June 1989 US$3.25 £1.25

Spaceflight

The International Magazine of Space and Astronautics

88905 КОСМИЧЕСКИЕ ПОЛЕТЫ № Т-6
(спейсфлайт)
По подписке 1989 г.

Editor:
G. V. Groves

Assistant Editor:
S. Young

Managing Editor:
L. J. Carter

Spaceflight Sales:
Shirley A. Jones

Advertising:
Suszann Parry

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

Tel: 01-735 3160.
Fax: 01-820 1504.

DISTRIBUTION DETAILS

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

* * *

Spaceflight is distributed in the UK and overseas through newsagents by AGB Impress, Cloister Court, 22-26 Farringdon Lane, London, EC1R 3AU. Tel: 01-253 3135.

* * *

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

* * *

Back issues of ***Spaceflight*** are supplied at £2.00 (US$4.00) each, inclusive of surface mail delivery.

* * *

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

* * *

Spaceflight

The International Magazine of Space and Astronautics

Vol.31 No.6 **June 1989**

Front Cover: Buran orbits high above the Earth in a painting by BIS member *Peter Eickmeyer.* Soviet officials have revealed Buran will fly again next year (see p.186).

Atlantis Gets Magellan Underway

The first interplanetary probe to be deployed by the Space Shuttle has begun its long journey to Venus. Atlantis blasted off on her second attempt and completed a flight which NASA officials described as '100%'. The Magellan probe was successfully deployed just over six hours into the flight. Onboard Atlantis for her four day mission were: Commander David Walker, Pilot Ronald Grabe and Mission Specialists Norman Thagard, Mary Cleave and Norman Thagard.

The First Launch Attempt

At the Flight Readiness Review, held on April 13/14, the launch of STS-30 was set for April 28 at 19:24 BST.

Ever cautious NASA officials included more than 38 hours of built-in holds in the STS-30 countdown to allow time to solve any last minute problems. The careful planning almost proved unnecessary, as what followed was described as the smoothest countdown in Shuttle history - until the final hour.

As the Sun rose on the morning of April 28, there was no threat from the weather, as there had been to the previous three missions. An Air Force Meteorological Officer said it was "perfect weather to go flying". The crew left their quarters about three hours before the planned blast-off and entered the orbiter 25 minutes later.

The countdown continued smoothly reaching the T-9 minute point without incident. During the 40 minute built-in hold planned for this point, the Mission Management Team, led by ex-astronaut Robert Crippen, polled the launch team seeking their approval for blast-off. But the Range Safety Officer refused to give his consent because of a malfunctioning range safety computer.

The fault had not been repaired at the point the countdown was scheduled to resume. The delay was now eating up the launch window. STS-30 had one of the shortest launch windows in the Shuttle's history - just 23 minutes. The window was dictated by the lighting conditions at the Trans-Atlantic Landing (TAL) site in Ben Guerir, Morocco. Launch rules allow a landing 15 minutes after sunset. Previously the rules prohibited a landing ten minutes after sunset, but this was extended shortly before STS-30. NASA Public Affairs Officer Hugh Harris, who was providing the countdown commentary, began to countdown the minutes left in the launch window. Launch Director, Robert Sieck, proposed the countdown should continue until the T-5 minute point, where it would hold until the problem was resolved or the launch window expired. But before this plan could be carried out a cheer went up in the Launch Control Center. The Range Safety Officer had given his 'go' for launch - the computer had been repaired. Bob Sieck radioed Commander Dave Walker in Atlantis' cockpit with the good news.

The countdown had been delayed five minutes and was to resume at 19:20 BST. Work began to synchronise the various countdown clocks on the ground and onboard the Shuttle to the new launch time of 19:29 BST. The countdown restarted and continued in the smooth fashion that had become accustomed for this mission.

The orbiter access arm was retracted, pilot Ron Grabe started the orbiter's Auxiliary Power Units (APUs), the orbiter switched to its internal power and the External Tank was pressurised. The countdown had entered its final minute, when Hugh Harris announced the clock would hold at T-31 seconds. A fault had been detected in a main engine recirculation pump and the countdown was ordered to stop. Lift-off could not take place that day - only 18 minutes remained in the launch window and the countdown would have to be recycled to the T-20 minute point.

Bob Sieck ordered the vehicle to be 'safed'. The orbiter access arm was moved back into position and the crew began to shutdown onboard systems, including the APUs and fuel cells. The crew left the orbiter, while engineers checked out the problem with the recirculation pump.

Pump Stops Launch

Prior to ignition the pump injects liquid hydrogen into the engine to cool its components before the bulk of the supercold fuel enters the engine. It was hoped the failure was with the pump's electrical supply from the launch pad so repairs could be made to allow a launch the next day. But engineers discovered the problem was a mechanical failure within the pump. A delay of three days seemed likely - then a second problem emerged. Replays of video from the launch pad cameras showed a vapour cloud in the region of the umbilicals that connect the orbiter to the external tank. Engineers immediately suspected a liquid hydrogen leak. Closer examination confirmed this. There was a small hole in the casing around a hydrogen pipe. The launch was at first postponed for at least three days. But after assessing the situation NASA delayed the launch a further three days.

The faulty pump and leaking pipe were replaced ahead of schedule and NASA officials reset the launch date for May 4 at 18:48 BST. However weather conditions were expected to be poor on the new launch date. Atlantis was only given a 60% chance of blasting off that day.

Launch Day

Sure enough the weather on launch day was the main problem. Showers drifted across the space centre and at the Shuttle Landing Facility (SLF) runway, located a short distance from the launch pad, strong crosswinds threatened to call-off the launch. Never-the-less NASA continued with the countdown as planned. The crew entered the orbiter and were strapped in their seats.

Prior to entering Atlantis the three STS-30 Mission Specialists stand on the 195 foot level orbiter access arm at pad 39B. (Left to Right) Mark Lee, Mary Cleave and Norman Thagard. The Mission Specialists were responsible for the deployment of Magellan. NASA

The countdown reached the T-9 minute point where it entered a planned built in hold. As expectedv meteorologists refused to give the 'go' for launch because of cloud near the SLF and the strong crosswinds. If Atlantis had to make a Return to Launch Site abort (RTLS) Commander Walker would have had to land the orbiter on the runway. NASA likes to have the best possible conditions at the SLF because any adverse weather would complicate what is already a very difficult manoeuvre.

Atlantis' launch window had extended to 64 minutes. But this was now being 'eaten up' by the delay. As the window grew shorter, Chief Astronaut Daniel Brandenstein flew the shuttle training aircraft through the clouds above the SLF. He reported back to Launch Control that the clouds were scattered and this part of the weather problem was dismissed. However the crosswinds continued to be unacceptable.

With the launch window drawing to a close, Launch Director Bob Sieck decided to continue with the countdown until the T-5 minute point where it would hold until the weather cleared. It was during this hold and with just ten minutes left in the window that winds dropped to a safe level. The countdown immediately resumed and Atlantis blasted off at 19:47 BST making a flawless ascent. The SRBs were successfully separated and later recovered at sea. (The initial examination of the boosters showed no problems with the joints.) The main engines completed their work and there followed what Commander Walker described as a rather bumpy External Tank separation. Two OMS burns placed Atlantis into a circular orbit of 160 nautical miles.

Continued p.186...

Arianespace Signs its Largest Contract

Arianespace has signed a deal with International Telecommunications Satellite Organisation to launch three Intelsat VII satellites. The deal, worth approximately $317 million, is the largest contact ever awarded to Arianespace.

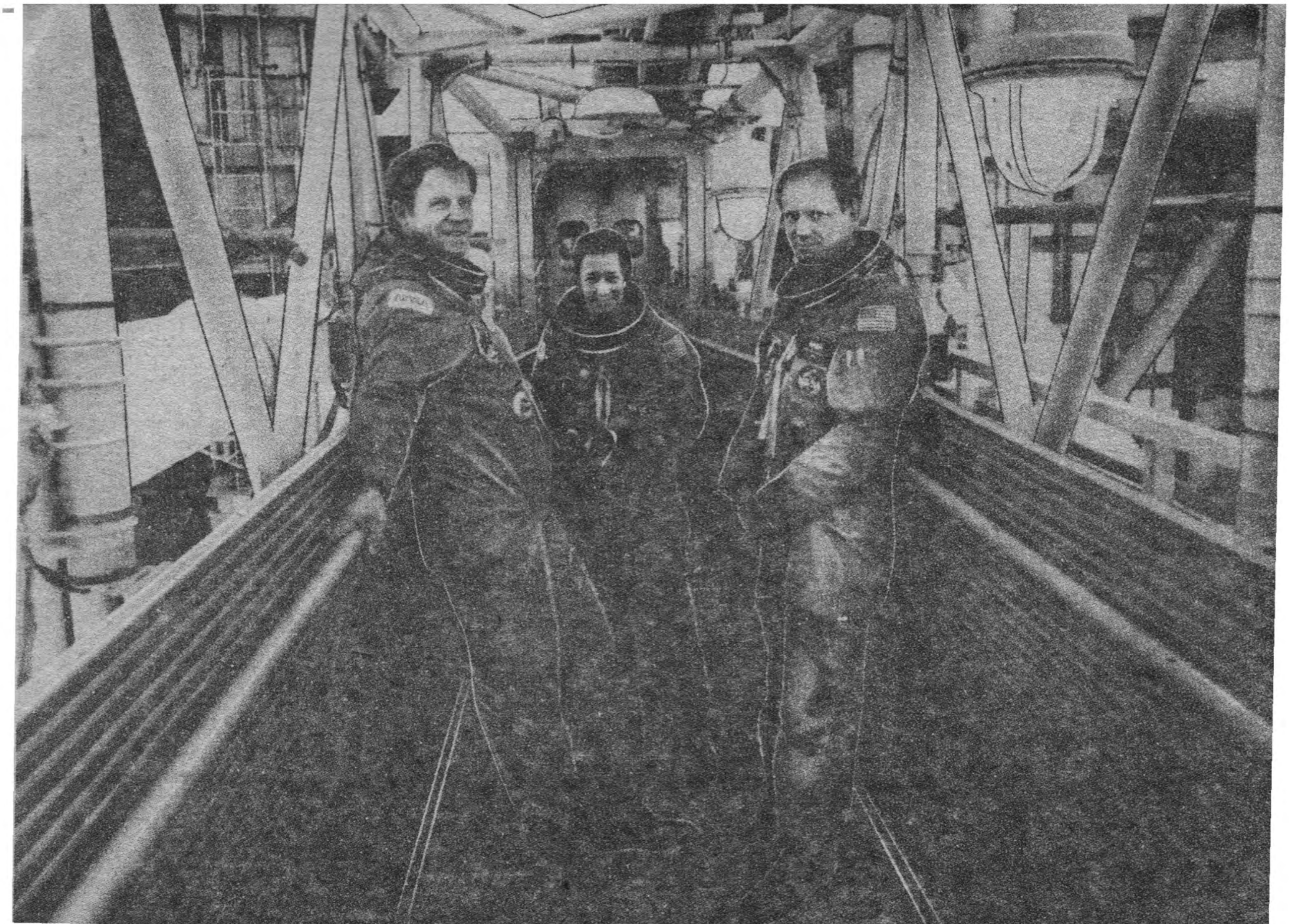
The Intelsat VII satellites are being developed and built by Ford Aerospace Corporation. The satellites are to be launched by Ariane 4: Intelsat VII-F1 in the third quarter of 1992; Intelsat VII-F4 in the fourth quarter of 1993; and Intelsat VII-F5 in the second quarter of 1994.

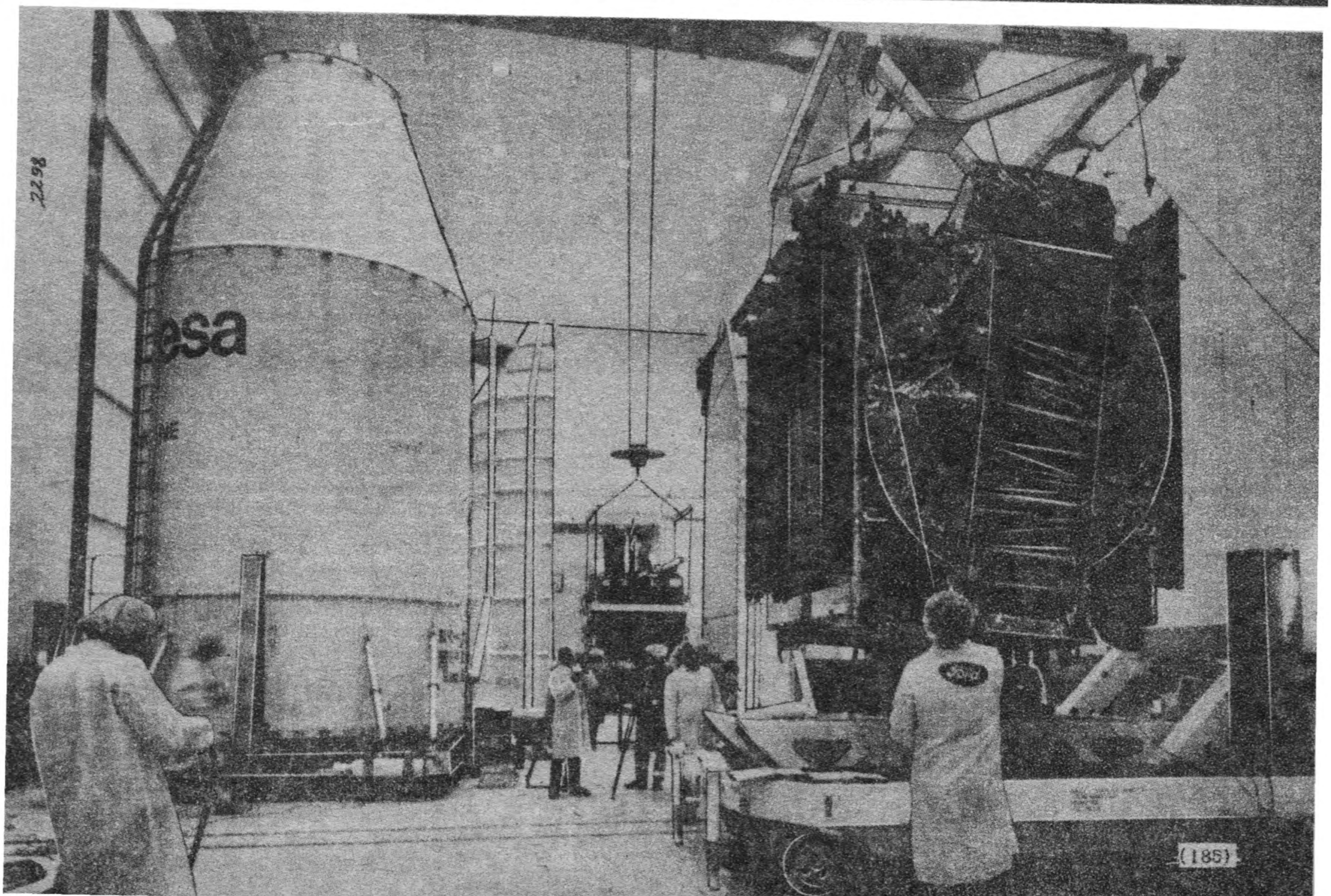
Ariane V34 is scheduled to launch the Intelsat VI-F1 satellite later this year. Ariane launch vehicles have successfully launched four Intelsat satellites in the past six years.

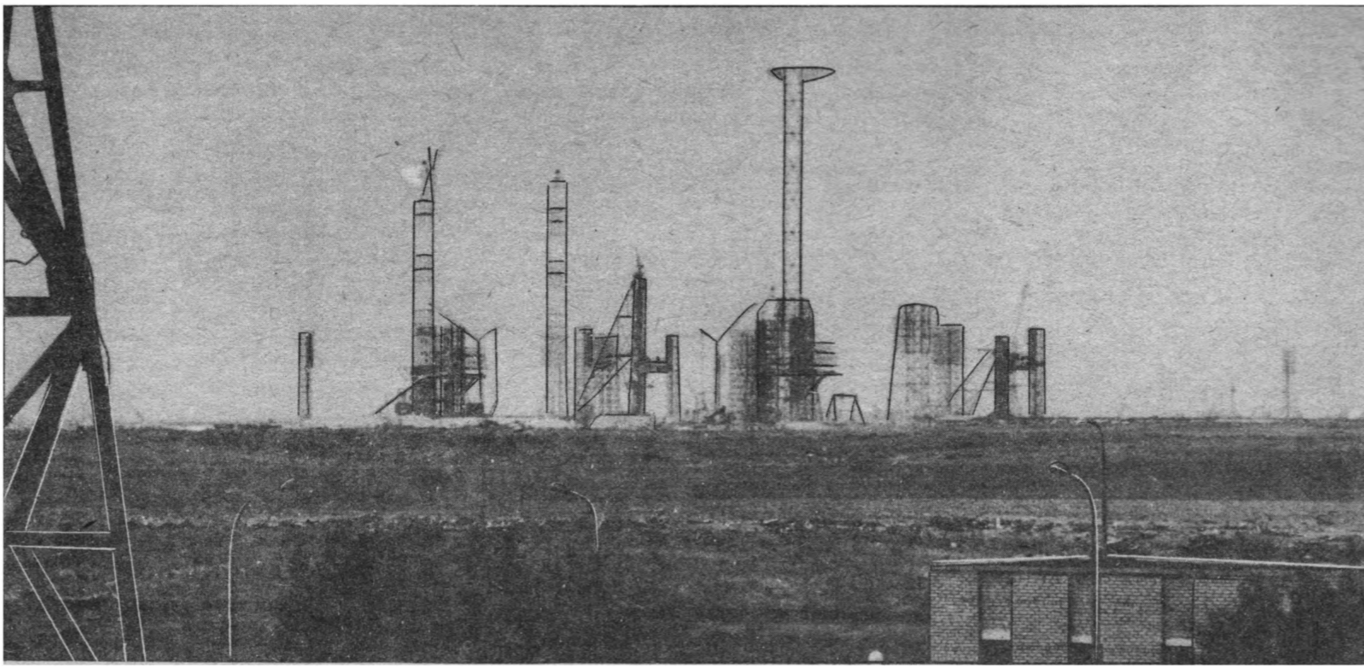
With this latest contract, Arianespace has now recorded a total of 71 launch service contracts. The company has 35 satellites to be launched, worth $2.35 billion.

- The first Ariane 4 to be equipped with four strap-on liquid propellant boosters was due for launch on April 28, with the Superbird A and DFS Kopernikus-1 satellites aboard. However, the flight was postponed until May 25 due to problems with the cryogenic third stage

(Right) The Superbird satellite during preparations for launch. The DFS satellite is in the background.




esa



A photograph of the Buran/Energia launch pads at the Baikonur Cosmodrome taken during May 1988. It is believed the left-most launch pad is where the first flight of Buran began. The access and emergency escape chutes can be seen leading into an underground bunker. The 100 metre rotating service tower is in the retracted position, located right of the Buran launch pad. A second shuttle pad can be seen in the centre of the picture. On the right hand side is the Energia-only launch pad from where the booster's maiden flight took place. The photograph will accompany an article by Peter Pesavento, which will appear in the Soviet Astronautics edition of **JBIS**. *Robert Windrem*

Buran - Manned Flight Puzzle

Docking With Mir Planned

The Soviet officials are making conflicting statements about when the Space Shuttle Buran will make its first manned flight. Two Soviet space officials say the manned mission will take place next year. But shuttle pilot Igor Volk does not expect a manned mission until 1992.

Vadim Kravitz, who supervised Buran's first flight, said in January a manned flight of the orbiter would take place "no earlier than in 18 months time". Kravitz said Buran was equipped with a docking unit for Mir and "docking will be part of the first manned missions." Nikolay Kardashev, deputy director of the Space Research Institute, has also said Buran will fly manned next year. He was speaking at a press conference in San Francisco, where he was attending the annual conference of the American Association for the Advancement of Science.

But Buran test pilot Igor Volk has said there are problems with Buran that will have to be resolved before it can fly again. He says the short comings lie in the automatic control system. Buran made some unexpected violent turns before its landing last November, says Volk.

Meanwhile Glavkosmos chief, Aleksandr Dunayev, has said the Soviet Union is not plannig a shuttle flight this year. Analysis of the first Buran flight is still underway he added.

The Soviets have revealed the mysterious payload carried by Energia on its maiden flight in 1987 was a mockup of the Buran fuselage minus wings and tailplane. The mockup failed to reach orbit when its third stage fired in the wrong direction. The designers of Energia have said the booster is to become reusable: "Strap-on rockets on the booster's body will be used to help at reentry and permit a soft landing. A parachute system is also provided and cushion supports will be used for landing. The second stage will be fitted with a delta wing to enable it to land as an aircraft."

Continued from p. 184.

Magellan Deployed

Six hours 18 minutes into the flight over the Pacific Ocean Mission Specialist Mark Lee operated a switch from Atlantis' flight deck triggering powerful springs to deploy Magellan and her IUS booster. An hour later the IUS motor fired and Magellan began the 15 month journey to Venus. The probe will fire its thrusters on May 21 to correct its trajectory.

With the major task of the mission completed the five astronauts spent the remaining three days of their mission working with the onboard experiments and Earth observation photography.

The crew had to contend with only minor problems during the first half of their flight. They woke on their second day in orbit to high humidity - this was soon corrected and returned to a comfortable level. A camera used for Earth resources photography was rendered useless when its shutter jammed - the crew were unable to solve this problem. The crew's water dispenser would not give an accurate measure of how much water was being injected into dehydrated food so the crew had to use their own judgement.

A commercially available home video camera was tested by Mary Cleave and proved suitable for future use onboard the Shuttle. The crew were able to photograph lightning over Africa as part of the Mesoscale Lightning Experiment.

The crew were confronted by a major problem late in the flight when one of the five General Purpose Computers (GPC) malfunctioned. The five computers have overall control of the Shuttle vehicle and are vital for monitoring the Shuttle's many systems. Although the faulty computer was a back-up it was decided the crew should attempt the first on-orbit replacement of a GPC. The crew successfully carried out the complicated procedure of removing the malfunctioning computer and replacing it with a spare carried onboard the orbiter.

A Flawless Landing

The crew spent their final day in orbit preparing for the return to Earth. Atlantis touched down on concrete runway 23 at Edwards Air Force Base at 20:43:33 BST on May 8. Winds proved favourable for a test of the Shuttle's ability to land in a strong crosswind. Atlantis passed the test with flying colours - boding well for the resumption of Shuttle landings at the Kennedy Space Center.

There was very little tile damage and NASA Administrator-designate Richard Truly said Atlantis was one of the cleanest spacecraft he had seen at the end of a mission. Minor tile damage was caused by rubber breaking loose from the left main landing gear. Overall about 12 tiles require replacement and there are about 100 small repairs which will require attention.

Atlantis was scheduled to be returned to the Kennedy Space Center on May 13 where preparations will begin for her next mission, STS-34, when she will launch the second interplanetary mission of the year: the Galileo probe to Jupiter.

Shuttle Risk High NASA Admits

1-in-78 Chance of Another Disaster

NASA has revealed that each Shuttle flight faces a 1-in-78 chance of 'catastrophic failure'. Such an accident would involve loss of the orbiter and possibly the astronauts as well. NASA is continuing its work to improve Shuttle safety and plans to transfer many payloads to unmanned launchers.

NASA's grim assessment of Shuttle safety is in contrast to the agency's optimistic beliefs before the Challenger accident when NASA quoted the chances of disaster as 1 in every 100,000 flights. At the same time the US Air Force was offering a more realistic evaluation of Shuttle safety. It believed a failure of a Solid Rocket Booster was most likely, with a possibility of 1-in-35.

A more safety conscientious NASA is now willing to accept the possibility of another disaster. James Thompson, the head of NASA's Marshall Space Flight Center, said the agency needed to avoid complacency after its recent successes and should continue to find ways to reduce risk.

"We shouldn't rest on any laurels after three launches," Mr Thompson said. "There are going to be failures in the future, and we should try to minimize that" by further improvements to the Shuttle, he said. "But NASA has to avoid the trap of saying all flights are going to be successful. That's just not on the cards."

Benjamin Buchbinder, manager of safety risk assessment at NASA Headquarters, said the 1-in-78 estimate was statistically the most probable, with the estimate's range of reliability extending as high as 1 flight in 168 and as low as 1-in-36.

It should be noted that although the Shuttle orbiter would be lost in the above scenarios, the crew might survive. For example a multiple main engine failure during the first few minutes of flight would result in a ditching at sea, but the crew could bailout before the fatal crash.

Ariane 2 Goes Out in Style

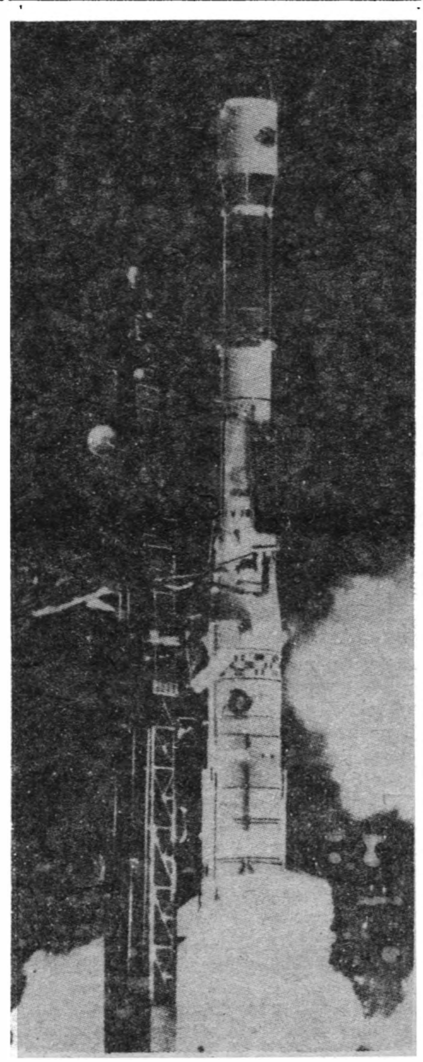
The final Ariane 2 blasted off from launch pad ELA-1 on April 2 carrying the Tele-X telecommunications satellite. The satellite was placed almost precisely in the designated orbit about 17 minutes after launch.

Tele-X is of the same design as the French TDF-1, but in addition to direct broadcasting it features commercial communications for video conferencing, video data transmission, and computer links. Tele-X was built for the Swedish Space Corporation by the Eurosatellite team (Aerospatiale, Alcatel-Espace, MBB, ANT, AEG and ETCA) and with the contribution of the Swedish firms, Saab and Ericcson. Tele-X is designed to serve Sweden, Norway and Finland.

The satellite, launched at 0228 GMT on April 2, was placed in the following initial geostationary transfer orbit:

Apogee: 35,979km ($\pm$ 100km) for 35,992km intended
Perigee: 250km ($\pm$ 1km) for 249.7km intended
Inclination: 3.96 ($\pm$ 0.005) degrees for 4.0 degrees intended

Tele-X reached its assigned position in geostationary orbit of 5 degrees East on April 14.



(Right) The final Ariane 2 blasts off from launch pad ELA-1 at 0228 GMT on April 2. *Arianespace*

DoD Cuts NASP Funding

After pressure from the White House, US Defense Secretary Richard Cheney has reversed his earlier decision to stop Department of Defense funding for the National Aerospace Plane (NASP). However, the DoD contribution to the project of $300 million has been slashed to $100 million. NASA intends to provide an additional $127 million for NASP. Meanwhile the US National Space Council has begun a review of the project and until it presents its findings NASA will have overall control of NASP.

Radars in Space

Marconi Space Systems has been awarded a contract by the UK Ministry of Defence to study space based surveillance radars. The aim of the study is to evaluate candidate radar solutions and to specify a space system capable of meeting any future UK operational requirements. Radars installed in satellites are uniquely able to provide 24 hour, all weather surveillance of immensely larger areas of the Earth's surface than are possible from ground or airborne systems, and can thus provide the earliest possible warning of potentially hostile situations. They also offer advantages in some civil applications, particularly in air traffic control, in areas which cannot be covered by ground based radars.

• Marconi Space Systems are providing the prime sensor, the Synthetic Aperture Radar, for Europe's first remote sensing satellite ERS-1, which will provide all-weather Earth observation of sea, coastal and land regions.

Brazilian Space Chaos

A dispute in Brazil over the launch of the first Brazilian satellite demonstrates the ambiguity of the Brazilian space organisations, writes *Theo Pirard*. The National Space Research Institute (INPE) supports a launch agreement with China for the use of a Long March 2, while the military Institute for Space Activities (IAE) favours the indigenous Satellite Launch Vehicle of Brazil (VLS). The VLS programme is suffering some technological delays. Meanwhile, the INPE's MECB satellites are taking shape and will be ready for launch in 1990...

Hauck Takes Navy Post

Astronaut Frederick "Rick" Hauck, veteran of three shuttle flights, left NASA in April to take up the post of Director of the Navy Space Systems Division at the Pentagon. "My 11 years with NASA have been extremely rewarding," Hauck said. "I am looking forward, however, to continuing my career in the Navy and to the new challenges it provides."

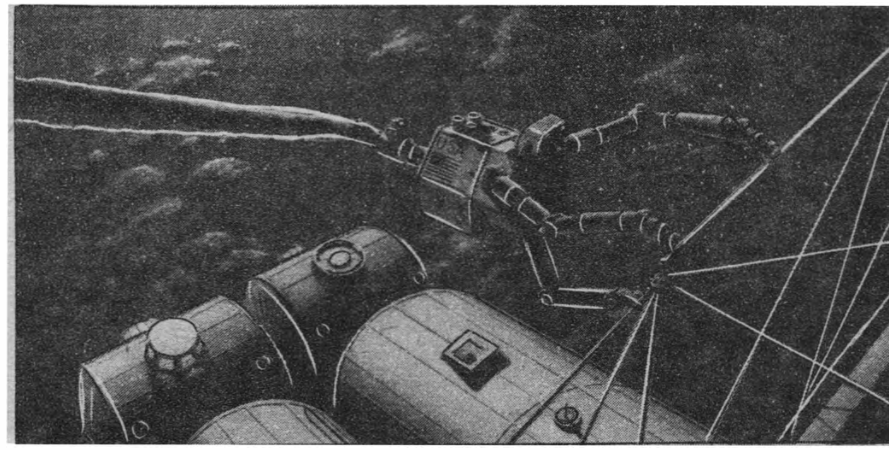
Space Station Robot Contract

Martin Marietta Space Systems has won the contract to develop and build the Flight Telerobotic Servicer (FTS) which will assist in the assembly and maintenance of the Freedom Space Station.

Under the $297 million contract the company will provide a prototype FTS for testing during two shuttle missions and a final operational version for the Space Station.

The FTS will enable astronauts to direct routine assembly and maintenance work without leaving the Space Shuttle or Space Station, thereby enhancing crew safety. The FTS will be equipped with multiple, highly dexterous robotic arms, advanced control systems, and video cameras for viewing. When Space Station assembly is complete, the FTS will use artificial intelligence, which will enable the computer to "think" like a human to perform tasks.

The FTS will be launched in the mid-1990s aboard an early Shuttle flight ferrying Space Station equipment to orbit. For Space Station assembly operations, the FTS will be attached to either Space Shuttle or Space Station remote manipulator arms, with crew members inside the Space Shuttle or Space Station directing FTS operations. FTS tasks for Space Station include installing and removing truss members, installing fixtures on the truss, changing orbital replacement units, mating thermal utility connectors, and performing inspection tasks.



An artist's impression of the FTS at work outside the Freedom Space Station. *Martin Marietta*

Eventually, NASA expects the system to perform complex tasks with a single command. As the Space Station develops the ability to service satellites and large space instruments, the robot would be used to minimise crew involvement. For example, large space instruments like NASA's Hubble Space Telescope would be brought to the Space Station's servicing facility where the servicer would perform autonomous functions like replacing telescope components.

Greens Spike Sunlight Project?

A five-year-old Soviet plan to light up the night sky with giant space mirrors has been deferred for some time, it has been learnt in Moscow. The plan has fallen victim to the growing power of the "green" movement for environmental protection in the USSR.

By Brian Harvey

The project was conceived in the early 1980s. The intention was that satellite reflectors would beam down light to illuminate parts of Siberia during the prolonged periods of winter darkness. One idea was to light up oilfields, thus making feasible the winter working of the oilfields. The project opened up prospects for increasing industrial output in a number of areas.

Energia

The project is by no means dead, but it has now been put off until the "completed" Energia rocket is ready to launch the large payloads required. As a result, experts say, it is now "probably a project for the next century" [1].

Ecologists are increasingly concerned about the general brightening of the Earth's atmosphere, it has been learnt. Astronomers also fear it will impede their access to the heavens. "There is also the problem of directing the light at selected targets and localising its effect. All this is being carefully studied. With the growing ecological awareness of the nation, no unsound project could receive the go-ahead" [2]. Other objections have revolved around the unpredictable consequences that might ensue should permafrost be melted.

Advocates of the concept explain that a solar power satellite high above the Earth would not be eclipsed by the Earth's shadow. Instead, using reflectors and mirrors, it could beam down light onto towns, streets, and transportation centres. Savings on electricity would be considerable and would come from a "clean" source.

Small Demonstration Satellite

Work on a small, experimental demonstration satellite began in early 1984 at the Moscow Aviation Institute and reached an "advanced stage" in May of the year. A 200kg satellite was to deploy a reflector 110m^2 across which would illuminate an area of 9km^2 to a brightness 50% greater than the full Moon. The experiment was expected to pave the way for an operational system by 1994 [3].

The satellite never flew. At the very time that it was being prepared for launch the USSR Academy of Sciences set up a committee to investigate the possible ecological effects of the sunlight-by-night scheme [4].

The demonstration satellite was to precede much more ambitious projects. "It is intended to be the forerunner of larger reflectors which could light a whole city or construction project at night with sunlight seven times brighter than a full Moon. Free illumination of five cities the size of Moscow would save enough electricity to repay the cost of the space reflector within four or five years" [5].

Pravda in November 1983 revealed that Soviet scientists were "already working" on the night-time lighting of the Arctic Circle region [6]. The EVA assembly work just then completed by Salyut 7 cosmonauts Vladimir Lyakhov and Alexander Alexandrov was heralded as opening the way for the type of assembly tasks that would be involved.

Grandiose Project

The experimental satellite seems to have progressed no further, and the plan now seems to have been put well down the line [7]. The Chernobyl accident, Glasnost, the new-found political clout of the Soviet ecological movement, and a healthy distrust of the grandiose (and ecologically suspect) schemes of the Brezhnev era may well keep it there.

References

1. Science and Engineering, *Radio Moscow*, April 30, 1989, in English.
2. Ibid.
3. Street lamps in the sky. *Soviet Weekly*. August 4, 1984.
4. Putting lights in the night sky. *Sunday Press*. October 14, 1984.
5. Sunshine at midnight. *Soviet Weekly*, May 12, 1984.
6. Basis laid for large space complexes. *Soviet Weekly*. December 3, 1983. Vide also Soviet plan: Sunlight at night. *Irish Times*. November 29, 1983. Academician Boris Paton: Towards a permanent space station. *Soviet Weekly*. February 4, 1984.
7. Huge satellites are key to Soviet plan to transform Sun's energy. *International Herald Tribune*. June 15, 1987.

Water Power for Space Station

A team of workers in the Propulsion and Power Division at the Johnson Space Center (JSC) is developing a propulsion system - fuelled by water - that will prevent the orbit Space Station Freedom from decaying.

A prototype of the propulsion concept, which separates water into its tow components, hydrogen and oxygen, and then uses them as propellants, is now being tested. Although the test system is far different in size, appearance and construction from what eventually may fly, the processes used are identical. McDonnell Douglas will eventually build the flight hardware.

A system of 24 thrusters will be needed at least four times a year to boost Space Station Freedom back to its proper, 220 nautical mile-high orbit. Using water as the raw propellant for such a system is uncharted ground, but it's an idea that makes sense.

The shuttle uses monomethyl hydrazine and nitrogen tetroxide, two chemicals that ignite on contact, to propel it in space. But the space station's system will break down water into hydrogen and oxygen by electrolysis.

If a traditional propulsion system such as the Shuttle's were used on the space station, propellants would have to arrive by special delivery. But with a water-based system, excess water that is now dumped as waste during each Shuttle mission can be used to refuel the station. Water is a byproduct of the Shuttle's power cells which combine hydrogen and oxygen to create electricity - the opposite of electrolysis. The amount of water created during each flight is much more than is needed by the crew and normally is dumped overboard.

"Every time a Shuttle goes up, the excess water can be transferred to the station," Don Blevins, assistant for programme management in the Propulsion and Power division, said. "It's basically a free resupply that way." Waste will be eliminated.

"We can save on the amount of propellants that have to be brought up to the station," he said. "And it can save a significant amount of money over the 30-year life of the programme."

The concept for the water-based thrusting system is new territory for several reasons, among them its complexity, extended lifetime and limits in weight and volume, Blevins said.

Once the electrolyzer separates the water into hydrogen and oxygen, the two gases remain saturated with water vapour and must be dried before they can be used as propellants, said Rex Delventhal, an engineer in the Propulsion Branch. First the gases go through phase separators, cylindrical tanks that allow the heavy water vapour to sink to the bottom. Then the gases are channelled into desiccant material dryers, that work using water absorbent materials.

The propellants are stored in tanks at a pressure of 3,000 pounds per square inch. The hydrogen and oxygen remain in gaseous form and burn as gases in the thruster, a major difference between other rocket engines that use propellants in liquid form, Delventhal added.

The test system has been working well, and tests appear to be proving the feasibility of the system, Blevins said. Two thrusters will be tested on the system, one built by Bell and another by Rocketdyne. The Bell thruster has been fired seven times so far in tests, the longest of which was a 12-second burn. Next the Rocketdyne thruster will be tested.

Once the series of tests is completed, work will begin on a Phase B system that will more closely resemble what may fly. The future testing will involve firing two thrusters simultaneously.

When it flies, the system must be capable of firing thrusters for a one and a half hour burn four times each year, each time boosting the space station from 10 to 15 miles higher. Without it, the station's orbit would eventually decay.

The thrusters need to have a functional life of about five years, Blevins said, which means at least 20 hours of use But the system also must be capable of milliseconds-long bursts to control and stabilize the station's altitude

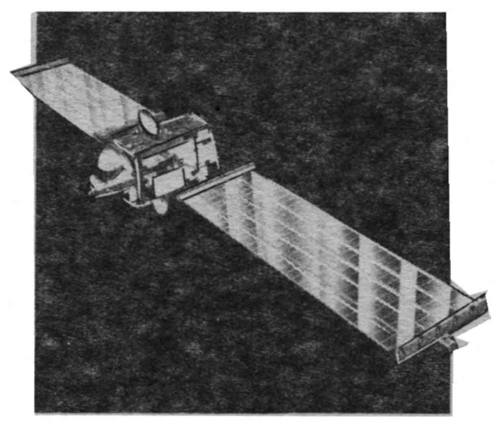
Olympus 1 Arrives in Kourou

The Olympus 1 communications satellite, built by a consortium of aerospace companies led by British Aerospace (Space Systems) Limited, has arrived in Kourou, French Guiana where it will be prepared for launch by Ariane in June 1989. When in orbit, Olympus 1 will be the world's most powerful civil communications satellite.

Prior to shipment, Olympus 1 successfully completed a series of rigorous environmental and mechanical tests undertaken at the David Florida Laboratories and at the National Aeronautical Establishment in Ottawa, Canada.

A specially chartered Belfast transport aircraft carried the satellite from Ottawa to Kourou. Test and check out equipment were transported by a Boeing 747 freighter - its cargo hold too small to accommodate the satellite. The body of Olympus 1 measures 2.9 m (9ft 6in) wide and is 5.5m (18ft 2in) high. In orbit its solar arrays measure 25.6m (84ft) from tip to tip - half the width of a football pitch.

Olympus 1 carries four separate communications payloads which will assist in the development of new communications services within Europe. Payload applications include high power direct broadcast TV, video conferencing, data transmission and tele-educational services.



Artist's impression of the Olympus communications satellite in orbit. *BAe*

Olympus 1 was built under contract to the European Space Agency as a technology demonstrator for a future class of large and powerful communications satellites. Future Olympus satellites could have solar arrays measuring up to 56m (184ft), providing up to 7.7kW of electric power-enough to power 40 channels of direct broadcast television or up to 250,000 simultaneous telephone calls.

Contract Follows Skylark Success

British Aerospace has received a contract valued at £1.5 million to supply the German Company MBB-ERNO with a further six Skylark Sounding Rockets, so extending one of the world's longest and most successful space programmes.

The six new rockets will be launched from Esrange, Sweden over the next three years as part of the MBB-ERNO microgravity programme. The two stage solid propellant powered rockets will carry modular payloads up to altitudes of 250 kms. At this altitude the payload module separates from the rocket and experiences six minutes microgravity time before returning to Earth by parachute. The payload is then recovered by helicopter for delivery to an on-site laboratory.

Typical experiments undertaken in weightlessness conditions include the study of crystal growth, biotechnology and the melting of metals.

This latest contract award follows the successful launch of the 410th Skylark Sounding Rocket on February 10, 1989, from the Esrange Rocket Range, near Kiruna, northern Sweden. This was the fourth Skylark Rocket to be launched as part of the German ROSE (Rocket Scatterometer Experiment) programme investigating the relationship between the solar wind and the Earth's atmosphere - the phenomenon known as the aurora borealis. Since the start of 1988 there have been nine consecutive Skylark launches, all of which have achieved mission objectives. The first Skylark was launched in February 1957.

Briton in Space

The signing of the agreement to launch the first Briton in space onboard a Soviet Soyuz capsule has been postponed. The agreement was due to be signed at Moscow Airport on April 14. But at the last minute the ceremony was cancelled It is now believed the agreement will signed in June when UK Minister Lord Young is visiting Moscow.

SATELLITE DIGEST - 222

Robert D. Christy

Continued from the May 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.

ASTRA 1A, 1988-109B, 19688

Launched: 0033*, 11 December 1988 from Kourou by Ariane 44LP.
Spacecraft data: Three-axis stabilised, box-shaped body, 3.18 x 2.03 x 1.52 m, with an aerial array on one face. Power is provided by a 19.3 m span solar array. The mass (in orbit) is 1045 kg.
Mission: Television broadcasting satellite, equipped with sixteen operational, and six spare, transponders.
Orbit: Geosynchronous above 19 degrees west longitude.

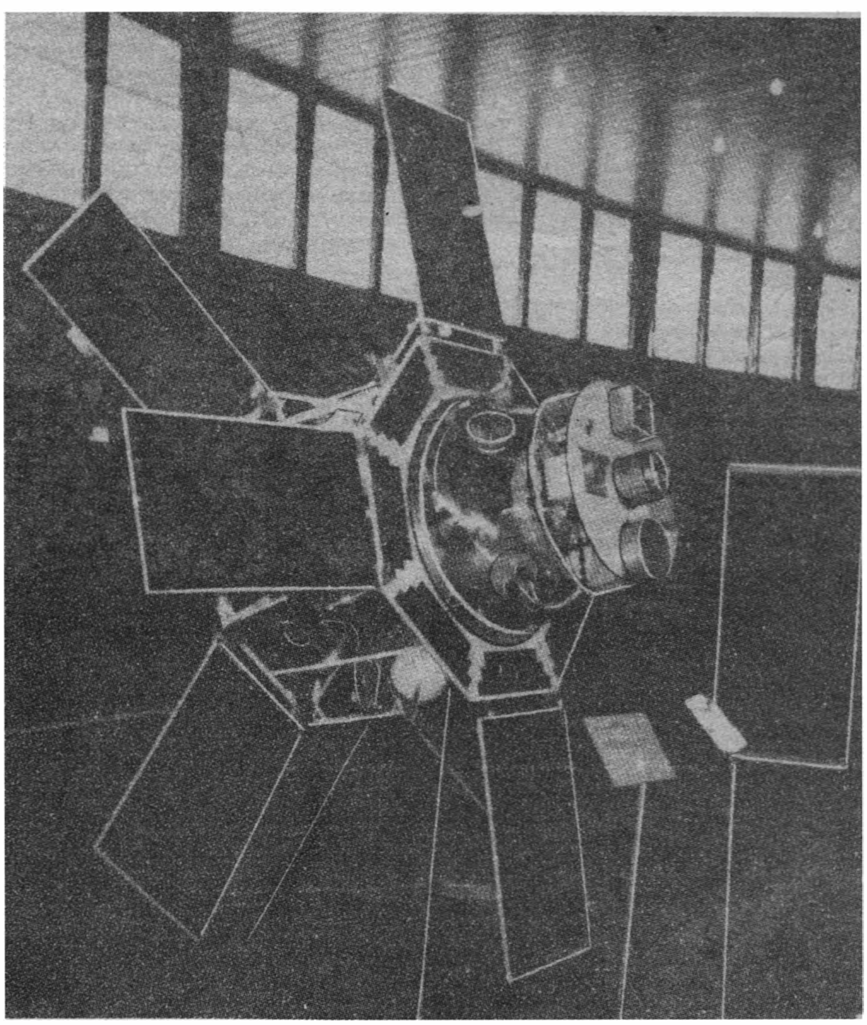
COSMOS 1984, 1988-110A, 19705

Launched: 1900, 16 December 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period, reentered after 59 days.
Orbit: 188 x 325 km, 89.64 min, 62.85 deg, manoeuvrable.

CHINA 25, 1988-111A, 19710

Launched: 1240, 22 December 1988 from Xichang by Long March 3.
Spacecraft data: Cylindrical, spin-stabilised body with de-spun aerial.
Mission: Communications satellite.
Orbit: Geosynchronous above 110.5 degrees east longitude.

A Molniya communications satellite photographed at a Soviet space exhibition recently held in Budapest, Hungary.
N.Schuminszky



MOLNIYA-3 (34), 1988-112A, 19713

Launched: 1416, 22 December 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 432 x 39056 km, 700.27 min, 62.80 deg, then raised to 444 x 39889 km, 717.35 min, 62.79 deg, to ensure daily repeats of the ground track.

COSMOS 1985, 1988-113A, 19720

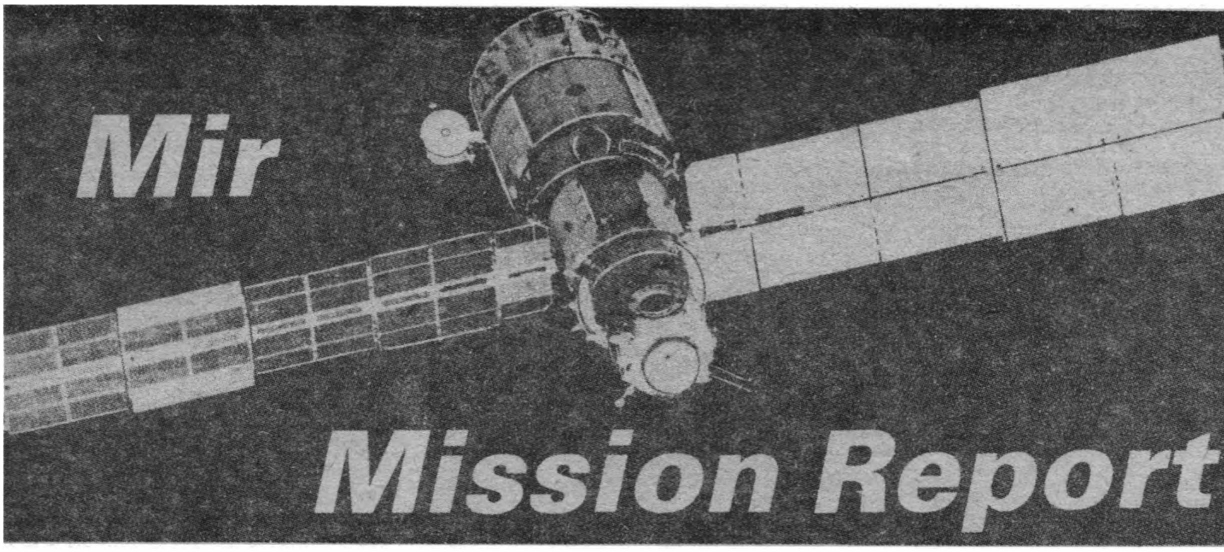
Launched: 1030, 23 December 1988 from Plesetsk, by F-2.
Spacecraft data: not available.
Mission: Military satellite, used to test ground-based missile-tracking radars.
Orbit: 526 x 534 km, 95.28 min, 73.57 deg.

PROGRESS 39, 1988-114A, 19728

Launched: 0412*, 25 December 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquid tank section and cylindrical instrument unit 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 equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 0537 on 27 December. It undocked at 0646 on 7 February 1989 and was de-orbited later the same day.
Orbit: Initially 187 x 237 km, 88.7 min, 51.63 deg, then by way of a 237 x 338 km transfer orbit to a docking with Mir in an orbit of 325 x 353 km, 91.26 min, 51.63 deg.

MOLNIYA-1 (74), 1988-115A, 19730

Launched: 0529, 28 December 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 637 x 38859 km, 700.45 min, 62.82 deg, then raised to 617 x 39736 km, 717.75 min, 62.85 deg, to ensure daily repeats of the ground track.



Cosmonauts Leave Mir Unmanned

When cosmonauts Volkov and Krikalev blasted off from their launch pad at the Baikonur Cosmodrome they were looking forward to an ambitious six month mission on board the Mir space station. Together with Dr. Polyakov, who was launched to the station in August 1988, they were to make two space walks and receive the space station's first 20 tonne add-on modules. Unfortunately things did not go to plan and the cosmonauts returned to Earth, without making the space walks, leaving the station empty for the first time in over two years and without the new modules having docked. Regular *Spaceflight* correspondent *Neville Kidger* has the details. He begins by bringing us up to date with the work carried out since the end of last year.

By Neville Kidger

Progress 39

The unmanned cargo craft Progress 39 docked with the Mir complex at 0535 (all times GMT) on December 27, 1988 after being launched from Baikonur two days previously. It delivered over 1,300 kg of cargo for the resident Donbass crew - Aleksandr Volkov, Sergei Krikalev and Dr. Valeri Polyakov.

Surprises for the three men included fresh fruit and vegetables and New Year gifts from their families.

The cosmonauts were the latest in the succession of resident and visiting crews to stay on the Mir/Kvant complex. But for the Donbass crew their stay was to be a significant one.

At the pre-launch press conference, Volkov had told reporters that the crew were to return in late April having received three Progress cargo ships, a new module and two EVA's by Krikalev and himself. The first month of the mission had already passed very eventfully with six cosmonauts on the complex, including Frenchman Jean-Loup Chretien.

There were few reports of the cosmonauts' activities over the New Year period but on January 2, 1989 they began a new series of Earth observations studying the natural resources of Siberia and the Soviet Far East.

Over the next few days the men also conducted several sessions of astronomical observations using the Bulgarian-made Rozhen system. An experiment named Polarizatsiya involved photometric observations of stars, galaxies and nebulae. Using the Bulgarian-made Parallax-Zagorka instrument the men observed the vertical distribution of luminescence in the polar, middle and equatorial latitudes of Earth and also the luminescence of the complex itself which results from the interaction with the atmosphere. Similar experiments were conducted on the US Shuttle to observe the glow given out from the spacecraft as it interacted with molecules of atomic oxygen in the rarefied atmosphere in orbit.

Ultraviolet pictures were taken using the Glasar telescope located in Kvant. Several areas of the constellations Auriga, Cassiopia, Orion and Vela as well as the X-ray observation of sources in the Vela constellation and the Small Magellanic Cloud. The X-ray telescopes were also located on the Kvant in an unpressurised section.

Medical tasks were also being undertaken on a regular basis under the supervision of Dr. Polyakov, who had joined the Mir crew in August 1988. These tests included extensive examinations of the men's cardiovascular systems using equipment provided by Soviet and French scientists.

On January 17, amidst the reports of routine technical replacement work, the Soviets announced that preparations were underway for the EVAs. The next day, at a press conference in Moscow, Glavkosmos chief Aleksandr Dunayev told reporters that the launch of the new module would now occur within the first six months of the year. This was the first official indication of the problems which were to disrupt the pre-announced plans for the Mir complex.

Continued Routine

One of the pieces of equipment being used by Dr. Polyakov in his work was a rapid blood analyses. The device, called Retroflon, was developed by the West German firm Boehringer Mannheim and was another indication of the growing commercial cooperation between the Soviets and the rest of the world. The commercialisation of the Soviet programme is bringing about some interesting developments (to be discussed later).

On January 24 TASS announced that the complex's orbit, which had been adjusted by Progress 39, was currently at a height of 376 x 340 km with a period of 91.4 minutes and an inclination of 51.6 degrees.

The cosmonauts were using a holographic gauge to check the optical properties of the portholes. It had been reported by earlier crews that the portholes had begun to collect a fine film of dust - some of which was wiped off during EVAs by the year-long-stay crew of Vladimir Titov and Musa Manarov.

Between January 24 and 26 the Soviets reported that the men were replacing a control in the thermoregulatory system with a new one delivered by Progress 39. After installing it they checked for leaks in the hydraulic line. Such repairing and replacement work is a large part of the cosmonaut's work in orbit.

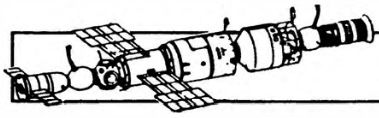
As January slipped away, the cosmonauts continued their routine. The Flight Control Centre often controls the orientation of the complex to use the Kvant X-ray telescopes to observe sources. Even as the cosmonauts slept the complex was oriented to view the southern constellation of Circinus to examine an X-ray source thought to be a double star.

In one of the first such descriptions for a while, the Soviets described a new technological experiment being conducted by the Donbass crew. The Yantar equipment was installed in the complex's airlock to obtain metal coatings in weightless conditions. A dual component alloy of silver-palladium and tungsten-aluminium was applied to a polymer film. Such experiments were conducted regularly on the Salyut 6 and 7 stations using a device called Isparatel.

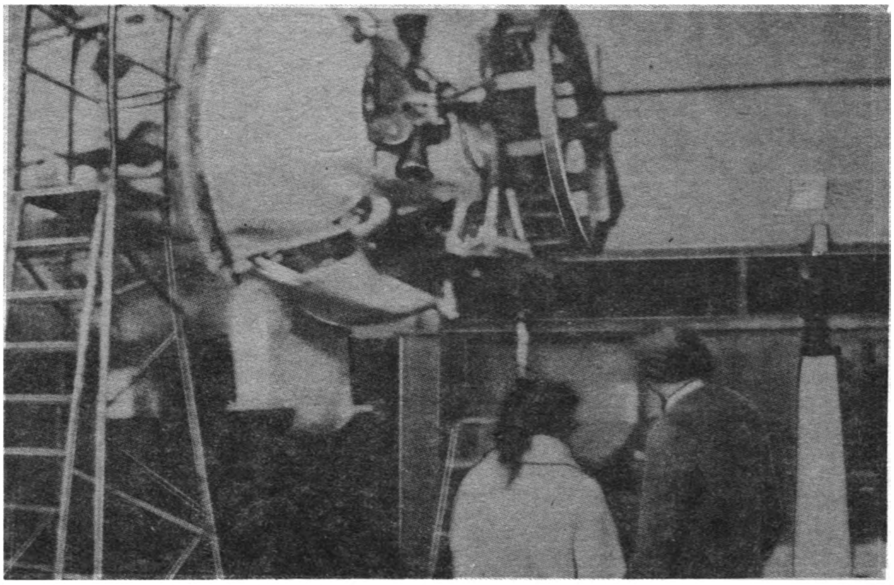
Beginning February 1, the Soviets said, the crew would begin visual observations of Soviet territory on a regular basis because the complex was beginning overflights of the country during daylight periods.

Another Setback

In early February Soviet radio revealed



MISSION REPORT



Forward view of the 're-equipment' module at the Star City training centre. The one metre diameter airlock and a group of thrusters are visible. *Central News*

the EVA planned for February had been scrapped. No reason was given at the time for the cancellation but it was later to emerge that the launch of the building block modules slipping to later in 1989. On being told of the delay and the fact that his crew would not receive the first module, Volkov reportedly said "technology is technology." Another source said a new crew would be launched in April and were to be replaced six months later.

Earth observations, experiments with the Yanter installation and medical tests occupied much of the first days of February. The Earth observations were supplemented by pictures obtained from an unnamed Cosmos satellite.

At 0646 GMT on February 7 Progress 39 was undocked from Kvant and was deorbited to destruction at an unspecified time later that day.

Another series of UV photography sessions was begun on February 8 with the first target being the constellation of Taurus.

Another Progress

At 0854 on February 10 the 40th Progress cargo ship was launched from Baikonur. It docked with the Kvant port two days later at 1030. Western sensors tracked the complex in an orbit of 364 x 347 km after the docking. The cosmonauts began unloading the various cargoes the next day as they continued their Earth observation experiments and astrophysics work.

During February 14 Aleksei Leonov told reporters in Moscow that the Volkov crew was to be replaced by the end of April. The next crew would "most probably" be commanded by Aleksandr Viktorenko.

Viktorenko was the reserve commander for Soyuz TM-7, which launched Volkov, Krikalev and Frenchman Chretien. His flight engineer on that occasion was Aleksandr Serebrov.

Serebrov had been training for an EVA from the new module using the one metre diameter forward hatch. He was to try out the Soviet version of the manned manoeuvring unit which had been shown to an international corps of reporters the previous November at Baikonur. The initial flight at least of the new unit would see Serebrov anchored by a tether to the Mir complex. The cord would be a nylon one with a metal core which could be severed in an emergency, Soviet officials told a Western reporter.

The Americans had practised flying a prototype of their MMU in an untethered mode but that was within the confines of the Skylab space station in 1973.

Leonov's statement did not mention Serebrov and gave rise to Western speculation that he had been dropped from the crew until the new module was launched. This speculation proved well founded when, after returning from Baikonur from a filming trip, the US analyst James Oberg revealed that he had met the Soyuz TM-8 flight engineer - a rookie called Aleksandr Balandin.

Leonov also revealed that the mission planners were unsure whether or not to return Dr. Polyakov to Earth. If he remained on the complex through the planned six-month long flight beginning in April he would have exceeded the year-long record of Titov and Manarov.

One Western analyst suggested Polyakov might wish to remain on the station rather than return and face another painful bone marrow operation. Prior to the TM-6 launch both Polyakov and his backup, Dr. German Arzamazov, had undergone painful bone marrow surgery to enable pre-and-post-flight comparisons to be made.

Tass announced on February 18 that the replacement crew would be launched on April 19.

Future Plans

The third anniversary of the launch of the Mir base block saw a number of interviews relating to the future of the complex.

Viktor Blagov, the deputy flight supervisor, said that the Mir complex would eventually have six spaceships or research laboratories. Kvant was already at the complex. A Soviet drawing released in 1987 had shown two Salyut-class and two Kvant-class modules docked at Mir's front docking unit. A new version reportedly shows four of the Salyut-class modules.

Blagov also said that it was planned to attach independent pointing platforms to the exterior of the complex on which telescopes or other sensors could be mounted. Such pointing systems would enable great savings of fuel on the complex.

TV pictures were shown of the "re-equipment" module at Baikonur and a second module, which the Soviets called "Optizont", undergoing final tests in the workshop.

Chief spacecraft designer Yuri Semenov told TV viewers that the first module was to be launched in the second half of 1989 and that between July and September the module would be equipped with the manoeuvring units. The second module would be launched shortly afterwards (so that symmetry could be retained for manoeuvring).

The second module, a space "factory" would grow crystals for the electronics industry and process biotechnological materials. The yield of the module would be about 100 kg of produce per year, Semenov said, after it had begun work in late 1990 or early 1991.

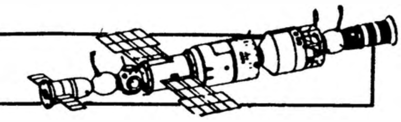
The designer said that Mir had already recouped 25 per cent of its costs to date. The new technology module would earn 1,000 million Roubles per year which would be "many hundreds of millions" of Roubles in profits.

The delay in launching the technology module may have been attributable to the development time of ecological monitoring equipment which it was to carry. The violation of announced plans was a "disease which we have in many, many cases... [which] also happens in the space branch," A Soviet journalist said. "Somehow we have never talked about this before."

Meanwhile, in orbit, the three man crew had been assigned an increased work load of experiments. One of these was Diagram in which measurements of the physical characteristics of the atmosphere were conducted using a magnetic-discharge transducer deployed outside the station's airlock by a rod. The experiment would help evaluate aerodynamic drag.

On February 23 the cosmonauts celebrated Soviet army and navy day by toasting Volkov, a Colonel in the Soviet Air Force. The men were allowed an "exotic" choice of foods - pickled cucumbers, fresh fruit, sweet-smelling Russian bee honey and others - which had been delivered by Progress 40. The menu for the Mir cosmonauts now includes about 70 dishes but excludes alcohol, the Soviets say.

TASS reported that Polyakov had reported that he had dreamed about his family. The agency said that cosmonauts tended to dream about earthly things such as home and family and rarely about space. The agency reported that studies at the Soviet Health Ministry's Institute of Biomedical Problems had discovered that cosmonauts - and most scientists and technocrats - dreamt in black-and-white whilst spiritual people tended to have colour dreams.



Progress 40 Departs

The low key coverage of the cosmonauts' activities continued to the end of February. The men continued Earth observations and medical examinations.

On February 24 the orbit of the complex was adjusted by Progress 40's engine so that the height of the complex above the Earth varied from 386 x 358 km with a period of 91.7 minutes. Refuelling of Mir's tanks was conducted at the end of February. On March 2 the Soviets said that the cosmonauts were filling the cargo ship with used equipment - a sure sign of the craft's imminent departure.

Sure enough, at 0146 on March 3 the cargo ship undocked and slowly separated from the complex. The undocking differed from the standard procedure when two large-sized multi-link folded structures on the side of Progress 40 unfurled one after the other.

The structures resembled an orange segment but more sharply angled than an ellipse. The "unique alloy" which was built into the structures enabled the structure to "remember" its original form. The deployment was achieved by heating up wire leads electrically to stretch the structure like a muscle.

Volkov's crew took still and video pictures of the experiment which, the Soviets said, could find application on future large-scale structures in space. One specifically mentioned use involved covering such structures with reflectors to reflect the Sun's rays to Earth. A more earthly use could involve opening and closing shutters on greenhouses as the temperatures fluctuated.

Progress spacecraft have often been used for experimental work. In 1985 the Soviets launched Cosmos 1669 which they described as similar to the Progress ships. The craft docked with Salyut 7 and performed a mission identical to that of a standard Progress cargo ship. At the end of its flight it undocked from the Salyut 7 station, backed away and then re-docked to confirm the reliability of the docking system, according to an American source. A similar experiment was conducted with Mir by the Progress 32 ship in 1987. This raises the question about the designation of Cosmos 1669 (which one contemporary Soviet report called Progress 25). Perhaps, with the onset of openness, the Soviets may reveal why cosmos 1669 was so designated.

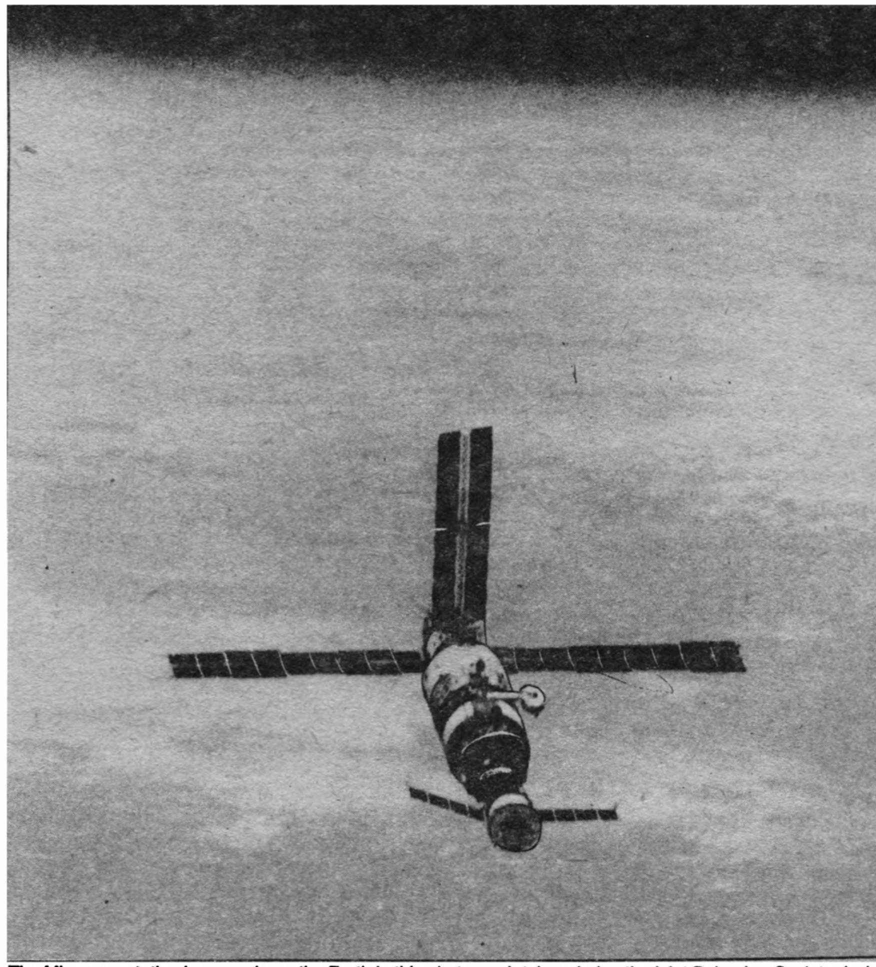
At 0108 on March 5, after two days of autonomous flights and tests of the structures, Progress 40 was deorbited to a destructive reentry.

More Astrophysics

Over the following week the cosmonauts laid emphasis on work with their astrophysics instruments. The mission was said to be entering a new stage in the UV photography with the Glasar telescope.

Readings of the charged particle environment in the complex were taken on a regular basis with the magnetic spectrometer Mariye. One specific task for the device was to register the intensity of high energy particle flows to assess if these were related to areas of seismic activity on Earth.

On March 16, the cosmonauts and ground controlled began a four-day-long cycle of X-ray observations of the central part of our galaxy.



The Mir space station is seen above the Earth in this photograph taken during the joint Bulgarian-Soviet mission of last year. The Soyuz TM-5 is docked to the Kvant module. *Novosti*

Progress 41 In Space

At 1854 on March 16, the third Progress cargo ship scheduled to resupply the Donbass crew was launched from Baikonur. Progress 41 docked with the Kvant port at 2051 two days later. The complex was tracked by Western sensors in an orbit of 363 x 349 km.

On March 20 the unloading of the cargoes began. A highlight of the work over the next few days was the use of the Bulgarian-made Spektr-256 spectrometer to scan the Earth's atmosphere in 256 wavelengths and measurements of the radiation levels in the complex with the French made Circe device.

Sunday March 26 was a historic day in the USSR with elections being held for the newly formed Congress of People's Deputies of the USSR. Successful candidates would include cosmonauts Valeri Ryumin, Svetlana Savitskaya and Viktor Savinykh. Many of the candidates stressed the curbing of expenditure on space ventures in the manifestos. The Donbass crew registered their votes by radio to the FCC who then passed their preferences on to the cosmonaut's constituencies.

TASS chose the same day to reveal how bureaucracy had reached Mir. Sergei Krikalev revealed that he had been served several written orders demanding that he report to a district army draft centre even though he was in space.TASS chided the "dim-wit bureaucrats" who had followed regulations to serve the order. Krikalev, the youngest Soviet cosmonaut in a quarter of a century, said that he was not prepared to return to Earth early. The mission was scheduled to end on April 29.

As March ended, the crew conducted yet more Earth and stellar observations. The cycle continued during the first days of April. One of the Earth observation aims was environmental monitoring of the northern Caucusus and areas adjoining the Black Sea and the Caspian Sea as part of a Soviet-block programme.

On April 4, TASS, in a regular statement, said the cosmonauts were to replace a number of power supply instruments, the warranty period of which was expiring. These had been delivered by Progress 41.

A Shock Report

Special attention was being paid to radiation levels, the Soviets said. This was because high solar activity was causing radiation levels to increase and cause spectacular displays of aurora. The Soviets reported that the men in space were in no danger because the levels were "not hazardous".

On April 10 Progress 41's engines were used to boost the orbit of the complex to 400 x 372 km with a 92.1 minute period. This was an unusually high orbit. TASS reported that the work of the Donbass crew was coming to an end and that they were to begin mothballing the complex, words generally associated

The Mir crew are surrounded by the recovery team and journalists after the return to Earth on April 27. (Left to right) Dr. Valeri Polyakov, Aleksandr Volkov and Sergei Krikalev. *Novosti*

with closing down a Salyut station.

Then TASS revealed that the cosmonauts were to return home on April 27 and that Mir was to continue its flight in the unmanned mode!

This was a surprise to many western analysts. An American report of the Soviets shutting Mir down had emerged from attempts by a US TV crew to set up a radio link-up between Mir and Shuttle Mission 29 (STS-30) which was due for launch on April 28. The Soviets had been evasive in their acknowledgement of the Americans efforts and eventually admitted that Mir would probably be unmanned at the time of the American flight.

Deputy flight director Viktor Blagov confirmed the postponement of the Soyuz TM-8 flight of Viktorenko and Balandin and said that the "adjournment" was due to the delay in the launching of the two new modules. New training was needed, he said.

An American source, however, claimed that there was a different reason for the shutdown of Mir - a power supply problem.

Writing in *Aviation Week and Space Technology*, Craig Covault claimed that Western analysts eavesdropping on the air-to-ground conversations of Mir had heard discussions of electrical problems. He said that "serious electrical power problems" were afflicting the operation of the station. The major user of the electrical power was the life-support system.

A repair crew would need to be trained, Covault wrote, and the same team which had worked to salvage the Salyut 7 space station after it had suffered a complete loss of electrical power was put in charge of the new effort. Krikalev had been part of the team which had prepared documentation and training simulations for Dzhanibekov and Savinykh for their epic 1985 flight which rescued the stricken Salyut 7 station.

One analyst told this writer that batteries on Mir had been recharged from the solar panels only to discharge during operation. New batteries had been flown up on Progress 41 but the problem had continued.

Soviet officials denied the report but, according to writer Tim Furniss, Mir flight controller Valeri Ryumin confirmed that there was a problem with the batteries as described above.

Return of the Donbass Crew

The three-man crew on Mir spent much of their last days in space preparing the complex for a period - the Soviets said three months - without a crew. They conducted some more Earth observations and used the X-ray telescopes.

An inventory of the items accumulated over three years of operation of the station was made.

In preparation for their meeting with Earth's gravity, the men began regular sessions with the Chibis pressure suit which uses a vacuum to simulate the pull of Earth's gravity on their legs.

At 0146 on April 21, Progress 41 was undocked from the Kvant port and, after an autonomous flight of over five days, entered the atmosphere of Earth to a destructive reentry, at 1202 on April 25.

The crew, meanwhile had packed up their experimental results in the Soyuz TM-7 descent craft and conducted their final few experiments. Soyuz TM-7 undocked from the front axial port of Mir at 2328 on April 26.

Retrofire occurred at about 0200 April 27. The descent cabin touched down at 0259 in windy conditions due south of Tikenekty, some 140 km north-east of the town of Dzhezkazgan.

Rescue workers carried Krikalev in his seat to the medical tent after egress from the cabin. It emerged that he had injured his leg after knocking it against a control panel. Krikalev later reassured reporters that he was fine and that the injury was "nothing out of the ordinary".

Certainly, the three appeared in good spirits on TV coverage of the post-landing press conference.

Volkov said that the station had been prepared for three months of unmanned flight and that all spent systems had been replaced. Polyakov revealed that the men had put their signatures on each new device as their personal "guarantee of performance".

The cosmonauts were later flown to Star Town outside Moscow to recover. Thirty-six hours after landing the cosmonauts were reportedly able to move around quite freely.

The cosmonauts were given traditional awards. For Krikalev and Polyakov there was the Hero of the Soviet Union title as well as the Order of Lenin and the Gold Star. Volkov, already a Hero of the Soviet Union, was not given the title a second time but he was awarded the Order of the October Revolution.

Commercialisation of Mir

When the Soviet manned programme resumes in August it will be under the terms of a programme that must justify its existence under public scrutiny and tight economic conditions in the Soviet Union.

Accordingly, the programme is being increasingly commercialised. Two recent deals struck by Glavkosmos and foreign partners highlight the lengths that the Soviet programme is opening up for commercial gain.

Advertisement hoardings, already seen at Baikonur and the FCC during international flights, are to be painted onto the hull of Mir itself. Two panels 2 x 3 metres are being sold by the Swiss firm Punto and will be painted next August. Under the same agreement, firms could send one kilogramme of materials to the station and have a three minute video advertisement made by the cosmonauts. The cost of the package one million Swiss Francs.

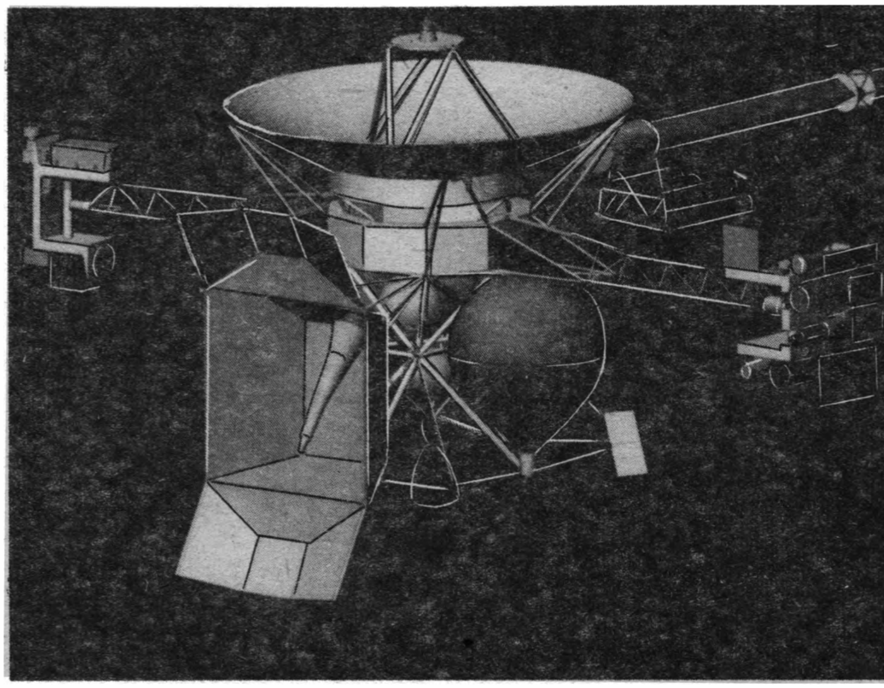
Glavkosmos recently signed a deal to fly a Japanese Journalist to Mir in 1991, where he, or she, will spend six days sending TV reports. The Tokyo-based TBS station is to provide the candidate . The thought of a Japanese newsreader sending down reports from orbit may be an interesting proposition but it had incensed many Soviet journalists who see it as a patriotic duty that the first journalist in space should be a Soviet.

A competition is underway to select a Soviet candidate for a flight to Mir but the question remains as to who will finance the deal. Glavkosmos sells opportunities for hard foreign currency. It is reported that the head of Soviet chemical industry offered hard currency to Glavkosmos head Aleksandr Dunayev for the flight. This move was severely criticised in sections of the press.

More scientific commercial agreements have been signed, or are under discussion with Austria, Great Britain, France and Malaysia.

Rendezvous with Comet Kopff

On August 14, 2000, after travelling for five years toward its goal, a sophisticated spacecraft carrying a dozen specialised scientific instruments orients itself to a precise attitude, makes a final check to ensure that all is ready, and then ignites its main rocket engine for a four-hour burn. With this manoeuvre, utilising over 1,800 kg of propellant, the spacecraft initiates a three-year rendezvous with the short-period comet Kopff, a meeting in which the spacecraft will study the comet in both its quiescent and active phases, will capture and analyse samples of its gases and dust, and will send a penetrator into its surface for *in situ* measurements.



The CRAF spacecraft with the penetrator in the foreground. NASA/JPL

By Sylvia Miller and Sima Lisman
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

The Comet Rendezvous Asteroid Flyby, or CRAF, mission is planned by NASA for a joint new start in fiscal year 1990 along with Cassini, a NASA/ESA Saturn orbiter with a probe to be released into the atmosphere of Saturn's large satellite Titan. These are the first two missions of the Mariner Mark II programme, so named after the new spacecraft being designed at the Jet Propulsion Laboratory for such challenging primitive-body and outer-planet missions. Launching in 1995 and 1996, respectively, these two mission will provide new perspectives on our origins: the formation and evolution of the solar system and the prebiotic evolution of molecules which may have led eventually to the origin of life.

In September 1988, NASA included in its fiscal year 1990 request to the Office of Management and Budget a new start proposal for the CRAF/Cassini initiative. In November, ESA officially gave its support to Cassini by approving funding for the probe, now called Huygens, which will be carried by the American-built Saturn orbiter. Back in Washington, the Office of Management and Budget approved the programme and, in January of this year, CRAF/Cassini became a line item in the budget submitted to Congress.

Earlier, the Ministry for Research and Technology (BMFT) of the Federal Republic of Germany agreed to supply the propulsion module subsystem for the CRAF spacecraft, an arrangement similar to that of Galileo, Cassini's sister mission to the Jovian system which is scheduled to be launched in October 1989. The CRAF science payload was selected in 1986 and included a West German instrument plus German support for a second instrument. In October 1989, Announcements of Opportunity will be issued simultaneously in the United States and Europe for the scientific payloads of both the Cassini orbiter and probe. With a fiscal year 1990 new start, the CRAF/Cassini programme will be ready to begin the development of the spacecraft and detailed mission plans leading to the next phase in the study of the primitive bodies and the outer solar system.

The Authors

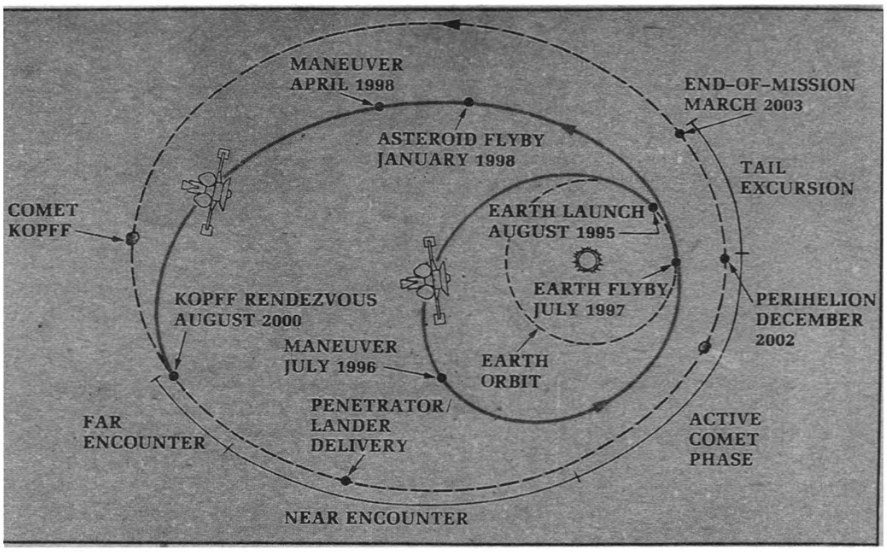
Sylvia Miller (left) has held the position of mission design engineer for CRAF since 1983. During her twenty years at JPL, she also worked on the Infrared Astronomical Satellite, Voyager, Seasat, and various advanced studies. She received her B.A. degree in mathematics from Douglass College and her M.S. degree in systems engineering from West Coast University.

Sima Lisman (right) has worked on the Mariner Mark II project in the spacecraft systems engineering section at JPL for over two years. She received her B.S. degree in electrical engineering from California State Polytechnic University and is pursuing an M.S. degree in electrical engineering at the University of Southern California.

Primitive Bodies

For understanding our origins, comets and asteroids provide important records of early solar system formation. These small bodies have suffered less of the heating and other modifications that have affected the inner planets and larger bodies. Comets are particularly interesting because they are probably icy remnants of the time of the outer planets' accretion, having been flung out into the Oort cloud halfway to the nearest stars or, alternatively, been stored in the region of the solar system just beyond the orbit of Neptune. Hence, the volatile material preserved in comets is probably closerst to that of the primordial solar nebula than that of any current body in the solar system.

Asteroids are thought to be similar to the planetesimals commonly believed to have formed the terrestrial planets and cores of the giant outer planets. The main belt of asteroids, a relatively stable region between the orbits of Mars and Jupiter, contains the boundary between the water-condensing region and the water-vapour region of the protosolar nebula. This difference is visible in the strata of spectral types observed among the aster-



CRAF's interplanetary trajectory.

oids across the belt. The apparent diversity of the asteroids ranging from differentiated, rocky objects to bodies rich in volatiles and hydrocarbons, tells us that we can learn much about the formation of bodies in the solar system by visiting a wide variety of these asteroids.

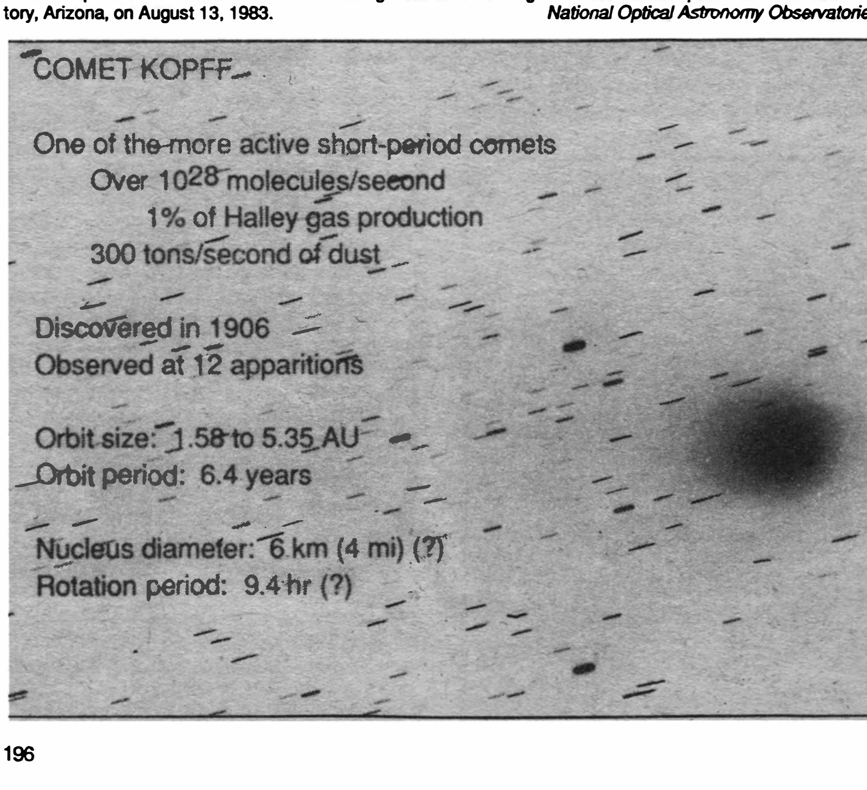
Not only will CRAF provide us with the opportunity to analyse primordial materials, but we will be able to observe physical processes that may be similar to those that occurred in the solar nebula. By travelling with a comet for half of its orbital cycle, CRAF will observe the processes that take place in the comet as it transforms from a relatively quiescent dirty ice ball at 4 and 5 Astronomical Units (AU) from the Sun to its active state near perihelion, when it is spewing forth dust and gas into its coma and tail. Not only are the processes within the comet of interest, but also the interactions between the comet's coma and the supersonic solar wind plasma are intriguing.

Comets and asteroids may also provide clues to prebiotic molecular evolution in the solar system. Recent research suggests that the early atmosphere on Earth may have been inhospitable to the development of the complex molecules necessary for the evolution of life, that these molecules may instead have been brought to Earth from the outer solar system by comets and asteroids.

The primary target selected for CRAF is P/Kopff. Discovered by August Adalbert Kopff in 1906 at Heidelberg Observatory, Comet Kopff has been observed during 12 perihelion passages. It was recovered again in February 1988, almost 4 AU from the Sun, with the next perihelion to occur on January 20, 1990. With its aphelion distance at 5.4 AU from the Sun, its perihelion distance at 1.6 AU, and an inclination of 5 degrees with respect to the ecliptic plane, its orbit is typical of short-period comets. It is one of the most active short-period comets in the solar system, however, and therefore and excellent target for the intensive studies planned for this rendezvous mission.

En route to Comet Kopff, the CRAF spacecraft will fly by the asteroid 449 Hamburga. Named for the city of Hamburg, Germany, this main belt asteroid has a semimajor axis of 2.6 AU. It was discovered in 1899 by M. Wolf and A. Schwassman, also at Heidelberg. Hamburga is of spectral type C, that is, its surface is thought to be composed of material similar to the carbonaceous chondrite meteorites. Type C asteroids are among the more primitive types of asteroids, with high volatile contents. With a substantial diameter of almost 90 km, Hamburga will provide a nice complement to the asteroids of the Galileo and Cassini missions.

Comet Kopff with relevant information. The image was taken through a 4-metre telescope at Kitt Peak Observatory, Arizona, on August 13, 1983. *National Optical Astronomy Observatories*



Advantages of a Rendezvous Mission

The exciting fast flybys of Comets Giacobini Zinner and Halley in 1985 and 1986, respectively, offered tantalising glimpses and data of the first encounters with this class of body. They raised many important questions, however, and emphasized the need for a lengthy stay with a comet. A rendezvous mission, wherein the spacecraft matches orbits with the comet, allows the comet to be observed in both its quiescent and active phases, including the important transition between the two. The spacecraft can, therefore, make measurements as a function of activity level and position with respect to the nucleus and the Sun. Detailed mapping of the surface is possible from close proximity for 100% coverage with a variety of lighting conditions. Long integration times are possible and a penetrator can be implanted in the nucleus for *in situ* measurements. Furthermore, low relative velocities allow dust particles to be captured intact for physical and chemical analyses. Finally, a long-duration visit means that there is time to adapt the mission plans to new, important information as the mission progresses.

Mission Plan

CRAF is launched from the Kennedy Space Center in Florida by an expendable Titan IV/Centaur launch vehicle on August 22, 1995. The mass of the spacecraft, propellant, and launch-vehicle adaptor is 5270 kg. The initial trajectory takes the spacecraft out past the orbit of Mars. There, a sizable manoeuvre is performed, lowering the perihelion of the orbit and creating the right geometry for a subsequent flyby of Earth. The resulting gravity assist from Earth, slightly less than two years after launch, increases the heliocentric speed of the spacecraft from 34 to 38 km/s and sends it on its way to rendezvous with Comet Kopff near the orbit of Jupiter. Using this Delta Velocity Earth Gravity Assist trajectory, the spacecraft can reach the outer solar system while requiring only a low, inner solar system launch energy.

During this cruise phase, science data gathering is limited primarily to the particles and fields experiments. Other instruments, such as the remote sensing instruments, are

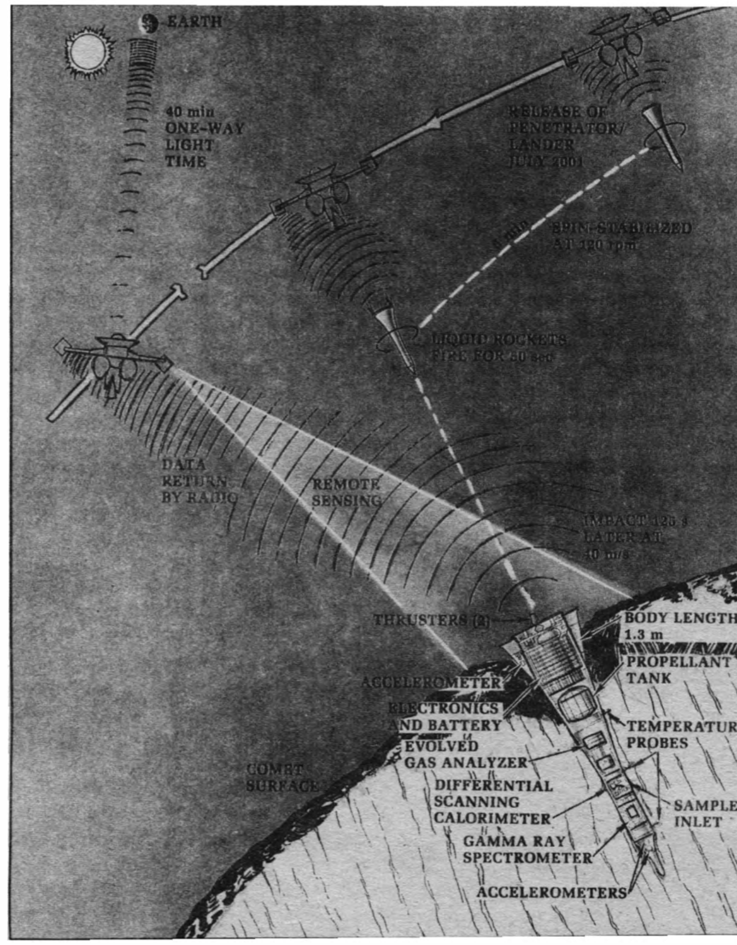
turned on at intervals for calibrations and occasional use. One 8-hour station pass per week with the Deep Space Network is planned for communications.

About six months after the Earth flyby, the spacecraft flies past 449 Hamburga with a relative speed of 17 km/s at closest approach. By targeting to within 80 radii (3,540 km), the mass of the asteroid may be determined with an accuracy of better than 10%. This mass determination, along with an estimate of the volume from images taken by the wide- and narrow-angle cameras, allows what may be the first estimate of the bulk density of an asteroid, a key parameter for bounding asteroid formation theories. All of the remote-sensing instruments are operating during the flyby, imaging the object and making compositional and thermal measurements, and the dust detector measures the number and mass of small particles encountered near the asteroid. The gas and plasma instruments search for any residual comet-like activity and any evidence of an intrinsic magnetic field.

In April, 1998, three months after the asteroid flyby, the spacecraft performs a plane-change manoeuvre for its final targeting to Comet Kopff.

During the late 1990s, observations using Earth-based telescopes refine the ephemeris of the comet. By approaching it from the Sun side, the spacecraft is expected to be able to find the comet with the onboard narrow-angle camera about a month before the planned rendezvous in August 2000. After acquisition is confirmed, the approach strategy and parameters for the critical rendezvous burn are finalised. This large burn takes place about 200,000 km from the comet's orbit, a safe distance away from the dust and debris that is expected to be orbiting the Sun in that vicinity. This debris could be hazardous to the spacecraft at the fast approach speed of over 2 km/s. The burn, which may actually be broken into two parts, leaves the spacecraft in an orbit around the Sun nearly matching that of the comet, with a residual approach speed of only 45 m/s. During this and subsequent phases, the spacecraft uses a minimum of nine station passes per week to communicate with Earth.

During the approach over the next four and a half months, remote-sensing instruments send back visual and infrared images which provide an initial characterisation of the comet nucleus: its shape, size, rotation rate, pole orientation, and state of activity. It is expected that the nucleus will by irregularly shaped, like the nucleus of Comet Halley, with an average diameter of about 8 km. Its pole may be nutating and precessing. At a distance of 2,500 km, the relative speed is reduced to 2.5 m/s for the final approach. Starting with this phase, the dust counter and neutral gas and ion mass spectrometer operate continuously, broadcasting the instantaneous dust flux and gas pressure, respectively, to the rest of the spacecraft. Based on these data, instruments may choose to automatically close their dust covers for protection. Dust analysers passively collect dust particles for future analysis. Initial estimates of the mass of the nucleus are obtained during this phase, particularly during a series of successively closer flybys, with a final approach to within 50 or 100 km. This phase ends with a manoeuvre which inserts the spacecraft into orbit around the nucleus for a 500-day near-encounter phase.

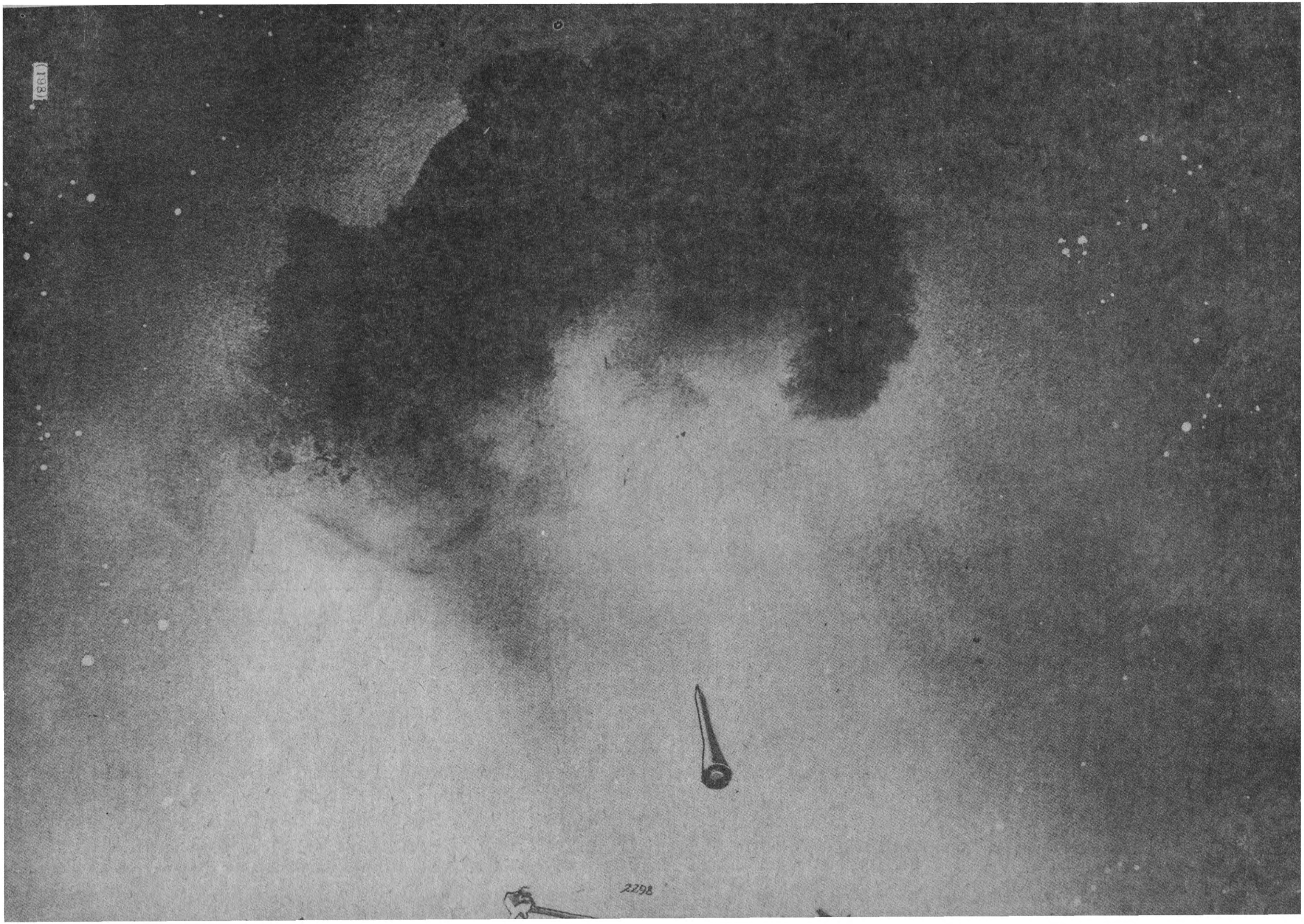


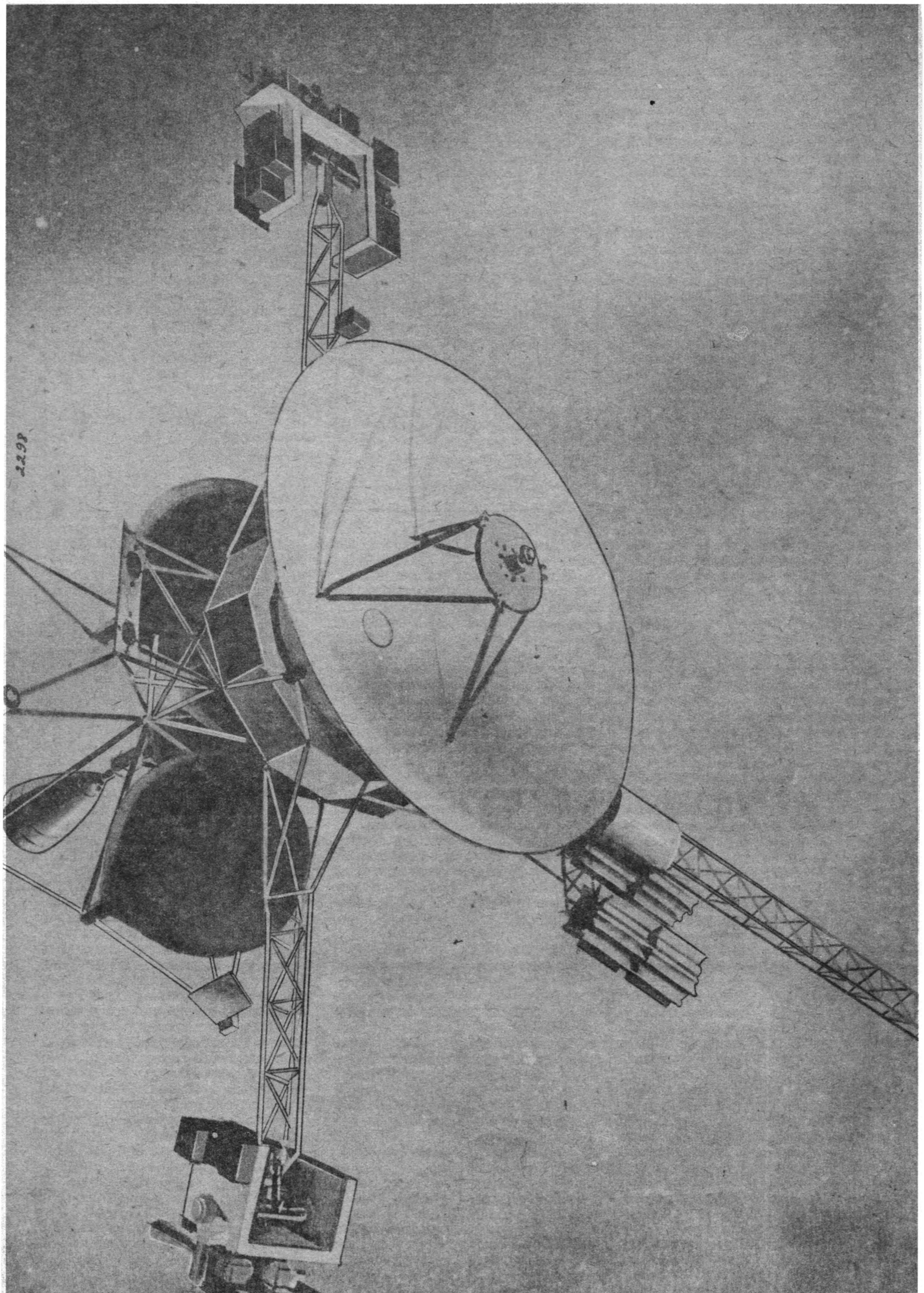
Penetrator/lander mission.

The initial orbits are planned to be circular with a period of ten days. In this gravitationally weak environment, a ten-day period corresponds to a radius of perhaps 60 km; the exact distance will depend upon the mass of the nucleus. The visual and infrared remote-sensing instruments send back to Earth detailed information about the surface composition, morphology, and temperature of the comet. Images from the narrow-angle camera have a resolution of better than one meter. Within two orbital periods, radio science refines the nucleus mass estimate to an accuracy of a fraction of one per cent. As with

CRAF SCIENCE INVESTIGATIONS

ACRONYM	INVESTIGATION	PRINCIPAL INVESTIGATOR/ TEAM LEADER	INSTITUTION
ISS	Imaging (Facility)	Dr Joseph Veverka	Cornell University
VIMS	Visual/infrared mapping spectrometer (Facility)	Dr Thomas B McCord	University of Hawaii
TIREX	Thermal infrared radiometer experiment	Dr Francisco P J Valero	NASA Ames Research Center
PEN	Penetrator	Dr William V Boynton	University of Arizona
COMA	Cometary matter analyzer	Dr Jochen Kissel	Max-Planck-Institut für Kernphysik
CIDEX	Comet ice/dust experiment	Dr Glenn C Carle	NASA Ames Research Center
SEMPA	Scanning electron microscope and particle analyzer	Dr Arden L Albee	California Institute of Technology
CODEM	Comet dust environment monitor	Dr W Merle Alexander	Baylor University
NGIMS	Neutral gas and ion mass spectrometer	Dr Hasso B Niemann	NASA Goddard Space Flight Center
CRIMS	Comet retarding ion mass spectrometer	Dr Thomas E Moore	NASA Marshall Space Flight Center
SPICE	Suprathermal plasma investigation of cometary environments	Dr James L Burch	Southwest Research Institute
MAG	Magnetometer	Dr Bruce Tsurutani	Jet Propulsion Laboratory
CREWE	Coordinated radio, electrons, and wave experiment	Dr Jack D Scudder	NASA Goddard Space Flight Center
RSS	Radio science (Facility)	Dr Donald K Yeomans	Jet Propulsion Laboratory


2298



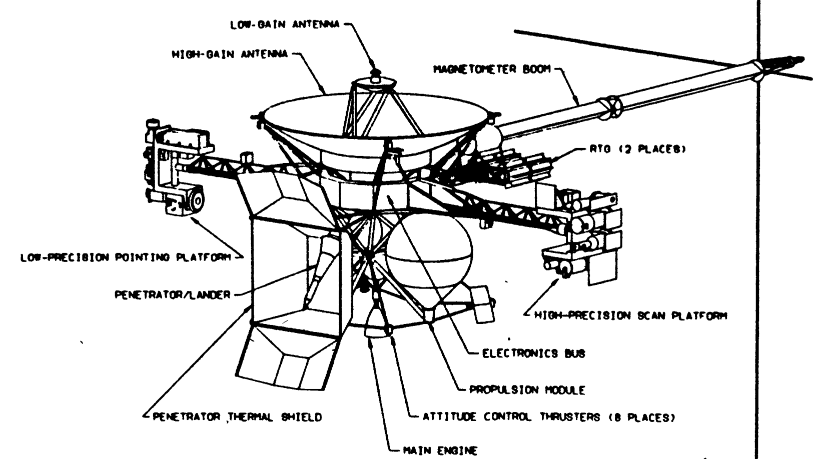
the asteroid, the mass estimate, together with a good estimate of the volume, produce the first accurate estimate of the bulk density of a comet. These data allow us to create and validate theories of the original accretion of the nucleus and of the processes that have occurred since then.

One of the results of this phase is the selection of a site for deploying the penetrator. Thought to be conglomerates of frozen gases and less volatile, organic and silicateous dust, comets may have crusts of dark, organic material. An area on the nucleus is sought where this crust is relatively thin (or absent) so that the ice below can be reached by the penetrator. A rather smooth surface is also desirable for a high probability of successful implantation. Candidate targets are selected and studied in more detail. With the site selected about a year after rendezvous, the spacecraft manoeuvres into the proper orbit for delivery. About 12 km above the site the penetrator spins up to 120 rpm, is released from the spacecraft, and, after a five-minute coast, fires two small liquid rocket engines for 50 seconds. It impacts the surface about 125 seconds later at about 40 m/s. About 1.3 m in length, the penetrator is expected to implant itself about a metre into the surface. It carries accelerometers for measuring the strength of the surface material, temperature probes for measuring thermal characteristics, a gamma-ray spectrometer to identify the elemental composition of the surrounding material, and instruments for onboard analysis of a small ice sample. The penetrator sends its data to the spacecraft at regular intervals during the next nine days for relay to Earth.

After the penetrator phase, the spacecraft continues to study the surface of the nucleus in detail with orbits of various sizes, inclinations, and orientations. As the comet and spacecraft approach the Sun, onboard instruments search for s ns of increased activity on the comet: bursts of gas and dust from weak spots in the crust, the formation of the coma, and the initial development of an ion tail. After the onset of activity, changes are expected to be visible on an hourly basis, providing an exciting movie-like scenario of the world of Comet Kopff.

At 2.5 AU from the Sun, about 200 days before the comet's perihelion, the activity is expected to have increased enough so that the spacecraft backs away from the nucleus to keep from accumulating too much dust and also to explore this interesting region of activity. No longer in orbit, the spacecraft executes about 20 slow flybys of the nucleus, approaching as close as perhaps 50 km for dust collection, but spending most of the time at distances of several hundred to several thousand kilometres. The spacecraft appears to trace out petals of a daisy around the nucleus in this exploration of the coma. While some instruments analyse dust particles for their elemental, chemical, and microscopic properties, others analyse sampled gases for their composition, velocity, and temperature. A set of plasma instruments studies the interactions of the gas and dust with the solar wind.

Centre Page: An artist's impression of the CRAF space craft and with its penetrator probe hurtling towards Comet Kopff.
NASA/JPL



CRAF spacecraft configuration, isometric view.

After perihelion, on December 12, 2002, the spacecraft begins an excursion into the comet's now fully developed ion tail. Instruments continue to study the interactions of the comet with the solar wind in an effort to understand the reasons for the constantly changing shapes of comet tails, the acceleration of energetic particles, and other plasma phenomena. Taking 90 days for the round trip, the spacecraft reaches a distance of 50,000 km from the nucleus before returning.

During the last ten days of the mission, as the comet's activity wanes, the spacecraft again flies by the nucleus for a quick assessment of changes that have occurred as a result of the perihelion passage. The nominal mission ends on March 31, 2003. If resources are available, an extended mission would be desirable, allowing a more thorough post-perihelion examination and a study of the comet's cooling-down processes for comparison to the heating-up processes already observed.

Spacecraft

As stated earlier, the CRAF spacecraft is the first of the Mariner Mark II series. These spacecraft are equipped to transmit large amounts of data to Earth over vast distances, generate electrical power far from the Sun and provide highly accurate pointing for remote-sensing instrument and delivery of penetrators and probes. By Mariner Mark II design philosophy, the spacecraft are modular and can easily be adapted to different missions. Where requirements of various missions differ, the design of common spacecraft elements is driven by the most demanding mission. The cost of over designing for the missions with less stringent requirements is more than compensated for by savings in the design, construction, test, and operation of identical components. Use of proven designs and even inherited hardware is maximised and new technology is used only when it is cost effective and a viable backup is available. Functional and block redundancy in engineering subsystems ensures spacecraft recovery from single-point failures. Standard data interfaces and telemetry formats are used to simplify the design and minimise the impact payload changes. Large design margins in mass and performance are maintained to aid in cost control.

Primary CRAF spacecraft elements include a high-gain antenna, two low-gain antennas, a ten-bay electronics bus, two radioisotope thermoelectric generators (RTG), two independently articulable instrument platforms, a fixed magnetometer boom, a propulsion module, and a launch vehicle adapter. During launch, the instrument platforms and the RTG boom are folded and latched to the adapter and the magnetometer boom is stowed in its canister. After launch and prior to separation from the Centaur upper stage, the instrument platform and RTG booms are deployed. The spacecraft is then separated from the adaptor using pyrotechnic devices and the magnetometer boom is extended.

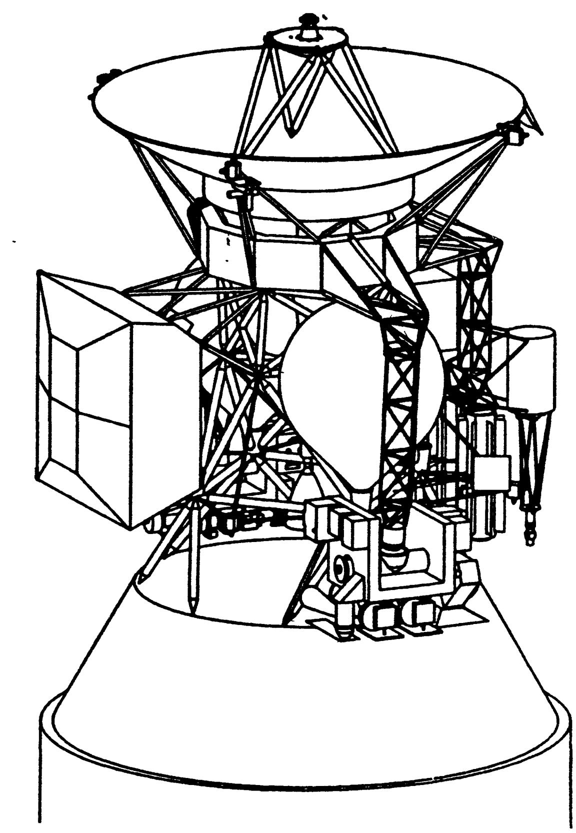
The structure subsystem integrates all spacecraft elements into the flight spacecraft system. Its main element is a ten-bay toroidal bus which houses most of the electronics and provides structural support for the spacecraft. The high-gain antenna is located on top of the bus. Two science booms are placed opposite each other to support the two instrument platforms, the high-precision scan platform and the low-precision pointing platform. These booms provide vantage points, giving the science instruments relatively clear fields of view. The magnetometer boom canister and the two RTGs are attached to a third boom. This boom lowers the RTG radiation at the spacecraft and reduces spacecraft magnetic interferences at the magnetometer. The propulsion module subsystem is mated with the bottom of the bus.

The propulsion module subsystem provides thrust for the spacecraft. Messerschmitt-Belkow-Blohm (MBB) has agreed to supply

this subsystem under contract to the German Aerospace Research Establishment (DLR) of the Federal Republic of Germany. Two large, conispherical, bipropellant tanks hold up to a total of 3,450 kg of monomethylhydrazine fuel and nitrogen tetroxide oxidizer for main rocket engine use. The main engine, used for large manoeuvres, is based on the 400-newton (90 Lbf) Galileo engine. A pressurant tank is located in the centre of the propulsion module. Reaction control system thrusters are 0.2-newton, monopropellant thrusters and are used in couples. They utilise hydrazine (N_2H_4) to provide thrust for attitude control and small manoeuvres. Four thruster clusters are placed around the perimeter of the high-gain antenna and four other clusters are placed at the bottom of the propulsion module.

The attitude and articulation control subsystem maintains three-axis control of the spacecraft and articulates the instrument platforms. The star tracker is a redundant Advanced Star and Target Reference Optical Sensor (ASTROS II) unit. It is an improved version of ASTROS I, which was to be flown on Shuttle flights to observe Comet Halley. The inertial reference units (four units in one package) are new fibre-optic rotation sensors (FORS) which have no moving parts and use light travelling through a long fibre-optic cable to determine spacecraft angular rates. Both the FORS and the star tracker are placed on the high-precision scan platform to provide two-axis, high-accuracy pointing for the remote-sensing instruments. This platform has a pointing control accuracy in inertial space of 2.0 milliradians, with 1.0 milliradian pointing knowledge, and a maximum slew rate of 17.5 milliradians per second. Its motion is momentum compensated by a reaction wheel system mounted on the propulsion module. The reaction wheels are used for nominal attitude control (including high-gain antenna pointing) of the spacecraft after comet rendezvous, with the small thrusters being fired periodically to off-load the accumulated angular momentum of the wheels. The low-precision pointing platform also provides two-axis pointing articulation. Its pointing control accuracy and knowledge are both 17.5 milliradians. Both platforms can be articulated through a wide range of angles to provide better instrument pointing without rotating the spacecraft bus. A resident microprocessor in the attitude control electronics and another microprocessor in the star tracker provide the necessary computations for the attitude control functions. Two redundant Adcole Sun sensors look along the direction of the high-gain antenna and residual Viking Orbiter gimbal actuators provide pointing control for the 400-newton engine during manoeuvres.

The radio frequency and antenna subsystems provide all the communications to and from Earth. Using only X-band frequencies (8.4 GHz), this telecommunication system includes a 3.7 metre, high-gain antenna (based on the Voyager design), two low-gain antennas, a new command detector unit (also being used by Mars Observer), a new NASA X-band transponder, a telemetry modulation unit, and a new 5.6 watt, solid-state power amplifier. The high-gain antenna size is determined by the distance between Saturn and Earth for the Cassini mission; a smaller antenna would be sufficient for the CRAF mission. The downlink data rates vary between 13 and 115 kilobits per second depending on the distance between the spacecraft and the Earth and the particular ground station being used. A low-gain antenna is used in the event of an emergency and during main engine burns, during which time the high-gain antenna is not able to point toward Earth. It is also used when the spacecraft is near Earth.



CRAF spacecraft configuration for launch by Titan IV/Centaur.

The power and pyro subsystem regulates and distributes all of the power needed by the spacecraft. This 30-volt DC power is supplied by two RTGs capable of providing 557 watts at the beginning of the mission. Two batteries, of 135 watt-hour capacity each, provide energy storage and allow intermittent engineering and scientific loads above the RTG capability. They are connected to the power bus through bidirectional converters.

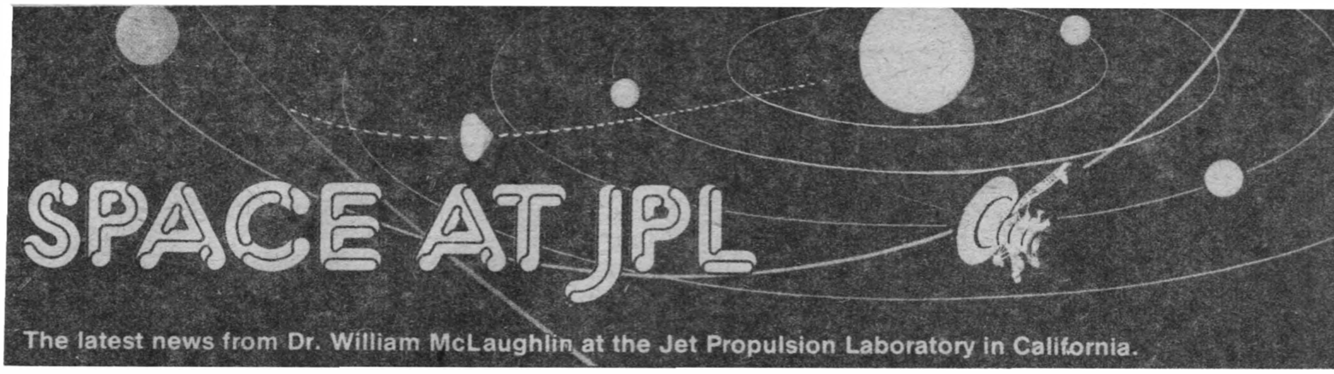
The command and data subsystem receives commands from Earth through the radio frequency subsystem and distributes those commands along with certain engineering data to the appropriate subsystems. It also collects telemetry packets from the subsystems either for transmission to Earth or for temporary storage. System-level fault detection and correction algorithms are resident in the command and data subsystem memory to ensure spacecraft integrity. The high-level programming language C is used to keep software development and maintenance costs low.

The data storage subsystem provides storage mediums for on-board data during times which downlink telemetry is not available or when the amount of onboard data exceeds the downlink capabilities. This subsystem uses a spare Galileo digital tape recorder with 0.9 gigabits of capacity. Four record rates up to 403.2 kbps and four playback rates up to 100.8 kbps are available. In addition, redundant 35-megabit, solid-state buffer memories provide data rate matching between the subsystems and the tape recorder, as well as between the tape recorder and the downlink. The buffers are also used as a backup to the tape recorder for critical data such as optical navigation frames and the penetrator relay data.

In addition to the above subsystems, thermal control of the spacecraft is provided by traditional methods such as electrical heaters, radioisotope heater units, multilayer insulated blankets, louvres, and radiators. Mechanical devices deploy and hold in position the instrument platform booms, the RTG boom, and the magnetometer boom.

Summary

The CRAF mission offers an opportunity to explore the mysteries of a comet during an extended rendezvous; it is the next logical step in the exploration of these remnants from the formation of the solar system. CRAF will also contribute to the reconnaissance of the other major class of primitive bodies, the asteroids. The vehicle to be used will establish a new, modular design for spacecraft which can carry out sophisticated missions in the outer solar system.



Neptune Encounter Begins

On June 5, at 6 hr 42 min 23 sec UTC (in spacecraft event time) at a range of somewhat less than 120 million km from Neptune, Voyager 2 will enter its "Observatory Phase" signalling the start of the planetary encounter which will last until October 2, with closest approach to the planet occurring at 04:00 UTC on August 25. This will be the fourth and last planetary encounter for the spacecraft that was launched on August 20, 1977 and will complete the Grand Tour of the giants Jupiter, Saturn, Uranus and Neptune.

Already, images of Neptune from Voyager 2 and from Earth-based telescopes indicate that the atmosphere of the planet displays features, unlike the bland face of Uranus. Previous flybys of Jupiter and Saturn by Voyagers 1 and 2 (Saturn was the last planetary encounter for Voyager 1; it is now in cruise toward interstellar space) determined that they have internal heat sources, which are a factor in their noticeable atmospheric dynamics. No internally generated heat was measured at Uranus. Hence, it is reasonable to anticipate that Neptune may possess some interesting internal processes to accompany its visual attractions.

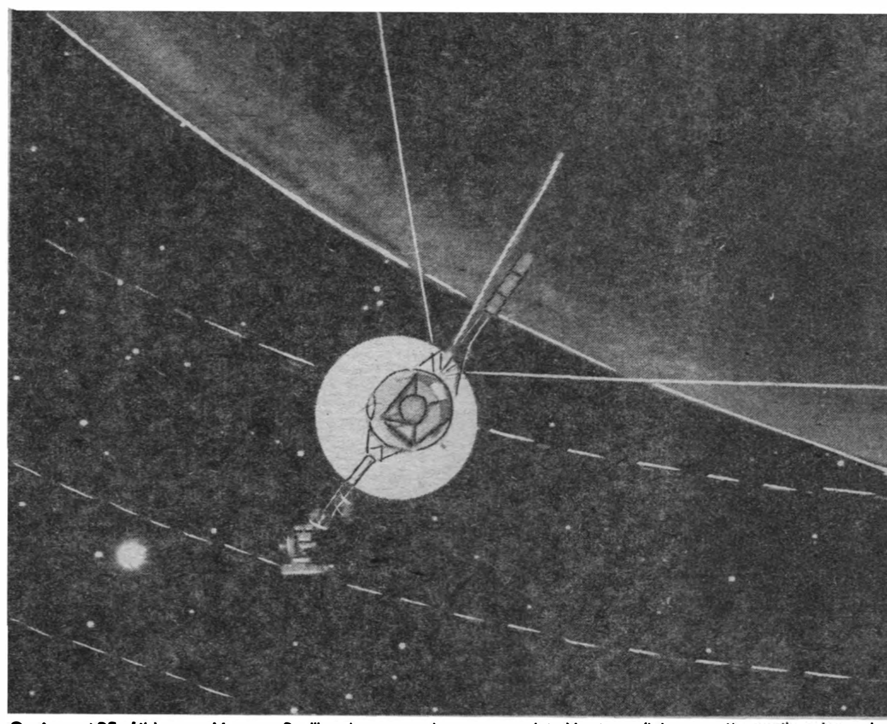
The anatomy of the encounter consists of four phases: Observatory (as mentioned above), Far Encounter, Near Encounter, and Post Encounter.

The Observatory Phase extends to August 6. It features synoptic views of the Neptunian system - the imaging system will be used to produce movies of atmospheric dynamics and the ultraviolet spectrometer will be scanned across the system - fields and particles measurements, instrument calibrations, and a trajectory correction manoeuvre.

Far Encounter begins at approximately 27 million km from Neptune and lasts from August 6 to August 24. The increasing apparent size of the planet permits atmospheric heat-balance studies and higher-resolution images (including views of the satellites Triton and Nereid and the possible system of rings) along with more movies. Two trajectory correction manoeuvres are scheduled for this phase.

The centrepiece of the flyby is the Near Encounter Phase, August 24 to August 29. During this time high-resolution remote sensing, probing of Neptune's and Triton's atmospheres with electromagnetic waves, and sampling of the fields-and-particles phenomena inside the magnetosphere will supply the highest-value science of the mission. Near Encounter observations were described in some detail in the December 1988 edition of "Space at JPL".

The Post Encounter Phase extends until October 2, when Voyager 2 will be about 56 million km beyond Neptune. It represents a last chance to gather data with the complement of 11 scientific experiments before the spacecraft sweeps well beyond the most distant planet. (In the December piece I erred in saying that Neptune would retain most-distant status until early in the next century. Roy D. North of Colorado Springs, Colorado, informed me that eccentrically orbiting Pluto will regain its distinction of being the most distant known planet on February 9, 1999.)



On August 25 of this year, Voyager 2 will make a very close approach to Neptune, flying over the north-polar region of the planet. At this distance the Sun shines with a brightness of only about one-tenth of a per cent of its apparent radiance at Earth. *NASA/JPL*

Norman R. Haynes is the project manager for Voyager. Prior to this assignment he managed the Systems Division at JPL and has held a variety of key positions at the Laboratory, including Mission Analysis and Engineering Manager for the Mariner 9 Mars-orbiting mission, launched in 1971. We discussed the plans that the Voyager Project has formulated to maximise the probability of successfully completing its survey of the Neptunian system, and the results of our conversation are reported below.

Last August the project compiled a list of possible events that could pose threats to the mission and ranked them in priority order, assigning a relative risk category to each (high, medium or low) and identifying the actions being taken to protect against loss. Nineteen items appeared on the list, and although Haynes said that subsequent knowledge would probably reorder the risk rankings if a recompilation were made, it is instructive to review the evaluation.

The first high-risk potential problem on the list would materialise if Voyager 2 lost its one remaining radio receiver and was therefore unable to receive commands from Earth. This concern is an old one, the primary radio receiver having failed in 1978, prior to the encounter with Jupiter. Partial protection against this contingency is provided through the means of a "Backup Mission Load" (BML): a sequence of commands carried on board the spacecraft and automatically activated in case of a receiver failure. This BML would autonomously conduct a reduced survey of the Neptunian system and send the data back to Earth.

The second of the two items in the category of high risk (again, relative to the other items on the list, not "high" in an absolute sense) would occur if one of the two Flight Data Subsystem (FDS) Computers were to fail. The Voyager spacecraft has two of these solid-state devices and one failed on Voyager 1 several years ago. Failures of isolated groups of memory cells of the FDS have been experienced on Voyager 2 over the years. The FDS is used to control the state of the instruments and to format data prior to transmission to Earth. Protection against this type of failure is provided by alternative software which could be loaded into the remaining FDS to accomplish the essential functions of this subsystem.

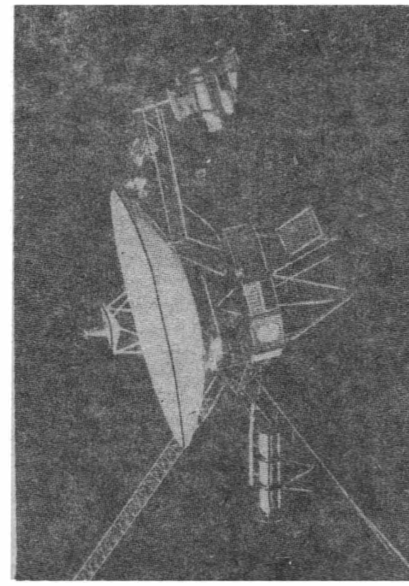
Entering the category of medium risk, we move from the domain of potential flight-hardware anomalies to activities conducted by people on Earth. Problems three and four on the

list focus on concern over the high activity required by the flight team in the time period around closest approach. The primary purpose of such activity is to incorporate the latest information about the Neptunian system and the spacecraft's ephemeris into the command loads for the spacecraft. Complex tasks, having to be done quickly, can breed errors. The response of the project has been to conduct a comprehensive series of test and training exercises, the most intensive in Voyager's history.

Skipping down the list to problem seven (medium risk), we find provisions made to cope with an earthquake or other natural disaster if it should knock out command and control facilities at JPL. A copy of the command load covering closest approach will be held at one of the tracking stations of the Deep Space Network and would be uplinked to the spacecraft at the appropriate time.

Environmental problems at Neptune, related to unexpected ring material, intensive flux of high-energy charged particles, or drag from a hyper-extended planetary atmosphere appear at the twelfth position on the list (low risk) and are treated by a variety of prophylactic measures. For example, a late trajectory-correction manoeuvre can adjust to a small degree the relation of the spacecraft's trajectory to regions of observed ring material. Software has been installed onboard the spacecraft to protect against the most deleterious effect from high-energy charged particles: introduction of timing offsets between Voyager's various onboard computers. In case the atmosphere of Neptune is more extended than current models predict for this north-polar flyby a few thousand km above the cloudtops, the control authority of the spacecraft's attitude-control system will be strengthened (to deal with torques which would be introduced by atmospheric drag). This strengthening will be accomplished by commanding the spacecraft's attitude-control thrusters, which periodically emit bursts of hydrazine to keep the spacecraft in equilibrium about its nominal attitude (orientation), to fire more than the usual amount of hydrazine propellant through their nozzles, per burst.

The mission has been carefully devised to obtain important scientific information from this distant outpost of the Solar System, and bulwarks against many of the slaps of chance are in place. Haynes summarised the status of the Voyager Project as the encounter begins: "we're ready".



The 3.7 m high-gain antenna dominates the visual aspect of the 815 kg Voyager spacecraft. *NASA/JPL*

Mountain Waves and Polar Ozone

Bruce Gary was staring out the window of an airliner on the way to Mexico in 1977 and, seeing some nearby cirrus clouds, speculated how useful it would be to know temperature profiles in that region. With knowledge of temperatures throughout a region of the atmosphere, Gary reasoned, dynamical behaviour, such as cloud formation and the clear air turbulence which shakes up airliners, might be more easily understood and predicted. A chain of events leading from the 1977 commercial flight to his recent instrumented flights of research over polar ice fields is infused with serendipity, according to Gary.

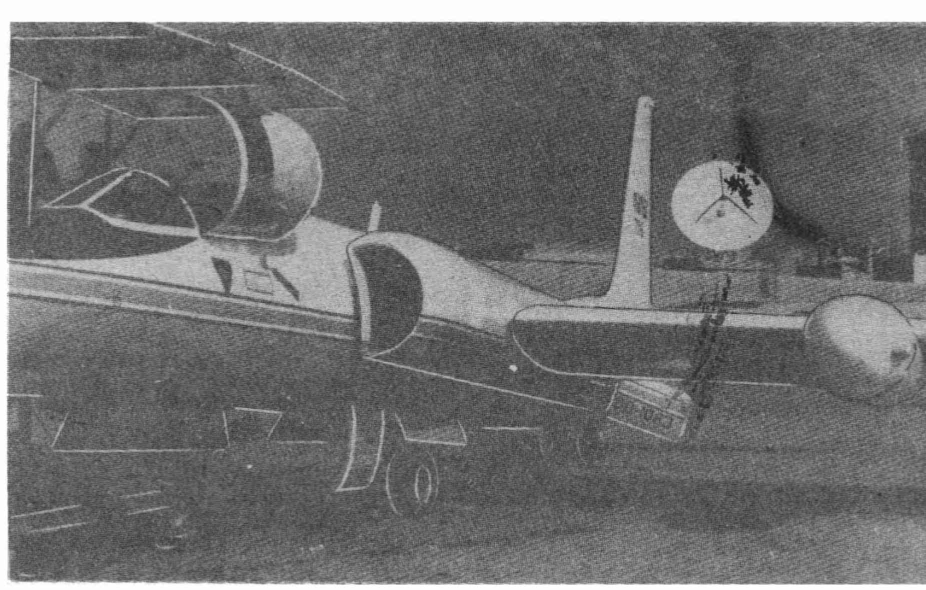
The Microwave Temperature Profiler (MTP) is Gary's answer to the challenge of obtaining temperatures at a distribution of altitudes in the atmosphere. The physical principle on which the instrument operates is the detection of microwave emission from oxygen molecules, which comprise about 21 per cent of the atmosphere by volume. Technically, it is a passive microwave radiometer operating at the frequencies 57.3 and 58.8 GHz, corresponding to a wavelength of approximately 6 mm. Thus, like a telescope it sits and waits for data to arrive, unlike active instruments (such as Magellan's synthetic aperture radar) which send out energy and then detect patterns and times of its return.

The MTP measures the number of photons per second at the receiving frequency and direction and thereby measures a quantity called "brightness temperature," which can be used to determine the physical temperature of the air at a specified distance along the line of sight of the instrument. When operated from an ER-2 aircraft at 20 km, the MTP measures air temperatures at about 1 km from the instrument with one frequency (58.8 GHz) and about 2 km distant with the other frequency. The mode of operation is to sweep the instrument's sensing antenna along an arc contained in a vertical plane and spanning ± 60 degrees from the horizontal. The MTP does not measure temperature continuously along the arc, which it traverses in 14 seconds. Rather, it pauses briefly at each of 10 points to accumulate enough photons to produce a respectable singal-to-noise ratio. Calibration is performed on every sweep using a microwave absorber of known temperature located a few centimetres from the antenna.

The MTP weighs about 25kg and mounts easily in a spear pod on the wing of a NASA ER-2 research aircraft (derived from the famous U-2 reconnaissance airplane employed by the military). Gary said that the MTP is the only airborne instrument of its kind, although microwave radiometers have been operated from the ground and installed in satellites. In fact, the MTP is a spin-off from an instrument carried onboard the Nimbus 6 satellite.

The original direction of Gary's studies was to develop techniques for measuring temperature profiles that might be employed in the direction of clear air turbulence, and to this end he flew a precursor of the MTP mounted in a Convair 990 aircraft of NASA in 1978, later transferring his operations to NASA's Kuiper Airborne Observatory, a modified C-141 which has made significant discoveries in astronomy. The microwave radiometer was also able to detect in real time the location of the tropopause, that temporally and geographically varying boundary between the troposphere - the lowest layer of air, in which most weather occurs - and the stratosphere; the tropopause usually exists somewhere in the region 10 to 15 km above the Earth's surface.

The Microwave Temperature Profiler (MTP), visible as a small cylindrical projection from the spear pod on the wing of a NASA ER-2 aircraft, has been used to measure atmospheric temperatures in support of ozone research over polar regions. *NASA/JPL*



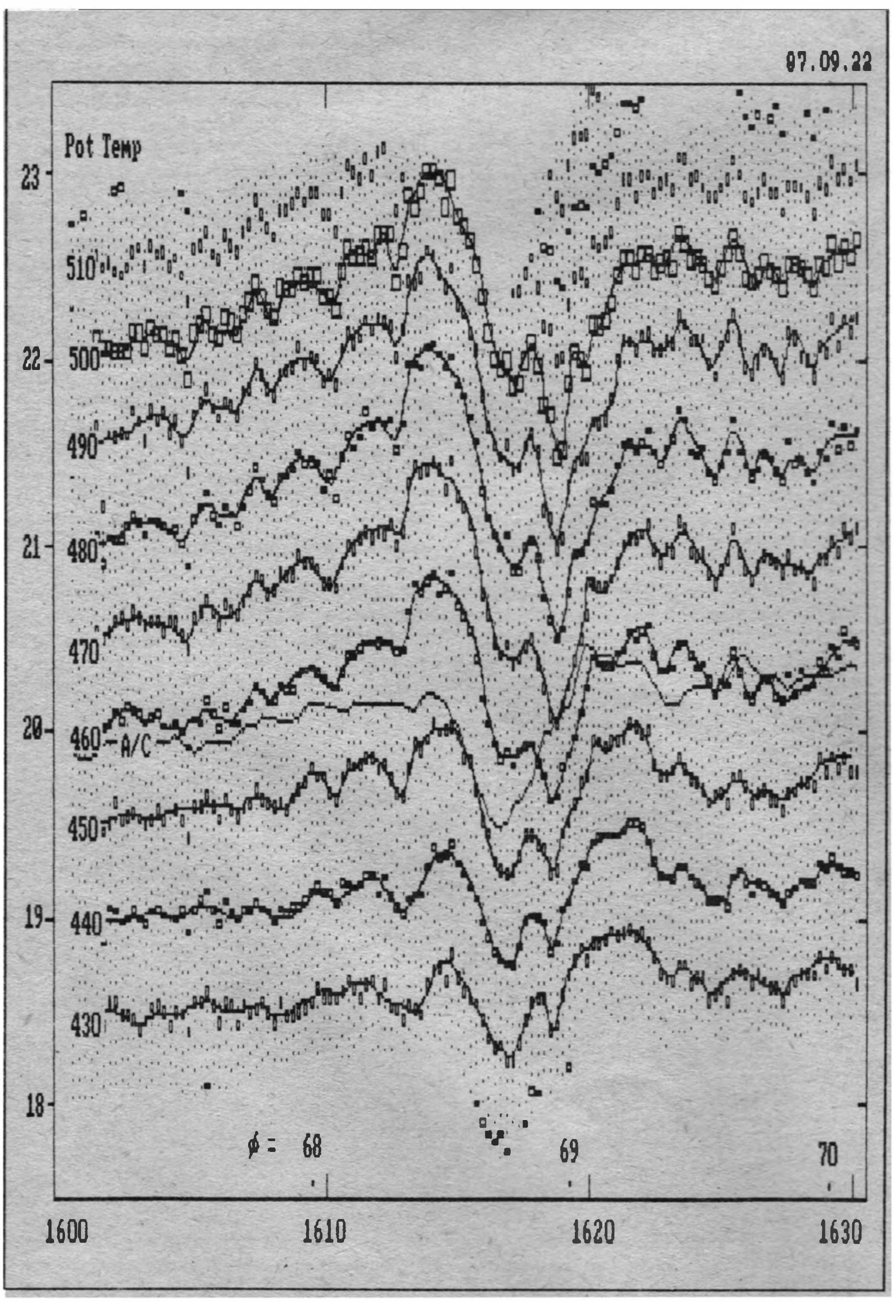
Operation of the MTP in the ER-2 aircraft commenced with the Stratospheric-Tropospheric Exchange Program (STEP) conducted over Australia in early 1987. This programme, which owes much to Ed Danielson of NASA's Ames Research Center, was planned for the purpose of determining why the stratosphere is so dry compared to the moist troposphere. Data collection by the STEP team was successful but has not yet been analyzed because the recently discovered decrease in ozone over Antarctica was designated a high-priority research item and has absorbed the energies of investigators. The stratospheric layer of ozone provides protection against the harmful biological effects of solar ultraviolet rays.

For 50 days, beginning in August 1987, 14 instruments were operated on an ER-2 flying over Antarctica in a multidisciplinary effort to investigate why ozone was apparently depleted from its stratospheric repository during the Antarctic spring. (Another expedition to Antarctica in September-October 1986, headed by Dr. Crofton B. Farmer of JPL and utilising a Michelson interferometer, is described in the December 1987 edition of this column.)

Gary's MTP was included in this suite of instruments for the purpose of locating the edge of the south polar vortex: the continent-sized swirl of air that circulates around the pole and which can be located through characteristic temperature and wind signatures at its boundary. It turns out to be most useful to convert MTP measurements to a quantity called "potential temperature": the temperature that the parcel of air would have if it were transported to the Earth's surface without exchange of heat energy ("adiabatically"). Surfaces of equal potential temperature are called "isentropes." While studying the edge of the vortex Gary constructed diagrams showing the altitudes of several isentropic surfaces versus time. Serendipity stepped in when he unexpectedly found large wrinkles in the isentropic diagrams. Normally such surfaces would more-or-less parallel the surface of the Earth. Correlating the atmospheric data with the ground track of the airplane revealed that the idiosyncrasies in the profiles faithfully tracked the presence of mountains; Gary had detected "mountain waves" in the stratosphere. Previously, it had not been known if mountain waves could propagate so far into the stratosphere and exhibit such large effects.

The Microwave Temperature Profiler (MTP) was used to obtain measurements of "potential temperature" at various altitudes and geographic locations over Antarctica. Altitude (km) is plotted on the vertical axis and the time of measurement (aboard the ER-2 aircraft) on the horizontal axis. The large fluctuations in potential temperature represent "mountain waves" generated by the underlying topography and may play a role in ozone depletion in the polar stratosphere.

NASA/JPL



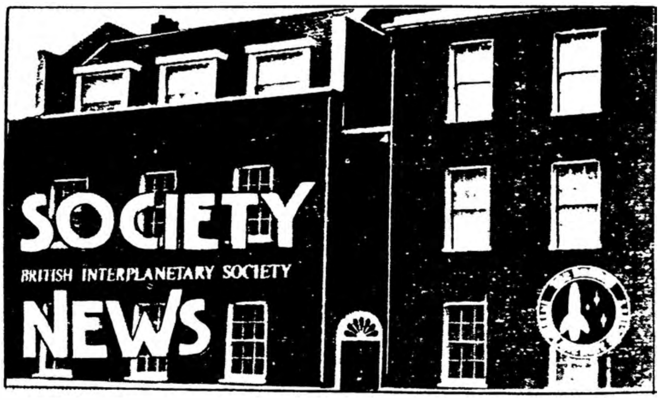
The significance of these waves is that a parcel of air, circulating with the polar vortex, moves along one of the surfaces of constant potential temperature and, encountering a mountain wave - a wrinkle in the mathematical surface - is lifted up about one-half km, then down one km and then back up one-half km to its original altitude, resuming horizontal motion. The parcel of air will cool in "real" temperature about 5 degrees Kelvin (although its potential temperature remains constant) during its initial rise in altitude, promoting the formation of polar stratospheric clouds.

Polar stratospheric clouds (PSC) have assumed an important role in ozone-depletion studies since it is believed that they constitute a workshop where that ozone killer, chlorine, is generated. The original source of much of the chlorine is thought to be from man-made chlorofluorocarbons. (See the March 1988 edition of this column for a review of the pertinent chemistry).

The importance of the role of PSCs associated with mountain waves in ozone destruction has yet to be determined, but in addition to their potential for facilitating the production of chlorine, Gary said that they also may play a part in denitrifying portions of the stratosphere. Compounds of nitrogen, particularly naturally occurring nitrogen dioxide, neutralise chlorine and hence prevent its destruction of ozone. The cooling of an air parcel as it rises has the potential to form water-ice particles, wrapped around nitrogen-containing cores. If the ice-coated particles are sufficiently large, they will fall under the force of gravity out of the air parcel before they have the chance to evaporate upon being subsequently warmed: denitrification would have taken place in that layer of the stratosphere.

Late last year Gary left for the Arctic in order to conduct additional ozone-related studies. Mountain waves like those over Antarctica were not detected, but conversations with PSC theoreticians on the expedition revealed that the models they were using for simulating a parcel's temperature versus time were not consistent with data obtained through his MTP usages over the years. They had overlooked a component of short-timescale temperature fluctuations (which are apparent in the MTP data) that must be added to the slowly varying temperatures in their simulations. Since temperature histories are crucial to models of PSC formation, and hence ozone balance, Gary's introduction of the so-called mesoscale domain of temperature fluctuations has begun to influence our understanding of an important aspect of cloud microphysics.

The understanding of the extent and mechanisms of ozone depletion is a difficult scientific problem that is slowly yielding to a multidisciplinary, international effort. There is commitment as well as analysis in Gary's work: "We are just one species on this living planet, and we have a responsibility, by virtue of our powerful understanding and insight, as well as our role in creating the environmental threat, to take a caring custody of our planet, and of the other life forms with whom we should share in gratitude."



Apollo 11 Celebrations

The Society is marking the 20th Anniversary of the first lunar landing on July 21, 1969 by holding an Anniversary Dinner at its headquarters. Guests of honour will include Patrick Moore, Keith Wright of the European Space Agency and David Wilkins of the European Space Operations Centre. Details appear in Society Meetings Diary overleaf.

The attention of members is drawn to the special series of four evening lectures to be given during the preceding month by well-known speakers and authorities on space. TV space news reporters Reginald Turnill and Frank Miles open the series on June 21. In the following week, Douglas Arnold recalls the Apollo story with a presentation from his extensive collection of space photography. The next lecture is by Bob Parkinson, author of the Society's book 'High Road to the Moon' which so impressively compares early BIS ideas on lunar exploration with its subsequent realisation in the Apollo Program. The final lecture during the preceding month highlights some of the scientific achievements of Apollo and is given by Keith Wright on Instrumentation on the Moon who was personally involved in the ALSEP (Apollo Lunar Surface Experiment Package) programme.

These lectures are highly recommended as an opportunity for members to recapture the spirit and excitement of Apollo and the beginning of lunar exploration. All lectures start at 7.00 p.m. and last for approximately 1 hour. Admission is by ticket and members should apply to the Society by letter in good time. This is particularly important for anyone who must travel some distance to attend. Attendance is restricted to Society members but, subject to places being available, each member may also apply for a ticket for a guest.

Inmarsat 10th Anniversary

The completion by Inmarsat of its first 10 years of operation is noted by the Society with particular pleasure as many developments essential to Inmarsat's role were foreseen and featured in Society discussions in earlier days.

Basic to high quality and reliable mobile communications is a geostationary communications satellite system, the idea of which was first proposed in 1945 by Arthur C. Clarke who, in the following year held office as Chairman (now President) of the Society.

Inmarsat will be holding a conference and exhibition in London on July 17-19 1989 to mark its 10th Anniversary and we are happy to record that Arthur C. Clarke will be delivering a Special Message to the conference by video, giving his personal view on the future implications of mobile satellite communications.

The first conference to be held in London on maritime satellites was organised by the Society on April 18, 1974, with the proceedings published in the October 1974 issue of **JBIS**. 1976 saw the beginning of mobile satellite communications using the Marisat system and in 1979 Inmarsat was created by international conference to organise a global service, which subsequently came into operation in 1982.

Later that year, when the Society held its SPACE '82 conference as part of its 50th anniversary celebrations, the Conference Banquet (***Spaceflight***, March 1983) was addressed by Olof Lundberg, the Director-General of Inmarsat, who has continued to head the organisation to the present.

Highlights of Inmarsat's recent history emphasise its rapidly expanding role in aeronautical and mobile land communications:

1985: Amendments to the Inmarsat convention to include aeronautical services

1987: World Administration Radio Conference assigns frequencies in the aeronautical and maritime bands to land mobile services

1988: Inmarsat begins land mobile trials

1989: Amendments to the Inmarsat convention include provision of land mobile services

1989: First public telephone call is made from a commercial aircraft *via* satellite, using the Inmarsat system

1989: Inmarsat begins Standard-C service using low-cost lightweight terminals.

The words of Olof Lundberg at the 1987 Satellite Summit Conference expressed Inmarsat's potential future: "I truly believe", he said, "that, through satellite technology, we now have the capability of providing communications for anyone, anywhere, even while he or she is on the move - in the air, over the seas or on land. Making that happen is up to us".

Our congratulations are extended to Inmarsat on its 10th anniversary with all good wishes for a great future.

Derek Webber Takes Up New Post at Inmarsat

Our congratulations to Derek Webber, a Fellow of the Society, on his appointment as Procurement and General Services Manager at Inmarsat's headquarters in London. Derek Webber has held a number of Inmarsat posts during the last seven years, including responsibilities for traffic forecasting, charging, financial evaluation and control, and most recently as Commercial Manager where he has been contributing to the market development of Inmarsat's new services in the aeronautical and land mobile areas. His professional involvement in space activities goes back as far as 1966 when he was an engineer carrying out launch vehicle and satellite thermal design work at Hawker Siddeley Dynamics, now part of British Aerospace.

Derek Webber

Marble Floor for HQ Entrance

For the last year the entrance hall to the Society's premises has been a scene of upheaval as various stages in the renovation of the building have been put in hand. Accounts of this work have already appeared in Society News (***Spaceflight***, January 1988 and March 1989).

The entrance hall itself is now benefitting from a 'face-lift', a major undertaking being the lowering of the hallway floor level by the equivalent of one step in height. This has led, in turn, to lowering the doorways to adjoining rooms, including that to the Conference Room. An important advantage to be gained from this is that the hallway, Reception Office and Conference Room

are now all on the same level. The removal of the step into the Conference Room is welcome from the safety point of view, particularly at the time of meetings when members and visitors, who may not be familiar with the surroundings, are on the move.

Another doorway affected by the change of floor level is the main entrance to the building. The existing door has been replaced by a new one to the required size in teak with all brass fittings. The outside entrance plinth has also been lowered and re-tiled.

On entering the building, the members' reception room, which lies to the right of the hallway, is accessed through an open arch, enlarged during the renovation work to allow for easier movement at busy times. The hallway, which comes in for continual use, was in need of a floor covering that would be serviceable over the years and match up to all conditions of weather and use. Marble was an obvious choice.

Commenting on the laying of the marble floor, the Executive Secretary said, "I see this as a major milestone in our refurbishing programme. Much of the work undertaken to date has been of a structural nature, such as rebuilding and strengthening walls and joists, alterations to ceiling heights and the layout of underground water pipes, electrical, hot water, security and telephone installations. Only a minimum has so far gone on 'visuals' such as tiling, lighting and decor, which add so much to the impression of a building. With the marble floor down, we have reached a turning point and from now on our improvements will become increasingly more apparent".

The transformation taking place at HQ is something that all members will be happy to see as not only worthwhile and necessary but more adequately reflecting the Society's role and status.

Joint International Conferences

The following conferences are being cosponsored by the Society:

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.

A NOTE FOR YOUR DIARY

Members may like to note the following forthcoming major events:

1. **SPACE '90** to be held on September 28-30, 1990 at the White Rock Theatre, Hastings. The meeting has the theme "Steps to Space" and will include a Reception and Dinner.

2. For the International Space Year (ISY), the Society plans to hold its **SPACE '92** meeting on October 2-4, 1992. The venue will again be Hastings and the theme will be "Space: Springboards to Success".

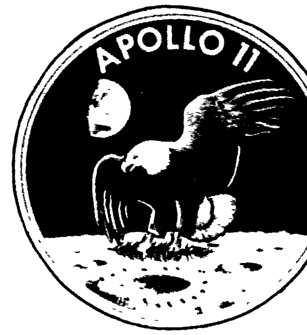
3. An extensive range of European activities for the ISY is to be expected. The European ISY Association, (EUR-ISY 1992) has been set up for this purpose. A general theme to be highlighted is 'Mission Earth' which will embrace work on surveillance and monitoring of the environment, extending the use of satellite remote sensing and improving weather forecasting.

4. In 1993, the Society's Diamond Jubilee year, a special **SPACE '93** will be held in London.

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 7.00—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 7.00-8.30pm

LEGACY OF APOLLO

A personal selection by Douglas Arnold of striking photographs - some well known, others little seen - recording Man's first steps on the Moon.

5 July 7.00-8.30pm

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 6.30 for 7.00pm

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 include Patrick Moore, Keith Wright of the European Space Agency and David Wilkins of the European Space Operations Centre.

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

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 Executive Secretary.

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

13 September 1989 10.00am-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 chosen 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.

Lectures

4 October 1989 7.00-8.30pm

BEHIND THE SCENES WITH MAGELLAN, VOYAGER AND GALILEO

Interplanetary exploration is showing a strong resurgence in 1989 with three major events leading the way: The Magellan launch to Venus, Voyager 2's flyby of Neptune and the Galileo launch to Jupiter. Bill McLaughlin, who is involved with all three projects at the Jet Propulsion Laboratory, will outline the missions and provide insights into the actual progress and results to date of these three endeavours.

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

Soviet Space Secrecy

Sir, As one deeply interested in the Soviet space program, I am thrilled to see the new *glasnost* making its presence felt as more and more details of their mammoth undertakings are slowly revealed to the world.

However, let us not become too enraptured by these welcome benefits of their new-found confidence. Soviet paranoia runs deep, along with their obsession with secrecy, and much has yet to come before true openness becomes a reality.

How long until we are finally treated to comprehensive documentation, film, and more importantly, quality colour stills (to match those released by NASA over the past 25 years) of such things as: the Sputnik launches; the Vostok and Voskhod programmes; the truth about Soyuz 1; details concerning the Zond series; the G-1 superbooster; Cosmos 434; the early Proton launches; the Soyuz 4/5 crew transfer; the truth about Soyuz 10; much more about Salyuts 1-7 (particularly exterior and interior shots of the first five stations); the KRT-10 radio-telescope experiment; Cosmos 1267, 1443, and 1686; many more EVA stills; and footage of the doubtless spectacular Soyuz T-10 launch abort; to name but a few.

There are many other mysteries which the Soviets still stubbornly refuse to resolve - far too many to even begin to list individually here. Much has happened since Gorbachev came to power, but let us not forget that this has merely been a teaser of greater things yet to come.

GUY PARRY
Melbourne, Australia

Challenger Accident

Sir, I would like to augment the recent article(s) by Ali Abu Taha shedding new light on the Challenger disaster by pointing out that the team investigating the black smoke puffs at launch calculated what the value of internal pressure would be for certain vibration rates of the casing [1]. The (different) team who graphed the 58-63 second period 'flicker' found a very dominant 30 per second fluctuation [2].

As 30Hz corresponds to at least 1200 psi [1] (double what it should have been), the obvious conclusion is that the SRB events, the 'jets' etc, were from overpressure transients *inside* the fuel.

The pattern is that of internal explosions, not melting.

A clear flame path well to one side of the famous joint hole runs down the SRB side at 274 degrees, implying a hole about 10 feet above the joint. This evidence is from the recovered pieces but there is further corroboration from cracks in the ET which ran into ET seam "2060" opposite the joint *from* an origination point near ET seam 1861 (the next seam above) [3]. Again, juxtaposition of facts previously considered in isolation, leads to a major conclusion: *ET breakup was precipitated by ejecta from the 274 degrees hole.*

We note also that the origination point of the 'flicker' [4] has the horizontal coordinate: Z - 45 (inches) = 324.8 degrees +/- 3 degrees. Though close enough to *vertical* bounds set by photographic detail to be on the joint, a 322-328 degrees location is too far off *horizontally* to involve the upper piece at all and must penetrate the side *below* the joint (the upper piece hole runs 294 degrees to 316 degrees).

Typical airline accident probes last 1-2 years, but the Rogers Commission had a 90 day limit, precluding the interrelation of all facts. This work *must* be *continued* and the lessons applied, or the accident rate will remain 4 per cent.

CHARLES WILSON
Ohio, USA

Reference
Appendices (vol. II-V) of the *Presidential* (Rogers) *Commission Report on the Space Shuttle Accident* (note 1: vol. V, p.1350, 2: vol. III, p. N-35, 3: vol. III, p. 0-405, 4: vol. III, p. N-85: but of the typos on p. N-84).

Ed. *NASA has recently reassessed the risk.* *See p.187 .*

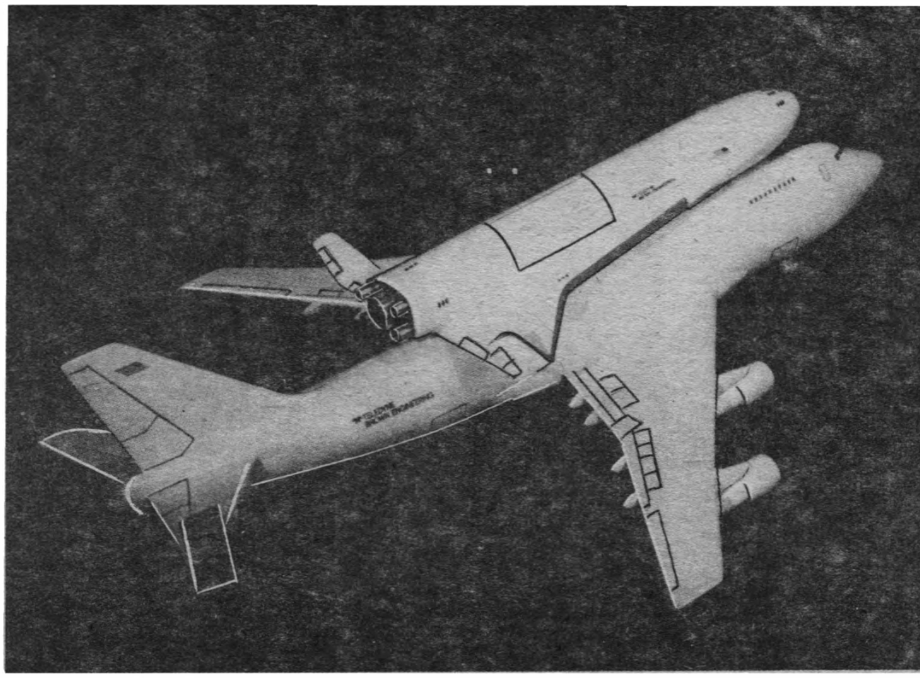
Apollo Videotape

Sir, in spite of the surprising revelation that NASA has apparently not preserved direct video recordings of Apollo television transmissions (***Spaceflight,*** November 1988, p.437), these historic transmissions fortunately still exist in their original form on videotape.

I am aware that the CBS television network in the United States has preserved videotapes, because in 1981, it put on sale an 80-minute video cassette on the Apollo 11 flight which includes videotaped highlights of the launch, the EVA, and the splashdown. Also included in the cassette are brief videotaped highlights from the Apollo 8 flight, and moonwalks from Apollo 14, 15 and 17. A short videotaped clip of a Gemini launch is also included, while previous flights are covered in the cassette with filmed newsclips transferred to video. The cassette, called "Man on the Moon," was produced by MGM/CBS Home Video for its "CBS News Collectors" series.

With the existence of this video cassette, it is safe to assume that at least CBS has preserved videotapes of its coverage of early US space flights. Perhaps other television networks have done likewise. It is certainly unfortunate that NASA has chosen to preserve these transmissions only on film, given the historic significance of these broadcasts and the generally poor quality of video transferred to film.

CHRISTOPHER GAINER
Montreal, Canada



The Teledyne Brown Engineering Spaceplane is a conceptfor an unmanned space launch vehicle that could be built with current technology. Complete reusability and engine-out capability allow it to reliably carry several tons to low Earth orbit and back at low cost. *Teledyne Brown Engineering*

Air Launch Into Orbit

Sir, I would like to reply to comments about air-launched spaceplanes made by Mr. Hassan in the April issue of ***Spaceflight***. The Teledyne Brown Engineering (TBE) spaceplane was sized to take advantage of the maximum lift capability of the Boeing 747-200F with some features of the -400 model added. The gross spaceplane weight of 182,000 kg was well in excess of the rated lift capability of the airplane, even with reduced airplane fuel load. 9,000 kg of additional wing spar structure was added to accommodate the extra mass, and it was assumed that the orbiter's incidence angle could be controlled in flight to allow use of the spaceplane wings to shorten the takeoff roll. At least half of the spaceplane's liquid oxygen would have been carried in a dewar located low in the 747 until flight velocity was great enough for the orbiter wings to carry some of the load. (A more important reason was to keep the 747 from rolling upside down just after takeoff). Engine thrust did not determine the orbiter gross weight; optimum weight for the available thrust is higher.

If the HOTOL design were to be changed to allow air launching, the wings could be made smaller and much lighter. This is because they would not need to lift the gross vehicle weight if the carrier aircraft provides some initial upward trajectory. Maximum TBE spaceplane wing lift was less than half the gross weight. Airplane thrust augmentation is needed to allow a climbing trajectory. In the case of the TBE spaceplane, the four small RL-10 rocket engines were to be started and run at reduced thrust to provide this.

Teledyne Brown displayed a model of the spaceplane at the 1987 Paris Air Show, and the Soviet delegation did indeed show considerable interest.

DAN DeLONG
Alabama, USA

Lunar Arches

Sir, I have seen Arthur J. Sturt's letter about the Martian face formation (***Spaceflight,*** December 1988, p.469). On the Moon there is an arch about 3,00 feet across and 600 feet high with three rib like structures connected to it. The lunar arch is near the crater Autolycus at co-ordinates 31° North by 3° East. I found it on an Apollo 15 mapping camera photograph [1]. I have seen other bridges or arches on Lunar Orbiter Photographs but not as clearly.

Much of the Moon has only been photographed at a resolution three or four times smaller than with Earth-based telescopes so possibly a new lunar orbiting probe could solve this mystery an find more unusual lunar features.

MICHAEL ROE
Cleaveland, UK

Reference

1. Astronomy, December 1985, p.16.

Buran Shuttle Crewmen

Sir, I was surprised to see the report by Victor Golovachev that all ten shuttle cosmonauts were selected in 1978 (***Spaceflight***, May 1989, p.152), particularly as it has already been reported that Schukin was selected in 1982. Previously I supposed that the Shuttle Group 1 (selected in 1978) consisted of Oleg Kononenko, Anatoli Levchenko, Rimantas Stankyavichyus and Igor Volk; and that the Shuttle Group 2 (selected in 1983) consisted of Yuri Scheffer, Alexander Schukin, Ural Sultanov, Maghomed Tolboyev, Sergei Tresvyatsky and Viktor Zabolotsky.

I assume that Alexei Borodai and Ivan Bachurin who are mentioned in the artical are two of the three reported non-cosmonaut test pilots [1]. Is there really a third?

MARK S. BURRELL
Tyne and Wear, UK

Reference

1. *Flight International* 18 February 1989.

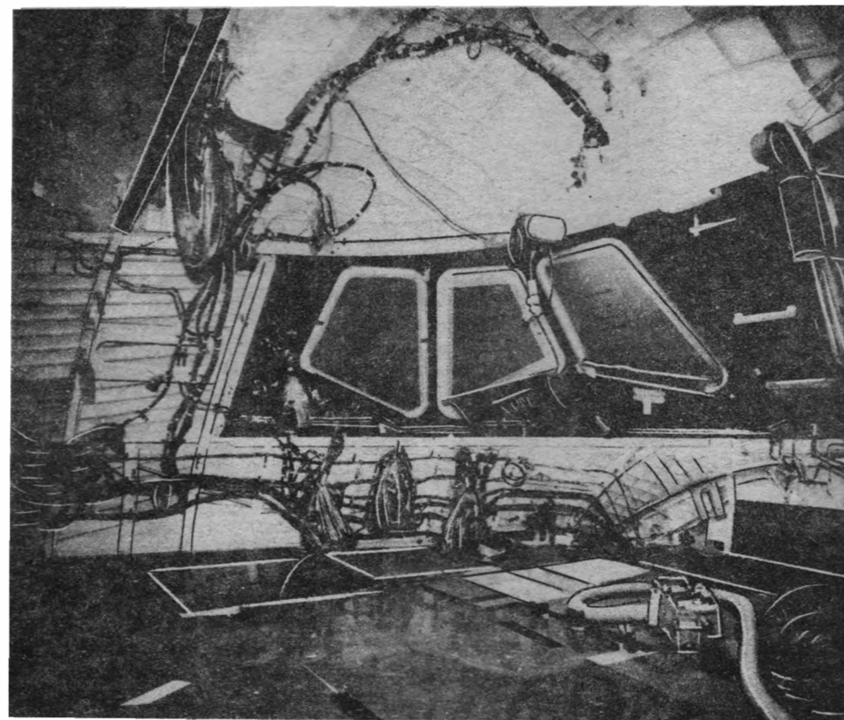
A Name for OV-105

NASA is shortly expected to announce the name of the replacement orbiter for Challenger, OV-105. The orbiter currently under construction by Rockwell International.

US school children were invited to suggest names for the new Shuttle. The name had to be that of a sea vessel used in research or exploration. This follows in the tradition of the four space worthy orbiters (John Bird writes about the previous orbiter names below).

More than 71,650 US students formed some 6,200 teams and submitted educational research projects to justify their names. The competition has now closed and finalists have been selected. The most frequently suggested name was Endeavour. Some of the other suggestions included Eagle, Resolution, Calypso, Nautilus, Rising Star and Victoria.

Meanwhile construction of the new orbiter at Rockwell International's Downey and Palmdale facilities continues to run smoothly. The orbiter is expected to be complete in April 1991 and is scheduled to make its first space flight in March 1992 on Shuttle mission STS-53.



The interior of the of the OV-105 crew module flight deck.

Naming the Orbiters

Each of the US Space Shuttles are named after vessels of another era. This article examines these vessels and their fascinating history. Each of the Space Shuttles also has a number designation.

By John Bird

Enterprise OV-101

The Enterprise was named after the United Star Ship Enterprise which appeared in the television classic *Star Trek*. As one of the thirteen Constellation class vessels, it was one of the largest in Star Fleet. Of the 430 crew members, one third were women. Horizontal and vertical turbolifts connected the decks. The highest level was the bridge, and there were eleven decks in the "saucer section". Below these decks was the engineering section. It contained a hanger deck and was attached to the anti-matter engines. The rooms included crew's quarters, sick bay, a transporter room, recreation halls, labs, storage areas, and computer banks. The otherSpace Shuttles were named after vessels not quite as advanced as the Star Ship Enterprise.

Columbia OV-102

The Columbia was a famous American ship that circumnavigated the globe starting from Boston in September 1787. It was also known as Columbia Rediviva. Rediviva means "brought back to life" in Latin and some historians suggest this means it was built in 1773 and rebuilt in 1787. Her epic voyage began with seal hunting on the west coast of the USA. The crew traded with the Indians in Oregon for furs, then sailed to China and traded the furs for tea, returning to Boston in 1790. Financially it was a loss, but Columbia set sail again in 1790. Columbia's length was 99 feet and it weighed 212 tons.

The Apollo 11 Command Module which took Neil Armstrong and his crew to the Moon, was also called Columbia.

Challenger OV-099

The Challenger was named after the HMS Challenger, an English research ship that operated from December 1872 to June 1876. It explored the Atlantic and Pacific Oceans. One of its main discoveries was the Mid-Atlantic ridge with its hills and valleys.

The Challenger was originally a Navy vessel, but for its research mission the weapons were removed except for two 64 lb. guns.

It had cabins for the Captain, Commander, and Director of Scientific Staff, spacious compartments for surveying operations, a chemical laboratory, and a photo studio.

The mission of the Challenger was to perform:

- sounding
- dredging
- water temperature observations
- chemical examination of sea-water
- magnetic observations

The operations were carried out continuously to further understanding of: physical and biological conditions, the great ocean basins, the direction and velocity of great drifts and currents, the fauna of the deep water, the zoology and botany of the regions of the globe that are comparatively unknown.

The Apollo 17 Lunar Module was also called Challenger.

Discovery OV-103

The Discovery was named after two ships. One is Henry Hudson's ship. He was looking for a northeast passage between the Atlantic and Pacific Oceans from 1610 to 1611. They instead found Hudson's Bay, and the expedition ended with a mutiny.

The Discovery was also named for one of Captain Cook's ships that explored the pacific. On his third tour of the world, he took two ships, the HMS Discovery and the HMS Resolution. This expedition went from 1776 to 1780.

Discovery weighed 298 + 85/94 tons which is approximately triple the weight of the 106 ton space shuttle and payload. This included:

- 13,051 lbs. of flour
- 12,192 lbs. of bread
- 3,249 gallons of brandy
- 436 gallons of wine
- 25 tons of water

Plenty of oranges and lemons were also taken. Some articles on board were not quite as modern as the equipment you would find on a space shuttle. The earlier Discovery carried axes, nails, saws, one dozen hammers, knives, scissors, files of sorts, chisels, old shirts, and kettles.

Atlantis OV-104

The Atlantis was named after a two masted ketch operated by Woods Hole Oceanographic Institute from 1931 to 1966. It travelled more than half a million miles, performing scientific research. Atlantis was replaced by Atlantis II, and the original Atlantis was then used as a summer school ship.

Dimensions of the ship were: 143.5 feet long, a beam of 29 feet, and rigged with a mainmast of 112 feet. Power was also available from a 400 horsepower Diesel engine. Cruising speed was nine knots and it could carry 19 people.

Regions of study were: the Gulf Stream, the western half of the North Atlantic, the Caribbean Sea, the Gulf of Mexico, and other locations throughout the world. An example of the experiments was the measurements of underwater currents. This was accomplished with undersea "weather balloons", which were neutrally buoyant floats that operated thousands of feet underwater. They were tracked from the surface by radio.

Military Shuttle Mission Postponed

NASA has postponed the STS-33 military Shuttle mission until after the launch of the Galileo Jupiter probe in October. The delay has been caused by slow progress bringing the orbiter Columbia back to flight status.

Columbia was originally scheduled for launch on July 1 carrying a classified Department of Defense (DoD) payload. A second military flight, STS-33 was scheduled for launch on August 10. But work to prepare Columbia for her first flight in more than three years has fallen behind schedule.

NASA's second planetary mission of the year must begin within its launch window which opens on October 12. With columbia delayed by over a month the space agency feared the Galileo launch would be endangered. To protect this important shuttle mission STS-33 has been postponed to an unspecified date after the launch of Galileo.

Richard Truly, Associate Administrator for Space Flight and NASA Administrator-designate, explained the situation. "NASA management has become increasingly concerned that the work in preparing the orbiter Columbia for its first flight in over three years is taking long enough that it might endanger the option to launch Galileo at the opening of its launch window. Our over-riding objectives in this situation are to protect the Galileo window and to fly Columbia as early as we can."

The Columbia delays have put further pressure on the already tight shuttle launch schedule. The Long Duration Exposure Facility, deployed on Shuttle mission STS 41-C in April 1984, is due to be retrieved by STS-32 in November. It was originally intended to retrieved LDEF after one year in orbit. Then in December the much awaited launch of the Hubble Space Telescope is due. A further nine Shuttle missions are scheduled for 1990. Truly says the agency is "Currently assessing manifest options downstream of Galileo."

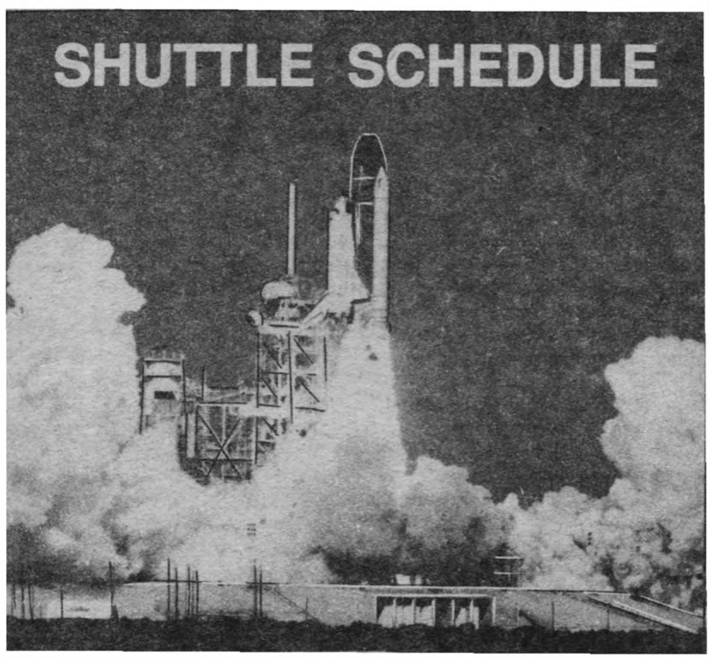
Shuttle Commander McBride Leaves NASA

Astronaut Jon McBride, a Navy Captain, left NASA on May 12, less than a year before he was due to command a Shuttle mission. He also announced his intention to retire from the Navy in the near future.

McBride was named last year to command the STS-35 ASTRO-1 mission, scheduled for launch in March 1990. Vance D. Brand will succeed McBride as STS-35 commander.

McBride recently completed an assignment as NASA Headquarters as the acting assistant administrator for congressional relations, a post he held since September 1987.

"I've spent an extremely rewarding 25 years with NASA and the Navy," he said. "This move has been a very difficult decision for me. But in the final analysis, I felt it was time to make a career change. I'll continue to follow developments in the space programme with keen interest."



Note: All dates are subject to change.

STS-28 Columbia

LAUNCH DATE: Early August 1989
PAYLOAD: DoD
SECONDARY PAYLOADS: -
ATLTITUDE: -
INCLINATION: -
DURATION: -
COMMANDER: Brewster Shaw
PILOT: Richard Richards
MISSION SPECIALISTS:
David Leestma
James Adamson
Mark Brown 9-13.8.89

STS-33 Discovery

LAUNCH DATE: Postponed until after STS-34
PAYLOAD: DoD
SECONDARY PAYLOADS: -
ATLTITUDE: -
INCLINATION: -
DURATION: -
COMMANDER: Frederick Gregory
PILOT: S. David Griggs
MISSION SPECIALISTS:
F. Story Musgrave
Kathryn Thorton
Manley Carter 23-28.12.89

STS-34 Atlantis

LAUNCH DATE: October 12, 1989
PAYLOAD: Galileo/IUS
SECONDARY PAYLOADS: -
ATLTITUDE: 160 n.m.
INCLINATION: 28.5 degrees
DURATION: 4 days
COMMANDER: Donald E. Williams
PILOT: Michael McCulley
MISSION SPECIALISTS:
Shannon Lucid
Ellen Baker 18-23.10.89
Franklin Chang-Diaz

STS-32 Columbia

LAUNCH DATE: November 13, 1989
PAYLOAD: Syncom IV-05, Long Duration Exposure Facility retrieval
SECONDARY PAYLOADS: IMAX-02
ATLTITUDE: 190 n m
INCLINATION: 28.5 degrees
DURATION: 5 days (plans to extended to 10 days)
COMMANDER: Daniel Brandenstein
PILOT: James Wetherbee
MISSION SPECIALISTS:
Bonnie Dunbar
David Low 10-21.1.90
Marsha Ivins

STS-31 Discovery

LAUNCH DATE: December 11, 1989
PAYLOAD: Hubble Space Telescope
SECONDARY PAYLOADS: IMAX Cargo Bay Camera (ICBC)
ATLTITUDE: 310 x 330 n.m.
INCLINATION: 28.5 degrees
DURATION: 5 days
COMMANDER: Loren J. Shriver
PILOT: Charles F. Bolden
MISSION SPECIALISTS:
Steven Hawley
Bruce McCandless
Kathryn Sullivan

STS-36 Atlantis 28.2.90

LAUNCH DATE: February 1, 1990
PAYLOAD: DoD
SECONDARY PAYLOADS: -
ATLTITUDE: -
INCLINATION: -
DURATION: -
COMMANDER: John Creighton
PILOT: John Casper
MISSION SPECIALISTS:
David Hilmers
Michael Mullane
Pierre Thuot

STS-35 Columbia

LAUNCH DATE: March 1, 1990
PAYLOAD: ASTRO-1, Broad Band X-Ray Telescope-1
SECONDARY PAYLOADS: -
ATLTITUDE: 190 n.m.
INCLINATION: 28.5 degrees
DURATION: 9 days (plans to extend to 10 days)
COMMANDER: Vance Brand
PILOT: Guy Gardner
MISSION SPECIALISTS:
John Lounge
Jeffrey Hoffman
Robert Parker
PAYLOAD SPECIALISTS:
Ronald Panse
Samuel Durrance

STS-37 Discovery

LAUNCH DATE: April 5, 1990
PAYLOAD: Gamma Ray Observatory
SECONDARY PAYLOADS: SSBUV-01
ALTITUDE: 243 N.M.
INCLINATION: 28.5 degrees
DURATION: 5
COMMANDER: Steven Nagel
PILOT: Kenneth Cameron
MISSION SPECIALISTS:
Jerry Ross
Jay Apt
Linda Godwin

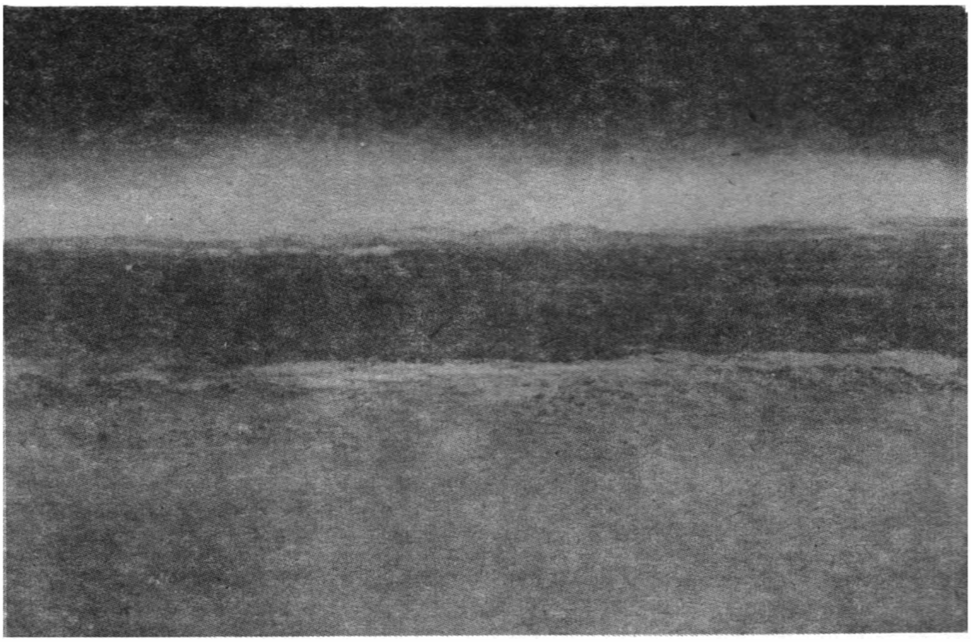
STS-38 Atlantis

LAUNCH DATE: May 10, 1990
PAYLOAD: DoD
Crew and other data not available.

STS-40 Columbia

LAUNCH DATE: June 7, 1990
PAYLOAD: SLS-1
SECONDARY PAYLOAD: GAS Bridge
ALTITUDE: 160 n.m.
INCLINATION: 39.0 degrees
DURATION: 8 days
COMMANDER: Bryan O'Connor
PILOT: John Blaha
MISSION SPECIALISTS:
Tamara Jernigan
M Rehea Seddon
James Bagian
PAYLOAD SPECIALISTS:
F Drew Gaffney
Robert Philips

Shuttle Highlights Environmental Damage



Over 35,000 Earth photographs were taken during the Shuttle's first 24 missions. With an additional 65,000 photographs taken prior to the Shuttle - from Mercury to Apollo - they form a unique record. Recent Shuttle missions, STS-26 and STS-29, have provided some of the clearest pictures of the Earth's surface. These pictures graphically reveal the damage Man has inflicted upon his planet.

At the Johnson Space Center the men and women of the Space Shuttle Observations Office (SSEOO) have seen the whole world without ever leaving their desks. They train Shuttle crews in photographing the world and then catalogue, analyze and conduct scientific investigations of the result.

Prior to each Shuttle mission, a special computer program, the Automated Mission Planning System (AMPS), takes the planned inclination and altitude and prints out a map detailing the orbits that will occur. Nighttime orbits and orbits that fall during high activity times for the crew are deleted, leaving a map of possible Earth observation opportunities.

Normally, about 25-30 specific target areas are outlined for a Shuttle mission. But those targeted areas are only part of the hoped-for results from each mission. The rest depends on the eyes and brains of the crew.

After a crew is assigned to a specific mission, one of the crew members is given responsibility for Earth observations during the mission. One of the SSEOO staff is given chief responsibility for each mission. The SSEOO produces a full-colour Earth Observations Preflight Manual for each mission, a book that details each target, complete with maps, histories and past satellite or Shuttle photos. A manual is given to each crew member.

Crews receive about 12 hours of briefings from SSEOO personnel prior to the flight. During the mission, the SSEOO monitors images from five satellites 16 hours a day, searching for opportune events for Earth photography. Updates on conditions at selected sites, plus any new photography requests are passed on to the crew by Mission Control

(Top)The western edge of a smoke cloud that obscured about a third of South America in the Amazon basin confronts the rising elevations of the Andes Mountains in this STS-26 photograph.

(Bottom) STS-26 Commander, Rick Hauck. uses a 70mm camera on Discovery's flight deck to record some new images of the Earth. ***NASA***

Following a mission the Earth observations film is developed overnight and is available for study the day after landing.

STS-26

Earth photographs taken by Discovery's crew during STS-26 last year were amongst the clearest in more than 20 years. Due to an unexpected rise in atmospheric clarity, visibility from STS-26 over the Northern Hemisphere was the best since the flights of the Gemini programme in the 1960s. The Discovery crew could see more than 700 miles away from the Shuttle, much farther than has been possible on previous Shuttle flights.

But the crew's most amazing and thought provoking sight passed directly below them: more than one million square miles of smoke shrouding South America's Amazon River Basin, the smoke cloud was more than three times the size of Texas. The cloud was the result of tropical forest, pasture and cropland being cleared and burned.

"All of us on the crew were fairly amazed at the size of the smoke pall over South America," Discovery's pilot Dick Covey said. "There was total... smoke from the Andes east, obscuring almost the entire continent."

Covey had chief responsibility for Earth observations on STS-26. During the four-day mission the crew took 1,505 photographs of the Earth. Discovery was launched into an orbit that kept it above only the tropical and subtropical regions, as are the majority of Shuttle flights. But that orbit took Discovery over about half of the world's surface, covering parts of 122 countries.

The Amazon smoke cloud seen by Discovery's astronauts was much larger than the previous largest smoke cloud over South America, seen during a 1984 Shuttle mission according to SSEOO specialist Mike Helfert. Erosion in cleared tropical areas was evident in photography from STS-26, as it has been in photos from previous flights. It is filling rivers, lakes and bays with silt. Such erosion was "most marked in East Africa," he added.

Across the globe from South America, photography from Discovery also captured effects that Chuck Wood, manager of the SSEOO, calls "the greening of Africa." Africa, an area stricken by a 20 year drought, appeared to have had a season of heavy rains, judging from Discovery's photographs.

In some photographs, standing water was seen in the Sahara Desert. In fact the "green line" generally marking somewhat of a southern edge to the Sahara has moved farther north than it has been seen by astronauts since Gemini photography from 1966.

Africa's Niger River was in full flood during the mission, and photographs of Blue and White Nile Rivers also showed evidence of recent flooding. Along the East African coast, many rivers showed strong silty plumes dissipating into the sea.

But two important gauges that have long been studied with space photography - Africa's Lake Chad and Lake Nasser - are still becoming smaller.

Since 1965, the surface area of Lake Chad has dropped by almost 95 per cent, and STS-26 photography showed it to be at its smallest extent ever photographed by astronauts - despite the obvious heavy rains Africa has received, Wood said. Lake Nasser was also at a record low for astronaut photography.

The clarity of the atmosphere during Discovery's mission allowed objects not usually seen in Shuttle handheld photographs to be apparent: for the first time, an aircraft was photographed as well as its contrail; individual buildings could be seen in the Canary Islands; a line of electrical pylons was seen in Southern Sudan; and oil platform flares were visible in the Gulf of Campeche.

The extreme Northern Hemisphere clarity may have been due to a lessening of volcanic dust in the upper atmosphere and the decrease of normally severe African dust and sandstorms, Wood said. "On some past flights, dust storms had extended from Africa halfway across the Atlantic. Astronauts couldn't see the water for dust," he added.

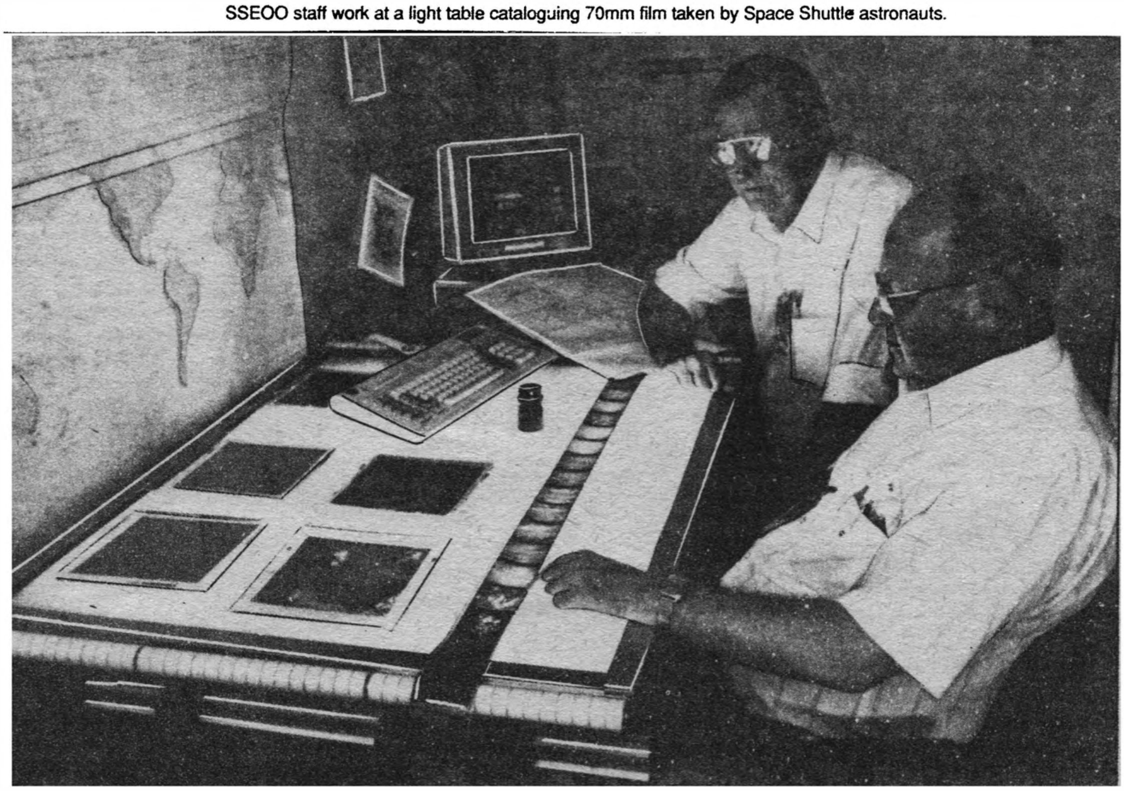
The crew, all veteran astronauts, quickly became aware of the increased visibility.

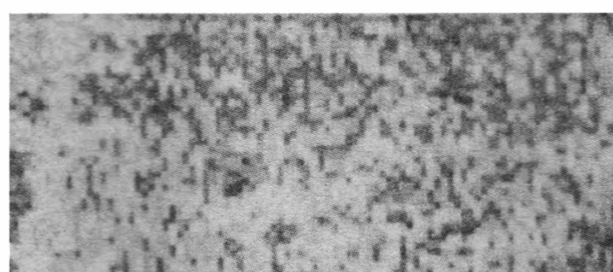
"We were able to see great distances north of our track," Covey said. "During one pass, I looked north to try and find Edwards Air Force Base, probably some 400 miles off our track. I found it and could make out the buildings, the ramp areas and details."

But the most striking photography to come out of the mission must be those which revealed the Earth's deteriorating environment.

"Circling the world every 90 minutes, you start to feel that the Earth just isn't as large as it seems on the ground," Covey said. "And you see that these things are really going to effect our environment."

SSEOO staff work at a light table cataloguing 70mm film taken by Space Shuttle astronauts.





Receiving Okean's Pictures

Lawrence Harris was most interested to read Brian Harvey's article on the Soviet Union's Okean oceanographic satellites (*Spaceflight* February 1989, p.62) because for several years he has been able to receive pictures from Soviet satellites including the Okean series. Mr Harris writes about his satellite tracking station he has constructed at his home in Plymouth, Devon.

By Lawrence Harris

My career began at the Appleton Laboratories, where I became involved in various space projects including the UK Ariel series of satellites and then IRAS (the Infra-Red Astronomical Satellite). When that project finished I returned to Plymouth with my family to start a new career. Realising just how much I missed working in space research, I decided to set up my own satellite tracking and data processing facility at home.

The equipment used for receiving and decoding the satellite signals includes two scanners, a fixed frequency receiver, a framestore and a computer fitted with a satellite signal interface. One receiver records data from the University of Surrey satellites, UoSATs 1 and 2. The main receiver is a Dartcom scanner dedicated to satellite use, fed by a roof-mounted crossed dipole aerial. A multi-band scanner is used for navigation, scientific and other satellites and is fed from a discone.

To receive data from a geostationary satellite I built a dish and bought a down-converter (a device that converts microwave frequencies down to the 137 MHz weather satellite band). A new dish from Dartcom was mounted separately to receive NOAA GOES-E satellite data - opening my horizon to world wide data acquisition.

Other facilities include a stereo tape recorder, to record Russian satellite signals with a time track for synchronisation and an Amstrad CPC6128 computer to process UoSAT data and produce satellite pass times in chronological order.

Last year I installed a new computer system fitted with a satellite signal interface, rather like a programmable framestore. This allows me to produce animated sequences which show the movement of weather systems and hold promise for scientific analysis, such as the plotting of thermal profiles of tropical waters and much more. My main objective was to analyse, to the limit, the signals transmitted by the various satellites and allow qualitative photography.

The equipment enables me to receive pictures from a variety of Soviet, American, European and Chinese spacecraft. I picked up one of the first transmissions from Feng Yun 1, the Chinese weather satellite and monitored the problems with it as they happened, months before I saw official releases. In fact I often receive signals from new Soviet spacecraft before the official announcements. Recently I picked up early transmissions from Meteor 2/18 and within a day or so was able to produce "dummy" Kepler elements enabling me to predict its future orbital track.

On one occasion I heard a "new" sound, later identified as Meteor 2/3, apparently switched on by accident during the commanding of a different satellite. If true, it may reveal details of the Soviet satellite command systems.

The Russians operate 2 distinct types of meteorological satellite - the Meteors and the Cosmos oceanographics. The Meteors include series 2 - the basic weather satellites operating mostly in Sunlight (though currently Meteor 2/17 is running night time infrared transmissions). Series 3 are higher orbiting craft carrying infrared sensors for night time pictures similar to the NOAA weather satellites, although their operations are rather irregular.

The Okean (oceanographic) series of satellites apparently dates from Cosmos 1076 in 1979. I first picked up Okean 1 signals on July 14, 1988 at about 2030UT (Universal Time) while carrying out routine scan for satellites. That transmission included "piano-key" telemetry, a radar image, and a visible-light image. The time of acquisition was inconsistent with other Cosmos satellites in this series, namely Cosmos 1766 and 1869, and so I concluded this was a new launch.

With other satellites that constantly transmit data orbital elements can be quickly constructed and hence predict future pass times, but the oceanographic satellites are only active for short periods, so I have to rely on official Kepler elements for future predictions. These may not appear in magazines for many weeks. Fellow RIG (Remote Imaging Group) member Des Watson has kindly provided my with such elements on various occasions. I then use my software to predict the potential passes.

The predictions enable me to be present when Okean is likely to transmit and therefore positively identification of the satellite. They consistently use 137.40 MHz and so I often leave a receiver on this frequency to find pictures recorded when I next check the equipment.

Unfortunately this frequency is also used by one or two of the Meteor satellites. These other transmissions can cause the tape recorder to run out so I use a electronic timer to switch off the units during known, unwanted transmissions.

Following the initial Okean picture in July 1988, Okean was seen to be capable of various transmission formats - sometimes transmitting a number sequence which I was able to understand with help from RIG articles. The most common format is one quarter microwave sounder image, one quarter radar image and the remaining half - a visible picture, though this is blank during night transmissions such as those received during winter.

Other picture formats may include numbers (edge codes) and can be most helpful. One parameter includes /moscow time in minutes and a simple programme can calculate the GMT time of transmission. This can then be used to apply a correction to the orbital elements! Sometimes stored pictures are seen.

Okean transmissions are often received while passing south-bound over Norway and Sweden. The radar image, if present, is devoid of cloud but detail is apparent in the coastal waters and the gulfs. Such detail is considerable and I had wondered to what depth the sensors probe. Recent articles suggest it to be about 50 metres.

The radar images are not transmitted continuously probably because radar is a heavy consumer of power. During a picture the radar section may end, probably under onboard control, and this portion reverts to visible format, ie the picture then contains one quarter microwave sounder and three-quarters visible image.

Previous oceanographic satellites that I have monitored seemed to only operate within range of the USSR but Okean has operated on passes that have come towards the UK, although so far it has always switched off while over Scotland. I expect that the Russians have ships in the Atlantic that can receive the data.

On December 13, at 0051UT I heard the starting carrier tone switch on. The picture included piano key telemetry and two images - microwave and radar each taking up a half width. I then received what I believe to be a previously stored picture possibly of the North Pole but I could not identify the area. I read that Okean was used to probe the polar ice during efforts to rescue the whales trapped off Alaska, so this was probably one of those transmissions.

Some superb images have been received - one radar image included a long track from Norway down through Lenin-

(Top) Lawrence Harris with his satellite receiving equipment at his home in Plymouth, Devon.
(Bottom Left) Mr Harris poses with one of his satellite receiving dishes.
(Bottom Right) An image from the Soviet Okean satellite showing the Gulf of Bothnia with added artificial colour. The dark band across the picture is merely the effect of photographing a television screen. ***Lawrence Harris***

grad almost to the Black Sea. This was in early January and shows what I presume is underwater detail in the lakes.

When the signal strength is sufficient I can process the data in the computer. One microwave/radar picture of the Baltic taken in December included Gotland and the coast so I expanded the image to reveal its maximum resolution at pixel level, adding artificial colour. Details of the system published in the February 1989 edition of ***Spaceflight*** indicate the resolution to be about 1.5 km at 3 cm frequency.

The microwave sounder and radar on Okean cover overlapping areas and one picture received in December included the Gulf of Finland, a favourite target in winter, probably to survey the ice flows that normally accumulate here, although there was no ice at the time. Such data would be useful to guide shipping.

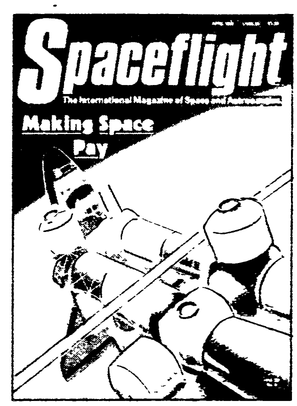
A complete analysis of Okean's pictures requires much time and I have spent many hours reprocessing recorded data. I also log every satellite transmission received - a habit from earlier days! All the monitoring has to fit in with domestic life as well and my children are well-used to calling me when a particular sound is heard!

My only regret is the difficulty in swopping notes with fellow enthusiasts. However, I intend to continue monitoring the various satellites and analyse data as time permits. I have a steady flow of visitors to see my set-up and occasional interest from the local media.

Spaceflight BACK ISSUES

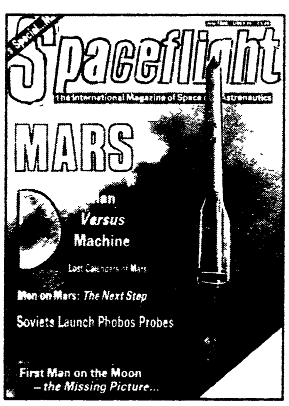
October 1987
A Special Issue celebrating the anniversary of the launch of Sputnik 1 with a unique insight and record of Man's first thirty years in space.

January 1988
Space Debns - Soviet Hardware Displayed - Ireland in Space



April 1988
Pnvate Sector Space Projects - Space Commerce '88 - Keeping Track of Mir -

June 1988
Space Simulation - Exclusive Interview with Cosmonaut Alexander Volkov - Mir Mission Report



July 1988
Special Mars Issue: Man on Mars - Project Phobos - First Man on the Moon: The Missing Picture

August 1988
Anane 4 First Flight Success - Space Art - Cassini Mission to Saturn

October 1988
Space Shuttle Issue: Shuttle Main Engine Story - Shuttle Crew Escape - Milestones to recovery - Mir Mission Report

February 1989
Special Soviet Issue. Space Walks - Buran Controversy - Mir Mission Report - STS-27 Mission Report

October 1987	☐	March 1988	☐	August 1988	☐	January 1989	☐
November 1987	☐	April 1988	☐	September 1988	☐	February 1989	☐
December 1987	☐	May 1988	☐	October 1988	☐	March 1989	☐
January 1988	☐	June 1988	☐	November 1988	☐	April 1989	☐
February 1988	☐	July 1988	☐	December 1988	☐	May 1989	☐

Spaceflight Back Issues are priced £2.00 (US$4.00) each, inclusive of surface mail delivery.

Please send me ***Spaceflight*** Back Issue(s)/Binder(s) as indicated above. I enclose a cheque/PO/International Money Order payable to the British Interplanetary Society totalling £...................................

Name:

Address:

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