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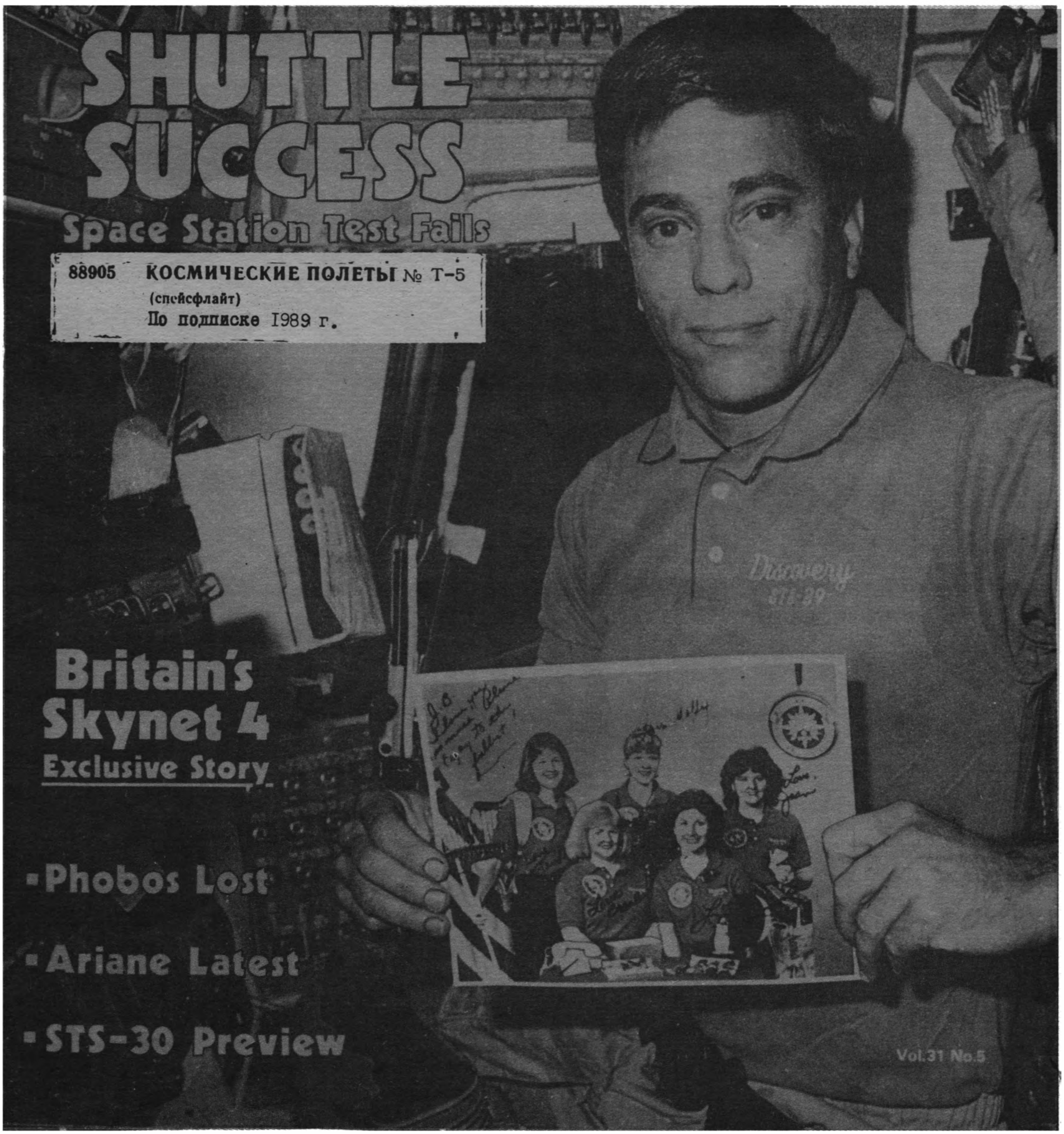
Spaceflight

The International Magazine of Space and Astronautics



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Vol.31 No.5 **May**

Front cover: Astronaut John Blaha holds up a picture of the STS-29 crew members' wives from the pilot's station on Discovery's flight deck The photo was sent up by the Text and Graphics System (TAGS) which made its inaugural flight on STS-29. *NASA*

Atlantis Poised for Launch

When the Space Shuttle Atlantis blasts off from pad 39-B at the Kennedy Space Center it will be carrying a precious cargo: NASA's first interplanetary probe since Voyager was launched 12 years, ago. By the end of the Magellan mission it is hoped the probe will have mapped over90 per cent of the surface of Venus. STS-30 is officially scheduled for launch on April 28, but a delay of four to five days seems inevitable.

The Crew

Atlantis will have a crew of five on this, her fourth flight. Mission commander, David Walker, is making his second space flight. He was the pilot of mission 51-A in November 1984. Pilot for STS-30 is Ronald Grabe, who was onboard Atlantis for her maiden flight, 51-J. The remaining crew members are mission specialists. Norman Thagard, a medical doctor, is a veteran of two shuttle missions, STS-7 and STS 51-B. Mary Cleave, will be the first woman to fly the shuttle since the Challenger accident. Women astronauts return to space after a break of over three years. Infact Cleave herself was the last woman in orbit when she flew on shuttle mission 61-B in November 1985. The only 'rookie' member of the crew is Mark Lee who joined NASA as an astronaut in 1984.

Launch Preparations

Preparations for the launch of Atlantis were complicated by the damage to the spacecraft's tiles that occurred during her last mission. Once fully refurbished, Atlantis was rolled over from the Orbiter Processing Facility to the Vehicle Assembly Building (VAB) on March 12, where the orbiter was attached to the Solid Rocket Boosters and External Tank. During Atlantis' tow to the VAB the assembled members of the press got a closer look than they bargained for, reports ***Spaceflight*** correspondent David Portree. The portside wing passed over their heads allowing close inspection of the heat-shield tiles, before they were moved to another location by security men.

The Atlantis stack was slowly rolled down the 4.2 mile gravel crawler-way to the launch pad on the morning of March 22 reaching the pad at 8am local time. After electrical and mechanical connections between the vehicle and the pad were made, work began on the final launch preparations.

Like Discovery, Atlantis' main engines received a new set of high pressure oxidizer turbopumps. The first of the pumps was installed while the vehicle stood in the VAB, leaving two to be replaced on the pad. One of the final two pumps had to be returned to the Stennis Space Center for further testing and was not installed until early April.

The STS-30 crew were at the Kennedy Space Center for the Countdown Demonstration Test, which serves a dress rehearsal for the launch. On April 7 the crew boarded the orbiter as they would on launch day. The mock countdown continued until T-5 seconds, at which point the crew and ground staff had to deal with a simulated main engine shutdown. Following the test the STS-30 crew familarised themselves with the escape methods if a malfunction occurs on the pad.

Magellan

The Magellan probe must be launched between April 28 and May 23 to make its interplanetary window. Although the launch was still scheduled for April 28 at the time of going to press, a delay of four to five days was expected. If the probe misses the all important launch window, Earth and Venus will not be in the proper alignment again for two years.

A delay of four to five days will not be a serious threat to the mission, infact some Magellan scientists would like to see the probe launched later. If Magellan is boosted toward Venus on April 28 it will arrive slightly faster than optimal, so its attached Star 48-B solid rocket motor will be unable to brake it into the optimum 3.15 hour orbit for which the mission is designed. Magellan project scientist Dr. Stephen Saunders stated that a May 5 launch would serve better the scientific purposes of the Magellan mission by allowing it to achieve the proper orbit around Venus. However, NASA officials would prefer to see Atlantis lift off on schedule rather than take the risk of a last minute problem delaying the launch past May 23.

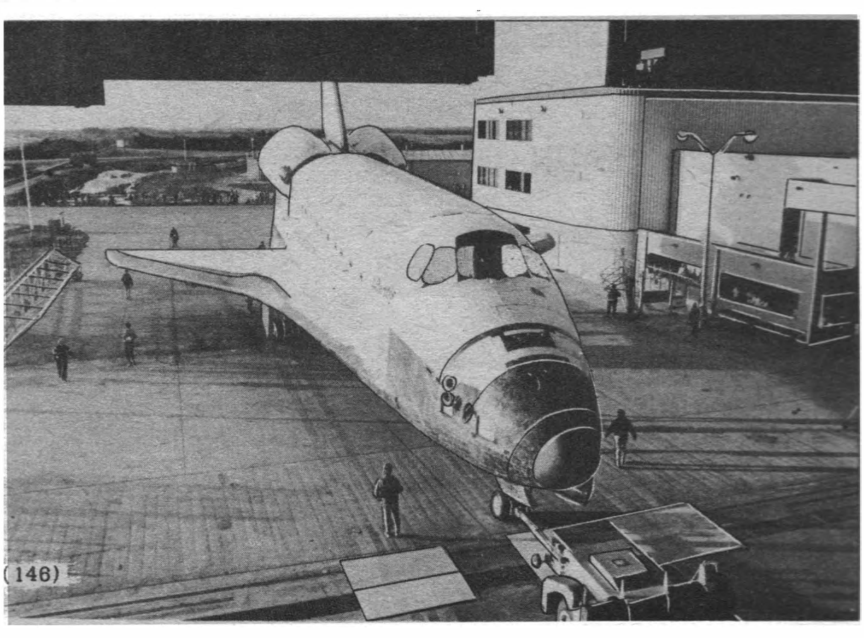
The Magellan probe will be boosted out of Earth orbit by an Inertial Upper Stage (IUS). The deployment sequence will be similar to that of the Tracking and Data Relay Satellite (the most recent TDRS launch was STS-29, see p.172 for a full report). All five crew members will be involved in the deployment of Magellan, although Mark Lee will have chief responsibility. The 3,500 kg spacecraft will be released from Atlantis' payload bay approximately six hours 18 minutes after lift-off. The IUS booster will fire about an hour later to start the probe on its 15-month journey to Venus. The spacecraft is due to arrive in August 1991.

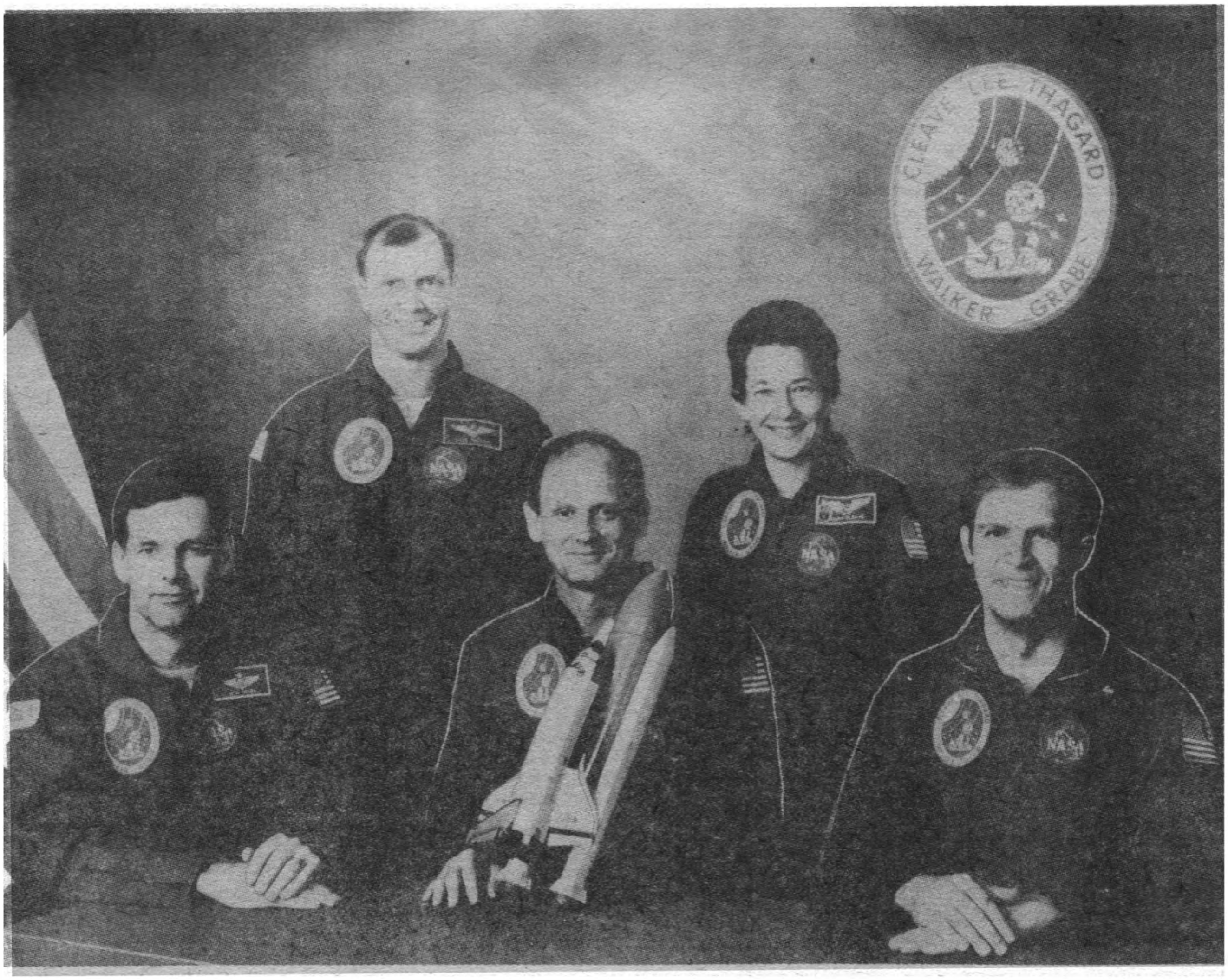
Magellan is to map the planet continuously for 238 days, the length of one Venusian day. By the end of that period 90 per cent of the planet will be mapped. Scientists plan to extend the mission to fill the gaps in mapping coverage at that time, if additional funding for the project is approved.

The recent failures of Phobos 1 and 2 have raised concerns that a similar fate could befall Magellan. NASA officials have strongly denied their spacecraft could be lost in a similar way. John Gerheide, JPL's Magellan project manager told the press the "riskiest part of the Magellan mission would be the insertion into the orbit of Venus, but he appeared confident of the outcome. "It's a smart spacecraft," he said. "It can heal itself of any problems."

In addition to the satellite deploy, the STS-30 crew will perform several mid-deck experiments, including the Fluids Experiment Apparatus (FEA) and the Meoscale Lightning Experiment (MLE). The later involves nighttime photography of violent weather systems on Earth (should they occur during the mission) to learn more about lightning.

The Space Shuttle Atlantis is towed to the Vehicle Assembly Building before mating to the Solid Rocket Boosters and External Tank.

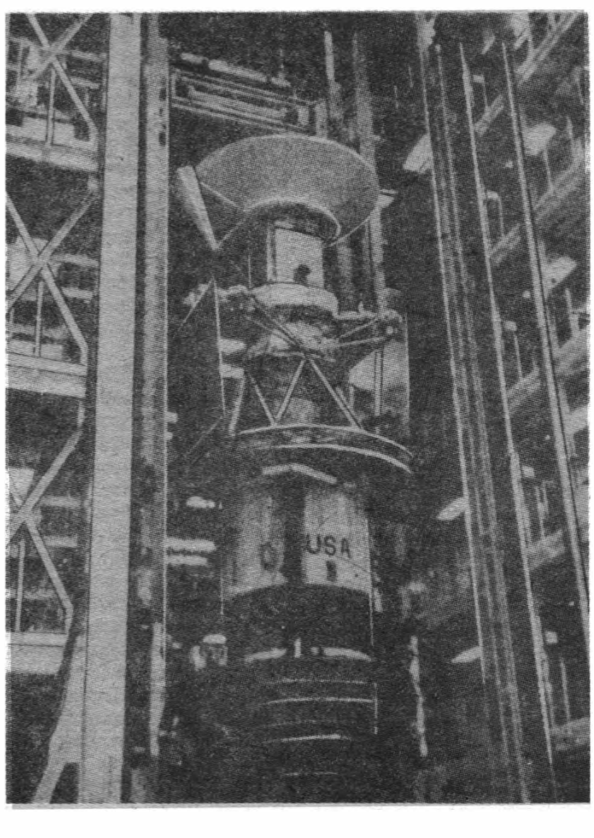


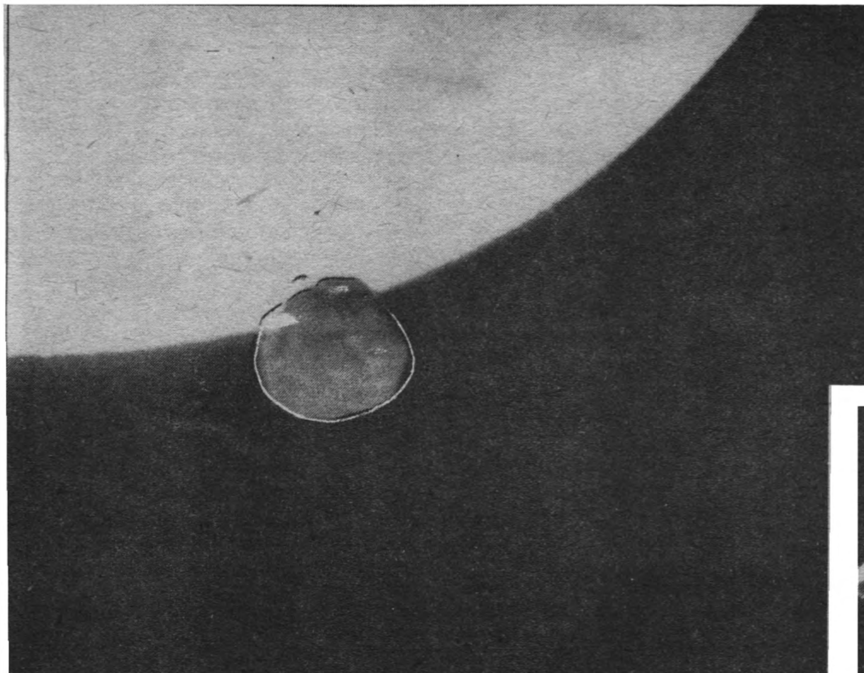


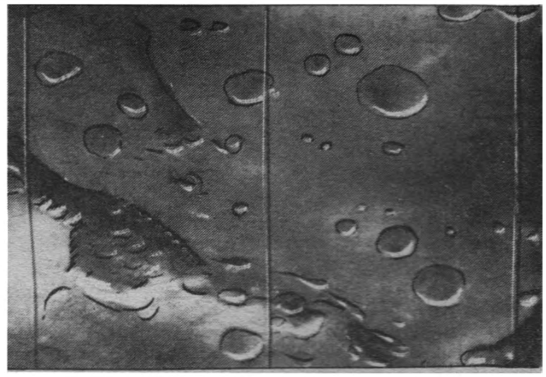
(Above) The STS-30 crew portrait. (Left to right) Pilot John Grabe, Commander David Walker, Mission Specialists Norman Thagard, Mary Cleave and Mark Lee. *NASA*

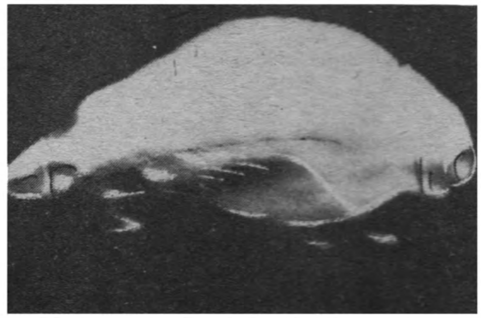
(Right) The Magellan probe and its Inertial Upper Stage Booster are prepared for transfer into Atlantis' payload bay. *D.Portree*

(Below) The Magellan mission emblem.









Phobos 2 Falls Silent

Before Phobos 2's untimely end, the probe transmitted many images of Mars and its largest moon. (Left) An image of Phobos seen against Mars. (Top right) A close up of Phobos. (Bottom right) Phobos 2's view of the surface of Mars. The pictures were taken from the television screen at the Mission Control Centre before any enhancement of the images. *Novosti*

Soviet scientists at the Flight Control Centre near Moscow have lost contact with the unmanned Soviet probe to Mars and its moon Phobos. It ends the ambitious flight before the planned encounter with the moon upon which rode much scientific interest and Soviet prestige.

By Neville Kidger

Controllers are unaware why the probe ceased radio contact with Earth on March 27, but theories range from a collision with the moon itself or an impact by a micrometeorite.

The probe had been turned towards Phobos to take further pictures of the moon to specify the parameters of its orbit. Soviet scientists were first alerted that all was not well when the probe failed to return the images. Attempts to recontact the probe have so far proved unsuccessful. Alexandr Dunayev, head of the Soviet space agency, Glavkosmos, is hoping "for a favourable outcome." But Western observers believe there is little chance of recontacting the probe.

The Soviets established a commission to determine why contact with Phobos 2 was lost. The commission was to report within a week. At the time of going to press its findings had not been made public.

According to John Pike, a member of the federation of American Scientists, who viewed the launch of Phobos 2 from Baikonur, the Soviets may have installed a "very stupid" computer on the probes with a view to saving weight. In an interview with *New Scientist* Pike said there had been a great deal of acrimony between the Institute of Space Research and the Babakin Bureau, which designed the craft, regarding the design of the Phobos probes. He speculates that in future the Soviets may design their probes in a more 'Western fashion' where the history of every component is documented thoroughly.

During the planned fly-by of Phobos the probe would have used laser and ion beams to discover the composition of the soil of Phobos and would have deposited two small landers onto its surface.

The first lander would have anchored itself to Phobos by means of a penetrator and lanyard to return TV pictures and other data. The second, weighing 50 kg would have used springs to "hop" around the surface in the low gravity of the moon.

Thirteen nations and organisations took part in the project with the USSR.

The Flight

Phobos 1 and Phobos 2 were launched from Baikonur by Proton rockets on July 7 and 12 respectively last year. They were placed into an interplanetary cruise phase shortly after reaching Earth orbit using an attached propulsion system.

In August the probes began relaying data back to Earth. On-board instruments returned X-ray and ultraviolet data on the Sun and the characteristics of interplanetary shock waves.

However, during a communications session scheduled for September 2 no signal was received from Phobos 1. An operator had sent an incorrect command which told the probe, in effect, to shut down. The probe's antenna lost its lock with Earth and the craft began tumbling, losing orientation with the Sun and causing the batteries to be depleted without being recharged.

Academician Roald Sagdeyev, then head of the Institute of Space Research in Moscow, described the loss of Phobos 1 as a "disastrous mistake". All hopes for the successful completion of the mission rested with Phobos 2.

In late December 1988 it was revealed that "isolated malfunctions" had occurred in some of Phobos 2's instruments. It was claimed that most of the faults had been corrected whilst others would not prevent the full research programme going ahead.

At 12:55 GMT on January 29 the propulsion system of Phobos 2 was ignited for 201 seconds to place the probe into Martian orbit after a journey of 470 million kilometres. A final correction to the approach path had been made six days earlier.

The Phobos 2's initial orbit was 79,750 km x 850 km; period 76.5 hours; inclination to the Martian equator 1 degree.

ESA reported that the probe reached the point of closest approach to Mars for the first time on February 1 at 18:39 GMT just 864 km above the surface. Science data stored on the probe's recorder was relayed to Earth at 12:00 GMT the next day during approach and around the first periapsis.

A series of engine firings, placed Phobos 2 into an almost circular orbit with an average radius of 9,670 km and an 8 hour period inclined at 0.5 degrees. This established the so-called observation orbit. At this point the propulsion system attached to the probe was discarded after being used six times during the flight. Smaller thrusters would be used for fine

Briton to Fly on Mir

The Soviet Union is to carry the first Briton into space under an agreement which was due to signed on April 14. The launch has been scheduled for 1991 and will last one to two weeks. During this time the British astronaut will carry out a number of scientific experiments onboard Mir.

British Astronaut Project Limited - a consortium of British companies - has been established to manage the venture. At the time of going to press the consortium was on the verge of signing the agreement with the Soviet space agency, Glavkosmos, and its commercial arm V/O Licensintorg.

The effort to launch the first Bntish astronaut will be a purely commercial one, with no Government funding. However the presence of UK Energy Secretary, Cecil Parkinson, at the signing ceremony in Moscow indicates strong Government approval for the project.

The cost to the British consortium will be in the region of $10 million, which is to be raised through various sponsorship deals.

The British astronaut is likely to be a scientist. He or she will need to be physically fit and able to speak fluent Russian. The training will take about a year and will cover emergency procedures and the basics of living onboard the Mir space station. A short list of five to ten candidates will be submitted to Glavkosmos by September. The space agency will then choose a prime candidate and a back-up, who will be trained for the flight at Star City near Moscow.

Meanwhile a Tokyo television company has paid for a Japanese journalist to spend a week aboard Mir. The Soviet press are said to be furious that the first journalist in space will not be a Russian.

Cosmonaut Grechko to Fly Again

Soviet cosmonaut Georgi Grechko, has revealed that he is to make a fourth space flight, writes *Neville Kidger.*

Writing in "Moscow News" in an article unrelated to space he said that he had received permission for the flight from the physicians and his superiors, but not from his wife who, he said, has poor health "partly due to my flights."

The veteran cosmonaut did not say when the flight was scheduled but it can be surmised that he will be launched in late 1989.

Grechko is now an Earth scientist and his involvement may be due to the presence of Earth environmental monitoring equipment which is to be installed on the second Salyut-class module which will be launched to Mir later this year. Grechko's experience may be needed for the operation of the equipment. In this instance he would probably be partnered by a rookie commander.

It cannot be ruled out, however, that Grechko could make a short-term visiting flight to Mir rather than a six-month-long flight which is the current duration for the resident crews on Mir.

Phobos Continued

manoeuvres.

The orbit had a radius some 300 km greater than that of Phobos. For three days the probe's instruments made observations of Mars' atmosphere, surface and near-planet space.

The first of nine TV sessions devoted to Phobos occurred between 12:35 and 13:25 GMT on February 21 when the probe was at distances ranging from 860 to 1,130 km from the moon. Phobos was centred in the images, providing the Soviets said, evidence of the accuracy of the navigational and ballistics data. These computations had involved inputs from NASA and the European Space Agency, the Soviets acknowledged.

Real time relays of pictures were not possible and the pictures of the moon were later replayed from the tape recorder of Phobos 2.

During the evening of February 27 controllers adjusted the TV camera using Jupiter as the target. The axes of the probe were fixed to the Sun and the bright star Canopus. Having verified the orientation of the probe by this method, the cameras were swung to take more pictures of Phobos.

The probe continued to slowly close on the moon over the next weeks.

Commenting on the orbital measurements made by the navigational teams, the Soviets said that when the probes were launched the ephemerides of the moon were known to an accuracy of 100 to 150 km. By early March this had been refined to 10 to 30 km. The accuracy had to be down to just several kilometres for success.

By March 14 the probe and moon were just 100 km apart. The Soviets planned the hover phase to occur on April 9 or 10.

Contact with Phobos 2 was lost on March 27 and shortly afterwards Albert Galeyev, head of the Institute of Space Research, reported the mission's abrupt ending.

Results

Whilst the loss of the approach and hover phase of the Phobos mission is a serious blow to Soviet science and prestige, the Phobos 2 mission did manage to gather many images of Mars and Phobos and provide data on the Sun and Mars' environment which will keep some of the international group of scientists busy for months or years to come.

The probe may have discovered radiation belts surrounding Mars similar to the Earth's Van Allen belts.

The Future

The next Soviet Mars probe will be launched in 1994 and will feature studies of the planet itself using both orbiter and balloons dropped into the atmosphere. There were plans to send a lander and a rover during this mission but these plans have been dropped.

In addition, studies released in 1988 showed that the Soviets were looking at the possibility of using the Energia launcher to send a series of heavy vehicles to the planet. The studies showed that between 1994 - 1996 Mars would be studied with heavy unmanned vehicles including orbiters, balloons, rovers and drillers.

The years 2000 to 2005 would see the development and testing of future manned mission elements including nuclear electrical jets, Mars landers including sample return vehicles.

The Soviet plan gives the years 2005 to 2010 as those intended for the manned mission to Mars.

Debris Figures

NASA's Goddard Space Center has reported that on December 31, 1988 there were 7,119 objects in orbit. Of these 1,809 were satellites and 5,310 were debris. Since the launch of Sputnik 1 in October 1957 19,759 objects have been orbited. Vanguard 1, launched by the US in March 1958 is the oldest satellite in orbit. The Soviet Union's oldest spacecraft is Luna 1 - launched in January 1959, the probe is in orbit around the Sun. The Apollo 11 Lunar Module is the oldest manned spacecraft in space - the historic craft that took the first men to the Moon is in Lunar orbit. The oldest Soviet manned spacecraft to remain in orbit is the Salyut 7 space station, launched in April 1982. During 1988 67 satellites reentered the Earth's atmosphere. They included Intelsat 3 F-5 - launched in 1969 by a Delta rocket. It was placed in an incorrect orbit, and finally burnt up in the atmosphere on October 14, 1988.

Cosmonaut Conscript

Soviet bureaucrats have been attempting to prosecute Mr Sergei Krikalev, aged 30, with draft-dodging. He failed to report for reserve duty in the Soviet army several months ago and has now been threatened with legal action. Mr Krikalev, although willing, has been unable to take his posting due to the fact he is currently 349 km above the Earth onboard the Mir space station. The Soviet press agency Tass reported the story under the headline "Space is no escape from dim-wit bureaucrats, cosmonaut learns".

Freedom Cupola

McDonnell Douglas has delivered a metal, wood and glass mock-up of a Freedom Space Station Cupola to NASA's Johnson Space Center. Freedom will have two similar cupolas attached to the forward resource nodes with one facing Earth and the other spaceward. These symmetrical octagon-shaped rooms are encircled with windows to provide clear views for astronauts involved in operations such as the docking of a Space Shuttle and the operating of tele-robotic devices. The cupolas will be used by NASA and McDonnell Douglas personnel to be sure the size, shape, interior design and work stations are suitable for those tasks.

Hubble Telescope Move

A modified US Air Force C-5A Galaxy will be used to transport the Hubble Space Telescope from Lockheed's Sunnyvale facility to the Kennedy Space Center in August. The telescope is to be launched by Discovery in December. It is currently undergoing final assembly and checkout activities in a clean room at the Sunnyvale facility.

Nomination for NASA Chief

Ex-astronaut Richard Truly has been nominated for the post NASA Administrator, succeeding James Fletcher who officially retired on April 8. Truly's nomination will have to be approved by Congress.

Truly will take his post at a difficult time for NASA. The agency's $13.3 billion budget has yet to be approved and once again space station Freedom is threatened by cuts in funding. Another major problem for NASA is also the 'brain drain' - top management and engineering officials are leaving the agency in large numbers for better paid jobs in the private sector.

Truly has had a long association with space flight: he became an astronaut in December 1965 when he joined the USAF Manned Orbiting Laboratory (MOL) programme. He was transferred to NASA in 1969 following the cancellation of the MOL project. Truly became a member of the support crews for Skylab 2,3 and 4 and the Apollo Soyuz Test Project. In 1977 he was a member of the Enterprise crew for the shuttle drop tests from a 747 aircraft.

In November 1981, 22 years after joining NASA, Truly made his first space flight aboard the second shuttle mission, STS-2. He went on to command STS-7 - Challenger's second flight and the first launch and landing at night.

Shortly after his second shuttle mission,

Truly on Challenger's flight deck during STS-7

Truly left the space agency to become Commander of the US Navy Space Command.

He returned to NASA in February 1986 as Associate Administrator for Space Flight and found his first task was to head the NASA investigation into the Challenger accident. Truly steered the shuttle programme back on track, his efforts culminating in the successful flight of Discovery in September 1988.

First Commercial Rocket Launch Successful

The first private commercial spacecraft was launched on March 29, by Houston-based Space Services Inc. (SSI), carrying a NASA-sponsored payload of microgravity experiments.

SSI's two-stage, solid-fuelled Starfire 1 rocket lifted off from the White Sands Missile Range in New Mexico at 9:41 a.m. CST, transporting the payload owned by the Consortium for Materials Development in Space at the University of Alabama-Huntsville 187 miles high and 50 miles down-range for a suborbital flight of 14 minutes 11 seconds.

Former astronaut and Flight Crew Operations chief Donald K. "Deke" Slayton, now president of SSI, said the launch of the 625.45-inch rocket could not have been any better.

Jim Davidson, an analyst for SSI, said the launch was noteworthy not only because it was the first commercial launch in the US, but also because it was launched on time and a day ahead of schedule.

The 630-pound payload contained six experiments designed to investigate the effects of microgravity on electroplating, dispersion of molecules, polymer foam production and polymer separation. The experiments experienced 7 minutes 6 seconds of near-weightlessness. The materials development consortium is one of 16 commercial space development centres sponsored and funded by NASA.

The payload's parachute deployed perfectly and the full payload was recovered, Davidson said. It was returned to Huntsville for evaluation by the principal investigators.

"There was a considerable amount of surprise and pleasure on the part of one principle investigator at the results of the foam experiment," Davidson said. When the payload canister was opened, an apparently perfect sphere of the foam was discovered, exactly as had been expected, he explained.

While there have been previous small private launches, this was the first payload large enough to require licensing by the Department of Transportation (DOT). Eight more commercial launches are scheduled this year, according to the DOT.

The launch represented a major boost to the commercial launch industry, which hopes to be able to support as many as 100 suborbital and 40 orbital launches every year.

SSI launched a dummy payload in 1982 from Matagorda Island after obtaining clearances from numerous government agencies because no private space launch had been attempted up to that point. This launch was the first under the National Space Policy created by President Reagan in February 1988 in an effort to encourage the commercial utilisation and exploitation of space following the Challenger accident.

Japan Signs Space Station Agreement

NASA Administrator Dr. James C. Fletcher and Japanese Ambassador H.E. Nobuo Matsunaga signed a Memorandum of Understanding (MOU) on March 14, for cooperation in the detailed design, development, operation and utilisation of the permanently inhabited space station Freedom. The agreement was signed at a brief ceremony at NASA Headquarters.

Comparable MOUs with the European Space Agency and Canada were signed, along with an intergovernmental agreement, in a ceremony held at the U.S. State Department last September. The MOUs signed between NASA and its three partners focus on programmatic and technical aspects of the cooperative effort and establish the management mechanisms necessary to carry out the Freedom programme.

The MOU with Japan will become effective upon written notification by each party that all procedures necessary for its entry into force have been completed. Until then, Japan will continue to work under an extension of the MOU signed with NASA in May 1985 at the start of the space station programme's definition and preliminary design phase.

Under the agreements, Japan will provide the Japanese Experiment Module (JEM). The JEM, to be permanently attached to the space station base, consists of a pressurised laboratory module, at least two experiment logistics modules and an exposed facility, which will allow experiments to be exposed to the space environment.

Experimenters will conduct materials processing and life sciences research in the laboratory module, while the logistics module can be used to ferry materials between the station and Earth and for storing experimental specimens and various gases and consumables.

Space station Freedom is an international space complex to be placed into orbit in the mid 1990s.

External Tanks to be used for Research

NASA and the University Corporation for Atmospheric Research (UCAR) of Boulder Colorado have signed an agreement that establishes UCAR's use of Space Shuttle External Tanks for suborbital experiments.

UCAR is interested in conducting experiments to be contained in the 5,000 cubic foot intertank area, between the fuel and oxidiser tanks. The experiments would be conducted during the suborbital trajectory of the External Tank following its jettison from the shuttle and prior to its destruction during reentry.

Under the terms of the agreement, NASA will assist UCAR in developing the suborbital use of the intertank areas for its experiments. The agency has agreed to make the space available on up to five External Tanks. The use of the intertank will not require any operational or programmatic changes in shuttle operations.

Roelof Schuiling

A reception was held at the Science Museum in London on February 22. to commemorate the commissioning of the Skynet 4B satellite (Left to right) Mr John Holt, Managing Director of British Aerospace Space Systems, Mr Tim Sainsbury, Parliamentary Under Secretary for Defence Procurement and Sir Peter Anson, Chairman of Marconi Space Systems. See Society News for further details and p.168 for a special feature on the Skynet satellite. *Marconi*

CORRESPONDENCE

Energia Motors

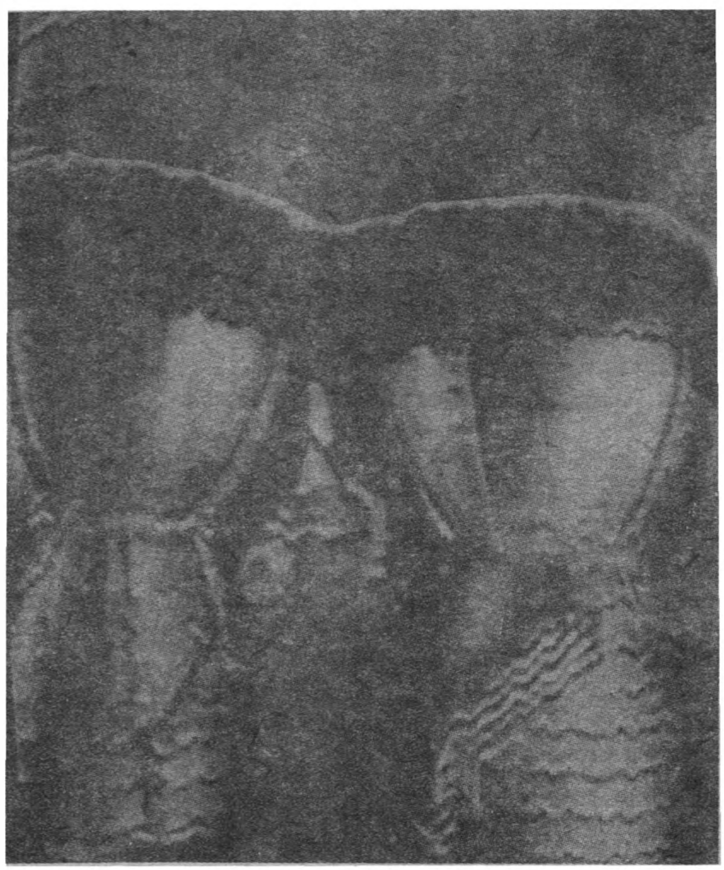
Sir, In 'Correspondence', ***Spaceflight,*** November 1988, p.438, Mr. A.T. Lawton suggests the Soviet Energia core stage engines are of the plug nozzle design. The photograph (right) shows the main engines of an Energia test vehicle, taken from a Soviet TV film [1]. It clearly shows the engines are of the bell nozzle design.

In the February 1989 issue of ***Spaceflight*** Mr. Tony Devereux suggests that the core stage of Energia is 60 m high by 8.5 m diameter. The actual dimensions of the Energia are core stage 59 m high, 8 m diameter, boosters 38 m high, diameter 4 m [2].

In answer to the correspondence over the Energia model displayed by Glavkosmos at Brighton during SPACE '87, the model is probably not very accurate but it gives a good impression of how large Energia is. I like to compare it with the aircraft models displayed in travel agents, not very accurate but they look impressive.

P. MILLS
Kings Lynn, Norfolk, UK

Acknowledgements and References
1. Special thanks to Mr. Neville Kidger, Mr. Phillip Clark and Mr. Rex Hall.
2. *Energia and Buran, The Soviet Space Union,* Tim Furniss, Flight International, February 1989, p.22-26.



(Right) Close up of the Energia main core-stage engines.
P.Mills

'Correspondence' continues on p.170.

Top Pilots Ready to Fly Buran

The Buran test pilots: (Anti-clockwise, starting top left) Volk, Zabolotski, Tresvyatski, Sheffer, Toboev, Stankiavicius and Sultanov. *All Photos Novosti*

If Soviet officials decide their shuttle is ready to fly manned, two of the test pilots pictured above will be seated in Buran's flight deck when she blasts off for the second time - probably before the end of the year. Soviet journalist, *Victor Golovachev,* talks to the leader of the pilots who will take the Buran space shuttle into orbit.

Under the leadership of 51-year-old Igor Volk, who spent twelve days in space in 1984, seven of the Soviet Union's top test pilots are training intensively for Buran's future flights into space.

When the group was formed in 1978 it numbered ten; but in that first year, pilot Kononenko was killed in a take-off accident.

More recently pilot Shchukin lost his life in a SU-26 test flight and last summer, pilot-cosmonaut Levchenko died of a brain tumour just eight months after returning from the Soyuz TM-4 mission to the Mir space station.

While future fight details and space crews are being decided on, the remaining seven - Stankiavicius, Tolboev, Sultanov, Zabolotski, Tresvyatski, Sheffer and Volk himself - are test flying. It keeps them fit, says Volk.

Test flying gives the pilot unique experience, the ability to foresee developments and, if necessary, act contrary to trained reflexes. In a flying emergency, a pilot naturally seeks a way out. A test pilot, however, carries the situation to the limit. His expertise enables him to plunge into a spin and yet find a way out. Test piloting experience is essential for the Buran trials.

Of course, the group does theoretical

and simulator training, but they are not as instructive as an actual test flight.

On one occasion in the shuttle trials the new plane piloted by Volk braked sharply along the runway prior to take-off. It was only after take-off that it was noticed that all the rubber had been burnt off the wheels. Ordered to eject, Volk did not obey and landed safely against all the odds.

I asked Volk about when the first shuttle plans were conceived: "It began in the first half of the 1960s. Suspended from a large aircraft one prototype rose to a height of 8-10 km, separated and landed after a short flight.

"There were several problems to solve: heat insulation in particular. The nose had to withstand temperatures of up to 1,500°C. Many experiments were carried out on the ground before we proceeded to the test flight stage.

"The first craft to test our new heat insulation tiles was launched in 1982. We then put up some satellites in '83 and '84. They all yielded priceless information on heat-insulation." Volk is referring to the Cosmos 1374, 1445, 1517 and 1614 mini-shuttles.

"Before Buran went into space, its sister ship had performed several flights within the atmosphere.

"Like the US Space Shuttle, the Buran engines do not work in the Earth's atmosphere: they return from orbit and land as gliders. But for atmosphere trials Buran's unnamed sister craft was fitted with four turbojet engines, enabling her to take off and land as aircraft do.

"On November 10, 1985, Stankiavicius and I were to take Buran on her maiden flight. We took off, rose to 1,000 metres, circled the airfield and landed twelve minutes later to a hero's welcome.

"The second, 36-minute flight took place on January 3, 1986. The 24th and final test flight took place on April 15, last year, seven-and-a-half months before Buran went into space.

"During the trials, Levchenko, Shchukin, Bachurin and Borodai flew her with the aim of testing the possibilities for a radio-controlled unmanned landing."

As well as the comprehensive flight testing, there were over 1,400 bench trials and in the flight simulators the crews 'flew' a total of 3,200 hours at the controls.

"In the flying-lab tests we developed the most sophisticated automatic landing systems; studied runway approach manoeuvring and acted out co-ordination between the ground and shuttle systems," Volk explained.

"For these tests we used the TU-154 and Mig-25 aircraft because, although Buran and the TU-154 have vastly different flight patterns, Buran's descent path is very steep and she levels out only before landing. We only had to 'spoil' the TU-154's aerodynamics slightly to simulate our shuttle's flight.

"Our flying labs performed over 1,000 simulated automatic unmanned landings. The testing was conducted at the Flight Research Institute and the Baikonur Cosmodrome, where Buran eventually made its historic successful unmanned landing."

"Any test pilot will tell you that 1,000 test flights is a lot. Each one was thoroughly prepared beforehand and the results meticulously analyzed afterwards. The pilots spared no effort. Their skill, experience and ability to assess the changing in-flight situation were all crucial to the success of the project."

Volk also praises the professionalism of the manufacturers who also played a major role in Buran's success. And he sounds a cautious note concerning Buran's future, particularly concerning the question of whether its next flight is manned or not?

"The first success should not produce such a euphoria that the strict technical standards required are lowered in any way. Space forgives no mistakes and a lot still has to be done before a manned flight aboard Buran can be seriously considered."

Spaceflight gratefully acknowledges the assistance of *Soviet Weekly* in the production of this report.

Three of the Buran test pilots have died since their selection: (Left to right) Shchukin, Levchenko and Kononenko.

Mir to Be Left Unmanned

Soyuz TM-8 Indefinitely Postponed

Cosmonauts Volkov, Krikalev and Polyakov are to return to Earth on April 27, leaving the Mir space station unmanned for the first time since February 5, 1987. The flight of a replacement crew, scheduled for April 19 has been indefinitely postponed.

News first reached the West when an ABC television team visited Moscow to make arrangements for a live television link-up between Mir and the Shuttle Atlantis. The Soviets were strangely uncooperative and finally revealed to the ABC team that the link-up would not be possible because Mir would be unmanned at the time of the Shuttle flight.

The Soviet news agency Tass confirmed the story on April 11 when it reported: "The cosmonauts are to return to Earth on April 27, while Mir will continue its flight in the unmanned mode." By this time the crew had already began preparations to leave the station. Their work included taking stock of the on-board equipment and consumables and carrying out maintenance work.

On April 10, Mir's orbit was boosted by 50 km into a 400 x 372 km 'storage orbit.'

It seems the space station is being left unmanned as an economy measure. The launch of a Soyuz craft costs about $20 million. In addition, there is the cost of launching regular Progress supply vessels and the operation of ground and tracking facilities. To continue this expenditure - when the Mir programme has no clear goals until the launch of the first 20 tonne module later this year - would provide ammunition to opponents of the space programme. There has been growing criticism of the size of the space budget in the Soviet press and it has also been an issue in the recent Soviet elections. The space programme is becoming an area for intense debate. Soviet space officials appear to be making voluntary cuts to their budgets in an attempt to appease the increasing number of critics.

The Soviets are expected to return to space when the Mir modules are ready for launch. A new crew will probably be launched in the Autumn. However the Soviets may wait until early 1990 before manning the station again.

Above the Planet

Salyut EVA Operations

Regular *Spaceflight* correspondent *Neville Kidger* concludes his review of spacewalks made from the Soviet Union's Salyut series of space stations. 1984 was a banner year for space walks from Salyut 7. Last month's instalment saw the docking of Soyuz T-12 on July 18, 1984 bringing the cosmonaut complement aboard Salyut for a time up to six. We now pick up the story recalling that on September 9, 1983 Salyut 7 suffered an oxidiser leak and it had been decided that the next crew would effect a full restoration of the Combined Engine Installation (Soviet acronym ODU).

By Neville Kidger

Completing a Job: August 8, 1984

During Soyuz T-12's visit, Dzhanibekov had given demonstrations and training to Kizim and Solovyov on the work required to seal off the oxidizer pipe. The training included suited-up rehearsals with an actual pipe section mounted on Salyut's wall. Videotapes were also provided showing Dzhanibekov in the Star Town hydro tank.

During the previous four EVAs devoted to the ODU fixing the cosmonauts had succeeded in installing two bypass lines on the reserve fuel supply system but the pipe now had to be sealed off. For this purpose a Portable Pneumo-Press (PPT) was developed. It consisted of a cigar-shaped gas container filled with compressed air, a piston-type actuator and a clamping device containing fixed and movable clamps. It was delivered to the station, along with other tools on Progress and Soyuz T ships in June/July.

At 0720 GMT on August 8, Kizim and Solvyov again began to don their space suits. This would be the tenth time these suits had been used by EVA cosmonauts.

Atkov remained in the work compartment. At 0846 GMT the hatch was opened for the seventh time of the 1984 tenancy and the two cosmonauts began to move along Salyut's exterior.

For the first time the men did not have a Progress or Soyuz T attached to the rear docking port which meant that the men had to deploy the work platform that they had used earlier into the outer diameter of the Salyut's work compartment.

Having secured the platform and their tool boxes, the men opened up the thermal skin of the engine section again. This was accomplished by 1030 GMT. Solovyov then located the required pipeline "in the cobweb of hydromanifolds".

Solovyov reported sometime later that the PPT had been secured to the line and that its valves were opened. 250 atmospheres pressure applied 5 tonnes of closure to the line to seal it. Kizim later reported to the FCC that "All is normal here". The cosmonauts had ignored medics advice to rest during the operation.

After replacing the thermal covering for the final time, the men packed away their tools and began to make their way back to the front of the station. Before returning into Salyut the men used a special holding and cutting tool to remove four photo-electric elements of one of the solar panels for analysis back on Earth. The sample was used to study the process of aging and degradation of silicon solar cells. The tool was devised so that the men could cut the solar panel segment without coming into contact with it with their gloves. Atkov later said the men's hands were scarred "as if they had been in a fist fight".

At 1346 GMT the hatch was closed for the final time of the 1984 occupation after an EVA of five hours - a Soviet record. It brought their total time outside the station to 22 hours 45 minutes. The only man with more time outside his spacecraft now was the American Eugene Cernan (24 hours 11 minutes).

Solvyov was later to describe his "great regret" at having to finish the men's sixth EVA.

The only EVA task left for the men was testing of the beam builder. If this task was accomplished before the launch of the Shuttle 61-B mission the Soviets could lay claim to yet another first.

1985: A False Start

Having restored the Salyut's ODU to working status again the Soviets planned a full scheduled of activities for 1985. A three man crew - Vladimir Vasyutin, Viktor Savinykh and Aleksandr Volkov - were to man the station. A Kosmos heavy module would be docked with the forward docking unit, possibly after a visiting crew had departed. EVAs were planned, at least two which would see the third set of solar panels supplemented with DSB's (Vasyutin/Savinykh) and another one, or possibly two, to test a beam erection device called Ferma Postroitel.

However before the three men could be launched power was lost on Salyut 7 and contact with the ground was severed. A two-man team of Vladimir Dzhanibekov and Viktor Savinykh was formed to fly to Salyut, dock manually with the dormant station and reactivate it.

The two men accomplished this difficult feat in June 1985 paving the way for the continued occupation of the station and the realisation of the original planned flight.

Before the original crew could be re-formed on the station the Soviets took the opportunity to conduct the EVA to attach the third set of DSBs.

A Busy Day: August 2, 1985

Whilst Savinykh had trained for an EVA to add DSBs during his long-term flight, Dzhanibekov had made an EVA during the Salyut T-7 visit for a special purpose only - to test a new piece of equipment.

However, Dzhanibekov had trained for a long-term flight on Salyut 7 before being put in charge of the Soyuz T-6 Soviet/French crew due to the "illness" of the original commander, Malyshev. His training probably included DSB additions in readiness for the long flight.

Salyut's hatch was opened at 0715 GMT on August 2. The two men carried the DSB containers to the solar panel. Using the winching and other tools they unfurled the first of two panels and, after completing that operation, waited as the FCC commanded the large panel to rotate 180 degrees so that its other side faced the men. The second panel was then unfurled. TV was shown during the EVA of the two men floating around the base of the panel.

On one of the main panels they fastened an experimental sample of a solar cell which would later be removed for a study of the effects of outer space's vacuum and radiation factors upon it.

Moving back to the hatch the men installed a French-made detector block called COMET. It consisted of four pairs of rectangular-shaped boxes mounted on a central spine. The boxes were placed on Salyut's exterior in the closed position and later opened to capture dust from comets Gicobini-Zinner and Halley.

Dzhanibekov and Savinykh then collected up cassettes with samples of bio-polymers and various structural materials for return to Earth and replaced them with new ones. The Soviets said that the men fulfilled expectations for the EVA.

In addition, the two also checked out new EVA suits which featured illuminated control panels and improved shoulder belts. Part of the rubber shell was made sturdier. The men's electrocardiograms were recorded on magnetic tape by portable medical equipment and other physiological parameters were also measured.

Dzhanibekov and Savinykh's EVA lasted for about five hours.

A Flight Cut Short

Savinykh remained on Salyut with Vasyutin and Volkov in September 1985. Georgi Grechko returned to Earth with Dzhanibekov after the first partial crew rotation in space history had seen the original crew begin work on Salyut 7.

With the solar panels supplemented, the only EVA task left for the men, apart from emergencies, was testing of the beam builder. If this task was accomplished before the launch of the Shuttle 61-B mission the Soviets could lay claim to yet another first. (On the Shuttle flight astronaut Sherwood Spring and Jerry Ross would test assembly techniques for large structures in orbit; previous large space structures have included Skylab's solar parasol and sail, the KRT-10 antenna and Shuttle 41-D's 102ft deployable solar array).

The first part of the programme was successful. The Kosmos 1686 heavy module docked with Salyut's front port on October 2. However, by mid-November the mission was in deep trouble with Vasyutin suffering from an as-yet-undisclosed illness.

The malaise forced a quick termination of the mission and on November 21 the men were back on Earth. Their mission had been due to continue until mid-March 1986.

Last Post for Salyut 7

On February 20, 1986 the Soviets placed the currently-operational Mir base block into orbit. Although the original plans for its occupation are not known, what is certain is that the early end to

the Soyuz T-14 mission meant that a crew had to be found who could fulfil a mission to both Mir, to check it out, and Salyut, to complete the work there.

Vladimir Solovyov was working at FCC when he was called to train for the flight. He would fly with Kizim on the epic mission.

Launched on March 13, the two men spent 51 days onboard Mir before flying over to Salyut/Kosmos 1686 at the beginning of May in the first operation of its type. For the two men it must have been a pleasure to renew acquaintances with the station.

Girder Constructors: May 28 and May 31, 1986

At 0543 on May 28, Kizim and Solovyov began their seventh EVA from Salyut 7. Within 15 minutes they collected and stored inside the transfer compartment cassettes containing biopolymers and materials samples and the French COMET dust collector.

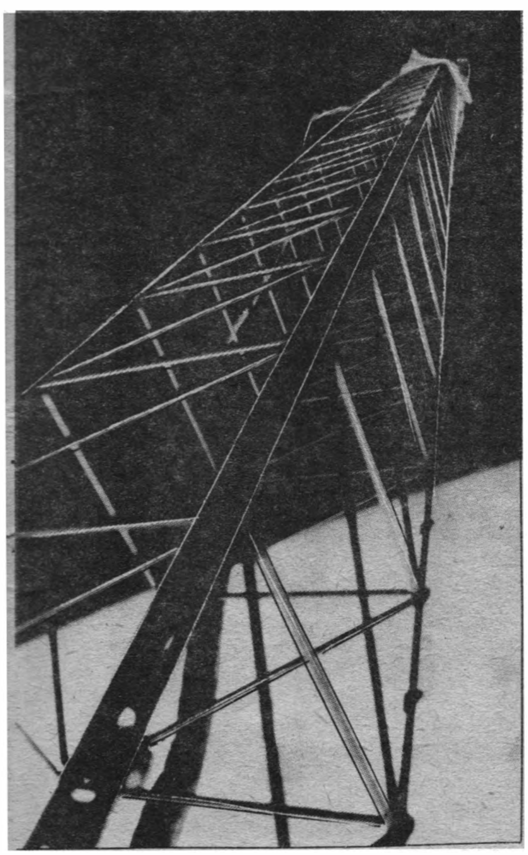
Their next task involved setting up a platform on the transfer compartment upon which they attached a one metre diameter, one metre tall cylinder with a weight of 150 kg. During this activity the men were heard breathing heavily. A TV camera was then set up on the platform.

During the next orbit the men, working in the same suits as Dzhanibekov and Savinykh had used, conducted the first part of the Mayak (Beacon) experiment.

The cylinder, named URS, contained a hinged metal lattice-work girder weighing 20 kg which was a rhombus 40 cm x 40 cm in cross section. The device was developed by V. Lapchinski of the Paton Institute (he also developed the Isparatel spraying device and the URI tool used earlier).

The girder could be deployed in three modes - manually, semi-automatically and automatically. The task for the cosmonauts on this planned 3-hour-long EVA was to test how the girder performed in open space.

In May 1986, cosmonauts Kizim and Solovyov deployed this large girder outside the Salyut 7 space station. They had been launched to Mir in March and transferred to Salyut 7 in early May. *Novosti*



At 0729 GMT the cosmonauts returned TV pictures of the girder stretching 15 metres above the station against the backdrop of Earth. The pictures were historic - they were the first shown live by the Soviets of an EVA in progress. The cosmonauts had used automatic control to unfurl the girder. They were to test all the deployment options during the EVA.

Towards the end of the EVA the men installed an optical device, called BOSS, on one of Salyut's windows. This was part of an experiment to test an optical wavelength transmitter for telemetry. Signals received from an instrument on the girder were to be converted into digital form by the optical device which then transmitted them via a 3 milliwatt laser through the porthole to the BOSS receiver were they are converted back into electrical signals for transmission to Earth. The unit featured triple redundancy in its main elements to improve reliability.

Kizim and Solovyov closed the hatch after stowing the girder back in the cylinder. They had been outside for three hours and 50 minutes.

The Soviets spoke of future versions of the girder being several kilometres in length and being used to link space settlements together in orbit.

On May 30 the Soviets announced that the men would conduct another EVA the next day - the first time the Soviets disclosed timings (although in 1984 they said further EVAs would follow in their report of the ODU restoration work).

Kizim and Solovyov began their eighth excursion outside Salyut 7 at 0457 GMT on May 31. TV was returned of the cosmonauts mounting a flat package of instruments on the top of the retracted girder. The package contained two instruments on the top of the retracted girder. The first was Fon (Background), which had a detector for measuring the density of the 'atmosphere' around the station. Solovyov noted that gases were separated out of the station's elements, such as the shield vacuum insulation. Such outgassing could interfere with precision optical instruments. As the cosmonauts extended the girder, with some difficulty, to a height of 12 metres, the Fon instrument measured the density of the surrounding gases and relayed them via the BOSS system to the ground.

The second instrument system mounted on the package was a seismic unit to monitor vibrations of the girder as it was extended. A light beacon was fitted atop the girder to give the men a reference point: via a TV camera, any oscillations of the structure could be monitored.

Live TV was shown of Kizim at the base of the girder. The cosmonaut then began to move along the length to cause vibrations and the girder was seen to rock slightly. Kizim stopped just a short distance up the girder. It was noted that the girder could be used to carry a cosmonaut, if required, but the first steps with the device were made near the station.

The girder was then folded back into its canister. The instruments were left attached. The men then used the URI tool, first tested by Dzhanibekov and Savitskaya to weld elements of the frame's structure. The URI had been modified so that it had a new crucible and was easier to operate. The Soviets said that by welding such lattice-and-pin frames "space assembly and construction workers" are to assemble large space structures.

With the URI tests accomplished the men had two more tasks to perform. They mounted a micro-unit test for deformations on the exterior of the station. The unit was to strain samples made from an aluminium and magnesium alloy. The results would give experts the test data they need to forecast the performance of materials from which large-scale space structures would be made, the Soviets said. Results of the test were to be telemetered to Earth over a lengthy period.

The men also removed the small piece of solar cell material that had been left outside by Dzhanibekov and Savinykh in 1985.

The cosmonauts went back into Salyut after an EVA lasting five hours. Together the two men had set world records for the number of EVAs - eight - and the time spent on them - 31 hours 36 minutes. These records are expected to stand for a long time.

Kizim and Solovyov returned to Earth on July 16 after another short stay on Mir. Salyut 7/Kosmos 1686 were boosted to a higher orbit in mid-August 1986. By Autumn 1989 the complex will again be close to Mir. The Soviets have said they intend to visit the station again and perhaps retrieve the samples. Whether this visit will be a fly around inspection or a docking and stay inside is unclear at the time of writing. The Soviets have announced the Buran orbiter is to retrieve 'blocks' of the complex.

Conclusion

The Soviet experiences outside the Salyut space stations undoubtedly strengthened their confidence in the ability of cosmonauts to do a wide variety of tasks in open space. The long delay in conducting such operations - by the time they made the first Salyut EVA the Americans had amassed over 200 hours of EVA experience - was due to their early problems with the civilian Salyut programme.

Finally, there was a coincidence with Salyut's first EVA and the first EVA on Mir. As with Salyut 6 that EVA, on April 11, was to aid the docking of two spacecraft (Mir/Kvant) and, perhaps more remarkable still, one of the participants was Yuri Romanenko who was involved in the first Salyut EVA. The EVA was unplanned and dangerous but the experience of Salyut ensured the Soviet's confidence and willingness to undertake the venture during the early days of the Soviet's permanent manning of the Mir complex.

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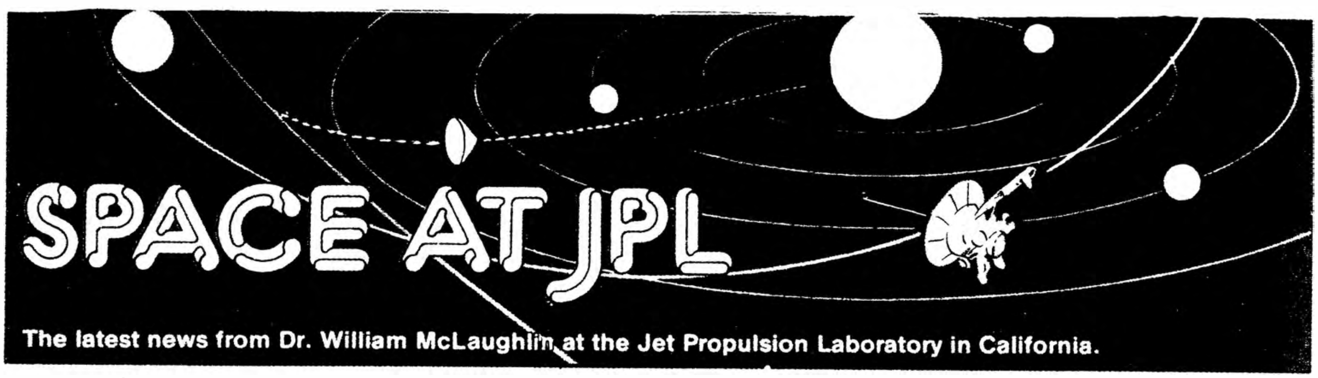
In addition the writer has used accounts carried in the US Congressional Reports *Soviet Space Programs: 1976-80 (with supplementary data through 1983)* and *Soviet Space Programs 1981-87* authored by Marcia S. Smith.

Finally, the writer thanks the following individuals for providing, over a number of years, data and translations which were used in this article: Phillip Clark, Ralph Gibbons, Ralph Gibson, Rex Hall, Mark Hillyer, James Oberg.



Mission to the Sun

The Sun is of exceptional practical interest to us, its dependents, and also furnishes a splendid avenue into the realm of stellar astrophysics. However, it is not easy to design a mission to our star. First, the Earth travels around the Sun in a nearly circular orbit at approximately 30 km/s, and this velocity vector must be forcibly altered in order to "drop into" the Sun. Second, at close range the Sun produces a very inhospitable environment for a spacecraft. "Solar Probe" is a mission under study at JPL which, if approved, could bring a spacecraft as close as three solar radii above the solar surface toward the end of the next decade (one solar radius equals about 700,000 km).

Solar Probe has been under consideration for several years (see the March 1983 edition of this column and the August 1984 issue of *JBIS*: in both publications the mission is referred to by its previous designation, "Starprobe"), and during this time the study has been managed by James E. Randolph of JPL. The primary objective of the mission is the study of the solar wind and its related fields, waves, and particles environments in the region of 4 to 60 solar radii from the centre of the Sun, where no spacecraft has previously ventured.

The basic mechanism of energy generation within the Sun comes from thermonuclear fusion, wherein hydrogen is converted into helium - see last month's column for an historical review of our growth in understanding the source of the Sun's energy - and the temperature at the centre is about 15 million degrees Kelvin (°K). Material in the solar interior is in "the fourth state" of matter, plasma, which consists of the nuclei of atoms together with their stripped orbital electrons (the other three states are solid, liquid and gas). The plasma on the whole is electrically neutral. The solar interior is so densely packed that a photon created at the centre of the Sun takes, on average, 30,000 years to migrate to the solar surface! (The original packet of energy, perhaps a high-energy x-ray photon, is transformed many times on its "walk" by interactions with the plasma and emerges at the surface as a photon of visible light.) If the photon were able to travel on a straight line, its journey from the centre of the Sun would take just over two seconds.

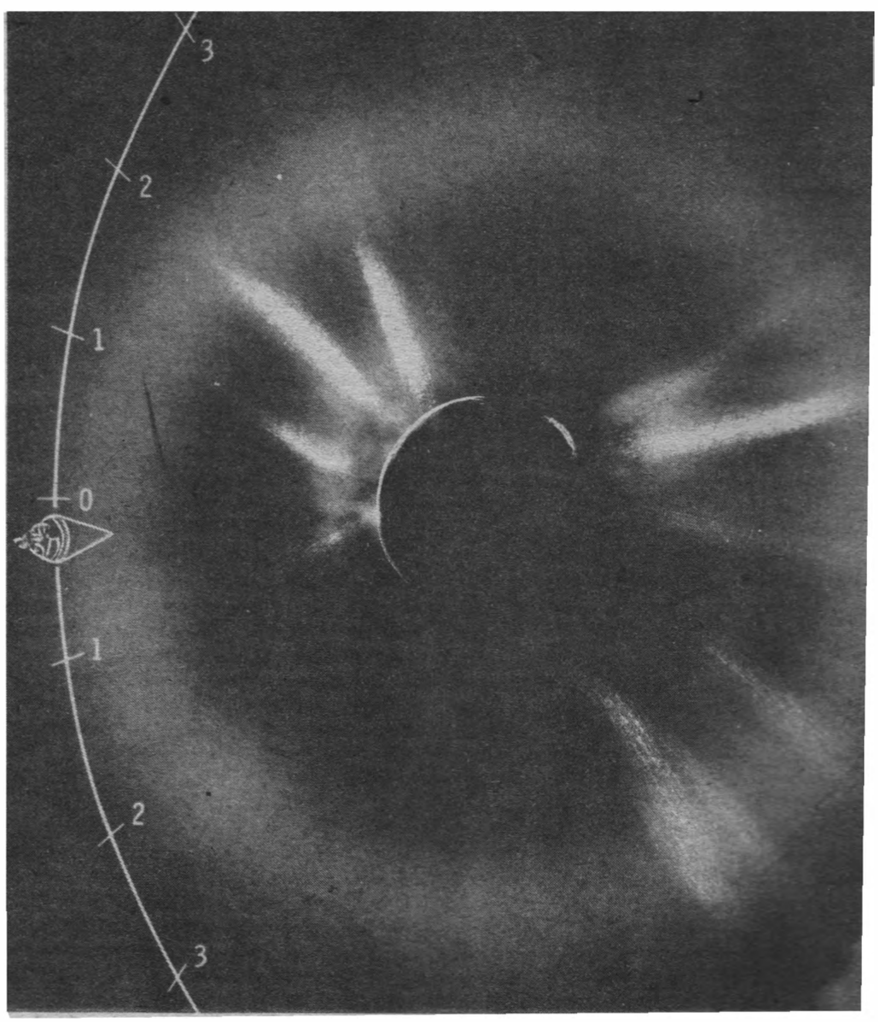
The surface of the Sun is called the photosphere and has an effective temperature of 5800°K. Above the photosphere lie the chromosphere and the corona; the latter is very hot, with a kinetic temperature of a few million °K, and does indeed constitute a startlingly beautiful crown for the Sun during a total eclipse.

The mechanisms by which the corona becomes so hot are an active area of research. A consequence of the hot corona is that the Sun cannot contain all of the plasma in the outer corona and a "solar wind" blows outward into the solar system, a phenomenon first explained theoretically by Eugene N. Parker (1958).

The solar wind is mostly composed of protons and electrons, reflecting the predominance of hydrogen in the Sun, and exerts a profound influence on the structure of the solar system. Not long after condensation of the Sun from the solar nebula (almost 5,000 million years ago), fierce solar winds cleared out much dust and gas from the early solar system. Today, a more benign solar wind impacts the Earth's magnetic field at about 400 km/s and helps mould the teardrop-shaped magnetosphere which enwraps our planet (Jupiter, Saturn, and Uranus have significant magnetospheres, as measured by spacecraft, and so probably does Neptune). Somewhere between 50 and 100 A.U. (an "A U." or "Astronomical Unit" is the distance from Earth to Sun and is equal to about 150 million km) the influence of the solar wind ceases - at the heliopause - and with regard to this measure interstellar space begins. It is possible that the Voyager or Pioneer spacecraft may survive long enough to traverse the heliopause and measure its properties. Exciting images constructed from observations by the Infrared Astronomical Satellite (IRAS) in 1983 show such transition zones for two stars; see p.241 of the March 1989 issue of *Sky and Telescope*.

Solar Probe should be able to detect where the solar wind accelerates from subsonic plasma flow to supersonic flow. It is expected that this takes place somewhere between 1 and 10 solar radii from the centre of the Sun, with the

The proposed Solar Probe Mission may fly within three solar radii of the surface of the Sun, sometime around the turn of the Century. (The image of the Sun was obtained during NASA's Skylab mission.) *NASA*



upper bound more likely.

Shielding from the fierce glare of the Sun is a prime necessity for Solar Probe and will be accomplished by means of a frontal cone of tough carbon-carbon: sufficient to withstand the heat of nearly 3000 Suns (by convention, 1 Sun is the solar radiation intensity felt at Earth). At its closest approach to the Sun, the Helios spacecraft experienced the intensity of nine Suns. The principal design challenge for the solar shield is not directly related to thermal protection but rather to minimising the rate of mass loss through sublimation. This rate will peak at about 2.5 mg/s from the glowing shield in the vacuum of space.

It is difficult to create conditions on Earth for an extended period of time that allow one to test large pieces of material in a simulated near-solar environment. The French solar furnace at Odeillo Font-Romeu in the Pyrenees is capable of generating an intensity of up to 15,000 Suns and has been employed in testing carbon-carbon in a space vacuum for Solar Probe. The energy for the furnace is, appropriately, derived from the Sun: the valley in which the furnace is located is populated by primary mirrors which track the Sun and reflect it onto a parabolic secondary mirror for focusing into the test chamber that, in Randolph's words, "only Mephistopheles would enjoy."

Jupiter serves as a gravitational broker for many interplanetary missions, and Solar Probe plans to use its services once more: to exchange the angular momentum of the spacecraft, outbound in a "fat" ellipse, for a reversal of course into a near straight-line approach to the Sun (actually travelling along a "thin" ellipse with eccentricity 0.992; a circle is a maximally obese ellipse, with eccentricity 0). The joint ESA/NASA Ulysses mission, scheduled for an October 1990 launch, also uses a Jovian gravity assist, but to flip the spacecraft significantly above the ecliptic for its journey of exploration above the poles of the Sun.

The gravity assist from Jupiter will be arranged so that Solar Probe's trajectory at the Sun is a pole-to-pole transit, accomplished in a mere 14 hours. At closest approach to the Sun, perihelion, the spacecraft will be travelling at 300 km/s. After encounter, the spacecraft will drift out to Jovian range again and, if its subsystems have survived the first solar encounter, be available for a second close passage, possibly even closer than the first one, about five years later.

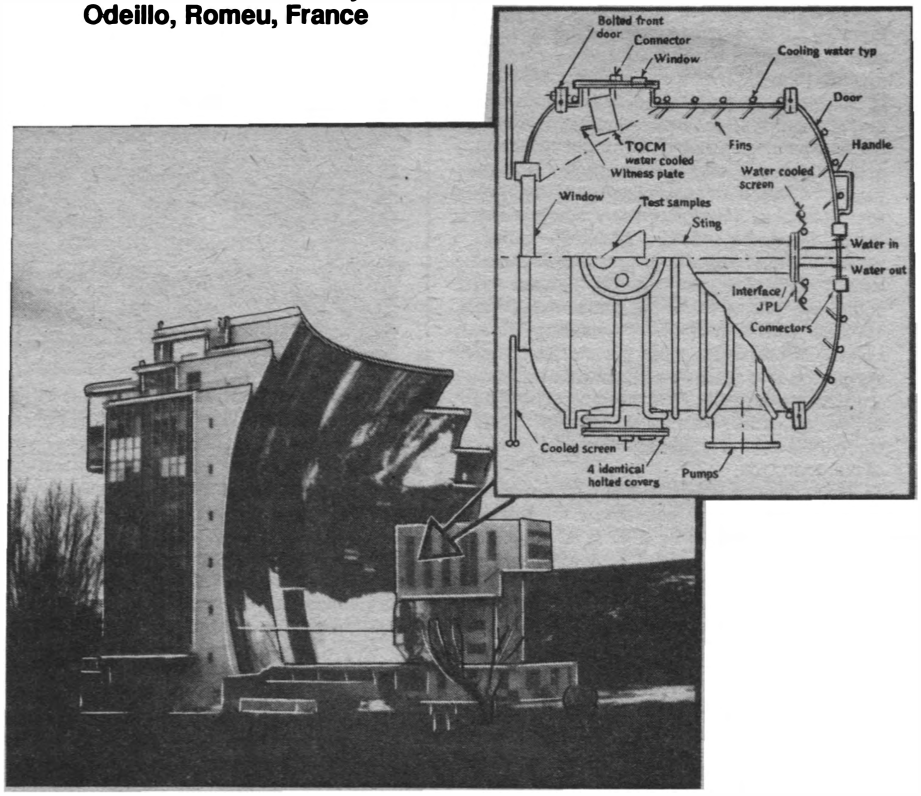
The estimated mass of the spacecraft is 1000 kg, with 200 kg of this amount devoted to the shield which must be solar pointed throughout the perihelion passage. Three-axis stabilisation has been selected as the means of attitude control for the spacecraft, but a small package of instruments will be spun at the apex of the shaded zone (umbra) behind the shield. Fields-and-particles experiments enjoy the wide fields-of-view afforded them by the spinning state. Power will be supplied by radioisotope thermoelectric generators rather than solar panels, a seemingly strange state of affairs for a solar mission, but the distance of Jupiter from the Sun precludes the choice of panels.

Some consideration is being given to the possibility of using the "Waverider" concept of a high-velocity redirection of the spacecraft's trajectory at Earth and/or Venus, in place of the gravity assist at Jupiter, by means of an aero-gravity manoeuvre. Under investigation by the Association in Scotland to Research into Astronautics (ASTRA), the Waverider was invented in the late 1950s by Professor T.R.F. Nonweiler, a founder member of ASTRA. A Waverider vehicle rides on its own hypersonic shockwaves and has potential for application to hypersonic airliners as well as bending the velocity vectors of spacecraft by passage through planetary atmospheres. The aero-gravity assist was suggested for this mission in 1977 by Randolph, and the Waverider would seem to fulfil the concept.

Solar Probe is an attractive mission because it scores high in each category of the triad of science, applications, and technology. It also quickens the pulse to think of venturing so close to the central fire.

CNRS/CNES Test Facility in Odeillo, Romeu, France

CNES Vacuum Chamber



The French solar furnace at Odeillo Font-Romeu in the Pyrenees is capable of achieving an intensity of thousands of Suns in a test chamber and has been used to test the carbon-carbon shield for NASA's proposed Solar Probe mission. Shown is the large secondary mirror which focuses sunlight from a set of primary mirrors (not shown) that track the Sun. *CNRS*

The Space Frontier

The philosopher and novelist, Olaf Stapledon (1886-1950) addressed the British Interplanetary Society on October 9, 1948 on the subject "Interplanetary Man?" (his text is presented in the November 1948 *JBIS,* p.213-233). Forty years later the substance of his remarks is remarkably fresh, and the discussion afterwards - among Stapledon, Arthur C. Clarke, R.A. Smith and others - is lively. Stapledon looked at how humans might go about colonising the planets: terraforming Mars, the Moon and Venus were discussed along with the complementary approach of eugenical adaptation of humans to fit planetary environments. But the principal emphases of his address where why we might undertake the colonisation of the planets and how these motives should relate to our fundamental values.

Space communities need not be limited to planetary habitats. A vigorous line of investigation has been pursued by Dr. Gerard K. O'Neill and others concerning establishment of space colonies in artificial stations, placed at a dynamically favoured location such as a Lagrangian point in the Earth-Moon system. In *The High Frontier* (William Morrow, 1977), O'Neill envisages an initial station with 10,000 inhabitants, supporting themselves through the generation of solar-derived power for use on Earth and obtaining much of the structural material for the station from the surface of the Moon.

Far-ranging space communities are embodied in the idea of a "world ship" - a self-sufficient vehicle which cruises interstellar or intergalactic space. A dramatic concept, extensively treated in fiction (Robert A. Heinlein's 1941 story "Universe," is a classic example), the world ship has been technically analyzed as well; see the June 1984 issue of *JBIS*.

Although humans have not yet founded what could be called a space colony, the thought that other, more advanced races might have done so has led to some interesting conclusions about extraterrestrial life. The physicist Enrico Fermi (1901-1954) once asked the question "Where are they?", initiating a series of questions concerning why it is that the Galaxy, some ten thousand million years old, has not spawned

species which have overrun our solar system and planet.

Numerous theories have been devised: there is no intelligent extraterrestrial life; the solar system has been quarantined by extraterrestrials ("the zoo hypothesis"); interstellar flight is difficult or unpopular; or evolution occurring during migration removes extraterrestrials from our epistemological domain. The last has some appealing properties, and I have treated it in may paper, "Human Evolution in the Age of the Intelligent Machine" (*Interdisciplinary Science Reviews,* December 1983, p.307-319). In that paper the possibility of dominant hybrid organisms, "hyborgs" synthesized from humans and computers, arising sometime in the next 100 to 100,000 years is examined. Postulating a similar evolutionary phase for all planetary-originating life, the time scale for substantive evolutionary change may be sufficiently short compared to that required for interstellar migration to preclude the arrival of hominids, "little green men", at our doorsteps.

Does history have anything to teach us concerning the future colonisation of space? Although we may not be able to forecast the engineering details and the chronology of events, might not the constraints of human nature and past behaviour serve as a guide? Stapledon developed a future history which covered the entire span of the universe! More modestly, Heinlein has strung many of his works of fiction on a future history scheme spanning several centuries.

But I wish to speak more of the lore of the professional historian than the products of the writer of fiction. Implicit in the query is the assumption that the time scale which we consider here is short enough to preclude significant variation of human nature through evolution; a few thousand years might be a good number to hold in mind.

Frederick Jackson Turner (1861-1932) read his essay, "The Significance of the Frontier in American History", at the 1893 meeting of the American Historical Association in Chicago. His thesis was developed in a series of books over the next few decades and rests upon two basic points: (1) the frontier is the moving boundary between settled regions and an area of free land, into which new settlers continually expand, and (2) the frontier is the fundamental agent which shapes the character of the larger society of which it is a part. That is, Turner claimed that the frontier explained American development.

The phenomenon of the American frontier is conventionally placed in the period between the English settlement of Jamestown in 1607 and the official recognition in 1890 by the Superintendent of the Census of the loss of the frontier line. There were natural geographic features in the continent that prompted a series of semistable frontier lines in the westward march: the Allegheny Mountains, the Mississippi River, the Great Plains, the Rocky Mountains, etc. In addition to the multiplicity of a temporal succession of frontiers, lines drawn at any one time would differ depending upon whether one were considering the expansion of trapper, trader, cattle raiser, or farmer.

Turner saw the effects of the frontier process upon American development manifesting themselves in several ways but none more important than their influence upon democratic institutions. The individualism inherent in pursuit of frontier life and the waves of change generated by an expanding societal boundary constituted an inimical setting for authoritarian institutions.

The young historian Turner caught the academic world by surprise, and he followed up his advantage so well that serious attacks upon his new orthodoxy were not mounted until the 1920s. Criticism focused upon the lack of Turner's recognition of the importance of European influences and the elements of urban economics. Also, it was asserted that other frontiers - in South America, Australia and Asia - had to be considered in testing the hypothesis of frontier influence; the American experience was only a small piece of a larger stage of historical change. (In one generalization, Walter Prescott Webb moved the start of the frontier period 100 years earlier, to the discovery of the New World, and investigated the economic effects of this larger domain upon European society. See his book, *The Great Frontier,* Houghton Mifflin, 1952.)

The residuum of Turner's work is a heightened perception of the importance of the frontier for historical evaluations, but historians will argue about the relative weight to be assigned to the frontier factor in the scheme of overall development.

The anticipated colonization of space would seem to have some resemblances to frontier theory, and I will draw out the analogy by presenting a particular thesis, only one of many that are possible.

1. The space frontier will be the moving boundary between settled regions and a volume of free space into which new settlers will continually expand.
2. The space frontier will be the fundamental agent which shapes the character of Earth and its attendant settlements.
3. The primary material effect of the space frontier will be the technological progress which its movement stimulates.
4. The primary nonmaterial effect of the space frontier will be the attitudes, of mythic proportions, which it generates with respect to the value of individual effort and of peaceful cooperation among nations.

The first two points might be labelled "the strong hypothesis" of the space frontier. The purpose of the preceding discussion was to give them some credence by exposing a vein of thought which celebrates the importance of the frontier in historical development. Of course, not only Turner's original thesis but also the aptness of the space-to-Earth analogy can be questioned. Without attempting to mount a detailed, and lengthy, argument about the validity of the analogy, I will content myself with the observation that common usage, through the term "space frontier", endorses a resemblance.

Just as Turner identified several frontiers existing at the same time, we would expect more than one space frontier to be operative. In fact, the multiplicity of frontiers is even now evident if we delineate the domains of communications satellites, planetary landers, planetary orbiters, planetary flybys, etc.

The third point does not imply that economic benefits obtained through mining, farming, power generation, and population relief will not be of economic benefit. The judgement comes from noting the exponential growth of technology and its positive correlation with the opening of new space frontiers. The third point also looks ahead to a time when accumulated technological change may have fundamentally altered the human condition, i.e., the thesis, if vigorously interpreted, leans toward the epistemological solution to "where are they?" (It is also consistent with several other solutions.)

Point four relates to Turner, through its emphasis on individualism, but also touches upon Stapledon's assertion that we must look to our own values as well as our engineering.

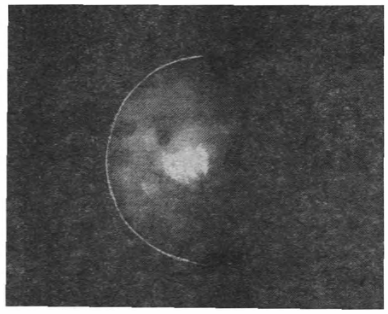
One might question the inclusion of individualism in an enterprise so firmly wedded to government and corporate support. However, this support focuses on technological and financial needs. Atop this infrastructure is a corps of individuals, among the general public and the space agencies, who are moved by the great spirit of adventure inherent in the exploration of space; try to watch Voyager encounter Neptune for the first time this August without a shiver of emotion.

The addition of "peaceful cooperation" to point four could be considered as wishful thinking, and perhaps it is. Certainly international cooperation was not a dominant factor in the evolution of the frontier on the North American continent (the history of arctic and antarctic exploration is somewhat more favourable). But the technological and financial challenges of space flight for a single nation, plus some favourable trends that have already been established, provide plausibility to this part of the thesis.

Finally, the phrase "mythic proportions" in point four is chosen with care. "Mythic" is not identified with the pejorative sense of "false". Instead, it signifies a potent belief which arises from our human biological and cultural roots. Joseph Campbell (1904-1987), in his *Myths to Live By* (Viking, 1972), sees the Apollo Moon walks as the start of a new, unifying force for our age.

Human nature functions at many levels. I usually write this column at home by a window that faces east. On nights when the full Moon rises, it always catches my attention: as a source of illumination, as a place where 20 years ago I helped send men, and as a symbol for stirring dim beliefs that go back to the Old Stone Age.

Voyager Approaches Neptune



On May 1, Voyager 2 will be 115 days away from its closest approach to the planet Neptune. Other Voyager 2 data follows:

DISTANCE TO NEPTUNE: 167,266,000 km
DISTANCE FROM EARTH: 4,283,436,000 km
HELIOCENTRIC VELOCITY: 18.895 km per second*

Values are for 0800 GMT on May 1, 1989 (figures are approximate).
* Velocity of the spacecraft relative to the Sun.

This image of Neptune was taken by Voyager 2 on January 23, when the spacecraft was about 309 million kilometres from the planet. A bright cloud feature is visible near the centre of Neptune's disc
NASA/JPL

Krakatoan-Class Volcanos

The uninhabited volcanic island of Krakatoa, in the Sunda Strait of Indonesia, blew apart in 1883. The awesome power of the release resulted in a 15m tidal wave and the deaths of over 30,000 people. Atmospheric effects, such as evinced by red sunsets and blue moons, were noticeable for years. A few tens of volcanic eruptions take place each year on Earth, but explosions with the force of Krakatoa are rare. Teams of investigators have been collecting data from a variety of sources, scientific and cultural, to identify, date accurately, and assess the human impact of large volcanic events within historical times. Dr. Kevin Pang of JPL and his colleagues are utilising ancient Chinese historical records to correlate societal effects with scientific measurements.

In a volcanic explosion, silicate ash is released into the atmosphere and can cause darkened days and ugly precipitates for a time, but the longer lasting effects of the event are due to gas releases. Sulphur dioxide combines with water in the atmosphere to form sulphuric acid droplets, and a significant amount of this compound is stored in the stratosphere as "dry fog". The phenomenon of dry fog was explained by the statesman and scientist Benjamin Franklin in conjunction with the eruption of Iceland's Laki volcano in 1783.

Suspended in the form of aerosol in the relatively quiescent stratosphere, above most weather, dry fog from a Krakatoan-class explosion can lower temperatures on Earth by a few degrees and affect the weather for years. The blocking of sunlight by the dry fog is particularly effective due to the large surface area presented by the legion of acid droplets. It also provides us with information about the volcanic event after being deposited in long-lasting snows such as those which blanket Greenland.

This information is encoded into the ice sheet in physical and chemical form. When a longitudinal cross section of an ice core is viewed under a microscope in polarised light, the annual layers of snow fall are distinguishable, much in the way that growth rings in trees can serve as dating devices, but counting the layers becomes more difficult at greater ages and depths because of distortion and flowing of ice under pressure. Depths of historical interest often involve a kilometre of overlying ice. Chemical measurements of the acidity of the ice-core sample reveal local regions where dry fog - sulphuric acid - has been pressed between the annual snows. Comparison of acid peaks with the count of annual layers provides a date for a presumptive volcanic event.

Pang said that for each of six anomalies which he has investigated, historical evidence has corroborated the hypothesis of a volcanic eruption. Additionally, physical corroboration comes from radiocarbon dating of organic materials such as trees or seeds, when the volcanic site is known, and through dating of frost-damaged tree rings.

European historical records provide a window to the relatively recent past. For example, Plutarch mentions various dire consequences of the assassination of Julius Caesar on the Ides of March in 44 B.C., "...the obscuration of the Sun's rays. For during all that year its orb rose pale and without radiance." Another telltale indicator of the involvement of vulcanism comes from the description of a contemporary comet, that classical acolyte of doom, as being reddish in colour. Michael Rampino and Richard Stothers, of the Goddard Institute for Space Studies in New York, have studied the cluster of historical events during this period of time and conclude that multiple eruptions of Mt. Etna in Sicily during 44-42 B.C. are responsible.

Ice core samples spanning this period of time validate the occurrence of a series of volcanic incidents through several surges in acidic levels. In this case, the historical data are probably more accurate than the physical data, so the ice-core method can be calibrated.

But by far the largest treasure of historical data is located outside of Europe in Chinese and other oriental records. The earliest such records predate European archives, going back to 2000 B.C. or even earlier, and are written on bone fragments and tortoise shells (in earliest times), moving in subsequent eras to bamboo strips, silk cloth, and paper. The Etna eruptions were responsible for three years of failed grain harvests in China and an inflation of the price of grain by as much as 1400 % between 44 and 42 B.C. (Grain price increases and human death statistics dolorously supply two quantitative societal measures of a volcanic event's severity.)

Pang and his colleagues at JPL, Santosh Srivastava and Dharam Ahluwalia, have joined forces with Professor Hung-hsiang Chou of UCLA's Department of East Asian Languages and Cultures to sift through oriental, especially Chinese, records, which have become more accessible in the last ten years. The intent of these investigators is to use oriental historical data, along with ice-core samples and tree-ring records, to refine and extend earlier researches based upon European records.

The Hekla 3 eruption in Iceland was 50 times the strength of Krakatoa and took place somewhere within 1159 to 1140 B.C., according to tree-ring data. (Trees in Europe show frost damage, reflected in the record of the rings. Hekla 1 and Hekla 2 were prehistoric eruptions, evidenced only be ice-core data.) Ice-core estimates of the chronology yield 1120 ± 50 B.C. for the explosion.

When Pang and his colleagues examined Chinese records for correlated events, they found extensive evidence manifested in a series of natural disasters. "In the summer of the fifth year of King Chou it rained dust at Bo". Snow in summer, over a foot deep, was reported. Agricultural consequences were present: "Frosts killed five cereal crops. Fibercrops failed. Heavy rainfall. The grain crops did not crow". From the historical evidence, they place Hekla 3 in the late 12th century B.C.

Certain worldwide events in the 6th century A.D. have been traced to the eruption of Mt. Rabaul on the island of New Britain in Papua New Guinea. Several European reports of a dimmed Sun correlate well with ice-core measurements (512-550) and tree-ring data (536-545). When Pang went to Chinese records he found summer snowfalls, crop failures, and major famines in this period of time. In fact, north of the Yellow River, where the short growing season increases human vulnerability to crop failures, 70 to 80% of the populace perished. The historical data yield a date for the eruption more precise than the physical evidence: 536-538.

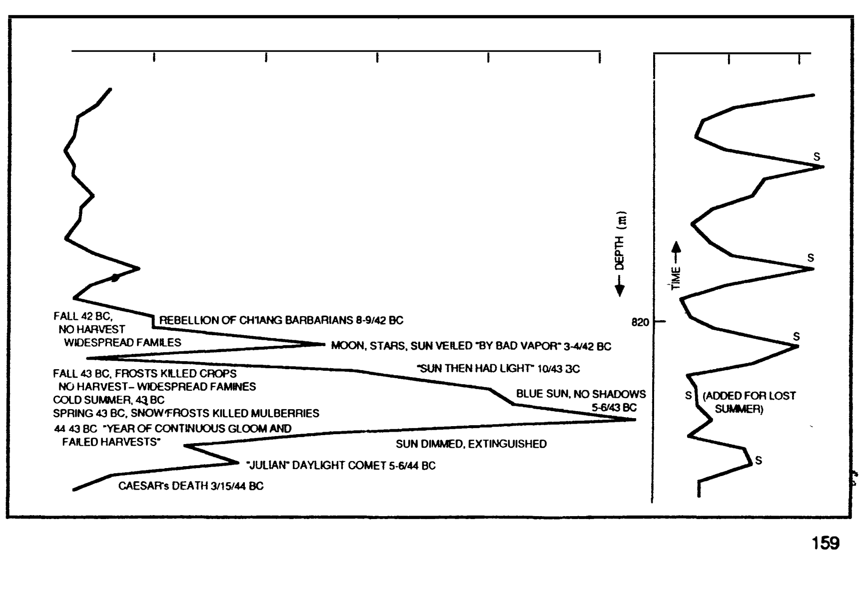
Using ice-core data and historical records, three other major volcanic events have been investigated by the JPL/UCLA team: a volcano of unknown location in Iceland (c. 209 B.C.), a volcano of unknown location (c. 269 B.C.), and the volcano on the Greek Island of Santorini (Thera): c. 1600 B.C.

The last volcano could have been a factor in the destruction of the Minoan civilisation and is currently under intensive investigation by Pang and his group in order to provide a reliable date: 1600 B.C. is their best estimate at present.

Inscribed tortoise shells from ancient China and kilometre-deep ice cores from Greenland have been linked in a most impressive web of interdisciplinary deductions.

"Dry Fog" (sulfuric acid) created by volcanic action and precipitated in Greenland becomes buried by annual snows and when retrieved by ice-core techniques serves as a source for dating large volcanic eruptions. The fluctuating line on the left measures the acidity of the ice-core and correlates with historical volcanic-like effects obtained from European and Chinese records. The nearly periodic line on the right is also derived from chemical analyses and provides a yearly chronology for the ice-core as a function of depth; the peaks labelled 'S' represent summers.

NASA/JPL



SATELLITE DIGEST - 221

Robert D. Christy

Continued from the April 1989 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1979, 1988-101A, 19647

Launched: 0140, 18 November 1988 from Tyuratam, by F-1.
Spacecraft data: Cylindrical, probably about 7 m long and 2 m in diameter, equipped with solar cell panels and with a mass around 5,000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 403 x 417 km, 92.78 min, 65.03 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1980, 1988-102A, 19649

Launched: 1500, 23 November 1988 from Tyuratam, by J-1.
Spacecraft Data: Not available, but the mass may be around 10 tonnes.
Mission: Electronic intelligence gathering.
Orbit: 849 x 854 km, 102.00 min, 71.01 deg.

COSMOS 1981, 1988-103A, 19651

Launched: 1450, 24 November 1988 from Plesetsk by A-2.
Spacecraft Data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 14 days.
Orbit: 227 x 272 km, 89.49 min, 62.83 deg.

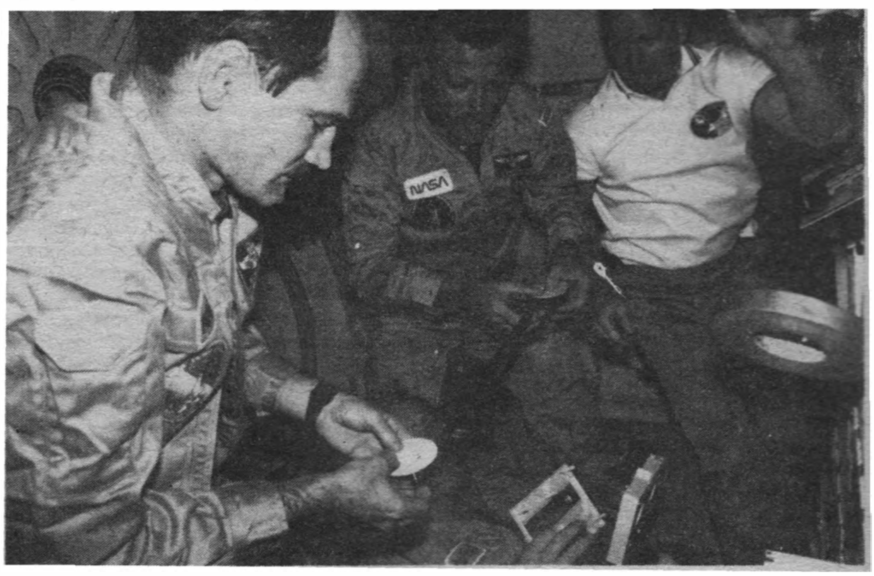
SOYUZ-TM 7, 1988-104A, 19660

Launched: 1550*, 26 November 1988 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried Soviet/French crew of Aleksandr Volkov, Sergei Krikalyov and Jean-Loup Chretien (France) to Mir. Docking with Kvant's rear port occurred at 1716 on 28 November. Chretien returned to Earth in Soyuz-TM 6, along with Mir long-stay crew members Titov and Manarov. They landed at 0957 on 21 December. At 0931 the same day, with Volkov, Krikalyov and Poliakov aboard, Soyuz-TM 7 undocked and re-docked at Mir's forward port some 20 minutes later.
Orbit: Initially 194 x 235 km, 88.73 min, 51.61 deg then by way of a 256 x 291 km transfer orbit to a docking with Mir in an orbit of 337 x 369 km, 91.55 min, 51.63 deg.

COSMOS 1982, 1988-105A, 19662

Launched: 0900, 30 November 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 406 km, 92.20 min, 70.01 deg.

NASA has released photos from the STS-27 shuttle mission, a military flight. Four of the mission's five crewmembers attempt to repair a video cassette in the mid-deck of the Earth-orbiting Atlantis. Left to right Guy S. Gardner, Jerry L Ross (partially obscured at bottom), Robert L Gibson and William N. Shepherd The cassette contains video of the tile damage survey recorded by Atlantis' TV cameras



STS-27, 1988-106A, 19670

Launched: 1431*, 2 December 1988 from Pad 39B, Kennedy Space Center.
Spacecraft data: Shuttle Orbiter 'Atlantis'.
Mission: Carried crew of Gibson, Gardner, Ross, Shepherd and Mullane. A primary mission objective was to launch the 'Lacrosse' military satellite. 'Atlantis' landed at Edwards AFB at 2336, 6 December 1988.
Orbit: 444 x 451 km, 93.51 min, 56.99 deg.

LACROSSE, 1988-106B, 19671

Launched: 2130*, 2 December 1988 from the payload bay of 'Atlantis'.
Spacecraft data: not available.
Mission: Military satellite, returning images of the ground, obtained via a radar system.
Orbit: 667 x 692 km, 98.32 min, 56.97 deg.

COSMOS 1983, 1988-107A, 19672

Launched: 1450, 8 December 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 200 x 254 km, 89.04 min, 62.83 deg.

EKRAN 19, 1988-108A, 19683

Launched: 1150, 10 December 1988 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99 degrees east longitude.

SKYNET 4B, 1988-109A, 19687

Launched. 0033*, 11 December 1988 from Kourou by Ariane 44LP
Spacecraft data: Three-axis stabilised, box-shaped body, 2.1 x 1.9 x 1.4 m, with an aerial array on one face. Power is provided by a 16 m span solar array. The mass (in orbit) is 790 kg.
Misson: Military communications satellite.
Orbit: Geosynchronous above 1 degree west longitude.

Ariane 4 Scores Another Success

The 29th Ariane blasted off from Kourou on March 6 carrying the first European operational weather satellite, Meteosat (MOP-1), and the first Japanese telecommunications satellite, JCSAT-1.

Ariane V29 was delayed three times. The launch, originally scheduled for February 28, was first postponed because of a strike by technicians working for the Thomson Company at the Guiana Space Centre. The dispute was resolved and the launch reset for March 4. But the countdown was halted three hours before lift-off when two umbilicals used to circulate air around the payload were pulled loose in a strong wind. The launch was rescheduled for the next day - but was delayed again, awaiting a spare part which was being flown to Kourou from France.

The Ariane was finally launched at 23:29 GMT on March 6 from the ELA-2 launch pad. The vehicle was an Ariane 44LP, equipped with two liquid and two solid propellant strap-on boosters. One minute six seconds after blast-off the solid propellant boosters separated. They were followed 1 minute and 23 seconds later by the liquid boosters. The first and second stages separated without incident. The Ariane's cryogenic third stage was ignited 5 minutes 47.8 seconds after launch and reached geostationary transfer orbit at T+17 minutes 41.7 seconds.

Parameters for the orbit at injection were:

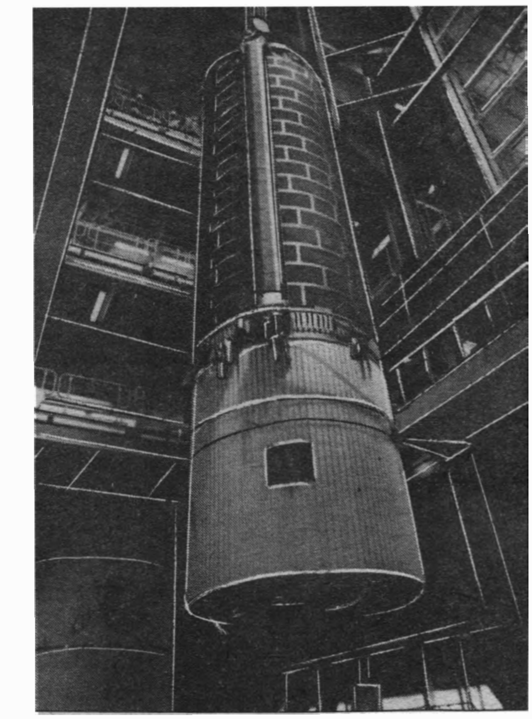
Perigee: 198.6 km (± 1km) for 200km intended

Apogee: 35,901 km (± 100km) for 36,060 km intended

Inclination: 7.04 (± 0.005) degrees for 7 degrees intended

Twenty minutes and 12.3 seconds after launch the JCSAT-1 separated followed by MOP-1 four minutes later.

• Arianespace has won the contract to launch the Japanese BS-2x direct broadcast satellite for the NHK company. The satellite will be placed into geostationary transfer orbit in December 1989 on an Ariane 44L, equipped with four liquid propellant strap-on boosters.



The Ariane V29 third stage is moved into position in the Vertical Assembly Building. The 2nd stage is visible in the background. *Arianespace*

MOP-1

MOP-1 (Meteosat Operational Programme-1) is Europe's first operational meteorological satellite. It follows three pre-operational satellites, launched by ESA, which have successfully displayed the capabilities of meteorological satellites:

• Meteosat 1 - launched in November 1977, by Delta from Cape Canaveral. The satellite provided data until its failure at the end of 1979.
• Meteosat 2 - launched by the third Ariane in June 1981 to replace its predecessor. The satellite is still operational and plays the role of Meteosat 3 back-up. The satellite will soon be deorbited as it is running out of fuel after seven and a half years of service.
• Meteosat 3 - launched by the first Ariane 4 in June 1988 to bridge a gap between the aging Meteosat and the first MOP spacecraft. Today, it provides the data used daily by weather forcasters.

The MOP-1 is the first of three satellites that will serve the meteorological community until the end of 1995. MOP-2 will be launched in 1990 followed by MOP-3 during the 1992-1994 period. All three MOP satellites are to be placed in geostationary orbit above the intersection between the Equator and the Greenwich meridian.

The primary task of the satellites is to produce cloud images every half hour, day and night. These images are transmitted in near real time to user stations located in Europe, Africa and elsewhere. There are over one thousand registered users, including national meteorological services, universities, commercial enterprises, schools and many amateur enthusiasts.

Cloud track winds, top cloud height and sea surface temperature can all be determined from MOP images.

The MOP satellites were designed by ESA, built by Aerospatiale and are operated by the Eumetsat organisation, representing 16 European nations.

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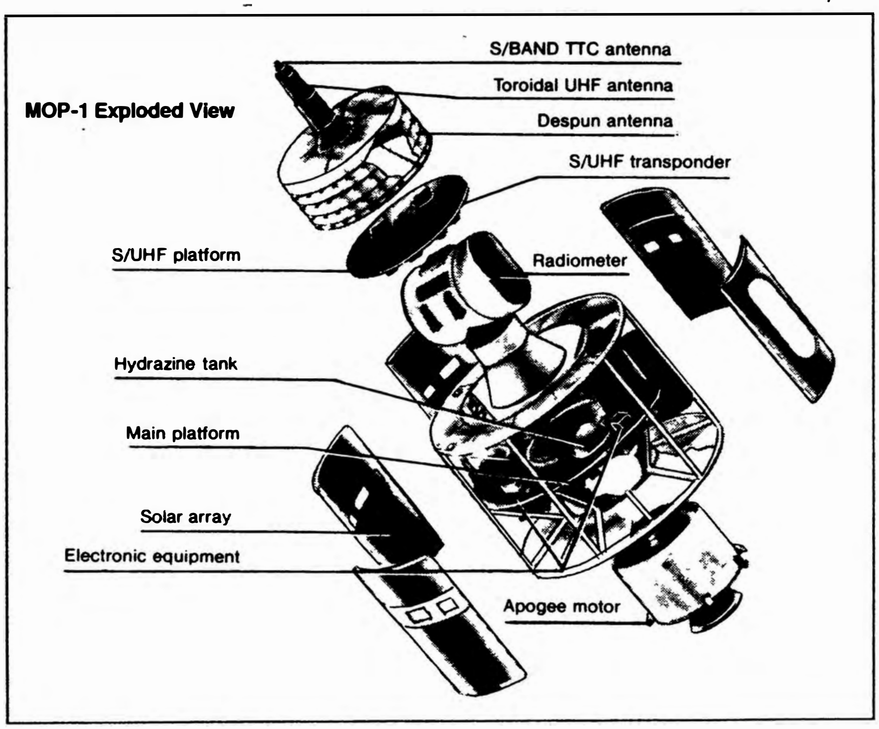

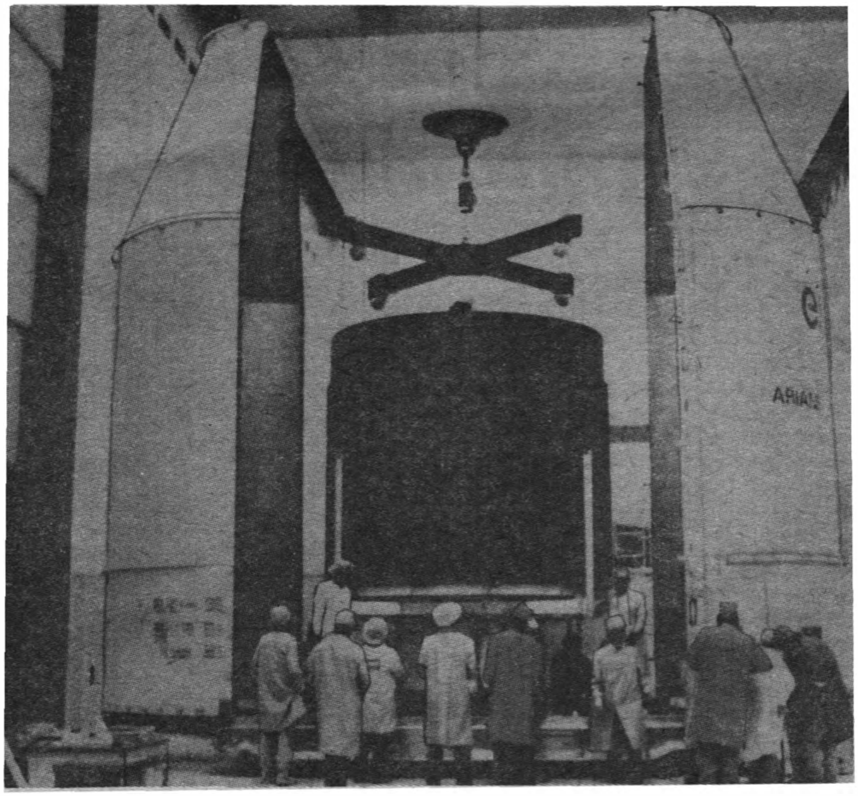
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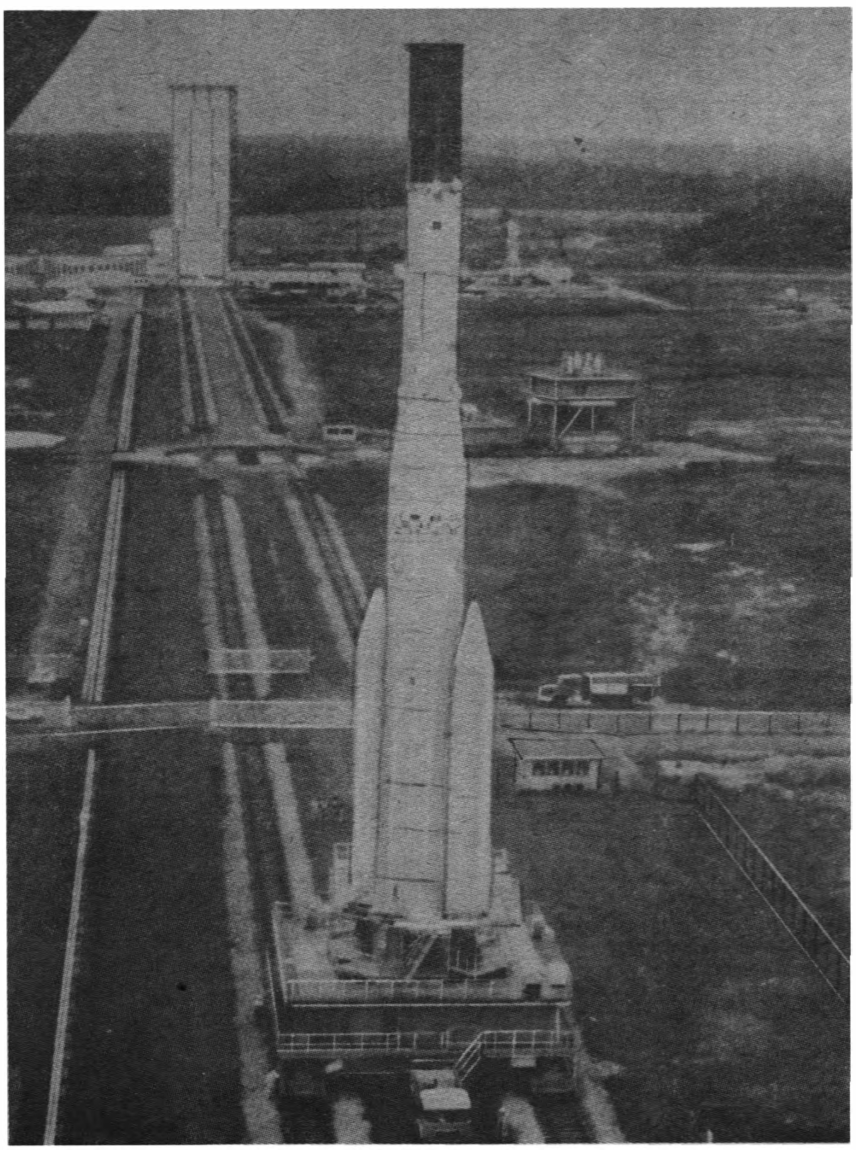

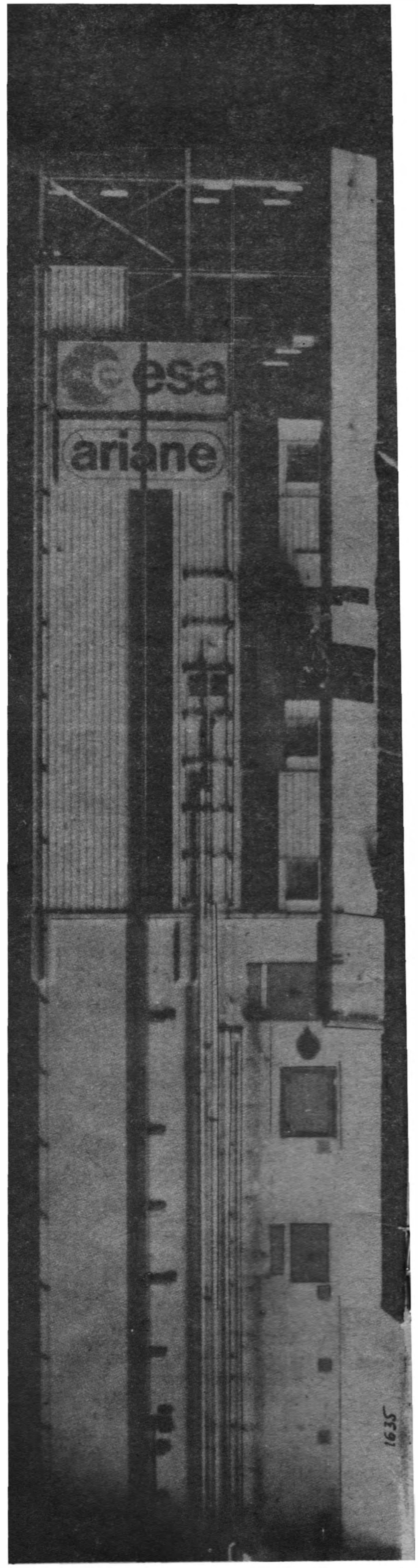
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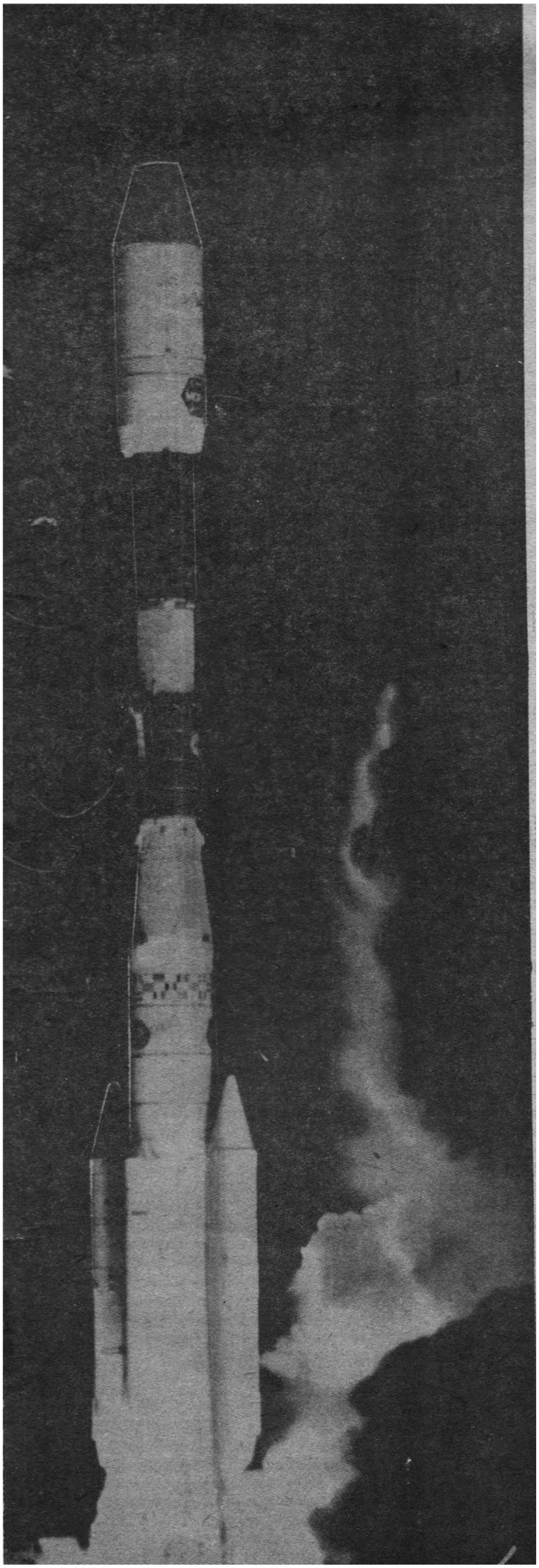

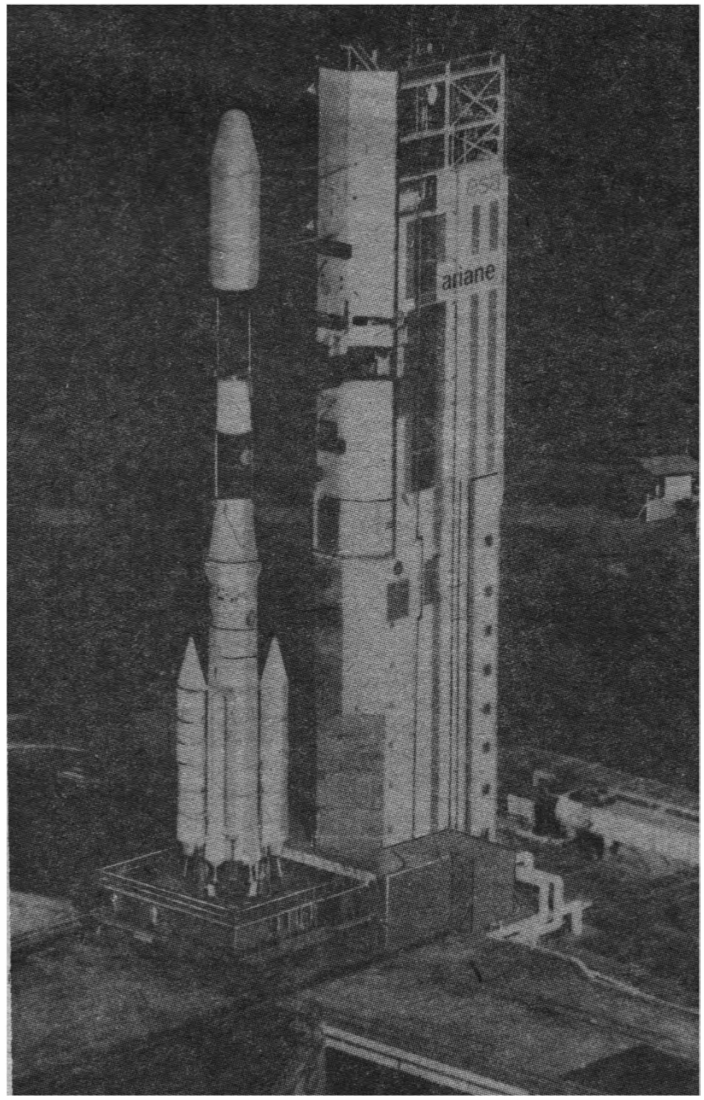
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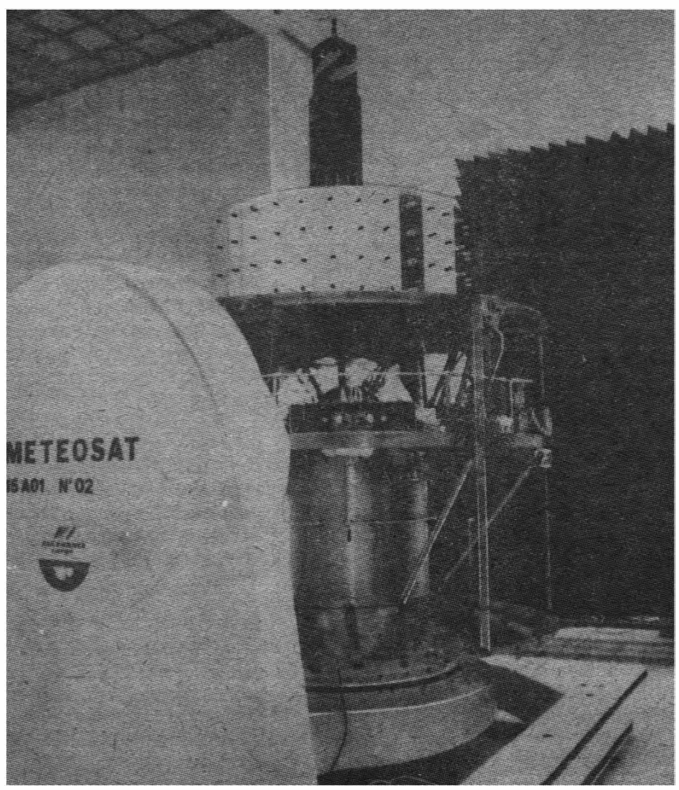

METEOSAT

Continued from p.161

JCSAT-1

JCSAT-1 is the first of two HS 393 satellites to be built for the Japanese Communications Satellite Company (JCSAT) by the Space and Communications Group of the Hughes Aircraft Company. The HS 393 is a larger, more powerful version of the Hughes HS 376 satellite and incorporates technology used for the Intelsat VI.

JCSAT is a joint venture between C.Itoh & Co. Ltd., Mitsui & Co. Ltd. and Hughes Communications Inc. This is the first time an American company has shared as an equity partner in a Japanese commercial satellite business venture.

Fully deployed, JCSAT-1 measures 10 metres in height and 3.66 metres in diameter. Its 2.4 metre antenna and multihorn feed array will produce a shaped beam on the contour of the four Japanese main islands and Okinawa, providing a signal strength of 50 dBW.

JCSAT-1 is stationed at 150 degrees east and is expected to have a life time in excess of ten years.

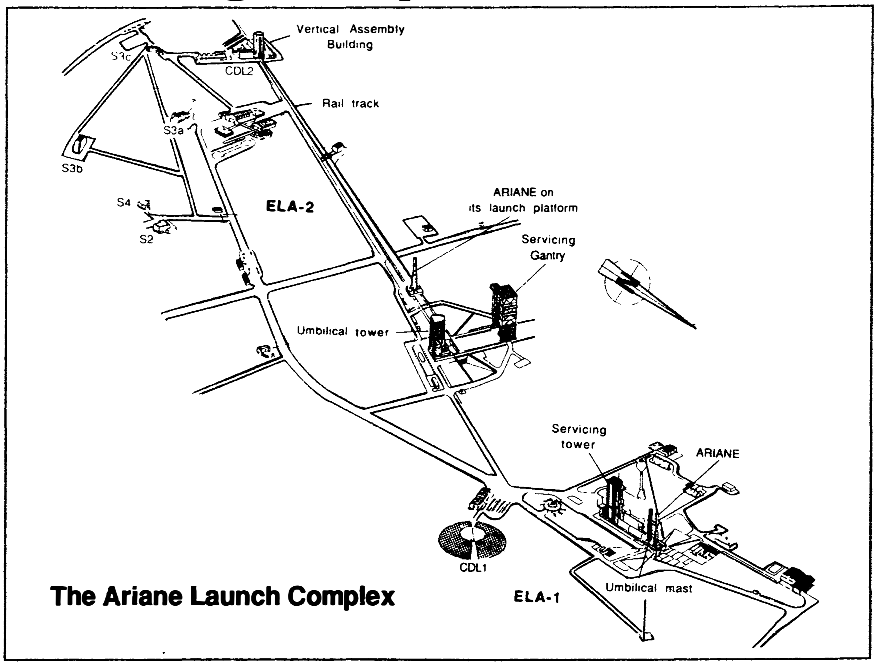
Kourou - The Jungle Space Centre

Ariane launches are made from the Guiana Space Centre (CSG) near Kourou, in the South American state of French Guiana. The Guiana Space Centre was set up by the French Government in April 1964 and built by the French space agency, CNES. It became operational in April 1968 with the launch of the Veronique sounding rocket. Following the Diamant programme and the Europa project, the CSG has been used for Ariane launch operations.

The CSG facilities are spread over an 18 km strip of the Atlantic coast between Kourou, which used to be a small fishing village, and Sinnamary, a sleepy river crossing.

Located 5.3 degrees north of the Equator, the CSG is ideally suited for the launch of satellites into geostationary orbit. The Centre's proximity to the Equator makes it possible to send into orbit, at an equal cost, a payload 17% heavier than the equivalent launched from Cape Canaveral. The reason for this increased performance is the rotation of the Earth from west to east - the rotation increases to maximum velocity at the Equator. Consequently at the Equator 6% of the velocity required to place a payload in orbit is free.

There are two Ariane launch pads, ELA-1 and ELA-2 (French translation - Ensembles de Lancement Ariane).



The Ariane Launch Complex

ELA-2

ELA-2 is for the launch of Ariane 2, 3 and 4 vehicles, it was first used in March 1986. The launch complex consists of two parts - the preparation area and the launch zone - linked by a rail track 1 km long. At the start of the rail track is the 80 metre high Vertical Assembly Building. Inside this building the Ariane vehicle is assembled upon a mobile launch platform. The strap-on solid propellant boosters are attached to the Ariane at the launched pad to minimize the risk of accidental ignition. It is also considered safer to attach the payload fairing, containing the satellites, after the launcher has arrived on the pad. This operation is usually conducted about five days before blast-off.

Once stacking and checkouts in the assembly building have been completed (in the case of an Ariane 4 this usually takes about a month) the vehicle is hauled to the launch pad along the rail track by a powerful truck. Weather conditions for the 45 minute journey are carefully monitored - a strong wind could topple the launcher. Once the assembly building is vacated, stacking of the next Ariane can begin.

At the pad, the Ariane is coupled to the 74 metre high umbilical tower, which provides fluid links between the launcher and the ground facilities. Two cryogenic arms extend to link up with the third stage of the vehicle.

The Ariane is then enclosed within a servicing gantry where final launch preparations can continue in a sheltered environment. The preparations include: assembly of the solid propellant boosters, final launcher checkout and assembly of the payload and fairing. Five and a half hours before launch the gantry is withdrawn to a safe distance.

ELA-1

ELA-1, used since December 1979, is designed for Ariane 1, 2 and 3 vehicles with a two month interval between launches. The ELA-1 complex differs from ELA-2 in that the Ariane assembly takes place on the launch pad. The stacking of the vehicle within a servicing tower takes approximately 10 days. Checkouts of the vehicle continue for 26 working days in the case of an Ariane 2 and 29 working days for an Ariane 3. The payload is placed atop the launcher about six days before launch.

The servicing tower that enclosed the vehicle is withdrawn on launch day, six hours five minutes before blast-off.

The ELA-1 launch pad will fall into disused when the final Ariane 3 takes to the sky, in June or July.

(Top Left) JCSAT-1 is lowered between the two halves of the Ariane payload fairing. (Bottom Left) Ariane V29 is towed to launch pad ELA-2. Note the payload fairing has not yet been attached. The Vertical Assembly Building can be seen in the background at the left. To the right of the Ariane stands a second mobile launch platform.
(Centre) Ariane V29 blasts off from pad ELA-2 on March 6.
(Top Right) An Ariane 4 stands poised for launch.
(Bottom Right) MOP-1 during prelaunch preparations.

Payload Facilities

The Payload Preparation Complex (EPCU) is placed at the disposal of Arianespace customers for the preparation of their satellites from their arrival in Guiana up to the mounting of the payload on the Ariane launcher. Designed for the preparation of five satellites simultaneously, the EPCU consists of several buildings:

- Buildings S1A and S1B are located in the CSG Technical Centre, and provide clean-room facilities for satellite preparation.
- Buildings S2 and S4 located near the two ELAs, are designed for solid kick-motor preparation and X-ray operations.
- Buildings S3A and S3B, located near the two ELAs, are assigned to satellite propellant filling operations and final integration, assembly of the satellites on a Spelda or Sylda dual launch system, and final encapsulation into the Spelda/ Sylda and the Ariane nose fairing.
- Building S3C is located close to S3A and S3B, and is used to monitor and control hazardous operations conducted in the latter.

A Way Forward for Britain?

A Philosophical Approach

Roy Gibson, former Director-General of the British National Space Centre, suggests a way forward for Britain in space. This article is based on a paper presented at the British Interplanetary Society's Space '88 meeting, held in Hastings last October.

I share the view that there is no point in harping on about the need for more U.K. Government funding for space. I sincerely believe that the Government made a serious mistake in not giving space a higher priority - I certainly have not changed my mind on that - but if the light is to dawn, it can only be through a rather complicated and lengthy process of self-persuasion, and not by any sniping, Minister-bashing, or still less by a head-on assault. I am hopeful for a gradual conversion - and to the extent that I can, still work for it. Since this is mainly a national occasion, I can afford to be a little recondite to saying "I resigned, but I am not resigned".

What can we do, to get the best out of the present situation?

Here at home, most of the necessary actions are easy to identify, and it is encouraging to see that some at least of them are being taken:

The British National Space Centre

Even though it has not been given control of the total U.K. spending on space, in the way we recommended, and although there has been only a very small increase in the money available, it is essential to keep the BNSC going and to encourage it to exercise a strong coordinating role wherever it can. Obviously this is a difficult task and the government's attitude encourages the participants, such as the SERC, NERC and even the Ministry of Defence, to set and pursue their own objectives with their own budget. BNSC could then quickly become just an arm of the Department of Trade and Industry. Ironically, this backtracking would come just at the time when other European governments are realizing the value of real intergovernmental coordination in space. Both the Germans and the Italians have created governmental space agencies, and the Norwegians have also reorganised themselves along these lines, too. Only in this way can a nation exercise any real influence over the European Space Agency - or indeed - in any other international body effecting space.

It was pleasing to see the appointment of Arthur Pryor to Head BNSC, for he has a fine reputation and this is an obvious demonstration that the post is still taken seriously.

To be realistic Arthur Pryor's BNSC

By Roy Gibson

will not have an easy task, but it is essential that everyone sees them as the centre for our space activities and - equally important - that they see themselves in the same light.

The Science Community

They seem to be surviving quite well, and they are still being solicited to join overseas groups in many parts of the world: a tribute to their competence and ingenuity. The crunch will come when the other 12 Members of ESA ask the U.K. to join them in increasing the mandatory science programme budget by five per cent per annum for a second period of five years-starting with 1989. The U.K. has so far said "No" - and that with the finesse and politeness which have characterised our recent European decisions. The amount of money is relatively small, but SERC do not consider it to be on their priority list, and, with the continuation of this fragmented approach, no other government department is volunteering to foot the bill. The danger is not so much in the damage to the ESA Horizon 2000 science programme - although it will certainly have deleterious effects - but much more the thwarting of the ambitions of our 12 European partners. We really must either find some way of raising the money, or at least, a legal trick to allow the others to continue without us - not as simple as it may appear.*

The Private Sector

Well, most firms have taken a cold shower in the past 12 months, and it is not easy to persuade them to re-start initiatives unless they allow returns to be foreseen in the not too distant future. From the very start of the BNSC, this was our weakest link. Many companies helped enormously in producing the National Space Plan -the work they did then was really excellent - but the bigger boys never did like the idea of organizing a sort of trade association, along the lines of the French Prospace, to widen the industrial participation. A scheme to have a kind of bolt-on extension to BNSC, which would feed information and intelligence to the private sector, was nearly ready to get off the ground when the axe fell last year. It is still needed. Showing the interest and the commitment of large numbers of private companies, is one of the critical elements in persuading the government to release more funds.

* In the event the UK voted in favour of the increase for science at the meeting of the ESA Council in December - although this will probably have to come out of existing funds

Roy Gibson

Marriage between Universities and the Private Sector

Several of these have been arranged and I find this very encouraging. It is particularly rewarding when the university contribution is multi-disciplinary, because the future exploitation of space needs the skills of a great number of disciplines and faculties.

My Philosophy

Perhaps we can best characterise the present situation by saying that the bleeding caused by negative decisions has been staunched. The patient is understandably weak, but beginning to look around and take stock. British space is not dead, but I would still put it on this "seriously ill" list.

In describing my philosophy I would recommend taking note of the following: Changes of ministers, indeed changes of governments, will not in the next five years or so result in any significant increase in governm nt investment in space. Furthermore, if I can play Cassandra, I believe that substantial cost increases in the ESA Hermes, Ariane 5 and Columbus programmes will be progressively revealed over the next few years, and that these will be used in the U.K. as a justification for our attitude at The Hague in 1987 This is likely to harden the government's attitude. Great regard though I have for ESA and its people, I consider that large increases in costs to completion are inevitable.

It will be tempting for ESA (and per-

haps for some national delegations) to conceal the worst news until the programmes have sufficient momentum to resist sudden stops - but, although it will make for a tough period, I am hopeful that ESA will have the courage to ferret out the facts and to make them public. In my view, the probability of cost increases is not a justification for the UK opting out; it will be a vindication for our proposed policy of keeping a major role in ESA and exerting influence from within.

Many ESA delegations regret our very much reduced role because no one has yet replaced us as the financial conscience of the Council.

But, so far as the size of our participation in these programmes is concerned, it is too late to change; I hope that, as money becomes liberated from completed projects, the UK will be spending it on becoming an intelligent user of other people's space infrastructure. It seems to me that there are three interesting areas of utilisation on which we should concentrate any space funding that becomes available:

Remote Sensing: An all-out attack on applications, giving the maximum incentive to the private sector to share in the investment - and to take their profit - even if it means modifying our traditional way of operating. This whole area of returns from Earth observation satellites needs a lot of new thinking. Building ERS 2, or even polar platform, is not an adequate substitute for a redefined national strategy.

Telecommunications: But, again, strictly directed towards new and predictable uses. We should be sceptical about flying new test beds and concentrate on the development of the new payloads which will be needed, not least by INTELSAT and Inmarsat. (Inmarsat, for example, is just about to announce to industry that it is starting the procurement process for the third generation of its satellites). And we should not ignore the vast markets available for the small, mobile terminals - against which the space segment looks commercially relatively uninteresting.

Space Station Experimentation: Perhaps smaller in its demand than the other two, it is - or will be - just as important. It

In my crisis philosophy there is room for Hotol, too - but a de-hotolised Hotol

is imperative that, in spite of many national prejudices against expenditure in this field, we put money into preparing to be regular and clever users of the new facilities being created largely by other people's money. When the time comes, they will be delighted to welcome us as customers. But this preparation for the Space Station era cannot happen spontaneously; it needs close coordination with industry and with universities not only in laboratory work but also in trying to take advantage of flight opportunities - not despising aircraft and sounding rockets, by the way. And above all, it requires 10 years of government seed funding; not large amounts, but a continued and assured flow to finance a carefully worked out programme, taking into account what others (notably the Germans and Japanese) are interested in and how they are organising themselves.

In my crisis philosophy there is room for Hotol, too - but a de-hotolised Hotol. It is my perception that the longer term benefits of Hotol (X minutes to Sydney, etc) have in fact militated against obtaining government support for fear of implicating them in a large technological white elephant. The way ahead I see is in active stimulation of a three or four technological programme which would concentrate mainly on the development of new materials. In this way one could hope to harness the interest - and the funds -of the non-aerospace firms; particularly those who have their own motives for wanting to see new materials developed. I personally would favour making this an international effort, though at this stage outside the framework of ESA: they have enough on their plate. And I would also hope that some small contribution could come from BNSC, to enable them to have adequate visibility of the project.

There are, inevitably, industrial - I would almost say behaviourial-consequences of this change of emphasis. But, to do it successfully, it still needs a strong, central coordination from BNSC and the active participation of the private sector. I hope we have the resolve to achieve this change in attitude in the comparatively short time left to us. It would mean a lower profile for the UK; less glamorous work and, frankly, taking fourth or fifth place in the ESA pecking order, but if we are to salvage something out of the mistaken government policy, we must adapt to this new role. In so doing I hope that we can maintain our competence more or less intact in critical areas, and prepare ourselves to be ready to exploit the farsightedness and the financial investment of our European partners. Maybe we can do the same for them in a subsequent generation of space development.

There - you can't expect me to be much more philosophical than that!

On the Way to Horizon 2000

The European Space Agency received a most welcome Christmas and New Year present when the ESA Council approved in principle the Long Term Plan. Thus the decision-making cycle which began at the Ministerial meeting in November 1987 in The Hague was completed.

By Norman Longdon

For the ESA Scientific Programme, it was particularly rewarding that the level of resources for the mandatory programmes was approved unanimously. This will mean that the scientific budget will have an annual average increase of 5% up to 1992. The space science communities throughout Europe can therefore look forward to the very imaginative and forceful programme known as 'Horizon 2000' going ahead.

At the same time, the ESA Science Programme Committee made up its mind on the next medium-sized project to be undertaken within the scope of Horizon 2000.

There were five candidates from which the project could be chosen, and it is of interest to see the scope of modern space science with a quick review of all the candidates. Although strong support was given to all the candidates, funding being limited, work on only one project of this size could be started at present.

The five missions competing for selection were:

- Lyman, an Observatory covering the ultraviolet wavelength range, to be jointly procured by ESA/NASA and Canada
- Quasat, a very long baseline interferometry mission, also an ESA/NASA/Canada cooperation,
- GRASP, a gamma ray Observatory and
- VESTA, a joint ESA/CNES/USSR mission to the asteroids,
- CASSINI/Titan Probe, an ESA/NASA cooperative venture including a Saturn Orbiter, and a Titan Atmospheric Probe.

The prime objective of the Lyman mission would be the spectroscopic study of faint astronomical objects in the 90 to 120 mm segment of the ultraviolet spectrum - a region that is known to be extraordinarily rich in key atomic and molecular transitions, but which has only been briefly explored by previous astronomical space missions. Lyman would be a true international astronomical observatory facility that would address a wide span of astrophysical topics, ranging from the physics of the atmospheres of planets and stars, to reconstructing the history of element creation in our Galaxy and the Universe as a whole.

Quasat would be an Earth-orbiting radio antenna to be used in conjunction with ground-based Very-Long-Baseline Interferometry (VLBI) networks in Europe, the USA, the USSR and Australia to produce radio images at frequencies of 22, 5, 1.6 and 0.3 GHz. By combining simultaneous space and ground observations with baselines of up to 50,000 km, Quasat could provide radio images forty to two hundred

times sharper than those from Earth-based VLBI networks, and one hundred thousand times sharper than those from the Hubble Space Telescope. The reason for going into space would be to create interferometer baselines longer than the Earth's diameter and thereby achieve improved angular resolution. However, equally important would be the fact that images of much better quality could be obtained because the spacecraft's orbital motion would produce excellent coverage of the interferometer aperture plane. The scientific research conducted with Quasat would address such problems as the physics of the central region of quasars and active galaxies the distance scale and rate of expansion of the Universe, and star formation.

If chosen GRASP would have been the first genuine high-quality spectral imager designed to operate over a wide spectral range with a high sensitivityover the entire operational range for an observation period of 30 hours. Fundamental new astrophysical data would be revealed by this exploratory mission to investigate gamma-ray sources in what is basically an unexplored waveband for the first time with both high spectral and high spatial resolution.

The heavenly bodies that orbit the Sun are classified into two main categories: the planets and their satellites, and the so-called 'small bodies', namely asteroids and comets. The Vesta missions, named after one of the largest asteroids, were proposed as a trilateral cooperative endeavour by the European, French and Soviet space agencies (ESA, CNES and Interkosmos). Two identical space systems would be launched in 1996 and would visit up to eight small bodies, including one or two comets, over a five-year period.

The Vesta missions would pursue and extend the small-bodies exploration programme that began with the flybys of Comet Halley by the Giotto and Vega spacecraft. They would also be the forerunners of the ambitious Comet-Nucleus Sample-Return mission, Rosetta, planned for the turn of the century.

It is clear that each of these four proposals was an exciting prospect, but only one could be chosen and the decision was made in favour of the Cassini mission.

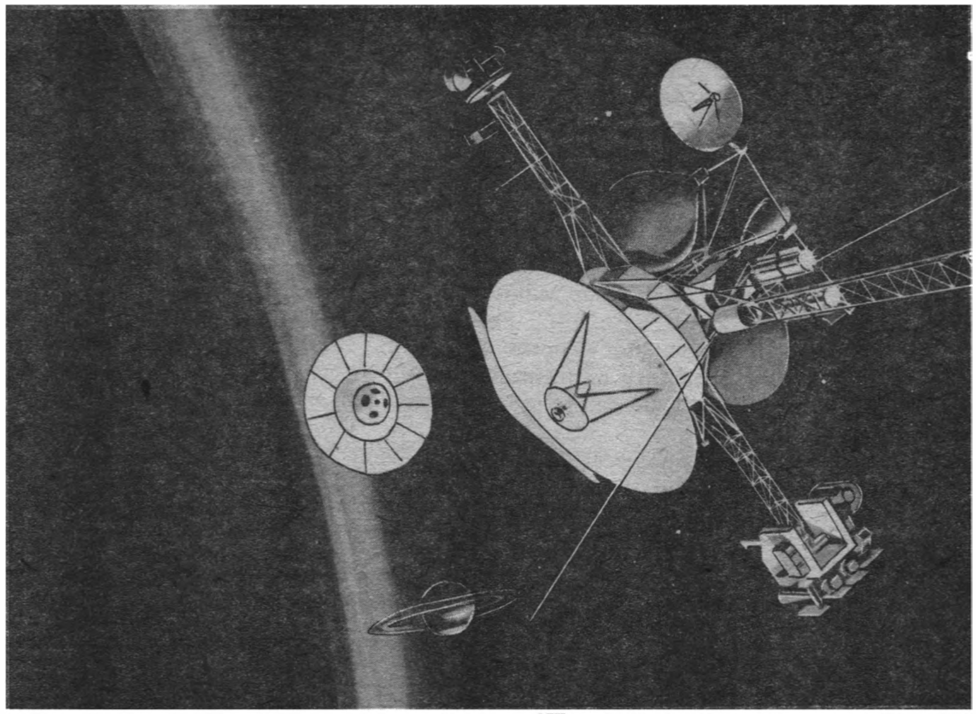
The unique scientific observations made by NASA's Pioneer and Voyager spacecraft yielded a wealth of information that has fundamentally changed our concepts of the Jovian, Saturnian and more recently Uranian systems in particular, and our view of the solar system as a whole.

A thorough exploration of the Jovian planetary system is the major objective of the Galileo mission, which consists of a Jupiter orbiter and an atmospheric probe, currently planned for launch in 1989.

The Cassini mission to the Saturnian system is the next logical step in the detailed systematic exploration of the outer solar system. Saturn's planet-sized moon Titan, with its intriguing atmospheric composition, is an especially interesting target.

The Cassini mission will consist of a Saturn Orbiter and Titan Atmospheric Probe, and is ideally suited to a joint venture. NASA will provide the Orbiter, launcher and Deep-Space Network for operations. ESA will provide the Titan Probe system and participate in the operations.

The Titan Probe has now been given a name: the Huygens Probe. It was the Dutch astronomer, Christiaan Huygens who discovered Titan in 1956. Present planning foresees a launch in April 1996.



Artists impression of Cassini and the Huygens probe above Titan.

The joint mission now awaits formal confirmation from NASA.

Horizon 2000 is built on four major 'cornerstones' of which the first - the Solar-terrestrial Science Programme (STSP), the ESA element of which is based on the SOHO and Cluster missions - is under way. SOHO, the Solar and Heliospheric Observatory, and 'Cluster', a four-spacecraft plasma-physics mission will attack outstanding scientific problems in solar, heliospheric and space-plasma physics through a unified and coordinated approach. Together they will address the major issues of the Sun-Earth relationship.

From the scientific side, the payload selection has been made. About 40 proposals were received, and investigated by a Joint ESA/NASA Evaluation Committee in combination with the ESA Programme Office. ESA and NASA jointly announced the payloads for both missions. Eleven instruments were selected for Cluster and twelve for SOHO.

The Cluster instrumentation is intended to cover a wide range of plasma parameters with high time and spatial resolution. With one exception, the instruments on all four Cluster spacecraft would be identical, instrument responses being an essential factor for the accurate determination of three dimensional features in geospace.

The instruments which were selected for SOHO should allow a coordinated approach to the main aims of the mission. Three instruments will be devoted to the study of the solar oscillations and the solar irradiance variations, for the understanding of the solar interior structure and dynamics. Six experiments consisting of telescopes, some with associated spectrometers will study the physical processes in the solar atmosphere in an attempt to understand the formation of the solar corona and the origin of the solar wind, and three groups of 'in situ' particle analyzing systems will study the composition of the resulting solar wind and energetic particles generated at the Sun.

Although their time is well into the future, early work on the other three cornerstones progresses.

The X-ray Multi-Mirror Mission (XMM) cornerstone should make a major step forward in x-ray astrophysics. It is planned as a unique mission in that it will have a very high energy collecting area due to the large number of nested x-ray reflecting mirrors, allowing it to observe to the edge of the known universe.

The Rosetta cornerstone, previously called CNSR (Comet Nucleus Sample Return) will have as its main task the return of a sample of cometary material to the Earth. Preliminary mission definition studies and preparation of the necessary technology are under way, the purpose being to define a mission concept acceptance to both ESA and NASA. Although nothing is finally settled the mission scenario foresees a launch in 2001, with the sample return some seven years later.

The Sub-Millimetre cornerstone would aim to provide Europe with a major space observatory for high throughput heterodyne spectroscopy in the 100 micron - 1 mm wavelength range; a range of wavelengths encompassing the last major window of the spectrum to be opened to scientific studies, it is considered of importance to the understanding of the processes of star formation and the determination of the rate of expansion of the Universe.

The on-going projects within Horizon 2000 include Hipparcos, the ESA elements of the Space Telescope, Ulysses and ISO (the Infrared Space Observatory). In some cases, of course, launch dates and associated events have been heavily influenced by the delay in the Shuttle programme. But with renewed confidence in the Shuttle, the manifests are being sorted out, and the project teams have definite goals to aim at.

The ESA scientific programme is broad in scope, demanding on the technologists as well as the scientists, and worthy of being counted as one of the major space exploratory programmes of the coming decades.

SKYNET 4
The Unknown Soldier

As far as the popular press were concerned, the launch of Ariane flight V27 on December 10 1988, was memorable for the launch of the Astra direct broadcast satellite. Few journalists stopped to realise that the Ariane 4 launch vehicle carried a co-passenger to Astra, Skynet 4B — a British military communications satellite. Few were even aware that Skynet 4B was the first military communications satellite to be launched by Ariane.

By Neil Pattie

The Skynet story began as far back as the 1960s, when the MOD recognised the advantages of a satellite system to provide secure strategic and tactical communications to its armed forces stationed around the world. Actual involvement with military communications satellites started with the US Initial Defence Satellite Programme (IDSCP) which later led to the UK pioneering the use of geostationary communications satellite called Skynet 1. In 1974 a more capable Skynet 2 satellite was launched.

The Skynet 3 programme was cancelled after a change in government policy removed the requirement for communications to permanent garrison areas "east of Suez". Resulting reduced space segment requirements, with emphasis on NATO areas, were satisfied by arrangements within the alliance.

In the late 1970's advancements in technology permitted the development of a new range of tactical terminals whose deployment would be constrained by the limited space segment capacity. This led the MOD, in 1981, to proceed with a new generation of military communications satellites — Skynet 4. Three Skynet 4 satellites were ordered to provide military echelons ranging from major headquarters to individual army units, ships and aircraft with communications of unprecedented security, reliability and survivability. British Aerospace was selected as prime contractor with Marconi Space Systems as sub-contractor providing the communications payload.

Skynet 4B

The three-axis stabilised design of Skynet 4 was a major departure from the spin stabilised design of the Skynet 1 and 2 series of satellites. The spacecraft platform is derived from the well proven OTS/ECS platform originally developed by BAe for ESA. In all, thirteen satellites of this class have been built for civil use.

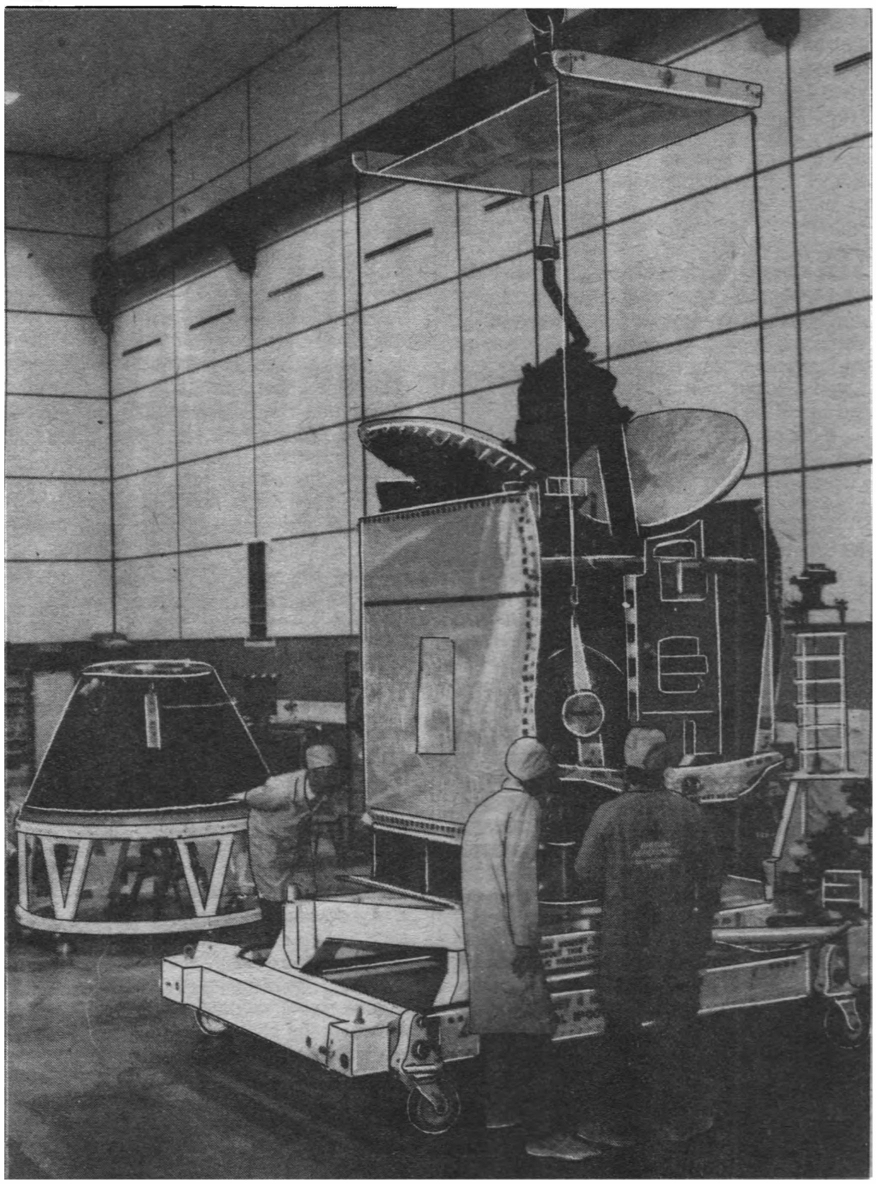
Weighing 1433 kg on launch (790 kg in GEO), Skynet 4 comprises a Service Module (SM) and Communications Module (CM). This arrangement enabled parallel manufacture of both modules at separate sites prior to integration. The SM, housing the central thrust cone and Apogee Boost Motor (ABM), also provides housekeeping and attitude and orbital control functions. The satellite's major structural elements are predominantly made of aluminium alloy honeycomb with aluminium or CFRP skins, glued together with epoxy resin.

Connected to the SM are two solar arrays supplying 1200 W at a regulated 42 V in sunlight. During eclipse periods, power is provided by two banks of rechargeable nickel cadmium batteries with an unregulated output between 30 and 37 V.

Thermal control is basically of a passive nature. The internal temperature of the satellite is carefully monitored and heaters are used to prevent the temperature of some units from falling to unacceptable levels. Secondary Surface Mirrors are mounted on the satellite's north and south faces and act as both good emitters and good reflectors of the sun's radiant heat and unwanted heat generated by the spacecraft's subsystems. Thermal blankets are also used to prevent heating by direct sunlight and to keep in wanted internally generated heat.

The CM is a 'U' shaped structure, a floor and two side walls. The top floor supports the antennas and the payload equipments and comprises:

The Skynet 4B military communications satellite being lifted from its integration trolley prior to an Ariane adaptor fit check



SHF package providing four channels at bandwidths from 60 to 135MHz using 40 Watts TWTAs. The SHF band will be used for communications to and from ground stations and surface vessels.

A UHF package of two transponders of 40 Watts, each serving one channel of 25kHz bandwidth. The UHF band will be used to communicate with submarines.

An EHF uplink channel for propagation experiments for future EHF systems.

Antennas:

SHF transmit and receive antennas, providing a variety of footprints from spot to Earth cover beams.

The UHF antenna is an Earth cover helix, deployed by telecommand once the satellite is on station.

This variety of spot and global beams enables Skynet 4B to serve an extensive inventory of Earth stations. The primary node of the Skynet network is the communications anchor station located at RAF Oakhanger in Hampshire. The Oakhanger facility is also used to control the satellites and is currently being up-dated by BAe with support from Marconi. Housed in existing premises the new Centre will be capable of controlling a number of communications satellites.

A major user of Skynet 4 will be the Royal Navy. Most of the fleet is fitted or is being fitted with enhanced SHF 'SCOT' warship terminals. Flight trials are already underway using airborne SHF terminals to demonstrate the feasibility of fitting larger RAF aircraft with terminals by the mid-1990s. These terminals have already undergone successful helicopter trials.

The Army is being equipped with mobile Land Rover terminals carrying a collapsible 1.7 metre antenna, whilst individual units have been supplied with even smaller manpack terminals capable of being carried by infantrymen in the field.

Skynet 4 has an ability to withstand different forms of electrical warfare. The spacecraft carries signal processing and anti-jamming equipment providing strong resistance to electronic counter measures attack. Built for an operational life of seven years, Skynet 4 was designed for robust system operation with good operational margins demanding the minimum of central control.

Launching Skynet 4B

Because of their military nature, Skynet 4 satellites were originally conceived to be launched by the Space Shuttle with support from British Payload Specialists. The first mission Payload Specialist, RAF Squadron Leader Nigel Wood would have been the first Britain in space but for the unfortunate accident which befell the Shuttle 'Challenger' in January 1986. As a result of the disaster, all four prospective British astronauts were grounded.

At the time of the accident, Skynet 4A was ready for launch aboard Shuttle. The subsequent delay in the Shuttle programme necessitated some redesign of the spacecraft for launch by an expendable launch vehicle (ELV). The necessary modification of the satellites, coupled with untimely failures in ELV programmes, resulted in Skynet 4B being the first of the three satellites ready for launch.

In September 1988 Skynet 4B was shipped to the Guiana Space Centre at Kourou, French Guiana. The satellite was prepared for launch in the S1A clean room where it underwent a series of integration systems tests. The solar arrays were then fitted, deployed for tests and then restowed. On October 31, the spacecraft was transferred to the S3A building where a BAe fuelling team filled and pressurised the satellite's tanks with hydrazine fuel and nitrogen. The ABM was then fitted together with the final blankets and the spacecraft was spin balanced.

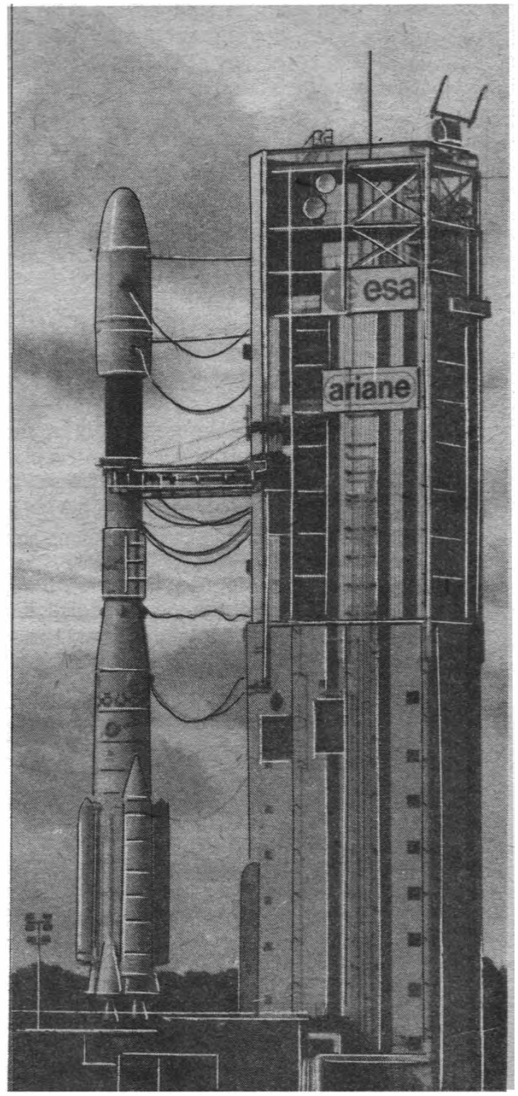
In late November, Skynet was mated with the Ariane adaptor and fitted to the top of the BAe manufactured SPELDA (Structure Porteuse Externe pour Lancement Double Ariane) — the dual payload structure which enables Ariane 4 to launch two or more satellites during the same mission. Astra 1A was already fitted inside SPELDA's cylindrical portion. After integration with the fairing, the entire structure was transported to the launch pad for mating with the launch vehicle.

On December 6 and 7, the Launch Rehearsal and Launch Readiness Review were held. The review gave clearance for launch and the countdown sequence commenced on 8th December.

On December 10 1988 (December 11 GMT) Ariane 4 successfully launched Skynet 4B into geostationary-transfer orbit. At 2029 GMT, on December 13 the satellite's ABM was successfully fired and drift orbit operations commenced. Sun acquisition was achieved at 0645 GMT, December 14th, and the solar arrays were deployed. On January 7, Skynet 4B arrived on station at 1° West.

On February 22, Lord Trefgarne, Minister of State for Defence Procurement, marked the introduction to service of the United Kingdom's Skynet 4B military communications satellite by making a call from Horse Guards Parade, London, to units in Germany. Using a man-portable transmitter, the Minister spoke via the satellite to Second Lieutenant Tony Clark of 21 Signals Regiment and Flight Lieutenant Richie Gardner of No 37 Squadron, RAF Regiment. Both officers were with units deployed in the field at RAF Wildenrath, near the West German/Dutch border.

In late 1989, Skynet 4A will be launched from Cape Canaveral by the first



Ariane V27 stands on the launch pad with the Skynet 4B enclosed within its payload shroud

commercial launch of a Titan 3 vehicle; 4C is scheduled for launch by Ariane 4 in May 1990.

In January 1987, BAe received a contract to supply NATO with two NATO IV satellites based on the Skynet 4 design. The specification and flexibility of the Skynet system combined with the keen commercial price meant that this was the first time such a contract has been awarded to a non-US supplier.

The unsung success of Skynet 4B also reflects the little known yet important role of Britain as both a major user and supplier of communications satellites. It should be a matter of national pride that there are currently nine British built communications satellites in orbit operated by a number of national and international organisations. Two more will be launched this year with a further seven scheduled for launch in the following two years.

CORRESPONDENCE

Hermes and HOTOL

Sir, This letter is written in response to two letters published in the April 1989 issue of ***Spaceflight***. The first letter by Peter Hall refers to logistics support of the Freedom Space Station (FSS). whilst the second by M.Q. Hassan discusses using the An-225 as a launch platform for HOTOL and similar vehicles.

Space Station Resupply

Presently, the FSS is designed to be assembled and supported logistically using, at least initially, only the Space Shuttle at a maximum rate of 5 flights per year. Indeed, it is this low flight rate which limits the extent to which the FSS can be utilised and expanded. For this reason it is very clear, as Mr. Hall points out, that an additional manned servicing vehicle could be required. Unfortunately, however, the design of Hermes at the moment, as I understand it, precludes its use for regular servicing activities for the following reasons:

1. Flight Rate; The Hermes fleet is capable of flying a maximum of three or four times per year and it is planned that most or all of these flights will be devoted to servicing the Columbus Free-Flyer. At most, only one or two flights per year would be available for FSS servicing.
2. Payload; Hermes is being configured to carry a maximum up payload of three tonnes. However, the FSS requires between 90-100 tonnes/year purely for logistics, servicing and payload resupply. Thus at two flights/year, Hermes could only provide less than 10% of FSS requirements.
3. Crew Size; Hermes has a maximum crew size of three, two of whom are pilots needed to fly the vehicle during re-entry and landing. Thus, Hermes would only be able to rotate 1 mission specialist per flight. It is planned to rotate the 6 to 8 member FSS crew over 3 months.

Mr. Hall is correct in saying that it would be worthwhile spreading our limited resources. However, for the reasons outlined above, this may not be, in my opinion, the most economical area for NASA to invest its funds in Europe.

Piggy-Back into Orbit

During my involvement with the HOTOL project at British Aerospace (Space Systems) Ltd in Stevenage, I performed a study looking at a broad cross-section of 'Launch Assist Systems' (LAS) or trolley options for HOTOL. These options range from a fully integral undercarriage to air-launching, as described by Mr. Hassan, and indeed I referred directly to the An-225 since, as Mr. Hassan pointed out, it does have a payload capability near that of HOTOL's all up mass 275 tonnes.

HOTOL, I would like to emphasize, is being configured *solely* to minimise the operational or recurring cost of the system and, hence, the cost per kg to orbit. Now, because the LAS is an integral part of the system architecture, it follows that the ultimate choice for the way in which HOTOL is launched must also be the most cost effective. (It is critical to note that 'cost effective' also means, *by implication*, a highly reliable and safe operational system).

At this time, we believe that a ground based LAS is the best option *simply* because it would result in the lowest cost to orbit, as well as the lowest overall life-cycle cost, compared with any alternatives including air-launching. Therefore, we have optimised the vehicle to take-off from the ground.

Air-launching is an interesting possibility. However, at the present time it does not seem to be the most economical route which, ultimately, must be the prime requirement for future launch systems like HOTOL.

RUSSELL J. HANNIGAN
HOTOL System Engineer
BAe (Space Systems) Ltd

The logistics of Mir

Sir, After nearly three years, the Russians have now achieved a permanent bridgehead in space with a crew of two to three men on board the Mir-Kvant space station weighing 32 tons. To maintain this, at least 6 Progress cargoes of 2.3 tons are required per annum, conveying some 14 tons of consumables, experimental equipment and materials and rocket fuel.

In 1989-90 it is clear that the plan is

a) to increase Mir's mass by about 70-80 tons with four purpose built modules, and
b) to increase the resident crew to about 6.

The latter will be essential if the entire mission is not to be one long exercise in housekeeping and packing! It can be shown that, to maintain six men and 120 tons of hardware in Low Earth Orbit, some 50-60 tons of logistical supplies per annum will be required. This would need a Progress flight every three weeks or some 15-16 per year.

Using the new Energia/Buran system with its 30 tons to Low Earth Orbit capacity, only two flights per year would be needed. On each of these, six crew and two shuttle pilots and 30 tons of materials could be conveyed to Mir - a six months supply - at one go. Also 20 tons of finished products could be brought back.

This would be consistent with a flight rate of two per annum of the V.K.K. by 1990, once the test flight programme is complete, and would thus allow for extensive experience with the new system before Mir 2 is launched in 1994-95.

MICHAEL MARTIN-SMITH
Hull, UK

Artificial Gravity

Sir, I am surprised that there seems to be no future developments or experiments to test and use artificial gravity vehicles with the Mir or International Space Stations. When one thinks of the benefits of artificial gravity to the way astronauts work in space, why has there not been even a small plan to use artificial gravity vehicles with these space stations?

Why, when there have been countless designs of artificial gravity vehicles for over thirty years now, has no one taken the initiative to start a space station which uses artificial gravity? If man is to take a foothold in space he is going to have to overcome the problem of weightlessness.

ROBERT METCALFE
Hants, UK

An Occulting Artificial Satellite

Sir, Astronomers have been waiting patiently for many years for suitable occultation events of various solar system bodies. Yet if the object could be occulted in space by a suitably arranged system of black panels, I am sure that fast photometry at a ground based observatory could deduce equivalent information about the object. Some observatories have used this technique with the dark limb of a waning Moon as the occulting edge. I envisage a satellite in near polar orbit at about 2000 miles height consisting of black panels and a radio commanded laser for precision tracking. It would be in an orbit designed to be transitting the zenith each night over a major group of observatories. Though it would have to have panels up to 100 feet in extent to occult bodies up to an arc second, multiple panels providing a sequence of occultations could make this a very comprehensive technique that could be a very useful facility to the astronomical community.

P.W. SHIMMON
W.Sussex, UK

Cosmos 1686 and Kvant

Sir, I have some theories regarding the picture of Cosmos 1686 in 'Correspondence' ***Spaceflight***, February 1989 (p.56). If the satellite's forward end is not the reentry capsule attached to the earlier Cosmos 1443, why must it be a telescope package, as Neville Kidger writes. The vehicle looks like the new module to be docked to Mir later this year, as illustrated on p.68 of the same edition. This module is said to have a large airlock to ease EVAs and was originally planned to fly before the joint Soviet/French mission for this purpose. Cosmonauts Kizim and Solovyov also carried out an EVA from Salyut 7 to erect a boom structure which was delivered by Cosmos 1686. Perhaps the module carried not only the boom but also an airlock.

At first sight Kvant seems to be an extra development and one not tested in advance. But it is more likely that Kvant conforms to the Soviet policy of reaching maximum reliability by using the same proven base units from many different spacecraft. In my opinion the tug module of Kvant has indeed flown at least once as a test vehicle. Could it have been Cosmos 1669, the small module that docked to Salyut 7 and was not from the Progress series of supply craft? Kvant itself is the backward section of a Salyut or Mir station, of which the propulsion unit surrounding the axial cross tunnel is replaced by the telescope unit. The gyros could have easily been tested as a system on another vehicle.

HEINZ MULLER
Bulach, Switzerland

Advertisements In Orbit

Sir, With reference to Mr. J.S.P. Wordie's letter (***Spaceflight***, December 1988, p.469) concerning the placing into orbit of a reflective ring and the opposition to it. I am concerned that such a ring may be used for other purposes.

With the cost of a satellite launch now within the yearly advertising budgets of many popular product manufacturers, how long will it be before the night sky is ablaze with company logos, giant silver hamburgers and soft drinks bottles.

P.S. NUTTON
Hants, UK

Tile Damage

Sir, In the STS-27 Mission Report (***Spaceflight***, February 1989, p.40) it was noted that the tile damage on the Orbiter Atlantis could have been caused by the impact of torn away insulation from the External Tank during launch.

One of the suspected reasons for this was said to be the age of the tank and the fact the tank was involved in cryogenic propellant testing at Vandenberg Air Force Base in conjunction with the Orbiter Enterprise.

While it is true that the tank was used in fit checks its is not true that the tank was used in cryogenic testing. The NASA official who suggested this scenario was wrong. Information from the manufacturers of the tank, Martin Marrietta, indicates conclusively there were no cryogenic tests on this or any other tank at Vandenberg. There has been no official comment on this from NASA.

LEE ROBERT CALDWELL
Toronto, Canada

Ed.- *We would like to thank Mr Joel Powell , who also raised this point..NASA has since revealed the Atlantis tile damage was caused by insulation breaking loose from the Solid Rocket Boosters.*

Discovery's Success

Discovery blasted off on her eighth mission on March 13 after a delay of almost a month. The third Tracking and Data Relay Satellite (TDRS-D) was successfully deployed, completing NASA's space communications network. The failure of the space station heat pipe experiment marred this otherwise successful mission. *Spaceflight* provides extensive coverage of the first shuttle flight of the year.

Reports By
Roelof Schuilling
and
David Portree
at the Kennedy Space Center

Launch Preparations

Preparations for STS-29 began immediately after Discovery was returned to the Kennedy Space Center (KSC) from Edwards Air Force Base on October 8, 1988. Discovery had to be launched by March 18, 1989 in order to roll Atlantis out to pad 39B in preparation for her important mission to launch the Magellan Venus probe. The second shuttle launch pad is at present undergoing modifications and refurbishment and is not expected to be available until the Autumn.

The day after Discovery's return to KSC, the vehicle was towed to Bay 1 of the Orbiter Processing Facility (OPF) for post-flight deconfiguration and inspections.

As planned, the three main engines were removed in October and taken to the main engine shop in the Vehicle Assembly Building (VAB) for the replacement of several components. During post-flight inspections, technicians discovered a small leak in the cooling system of the main combustion chamber of the No.1 main engine. The engine was returned to the manufacturers, Rocketdyne, for repairs and a new engine (2031) was delivered from NASA's Stennis Space Center in Mississippi.

Discovery's three main engines were installed before the end of last year (engine 2031 in the No.1 position, engine 2022 in the No.2 position and engine 2028 in the No.3 position).

The right hand Orbital Maneuvering System (OMS) pod was removed in late October and transferred to the Hypergolic Maintenance Facility where a small internal leak was repaired. The forward Reaction Control System assembly was also removed for cleaning and flushing. The orbiter's flash evaporator that malfunctioned during STS-26, causing uncomfortably high temperatures onboard Discovery, was replaced. Post-flight inspections had revealed the system was clogged with foreign material.

The Solid Rocket Booster (SRB) segments began arriving at KSC in September, and the first segment - the left aft booster - was stacked on Mobile Launcher Platform 2 on October 21. Booster stacking operations were completed in early December and the External Tank was mated to the boosters on January 16.

The TDRS-D arrived at the Vertical Processing Facility (VPF) on November 30. Work to prepare the IUS booster suffered a serious setback when a technician slipped and fell against the Inertial Upper Stage (IUS) first stage nozzle damaging it beyond repair and rendering the entire first stage useless. A replacement first stage was transported to the Cape and installed in time to meet the launch schedule. The TDRS and IUS were joined together on December 29 and the connections between the two tested during the first week of January.

Launch preparations were running smoothly, and it appeared the schedule could easily be met. But the flight of STS-27 revealed a potentially dangerous situation. Postflight inspection and analysis of the No.3 main engine high pressure oxidizer turbopump revealed cracks in the inner race of one of four bearings in the pump. The cracks were believed to be due to stress corrosion caused by moisture entering the pumps during manufacture.

A decision was made to replace the oxidizer turbopumps with ones manufactured under a different process that eliminated the moisture problem. Shuttle managers decided to continue with preparations for STS-29 as the new turbopumps could be installed once Discovery was on the launch pad.

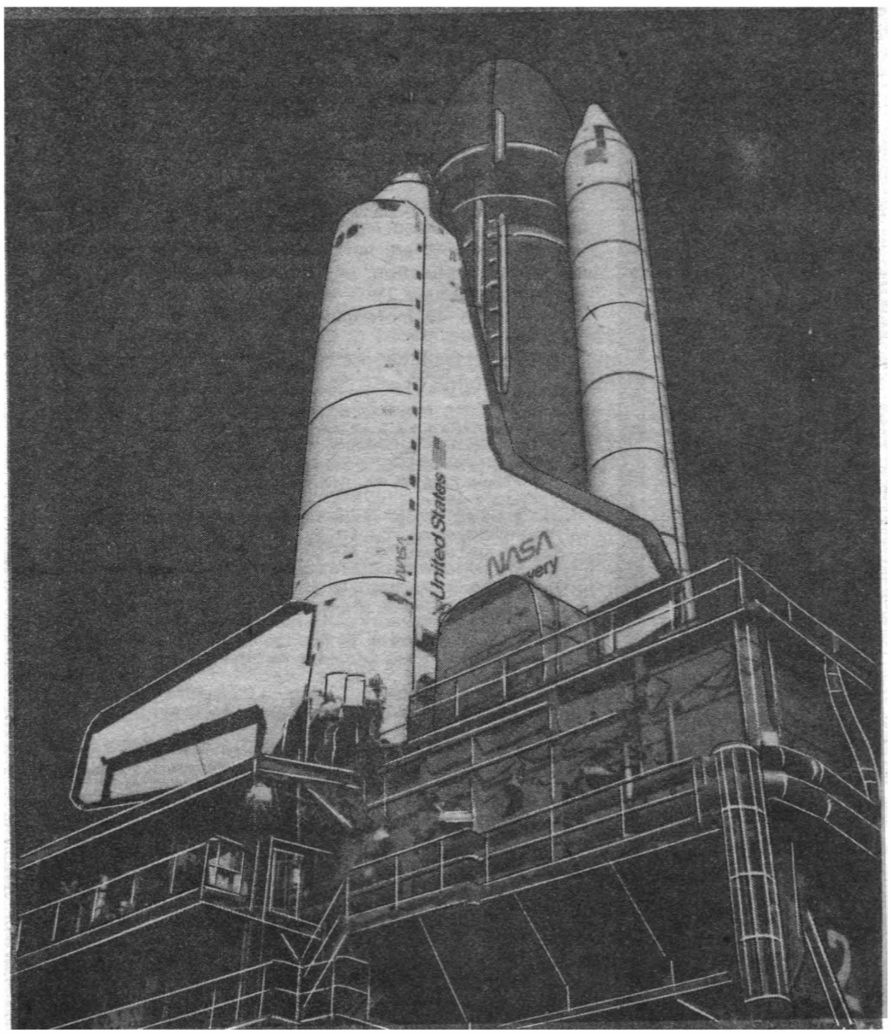
In addition to the concerns about the oxidizer turbopumps, considerable damage to Atlantis' heat protection tiles during STS-27 prompted an investigation to determine the cause. It was discovered insulation from the top of the right hand SRB had broken away and struck the orbiter during the launch. Efforts were made to prevent the same incident occurring on STS-29.

Discovery was towed the 400 yards from the OPF to the VAB on January 23 for mating to the External Tank and SRBs. The orbiter was hoisted into a vertical position by the 250 ton VAB crane and attached to the External Tank on January 25.

On February 3, the assembled shuttle vehicle was rolled out of the VAB atop its mobile launch platform for the 4.2 mile trip to launch pad 39B. TDRS-D and its IUS upper stage had been moved to the changeout room at the pad on January 17. The satellite was fuelled with hydrazine before being installed in Discovery's payload bay on February 6.

The Countdown Demonstration Test began at the T-24 hour point on February 6 and was completed at T-5 seconds with a simulated main engine shutdown. During the final stages of the

Discovery after departing the Vehicle Assembly Building during roll out to Pad 39B at the Kennedy Space Center on February 3. *NASA*

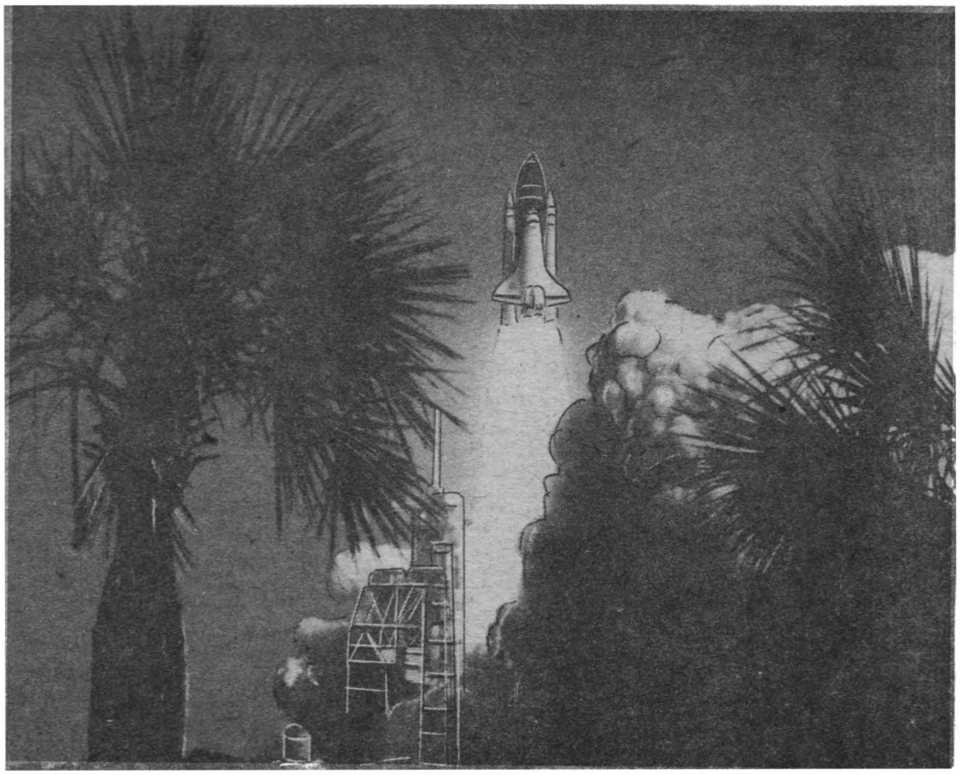


test the STS-29 crew boarded Discovery as a rehearsal for launch day.

While the mock countdown went ahead work began to remove the questionable oxidizer turbopumps from Discovery. Replacement units began arriving at KSC on February 15 from the Stennis Space Center, where they had undergone rigorous testing. The pumps were delivered and installed earlier than expected and the work was completed on February 22.

Shuttle managers met on March 2 and 3 for the Flight Readiness Review and set Discovery's launch for March 10. However on March 5, Discovery's Master Events Controller failed. The controller is responsible for the operating the pyrotechnic devices that separate the SRBs and External Tank. Columbia's controller was removed and installed in Discovery's aft compartment. To avoid the risk of accidental detonation, the pyrotechnic charges were removed prior to the installation and testing of the new controller. By the time the charges had been reconnected and the new Master Events Controller tested, the launch date slipped two days to 13:07 GMT on March 13.

The countdown began shortly after midnight on Friday March 10. The STS-29 crew had arrived at KSC earlier that afternoon. The countdown proceeded as planned until the first built-in hold. High winds caused the final closeout operations on the shuttle to be delayed. To compensate, the first built-in hold was extended and the second compressed. By the evening of the next day the count was back on schedule, there were no further delays until the morning of the launch.



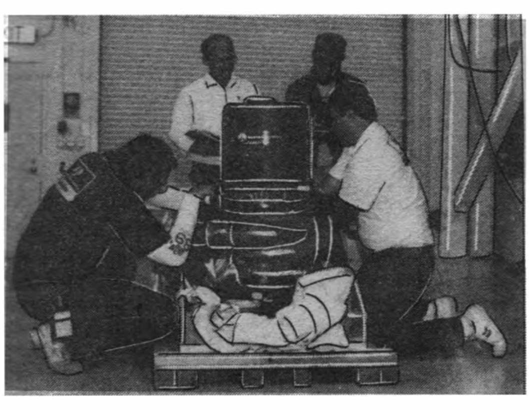
Discovery is framed by palm trees as she blasts off at 14:57 GMT on March 13. *NASA*

Ascent

On the morning of March 13, the rising Sun conspired with the moisture-laden Florida air producing dense ground fog that obscured the launch pad and prevented the range safety crew from monitoring Discovery's ascent. The upper third of the 200 metre tall VAB was lost in cloud. In addition upper wind conditions required additional analysis to ensure that structural loads during launch would not be excessive. A decision was made to continue with the countdown until the T-9 minutes mark - a built-in hold is scheduled at this point, usually lasting ten minutes. The launch team decided that this would be the optimum point to wait for the fog to clear and the analysis of the upper wind conditions to be completed. At 13:00 GMT US Air Force sources gave Discovery only a 40% chance of launching that day.

The countdown commentary was provided by NASA Public Affairs Officer Lisa Malone - the first woman to do so in the history of the US manned space programme. At 14:48 GMT, Lisa was able to inform the press and public the countdown had resumed. The fog had dissipated, the upper wind analysis had been completed and the rising cross-winds which might have hampered a Return to Launch Site abort were judged to be within constraints.

Technicians inspect the first of the replacement oxidizer turbopumps to arrive at KSC. *NASA*



The last nine minutes proceeded under the control of the Ground Launch Sequencer. At T-31 seconds the ground computers gave a 'go' for 'Auto Sequence Start' - the countdown was now under the control of the orbiter's onboard computers. At T-6.6 seconds the main engines were fired, by T-0 they had reached full power and the SRBs were ignited. The launch pad's eight holddown posts released their grip on the vehicle and the 28th shuttle mission began. The sound of the launch reached the press grandstand 15 seconds later and shook it, drowning out the cheers which had begun at the moment of SRB ignition.

As the shuttle cleared the launch tower, control of the mission shifted to Houston. Nine seconds after blast-off, the main engines and SRBs steered the orbiter into a 120 degree roll, putting the shuttle into a 'heads down attitude' and on the correct trajectory for a 28.5 degree inclination orbit.

As Discovery climbed towards orbit, long-range tracking cameras were trained on the vehicle to check the SRB insulation remained intact.

The throttle down of the main engines to 65% was achieved at T+28 seconds, returning to 104% 39 seconds later. At T+2 minutes 6 seconds, the two SRBs cleanly separated from the External Tank, leaving the three main engines to lift the shuttle into orbit.

The main engine finished their work at T+8 minutes 32 seconds. Twelve seconds later the External Tank separated from Discovery. Shortly after separation, Discovery's crew photographed the departing tank through the flight deck upper windows to record the extent of thermal damage to the tank's skin (see overleaf for photograph).

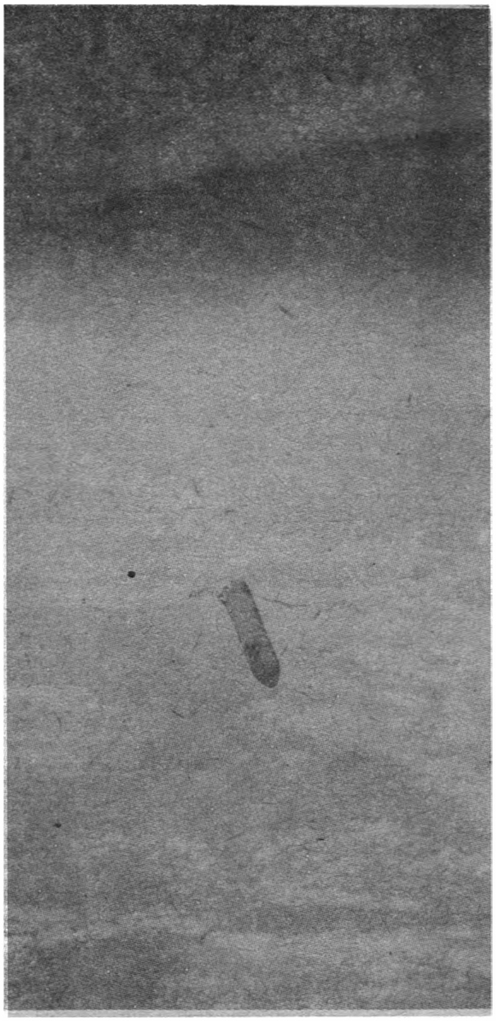
A firing of the OMS engines at T+40 minutes circularised Discovery's initial orbit of 156 x 35 nautical miles (nm) to 160 x 160 nm.

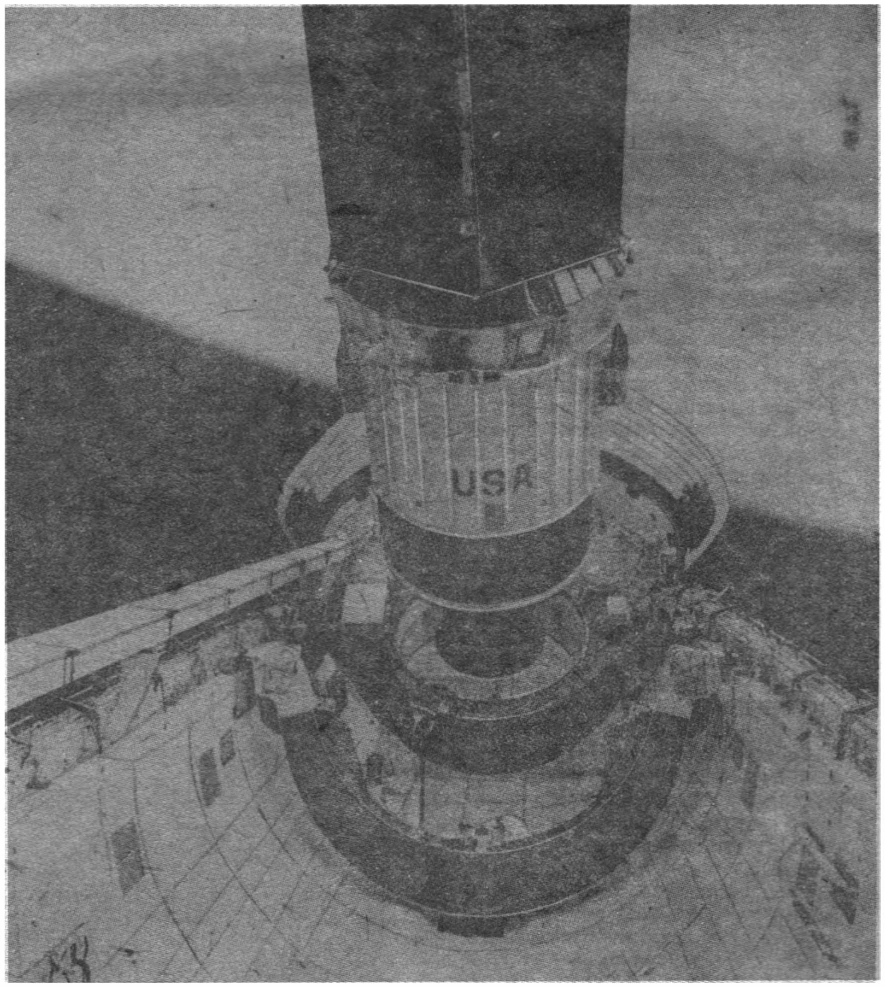
Day One: March 13, 1989

As Discovery's crew awaited a 'go' for on-orbit operations Discovery completed its first orbit and passed over the Kennedy Space Center. Commander Coats chose this "fitting time" to pay tribute to "all the main engine people that did such a good job getting our engines in shape." Coats was referring to the quick replacement of the main engine turbopumps in time to beat the March 18 deadline for launch.

The first problem was detected early in the flight. During a post-ascent checkout of Discovery's onboard systems there was an unusual pressure fluctuation in cryogenic hydrogen tank No.3 which threatened to shorten the mission by a day. The cryogenic hydrogen and oxygen tanks feed the orbiter's fuel cells, which provide power for the shuttle. The suspect tank was shutdown and the crew was asked to power down some non-essential systems, including the cabin lights.

The 18 metre long payload bay doors were opened 1 hour and 20 minutes into the flight exposing Discovery's precious cargo. Extensive checkouts of the TDRS-D satellite were made. At approximately T+4 hours and 30 minutes the satellite was tilted to 29 degrees on its Airborne Support Equipment (ASE). Checks on the satellite continued and almost six hours into the mission the crew were given the 'go' for deployment. The astronauts fired charges to sever umbilical connections between the shuttle and the TDRS/IUS, then tilted the ASE structure to its deployment angle of 52 degrees.




USA


(174)

At T+6 hours and 13 minutes pyrotechnic charges separated TDRS-D and its IUS booster from the ASE. This action released compressed springs which provided the force to jettison the TDRS/IUS at approximately 0.1 metres per second.

Commander Coats fired Discovery's Reaction Control System (RCS) thrusters moving the shuttle away from the departing satellite. An OMS firing, 15 minutes after deployment, further separated the two spacecraft. After manoeuvring to observe the TDRS/IUS combination, Coats turned the orbiter so its belly faced the satellite, thus protecting the shuttle's windows from the exhaust of the IUS booster.

Exactly an hour after deployment the IUS first stage ignited, firing for 146 seconds. Approximately six hours 12 minutes after deployment the IUS second stage fired for 108 seconds.

With the main objective of the mission successfully completed, the STS-29 crew conducted further IMAX photography and activated the Protein Crystal Growth Experiment. After a busy day in orbit the crew went to bed about ten hours after blast-off.

Day Two: March 14, 1989

The crew of Discovery were woken by Mission Control at 03:37 Houston time by a tape recording of musician James Brown singing "I feel good". Brown is currently in jail in South Carolina and Michael Coats accused Mission Control of getting Brown out on parole so he could wake the shuttle crew.

A full day of activity ensued. The SHARE heat pipe experiment was powered up, however, the experiment had to be shutdown. Readings indicated unexpected fluid behaviour - it was believed that heaters were evaporating ammonia faster than it could recirculate.

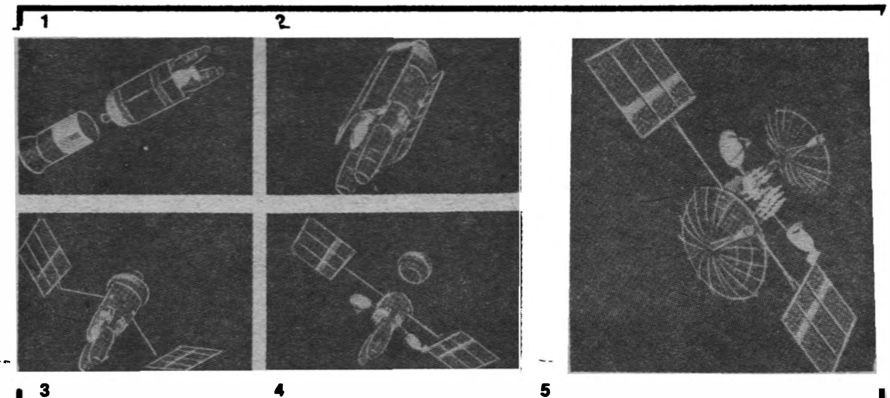
Extensive IMAX photography was undertaken. However during operation the belt on the camera's drive mechanism came off track causing the loss of about 200 feet of film. The Discovery crew replaced the belt and normal camera operations continued.

Checks of the Chromex experiment revealed a slight over-heating problem. Mission Control began an analysis of the problem.

Day Three: March 15, 1989

The crew of Discovery was woken early on day three by Mission Control playing a brass band's rendition of the US Marine Corps Hymn. Mission Specialists Springer, Buchli and the CAPCOM - who selected the music - Ken Cameron were all members of the Marine Corp. Commander Coats, a Navy man, joked with Mission Control that he had "Two Marines

(Top left) Astronaut James Bagian took this photograph of the External Tank (ET) about eight minutes after it had separated from Discovery. Note the burn scar on the left of the ET, above the SRB forward attach point, caused by the SRB separation motors.
(Top right) The TDRS-D satellite slips from its berth in the payload bay. Note the SHARE radiator located along the edge of the left hand side of the payload bay.
(Bottom) Commander Coats is photographed updating the STS-29 flight plan. A drink dispenser floats in front of him.
NASA



1. The first stage of the IUS separates from the TDRS.
2. Afterthe first stage separation, the satellite's outboard solar panels unlatch.
3. A flat array is created and inboard solar panels are unlatched enabling the array booms to extend.
4. When the solar panels are fully extended, the space/ground link and C-band antenna are sequentially deployed and the second stage of the IUS separates from TDRS.
5. The large umbrella-like single access antennas open and the TDRS is fully deployed.

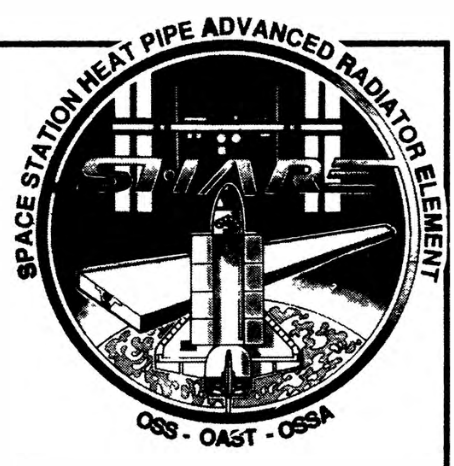
TDRS-D *Completes NASA's Tracking Network*

TDRS-D is the third TDRS satellite to be placed in orbit. TDRS-1, launched on STS-6 in April 1983, is located in the TDRS-East position at 41 degrees West, East of Brazil over the Atlantic Ocean. TDRS-3 was launched by Discovery during STS-26 last September. The Satellite is located in the TDRS-West position at 171 degrees West, just south of Hawaii.

TDRS-D, renamed TDRS-4 after reaching orbit, will replace the aging TDRS-1 at 41 degrees West. TDRS-1 will be moved to 79 degrees West where it will serve as an on-orbit spare incase one of the operational satellites malfunctions.

(For further details of the TDRS system see ***Spaceflight*, November 1988, p.443.**)

SHARE *Experiment Fails*



The SHARE (Space Station Heat Pipe Advanced Radiator Element) experiment was to test a new method for a potential cooling system of space station Freedom. Despite repeated attempts by the crew, the experiment refused to operate. Air bubbles trapped in the radiatorwere thought to be responsible. The experiment was mounted on the starboard sill of the Orbiter's payload bay with a small instrumentation package mounted in the forward payload bay.

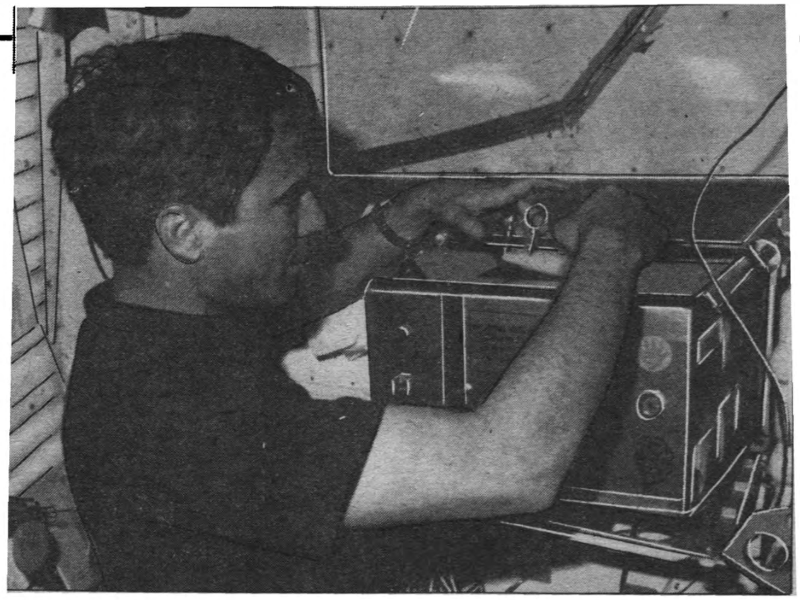
The heat pipe method uses no moving parts and works through the convection current of ammonia. Three electric heaters will warm one end of the 51-foot long SHARE. The heaters turn liquid ammonia into vapour which transports the heat through the length of the pipe, where a foot-wide aluminum fin radiates it into space. The fin is cooled by the space environment, and the ammonia is, in turn, condensed and recirculated.

Two small pipes run through the centre of the radiator down its length, branching out like the tines of a fork at the end that receives heat, called the evaporator. The top pipe holds the vaporised ammonia; the bottom holds liquid ammonia. In the evaporator portion, a fine wire mesh wick, which works along the same principle as the wick of an oil lamp, pulls the liquid ammonia from one pipe to the other, where it vaporises. Small grooves allow the condensed ammonia to drop back to the bottom pipe.

The radiator for SHARE weighs about 135 pounds, but with its support pedestals, support beam, heaters and instrumentation package, the total experiment weighs about 650 pounds.

Each of the experiment's two 500-watt heaters and single 1,000-watt heater is controlled individually and can be switched on in turn, applying heat that increases steadily in 500-watt increments up to a maximum of 2,000 watts.

The experiment was to have been activated for two complete orbits in two different attitudes, the first with the payload bay toward Earth and the second with the orbiter's tail toward the Sun. The heaters can go through a complete 500 watt to 2,000 watt cycle. This simulates the heat that needs to be dissipated from the space station and the two attitudes will provide data on the heat pipe's operation in different thermal environments.


John Blaha, checks the chicken embryo experiment incubator on the middeck of Discovery. *NASA*

Student Experiments

Chicken Embryo Development in Space

This experiment, proposed by John Vellinger, was one of two experiments flown under the Shuttle Student Involvement Programme (SSIP). The experiment was designed to determine the effects of space flight on the development of fertilised chicken embryos. Discovery carried 32 chicken eggs - 16 fertilised two days prior to launch and the other 16 fertilised nine days prior to launch. An identical group of 32 eggs remained on Earth as a control group.

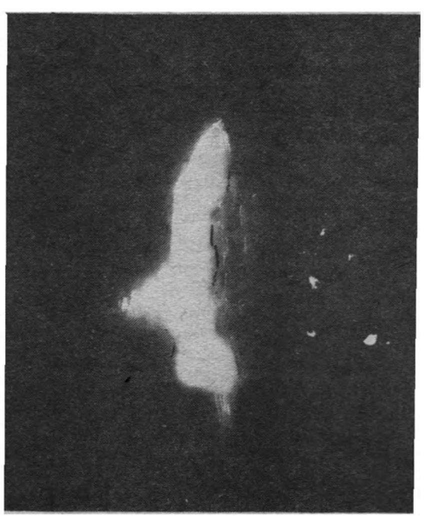
On return to Earth, half of both group of eggs were opened and examined to identify any differences in cartilage, bone and digit structures, muscle system, nervous system, facial structure and internal organs. The second half (16 space flight and 16 control) were hatched 21 days after fertilisation. All the embryos fertilised two days before being carried into orbit were found to be dead, experimenters are now trying to determine the cause.

The experiment first flew on STS 51-L and was lost when Challenger was destroyed. John Vellinger had been waiting more than nine years for his project to fly in space.

The Effects of Weightlessness on the Healing Bone

The second SSIP experiment, proposed by Andrew Fras, was to establish whether weightlessness inhibits bone healing.

Observations from previous space flights have shown that minerals, calcium in particular, are lost from the body, resulting in a condition similar to osteoporosis. Calcium is the main mineral needed in bone formation. Four Long Evans rats had a minute piece of bone removed from a non-weight bearing bone prior to launch. A similar group of rats remained on Earth as a control group. After Discovery's return to Earth, effects of weightlessness on the origin, development and differentiation of the osteoblasts (bone cells) and their production of Callus were studied.



AMOS

The AMOS (Air Force Maui Optical Site Calibration Test) experiment allowed ground-based electro-optical sensors located on Mt. Haleakala, Maui, Hawaii, to collect imagery and signature data of the orbiter as it passed overhead.

The observations made of Discovery, while performing Reaction Control System thruster firings, water dumps or payload bay light activation, will be used to support the calibration of the AMOS sensors and the validation of spacecraft contamination models.

(Left) Discovery on its final day in orbit is pictured by a US Air Force tracking system. *NASA*

standing at attention" and he didn't know what to do with them.

Flight controllers studying the hydrogen tank problem discovered similar readings had been received from Discovery during STS-26, and traced the problem to erratic heater operations. Two heaters are used to adjust the pressure of in each tank and force the liquid hydrogen into a pipe that carries it to the fuel cells. The crew were told to activate heater B in tank No.3, and the system operated normally.

Discovery's crew again attempted to operate the SHARE experiment. But the operation was terminated 28 minutes into the run when the experiment seemed to be drying out. Indications of what appeared to be bubble formation in the ammonia were being seen. Operations of the heat pipe in a one-gravity environment had not shown that behaviour.

The Chromex experiment appeared to be operating normally. The crew had applied temperature-indicating decals to the outside of the experiment in order to monitor its temperature which had been causing concern earlier in the flight..

Extensive IMAX photography of the Earth was conducted with particular emphasis on environmentally threatened areas. Mission Specialist Dr. James Bagian took a series of blood pressure and heart rate readings of crewmen.

Flight controllers determined that the landing at Edwards Air Force Base would occur one revolution earlier than originally planned due to lighting conditions. This would also give Discovery an additional back-up landing opportunity.

Day Four: March 16, 1989

A few minutes before the astronauts were to be awakened on day four, Discovery's crew turned the tables on Mission Control and sent Houston a wake-up message. It consisted of the theme music from the popular television and film series Star Trek and was followed by a taped message by actor William Shatner, who plays Star Trek's Captain Kirk. He told Mission Control the crew were prepared to "Boldly go where no astronaut has gone before".

Later that morning, President George Bush made his first presidential phone call to a spacecraft, congratulating the crew and all of NASA for the success of the mission. The President told the crew. "The space programme, especially space station Freedom, is an investment in our future. We're living in tough budgetary times, but I am determined to go forward with a strong, active space programme."

The SHARE heat pipe experiment continued to malfunction. The crew fired Discovery's thrusters in an attempt to shake loose a suspected air bubble that was thought to be blocking the pipe.

The IMAX camera photography continued, and the crew provided television coverage of the chicken eggs while discussing the experiment with developer John Vellinger.

Television coverage also caught a spectacular water dump from Discovery's fuel cells. Excess water was pumped overboard for ten minutes as the shuttle passed over the Pacific Ocean. The television camera caught the discharge as it trailed away from the orbiter. At the same time, the AMOS sensors in Hawaii monitored the discharge.

During a test of the Text and Graphics System (TAGS) that will be used to uplink photographs and graphics on future missions, a copy of the Johnson Space Center's inhouse news-

paper, "Space News Roundup", was sent to Discovery. CAPCOM Pierre Thuot said the transmission marked the first newspaper delivery to a US spacecraft.

Day Five: March 17, 1989

Preparations for reentry and landing dominated the activity on day five. Checking out of the Shuttle's flight control surfaces and RCS were underway in the morning. Equipment stowage and the shutdown of experiments were carried out later. In addition, the crew took part in a news conference with television reporters.

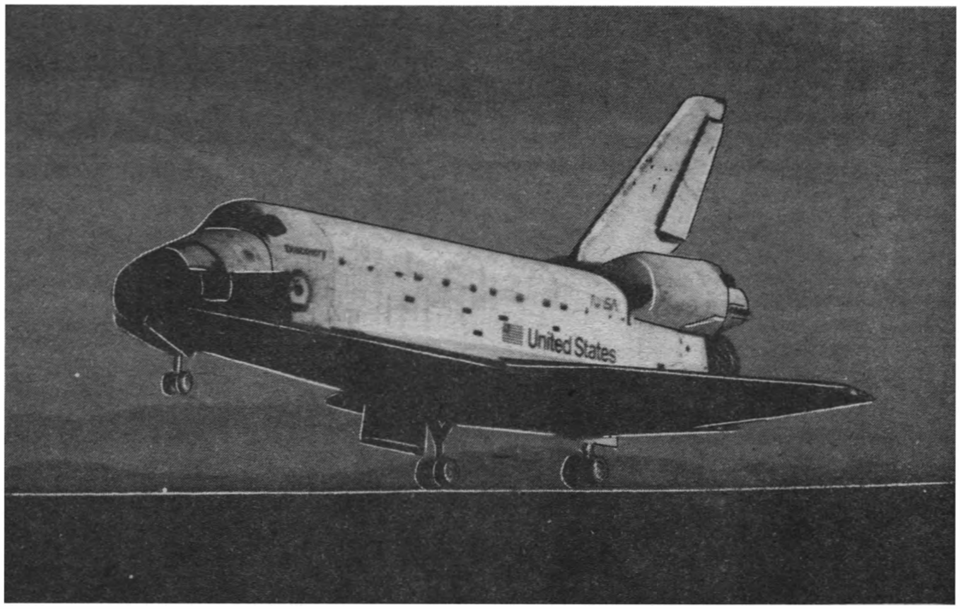
Despite continued efforts to free the suspected bubbles in the SHARE radiator, including rotating Discovery by firing thrusters, the experiment continued to malfunction.

Day Six: March 18, 1989

On the final day of the mission, crew member's children woke them with calls of 'wake up' and 'get up'. The crew made their final preparations for landing and closed the payload bay doors. At 07:35 Houston time Discovery's OMS engines fired for two minutes 37 seconds to begin the descent.

Winds proved too calm for a planned crosswind landing test. Instead, NASA officials opted for an alternative test - a braking exercise on the concrete Runway 22 at Edwards.

At 08:35:49 Houston time, Discovery's main landing gear touched down at Edwards Air Force Base. The nose gear contacted the runway 11 seconds later and wheel stop occurred at 08:36:40. Over 450,000 people had come out to watch the landing. The crowd was second only to that at the July 4, 1982 landing of Columbia.



Discovery's main gear touches down on the concrete Runway 22 at Edwards Air Force Base, California after after a successful five day flight. *NASA*

After leaving the orbiter, Commander Coats told the crowd. "We have just concluded a five-day flight with essentially zero problems, and that's really a credit to the people who work so hard to build and get these shuttles ready to fly."

NASA had no time to celebrate the first shuttle flight of 1989. With six more missions planned before the end of the year, work began the moment Discovery blasted off to prepare the pad for Atlantis and its payload - the Magellan probe. Within days both were in position on pad 39B, poised for an April 28 launch.

STS-29 AT A GLANCE

ORBITER: Discovery (OV-103)
LAUNCHED: 14:57 GMT, March 13, 1989
LAUNCH SITE: Pad 39B, Kennedy Space Center, USA
LANDED: 14:36 GMT, March 18, 1989
LANDING SITE: Runway 22, Edwards Air Force Base, USA
LIFT-OFF WEIGHT: 4,525,139 pounds
LANDING WEIGHT: 194,616 pounds
APOGEE: 160 nautical miles
PERIGEE: 160 nautical miles
INCLINATION: 28.45 degrees
DURATION: 4 days 23 hours 39 minutes 40 seconds
ORBITS: 79.5

COMMANDER: Michael L. Coats
PILOT: John E. Blaha
MISSION SPECIALIST 1: James F. Buchli
MISSION SPECIALIST 2: Robert C. Springer
MISSION SPECIALIST 3: James P. Bagian

PRIMARY PAYLOAD: TDRS-D/IUS-9
SECONDARY PAYLOADS:
- Space Station Heat Pipe Advanced Radiator (SHARE)
- Orbiter Experiments, Autonomous Supporting instrumentation System (OASIS)
- Protein Crystal Growth (PCG)
- Chromosome and Plant Cell Division in Space (CHROMEX)
- IMAX camera
- Air Force Maui Optical Site Calibration Test (AMOS)
- Chicken Embryo Development in Space (SSIP 83-9)
- Effects of Weightlessness in Healing of Bones (SSIP 82-08)

THE CREW

COMMANDER
Michael L. Coats (Captain USN)

Born on January 16, 1946, in Sacramento, California, Coats considers Riverside, California, his hometown. He became an astronaut in 1978.

Coats was a member of the STS-4 support crew, and was Capsule Communicator (CAPCOM) for STS-4 and STS-5. He was the pilot of the 14th shuttle mission (STS 41-D) launched August 30, 1984, Discovery's maiden flight. In February 1985 he was assigned spacecraft commander of STS 61-H. Following the Challenger accident he continued training with his crew in preparation for the resumption of shuttle flights.

During launch and landing, Coats occupied the left forward seat on the flight deck.

PILOT
John E. Blaha (Colonel, USAF)

Born on August 26, 1942, in San Antonio, Texas, Blaha, made his first space flight on STS-29. He joined NASA as an astronaut in 1980.

From September 1981 to March 1983 Blaha was a member of the Space Shuttle ascent/entry development and verification teams. During this period he managed and led the design, development and integration of the Orbiter Head-up Display System. From April 1983 to October 1984 he was an ascent, orbit, planning and entry CAPCOM in Mission Control for 7 shuttle flights. He was assigned as lead CAPCOM for Missions STS 41-D and STS 41-G. In January 1985 he began to train as pilot with the STS 61-H crew at the time scheduled to fly in December 1985. Due to payload rescheduling, the 61-H crew was reassigned to launch in June 1986. Following the Challenger accident, Blaha was assigned to as the Astronaut Office representative of the Space Shuttle ascent/abort reassessment team and the Orbital Maneuvering System/Reaction Control System reassessment group. In September 1987, Blaha was assigned to the Orbiter Project Office where he was the astronaut representative at Orbiter Management Reviews and Orbiter Configuration Boards.

Blaha occupied the right forward seat on the flight deck.

MISSION SPECIALIST 1
James F. Buchli (Colonel, USAF)

Born on June 26, 1945, in New Rockford, North Dakota, he considers Frago, North Dakota, his hometown. He is a member of the astronaut intake of 1978.

Buchli was a mission specialist on STS 51-C launched on January 24, 1985. The first military shuttle mission included the deployment of a modified Inertial Upper Stage from Discovery.

He next flew October 30, 1985, as a mission specialist on STS 61-A, the West German Spacelab D1 mission.

Buchli was a member of the support crew for STS-1 and STS-2, and on-orbit CAPCOM for STS-2.

Buchli occupied the seat immediately behind and between the Commander and Pilot on the flight deck, he assisted in monitoring the orbiter's systems.

Continued...

MISSION SPECIALIST 2
Robert C. Springer (Colonel, USMC)

Born on May 21, 1942, in St. Louis, Missouri, Springer considers Ashland, Ohio, his hometown. He became an astronaut in 1980 and was making his first space flight.

Springer's NASA assignments have included support crew for STS-3, concept studies for the Space Operations Center, and coordinating the various aspects of final development of the Remote Manipulator System for operational use. In 1984 and 1985 he worked in the Mission Control Center as a CAPCOM for seven flights. Springer was responsible for Astronaut Office coordination of design requirements reviews and design certification reviews, part of the total recertification and reverification of the Space Shuttle, prior to STS-26's return to flight.

During launch Springer occupied the right aft seat of the orbiter flight deck. For the landing he exchanged seats with Bagian and rode in the orbiter middeck.

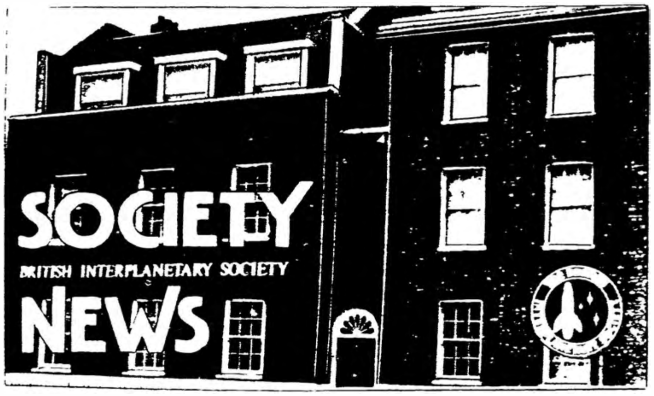
MISSION SPECIALIST 3
James P. Bagian (M.D.)

Born on February 22, 1952, in Philadelphia, Pennsylvania, Bagian was making his first space flight. He became an astronaut in 1980.

Bagian participated in the planning and provision of emergency medical and rescue support for the first six shuttle flights and has participated in the verification of Space Shuttle flight software. In 1986, Bagian became an investigator for the 51-L accident board and has been responsible for the development of the pressure suit and other crew survival equipment. Bagian has also been a member of the NASA Headquarters Research Animal Holding Facility Review Board.

During ascent Bagian sat in the middeck and for landing occupied the right aft position in the flight deck.

The crew of STS-29 along side their spacecraft after a successful landing at Edwards AirForce Base (Left to right) John Blaha, James Bagian, Michael Coats, James Buchli and Robert Springer *NASA*



£2,800 For Desk-Top Publishing

The Council gratefully acknowledges the sum of £2,800 received by the Society under the Will of the late Mrs Ethel Nicklin, whose former husband was a long-standing Fellow of the Society noted for his generosity in supporting our work.

The Council has decided that the present gift should be used for the purchase of equipment needed to enable the Society to change over to desk-top publishing, which will advance its publishing activities to the greater benefit of all members.

The new desk-top publishing system will enable typesetting to be undertaken more speedily than at present and result in worthwhile production economies. It will also introduce greater flexibility in the make-up of magazines, especially the handling of late items. The change-over applies to both ***Spaceflight*** and ***JBIS***.

A major advantage, which will be particularly beneficial to ***JBIS***, lies in the fact that material for publication can be transmitted electronically or by disk, provided that the latter is compatible with our own equipment. Our "Notes for Authors" are being revised to take account of these new arrangements and will contain full information on these plans. With an increasing number of authors setting material on their own word processors, advantages of the new system can only increase with time.

At the time of writing the new equipment has been delivered to the Society and, after a short period for staff training, should soon be operational.

Professor A M Low

Professor A M Low: Colour Photograph Needed

We are interested to learn that the Space Center at Alamogordo, New Mexico is in the process of constructing an exhibit gallery chronicling the history of rocketry. The Society is already associated with the Center's International Space Hall of Fame through the induction there of one of its early Presidents, Archibald M Low. We have now heard from George M House, Curator of the Center, that he would also like to obtain a colour photograph or slide of Professor Low.

The Society does not hold such a photograph so, if anyone has, or knows the source of such a colour picture, the Executive Secretary would be pleased to receive details.

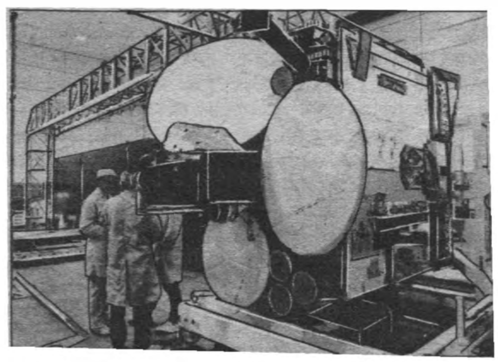
News... Society News... Society

Skynet 4B Celebratory Reception

The Society was representated by its Executive Secretary at a Celebratory Reception held at the Science Museum in London on Wednesday February 22, 1989 to mark the successful launch and commissioning of Skynet 4B Military Communications satellite. The 350 Guests assembled were welcomed by Sir Peter Anson, Chairman of Marconi Space Systems, who recalled not only the origins of the programme but the dark days of 1974-79 when the Chiefs of Staff took the view that no more British military satellites should be procured.

Mr. John Holt, Managing Director of British Aerospace Space Systems, also welcomed the Guests and introduced Mr. Tim Sainsbury, Parliamentary Under Secretary for Defence Procurement, who congratulated all from Industry, Government and the Armed Forces, who had combined in producing such a remarkable satellite, and also made the inaugural call over the Skynet link to Germany.

The Skynet 4B military communications satellite with deployed solar array in the assembly hall at British Aerospace, Stevenage. BAe



International Space Year 1992

The year 1992 will be specially significant throughout the space communityand particularly so for the Society as it will be the year leading to our 60th Anniversary in October 1993.

The Society is already planning a programme for 1992 with emphasis on its work over the period 1933-1992 and a detailed look towards the future. The theme will be "Space - Springboards to Success" and will highlight those steps which have brought about remarkable advances in our understanding and utilisation of space and those which auger well for future progress.

These plans should dovetail well with many international arrangements intended to give expression to similar aims and sentiments. The International Space Year (ISY) is designed to celebrate 35 years of space accomplishments, emphasising public education in space and pinpointing future advantages. A longer-term aim will be to encourage international space cooperation in projects extending into the next century. These aims have been endorsed by the UN Committee for the Peaceful Uses of Outer Space, ESA, BNSC, the IAF and the IAA. NASA has been designated as coordinator for US activities. 1992 also marks the 500th Anniversary of the epic voyage of Columbus in 1492 and comparisons with the exploration of space have not been overlooked. In fact, it was on account of the Columbus Anniversary that the year 1992 came to be chosen for the ISY. Significantly, Washington has been chosen as the venue of both the 43rd IAF Congress and the 29th COSPAR Conference, this time held as a joint gathering from 27th August to 7th September 1992. In Britain, the BNSC will be convening a meeting of international participants on the use of Earth observation data from space for modelling the 'greenhouse' effect and other related issues of global environmental concern. On March 1st, 1989 the European ISY Association was created on the initiative of Eurospace to bring together the European space industry, European organisations, national organisations and other bodies and individuals who will be involved in the ISY.

Two Rare Lunar Books

The Society has been very fortunate in obtaining a copy of the two volumes entitled *Selenotopographische Fragmente zur genauern Kenntniss der Mondflache, ihrer erlittenen Veranderungen und Atmosphare, sammt den dazu gehorigen specialcharten und Zeichengen*, (Moon Fragments) by Johann Hieronymus Schroeter, published in 1791 and1802 respectively. Schroeter's works are very rare as most of the copies of his books were destroyed when the French Army burnt his Observatory in 1813. The loss of all his books and observations affected him so deeply that, unable to restore what had been destroyed, he died within three years.

Schroeter's claim to fame arises from the fact that, over the period from 1785-1813, he undertook a systematic and intensive survey of the Moon's surface which laid the foundations of modern selenography. He was looking for signs of change and, in doing so, made many discoveries about lunar features, including first detection of its rills. He also introduced a new method of measuring the heights of lunar mountains. Before his work the only lunar map of real value was that by Tobias Mayer, just 7 1/2" across, published in 1775.

The text in our two volumes is complete but all the original plates had previously been extracted. The gaps have now been filled by inserting photographic facsimiles of the originals.

Bequests To The Society

Valuable support comes to the Society from time to time by way of bequests which enable it to advance its programme of development and to fulfil its role as a Learned Body promoting the advance of space technology and astronautics.

The attention of members is drawn to this avenue of support for the Society's work and to the "Notes on the preparation of Wills and Codicils" which are available from the Society on request.

Joint International Conferences

The following conferences are being cosponsored by the Society:

The 8th Annual International

SPACE DEVELOPMENT CONFERENCE

May 26-29, 1989

Themes will be Apollo: 20 years later, An Overview of Space, Space Technology, Business and Space, Meet Space Leaders, etc, etc. To be held at the Hyatt Regency O'Hare Hotel, Chicago, USA.

INTERNATIONAL CONFERENCE ON SPACE POWER

June 5-7, 1989

Organised under the auspices of the IAF Space Power Committee and hosted by the Lewis Research Center in Cleveland, Ohio, USA.

TOWARDS THE INTERNATIONAL SPACE STATION AND COLUMBUS

October 4-6, 1989

Hosted by the DGLR Hamburg, W. Germany.

40TH IAF CONGRESS

October 7-13, 1989

The 40th Congress of the International Astronautical Federation will be held at Beijing, China. The theme will be 'The Next Forty Years in Space'.

Members of the Society wishing to present papers may obtain procedural details for the submission of abstracts from: The International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

Further details of the above meetings can be obtained from the Executive Secretary. Please enclose a SAE.

Visit

13 May 1989 10.30am-12 noon

UKAEA CULHAM LABORATORY

A tour of the United Kingdom Atomic Energy Authority's Culham Laboratory which is concerned with nuclear fusion and plasma physics research, and is the home of the Joint European Torus (JET) Project.

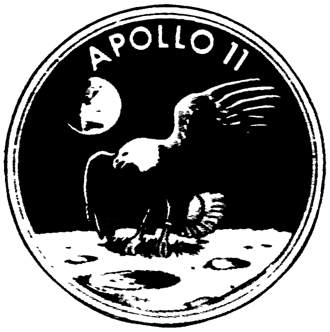
The programme starts with a half hour introduction to the JET Project, followed by a tour of the JET Joint Undertaking.

Admission is by registration only. Members should apply without delay, as late applicants will not be accepted. Please enclose a SAE.

LIBRARY OPENING

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.

Special Event



To commemorate the 20th Anniversary of the historic Apollo 11 lunar landing the British Interplanetary Society has organised a series of lectures to celebrate Man's first steps on the Moon, concluding with a dinner at the Society's Headquarters.

Details of the meetings follow:

21 June 7.30—8.30pm

'I WAS THERE'

Reg Turnill and Frank Miles recall the atmosphere and events of twenty years ago. Reg Turnill was reporting from the US during Apollo 11, while Frank Miles was a member of ITN's 'Space Unit' covering the mission from London.

28 June 7.30-8.30pm

LEGACY OF APOLLO

A lecture by Douglas Arnold illustrated by striking photograph of Man's first steps on the moon.

5 July 7.30-8.15pm

GOING TO THE MOON

Dr. R.C. Parkinson considers the BIS contribution to manned lunar concepts. Beginning with its design for a Moonship in 1939, the BIS continued thinking about ways of reaching the Moon throughout the 1950s. This talk illustrates some of the concepts, which culminated in the US Apollo programme.

19 July 7.00-8.30pm

INSTRUMENTATION ON THE MOON

A lecture by Keith Wright. Each of the Apollo Lunar landing missions carried an "Apollo Lunar Surface Experiment Package" (ALSEP) which would be set up by the astronauts in order to transmit data about the lunar environment after the astronauts return to Earth. The talk will provide an overview of the Package design, the experiments carried and deployed, the experimental results obtained, and will include some personal recollections of the Apollo pre-launch activities at Kennedy Space Center.

21 July 8.00pm

APOLLO 11 ANNIVERSARY DINNER

The Society will conclude its Apollo 11 celebrations with a four course meal on the anniversary of Man's first steps on the Moon. (Guests of honour will announced later).

Admission to lectures is free . Apollo 11 Anniversary Dinner tickets are £28. All events will be held in the Society's Conference Room, 27/29 South Lambeth Road, London, SW8 1SZ. Meetings are restricted to Society members. Subject to space being available members may also apply for a ticket for one guest. Please apply to the Executive Secretary, enclosing a SAE.

Symposia

3 June 1989 10am-4.30pm

SOVIET ASTRONAUTICS

The programme wil include the following topics: New Developments in Soviet Cosmonautics, Cosmonaut Teams, Earlier Soviet Programmes in Historic perspective.

Venue: The Conference Room, British Interplanetarty Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Exectutive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

13 September 1989 10am-4.30pm

SPACE STATIONS AND BEYOND

The Second BIS Space Infrastructure Symposium

Following the success of the first infrastructure symposium in November 1988, the British Interplanetary Society is organising a second with the theme of "Space Stations and Beyond".

This series of symposia is the only current forum for discussion of major infrastructure topics such as:

Launch Systems	Aerospace Planes
Space Stations	Inter Orbit Transportation
Lunar Bases	Manned Planetary Exploration

The theme has been choosen because of the studies underway both in America and Europe to plan the next major programmes to be undertaken after the Freedom/Columbus space station is established. Options under study include lunar bases, manned Mars missions and an autonomous European space station.

Venue: The Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Exectutive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

27 September 1989 10.00am-4.30pm

BRITISH SOLID PROPELLANT ROCKETRY

The emphasis will be on British post-war solid propellants and the development of associated rocket motor and launch vehicles.

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary. Please enclose a SAE.

General Lectures

3 May 1989 7.00-8.30pm

UK INVOLVEMENT IN SATELLITE NAVIGATION

The UK has a long tradition of innovation and excellence in navigation based on our background as a trading nation. The UK has been particularly active in the application of the new techniques of satellite navigation. The presentation will describe the evolution of satellite navigation, highlighting the important scientific and commercial contributions of the UK to systems such as Transit and Navstar.Finally, what does the future hold in this most exciting of fields?

Venue: 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 stamped addressed envelope.