall see any prototypes until the next century.

These spaceplane projects have been spurred by the need to reduce the cost of reaching a low Earth orbit. Their backers argue that, despite high capital expenditure on research and development, such reusable systems would eventually cut the cost of putting a payload into orbit by a significant factor. One can, however, go back to the pioneering days of space technology research to see that this aerodynamic approach is nothing new.

BY DOUG MILLARD
Science Museum, London

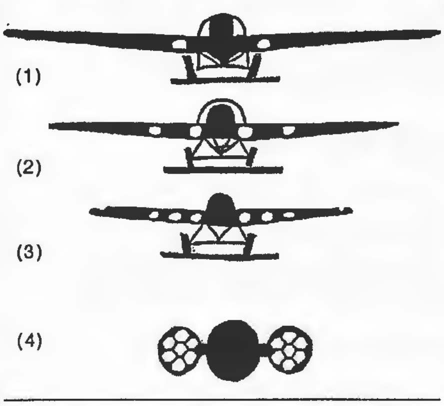
Oberth's Legacy

One of the greatest influences on the early rocket engineers was Hermann Oberth. His 1923 book "The Rocket into Interplanetary Space" explained with mathematics and text how space flight could be attained *via* the development of ballistic based rockets. History has born out his expendable launcher philosophy but this may be due to political expedient (Peenemunde, Sputnik, Kennedy and so on) rather than scientific logic.

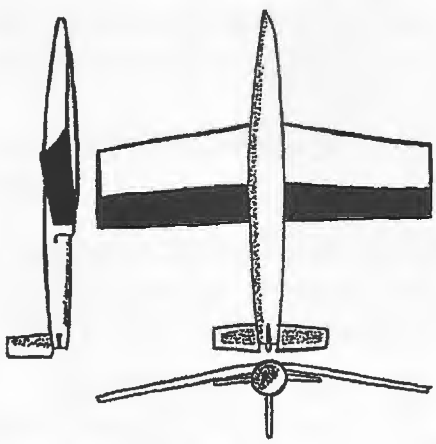
There were other engineers who acknowledged Oberth's vision but disagreed with his ballistic based methods. Max Valier, an Austrian science writer, put forward the idea of progressively converting a Junkers G-23 aircraft into a spaceship. A compatriot, Franz von Hoefft, outlined plans for a seaplane with an orbital third stage. However, it was Eugen Sänger, another Austrian, who analysed the aerodynamic route to space most systematically and went on to become one of the century's greatest proponents of space flight. His philosophy ran: stratosphere plane - spacecraft - spacestation - interplanetary spaceship - interstellar spaceship.

Max Valier's idea for cconverting a Junkers G-23 into a stratospheric plane and thence to a spaceship.

(1) 2 rocket motors added.
(2) 4 rocket motors added wing shortened.
(3) 6 rocket motors added wing shortened pressurised cabin.
(4) vertically launched spaceship.



Based on a lecture given at the British Interplanetary Society on October 7, 1992.



Sänger's Silverbird of 1933.

Sänger's Silverbirds

In 1933, whilst working at the Technische Hochschule in Vienna, Sanger published his design for a high altitude rocket plane. It was to have petrol and liquid oxygen propellants and reach velocities of about 10,000 km per hour and altitudes of between 60-70 km.

Towards the end of the 1930s Sänger issued another design which, in order to save weight, would be launched from a rocket driven sled accelerating to 1,800 km per hour. It is interesting to note that HOTOL is designed for launch from a trolley for the same reason.

Sänger referred to his craft as "Silverbird", though colleagues nicknamed it "Flatiron" in deference to its domed body and flat bottom.

Artist's impression of Dyna-Soar launch.
Boeing

With the onset of World War II, Sänger was required to adapt his craft for use by the German military. Thus, the "Racketenbomber" was born, a 100 tonne high altitude rocket plane which would be launched from a sled driven by two A4 rocket engines. Its liquid-propellant engine would develop 100 tonnes of thrust and achieve a maximum velocity of just under 29,000 km per hour. The vehicle would peak at an altitude of 300 km, after which it would descend and skip aerodynamically off the top layers of the atmosphere rather like a stone skimming across the surface of a lake. This skip flight trajectory would enable the craft to orbit the Earth and release its four tonne bomb over New York.

However, this project was cancelled in 1942 and Sänger saw the war out working on ramjet engines for fighter aircraft. It would be many years before he could return to his "Silverbirds".

Peenemünde's Wings

Sänger worked for the air force. At Peenemünde, on the Baltic coast, the German Army's ballistics programme was proceeding apace under the aegis of General Dornberger and the young von Braun. As well as honing the A4 missile. Dornberger's engineers also investigated winged rockets as a means of extending missile strike range.

The A4b was built and launched twice. On the first occasion it exploded almost immediately but on the second it became the first winged vehicle to

the Future
Spacelane Development

exceed the speed of sound. The Germans had even more ambitious plans with a piloted "A" variant which, like Sänger's Racketenbomber, would have been capable of bombing North America.

Post-War

If the thinking done in Europe during the 1930s represents a preliminary stage in spaceplane research, then the next phase probably occurred in the United States at the end of World War II.

Plans had been laid by the US Air Force in 1944 to tackle the sound barrier. This was broken in 1947 when Captain Yeager flew the X-1 research aircraft to Mach 1.06. The triumph was an overture for a succession of X-plane variants which nudged the speed and altitude records upwards.

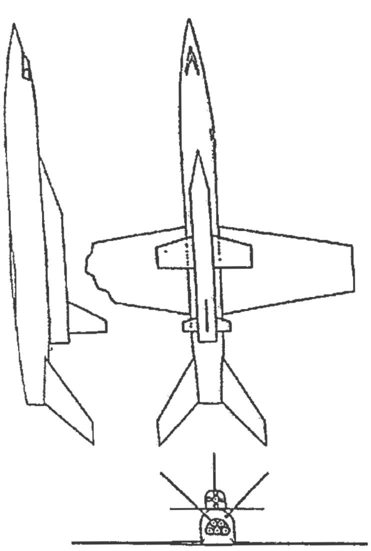
The next target was clearly to fly to the edge of space.

Calls were put out by the NACA (National Advisory Committee for Aeronautics) for vehicle designs. One of the proposals that came back in 1953 was the Drake-Carmen composite vehicle from NACA's own High Speed Flight Station. The upper stage of this TSTO (Two-Stage-To-Orbit) concept would separate at altitude and then boost to orbit before descending on a gliding flight path.

Many other designs were poured over but the craft which eventually received a go-ahead in 1955 was the X-15. This first flew in 1959 and went on to become the most successful high speed and altitude research aircraft ever built.

The X-15 flew to the edge of space. Indeed, the plane exceeded the threshold of 80.5 km (50 miles) on ten occasions and earned the pilots their astronaut wings. Everything augured well for the final target, that of developing a true orbital spaceplane.

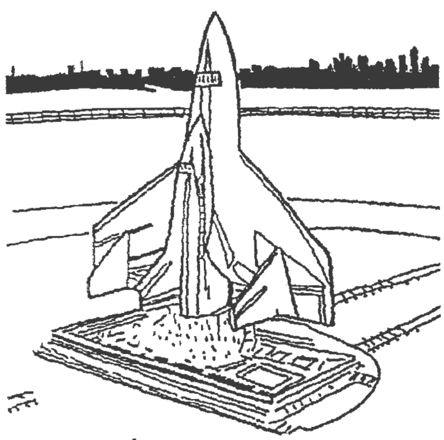
The NACA's Drake-Carmen TSTO Spaceplane.



Into Orbit?

During the early and mid-1950s the USAF had examined a range of orbital strike and reconnaissance craft concepts. BOMI (Bomber-Missile), devised by Walter Dornberger (late of Peenemunde), System 118P and Brass Bell were all conceived at the Bell Aircraft Corporation. ROBO was a winged orbital rocket bomber project under investigation in USAF research facilities. HYWARDS was to be a research aircraft aimed at validating the preceding systems.

Finally, in 1957 and, interestingly, just one week after Sputnik 1 had been launched by the Soviet Union, the USAF drew the various programmes together and announced the initiation of DYNA-SOAR (Dynamic-Soaring). This evolved into a small piloted delta-winged orbiter launched on a modified

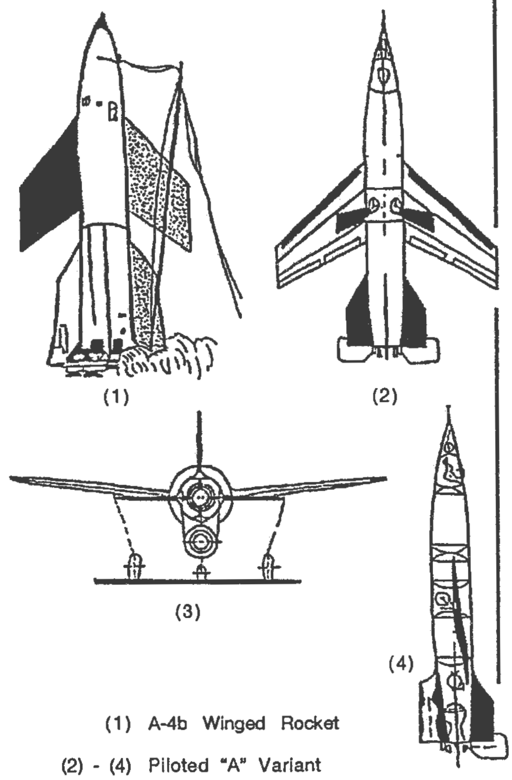


Dornberger and Bell's Bomi.

Titan booster. With an expendable booster system, however, it was clearly not a true spaceplane and merely represented another technological step towards total reusability.

USAF personnel were still pondering total reusability, however, in the shape of Aerospaceplane, a SSTO (Single-Stage-To-Orbit) vehicle that would be,

> "...of tremendous big winged design ... propelled from the ground horizontally by turbojets. The craft would carry liquid hydrogen and would scoop oxygen from the upper atmosphere which would be liquified. With fuel thus obtained ... the vehicle would be ready to penetrate space and then to return to the atmosphere for landing at an airfield."
>
> *Space Daily* July 18, 1962, p.75



(1) A-4b Winged Rocket

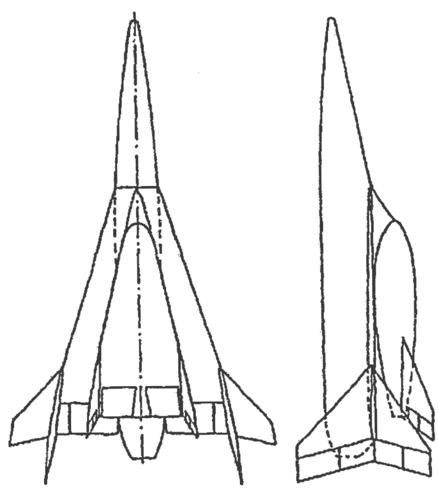
(2) - (4) Piloted "A" Variant

This project would have been virtually impossible to achieve in the early 1960s and it was no surprise when it was cancelled in 1963. DYNA-SOAR, by this time labelled X-20, was also shelved in the same year. US resources were being funnelled into the Apollo and Gemini programmes and the aerodynamic way into space seemed well and truly eclipsed by the tried and tested ballistic systems.

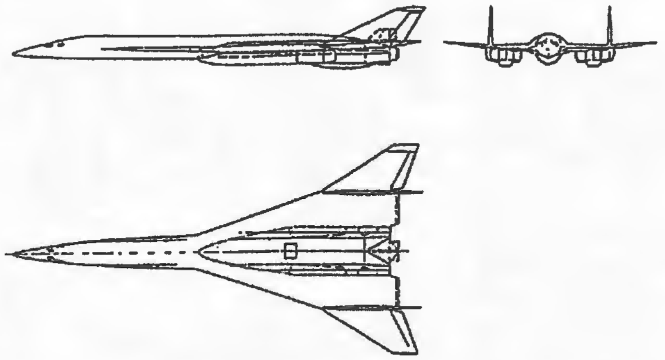
Europe

In Germany, however, Eugen Sänger was lobbying hard for Europe to develop a form of spaceplane, the Aerospace transporter. He worked with the Junkers company on a TSTO design as a precursor to an SSTO vehicle. Messerschmitt-Bolkow-Blohm (MBB) were also looking at a TSTO spaceplane.

MBB TSTO concept of the 1960's.



Work was going on in other European countries as well. In France, the Dassault company, in association with the French space agency CNES, proposed a small "Space Taxi" orbiter which would be launched at altitude from an aircraft.



Dassault/CNES TSTO Concept incorporating ventrally slung "Space Taxi".

Research was also carried out in Britain where a variety of partially and wholly reusable winged launchers were investigated during the 1960s. The best-remembered is the British Aircraft Company's Three-Stage-To-Orbit MUSTARD (Multi-Unit Space Transport and Recovery Device) which, while totally reusable, was launched vertically. This system was of particular interest to the Americans who, by the end of the 1960s, were once again thinking seriously about a totally reusable spaceplane.

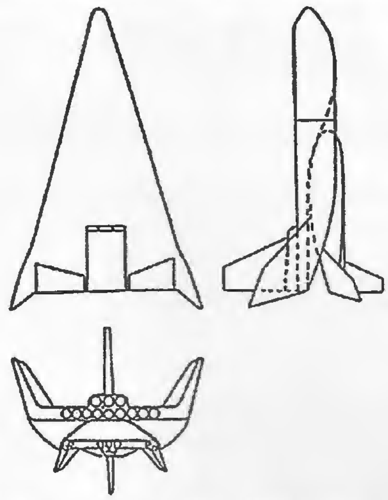
Reusable Shuttle

The US vehicle would form part of a Space Transportation System to supply and maintain an orbiting spacestation with a view to further interplanetary missions e.g. to Mars. This mirrored Sanger's philosophy from the 1920s and 1930s.

The AACB (Aeronautics and Astronautics Coordinating Board) had reported in 1966 with a suggested development timeline from partially to totally reusable launcher systems. In 1969, NASA invited US aerospace concerns to produce initial designs for a Shuttle.

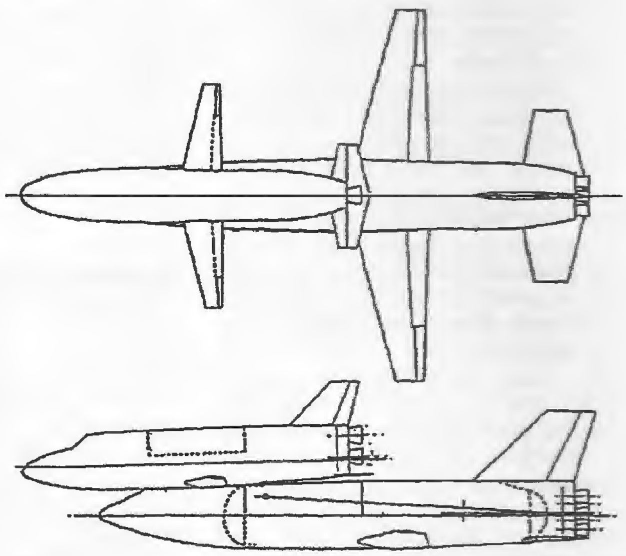
NASA's Langley Research Centre proposed a TSTO arrangement based on the HL-10 Lifting Body design. Both stages would employ airbreathing propulsion systems which draw oxygen from the atmosphere.

Another design which attracted a great deal of attention came from Max Faget of the Manned Spaceflight Center, Houston. This TSTO system comprised a huge winged first stage from which an orbiter, already resembling the eventual Shuttle, would be launched.



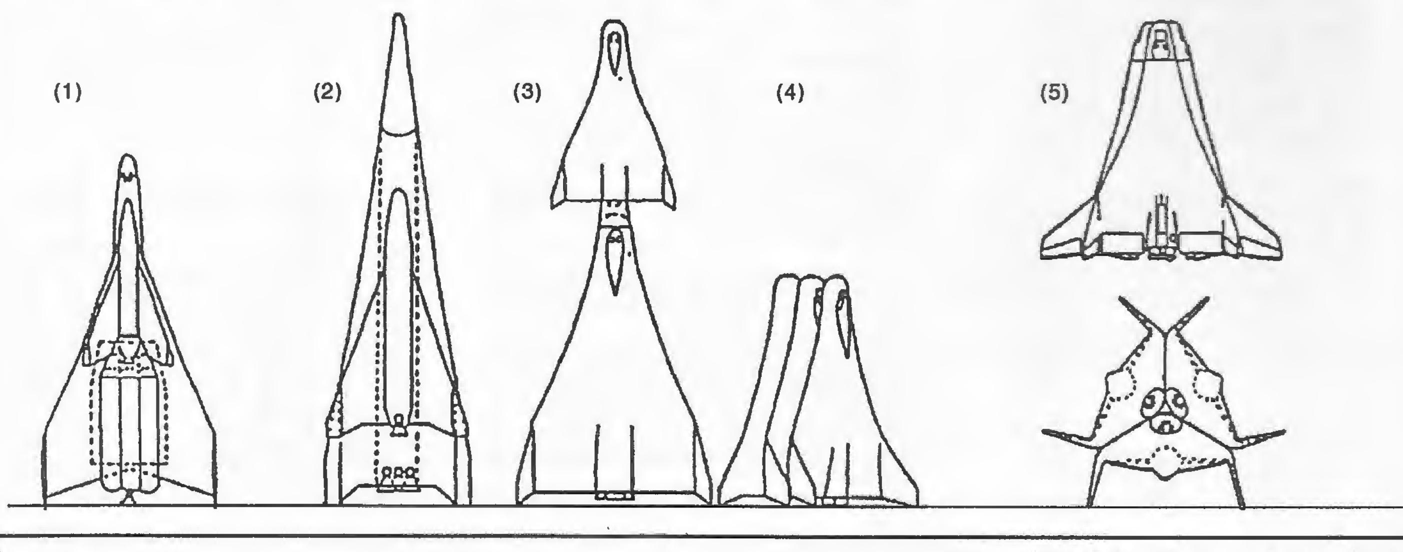
TSTO Shuttle based on Langley's HL-10 lifting body.

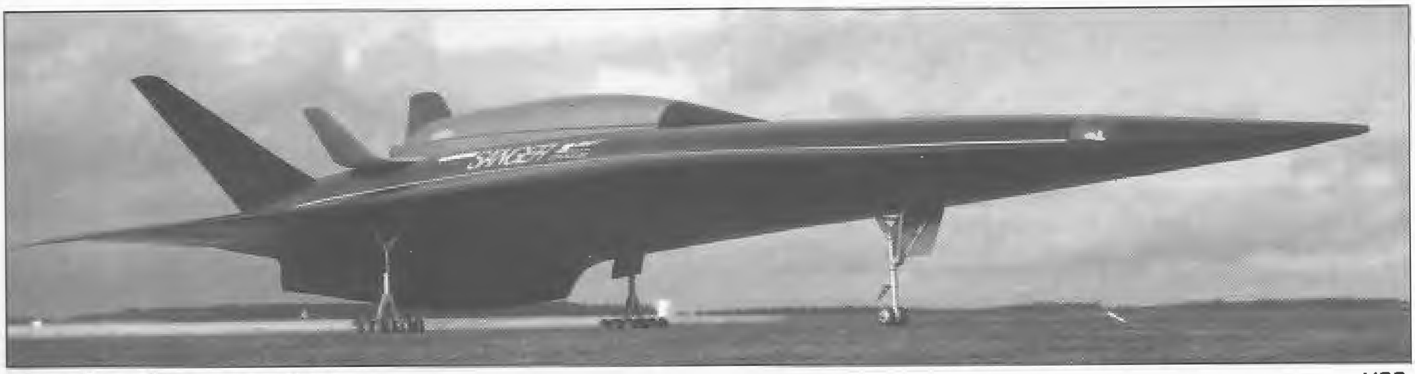
The second round of designs revealed some impressive looking TSTO vehicles from North American Rockwell and McDonnell Douglas. Total reusability was still the aim and it began to look as though the earlier visions of pioneers might at last be realised. Then the limiting factor of money appeared.



Manned Space Flight Center's TSTO Shuttle from Max Faget.

Partially/Totally Reusable Vehicles Reviewed by the British Aircraft Company: (1) Horizontal Take Off, Partially Reusable; (2) Horizontal Take Off, Reusable; (3) Vertical Take Off, Reusable; (4) Vertical Take Off, Reusable (MUSTARD); (5) Alternative configuration for "MUSTARD".

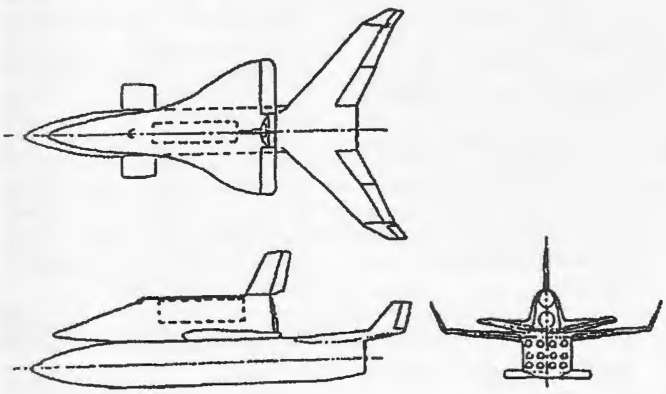




1:85 model of Sänger with HORUS. MBB

Partially Reusable

In 1971 the US Office of Management and Budget expressed its unwillingness to support NASA above its fiscal limit for the year of $3.2 billion. Any technological reservations with the latest round of Shuttle designs were amplified by this problem of insufficient funding and NASA eventually settled for a partially reusable Space Transportation System. The Shuttle, as we know it, was therefore conceived and ten years later Columbia was launched on its maiden flight. The wait for a true spaceplane continued.



Second round McDonnell Douglas TSTO concept.

HOTOL

In 1982 the British Interplanetary Society held a Space Transportation symposium. Amongst those attending were Alan Bond of the United Kingdom Atomic Energy Authority laboratories at Culham and Bob Parkinson of British Aerospace. They subsequently realised that the symposium had triggered complementary thoughts. Parkinson had drafted a SSTO horizontal take off vehicle while Bond had outlined an innovative hybrid airbreathing rocket engine which would propel it.

This spaceplane concept was known, at first, as SWALLOW but, more by accident than design, it eventually acquired the acronym HOTOL for (HOrizontal Take Off and Landing.

HOTOL was conceived as an unpiloted space plane capable of putting an 8-tonne satellite in a 300 km orbit. Proof of Concept studies were successful but progress was hampered by insufficient funding and a security classification which effectively prohibited alternative backing from overseas.

The original HOTOL is now in obeyance while an interim scheme is investigated. British Aerospace and the Russian Central Institute of Aerohydrodynamic research have been looking at a TSTO system in which a modified HOTOL is to be launched from an Antonov 225 aircraft. INTERIM HOTOL would use conventional rocket motors rather than the hybrid RB545 of the original.

Alan Bond is not connected with INTERIM HOTOL and is in the process of putting together his own consortium to support development of SKYLON, a new SSTO vehicle employing an improved hybrid airbreathing rocket engine.

Other Studies

The HOTOL public announcement at the 1984 Farnborough Air Show caused quite a stir and it was not long before other countries were following suit with their own spaceplane concepts. Some were new and other were dusted down and updated versions of earlier research programmes.

MBB unveiled their appropriately named SÄNGER, a TSTO spaceplane which would use turbo-ramjets on the first stage and rocket motors on the piloted orbiter. An alternative unmanned second stage was later abandoned.

Dassault resurrected their TSTO scheme from the 1960s as STAR-H. Following separation from the reusable first stage the second would use an expendable booster to achieve orbit. This would not therefore be a truly reusable spaceplane. Spaceplane research was also announced in the Soviet Union (which had been investigating an Antonov TSTO system before INTERIM HOTOL surfaced), Japan and India.

NASP

In his 1986 State of the Union Address, President Reagan referred to a new "Orient Express" which could cut the journey time from New York to Sydney to a couple of hours. He was talking of the National Aerospaceplane (NASP), a SSTO concept which, in reality, was still years away from a demonstrator vehicle, let alone a passenger-carrying space liner.

NASP was the most ambitious of the 1980s spaceplane projects. With a sizeable military function it had to follow particularly demanding flight profiles and this called for highly advanced propulsion, thermodynamic and control systems. It swallowed up huge amounts of research funding and, with the ever present financial constraints, there was no guarantee that Congress would even allocate sufficient money to build an X-30 demonstrator vehicle.

The Future

It is the question of money which once again seems likely to delay spaceplane development around the world. Many engineers will argue that vast sums do not have to be thrown at spaceplane research. David Ashford, for example, has devised an incremental approach to spaceplane design which makes maximum use of existing technologies.

Nevertheless, any long-term project requires considerable financial backing and the spaceplane proponents have, as always, to compete with many other causes. Perhaps, as we wait again, we must simply draw on the confidence of Eugen Sänger who said in 1925, "Nevertheless, my Silverbirds will fly".

Bibliography

1. "The Silverbird Story: A Memoir", Irene Sänger-Bredt, 4th IAA History Symposium, pp.195-228.
2. "Winged Rocketry", Major James C. Sparks, Dodd, Meade & Co. 1968.
3. "The Path to Space Shuttle: The Evolution of Lifting Reentry Technology", R.P. Hallion, JBIS, 36, 12, pp.523-542.
4. "The Hypersonic Revolution" V2, R.P. Hallion, Aeronautical Systems Division, Wright Patterson Air Force Base 1987.
5. "The X-Planes", Jay Miller, Aerofax Inc. 1988.

Paris Visit

Science à la Carte!

Brian Harvey **writes about a science museum in Paris that is well worth a day's visit. For space enthusiasts there is much to interest them.**

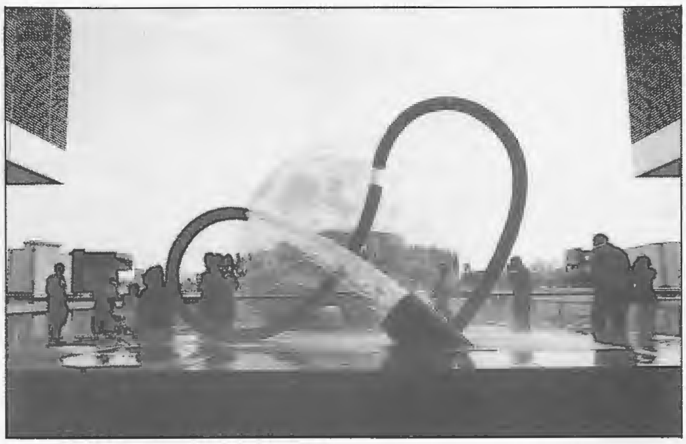
BY BRIAN HARVEY
Dublin

Most museum-going space enthusiasts think in terms of the lavish displays of the Smithsonian museum in Washington DC or the VDNK in Moscow. An impressive, though more modestly-sized space exhibition is now relatively close at hand in the futuristic Cité des Sciences et de l'Industrie (City of Science and Industry) in Paris, France.

Cité des Sciences is built on the site of the old Paris abattoirs to the north-east of the city. It is a large complex of glass-and-steel 40 m-tall 30,000 m² science museums, full of lifts, walkways, ramps, bridges and platforms. Cité des Sciences is about hands-on science: the format is learning through doing, seeing, touching and hearing. Visitors explore such diverse subjects as mathematics, optics, sound, robots, the world of microbes, computers and time.

Outside the main science building are two special attractions: the *géode*, a round cinema-roof 1000 m² projection building with several shows daily; and a French navy 1957 submarine, the *Argonaut*, which one can walk through accompanied by a headset commentary. The *géode* generally shows educational programmes, last summer's special being *Blue planet*, a spectacular and beautiful tour of the Earth through the eyes of the NASA space shuttle's IMAX-camera.

Two floors of the main science block are devoted to the space exhibition which is dominated, as one might expect, by France's national space programme and its cooperative ventures with other countries. There are excellent models of Ariane, Salyut 7, Freedom and Mir; and a lifesize exhibit of Spacelab with model astronauts at work on a typical mission. There are several audio-visual displays of the history of space exploration (notably even-handed in their treatment of Russia and America); there is a series of models of current scientific missions; and there are a number of rocket motors on display, the most striking being the HM-7 used on Ariane. For astronomers, there is a planetarium.



Modernistic figure-of-8 water foundation, géode in background.
Photo supplied by author

Although the Russian-French *Antares* manned mission had only just ended, a week later the Cité was already showing edited takeoff-to-touchdown mission highlights on continuous-tape video, amply supported by a full press dossier on the mission.

Cité des Sciences is worth a full day's outing, and as they say, it is suitable for children and adults of all ages. Some children might even consider it a rival to Eurodisney.

BIS Visit

British Telecom London Teleport Isle of Dogs

The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members - especially those interested in Space Communicatons - will be made to BT London Teleport at the Isle of Dogs, London, on 31 March 1993 from 10:15 am to 2 pm.

London Teleport is on the North Bank of the Thames, adjacent to the Woolwich Ferry Terminal and 300 yards from North Woolwich Station on the Central Line

The visit will include:

- A Presentation on the Facilities
- A tour of the Complex which will include an opportunity to view a range of different types of antennae and associated Earth Station Equipment
- Complimentary Buffet Lunch and refreshments will be Provided
- Discussion session to follow after lunch

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

BIS Visit

Royal Aircraft Establishment/Defence Research Agency

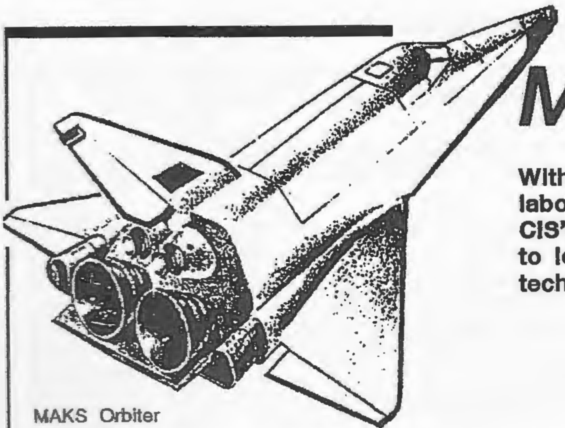
The Society is pleased to announce that, as part of its 60th Anniversary Celebrations, a visit for Society Members to the Royal Aircraft Establishment/Defence Research Agency at Farnborough, Hants has been arranged for 21 May 1993.

The visit will include a tour of facilities concerned with:

- Remote Sensing Imagery Producitọn (Optical & Radar)
- Radar Systems Research
- Power Systems Technology
- Electric Propulsion
- Chemical Propulsion
- Small Satellite Programme (STRV-1a and 1b)
- Measurements of Space Radiation Environment
- Space Test Facilities
- Complimentary Lunch and refreshments will be Provided

Registration forms and location maps are available from:
The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ

MAKS - Eastern Promise ?



MAKS Orbiter

With the opening up of the former Soviet Union many opportunities to collaborate on major space projects now exist. One of the most exciting is the CIS's aerospaceplane project called MAKS, which offers a promising route to low cost flexible transportation into low Earth orbit. So the history and technical details of the project are of interest.

BY MARK HEMPSELL and **BOB PARKINSON**
BIS Council Members

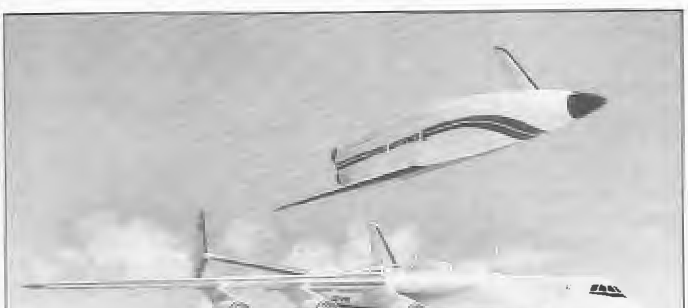
At the Paris Air Show in 1989 the Soviet Union publicly displayed their massive An-225 carrier aircraft - the largest aeroplane in the world - carrying the Buran Space Shuttle on its back. Billed as a "heavy lift" aircraft it was capable of transporting the Buran Shuttle and components of the Energia launch system, or of carrying large and heavy payloads (chemical processing plants and even entire ships were mentioned) to remote sites by air. When a delegation from British Aerospace were shown around it, the first sight that greeted them as they entered the enormous hold was a poster showing the An-225 carrying HOTOL.

The An-225 design team had always seen one of its roles as a carrier for Single Stage To Orbit (SSTO) launch systems. Since its carrying capacity of about 275 tonnes matched the mass of the airbreathing HOTOL to within 5 tonnes, the Soviets were interested in discussing whether their aircraft could be used to replace the launch trolley; widely considered to be HOTOL's Achilles heel. The result of these discussions were joint studies between British Aerospace and the Soviet aerospace industry into the potential of the An-225 in the HOTOL concept.

Over the next three years a proposal called the Interim HOTOL evolved. This was a pure rocket version of HOTOL which, like the original airbreathing version, would be fully reusable and carry a payload of about 7 tonnes into orbit. It was called the Interim HOTOL because it was never intended to be a development instead of the airbreathing system. Rather it was seen as a way of still significantly improving launch costs by the year 2000 (the original goal of the project) despite the delays in starting the development of the airbreathing engine which meant it could no longer be ready in time to meet this target. The airbreathing system, which has always been seen as the best long term approach, could then be introduced later, bringing launch costs down still further.

Very early during the joint work with the Russian and Ukrainian engineers British Aerospace were introduced to the NPO Molnija design bureau in Moscow - who were responsible for the design of the Buran orbiter. NPO Molnija had their own project for utilising the huge lifting capacity of the An-225 as the basis for a reusable launch system, which they called MAKS (Mnogotselevaya Aviatsionno Kosmicheskaya Sistema or Multi-Purpose Aerospace System). MAKS was in an advanced state of design and although it did not meet all the HOTOL requirements it has been seen as an alternative route to low cost, on demand access to space.

Artist's impression of INTERIM HOTOL launch from Antonov 225. *BAe*



Antonov 225 at 1990 Farnborough Airshow. *D. Millard*

More recently other European countries have started to take an interest in the MAKS concept. With serious problems in the Hermes programme, the Council of Ministers have proposed "greater and deeper co-operation with Russia to arrive at a crewed space transportation system." Thus MAKS has become a serious contender as a collaborative replacement for Hermes.

An-225

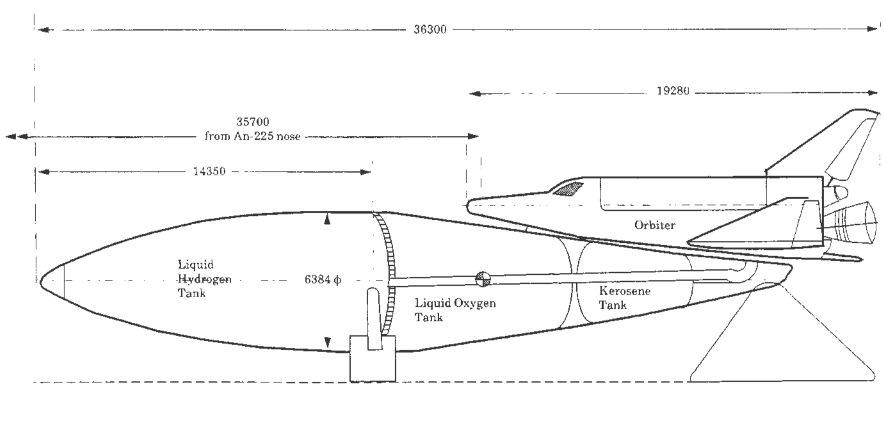
The An-225 aircraft is a development by the Antonov design bureau which is located in Kiev in the Ukraine. It is an enlargement of the earlier transport aircraft - the An-124 "Russlan" which was a Soviet equivalent of the American C-5A "Galaxy" military transport. The An-124 is actually about 5% bigger than the C-5A (making it the previous record holder as the world's largest aircraft) but looks very similar - a four engined, high wing, roll-on roll-off transport - and it had a very similar mission. An-124s are currently doing sterling work supporting emergency airlifts in various of the world's trouble spots.

At the moment there is only one An-225. It was constructed from a production An-124 by adding a new centre section to the wing, carrying two extra Lotarev D-18 engines, modifying the tail to a split fin arrangement, and adding a new centre section to the fuselage which takes the additional undercarriage to carry the massive 50% increase in size over its "smaller" brother! The way in which the An-225 is a modified An-124 is very clearly shown on the flight deck, where instruments for the engines are arranged in banks of four, with the extra dials for the extra engines added where space permits. With six throttle control levers in a row between the pilots seats, one feels a big pair of hands are needed to fly it.

The Antonov Bureau christened the An-225 "Mriya", which is Ukrainian for dream. It was, they said, big enough to carry anybody's dream. The name is very definitely

Ukrainian - the Russian alphabet does not even have a letter "ï".

Although there is currently only one experimental An-225, it is clear that further aircraft can easily be constructed using components from the An-124 production line. Its potential is enormous. Not only does it have the capability to carry up to 275 tonnes, it has an impressive 10,000 km range to carry an unfueled MAKS or HOTOL to remote launch sites. As one example of its flexibility, when the HOTOL team wanted to design for operations out of the "hot and wet" launch site at Kourou and it appeared the take off acceleration would be too low. The Antonov designers rapidly came up with a scheme for an eight engined version, by simply podding the inboard engines in pairs - the wing was already strong enough for the extra forces involved.



MAKS Orbiter and External Tank

Prepared by British Aerospace Space & Communications Ltd

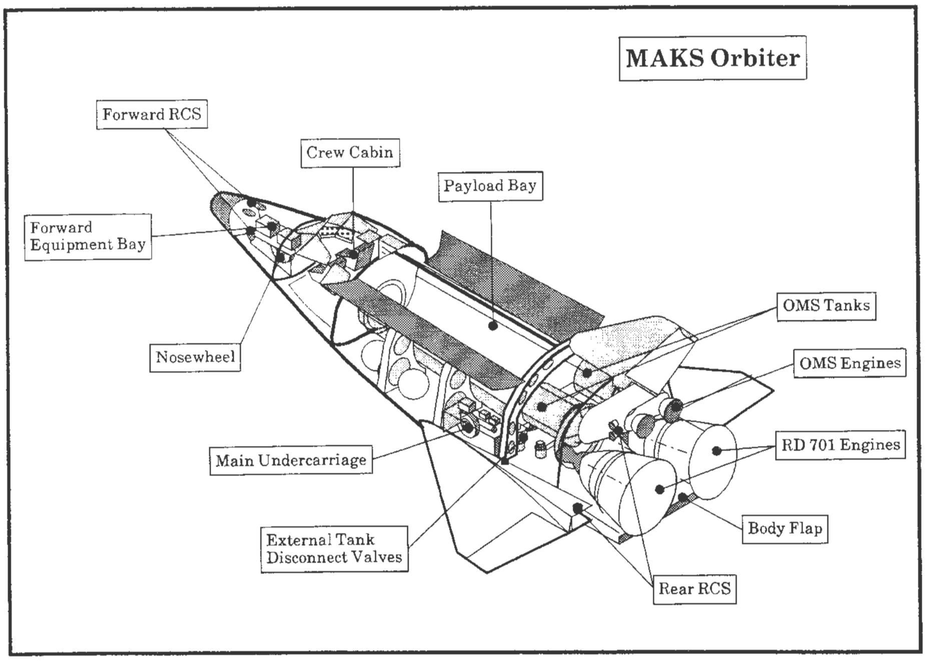
The An-225's suitability as a SSTO carrier is not just because it can carry a large payload. The detailed design is also intended for the role. It has suitable hardpoints on its back and provisions for many of the other systems needed for this task. This was partly to enable it to be a carrier aircraft for the Buran space shuttle, but also because it had been designed from the start as a launch platform for MAKS. This brings us to the history of the MAKS project

History

In 1982 the US Air Force had a proposal for an air launched Space Sortie System. This was a small reusable vehicle intended to be operated in much the same way as a military aircraft, and to perform "rapid access" missions to low Earth orbit with minimal payloads. The orbiter vehicle was to be carried aloft by a modified Boeing 747-200, and used a drop tank (with about two thirds of the propellant) and a winged reusable orbiter which carried the remainder of the propellants, engines, crew and payload. The Space Sortie System used "off the shelf" engines in the form of nine RL-10s as used on the Centaur stage. In addition a further seven RL-10s were installed in the tail of the 747 to augment the thrust and provide a high flight path angle for separation.

The Space Sortie System was seen as a way of providing an "on demand" small launch capability, operating out of conventional military airfields and capable of being launched into a variety of orbits at short notice. In theory the Sortie vehicle could have flown over any point on the Earth's surface within 90 minutes of take off. The winged orbiter would then have sufficient cross-range to land at a predetermined Air Force base within the USA. Unfortunately the carrying capability of the Boeing 747 restricted the system payload to about 3 tonnes into a 28.5 degree orbit and less than a tonne into a polar orbit (were the real military interest lay). With such a limited capability the idea died before it could be turned into hardware, like so many promising concepts before and since.

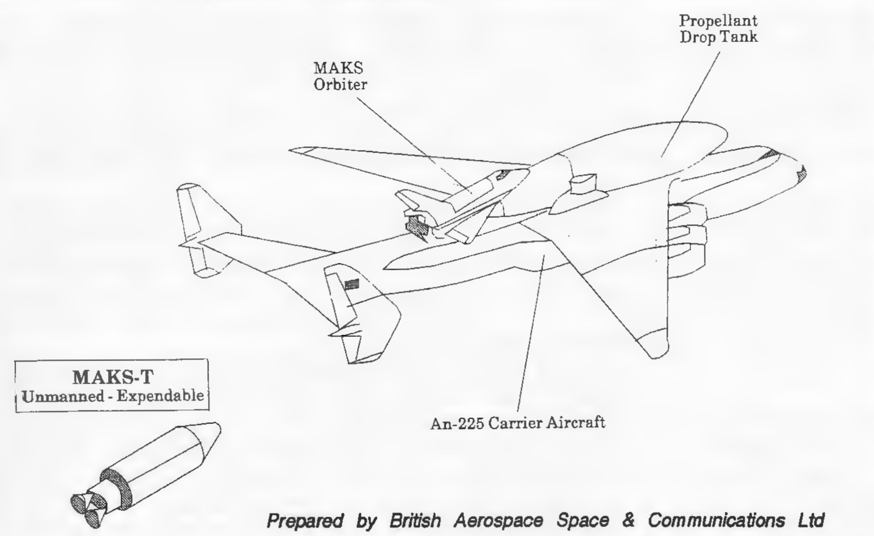
About the same time as the USAF was looking at the Space Sortie System, NPO Molnija started looking at a similar system based on the An-124. This was the birth of the MAKS project. Like the American study they found the concept technically viable, but the carrying capability of the An-124 restricted possible payloads to the point where they were too small to be of interest. In 1985 the study moved to considering launching from the new An-225 and the Council of Chief Designers approved development of the An-225 with one of the defined requirements being to carry MAKS. A little later work also started on a new engine for MAKS, the RD701, which is discussed later.



Vehicle

The current MAKS configuration has a 20m long winged orbiter and a single drop tank containing all the ascent propellant in an arrangement similar to the USA Space Shuttle. At separation from the An-225 the MAKS stack (orbiter plus tank) is 36.3 m long and weighs 275 tonnes of which 27 tonnes is the orbiter, 11 tonnes is the dry external tank, and the remaining 237 tonnes is propellant.

The drop tank is a major difference to the Interim HOTOL concept. It has a maximum diameter of 6.4 m and is largely manufactured from aluminium/lithium alloy. The forward hydrogen tank is separated from the oxygen tank by an insulated "common bulkhead" in a similar arrangement to that used on the USA Centaur and Saturn 5. The kerosine tank is in the rear of the elongated tear drop shape. Because the propellants are stored externally from the orbiter it is much smaller than the Interim HOTOL (see table). A conse-



Prepared by British Aerospace Space & Communications Ltd

quence of this is that the payload bay is much smaller than in the HOTOL concepts. It is 6.8 meter long and tapers from 3.0 m at the rear to 2.6 meters at the nose.

The NPO Molnija design team led by Chief Designer Gleb Lozino-Lozinsky plan three versions of MAKS. The manned version which would be used for crew transfer and other missions requiring manned intervention. The manned vehicle has a small cabin which carries a crew of two but it would be possible to add a passenger cabin in the payload bay to increase the crew size. The accommodation is much smaller than Shuttle, Buran, or even Hermes and is not intended to turn the orbiter into a mini-space station with long orbital flights. MAKS is seen as solely a transport system for payload and crew delivery and the maximum mission is only 5 days.

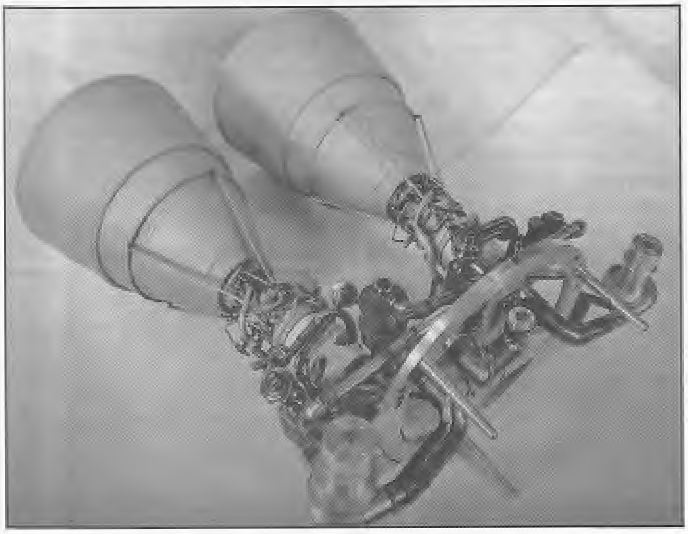
The unmanned version for delivery of cargo follows closely the HOTOL unmanned philosophy. However whereas HOTOL's approach was to add crew to a primarily unmanned system, the MAKS' approach has been to take the crew out of a manned system. This unmanned version would remove the crew cabin allowing the payload bay to be extended to 8.75 m and adding over a tonne to the payload mass.

A third totally expendable version of MAKS is also understudy called MAKS-T. In some respects this concept is reminiscent of the Shuttle-C proposals in that most of the systems are common with the reusable MAKS, but in this case all the hardware is thrown away. Although the cost per launch rises dramatically, the MAKS-T could place 16 tonnes into orbit, which is close to the performance of Ariane 5 and Titan III.

The technology used in the MAKS orbiter is described by NPO Molnija as "conventional" and uses the experience gained on the Buran shuttle. Their estimated payload is 8.5 tonnes for the manned version into a 200 km 51° orbit and 9.5 tonnes for the unmanned version. These estimates may be a little optimistic, but it is clear that there is considerable commonality in a number of key technology areas with the ESA work on Hermes, and a joint CIS/ESA programme would have some confidence in achieving very competitive payload masses.

Engine

While originally a conventional oxygen/hydrogen vehicle the MAKS designers discovered that the performance of the vehicle would be very significantly improved by using a tripropellant system. As a consequence a new engine development was started with the unique feature of being able to burn three propellants together in the same combustion chamber. The engine is designated the RD-701 and has been under active development by the NPO Energomash, under its general director Boris Katorgin, since 1988. The MAKS orbiter has one of these engines mounted in the rear engine bay.



RD701 tripropellant rocket engine mock-up.

Energomash is based in a Moscow suburb called Khimky and produces the RD-170 a four chambered oxygen-kerosine engine used on the Energia boosters and the RD-171 derivative used on the Zenit launch system. The experience gained on the engines was exploited as a basis for the RD-701.

The RD-701 is a twin chambered engine (i.e. it has two separate nozzles) capable of operating as an oxygen-hydrogen-kerosine engine (Mode 1) for high thrust, or a pure oxygen-hydrogen engine (Mode 2) for high performance measured by specific impulse. As with all modern CIS rocket engines the RD-701 uses a "closed cycle" in which exhaust from the pump turbines is fed into the main chamber for increased efficiency. Each chamber has two pumps feeding it, one pump supplies both the kerosine and liquid oxygen and the other the liquid hydrogen.

RD-701 Performance

		MODE 1	MODE 2
Vacuum Thrust (kN)		2 x 2000	2 x 785
Vacuum Specific Impulse (N sec/kg)		4071	4532
Launch* Specific Impulse (N sec/kg)		3885	-
Flow rates	LOX (kg/s)	2 x 388.4	2 x 148.5
	LH2 (kg/s)	2 x 29.5	2 x 24.7
	Kerosine (kg/s)	2 x 73.7	-
Expansion Ratio	(Extension down)	170	170
	(Extension up)	70	-
Chamber Pressure (bar)		300	150

* 10 km altitude - Nozzle extension up

Another interesting feature of the RD-701 is its use of a deployable nozzle extension which is lowered into place when the engine is in near vacuum to increase the performance. This increases the engine length from 3.8m to 5.4 m and gives an exit diameter of 2.4 m. When in place and operating in the oxygen-hydrogen mode the RD-701 has a specific impulse of 4532 N sec/kg; some 100 N sec/kg higher than the US Space Shuttle main engines.

As with the US Space Shuttle the engine is fed from the external tank, via fast acting couplings on the undersurface of the orbiter, through into the rear of the payload bay into the engine's feed pumps. Also like the US Space Shuttle the orbiter has integral orbital manouvering engines for orbit injection, rendezvous, and reentry manoeuvres.

Mission

The launch process starts with the MAKS Orbiter being integrated to the external tank. The payload is then installed within the payload bay and the complete Orbiter/tank assembly is then lifted onto the back of the An-225. The propellants are loaded into the external tank just before take off.

At the end of the runway the whole assembly weighs 620 tonnes. After a conventional aircraft take off, the An-225 carries MAKS to an altitude of between 9 km and 10 km with an airspeed of Mach 0.8 (240 m/s). Up to one hour can elapse between take off and the launch of the MAKS orbiter. In this time the An-225 can travel up to 750 km from the airfield. This gives wider range in flexibility in launch time and inclination than a fixed launch site.

The separation manoeuvre is a delicate one. The MAKS vehicle must perform a pull up to separate it from the An-225, and light the rocket engine without damaging the carrier aircraft. As with the Interim HOTOL it is likely that the An-225 will perform a powered dive manoeuvre with a pull up, at the moment of separation. Although by way of contrast the US Space Sortie System proposed another approach of climb and "push over" to separate.

At ignition the engines must provide maximum thrust driving the MAKS vehicle, which is heavy with fuel, into an ascent trajectory out of the atmosphere. So the RD-701 is in its tripropellant mode. When the pressure has dropped to close to vacuum the nozzle extension is lowered to increase the expansion ratio and hence improve the engine performance.

When all the kerosine has been used the engine switches to liquid hydrogen and oxygen mode and is working at maximum performance. In this mode the engine thrust is reduced by more than half. This is acceptable as the system is now considerably lighter than at launch due to the propellant that has been burnt.

Like the Shuttle, MAKS discards the external tank before reaching orbital velocity, leaving it to destructively reenter the Earth's atmosphere and burn up. The MAKS orbiter then uses the smaller orbital manouvering propulsion system to reach its final orbit, which can be between 200 km and 800 km altitude. After performing the mission MAKS would perform a deorbit burn, reenter the atmosphere, and then, like the Shuttle, it would glide down to a runway landing at the launch site.

For a typical "transport and maintenance" mission to a space station such as Mir, MAKS would carry a rendezvous system, a "Mating Module", and a pressurized cargo compartment. The Mating Module would be mounted in the payload bay immediately behind the crew compartment. In addition to connecting the crew cabin and cargo compartment, it would carry an expanding adapter tunnel with the docking interface on it. This would be the connection to the space station. The Mating Module has an internal volume of 3 m^3 and the cargo compartment a volume of 20 m^3. If additional crew were required the pressurised cargo compartment would be replaced by a passenger module. MAKS could also carry a manipulator similar to the Shuttle Canadarm or the Hermes HERA system.

Other mission for MAKS could included satellite deployment, conducting non deployable experiments, reconnaissance (military and civil) and satellite repair or recovery.

Programme

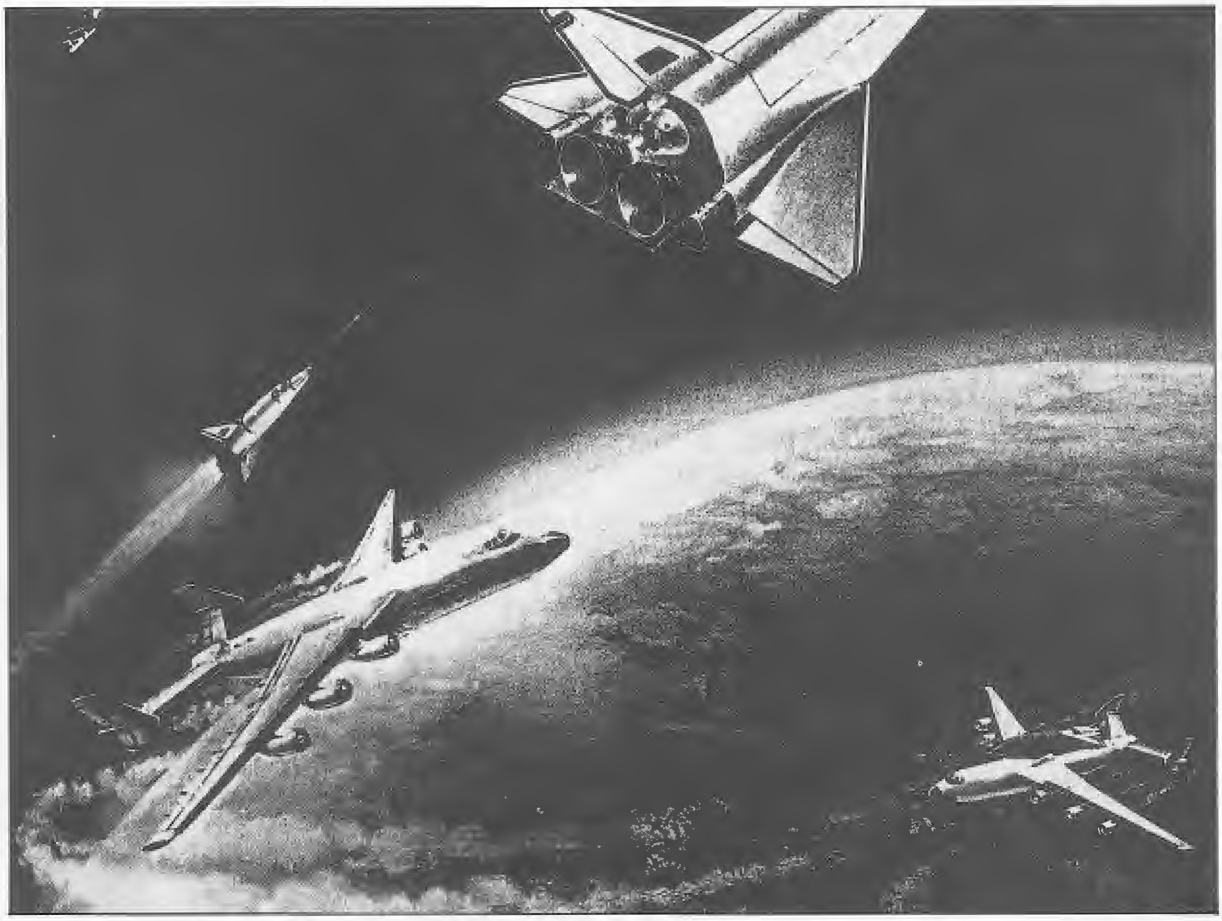
Since 1982 NPO Molnija have made considerable progress on the concept. The An-225 has flown and proven its performance. The RD-701 is 25% of the way through its development, and engineering mock ups have been made (see figure). MAKS structural models for strength and interface evaluation and a cockpit mock up for human interaction analysis have also been constructed.

Overall there has been considerable progress on MAKS development and NPO Molnija believe that a properly funded programme could achieve a first flight in 1997 with the system operational by 1999. This would meet the original intention of the HOTOL programme to get a reusable launch system with low cost on demand access to space in operation before the end of the century.

The NPO Molnija estimate the development costs at around 3.5 billion ESA accounting units (au). British Aerospace using West European costings estimated 6.2 billion au for the total programme. This difference is interesting in that it highlights the lower costs in the CIS. This is partly the lower labour costs, but is also a measure of the more efficient project management methods used. A joint ESA/CIS programme would probably cost somewhere between these two estimates, although it is to be hoped that ESA nations can absorb some of the cost effective project methods of the CIS approach, rather than inflict its expensive methods on to the CIS.

The Future?

There are now two proposals (Interim HOTOL and MAKS) based on the An-225 that would meet the HOTOL project objective to achieve low cost on demand delivery into orbit before the year 2000. So which is the best way forward?



Artist's impression of the MAKS system in operation.

Interim HOTOL would have the better cost performance. Its payload mass is very similar to MAKS, but the payload bay is larger and compatible with other launch systems such as the Shuttle and Ariane. It would also have lower operational costs due to simpler ground handling and its total reusability. British Aerospace estimate each Interim HOTOL flight will cost 10.3 million au.

MAKS launches will be more expensive; British Aerospace estimate 12.8 million au per launch. MAKS advantage is the lower development cost which is between 3 - 4.5 billion au to complete the project, compared with the British Aerospace estimate of 6.8 billion au for the Interim HOTOL. This lower development cost is in part due to its less ambitious technology and also the very large investment the CIS has already made in the vehicle.

The question of best approach then centres on whether the lower operational costs of the Interim HOTOL can repay the higher development costs. This depends on how long the system is expected to be in operation and to answer that question requires planning of when the advance airbreathing launch system is to be operational.

However it is not only the HOTOL team that are likely to be interested. MAKS is also very similar in overall performance to the early Hermes (1985 vintage) when it had an external payload bay and was intended for a real infrastructure role. The technologies required by MAKS are also very similar to Hermes. So MAKS may prove a more practical and cheaper route to realising the Hermes goals. Given MAKS could go some way to meeting both British and continental European infrastructure objectives it makes an interesting candidate for CIS-ESA cooperation.

It is clear MAKS represents a unique opportunity for Western European nations to recover the lost momentum of their infrastructure programmes. While it does not completely satisfy either the British "economic capability" thinking typified by HOTOL, or the French "prestige and technology" thinking typified by Hermes, it is a workable compromise between the two. Thanks to the efforts the CIS have already made, it can be put in place quickly and comparatively cheaply.

However to start a joint ESA/CIS project and to carry it through to a successful conclusion, avoiding the problems afflicting Hermes and Columbus, will take a much clearer vision of the purpose of space within Europe and better management within the western European space industry. Without such a new start the promise of MAKS will almost certainty never be realised.

Comparison of MAKS, Interim HOTOL and Hermes.

	MAKS Orbiter	Interim HOTOL	Hermes
Length (m)	19.3	36.5	18.6#
Wing span (m)	12.5	21.6	9.0
Launch mass (less payload) (tonnes)	18.4	31.5	21.4#
Payload mass (tonnes)	8.5##	7	3
Payload bay diameter (m)	3 to 2.6	4.6	None*
Payload bay length (m)	6.8	7	None*
Crew	2**	0†	3

\# Includes expendable Resource Module
\## Unmanned version 9.5 tonnes
* Hermes payload is carried within the pressurised cabin and Resource Module
** Unmanned versions and passenger carrying versions also under study
† 4 to 6 people would be carried in the manned version

'On Console' for 14-Day Mission

Huntsville Operations Control Center in Action

As an assistant to the Mission Scientist, *Dale M. Kornfeld* worked at the Mission Scientist console position in the Payload Control Room M-203 at Marshall Spacelab Mission Operations Control during the 14-day STS-50 United States Microgravity Laboratory-1 (USML-1) shuttle mission. He writes for *Spaceflight* about the impressive team support organisation at the NASA Marshall Space Flight Center in Huntsville that swings into action during each shuttle Spacelab mission.

Huntsville Spacelab Mission Operations Control Center. From Left: Ann Bathew (DMC), James Downey, Dale Kornfeld (Assistant MSCI) and Don Frazier (MSCI).

BY DALE M. KORNFELD
Alabama, USA

The Payload Control Room M-203 is called the "front room" because the main cadre team leaders are located there and the NASA Public Affairs Office TV cameras broadcast views of us sitting at these consoles. There are several other payload support "back rooms" at MSFC, where the rest of the team members sit at their consoles (but no TV cameras), plus the Science Operations Area rooms where all the Principal Investigator teams man their consoles.

Personnel Organisation

The Mission SCientist (MSCI) is leader of the PI (Principal Investigator) science experiment teams. For USML-1 it was Dr Don Frazier. The MSCI manages all science-related activities during all phases of the shuttle mission, approves all science inputs to the flight timeline, directs all science meetings and mediates any PI conflicts concerning science and onboard resource requirements. He reports directly to the Marshall Payload Operations Director. The POD is chief of all payload cadre at Marshall and is the counterpart of the Flight Director at Houston.

STS-50 USML-1 Mission Payload Operations.

Our Mission Scientist Team monitored on the console every step of every experiment as it was being conducted by the crew. We worked with all the Principal Investigator Teams to help resolve experiment anomalies and interfaced between them and the other MSFC cadre when necessary to reschedule activities.

An Alternate Payload Specialist sat nearby and worked with us on each shift. The APS is a trained alternate crewmember who would have flown if a primary crewmember had had to drop out. He assisted the Mission Scientist team, PI teams and other cadre on crew science and hardware procedures and overall Spacelab operations.

Dozens of additional support people are involved at MSFC, without which we could never have a successful shuttle Spacelab mission. All the PI and cadre teams are located at Marshall and are involved strictly with the Spacelab module and science experiments whereas the function of those at Houston is to monitor and control the Shuttle itself after launch from Kennedy Space Center.

The 14-day USML-1 flight was the longest Shuttle mission to date and we can now say that it was the most perfect shuttle science mission ever flown. The Mission Scientist and two Assistants manned our consoles during each shift for 15 straight days. We had our "call-to-stations" and went on console two days before launch but were released early on the last day, after all science operations had been completed and when the landing was postponed a day due to rain at Edwards AFB. The seven member astronaut crew divided into two 12-hour shifts, Red and Blue, in order to work around the clock during the whole mission. I worked mostly the Red Shift.

The entire Huntsville and Houston mission cadres and the flight crew trained as a group during a long series of sims which began in December 1991. Sims are one or two-day mission simulation exercises on the consoles, with the crew working in the Huntsville Payload Crew Training Complex (PCTC) Spacelab simulator. The mission went a lot smoother and easier than any of the sims, since during each sim all sorts of awful things are programmed to happen to the hardware, shuttle, or experiments, in order to train the crew and all of us to respond to malfunctions. It became apparent soon after launch that this was not just another sim, because everything was actually working great. The launch phase and all Spacelab module and experiment activations proceeded perfectly and our job was not very hard. The only minor hardware glitch was when a microswitch failed on the new carbon dioxide air scrubber system but the crew quickly fixed it and it ran perfectly for the rest of the mission.

Working this mission as a cadre member was quite a change from my usual laboratory research and now that it is over I can look back and say it was a lot of fun. However, during training (with all those awful sims) and while the mission was underway, it was a pretty intense experience.

Just about everything planned during the entire mission was accomplished and some extra experiments and activities were performed beyond what was scheduled.

Cadre Teams Located at MSFC

Operations Controller Team: composed of the Operations Controller, Crew Interface Coordinator, Payload Systems Engineer, Crew Procedures Engineer, Mass-memory Unit Manager and PAYload COMmunications Manager;

Payload Activity Planning Team: composed of the Payload Activity Planner, TimeLine Engineers, ORBITal analysis Engineer, and Payload Replanning Engineer;

Data Management Team: composed of the Data Management Coordinator, Data REPlanner, Data Flow Analyst and TV OPerationS.

SPACE SHUTTLE: STS-53

Last Mission with Classified Payload

Landing Diverted to Edwards AFB

Together with a classified Department of Defense primary payload, Space Shuttle Discovery also carried two secondary payloads and a number of middeck science experiments. The secondary payloads included studies of Shuttle glow phenomena, cryogenic heat pipe development and detection of simulated orbital debris. Middeck experiments studied the potential to produce pharmaceutical microcapsules for medicine and physiological studies.

BY ROELOF L. SCHUILING
At the Kennedy Space Center

Although this mission was Discovery's fifteenth flight, the orbiter had not been in space since January 22, 1992 when it returned from mission STS-42. Since then 78 major modifications have been carried out on it, the most significant being the addition of a parachute drag for landing, and the capability for redundant nose wheel steering. The orbiter also underwent a number of inspections.

In late July the three main engines were installed on Discovery with main engine 2024 in the number 1, or centre, position with engines 2012 and 2017 in positions 2 and 3.

Also in late July and August the unclassified secondary payloads GCP (Glow and Cryogenic Heat Pipe) and ODERACS (Orbital Debris Radar Calibration Spheres) were installed. Discovery's primary payload was a Department of Defense payload which was installed at the launch pad.

On November 3, Discovery was transported to the Vehicle Assembly Building, where it was rotated to a vertical position and mated with the External Tank and two Solid Rocket Boosters. On November 8, the completed Shuttle vehicle was rolled out of the Vehicle Assembly Building and out to Launch Pad 39A.

While at the launch pad Discovery underwent a simulated countdown, received its primary payload on November 19, and loaded hypergolic propellants for its manoeuvring system and reaction control system engines.

On November 30 the launch countdown was picked up 3 hours early to give extra time for fuel cell cryogenic reactant operations. The countdown proceeded without major impact until an extended hold at T-9 minutes on December 2.

The launch had been scheduled for 6:59 am that morning; however, cold weather delayed the launch until 8:24 am. Temperature overnight had dipped to 47 degrees and a coat of ice and frost had accumulated around the cryogenic propellant areas of the External Tank.

With sunrise scheduled to occur at 6:58 am, mission managers elected to continue with the countdown and then to extend the built-in hold at T-9 minutes. The hold was extended for an hour and twenty-five minutes during which period the Kennedy Space Center's Ice Evaluation Team went to the launch pad to monitor the ice buildup on the tank. The Ice Evaluation Team monitors the Shuttles on each launch to insure that no hazard from ice buildup is present. The concern of the launch team is that should an ice buildup be shaken loose at launch, some ice debris could hit the

The Space Shuttle Discovery soars into a cloud-studded sky from the Kennedy Space Center's Launch Complex 39A on December 2, 1992 at 8:24 am. It carried a crew of five, a classified Department of Defense primary payload, two secondary payloads and a varied complement of middeck science experiments. Cold weather delayed the launch by 2 hours 25 minutes.
NASA

Pilot Robert D. Cabana (front, left) and Commander David M. Walker (front, right) lead the way from the Operations and Checkout Building, enroute to the Space Shuttle Discovery at Launch Pad 39A. Behind them are Mission Specialists Michael "Rich" Clifford (left), Guion S. Bluford, Jr, and James S. Voss. The crew is all-military: Cabana, holding the "Beat Army" banner, is in the Marine Corps; Clifford and Voss are Army. *NASA*

Shuttle's thermal protection tiles and damage them. As the Sun came up and warmed the area, the Ice Evaluation Team reported that the frosty coating was melting. After about an hour, they determined that no further concern existed and the team returned to the Launch Control Center.

The countdown picked up and proceeded flawlessly to the liftoff point and Discovery began its ascent northward to a 57 degree inclination orbit. The Solid Rocket Boosters cutoff on schedule at 2 minutes 4 seconds into the mission and the main engines cutoff at 8 minutes and 42 seconds into the flight. Following the burn of its orbital manoeuvring engines, Discovery was placed in a circular orbit at an inclination of 57 degrees and height of 200 nautical miles with all systems operating normally.

Flight Day One

Following its successful liftoff at 8:24 am (all times KSC time) Discovery performed a circularising manoeuvring system engine firing to place it in a 200 nautical mile orbit. At approximately 10:00 am the orbiter's payload bay doors were opened and the crew was given a "go for orbital operations". Discovery's first business involved the classified Department of Defense payload which was deployed at 2:18 pm with all activities proceeding as planned. Mission commentary, television and Space Shuttle-ground communications were then resumed.

The crew activated several secondary experiments, including the Cosmic Radiation Effects and Activation Monitor (CREAM) and the Radiation Monitoring Equipment (RME), which made complementary measurements of the radiation in the crew cabin. The crew also began medical tests which are performed on many Shuttle flights to study the effects of weightlessness. These involved photography of the retina and measurement of pressures within the eye.

Discovery's crew activated the Glow Experiment/Cryogenic Heatpipe (GCP) payload which is a Hitchhiker programme payload from the Goddard Space Flight Center where their experimental data were received after being removed from the Shuttle's downlink data stream at Mission Control.

Flight Day Two

The morning was spent working with several experiments and making Earth observations from the 57-degree inclination orbit. The crew activated the hand-held Earth-oriented Real-time Cooperative User-friendly Location-targeting and Environmental Systems (HERCULES) experiments, a modified camera system designed to enable an astronaut to precisely determine the latitude and longitude of terrestrial features as they are being photographed from orbit. This was the first HERCULES flight. Sites observed included Eleuthera Island in the Bahamas, Minch Peninsula in Denmark and Galveston Island, Texas.

The Battlefield Laser Acquisition Sensor test (BLAST) uses a laser receiver to detect laser energy from ground-based locations to provide data for the development of sensor technology for laser communications. BLAST was activated but the two opportunities on this day were unsuccessful due to ground site problems.

The Fluid Acquisition and Resupply Experiment (FARE) was used to investigate the physics of fluid transfer in microgravity. Such information is needed to plan operations involving fluid replenishment on long-term space missions such as the Space Station and the Extended Duration Orbiter flights.

Later in the day the crew performed two manoeuvring system engine burns to reduce altitude from 200 to 175 nautical miles. The reduction was in preparation for the release of a series of metal spheres planned for the following day.

STS-53 Crewmembers

Commander of the five man crew was David M. Walker who served in the same capacity on Mission STS-30 in May of 1989. Walker was also the pilot on STS-51A, his first space flight, in November of 1984. The pilot was Robert D. Cabana who was also the pilot of the STS-41 mission in October of 1990. Mission specialist 1 was Guion S. Bluford Jr who was a veteran of STS-8, STS-61A and STS-39; during which he accumulated over 500 hours of space flight. James S. Voss was mission specialist 2 and had flown on STS-44 in November of 1991. Michael R. Clifford, mission specialist 3, was making his first flight.

Flight Day Three

The crew had planned to release six spheres from the Orbital Debris Radar Calibration Spheres (ODERACS) experiment on this day. The spheres were in two sets of three with one set of aluminium and one of stainless steel. Each set comprised a two, four, and six-inch diameter sphere. The purpose of the experiment was to provide known targets for the calibration of ground-based radars used to study orbital debris. The release had been planned for 6:22 am. However, about ten minutes before the planned release the crew reported they were not getting good signals through the deployment system electronics. The system was rechecked and the crew attempted to use a second input location to the ODERACS electronics but the expected response from the experiment was not received. The 20-minute deployment window was passed without success and the experiment attempt was terminated as ground controllers began an analysis to determine the probable cause of the problem. The next deployment opportunity would not come until Flight Day Five. Later in the day the crew used a test kit from the standard Shuttle tool kit equipment to verify connections in the cabin.

Flight Day Four

The crew continued work with the secondary payload experiments during the day. Later in the day, after considerable analysis, ground controllers passed the word to the crew that the decision had been made not to attempt any further ODERACS deployment activity. Their analysis indicated that the most likely problem was a dead battery within the payload bay-mounted experiment. The decision was based on the review of manufacturing, ground processing and in-flight data; however it would be impossible to verify that conclusion until after the mission had landed.

Flight Day Five

The Discovery's crew continued a variety of scientific and engineering studies on their fifth day in space and also took time out to hold an in-flight press conference with reporters on the ground at NASA Centers.

Landing weather predictions of possible marginal conditions

At Launch Pad 39A, the white room closeout crew helps STS-53 Mission specialist James S. Voss (left), Michael "Rich" Clifford and Pilot Robert D. Cabana prepare to enter the cockpit of the Space Shuttle Discovery, awaiting liftoff at 6:59 am, EST. *NASA*

prompted a request from Mission Control that the crew power-down non-critical equipment to save electricity. This would add to the Discovery's power margins in the event that the flight might have to be extended beyond its current reserves. The amount of electricity available aboard a Space shuttle is related to the usage of cryogenic hydrogen and oxygen in the electricity-producing fuel cells. Reducing the power usage prolongs the reserve of those reactants.

Flight Day Six

It was a busy day for the crew as Guy Bluford, Jim Voss and Rich Clifford performed secondary payload experiment operations including HERCULES and BLAST data takes, visual function tests, and an experiment designed to produce pharmaceutical microcapsules in space. The microcapsules contained ampicillin and would later be compared with ground-produced ampicillin microcapsules for comparison.

The day's activities included a Flight Control System checkout to verify the mechanical and hydraulic systems which are required for the shuttle's landing. This checkout also verified displays and sensors used by the crew during landing. In addition the crew performed a test of the Reaction Control System with a thruster firing test. Checking out orbiter systems in preparation for landing is usually performed on the day prior to landing; however on STS-53 it was moved up one day to provide uninterrupted data gathering for the GCP glow experiment on the day before landing. Due to the launch time, the day, and the high inclination orbit parameters, Discovery had not spent the time in darkness required for the final day's test until December 8.

Following these operations, an orbital manoeuvring system burn was performed to lower Discovery's orbit and set up an additional possible landing opportunity for the KSC runway due to the predicted marginal weather conditions at the planned landing time.

Flight Day Seven

Much of the crew's activity involved studies of the Glow effect in a night environment. Onboard thrusters were fired and data were also taken during fuel cell purge and overboard water dumps to determine the effects of these activities on the fluorescent effect created as the Shuttle encounters atomic oxygen in orbit.

The secondary payload activities were completed and the equipment stowed for landing. FARE completed its eighth and final run. HERCULES was stowed after having taken more than 200 photographs, eight times as many as planned. BLAST had completed 20 attempts to send laser information to orbit; however poor weather and ground equipment problems allowed only two receptions by the Shuttle equipment and further analysis will be done on the system.

Other experiments involving radiation studies, analysis of tissue loss, studies of cloud fields from orbit ad visual function test equipment were stowed in preparation for landing.

Before going to sleep, the crew performed a small two foot-per-second thruster jet burn to avoid a piece of space debris.

Flight Day Eight

After final preparations for the planned Kennedy Space Center Landing were completed the mission was diverted from KSC due to cloud cover. The STS-53 mission ended with touching down on the Edwards Air Force base, California after 7 days, 7 hours, 19 minutes and 19 seconds of space flight. Discovery's main gear touched down on runway 22 at 3:43:17 pm Florida time on December 9, 1992 (local California time was 12:43:17 pm). Nose gear touchdown was at 3:44:04 and wheel stop at 3:45 pm.

The crew departure from the orbiter was delayed due to a leak in one of the orbiter's nose thrusters. Ground personnel performed extensive checks to insure that no danger to the crew was present before the hatch was opened and the crew left the orbiter an hour and a half later than planned. Later that day the Discovery began preparations for its return to florida aboard the Shuttle's 747 ferrying aircraft.

Launch Report

Shuttle: Prelude to Space Station Work in 1993

With the launch of the first element of Space Station Freedom just three years away, NASA will continue to use the Space Shuttle fleet in 1993 for research associated with Space Station assembly and operations.

The space station programme is on schedule to complete its first Critical Design Review (CDR) in June. The CDR marks a commitment on the part of the space station programme managers to proceed from the design stage to the fabrication and acquisition of flight hardware and software. The CDR includes the review of thousands of engineering drawings and other design documents by NASA and contractor personnel.

Beginning with the first Shuttle flight in January (see p.96 for a report on STS-54) and ending with the eighth mission in December, astronauts will conduct spacewalks, materials and life sciences research and small-scale experiments to prepare for long-duration stays in space aboard Freedom. Spacewalks will be conducted on at least three flights in 1993 to prepare astronauts for station assembly and maintenance. These will help to predict the length of specific tasks and investigate the use of handrails and foot restraints while manoeuvring equipment similar to that being designed for Freedom.

Columbia (STS-55)

The first Spacelab module flight of 1993 is a German-sponsored mission of 9 days duration to continue studies in materials and life sciences research to further technology development for use in the space station era. (See opposite).

Discovery (STS-56)

Included on this flight is ODERACS or Orbital Debris and Radar Calibration Spheres. This experiment will help calibrate ground-based instruments used to track orbital debris. Three pairs of precisely-machined metal spheres of different diameters will be released from a canister in the payload bay and will be tracked by ground radar to calibrate them more accurately. This will allow a better determination of the life expectancy of space debris, assisting in the development of Freedom's protective shield. ODERACS was flown on STS-53 in December 1992, but a loss of battery power inside the canister prevented release of the spheres. (See p. 86).

Endeavour (STS-57)

An experiment, which first flew on the STS-54 mission in January, will be flown as a full experiment on this mission to grow larger, high fidelity tissue cells for clinical research. STS-57 will carry cancer cells to be grown in the chamber and brought back for study. On the ground, cells tend to lose their neutral buoyancy or ability to remain suspended in the nutritional fluids inside the chamber. In space, however, the cells can grow larger without floating toward the chamber walls. On the Shuttle, the experiment will serve as the "foundation experiment" for the development of bioreactor technology on the space station. Growing cells to full maturity may take several months, which only can be done on long-duration flights aboard the station.

Spacehab, which has its first flight, will carry a space station flight experiment called the Environmental Control and Life Support Systems Flight Experiment, containing two critical components of Freedom's environmental control system. This mission is being considered for another spacewalk to continue proficiency training for space station assembly and maintenance.

Discovery (STS-51)

The crew of STS-51 will expose various materials to the space environment to determine which are best for use in future spacecraft design, including the space station, to ensure long-term survivability in space. Freedom is designed for a minimum 30-year life.

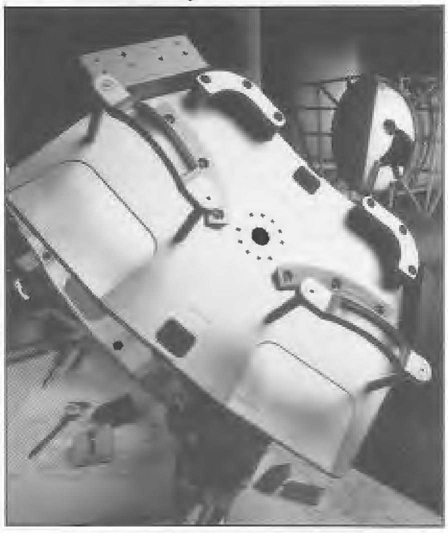
This flight is being considered for another spacewalk to continue proficiency training for space station assembly and maintenance. Current plans call for EVAs to occur on either this mission or on STS-57 in April, or both.

Columbia (STS-58)

This Life Sciences mission (SLS-2) is the second devoted exclusively to understanding how the human body reacts and adapts itself to the space flight environment and is of particular interest since plans call for astronauts to live aboard Freedom for periods of 90 days or more. It will continue the medical evaluations of SLS-1 which flew for 9 days in June 1991.

This will be the second "extended duration" Shuttle mission. STS-50 in June 1992 lasted 14 days and is the longest shuttle mission to date. SLS-2 will continue the process of certifying the Shuttle to conduct longer duration flights docked to Freedom.

A Foothold in Space



Lockheed, the principal subcontractor on the Space Station Freedom program, has developed an articulating portable foot restraint to aid astronauts while working outside Space Station Freedom. Lockheed Engineering & Sciences Company (LESC) designed the device for NASA to be attached at various points along the orbiting structure to aid astronauts who will assemble and maintain Space Station Freedom during extravehicular activity. The restraint can also be used with a portable work platform.
Eric Schulzinger/Lockheed

Discovery (STS-60)

This second Spacehab flight will carry a large complement of secondary experiments in the additional middeck locker space. The module is attached to the orbiter's airlock and more than doubles the space to conduct secondary materials and life sciences investigations as precursor experiments to those that will fly on Freedom.

A Russian cosmonaut will be among the crew member aboard Discovery for STS-60 (see ***Spaceflight***, December 1992, p.382). A series of medical evaluations will further investigate the adaptation of the human body to space flight as well as readaptation to the Earth environment.

Endeavour (STS-61)

The final mission of 1993 highlights the first servicing mission to the Hubble Space Telescope (HST). The work scheduled, as well as spacewalks involved will provide further data for the space station era.

Long-Stay Mir Missions to Continue in 1993

The Russian manned flight programme of 1993 got underway with the launch of cosmonauts Gennady Manakov and Alexander Poleshchuk in Soyuz TM-16 and its docking with the Mir space station in late January. The docking procedure provided a test for a manned docking system that may be used in a joint mission with the US planned for 1995.

The future of the Russian space programme is however in doubt due to funding problems, but it is hoped to keep Mir in orbit beyond its originally intended lifespan until at least 1996. Manakov and Poleshchuk are expected to return to Earth in the Soyuz TM-16 landing capsule on about 14 July.

Cosmonauts Anatoly Solovyov and Sergei Avdeyev, who had been aboard Mir since 29 July 1992, returned safely to Earth on 1 February in the Soyuz TM-15 landing capsule touching down on the steppes of Kazakhstan.

The next manned flight to Mir will be the fourth Russian-French flight with Frenchman Jean-Pierre Haignere (back-up Claudie Andre-Deshaye) spending 20 days at Mir before returning to Earth in the Soyuz TM-17 landing capsule. This mission was originally planned for 1994 but was brought forward to 1 July 1993 in the absence of other contenders for cosmonaut-research flights. The accompanying cosmonauts, who are expected to be Tsibliyev and Kaleri, will return to Earth in January 1994.

For the end of 1993 a main Mir mission is planned with a physician to spend a year and a half in space.

India Set to Launch New Space Vehicle

A four-stage Indian rocket, the Polar Satellite Launch Vehicle, will place a one-ton remote-sensing satellite in orbit on its first launch in March from Sriharikota, India's main launch pad, which is close to the city of Madras.

The PSLV, which incorporates advanced liquid propulsion technology, is a successor to the Augmented Satellite Launch Vehicle, successfully launched in May 1992 after several abortive efforts. The PSLV is one of two powerful rockets that India is developing. The other is the Geostationary Launch Vehicle, whose planned development by 1996 will give India an undisputed intercontinental ballistic missile capability. According to the Indian government, the development of the PSLV and GSLV will make India self-reliant in space technology and enable it to compete in the multibillion-dollar international space market. India has the most advanced space programme in the Third World. In 1980, it surprised the international community by placing a satellite in orbit.

ESA Launch Diary for 1993

Ariane Programme and Space Shuttle Involvement

March

STS-55/Spacelab D2: Second German Spacelab mission with heavy ESA involvement. Launch delayed until early March.

STS-56/Atlas 2: Follow-up of Atlas-1 mission for atmospheric applications and science. Launch scheduled for late March but may be delayed.

April

Ariane V57: Launch of Astra 1C telecommunications satellite with Arsene as secondary passenger.

STS-57/Eureca: Retrieval mission of ESA's Eureca platform.

May

Ariane V58: Launch of Hispasat 1B and Insat 2B telecommunications satellites.

June

Ariane 5 M1: First firing test of solid rocket booster with flight structure in Kourou.

September

Ariane V59: Launch of Spot 3 and Stella for France.

October

Ariane V60: Launch of Intelsat VII-F1 telecommunications satellite.

Ariane 5 M2: Second firing test of the Ariane 5 solid rocket booster with flight structure in Kourou.

November

Ariane V61/MOP-3: Launch of ESA's meteorological satellite Meteosat MOP-3 and the Mexican telecommunications satellite Solidaridad 1.

Maser 6 and Texus 31 sounding rocket launch with major ESA payload participation.

December

STS-61/HST servicing: Repair mission of Hubble Space Telescope with ESA astronaut Claude Nicollier on his second shuttle flight.

Ariane V62: launch of DirecTV1 and Thaicom telecommunications satellites.

Dates of launches are very dependent on many factors such as readiness of spacecraft and/ or launcher system and may remain unknown for quite some time.

— STS-55 —

ESA's Spacelab in Launch Delay

Europe and ESA look forward to being once more in the forefront of manned space flight with the launch of the second German Spacelab mission (D-2). The original February launch has, however, been put off until at least the second week of March to allow inspection of all 22 pumps of Columbia's engines following a mix-up involving the use of old instead of new metal clips to hold the pumps' seals in place.

Columbia carries in its cargo bay the ESA developed Spacelab on a 9-day mission to conduct fundamental research. A crew of seven astronauts, five from NASA and two payload specialists from DLR - the German Aerospace Research Establishment - have the task of carrying out some 90 experiments, 32 of which have been funded and developed under ESA responsibility for scientists from university and research institutes spread all over Europe.

Spacelab, as a manned orbiting laboratory, has already flown six times. The year 1993 marks the 10th anniversary of the first flight in November 1983 (STS-9/ Spacelab 1).

As was the case for the Spacelab D-1 mission in 1985, DLR has been entrusted by the German Federal Ministry for Research and Technology (BMFT) with the project management, the training of the scientific astronauts and the operation of the payload. DLR's dedicated space operations control centre for D-2 is located in Oberpfaffenhofen, near Munich.

Pegasus Launch

At 9:32 am EDT on 9 February, a Pegasus rocket launched from a B-52 aircraft at 43,000 feet altitude and some 80 miles off Florida's east coast carried a Brazilian environmental sciences satellite into Earth orbit.

From an altitude of about 550 miles, the satellite, built and owned by Brazil, is to be used to collect environmental data from ground sensors in the Amazon River Basin and surrounding rain forests and replace the need for arduous ground trips into remote regions.

Delta Launch

A Delta II rocket blasted off at 9:55 pm on 2 February from Cape Canaveral Air Force Station to launch the 18th of a series of navigation satellites. The $65 million Navstar Global Positioning System satellite is capable of locating receiver-equipped military personnel within 50 feet and measuring their speed to within a fraction of a mile per hour and giving time to within a microsecond. US military forces relied heavily on Navstar satellite during the Gulf War. Civilians using the satellites can determine their positions within 325 feet. The Air Force eventually wants 24 Navstars in orbit 12,500 miles high.

The First Reusable SSTO S

For the Exploitation of Space and Expansion of Humankin

In August 1991, the Strategic Defense Initiative Office (SDIO) awarded a $58.9 million, Phase II SSTO Technology Demonstration contract to the McDonnell Douglas Space Systems Company (MDSSC). The contract calls for MDSSC to design an Single-Stage-to-Orbit (SSTO), totally reusable spacecraft that can carry SDIO's relatively large numbers of small payloads (under 20,000 lbs). Current launch vehicles cost over $10,000 per pound-to-orbit; SDIO's goal is to cut that to less than $1,000 per pound. The award follows a competitive Phase I definition and risk-reduction study, begun in December 1990 by MDSSC, General Dynamics, Boeing and Rockwell.

Artist's impression of the Delta Clipper Single-Stage-to-Orbit spacecraft on the laun

Background

MDSSC's winning answer is the Delta Clipper, a vertical take-off and landing (VTOL) design. For the Phase II contract, MDSSC will construct a 1/3 scale flying prototype, the DC-X, that, although not capable of orbit, will demonstrate the design's launch, manoeuvring, hovering and landing capabilities. If Phase II is successful, then during Phase III of the SSTO project, to last from 1993 through 1996, MDSSC will design, construct and test the DC-Y, a full-scale, orbit-capable prototype. Finally, during Phase IV, MDSSC will design - for first launch sometime during 1999 - the production version of the Delta Clipper (designated, not accidentally, the DC-1).

It should be noted that, for the time being, Phases III and IV are contingent upon additional funding from sources outside the SDIO, such as NASA or the Air Force, or even private investment. Unfortunately, SDIO's budget is not capable of funding the DC-Y or the DC-1 unaided.

To provide the wide range of expertise necessary, MDSSC has formed a wide-ranging team of aerospace companies. MDSSC (itself a subsidiary of McDonnell Douglas) is performing systems engineering and project management, Aerojet GenCorp and Pratt & Whitney are developing the engines; Messerschmitt-Bikow-Blohm is designing the landing gear and providing general reusable systems and VTOL experience; Martin Marietta is providing experience in cryogenic ground operations and NASP-derived technology; two other McDonnell Douglas subsidiaries, Douglas Aircraft Corporation and McDonnell Aircraft (MCAIR), are providing commercial and high-performance military aircraft technology; and a large group of other subcontractors are bringing expertise in various space systems.

Technical Characteristics

The full scale Delta Clipper will stand 127 feet high and be 30 feet wide at base, weigh approximately 80,000 pounds empty, carry 20,000 pounds of cargo and burn 940,000 pounds of liquid hydrogen and oxygen through a ring of engines in its base. The 1/3 scale DC-X will use four modified Pratt & Whitney RL-10A-4 bell-nozzle engines. MDSSC has not decided upon the exact configuration for the DC-Y yet; either multiple bell-nozzled engines (10 or 12) or a variation on the Rocketdyne-developed "aerospike" engine may be used.

Unlike conventional rocket engines, which have bell-shaped nozzles in which the gases from the combustion chamber expand, the aerospike engine features a toroidal combustion chamber, with a ring of exhaust ports running around the base of the spacecraft. The chambers' exhaust gases expand against a large central cone, or plug, which is made of high-temperature materials and regeneratively cooled by the cryogenic fuel. In general, the nozzle of a rocket engine must be optimised for a particular altitude of operation. Initial design work on the aerospike engine indicated that, unlike fixed-bell nozzle rocket engines, it would automatically adjust itself for altitude. In addition, since an aerospike engine makes up the entire base of the vehicle, the plug can double as a heat shield for reentry. However, the Clipper does not require this capability and recent studies indicate that the aerospike may not be as efficient at higher altitudes as originally thought. Both the aerospike engine and conventional bell-nozzled engines are being integrated for the DC-Y and the DC-1.

In a dramatic departure from earlier SSTO designs, which reentered the atmosphere tail-first in a manner similar to an Apollo capsule, the Delta Clipper reenters nose-first at a high angle of attack. Its shape is, in fact, a supersonic lifting body/flying wing capable of 1,600 miles of cross-range manoeuvring during reentry. Four extendable control surfaces around the base, together with manoeuvring thrusters, provide control in the atmosphere. Once the craft has reached approximately 20,000 feet and 180 knots, the

pacecraft

d into the Solar System

BY W. PAUL BLASE
Virginia, USA

ch pad. McDonnell Douglas

engines ignite and idle and the nose is pulled up so that the craft is vertical with its base downward. The engines are then throttled up and the craft hovers, descends, extends the landing gear and lands. A landing pad less than 300 feet in diameter is all that is required.

Although the National Aerospace Plane program (NASP), will not construct the hypersonic X-30 for several years yet, the Delta Clipper may truly be called the first NASP derivative. It draws heavily upon NASP for advanced composite materials for its structure and fuel tanks, new thermal shielding materials and thermal and aerodynamic computer simulation software. The structural truss of the Clipper is graphite/epoxy; the skin is graphite/epoxy and aluminium in a honeycomb sandwich; and carbon-carbon and carbon-silicon carbide insulation shield the Clipper from the heat of reentry. The landing gear is made from titanium-silicon carbide composite; the liquid hydrogen (LH) tank is graphite/epoxy and the liquid oxygen (LOX) tank is made from a new aluminium-copper-lithium alloy.

All current rocket launchers are derived from 1960s era ICBM designs, and man-rating procedures are merely ways of producing man-rated ammunition. Rocket designers are conservative by nature and the high cost of both the vehicles and their payloads causes them to refine the same basic concepts continuously to finer and finer degrees, taking few risks with radically new ways of doing things. This has resulted in a situation very much like trying to pull a semi-trailer with a racecar. Like a racecar, ICBM-based rockets are designed to get maximum performance from minimum equipment. Technology is pushed to the very brink to wring out that last ounce of thrust. However, it is an engineering truism that when one gets near the theoretical limits of a system, every additional 10 percent increase in performance doubles the systems cost and halves its reliability.

This high-performance design philosophy has several side effects that, in turn, drive launch costs even higher. First, the premium placed on vehicle mass means that there is no room for redundant control systems. There is no spare engine thrust and there is little capacity for rugged, resilient construction. Adding in the fact that the vehicle is meant to be a one-shot, disposable system, with no capability to safely recover from an aborted launch, the following hold true:

- launches are generally delayed (at substantial cost) if there is any hint of a possible problem with the vehicle;
- launches are delayed if there is any possibility of bad weather;
- any failure in a rocket during a flight almost certainly results in the vehicle's (and cargo's) destruction, either through the failure itself or by range-control when the rocket threatens to leave the flight path.

Not only do these factors drive up cost directly but the high risk means that launch-insurance premiums are astronomical.

Secondly, the complexity of current launch vehicles and their heavy requirement for service means that many personnel are required to launch and maintain them. The Space Shuttle, for instance, requires over 40,000 people to maintain it, support its operation, and turn it around between missions. To paraphrase an individual interviewed for this article: adding hardware to a project increases its cost linearly; adding people increases costs exponentially. The greater the number of people involved, the greater the infrastructure that must be devoted to supporting *them*, the greater the chances for errors, and the larger (and slower) the bureaucracy required.

Since the *raison d'etre* for the entire SSTO effort is low launch costs, the Delta Clipper is designed from the start to be a true, long distance cargo haulier. In fact, the Clipper is intended to operate in the same manner as a modern commercial aircraft. Like an airliner, its design is centred on flexibility, a long service life and the troika of safety, reliability and ruggedness.

Delta Clipper is capable of carrying either passengers or cargo. In an interesting twist, the Delta Clipper's cargo is carried not in the nose of the craft (a traditional location), but in two bays in the centre, with LH and LOX tanks above and below. Each bay contains a mission module that may, in turn, contain either crew or cargo. The Clipper may fly unmanned with two cargo modules, say for a routine satellite launch or space station resupply mission. If a manned mission is required, one module would contain a crew/control cabin; the other may then contain either cargo, a pressurised working module, or a remote manipulator arm similar to the one used in the Shuttle. Externally, the modules are identical, having standardised connections to the

Clipper for power, cooling and the control interface. A customer can take as long as it likes to fit a cargo into a module and then launch it on the next available Clipper.

Adding to this flexibility is the fact that since the Clipper does not drop stages after launch and because of its inherent reliability, it need not be launched only from coastal sites. Since the craft ascends vertically for the first part of the launch, like any rocket, noise pollution is kept to a minimum and the launch sites could be incorporated into existing airports. It also, incidentally, means that no carrier vehicle is necessary to move a Clipper from one launch site to another: the craft merely does a suborbital hop.

Reusability and a long service life are, of course, a major feature. It is important to note, however, that this extends beyond the basic structure of the craft to all the components and subsystems. The Space Shuttle is reusable but its engines and many other onboard systems must be serviced or replaced between launches. In contrast, MDSSC is specifying a 20 year lifetime for the structure of the Clipper and a minimum of 200 launches between major overhauls on the engines, figures comparable to a modern jet airliner. All of the electrical and hydraulic systems are also designed for long, maintenance-free service.

"Airliner" Approach

Long component service lives are made possible by the Clipper's 4:1 dry-weight to payload ratio, almost 2.5 times that of the Space Shuttle. Lowering the spacecraft's mass to such a low level, for a given payload size, enables the designers to use simpler and more reliable, *albeit* heavier, engines and other essential components. It also enables them to use more engines in the base of the craft. This last means that each engine may be run at a greatly reduced power level during flight. The normal operating level for the Clipper's engines is to be 90% of rated power; the engines would go to 100% of full rated power during an emergency abort situation (two engines out), could safely be driven to 110% for limited periods and redline (damage to the engine is probable) at 115%. In contrast, the Space Shuttle's main engines, which must be completely overhauled and tested between flights, routinely operate at 105% of rated performance.

A long service life pays back for two reasons. First the cost of constructing a launch vehicle can be amortised over many launches. It also means that every Delta Clipper, and every component, may be flight tested before its first cargo-carrying launch. It is never necessary to fly a critical mission with unproven hardware.

As part of its "airliner" approach to space operations, MDSSC is currently working with the Federal Aviation Administration to develop a set of criteria for fleet-certifying the Delta Clipper in almost exactly the same way that airliners are certified. This certification requires a vehicle designed to operate within a specific set of margins with respect to thermal and mechanical loads, and to incorporate aerodynamic controls capable of handling the entire span of normal and some abnormal flight conditions. It also covers all the craft's maintenance and support infrastructure, both equipment and procedures.

Like an airliner, the Clipper is being designed so that it can either continue with flight or safely abort and land under a wide variety of conditions. During takeoff, it will be able to achieve orbit if any two engines fail, and will be able to safely land on half of them. It will be capable of landing in any flat area after hovering to burn off fuel if an emergency landing is necessary. It is being designed for all-weather capability and will be able to land under the 43 knot sharp-edged wind gust conditions required by the FAA for commercial aircraft. The end result is maximum confidence that the craft is both safe and reliable under all rated conditions. Not only can the Clipper operate under conditions that shut down current launch vehicles (e.g. the frequent delays in Space Shuttle launches due to inclement weather at the emergency landing sites), but it will yield significant reductions in insurance premiums, both for the carrier and for the customers.

The airline-style operating approach also extends to the launch support facilities. The Delta Clipper does not require a complex launch facility or gantry. The launch pad consists of flame ducts and support pylons (to save weight, the landing gear is not designed to support a fully-fuelled vehicle). The cryogenic fuel-handling equipment is built into the pad and the entire refuelling operation made as automatic as possible. No special vehicles or facilities will be required to service the Clipper or to load the cargo modules. Everything can be done on the pad with ordinary scissor-jack trucks of the kind now used in airports.

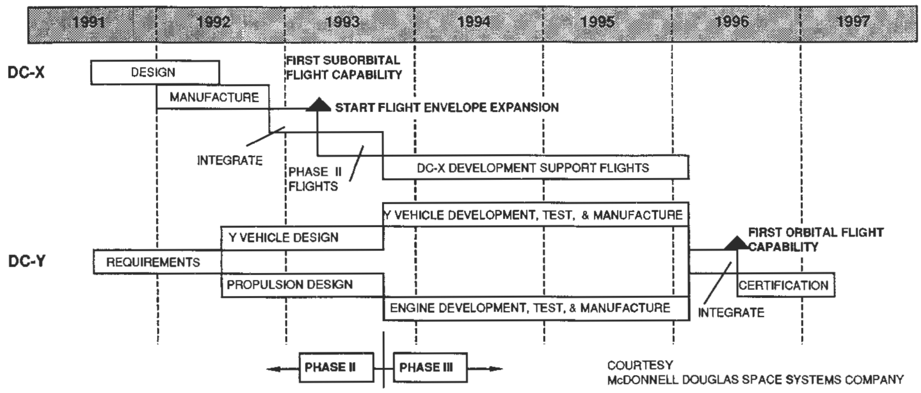
Even more importantly, the Delta Clipper's airliner approach to rocket design reduces launch costs by reducing the number of people required to support the system. It will require less than 600 people per craft, including administrative personnel - a number comparable with that required by commercial aircraft. The rugged, redundant design of the structure, engines and control systems means that very little servicing will be required between launches. Most servicing will be accomplished during routine maintenance operations. In addition, the Clipper is designed for maintainability, so that service that is required can be performed easily and quickly. Engines can easily be pulled out for servicing, and all line-replaceable-units (primarily avionics) that need most maintenance are easily accessed *via* the cargo bays. The fleet certification procedure helps to ensure that components will not fail between scheduled overhauls (as long as normal flight margins are not exceeded). As a result, it is predicted that the Delta Clipper can be turned around between landing and launch in less than a week, possibly even within a day.

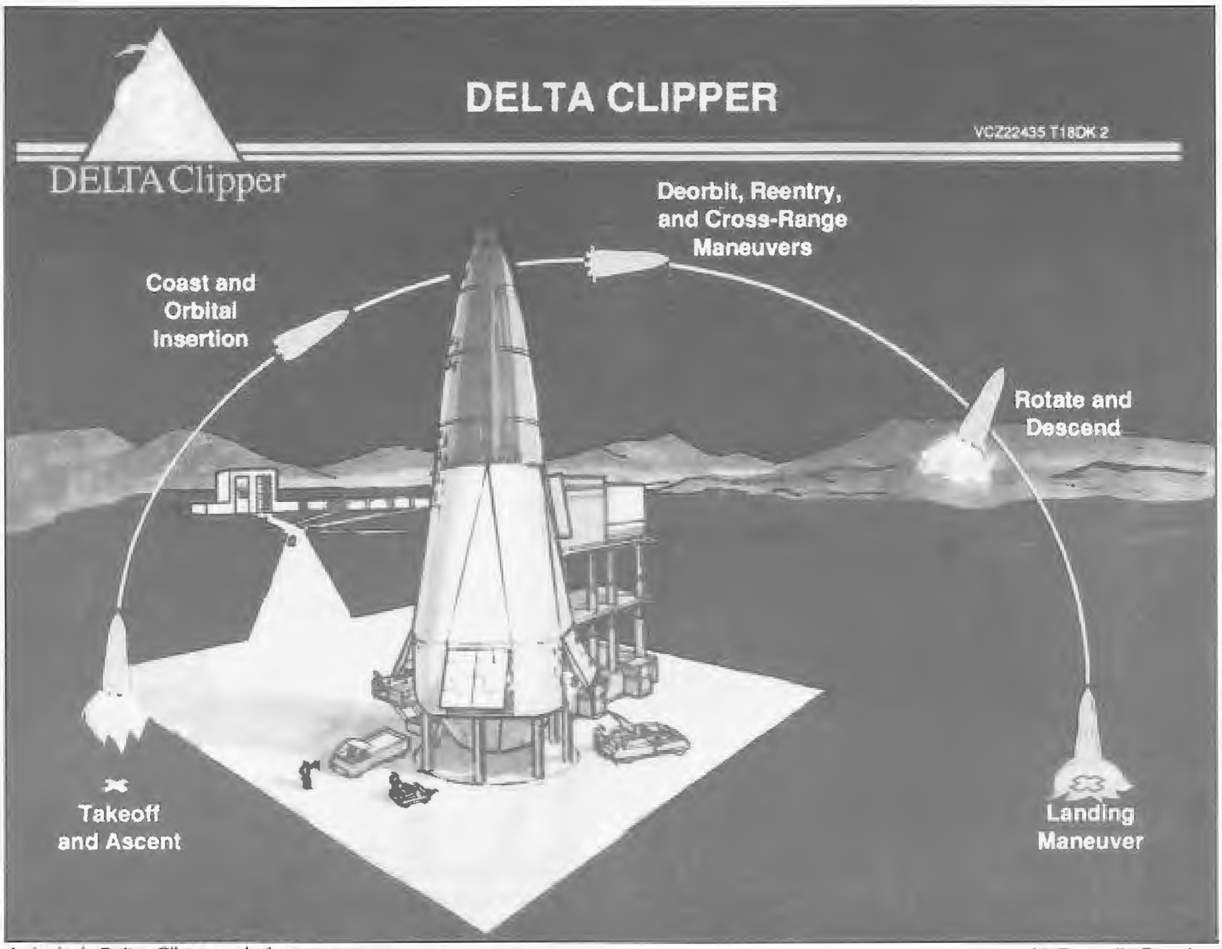
From a Long History of Ideas

The craft is the end result of over thirty years of designs and dreams. Its roots began in the late 1950s with the Douglas Aircraft Reusable Interplanetary Transport Approach (RITA), a nuclear SSTO rocket which used engines similar to the recently announced Timberwind nuclear rocket. RITA was based, in turn, on work done by Douglas Aircraft for a nuclear-powered bomber for the US Air Force earlier in the decade. Chief design engineer for the Douglas Missiles and Space Department and in charge of the RITA work, was Maxwell Hunter.

In 1969, Douglas Aircraft aerospace engineer Philip Bono proposed a series of SSTO designs [1], based upon the Rocketdyne "aerospike" engine design. Bono had joined

Schedule for the development of the Delta Clipper. *McDonnell Douglas*





A typical Delta Clipper mission sequence. *McDonnell Douglas*

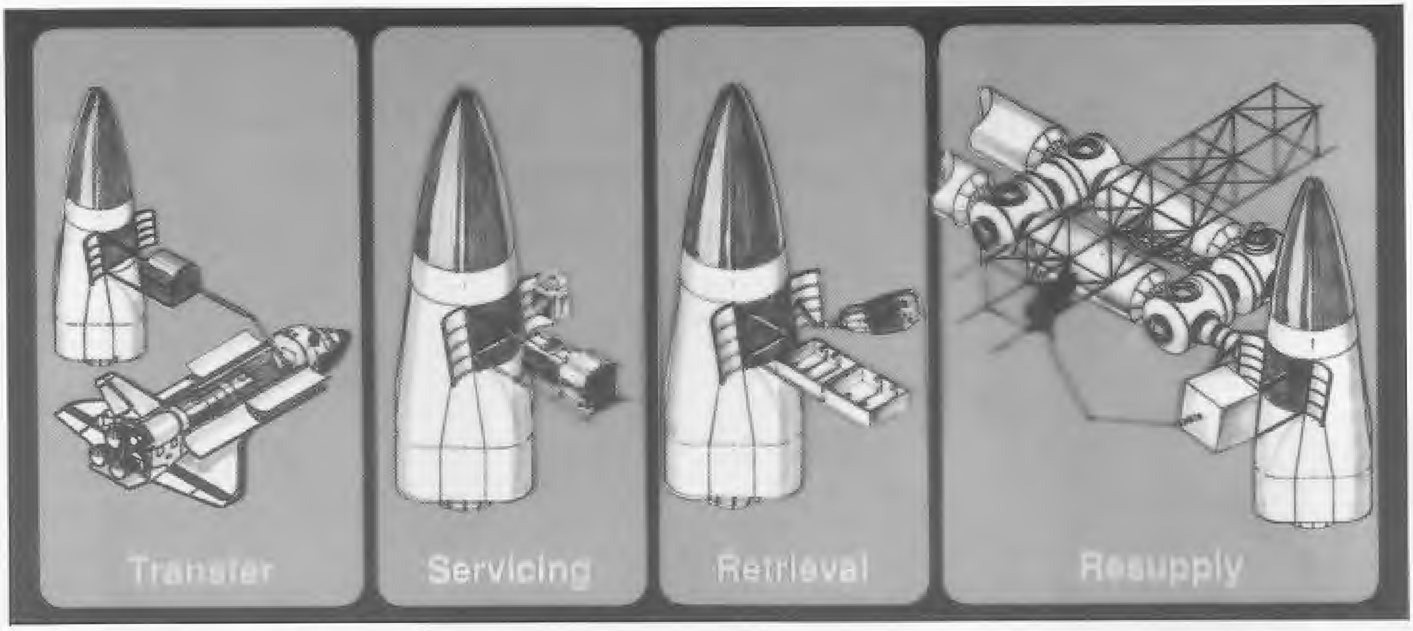
Hunter's organisation in 1960 - too late for the RITA work, but just in time to become involved in a Douglas rocket effort started as a response to Sputnik. Utilising the earlier RITA work; NASA and the US Air Force work on lifting bodies, particularly the Boeing Dyna-Soar (never built) and the X-24A; and basic Saturn rocket technology, Bono's designs progressed from the Saturn Application Single - Stage - To - Orbit (SASSTO), which consisted of a Gemini crew capsule on top of a 45 foot fuel/aerospike engine module, to the *Ithacus*, a monstrous 200 foot tall intercontinental passenger/cargo carrier that could haul 1,200 passengers 7,500 miles in slightly over 1/2 hour. Of greatest interest, and bearing the greatest resemblance to the Delta Clipper, is the *Hyperion* - a bullet shaped SSTO capable of carrying 8,100 pounds into low-Earth orbit. This design carried the cargo in a nose fairing on top of the fuel tanks and, using the capability of the aerospike engine to serve as a heat shield, reentered the atmosphere tail-first and then hovered to a vertical landing.

Although Bono's ideas never came to direct fruition, they were picked up by a private aerospace consulting engineer, Gary Hudson - founder of Pacific American Launch Systems, Inc., an aerospace consulting company. In 1972 Hudson proposed the *Phoenix*, a 53 foot Hyperion-style SSTO capable of hauling 5 tons into LEO. Up until 1991, Mr Hudson attempted, with some success, to obtain private venture capital to construct and operate Phoenix as a private launch service, totally independent of government financing and run in the same manner as an airline. Unfortunately, several occurrences in the space industry, including the destruction of the Space Shuttle Challenger and the DARPA (Defense Advanced Research Projects Agency) decision to contract with another launch company, Orbital Science, caused his backers to pull out. During the SDIO SSTO effort, Mr Hudson consulted with Rockwell and Boeing in their Phase I proposals.

In 1965, Maxwell Hunter left the National Space Council staff, which he had joined after leaving Douglas in 1961, for Lockheed. Immediately after his arrival he began work on the *Starclipper*, a direct SSTO descendant of RITA. One of the most important results of this work was his application of ATA (Air Transport Association) cost-effectiveness formulae to the operation of RITA and *Starclipper*. These formulae, an aeronautics industry standard set, are usually used to estimate the operating costs of proposed transport aircraft for civilian use. The results showed that it was possible to build a launch system that could operate for costs comparable to those of commercial aviation; results that would subsequently be crucial to Hudson's *Phoenix* and the Delta Clipper.

Among other accomplishments during his stay at Lockheed, Hunter directed both the programme that developed the thermal protection tiles for the Space Shuttle and the early phases of the Hubble Space Telescope. It is interesting to note that the highly successful Shuttle tile material was originally proposed and developed for the *Starclipper* effort, to replace the one-time-use ablative insulation used for the Mercury, Gemini and Apollo capsules.

During the early 1980s Hunter directed Lockheed's 'X-Rocket' study. Based upon Gary Hudson's *Phoenix*, the 'X' was a 60 ft high Hyperion/Phoenix style SSTO that featured the basic blunt cone shape and reentry/hover-to-landing mission profile of its predecessors. It is a direct ancestor of the DC-X, featuring a nose-first atmospheric reentry and multiple bell-nozzled engines in a plug-cluster configuration, similar to the aerospike, but with discrete engines arranged in a ring, instead of a continuous toroidal combustion chamber. Most importantly, it featured the *Phoenix* concept of a drastic reduction in the "standing army" (Hunter's term): the number of people necessary to maintain and support the craft between launches.



Typical on-orbit activities of the Delta Clipper craft. *McDonnell Douglas*

Although Lockheed cancelled the 'X-Rocket' program, Hunter - after retiring in 1985 - kept the idea alive. He renamed it the "SSX" (Space Ship eXperimental), and promoted the concept both in collaboration with Gary Hudson and by himself. In 1988, Hudson and Hunter briefed and sold the Phoenix/SSX SSTO concept to the Citizen's Advisory Council on National Space Policy and to US Army General (retired) Daniel O. Graham of High Frontier, an organisation that promotes the large scale development of space - including the Strategic Defense Initiative.

In 1989, Hunter and High Frontier Presented the Phoenix/SSX SSTO concept to the National Space Council, chaired by Vice President Dan Quayle. Then , the Air Force (through The Aerospace Corporation, a California based consulting firm) reviewed the concept, releasing a generally favourable report in July 1989. The SDIO SSTO Phase I study contracts followed a year and a half later.

Looking to the Future

Like its predecessors, the Douglas Aircraft Corp. DC-2 and DC-3 of the 1940s, the Delta Clipper promises to transform an industry. By taking advantage of the latest technology, yet insisting that this technology be proven and by insisting that the reduction of operational costs be a major design criteria, McDonnell Douglas stands a good chance of accomplishing its goal of creating a spacecraft that can be operated as efficiently as a commercial airliner.

Current launch systems are expensive and, by the standards of every other transportation industry, unreliable. In a classic Catch-22 lock, no truly new rocket designs have been tried (including the Shuttle) because the launch market is so small, while many potential customers and private investors are scared away from space because of the high costs involved in getting into orbit. Launch facilities are built and operated by national governments, for national agendas, and the support services necessary for launching a spacecraft are generally provided either by a government agency or by a government contractor. There is no independent, non-government infrastructure, such as the abundance of private industries that support commercial aviation.

The Delta Clipper promises to bring the cost of access to space down to the point where private enterprise can own and operate spacecraft. The reusability and long design life will allow an operator to amortise the cost of the craft over many launches, reducing the cost per launch.

Additional savings may be realised through its low required maintenance, non-complex ground facilities and the lower number of people required for operation. Finally, the craft's reliability and safety should greatly lower the cost of launch insurance - a major contributor to launch costs. Together, all these factors should work together to drive down launch cost to the point where a truly commercial launch industry, along the lines of the modern airline industry, is feasible.

As for any new industry, once the cost reaches a certain point new uses for it will be found and the whole process will begin to snowball. Once launch costs drop to the point where industry can afford to experiment with Null-G and high-vacuum processes on a routine basis, space stations can be built along the lines of modern industrial laboratories, either by the industries themselves, or by separate service companies serving many customers. Once space stations become economically feasible for industrial purposes, satellite builders can construct their 'birds' for in-orbit assembly and repair - thus drastically reducing *their* costs.

This last step would trigger a need for in-orbit 'tugs' and other vehicles designed purely for in-space use. We now reach the point where service and supply companies spring up to service the requirements of the space industry and the historical demand/cost snowball cycle begins. The current high cost of the technologies required for space travel (such as advanced composites and radiation-resistant electronics) is due, in large part, to the limited markets for them. A larger market for a technology means that mass-production techniques can be applied and that specialty companies can be formed to produce them, typically at very high efficiencies. The reduced cost then increases the number of potential uses for the technology, making an even larger market and inspiring even more methods and techniques for manufacturing the technology and meeting demand - and even more applications.

As a result of this whole process, the cost of space travel should drop, within twenty or thirty years, to the point where such developments as lunar colonies and Solar Power Satellites become economically feasible. Just as trading between continents was made possible by the development of the large cargo vessel, and modern urban society was made possible by the automobile and telephone, so the Delta Clipper should, ultimately, make possible the exploitation of space and the expansion of humankind into the Solar System.

Reference

1. Bono, Philip and Gatland, Kenneth, "Frontiers of Space", Macmillan Publishing Co., Inc., New York; 1976.

Society News

Developments in X-Ray Astronomy

The meeting at the Society's HQ on 6 January featured a most interesting talk by Professor Ken Pounds of Leicester University describing the "Development of X-ray Astronomy in the UK".

Professor Pounds recalled that X-ray astronomy began just over 30 years ago when a small detector was launched by a sounding rocket from White Sands Proving Ground. Its (unsuccessful) objective was to study X-ray emission from the surface of the Moon, not accomplished until 29 June 1990 when the historic ROSAT picture was taken of the Moon in X-rays.

X-ray astronomy has proved to be a highly productive area of study. The last 20 years has seen an escalating number of discoveries, a tendency which will probably continue until the turn of the century.

Three areas of fundamental importance which are currently dominating astronomical research are:-

1. The Early Universe, Dark Matter and the Origin of Galaxies.
2. The Physics of Stellar Collapse e.g. the collapse of stars, novae and black holes.
3. The formation of stars and planets and the origin of life.

The first two are being addressed by observations in the X-ray band. ROSAT, visible as a naked-eye object of magnitude 3 or 4 which goes over the UK 3 or 4 times daily, was used to illustrate the problems in the design of X-ray telescopes, while Tycho Brahe's nova of 1572 and Abell 2256 were used to illustrate some of the scientific results achieved. It was pointed out that the number of satellites orbiting or projected, which are concerned with the study of the Universe in the optical, ultraviolet, millimetre and infrared wavelengths, is quite substantial. There is COBE (mm), Hipparcos (optical), IUE (UV), Hubble (optical) and Rosat (X-ray). The status of those currently listed by ESA alone for the next decade illustrates the point also, *viz* the Infrared Space Observatory (ISO), the Solar-Terrestrial Science projects (Soho and Cluster), Cassini/Huygens and XMM. Additional examples are Astro D, a Japanese X-ray mission scheduled for 1993, and SIRT-F, the US infra-red 'Great Observatory' scheduled for the turn of the century.

Themes for 1993-1994 issues of JBIS

A major ***JBIS*** innovative publishing project is underway which will feature many new aspects of space flight throughout 1993-1994, the Society's 60th Anniversary year.

Details of those now listed for 1993 are as follows:-

Jan	New Space Concepts (Pt IV)
Feb	Science Systems in Space
Mar	General Issue on Space Medicine and Space Astronomy
Apr	Advances in Space Technology
May	Pioneering Rocketry & Spaceflight (Pt II)
Jun	Marcol in Space (Pt II)
Jul	Terraforming
Aug	Space Science: Developments in X-Ray Astronomy
Sep	Report on the Extreme Ultraviolet Explorer Misson
Oct	The Impact of Space on Social Culture
Nov	Nanotechnology (Pt II)
Dec	Turin Conference on Space Missions and Astrodynamics

The list embraces the past history of space flight, some of its most important current projects, future developments in space propulsion, nanotechnology and the impact of these topics on human culture.

1994 will see the appearance of Part III of Exobiology, an outstanding series of fundamental studies which examine the biological development of life together with two educational issues, *viz* - Support of the University Community for Space Science and Technology and Space Educaton in the 90s and Beyond. Two Journals will examine further the incredible developments in computer technology applied to space flight, in which the UK plays a leading role, while several other issues will expand our knowledge base on space history.

* * *

OBITUARY Patrick Girton

We are extremely sorry to record the death of Patrick Girton, a long-standing and active member of the Library Working Group. During the war years Pat was in Air Sea Rescue, a part of Coastal Command. Pilots would call on him after they had returned to base to say "Thanks for getting us back home". Pat joined the Society as a Member in January 1959, subsequently transferring to the former grade of Associate Fellow in 1975 and to full Fellowship some years later.

Besides his other activities for the Society, Pat's expertise as a technical company representative was always freely available to the Society. He was always cheerful and supportive of the Society's work and will be sadly missed by all his colleagues.

Endeavour's Third Mission

The STS-54 flight crew enjoys breakfast in the Operations and Checkout Building prior to suiting up and heading to Launch Pad 39B. From left are Mission Specialist Gregory J. Harbaugh; Pilot Donald R. McMonagle; Mission Commander John H. Casper; and Mission Specialists Mario Runco Jr. and Susan J. Helms. *NASA*

First Training EVA for Space Station Assembly

The Space Shuttle Endeavour was launched on Shuttle Mission STS-54 from the Kennedy Space Center's Launch Complex 39B at 8:59 am on Wednesday January 13, 1993. This was the third mission for the Endeavour orbiter and it was KSC's first launch of 1993.

BY ROELOF L. SCHUILING
At the Kennedy Space Center

The primary objective of STS-54 was the deployment of the fifth Tracking and Data Relay Satellite (TDRS-F) to reach orbit. TDRS satellites now on-orbit provide data transmission and relay services not only to NASA Space Shuttles but also to the constellation of scientific satellites circling the Earth. The STS-54 TDRS-F was delivered to the Kennedy Space Center in September for prelaunch processing and mating with the Inertial Upper Stage booster (IUS). The IUS was also delivered to KSC in September of 1992. The TDRS-F was produced by TRW in Redondo Beach, California for NASA's Goddard Space Flight Center, and the IUS-13 was produced by the Boeing Aerospace Company in Seattle, Washington for the US Air Force who manage the IUS program.

In the Vertical Processing Facility, workers are installing an Inertial Upper Stage (IUS) booster in a test cell. The IUS is used to push the Tracking and Data Relay Satellite into geosynchronous orbit following deployment from the Space Shuttle. *NASA*

In the orbiter's payload bay were two Diffuse X-Ray Spectrometers (DXS) instruments, designed to determine the wavelength and intensity of the strongest X-ray lines emitted by stellar gases. The gases are released when stars, at the end of their life cycles, explode and create supernovas that release hot plasmas.

Endeavour's preparations for STS-54 began with its landing following the STS-47 mission. Endeavour was rolled into the KSC's Orbiter Processing Facility's Work Bay One on September 21, 1992 and remained in the OPF until November 23 as it underwent preparations for this mission which included the installation of the two Diffuse X-Ray Spectrometer Instruments on opposite sides of the forward payload bay. Endeavour was mated to its External Tank and Solid Rocket Boosters in the KSC Vehicle Assembly Building on November 23 and underwent checks to verify the interfaces between the orbiter and the other Shuttle components. On December 3, after waiting for the STS-53 launch of Discovery from the adjacent Launch Complex 39A pad on the previous day, the STS-54 shuttle was moved to Launch Complex 39B. The TDRS-F satellite had arrived at the launch pad on November 10 and was installed in the orbiter's payload bay on December 4.

The afternoon of January 10 saw the arrival of the STS-54 flight crew from Johnson Space Center. The countdown clock for the STS-54 mission started at 1:00 pm on January 10 at the T-43 hour mark. At the T-27 hour point, the countdown entered its first built-in hold of four hours during which the launch crews completed final preparations for loading the fuel cell reactants.

The countdown entered a built-in hold at 5:00 am on January 12 at the T-11 hour point. While other built-in holds are usually of standard lengths, the T-11 hour hold - sometimes called the "long hold" - may vary from mission to mission as it is timed to bring the final minute count at the T-0 point to the correct minute count at the desired launch time. For STS-54 this built-in hold was planned for 12 hours and 32 minutes which, with the two 10 minute holds in the final hour, would bring the count to T-0 at 52 minutes after the hour - the planned launch time. After the T-11 hour hold preparations con-

tinued on schedule.

After breakfast the crew received briefing on worldwide weather conditions from Mission Control in Houston and left for the launch pad aboard their "transfer van" at about T-3 hours, arriving at the "white room" at the end of the access arm about 6:00 am.

At T-1 hours the crew and the launch team received another weather briefing and the weather looked good for the launch. The countdown was not without concerns however. Launch crews dealt with a backup heater failure on the air-conditioning system, helium signature traces in the External Tank interstage area and an overfilled drinking water tank. A further issue was an upper wind condition that was slightly over limits for a "worst-case" scenario involving the loads on several wing struts if the orbiter were to experience an engine failure precisely as it was at the Mach 1.5 point in its ascent. Analysis of the projected loads and flight conditions continued during the final period of the countdown.

The final ten minute built-in hold at the T-9 minute point was extended approximately seven minutes in order to complete a thorough review of the upper wind loads condition. It was necessary to insure that all shuttle management and operations personnel understood the reasoning involved before resuming the count for the final nine minutes.

TRW technicians are seen inspecting TDRS-6 before it was shipped to Cape Canaveral to begin launch preparations. *TRW*

As the STS-54 countdown resumed, the Ground Launch Sequencer began computerised final countdown activities. At T-31 seconds the Endeavour's internal computers got the "go" to start their own terminal countdown sequence. At approximately T-6.6 seconds the main engines started and at T-0 the Solid Rocket Boosters ignited and simultaneously the booster rocket's explosive bolts fired to separate the STS-54 Shuttle from Launch Complex 39B.

The ascent into orbit followed the planned timeline with Solid Rocket Booster cutoff and separation at 2 minutes 5 seconds into the flight and main engine cutoff at 8 minutes 37 seconds mission elapsed time. External Tank separation came 12 seconds later.

During its ascent, Endeavour shut down one of the three Auxiliary Power Units early as temperatures in the cooling oil system were above normal. This constituted no hazard as the other two units were operating well and the units are not used on-orbit. After the launch Shuttle Operations Director Brewster Shaw indicated that the most likely cause was an ice buildup in the cooling system and that this would provide no concern as the ice would melt or sublimate away in space prior to the unit's next use on landing.

At 39 minutes 55 seconds into the mission Endeavour performed an Orbital Manoeuvring System burn of about 2 minutes 24 seconds to circularise the orbit at approximately 160 by 162 nautical miles with a 28.45 degree angle of inclination. STS-54 was ready to begin its mission.

Flight Day One

The deployment of the IUS/TDRS combination was the first major activity of STS-54. At 3:12 pm (all times are based on KSC's timezone) Mario Runco activated the deployment mechanism and the communications satellite and its booster were eased away from the payload bay by a set of powerful springs. Mission commander John Casper then moved the Endeavour away from the spacecraft before firing the orbiter's manoeuvring engines to move to a safe distance before the IUS engine was fired.

Control of the IUS was taken over by the US Air Force Space Control Facility in Sunnyvale, California. The first stage of the IUS engine burn came shortly after 4:12 pm and lasted about 151 seconds. TDRS-IUS separation occurred shortly after 10:00 pm. IUS controllers reported all engine firings were normal and the TDRS spacecraft was in geosynchronous orbit.

The Diffuse X-ray Spectrometer (DXS) instruments in the payload bay were activated and began taking science data on orbit 7 but on orbit 10 the

The Space Shuttle Endeavour gets NASA's 1993 launch schedule off to a rousing start with a flawless liftoff at 8:59:30 am, EST, January 13, from Launch Pad 39B. *NASA*

starboard instrument experienced problems with high radiation counts and high voltage and the instrument's systems automatically shut down to protect the detectors. Consequently in place of DXS operations the crew performed tests to evaluate the effectiveness of the Shuttle's star trackers to help in the alignment of the onboard navigation system by pinpointing specific stars through the upper layers of the Earth's atmosphere.

Flight Day Two

The science data timeline was resumed on orbit 19 although radiation counts were still higher than expected. The DXS instruments then continued to operate throughout the mission.

Susan Helms worked with the Commercial Generic Bioprocessing Apparatus (CGBA) which collects information on various biomaterials in 28 investigations. Operations began with the Physiological and Anatomical Rodent Experiment (PARE) and the Chromosome and Plant Cell Division In Space Experiment (CHROMEX) as well.

Flight Day Three

The crew took time out for an orbital press interview with radio station WOR in New York. They were asked about the new Waste Containment System which was making its first flight on STS-54 and was performing well.

Other activities during the day included using the Solid Surface Combustion Experiment (SSCE) to burn a small piece of Plexiglas to determine combustion characteristics in microgravity. This experiment has flown on a number of other Shuttle missions and is planned to fly on several more.

The crew also activated an experiment which was designed to examine fluid and nutrient flow through a rotating chamber. This device will be flown on a later Shuttle mission carrying cancer cells. In ground laboratories these cells tend to move out of the nutrient and impact the chamber walls, but in space the cells remain suspended in the fluid allowing full development without disturbance.

The atmospheric pressure in the cabin was lowered to 10.2 psi in order to reduce the level of nitrogen in the bloodstreams of Mario Runco and Greg Harbaugh in preparation for their spacewalks scheduled for Flight Day Five.

Crew members took part in a series of physics experiments with students from schools in New York, Ohio, Michigan and Oregon. The experiments were televised and the crew answered questions from the students.

Flight Day Four

Mario Runco and Greg Harbaugh checked out the EVA spacesuits which they planned to wear for the spacewalk scheduled for the following day and reported that the suits were in good condition.

The astronauts took photographs to add to the collection of Earth surface photographs which have been returned since the early 1960s. The photos are catalogued by the Earth Observation Project at the Johnson Space Center, which provides a liaison to various ongoing scientific research efforts around the world, and enables Shuttle crews to record features of interest to scientists. (See ***Spaceflight***, January 1993, pp.27-30 for details).

TDRS ground controllers reported that TDRS-6 (after achieving orbit TDRS-F was redesignated TDRS-6) was being moved to its checkout position southeast of Hawaii at a rate of 2.9 degrees of longitude per day. Following successful checkout, the TDRS-6 would be moved to its position of 62°W.

Flight Day Five

The EVA scheduled for Flight Day five was the first in a planned series of spacewalks to be performed during the remaining three years leading up to the on-orbit assembly of the Space Station in 1996.

Mario Runco and Greg Harbaugh left the Endeavour's payload bay airlock hatch at about 5:50 am, about 40 minutes behind the planned schedule as the donning of their spacesuits and preparation of the gear had taken somewhat longer than planned. They performed a variety of tasks designed to define the differences between spacewalks on-orbit and simulations in training on the ground. The two climbed back into Endeavour's airlock at 10:11 am.

Crewmembers

The five-member crew included four veteran astronauts who had each flown once before. John H. Casper, 48, Col. USAF was commander of Endeavour's third flight and had flown as pilot on Atlantis' STS-36 mission in February 1990 and was selected by NASA in May 1984.

The pilot for STS-54 was Donald R. McMonagle, 38, Col., USAF who had flown as mission specialist aboard the 8-day April 1991 STS-39 flight of Discovery. He was selected by NASA in June 1987.

Mission Specialist-1 was Gregory J. Harbaugh, 35, a civilian who went to work, at NASA in Houston following his graduation from college in 1978. He was selected as an astronaut in June 1987 and later flew on STS-39 also.

Mission Specialist-2 was Mario Runco, Jr, 39, Lt. Cdr., USN. A former New Jersey State Police trooper, Runco too was selected as an astronaut by NASA in June 1987 and served as mission specialist on STS-44 in November 1991.

Mission Specialist-3 was Susan J. Helms, 33, Major, USAF. She was selected as an astronaut in January 1990. STS-54 was her first space flight.

Due to the late start the spacewalk was slightly shorter than planned; however, the majority of the planned tasks were accomplished. Flight controllers chose to end the spacewalk at the previously planned time despite the late start in order to allow work with the DXS instruments to continue. One of the mission rules governing this, and the upcoming spacewalks in the series, makes the EVA activity lower in priority than the experiment operations, and prohibits an EVA from impacting major experimental activities.

The DXS instruments, after undergoing heating and flushing of their P-10 gas (a mixture of argon and methane), were providing good science data. The DXS team and the Houston Mission Control Center personnel worked together to reschedule mission time to provide the DXS instruments with additional observing time. Because there had been periods during the mission when DXS had not been planned to operate, controllers were able to provide up to 15 additional orbital opportunities for DXS observations. By this time the DXS science team was reporting high quality data that was as good as that anticipated before the flight. The port instrument appeared to be yielding data with greater than anticipated efficiency. This was felt to be due to the instrument's electron rejection magnets doing a better job in screening out electron contamination from the Earth's radiation belts than had been expected.

Flight Day Six

On their final full day in space the crew shut down one of Endeavour's electricity-producing fuel cells. This was a step in certifying the orbiters for long duration periods while docked to the Space Station later this decade. Shutting down the fuel cells will be a routine occurrence in the Space Station operational era since the electricity for the Shuttle orbiter can be provided by the station without using up the orbiter's fuel cell reactant supply. The operation went as planned with the number 2 fuel cell being shut down during the period when the orbiter was undergoing its checks and tests for the landing during much of the day. Both shutdown and restart went well.

Reaction jet firings and systems tests as well as CGBA deactivation and stowage operations took up much of the day. Preparations for landing envisioned two possible landing opportunities for Endeavour at the Kennedy Space Center; one at 7:02 am on orbit 95 and one at 8:38 on orbit 96.

Flight Day Seven

Due to a shallow ground fog on the KSC runway, flight controllers chose to take the second of KSC's landing opportunities on the morning of January 19. About an hour before the landing Endeavour fired its manoeuvring engines to slow its speed and begin its descent. Re-entry and approach went well. The orbiter passed high over the Kennedy Space Center in the morning sunlight and began a sweeping right turn that took it out over the Cape Canaveral Air Force Station and the Atlantic Ocean before curving back to line up with KSC's runway 33. Touchdown came at 8:38:17 am approximately 1,500 feet from the runway's threshold. The orbiter rolled approximately 8,700 feet before stopping.

By 2:00 pm Endeavour was back in the Orbiter Processing Facility's work bay one for deservicing and for the preparations which will lead to its next mission: STS-57.

TDRS Spacecraft Launch and Operational Status

Spacecraft	*Mission*		*Functional Status*	*Longitude before/after TDRS-F launch*
TDRS-1	STS-6	Apr 5, 1983	Partial	171°W/85°E
TDRS-2	STS-51L	Jan 1986		
TDRS-3	STS-26	Sep 29, 1988	Partial	62°W/171°W
TDRS-4	STS-29	Mar 13, 1989	Full	41°W/41°W
TDRS-5	STS-43	Aug 2, 1991	Full	174°W/174°W

SATELLITE DIGEST-250

Satellite Digest is our regular listing of world space launches. It is based upon a more detailed monthly satellite listing published by the Molniya Space Consultancy prepared by Phillip S. Clark.

Spacecraft	Int'l Desig.	Launch	Launch Site	Launch Vehicle	Mass kg	Orbital Epoch	Incln. deg	Period min	Perigee km	Apogee km	Notes
Superbird A1	1992-084A	Dec 1.95	Kourou	Ariane 42P	2,780	Dec 12.34	0.09	1,436.09	35,759	35,814	1
Molniya-3 43	1992-085A	Dec 2.08	Plesetsk	Molniya	1,750 ?	Dec 14.47	62.83	717.77	416	39,939	2
STS-53	1992-086A	Dec 2.57	KSC	Discovery	87,565	Dec 3.85	57.00	91.01	318	331	3
DOD-1	1992-086B	Dec 2.57			10,530	Dec 3	57	91.9	370	370	
Cosmos 2223	1992-087A	Dec 9.48	Tyuratam	Soyuz	7,000 ?	Dec 10.21	64.66	89.85	241	293	4
Cosmos 2224	1992-088A	Dec 17.53	Tyuratam	Proton-4	2,200 ?	Dec 17.51	2.30	1,448.43	35,877	36,179	5
Navstar 17	1992-089A	Dec 18.94	ER	Delta-2	1,667	Dec 31.32	54.75	717.98	20,040	20,325	6
Optus-B 2	1992-090A	Dec 21.47	Xi Chang	CZ-2E	7,650 ?	Dec 21.79	28.13	97.14	208	1,036	7
Cosmos 2225	1992-091A	Dec 22.50	Tyuratam	Soyuz	6,500 ?	Dec 23.61	64.91	89.73	214	309	8
Cosmos 2226	1992-092A	Dec 22.53	Plesetsk	Tsyklon-3	1,000 ?	Dec 23.23	73.63	116.03	1,479	1,526	9
Cosmos 2227	1992-093A	Dec 25.25	Tyuratam	Zenit-2	9,000 ?	Dec 26.30	71.02	101.96	849	854	10
Cosmos 2228	1992-094A	Dec 25.84	Plesetsk	Tsyklon-3	2,000 ?	Dec 26.17	82.53	97.75	633	669	11
Cosmos 2229	1992-095A	Dec 29.56	Plesetsk	Soyuz	6,000 ?	Dec 29.86	62.81	90.45	218	376	12

NOTES

1 Superbird is a Japanese satellite, operated by Space Communications Corporation, Tokyo and used for domestic communications in Ku- and Ka- bands. Satellite body is a box 3.4 metres high, 2.4 metres x 2.2 metres with a solar panel span of 20.3 metres after deployment. Mass given above is at launch: on station the mass is 1,665 kg and at the end of its operating life the mass should have dropped to 1,255 kg. Deployed over 158°E. Actual launch time was 22.48 GMT.

2 Communications satellite, co-planar with Molniya-3 34. Shape is cylindrical body, 1.6 metres diameter, 3.6 metres long with six vanes of solar panels deployed to give a windmill appearance.

3 First flight of shuttle orbiter Discovery after refurbishment. Crew comprised D M Walker (commander), R D Cabana (pilot), G S Bluford (mission specialist, MS-1), J S Voss (MS-2) and M R Clifford (MS-3). Orbiter has a body diameter of 5.5 metres, body length 37 metres and wingspan 23.8 metres: mass given above is that projected for landing. Launch was at 13.24 GMT and landing at Edwards Air Force Base was 20.44 GMT. Primary payload was DOD-1, the final primary Department of Defense classified payload to be carried into orbit by the space shuttle. Mass quoted above includes support equipment which remained in the shuttle orbiter's payload bay. USSPACECOM has not released orbital data for DOD-1 and that quoted above is taken from the Rockwell International STS-53 Press Information publication. Landed December 9.86.

4 Payload is fifth generation photoreconnaissance satellite, expected to remain in orbit for seven months or more. Design details unknown, but probably cylindrical (diameter 2.3 metres, length 7 metres ?) with a spherical re-entry capsule. Similar Cosmos 2183 (1992-018A), launched 1992 April 8, still operating as Cosmos 2223 began its mission.

5 Cosmos 2224 is fourth satellite in the Prognoz remote sensing series, previous satellites having been Cosmos 1940, Cosmos 2133 and Cosmos 2209. The latter two satellites are currently operating over 336°E. No description of this class of satellite is available. As of 1993 January 4 the satellite was still drifting in an orbit close to the one listed above.

6 Eighth flight of Block 2A Navstar satellite. Satellite is a cylinder plus four vanes: approximate dimensions 2.4 metres long, 1.8 metres diameter and a span of 5.3 metres. Mass quoted above includes propellant: dry mass is 844 kg. Actual launch time was 22.28 GMT.

7 Optus-B 2 is an Australian communications satellite, previously known as AUSSAT-B 2: launched by Chinese as a commercial venture. Satellite is a Hughes HS-601 model. Central body of satellite a box 2.3 metres on each side with a solar panel span of 22 metres (if they are deployed). Dry mass of satellite 1,272 kg: propellant mass approximately 1,700 kg. Satellite should have been deployed close to 160°E. The above mass assumes that the complete satellite reached orbit, although it is clear from debris found under the ascent path that at least part of the satellite was destroyed during the ascent. Although delivered to the correct orbit, the third stage failed to fire, probably because of the damage which it and the satellite sustained during the journey to orbit. Actual time time was 11.20 GMT.

8 Fourth generation photoreconnaissance satellite belonging to either the topographic/mapping sub-group (lifetime about 45 days) or a new special sub-group first flown in 1989 (lifetime about 60 days). Details of the satellite design are unknown.

9 Geodetic satellite in the GEO-IK series. Design apparently based upon the Tsikada-class navigation satellites. Cylinder, approximately 2 metres diameter and 2.1 metres long plus gravity-stabilising boom plus ten vanes of additional solar panels deployed.

10 Second successful launch of Zenit-2 booster in five weeks after three successive failures. Satellite is believed to be an ELINT payload, details of which are unknown. Orbital plane is 90° away from Cosmos 2219, launched 1992 November 17, and is identical with the orbital plane intended for the failed launches in 1990 October and 1991 August. Zenit second stage disintegrated soon after satellite deployment - the first disintegration of a Zenit rocket body in orbit.

11 Cosmos 2228 believed to be a small Worldwide ELINT satellite, the appearance of which is unknown. Co-planar with Cosmos 2058.

12 Tenth Bion biological satellite to be launched. Carried two monkeys, plants and insects: payload included ESA's Biobox experiment. Spacecraft design based upon the original Vostok craft: sphere cylinder with a diameter of 2.4 metres and a length of 5.9 metres. Descended on 1993 January 10. Orbital data of spacecraft at time of recovery still awaited as this Table is closed for publication: similarly, the decay notice for the Soyuz third stage had not been issued through to 1993 January 5.

ADDITIONS AND UP-DATES

1978-024D Molniya fourth stage from Molniya-1 39 launch decayed from orbit 1992 Dec 11.

1980-002F Molniya fourth stage from Molniya-1 46 launch decayed from orbit 1992 Dec 4.

1987-040A Gorizont 14 has been rediscovered by USSPACECOM after being lost in June-July 1992. It is now drifting in the following orbit - 1992 Nov 22.68, 5.87°, 1,474.55 minutes, 36,406 km, 36,667 km, 249°.

1991-072A Cosmos 2164 decayed from orbit 1992 Dec 12.

1992-054B CZ-2E second stage from Optus-B 1 launch decayed from orbit 1992 Dec 12.

1992-081B Molniya third stage from the Cosmos 2222 launch decayed from orbit 1992 Dec 28.

International Space Report

Launch Failure 'Not Rocket Carrier'

BEIJING - An investigation into the launch failure of a US-built Australian satellite on 21 December 1992 has found that the Chinese carrier rocket operated normally and was not to blame. The satellite, manufactured by Hughes Aircraft Company and owned by the Australian-based firm Optus Communications, was launched aboard a Long March 2-E rocket from China's Xichang Space Centre in southwest Sichuan Province.

The rocket appeared to place the Optus B-2 satellite in orbit but a small explosion had occurred and the satellite broke up. The report said the explosion occurred in the satellite vehicle itself about 45 seconds into the launch. It did not speculate on a cause, but said the outcome indicated "the performance of the Chinese rocket is very reliable". Chinese officials had worked feverishly since the incident to pin the blame on something other than their rocket, fearing a major embarrassment to the country's fledgling commercial space programme.

Launch Failure was 'Faulty Engine'

CAPE CANAVERAL - A faulty engine valve caused the Atlas launch failure of August 1992 and most likely also caused the first failure in April 1991, according to General Dynamics Corporation. After the second failure in August 1992, General Dynamics put the launcher on hold. In financial terms the combined losses topped $250 million.

In both cases, the rockets began to tumble and had to be blown up six to eight minutes after liftoff from Cape Canaveral, with the loss of their communications satellites.

With the problem now identified, General Dynamics Space Systems said Atlas flights will resume in March. The valve in one of the upper-stage Centaur rocket engines failed to close before liftoff, allowing air into that engine during ascent. The air then solidified in the liquid hydrogen fuel pump, preventing the engine turbine from rotating. Extra valves are being added to Centaur engines, which are built by Pratt and Whitney, as a safeguard.

Tracking Cars from Space

LONDON - Researchers at the Ford Motor Company Dunton Engineering Centre are working on a low-cost device that will tell you exactly where your car is after it has been stolen. Or if you are on the hard shoulder of the motorway with a mechanical breakdown and there is no phone in sight you just push a button and the emergency services are on their way.

The company believes the system could be ready for use in five years and tests are currently underway with a prototype vehicle in Essex, southern England. The system combines mobile telecommunications technology with the Global Positioning System (GPS) of satellites set up by the US military.

In operation, a driver would use a control on the dashboard to select from a choice of services such as breakdown, police, ambulance or fire which are displayed on small displays. At the push of a button, a message is transmitted to a base station detailing the make and model of the car, its registration number and its position within five yards (metres). In case of breakdown, the message could also include details from the vehicle's diagnostic system about the faults. Within seconds of sending the message, the driver will see the expected arrival time of the services on his dashboard.

In case of car theft, the police could contact the base station with a vehicle identification number and the owner's personal identification number. The base station can then track down the vehicle and, if the stolen car is moving, police can be constantly updated about its position.

Air Breathing Rocket

ALL INDIA RADIO reports that the Indian Space Research Organization has achieved a significant breakthrough by successfully test-firing an Air Breathing Rocket ABR-200. According to Dr Manoranjan Rao of the Vikram Sarabhai Space Centre, the rocket will be able to carry a much higher payload when the technology becomes operational.

'Marsokhod' Test

MCDONNELL DOUGLAS is conducting a series of tests to evaluate a Russian-built six-wheeled prototype planetary rover. A Russian team which operated two unmanned "Lunakhod" rovers on the Moon's surface in the 1970s is now preparing a "Marsokhod" vehicle for the upcoming Russian Mars '96 mission. The Russian team consisting of representatives from the Russian Academy of Science's Space Research Institute (IKI), the Babakin Centre (the primary supplier of interplanetary spacecraft for the former Soviet Union) and the Mobile Vehicle Engineering Institute (VNIITransmash) brought a prototype rover to the United States for testing in Huntington Beach. McDonnell Douglas Aerospace is looking to develop closer ties with leading space organisations of the former Soviet Union. While the upcoming efforts will focus on rovers, McDonnell Douglas Aerospace intends to investigate other possible areas of future collaboration.

A New Ariane 5 Contract

AVICA EQUIPMENT, Hemel Hempstead, which is the UK's only company contributing to the Ariane 5 space programme, has won a new contract to manufacture components for the EPS propulsion system. The agreement with MBB Space Transportation Systems & Propulsion division is for high performance gimbals joints. The initial development contract is for 90 units.

Avica, a division of Meggitt Aerospace, part of Meggitt plc, has already been awarded a four year, multi-million pound contract by the French company Societe Europeenne de Propulsion (SEP) to manufacture fuel and hot gas ducting for Ariane 5. Avica has been involved in all the Ariane programmes and has been on Ariane 5 since 1986.

Space Radars Study

GEC Ferranti Defence Systems, Milton Keynes UK, which will form part of GEC-Marconi Avionics, has won a £250,000 study contract from the UK Defence Research Agency at Malvern to investigate architectures for space-based radars.

The company will be the prime contractor, working with Matra Marconi and the GEC Marconi Research Centre at Great Baddow. Responsibility for the contract at Milton Keynes will fall to the Advanced Technology Laboratory and the Special Projects Department.

UK Firm to Build ESA Satellite Spectrometer

CHISLEHURST, Kent. Sira, the UK instrumentation technology and space hardware company, has been awarded a contract by ESA for the third phase of MERIS (the MEdium Resolution Imaging Spectrometer project), which is the world's first remotely-programmable imaging spectrometer designed to be operated on an Earth-orbiting satellite. The award follows detailed design and prototyping work by Sira as part of an international team headed by Aerospatiale, reporting to ESA's prime contractor, Dornier Systems.

MERIS will be central to ESA's first Polar Earth Observation Mission (POEM 1), which will monitor the environment on a global scale providing complete coverage of the Earth every three days.

The spectrometer is programmable in flight from the ground, allowing it to undertake a general monitoring role or focus on a particular environmental concern when it arises. It differs from earlier instruments, such as SPOT, LANDSAT and CZCS, in that pre-selection of spectral bands is not necessary.

Scheduled for launch on the European Polar Platform (ENVISAT) in 1998, MERIS will image the Earth in the visible and near-infrared wavebands with a ground resolution of 250m and a spectral resolution of 1.25nm.

This combination of spatial and spectral ranges makes MERIS ideal for detailed water quality and land measurements, such as plankton content of sea-water, depth and bottom-type classification, monitoring of extended pollution areas and synoptical monitoring of vegetation. There is also interest in deriving atmospheric data from the output of MERIS.

The final construction phase of the MERIS project will take the spectrometer through structural, engineering and qualification models to the final flight model stage. Flight models and spares have been timetabled for delivery in mid-1996.

New Structure for Ariane 4

BRITISH AEROSPACE SPACE SYSTEMS, Stevenage, UK has delivered to Arianespace the first protoflight Mini SPELDA. SPELDA (Structure Porteuse Externe Lancement Double Ariane) is the French acronym for "Structure for double launch capability on Ariane 4".

SPELDA is an integral part of the external structure of the launch vehicle and provides the largest internal usable volume at minimum mass. It was initially developed under an ESA contract between 1982 and 1986 with the initial production of six being delivered between 1985 and 1989. Between 1986 and 1989 the SPELDA Improved Programme (SIP) led to significant improvements to the design and production methods. In 1987 Arianespace and British Aerospace Space Systems signed a Memorandum of Understanding for the production of 20 SPELDAs. British Aerospace is currently working on the final batch and looks forward to further orders.

The original and subsequent SIP programmes covered the development of Short and Long SPELDAs. During 1990, Arianespace saw an opportunity to add a Mini version to the programme to significantly enhance the flexibility of Ariane 4. British Aerospace was selected to develop Mini SPELDA in January 1991.

The first flight using the Mini SPELDA, Ariane 4 Flight V58, is scheduled to take place in May when the new structure will house the Insat 2B satellite inside and support the Hispasat 1B satellite on top.

Propulsion Module Tests

MCDONNELL-DOUGLAS. During the space shuttle's second space station assembly flight, two propulsion modules will be positioned on Freedom. Two more will be added following mantended capability, and an additional pair prior to permanent manned capability.

Early modules will have 13 thrusters, located at both ends and on the top of each module. On later modules the number of thrusters will be scaled down to nine. The thrusters can be fired independently, allowing precise positioning of the station.

Static firing test of propulsion development units has now begun at NASA's White Sands Test Facility in New Mexico with units having 10 small thrusters, each with an operational range of 9 to 25 pounds thrust, and three large thrusters with 20 to 55 pounds thrust.

Eureca Retrieval

ESA, Paris - Within five months of its launch on 31 July 1992, more than three quarters of the planned experiments on-board Eureca had been successfully completed and the remainder should be completed by mid-February 1993.

The satisfactory progress of the mission proves the underlying concept of operating a complex space research facility by means of satellite autonomy and on-board operations that are pre-programmed and controlled during scattered daily control centre contact times totalling only around 5% of the duration of the mission on average.

Eureca, currently orbiting at an altitude just below 500 km, is to be retrieved together with its experiments and samples, at the beginning of May 1993 by Endeavour on flight STS-57.

The Eureca mission's output consists of experimental data that is sent regularly to the ground for scientific and engineering analysis, materials processed in the very low residual gravity that is offered by the Eureca mission, samples exposed to space, surface forces research, space particle collection and new technology applications.

While a significant portion of the mission's yield is contained in its abundant and continuous data generation, the primary mission objective is the analysis in ground-based laboratories of biological and material samples and the ability, in principle, to re-use the spacecraft and payloads again in a later flight.

To date, more than 122,100 data requests (on average around 800 per day) from various remote locations/investigators (experiment home institutes, DLR's Microgravity user Support Centre, industry and ESTEC) have been served by the Eureca Data Disposition System (DDS) at ESOC, using mainly packet switching public data networks (PSPDNs) to transmit a total data volume in excess of 6000 million bytes (on average around 35 Megabytes per day).

Astronaut Chief

NASA - Robert "Hoot" Gibson has been named chief of the 89-member astronaut corps replacing Dan Brandenstein, who left the space programme in October 1992. Gibson, who became an astronaut in 1978, has commanded three shuttle flights, the most recent in September 1992 and served as shuttle pilot once. His wife, Rhea Seddon, is also an astronaut. Loren Shriver, who has flown in space three times, has been named deputy chief astronaut.

Space Mirror Test

MOSCOW - A 20-metre wide mirror made of Kevlar coated with a thin layer of aluminium and shaped like a parachute was successfully unfurled from a rotating Progress spacecraft in orbit close to the Mir space station at 7:53 pm (EST) on 3 February. The experiment, which lasted 6 minutes, was the first tentative step in a project to provide nighttime illumination for polar areas. At the end of the experiment the reflector was detached from the spacecraft and destroyed on re-entry.

Since the reflective banner was orbiting the globe, the spot on Earth moved quikly across Europe toward the former Soviet Union.

Two UK Institutes Join ISU

OXFORD - The Extreme Environments Laboratory (EEL) and the Oxford School of Architecture of Oxford Brookes University are to become an affiliated campus to the ISU (International Space University) for Space Architecture.

The Cranfield Institute of Technology, with its partners, has likewise won affiliation for the Space Physical Sciences.

A permanent site has been selected for the Central Campus of the International Space University at Strasbourg and is to be in operation by 1995-96.

An advanced communications system, known as ISUNET, will link the ISU Central and Affiliate Campuses electronically with world space agencies and industry providing instant access to the leading scientists, engineers and space-related projects in the world.

Radar Altimeter for ERS-2

ROME - The radar altimeter for the ERS-2 Earth observation satellite of the European Space Agency has been delivered by Alenia Spazio to Dornier (DASA Group). The launch of ERS-2 is expected sometime in 1994 and is part of the Earth surface observation mission which began in 1993 with the launch of ERS-1.

The radar altimeter which was developed by Alenia Spazio and installed on the ERS-1 is performing very well in observing both the ocean surface (topography and condition) and the polar ice sheets.

Alenia Spazio has also been given a contract worth about 100 billion lire for a radar altimeter to be installed on board ESA's ENVISAT satellite which is due to replace the ERS series.

SPACE AT JPL

Radar Observation of Earth

BY DR WILLIAM I. McLAUGHLIN
Jet Propulsion Laboaratory, California, USA

The great value of radar observation of Earth from orbit was clearly affirmed in 1978 by results from Seasat. The SIR-A and SIR-B missions employed radars derived from Seasat in their November 1981 and October 1984 shuttle flights, respectively. See the February 1985 edition of this column for a report on SIR-B. Originally "SIR" denoted "shuttle imaging radar"; now the "S" stands for "spaceborne." A higher-frequency radar developed by Germany, the Microwave Remote Sensing Experiment (MRSE), was flown on the first shuttle-Spacelab mission in 1983. Now, the U.S., Germany, and Italy are partners in the joint SIR-C/X-SAR shuttle-based mission to go aloft in late 1993 or early 1994.

The etymology of "SIR-C/X-SAR" can be unraveled by first looking at "SIR-C"; it is historically based, being the third in the series (fourth if Seasat is counted), and represents the U.S. contribution to the joint project.

The "X-SAR" root represents the European contribution and is a technically focused term in that "X" denotes the wavelength region, "X-band", about 3 cm, of the microwave domain utilized by this instrument. "SAR" stands for "synthetic aperture radar".

"Synthetic aperture" is a reference to the synthesis, through the orbital motion of the shuttle, of a larger antenna aperture than the physical device presents. The U.S. and European radars each are SARs as was the radar utilized by Magellan in its mapping of Venus. Dr. Charles Elachi is an Assistant Laboratory Director at JPL and manages the Office of Space Science and Instruments. He has been instrumental in bringing SARs to bear on problems in Earth science. See his "Radar Images of the Earth from Space" in the December 1982 *Scientific American.*

For spaceborne radars, pulses of microwave energy are bounced off Earth and the backscattered signal, collected by the spacecraft's antenna, carries scientific information about the scatterer: the Earth's surface. The thoroughness of probing of the surface is increased by exercising more features of the electromagnetic spectrum. Three primary characteristics of the radiated energy are available for manipulation by the investigator: frequency, polarization, and angle of incidence on the Earth's surface.

The three frequencies available to SIR-C/X-SAR are, expressed in terms of wavelength, L-band (23 cm) and C-band (6 cm) for SIR-C, and X-band (3 cm) mentioned above for X-SAR.

Polarization, which imposes constraints on the vibrations of the electromagnetic field comprising the microwave transmission, is "vertical" (V) or "horizontal" (H). The two radar frequencies of SIR-C can each assume four polarization states, HH, VV, HV, and VH, while X-SAR will be used in the VV-polarization mode. Thus, in effect these are 2 x 4 + 1 = 9 radars available for scientific investigations, and, moreover, these mine channels can be used simultaneously, wherein 10KW of radio-frequency power is required. The Seasat and SIR-A radars were constrained to glance off the Earth at one fixed angle. On SIR-B it was possible to vary the angle of incidence in order to obtain more information. The directions of the beams for the SIR-C radars are electronically steerable, while X-SAR changes direction through mechanical rotation of the antenna.

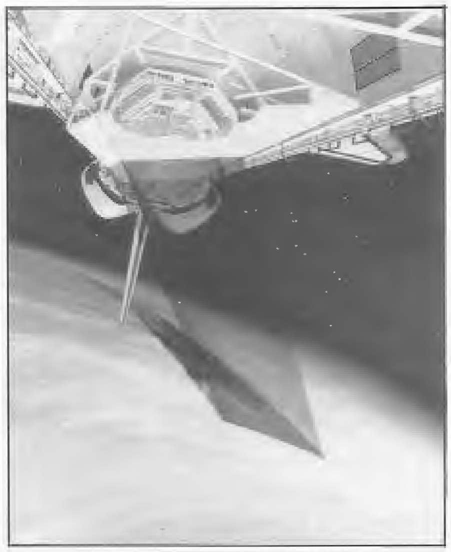
The flight of SIR-C/X-SAR will result in the collection of 50 hours of data, which corresponds to about 50 million square kilometres of ground coverage. The U.S. Project Manager, Michael J. Sander of JPL, commented to me that radars are so prolific in the production of data that they can "drench you up to the waist in bits". In particular, he was thinking ahead to the EOS-SAR ("EOS" stands for "Earth Observing System") mission of NASA which is scheduled for launch about the year 2000.

Hence, Sander remarked, one of the prime objectives of SIR-C/X-SAR is the development of algorithms for data processing. This development is facilitated by 19 "supersites", spread through the Americas, Europe, Africa, and Australia, where measurements taken from the satellite can be calibrated with *in situ* observations by investigators present at these sites. The goal is to develop algorithms which allow *quantitative* evaluation of observations in terms of the backscattered signal received at the satellite.

For example, one would like to be able to estimate the amount of biomass in the form of trees in a region in order to compute the amount of carbon captured by trees. (Recall that knowledge of the quantity of carbon dioxide present in the atmosphere is key to any predictions concerning the "greenhouse effect", and plants utilize carbon dioxide as an input to their metabolic processes.) In support of this particular measurement, a forest at Oberpfaffenhofen in Germany, one of the 19 supersites, was calibrated by measuring the locations and diameters of its constituent trees in order to provide "ground truth".

An important aspect of ecological studies is the evaluation ofthe status of rain forests.

An important ingredient in meteorological studies is the measurement of rainfall on a global basis.



An artist's conception of SIR-C/X-SAR shows this radar system in the bay of the shuttle as it gathers scientific information during an upcoming flight. *NASA/JPL*

Photography of the supersites is already underway on a time- available basis from the shuttle in order to create a reference file which includes more than just radar-frequency data. A NASA DC-8, "AirSAR", has been adding to the file too.

SIR-C/X-SAR itself will generate data at a rate of 180 megabits per second. It is possible to send 50 megabits per second of the data stream through the space link from shuttle to Earth via NASA's Tracking and Data Relay Satellite System (TDRSS). Most of these data will be from X-SAR. The remainder of the radar data (including a backup copy for the X-band set) will be stored on 160 data tapes onboard the shuttle for conveyance to Earth.

The X-SAR contributed by the Europeans employs an elegant graphite-epoxy antenna which is a technological step forward for the state-of-the-art.

The U.S. radar is electronically sophisticated, but no attempt has

been made to produce a light-weight structure. Two years ago, when Sander became project manager, he inherited a complicated, folding design for the SIR-C antenna. The reason for this state was to leave room in the shuttle bay for another payload. However, with the heavy demands of SIR-C/X-SAR on shuttle resources such as power and crew time (the experiment will operate 24 hours a day), it would seem unlikely that a second payload could be accommodated, other than volumetrically. Therefore, it was no loss to change plan and build a solid, massive structure in place of the original design, and the benefit was a reduction in complexity and cost. The SIR-C antenna is the most massive piece of flight hardware ever built at JPL and has a mass of 10,500 kg, dimensioned 12 meters by 4 meters.

The complete scientific program of SIR-C/X-SAR spans several disciplines: geology, hydrology, ecology and vegetation science, oceanography, and meteorology.

Among the geological questions to be addressed are some related to patterns of past glaciation and tectonic history. The ability of the radar to penetrate extremely arid sheets of sand will allow mapping of buried structures, including paleodrainage features.

Water often gives a distinctive radar signature, and, for example, soil-moisture measurements will be feasible as one of several hydrological parameters to be determined.

An important aspect of ecological studies is the evaluation of the status of rain forests. Models will be developed to discriminate between backscatter responses from a canopy of vegetation and the underlying soil. The structure of canopies and the identification of vegetation types are within reach of SIR-C/X-SAR.

The Topex/Poseidon mission launched in August 1992 (see the December 1992 edition of this column) is using a radar altimeter to investigate the patterns of circulation of the oceans, SIR-C/X-SAR observations will complement these measurements, contributing to the theory of wave imaging and internal wave behaviour.

An important ingredient in meteorological studies is the measurement of rainfall on a global basis. SIR-C/X-SAR will undertake a proof-of-concept demonstration of rainfall measurement from space.

The SIR-C/X-SAR mission has three signs of a space classic in the making: good science with an evolutionary track to facilitating even better science; technological advances in an important area; and another notch on the stick of successful international collaborations.

Zones for Planets

Searches for extraterrestrial intelligence are aimed at finding evidence at the high end of the biological scale while searches for extra-solar-system planets probe the basis for biology as we envisage it. Methods of detecting planets about other stars are varied and include not only direct imaging but also indirect techniques such as measuring the "wobble" induced by a planet in the slowly evolving track of a star across the sky. A new method has recently been utilized to analyze the structure of material known to be orbiting certain stars and has found indications that this structure may, in part, derive from imbedded planets.

Earlier in this century, the favoured theory for the origin of the solar system was the tidal hypothesis developed by Sir James Jeans (1877-1946) and Sir Harold Jeffreys (1891-1989). In this scenario, a star passing by chance through the neighbourhood of the Sun drew material from that body through the action of gravitational force. The solar material, rather than falling back to its place of origin, was induced to orbit the Sun and eventually produced the retinue of planets which we know today.

However, subsequent scrutiny was not kind to the tidal hypothesis, and currently the nebular hypothesis holds sway as the root principle of cosmogony. This theory presumes that a portion of a molecular cloud within our galaxy collapsed as a result of gravitational forces within the cloud, forming a protostar. When temperatures rose high enough within the protostar, nuclear reactions were initiated: a star, our Sun, was born. (The philosopher Immanuel Kant (1724-1804) and the astronomer and mathematician Pierre Simon Laplace (1749-1827) had each formulated a version of the nebular hypothesis.)

During the protostar phase, the infalling material formed a roughly spherical structure enclosing the central object. Later, in the so-called T Tauri phase (T Tauri is a star in the constellation Taurus and serves as a model for low-mass stars in this portion of their development cycle), only a disk of material remained around the Sun. For our Sun, after planetary formation was complete, very little else of the disk remained.

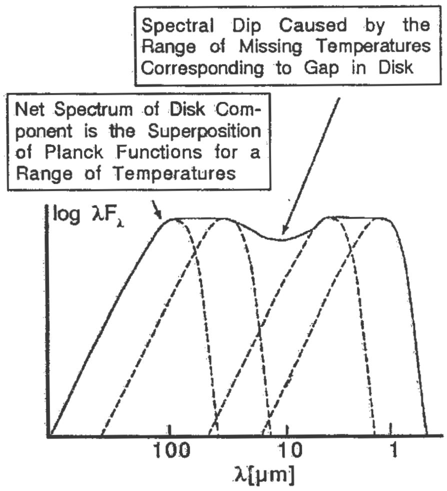
Drs. Kenneth A. Marsh and Michael J. Mahoney of JPL have applied a few basic ideas of physics to thinking about how the process of planet formation, if it were taking place in the circumstellar disk of a T Tauri star, might be observable from the Earth.

The first idea, already extant in the astronomical literature when they began their research, is that a gap in the circumstellar disk would be created as a planet started accreting from the primordial material. Tidal disruption by the growing protoplanet is thought to be the primary mechanism of zone clearing, complemented by gravitational resonance effects between the protoplanet and other circumstellar material.

For the next step in the chain of reasoning, it is necessary to note that temperature decreases in a circumstellar disk with increasing distance from the star. This is intuitively plausible since the disk material is heated by radiation from the star. For the class of T Tauri stars, the temperature fall-off has been estimated to be approximately proportional to the square root of the distance. Thus, if particle A were four times the distance from the star as particle B, A would have a temperature one-half that of B.

Now, one cannot directly measure, as in thermometry, the temperature of a point in a circumstellar disk. However, there is a relation between the wavelengths of light emitted from a particle in the disk and the temperature of that particle, and it is possible to measure the amount of energy being emitted from the whole disk of particles as a function of wavelength. The crucial point of the argument of

Effect of Gaps on Spectral Energy Distributions



The dotted lines outline four illustrative "Planck functions", each of which describes the energy (vertical axis of chart) radiated over a spread of wavelengths (horizontal axis of chart, wavelengths measured in microns) by a particle of matter at a certain temperature. The Planck functions shift to shorter wavelengths (to the right) for warmer particles. For a ring of particles about a star - a circumstellar disk - a gap in the disk would manifest itself as a dip in the energy spectrum as measured from Earth. One cause of a gap might be clearing due to planetary formation. *NASA/JPL*

Marsh and Mahoney is that if the emission spectrum of the disk is seen to be deficient in a region of wavelengths, then, due to the known relationships between wavelength and temperature *and* between temperature and location in the disk, a deficiency in the amount of material can be inferred for certain locations in the circumstellar disk.

To anticipate the "bottom line", Marsh and Mahoney did find likely cleared Zones in the circumstellar disks of two stars, HK Tauri and GK Tauri, and conclude that these may be regions where planetary formation has taken place. However, their analysis was more careful than this summary has indicated, and it is worthwhile to pursue some of these details.

First, as a point of physics, the plural in the phrase "the wavelengths of light emitted from a particle", acknowledges that, unlike a laser, a particle of matter will emit energy with a whole range of wavelengths, i.e., not monochromatic emission. Planck's formula is a mathematical expression which quantifies this fact and shows how the amount of energy emitted at a given wavelength varies with the temperature of the emitting object. The graph of Planck's formula shows a maximum of energy emission which shifts to shorter wavelengths as the temperature of the emitting body increases; a hot stove can glow cherry red, and, as its temperature is increased, the red colour of the glow will become less pronounced. (Red represents the longest visible wavelengths.)

Picture then what happens to the output of energy emission versus wavelength when certain temperature values are not achieved in the circumstellar disk as a result of the presence of clear zones; there will be a dip in the expected amount of energy in those wavelengths where the temperature-dependent Planck formulas representing the missing material would have reached a maximum. It is as if one had removed a whole block of performers from an orchestra: certain characteristic tones would be reduced for the performance.

When Marsh and Mahoney analyzed the spectra (energy output versus wavelength)of two T Tauri stars, GK Tauri and HK Tauri, they modeled three components which contribute to these curves (considering the data as graphically represented): the star, the circumstellar disk, and the boundary layer between star and disk. The boundary layer is a turbulent region due to star/disk interactions, which are exacerbated by differing speeds of rotation, and emits an excess of high-energy, ultraviolet light. Using a mathematical model built from these components, and including in the model a depleted region of the disk ("the gap", "the clear zone": where planets might be abuilding), they were able to reproduce to good fidelity the observed spectra of GK Tauri and HK Tauri by adjusting parameters of the model. The key parameters were the inner and outer radii of the depleted region.

In order to strengthen the case that large orbiting bodies in a circumstellar disk would indeed produce energy dips in a region of the spectrum of the system, Marsh and Mahoney selected two test cases, GW Orionis and DF Tauri, of T Tauri stars that have a known (stellar) companion. The binary nature of GW Orionis had been revealed (R. D. Mathieu, et al. in the *Astronomical Journal*, vol. 101, p. 2184, 1991) through analysis of periodic shifts in its spectral lines. The double star DF Tauri's orbital parameters were obtained through observing the two-step diminution in the brightness of the system during an occultation by the Moon (M. Simon *et al.* in the *Astrophysical Journal*, vol. 384, p. 212, 1992). These two stellar systems showed dips in their spectra which fit the analytical model of Marsh and Mahoney.

The investigators have documented a portion of their work in the *Astrophysical Journal* (vol. 395, p. L115, 1992), and a second paper has been written and is in the review cycle.

The path which lead to their discoveries started from a JPL study as to what kinds of science would be possible from a future lunar base. When considering observations of planets about other stars, Marsh was stimulated to think about what could be done from the surface of the Earth and obtained the central insight. Mahoney said that he played "devil's advocate" to Marsh's idea for several months. But, as the hypothesis survived test after test, both investigators swung over to the role of advocate and the planetary-formation theory emerged.

What is the Problem?

Perhaps all endeavours in science and engineering could be forced into the category of "problem solving", but one should probably leave space for faculties such as "pure invention" and "leadership". In any case, mastery of the art of problem solving is of crucial importance to progress in space programs. The art seems to be innate for many gifted people, but there are stratagems and principles which have been evolved over a long period of time for the purpose of steering through obscurities. It makes sense to view the subject of problem solving as a set of examples along with a theoretical component.

The term "heuristic" has been used to denote a set of techniques with which to address problems. The mathematician George Polya (1887-1985) had a distinguished professional career but made time to supplement his more technical works with a small masterpiece: *How to Solve It* (second edition, 1957, Princeton University Press). By example and by an integrated approach to problem solving, Polya has provided a most useful heuristic for university students and others harried by the necessity "to solve it".

Polya's approach is divided in logical fashion into four phases:

(1) understanding the problem,
(2) devising a plan,
(3) carrying out the plan, and
(4) looking back.

The heart of the issue, devising a plan, includes discussion, for example, of the efficacy of looking at related problems or trying to solve more general or more special cases of your problem.

The basic idea in any problem situation is to look continually at the matter from a series of fresh perspectives until the path to the solution becomes clear. I am reminded of the chicken who starved while looking at feed through a wire fence, unaware that the fence extended only a few feet to either side. An extreme example of the power of variation, in this case "ignorant" variation, is given by the role of mutation in the theory of evolution.

One method of varying the problem recommended in Polya's heuristic is to drop part of the condition and see if you can solve the resulting, related problem. This was done by Galileo's mission designers when they were faced with the problem of getting the spacecraft launched to Jupiter after the 1986 explosion of Challenger; the powerful Centaur upper stage was banned for use on the shuttle as part of the overall safety review. The engineers knew that planetary gravity assists were a possible substitute, but, seemingly convenient Venus was unavailable because it was too close to the Sun and Galileo was not thermally prepared for these warmer environs. But they dropped this condition and showed, dynamically, that the use of Venus and Earth for gravity assists would do the trick. The Galileo Project was delighted and carried out the necessary thermal modifications to the spacecraft.

Incidentally, Galileo has made its closest approach to Earth on December 8, receiving the second gravity assist from our planet and is on its way to Jupiter. The navigation to the aim point at Earth was excellent, less than 1 km deviation for the 300 km altitude flyby. Scientifically, valuable data for Earth and Moon (including polar regions) were obtained, and the instruments were calibrated for their primary use at Jupiter.

Donna Wolff, who supervises the Mission Planning Group at JPL, recently addressed the question of how to make spacecraft more operable, i.e., more user friendly. She convened a group meeting that worked on the premise of listing attributes that would make a spacecraft less operable. What deep psychological resources can be mobilized, in all of us, when the problem is rotated by 180 degrees!

With this approach the group easily came up with a number of "recommendations." Equip the spacecraft with a "wimpy" propulsion system so that the flight team must spend long hours conducting manoeuvres. Include many appendages in the vehicle's architecture, many deployable, thereby complicating both initialization of the flight system and planning clear lines-of-sight for remote-sensing observations. Insist on many moving parts so that the likelihood of component failure is enhanced, promoting arduous procedural workarounds. Insure the necessity of extensive and exacting planning at all times by building no margins into the power and data subsystems, and, as a bonus, make sure that all of the subsystems affect one another.

The ability to alter our stance with respect to a problem is important but so is the stock of knowledge from which we draw. One of Polya's primary questions is "have you seen it before?" Without experience even the best of associative memories falls short.

I was motivated to write "Prediscovery Evidence of Planetary Rings" (***JBIS***, August 1980) in order to explore the possibilities for discovery inherent in slight or even contradictory bodies of evidence. Answering Polya's question by reflecting on the then-known rings about Jupiter, Saturn and Uranus, I predicted, by analogy, rings about Neptune. (However, whatever small merit might inhere in this act of prescience was erased by my waffling about the case of Pluto, as I note upon rereading the paper.)

Piling up large collections of facts is normally not a productive activity, unless you plan to specialize in being a contestant on game shows. I have observed that those facts and experiences which seem to serve me best, and remain available for long periods of time, are ones that have been attached to centres of personal interest.

This view of the northern polar region of the Moon was obtained by the camera of the Galileo spacecraft as it flew by our satellite in December 1992. The range is 121,000 km. The large lava plain is Mare Imbrium. The north pole of the Moon is toward the darkened region in the cratered area.
NASA/JPL

For example, for reasons of psychology unknown to me, I had been interested since graduate school in representing, in part, trajectories by recording their intersections with spaces of lower dimensionality than the one in which they reside. (Technically, Henri Poincaré's "surface of section" is perhaps the prime example of the technique.) Finally, in 1976 this base of knowledge came to life when it was transformed into a way of graphically representing the scientific consequences of different observational strategies for the Infrared Astronomical Satellite (IRAS), launched in 1983.

The abilities to shift perspective and to bring previous experiences to bear on a problem are the linchpins of technique. However, I believe that there is an even more fundamental attribute of the successful problem solver. As Polya phrases it: "The open secret of real success is to throw your whole personality into your problem."

Isaac Newton (1642-1727) not only provoked the admiration of his contemporaries for his astonishing set of discoveries but also left them wondering how it was possible to accomplish so much. When asked how he discovered the law of gravitation, he responded, "by thinking about it all the time." Using the law of gravitation and his three laws of motion, he was able to explain, among his many successes, numerous features of the Moon's motion. Even the great Newton showed limits to his power of concentration when he complained that the lunar theory made his head ache.

Even if one accepts the doctrine of concentration as the basic condition of discovery, it is clear that we cannot all excel in all areas; we return to the importance of personal interest, not just in acting as an attractor for the retention of facts, but as a way to multiply our natural powers manyfold.

Newton's two remarks - on concentration and one of its affects - were suspended in my mind for a number of years (undoubtedly attached to a Polya-related cluster of facts) before I realized that the second lent credence to the first. What if Newton was telling the exact truth and stating the most important "secret" of his heuristic: hard work without distraction? This, of course, is a variant of Polya's "...throw your whole personality into your problem."

Although one can shrug off this hypothesis by pointing to "acts of brilliance" by prodigies, the method of the effortless solution is only one path to an end. It is the results that count. To counter the example of the inexplicable prodigy, I submit the life and work of the philosopher Immanuel Kant, an admirer of Newton, who, to the best of my knowledge, "ground it out." Like Newton, he changed the way we think about the world.

Even if one accepts the doctrine of concentration as the basic condition of discovery, it is clear that we cannot all excel in all areas; we return to the importance of personal interest, not just in acting as an attractor for the retention of facts, but as a way to multiply our natural powers manyfold.

The French abbé Ernest Dimnet (1866-1954), in his delightful book, *The Art of Thinking* (Simon and Schuster, New York, 1928), is one of many commentators who endorses a blend of concentration, "interior solitude", with following personal bent, "be yourself." The two ideas are conjoined in the following passage from Dimnet. "Genius never plods. When Buffon defines it as a 'long patience' he means not the patience of doggedness, but the perseverance of enjoyment. Who will believe that, during the seventeen years of his quest after his law, Newton did not derive immense pleasure from what we wrongly call his work, but which ought to be called the fascinating occupation of his mind? Genius is well known to be able to devote longer stretches to its work than ordinary talent which needs intervals of relaxation. The reason is that the relaxation of genius lies in the consciousness of doing what it loves to do and would hate to forego."

The art of problem solving, then, is a tapestry of many threads, including: agility, knowledge, and compulsive persistence. Indeed, the effort can make your head ache, but the exhilaration of success is a unique pleasure.

Correspondence

Historical Space Video Recordings

Sir, As this matter still appears to be one of contention (***Spaceflight***, January 1993, p.34), I decided to find out the facts once and, hopefully, for all.

I asked in my second letter an open question as to which 'space footage' we were actually worried about, and I accept that the "television space studio" footage appears just as important as the NASA footage. My original correspondence with Ian Broadbent - which was not through the columns of ***Spaceflight*** - revolved around the idea of the BBC releasing, for home viewing, compilation videos of the Apollo coverage. Consequently I did a certain amount of research, firstly for Ian, secondly for my own interest, into just what was still available in the BBC's Film and Video Library. Hopefully readers will accept that entries in any library under "Space", or even "Apollo", could be fairly large, which is the case, and the 'Space Studios' themselves were not singled out at that time. However as it now appears that it is these Studios themselves that are the main interest, I contacted the Library again to check the entries yet again. However this only confirmed what I had in fact already suspected, that the Space Studios were not actually recorded, with the consequence that it makes any subsequent releases somewhat academic.

To quell the cry of "Why not?" you have to remember that the Apollo missions were late sixties/early seventies and although it may seem strange that television technology lagged behind, say, manned space flight, it did to a certain extent. We were only just in colour in the UK in 1969, (BBC-2 in 1967; BBC-1 and ITV, 1969) and professional video recorders were still on the 2" format and correspondingly large. The Space Studios also went on for some hours each day and would have used up several spools every transmission. Therefore it was decided not to record what was after all a live programme. (This was not that the Space Studios were being victimised, this was common with all live programmes). In addition, and as I said in my first letter, we cannot even resort to a non-broadcast quality of tape (which has been done to reconstruct some episodes of Doctor Who), as this was also before the common use of 'domestic' video; VHS had still to arrive, and Phillips 1500 and 1700 were still hardly plentiful.

Although the main content of the live Space Studios never existed on tape, pre-recorded inserts used throughout the programme were on film and do still exist. Memories of later programmes using clips from these Studios probably relate to these filmed inserts. As I discovered, first time around, it seems that the majority of the 'other' space programmes - Horizon etc - do still exist and so maybe there is a possibility of "reconstructing" the basic feeling of the time of Apollo television coverage? If anything new comes out of this, you will - as they say - be the first to know.

MAT IRVINE
Bucks, UK

Radio Amateur Activity from Space

Sir, Having been a shortwave listener since 1978, I first became interested in listening to Radio Amateur traffic from Space on the 2m amateur VHF-band in November 1985 when Germany had their D1-mission up.

Included on this mission was amateur activity with the callsign DP0SL, on a downlink frequency of 145.575 MHz and modes FM/CW. I happened to hear their CW-beacon only once.

Amateur activity was started back in November 1983 when Owen K. Garriot, callsign W5LFL, was active onboard the STS-9 mission on mode FM. In July 1985 this was followed by Tony England, callsign W0ORE, who was active from onboard the STS-51F mission on modes FM/SSTV.

In December 1988, I heard activity for the first time from Mir on the 2m-band. It was Musa Manarov, callsign U2MIR, who was very active. I managed to hear Musa a total of three times. Less active on this mission was also V. Titov, callsign U1MIR, and V. Polyakov, callsign U3MIR. This activity from Mir started back in March 1988, when Musa asked Ground Control for some copies of the Radio magazine to be sent up and the Psychological Support Group asked the staff of the magazine for some copies. They were delighted about the request and included a letter to Musa asking if the crew where interested in becoming licensed as amateurs. They were, apart from a few problems, Musa said. None of the crew was licensed as a Radio amateur, there was no amateur radio equipment onboard, and they also needed a special antenna. These problems were solved and the cosmonauts became active in November 1988.

A great help in my listening to Mir were three articles in ***Spaceflight*** in October 1987, p.80, March 1988 p.108 and April 1988, p.156, although there was one problem. Here in Denmark, and I suppose in some other countries too, we are not allowed to listen to the frequencies mentioned. Then due to antenna problems I was not able to listen to the amateur 2m VHF-band until shortly before the Juno mission in May 1991.

In the meantime until May 1991 there had been some activity from the Mir space station and also from STS-35 in December 1990, callsign WA4SIR, and from STS-37, callsign KB5AWP. Then from May 1991 until mid August 1992 there was a lot of activity from Mir on the 2m-band, more precisely on 145.550 MHz. The activity has been both from Russian cosmonauts and from foreign guest cosmonauts as follows:

May-91	Helen Sharman, callsign GB1MIR, whom I only heard once on mode FM.
Oct-91	Franz Viehböck, callsign OE0MIR, automatic transmission on mode FM/Packet whom I heard a total of four times. In connection with this mission the Austrian Radio Amateur Association issued a very informative 64-page booklet.
Nov-91 to Mar-92	A. Volkov, callsign U4MIR, and S. Krikalev, callsign U5MIR, were very active on 145.550 MHz and mode FM/Packet which gave many amateurs on the ground their first qso'es with a manned Spacecraft.
Mar-92	Klaus D. Flade, callsign DP1MIR, was active from Mir on Mode FM. I heard Flade twice. In connection with this mission German amateurs had set up a Ham-station at DLR, which sent out info about the mission every day on the 80m amateur band, more precisely on 3695 kHz LSB.
Mar-92	Also saw amateur activity from onboard the STS-45 mission. Onboard this mission was a total of four amateurs who used the callsign N5WQC, which I heard a total of nine times on mode FM. Languages used were English, French, Dutch and Norwegian. This is the first time ever that I have heard a Scandinavian language spoken from a manned spacecraft, but Kathy Sullivan does speak very good Norwegian.
Aug-92	The French cosmonaut that was sent up to Mir in late July has been heard on 145.550 MHz in French talking to a French station. Unfortunately my French is not the best, so I did not catch his callsign, although I heard him a total of three times.

On the amateur HF-bands there are some nets and stations to be heard that are connected to amateur activity to and from space:

AMSAT-UK net Mon/Wed	on 3780 kHz +/-	at 1900 local time.
AMSAT-UK net Sunday	on 3780 kHz +/-	at 1015 local time.
AMSAT-EU net Saturday	on 14280 kHz +/-	at 1000 UTC.
AMSAT-In net Sunday	on 14282 kHz +/-	at 1900 UTC.

Goddard Space Flight Center, callsign WA3NAN.
Johnson Space Center, callsign W5RRR.
Jet Propulsion Laboratory, callsign W6VIO.

There might also, in the time ahead, be an amateur club set up sending information about the Mir-mission from NPO Energiya, near Moscow. WA3NAN often sends out information and relays STS-flights on the following HF frequencies: 3860, 7185, 14295 and 21395 kHz.

To hear any of the above mentioned frequencies you must have a radio that is capable of receiving in the SSB-mode.

In connection with the Austro Mir 91-mission, the Austrian Shortwave Service sent out a lot of information in their German language service, which was also about the amateur experiment Aremir.

In the spring of 1993 a German SAFEX D2 will take place onboard a space shuttle. Unfortunately due to its low inclination this mission will not be audible here in Northern Europe. To compensate for this German amateurs will set up a relay station at Tenerife which will send to and from the Shuttle on the 2m amateur band and relay to and from Europe on the 20m/15m amateur bands. In connection with the D2-mission the DLR-clubstation DF0VR will again be active as during the D1 and the Mir-92 mission.

Further reading may be found in ***Spaceflight*** :

1990 February p.70 and June p.186;
1991 February p.46-53, April p.116-117, June p.196-197, July 226-231 and August p.268-269;
1992 May p.146 and 147.

J.K. ANDERSEN
Skagen, Denmark

Space Music and Songs

Sir, Having read Mark Hempsell's December 1992 ***Spaceflight*** article, I look forward to the release of Tasmin Archer's debut album in the USA. I would like to thank Mr Phillips' response to that article, published in the January 1993 ***Spaceflight***, which listed several space songs of which I had not heard. Hopefully, I can now return the favour by adding to the list he offered in his letter.

Mozart's Symphony No 41 was called "Jupiter", while Mahler's Symphony No 1 was called "Titan", although it is questionable whether these can be considered space music.

There are two electronic versions of Holst's "The Planets" - one by Isao Tomita and another by Michael Gleeson. Morton Subotnick's "Return" was commissioned to commemorate the return of Comet Halley to the inner Solar System in 1986. Also in the genre of electronic music, the Voyager missions inspired at least three works:

Wendy Carlos	"Digital Moonscapes"
Ian Tescee	"Io"
Michael Lee Thomas	"Voyager - Grand Tour Suite"

Turning to pop music, we must first of all remember "Fly Me to the Moon", which Frank Sinatra made famous. However, perhaps the first song of the Space Age was "Telstar", an instrumental recorded by the Tornadoes, which was inspired by the launching of the telecommunications satellite of the same name.

I recall a song about an alien called "Purple People Eater", which dates from the late 1950s or early 1960s. Perhaps someone can supply the name of the artist. Other Close Encounters set to music were:

The Byrds	"Mr Spaceman"
Creedence Clearwater Revival	"It Came Out of the Sky"
Jefferson Airplane	"Have You Seen the Saucers?"
Styx	"Come Sail Away"

David Crosby's "Triad" (also recorded by the Jefferson Airplane), with its free love theme and its reference to "water brothers", seems to have been inspired by Robert A. Heinlein's novel *Stranger in a Strange Land*, and as such might qualify as the first Martian love song. The Jefferson Starship's first album, "Blows Against the Empire", an account of the hijacking of the first starship by a throng of hippies, is reminiscent of the Heinlein novella *Methuselah's Children*.

The Moody Blues wove space themes into their music in songs such as "Higher and Higher", "Floating" and "The Best Way to Travel". Other space rock songs of the 1970s were:

The Steve Miller Band	"Space Cowboy"
Yes	"Starship Trooper"
Aerosmith	"Spaced"

Mr Davey mentions in his letter, also published in the January 1993 ***Spaceflight***, that John Denver is on the National Space Society's Board of Governors. Several years ago, Denver tried to get a ride on the Space Shuttle, but in the wake of the Challenger accident, NASA turned him down. He also approached Glavkosmos about a Soyuz mission to Mir, even offering to pay his own way, but they could not agree on a price. Denver later wrote "Flying for Me", a tribute to the Challenger's last crew which also gave voice to his own yearning to go into space.

There is a Grateful Dead song called "Dark Star", not to be confused with the Crosby, Stills and Nash song of the same name. Also, in tradition spanning more than twenty years, the Grateful Dead have segued into dissonant instrumental improvisations midway through the second set of their concerts. Obviously, no two such performances are the same, but among Deadheads these are collectively known as "Space". Several of these improvisations have been collected on the album "Infrared Roses", where they have been given individual names. Lastly, of all the space songs I have heard, my favourite by far is the Grateful Dead's very moving anthem "Standing on the Moon", which commemorates the twentieth anniversary of the Apollo 11 landing.

The discussion of space music in this letter and in the ***Spaceflight*** references cited above has been confined to that produced by Western culture. We should consider that in Russia, where the former Soviet government actively tried to promote a "space culture" for three decades, there are certainly many works of which the Western world is not generally aware. I would enjoy hearing from our Russian members on this subject.

THOMAS GANGALE
California, USA

Songs and Space

Sir, I am writing in response to the Correspondence Column in the January 1993 issue of ***Spaceflight***, in which my letter, concerning the general paucity of songs and music supporting space flight, seemed to be at least partially contradicted by the letters from Messrs Cresdee and Phillips, also published in that issue.

While I am happy to accept the existence of the various titles mentioned by them and, indeed others (I have a tape by Barbara Dickson, containing a song - 'The Same Sky' - about an astronaut), I feel that your other correspondents have missed the point, which is that most of the works are either purely descriptive - 'Space is a big, strange place' - or metaphorical, using astronautical terms to describe rather more 'down-to-earth' situations (as is the case with Miss Dickson).

A number of songs are actually critical of space travel, usually from a 'Green' or 'New Age' viewpoint.

I believe the point I made was a perfectly valid one - that 'Sleeping Satellite' is one of a very limited number of songs that actually and specifically support the idea of space exploration.

P.W. DAVEY
Dorset, UK

The Editor welcomes items of correspondence for publication. The right is reserved to shorten material as appropriate.

Russian Space Transportation Possibilities

Sir, I have been reading with great interest the prospects of cooperation between ESA and Russia in developing spaceplanes and space station hardware. It shows the need for a shuttle type spacecraft in the 20-24 t gross weight category or about a quarter of the weight of the US STS or CIS Buran.

If Hermes is to be used for Mir-2 station support as well, then the AR5/MK2 will not have sufficient power to deliver an effective payload to 51.6 degree inclination. The Proton KM launcher could in principle launch the Hermes with its resource module, delivering greater payload to the required inclination. It would give Hermes the unique flexibility of supporting both 28.5 and 51.6 degree inclinations for space station operations.

On the other hand the proposed Maks spaceplane does provide an attractive solution to low cost payload delivery replacing eventually the current SL4, SL6 and Tsyklon launchers. Its unique RD-701 fits in the thrust category of a second stage for the Zenit launcher. The Proton KM's new LH_2/LO_2 escape stage would also fit as a third stage for the Zenit 3 launcher. Together they would boost Zenit's payload/height characteristics considerably.

NPO Molniya seems to have more than one design for the spaceplane [1]. One design puts the cosmonaut cabin behind the payload bay. No main engines would fit in this version.

M.Q. HASSAN
The Middle East

Reference

1. Interavia/Aerospace World Business & Technology, October 1992, p.124.

Soviet Launch Vehicle Classifications

Sir, In my previous letter, published in the August 1992 issue of ***Spaceflight***, I guessed that Chelomei's UR-200 rocket might be used for launching the Polyot manoeuvring spacecraft in 1963-64 and that Korolyev's SS-10 Scrag ICBM was probably used for two first FOBS-related missions in 1966.

My further inquiries have shown that, though the reasoning behind above statements is true, the conclusions turned out to be too far-reaching.

1. The UR-200 was indeed supposed to launch the Chelomei-made ASATs of which the Polyots were prototypes [1]. But the UR-200 was test-fired with a live first stage only [2] and the Polyots were to be launched by the production-line two-stage R-7 (the SS-6) boosters. Since third stages were in a short supply, the Polyots were launched underfuelled and used their own engines for an orbit insertion [3].
   So, the SL-5 launcher was in fact neither A-m nor the "D-0" UR-200. It did not exist as a separate type and was the same basic A launcher, which already bears two DoD designations - the SL-1 and the SL-2!
2. The Scrag (its equivalence with the SS-10 was assumed from Congressional Reports) was indeed designed as a FOBS weapon and its genuine name was the GR-1 standing for "global rocket". However, it was never launched and its designers ironically nicknamed the GR-1 "an intercontinental missile Moscow to Leningrad" [4].

Thus, the "E" class of the Sheldon system had to emerge, but failed to do so.

MAXIM V. TARASENKO
Centre for Arms Control,
Energy and Environmental Studies,
Moscow Institute of Physics and Technology

References

1. Leonard S. Legezo, "The Activities in the USSR for the Creation of an Antisatellite System", A presentation at the ISY Conference, Moscow, March 30, 1992.
2. Igor B. Afanasyev, Private communication.
3. Vladimir A. Polyachenko, "On the activities of the OKB-52/TsKBM under the Kosmos programme", A presentation at the ISY Conference, Moscow, March 30, 1992.
4. Igor B. Afanasyev, "Aviatsia i Kosmonavtika", No.8, 1992, p.34.

SOCIETY MEETINGS DIARY

LECTURES

Venue: All Lectures will be held in the Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Admission is by ticket only. Members should apply in good time enclosing a sae. Subject to space being available each member may also apply for a ticket for one guest.
It may occasionally happen that, for reasons outside its control, the Society has to change the dates or topics of meetings. Where time allows, every effort is made to avoid inconvenience to members either by notice of change in ***Spaceflight*** or by special advice to each participant. Please, therefore, always recheck the scheduled meetings in the latest issue.

3 March 1993 — 7 pm - 8.30 pm

Armchair Interstellar Exploration

A.T. Lawton

Although he dreams and plans, it is very unlikely that many men will undertake manned interstellar flight. For those who will never go to the stars - the stars must come to him.

Developments in technology e.g. interferometry, large apertures, new types of high resolution detectors and high fidelity data links will enable this to happen.

As of now they allow us to see solar cycles on other Sun-like stars, detect planetary dust clouds around them and deduce the possible presence of Jupiter like planets.

These techniques can be extended with precision spectrometry to form a catalogue of stars with planetary systems closely resembling our own Solar System.

This is Armchair Interstellar Exploration whereby if we do go, or send a one way robot as proxy, we will have maximum chance of success in locating other life forms.

17 March 1993 — 7 pm - 8.30 pm

Mission Control and Control Centre Operations

D.E.B. Wilkins

The lecture will discuss spacecraft opertions in general, the technology involved and the practice of operations since the early days of space flight.

The lecture will not dwell on the historical aspects of spacecraft control though references will be made to the significant advances achieved in those early years, 1957 - 1969.

The lecture will be presented in three parts: Past, Present and Future, and will be based on the experience and activities of the speaker in the fields of Spacecraft Control and Systems Engineering.

The early NASA Manned Mission control methods will be briefly discussed and the ESA experience in scientific and applications missions described in some detail to expand discussion on Mission Control.

7 April 1993 — 7 pm - 8.30 pm

Cassini

Mr C. Cochrane

Cassini is a project planned by ESA and NASA for a spacecraft to survey the planet Saturn and its environs. During the journey to Saturn, fly-bys and investigations will by made of asteroids and Jupiter. After arrival at Saturn the spacecraft will orbit the planet for a further four years, using remote sensing to examine its satellites, rings and the planet itself. A sophisticated probe will be released in the first orbit to land on the mysterious moon Titan, to explore its atmosphere and surface.

The presentation will describe the scientific objectives of the mission, its trajectories and explain the engineering problems of the Titan Atmosphere Probe, concluding with a review the feasibility of the proposed solutions and present the innovative features of this fascinating mission.

5 May 1993 — 7 pm - 8.30 pm

Results from ERS-1

Dr G.E. Keyte
DRA Farnborough

The European Space Agency's ERS-1 satellite was one of the most complex remote sensing satellites ever launched. Despite its complexity, it has functioned almost perfectly since launch in 1991 and has enabled a wide range of research and application projects to be undertaken.

This paper briefly describes the main characteristics of the ERS-1 instruments and gives an account of their 'history' since launch. Some of the main results obtained from each of its instruments are reviewed, covering both the two microwave instruments (the Active Microwave Instrument and the Altimeter) as well as the instrument provided by the UK, the infra-red radiometer (ATSR). It will conclude by reviewing the future development of microwave remote sensing satellites after ERS-1.

14 August 1993

48th Annual General Meeting

The 48th Annual General Meeting of the Society will be held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ, on Saturday, August 14, 1993 at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Corporate Members (i.e. Fellows of the Society) only, who should apply in good time enclosing a stamped addressed envelope.

Council nomination forms are obtainable from the Executive Secretary. These must be completed and returned not later than 12 noon on May 22, 1993. If the number of nominations exceeds the number of vacancies, election will be by postal ballot. Voting papers will then be prepared and circulated to all Corporate Members.

SYMPOSIA & CONFERENCES

24 March 1993 — 10 am - 4.30 pm

European Rocketry in the 1930's

As part of the Society's Anniversary Year the History Working Group are holding a Symposium on European Rocketry in the 30's. Contributions have been invited from Germany, France, Russia and the UK. The 30's is seen as a particularly interesting decade in that much theoretical and practical work was undertaken that laid solid foundations for later projects.

Whilst much publicity has surrounded the experimental and theoretical work carried out in Germany an enormous amount was also carried out elsewhere, particularly in Russia. Much of this story has yet to be told.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

19 May 1993 — 10 am - 5.15 pm

Electric Propulsion of Spacecraft

Dr D.G. Fearn
DRA Farnborough

A one-day technical symposium under the chairmanship of Dr D.G. Fearn, Defence Research Agency, Farnborough, Hants.

Papers will be presented on the status of different ion thrusters and propulsion systems under development as well as other topics relevant to electric propulsion.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

12 June 1993 — 10 am - 4.30 pm

Soviet Astronautics

The symposium is in its 13th year as an event which reviews the space programme of the former Soviet Union. The programme for 1993 will include talks on the following topics: The Biosputnik programme up to 1993; USA-Russian Manned Cooperation 1992-1995: update on the Manned Operations on Mir; Obscure Unmanned Soviet Satellite Missions, and others still to be decided. A Film will be shown including clips never seen before in the UK. There will be opportunities to ask questions of some of the leading experts on the Soviet Space Programme in the West.
Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.
Advance Registration is necessary.
Registration: Forms are available from the Executive Secretary. Please enclose a sae.

VISITS

31st March 1993

London Teleport
(Isle of Dogs)

A one-day visit with briefings and tour open to a limited number of members interested in the EUTELSAT and similar programmes.

Pre-registration is necessary. Details of programme and Registration forms are available from HQ on request. (See p.78).

21 May 1993

Royal Aircraft Establishment/Defence Research Agency
(Farnborough, Hants)

A one-day visit with briefing and tour open to a limited number of members interested in remote sensing, advanced propulsion systems etc.

Pre-registration is necessary. Details of Programme and Registration forms are available from HQ on request. (See p.78).

LIBRARY

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30pm and 7pm. Membership cards must be produced.

2 WAYNE

JOIN THE BRITISH INTERPLANETARY SOCIETY

When you join the British Interplanetary Society *Spaceflight* will be mailed directly to your home address each month, hot off the press.

As a member of the Society you will become part of a worldwide organisation which promotes space and astronautics and be able to attend the wide range of Society meetings, visits and other special events. Members also receive discounts on Society publications and entry to symposia.

This offer includes either a FREE *High Road To The Moon,* a 120 page book containing pictures by R.A. Smith *or* an official Society pin-on lapel badge *or* a voucher that entitles you to £5 OFF any title in the BIS Video Collection.

APPLICATION FOR MEMBERSHIP OF THE BRITISH INTERPLANETARY SOCIETY

I apply for Membership which will include a subscription to ***Spaceflight*** and one of the following special offers:

High Road To The Moon, a 120 page book containing pictures by R.A. Smith ☐ †
or a voucher worth £5 off the price of any title in the BIS Video Collection ☐ *
or an official Society pin-on lapel badge ☐ †

I enclose £35 (US$70) for a 12 month subscription from January-December 1993 ☐

A special reduced rate of £26 (US$52) is available for those under 22 or over 65 years.

Full Name (please PRINT surname first)	**Title**
Postal Address	**Date of Birth**
Professional Affiliation & Address (if applicable)	**Job Title or Position**
Signature / **Date**	***Application constitutes acceptance of the Society's Constitutional Rules***

Send to: The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England

NB Videos available in VHS PAL format only. *Offer closes 30 June 1993. † While stocks last.