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Spaceflight

The International Magazine of Space and Astronautics

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По подписке 1991 г.

Shuttle Crew Saves Astro Mission

Jupiter Probe Passes Earth

'Ditch Shuttle' - Says Report

Competition for US Cosmonaut Place

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 33 No.2 **February 1991**

FRONT COVER: STS-35 Mission specialist Mike Lounge is helped into his pressure suit by a technician shortly before the launch of Columbia. NASA

'Phase Out Shuttle - Scale Down Space Station' Says Report on Future of US Space Programme

NASA, though imperfect, remains the gathering place for the United States' greatest body of space expertise and is the appropriate organisation to take the nation's space programme into the future, said a special group charged with making recommendations about that future.

The Advisory Committee on the Future of the US Space Program, headed by Martin Marietta Chief Executive Officer Norm Augustine, presented its report in December.

The 12-member task force was appointed in August after a series of troubles, including discovery of the Hubble Space Telescope's spherical aberration and Columbia's and Atlantis' hydrogen leaks.

The committee cites nine specific concerns but, in spite of those concerns, said sweeping management changes are inappropriate.

"Briefly stated, the Committee believes that NASA, and only NASA, realistically possesses the essential critical mass of knowledge and expertise upon which the nation's civil space programme can be sustained - and that the task at hand is therefore for NASA to focus on making the self-improvements that gird this responsibility," the report says.

The committee's concerns include the lack of national consensus regarding the goals of the country's space programme; continuing changes in project budgets; institutional ageing; the natural tendency for projects to grow in scope, complexity and cost; the fact that space projects tend to be very unforgiving in any form of neglect or human failing; and the material foundation of any major space project as NASA's technological base.

""NASA and I intend to take each of the recommendations most seriously as we take a look at how they can be implemented," said NASA Administrator Richard Truly.

The Augustine Committee will be reconvened in mid-1991 to assess how NASA and the National Space Council has implemented the recommendations.

Shuttle Concerns

Regarding the Space Shuttle, the committee said the system offers significant capabilities to carry out missions where humans are uniquely required: however, it "is also a complex system that has yet to demonstrate an ability to adhere to a fixed schedule," according to the report.

The committee recognized the Shuttle's flexibility and capability to provide human presence in space. The Shuttle also permits the recovery of costly launch vehicle hardware which would otherwise be expended, the report says.

However committee members said,

NASA Administrator Richard Truly says he will take the Augustine Committee recommendations "most seriously". *NASA*

the shuttle "tends to be complex with relatively limited margins; it has not realized the promised cost savings; and should it fail catastrophically, it takes with it a substantial portion of the nation's future manned launch capability and, potentially, several human lives."

"We are concerned that the Space Shuttle is the maybe, the thin reed that, supports our entire civil space programme," said Norm Augustine. "We conclude that it is time to begin phasing over from the Space Shuttle to an unmanned, but manned rateable, heavy-lift launch vehicle that could be available in the fairly near future."

NASA should not build a new Shuttle orbiter (OV-106), the Committee says. Instead, the funds should be diverted to enable the construction of the heavy-lift launcher. The committee added that funds should not be taken from the construction of support hardware needed to assure the shuttle's continued operational viability.

However, according to Truly, cancelling the proposed new orbiter would not free enough funds to build the cheapest form of heavy-lift vehicle.

"You cannot get a Shuttle-C and the necessary space rendezvous tug for just the cost of a new orbiter," he said. Truly stressed that if a new Shuttle was deferred the ability to construct new orbiters should not be abandoned.

Despite its criticisms, "The committee recognises the important role of the space shuttle for missions where there is the need for human involvement and notes the Space Shuttle is absolutely essential to America's civil space programme for the next decade to come. Necessary steps to assure the viability of space shuttle operations this decade should therefore proceed".

Rethink Space Station

"The space station, in its present configuration, we believe is too complex, far too costly, depends too much on the Space Shuttle and does not permit adequate testing before placement on-orbit," said Augustine. "We have recommended that the redesign, which is underway, be continued and not limited necessarily to the 90-day period Congress has allocated for that. We should take whatever time it takes to reconfigure the space station so that we will have a system that will be viable and will earn the support of both the Congress and the public."

The report says that the "redesign is simply too important to take less than whatever time may be needed for a thorough reassessment and the establishment of a configuration that can earn stable long term funding and support."

Space Station Freedom cannot be justified solely on the basis of the non-biological science it can perform nor as a transportation node, the Committee said.

"However, the space station is deemed essential as a life sciences laboratory, for there is simply no Earthbound substitute," the report says.

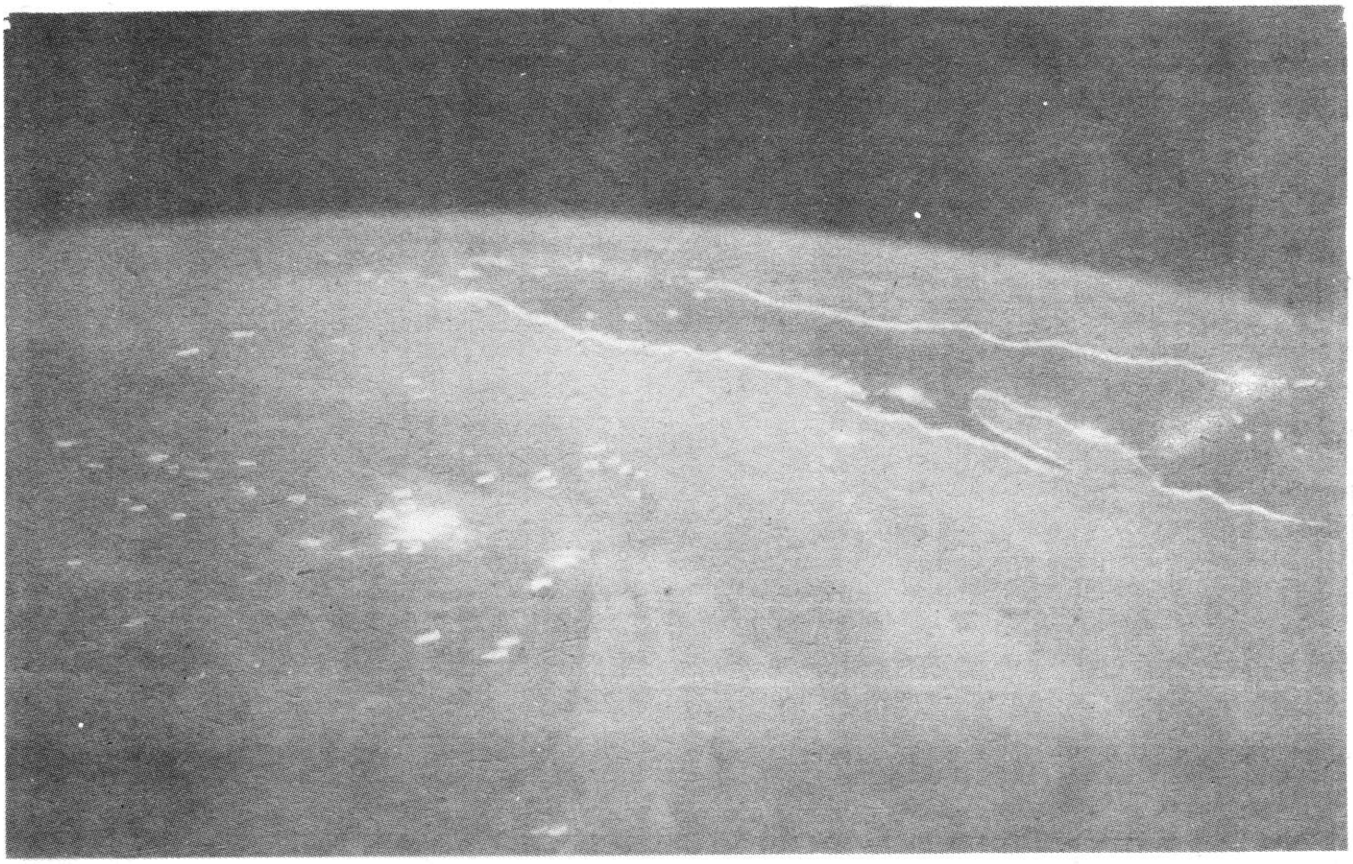
Freedom should have two justifying objectives: the primary life sciences and microgravity experimentation, the Committee said. It added that it believes Freedom can be simplified, reduced in cost, and constructed on a more evolutionary, modular basis.

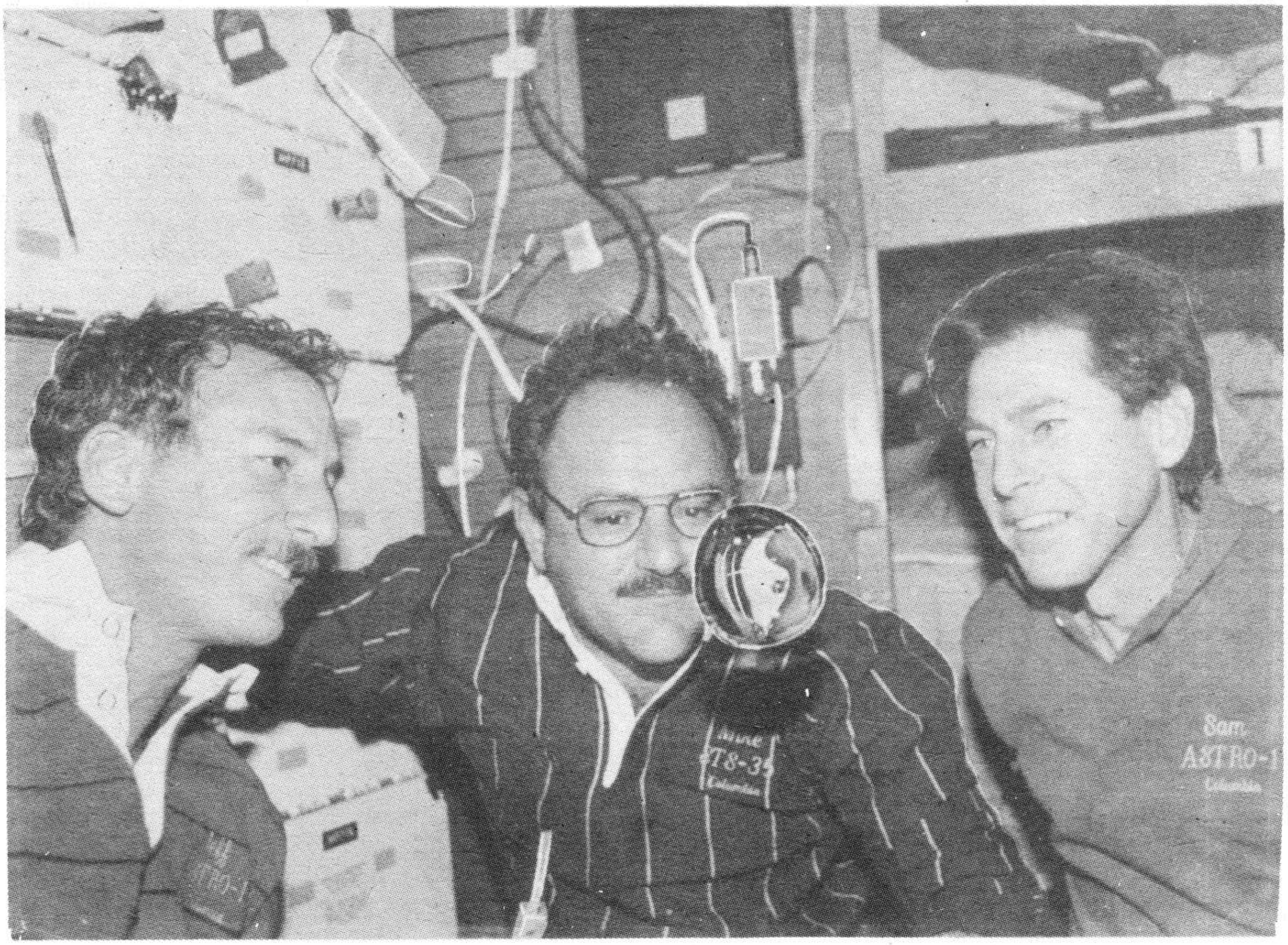
NASA Organisation

The group also expressed concern about the existing US civil service system which is "hopelessly incompatible with the long-term maintenance of a leading-

TOP: A nighttime high oblique view of the Persian Gulf area taken during Shuttle mission STS-35 in December. Major cities and oil fields of the countries of Saudi Arabia (foreground), Iraq (top left), Iran (top centre and top right), Kuwait, Bahrain, Qatar and portion of the United Arab Emirates are visible in the 35mm scene. The larger white spots scattered throughout the scene represent cities. Those include Kuwait City; Baghdad, Basra and Faw in Iraq; Ab Dawhah in Qatar; Riyadh, Al Jubayl, Dharan, Al Huf, Ad Dilam and Al Hariq in Saudi Arabia; and Bahrain along with its causeway to the mainland. Flares characteristic of oil field practices in this region are visible both onshore and offshore.

BOTTOM: On Columbia's middeck STS-35 Blue shift team members (left to right) Hoffman, Lounge and Durrance demonstrate the behaviour of a water bubble in the weightlessness of space. The bunk-style sleep quarters for the seven-man crew are in the background. A full report on Columbia's mission appears on p.46. *NASA*

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ASTRO-1

NEWS IN BRIEF

$150 million Japanese Satellite Fails

The Superbird-A Japanese communications satellite, launched in June 1989, has failed in geostationary orbit after its attitude control system malfunctioned in December. The owners of the satellite, Space Communications Corporation, have filed a $150 million insurance claim. It is believed a valve either malfunctioned or was accidentally opened allowing the satellite's oxidizer supply to leak overboard, leaving the attitude control system useless. This is the second major setback for SCC in under a year. In February 1990 the Superbird-B satellite was destroyed when Ariane V36 exploded. Some SCC customers may be transferred to the two JC-Sat spacecraft. Meanwhile, the next Superbird satellite is tentatively scheduled for a November 1991 launch.

Hubble Failure

One of the Hubble Space Telescope's four primary attitude control gyroscopes failed on December 3 causing ground controllers to switch to one of the two back-up units. The faulty gyroscope could be replaced during the planned June 1993 Shuttle mission to repair the orbiting observatory.

Almaz Delayed Again

The launch of the Almaz radar remote sensing spacecraft is now scheduled for late January, according to reports. The mission has been delayed to allow further testing of an antenna that will transmit radar data to a relay satellite.

US/Japanese Cooperation on Manned Space Flight

NASA has invited two Japanese candidates to join NASA's next Mission Specialist training class, beginning in July 1992. NASA has also expressed its intent to offer a place on the Shuttle to one or both the Japanese astronauts in the years following their training programme. NASA has also offered places for Japanese engineers to work in Mission Control at the Johnson Space Center. Japan will need experience in mission operations prior to its involvement in the international space station.

New Brakes for Atlantis

The Space Shuttle Atlantis is being fitted with carbon-carbon brakes before its next mission in April. The new carbon-carbon brakes have performed flawlessly on the last two landings of Discovery. Eventually all four Shuttle's will be equipped with the new brakes which, according to NASA, offer greater safety and reliability and replace the earlier beryllium units.

Continued from p.38

edge, aggressive, confident and able work force."

To address that, the Committee recommended major reforms in the civil service regulations as they apply to specialty skills or, if that is not possible, exemptions for at least 10% of NASA employees to operate under a tailored personnel system.

In the absence of either of the two recommendations, the committee suggested that NASA consider selectively converting some of its centres to university-affiliated Federally Funded Research and Development Centres.

According to the report, the committee also believes NASA is "currently overcommitted in terms of programme obligations relative to resources available - in short, it is trying to do too much and allowing too little margin for the unexpected."

"The result," the report says, "is the frequent need to revamp major programmes which sometimes results in forcing smaller [scientific] pursuits to pay the bill for problems encountered in larger [frequently manned] missions."

Though the committee concluded that America does want an energetic, affordable and successful programme, the question remains as to what that programme should be.

Mission To and From Planet Earth

The report suggests that the nation's space programme should use science as the fulcrum to balance two keystones - Mission to Planet Earth and Mission from Planet Earth.

The Mission to Planet Earth, as defined by the committee, brings space down to Earth by addressing critical everyday problems which affect all its inhabitants.

"Mission to Planet Earth, as we would define it, comprises a series of earth observing satellites, probes and related instruments and a complementary data handling system aimed at producing a much clearer understanding of global climate change and the impact of human activities on Earth's biosphere," the report says. "This effort provides us with a much better understanding of our environment, how we may be affecting it and what might be done to restore it."

Mission from Planet Earth focuses on space exploration and would include most of the manned space undertakings which tend to be the most costly aspect of the overall space programme.

The Committee added that it "wholeheartedly endorses a far-reaching, but we believe realistic, undertaking in manned space activity, carefully paced to the availability of funds."

According to the report, the Committee supports President George Bush's goal to explore Mars but believes the goal should be tailored to available funds rather than adhering to a rigid schedule. Using this approach, Committee members believe a sound long-term human exploration programme can be pursued.

The Committee also stated that NASA's technology base must be replenished and recommended that NASA begin plans to develop a heavy lift launch vehicle, capable of evolving into a manrated vehicle.

The Committee also said NASA should continue to help nurture a commercial space industry and that it applauds the agency's on-going efforts to enhance the nation's mathematics and science programmes.

Cosmonauts Repair Hatch During EVA

Soviet cosmonauts Viktor Afanasyev and Musa Manarov completed an EVA in the early morning of January 8 which saw them finally complete the operation to replace the damaged hinge of the airlock of the Kvant-2 module. The hinge had been buckled during an EVA by cosmonauts Anatoli Solovyov and Aleksandr Balandin on July 17. The cosmonauts were forced to perform an emergency depressurisation of the second section of the module in order to return into the complex.

During a subsequent EVA by the two cosmonauts on July 26 the hatch door was closed but the mission managers knew that a repair was necessary. The Kvant-2 EVA hatch is the first in Soviet manned space practice to open outwards and one designer was scathing in his criticism of the actions of the cosmonauts. The findings of the subsequent inquiry have not been publicised.

The first attempt at repair came on October 30 when cosmonauts Gennadi Manakov and Gennadi Strekalov spent 3 hours and 34 minutes attempting this. Those cosmonauts, however, discovered that the hinge pin was buckled, which necessitated the replacement of the whole hinge.

When Afanasyev and Manarov arrived at the Mir complex in Soyuz TM-11, then brought with them a replacement hinge designed for fitting in the conditions of open space. The cosmonauts began preparations for their foray into open space over the New Year and, on January 6, TASS announced that the EVA was scheduled to begin at 1647 GMT on January 7. It was expected to last for 4 hours.

The EVA actually began at 1703 GMT when the cosmonauts opened the Kvant-2 hatch. They dismantled the existing hinge and replaced it with the new one.

However, that was not their only job during the EVA. Working outside the module, the two men fastened a metal truss mounting device to the exterior of the complex in preparations for the EVA task - the re-location of the Kristall module solar arrays to the Kvant astrophysics module. A jib device will be mounted on the truss for that complicated operation.

In addition, the men removed a TV camera from the Gemma videospectral system mounted outside Kvant-2 and retrieved a cassette with materials samples which had been exposed to space for a year.

They completed the EVA after 5 hours and 18 minutes.

Neville Kidger

Texas Firm Offers Ride to Mir

By Curtis Peebles
California, USA

In October 1992, a lucky American will win a flight to the Soviet Mir space station if the plans of Space Travel Services of Houston, Texas are successful. The firm announced the offer on December 17, 1990. James Davidson, senior vice president of Space Travel Services said "Our long-term business strategy is to arrange for space travel opportunities for anyone who wishes to go into space. To introduce this service and our company to the general public, we've arranged for a little sweepstakes. The trip to the Mir space station is the ultimate adventure."

Would-be American cosmonauts can enter by calling 1-900-258-2MIR. The caller is charged $2.99, (over half of which goes to Space Travel Services.) Free entries can be sent by mail. So many calls were made in the first hours after the press conference that the phone lines were overloaded. According to the Associated Press over 120,000 people called the line on the first day.

The offer attracted both attention and confusion. On the afternoon of December 17th, the TASS news agency said they had no knowledge of the offer and called it a "hoax". The next day the Soviets confirmed a contract had been signed. Agreement had been reached with Space Commerce Corp (which markets Soviet launch services in the US) and NPO Energiya on November 30. To add to the confusion, Space Travel Services officials were called before a Grand Jury to answer charges of running an illegal lottery. (Texas law prohibits charging to enter a contest.) Because the rules allow free mail entries, these accusations were quickly dismissed.

Entries will be taken until December 1, 1991. Then 11 finalists will be picked by random drawing. They will undergo Soviet spaceflight physical and a prime and back up will be selected. They will undergo 6 months of training and Russian language lessons.

The launch would be made in October 1992 and last one week. The winner will also receive $500,000 in cash. If the winner chooses to remain earthbound or they are unable to make the flight, they would get $1.5 million.

Space Travel Services officials did not disclose the exact amount they paid for the flight, but confirmed it was more than the $12 million the Japanese Tokyo Broadcasting System spent to put a reporter aboard Mir in early December 1990.

If the flight is made as planned, it would be the first time an American had flown to Mir. It would also be the first joint US/Soviet flight since the ASTP mission of 1975.

Medicine Reduces Space Sickness

Physicians at NASA's Johnson Space Center (JSC) have reported that a new treatment for space sickness has proven to be very successful on recent Shuttle missions.

Promethezine, an intramuscular treatment administrated after onset symptoms, has helped decrease the symptoms of space sickness on 14 occasions since NASA's return to flight in September 1988, according to Dr Sam Pool, Chief of the Medical Science Division at JSC.

Since the early days of space flight, many space travellers have experienced this space motion sickness. Symptoms resemble those of Earth-based motion sickness and may include headache, malaise, lethargy, stomach awareness, loss of appetite, nausea and/or occasional vomiting. Symptoms tend to worsen during body movement, especially movements of the head.

During the first 24 Shuttle missions, about 67 per cent of the 85 crew members making the first flight reported symptoms of space sickness. About 30 per cent reported mild symptoms; 24 per cent, moderate symptoms; and 13 per cent severe symptoms. Most recovered by the end of the third day in space. In one extreme case, a Soviet cosmonaut aboard the Salyut 6 space station was ill for 14 days. The incidence of space sickness among those making a second flight dropped to 46 per cent.

During the first 24 Shuttle missions, scopolamine and a combination of scopolamine and dextroamphetamine, given orally, were used to treat space sickness. However, recent studies at JSC have shown that the oral absorption of scopolamine and other medications in weightlessness is unpredictable.

Since the introduction of intramuscular promethazine therapy, Shuttle crew members have not experienced severe cases of space sickness and almost all have been essentially symptom free before the end of the second flight day. Astronauts now receive training in administering the medication should space sickness develop during a mission.

Salyut 7 to Reenter

The Salyut 7 space station and the attached Kosmos 1686 module will reenter the Earth's atmosphere in February, Soviet space officials have confirmed. Fragments of the spacecraft may survive and reach the ground the Soviets have admitted.

In the January 1990 issue, *Spaceflight* exclusively revealed that Salyut 7 was out of fuel and would make an uncontrolled reentry, possibly endangering populated areas. In December 1990 the story was confirmed by the Soviet news agency Tass. The agency said countries likely to be affected by falling debris will receive a "timely warning".

In January, a press conference at the Soviet Foreign Ministry was told the 40-tonne space complex would reenter around February 10 or 11 (plus or minus ten days). The space station could fall anywhere between the latitudes of 51.6 degrees north and 51.6 degrees south.

Dr Leonid Gorshkov of NPO Energiya told reporters that there are no radioactive or other harmful substances aboard the station. He expressed the hope that if pieces do survive reentry they would cause no harm.

Salyut 7 was launched in April 1982 and remained in use until 1986. During that time it received ten Soyuz spacecraft. In October 1985 the 18 tonne Kosmos 1686 module was docked to the station and remains attached to this day. In August 1986 the engines of the module were used to boost Salyut 7 into a 492 x 474 km orbit. Since then increased solar activity has brought about the space station's rapid orbital decay. The Soviets had planned to use the Buran space shuttle to retrieve it but the programme's technical and budgetary difficulties put pay to that.

The reentry of past Soviet space stations have been carefully controlled so any fragments would fall harmlessly into the ocean. With no remaining fuel it is impossible to perform this procedure with Salyut 7.

A plan to safely deorbit the station using a Progress or Soyuz craft was abandoned due to budgetary reasons cosmonaut Vladimir Dzhanibekov told ***Spaceflight.***

Ariane For Astra

Arianespace and the Luxembourg-based Societe Europeenne des Satellites (SES) have signed contracts for the launch of Astra 1C and Astra 1D, the third and fourth in a series of satellites for television direct broadcasting.

The original Astra 1A satellite was launched an Ariane 4 in December 1988, with Astra 1B due to follow in February. The launches of the third and fourth satellites are scheduled for the beginning of 1993 and the beginning of 1994, respectively.

SES's newest Astra satellites will each carry 18 TV channels and multiple radio channels to continental Europe and Great Britain. The satellites, Hughes Aircraft HS 601 models, will weigh about 2,700 kg at lift-off.

NASA Names New Shuttle Crews

NASA has announced crew members for future Space Shuttle flights, namely, STS-48 the deployment of the Upper Atmosphere Research Satellite (UARS), STS-46 the flight of the Italian-built Tethered Satellite System, STS-49 the Intelsat re-boost mission and STS-50 the United States Microgravity Laboratory (USML-1).

STS-48, scheduled for November, is a mission to deploy the seven-tonne UARS spacecraft to study the Earth's upper atmosphere on a global scale. The satellite will play an important role monitoring the depletion of the ozone layer. Crew members are:

CDR: John O. Creighton
PLT: Kenneth S. Reightler
MS: James F. Buchli, Mark N. Brown & Charles D. 'Sam' Gemar

Creighton, a Captain in the US Navy, will be making his third space flight. He was pilot on STS 51-G in June 1985 and commander of STS-36 in February 1990.

Reightler, a Commander in the US Navy,

STS-48 Commander John Creighton. *NASA*

is the only rookie astronaut on this flight. He was selected as a Shuttle pilot in 1987.

Buchli, a Colonel in the US Marine Corps, will be making his fourth space flight. He previously flew on STS 51-C in January 1985, STS 61-A in October 1985 and STS-29 in March 1989.

Brown, a Colonel in the US Air Force, made his first space flight in August 1989 on the classified STS-28 DoD mission.

Gemar, a Major in the US Army, first flew on DoD mission STS-38 in November 1990.

During STS-46, scheduled for March 1992, the Tethered Satellite System will be deployed from the orbiter payload bay on a 12-mile long tether where it will collect electrodynamic data in the upper reaches of the Earth's atmosphere. Also, the European Retrievable Carrier (EURECA), a free-flying reusable platform for microgravity experiments, will be deployed. The crew members are:

CDR: Loren J. Shriver
PLT: James D. Wetherbee
MS: Franklin R. Chang-Diaz, Jeffrey A. Hoffman, Claude Nicollier (previously announced) & Andrew M. Allen
PS: A prime and back-up payload specialist will be selected from the two candidates, Umberto Guidoni and Franco Malerba

Shriver, a Colonel in the US Air Force, will be making his third space flight. He flew as pilot on STS 51-C in January 1985 and commanded STS-31 in April 1990. Shriver replaces Robert 'Hoot' Gibson, who was removed from the mission for disciplinary reasons (see ***Spaceflight,*** August 1990 p.263).

Wetherbee, a Commander in the United

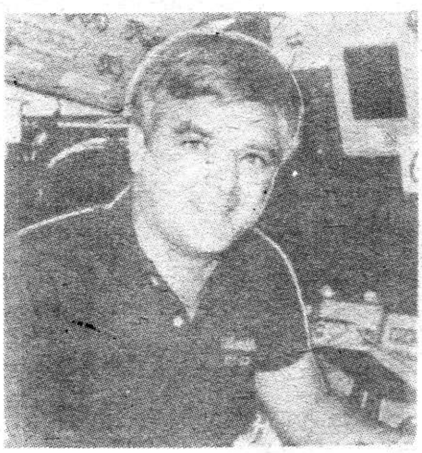
Loren Shriver to command STS-46. *NASA*

States Navy, flew as pilot on STS-32 in January 1990.

Allen, a Major in the US Marine Corps, will be making his first space flight. He was selected as a pilot astronaut in 1987.

STS-49, scheduled for launch in May 1992, is one of the most ambitious Shuttle flight ever planned. On its maiden flight, the Space Shuttle Endeavour will rendezvous with and recover the stranded Intelsat VI telecommunications satellite. During a record breaking three spacewalks two astronauts will attach a new upper stage to the satellite to boost it into its intended geostationary orbit. The seven crew members are:

CDR: Daniel C. Brandenstein
PLT: Kevin P. Chilton
MS: Pierre J. Thuot, Kathryn C. Thornton, Richard J. Hieb, Thomas D. Akers & Bruce E. Melnick



Chief Astronaut Dan Brandenstein will command STS-49. *NASA*

Brandenstein, a Captain in the US Navy, will be making his fourth space flight. He was pilot on STS-8 in August 1983 and commander on STS 51-G in June 1984 and STS-32 in January 1990. He holds the post of Chief Astronaut.

Chilton, a Major in the US Air Force, will be making his first space flight. He was selected as a pilot astronaut in 1987.

Thuot, a Commander in the US Navy, first flew on Shuttle mission STS-36 in February 1990. Thuot is expected to be selected for the mission's space walk as he has been working on procedures for the Intelsat reboost for some time.

Thornton will be making her second space flight. She first flew on STS-33, a dedicated DoD mission.

Hieb is due to make his first space flight on STS-39 in February or March.

Akers, a Major in the US Air Force, first flew on STS-41 in October 1990.

Melnick, a Commander in the US Coast Guard, made his first flight on STS-41.

STS-50/USML-1, scheduled for June 1992, is a complement of microgravity materials processing experiments housed in a Spacelab pressurised module in the payload bay. The flight, the first extended duration orbiter mission, will last a record breaking 13 days, the longest Shuttle mission to

Dick Richards will command the 1992 STS-50 USML-1 mission. *NASA*

date. The crew members are:

CDR: Richard N. Richards
PLT: John H. Casper
PLC: Bonnie J. Dunbar (previously announced)
MS: Kenneth D. Bowersox & Carl J. Meade
PS: Two prime and two back-ups will be selected from the previously announced candidates: Lawrence J. DeLucas, Joseph M Prahl, Albert Sacco & Eugene H. Trinh

Richards, a Captain in the US Navy, will be making his third space flight. He was pilot on STS-28 in August 1989 and commanded STS-41 in October 1990.

Casper, a Colonel in the US Air Force, made his first space flight as pilot on STS-36 in February 1990.

Bowersox, a Lieutenant Commander in the US Navy, will be making his first space flight. He was selected as a pilot astronaut in 1987.

Meade, a Lieutenant Colonel in the US Air Force, made his first space flight in November 1990 on STS-38.

Acronyms
CDR: Commander, PLT: Pilot, PLC: Payload Commander, MS: Mission Specialist, PS: Payload Specialist

SATELLITE DIGEST-238

Satellite Digest is produced in two sections. Orbital Data is in the form of a table which lists each satellite's name, international designation, launch time and date, launch site, launch vehicle, perigee, apogee, period and inclination. Launch times are approximate, except when marked with an asterisk, when the time given is that issued by the launching agency. All times are GMT, unless otherwise stated. Soviet launch vehicles have been named by the US DoD system of classification and, when known, by the Soviet name. Orbital data has been provided by the Royal Aerospace Establishment. The first section, Satellite Data, contains notes on each satellite's mission.

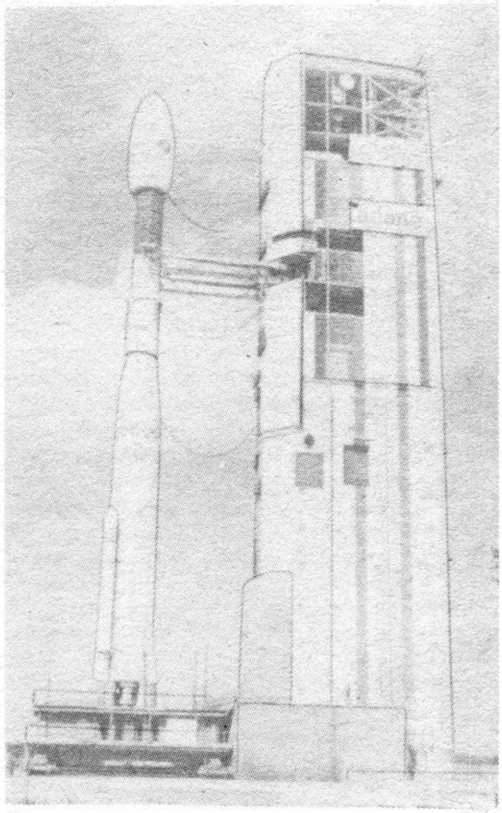
GORIZONT 21 (1990-94A): Geostationary communications satellite. Part of the Orbita-2 network.
USA 65 (1990-95A): Possibly a Defense Support Program (DSP) satellite for early warning purposes.
KOSMOS 2103 (1990-96A): An EORSAT (Elint Ocean Reconnaissance Satellite) designed to monitor US Navy radio transmissions. Manoeuvrable.
STS-38 (1990-97A): The Space Shuttle Atlantis on a classified mission for the US Department of Defense. Deployed a military payload into geostationary orbit. (For further details see ***Spaceflight,*** January 1991, p.24.)
USA 67 (1990-97B): Possibly a Magnum-type Electronic Intelligence (ELINT) satellite positioned in geostationary orbit over the Gulf region. Deployed from Atlantis on an Inertial Upper Stage (IUS) booster.
KOSMOS 2104 (1990-98A): Photo reconnaissance satellite based on the Vostok capsule. Recovered on December 2, 1990.
KOSMOS 2105 (1990-99A): An early warning satellite in a highly elliptical orbit.
SATCOM C1 (1990-100A): Provides telecommunications for cable television. Stationed at 137 degrees west.
GSTAR IV (1990-100B): A telecommunications satellite equipped with 16 transponders which cover the entire US mainland. Stationed at 125 degrees west.
MOLNIYA 1-79 (1990-101A): Domestic communications satellite in a highly elliptical orbit.

SATELLITE DATA

GORIZONT 22 (1990-102A): The first dedicated geostationary telecommunications satellite for the Russian Soviet Federation of Socialist Republics.
NAVSTAR 2A-01 (1990-103A): A navigation satellite that forms part of the Global Position System (GPS). Includes additional survivability and sensor improvements.
KOSMOS 2106 (1990-104A): An Electronic Intelligence (ELINT) satellite.

UPDATES

EXPLORER 37 (1968-17A): Decayed November 16, 1990. Returned radiation data despite being launched into the wrong orbit.
KOSMOS 2059 (1990-33A): Recovered November 22, 1990. A photo reconnaissance satellite.
PROGRESS M-5 (1990-85A): Undocked from Mir and de-orbited on November 28, 1990. Released a recoverable capsule that was recovered in Khazakhstan.
KOSMOS 2101 (1990-87A): Disintegrated on November 30, 1990. A reconnaissance satellite launched from Plesetsk on October 1, 1990.
KOSMOS 1631 (1985-18A): Decayed December 8, 1990. Possibly used for radar calibration.
BADR-1 (1990-59A): Pakistan's first satellite, launched by a Chinese Long March 2E, decayed on December 8, 1990 after 145 days in orbit.



The Satcom C1 (1990-100A) and GStar (1990-100B) telecommunications satellites were launched on the first Ariane 42P, seen here on the ELA-2 launch pad at the Kourou Space Centre in French Guiana. Both satellites are owned by Hughes Communications Inc. *Arianespace*

ORBITAL DATA

Name & International Designation	Launch Time	and Date	Launch Site	Launch Vehicle	Perigee (km)	Apogee (km)	Period (min.)	Inclin. (deg.)
GORIZONT 21, 1990-94A	1438	November 3	Baikonur, USSR	SL-12 Proton	35,780	35,794	1436.01	1.40
USA 65, 1990-95A	0043	November 13	LC-41, CCAFS, USA	Titan 4/IUS	GEOSTATIONARY ORBIT			
KOSMOS 2103, 1990-96A	0611	November 14	Baikonur, USSR	SL-11	403	419	92.79	65.00
STS-38, 1990-97A	2348*	November 15	LC-39A, KSC, USA	Atlantis	221	267	89.19	28.47
USA 67, 1990-97B					GEOSTATIONARY ORBIT			
KOSMOS 2104, 1990-98A	1633	November 16	Plesetsk, USSR	SL-4 Soyuz	232	283	89.65	62.81
KOSMOS 2105, 1990-99A	0224	November 20	Plesetsk, USSR	SL-6 Molniya	580	39,760	717.46	
SATCOM C1, 1990-100A	2311*	November 20	Kourou, French Guiana	Ariane 42P	35,658	35,725	1,431.13	0.17
GSTAR 4, 1990-100B					35,269	35,720	1,421.09	0.06
MOLNIYA 1-79, 1990-101A	0350	November 23	Plesetsk, USSR	SL-6 Molniya	607	39,734	717.51	62.83
GORIZONT 22, 1990-102A	1326	November 23	Baikonur, USSR	SL-12 Proton	36,487	36,601	1,474	1.47
NAVSTAR 2A-01, 1990-103A	2139*	November 26	LC-17A, CCAFS, USA	Delta II	19,933	20,280	714.88	54.89
KOSMOS 2106, 1990-104A	1633	November 28	Plesetsk, USSR	SL-14 Tsyklon	518	537	95.24	82.51

Juno Gets Soviet Go-Ahead

May 12 Launch Date For British Astronauts

After nine months of uncertainty, the Moscow Narodny Bank has announced that it has reached an agreement for the Juno Mission to proceed. The launch of the British astronaut has been tentatively scheduled for May 12, 1991. The Anglo-Soviet space flight was in doubt after attempts to raise sponsorship to cover the cost of the mission proved unsuccessful. British astronauts Tim Mace and Helen Sharman have remained in training throughout the mission's difficulties. In late January one of the two will be named as the primary candidate for the mission.

Little is known about the agreement that will allow the Juno mission to go-ahead.

"The details of the agreement between the Bank and NPO Energiya are confidential and we are respecting that at the Soviet's request," said Christopher Hayes, Juno Project Manager at the Moscow Narodny Bank.

"But we have stated that money has changed hands - this is not a free flight," he told ***Spaceflight.***

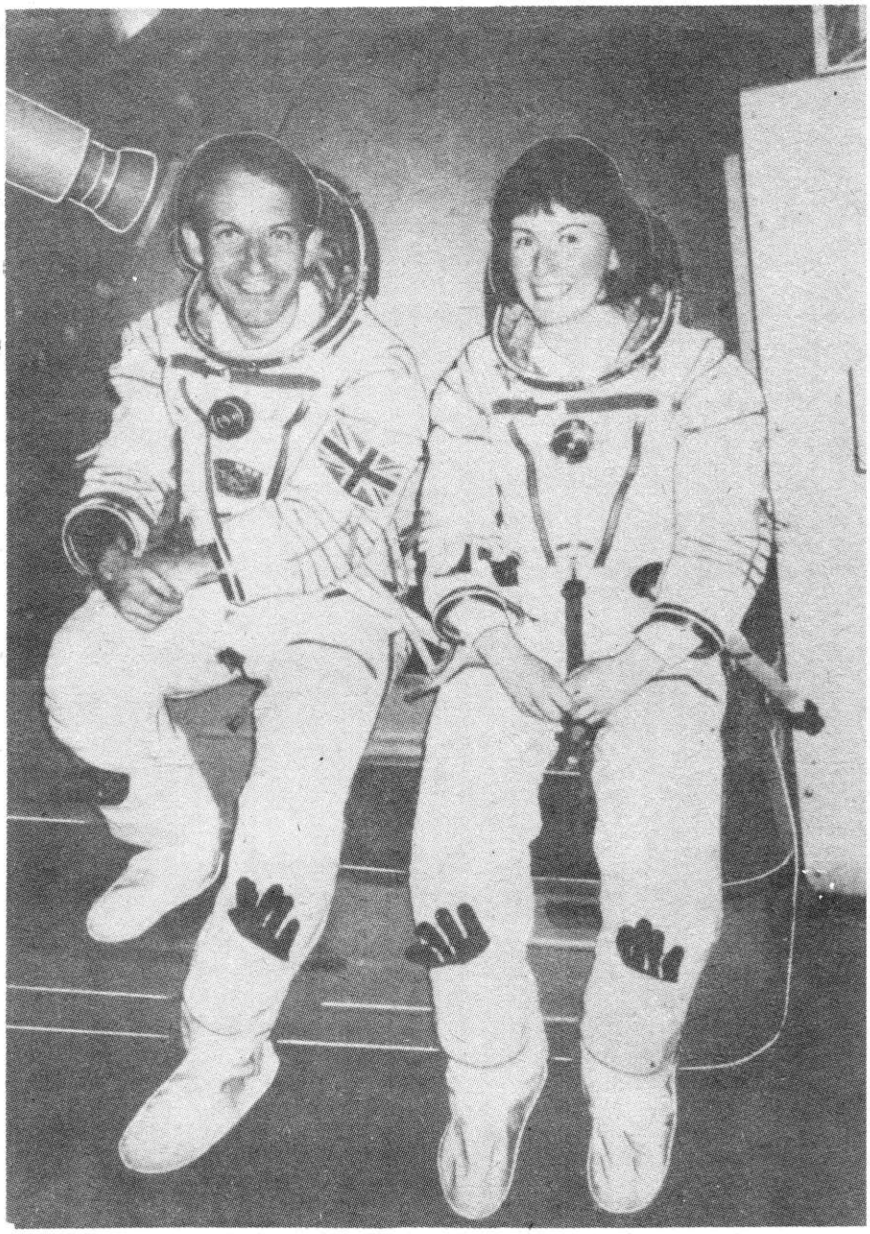
No UK Science

The mission will go forward in a scaled-down form, with plans for a British scientific programme just about abandoned. Instead, NPO Energiya is to provide a scientific programme for the British astronaut.

The Juno science programme was managed by Professor Heinz Wolff of the Brunel Institute for Bioengineering. Twenty-six experiments from a range of institutions and industry had been selected to fly. Under the original plans sponsorship would have funded the development and construction of the experiments. Unfortunately, the scientific programme cannot be accommodated within the project's new budget. In addition, Professor Wolff says it is now impossible to meet the deadlines for a May launch.

According to Mr Hayes, the experiments selected for the British astronaut by Energiya will form "a very credible and very serious science programme."

"We have been told that it covers a whole range of metallurgical, biotechnological, medical and organic chemistry experiments," he said.



Tim Mace (left) and Helen Sharman pictured in their flight suits. *Juno*

Meanwhile, Professor Wolff is continuing his efforts to get a British scientific mission flown with the Soviets. As this is issue of ***Spaceflight*** went to press negotiations with NPO Energiya were continuing.

Juno Still Seeking Sponsors

The Moscow Narodny Bank says it still believes that there are marketing opportunities for Juno and is looking for potential sponsors.

One of the most important aspects of the new sponsorship drive is to establish what television coverage the mission will receive. Ideally, Juno would like an exclusive arrangement with a television network.

"It provides us with an ability to say to a potential sponsor 'the mission is going to happen, here is the kind of exposure that you are going to have'," Mr Hayes explained.

"We are talking to ITN and ITV to gauge their interest and they have brought it to the network and we are expecting an answer from them soon," he said.

"If we cannot sign an exclusive arrangement with TV there will still be

coverage but it might not be quite as extensive as we initially thought."

The search for sponsors is following a number of approaches, Mr Hayes told ***Spaceflight:***

"One is to talk to those companies we had talked to previously who had expressed an interest at the time and in some cases had expressed a continuing interest to the effect of 'when you get it together come and talk to us again and we will see what we can do.' Another route is to use some of the agents we had before. They have been told that if they have companies interested here is the way we would like to proceed. We are also using the offices of the Bank. They deal with British-Soviet trade and British investments in the Soviet Union. They have given us a number of leads, companies who maybe interested in getting involved with Juno, possibly more for the Soviet side. Also, we have been approached by some public relations firms acting on behalf of their corporate clients who are looking to see if there is any opportunity to get the clients products and services associated with the mission."

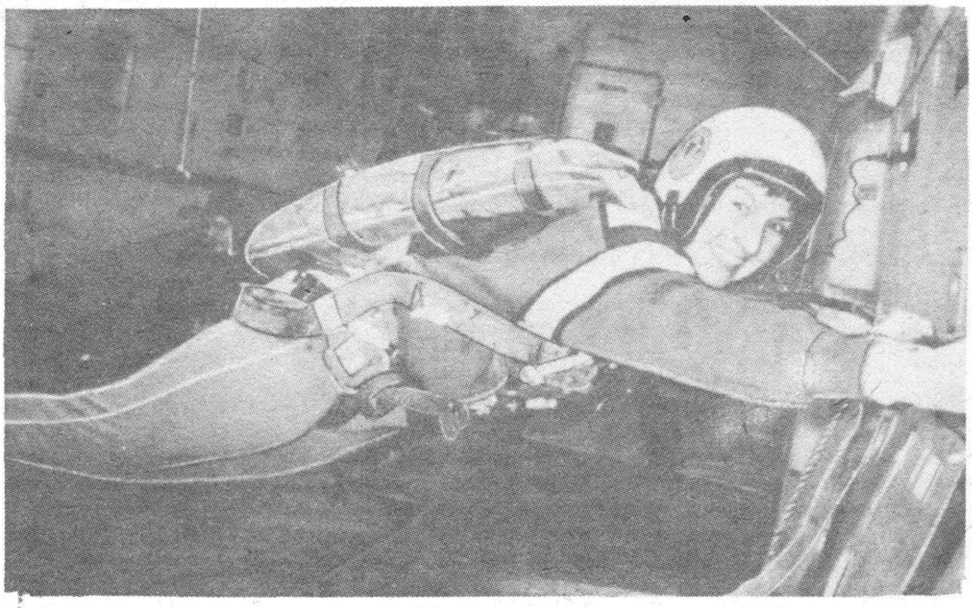
In addition to straight sponsorship Juno is looking for 'goods-in-kind' - services and products the project would have to pay for in any event, for instance air travel to the Soviet Union.

Former mission sponsors Zeon and Memorex have again been approached. Zeon has expressed an interest but it is not clear on what terms they will return. As we went to press, a response from Memorex was expected soon.

But will it be any easier for Juno to find new sponsors after the less than successful first attempt?

"On the positive side we have a definite launch date - it is going to happen," Mr Hayes told ***Spaceflight.*** "Four months gets people's attention and sharpens their minds that they have to make a decision to take advantage of it.

"On the negative side you have the Gulf situation, continuing uncertainty in the Soviet Union and a UK economy that is no where near as buoyant as it was in mid-1989 - expectations are even worse than they were at the end of 1990."



Helen Sharman undergoes weightlessness training on a parabolic air flight. *Juno*

Astronaut Selection

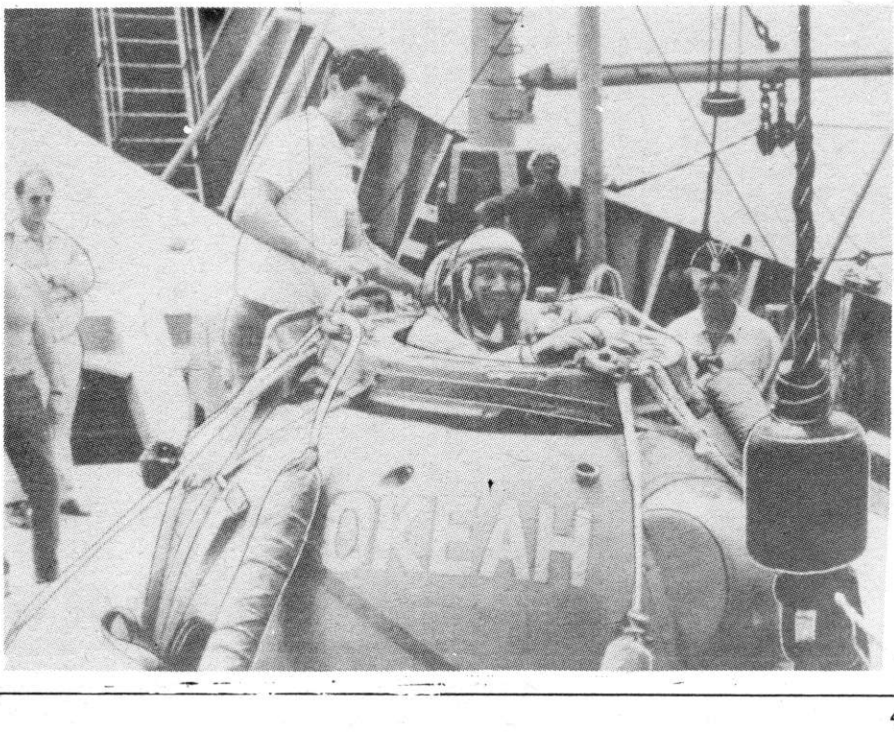
At a Moscow press conference on January 24, the project will announce which astronaut will fly. The British astronaut will join Soviet cosmonauts Anatoli Artsebarsky and Sergei Krikalev for lift-off in the Soyuz TM-12 spacecraft. At the end of the eight-day mission he or she will return with Viktor Afanasyev and Musa Manarov in Soyuz TM-11.

The training of the British astronauts has not been interrupted during the project's problems. Their programme has included weightlessness training during parabolic aircraft flights, parachute jumps and practice with helicopter teams for both ground and sea landings. Lectures and medical examinations have continued throughout their training. More recently the astronauts have began training on the Mir and Soyuz mock-ups at Star City.

Tim and Helen began their training in November 1989 with an intensive three month course of Russian language tuition.

According to Yuri Semyonov, Constructor General of NPO Energiya, the Soviets are "extremely satisfied" with the astronauts progress.

Tim Mace emerges from a Soyuz capsule mock-up during a training session for a splashdown at sea. *Juno*



Second Chance for Juno Candidates

It now seems likely the final 16 Juno candidates will have a second chance to become an astronaut. The British National Space Centre has asked Juno to contact the candidates to see if they wish their names to go forward for the ESA astronaut programme. The space agency plans to have at least one astronaut from each member country for its recently formed astronaut corps.

Shuttle Crew Saves Astro Mission

Columbia Comes Home One day Early

NASA ended a long and frustrating series of launch delays for the Space Shuttle Columbia and its Astro-1 payload early on the morning of December 2, 1990 when mission STS-35 lifted off from Launch Complex 39B at the Kennedy Space Center. The mission, which was the first for Columbia since the Shuttle fleet began experiencing a series of hydrogen leaks in May, blasted off at 06:49 GMT into the Florida night sky. Once aloft, a series of technical problems dogged the mission, but the seven astronauts were able to save the mission by manually taking control of the observatory. *Spaceflight* was briefed on the mission by astronauts Vance Brand and Bob Parker

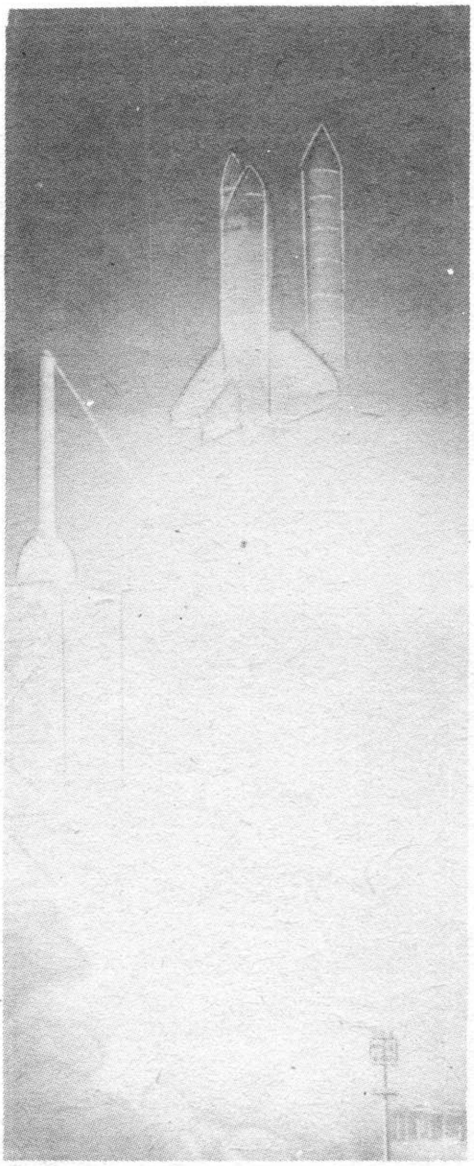
The Astro mission was due for launch in 1986 but put on hold by the Challenger disaster. At the time of the accident, Astro had completed its ground integration and testing and was ready to be installed in Columbia. The flight, designated STS-61E and scheduled for March 6, 1986 was to have been the next Shuttle mission after Challenger.

At that time the Astro-1 mission consisted of three ultraviolet telescopes and a wide field camera. By the time of the resumption of Shuttle missions in 1988 the observatory had undergone several changes. The payload was originally equipped with a wide field camera which was to be used for images of comet Halley. This camera was removed as Halley was much too far away by 1990 for photos. Another change to the configuration was the addition of the Broad Band X-Ray telescope. This instrument was added when the weight capabilities of the Columbia were increased in 1987. Also, in February of that year Supernova 1987A occurred. The flight of the X-Ray instrument as part of the Astro-1 promised to provide vital scientific information on the supernova phenomenon.

The Astro-1 is the first Spacelab mission devoted to a single discipline - astrophysics. Astro-1 consists of four instruments capable of performing independent or coordinated observations of astrophysics targets. They include the Hopkins Ultraviolet Telescope (HUT), the Wisconsin Ultraviolet Photo-Polarimeter (WUPPE), the Ultraviolet Imaging Telescope (UIT) the Broad Band X-Ray Telescope (BBXRT).

By Roelof Schuiling
at the Kennedy Space Center
and Steven Young

The three ultraviolet telescopes are mounted on a cruciform support structure attached to a Spacelab Instrument Pointing System (IPS). The IPS is mounted on two Spacelab pallets built by British Aerospace. The observatory's control systems were contained in a pressurized container at the front of the pallets, known as an 'Igloo'.



Columbia blasts-off into the Florida night sky with the Astro observatory aboard. *NASA*

On-orbit operations involved three ground control centres. The normal mission control activity was carried out at the Houston Johnson Space Center, though both Marshall and Goddard Space Flight Centers were engaged in supporting the payload operations. Beginning with Astro-1 all Spacelab science activities are controlled from Marshall's Spacelab Mission Operations Center. A special team at Goddard operated the BBXRT, although some members of the BBXRT were stationed at Marshall to assist in science planning operations during the flight.

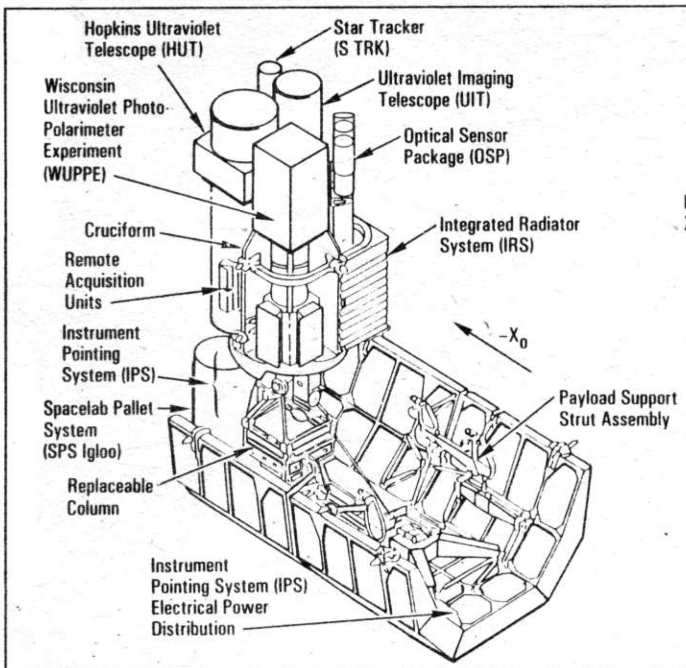
The astronauts were to operate the ultraviolet telescopes and their pointing system from the Columbia's aft flight deck. The BBXRT, however, was controlled from the ground control centre at Goddard after the flight crew activated the telescope.

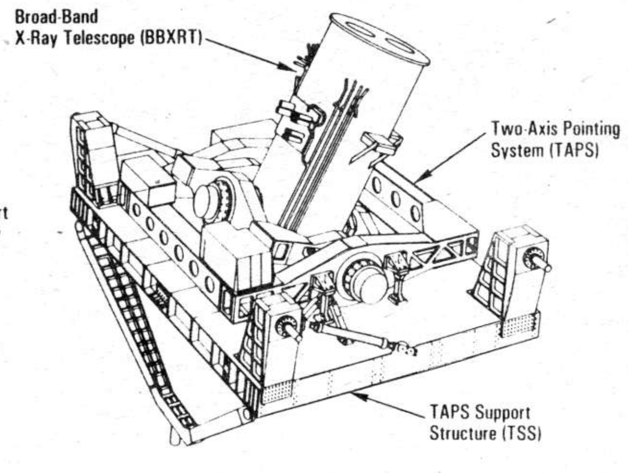
Six Month Delay

Columbia was first rolled out to launch complex 39A on April 22, 1990 for a launch in May. The planned May 17 launch was postponed, however, due to a leak in the orbiter's coolant system. A launch attempt on May 30 was aborted when Columbia's liquid hydrogen leak problem was discovered. After replacing the orbiter's 17-inch disconnect it was believed the problem was solved. A malfunction on the BBXRT delayed the next launch attempt, scheduled for September 1. The next launch attempt on September 6 was called off because leaking hydrogen was still being detected. Engineers believed they had finally plugged the leaks when the countdown began for a September 18 launch. But once again the leak was detected. Columbia had to make way for the launch of Discovery with the Ulysses probe and then the Atlantis DoD mission. The orbiter was finally cleared for flight when a tanking test on October 30 revealed no hydrogen leakage. Engineers had identified the source of the previous leak as a damaged seal on main engine number two.

On November 27 the formal Flight Readiness Review by programme managers confirmed December 2 as the projected launch date. The liftoff goal was 1:28 am. The launch window ran from 1:28 to 7:00 am, though crew considerations would limit the window to two hours and thirty minutes once the astronauts were installed in the

THE ASTRO OBSERVATORY





Hopkins Ultraviolet Telescope

The HUT uses a spectrograph to examine faint astronomical objects such as quasars, active galactic nuclei and normal galaxies. It is the first major instrument capable of studying far and extreme ultraviolet radiation and will make the first observations of a wide variety of astronomical objects in the far ultraviolet region below 1200 Angstroms as well as pioneer detailed study in the extreme ultraviolet region.

The HUT has a 36 inch f/2 iridium coated mirror which focuses incoming light back to a spectrograph. HUT's wavelength range is 850 to 1850 and 425 to 925 Angstroms. The unit's special resolution is 3 Angstroms and the detector is a Reticon self-scanning array of 1024 photodiodes fibre optically connected to a microchannel plate intensifier. HUT was conceived by Johns Hopkins University scientists to take ultraviolet astronomy beyond the brief studies previously conducted with sounding rockets.

Wisconsin Ultraviolet Photo-Polarimeter Experiment

The WUPPE, developed by the University of Wisconsin Space Astronomy Laboratory, is designed to measure polarization and intensity of ultraviolet radiation from celestial objects. The primary mirror is 20 inches in diameter for the f/10 Cassegrain telescope instrument. A spectropolarimeter records both the spectrum and polarisation of the incoming light.

The WUPPE operates in the 1400 to 3200 Angstrom range and has a 6 Angstrom spectral resolution. Its detector is also a self-scanning 1024 photodiode Reticon array connected to a microchannel intensifier.

Ultraviolet Imaging Telescope

The UIT, sponsored by the Goddard Space Center, is a combination of telescope, image intensifier, and camera.

The 15.2 inch Ritchey Chretian f/9 telescope has two selectable cameras, each of which has a six-position filter wheel. One camera operates in the 1200 to 1700 Angstrom band and the other operates in the 1250 to 3200 Angstrom region. Unlike the WUPPE and HUT, which transmit data to the ground, UIT records its data on film which was removed following the mission.

Broad Band X-Ray Telescope

The BBXRT was originally developed to fly as a component of a high energy observation payload and has its own pointing and support systems. Although physically mounted aft of the Spacelab pallets, BBXRT is connected to the Astro-1 avionics system.

The BBXRT is composed of two grazing incidence X-Ray mirrors. The extremely high energy of X-Ray photons precludes the use of reflecting surfaces for such a mission as the photons would penetrate the surface. The BBXRT uses concentric nested circular surfaces set at a slight angle to the incoming photons to focus them on to detectors. BBXRT is one of the first telescopes to observe astronomical targets emitting X-rays above 4 thousand electronvolts. The telescopes focus the photons on to solid-state spectrometers which are improved versions of those flown on the Einstein Observatory. They detect nearly 100% of the incident X-rays over an energy range of from 0.3 to 12 thousand electron volts and are cryogenically cooled by an argon cryostat.

Columbia.

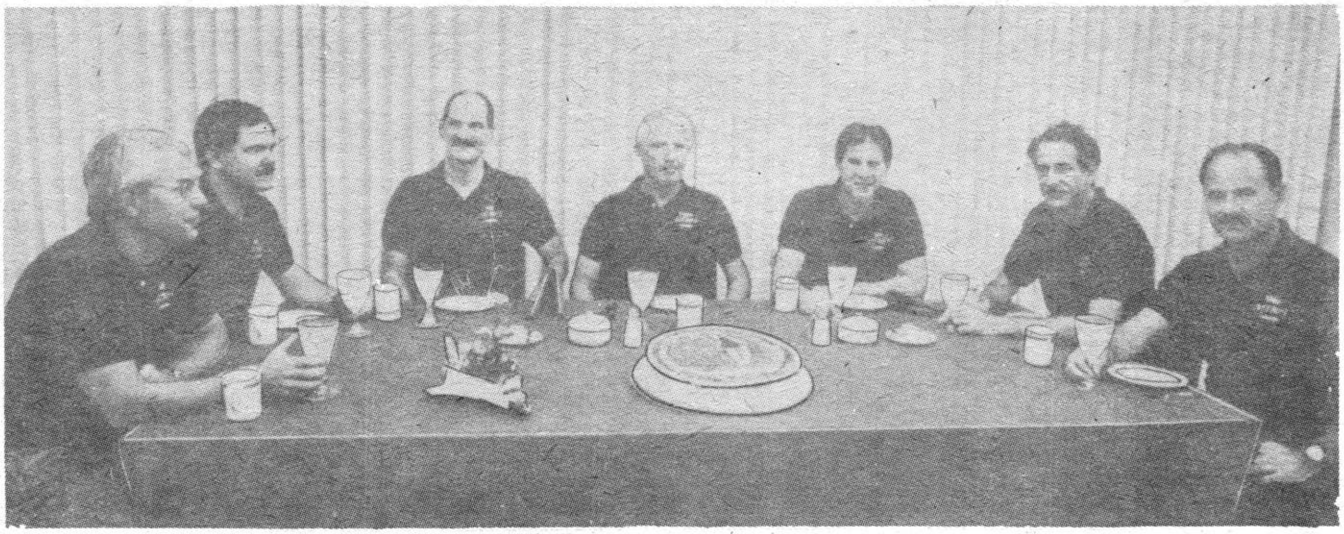
The countdown began at 1:00 am on Thursday November 29 with verification of the orbiter's flight software and checkout of the navigation aids. At 11:25 on the evening of the 29th the flight crew arrived at the Kennedy Space Center from Houston. The countdown activity continued on schedule through the 30th and on the 1st of December final preparations were made. Flight crew equipment was stowed, the protective support structure was rotated away from the Shuttle, the fuel cells prepared for launch, and, on the evening of the 1st, the cryogenic hydrogen and oxygen propellants were loaded. The hydrogen propellant load went well with none of the leaks which had plagued the previous STS-35 countdowns.

For the first time since the Challenger accident a crew of seven was carried aboard the Shuttle. Conditions in the crew cabin were a little cramped as mission commander Vance Brand explains:

"We were fairly crowded because, due to our shift arrangement and 24 hour a day work schedule, we had four bunks in the cabin and they take up quite a bit of room over what you would have on a flight that does not have shift operations," Brand said. "We were all up during shift overlap times and you just might find yourself waiting in line at the water fountain."

Pilot for STS-35 was Guy Gardner, mission specialists were Jeff Hoffman, Mike Lounge and Bob Parker. Sam Durrance and Ron Parise were payload specialists.

The crews were divided into two shifts the Blue Team and the Red Team. Vance Brand was not assigned



The crew enjoy a light breakfast before launch. (Left to right) Bob Parker, Ron Parise, Guy Gardner, Vance Brand, Sam Durrance, Jeff Hoffman and Mike Lounge. *NASA*

to any particular shift.

"I hoped to straddle the two shifts," he told ***Spaceflight.*** "As it turns out I did straddle to some extent but was doing most of my work on the Red Shift because it was required that the pilot Guy Gardener and I be on the same shift for launch and landing. We had to be well rested for those events so I couldn't move over onto the Blue Shift for more than a couple of hours which was unfortunate but it all worked out good."

Cloud Deck Delays Launch

After the crew boarded the countdown proceeded normally with no significant technical problems. However, lift-off was delayed because a thin broken cloud deck at an altitude of 7,000 feet had moved in over the Kennedy Space Center. A weather aircraft confirmed that the landing aids at the Shuttle Landing Facility were visible from 8,000 feet should a Return to Launch Site Abort occur. But from the other direction, from the ground up, there was a violation of a range safety rule that states that visual tracking of the Shuttle should be possible up to 8,000 feet.

The rule was introduced after the Challenger disaster. Before the accident it was believed that SRBs would tumble if the Shuttle vehicle broke up. However, the Challenger accident demonstrated that the boosters do in fact fly by themselves, possibly endangering populated areas.

Launch Director Bob Seick was surprised by the 'no-go' decision from the Range Safety Officer when it came during the T-9 minute planned built-in hold.

"There was some consternation," Seick admitted later. "We had looked at the weather ten to 20 minutes before that and our communication was that we did have an acceptable condition to launch both from a range and a flight stand point," he said

Colonel John R. Wormington of the USAF Eastern Space and Missile Center told a post-launch press conference how the range safety team reacted to the problem: "When it became evident that we were not going to get the optics pass 7,000 feet we scrambled a helicopter with a range safety officer onboard to provide the coverage for that final thousand feet to 8,000 feet," he said. "The problem with being in a helicopter is that you have no visual references other than what you can see down to the ground so we had to find a place for that helicopter to be where the range safety officer could confirm that they could get visibility down to the ground from eight thousand feet. Once we did that we were cleared for launch."

It is not standard procedure to have a helicopter standing by for this purpose.

"It was a lot of ingenuity and creativity on the part of the range safety team," said Wormington. "Once we found we were heading into this condition we took one of the range safety officers out of the ground surveillance area where we were watching ships and aircraft and got her to the helicopter."

The launch was delayed 21 minutes while the range safety helicopter got into position. The final nine minutes of the countdown proceeded without a hitch.

Launch

The blast-off at 06:49 GMT was visible for hundreds of miles around. The view from the flight deck was also spectacular.

"As soon as the Solid Rocket Boosters lit it became like daylight," Vance Brand told ***Spaceflight.*** "It was very bright in the cabin."

As Columbia soared skywards it illuminated the troublesome cloud deck as it passed through.

"It was really spectacular to look out the windows and watch that approach," pilot Guy Gardner later recalled.

SRB separation occurred smoothly just over two minutes into the flight. The three main engines fired for a further six minutes before cutting out.

Shortly after the External Tank had been jettisoned Brand performed a pitch manoeuvre so the crew could photograph the departing tank. This Development Test Objective (DTO) has been conducted on several other recent Shuttle flights to study the performance of the tank's thermal protection system.

STS-35 at a Glance

ORBITER: Columbia OV-102
LAUNCHED: 06:49:01.0789 GMT, December 2, 1990
LAUNCH SITE: MLP-3, Pad 39-B, Kennedy Space Center, USA
LANDED: 5:54:08 GMT, December 11, 1990
LANDING SITE: Runway 22, Edwards Air Force Base, USA
APOGEE: 193 nm
PERIGEE: 185 nm
INCLINATION: 28.45 degrees
DURATION: 8 days, 23 hrs, 5 min, 8 sec
ORBITS: 142

COMMANDER: Vance Brand - Red/Blue Team
PILOT: Guy Gardner - Red Team
MISSION SPECIALIST 1: Jeffrey Hoffman (EV1) - Blue Team
MISSION SPECIALIST 2: John 'Mike' Lounge (EV2) - Blue Team
MISSION SPECIALIST 3: Robert Parker - Red Team
PAYLOAD SPECIALIST 1: Samuel Durrance - Blue Team
PAYLOAD SPECIALIST 2: Ronald Parise - Red Team

Day One: December 2, 1990
Telescopes Activated - Problems Start

Columbia's Orbital Manoeuvring System (OMS) engines were fired for about four and a half minutes to place the Shuttle into a 189 x 190 nautical mile (nm) orbit. The launch was so precise that an additional 'trim burn' to refine the orbit was not necessary.

About three hours into the flight Bob Parker turned on the power busses of the BBXRT to start activation of the payload. The checkout of the X-ray telescope was performed by ground controllers at the Goddard Space Flight Center.

An hour later Parker made the first call to NASA's new Spacelab Mission Operations Control. The modern facility, based at the Marshall Space Flight Center, has the call-sign "Huntsville".

"Huntsville, this is Astro," radioed Parker to Michelle Snyder, the crew interface coordinator.

"Bob, we just want to let you guys know that everyone here is really excited and we're looking forward to a great ten-day mission and a lot of terrific astronomy," replied Snyder.

"Let's get this show on the road," Ron Parise radioed back.

With the formalities over Huntsville and the crew began the activation of the Astro telescopes.

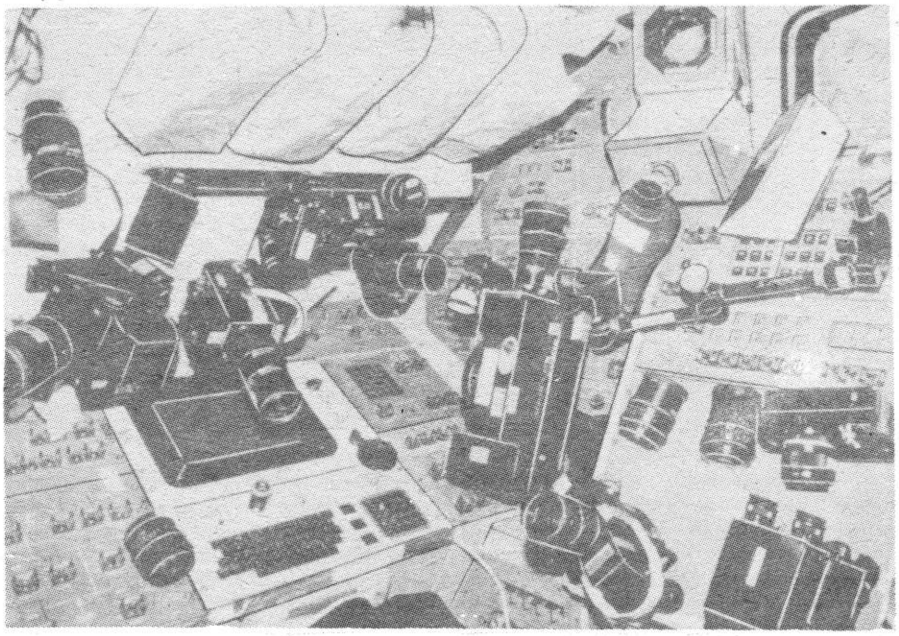
At 11:23 GMT Parise took the first steps to activate WUPPE while Parker began work to ready the Instrument Pointing System (IPS). At 12:36 GMT, Parker was given the go-ahead to unlatch the IPS and bring it upright. Seven minutes later the pointing system and its battery of telescopes were standing 90 degrees from the payload bay.

Activation of the Hopkins Ultraviolet Telescope went smoothly. The only surprise was when a small aperture door opened unexpectedly. However, the crew were able to close it within minutes with no apparent ill effects.

During the checkout of WUPPE a problem was encountered with one of the telescope's Dedicated Experiment Processor (DEP) computers. In attempting to load targeting information the computer became stuck in a load mode. Efforts to rectify the situation failed and the WUPPE was switched over to the backup DEP.

Later, the HUT achieved 'first light' for the Astro observatory when the star Beta Doradus was observed. The sighting was part of the Astro observatory's joint focus and alignment exercise, a lengthy procedure to focus the ultraviolet telescopes on a common area. Because of its computer failure, WUPPE was not ready in time to participate in the focusing operation.

The first major setback occurred about nine hours into the mission when



After the failure of the Data Display Unit (the large white panel visible on the left) the aft flight deck area was used as a storage area for cameras and other photographic gear. NASA

one of the two Data Display Units (DDUs) on the aft flight automatically shut down due to a sudden temperature rise. The DDUs are the astronaut's link with the Spacelab equipment in the payload bay. Each unit consists of a keyboard and display screen. The astronauts enters its commands for the IPS through the DDU.

After the failure, Vance Brand reported that he detected a 'hot smell' from the unit, but no smoke was seen. The DDUs have a history of overheating. Mission control was concerned about the burning smell and decided to use the second DDU rather than try to reactivate the failed unit.

The crew later examined the failed unit and discovered its cooling ducts appeared clogged with lint, possibly from the astronauts clothing.

Astro Mission Manager Jack Jones told a press conference that the loss of the DDU would not cause any serious limitations.

"It means the two crewmen in the aft flight deck, the mission specialist and the payload specialist, will have to share the [remaining] display unit," he explained.

Jones said the two crewmen would not need to use the computer at the same time.

"It is more-or-less a serial operation, with the mission specialist going first and then handing over to the payload specialist," he explained.

"We had trained for a case where one [DDU] might fail," Bob Parker told ***Spaceflight.*** "It was a bit more frantic and hasselled than it would have been with two DDUs but it was something we had anticipated and we proceeded with our plans."

The calibration of the Instrument Pointing System also ran into trouble. One of the three star trackers on the IPS was failing to recognise and lock on to dimmer stars, as it had been programmed to.

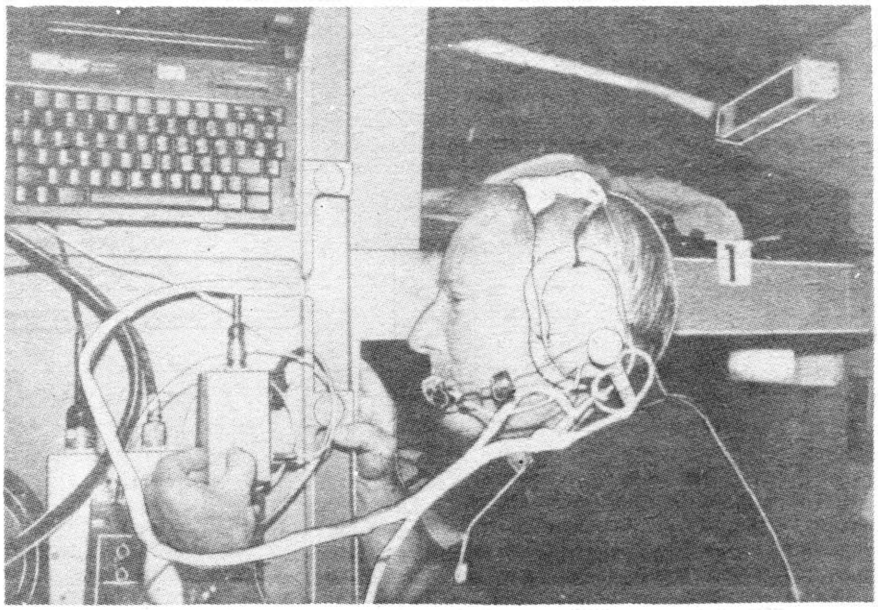
Day Two: December 3, 1990
Observations Begin

Activation of the Astro package had been expected to take approximately twenty-two hours. However, due to the problems, the process lasted well into the afternoon of the second day. The IPS star tracking capability was experiencing difficulty with automatically locking on to dimmer stars, the BBXRT was experiencing difficulty in aligning their pointing system and telescope, and the WUPPE was behind schedule due to the efforts to understand the failure of the instrument's Dedicated Experiment Processor.

As the day wore on the activation process continued and payload operations began to settle into the type of routine which had been planned for the flight. At approximately one day and fifteen hours mission elapsed time, the three ultraviolet telescopes were able to make simultaneous observations on the same target. The IPS pointing difficulties, while not corrected, were being overcome by utilizing software refinements and a contingency pointing procedure with greater manual crew control. The latter procedure involved typing data into the flight deck keyboard and using a crew-operated joystick.

Day Three: December 4, 1990
Astronauts Sight Mir Space Station

Two days, nine hours and 40 minutes into the mission, Columbia



Mission Commander Vance Brand communicates with his family via the Shuttle Amateur Radio Experiment (SAREX) on the orbiter's middeck. *NASA*

passed 200 nm from the Soviet Union's Mir Space Station. Jeff Hoffman was able to see the station with the aid of gyro-stabilised binoculars.

At the next opportunity, 46 minutes later, Mir came within 38 nm of Columbia. From the astronauts point of view, the space station passed over the port OMS pod from left to right. It was visible for about 20-30 seconds. Mike Lounge reported seeing Mir with his naked eye. During the closest approach the astronauts had planned to contact the Soviet space station using the SAREX amateur radio equipment. However, as Flight Director Al Pennington explained, the cosmonauts were too busy to man their own amateur radio.

"The Soyuz spacecraft was in the process of going through its final docking sequence," he said. "We had talked to the Soviets and said we would not try to do any SAREX work with them."

According to Pennington the crew were pleased to have made just visual contact.

"We had a real good day from that standpoint. The crew was very enthused about the sightings."

The only other opportunity to contact Mir was on the last day of the mission but the chance was lost when Columbia had to return early due to bad weather at Edwards.

"Naturally it was a disappointment," Vance Brand told ***Spaceflight.*** Brand was the Command Module Pilot on the Apollo Soyuz Test Project and had joked before the mission that his Russian was a little rusty but was sure he could manage a conservation.

The third day saw the science operation aboard Columbia finally get underway. The BBXRT was now up and operating and received "first light" from a planned source - Capella - for a long observation. The BBXRT was now operating with better resolution and across wider spectrum bands than any previous instrument. The X-Ray telescope also made observations of the Crab Nebula and the binary star system Cygnus X-3.

The three IPS ultraviolet telescopes were up and running but the star trackers were still causing problems and the astronauts were having to point the telescopes as Bob Parker explained:

"The intention had been when we planned the mission that we would basically let the star trackers and the computers find the stars on their own and do it really automatically. That didn't work so we had a way of looking at some other star trackers and we knew which stars and what the field they should be seeing. We then moved the telescope manually. We were using a control stick inside the cabin to move the IPS through some motors and a computer and basically watching the scene on a TV screen. So it was very much like what you would do in an observatory dome."

When software patches failed to solve the star tracker problem the crew and mission controllers decided to continue the manual pointing.

"We opted to continue that procedure the whole flight," said Parker. "In part because it turned out that that was perhaps a little bit quicker than letting the computers to do it automatically and we thought at the time a little bit more reliably."

The crew was able to acquire data from a supernova remnant located in the Large Magellanic Cloud, our nearest neighbouring galaxy. In addition, observations were made of white dwarf stars, Betelgeuse, Alpha Orionis, the Wolf-Rayet star Theta Muscae, and star clusters containing variable stars. In addition the WUPPE made the first ultraviolet observations of a star (Alpha Camelopardalis) which is polarized by dust in the interstellar medium within the plane of the galaxy.

Day Four: December 5, 1990
Nighttime Earth Seen

During the day Astro was able to perform a significant number of the planned observations. During the early hours of the morning all four telescopes observed the Crab Nebula.

Later in the day Columbia experienced a minor thruster problem which interrupted the normal payload observations. Managers at the Huntsville payload control centre instructed the crew to close the doors on the telescopes to prevent contamination while a series of thruster firing tests corrected the problem. Normal observations were then resumed.

With the cabin lights dimmed to save power the astronauts eyes were able to pick out great detail on the dark side of the Earth.

"On a clear night we could see about one-third of the United States," said Brand. "For example, as we were approaching the Baja Penninsula south of California we would pick up Los Angeles, San Diego and the bay area. We could not see Seattle because it was clouded in. We would proceed east and come over the Gulf of Mexico we could pick up Houston, Denver, Chicago and New Orleans. Basically, the central part of the United States, all the way up to the northern border. As we approached the Florida peninsula we could see up the east coast. We could see Boston, the New York area, Baltimore and Washington DC as a pair of cities. We could see along the shore of Lake Erie and down south around Atlanta. Of course we could not do this in daytime because at night you have good contrast between dark terrain and bright lights in the cities.

"It was a fantastic view. Unfortunately, we were not able to get too many photographs of it. The eye seems to do a lot better than camera equipment. We are recommending that on a future flight when they try to take pictures of that, that they have a bracket mounted camera, very sensitive film and a long exposure," he said.

Day Five: December 6, 1990

The observational successes of the ASTRO-1 instruments had improved to over 90 percent of the desired observations as the round the clock schedule continued. As the fifth day of the mission began, observations were underway of shock waves being driven

into an interstellar cloud on the edge of a supernova remnant as well as of colliding galaxies. One UIT astronomer noted that the total observing time from all ultraviolet imaging from rocket flights had been about thirty minutes and they had now increased that by a factor of ten.

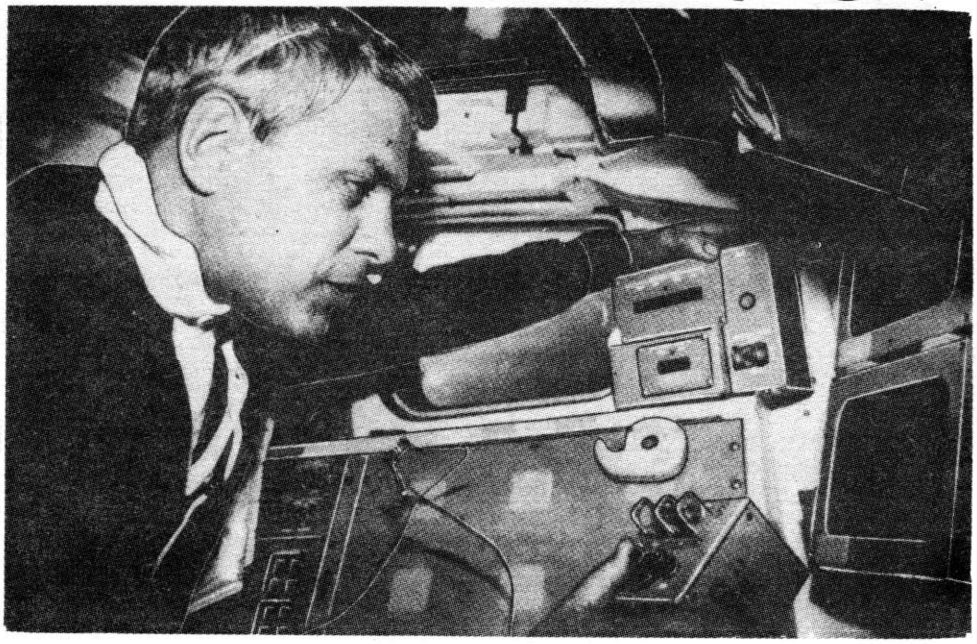
The optimism was not to last, however. At five hours and fifteen minutes into the day, the unthinkable happened. The second Data Display Unit on the aft flight deck unexpectedly shut down. The crew were left with no means of controlling the Astro telescopes.

"I went to bed not knowing what sort of plans people would come up with," Bob Parker told ***Spaceflight.*** "I had an inkling that ultimately we could probably control the observatory from the ground but I was quite pleasantly surprised when I came back to work 12 hours later to find that in fact we were already controlling it from the ground and we were doing this quite successfully."

Controllers and science support personnel had developed an approach that involved teamwork between the Johnson and Marshall Space Centres and the crew of Columbia. The approach utilized Johnson Space Centre to control the IPS pointing unit and Marshall to control the telescopes with the astronauts manually doing the fine pointing. The process was to operate each of the three ultraviolet telescopes in sequence, going from the relatively wide field UIT, to the HUT, and then to the narrow field of WUPPE.

Bob Parker explained: "The way the procedure basically worked was with the people in Houston pointing the IPS fairly close to the stars that we were interested in observing then turning things over to the people at the Marshall Space Flight Center, where the principal investigators were and letting them configure the instruments. We could then see the star field and move the telescope to acquire the proper star and proceed with our manual guiding that we had been doing the day before. What this really meant was that instead of us using the computer to acquire the stars and run the instruments we had onboard, the ground did that and all that was left for us to do was the fine acquisition of the field and the guiding of the telescopes to keep them pointed accurately at the star. That to some extent was a simple task but in fact it required fairly intense concentration for periods of half to three-quarters of an hour at a time."

Approximately 12 hours after the failure of the Display Unit, astronaut Sam Durrance used a joystick to refine the pointing commands from the ground and brought the UIT on to its target - supernova 1987A. Alternate astronaut Ken Nordsieck at the Marshall control centre provided verbal directions for locking the UIT onto the supernova.



On the aft flight deck, astronaut Bob Parker uses a joy stick to control the pointing of the Astro observatory after the failure of the automatic system. *NASA*

During the day BBXRT continued to acquire observational data as the X-Ray instrument was controlled by a ground control centre at Goddard Space Flight Centre and did not use the on-board Data Display Units. A minor misalignment problem with BBXRT lost minimal observational time.

Day Six: December 7, 1990

Within twenty-two hours of the display unit's failure all three of the ultraviolet telescopes were obtaining data on quasar Q1821 as ground controllers refined their contingency pointing operation with the flight crew. All four of the instruments, including the X-Ray telescope, obtained data on the quasar Q1821.

Blue shift astronauts Sam Durrance and Jeffrey Hoffman took time off from their observational duties during the day to teach a class in space astronomy to a group of students monitoring the flight at the Marshall centre. The lesson focused on the visible and invisible universe and showed how ASTRO-1 could expand our views of the heavens. Later, following a crew shift change aboard Columbia, the students had an opportunity to question red shift astronauts Ron Parise and Bob Parker about the progress of the mission.

Later in the day attention aboard Columbia turned from the stars to the planets as astronaut Durrance coordinated commands to bring the ultraviolet observations on to the planet Jupiter using its moons Io and Europa as guides. The ground-and-orbital command system was working well by this time and astronomical observations were continuing at a near-normal rate.

Day Seven: December 8, 1990

The Goddard-controlled BBXRT was very active, taking observations of supergiant, red dwarf, and low and high mass binary stars. X-Ray observations were also made of spiral and Seyfert galaxies, star clusters, and supernova remnants. The BBXRT observations often were made in conjunction with ultraviolet observations of the same object.

The ground science team continued to direct the astronauts in pointing the three ultraviolet telescopes. Observations were made of Seyfert galaxies, pulsars, supergiant and variable stars, together with observations of the interstellar medium.

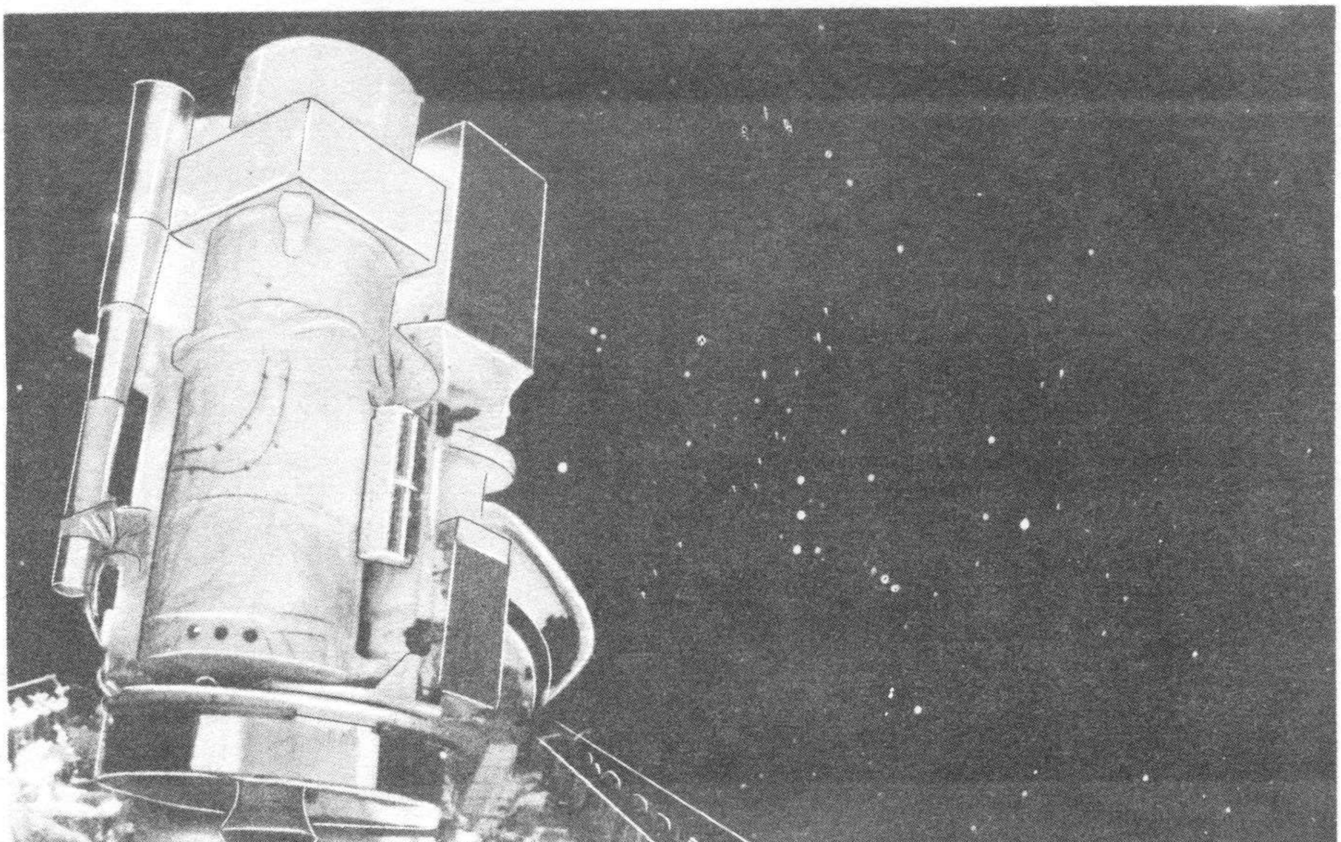
As the day wore on it was discovered that Columbia's waste water dump line was blocked. If the waste water tank could not be emptied the mission would have to end early. The crew tried, without success, to clear the blockage by venting air through the line.

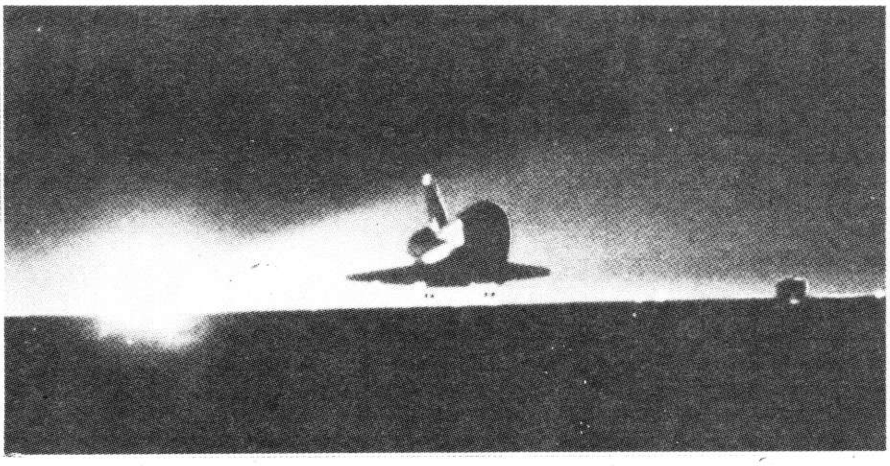
The crew and mission control had developed a method of transferring waste water into bags for onboard storage which, together with reduced water usage, promised to ease concerns about the waste water dump system.

"It kept us busy at first getting the bags filled but afterwards we found it only to be a minor inconvenience," said Brand.

Later on the seventh day communications between the crew and the ground took a different twist as an


Sam
ASTRO-1
Columbia





Columbia nears touchdown at Edwards Air Force Base in southern California. The 21:54 PST landing brought the STS-35 mission to a successful end after almost nine days in orbit. *NASA*

Pilot Guy Gardner goes trhough a checklist during Columbia's descent. *NASA*

amateur radio experiment being operated aboard the Columbia enabled the ASTRO-1 Mission Manager Jack Jones an astronaut Ron Parise to chat informally by ham radio. Both Jones and Parise are licensed amateur radio operators.

Day Eight: December 9, 1990

The four specialized telescopes and their pointing systems continued to operate with virtually no anomalies. Among the successes of the day were BBXRT's discovery of its ability to take observations much closer to the line of the Sun than had been expected and the first successful observations of a cataclysmic variable star.

The waste water blockage no longer threatened to cut short the mission. However, weathermen were keeping a close eye on a developing weather pattern which threatened the planned landing at Edwards Air Force Base late on December 11.

Day Nine: December 10, 1990

The weather picture for California continued to deteriorate. The weather at the planned landing time was estimated to be unacceptable, as was the weather the following day. Johnson Space Centre mission controllers made the decision to bring the mission into Edwards Air Force Base late on the ninth day of the flight.

ASTRO-1 science activities during the morning consisted of joint observations of several galaxies, supergiant stars, binary star systems and quasars. Prior to deactivation of the telescopes, the science management team remarked that they considered the mission a complete success and expect the science gain from this Spacelab flight to exceed all previous science flights.

Deactivation of the HUT came first, followed by the UIT and the WUPPE. The BBXRT was then deactivated during which period the ultraviolet instrument cluster power down and IPS deactivation occurred.

The Columbia was readied for its deorbit manoeuvre and returned to Earth, landing on Edwards Air Force Base shortly before the end of the ninth day of the mission.

Nighttime Landing

Columbia, heavier than usual with Astro aboard, followed a 17 degree glide slope rather than the normal 19 degrees slope. The orbiter also touched down a little faster.

"We targeted for a touchdown speed of 205 knots instead of the 195 knots that you would normally target for when you land a lighter vehicle," said Brand.

The nine-day mission had an interesting effect on the crew. They found themselves an inch or two taller than usual having 'stretched out' in weightlessness.

Touchdown occurred at 05:54 GMT on Runway 22.

The mission had overcome a number of difficulties to achieve its successes. The HUT had made 101 observations of 75 targets, UIT had 89 observations of 64 targets, WUPPE made 88 observations of 70 sources, and the BBXRT had 116 observations of 76 targets. In his post-mission analysis of the effort mission scientist Dr. Ted Gull summarized the science team's feelings when said "The science that will come out of this data is going to be tremendous. We're going to help rewrite the textbooks".

"We are aware that the principal investigators are very happy with the data that they did get," said Bob Parker. "I am sure that ten years ago when they first started planning for this mission they were hoping for a lot more observing time. But when an astronomer goes to an observatory on the ground and he has clouds, he cannot, observe."

For veteran astronaut Vance Brand STS-35 was his last mission. Aged 59, Brand, making his fourth space flight, became the oldest man to fly in space.

"I would love to make another flight," he told ***Spaceflight,*** "but the line of astronauts is too long - I think we have 11 crews assigned right now. Therefore I have no intention of making a fifth [mission]. Although I really enjoyed this last flight I have a very good feeling for what was accomplished - for the team work that resulted in good work arounds and really getting a good result from the mission after some critical equipment failures."

Brand believes the mission demonstrated the importance of manned space flight.

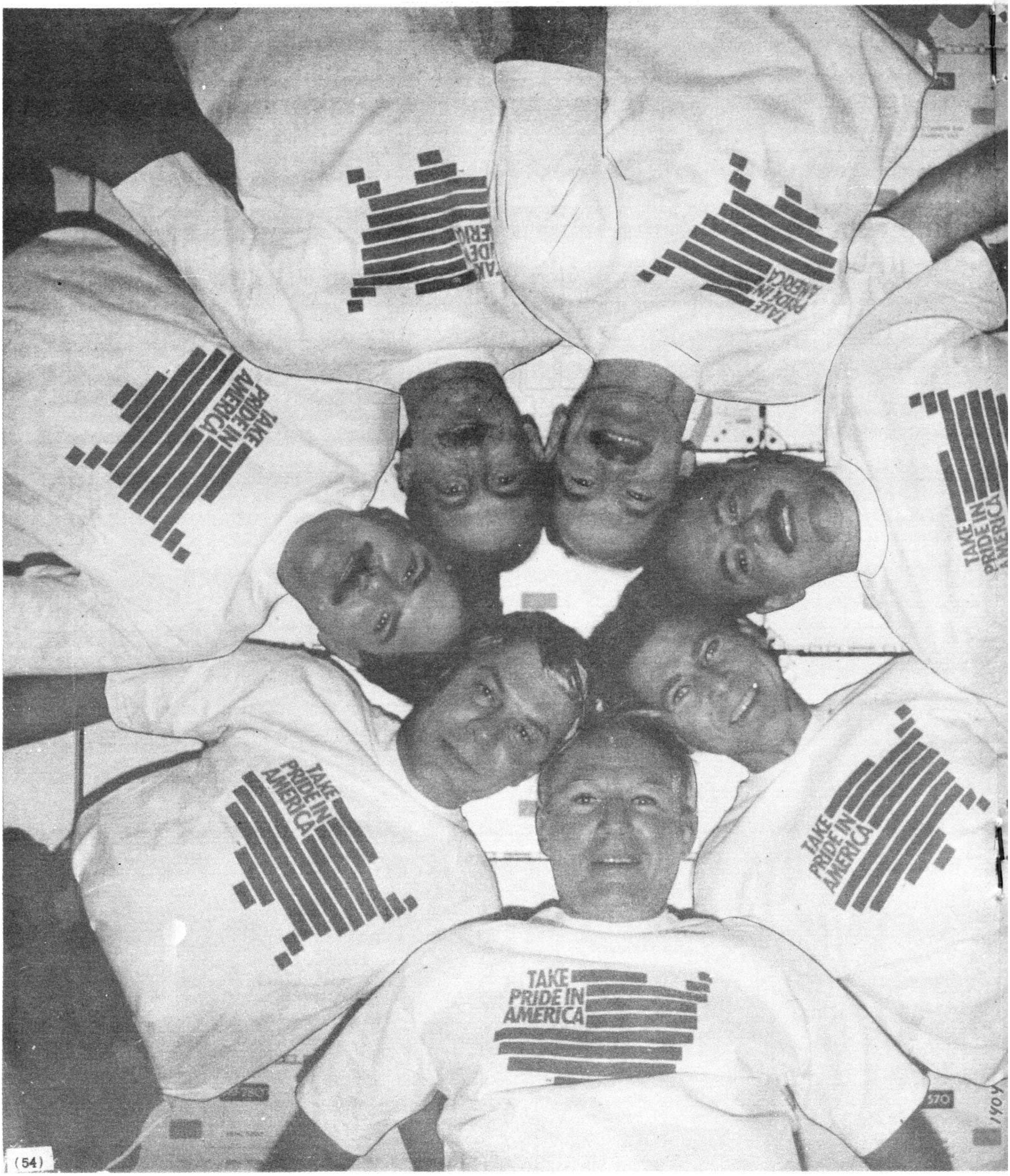
"On this flight man was a crucial element and I think it did show that if we hadn't have had people on board we would have effectively lost the payload results," he said. "I think that science missions are certainly in the category of needing people on board, especially those experiments and science that require some judgement."

TOP: Sam Durrance (left) and Jeff Hoffman give Earth-based students a lesson in Astronomy for the 'Space Classroom' project. Hoffman is believed to be the first person to have worn a shirt and tie in orbit.
BOTTOM: The Astro observatory is pictured with a starry background in this 35mm photograph. Orion appears to the right of the telescope. The constellation is also featured in the STS-35 mission patch. *NASA*

CENTRE PAGES

MAIN PICTURE: The seven STS-35 astronauts pose for their traditional in-flight portrait. Vance Brand is at bottom centre. Others, clockwise from lower left, are Bob Parker, Ron Parise, Jeff Hoffman, Guy Gardner, Mike Lounge and Sam Durrance.
TOP RIGHT: The Ultraviolet telescopes of the Astro observatory are pictured against the blue and white Earth in this scene taken through Columbia's aft flight deck windows.
BOTTOM RIGHT: The two STS-35 Payload Specialists pictured during the 'change of shift'. Parise, of the Red Team, holds Durrance, of the Blue Team with his forefinger. *NASA*

STS-35: ASTRO



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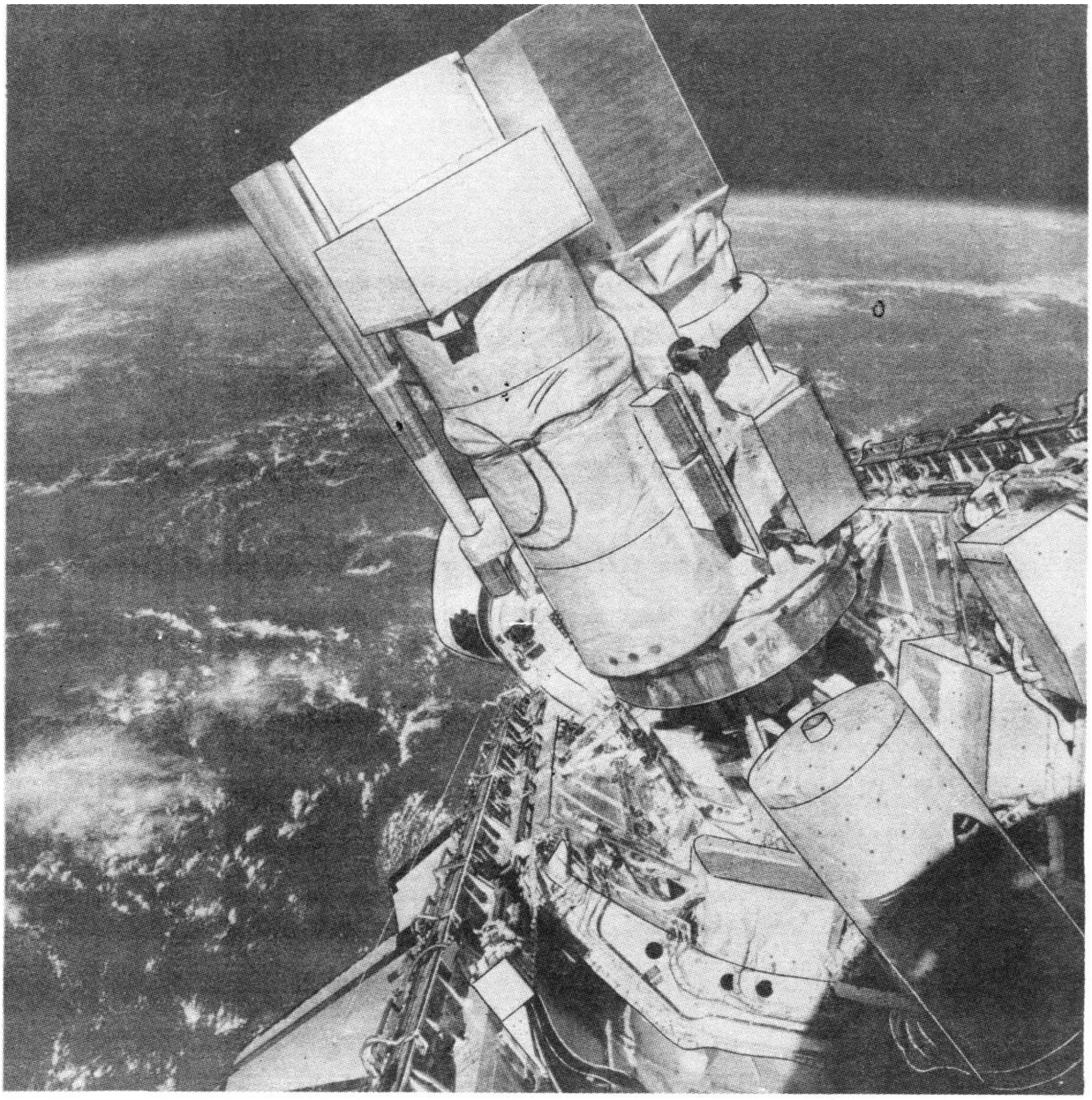
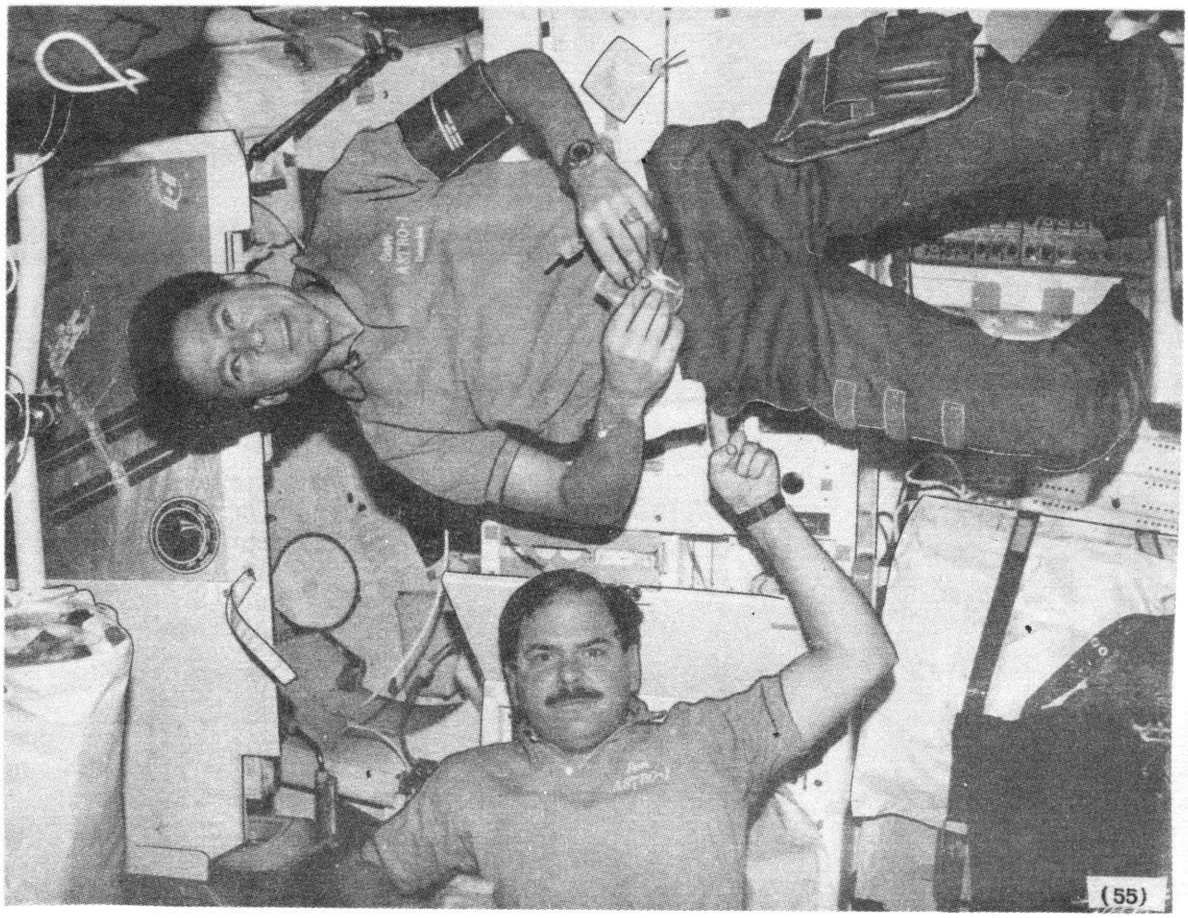




Galileo's Earth Flyby

By Dr W. I. McLaughlin
Jet Propulsion Laboratory

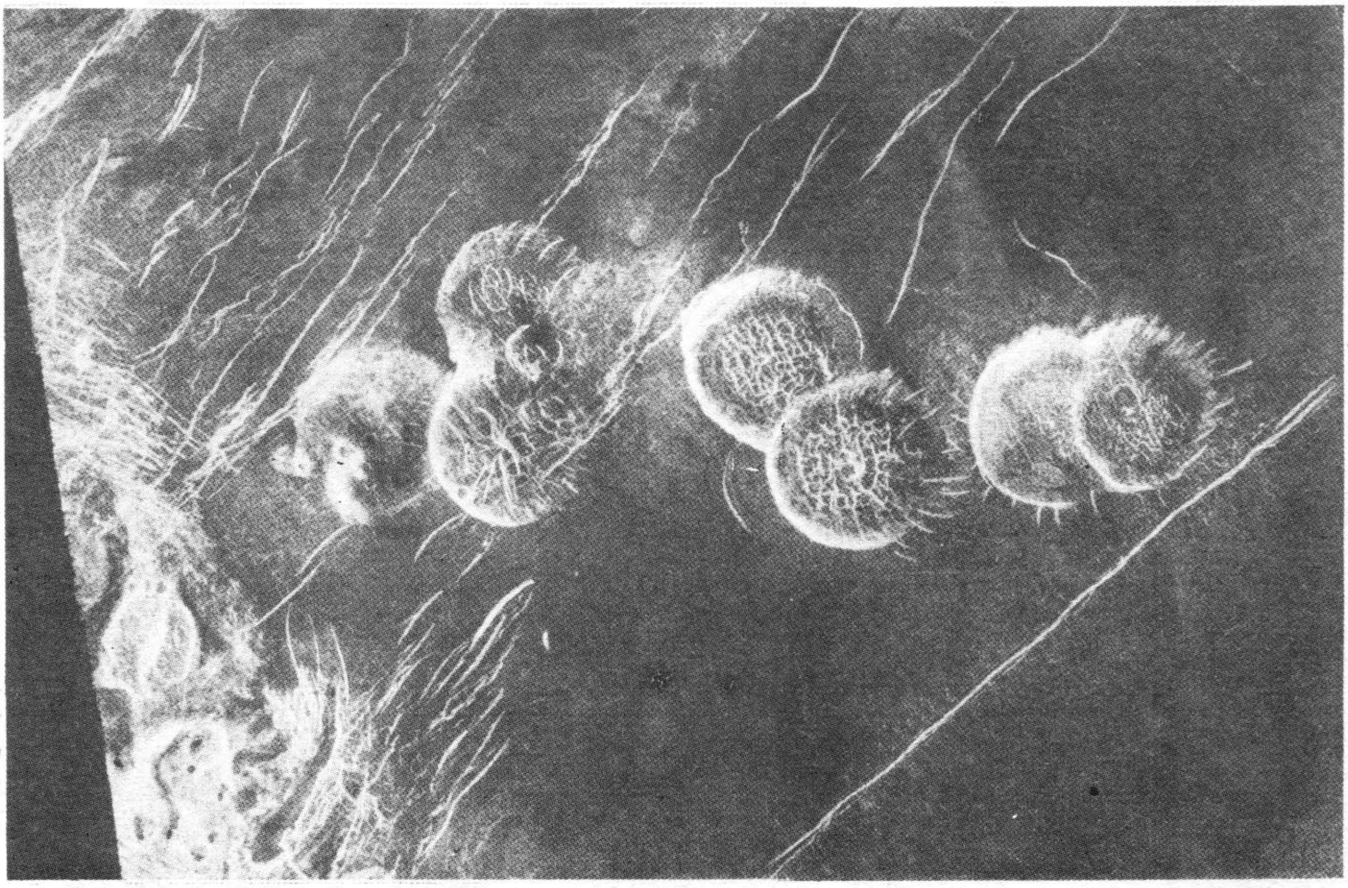
The path to Jupiter for Galileo includes flybys of Venus (February 1990), Earth (December 1990), and Earth again (December 1992) in order to acquire the additional energy needed to reach the giant planet. Prior to the cancellation of the intended use of the Centaur rocket as an upper stage with the Shuttle, which was done after the Challenger accident, the plan was to send the Galileo spacecraft directly from Earth to Jupiter. (Launch would have been in 1986 and Jovian encounter in 1988.) Now, with the gravity assist from Venus successfully behind it, the spacecraft has been navigated to a precise encounter with Earth; closest approach took place on December 8, 1990 at 20 hours, 34 minutes, and 34 seconds (UTC) at an altitude of 960 km. This was only 8 km above the targeted altitude of 952 km.

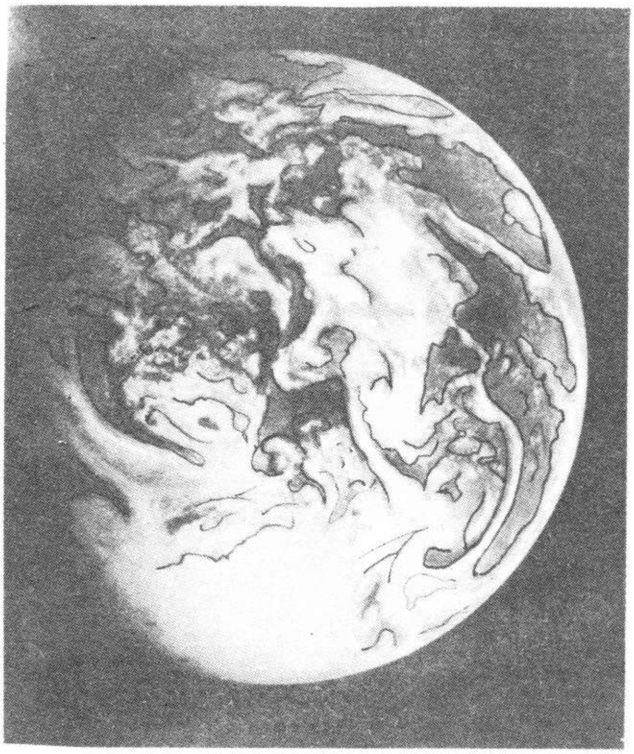
The encounter with Earth last December increased Galileo's speed in solar orbit by approximately five kilometers per second. The gravity-assist technique captures the imagination with its bounty of added energy for just the price of accurate navigation. Even in that other "natural" method of urging a spacecraft onward, solar sailing, a special apparatus has to be built. The gravity assist, apart from its intrinsic utility, constitutes a metaphor for the dream of controlling the world through the power of thought and "getting something for nothing". If that pronouncement seems farfetched, then please supply a second explanation for the interest which this topic in trajectory analysis excites, as shown in the inquiries received by myself and other writers on the subject of space.

For those with a modicum of mathematical skills, Robert J. Cesarone of JPL has written a tutorial on gravity assists: "A Gravity Assist Primer" (AIAA Student Journal, Vol. 27, pp. 16-22, Spring 1989). An intuitive feel for the process may be acquired by considering a spacecraft passing behind the trailing hemisphere of a planet moving in its orbit. The tug of gravity by the spacecraft on the planet, feeble though that may be, works against the motion of the planet and subtracts from it a small amount of energy. In turn, the spacecraft receives energy in the transaction. The second ingredient in the gravity assist is a change in direction, bending the spacecraft's trajectory, which is easy to accept as a result of the gravitational pull of planet upon vehicle.

The kind of qualitative explanation that I have sketched above for the gravity assist was adopted as a full program of exposition by Sir George Biddell Airy (1801-1892) in his 1884 book *An Elementary Explanation of the Principal Perturbations of the Solar System* (Macmillan and Co.). Although "elementary" in only a relative sense, it is a refreshing alternative to exclusively symbolical treatments of celestial mechanics and represents an attempt to get behind the formalism to reach a deeper level of understanding. Ironically, it may have been this usually admirable trait which led Airy, the Astronomer Royal, to put aside the calculations of John Couch Adams (1819-1892) on the location of a planet

This image of the eastern edge of Alpha Regio was acquired on November 7, 1990 by the Magellan spacecraft now in orbit about Venus. The spacecraft's synthetic aperture radar, cutting through the obscuring layers of clouds, has revealed seven circular, domical hills averaging about 25 km in diameter. They may have been formed by lava flows from central vents and have undergone considerable fracturing. NASA/JPL

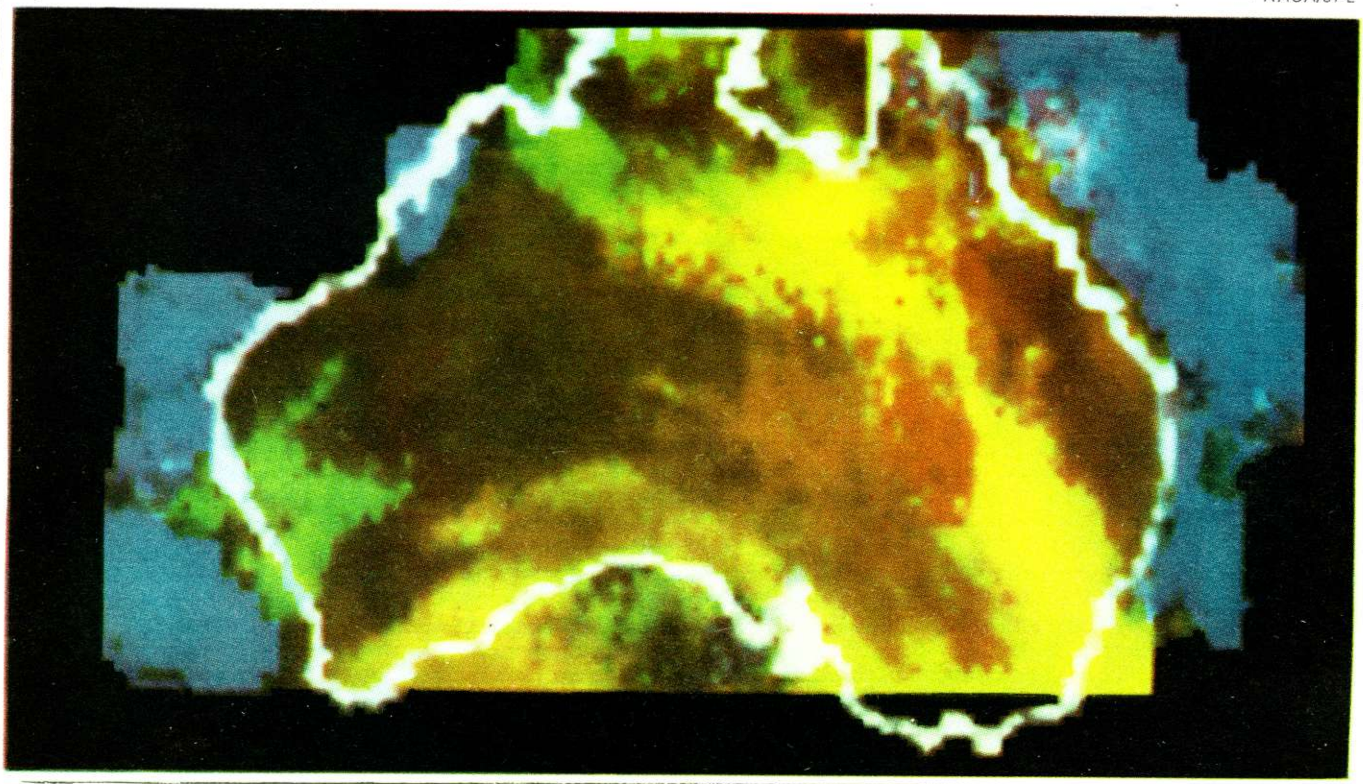




Above: A view of South America on December 8, 1990 is shown in this image obtained by the interplanetary spacecraft, Galileo, as it swung through the Earth-Moon system, bound for an eventual insertion into orbit about Jupiter in December 1995. *NASA/JPL*

Above right: Clouds on the night side of Venus are shown in this false-color image. Data were taken by the Galileo spacecraft as it approached the planet on February 10, 1990. Viewed from an altitude of about 100,000 km, the map (by the Near Infrared Mapping Spectrometer) shows the turbulent atmosphere some 50 km above the surface and 10-15 km below the visible cloudtops. *NASA/JPL*

Below: This multispectral map of Australia and surrounding seas was obtained by the Galileo spacecraft's Near Infrared Mapping Spectrometer shortly after closest approach on December 8, 1990 from an altitude of about 85,000 km. The wavelength of 0.873 microns is represented by blue, 0.939 microns by green, and 0.984 microns by red (visible light spans the range from 0.4 to 0.7 microns). The purplish color off the northeast coast marks the shallow waters of the Great Barrier Reef and the Coral Sea. Here the blue, from water absorption, combines with the red, from reflection from coral and surface marine organisms to produce the blend of colours. *NASA/JPL*



beyond Uranus. The honor of the visual discovery (1846) of Neptune went to Johann Galle (1812-1910) at the Berlin Observatory, based upon the calculations of Urbain Leverrier (1811-1877). Colin Ronan discusses the circumstances of the chase in *Their Majesties' Astronomers* (The Bodley Head, London, 1967).

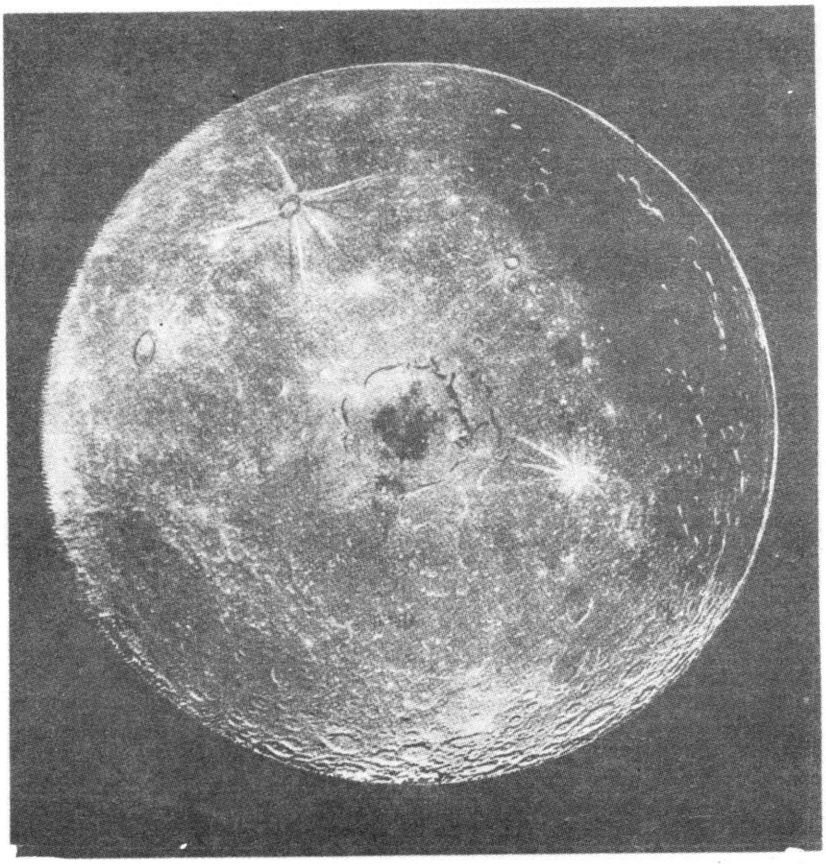
Although the three gravity assists, which give rise to the "VEEGA" (Venus-Earth-Earth Gravity Assist) name commonly applied to the trajectory, are the reasons for passing closely by Venus and Earth, they are not the only benefits to be obtained. A preview of some results from Venus was given in the May 1990 edition of this column, and more information will be forthcoming since Galileo dumped the Venusian contents of its tape recorder to ground antennas as the spacecraft moved closer to Earth. (Galileo's high-gain antenna has been furled for thermal-protection reasons during its passage through the warm environs of the inner solar system.)

A press conference was held on December 19 in von Karman Auditorium at JPL to present some of the scientific results from Galileo's passage through the Earth-Moon system.

The Project Scientist, Dr. Torrence Johnson, provided some feeling for the scope of the investigations with a summary of hypothetical report if Galileo were an "Arcturan" probe going through the Earth-Moon system for the first time. The Arcturans would be able, for example, to assert that the extensive covering of Earth by water could only be a thin veneer, a fact known from the deduction of Earth's density from mass and volume measurements. The presence of a magnetic field would allow them to infer that the Earth possesses a fluid, conducting core. The south polar region features an ice continent, but the north polar region could not be observed. The atmosphere contains surprisingly little carbon dioxide and its general composition could be the consequence of life on the planet. Support for this hypothesis comes from detection of radio signals which were probably not of natural origin. Volcanism could only be inferred and plate tectonics were not detected.

Johnson closed with the comment that the Arcturan Academy of Sciences would certainly recommend that their government fund another mission to Earth, preferably an orbiter.

Various scientific investigators continued the press conference with a presentation of highlights. A significant characteristic of the Galileo encounter was the rapidity with which this interplanetary spacecraft moved through the magnetosphere, permitting a "snapshot" of the system to be obtained. It was also fortunate that passage occurred at a time of a high level of disturbance, allowing, for example, observation of disruptions in the plasma sheet contained in the tail of the magnetosphere. Knowledge of the plasma sheet relates to understanding the processes that drive the auroral phenomena which diversify skies in higher latitudes on Earth. "Lightning whistlers" were detected; they travel outward from Earth along magnetic field lines.



The solid-state imaging system onboard Galileo captured this picture of the Moon on December 9, 1990 from a range of somewhat over 550,000 km. The large, circular feature is Mare Orientale which was formed about 3.8 thousand million years ago by the impact of an asteroid-size body. *NASA/JPL*

A preview of an Earth-rotation movie was shown: 600 of the ultimate 1500 frames of the movie were strung together to display our blue-and-white planet in motion. The clarity of the imaging results was striking and the reflective zone of sunlight-on-water added to the effect. The slowness of the visible evolution of weather patterns compared to the rate of Earth's rotation surprised me, an Earthling immersed in daily weather. Of course, it is a question of the spatial scale seen from the two perspectives.

The Moon was not neglected during the flyby. Lunar mapping with the Near Infrared Mapping Spectrometer (NIMS) certified the operation of that instrument as performing even better than specification (the entire Galileo encounter served to calibrate and characterize instruments for their use at Jupiter). The NIMS has spectral resolution about 50 times better than the camera ("SSI", which stands for "Solid State Imaging" system), but the camera has about 50 times better spatial resolution; hence their results are complementary.

The objectives of lunar imaging science were directed toward: (1) composition of farside crust, (2) structure of the Mare Orientale impact basin, (3) character of unexplored regions near the south pole and (4) improved coordinates for lunar features. With regard to the second objective, some confirmatory evidence was obtained for a hidden mare ("mare", the Latin for "sea", denotes the dark, flat regions of the Moon so prevalent on the side visible from Earth), which had previously been suspected. This mare would predate the formation of the Orientale basin.

Preparations are underway for Galileo's encounter with the asteroid Gaspra in October of this year. The path to Jupiter is demonstrating the power of a fully instrumented spacecraft to derive value from a variety of solar-system environments. At present, our images of the Jovian system are dominated by the results from the two Voyager flybys. But, like the Arcturans, we have a lot to learn. Galileo will be our teacher.

Ignorance in Motion

Motion is a topic whose multiple facets have been examined in great detail from classical times to the present day. Despite the triumphs of Isaac Newton (1642-1727) and his followers, the subject of motion continues to present new aspects for investigation: Einstein's theory of relativity early in the century and, more recently, gravity assists and other developments of trajectory analysis in support of space flight. These accomplishments demonstrate the dictum of Francis Bacon, "Knowledge Itself is power", but ignorance, on occasion, has its merits. A new solution to Zeno's anciently posed paradoxes of motion and the formulation of the modern theory of chaotic motion, with applications to the solar system, are built upon a foundation of ignorance.

Zeno of Elea (c.490-430 B.C.) formulated arguments against the possibility of motion with the intention of buttressing the teachings of an earlier Greek philosopher, Parmenides (born c. 505 B.C.). Parmenides was a monist; he believed that "reality" was a single, indivisible, unchanging whole. The world we observe is, in some sense, an illusion. Zeno did his job very well; after almost 2500 years people still address issues he raised. The philosopher Alfred North Whitehead (1861-1947) said: "No one has ever touched Zeno without refuting him, and every century thinks it worthwhile to refute him."

Zeno's writings have not come down to us directly but have been transmitted as summaries in the works of Aristotle (384-322 B.C.). For purposes of the present exposition, Zeno's complaints about the concept of motion – imagine a spacecraft in flight -- are three: (1) The process cannot be described finitely: before the spacecraft reaches the target it must travel to the halfway point of its trajectory, then to the three-quarters point, then to the seven-eights point, etc. The "etc." means that an infinite number of "checkpoints" must be passed; (2) Not even a single step can be taken: any step (segment of the motion), however small, will by necessity have passed over some "unreported checkpoints". An attempt to remedy this by taking only a half-size step still leaves unreported checkpoints, and continued efforts to shrink the initial step only produce an infinite regress and do not solve the problem. Thus, Zeno says that the spacecraft not only cannot get to its target; it cannot even get started; (3) The process is not dynamic: at every instant of time the spacecraft, by definition of an instant, is "frozen" and not moving. Where is the motion in "motion"?

Zeno's demands upon any description of motion for finiteness, accountability, and evidence of dynamics are stringent, and the inability to answer them promotes a feeling of unease. My colleague, Sylvia Miller, and I, believe we have solved the puzzle and it may be worthwhile to quell Whitehead's restless centuries in the next few paragraphs.

In the last 25 years, a fascinating new branch of mathematics has been flourishing. Originated by the logician Abraham Robinson (1918-1974), "nonstandard analysis" rescues the concept of "infinitesimals" from the mathematical trash heap and gives it intellectual respectability. Even more recently the mathematician Edward Nelson has devised a version of nonstandard analysis that mirrors the modern scientific view of the world, a view that emphasizes the place of "observability."

Nelson's approach ("Internal Set Theory: A New Approach to Nonstandard Analysis," *Bulletin of the American Mathematical Society*, Vol.83, pp. 1165-1198, 1977) begins by adding the adjectives "standard" and "nonstandard" to the vocabulary of mathematics, and each number can be labelled by one of these two descriptors. Nothing has changed except that Nelson has, in effect, supplied us with a set of spectacles (in the form of some rules of manipulation to go with his adjectives) enabling us to discern new properties of old objects. The standard numbers, it turns out, are all the specific numbers: 2, π, 10^{-100}, etc. The nonstandard numbers are ones we just cannot describe concretely. Surprisingly, members of the latter class exist.

Such a feeling of indescribability for very large or very small numbers had been expressed, in almost indignant fashion, by the well known mathematician Emile Borel in his book, *Probability and Certainty* (Walker and Company, New York, 1963), written for a popular audience, and in a similar vein D. van Dantzig wrote a paper entitled "Is $10^{10^{10}}$ A Finite Number"! Nelson captures these intuitive feelings in a rigorous manner. His infinitesimals are defined to be nonstandard numbers that are greater than 0 but smaller than every standard number and he shows that, indeed, they exist.

How can this approach be used to satisfy Zeno's complaints? Imagine the trajectory of the spacecraft partitioned into a large (but finite) number of infinitesimal segments. (Although large, the number of partitioning infinitesimals will still be finite since, except for a certain aura of "unknowability", the infinitesimals are just ordinary lengths.) With the proper choice of infinitesimal segments, it can be shown that the spacecraft will arrive at the halfway point, then the three-quarters point, and every check point which, in Nelson's terminology, is "standard". Thus, this description of motion is finite and includes all the "concrete" checkpoints. But is it valid? If, say, the steps were of length 10^{-100}, small but describable, then Zeno could justly complain that one had not considered steps half that size: $\frac{1}{2} \times 10^{-100}$. What makes the infinitesimal steps immune to Zenonian criticism is their "indescribability". In the same manner, nonstandard (not "concrete", "indescribable", "unknowable") checkpoints need not be considered in the description since they are not subject to location through measurement; they have no numerical meaning. In this case, ignorance is indeed bliss. In science, one should avoid discussing the internal structure of an object, such as two halves of an infinitesimal interval, if internal properties can never, not even in principle, be measured. Technically, the prohibition can be formulated in terms of Immanuel Kant's (1724-1804) theory of knowledge, but one can capture the essence with the remark that we are not held accountable for estimating how many angels can dance on the head of a pin.

This approach answers Zeno's first and second objections, as listed above: lack of finiteness and lack of accountability. The third, "frozen object", objection is handled by noting that the spacecraft is clicking through infinitesimal steps at times we cannot see it moving; we can only hope to measure its position at standard points. "Moticn takes place in the dark."

This resolution of Zeno's objections against motion, although of considerable historical significance, represents a limiting case for problems encountered in the physical world. "Chaotic motion" shows ignorance in a less favorable light. In Zeno, ignorance facilitated a satisfactory account of motion; in chaotic situations ignorance limits our ability to predict the result of a motion once it is initiated. The essence of chaotic motion is the fact that certain dynamical systems -- chaotic systems -- will drastically change their future course if their initial states are altered, even slightly. A speculative image from meteorol-

ogy has been used to capture the idea; can the flap of a butterfly's wing today in China fundamentally alter the weather in England a month later?

Consider Hyperion, a small satellite of Saturn. It orbits Saturn every 21 days in reasonably regular fashion, but the direction of its spin axis and the rate of spin about that axis can change dramatically in just a few orbital periods. In other words, Hyperion is probably tumbling chaotically. The reason for this state of affairs is that Hyperion, as determined from Voyager 2 images in 1981, is an irregularly shaped body, which is moving in an eccentric orbit about Saturn. The eccentricity of the orbit produces a varying gravitational force over an orbital period, acting with the irregular shape, gravitational torques are induced which bedevil this rock. Although Hyperion appears to be the only satellite that is currently tumbling chaotically, other irregularly shaped satellites, such as Phobos and Deimos which orbit Mars, probably passed through a chaotic phase in their dynamical evolution.

The discovery of the first asteroid, Ceres, in 1801, was heralded as a confirmation of the Titius-Bode "law" (1772) of planetary distances. However, as more and more asteroids were discovered (many thousands are now known), irregularities in their distribution posed a state-of-affairs to be explained. It was noted that several "gaps" in the distribution occurred at distances from the Sun where a body would orbit the Sun in a period of time simply related to the period of revolution of gravitationally mighty Jupiter, e.g., 2 revolutions per 1 revolution of Jupiter ("2:1") or 3 revolutions per 2 revolutions of Jupiter ("3:2"). The 3:1 Kirkwood gap shows, under analysis, that chaotic motion is probably operative in this zone. The actual formation of the gap is caused by large eccentricities which are produced in the orbits of the disturbed asteroids and result in their crossing of the orbits Earth and Mars and being, eventually, swept up by these planets.

The motion of Pluto is "suspiciously complicated", in the words of J. Wisdom (his paper "Chaotic Behaviour in the Solar System" is included in *Dynamical Chaos*, Princeton U. Press, 1987, pp. 109-129), but the presence of chaotic behaviour has not been verified.

Knowledge of chaotic behaviour is not limited to reflections on observations of physical systems such as satellites, asteroids and planets in motion. Considerable theoretical work has been done. There is a famous result, the KAM theorem, named after the mathematicians who devised it: Kolmogorov, Arnol'd and Moser (the first two are Soviets, the third is a German). The KAM theorem gives certain conditions wherein the presence of chaos is restricted as to its extent. Often, numerical integrations provide insight into the behaviour of a dynamical system, so plotting the results in a so-called "phase portrait" can show regions of the system where chaos is dominant and other regions where "smoother", more predictable, motions will take place. Under outside influences, a system can move from chaotic to smooth regions, or *vice versa*, as noted above in the cases of Phobos and Deimos.

The discovery of chaotic motion effectively ended the boast of Pierre Simon Laplace (1749-1827) that he could predict all the subsequent dynamical evolution of the universe given the position and velocity of its constituent particles at some epoch. (Of course, relativistic theory and the probabilistic uncertainties in the microworld of quantum theory also undermine the Laplacian stance, as does the partial surrender represented by the synoptic parameters of statistical mechanics.) More than just the sheer number of particles would be working against him; the required precision of knowledge of their initial states would prove an enormous additional informational burden. While ignorance can limit our powers of prediction of the consequences of motion once it has started, ignorance makes possible, if we take Zeno seriously, rational belief in the fact of motion.

Light on the Keck Telescope

What will be the largest optical telescope in the world, upon completion, saw "first light" on the night of November 24, 1990 when the Keck Telescope successfully imaged the galaxy NGC 1232. Nine of the eventual 36 mirrors of the partially completed telescope, located on Mauna Kea in Hawaii, were in place and utilized for this event. In this configuration, its light collecting area equals that of the 5m Hale Telescope at Palomar Observatory. Dr. Edward C. Stone, chairman of the board of the California Association for Research in Astronomy (CARA), characterized first light. "It tells you that the fundamental character of the telescope is correct. It doesn't mean that you have necessarily solved all the last, little, tiny details – that's what you do in the year or so following first light – but it tells you that you have a concept that works." According to Project Manager Gerald M. Smith, first light "is a very significant milestone in the completion of the telescope. We're convinced that if it works with nine mirrors, it will work with all 36. It's been a lot harder than we thought it would be. It's very satisfying seeing it nearing the end."

Stone was recently appointed as Director of JPL (see the October 1990 "Space at JPL"), and Smith was the project manager for the Infrared Astronomical Satellite (IRAS).

The progress of the Keck Telescope has been tracked in these pages on a regular basis: April 1984, June 1985, January 1986, February 1988, and February 1990. So, when the Project Engineer, Bill Irace (he and I were colleagues on IRAS), and I recently talked on the telephone, I felt like, at least, a distant cousin helping to celebrate first light with the project team.

The Project Scientist, Dr. Jerry Nelson of the University of California, Berkeley, developed many of the innovative techniques used to fabricate and control the mirror segments which comprise the primary mirror (see the references). "It tests our ability to fabricate the optics, to polish the surfaces, and tests our ability to make the active control system work properly," he said, in reference to first light.

The galaxy that posed for the Keck Telescope, NGC 1232, is also known as Arp 41 and is located in the constellation Eridanus, "The River". This galaxy is approximately 65 million light years distant and some 100,000 light years in diameter. It is a normal spiral galaxy (Type Sc) with similarities to our Milky Way galaxy.

A total of 42 mirror segments will be produced; 23 have been polished to date. Six of the 42 segments will be employed as spares when segments are removed for servicing. The positions of the segments are individually controlled to an accuracy of about two millionths of a centimeter, with adjustments being made twice per second by computers. When completed, the mosaic of 36 hexagonally shaped segments will form a mirror with a diameter of ten meters.

Four scientific instruments, two cameras and two spectrographs, will be utilized with the telescope in the visible and near-infrared domains of the electromagnetic spectrum. Scientific operations are scheduled to com-

mence in late 1991. The Keck Telescope and NASA's 2.4m Hubble Space Telescope will be able to be used in complementary fashion. The Hubble Space Telescope, with its location above the disturbances of the atmosphere, has the advantage in resolving power, the ability to see fine detail, while the Keck Telescope's 17-times larger collecting area yields an advantage in gathering photons. Thus, the Keck Telescope could obtain the spectrum of a distant galaxy imaged by the Hubble Space Telescope, and this spectrum, through measurement of the associated red shift of spectral lines, would yield the galaxy's recession velocity and through Hubble's law (the astronomer, not the telescope), its distance.

CARA is a partnership between the California Institute of Technology (the parent organization of JPL) and the University of California at Berkeley. The W. M. Keck Foundation provided a $70 million grant to build the observatory and telescope, the largest private contribution ever made for a scientific project.

The large-scale structure of the universe is a subject that has always excited our species. It is a delight to behold stars in the night sky or fields of distant galaxies and the intellectual return is one of the most satisfying set of insights that we are privileged to receive in this life.

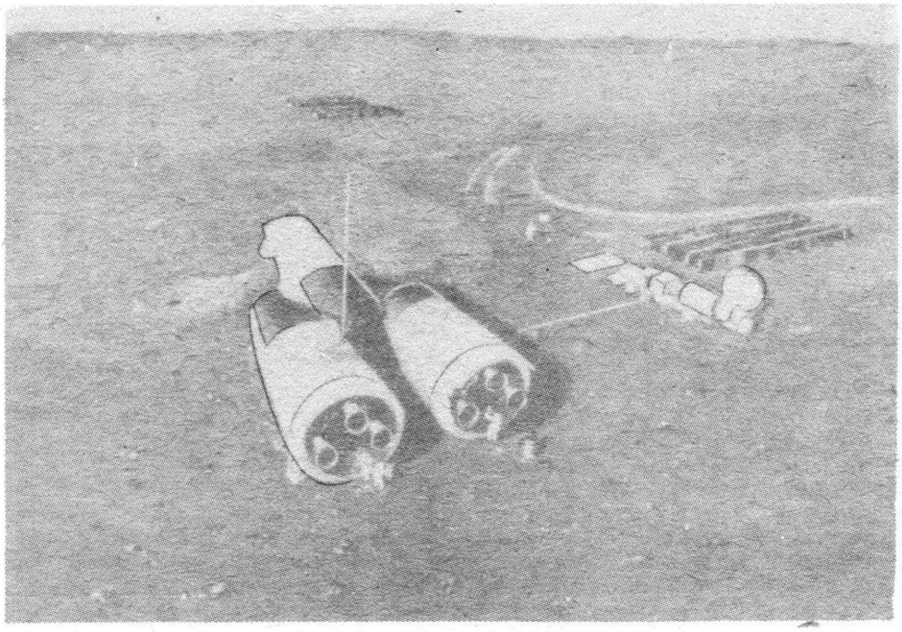
The galaxy NGC 1232 was imaged by the Keck Telescope on the night of November 24, 1990, using nine of the 36 mirrors which will be in place when this segmented-mirror telescrope is complete. Already equivalent in light-collecting capability to the 5m telescope at the Palomar Observatory, the Keck Telescope, with an eventual 10m primary mirror, will be the largest optical telescope in the world.
CARA

Some Unconventional Approaches To The Exploration Of Mars

Most conventional thinking on the exploration of Mars postulates an "Apollo-style" approach involving landings at a variety of sites on the planet in a series of semi-independent missions. Some type of roving vehicle is usually invoked for traverses limited in length by the surface stay time and the energy supply of the vehicle.

The use of local resources in conjunction with a larger variety of vehicle concepts offers a different approach. Long-range exploration of literally globe-girdling extent become possible at much higher speed than might ordinarily be expected. A permanently staffed outpost and a series of supply depots, properly disposed, would allow this exploration to proceed at no greater risk than would be expected from a more conventional approach. In fact, by offering more options for rescue and recovery in the case of accident or failure, it is argued that this approach offers greater safety to the crew as well as much enhanced science return. While costs are difficult to estimate, it appears that this approach may not be substantially more costly than the conventional approach. Certainly the science return, in terms of information per dollar spent, would be enormously greater.

Since no one has yet explored Mars in the sense intended here, i.e. with human crews operating equipment on or in the vicinity of the planet, it might be argued that any approach to exploring Mars is unconventional. However, one can define "conventional" in this context as the type of mission profile which has generally been espoused. These missions have, in the main, been characterized by huge masses departing Earth, and a desire to reduce the total trip duration. Usually this last would be at the expense of time spent at Mars even if the interplanetary flight time was lengthened. Surface exploration is usually brief and of limited range depending upon battery powered rover vehicles operating during a relatively brief stay. The mission profiles for these missions, often referred to as "sprint missions", generally involve use of a long flight time return trajectory which requires very large Mars departure energy and often involves a Venus flyby. A common term for these missions is "opposition class" to distinguish them from the lower energy "conjunction class" which involve longer total time but



An early Mars base using cargo rocket hulls. *Carter Emmart*

By J.R. French

much lower energy requirements and allow more time on Mars.

There are many who feel that the sprint approach is entirely wrong. If we are to spend all the time, money and effort to go to Mars at all, it seems foolish not to maximize the return on that investment. This type of thinking leads to the desire, not only to minimize the investment but, more importantly, to attempt to obtain the maximum result in terms of exploration and utilization of Mars.

Space Transport

How might one minimize the investment in a Mars mission? One way is to minimize the mass which must be transported into low Earth orbit (LEO). A perusal of the mass list of any Mars mission will show that the huge majority of the mass lifted from Earth is propellant. This is particularly true of the short stay time missions mentioned earlier, which have very large energy requirements.

Reducing propellant requirements is one obvious way of reducing the investment in a Mars mission. Propellant requirements may be reduced by increasing the performance (specific impulse) of the rocket engine. Unfortunately, we are already so close to the theoretical limits of chemical propulsion that very little help is to be expected from that direction. Nuclear thermal rocket engines can, potentially, double the specific impulse of chemical rocket engines but the strong anti-nuclear bias which has developed in the US and much of the rest of the world may preclude development of such engines. Low thrust concepts such as electric propulsion or solar sails can reduce mass in orbit but involve long flight durations which are probably unsuitable for manned missions.

One solution to the propellant mass problem is suggested by analogy to the transatlantic airlines. An airliner flying a London-New York round trip does not depart Heathrow with enough fuel on board for the round trip. While this is certainly possible in engineering terms, such an aircraft would probably not be economic. In fact, the aircraft carries enough fuel for the one way trip (with some margin) and refuels for the return trip. The analogy for Mars is sound. The use of the natural resources of Mars to generate propellant for the return trip offers substantial reduction in the required mass departing Earth.

Extensive work by Ash et al [1], Frisbee et al [2] and others, have documented techniques for generating propellant using Martian resources. Oxygen and carbon monoxide can be made from the carbon dioxide atmosphere. The atmosphere, along with water (either local or brought from

Earth), can be used to synthesize oxygen and methane. Hydrogen can also be used with the atmosphere to make oxygen and methane.

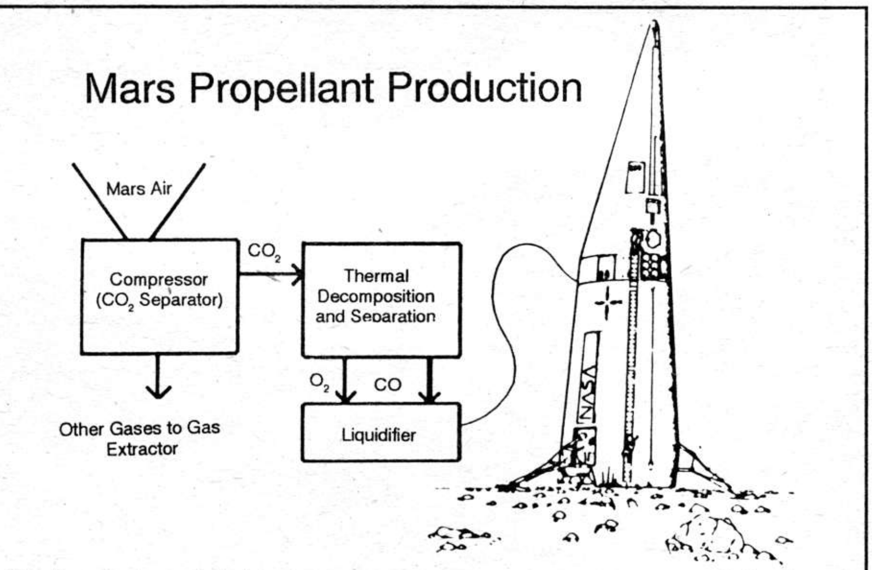
Some of the first serious looks at using this technology were taken as part of studies of Mars Sample Return missions led by the author at Jet Propulsion Laboratory in the 1970s. The aim was to try to fit a sample return mission within the capability of the Titan IIIE - Centaur, the most powerful vehicle available after the Saturn V was sacrificed to the Shuttle. The promise of the technique was obvious in these studies but the concept was too avant garde for that era.

The "Case for Mars" [3] conference workshops applied the concept of in situ propellant production to a manned mission to Mars, specifically to support of a permanent base. The author chaired the workshop which developed the mission strategy and was primarily responsible for design of the Mars Shuttle craft to be used to deliver the crew to Mars and then, loaded with Mars-produced oxygen and carbon monoxide, lift them off for the journey home.

Use of in situ generated propellant and other propellant saving techniques such as atmospheric braking to orbit (aerocapture) and free return trajectories allowed delivery of a crew of 15 along with 75 tonnes of equipment for an Earth departure mass similar to that required to take a crew of three on one of the "sprint" missions described earlier. Which offers the greater return on investment: two or three persons on Mars for a few days with meagre equipment or a crew of 15 with substantial equipment operating for years out of a relatively comfortable permanent base?

The Case for Mars approach is admittedly a major exercise. Baker and Zubrin [4] have recently outlined an approach which also uses in situ propellant manufacturing and some of the other features mentioned above but involves smaller crews and less equipment delivered to Mars. They postulate taking hydrogen from Earth and generating methane and oxygen for the return. In Case for Mars we had considered taking water but had rejected it because the mass required was so great that there was little advantage. Hydrogen was also rejected because of the perceived difficulty in long term storage. Baker and Zubrin argue that storage can be dealt with and that the advantage in reduced mass for the high performing methane-oxygen vs the low performing carbon monoxide-oxygen makes solution of the storage problem worthwhile.

It may be asked why Martian water is not used. The reason is accessibility. The amount of water in the atmosphere is impractically small, the polar caps are inconvenient and the ice difficult to mine. Permafrost with significant water content may exist down to the mid latitudes but obtaining the water would be very difficult. On the whole the use of Martian water seems impractical for first generation exploration but could be vital for later phases.



The Propellant manufacturing process. *Carter Emmart*

In Case for Mars the base would be established on the first mission with crew rotation and resupply missions launched at each subsequent opportunity to maintain the permanent base. Baker and Zubrin propose a launch at each opportunity as well but each landing at a different site. Each landing site would be in surface rover range of its predecessor thus resulting in a chain of outposts with power generation and propellant manufacturing capability stretched across a span of the planet. Clearly, one or more of these could be expanded into a large permanent base.

While these scenarios involve chemical propulsion, nuclear propulsion and low thrust concepts also benefit from in situ propellant. Low thrust propulsion is limited to orbiting the planet so that high thrust transport to and from the surface is still required. High thrust to weight nuclear systems that can land on the planet will still benefit from in situ propellant but the significance is somewhat diminished because of the higher performance relative to chemical systems.

Incidentally, a nuclear thermal engine can, in theory at least, use almost any fluid as reaction mass (propellant) including atmospheric carbon dioxide, though the need to store carbon dioxide at relatively high pressure to maintain it as a liquid is something of a problem since it militates against light weight tankage. Performance of a nuclear thermal engine is poor relative to the same engine using hydrogen but this is not necessarily unacceptable in a low gravity Mars environment. Zubrin [5] has suggested that a nuclear powered vehicle using carbon dioxide might hop from one site to another on Mars, reloading itself with carbon dioxide reaction mass each time it lands. The safety problems associated with radiation from the reactor needs to be assessed. The classic "shadow shield" may not suffice because of reflection from the atmosphere and from the surface during takeoff and landing. Certainly it will not protect the crew during surface operations. Given solution of such concerns, the concept is most attractive since it would allow access to many sites on Mars and repeated trips to and from Mars orbit all at no additional Earth departure mass penalty. The power and flexibility of such a vehicle for exploration makes it definitely worthy of attention.

It was stated earlier that low thrust propulsion might not be suitable for manned missions because of the long flight times. In fact, the interplanetary phase of such a mission may often be no longer than for a ballistic mission and may even be shorter. The long times arise primarily in spiralling in and out of the planetary gravity wells, an operation to which low thrust propulsion, especially solar sail or solar electric, is poorly adapted.

Garvey [6] has proposed another approach. A solar sail vehicle would depart from Earth, perhaps from a lunar libration point to minimize spiral-out time. It would then shape a rapid trajectory to Mars but make no attempt to rendezvous with the planet. The crew or unmanned cargo would then descend to Mars in a vehicle, perhaps similar to the Mars shuttles in the Case for Mars concept, while the sail vehicles flies past the planets and

shapes a return to Earth. A crew departing the Mars base might rendezvous with the sail as it passes Mars for the trip home. This is similar to the Case for Mars concept except that the sail offers a much shorter trip home than the 1_ times around the solar system free return orbit used in Case for Mars. A similar approach using electric propulsion is also feasible.

An alternate approach is suggested in which the sail might be manoeuvred into a halo orbit about Mars L-2. When exploration is complete, the sail would leave the L-2 orbit and swing by Mars prior to heading back to Earth. The crew would rendezvous during the swing by. These two approaches are compatible in that the L-2 parking concept might be used for early exploration missions while the flyby would provide crew rotation and resupply to a permanent outpost. The hardware would be much the same for either type of mission.

The primary advantage for parking the sail at L-2 is that it obviates the need for the sail to operate in circular orbit deep in the planetary gravity field.

Mars Surface Transport

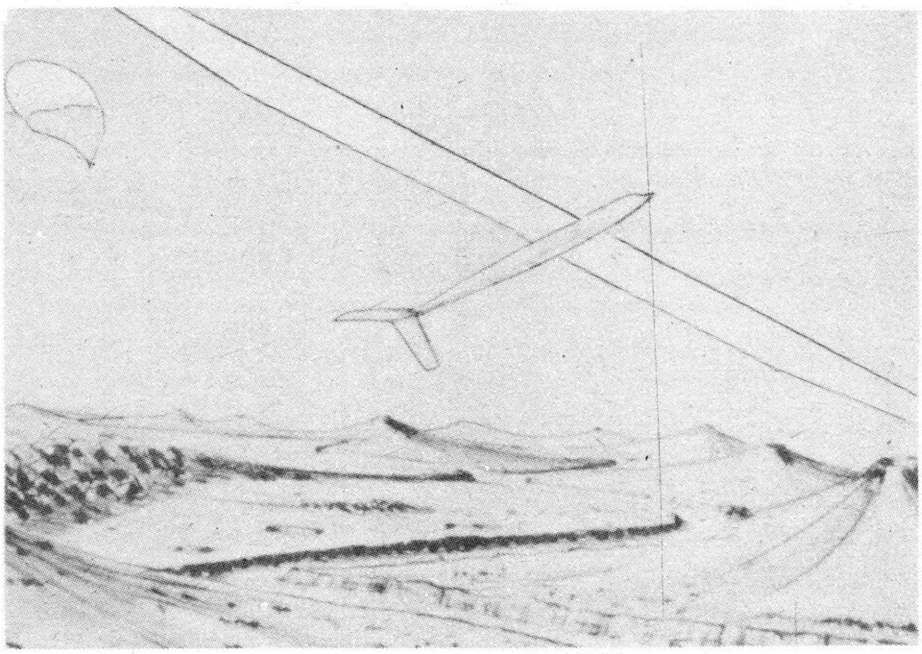
Although obvious, Wernher von Braun was among the first to state explicitly the need [7] for long range surface mobility on the Moon or Mars if the explorers are to do anything other than "...walk importantly about the base of their rocket ship", as one writer phrased it.

Conventional wisdom for both manned and unmanned rovers, as well as our Apollo experience, has favoured electrical rovers with battery power only. The Soviet Lunakhod used solar arrays to achieve longer operating life. The low power constrained the speed to be quite low but, since the vehicle was teleoperated from Earth, this was desirable in any case because of the control lag. Similarly, the US has studied long range Mars rovers using radioisotope thermoelectric generators (RTGs) for power. Again, the limited power constrains speed but, given our limited capability in robotics, that is just as well.

The battery powered Apollo lunar rovers, being designed for relatively short life and to be operated by a local driver, moved about at a spritely 6 or 7 km/hr. For exploration on Mars, at least this speed capability would be desired and for long range perhaps 3 or 4 times this speed might be useful. One would not always be able to go this fast but in clear smooth areas or along known trails, higher speed is desirable. Higher speed means more power. Add a requirement for long range and endurance and energy storage becomes a major consideration. Batteries become excessively heavy, which demands still more power and so on. RTGs are impractical for very high power levels both because of the mass and the very large amount of radioisotope required.

Nuclear reactors have occasionally been proposed for long range rover vehicles. While this may be technically possible, the practicality is suspect because of the massive radiation shielding required. Shadow shielding does not work well because of reflection and refraction of the radiation by the surface material and the atmosphere. Even if shadow shielding worked, forcing the crew to always be inside a 15 degree cone at the front of the vehicle seems undesirably restrictive.

A Mars airplane in flight. JPL



Solar powered automobiles have been built in recent years which show reasonable endurance and a fair turn of speed. The light weight and resulting fragility of these vehicles generally restricts their use to improved roads. The great weight of a pressurized rover is probably out of the realm of solar power. However, a lightweight unpressurized vehicle similar to the Apollo rover might be practical on Mars for daytime travel. The need to operate over unimproved surfaces might be counterbalanced by the reduced gravity so as to allow a sufficiently lightweight structure to provide reasonable performance capability. MarsÆ greater distance from the sun would require almost double the solar array area needed at Earth for a given power level.

As on Earth, the best choice for high energy density power storage is chemical propellant. The problem is, of course, that on Earth the majority of the propellant comes from the air while on Mars, with its basically inert atmosphere, both oxidizer and fuel must be carried. Nevertheless, if the storage and energy conversion mass can be kept low enough, chemical propellants maintain a substantial edge.

Von Braun proposed rovers powered by gas turbines which burned hydrogen peroxide and fuel oil with the flame temperature moderated by water injection. Residual propellant from the lander vehicle might also be used, with the combustion diluted with water to keep gas temperature at a level which the turbines could tolerate. This is not a bad concept. Although one might consider other engine cycles, the use of otherwise wasted residual propellant is clearly attractive. One might consider other thermodynamic cycles which would be useful and might eliminate need for the diluent water. Long range rovers are most compatible with room temperature storable propellants proposed by von Braun. The moderate cryogens such as oxygen and methane are more of a problem but still should be usable. Hydrogen, because of its low density, low temperature and probable loss rate, will be much harder to adapt for these purposes.

For long term use on Mars, it will be desirable to be able to refuel the chemical powered rover vehicles. The series of landings proposed by Baker and Zubrin would result in a series of stations across the planet with sites chosen to be within accessible range, by a rover or ballistic hopper, of each other. Exploration could branch out as far as the operating radius (approximately _ the range) of the rover. We had discussed, as an extension of the Case for Mars base the deployment of small "filling stations" powered by

small reactors, RTGs, or even solar power. Such units might be deployed either by unmanned landings or by manned rovers. In any case, a slowly spreading matrix of unmanned supply bases would allow human access to increasing areas of the planet and provide for rapid transport between the sites since energetic chemical propellants rather that the inherently power limited solar power units would be used.

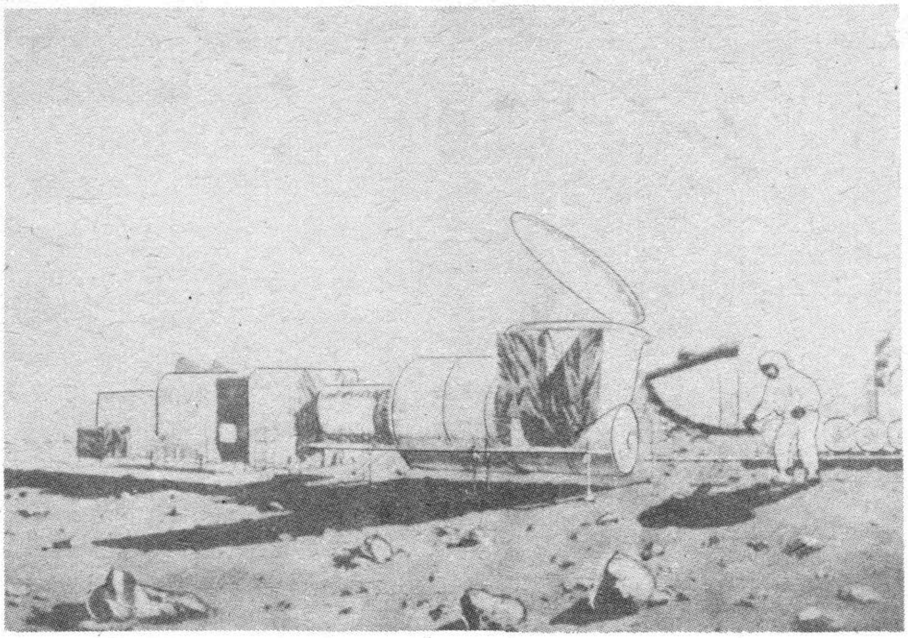
The question of what propellant might be used favours carbon monoxide and oxygen once more simply because the feedstock is readily available. The more energetic combinations would certainly be desirable but, as observed previously, these require water. Hauling water (or hydrogen) to the propellant manufacturing sites negates most of the advantages so it seems unlikely that these reactions would pay off. In the unlikely event that readily available liquid water exists, this conclusion might change.

In discussing transport about the surface of Mars, one should not overlook aircraft. The atmosphere of Mars is as thin as that of Earth at 30,000 m. Aircraft have been built to operate at that altitude on Earth and could certainly fly in the atmosphere of Mars. To fly at moderate speeds, a high aspect ratio wing with relatively low loading is indicated.

Factoring such a wing into the range equation along with the 0.38 gravity yields the potential of a very long range. Studies by Developmental Sciences Inc., sponsored by JPL [8], indicated that an aircraft of this type, using a monopropellant hydrazine "steam engine" to drive a large propeller, could achieve range of 2000 to 4000 km with a payload fraction of 33% to 13%. The fact that this combination of a relatively inefficient piston engine and a relatively low energy propellant is so effective bodes well for more energetic bipropellant combinations.

The possible use of energetic bipropellants, whether Mars-produced or residuals from the lander, offer considerable promise for long range, relatively high speed transport on Mars. The general comments that follow concerning use of such propellants apply equally well to aircraft and surface vehicles.

Complexity of the system is certainly increased with use of bipropellants both because of the need for dual propellant storage and feed systems and because the propellants deliver a much higher gas temperature than the decomposing hydrazine. This can be overcome either by operation far off the stoichiometric mixture (a substantial excess of one propellant) or by using the atmosphere as a diluent. Both approaches are undesirable, the latter because of the very large amount of energy required to compress the atmosphere to a useful pressure and the former because of the mass penalty of carrying extra material which contributes no energy.



A plant for manufacturing propellant from the Martian atmosphere. *Carter Emmart*

Several possibilities exist for using bipropellants at an efficient mixture ration without diluents. One possibility is that current materials work, particularly in ceramics, may lead to engines, either piston or turbine, which can withstand the temperatures inherent in near-stoichiometric operation. Another possibility is to use near-stoichiometric combustion, probably in a staged fashion, to heat the working fluid of a Stirling or Rankine cycle engine to a desirable operating temperature.

Waste heat rejection from closed cycle engines of these types is always a problem, especially for mobile systems. It can be a major difficulty for aircraft. Experience with earthly aircraft engines has shown that cooling drag can be a major percentage of total aircraft drag. The proposition becomes more difficult at Mars because of the reduced density of the atmosphere. An approach like that used on liquid cooled racing planes before World War 2, where the entire skin becomes a heat rejection surface, may be worth resurrecting. In any case this is clearly an area requiring more analysis.

An approach which ought to be investigated is the use of various bipropellants in fuel cells. This might work especially well with Mars-generated oxygen and carbon monoxide since both the reactants may be introduced as gasses and the product is a gas. Operation on methane and oxygen may also be possible. The electricity produced could be used to drive a light weight samarium-cobalt motor to turn the propeller. The product carbon dioxide returns to the Martian atmosphere in the same form as it was originally taken out. Operation of fuel cells on these and other propellant combinations would probably be a worthwhile field of research for use on Mars and perhaps on Earth as well.

This concept raises the question: Why not a battery powered airplane? The JPL/DSI studies indicate that this is possible if one invokes lightweight motors and optimistic energy density numbers for the batteries. The problem is that, to get the energy density required, the batteries must be non-rechargeable primary cells. Also, long aircraft range depends strongly upon reduction in mass as the flight proceeds. Batteries do not become lighter as the stored energy is used. To get appreciable range, the electric airplane must drop batteries as they are discharged. This might be acceptable for a one-shot "disposable" airplane but would not be suitable for long term multiple use.

Surface Operations

How might some of the vehicles discussed be applied to exploration? The application of rovers is, to an extent, obvious. Lightweight, unpressurized rovers would be used for short range transport, either for exploration or operational functions of a few hours duration where being confined in a pressure suit would be acceptable. If the vehicles are chemically powered, they could be substantially faster than the Apollo rover, thus allowing much longer traverses. An additional potential improvement, especially compatible with chemical propellant, is for the vehicle to provide life support consum-

ables to the crew, so greatly enhancing endurance. Thus, traverses of a few hundred kilometres (over slightly improved tracks) are not unreasonable for such vehicles.

Longer term and longer distance traverses would require the large pressurized rover previously discussed. Operating from or between propellant manufacturing sites, possibly using a small rover as an adjunct for trips into difficult or hazardous locations allows for major exploration as well as rapid operational movement from site to site.

How might the airplane discussed earlier fit in? An aircraft capable of carrying one or several persons would certainly be useful. Physical realities, however, would make such a vehicle rather large although not necessarily heavy. To minimize weight and resulting wing size, it might be desirable to leave the vehicle unpressurized, requiring pressure suits for the crew. This leads to the rather whimsical concept of an open cockpit aircraft operating over Mars.

The usefulness of a manned aircraft for both exploration and operational functions is obvious from analogy with Earth, though an aircraft need not be manned to be useful. Operating a small, unmanned vehicle as a remotely piloted vehicle (RPV) offers a variety of useful functions. Detailed photographic, magnetic, and compositional mapping over substantial areas is a possibility. In an operational application, the RPV could be sent out to create a photographic route map prior to a long range rover sortie. Having a high resolution map of the proposed route would make it much easier for the rover to make use of its speed potential as well as enhancing safety and possibly identifying points of interest along the route that might otherwise be missed.

Navigation methods used for unmanned aircraft on Earth would be applicable on Mars. The basic mode would no doubt be inertial. Such systems benefit from occasional updates which might be obtained from star sights or navigation satellites if such vehicles have been deployed. The kind of terrain matching used by cruise missiles on Earth might not be applicable because of the detailed profile maps required might not be available, though preliminary work at JPL several years ago indicated that an aircraft would most probably be able to navigate by landmark identification based upon moderate resolution (Viking orbiter class) satellite images. This mode is very little different from the case of a human pilot navigating by dead reckoning between landmarks.

Comparison of Scenarios

Enthusiasts of sprint missions will declaim against the perceived greater complexity, increased risk, or increased cost of the types of missions offered as more attractive alternatives.

The charge of greater complexity may in some degree be valid as concerns operations on Mars since, in Case for Mars at least, a greater variety and capability of vehicles and an array of propellant manufacturing sites were postulated. The Baker/Zubrin concept, carried to its logical conclusion would be similar. However, these complexities are, for the most part, ancillary. The mainline activities: launch from Earth, deep space flight, Mars landing, Mars departure, etc. are all much the same, differing mostly in detail. The Baker/Zubrin approach is actually simpler since it avoids an Earth orbit phase entirely. While a much more detailed analysis would be required to assess reliability and crew risk factors, it seems that, with proper planning, mission risk factors can be much the same for the various concepts.

An aircraft capable of carrying one or several persons would certainly be useful. Physical realities, however, would make such a vehicle rather large although not necessarily heavy.

Addressing crew risk more specifically, the Case for Mars and the expanded Baker/Zubrin approach offer one major advantage over other approaches. Both make use of the local resources and work to develop a permanent infrastructure on the surface of Mars. Once that infrastructure is in place and working, the ability to return to Earth becomes less essential. In Case for Mars of course, the aim is to provide a permanent base. While this is less the focus in Baker/Zubrin, at least in the early stages, the possibility for a continuing stay over clearly exists. In the more conventional mission concept, a survivable malfunction of the ascent stage or the return vehicle prior to liftoff would doom the crew to die on Mars when the limited supplies are exhausted. The alternative of an extra year or two on Mars continuing the work you went there to do; while it may not be as good as going home, certainly sounds more attractive.

Estimating costs is also speculative and will vary widely with assumption. It is not difficult to imagine developing and qualifying a propellant manufacturing system for under a billion dollars. This is a great deal of money but, in the strange economies of modern space transport,is only about 3 launches of a Shuttle or Shuttle-derived heavy lifter. Clearly, a technique that can save even a modest number of launches is a worthwhile investment.

The earlier comments regarding complexity also tie directly to cost. Most of the mainline developments will be common to all scenarios and, while the details may vary, the broad requirements and therefore, probably, the development costs will be much the same. Often, this will not be the result seen in analysis by large agencies of concepts which they view as "competing". An observer attempting to make an unbiased assessment would be well advised to consider the provenance of the numbers.

Conslusion

A variety of promising approaches to Mars exploration and utilization exist which have not been factored into conventional planning or have received only lip service. Properly applied, these concepts: propellant manufacturing, aerocapture, high speed rovers, airplanes, arguably at least offer far greater capability for little more cost. If humankind is to truly expand into this new world rather than pay a token visit, concepts of this sort must form part of the plan.

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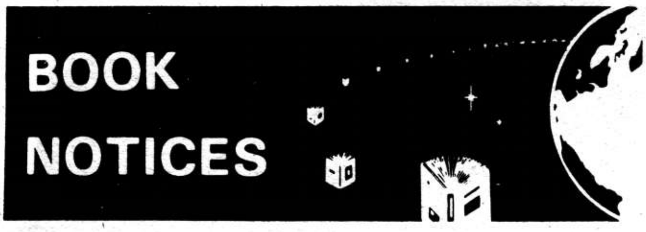


Space Technology and Planetary Astronomy

J.N. Tatarewicz, Indiana University Press, 10th & Morton Sts., Bloomington, Indiana 47405, USA, 1990, 190pp, $29.95.

Following the success of the first Sputnik launches, an area of great alternative interest to US planners was the exploration of the solar system. However, when the newly-formed NASA came to look for US expertise on the Moon and planets, they discovered that most astronomers had long since turned their telescopes away from them and towards the stars.

The problem thus arose of where to find suitable astronomers, able and willing to take part in planetary space projects.

The answer, as this book shows, was to *create* them. NASA, in effect, conjured into being not only an entire scientific and technological system of sophisticated instruments, but also the highly-trained people motivated to use them. Thus, from an obscure backwater in astronomy, the study of planets was boosted to one of major importance.

This book discusses planetary studies during the period between 1959 and 1981. Primarily, it is about a small scientific speciality which was suddenly elevated to prominence by other events and the response of those interested parties to their sudden new status. The book does not pretend to provide a detailed history of planetary science or even of planetary astronomy during this period. It concentrates solely on the NASA programme of research support and instrument development which sought to alleviate the shortage of planetary expertise and to provide the basis for a broader programme of planetary exploration by space probes to follow. It shows how the situation arose and how it interacted with many other elements in science, technology, politics and economics, besides its resulting effects.

In retrospect, NASA did its job too well for when budgets became tight during the late 70s, those scientists who had staked their careers in the support of a single patron found themselves facing a harsh reality.

Standing on the Shoulders of Giants: A Longer View of Newton and Halley

Ed; N.J.W. Thrower, University of California Press, 2120 Berkeley Way, Berkeley, CA 94720, USA, 429pp, £39.95.

The professional relationship between Isaac Newton (1642-1727) and his younger contemporary, Edmund Halley (1656-1742) was one of the most fruitful in the history of science. In 1686, Halley received the manuscript of *Principia* from Newton and, several years later, predicted the return of the comet that now bears his name, using Newton's Law of Gravitation.

For decades since, scholars have been puzzled by Halley's publication, at his own expense, of Newton's *Principia*, as well as his subsequent relationship with Newton. Even more enigmatic are Newton's concern with alchemy and the views of both scientists on theology.

In this volume, 18 scholars grapple with these questions, examining such matters as patronage and the institutions to which they relate as well as dwelling on the scientific advances which resulted.

Their aim is to provide further insight into what was, in effect, a scientific revolution and its relevance to present day problems.

Essentially, the book is divided into four sections. The first three relate to Newton, Halley and their relationships and attitudes. The fourth discusses comets. This last includes references to earlier appearances of Halley's Comet as well as to the first International Halley Watch viz the search for its recovery on its first predicted return in 1758.

Comet Halley: Investigations, Results, Interpretations

J.W. Mason, Simon & Schuster International Group, 66 Wood Lane End, Hemel Hempstead, Herts, HP2 4RG, 1990. Vol. 1 Organisation, Plasma Gas, 512pp, £58.95. Vol. 2 Dust, Nucleus, Evolution, 512pp, £58.95, (2 Vol. Set £106.00)

This major two-volume work contains a comprehensive review of the complex and diverse multi-national observational programmes carried out during Halley's Comet 1985/6 return.

Over 40 of the world's leading cometary scientists from 17 countries have contributed to a unique publication which provides definitive reference material on all aspects of the comet. Scientists from astronomy, physics, chemistry, meteoric research and history have all worked together to compile a work which features many new results.

Both volumes are divided into three sections, each of which examines some particular aspect of the comet and describes the results of the scientific investigations which were carried out. The first volume opens with a description of the structure of the International Halley Watch and addresses the importance of the enormous quantity of scientific data which was accumulated. The second section deals with the many studies conducted to unravel the complex interaction between the solar wind plasma and its magnetic field, with the plasma of the comet. The third section, on gas, describes the hydrogen coma of the comet, its jet and shell structures within the coma and variations in the gaseous output of the nucleus.

Volume 2 deals mainly with dust, the nucleus itself and cometary evolution. Halley's comet featured many dust emissions both in the form of jets and as a dust tail. The formation of meteoroid streams produced by the comet is also considered.

The following section, on the nucleus, summarises the detailed results obtained by Vega and Giotto while the section on evolution describes the complex processes which govern the long-term motion of the comet and how ancient observations have been used to refine its orbit over past epochs.

Composite CCD picture of Halley's Comet, the pointlike structure in centre, at a distance of 1735 million km from Earth (well beyond the orbit of Saturn) showing that its coma has now completely disappeared. *ESO*

Return to the Red Planet

E. Burgess, Columbia University Press, 562 West 113th Street, New York, NY 10025, USA, 1990, 222pp, $34.95.

Although the Mariner and Viking Missions have greatly enlarged our knowledge of Mars, many mysteries remain and the planet is now seen as a more complicated world than previously thought.

The author examines our view of Mars from its place in human mythology to the many recent discoveries about the planet. What is known about the planet is then explored, ranging from its cratered, volcanic terrain and mysterious dust storms to its climate, atmosphere and geology. The evidence for and against water on Mars and the arguments for and against the probability of life having evolved on the planet are also included, followed by a description of Soviet and American projects for Martian exploration and the exciting opportunities for international cooperation thus offered. Spin-offs, in terms of the economic potential of Mars in mining and manufacturing, as well as its usefulness as a base for further exploration of the Solar System, are suggested.

In short, the author argues for a bold and well-conceived plan for the exploration of Mars which will provide new opportunities and lead to many new creative challenges.

Topics in Remote Sensing 2: Archaeological Prospecting and Remote Sensing

I. Scollar *et al*, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1990, 674pp, £95.

Archaeological prospecting, when used in conjunction with image processing, has emerged as a major research tool. Its aim is to build a visual geographical system which can then be used by conservationists, historians and scientists alike.

Excavation is tantamount to destruction and results in the store of raw material about the past dwindling at an enormous rate. This book surveys some of the modern highly ingenious and non-destructive methods for detecting and mapping the remains of ancient cultures no longer apparent from the present-day surface. Its team of authors comprises an archaeologist, two geophysicists and an applied mathematician.

Techniques described include low-level air photography, magnetic, thermal, electric and electromagnetic geophysical prospecting. A mathematical analysis of the phenomena and measurements is given together with the techniques for the interpretation of results with the aid of computerized image processing. Spaceborne investigations are mentioned only marginally, for those archaeological discoveries found from satellite photographs have been largely fortuitous and of value, mainly, when relating to major complexes or structures. The methods and techniques described in this book, however, are also applicable to spaceborne operations in many cases and may increasingly be used for such purposes in future.

Basics of Modern Cosmology

A.D. Dolgov, M.V. Sazhin & Ya. B. Zeldovich, Editions Frontieres, B.P. 33, 91192 Gif sur Yvette Cedex, France, 1990, 247pp, Hard Cover FF240, US$40, Soft Cover FF170, US$28.

Modern cosmology is developing rapidly in two main directions. The first is concerned in the investigations into the structure of the Universe, background radiation and direct searches for the "hidden mass". The other is concerned with the early stages in the history of the universe, a domain popular not just with cosmologists but also with physicists, especially those probing the problems of elementary particles and fundamental reactions. The early history of the Universe provides a natural laboratory where extreme conditions applied, conditions totally impossible to duplicate, even with the most modern technology.

Much of contemporary science is concerned with attempting

to unite disparate disciplines, hence this book links elementary particle physics - the study of the very small - to cosmology - the study of the very big. This link is put forward as filling the vacuum within the framework of quantum theory, in the hope that the outcome will provide a coherent model of the formation of the universe and for the emergence of its internal structures.

The book thus takes the form, mainly, of a physicist's view of a field which is growing rapidly, yet first seen though through very different eyes over 2000 years ago.

The authors assume that the reader is familiar with special relativity. Knowledge of general relativity, though useful, is not necessary. However, a mathematical background is also taken for granted.

Exercises in Practical Astronomy Using Photographs: With Solutions

M.T. Bruck, Adam Hilger, IOP Publishing Ltd, Techno House, Redcliffe Way, Bristol, BS1 6NX, 1990, 108pp, £18.50.

Astronomy doesn't lend itself to class experiments: actual telescopic observations, even in good climates, has to be limited and restricted to cloud-free evening sessions.

This book will, therefore, undoubtedly prove to be an admirable adjunct to class tuition which is normally greatly restricted in scope as practical work in astronomy at elementary and intermediate levels presents difficulty for teachers.

This book fills the gap by providing class studies to accompany courses in elementary astronomy and astrophysics. It also aims to fill a need in astronomy tuition for "more advanced" resources. Some of the exercises included arose from teaching packages produced by the author with the cooperation of the Royal Observatory, Edinburgh, making use of film copies of first-class photographs taken with the UK 1.2 m Schmidt Telescope in Australia.

The set of exercises, covering 12 topics, is sufficient for a one-year course. Astronomical photographs of good quality have been included on which different types of objects may be studied with equipment as simple as rulers and protractors. Ample hints and work solutions are added to enable students to work independently of their tutors.

New Windows to the Universe

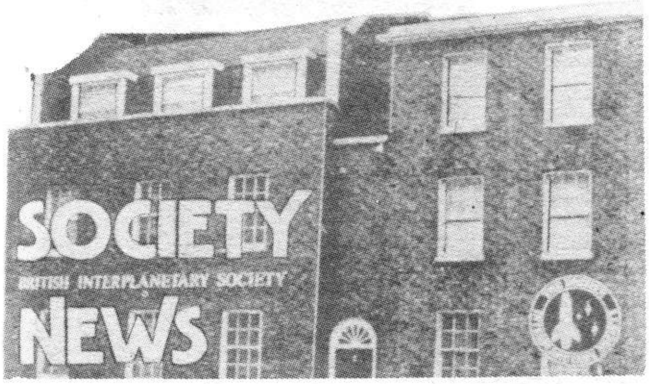
Eds. F. Sanchez and M. Vazquez, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, 1990, 564pp, £45.

This volume reproduces invited review papers and general lectures presented at the 11th European Regional Astronomy Meeting of the IAU in 1989, the shorter contributed papers being published separately elsewhere.

The title embraces six major areas of current interest in astrophysics. Approximately half the book is taken up by the first section which examines the Sun and Sun-like stars, though the "Sun-like" aspects need to be treated with some caution as they embrace a wide spectrum of stars, practically none of which would match as exact copies. In general, the parameters are stars with about the same mass and luminosity though, in fact, these span a large range in age, some being as old as the galaxy itself while others are newly-formed. Furthermore, due to the existence of their outer convection zones, the abundance ratios in the atmospheres of solar-type stars can vary considerably, a matter of some importance as it can yield information about the dynamical evolution of the galaxy.

Examination of solar-type stars are continued to some extent in the second major section, concerned with stellar structure and evolution and with Supernova 1987A receiving particular attention. It also includes a paper on supernova statistics, an area of great importance but one where a considerable amount of work still remains to be done.

The final sections of the book are concerned with astronomical instrumentation and a number of currently on-going astronomical projects.



£7,000 Bequest For HQ Development

The Council wishes to record with grateful thanks the receipt of a further sum of £7,000 from the Estate of the late James Hugo Ford, an enthusiastic Fellow of the Society who was most generous in his lifetime and who wished to assist the Society further on his decease.

This further contribution is very timely as work is at present in hand on the extension to our HQ premises, the refurbishment of the adjoining Conference Room and improvements to the Library. Mr Ford's bequest will go towards the cost of the Conference Room, which is very much in line with what he would have wished.

Gifts are of enormous help in the development of the Society's work: the fact that the Society has its own premises is largely due to the response by members and others to the Society's Development Appeal over past years. Besides this the Society has an urgent need for space-related items, either as collections or individual items of unique interest, embracing artifacts, books, records and papers suitable for retention in our Archives.

The Executive Secretary is always willing to give advice to members with such thoughts in mind. A specimen of the usual clause suitable for inclusion in a Will (or Codicil to a Will) is given below.

"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."

Gift Aid

A new Tax concession now in force allows companies and individuals to make single gifts to the Society and receive the benefit of tax relief. There is a statutory minimum limit of £600 but no effective upper limit.

This means that, for the first time ever, single gifts can be made to the Society, tax free, at any time. Benefits which the new scheme provides are:

(1) There is no commitment: gifts can be made at will.
(2) This will be very useful for those who receive bonuses or unexpected windfalls.
(3) It is even more attractive to higher rate taxpayers, because of the difference between the 25% basic tax rate and the higher rate they have to pay is actually refunded to them!
(4) It will suit companies, particularly, with a high profit one year which may not be repeated. Such companies could then make a one-off gift to reduce their tax liability.
(5) Companies giving gifts on the earlier basis may find that the previous discretion by the Inland Revenue in allowing these to be offset against tax is likely to be given less freely in future.

Administration of the new scheme is simple. There is a form to be signed, of course, but this can be done subsequently, unlike the requirements for a Deed of Covenant.

Asteroid David Hughes

Dr David W. Hughes, Reader in Astronomy in the Department of Physics, University of Sheffield and a Fellow of the Society, has joined the growing band of BIS Fellows with an asteroid named after him. The award is in recognition of his excellent research work on small bodies of the solar system, and especially on the relationship between comets, meteoroid streams and meteors. The citation also mentions his work as a popularizer of solar system astronomy and as Vice President of both the Royal Astronomical Society and the British Astronomical Association.

Dr David Hughes

Asteroid 1985 YP, accordingly, has now been numbered 4205 and named David Hughes. It was discovered on December 18, 1985, by Dr E.L.G. Bowell of the Lowell Observatory, Flagstaff, Arizona. At the time, Bowell was searching for small asteroids using the telescope at the Lowell's Anderson Mesa Station.

Most Asteroids remain well within the region between the orbits of Jupiter and Mars but 4205 is unusual. Ted Bowell, in a letter to Dr Hughes, says "I was able to pick out a Mars-crosser for you with the thought that you might show it to be an extinct comet".

David Hughes (No. 4025) is 4 kilometres across and orbits the Sun every 2 years 3 months and 7 days. At its closest it is 1.469 AU away and at its furthest, 1.984 AU away (an AU is an astronomical unit of 150 million kilometres, i.e. the average distance between the Earth and the Sun). The asteroid has an orbit inclined at 16.475 degrees to the orbit of the Earth. Due to the fact that 4205 crosses the orbit of Mars, the asteroid is perturbed considerably by the gravitational field of that planet and this could, over a period of a million or so years, cause it to hit the surface of either Mars or Earth. If this happened, asteroid David Hughes would produce a crater some 100 km across.

Asteroid 4205 has an absolute magnitude of 14.6 so, at its closest to the Earth, it is about 600 times fainter than the faintest star visible with the naked eye. One needs a telescope with an objective mirror larger than 16 inches in diameter to see it with ease.

Minor Planet Compendium

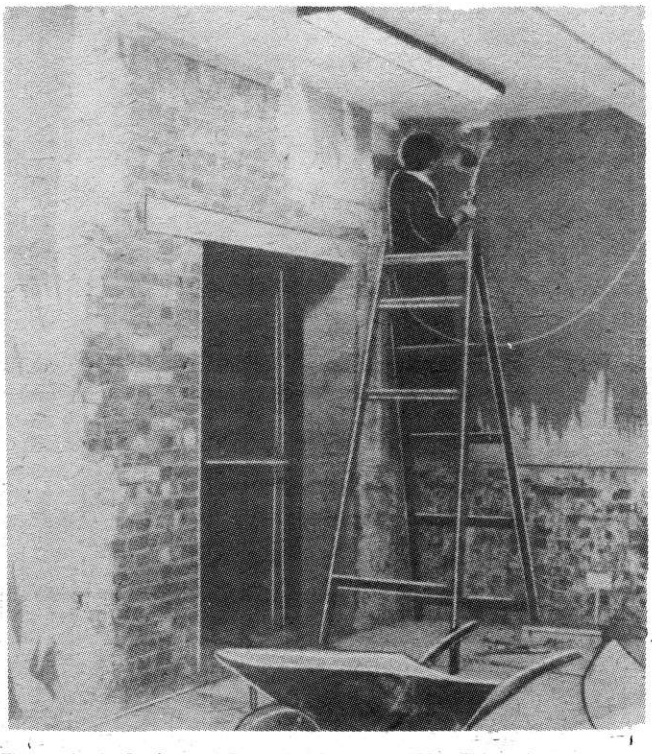
The Chairman of the new Working Group on the Origin of Minor Planet Names of the International Astronomical Union (IAU) reports that work is well under way on this dictionary. With a total number of minor planets now exceeding four thousand, only 160 names have unknown origins while 59 more are uncertain or questionable.

Conference Room

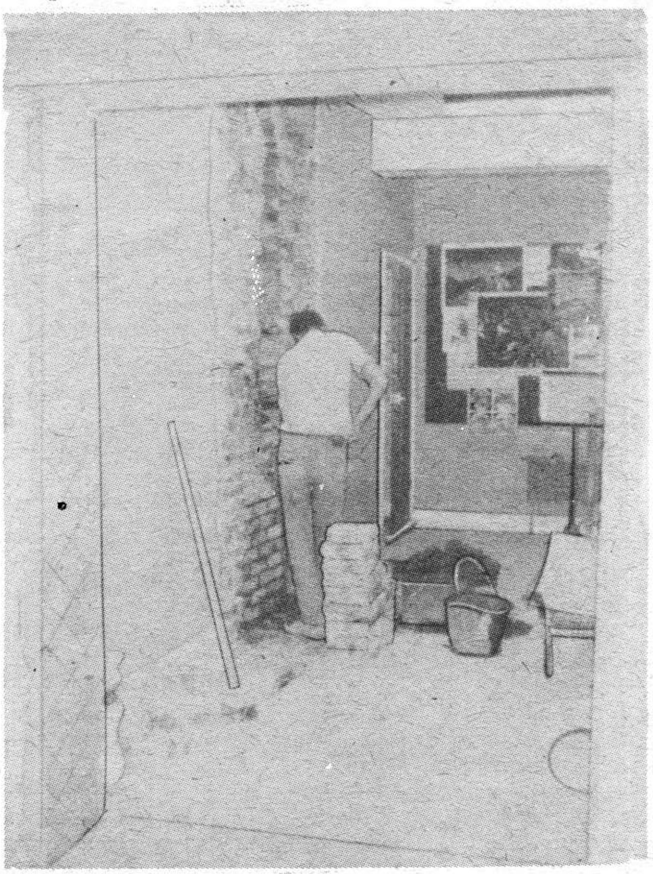
Members may be interested in a few details about the refurbishment of the Conference Room.

Contractors have been at work installing a new ceiling, others installing a combined heating and ventilation system of mammoth proportions, while an electrician has been renewing the lighting system completely. The result of all this has been that debris has been accumulating at a much faster rate than its removal. Added to this is the fact that the work is really a race against time. Not only has the building and reconstruction work to be completed but also re-decorated to make both the Conference Room and Library usable again for our future meetings programme.

On seeing the Conference Room recently Professor Groves commented *"We've turned the corner"*. In spite of the continuing chaos and disorder, there are signs of "things taking shape" and the Spring should soon see these much-improved facilities in place.



The Society's Conference Room in November 1990. The archway connects with the newly-built extension which will serve as an annexe to the main Conference Room and as an exhibition area.



Work in hand in November 1990 on the removal of an obsolete chimney in the Library. The photo is taken from within the extension that has now been added. It shows a part of the original Library through a connecting archway that has been cut in what had been the former outer wall.

Camille Flammarion Medallion

The Society has acquired a rectangular bronze medallion (60 mm x 75 mm) issued by the Astronomical Society of France in 1942 to commemorate the 100th Anniversary of the birth of its Founder, Camille Flammarion (1842 - 1925). It shows the bearded features of Flammarion on the front and his observatory at Juvisy in 1883 on the reverse. It also bears the name Abel La Pleur, Sculptor.

Flammarion studied at the Paris Observatory from 1858 - 1862 under Le Verrier. He founded the monthly magazine *l'Astronomie* in 1882 and, after moving to the Observatory at Juvisy in 1883, founded the Astronomical Society of France in 1887.

He published many works to popularise astronomy, *Popular Astronomy* (1894), perhaps, being his best-known work.

OBITUARY

We regret to record the death of Robert James Bremner, a Fellow of the Society for over 40 years. The Late Mr Bremner was a signatory to the Society's Constitution when it was incorporated in 1945 and served on its Council during 1946. He subsequently emigrated to America where he made a new home.

The following letter received from his wife conveying the sad news also encapsulates his life-long interest in the work of the Society.

I am writing to inform you that my late husband, Robert James Bremner died on March 4th 1990.
He was a lifelong member of your Society and read all of your publications with great interest.
Last year he was in England and wanted to go to your offices to see the place so, he and I walked there from Waterloo station but, unfortunately your office was closed as it was a Saturday morning.
He was disappointed but still glad that he saw the buildings and place from outside as he'd always wanted to go there.
I believe that the British Interplanetary Society helped, and inspired his interest in his work in aerospace, which is why he really came to America in the first place.

Pamela Jean Bremner

SOCIETY MEETINGS DIARY

SYMPOSIA

27 March 1991 **10 am - 4.30 pm**

SOUNDING ROCKETS

This symposium will trace the history, development and application of Skylark, which has contributed extensively to Upper Atmospheric and Microgravity Studies over many years.

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

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

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

6 March 1991 **7 pm - 8.30 pm**

TREASURES OF THE RAS LIBRARY

P.D. Hingley

This talk will describe astronomical literature which is both historically significant and of aesthetic appeal.

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 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 wartime 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.

JOINT INTERNATIONAL CONFERENCES

11-13 April 1991

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: Ministry of Research and Technology, 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.