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Spaceflight

The International Magazine of Space and Astronautics

SHUTTLE
10 Years On

GAGARIN
30 Years On

First Briton in Space Selected

Shuttle Spacewalk Planned for April

Flying the Shuttle
By NASA's Chief Astronaut

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Vol. 33
No.4

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Editor:
G. V. Groves

Assistant Editor:
S. Young

Managing Editor:
L. J. Carter

Spaceflight Promotion:
Shirley A. Jones

Advertising:
Suszann Parry

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

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

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Spaceflight
The International Magazine of Space and Astronautics

Vol. 33 No. 4 **April 1991**

FRONT COVER: Our front cover this month features the aft of the Space Shuttle Discovery silhouetted against the Earth's horizon. Insert are the crew of STS-1 and Yuri Gagarin This month is the 10th anniversary of the first Shuttle mission and the 30th of man's first space flight.

Space Station Shrinks in Re-design

NASA Gets Extra Time for Freedom Review

NASA is not expected to reveal its new design for Space Station Freedom until early April after being granted extra time by Congress to complete the work. The new-look Space Station will feature smaller modules, reduced power and shorter truss sections. In November last year the US Congress told NASA to redesign Freedom and to expect an annual budget of no more than $2.6 billion for the project.

The revised Space Station has 8.2-metre long modules, half the original size. The smaller modules can be launched by the Space Shuttle fully equipped, unlike the old design which had to be fitted out once in orbit. ESA has not yet decided if the. Columbus laboratory module will be halved in size

The Space Station's truss structure will be 90 metres long, instead of 150 metres. The truss would be launched in fully assembled sections that can be linked together in orbit. The space station will produce 60 kW of electrical power, instead of 75 kW and will have one sixth of the data transmission capacity of the original design.

The new design will require 23 Shuttle missions before it reaches the permanent manned capability stage, compared with 34 for the original design. With the number of Space Station dedicated Shuttle flights limited to four per year, the assembly sequence could take up to six years. The first launch of space station hardware is scheduled for 1995. The space station could receive its first crew in the man tended mode in December 1996, about seven months later than originally planned. There will be just four crew members when the Space Station is permanently manned early in the next century.

Long Duration Mir Mission For US Astronaut?

According to reports on the US CBS television network, an American astronauts will make a long duration stay aboard the Soviet Union's Mir Space Station as part of a new agreement on space cooperation.

According to CBS, the project envisages the flight of a Soviet cosmonaut on the US Space Shuttle and a four to six month mission for an American astronaut aboard Mir.

The project could be implemented within the next 12-18 months John Logsdon, of the US Space Policy Institute, told CBS.

NASA spokesman Ed Campion told ***Spaceflight*** that such an agreement would be announced by the White House not NASA.

There have been rumours of a joint US-Soviet space venture for some time. During his visit to the Johnson Space Center in December former Soviet Foreign Secretary Eduard Sheverdnadze hinted that a US-Soviet agreement on cooperation in space would be signed at the next summit meeting between President Bush and President Gorbachev. The meeting was scheduled for earlier this year but postponed because of the Gulf War and other factors. Reports indicate that the summit may take place in May.

First Titan 4 from VAFB

The US Air Force has launched the first Titan 4 booster from Vandenberg Air Force Base in California. The Titan 4 lifted off from Space Launch Complex 4E at 04:03 on March 8. The payload is believed to be a spy satellite destined for polar orbit. Officials would only say that the payload is classified.

Amateur Waverider Experiment Could Fly on Juno

A Progress cargo spacecraft, scheduled for launch on March 19, could be carrying a unique experiment designed by Scottish amateurs from the STAAR research organisation. If it flies the experiment will be performed by British cosmonaut Helen Sharman during the Juno mission.

By Neville Kidger

The experiment envisages low-speed trials in a microgravity environment of a waverider - an aerodynamic shape proposed for space vehicles as long ago as 1900 by Professor Terance Nonweiler.

The concept has drawn interest from the NASA Jet Propulsion Laboratory who are studying use of the concept in a proposed solar exploration spacecraft which would skip through the atmosphere of Venus to close to a distance of just 4 million kilometres from the Sun.

The Scottish experiments, designed by John Bonsor and Ken Bradshaw of STAAR research use scale models of waverider designs which are to be tested on the Mir station in two different modes.

The first test envisages the catapult launch of two models each of a different design, attached to a tether, at various angles of attack along the length of the Mir base block. This should provide, in the absence of gravity, an entirely aerodynamic study of motion of the models.

Up to 40 separate launches of the models would be conducted by Helen Sharman over a four hour period.

In the second test the models would be tethered to one of the large air duct hoses in the Mir complex to simulate the flow of air around them. This would be similar to, but hopefully more realistic than, air flows experienced in wind tunnels on the Earth where the need to have rigid mounts for the model and other factors complicates the data from the tests.

The flow of air around the models would be photographed by Sharman. To see this flow the designer will use wool around the exterior of the model in preference to smoke.

The examination of the data obtained during the experiments will be analysed by the designers and schoolchildren - the project has educational value too.

The models were taken to the USSR on Monday March 11 and are currently being evaluated by the Energiya NPO.

Even if the Juno mission does not include this experiment on its manifest, STAAR researcher John Bonsor remains hopeful that the experiment will fly to Mir during the International Space Year, 1992.

Christopher Hayes, Juno Project Manager, says a number of British scientific experiments are being considered by the Soviets. The individual organisations are talking directly to NPO Energiya, Juno is simply providing advice on how to approach the Soviet authorities he said.

Rare Isotope Found On LDEF

Scientists from several US government and university laboratories have reported finding the rare atmospheric isotope Beryllium-7 present on the surface of NASA's Long Duration Exposure Facility (LDEF).

The isotope Beryllium-7 is radioactive and produced naturally by cosmic ray reactions in the Earth's atmosphere. Although very rare, the isotope is detectable by modern nuclear instrumentation and has been studied in the past as a means of tracing the distribution and transport of atmospheric gases in the lower atmosphere, said Dr. Gerald J. Fishman of NASA's Marshall Space Flight Center, Huntsville, Alabama.

"The finding is thought to be significant from at least two different aspects," said Fishman. "First, it is known that the isotope is mainly produced at much lower altitudes in the atmosphere than where the LDEF was orbiting. The detection and measurements show that some, as yet undetermined, process efficiently carried it to high altitudes.

"Additional and more detailed measurements of this type may lead to a better understanding of the movement of rare atmospheric components over the globe at high altitudes," he said.

"Secondly, prior to this finding, there was only one atmospheric gas known to strongly interact with orbiting spacecraft. That gas, atomic oxygen, has been found to be very significant, leading to the degradation of various spacecraft surfaces. The detection of Beryllium-7 on the LDEF surface will allow scientists to study in greater detail the interaction of gases with spacecraft in low Earth orbit," said Fishman.

"A team of scientists found the isotope on the LDEF during measurements at the Kennedy Space Center shortly after its return. At approximately the same time," said Fishman, "researchers working with removed external spacecraft components at the Marshall Space Flight Center and the University of Alabama in Huntsville, confirmed the Beryllium-7 presence and showed that it was confined to a very thin layer - the surfaces on the leading edge of the LDEF." The NASA scientist is part of a radiation group investigating materials and radiation data returned from LDEF.

The Long Duration Exposure Facility was returned from space by the Space Shuttle Columbia in January 1990 after nearly six years in Earth orbit.

LDEF is a 12-sided cylindrical structure 9 metres long and 3 metres in diameter. The LDEF spacecraft was designed to test the performance of spacecraft materials, components and systems that have been exposed to micrometeoroids, space debris, space vacuum, atomic oxygen, solar ultraviolet and space radiation for an extended period of time.

NASA Contract for Pegasus

Orbital Sciences Corporation has been selected by the NASA to negotiate a contract to provide launch services using its Pegasus air-launched booster for the Goddard Space Flight Center's Small Expendable Launch Vehicle Services (SELVS) programme. The total contract, consisting of seven firm launches and three optional launches, is valued at approximately $80 million.

Orbital will conduct the first Pegasus launch for SELVS in 1993, with an expected launch rate of two flights per year. The launches will support Goddard's Small Explorer programme of small, affordable scientific satellites for space physics, astrophysics and solar exploratory missions. The SELVS procurement continues NASA's approach of purchasing space launch services from the private sector, helping to stimulate the American space industry.

"The NASA award is a strategically important order for Orbital that firmly establishes Pegasus as the vehicle of choice in the small satellite market," noted Robert R. Lovell, President of Orbital's Space Systems Division. "We are extremely happy that NASA has committed to being a critical "anchor customer" for Pegasus. We look forward to working with Goddard on its important Small Explorer scientific programme".

Pegasus is the world's first privately-developed and operated Earth-to-space vehicle. It uses an innovative air-launch approach to place small satellite payloads weighing up to 360 kg into low-Earth orbit. Pegasus was developed in a privately-financed joint venture between Orbital and Hercules Aerospace Company, and made its first flight into space in April 1990.

Space Station Processing Facility Contract Awarded

NASA's Kennedy Space Center has awarded Metric Constructors of Tampa, Florida, a $56,215,000 contract to construct the Space Station Processing Facility (SSPF).

Located in the KSC Industrial Area just east of the Operations & Checkout Building, the 457,000 square foot SSPF will be occupied by about 1,000 NASA and contractor employees.

The SSPF will have over 63,000 square feet of dedicated payload processing space, which includes a high bay and intermediate bay. A 5,000 square foot airlock will be adjacent to the primary processing area. Both the airlock and processing area will be 100,000 parts-per-million rated clean rooms.

A visitor viewing window, which will allow NASA tour guests to view Space Station Freedom preflight operations, has been designed into the building's processing area.

NEWS IN BRIEF

Space Lottery Falls Foul of the Law

The sweepstake to win a flight to the Mir space station has run into trouble. Space Travel Services of Houston has been forced to close its special phone line after police raided the company's headquarters. Earlier, Space Travel Services believed it had proved it was not breaking Texas laws which prohibit lotteries. (See *Spaceflight*, February 1991, p.41)

Second Inmarsat-2 Launched

A McDonnell Douglas Delta II has launched the second Inmarsat-2 satellite for mobile communications. The expendable launch vehicle blasted off from launch pad 17B at Cape Canaveral Air Force Station on March 8 at 22:59 GMT. Fifty minutes later the satellite was injected into a geostationary transfer orbit. The spacecraft was the second of four Inmarsat-2 satellites are built by British Aerospace. The two remaining satellites in the series will be launched by Ariane later this year.

Columbia Better Than Ever

Engineering data has shown that Columbia had its lowest ever concentration of hydrogen in its aft compartment during the STS-35 launch in December. "Columbia was very tight," said NASA Associate Administrator for Space Flight Dr William Lenior. Attempts to launch Columbia during the summer of last year were thwarted by elusive liquid hydrogen leaks.

OSC in Japan

Okura & Co. Ltd of Tokyo is to exclusively market and sell the Pegasus air-launched booster and other Orbital Sciences Corporation launch vehicles in Japan. The Pegasus booster made its first successful launch in April 1990. The four-stage Taurus ground-launched vehicle, derived from Pegasus, is due to make its first launch next year.

Titan Pad Work Stopped

Work to convert the Shuttle complex at Vandenberg for Titan 4 launches has been stopped, according to reports. The SLC-6 launch pad, originally intended for Shuttle launches into polar orbit, will stay in mothballs until needed for future launch systems.

New Shuttle Training Aircraft

NASA has taken delivery of its fourth Shuttle Training Aircraft (STA), designated NASA 945. The aircraft, a Grumman Gulfstream II, has been modified to mimic the Space Shuttle's flight characteristics. Shuttle commanders and pilots spend many hours in the STA practising their approach and landings at Edwards Air Force Base and the Kennedy Space Center. The aircraft will become operational in April.

ESA/Soviet Radio Telescope Proposed

The European Space Agency (ESA) and the Moscow-based Astro Space Centre have released an assessment study of a mission in which a large radio telescope in Earth orbit would observe compact radio sources in the stellar sky with unprecedented clarity.

The mission, named IVS, would also co-operate with radio telescopes on Earth in a programme of Very Long Baseline Interferometry (VLBi).

The mission has been proposed for consideration as the new ESA medium-size science investigation as part of the Horizon-2000 programme. From its inception the IVS programme was conceived as a joint ESA/Soviet mission but, the report states, there is a possibility of US involvement.

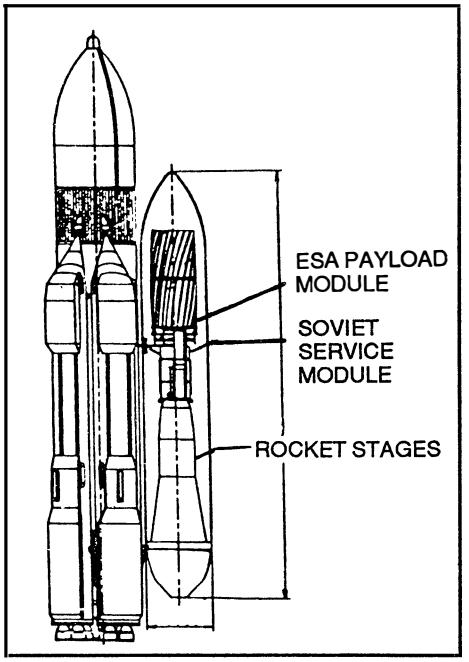
The IVS proposal was submitted to ESA on behalf of a large group of European, Soviet, American, Australian and Japanese radio astronomers.

IVS would use a Soviet-made service module based upon a Standard Space Platform (SSP) currently under development by the Energiya NPO for use on geostationary communications satellite.

The SSP is a rectangular structure of 5.5 x 3.3 x 2.5 metres with boom-mounted deployable solar arrays and deployable radiators. Power supply is 15 kW in the standard version but for the IVS mission this would be just 5 - 6 kW. The size of the solar arrays and radiators would therefore be smaller on IVS than on the standard bus.

ESA would provide the payload module, the main feature of which is the 20-metre diameter dish of the radio telescope capable of operating with a high efficiency at 60 GHz. The telescope would feature a Cassegrain configuration with a 2 metre diameter secondary. The payload module is mounted on a 2.5 metre diameter machined ring.

The total estimated mass of the service module (excluding the propulsion module) is 7,500 kg of which 3,300 kg is structural mass and 4,200 kg is equipment mass.

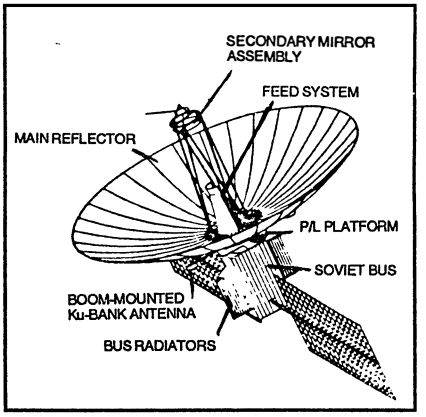


The dry propulsion module mass is 3,500 kg and the mass of the propellant is 11,500 kg, making a total mass of 15,000 kg for the module.

With a payload module mass of 4,747 the total in-orbit mass of the IVS will be 27,247 kg and the end-of-life mass 15,747 kg.

The launch of the IVS spacecraft would be on an Energiya rocket from Tyuratam in about 2001, if approval was given in April 1991.

The operational orbit will be between 45 to 65 degrees inclination and the perigee will be about 6,000 km. However, the apogee will be varied from an initial height of 20,000 km to 40,000 km and finally to 150,000 km to support the VLBI portion of the mission.



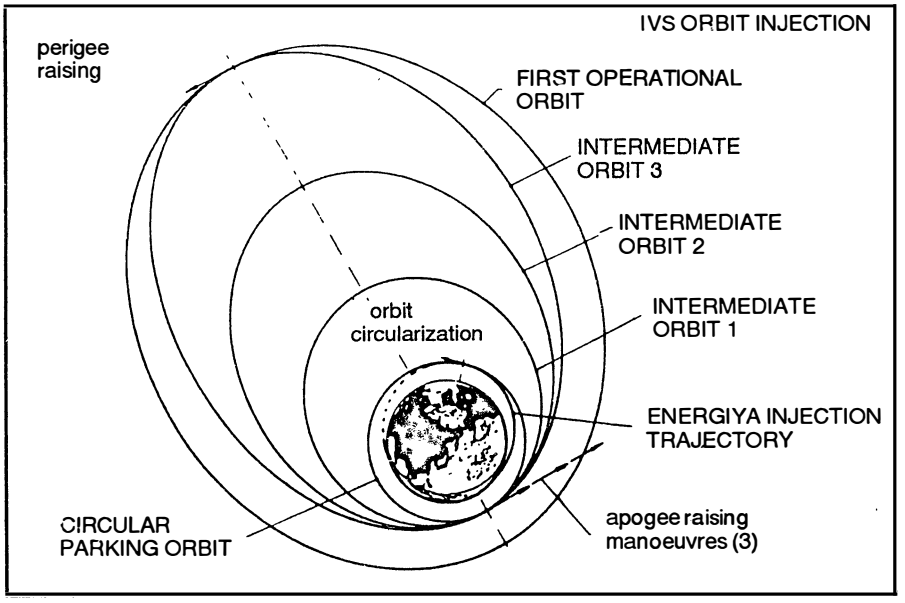
The telescope will, in addition to VLBI studies of specific sources, be conducting oxygen spectroscopy with its single dish and observing the Cosmic Microwave Background.

The mission is expected to last for three years but the assessment study says that the design should allow for a six year lifetime.

Other science projects being submitted for consideration are:

- INTEGRAL, an ESA/NASA collaboration in which a spacecraft would be dedicated to fine spectroscopy and positioning of celestial gamma-ray sources.
- STEP, which is described as a mission of "Fundamental Physics" in which the rate of fall of test masses in an Earth-orbiting satellite would be measured in a modern version of the experiment said to have been conducted by Galileo when two balls were dropped from the leaning tower of Pisa. The project would be a joint ESA/NASA venture.
- PRISMA, an ESA project in which a spacecraft would conduct studies of astroseismology and stellar activity monitoring to help answer fundamental questions about the internal structures and external atmospheres of stars.
- MARSNET. This joint ESA/NASA study envisages a network of small science stations landed on the planet Mars to determine the internal structure of the planet, the chemical and mineralogical make-up of the rocks and the study of atmospheric circulation and weather patterns. A further aim is the study of the exobiological conditions existing on the planet.
- OPT, or Orbiting Planetary Telescope. This Joint ESA/NASA/DARA study is for a spacecraft used to examine planetary bodies from an Earth orbit of 100 x 70000 km orbit. It is a project developed from a national German proposal called Planetteleskop. The 1 metre diameter Richhey-Churetien reflecting telescope is, in the words of the report, to be to planetary science what the International Ultraviolet Telescope (IUE) was to ultra-violet astronomy.

Neville Kidger



NASA Agrees to Launch Canadian Radarsat

NASA has agreed to launch Canada's Radarsat spacecraft. The launch, will take place in June 1994 on a medium class expendable launch vehicle.

The satellite's synthetic aperture radar (SAR) will be able to penetrate cloud cover and darkness, scanning the Earth in swaths varying from 50 to 500 km.

The SAR will produce high resolution (10 to 100 metre) images of the Earth's surface and will be used in the first year-round monitoring of conditions along arctic sea routes. The SAR will also provide the first comprehensive map of the Antarctic contential ice sheet. In addition, the SAR's sensitivity to soil moisture and vegetation will provide valuable data useful for crop assessment and forestry. The satellite will also be used for surveillance of natural disasters including floods, drought, forest fires and other such phenomena.

In return for providing the launch and communications support, NASA, NOAA and other US Government agencies will have access to the SAR data.

The Radarsat programme is run by the Canadian Space Agency.

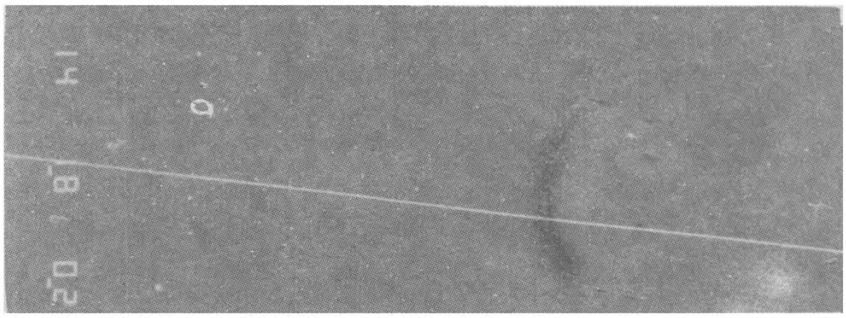
Comet Contract for Tecnospazio

The European Space Agency has selected Tecnospazio for the technological development of the Sample Acquisition System of the spacecraft Rosetta for the cooperative ESA/NASA mission "CNSR/Comet Nucleus Sample Return".

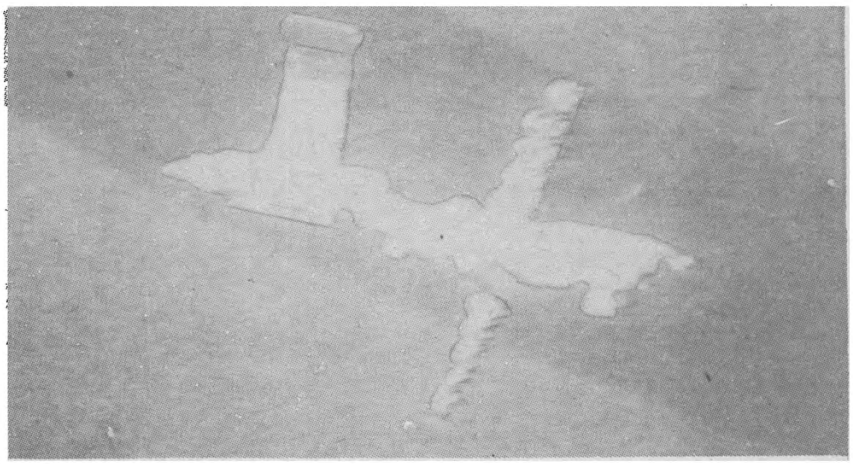
In the CNSR mission the Rosetta spacecraft will land o a comet, collect soil samples and carry them back to earth.

The SAS of the Rosetta spacecraft will operate under extreme temperature conditions and shall have a high degree of autonomy. The cometary soil has no well known characteristics and it may have a consistency varying from dirty snow to hard rock. The SAS shall therefore include an autonomous robot, able to recognize the characteristics of the soil and select the appropriate conditions.

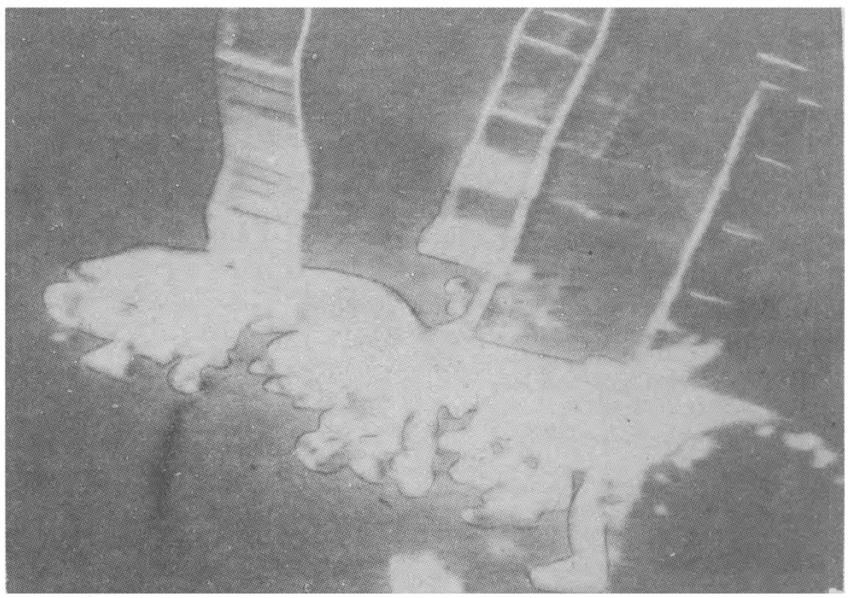
The Final Days of Salyut-7



The Salyut-7 space station passes over the south coast of the UK in Hampshire (above). The photograph was taken on the evening of January 14 just over three weeks before the 40-tonne station reentered the atmosphere, scattering debris across South America. The photo, by *Douglas Arnold,* shows Salyut's reflection growing fainter as it moves towards the East and the terminator between night and day.



The Kosmos 1686 module remained attached to Salyut-7 until its reentry. The Soviets have yet to release any clear photographs of the station. These TV pictures of Salyut-7 (right) docked with Kosmos 1686 (left) were provided by *Dietrich Haeseler*



In South America large pieces of Salyut-7 and Kosmos 1686 have been found. Fragments of the station were found about 20 km from the Argentine capital. A cylindrical piece 3.5 metres in diameter fell near the city of Chaniar. An eight kilogramme ring with a diameter of 1.5 metres was found 130 km from the city of Rosario. A 3.2-metre long pipe weighing four kilogrammes fell in the Andes mountains near the Chilean City of Puerto Montt. The Soviet government has offered to pay compensation for any damage caused by the falling debris.

The five-member crew of STS-37: (left to right) Kenneth Cameron, Jay Apt, Steven Nagel, Jerry Ross and Linda Godwin. NASA

Atlantis Set for GRO Launch

Astronauts to Make First US Spacewalk Since 1985

The postponement of Discovery's STS-39 mission has made way for the launch of Atlantis on STS-37 in early April. The deployment of the Gamma Ray Observatory (GRO) and America's first space walk in more than five years will be the highlights of Atlantis' five-day mission. During the six-hour space walk astronauts Jerry Ross and Jay Apt will try out special 'carts' that could be used on Space Station Freedom to move along the truss structure.

As this article goes to press, Atlantis is scheduled for launch at 09:20 EST on April 4 from pad 39B. The mission has a launch window lasting two and a half hours.

Discovery's five member crew is led by mission commander Steve Nagel a veteran of two Shuttle missions, STS 51-G and STS 61-A when he flew as pilot. Nagel's pilot for STS-37 is Ken Cameron. Selected as an astronaut in 1984, he will be making his first space flight. As the Intravehicular crewmember, Cameron will assist Ross and Apt into their space suits and help coordinate the space walk from the flight deck. He is also the back-up arm operator.

The three mission specialists (MS) for STS-37 are Linda Godwin, Jerry Ross and Jerome (Jay) Apt.

Designated MS1, Linda Godwin will be responsible for the operating the Remote Manipulator System (RMS) during the space walk and GRO deployment. Prior to her selection as an astronaut, she worked in Payload Operations at the Johnson Space Center. STS-37 will be her first mission.

Jerry Ross, MS-2, will be making his third Shuttle flight on STS-37. He made two spacewalks during STS 61-B in late-1985 and was a MS for STS-27, a classified DoD mission. During launch and reentry Ross will serve as the 'flight engineer'. He will help Nagel and Cameron monitor the orbiter systems from the aft-centre seat on the flight deck. Ross is designated EV-1 for the space walk. He will wear red bands on his space suit to distinguish him from Apt. In addition, Ross is responsible for Earth observations during the mission and is the flight's

medical officer.

Jay Apt is the crew's expert on GRO. Serving as MS3, he is responsible for activating the observatory and preparing it for deployment. During the space walk he will be designated EV2. Before his selection as an astronaut in 1985, he worked with Linda Godwin in Payload Operations at JSC. Prior to that he worked at the Jet Propulsion Laboratory. During the mid-70's he was involved in the Pioneer Venus mission.

GRO Deployment

The primary payload for STS-37 is the Gamma Ray Observatory or GRO (pronounced 'grow'). The spacecraft is the second in NASA's 'Great Observatory' series. As its name suggests, GRO is designed to study gamma radiation emissions, a high frequency band at the far end of the electromagnetic spectrum.

The observatory will carry the most sensitive set of instruments ever put in space for gamma ray astronomy, according to Alan Bunner, the GRO Program Scientist at NASA Headquarters. The observatory should help answer some of the fundamental questions in astronomy and astro-hysics today, he says.

Weighing in at 17 tonnes, the observatory will be the heaviest civilian spacecraft put in orbit by the Shuttle. It occupies about two thirds of the payload bay.

Preparations for the GRO deployment will begin on day one. Shortly after the crew has been given a 'go' for on-orbit operations, Godwin will unberth the robot arm and put it through its paces to test the various systems.

"Also as arm operators, it is our first time to get a feel of what the arm is really like [in space]," Godwin explained.

Once the checkout is complete, GRO will be inspected by the black and white television camera at the end of the arm. The pictures will be transmitted to the ground where experts will look for any signs of damage. The arm will then be returned to its cradle until its is needed for deployment.

On Flight Day Two, Jay Apt will power-up the observatory and set up a communications link between GRO and the ground *via* the orbiter. Controllers at Payload Operations Control Center (POCC) at the Goddard Space Flight Center will then begin a two-hour checkout of the spacecraft.

The cabin air pressure will be reduced to 10.2 psi to shorten the astronauts 'pre-breathe' time before their space walk. The three space suits aboard Atlantis will also be checked. Ross and Apt have trained for an emergency space walk during the GRO deployment. If necessary, the astronauts can release GRO from the payload bay and deploy the satellite's appendages manually.

The observatory will be deployed on Flight Day Three. The crew will be woken at about 1 day, 17 hours Mission Elapsed Time (MET).

After breakfast, Ross and Apt will put on their bio-medical sensors in case a space walk is required.

To keep GRO's solar arrays in the shade during their deployment, Atlantis will be manoeuvred so the Sun is on the belly of the orbiter.

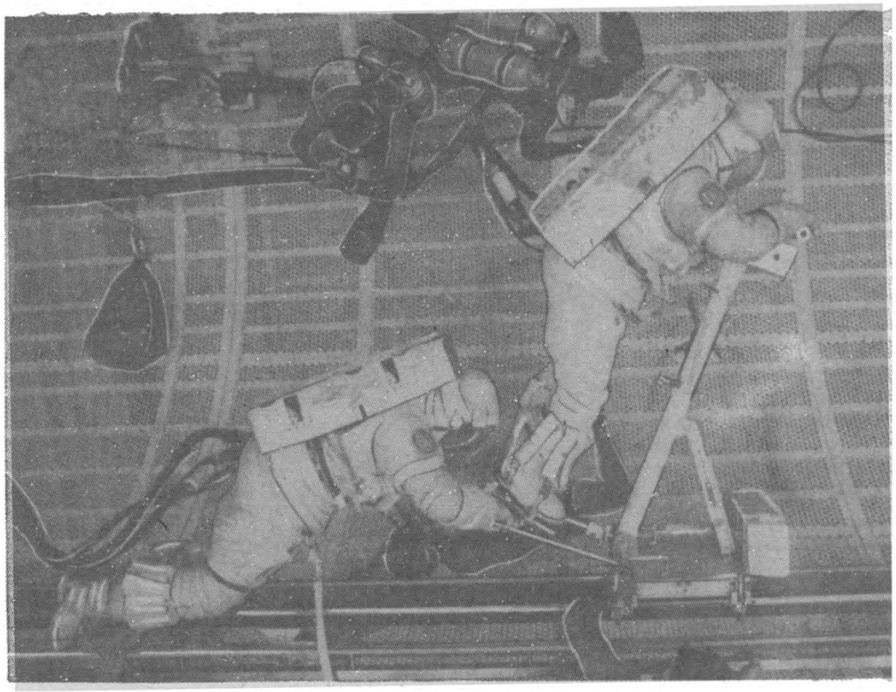
The observatory will be powered up and checked out by the POC. If all is well Linda Godwin will be given a 'go' to grapple the spacecraft with the robot arm. Apt will then transfer GRO to internal power and release the umbilicals from the orbiter.

When Mission Control gives the go-ahead, the astronauts will unlatch the observatory and Godwin will carefully lift it out of the bay on the end of the RMS.

"It is the heaviest [object] that we have ever moved with the arm," says Godwin. "So we will move it very slowly."

She will then roll GRO over so the instruments point towards the payload bay. The observatory will remain in this position until its release.

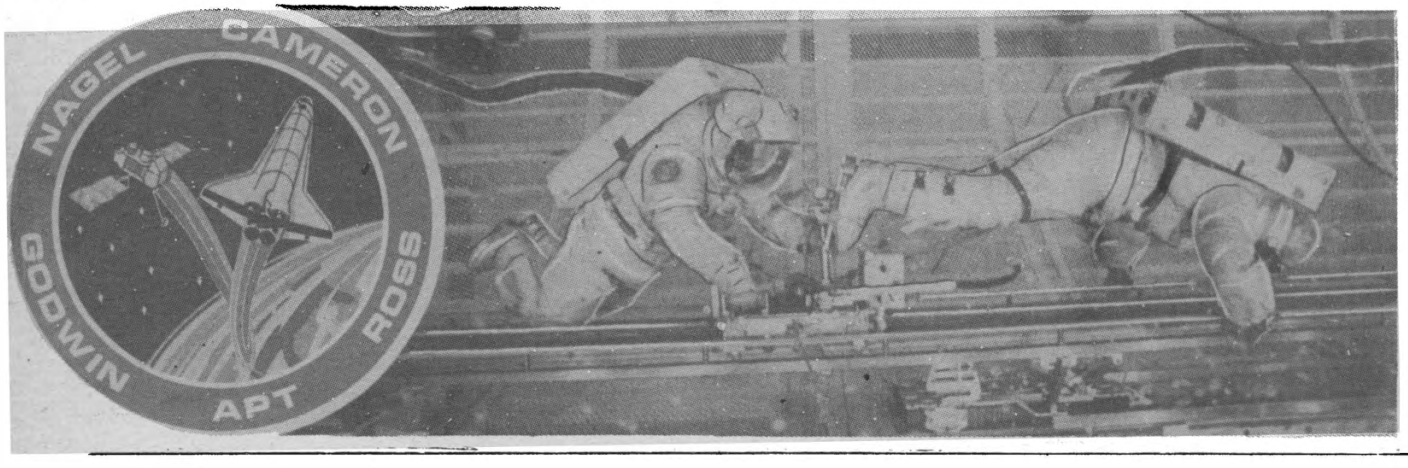
Commands from the POCC will deploy the two solar arrays, one at a time, and rotate them to 45 degrees. It will take about four minutes to unlatch the arrays,



Jerry Ross and Jay Apt practice one of the experiments they will do in space on STS-37. The crew uses an electrically powered version of a cart designed to move astronauts up and down the Space Station Freedom Truss. Apt is pulling Ross along to test the cart's ability to carry one person plus cargo. *NASA*

The STS-37 mission patch featuring Atlantis and the Gamma Ray Observatory. *NASA*

Astronaut Jerry Ross prepares to test a hand-powered version of the CETA experiment. Ross pulls the cart along hand-over-hand during the test while fellow crewman Jay Apt holds on to the back. *NASA*



about nine and a half minutes for deployment and another three minutes to rotate them.

Mission Control will be paying particular attention to the deployment of the arrays to make sure there are no thermal distortions in the panels, said Chuck Shaw, STS-37 Lead Flight Director.

Nagel will then manoeuvre Atlantis to point the spacecraft's solar arrays at the Sun. The observatory will remain in that position for about three and a half hours to re-charge its on board batteries.

During that period the observatory's High Gain Antenna will be deployed for communications *via* the Tracking and Data Relay Satellites (TDRS).

While the batteries charge, the POCC will conduct a full systems checkout to ensure that they have a healthy spacecraft before release. About 30 minutes prior to deployment, ground controllers will again rotate the solar arrays and the orbiter will be moved to put the Sun perpendicular to the arrays.

The commander will make sure the orbiter is in a stable position and Godwin will release the arm from GRO's end effector and move it away. Nagel will then fire the RCS thrusters to move the orbiter down away from the observatory at about 0.15 metres per second.

Unlike geostationary or planetary missions, GRO does not have many hard orbital requirements for its release.

"We can deploy in any attitude, on any orbit," says Shaw.

The planned release time occurs during orbit 34 at MET 2 days, 3 hours, 35 minutes.

About 22 minutes later, Atlantis will perform a 0.6 m/s out of plane separation manoeuvre. The orbiter will drift for about 15 minutes before Nagel makes a 0.9 m/s posigrade manoeuvre to place Atlantis above and behind the observatory. The Shuttle will maintain a communications link with GRO so the POCC has two methods of commanding the observatory, either through the orbiter or *via* the TDRS satellites.

If the observatory's solar arrays or antenna fail to deploy, Ross and Apt will make a spacewalk to deploy them manually. If the spacewalk becomes necessary, the observatory will be lowered towards the payload bay so the astronauts can climb aboard.

Six-Hour Spacewalk Planned

The spacewalk or EVA (Extravehicular Activity) is planned for Day Four of the mission.

The airlock will be depressurised at MET 2 days, 22 hours, 15 mins and shortly afterwards the astronauts will open the hatch and enter the payload bay. The space walk could begin a little early if the crew are ready, said Shaw.

"I can guarantee you, Jay and Jerry are real anxious to go EVA," he joked.

The spacewalk is scheduled to last six hours but may go on longer if the space suits have enough consumables.

Astronauts' main task will be to conduct the Crew and Equipment Translation Aid (CETA) experiments. Ross and Apt will try three different carts designed to move spacewalking astronauts along the truss structure of Space Station Freedom. If an astronaut were simply to move hand-over-hand along the truss with no special equipment it could cause excessive wear and tear in the truss and suit. Also, it would be difficult to carry cargo.

The CETA test equipment consists of a 14.6 metre long rail mounted on the port side of the Shuttle's payload bay. Three different types of carts will be attached to a truck that rides along the rail. The first is a simple manual cart which the astronaut moves along the track by pulling himself hand-over-hand. The second cart is a mechanical version. The astronaut will pump up and down on a lever that drives a gear chain to propel the truck along the rail. Jerry Ross says the cart is very similar to an old railroad hand car. The third and most complicated cart is an electrical version. The astronaut turns two crank handles to drive an electric generator which will, in turn, drive electric motors to move the cart. All three carts have brakes similar to those on a bicycle and can be moved in reverse.

The forward section of rail on which the truck will run will already be in place. A second 7.3 metre section will be joined to it by the astronauts.

The CETA experiments will take approximately half the EVA. The manual cart will be tested first. Each astronaut will make eight runs (up and down) along the track, reaching maximum speeds of about 1.8 metres per second. They will evaluate the cart's braking profiles and determine what is the best way to pull or push the cart along.

The astronauts will next evaluate the mechanical cart. Each astronaut will make six runs at nominal and maximum speeds.

Ross and Apt will then make four runs each on the electrical cart.

The CETA equipment was only designed to carry one person but, for the tests, the other astronaut will ride 'piggyback' to simulate cargo.

Next, tethered to a shuttle running along the rail, the astronauts will evaluate two types of handrail, with round and rectangular hand grips. Each astronaut will make two runs along the rail.

The astronauts will then begin parallel activities with the Mobile Foot Restraint (MFR) on the end of the RMS and the Crew Loads Instrumented Pallet (CLIP).

The MFR evaluations will see how fast an astronaut can be moved on the end of the RMS. The robot arm will be moved at speed of up to 0.4 metres per second.

"That's faster than we have ever done with anyone on the arm," said Linda Godwin.

The length of spacewalks were astronauts need to be repeatedly moved from one work place to another could be drastically reduced if the arm was moved faster. NASA needs to determine exactly how fast the astronaut can be moved.

"If you go too fast the thing could become non-productive because the crew member is just trying to hang on," said Chuck Shaw.

While Apt is conducting the MFR tests, Ross will be using the CLIP experiment, a work station mounted to the side of the Shuttle's payload bay. Standing in a instrumented foot restraint the astronaut will perform a variety of tasks such as undoing a bolt to see how much stress is placed on the work station.

Ross will then do the MFR evaluations and Apt will use the CLIP experiment.

The astronauts will both perform an individual test on the MFR. Standing on the arm, Apt will push against the aft bulkhead of the payload bay with a force measurement tool to see how much force is required to make the RMS brakes slip, while Ross will see if an astronaut can move the arm manually to guide a payload into its berth. Linda Godwin will place the arm in 'limp' mode for the test by switching off its motors and brakes. Ross will then move the arm to return the MFR to its stowage point.

Chuck Shaw likened the 'limp' mode test to a construction worker guiding a beam into position as it is lowered by a crane.

If time permits the astronauts will try to cross a rope strung across the middle of the payload bay. They will also have to stop in middle of the rope and turn back.

"We do not anticipate that to be a very easy task for them," said Shaw.

The astronauts will then stow the CETA rail and return to the cabin.

Jerry Ross will try out a pair of new 5000 series gloves during his EVA said Shaw.

"The 5000s are a spin-off from the 8 psi space suit development that is being conducted in concert with the space station activities," explained Shaw. "It should give a bit more tactility with the fingers. Crews have always remarked that their hands get tired during extended EVAs so this part of an effort to make the gloves a little less fatiguing to crew members. It will be interesting to see what Jerry's comments are on that. He has liked them so far in training"

Shuttle-Mir Link

STS-37 will be carrying a variety of experiments in the orbiter's middeck.

A more powerful version of the Shuttle Amateur Radio Experiment (SAREX) will be aboard Atlantis. The equipment will be similar to that carried on STS-35 in De-

cember last year but will include the ability to transmit and receive television images. All five STS-37 crew members hold amateur radio licences.

The astronauts will attempt to communicate with the cosmonaut aboard the Mir space station using SAREX. The first opportunity will occur at about MET 9 hours, 24 minutes the second will be three days, eight hours later. If Atlantis' launch is delayed, the opportunities will occur one day later for each 30 minutes of delay. On STS-35 the crew was unable to communicate with Mir because their flight was ended early and the cosmonauts were too busy during an earlier opportunity.

Other experiments being flown on STS-37 include the Bioserve Instrumentation Technology Associates Materials Dispersion Apparatus (BIMDA), Protein Crystal Growth II (PCG II), the Space Station Heat Pipe Advanced Radiator Element II (SHARE II) and the Radiation Monitoring Equipment III (RME III).

The crew will also test a Panasonic Super VHS home video recorder to see if it is suitable for use in orbit. Video recorders presently used on the Shuttle only take 30 minute tapes.

"The home [video recorders] are light years ahead of what we are flying on the orbiter," said Shaw.

Other models will be tested on the Shuttle during upcoming missions and may eventually replace the orbiter's present video recorders.

From left, Langley Research Center's John Gustafson and JSC's Ed Whitsett, Steve Poulos and Jim O'Kane inspect the Crew and Equipment Translation Aid (CETA) transportation cart that will fly aboard STS-37. The four engineers have headed a team of hundreds that have contributed to the project. *NASA*

Return to Earth

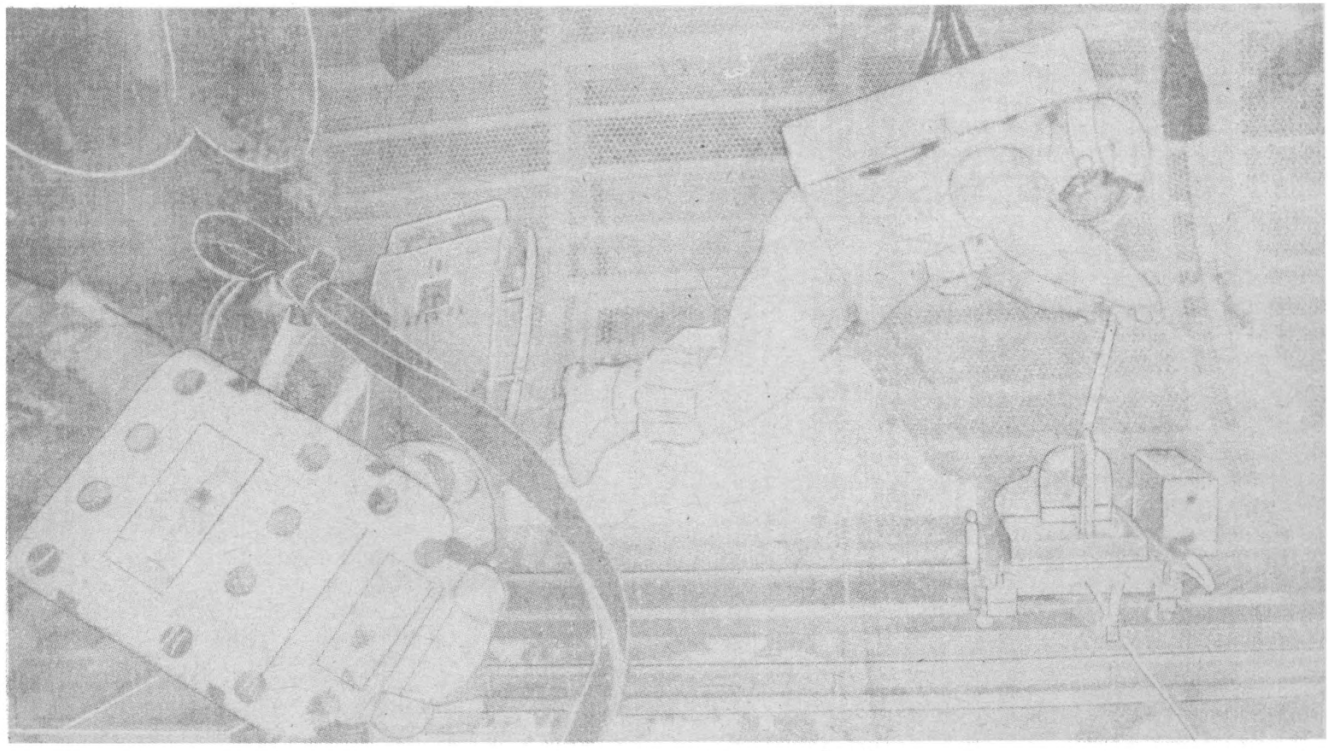
The astronauts will return to Earth on Day Six of the mission. At MET 4 days, 23 hours, 12 minutes, during orbit 77, the astronauts will perform a 121 metres per second OMS burn to bring Discovery out of orbit. Landing will occur at MET 5 days, 12 minutes on dry lake bed runway 15 at Edwards Air Force Base in California. Landing is planned on runway 15 to see how the orbiter behaves on the harder lake bed surface found in the northern areas of Edwards.

"We are going to try to land there with no braking at all and roll along the lakebed and measure the deceleration that the vehicle feels," explained Shaw.

If weather conditions are unsuitable for Runway 15, Atlantis will land on one of the other runways at Edwards and perform a carbon brake test. Atlantis is flying with the new carbon brakes for the first time on STS-37 and engineers want to see if they perform any different to those on Discovery.

Readers in the UK can hear the latest news on mission STS-37 by calling the British Interplanetary Society SPACELINE *on* 0898 88 1975. *(Calls cost 33p per min cheap rate and 44p per min at all other times.)*

Astronaut Jay Apt practices using a mechanical version of the Crew and Equipment Translation Aid, a type of railroad handcart planned as a spacewalker's transportation system along the truss of Space Station Freedom. *NASA*



On the Flight Deck

Dan Brandenstein, NASA's Chief Astronaut, has served as pilot on one Shuttle mission and commanded two more, he is currently training for a fourth flight. In this interview with James Hartsfield, Brandenstein describes flying the Shuttle from his unique position on the flight deck.

"I really don't think people understand the versatility of the shuttle," Brandenstein says. "I don't think they understand what it can do and really how complicated it is. As a crew member, as a commander, you become more familiar with it with each flight and the more you understand just how elaborate it really is".

When the silent clock strikes zero, more than 250 NASA television and film cameras are trained on the shuttle. Commercial television cameras line platforms three miles away, and the scenes on which they focus are transmitted around the world. Still cameras are planted remotely in the swamps around the launch pad and even more cameras click in the press grandstand.

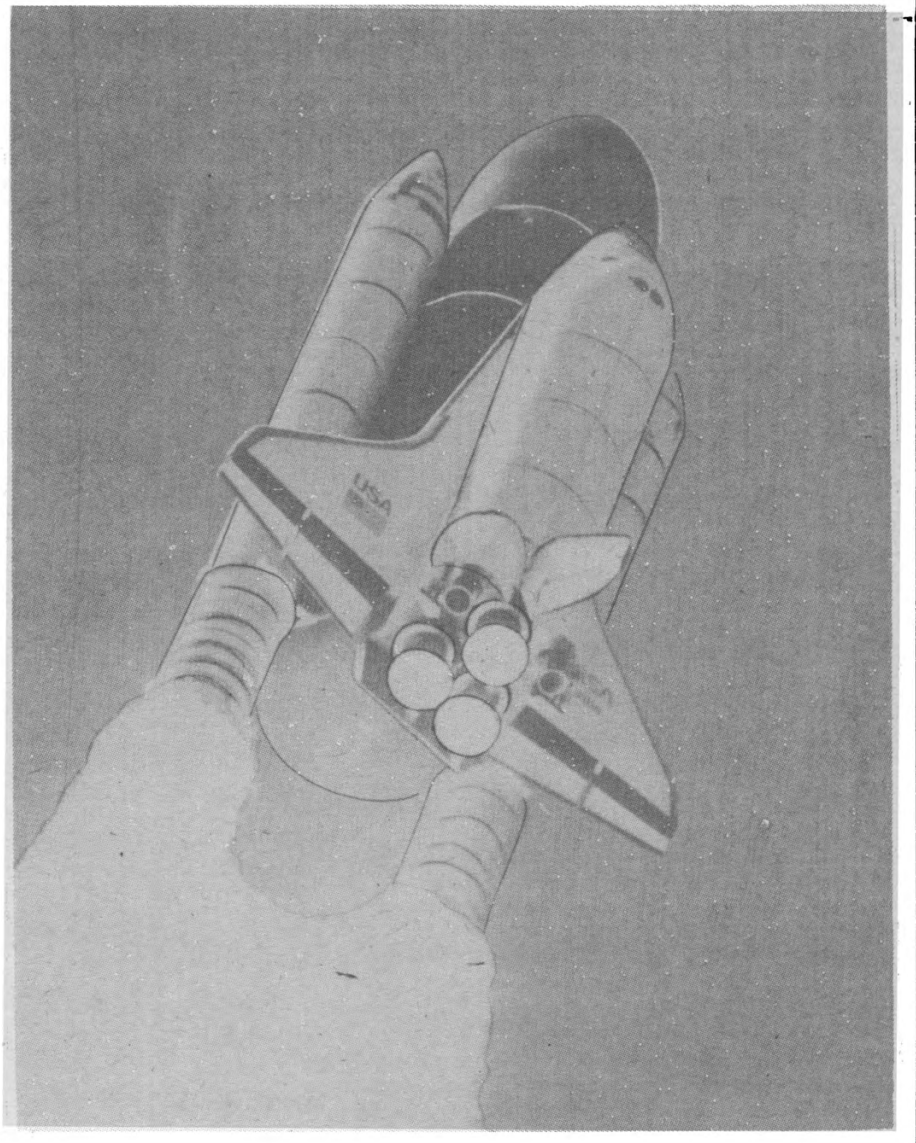
At ignition, the solid rockets go from zero to 44 million horsepower in a split second. The main engines produce a power equal to that generated by 23 Hoover Dams.

But all the eyes that study it as a spectacle, both electronic and human, can't see it from the perspective of that single, front left seat.

"For a certain amount of time, from liftoff through the roll programme, you feel you don't have much control to fall back on. The roll programme would be a very difficult manoeuvre to fly manually. Beyond that, we practice flying ascents manually in the simulator, and I feel very confident that if you had to, you could fly it.

"I've flown three times on the Shuttle, but I've probably looked out the window for only two or three glances on ascent. You are really focused on making sure the vehicle is operating properly. You're cycling through the various displays and you're monitoring the trajectory very closely to be sure it's doing what it's supposed to be doing. In that dynamic a region, if it starts to go wrong, you can't be hesitant."

Eighty NASA cameras still focus on the shuttle at 150,000 feet, two minutes and 10 seconds after launch, when the solid rockets burn out. From the ground, they appear to fall away like arrows at the height of their flight, with a slow grace that camouflages the explosive charges that push them away. The spacecraft is moving more than four times the speed of sound.



Spectacular view of the Space Shuttle Atlantis blasting off from launch pad 39B. *NASA*

By James Hartsfield
Johnson Space Center, USA

"Before my first Shuttle flight, the highest altitude I'd been to was probably a little over 50,000 feet."

"When the solids go, you felt a dip. It feels like you're falling for just a second. After SRB sep is past, it gets so smooth. I always refer to it like a sewing machine. It just kind of purrs."

For six and a half minutes after the solids have expired, the main engines continue to burn, pulling fuel from the external tank at a rate that would drain an average swimming pool in less than nine seconds. To those watching, it is simply streaking toward space, continually climbing, constantly accelerating and slowly disappearing. But to those flying, it is passing through boundary after boundary, climbing a set of safety-net stairs to orbit.

"You are always busy monitoring systems. You give the middeck folks a play by play of what's happening now and what's about to happen, to keep them informed. Your concentration on trying to keep track of options does decrease. When you pass the negative return call, you don't have to worry about a return-to-launch-site abort. But you still have a variety of abort boundaries to go through.

"Then, when you get the press-to-main engine cutoff (MECO) call, your transatlantic aborts are gone, so you kind of relax on that. But you still have more things ahead.

"We're comfortable with the whole

system as we have it now. As long as you can override something that's automated if it isn't doing the right thing, and as long as you can do that before it puts you in a situation that you can't recover from, then automating things is better."

"Anytime that you can have more capability by doing it automatically, that's the thing to do. Given enough computer power and enough sensors, you can automate a lot of things. But anything that happens has to fall within something that you've programmed. You gain by having a man in the loop in a lot of areas, areas where there are so many variables, because he has the ability to take over if something happens that falls out of what the computers can handle, Humans are creative. They're intuitive and can make decisions. You have to take some trade-offs."

When the main engines cut off, the shuttle is about 70 miles high and travelling around 17,400 miles per hour. But the sensations in the front left seat say it may as well be sitting still.

"What's really strange is that when the engines cut off, your arms just float up. It doesn't feel like you stopped. The G's build up the most right before MECO and you're being pushed back, but you are not thrown forward in your straps when the engines shut down. The acceleration that pushed you in the seat is gone and you're just floating."

All that remains to put the shuttle in orbit now is a slight boost, an adjustment, without which the spacecraft would descend as quickly as it rose. The orbital manoeuvring system engines are a fine-tuning mechanism, easing the Shuttle into a free-fall around Earth, too fast to come down, too slow to go higher.

"Relative to the sensations of ascent, the OMS burn is not much. But once you've been in zero-g for a while, any burn is very noticeable. You're more sensitive. The burn is a bit of a jolt when it starts and it's just a smooth, gentle acceleration after that. You don't really see yourself get any higher it is so gradual. You do a burn on one side of the Earth and you don't really see that you're any higher until you're half an orbit away."

"You can't relax afterward, because then you're into post-insertion. You're configuring for on-orbit operations. You're opening the payload bay doors, stowing the seats, getting out of your suits and adjusting all the systems for orbit. It's a very busy time and it normally sets the tone for the mission. You want to get through that and stay ahead of the timeline, because as soon as post-insertion is done, you start getting into the meat of the mission. You don't want to get behind or get caught short.

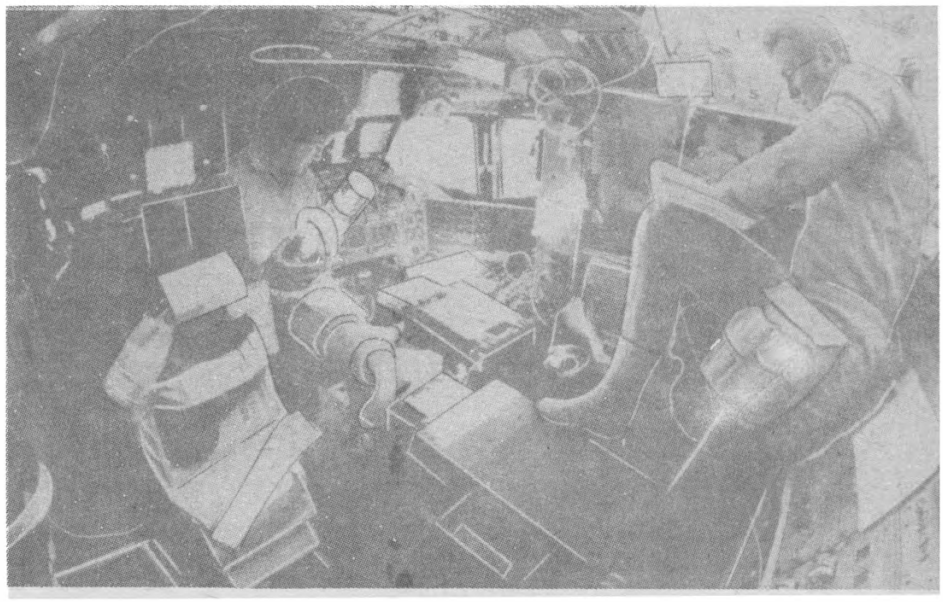
"It isn't really until the pre-sleep period on the first day when you can really kind of relax and say, "We're all caught up; We got today done". Then you can eat a slow meal. In fact, for lunch on the first day, we usually just carry a bag of sandwiches we can eat on the run."

Brandenstein's first flight, STS-8, launched at night. The shuttle reached orbit in darkness.

"We launched at night, we crossed the Atlantic at night, and, just as we got to Africa, we saw the first Sunrise. Of all three flights, seeing that first sunrise is something that's most memorable to this day. In your training, you get briefed on what things are going to be like but no one ever said how phenomenal those sunrises were. It was so gorgeous, it just took my mind away.

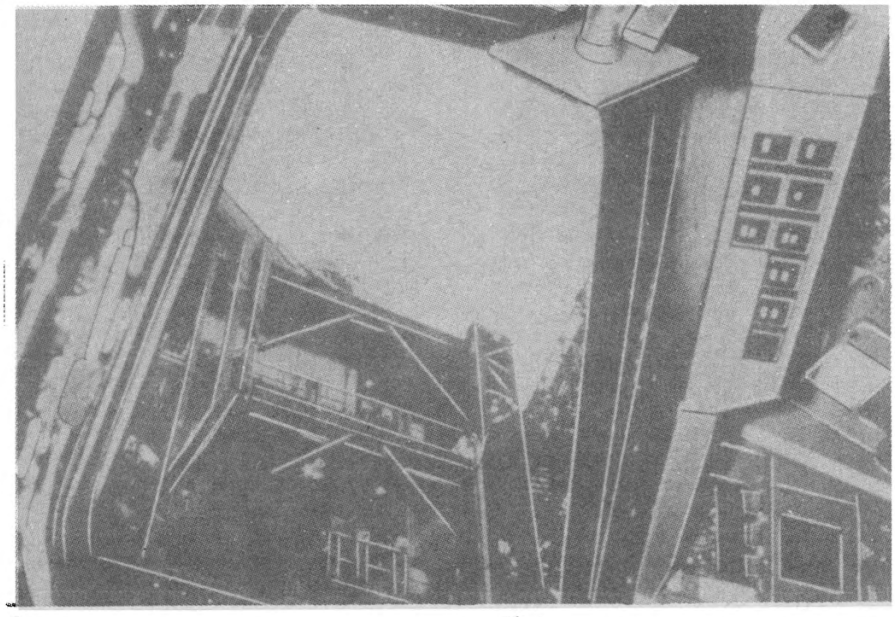
"Sunsets and sunrises happen very fast. At Sunrise, you see a sliver of sky turn blue, and then you get this tremendous spectra of colour all along the horizon. The colours are just so vivid and so bright that it is really amazing".

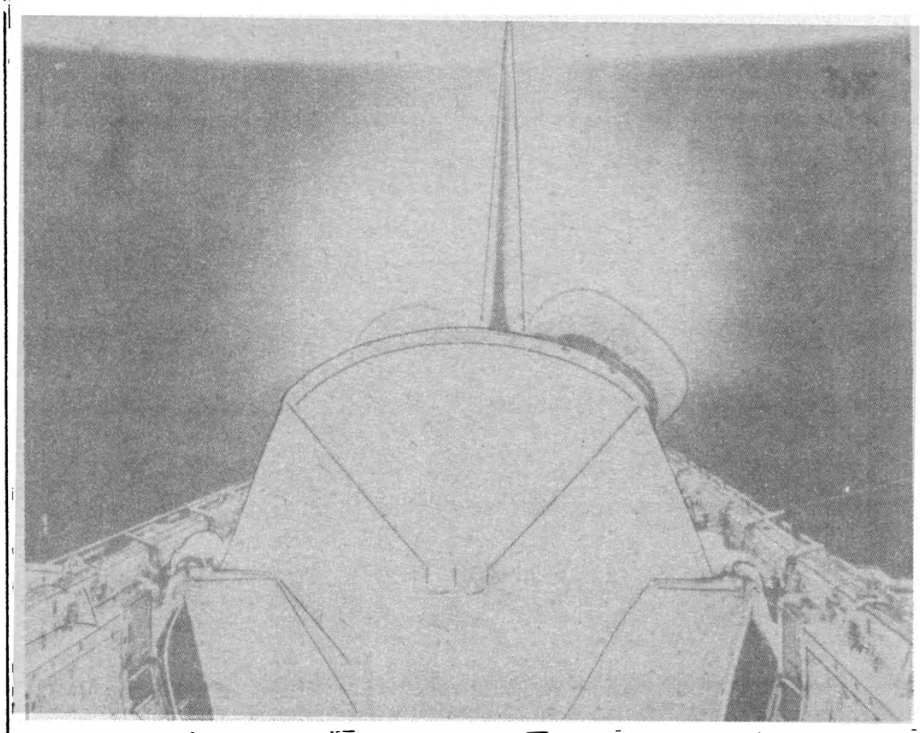
"You have to have what we sometimes refer to in the flying business as "situation awareness". You have to know what's going on all around you. You have to have a big picture of all the systems on board. But, then again, by the time we fly, we've been trained by so many experts that we also have a very intimate knowledge of each par-



Remarkable portrait of activity on the flight deck during the space telescope deployment mission, taken with a 35mm camera with wide-angle lens and using ambient light. Kathy Sullivan (left) and Loren Shriver (right) *NASA/ Space Information Canada*

The view from the shuttle cockpit. The top of the Fixed Service Structure at pad 39A fills the commander's windows in this photo taken aboard the orbiter Columbia on November 1981 *NASA/Space Information Canada*





The orbiter's Orbital Maneuvering System engines create a spectacular sight when fired in orbit. *NASA*

ticular system.

"I sleep on the flight deck. The rest of the crew sleep downstairs. If something happens during the night, you're right there ready to respond. If there is an alarm, you can get to it quickly and not disturb the whole crew, especially if it's something that's not very significant.

"I sleep well on orbit, but I don't think I sleep as soundly as I do back home. I believe it's mainly because I don't want to get too sound asleep just in case there is an alarm or something.

"Day-to-day, when you are doing experiments, eating dinner, or doing housekeeping chores, you let the caution warning system do its job. You don't monitor things very much. But when you have a spare moment, you go and cycle through the displays."

Flight in orbit is not flight, although it is called that for lack of a better word. Movements of the shuttle in space are adjustments made to a perpetually falling object through the use of 38 primary jets, six small jets or the two large OMS engines. The wings are simply waiting. Due to the unnatural feel of orbital mechanics, flight is now a precise calculation of cause and effect more than it is a human feel for what will occur and why. The idea of any movement at all is relative to where you are looking.

"You don't have a sensation of speed such as driving fast down the road, because poles aren't whizzing past you, you aren't hearing the rumble of wheels on the ground. It's not even like flying an airplane at low altitude, where you see the terrain zipping past, you feel the turbulence and you hear the wind noise. You're in a silent environment other than the cockpit noise, and the only sensation you have is when you look out the windows and see the ground tracking below you. But to see continents come and go, to take on the order of 10 minutes to cross the United States, it's obvious you're really humming. But it's a different sensation of speed. You don't have the acceleration. It's just zero gravity, floating at almost 18,000 miles an hour."

"We did some preparatory burns the day before we caught up to the Long Duration Exposure Facility and, with those, you don't really feel like you're catching up to anything. They are just OMS burns. But the night before the rendezvous, when we went to bed, with the Sun angle right, we could see LDEF, though we didn't really get close to it until the next day."

"The reaction control system feels very tight when you are flying close to another object. You fire the primary jets and the vehicle gets a big thump, shakes and it moves.

"You can control it to within inches. We did that when we retrieved LDEF and we retrieved Spartan on my second flight. The flight control systems hold an attitude so well. It makes flying it so precise. You can make very specific movements.

"It is a tribute to how well designed it is. Still, you can't always get it perfectly stopped relative to another object, so you might just move it so far and let it take a very slow drift".

To go from zero to almost 18,000 mph in eight and a half minutes is a feat, but the bigger feat is to go from 18,000 mph to zero and remain intact. The shuttle poses for its return to air and wind and land like the traveller who pulls coat collar tight and puts chin and chest into a bitter winter breeze: It takes a posture of defiance. To designers, crew and flight controllers, it is called a high angle of attack - its nose is angled high and its most durable portion, the tiles underneath, greet Earth first in a battle between air and speed.

"The deorbit burn feels just like the OMS burn on ascent. But as soon as you're done with it, you pitch around to get the nose forward and up. Then, as you start your fall toward the atmosphere, you do notice that you're coming down. It looks like you are getting closer to the Earth. But you normally go into night very quickly, and then your visual cues are gone.

"Then, in darkness, the first sensation you get is when you are a bit into the atmosphere and the Gs start building up. It still doesn't feel like a descent - it feels like being in an airplane and pulling Gs. It just feels like you're squishing down in the seat. The only real sensation of descent is from watching the altimeter click off.

"From the sensation, without instruments, you wouldn't know the difference between Mach 25 and Mach 1".

The shuttle's entry is automated from the deorbit burn through three gradual, sweeping S-turns, one of which can take half an ocean to complete. The atmosphere is the only brake it has to slow it from Mach 25 to 200 miles an hour. The friction between air and spacecraft produces temperatures of almost 3,000 degrees Fahrenheit. To release the energy it received at launch, it creates as much of a spectacle on entry.

"You don't get used to seeing the plasma build up. At about 350,000 feet, you start to see a little pink out of the windows, coming up from the bottom.

"It turns into kind of a pink glow and, from that, becomes an orange glow. It then becomes a very deep orange, before it turns practically white - it is so hot. The plasma flow is that dense. In fact, on the corners of the windows, you can see a turbulent flow with swirls in it. It's sort of like rain on the car window, but it isn't drops, it's a flow pattern.

"Then at about 180,000 feet, it goes in reverse: the white gets less dense, then it goes to orange, then pink and then it's gone.

"During this phase, you come into daylight. The Earth is still dark, and the upper part of the sky is still dark, and in those areas you can still see the plasma. But where the Sun is rising, you can't see it because of the light

background. On both extremes, you have the orange, pinkish plasma. In the middle, you have a blue stripe where the Sun is coming up. It only lasts a few seconds".

"You've trained to the point where you know that if you had to take over, you could do it. But you don't even hold your hand on the stick all the time during entry. You are just monitoring systems, cycling through displays on the screens and checking them against your checklist cards. It's a very close analogy to an airplane on autopilot.

"When you see the Sun come back up again, it's obvious that you're much lower than you had been. But even then, when you break out of night, you don't have a sensation of going down. You still feel mostly just forward velocity".

As the shuttle descends and slows, the jets that have kept it stable are replaced by the rudder and elevons for control. Flight becomes flight again in the traditional sense.

"You can hear the primary jets fire, and you can see them in front. But you don't hear wind noise.

"You don't notice the change from the jets to the aerosurfaces; it's very subtle".

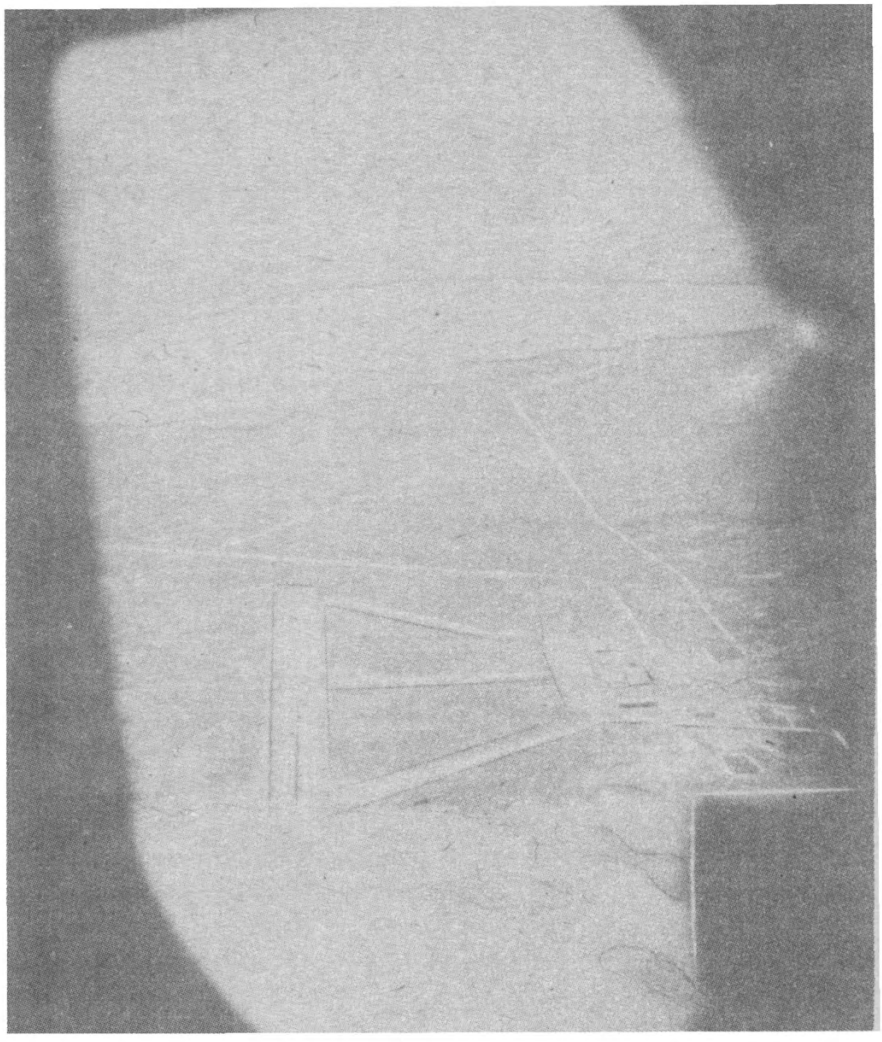
"When we go subsonic, at about 60,000 feet or so, we take over manually, flying it around the heading alignment circle all the way to touchdown. That way, when you get to the landing phase, you're in tune with the vehicle. You're aware of its responses".

"The shuttle has an autoland capability built in, but it has never been tested. Early in the programme, we looked at a possible test of it, but the concern is that if it errs close to the ground, there's nothing you can do to take over. Say it made an error at 50 feet from touchdown, you've got a pilot who had been in orbit five days, done the entire landing on autopilot and suddenly had to take control. In an unpowered vehicle, he'd essentially be helpless. There wouldn't be time to make a proper correction. Trying to take over suddenly without getting used to the vehicle first would be difficult. The tendency would be to overreact.

"On first landings, almost everyone notices a sort of time compression. The events seem to happen faster than they did in the simulator or in the Shuttle Training Aircraft. The STA is very accurate in duplicating the shuttle, so your landing feels very much the same; you feel like you've done it before. The time compression is probably due to anxiety, because it doesn't seem to happen the second time you land".

"The shuttle goes through "mach buffeting" as it goes subsonic. It's a shaking kind of like a car going down a gravel road, due to air transitioning from supersonic to subsonic flow over the wings, and it lasts about 10 to 15 seconds".

"I've flown 747s and the KC-135, which are big airplanes. In them, you have a certain lag in the responses. But the shuttle flies more like a fighter than a big airplane. You know you are flying a large aircraft, but the controls are positive and crisp".



Concrete runway 22 looms out of STS-6 pilot Karol Bobko's forward window during the final approach of the orbiter Challenger at fabled Edwards Air Force Base *NASA/Space Information Canada*

"You don't get much of a sensation of descent until you drop the nose on final. The approach pattern is much different than a fighter, carrier approach or anything else. In the shuttle, you have no power, and most of the time you're constantly decelerating. On the outer glide slope to the runway, you maintain a constant speed of 290 knots by opening and closing the speed brake. You feel the speed brake take hold and you feel the drag in general".

On its final approach to the runway, the shuttle descends seven times more steeply than a commercial airliner. It is dropping from the sky 20 times as fast. Less than 2,000 feet above the runway, it pulls up to reduce its angle of descent to just slightly less than that of an airliner. Its final manoeuvre before touchdown is a slight flare upward of the nose, to slow it even more and allow a gentle easing down of the nose landing gear after the main gear has touched Earth.

"You don't feel the final flare. The only big difference on touchdown is between the lakebed and the concrete runway. Rollout on the runway is much smoother. The lakebed is pretty rough.

"If you bring it to touchdown right, you hardly notice it. It's smoother than a landing in a commercial jet.

"When it was first being designed, they said the shuttle was going to fly every two weeks, 60 missions a year. That was obviously far too optimistic. If you could simplify the turnaround, reduce the care and feeding, then that would be a big help. But I don't consider today's flight rate any type of a drawback to the vehicle, simply because there is nothing else like the shuttle, nothing else that can do what it can do.

"It is being a part of a team that accomplishes a mission that you remember. That's the whole thing. You take it in steps. You are proud of your part in it; you are proud of your crew; you are proud of everyone that worked on the flight; and you are proud of the whole team that made the shuttle perform. When you walk away and you're all done, that's what you remember and that's what really makes you feel good".

Additional Photographic research by Joel Powell of Space Information Canada.

Cracked 'Hinges' Postpone STS-39

Delays Mean One Less Mission In 1991

Shuttle mission STS-39 has been delayed because of cracked 'hinges' on the orbiter Discovery. The Shuttle has been rolled off the launch pad and returned to the Orbiter Processing Facility for repairs. Discovery's mission has been postponed until late-April or early-May. The Space Shuttle Atlantis will be launched in early April, as originally planned.

The cracks were found on the hinge mechanisms of Discovery's umbilical doors where propellant lines from the external tank enter the orbiter. The doors are closed after the tank has separated to protect the umbilical opening from the heat of reentry. The orbiter would almost certainly be destroyed if the doors fail to seal.

Each door has two hinge mechanisms that consist of a system of bell cranks and push rods operated by electromagnetic actuators. While the Shuttle is attached to the tank, the doors are latched open flush against the orbiter's belly. Almost immediately after ET separation the 50-inch square doors are commanded to close by the pilot. It takes approximately 24 seconds for the doors to shut. Three latches on each door ensure that the doors are fully sealed. Microswitches confirm that the doors are closed.

The closure mechanism is tested in the Orbiter Processing Facility (OPF) before each mission but the hinge mechanisms are not examined.

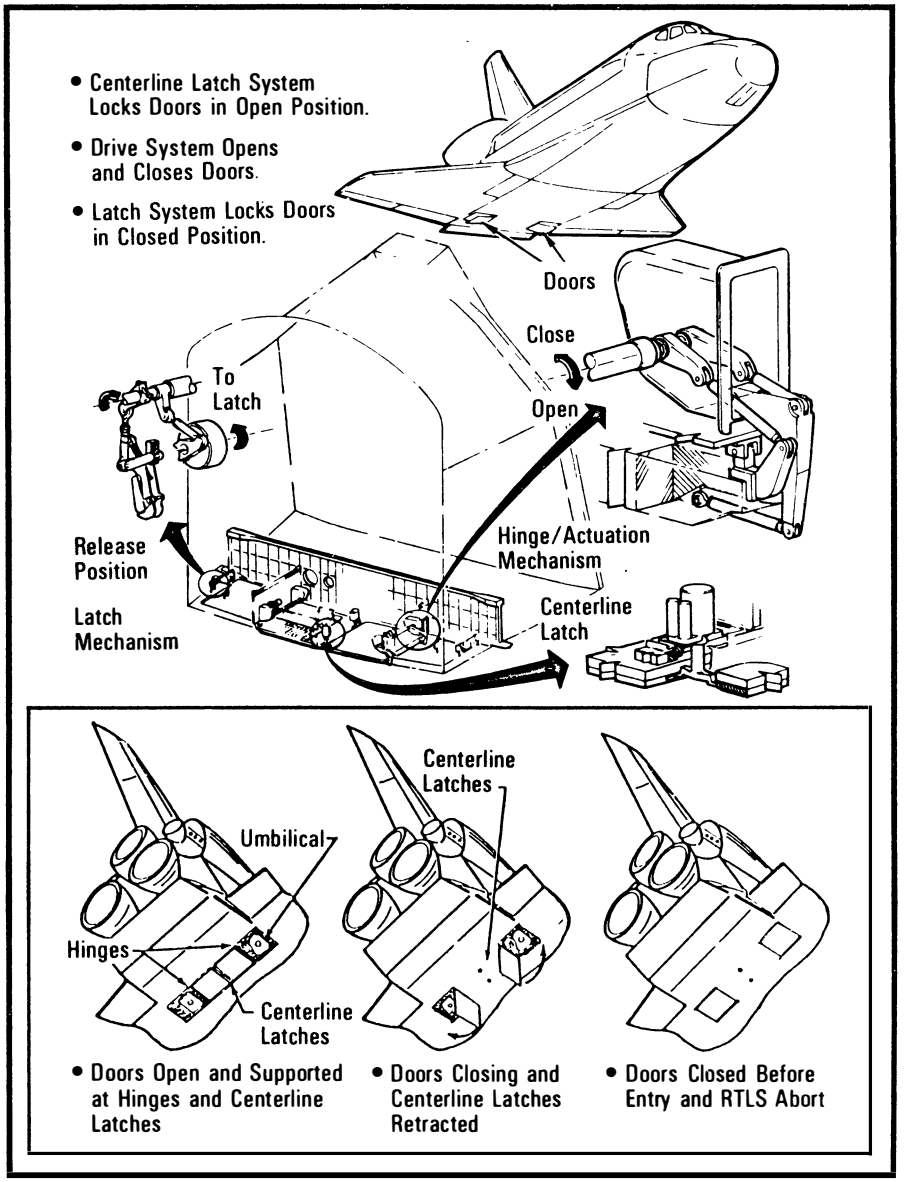
"The cracks are up inside the structure," said Bob Sieck, Shuttle Launch Director. "It is the kind of area that you wouldn't go to in a normal routine inspection."

The damaged hinges were not found until after Discovery had been moved to pad 39A and then only by chance. A launch pad worker was installing a 'purge curtain' around the umbilical door opening when he noticed something suspicious and alerted engineers.

Detailed inspection revealed two cracks, one on the aft hinge of the right hand door, the second on the forward hinge of the left hand door. The two-inch cracks are located on a lug that supports part of the door hinge mechanism.

NASA faced three options: Discovery could be launched 'as-is', repairs could be made at the pad or the Shuttle could be returned to the OPF where the cracked lugs could be replaced.

It soon became clear that a repair on the pad was unlikely. With Discovery mated to the External Tank, access to the hinges is difficult. Also, if the hinge mechanism was dismantled the doors would require testing to confirm they would close. The doors can only be cycled open and closed when the Shuttle is in a horizontal position in the OPF.



Shuttle managers were left with a straight choice: fly as-is or roll back. They had plenty of time to analyse and discuss the problem because Discovery could not be rolled off the launch pad until an OPF bay became vacant.

Meanwhile STS-39 launch preparations continued. The Terminal Countdown Demonstration Test was performed on February 19 and 20 as a full dress rehearsal for launch. The seven man crew were aboard Discovery for the final hours of test, which concluded with a simulated main engine cut-off at 16:09 GMT on the 20th.

While they were at the launch site, the astronauts examined the cracked hinges and later reviewed the engineering data. Afterwards, Mission commander Mike Coats was said to be 'comfortable' to fly with the cracks. However, the engineering community was divided.

Small fatigue cracks had also been found on three of the four hinges on Columbia. The cracks were much smaller than those on Discovery but a picture was beginning to form.

The fatigue cracks were caused by opening and closing the doors during ground operations, said Dan Germany, manager of the Shuttle office at the Johnson Space Center.

"A small crack initiation starts," he explained. "Then with any particular overload that might occur, that crack tends to open up like what we are seeing now [on Discovery]."

During Discovery's lifetime its umbilical door hinges had been cycled between 70-80 times, Germany said. NASA is now

looking at making the hinge lugs stronger so they can better cope with the stress.

"We did not expect to see the 'starter cracks' in this particular mechanism with this small number of cycles," said Chester Vaughan, Shuttle chief engineer at NASA Headquarters.

However, engineers were optimistic that Discovery could fly as-is. They believed that the cracked hinges would work normally because the mechanism is not under stress when the doors close in zero gravity.

During tests in the OPF, Columbia's doors were successfully opened and closed with the hinge mechanism modified to simulate a total failure of the cracked lug. Also, rubbing within the cracks on Discovery indicated that the doors were cycled after the cracks occurred.

"From an engineering standpoint we feel reasonably comfortable that the door would do its job in a zero gravity environment," Vaughan told a press conference.

Cause of Overload Main Concern

However, what was really concerning Shuttle engineers and managers was how the hinges had been overloaded to force the small fatigue cracks open.

As engineers searched through Discovery's records they found an incident that NASA Associate Administrator for Space Flight, Dr William Lenior, describes as "highly suspicious". During preparations for STS-39, Discovery's left-hand external tank door was accidentally commanded to close while it was latched open. A loud crack was heard but workers were not over-alarmed because cracks are frequently heard when the doors are closed.

"Our analysis says that event had the potential to overload [the lug] if a fatigue crack had already formed," Lenior said.

In the case of the right-hand door there is no clear explanation how the hinge was overloaded. During preparations for STS-41, the umbilical doors were prevented from closing when a nut was caught in the hinge mechanism. But NASA does not believe that that incident caused enough force to crack the lug open.

It was this unknown factor that finally led Shuttle managers decide on February 27 to postpone Discovery's mission.

"The analysis says [the hinge mechanism] is OK and it will work," said Lenior. "But none-the-less, not knowing what it was that broke these, leads us to the conclusion that prudence calls for us to roll back and fix it."

Lenior said the decision to roll back Discovery proves that the system set up after the Challenger accident works.

"This is one of those real challenging cases," he said. "We are safety orientated - whenever we have to err we are going to err on the safe side. If think that most of us came to the conclusion that we were walking right on that fine line and given that we conclude we are walking on that fine line we must take a step on the safe side."

However, Lenior went on to say that if there was some critical reason for the Shuttle to be launched as soon as possible he would not have hesitated to fly Discovery in its present condition.

The decision to roll Discovery back to its hangar was not unanimous. It is reported that as late as February 26, senior Shuttle managers voted eight to six in favour of proceeding with the mission.

Discovery was rolled back to the VAB on March 7 and was to be returned to the OPF on March 14. It will spend two weeks in the OPF while its cracked lugs are replaced with lugs taken from the new orbiter Endeavour. The orbiter will then be rolled back to pad 39A.

Columbia's cracked lugs have been removed and returned to the supplier for repairs.

Cracks Found on Atlantis

It was thought that Atlantis was free of cracks until just prior to its roll over to the VAB when dye penetration and borescope inspections revealed starter cracks in two hinge lugs. The cracks were much smaller than those on Discovery and Columbia. NASA decided to go-ahead with Atlantis' mission, said spokesperson Lisa Malone, because the cracks would pose "no threat to vehicle performance, either on the ground or in flight."

the cracked lugs on Atlantis will be repaired after the mission.

Atlantis was moved to the VAB on March 8 and attached to its External Tank and Solid Rocket Boosters the following day. Atlantis arrived at launch pad 39B on March 15.

The launch remains targeted for the end of the first week in April but there is no contingency time left in the schedule said NASA spokesman Ed Campion. A firm launch date will be set at the Flight Readiness Review on March 26 and 27.

Six Flights in 1991

Discovery's mission will be delayed almost two months.

"There are going to be some downstream effects from this," said Shuttle director Bob Crippen. "It is going to impact us with at least the loss of a mission this year."

As this issue of ***Spaceflight*** went to press NASA managers were still discussing a revised manifest. A provisional schedule for part of 1991 reads as follows:

Early April - STS-37, Atlantis with the Gamma Ray Observatory.
Late April/Early May - STS-39, Discovery with the IBBS/SPAS and AFP-675.
Late May - STS-40, Columbia with the Spacelab Life Sciences laboratory.
July/August - STS-43, Atlantis with the Tracking and Data Relay Satellite (TDRS-E).
Mid-September - STS-48, Discovery with the Upper Atmosphere Research Satellite (UARS).

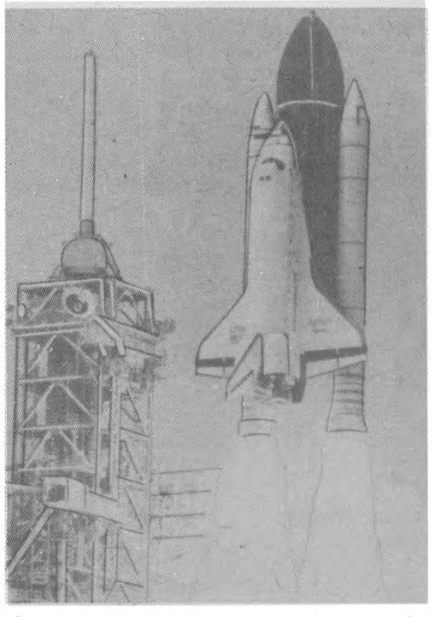
A number of factors have influenced the schedule. First, after STS-40, Columbia is being flown to Rockwell International's Palmdale facility for maintenance and inspection. It will not be available again until mid-1992. Secondly, the UARS deployment is being treated as a priority mission. Scientists want the spacecraft to study depletion of the ozone layer over two winters. Because the spacecraft has a lifetime of 18 months it is essential that the launch takes place before this winter.

Dr Lenior noted one advantage of this new Shuttle 'shuffle'.

"We will be launching in near numerical order," he told a press conference.

With mission STS-34 followed by STS-33, 32, 36, 31, 41, 38 & 35, many journalists have joked that NASA's Shuttle numbering system is deliberately designed to confuse the press and public.

Bob Crippen was quick to add that the return to near numerical order was purely 'by accident'!



Yuri Gagarin's Immortal Day

Thirty years ago, on April 12, 1961, Soviet Air Force pilot Yuri Alekseyevich Gagarin, riding atop a powerful booster rocket, inside the Vostok spaceship developed by Chief Designer Sergei Pavlovich Korolev, ascended into low Earth orbit.

After a single orbit of the Earth Gagarin landed in a ploughed field. The first ever manned space mission and a great boost to Soviet science and technology in the eyes of the world ensured that Gagarin entered the ranks of the immortals.

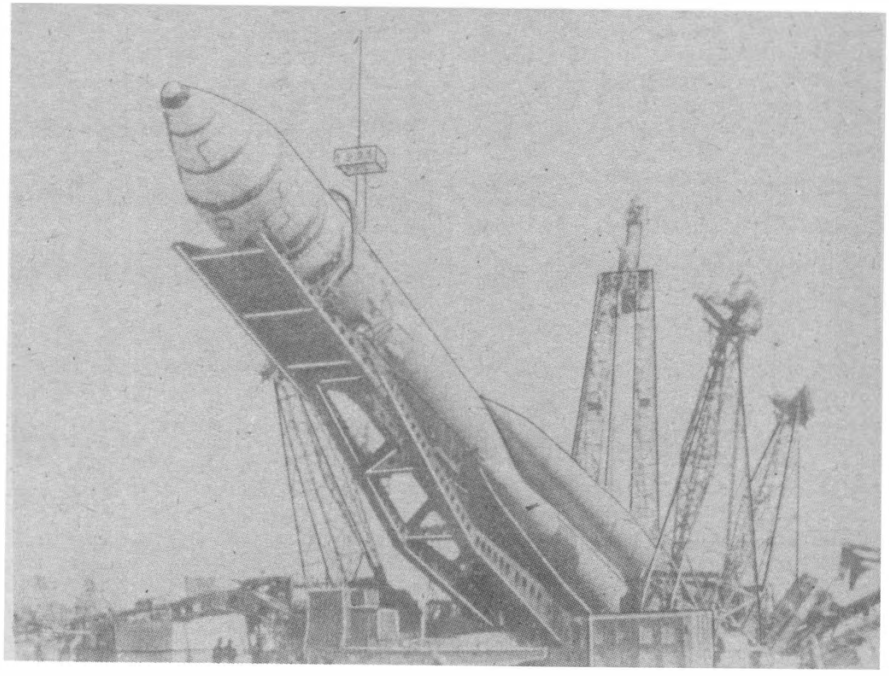
In the intervening years many facts, once hidden by the Soviets in their desire to keep much of their space programme secret, have surfaced. At first the Soviets ordered Gagarin to lie about the fact that he had ejected, as planned, from the descending spacecraft. The design of the spacecraft itself was not revealed until 1965. The design of the rocket was unveiled in 1967.

Despite many sensational contemporary stories of cosmonauts being stranded and dying in orbit, or returning to Earth in a mentally unbalanced state and other fates, it is now established that Gagarin's flight was the first attempt by the Soviets to launch a manned spacecraft.

One thing that has not altered is the perception of a young pilot who risked his life to pave the new frontier for humanity.

Gagarin, by all accounts, was a man of humility who understood his feat and was proud of it but remained a real human being. He was a young husband and father of two girls. The Soviet media made much of his communist credentials. Countless books and films have been made which glorify him and the achievement of that day in 1961.

The history of the Vostok programme has been written elsewhere in a far more detailed manner than can be dealt with here and the reader is referred to those texts. Thirty years after the events of April 12, 1961, however, we can tell the story of the flight of Yuri Gagarin as it really happened.



Gagarin's Vostok rocket is moved into the vertical position on the launch pad.

By Neville Kidger

Crew Selection

Gagarin was chosen from an initial batch of 20 candidates who began to report to their training camp in March 1960. Six were chosen from this group to train intensively for the first manned flight into outer space. They were: Yuri Gagarin, German Titov, Gregori Nelyubov, Andrian Nikolaev, Pavel Popovich and Valeri Bykovski.

The small group was chosen after the Vostok simulator had been built on the understanding that it would be too time-consuming to train all the candidates in the group. The simulator instructor was test pilot Mark Gallei.

Gagarin was the first to volunteer to try out the spherical Vostok capsule. By all accounts, Gagarin was the overwhelming choice of the group of candidates to make the first flight. In a poll, only three other names were suggested by the cosmonauts as candidates for the first mission.

Vostok Flight History

The Vostok spacecraft made several flights before the first manned launch, with a mixture of success and failure.

The first Vostok spacecraft launched on May 15, 1960, had no thermal coating, no parachute system and no ejection seat mechanism. It was launched to test flight control systems and was not intended for return to Earth. However, the spacecraft's infrared sensor failed and the spacecraft was oriented with its braking nozzles downwards. The braking system, when it was activated, fired the spacecraft into a higher orbit.

The second Vostok, launched August 19, 1960, landed safely with the first live specimens flown into space and returned to Earth. These were two dogs - Belka (who vomited on the fourth orbit) and Strelka, two rats, 28 mice and a swarm of pomace flies.

The third mission, launched on December 1, 1960, failed to return safely to Earth when the braking system malfunctioned and the craft burned up in the atmosphere. The test animal aboard became the first to die during reentry from a space mission.

Three weeks later a Vostok was involved in a launch failure. The descent section of the craft was safely separated and the animals aboard survived.

The next launch was on March 9, 1961. The craft carried a dog, Chernushka, and an anthropometric mannequin which held cages with rats, mice and tissue and microorganism samples attached to its chest, stomach and legs. The flight lasted 115 minutes.

Despite the success of that flight Korolev ordered one more test of the system.

Death of the Youngest Cosmonaut

Just two days before that flight the youngest of the cosmonauts, Valentin Bondarenko, was killed in an accidental fire in the isolation chamber. Bondarenko was completing the 10-day-long test when a cotton ball he was using to wipe off electrode adhesive, soaked in alcohol, fell on to an electric

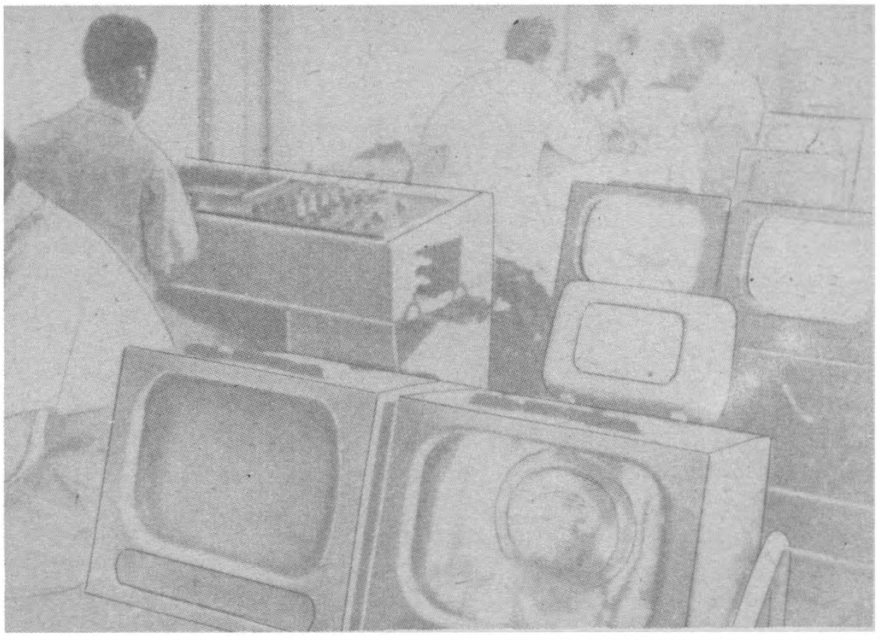
stove. The oxygen in the atmosphere caught fire and Bondarenko was engulfed in flames.

His woollen training suit ablaze, Bondarenko tried to extinguish the flames himself but, by the time help from outside was able to reach him, he was badly burned. Bondarenko died in hospital later that night from extensive burns.

Final Unmanned Mission

The launch of the final unmanned Vostok, on March 25, 1961, was witnessed by the six cosmonauts training for the first manned flight. The mannequin, a dog - Zvezdochka and other biological objects were the passengers on the flight.

At a Moscow press conference three days later Dr. Oleg Gazenko held aloft the dogs, Chernushka and Zvezdochka, for the benefit of the Soviet and Foreign journalists gathered in the hall. In the front row, ignored by the journalists, sat Gagarin, Titov and other cosmonauts. Gagarin must have pondered that the next press conference in the hall would be his own.



Gagarin's TV image appears on screens in the flight control centre.

Vostok-1 Pre-Flight

The decision to launch a manned Vostok spacecraft was taken by the Soviet government on April 3. Cosmonauts not included in the group of six were deployed to various ground measurement centres throughout the USSR.

On April 5 the group of six were flown to the cosmodrome. Also in the fleet of three planes were Nikolai Kamanin, the head of the training detachment, Dr. Evgheni Karpov, the cosmonaut's doctor, other medical men and cameramen.

Leaving his family behind in Moscow, Gagarin lied to his wife and told her the flight was scheduled for April 14 so that she would not worry too much before the actual date.

On April 7 the cosmonauts tried on spacesuits and tested themselves in the actual Vostok spacecraft. The craft was to weigh 4,725 kg.

On April 8 a State Commission approved Yuri Gagarin as the prime candidate for the flight, with German Titov as his reserve.

During a later meeting of the Official State Commission, Gagarin was midway through a statement when the official cameraman ran out of film. He had to repeat the whole statement again for the benefit of the cameras!

The carrier rocket with Vostok-1 atop was rolled out to the launch pad on April 11 and slowly erected to the vertical. Gagarin and Titov saw the rocket on the pad. By 2200 Moscow Time, with electrodes on their bodies, the two cosmonauts were asleep.

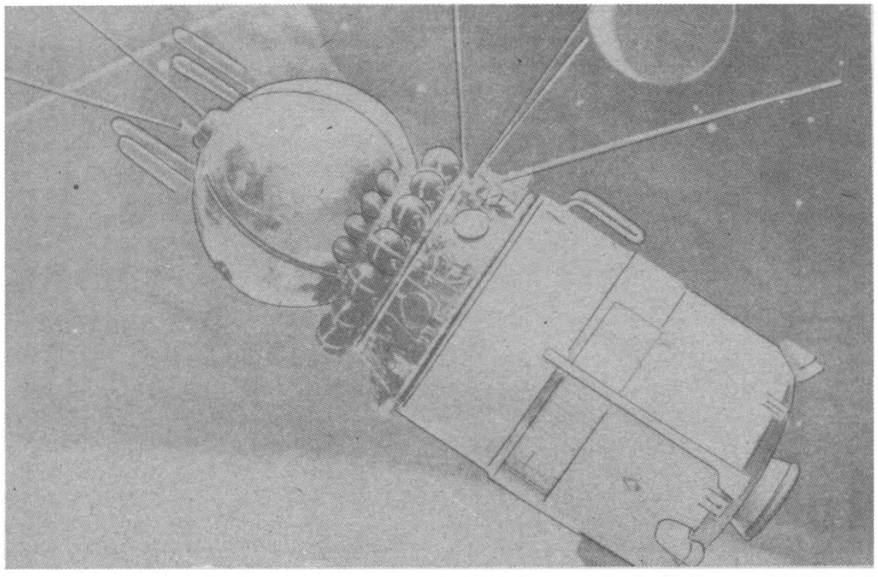
A secret medical monitoring experiment was conducted by biologist Vladimir Yazdovski when he attached strain gauges to their mattresses to monitor if the men tossed and turned. However, they had a peaceful sleep, . Korolev called at the small cottage during the night to check up on the cosmonauts.

Final test of the carrier rocket on the pad began at 0300 MT. Elsewhere, the other cosmonauts were at their posts some 4 hours before the planned launch of the spacecraft.

Gagarin and Titov were woken at 0530 MT. The men were presented with a bunch of early wild flowers by Dr. Karpov. The flowers were a gift from the woman who lived in the cottage in which they had slept. Breakfast was food from a tube.

At 0600 MT they were briefly examined by doctors and sensors were attached to their bodies. The men then put on their orange space suits. Titov was first to be dressed because the doctors did not want Gagarin to overheat in the suit because the only power source for the fans was in the bus

A model of the Vostok spacecraft in which Gagarin made his historic orbit of the Earth.



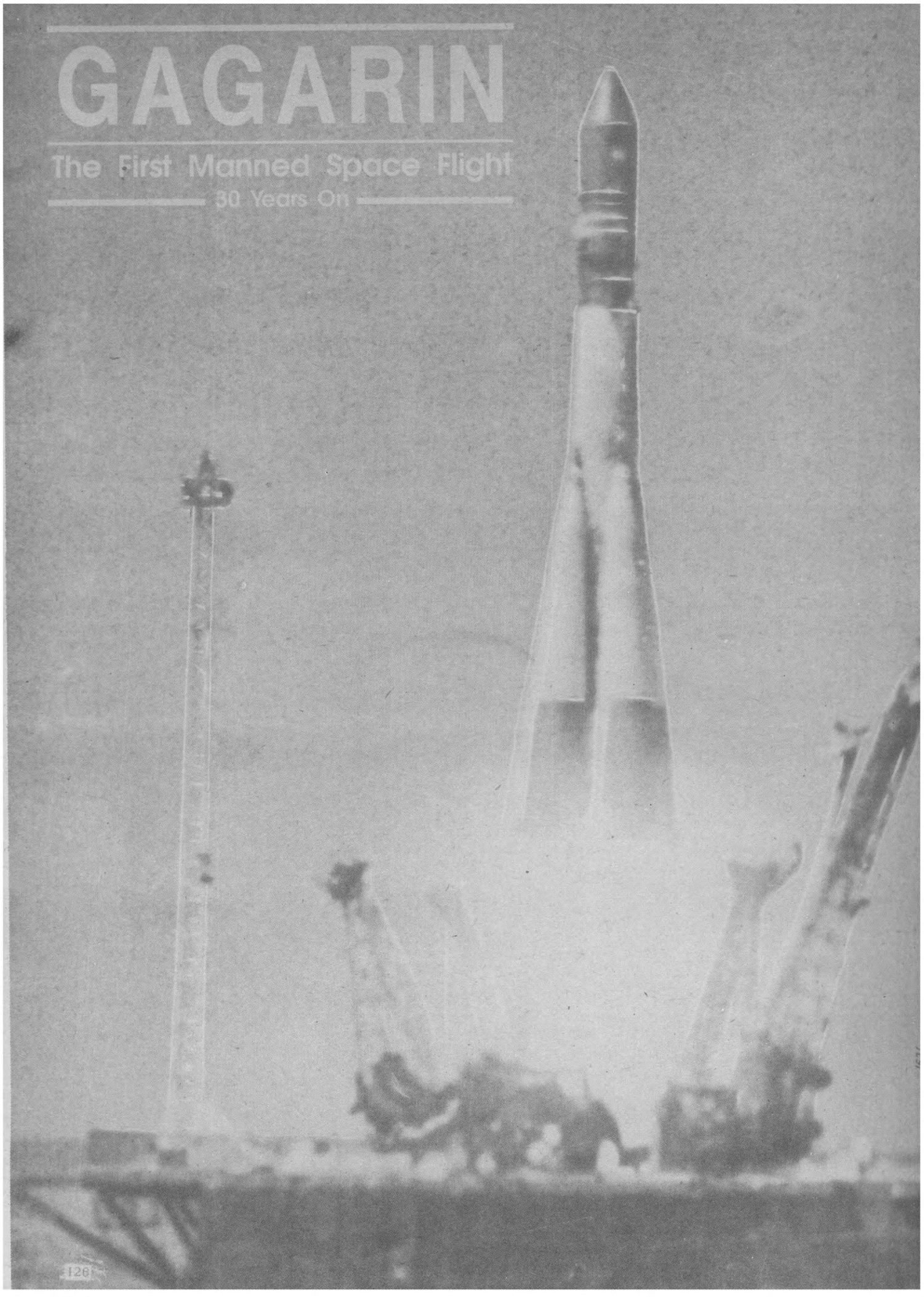
CENTRE PAGES

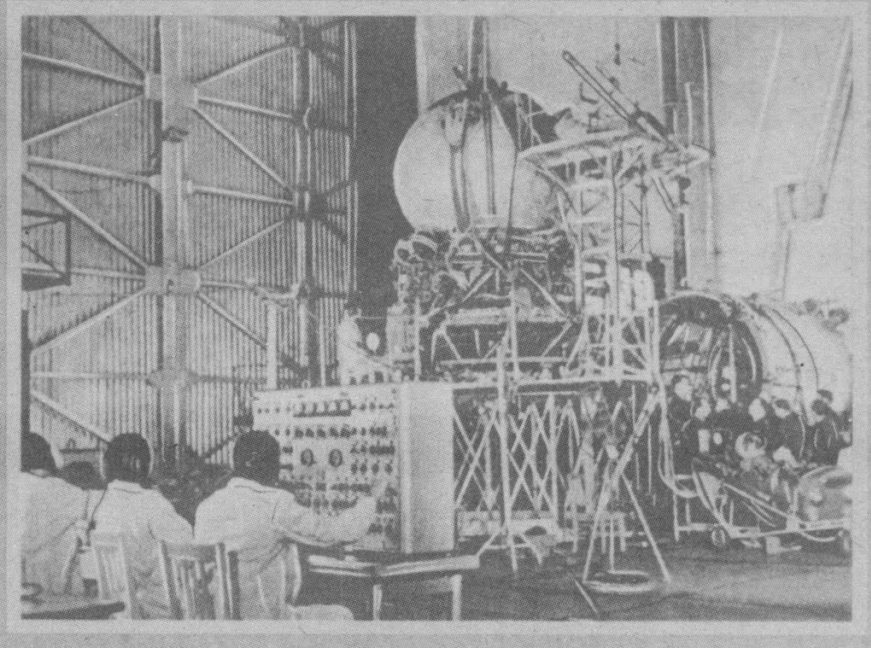
Vostok-1 blasts off from the Baikonur Cosmodrome on April 12, 1961 carrying the first man into space, Yuri Gagarin.

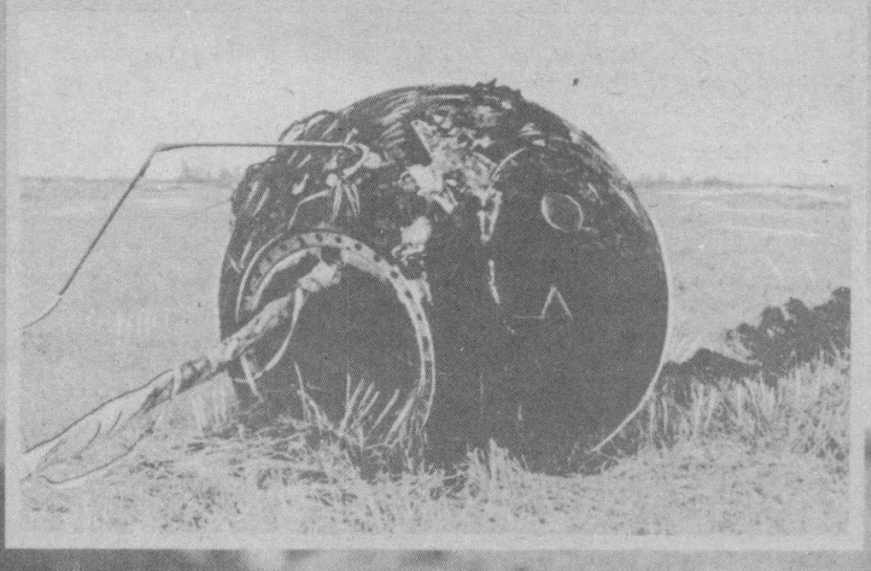
TOP INSERT: Yuri Gagarin is pictured in his orange pressure suit prior to launch.

CENTRE INSERT: A Vostok capsule is prepared for launch.

LOWER INSERT: A Vostok descent capsule, charred by reentry, lies in a field.


GAGARIN
The First Manned Space Flight
30 Years On





A triumphant Khrushchev welcomes Gagarin back to Moscow.

which would take them to the launch pad.

Titov sat behind Gagarin in the bus while the other cosmonauts told jokes.

On arrival at the launch pad Gagarin delivered a brief report to the Chairman of the State Commission. After final embraces Gagarin strode up the steps of the launch gantry to the lift. He turned and waved to the crowd below. It was a 2-3 minute ride to the apex of the rocket in the lift.

With a film crew also in the crowded gantry Gagarin was aided into the seat of Vostok by an engineer and observed by Aleksei Ivanov, the senior designer of the Vostok craft. Gagarin switched on the radio system at 0710 MT, moments after being fastened into the spacecraft. In the two hours before the launch Gagarin spoke with Korolev, Kamanin, future cosmonauts Popovich and Leonov and various flight controllers. The tape of this two hours is preserved.

In conversations the ground was referred to as "Zarya" (Dawn) and Gagarin by his call-sign "Cedar".

During this period the hatch of the spacecraft was opened again for engineers to check a warning indicator which had not registered the closing of the hatch. This required the engineers to unscrew the 30 nuts which secured the hatch. Ivanov later admitted that when Korolev radioed to reveal the lack of indication from the sensor his "blood froze".

After final checks on the hermeticity of the seal, Ivanov and his three engineers left the Vostok just 30 minutes before the launch was scheduled.

Gagarin requested that music be piped to him during the final hour of the countdown and reported slight vibrations from the lowering of the scaffolding around the rocket.

Ten minutes before launch Gagarin reported that his helmet was closed.

Korolev, in the central control bunker, used a radio to communicate with Gagarin. There was a red telephone which he could use to order the automatic ejection of the cosmonaut from the rocket. Only Korolev, Semenov and Voskrenski had the code word for that emergency activity.

Three minutes before launch, Gagarin's pulse reached 109 beats a minute. He reported to Korolev that he was in a good mood and ready for the launch.

Flight of Vostok-1

At 0907 (all times are Moscow Time) the Vostok rocket lifted off from the pad. The tape recorded Gagarin saying "Off we go," as the ascent began. Within seconds he reported that there was only a slight noise in the cabin and that everything was proceeding normally.

In the next minutes he reported that vibrations and g-loads were normal. He felt the cessation of thrust from the first stage, the four liquid-propellant strap-on boosters, and their separation. Three minutes after launch the fairing covering the spacecraft separated. Gagarin reported seeing the Earth clearly through the porthole of the spacecraft. He could see rivers and the folds of the terrain.

0912. The central core of the carrier rocket had ceased to provide thrust and was discarded. Gagarin radioed that he felt the ignition of the third stage. During the powered leg of the flight his pulse reached 150 beats per minute. During the ascent Gagarin reported heavy cloud cover over the Earth's surface but he could see mountains and forests intermittently.

During the ascent there was a temporary break in the communication line which caused concern in the control centre.

Konstantin Feoktistov later recalled that "such breaks considerably shorten a designer's life".

0921. Gagarin reported that staging had taken place and that he was now weightless. He said that he felt fine and cheerful but complained, however, that the internal TV light was too bright for him to see much. But he did report that he could not see any stars out of the window. The sunlight was also very harsh.

The orbit of Vostok ranged from 181 km to 327 km with a period of 89.34 minutes and an inclination of 64.95 degrees.

Gagarin's attempts to write down his observations in a notebook fell victim to the new state of weightlessness. After jotting down an observation he let go of the pencil which, although supposedly secured by a length of string, floated away and was lost - the string had come undone. He had to record his observations on tape from then on.

0926. Gagarin reported that he was experiencing no unpleasant effects of weightlessness. Despite a clockwise rotation of the craft he was able to report that the flight continued "marvellously".

0947. Gagarin transmitted a report on the condition of the spacecraft. Two minutes later he reported that he was in the Earth's shadow. On Earth Boris Volynov, a future cosmonaut, was confused at the

new term "in the shadow of the Earth".

0957. As the spacecraft flew over the American continent Gagarin thought about his contemporaries in the American astronaut corps. The Mercury Seven, along with the rest of the world, were unaware of the flight of the Soviet cosmonaut.

0958. Moscow Radio reported that Gagarin was in orbit.

1006. Gagarin reported that he could now see the Earth's horizon. He said it was a "very beautiful" rainbow from the top of the Earth downwards. By now he said that he could see stars through the porthole.

1009:15. The spacecraft passed into sunlight again. Gagarin watched the Sun rise through his porthole and reported the operation of the solar orientation system. He said that it was possible to orient the craft.

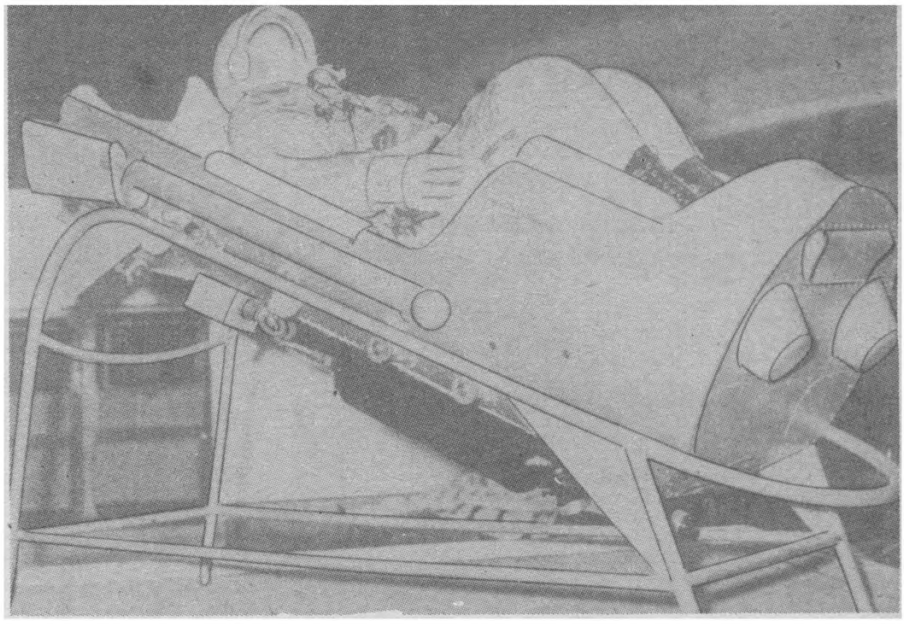
1018. Gagarin gave a status report on the pressures of the fuel tanks.

1024. Gagarin gave a report on pressures and temperatures. The internal temperature of Vostok was 20 degrees C. humidity 65. Retro-fire was one minute away.

1025. The retro rocket system fired and Vostok was brought down from orbit. The descent cabin, in which Gagarin was lain, separated from the instrument section and the descent cabin was enveloped in a plasma sheath. On Earth, Korolev and his team awaited the news that signals had been received from the descending craft.

Finally, the signals were received and the celebrations began.

At an altitude of 7 km and a speed of 220 metres per second the parachute opened pushing Gagarin into his seat. The hatch of the cabin was explosively jettisoned shortly afterwards and two seconds later Gagarin was blasted clear of the descent cabin in his ejectable seat.



Gagarin used an ejection seat similar to this to leave his capsule.

The seat fell away from the cosmonaut four kilometres above the Earth and Gagarin continued his descent under his own parachute and emergency life support system. The main parachute system of the descent module opened at the same altitude. The cabin came to rest a few dozen metres from a deep ravine.

1055. Yuri Gagarin landed in a field some 26 km south-west of the town of Engels in the Saratov Region, not far from the village of Smelovka. In his orange flight suit he approached a woman and little girl with a calf. The cosmonaut was asked if he came from space and Gagarin replied "As a matter of fact, I have".

On that day a wooden post with a plaque was erected on the spot where Yuri Gagarin had landed. It said simply:

"Do not Remove! 12.04.1961, 10:55 Moscow Time".

Although it was later replaced by a small stone obelisk this historic post served to tell the world that a new era had begun. One man had flown into the Cosmos and returned. Whilst man has reached the Moon and will reach distant planets on future days there will never again be another day like April 12, 1961. On that day humanity left the cradle in which it was born.

Gagarin is pictured here during training with Vladimir Komarov. Gagarin was the Komarov's back-up for the ill-fated Soyuz 1 mission. After an apparently normal lift-off on April 23, 1967, the Soyuz spacecraft malfunctioned and Komarov lost his life when he attempted an emergency reentry. A year later Gagarin himself was killed in an air crash. The ashes of both men were place in the Kremlin wall.

Acknowledgements

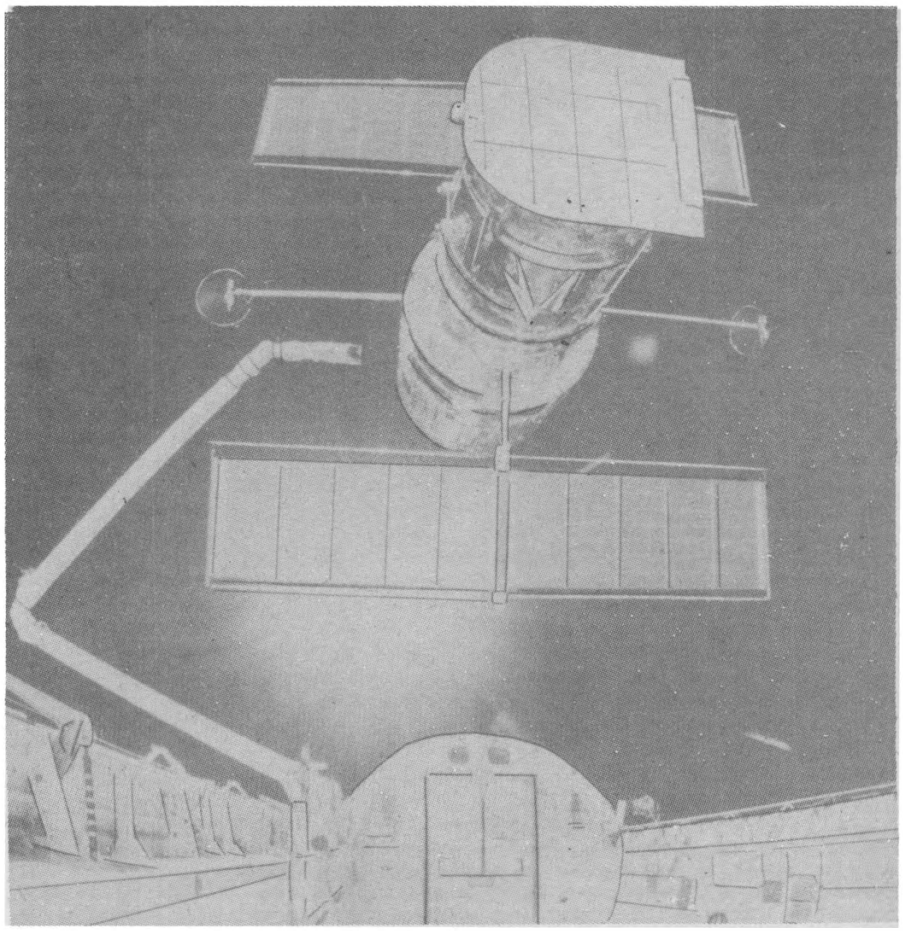
This account of the flight of Vostok-1 has drawn heavily upon two major sources. These are:

"Cosmonaut No. 1" by Yaroslav Golovanov. Published in *Izvestiya* April 2-6 1986.

"Our Gagarin" Author and Compiler Yaroslav Golovanov, Progress Publishers, Moscow, 1978.

FIXING HUBBLE

Ambitious Repair Planned for 1993 Shuttle Mission



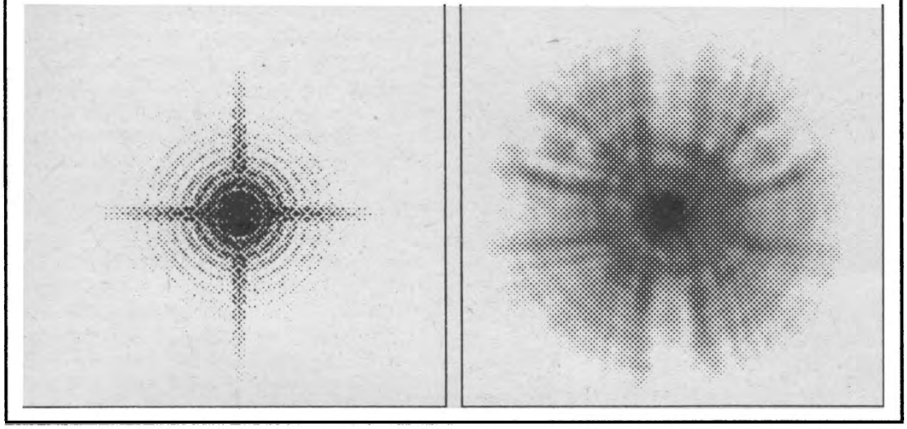
In 1993 the Space Shuttle will return to the Hubble Space Telescope and attempt an ambitious repair of the observatory's faulty optics. *NASA/Smithsonian Institution/Lockheed Corporation*

In June 1990, NASA announced that the Hubble Space Telescope (HST) could not be focused properly because its 2.4 metre primary mirror had been manufactured to the wrong shape. After their initial dismay, astronomers and engineers turned their attentions to fixing the orbiting observatory. In August the Director of the Space Telescope Science Institute (STScI), Dr Riccardo Giacconi, formed the HST Strategy Panel to identify ways of restoring the telescope's capabilities. The panel's report recommends a fix that can be accomplished during the scheduled 1993 Shuttle visit to Hubble. The plan is ambitious but if successful the telescope's four scientific instruments will perform as originally planned. *Spaceflight* was briefed on the recommendations by Robert Brown the panel's Co-Chairman.

Astronomers and engineers realized that there was a problem with the images of the HST shortly after it was launched in April 1990. The quality of the images failed to improve despite attempts to adjust the alignment of the optics. NASA concluded in June that the HST primary mirror had been manufactured with the wrong shape. Compared with the desired profile, the edge of the mirror surface is too low by 0.002 mm. NASA convened an investigatory board in July 1990 under Dr Lew Allen, which reported in November 1990 how the error probably occurred. In late 1980 or early 1981, a technician had improperly assembled a measuring device used to figure the primary mirror. Though tests at the time indicated a problem the warning was not heeded and the HST was assembled and launched with the flawed mirror.

The deformity of the HST mirror causes spherical aberration in the images. This means light rays come to a focus at different distances depending on the radius at which the rays strike the mirror. Light from the edge of the primary mirror comes to a focus about 38 mm beyond where the innermost rays converge. The centre of a star image seen by the telescope in visible light was expected to have a core radius of 0.1 arcsec containing about 70 per cent of the light. However, with spherical aberration only 15 per cent of the light falls within the core, the remainder is spread about in a complex halo of radius 3 arcsec.

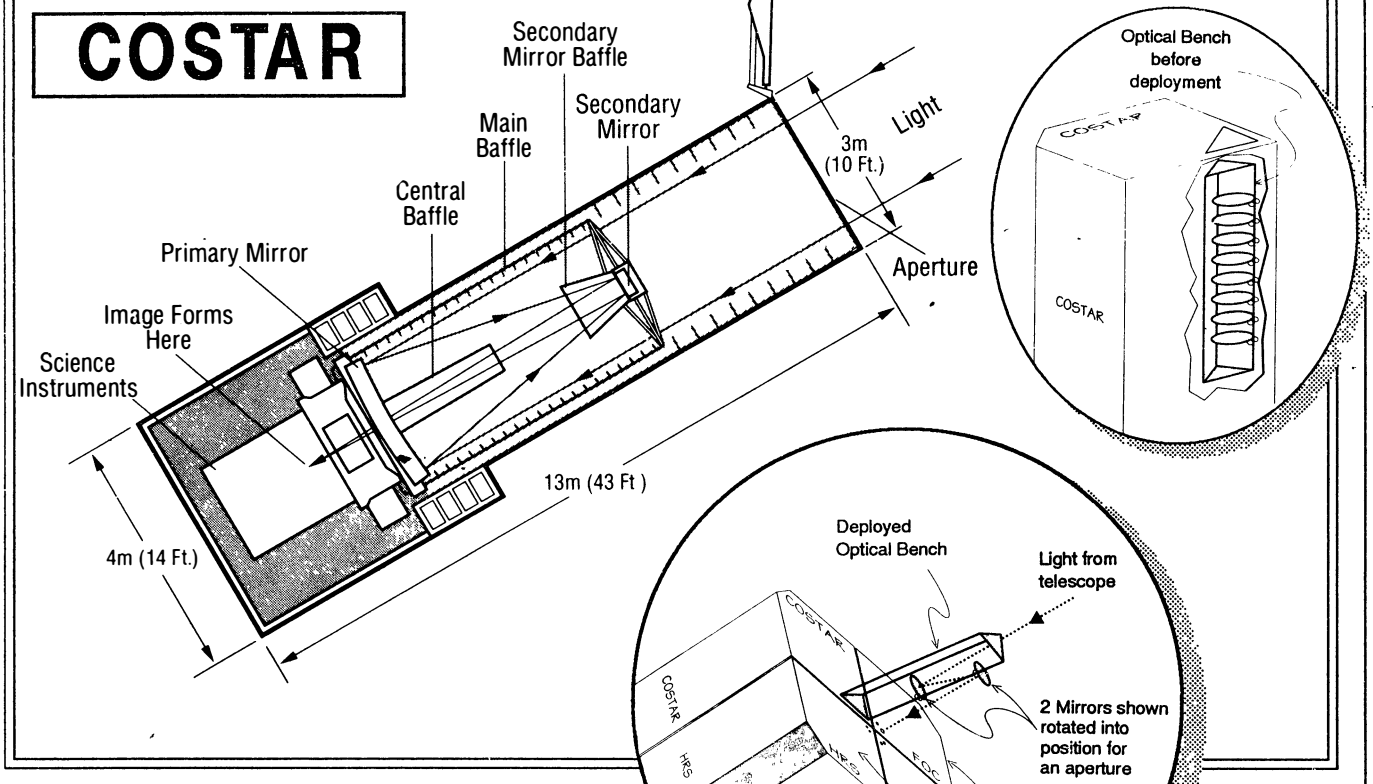
The expected HST appearance star image. An actual HST star image.



Despite the problem, the telescope is accomplishing good science but many crucial investigations - including many of the original justifications for HST - are on hold until the problem is solved.

Engineers now believe they understand the optical problem well enough to design a highly effective optical correction.

Soon after the spherical aberration was discovered, NASA announced that the new instruments being developed could be fitted with corrective optics to compensate for the problem. The first of those instruments would be the Wide Field/Planetary Camera 2



(WF/PC-2), scheduled for launch in 1993, followed in 1996 by an infrared instrument called NICMOS and a spectrometer called STIS. Unfortunately, the European Space Agency does not have the funds to build a modified Faint Object Camera, one of the telescope's most important instruments.

In August the STScI formed the HST Strategy Panel to review the various options for fully recovering the capability of the telescope in the shortest possible time.

The 17-member Panel reviewed almost 30 proposals for the Hubble fix. The panel looked at each option to determine the risk to the observatory, the feasibility of manufacture and if spacewalking astronauts could perform the repair in orbit.

"We looked at some solutions that had astronauts doing things like going down inside the tube of the telescope, bolting things to the front of the telescope and all kinds of crazy things," said Robert Brown.

COSTAR

After examining all the options the Panel made a unanimous recommendation to NASA late last year. Robert Brown explained:

"Our idea was to build a box that looks just like a replacement instrument but its only function would be to carry individual corrective optics up to the telescope and then on command deploy those optics in front of the axial instruments."

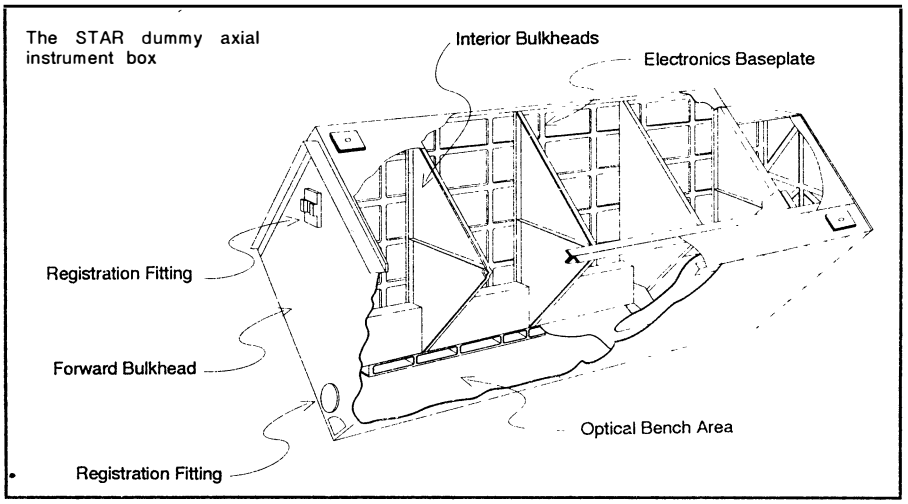
The concept is to adapt the existing Space Telescope Axial Replacement (STAR), a dummy axial instrument that would have been installed in the telescope had one of the science instruments not been ready for launch. Known as COSTAR (Corrective Optics STAR), the box would be modified to carry corrective optics for three of the four axial instruments.

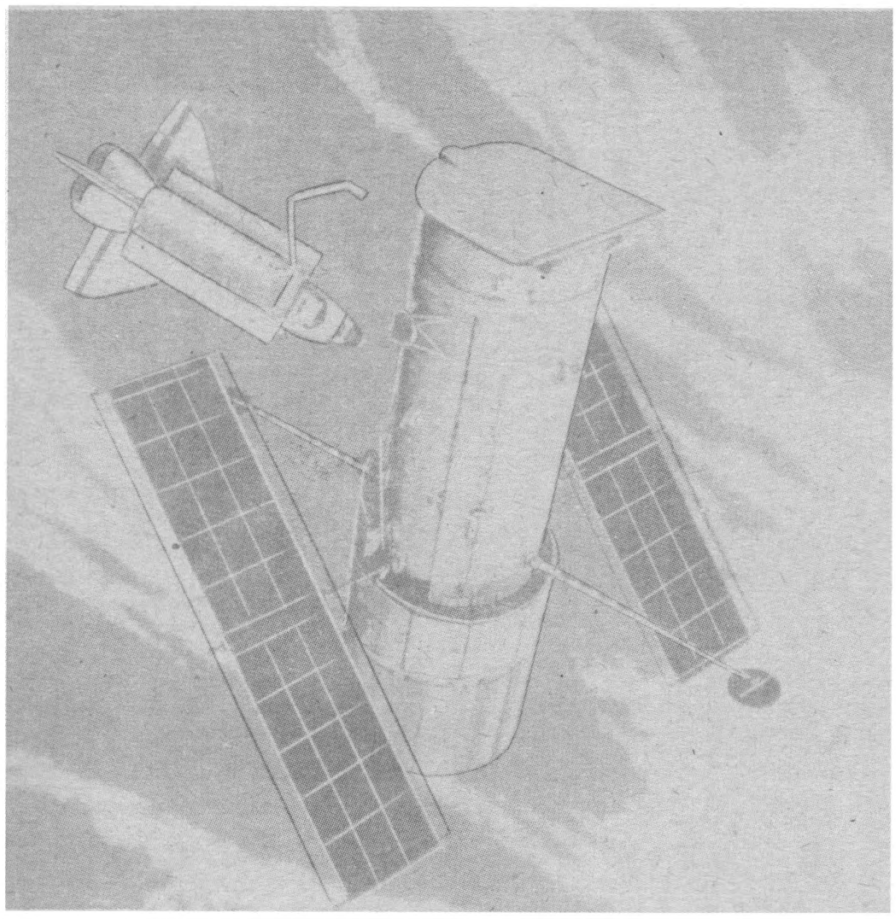
The plan has one drawback. To install COSTAR one of the existing axial instruments must be removed.

"We all agreed that if one had to be taken out to accommodate this fix, then it should be the High Speed Photometer (HSP)," Brown told ***Spaceflight.*** "It carries less of the scientific burden than the other three [instruments] and it is a very simple instrument and was the least expensive."

Once COSTAR has been installed in the telescope, a foot-long optical bench would be extended above the axial instruments. Then, corrective optics would be rotated into position over the apertures of the three remaining axial instruments, namely the Faint Object Camera (FOC), the Faint Object Spectrograph (FOS) and the High Resolution Spectrograph (HRS).

The HST Strategy Panel presented its recommendations to NASA in No-





The Space Shuttle rendezvous with the Hubble Space Telescope in orbit. The solar arrays and other appendages will be stowed before it is placed in the payload bay. *Lockheed*

vember last year and received a favourable reaction, says Brown. The space agency conducted a rapid one month study of the concept to, as they put it, 'check there were no boulders in the road'. A second study was conducted by Ball Aerospace.

"[Those studies] said there was no definite impediment to it [and] a green light was given to proceed with the next level in design," Brown said.

NASA estimates that COSTAR will cost in the region of $20-30 million. The space agency has not yet made the final decision to go-ahead with COSTAR.

WF/PC-2

The COSTAR concept would not help the Wide Field/Planetary Camera (WF/PC) so the HST Strategy Panel recommends NASA proceed with its existing plan to install corrective optics in the new WF/PC-2 instrument.

The panel also recommends that NASA fix the pointing capability of the telescope.

"It does not make any sense to repair all the optics and restore the basic optical performance of the telescope if we do not get the pointing problems fixed," said Brown.

Some of these pointing problems are related to the mirror but there is also the problem with the telescope's solar arrays. Temperature changes cause the arrays to flex when the telescope crosses the terminator between night and day. These oscillations are passed on to the telescope affecting its pointing accuracy. The Panel is recommending that Solar Arrays be replaced during the 1993 servicing mission.

The Panel has also suggested improvements to enhance the telescope's pointing performance in the coarse track mode. The necessary measures can be taken on the ground.

"This is something that we can start working on now and we gave a strong recommendation that we should do so," said Brown. "It is basically a plan to improve one element of the coarse track performance to be able to lock on fainter guide stars with nearly as good pointing as we get out of fine lock."

Brown said it was very important to be able to acquire faint stars for guidance because many of the most interesting astronomical targets are at high galactic latitudes where there are very few guide stars.

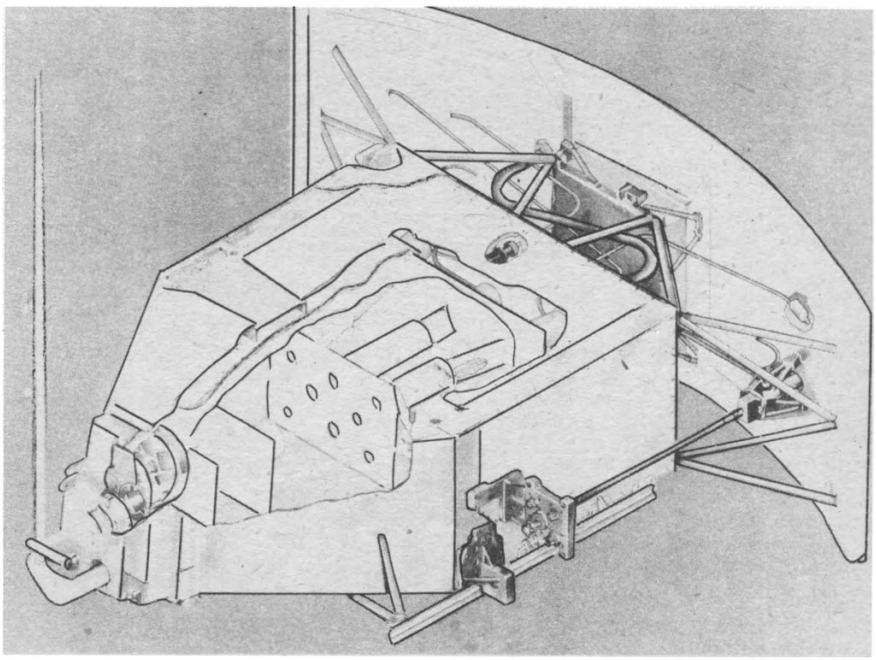
"The only stars that are there are faint ones," he explained. "You have got to be able to lock on to faint guide stars and the problem in the primary mirror has made it so that the guidance system is not as sensitive as it was expected to be."

Three Spacewalks Planned

A record breaking three spacewalks are planned for the 1993 servicing mission. During the first EVA (Extra Vehicular Activity) the two astronauts, designated EV-1 and EV-2, will begin by replacing a Rate Sensor Unit (RSU) that failed late last year.

The WF/PC instrument will be removed by EV-2 standing on the Manipulator Foot Restraint (MFR) at the end of the Shuttle's robot arm. Next, the telescope will be rotated on its support structure and both crew

The new generation WF/PC instrument will be fitted with corrective optics and installed in the telescope in 1993. *NASA/JPL*



members will remove the HSP instrument. Immediately afterwards the astronauts will install the COSTAR box in its place. While the astronauts stow the HSP the telescope will be rotated 90 degrees so the empty WF/PC compartment once again faces forward. Video cameras will be set up looking through the compartment to record the deployment of the COSTAR optical bench. In the event of a malfunction it may be possible for the EVA crew to intervene to extend the bench manually.

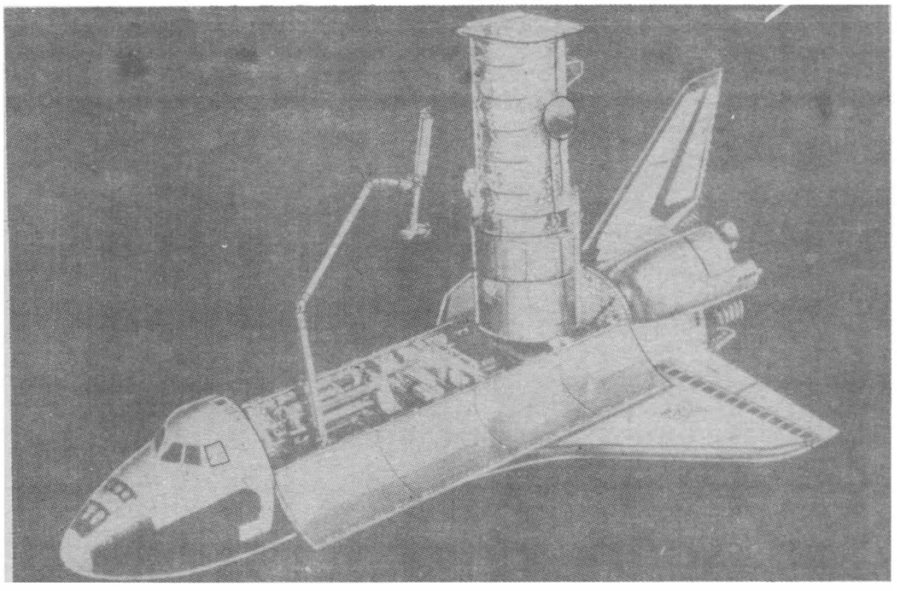
Once COSTAR is successfully in place the astronauts will remove WF/PC-2 from its launch container and install it in the telescope.

The second EVA is dedicated to replacement of the two solar panels with new arrays that will not oscillate when the telescope crosses from night to day.

Each solar array is installed on the HST by means of a Marman (or manacle) clamp and three sets of ganged electrical connectors. A portable grapple fixture will be installed on the array so it can be removed by the Remote Manipulator System (RMS) arm. The electrical connectors are broken and the loose cables secured. Then the Marman clamp is opened and both EVA crew members guide it into the RMS end effector, pre-positioned a few inches away. The RMS is used to move the array to a temporary stowage location. The new solar array is then removed from the solar array carrier using the same operations, with the RMS positioning it a few inches away from the open Marman clamp and latches on the telescope. The reverse actions are used to install it.

Subsequently the HST would be rotated one hundred and eighty degrees, and the process completed on the second solar array. This replacement of the awkwardly sized arrays is made easier by the RMS but it can be done without one, albeit more slowly. There should be ample time during the six-hour EVA, especially if the RMS is fully functional, to replace the arrays. If sufficient time remains, replacement of one or both of the two Engineering and Science Tape Recorders could be completed. These units are located in System Support Module equipment bays and are installed using four bolts engaging keyhole slots and three electrical connectors.

If necessary, the third EVA would first clean up any "left-overs" from the first two spacewalks. Also it may be necessary to perform some internal modifications to the FOC. The complexity of this task is believed to be comparable to that of replacing the Coronagraph-Polarimeter Main Electronics Box on the Solar Max satellite successfully accomplished on mission STS 41-C.



One of the telescope's solar arrays is removed by the Shuttle's robot arm. *BAe*

On completion of this work the HST will be grappled by the RMS for deployment. Once the umbilicals and latches between the HST and the service structure have been released, the observatory would be manoeuvred to the appendage deploy position and the solar arrays and High Gain Antenna deployed. During this operation the EVA astronauts will remain in the payload bay in case manual intervention is required. Once the appendages have been successfully deployed they can return to the crew cabin and the telescope will be released to continue its mission.

Former astronaut Bruce McCandless served on the HST Strategy Panel. McCandless worked on the telescope project for almost a decade. He advised the panel on what could and could not be done by a space walking astronaut.

"Bruce gave us a lot of confidence that we could do all the things that need to be done on that servicing mission," said Robert Brown. "The beauty of it is that each of the operations is something that the astronauts have always planned and practised to do."

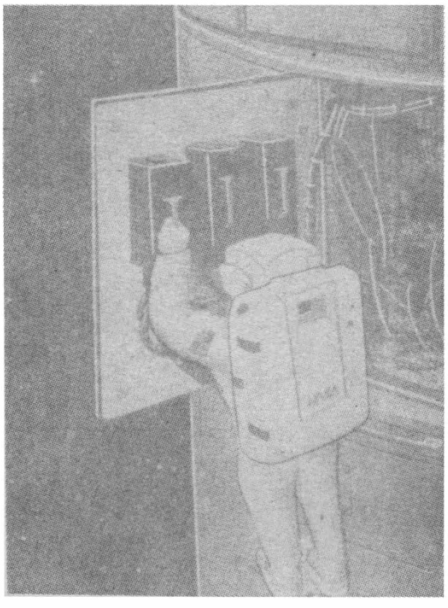
Robert Brown is confident that the repair will work.

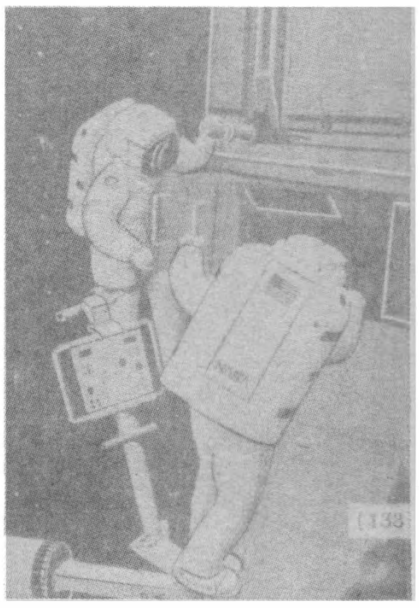
"The beauty of this solution compared with the other ones is that it compartmentalises the risk," he explained. "Each of the four optical corrections is independent. If [COSTAR] did not provide any benefit [it] could always be retracted.

"Also it does not interact at all with WF/PC-2. So in the worse case say it went in and did not do anything, you are no worse off than you were.

"If NASA moves ahead with this they have the option on the first revisit to the telescope in 1993 to recover all the capabilities that were degraded by spherical aberration. Then we are back on track and we can pick up the rest of the 15 year programme at that point."

These artist's impresssions demonstrate how the astronauts will replace various Hubble components during the servicing missions *Lockheed*

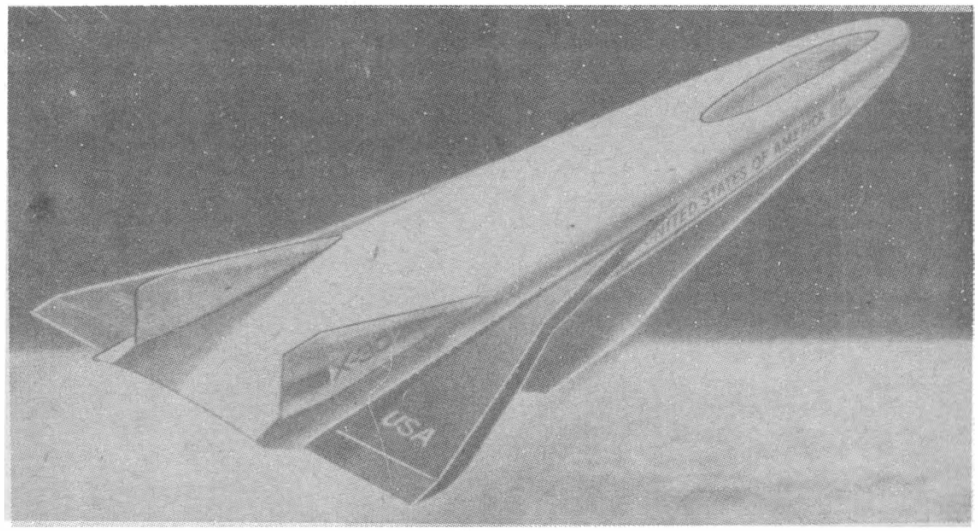




NASP As An American Orphan:

Bureaucratic Politics and the Development of Hypersonic Flight

Contrary to the statements from the US Department of Defense (DOD) that the primary reason it does not back the National Aerospace Plane (NASP) programme is because NASP has no mission, NASP is, in fact, a technology development programme not in search of a mission but one in search of a home. Since NASP's inception as a programme to develop the technologies necessary for hypersonic flight, a major stumbling block has been its failure to acquire a compatible bureaucratic sponsor. Neither the military services nor the National Aeronautics and Space Administration (NASA) have wholeheartedly adopted NASP as a priority programme, given what they see as other more pressing needs.



By Joan Johnson-Freese and Roger Handberg

NASP Background

Originally a small, (approximately $5 million per year) applied research and development programme managed by the Defense Advanced Research Projects Agency (DAPRA), NASP began to run into trouble in 1988. In 1986 overall responsibility for the programme had been transferred, earlier than originally planned, from DAPRA to the Air Force, to become a joint programme with NASA on an approximately 80-20 split of funding and with a Joint Programme Office (JPO) established at Wright-Patterson Air Force base in Ohio. Although the transfer had ostensibly been made to ensure more orderly programme development, many felt that the transfer had actually been done to slow down the work which had been accomplished by the enthusiastic, to some an over-zealous, programme director at DAPRA, Robert Williams. It is through such bureaucratic manoeuvres that programmes opposed for various reasons can be severely constrained and even destroyed.

In 1986 President Ronald Reagan chose to include the programme in his annual State of the Union address. In that speech, the still young technology development programme was transformed into the "Orient Express," an airplane which would transport people from Tokyo to New York in less than two hours. This approach immediately placed the programme under intense scrutiny as one which would have to yield sizable public benefits if it was to justify the large increase in programme funding necessary to take the programme from basic research through development and into operation. To many, the programme then appeared as one designed more to produce yet another rich man's toy rather than a high technology programme which would yield NASP-derived vehicles (NDVs), the most immediate and essential purpose of which would be to provide on-demand access to space, for therein lay NASP's real importance and justification.

Currently, the United States is totally dependent on the shuttle for manned access to space. This was one of the problems of the US space programme cited in the recently released Augustine Commission Report on the Future of the US Space programme. Some specific problems which stem from relying on the shuttle are discussed later but even including expendable launch vehicles (ELVs), the current cost-per-pound-to-orbit figure is estimated to be over $4000. At that price it is no wonder that the "commercialisation of space," touted in the early 1980s, has been downplayed of late, if not forgotten in all but the communications satellite field, which has been well established since the 1960s.

By contrast, NASP would provide cheap, reliable, and easy access to space, as well as technologies that would not only add to an overall defence technology base but help to maintain US leadership in technologies critical to the aerospace industry, show important benefits to a wide spectrum of high tech industries and provide revolutionary methods of transportation; civilian, military and space-oriented. Possessors of such technologies, it is argued, will lead the way into the next century. Those who do not will be left behind.

Since 1988, NASP has had to fight for its existence. Originally, most scepticism centred on the difficulties posed by the advanced technologies required. More recently, however, after many of the most difficult technologies had been proven feasible, NASP has been a victim of bureaucratic politics. Although significant factions in both NASA and DOD support NASP, the official DOD position since 1989 has become increasingly hostile. Shortly after coming into office, Secretary of Defense Richard Cheney cancelled the NASP programme and although this was later revoked by President Bush, on the advice of the National Space Council, the decision as to whether or not to build an X-30 prototype, which was originally to be made in 1990 if the requisite technological readiness had been demonstrated, was deferred to 1993. Programme stretchouts of this type are typical of long-term, risky high-tech projects and almost inevitably result in the same politicians who instigate and agree to the delays later coming back to question programme managers why the programme has cost more than originally projected.

The reasons why neither NASA nor DOD support NASP provides a classic study in bureaucratic politics. Political scientists have long established (Graham Allison's 1971 study *Essence of Decision* being a seminal

work) that bureaucracies operate within fairly fixed parameters. Each organisation does certain things well; therefore, solutions to problems get defined in terms of those preferred solutions. If the problem crosses the boundaries of several agencies, each deals with the problem in the context of its particular interests and abilities. The broader perspective has to be furnished by some outsider, usually a superior such as the President. The "Orient Express" speech alone was insufficient to guarantee programme support and longevity since the necessary follow-up did not occur. The Adminstration had other, more immediate political difficulties, political programme priorities (such as the Strategic Defense Initiative) and the typical end-of-administration slowdown that occurs as time runs out.

The rationales behind the arguments used by NASA and DOD/the Air Force are both ironic and frightening in the clear refusal to look beyond an immediate budget year or evaluate the impact of their decisions for later years. Short-term considerations driven by the budget crisis have come to dominate decision makers to the point that important choices that may foreclose the future are made haphazardly.

The Shuttle, The Name of the Game for NASA

NASA has, by and large, staked its bureaucratic future on the shuttle, a gamble that has largely consumed its fiscal resources and the energies of its management team. As a result, NASA has little interest or motivation in sponsoring a potential rival launch system. The most touted successor programmes from NASA's perspective are, effectively, linear extensions of the shuttle: specifically the Advanced Manned Launch System, (AMLS), once known as Shuttle II, and the unmanned cargo version of the shuttle, Shuttle-C. Yet with the Bush Administration priorities clearly favouring the Space Station and the Space Exploration Initiative (SEI), the chances of NASA receiving funds to develop these successor vehicles seems remote. The ironic aspect is that, without new launch vehicles, the viability of these other initiatives is in serious question due to lack of lift capacity of the present shuttle fleet.

The political realities of the shuttle programme have overburdened NASA to the point that other programmes have been sacrificed to support its continuation. It takes twelve thousand people to launch each shuttle. Politically, that translates into twelve thousand jobs, which constitutes the single largest committed constituency that NASA has, and one that cannot be ignored even when that number is viewed from the perspective of the resulting extremely high economic cost per launch, approximately $4700 per pound to orbit.

NASA has optimistically projected a minimum of twelve shuttle launches a year for the foreseeable future but has, in fact, averaged four a year over the course of the programme. That average includes the hiatus caused by the Challenger tragedy. Building the Space Station Freedom, even scaled down but on schedule, will consume all available shuttle flights, leaving virtually no excess lift capacity for other needs. Nor do NASA's projections envision or, at least, publicly contemplate the operational loss of another shuttle which, based on statistical averages, is a high probability event in the opinion of some analysts.

NASA has optimistically projected a minimum of twelve shuttle launches a year for the foreseeable future but has, in fact, averaged four a year over the course of the programme.

For these reasons, NASA is not interested in pursuing the development of a hypersonic technology which, potentially, could alleviate the bottleneck posed by the shuttle in its present operational environment. NASA, like many other organisations, appears to have fallen into a pattern in which a current technology dominates its vision almost to the exclusion of other alternatives. An indication of the extent of the problem comes from physicist James van Allen, quoted as saying of NASA Administrator Admiral Richard Truly that "he hardly notices what else is going on in the agency besides the shuttle" [1]. Learning how to develop and successfully operate NASP would involve an entirely different set of organisational reflexes. Despite its ongoing problems, NASA is comfortable, even in its discomfort, with the shuttle. Change disrupts well settled routines and policy decisions allocating resources and responsibilities within the agency, so it is best to let sleeping dogs lie. Such an attitude is a major factor why external groups are beginning to move away from NASA toward other launch options: NASA is seen as lacking the necessary flexibility to adapt to its new environment.

The hypersonic, in the eyes of NASA and the Air Force, also suffers from the "not-invented-here" syndrome, referring to the premise that the programme was not conceptualised or originated in-house. This is a definite strike against any programme, and especially for one originated in one agency and then transferred to another. Thus, for reasons specific to NASA, NASP does not fit into the agency's future in any meaningful way. This neglect, benign or otherwise, contrasts to several potential civilian rivals in the space launcher business such as those of the Japanese, Germans and French who are aggressively pursuing the hypersonic option. Therefore, in the American context, the hypersonic is likely to be developed successfully only if backed by the Department of Defense and, more specifically, the United States Air Force.

Is NASP a Plane? Air Force Resistance

By 1985 Robert Cooper, then director of DAPRA, and Robert Williams had won over the then White House science advisor George Keyworth, regarding the potential of hypersonic flight. Both realised that this would not be enough and that DAPRA did not have the resources to go it alone.

Cooper told Williams he would have to build a coalition of supporters at NASA and at Defense - NASA had an ongoing role in aeronautical research and Defense had a big budget and an air force.

The key to winning Defense was winning over the Air Force, since a space plane would logically fall under its domain [2].

Originally, under Casper Weinberger, support was strong both within the Air Force and the DOD, culminating with the unfortunately worded announcement of the National Aerospace Plane project by President Reagan. Things began to go astray when, internally, it became evident that NASP was going to require a significant commitment in the Air Force budget and when the attitudes of top Air Force and DOD officials were swayed by alternative arguments.

Now, Air Force interest in the NASP programme appears uneven at best. This is partially a function of the "not invented here" syndrome and partially a function of a reducing budget. One project which seems to be usurping Air Force interest in NASP is the Advanced Tactical Fighter (ATF). Full scale development of ATF is expected to yield approximately $13 billion in contractor awards, compared to the $3.3 billion estimated cost for the NASP technology development programme. It is estimated that $2 billion annually over ten years would be sufficient funds for an operational fleet of six NDVs; compared to the $4 billion spent annually to keep the shuttle fleet

of three operational.

Although the uncertainty of the NASP timetable and X-30 development costs seems to bother the Air Force and DOD, it apparently does not bother them in relation to the ATF, a more traditional programme. Air Force General Robert Herres was quoted as saying, in relation to the ATF:

I've always wondered (about) people in our bureaucracy that lay out schedules for research, development, test and evaluation activities...We're about to go out and do something we've never done before, yet we're supposed to know exactly when we're going to be finished with each phase and what it's going to cost. [3]

But then, again, ATF is an in-house Air Force project.

The dynamics of normal Air Force programme development have also played a role in the Air Force's uneven response to NASP. From Billy Mitchell through the present, the Air Force has focused much of its attention on some version of the manned bomber.

On the other hand, the Air Force has long desired to break NASA's lock on manned space flight. Air Force efforts date back to its proposed Man-in-Space-Soonest (MISS) programme in 1958 and the Dyna-Soar programme (based on Dr. Eugene Sanger's work in wartime Germany, which now serves as the foundation for German hypersonic efforts). Dyna-Soar was actually funded at low-levels between 1957-59. NASP would provide the Air Force with access to this long sought after prize, as it is currently configured with a cockpit seating two people side-by-side.

In NASP's favour is the fact that it provides an ongoing role for the Air Force. As a service that grew out of an older established military organisation, the Air Force is sensitive to potential claimants to its role. If for no other reason than earlier historical examples, the Air Force is extremely conscious of the dangers of being defined as obsolete. The Air Force is not presently badly off but the leading edge of technological superiority is a tenuous advantage easily lost. This is a fact that keeps the Air Force very sensitive to possible technological short-falls, including the hypersonic arena.

The public results of this internal Air Force dilemma have been confusing at best. First was the statement about NASP made by General Lawrence A. Skance, commander of the Air Force Systems Command, that:

We are talking about the speed response of an ICBM and the flexibility and recallability of a bomber, packaged together in a plane that can scramble, get into orbit, and change orbit so that the Soviets can't get a reading accurate enough to shoot at it.[4]

Then there have been more recent, and repeated, statements by Defense Secretary Cheney and Air Force Secretary David Rice, supported and encouraged by the DOD Office of Programme Analysis and Evaluation Director David Chu, that the Air Force has no mission for NASP - statements supporting the cancellation of the programme.

Another factor in the hypersonic equation is that decisions are being made in the context of massive upheavals in international politics which are creating real uncertainty concerning all defence spending. Agencies such as the Air Force struggle to protect what critical assets they have, with long-term future projects often deferred as part of that fight, on the operative assumption that the entire issue can be readdressed at some future date, an assumption which may be erroneous if technology development moves fast enough and successful development occurs elsewhere.

In NASP's favour is the fact that it provides an ongoing role for the Air Force.

The United States has assumed that NASP technology is too valuable to share with others. According to aerospace industry analyst Wolfgang Demisch,

"space planes represent cutting-edge technology, which the US would be reluctant to share. If (the Japanese) put up some money and get all our advanced technology in return, that would not be a good deal". [5]

But the reverse must be assumed to be also true. Whether it is an ally or a potential rival, the successful hypersonic developer will be unlikely to provide assistance except at a high price, either politically or economically. And there are other countries not only forging ahead, but looking to do so in some interesting collaborative ventures. British Aerospace and the Soviet Ministry of Aviation Industry are undertaking a study to assess the feasibility of launching a rocket-engined version of the British entry in the hypersonic sweepstakes, the HOTOL (Horizontal Takeoff and Landing Vehicle), from the Antonov An-225 heavy-lift transport, to create a low-cost satellite launch system. Japan has been reviewing hypersonic technology progress with the European Space Agency (ESA) for several years with an eye towards eventual collaboration.

Totally dropping out of the hypersonic business may not be a viable option, given that the value placed on the technology that is being developed in conjunction with the NASP. Also, because, reluctant as some people are to admit it, at some point the United States will clearly be in need of a successor to the shuttle. Slowing the programme to a crawl would be far more politically typical and palatable. Meanwhile, however, competitors in the hypersonic development process are moving forward in a steady but thorough fashion.

Potential Uses of Hypersonic Technology

Since part of the issue is whether sufficiently important hypersonic missions exist for the Air Force or Navy, we will briefly summarise potential missions that have been identified in other forums.

According to a 1988 study from the General Accounting Office (GAO) a hypersonic cruise airplane with sustained cruise capability between Mach 5 and 14 could have significant applications, including a

(a) hypersonic airplane to carry out interdiction, reconnaissance, surveillance, and precision targeting and weapons guidance missions;
(b) hypersonic bomber for strategic bombing operations; and
(c) hypersonic transport for strategic airlift missions.

According to NASP programme officials, an aerospace plane deployed at just six bases around the world (on the east and west coasts of the United States, in Alaska, on Guam, and on the British possessions of Diego Garcia in the Indian Ocean and Ascension Island in the South Atlantic Ocean) could deploy anywhere in the world in 45 minutes or less and be within no more than a 4,000-nautical mile range of a recovery base. This capability is not possible with current aircraft.

(d) A single-stage-to-orbit space launch vehicle could also have important Air Force and Navy mission applications such as

(i) high altitude reconnaissance
(ii) deploying, servicing, repairing and retrieving communications, surveillance, navigation, warning, and weather satellites in low earth orbit.

A more recent study has been carried out by a National Research Council (NRC) committee on a contract between the Air Force and the Naticnal Academy of Sciences entitled *Hyper-*

sonic Technology for Military Application. Six points were raised in the section reviewing findings and recommendations:

(1) Hypersonic aircraft technology, in association with air-breathing propulsion, offers potentially large increases in speed, height and range of military aircraft and may enable or extend important Air Force missions.
(2) Operational hypersonic aircraft will necessarily have very large turning radii, and useful missions therefore require global or near-global range.
(3) Cryogenic fuels are necessary. Studies of hypersonic aircraft missions should therefore include a careful examination of the base support requirements which they imply.
(4) The simplest class of hypersonic cruise vehicle would fly up to Mach number 8.
(5) The most attractive potential Air Force missions involve flight to orbital or near-orbital speeds above the sensible atmosphere. In contrast to ballistic missiles and satellites. They also offer flexible recall, *en route* redirection and return to base.
(6) Sustained hypersonic flight in the atmosphere between the two extremes of (4) and (5) present major technical difficulties. Problems of surface heating, thrust, vehicle stability and control, infrared signature, aiming, and weapon release could make any potential military advantage in this speed range unlikely.

The above points are important because they illustrate the potentialities and the problems of the NASP option, whereas the earlier GAO report is more focused on potential. At some point, the space mission will have to be clearly delineated in terms outside of the ambit of Earth-based strategic missiles. NASA may be the logical choice and the Air Force, or some new organisation, may be involved.

The commercial aspects of NDVs need also be considered. JPO assumes a fleet of six vehicles, each capable of 25,000 lb to low Earth orbit (LEO) available by 2004 at a cost per pound to orbit of not more than $300. Such NDVs would be capable of launching 75% of payloads presently listed in the National Mission Model. The remainder could be lifted by an occasional shuttle launch, or more preferably by a heavy lift vehicle such as the Advanced launch System (ALS). These heavy lift vehicles would be used as little as possible but could also fill in the event of an NDV fleet standdown due to unforeseen problems.

Conclusions

The politics associated with the hypersonic programme are both international and domestic in scope.

In this article we have looked primarily at the US domestic scene, where the hypersonic is regarded as an expensive research and development programme in a fiscal environment becoming increasingly austere in outlook. Because of the bleakness of this fiscal picture, the NASP programme must obtain the backing of a strong bureaucratic actor. That is clearly the military (especially the Air Force) unless NASA dramatically changes its view of the shuttle, a programme that now dominates the agency's budget and thinking.

At a October 1990 international hypersonic conference in Orlando, Florida, NASA Deputy Administrator J.R. Thompson said:

I believe some derivative of the National Aerospace Plane will be our primary people carrier to space and will follow the Space Shuttle to transport men and women to space stations, to repair satellites, and to rendezvous with other spacecraft for lunar scientific outpost expeditions. [6]

Although this statement may be interpreted as a welcome sign of increasing NASA support, the 1991 NASA budget figures still show a cut in NASP funding from the amount of $119 million requested, to $75 million. The shuttle budget, on the other hand, is maintained at a level where $125 million was merely the affordable amount cut from its production and operations programme.

That NASP's continued existence may depend on the support of the military is especially ironic since the United States in the space field has clung to the dream of the peaceful use of space for science and commerce. NASA's existence is a product of that dream although, at times and due to budget exigencies, NASA has sought military connections, sometimes to its detriment. Despite the dream of space as a civilian and peaceful frontier, the other driving dream has been ready manned access to space, a dream placed in jeopardy due to the shuttle's problems. Former NASA Administrator Thomas Paine has, for example, publicly criticised the space station effort, in part because of what he termed as unrealistic dependence on regular shuttle flights. To achieve the goal of a ready manned access to space, the military may be asked to enter space in ways unforeseen for a generation. This could be a return to the period just before the establishment of NASA when the dominant domestic space players were within the military alone. Control over the hypersonic programme could make that a real possibility if the Air Force continues in the leadership role to develop the NASP system. Failure to develop the hypersonic would be a step backward for the United States. That is now a real possibility, as the programme languishes between slow-go and no-go. Contrary to American myth, orphans do not usually do well. Right now the hypersonic is an orphan with all which that portends for the future.

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3. Barbara Amouyal, "ATF Contractors Muscle Air Force for More Money", *Defense News*, 11 December 1989, p 42
4 Stephen W. Korthals-Atlas, "Will the Aerospace Plane Work?" *Technology Review*, January 1987, p.43
5 T A Heppenheimer, "How Much Hype is in Japanese Hypersonic", *Air & Space*, August/September 1989, p 60
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About the Authors

Joan Johnson-Freese is an Associate Professor of Political Science and Director of the Center for Space Policy and Law at the University of Central Florida. Prior publications have focused primarily on international cooperation and competition in space, and domestic space policy decision-making.

Roger Handberg is a Professor of Political Science and Associate Dean of Graduate Studies at the University of Central Florida. He has published extensively on science policy and the American political process.

Helen Sharman Selected for Juno

The Juno project has announced that Helen Sharman is to become Briton's first astronaut, with Tim Mace serving as her back-up. The British astronaut and two Soviet cosmonauts will be launched on the Soyuz TM-12 mission, currently scheduled for blast-off on May 12. The British astronaut will spend six days aboard the Mir space station performing a series of experiments for the Soviet NPO Energiya design bureau. A British scientific programme has been abandoned because of a lack of sponsorship.

The crew selection was announced at a press conference on February 22, by Juno Medical Director Air-Vice Marshal Peter Howard. He said the decision was based on a number of factors including, individual capabilities, medical fitness, crew compatibility, language, technical expertise and communications skills. The Juno team travelled to Star City to hear presentations from Vladimir Shatalov and Alexei Leonov about each astronauts' progress. The Soviets did not recommend which astronaut should fly because both Tim and Helen had reached the same high standard. In previous international flights it had always been clear which astronaut should fly, Air-Vice Marshal Howard told ***Spaceflight***.

On their return to Star City, Helen began training with prime crew members Anatoli Artsebarski and Sergei Krikalev, while Tim joined Aleksandr Volkov and Aleksandr Kaleri on the back-up crew.

"They are both great crews," said Helen. " It is obvious right away that they all get on together."

The final decision which crew flies will not be made until the State Commission meets 24 hours before the launch. The astronauts also have further medical evaluations to go through before they are declared fit to fly.

The two British astronauts began training for Juno in November 1989. The first three months in Star City was spent learning Russian. After passing their language exams they began to attend lectures given entirely in Russian.

"We started with flight ballistics and astrodynamics, which is pretty heavy stuff if you've just learnt Russian," Tim told ***Spaceflight***.

During the lectures the astronauts are expected to make their own notes in Russian. There are no manuals or text books for any of the subjects.

Tim and Helen started work on the Soyuz spacecraft in July 1990.

"We looked at the systems, how they are controlled and the flight dynamics of the craft itself," Tim explained.

After August the astronauts began their lessons about the Mir Space Station.

Just after Christmas, Tim and Helen started training with the Soviet cosmonauts assigned to the mission. They both took turns training with the prime and back-up crews.

"We do most of our work with them in the Soyuz descent module," said Tim, "about one session per week for each of us."

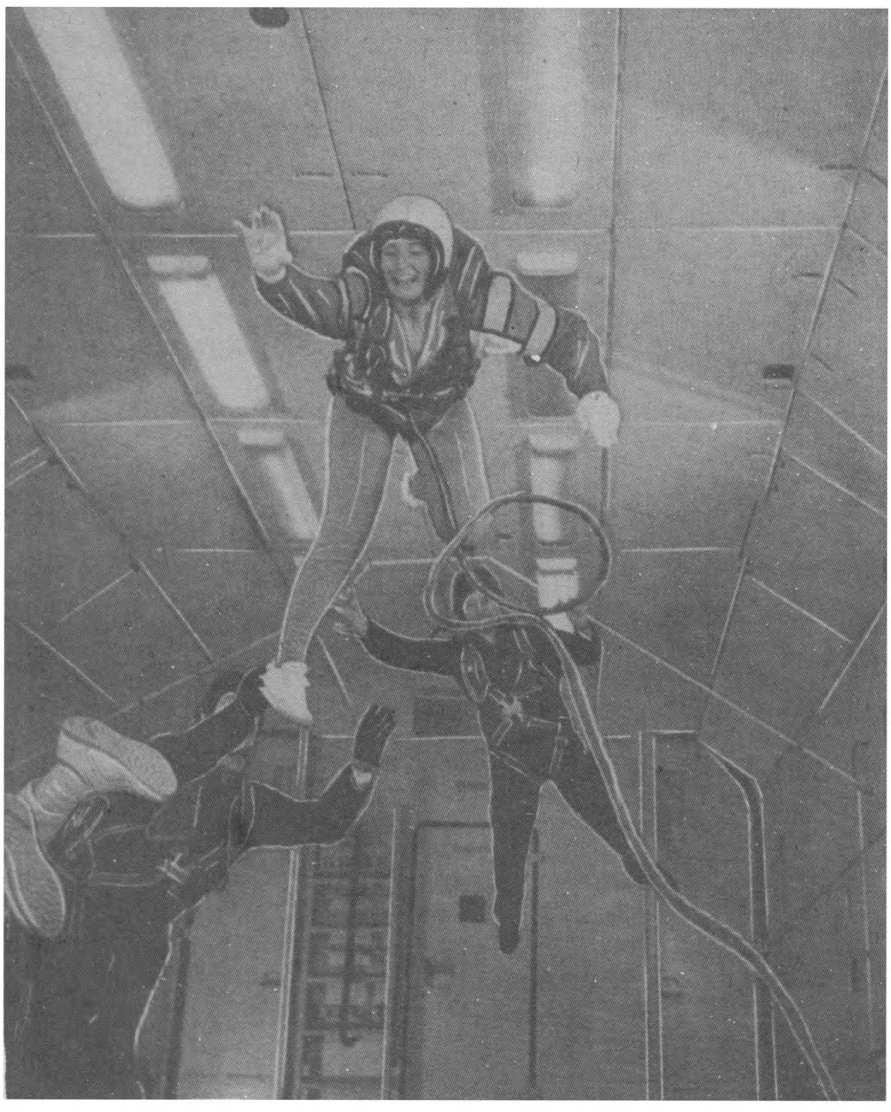
The joint training sessions amounted to about six hours per week but Helen expects they will spend more time together as the mission approaches.

The British astronaut will be responsible for operating some controls in the Soyuz capsule, as Tim Mace explains:

"You couldn't just sit there as a passenger because you block off the commander's access to certain systems. So you have to play an active part."

The tasks will include operating a valve that routes waste water in the atmosphere to tanks in either the descent capsule or orbital module. The British astronaut will also be responsible for the radio systems, atmosphere controls for the suits, the navigation computer, a manual override for the cabin oxygen supply and

Helen Sharman is pictured in weightlessness during training on a parabolic aircraft flight.



Tim and Helen pose with a model of the Soyuz rocket after the announcement of the crew selection.

the television system.

"The television system is particularly useful when we are docking," Helen told ***Spaceflight***. "There are two lenses, a wide angle and a narrow angled lens and you have to switch between them."

There are also two pneumatic supply valves directly in front of the commander that are just out of his reach when he is strapped in but it is quite easy for the British astronaut.

Tim and Helen have a good knowledge of their spacecraft but do not feel capable of flying it by themselves.

"It is a knowledge of what's going on rather then a working knowledge," said Helen.

The astronauts have already begun training with the twenty Soviet experiments to be conducted aboard Mir. Some of the experiments are already on the station, others will be carried on the Progress and some with the astronaut in the Soyuz. As we went to press the launch of the Progress-M7 was scheduled for March 19.

Helen Sharman, 27, was a research technologist at Mars Confectionery in Slough, Buckinghamshire, before being selected for astronaut training. She left Sheffield University with a BSc in Chemistry in 1984 and joined GEC as an engineer working on the materials used in the manufacture of cathode ray tubes.

Her work with Mars involved researching the chemical and physical properties of chocolate, recipe development and research into new raw materials. Helen enjoys cycling, running, badminton, squash, swimming and playing the piano and saxophone.

Tim Mace, 35, is a Major in the Army Air Corps. During his career, he has served with NATO forces in Europe and also worked in Central America where he was involved in jungle support flying. He has a BSc in Aeronautical Engineering and, as a graduate of the Military Flying School, is an advanced Instructor of helicopter pilots. His pursuits include freefall parachuting: he won the 1989 British Freefall Parachuting championships.

Both Tim and Helen are members of the British Interplanetary Society.

"I am delighted that the first Briton in space will be a BIS member," said Tony Lawton, President of the Society. "I hope Tim and Helen will be the first of many British astronauts."

Tim and Helen confirmed that they have applied to join the ESA astronaut programme.

Meanwhile the Moscow Narodny Bank has signed its first merchandising deal with Zeon, one of the project's former sponsors. The company is planning a 'Juno Watch' to commemorate the flight of Britain's first astronaut.

As this issue went to press there was no word on the exclusive television rights to the Juno mission. The high cost of the Gulf War coverage has left TV companies with little funds to spare. Talks are currently underway with three television companies, said Christopher Hayes, the Juno project manager.

Negotiations with potential sponsors are continuing.

Tim Mace hits the water during splashdown training as he jumps backwards off a mock-up of the Soyuz capsule.

What's the Forecast? Part 2

The laconic voice announcing that the apogee boost motor had fired and injected MOP-2 into its geostationary orbit was only the surface calm response to the deep anxieties which affect all who have a stake in a satellite launch and operation. This is never more so than when there are 'customers' for whom the satellite represents business on an international scale.

MOP-2 with its design lifetime of five years, will begin its service life after a commissioning period. EUMETSAT, representing 16 nations, will then have MOP-1 and MOP-2 available for operational service to the national meteorological offices of its member states. ESA's responsibilities within the Meteosat Operational Programme include, in addition to the construction of the spacecraft, orbital operations on behalf of EUMETSAT.

The main object of the Operational Programme is to acquire images of the Earth and, together with a set of meteorological products extracted from the image data, to deliver these to the customer in accordance with an agreed schedule.

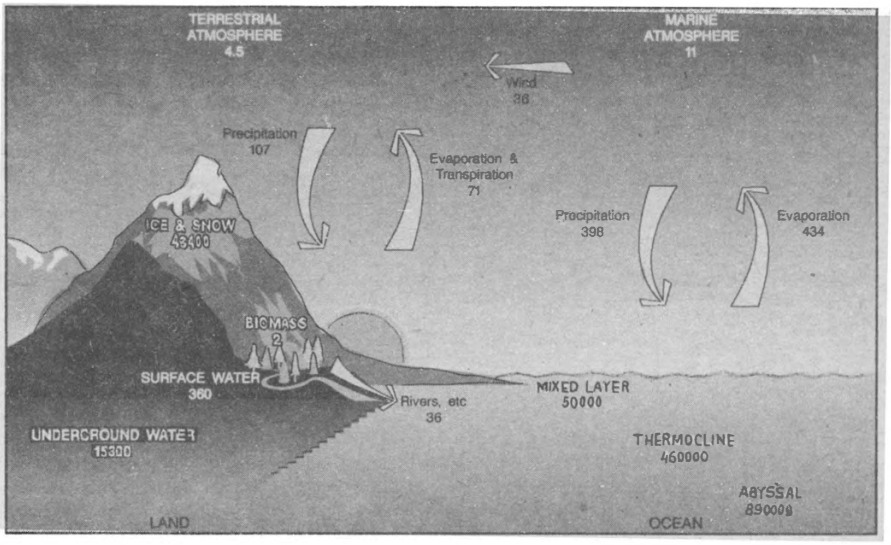
To succeed the operational programme must provide its customers with timely availability of derived products. Those products must not only be of the highest quality but the programme must take account of the customers wishes for new products.

So often the question arises, "Yes, but what will be the product of a particular new satellite system?" The truthful answer many times is "We don't know until it is up there", and many times the doubting Thomases amongst potential users are the first to come forward with demands for new data or new ways of presenting the data, once the operational phase has begun.

Success depends in large part on the performance of the ground segment, which calls for research into ways and means while keeping a 24 hour service going. That service is not only in the visible band. There are three channels transmitting simultaneously to the ground station, the other two being the thermal infrared and the water vapour bands.

Earth-imaging basic data is provided by the multispectral radiometer, the principal payload of the satellite. This operates in three spectral bands *viz*:

- 0.5 - 0.9 μm	- visible band
- 5.7 - 7.1 μm	- infrared water vapour absorption band
- 10.5 - 12.5 μm	- thermal infrared (window) band.



By Norman Longdon
ESTEC, The Netherlands

The infrared and water vapour images are composed of 2500 lines of 2500 picture elements while the visible image has 5000 lines of 5000 picture elements. The spacial resolution is approximately 5 km for infrared and water vapour and 2.5 km for visible images.

The visible channel measures solar radiation reflected from the Earth's surface from the oceans, land masses and the clouds, which appear, respectively, dark grey, light grey and white in the images. The thermal infrared channel measures thermal radiation emitted from the surfaces. The darker areas in these images are the warm zones - land, oceans and low clouds - the white areas are cold regions of high clouds. The water vapour channel measures the thermal radiation emitted by the middle troposphere and mainly absorbed by water vapour. The troposphere is the lower layer of the Earth's atmosphere rising from sea level to altitudes of between about 8 km at the poles and 18 km at the equator. The dark areas in the water vapour images represent regions of relatively low humidity; the brighter areas indicate regions of high humidity.

The Ground Segment

The four main components of the ground segment have rather lengthy titles but provide an excellent service. The Data Acquisition, Telecommand and Tracking Station (DATTS) is sited in open country at Odenwald, about 40 kilometres from Darmstadt in Germany. In Darmstadt itself, within the European Space Operations Centre, are the other three elements: the Meteosat Ground Computer System (MGCS). The Meteosat Operations Control Centre (MOCC) and the Meteorological Information Extraction Centre (MIEC).

The names indicate the dual role played by ESOC. It is carrying out its traditional tasks of controlling the spacecraft and its payload but, at the same time, it has the responsibility for collecting, processing and redistributing the data to the users *via* the satellite itself or through surface links.

The large 15 m parabolic DATTS antenna at Odenwald receives the data, which are, then, in an unprocessed or 'raw' state. The data are split into separate components and, after precise timing details have been added, are transmitted, within seconds of receipt, *via* surface links, to ESOC.

The MGCS now takes over as the images arrive through the 'front end processors'. The raw data are now analysed and transformed into a more usable form. The radiometer has been scanning the Earth in an East-West direction, in steps from North to South and each line of the processed data, taking 0.6 seconds to accomplish, corresponds to one of the 2500 steps which the radiometer took during a half hour cycle of activities for the three channels.

The raw data are stored on magnetic tapes: the processed data are passed from the front end processors to the mainframe computer and stored on magnetic disks ready for further processing.

The work now approaches the final product which will go out to the mete-

orologists, as the MIEC staff start the extraction of the 'products' from the data. The products routinely available through MIEC activities include:

(a) cloud motion winds
(b) sea surface temperatures
(c) cloud top height maps
(d) upper tropospheric humidity values
(e) cloud analysis
(f) basic climatological data set
(g) precipitation index

The first five of these products are quality controlled by a meteorologist before the results are coded and distributed.

Data Dissemination

The data must now flow to the users with all possible speed, to allow national meteorological offices to prepare their forecasts. The satellite again shows its versatility by the role it plays in distributing the processed data. The image data passes along the route from the ground computer system in ESOC, through the ground station to the satellite and then on to the user stations.

User stations can be quite simple affairs with the capacity to receive analogue data. The more complex Primary Data User Stations receive digital data designed for users needing pre-processed data in a form suitable for further, on-the-spot, computer processing.

The satellite has even more to offer. There are telecommunications channels designed for the collection of environmental data from automatic and semi-automatic data collection platforms (DCP), which may be located anywhere within the satellite's coverage area. These include not only fixed DCPs but ships and aircraft passing through the zone, which add to the scarce data available from the large ocean areas.

A further service is provided, thanks to the French Meteorological Service ground station at Lannion in Brittany. Data from the United States' weather satellite covering the Western part of the Atlantic is received by the station and then processed so that it is compatible with the Meteosat Operational Programme system. This is then beamed to the 'duty' MOP satellite and from there down to user stations.

It is now clear that the images seen on weather forecasts represent only a tip of the iceberg of the images and data constantly being derived from, processed in and disseminated from the Meteosat Operational Programme. Forecasts are the outcome of the most thorough analysis relentlessly being updated in the meteorological offices around the world.

The number of parameters which must be built into any analysis of climate and weather can be illustrated in broad terms by the graphic representation on this page of some of the elements to be taken into account.

Natural Disasters

Resolution of the images does not allow detailed scrutiny of natural disasters but it is possible to track certain events and, from the data, to infer and predict outcomes - at least in broad terms.

Hurricanes are a good example of what can be achieved. A hurricane, i.e. a tropical storm with sustained wind speeds in excess of 64 knots and with those close to the central core often far higher, can be readily observed in MOP images. They can be tracked on a half-hourly basis from image to image, facilitating forecasts of their progress. Their characteristic cloud patterns in the imagery enable the meteorologists to estimate their violence and destructive potential.

Those area prone to such storms - the Eastern seaboard of the United States and the Caribbean, the Arabian Sea and the southwest Indian Ocean, can be given early warning of those storms which begin their life cycle within the Meteosat zone.

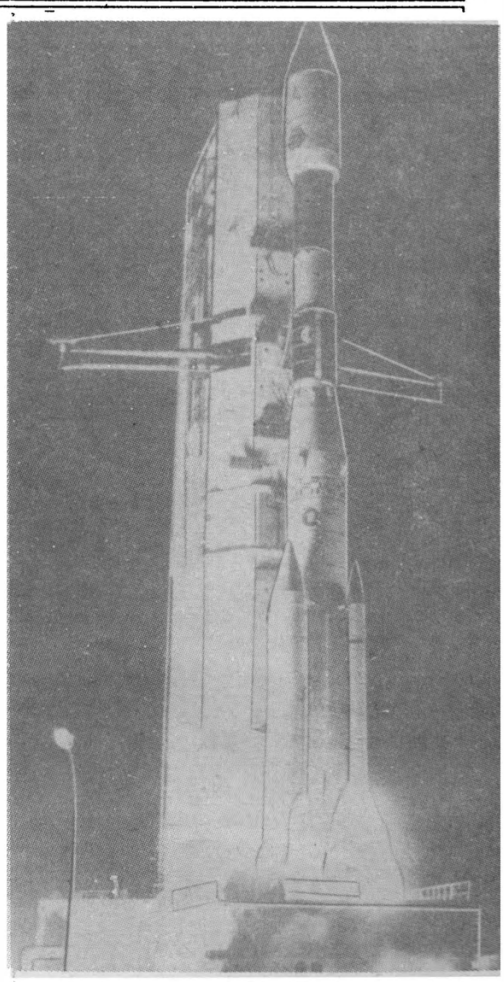
Potential areas of widespread flooding from causes such as local stoms in mountainous regions and following thaws in snow covered areas can be identified.

MOP also plays a part in drawing attention to droughts. Long absences of rain-bearing clouds over areas of marginal agricultural activity can be monitored and warnings given of possible drought and famine. The infrared image can be used to corroborate evidence, for the diurnal rate of temperature change recorded can be linked to soil moisture.

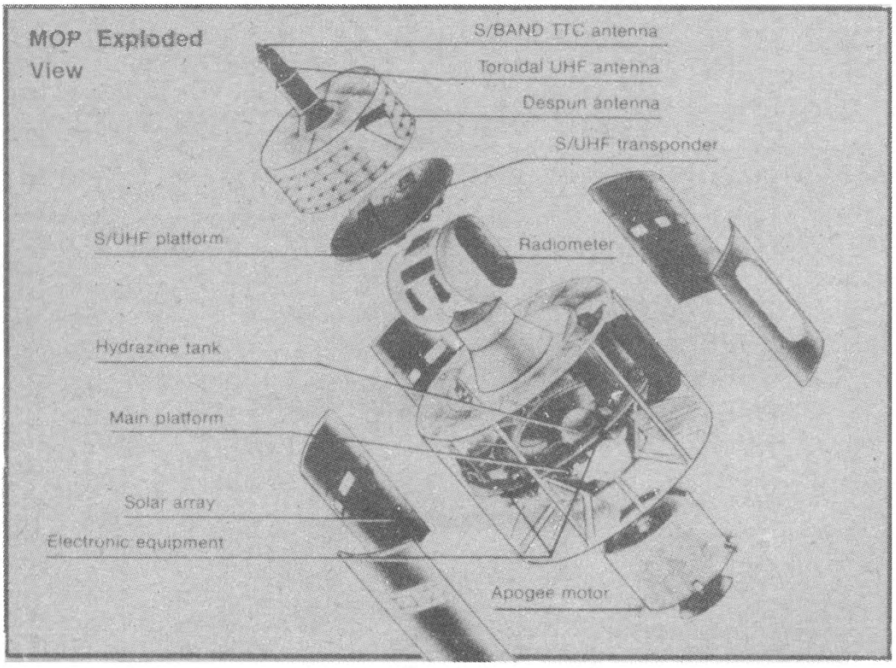
It is not only satellite systems such as Meteosat which require considerable advance planning for future generations: This applies also to the ground sector.

Studies of potential satellite and payload design have been under way for some years. In June 1990 the EUMETSAT Council decided to adopt a spin-stabilised satellite concept for the Meteosat Second Generation, with instrumentation included for visible and infrared imaging, high resolution visible imaging and monitoring of atmospheric instability.

The ground sector is also constantly under review, not only to be able to process and use the new imagery foreseen to the best advantage but also to make use of the latest technological innovations such as artificial intelligence for maintaining and, where possible, improving on the excellence of the service given to the meteorological community.



Ariane V42 blasts-off on March 2 with the MOP-2 satellite aboard. *Arianespace*



The BIS Video Collection

The British Interplanetary Society is proud to offer a stunning record of man's exploration of space brought to your home by *The BIS Video Collection.* Three new cassettes in this exciting collection are now available.

STS-26

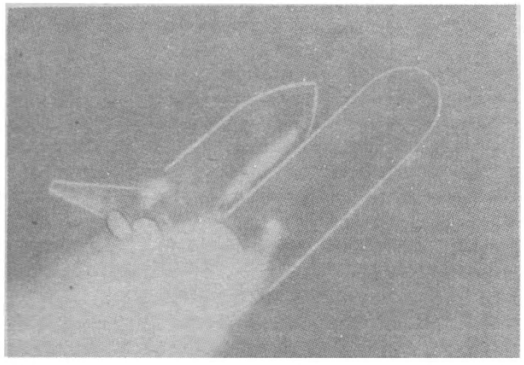
The Return to Flight

On September 29, 1988 Discovery blasted-off from the Kennedy Space Center it was the first Shuttle launch since the Challenger accident.

This video depicts the highlights of the STS-26 four-day mission During the flight, the five-man crew deployed a Tracking and Data Relay Satellite and performed a series of microgravity experiments. It concludes with the successful landing at Edwards Air Force Base in California on October 3.

There is no comentary on STS-26 Mission Highlights, apart from the astronauts' transmissions and occassional announcements from the NASA Public Affairs Officer The tape is accompanied by a FREE mission guide.

Running Time 57 minutes



CHALLENGER

Accident Investigation

On January 28, 1986, the Space Shuttle Challenger exploded 73 seconds after blast-off from the Kennedy Space Center. All seven STS 51-L crew members died.

This video, prepared by the Photo and TV Support Team of the 51-L Data and Design Analysis Task Force, documents task force activities and findings. It also provides a concise, technical explanation of the cause of the Challenger accident.

Running Time 29 minutes

A COLLECTION OF "THE MOVIES"
LA, Earth, Mars and Miranda

plus

VOYAGER 2 NEPTUNE ENCOUNTER

Created by the Jet Propulsion Laboratory, this video, features four short productions which use satellite/space probe images and supercomputer graphic animation. In 'L.A. - The Movie' the Los Angeles area is seen from space, then the view moves downward to provide a point-of-view tour around the animated city. 'Earth - The Movie' begins with animation of the entire planet as it is rotating in space. It continues with a point-of-view movement down to the surface and past the continents. "Mars - The Movie' features point-of-view movement around one geologic area on the planet. A simulated excursion over the Uranian moon, Miranda, is showcased on 'Miranda - The Movie'.

Running Time: 17.5 mins

At the start of this tape is an additional feature, 'Voyager 2 Neptune Encounter'. Containing 17 individual segments, this production illustrates the various aspects of Voyager's encounter with Neptune. The segments progress from computer animation of the Voyager mission to actual photographs of Neptune and Triton.

Running Time: 29 mins

Also available: **STS-32** Video Highlights, **STS-31** Video Highlights,
The Eagle Has Landed: The Flight of Apollo 11 and **STS 41-C** Video Highlights

Tapes are VHS PAL format only. Please check your equipment is compatible. Allow 28 days for delivery in the UK & six weeks overseas

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		☐ STS 41-C Video Highlights	£15 (US$30)

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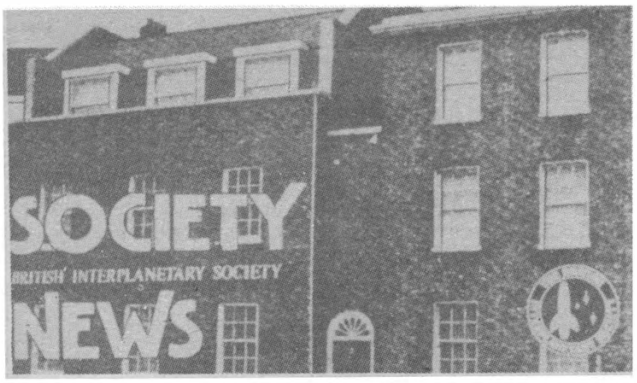


New Society Officers

The new Society President is Mr A.T. Lawton who has taken Office following completion of the Term of Office by Mr G.W. Childs.

A.T. Lawton.

R.C. Parkinson.

C.R. Turner.

In accepting Office, Mr A.T. Lawton praised the work undertaken by his predecessor, which had seen the Society introduce a much-improved ***Spaceflight***, a significant advance in the presentation of ***JBIS*** and the fulfilment of the Society's plan to enlarge its premises.

The work which lay ahead was still considerable but bright with promise. Work on the renovation and restructuring of both the Library and Conference Room were already substantially in hand, along with many ancillary projects. The way was becoming clear for initial studies to begin on the final development phase i.e. the creation of Council and Committee rooms by the complete restructuring of the top floor of our existing premises and adding a further storey to our Extension.

All this work would lead to a substantially stronger base from which the Society could operate. Associated with these were arrangements to ensure that the Society's 60th Anniversary Celebrations would be as rewarding as possible, that its newly-proposed Archival Collection should be well housed and that, with all the construction work behind us, the Society would enter a new phase of strengthening its Publications and Member services.

The two new vice-Presidents, elected at the same meeting, were Dr R.C. Parkinson and Mr C.R. Turner.

Bob Parkinson is already well known to members of the Society by virtue of his work on HOTOL and his contributions to concepts of lunar and planetary colonisation. Mr Turner, who earlier completed his own term of Office as President, was formerly Technical Secretary of EUROSPACE.

HQ Renovation - An Update

Our two illustrations this month give a good idea of how work is progressing on the renovation both of our Conference Room and Space Library.

A new ceiling has been installed in the Conference Room and paintwork completed in a soft pastel shade, the new arches looking particularly attractive. An early opportunity for members to view the way the work is shaping up took place on March 6th for those attending the talk by Mr Hingley. However, although there are still many small jobs to be completed, the work is now in its final stages and should be completed within the next month.

The panelling of the Library has now also been completed and some attempt made to re-erect the bookshelves and reduce the piles of books which fill the floor. A slight further delay is expected before this work can be completed as the shelving not only needs to be rearranged but also requires a number of changes to fit the new layout. This poses problems similar to those of a jig-saw puzzle but, with the help of members of the Library Committee, a re-erecting, re-sorting and general cleaning-up programme is well in hand.

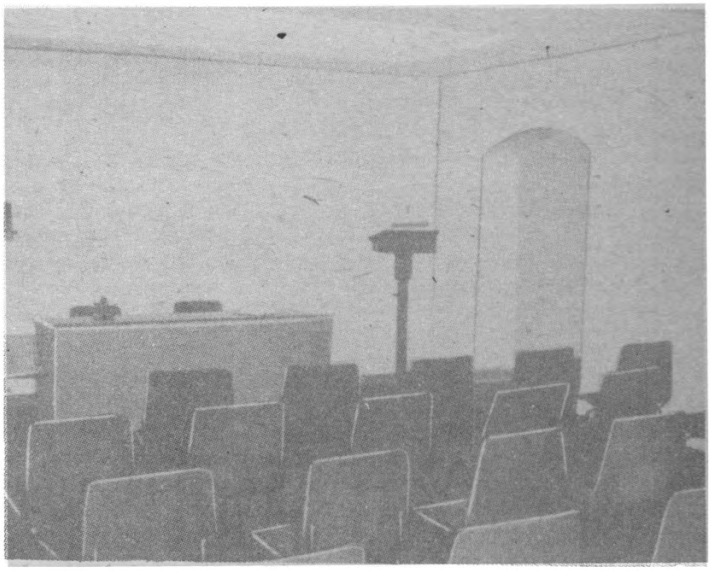
The opportunity will be taken to create a much better presentation of books, with room for expansion in many key areas. To accomplish this, books of a general nature which hitherto found a place on our shelves will be withdrawn and disposed of. Members interested in acquiring withdrawn Library books have only to write to our Office for a list of those available, enclosing a foolscap reply-paid envelope. Prices are very reasonable and any surplus will be used by the Library Committee to acquire works which would not otherwise be available to us.

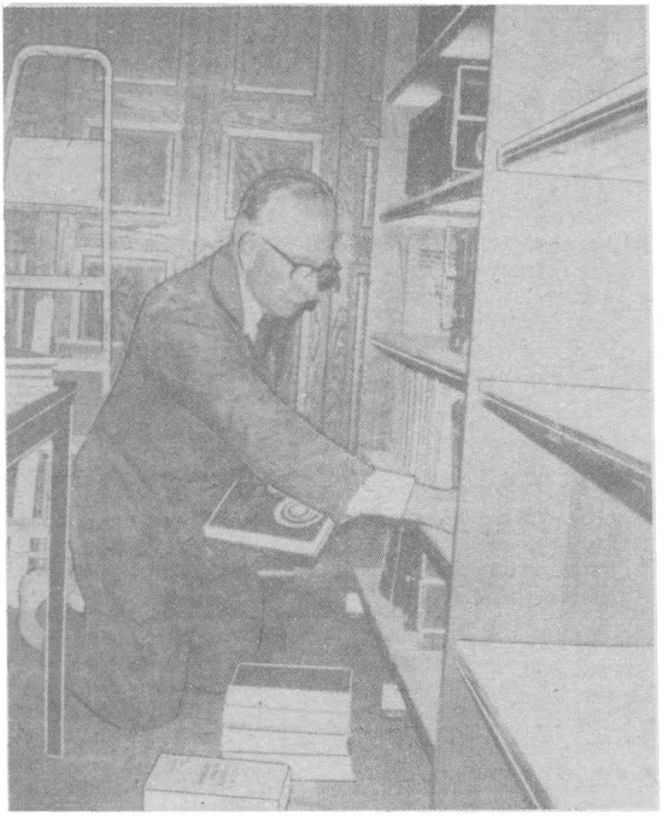
A new Librarian's Office has been installed as part of the first floor extension, thus providing much-needed working space for the very first time. Storage shelving needed for this is currently on order but is not likely to be available for several months yet. In the meantime, the office is being used to provide "elbow room" in the marathon task of re-sorting all the books and reports once more.

While we are awaiting the construction and installation of the new stairs, together with a re-plastering of the walls and all the mess that entails, work is moving to the rear of the building where re-painting has to be done before the scaffolding is removed. The courtyard will then be made up and re-surfaced ready for use.

All this work is expected to be completed by the early

The Conference Room ready for use in time for the March 6 meeting





Library books are re-shelved by Mr Eric Waine. Much work still remains to be done in the Library before it can be opened for use.

Summer, approximately one year ahead of schedule. A gap is then expected in the proceedings while the various Local Government and other permissions are sought and processed, before the final phase is tackled, this involving adding a further storey to our existing Extension and the complete rearrangement of the enlarged top floor of our building to provide very attractive facilities for Council and Committee meetings.

Gifts to the Society

The Society is delighted with the valuable support given by members from time to time in the form of bequests. These are a substantial aid to its development programme and to its role of promoting space developments more effectively.

These arrangements can be made quite easily by a simple Clause in either a Will or Codicil reading:-

"I give, devise and bequeath to the British Interplanetary Society Limited of 27/29 South Lambeth Road, London, SW8 1SZ, the sum of £... (followed by the amount in words) free of all duties."

Following a change in the Law, effective from October 1990, it is also now possible to make a single (i.e. one-off) gift to the Society which can be charged against business profits and is allowable for Tax purposes. The previous requirement was for a Deed of Covenant which had to run for a number of years and which took no account of any changes which might face a business from year to year.

Those wishing to support the Society in either of the above ways but needing further information should write to the Executive Secretary.

SOCIETY MEETINGS DIARY

SYMPOSIA

1 June 1991 **10 am - 4.30 pm**

SOVIET ASTRONAUTICS

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

Venue: The Conference Room, The 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

3 April 1991 **7 pm - 8.30 pm**

A REVIEW OF PROPOSALS FOR HOTOL-TYPE SPACEPLANES

Alan Bond

The requirements on space transportation from the Earth to LEO for the early decades of the 21st Century will be assessed and the spaceplane proposals being offered to meet them will be reviewed. Particular attention will be focussed on the technology and economic aspects of these proposals and the author's opinions as to their success in addressing the important issues will be offered.

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

Admission is by ticket only. Members should apply in good time enclosing a sae.

1 May 1991 **7 pm - 8.30 pm**

HABITABLE PLANETS AND THE ECOSPHERE

M.J. Fogg

Previous estimates of the abundance of habitable planets in the Galaxy indicate that they are relatively rare. However, modern research concerning the terrestrial carbonate-silicate cycle now suggests that the habitable zone (the ecosphere) about main sequence stars may be wider than previously thought. This lecture presents the results of a computer model which shows that the abundance of planets potentially bearing life, although not necessarily Earthlike planets, may be significantly greater than indicated by past models.

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

Admission is by ticket only. Members should apply in good time enclosing a sae.

5 June 1991 **7 pm - 8.30 pm**

THE HISTORY OF WESTCOTT

J. Harlow

Many Fellows of the Society have contributed to work at the Westcott site, which has been known under a variety of names for nearly 50 years now. Its history will be presented from its initial use as a war-time airfield to the end of its operation under the jurisdiction of the Ministry of Defence on 31 March 1984. The beginnings and evolution of activities associated with both Solid Propellant rocket motors and Liquid Propellant engines will be discussed along with other interesting technologies.

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

Admission is by ticket only. Members should apply in good time enclosing a sae.

3 July 1991 **7 pm - 8.30 pm**

INTELSAT, THE GLOBAL SATELLITE COMMUNICATIONS SYSTEM: PAST, PRESENT AND FUTURE

P.T. Thompson

The International Satellite Telecommunications Organisation, INTELSAT, has been in existence for over 25 years and has provided a highly successful global communications network. The manner in which this has been achieved and its future plans will be outlined.

The performance of the seven generations of satellites used by the organisation will be covered as will the evolution of the international services that use this technology. From the early days of having one satellite to the current situation with over 800 major earth stations operating to 13 satellites this evolution provides complex planning challenges, where the traffic demands double every 4-5 years.

A slide based talk will be the main method of conveying this material but in addition two short video tapes of the manufacture and testing of the INTELSAT V & VI satellites will be shown.

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

Admission is by ticket only. Members should apply in good time enclosing a sae.

INTERNATIONAL CONFERENCES

27 - 30 August 1991 ***Note Change of Date***

POWER FROM SPACE '91

The path to making power from space available to mankind is long and difficult but for that very reason it is necessary to begin now. This meeting, organised by the Societe des Electriciens et des Electroniciens and the IAF, and co-sponsored by the Society, will address the major issues of power from space.

Venue: Ecole Supérieure d'Electricité, Paris, France.

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

5-12 October 1991

42nd IAF CONGRESS

To be held in Montreal, Canada, hosted by the Canadian Aeronautics and Space Institute.

The theme will be "The Next Century - Prospects for Space".

Members of the Society wishing to present papers may obtain procedural details for the submission of Abstracts from the IAF, 3-5 Rue Mario-Nikis, 75015 Paris, France.

The 43rd IAF Congress will be held in Washington, DC over the period 28 August to 9 September 1992 and will be combined with the 29th Plenary Meeting of COSPAR.

The meeting will be hosted by the AIAA and held under the auspices of the NAS and NASA.

2 - 4 October 1992

SPACE '92 INTERNATIONAL SPACE PROJECTS

The Society's biennial two day meeting will be held at the White Rock Theatre, Hastings 2-4 October 1992. With the theme of "International Space Projects".

Offers of papers are invited. Please contact the Executive Secretary.

LIBRARY

IMPORTANT NOTICE

Work on the HQ Extension requires closure of the Library until further notice.