MARCH 1986

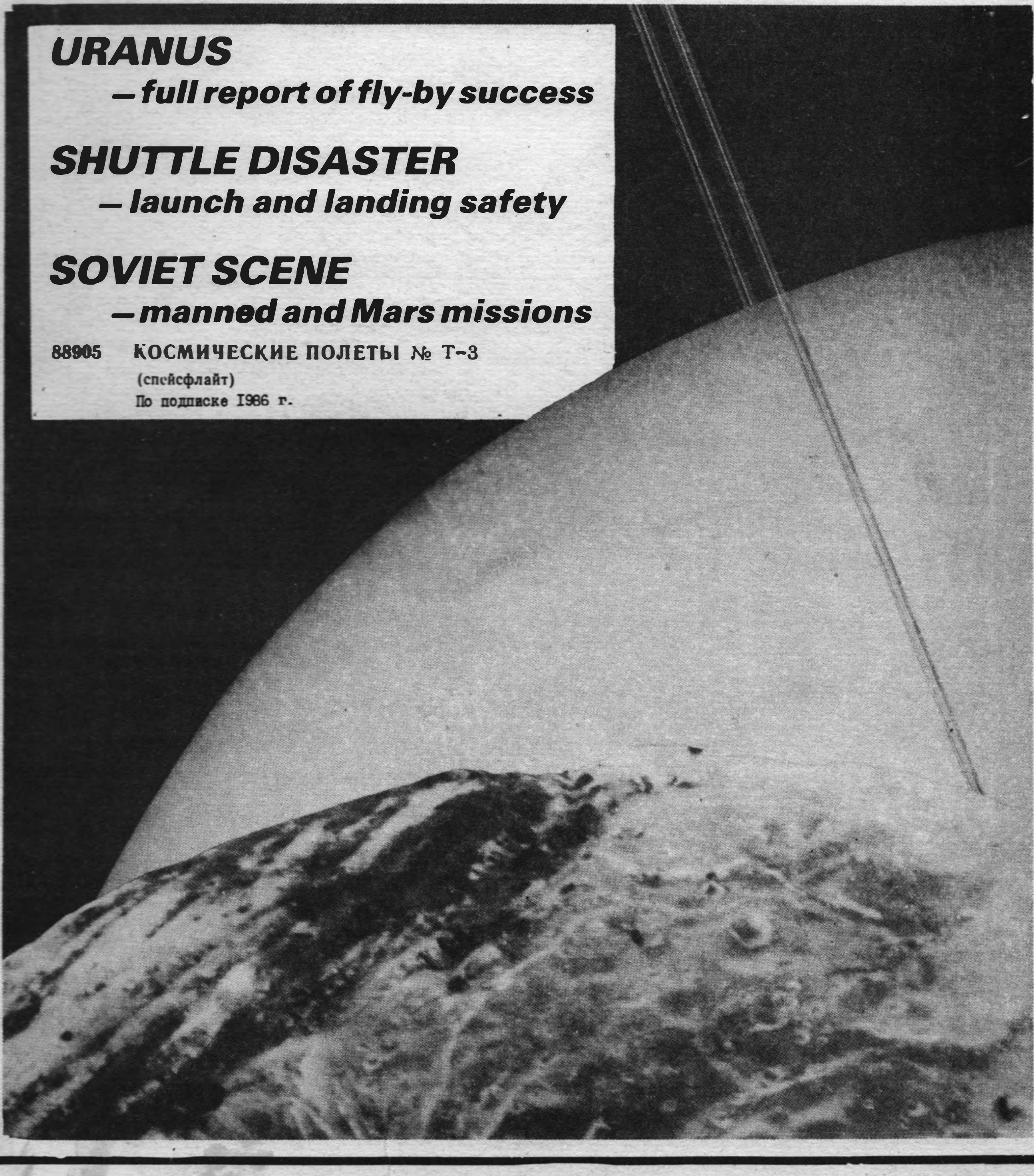
Spaceflight

The International Magazine of Space and Astronautics

URANUS
—full report of fly-by success

SHUTTLE DISASTER
—launch and landing safety

SOVIET SCENE
—manned and Mars missions



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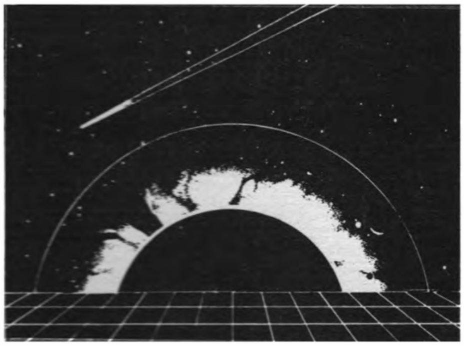

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Vol. 39 No. 3 March 1986

Front Cover: A future visitor preparing to land on the icy surface of Uranus' moon Miranda might witness this stunning view towards the planet's cloudtops, some 105,000 km away. This montage of Voyager 2 images obtained in January shows Uranus overlaid with an artist's conception of the planet's dark rings. A portion of the Voyager close-approach image of Miranda in the foreground shows the view along one of the huge canyons that the spacecraft has revealed on the moon's surface. More photographs and a report of this exciting phase of the Voyager 2 mission start on page 120.
JPL

Spaceflight
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COURAGE AND COMMITMENT

The aftermath of the Shuttle launch disaster on January 28 now casts a shadow of uncertainty over a major part of the US Space Program. The technical reasons for the vehicle's structural failure need to be resolved beyond any possible doubt and a Board of Enquiry has this task in hand. A large amount of photographic and material evidence is available for evaluation and the precise sequence of events leading to the failure should not be difficult to identify. Less certain is the time-scale for implementing the remedy as this may involve re-design, manufacture and extensive testing to ensure that no repetition can possibly occur.

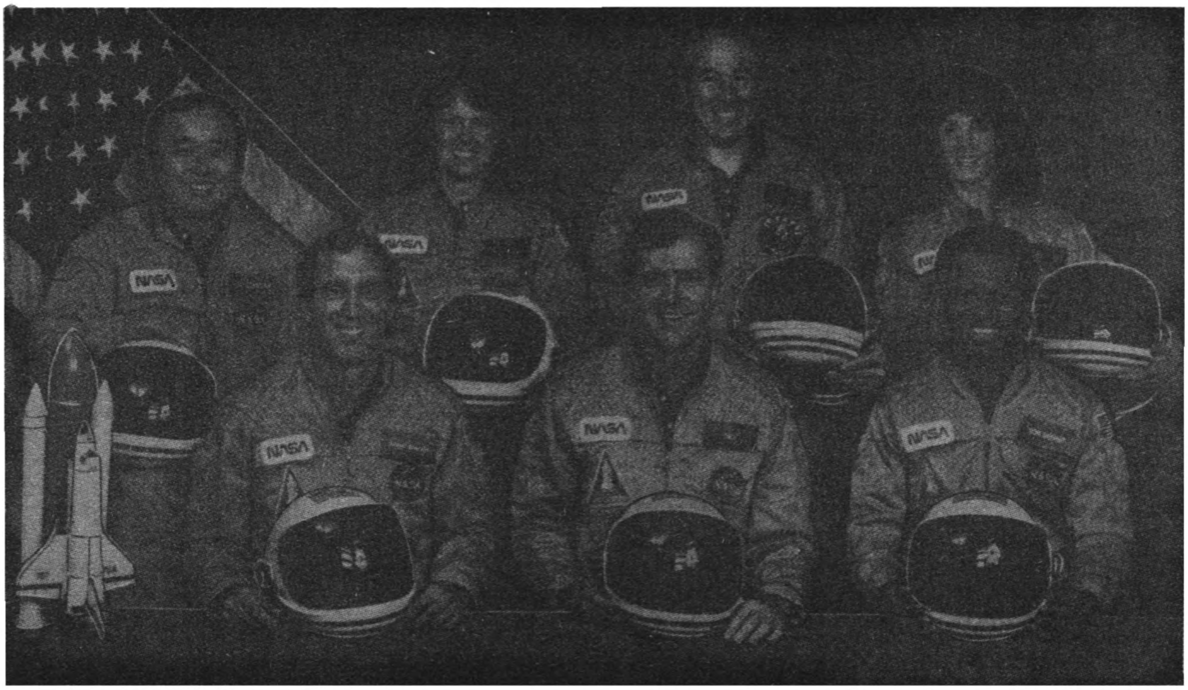
With the Shuttle fleet grounded for a lengthy period, a whole range of Space endeavours scheduled for 1986 will inevitably be hit. The urgent need for of new communications satellites to be placed in orbit can probably be partially met by re-allocating these payloads to unmanned launch vehicles, but for scientific payloads which lack such financial backing the outlook is bleak. In the case of the two interplanetary spacecraft Ulysses and Galileo, only a limited launch window is open for 1986 beyond which their launch must wait until 1987. But the one aspect of the US Space Program for which no alternative exists is the Manned Space Program.

The Shuttle was designed and introduced in the confident belief that man has an essential role to perform in Space – that Space will be just as much a part of his domain as land, sea and air. To date, the activities of astronauts on EVA's and in returning defective spacecraft to Earth have confirmed this belief. The seven or eight crew capacity of the Shuttle has enabled Payload Specialists to monitor the performance of the various Shuttle payloads and also to extend the experience of space flight to the international community.

The first UK astronaut was scheduled to have flown in Space under this arrangement in June. Ironically, the ill-fated Challenger carried the first civilian passenger in a demonstration of the accessibility of Space to the ordinary person. The reversal of fortunes for the Shuttle Program and for NASA could not have been more sudden or more extreme.

As the initial shock of the disaster with the tragic loss of the seven crew members passes, it will be seen that nothing fundamental has happened to change the view that man has an essential role in spaceflight. The plans for a Space Station in the 1990's are just as meaningful now as they were before January 28. The NASA organisation has shown courage and dedication over the years and we are confident that these qualities will enable it to overcome the body-blow that it has been dealt by the loss of the Challenger and crew and will see it through to success again.

Viewpoint



Francis Scobee (46), the spacecraft commander, was on his second flight, the first being in 1984 when he piloted mission 41C.

He became an astronaut in 1978 and prior to that attended the Aerospace Research Pilot School at Edwards Airforce Base, flying such varied aircraft as the Boeing 747, the X-24B, the F-111 and the C-5. In total he had logged more than 6,500 hours of flying in 45 types of aircraft.

He was married and had two children.

Michael Smith (40) was Challenger's pilot. He flew A-6 Intruders and completed a Vietnam cruise while assigned to Attack Squadron aboard the USS Kitty Hawk.

Smith, married with three children, became a NASA astronaut in 1980. He had flown 28 types of civilian and military aircraft, logging over 4,300 flying hours.

Judith Resnik (36) was one of three mission specialists on Challenger. She had a degree and PhD in electrical engineering.

She became an astronaut in 1978 and had previously flown on mission 41D logging 144 hours in space.

Ronald McNair (36) was mission specialist and had also joined the astronaut group in 1978. He had a degree and PhD in physics and while at the Massachusetts Institute of Technology performed some of the earliest developments of chemical and high pressure lasers.

Married with two children, he flew on mission 41B, which saw the first flight of the manned manoeuvring unit, and had logged 191 hours in space.

Ellison Onizuka (39), mission specialist, became a NASA astronaut in 1978.

He was an aerospace flight test engineer for the Sacremento Air Logistics Center.

A mission specialist on Shuttle flight 51C, the first dedicated DoD mission, Onizuka had spent 74 hours in space. He was also married and had two children.

Gregory Jarvis (41), payload specialist, was an electrical engineer and worked designing circuits on the SAM-D missile. Later, as a communications payload engineer he worked on advanced tactical communications satellites before joining Hughes where he was a subsystem engineer on the Marisat programme.

He was married and had no children.

Christa McAuliffe (37), a high school teacher, chosen to be the first private citizen to go into space. She had taught English and American History since 1970 and prior to selection as NASA Teacher in Space also taught economics, law and a course she developed "The American Woman".

McAuliffe, married with two children, was selected as primary candidate for the NASA Teacher in Space project in July 1985.

To the Chief Administrator, NASA

The British Interplanetary Society extends its deep condolences to NASA and the relatives and friends of the gallant crew of the Space Shuttle Challenger who on 28th January 1986 gave their lives in the great endeavour of Space Exploration.

BIS, London

72 Seconds to Disaster

The Challenger launch tragedy has sent a shock wave through the American space programme. In this special 12-page report* Spaceflight *examines the immediate implications and looks in detail at important aspects of the Space Shuttle programme. Written by Clive Simpson, Keith Wilson, Frank Sietzen, Roelof Shuiling and Gordon Harris.

Mission 51L

Challenger rose off the launch pad at 1638 GMT on January 28 and was climbing smoothly when it suddenly exploded in a huge fireball about 90 seconds after lift-off. Debris from the 100 ton spacecraft came down over the Atlantic Ocean about 29 kilometres down range from the Cape Canaveral launch site.

The explosion occurred at a height of 15,000 metres while the Shuttle was travelling at three times the speed of sound. Ground control had given the order to throttle up to full power only seconds before.

Television cameras covering the launch live showed flaming debris trailing with white smoke as it fell into the sea. The solid rocket boosters could also be seen spiralling out of control. They were destroyed by remote control at the order of flight safety officers to prevent any possible impact on populated areas.

No escape capsules or emergency parachutes were carried by the Shuttle and in such an accident it is doubful whether such devices could have been used effectively by the crew.

The deaths of the seven member crew made this the worst disaster in the history of the American space programme and the first ever in-the-air tragedy out of 56 manned missions.

A MESSAGE OF HOPE

President Reagan mourned the loss of seven American astronauts in the explosion of the Space Shuttle on January 28 and praised their courage in remarks to the nation over television and radio.

Nineteen years ago, almost to the day, we lost three astronauts in a terrible accident on the ground. But we've never lost an astronaut in flight; we've never had a tragedy like this. And perhaps we've forgotten the courage it took for the crew of the Shuttle. But they, the Challenger Seven, were aware of the dangers, but overcame them and did their jobs brilliantly. We mourn seven heroes.

We have grown used to wonders in this century. It's hard to dazzle us. But for 25 years the United States space program has been doing just that. We've grown used to the idea of space, and perhaps we forget that we've only just begun. We're still pioneers. They, the members of the Challenger crew, were pioneers.

And I want to say something to the school children of America who were watching the live coverage of the Shuttle's take-off. I know it's hard to understand, but sometimes painful things like this happen. It's all part of the process of exploration and discovery. It's all part of taking a chance and expanding man's horizons. The future doesn't belong to the faint-hearted. It belongs to the brave. The Challenger crew were pulling us into the future, and we'll continue to follow them.

I've always had great faith in and respect for our space program, and what happened today does nothing to diminish it. We don't hide our space program. We don't keep secrets and cover things up. We do it all up front and in public. That's the way freedom is, and we wouldn't change it for a minute.

We'll continue our quest in space. There will be more Shuttle flights and more Shuttle crews and, yes, more volunteers, more civilians, more teachers in space. Nothing ends here. Our hopes and our journeys continue.

I want to add that I wish I could talk to every man and woman who works for NASA, or who worked on this mission, and tell them, "Your dedication and professionalism have moved and impressed us for decades. And we know of your anguish – we share it."

There's a coincidence today. On this day 390 years ago, the great explorer, Sir Francis Drake, died aboard ship off the coast of Panama. In his lifetime, the great frontiers were the oceans and an historian later said, "He lived by the sea, died on it, and was buried in it."

Well, today, we can say of the Challenger crew their dedication was, like Drake's, complete. The crew of the Space Shuttle Challenger honoured us by the manner in which they lived their lives. We will never forget them, nor the last time we saw them, this morning, as they prepared for their journey and waved good-bye, and "slipped the surly bonds of Earth" to "touch the face of God."

Launch of Challenger had been postponed three times due to poor weather at the Cape and on the morning of lift-off had been put back some two hours because of ice on the launch pad caused by freezing overnight temperatures. At one point during the night long icicles were seen hanging from the Shuttle's giant launch pad structure.

The following is a transcript of mission control communication and commentary:

Public Address Officer: One minute away from picking up the count for the final 9 minutes of the countdown in today's launch. The countdown is simply a series of checks that people go through in preparation to insure that everything is ready for flight: The countdown for a launch like the 51L mission is four volumes and more than two thousand pages.

Fifteen seconds away from resuming the countdown and looking at the launch of 51L at 11:38.

And we are at T-9 minutes and counting. The ground launch sequencer program has been initiated.

Voice: APU voice recorder?

Challenger: LPS will do.

Voice: An LPS place all (garble) printer pointers on one.

Challenger: Okay, got it.

Voice: And I still need your verification when you get motion on the opposite corner.

Challenger: Initial copy.

Voice: (garble) this was not performed.

PAO: T minus 8 minutes 30 seconds and counting. All the flight instrument recorders are turned on. Mission Control has turned on the auxiliary data system. This package of flight data from the aerodynamic information coming back as the Orbiter flies through the atmosphere. Coming up on the eight minute point. T minus 8 minutes and counting. Orbiter Test Conductor, Roberta Wryrick, has requested that Houston send the stored program commands which is the final update on antenna management based on lift-off time and sets the system which makes the Orbiter compatible with down range tracking stations.

Challenger: Okay, that's the point.

PAO: T minus 7 minutes, 30 seconds and the ground launch sequencer has started retracking the Orbiter crew access arm. This is the walkway used by the astronauts to climb in the vehicle. And that arm can be put back in place within about 15 to 20 seconds if an emergency should arise. Coming up on the 7 minute point in the countdown. T minus 7 minutes and counting. The next major step will be when pilot Mike Smith is given a go to perform the auxiliary power unit prestart. T minus 6 minutes and 30 seconds and counting.

Voice: (garble) voice recorders?

Challenger: Roger, wilco.

PAO: Coming up on the 6 minute point in our countdown. – can you prestart?

Challenger: (garble) some more.

PAO: T minus 6 minutes and Orbiter Test Conductor has given pilot Mike Smith the go to perform the auxiliary power unit prestart. Mike has reported back that it is in work. He will configure switches in the cockpit to put the auxiliary power units in the ready to start configuration. Mike Smith reporting that prestart is complete.

T minus 5 minutes 30 seconds and counting and Mission Control has transmitted the signal to start the on-board flight recorders. The two recorders will collect measurements of Shuttle system performance during flight to be played back after the mission. Coming up on the 5 minute point. This is a major milestone where we go for auxiliary power unit start. T minus 5 minutes.

Challenger: Lets go for orbiter APU start. PLP022 performed APU start.

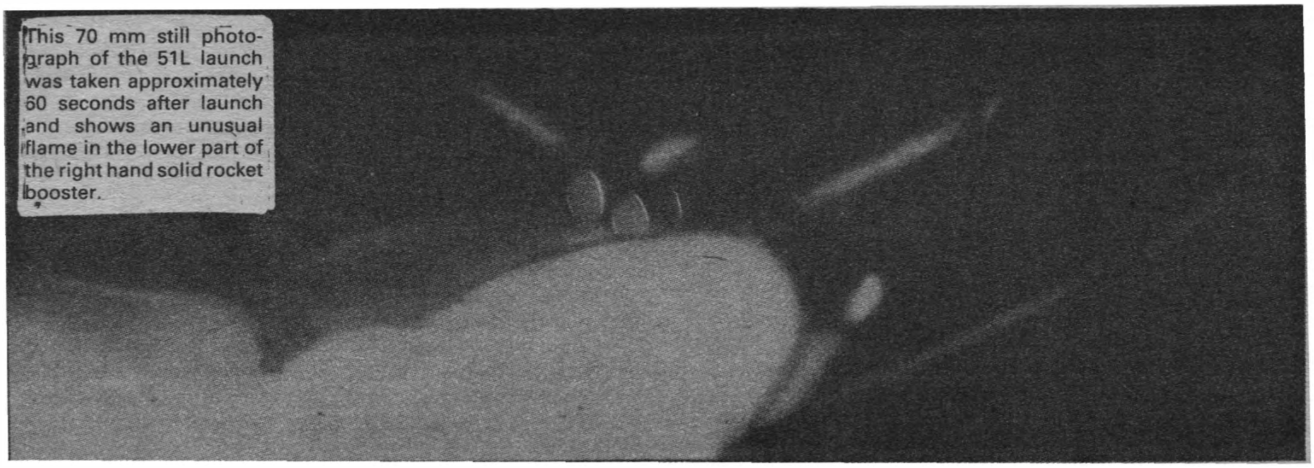
PAO: And we had the pilot ordered to perform the APU restart. Lox replenish has been terminated and liquid oxygen drain back has been initiated. Pilot Mike Smith, now flipping the 3 switches in the cockpit to start each of the 3 auxiliary power units.

T minus 4 minutes 30 seconds and counting. The solid rocket booster and external safe and arm devices have been armed. We have had a report back from Mike Smith that we have three good auxiliary power units. Main fuel valve heaters on the Shuttle main engines have been turned on in preparation for engine start.

T minus 4 minutes and counting. The flight crew has been reminded to close their air tight visors on their launch and entry helmets. And a final purge sequence of the main engines is under way. T minus 3 minutes and 45 seconds and counting. The Orbiter aerosurface test is started. The Orbiter flight control surfaces are now being moved through a preprogrammed pattern to verify that they are ready for launch. T minus 3 minutes and 30 seconds and counting. Orbiter ground support equipment power bus has been turned off and the vehicle is now on internal power. T minus 3 minutes 15 seconds. Aerosurface checks are complete and aerosurfaces in launch configuration. Gimbal checks of the Orbiters main engines are now under way.

T minus 3 minutes and counting. Gimbal checks now complete. External tank liquid oxygen pressurisation has started and purging of the Shuttle's main engines is terminated. T minus 2 minutes and 44 seconds and counting. Retraction has started of the Gaseous Oxygen Vent hood and the ground launch sequencer will make a final check to make sure that that arm is fully retracted at T minus 37 seconds. T minus 2 minutes and 20 seconds. And we have had the pilot, Mike Smith has cleared the caution and memory system. No unexpected error is reported. Liquid oxygen, all its pressure checks are under way. And the liquid oxygen tank approaching flight pressure.

T minus 2 minutes and counting. The liquid hydrogen replenish has been terminated and liquid hydrogen



This 70 mm still photograph of the 51L launch was taken approximately 60 seconds after launch and shows an unusual flame in the lower part of the right hand solid rocket booster.

pressurisation to flight level is under way. The vehicle is now isolated from all ground propellant and fluid loading equipment. T minus one minute and 44 seconds and counting.

Coming up on the 90 seconds point in our countdown. 90 seconds and counting. The 51L mission ready to go. The liquid hydrogen tank now at flight pressure and all three engines ready to go. Coming up on the one minute point in our countdown. Sounds suppression water system now armed. Hydrogen burn ignitors have been armed. These ignitors will be fired at T minus 10 seconds to burn off any residual hydrogen gas. T minus 45 seconds and counting. The solid rocket booster flight instrumentation recorders have gone into the record mode. Coming up on the 30 second point in our countdown. T minus 30 seconds and we have had a go for auto sequence start. The SRB hydraulic power units have started. T minus 21 seconds. And the solid rocket booster engine gimbal now under way. T minus 15 seconds. T minus 10, 9, 8, 7, 6, we have main engine start, 4, 3, 2, 1 and lift off, lift off of the 25th Space Shuttle mission and it has cleared the tower.

Mission Control Center: Watch your roll, Challenger.

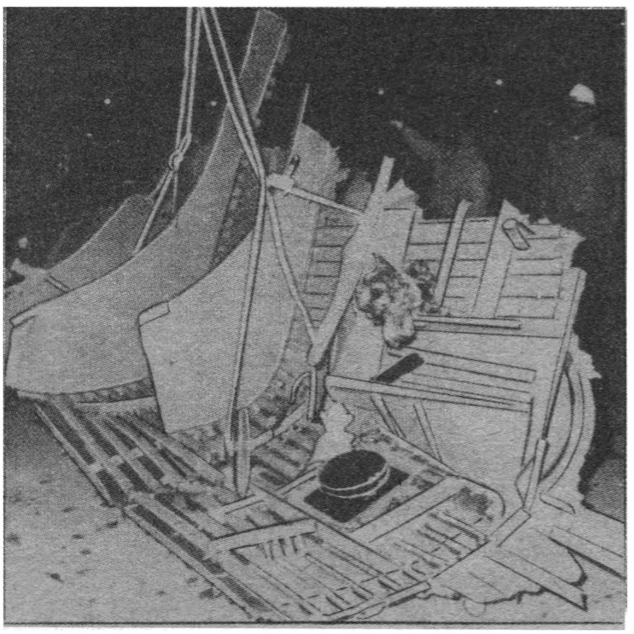
PAO: Roll program confirmed. Challenger now heading down range. Engines beginning throttling down now at 94 percent. Normal throttle for most of the flight is 104 percent. Will throttle down to 65 percent shortly. Engines are at 65 percent. Three engines running normally. Three good fuel cells. Three good APU's. Velocity 22 hundred 57 feet per second. Altitude 4.3 nautical miles, down range distance 3 nautical miles. Engines throttling up, three engines now at 104 percent.

MCC: Challenger, go with throttle up. Roger, go with throttle up.

PAO: One minute, 15 seconds, velocity 29 hundred feet per second, altitude 9 nautical miles, down range distance 7 nautical miles.

Flight controllers here looking very carefully at the situation. Obviously a major malfunction. We have no downlink. We have a report from the flight dynamics's officer that the vehicle has exploded. The flight director confirms that. We are looking at checking with the recovery forces to see what can be done at this point. Contingency procedures are in effect. We will report more as we have information available. Again, a repeat, we have a report relayed through the flight dynamics officer that the vehicle has exploded. We are now looking at all the contingency operations – waiting for word of any recovery forces in the down range field.

Wreckage from Challenger retrieved from the Atlantic Ocean and returned to Cape Canaveral aboard the USCC Cutter Dallas.



FLIGHT RECORD

Gordon L. Harris reports from the Cape

The US space programme came to dead halt following launch of Challenger on its 10th mission January 28 at 11:38 am Eastern Standard Time. The orbiter and its crew of seven vanished in a giant fireball approximately 72 seconds after liftoff. Three Shuttles remain idle at Kennedy Space Center while the agency seeks an explanation for the tragedy.

Adult members of astronaut families and some children stood in horror watching meandering vapour trails in a blue, cloudless sky. Debris rained down into the Atlantic Ocean for more than 30 minutes after the giant flareup.

NASA placed the cost of Challenger at $1.2 billion. With it was consumed a $100 million satellite, part of the worldwide tracking and data relay system, and a smaller device intended to photograph Halley's comet.

Challenger, second of the fleet to roll out of the Rockwell production plant in Palmdale, California, made its debut as STS-6 in April 1983. Later that year the orbiter carried the first US female astronaut, Sally Ride on STS-7 and Guion Bluford, first black astronaut, on STS-8. The ship completed Mission 41D in February 1984, first to land on the KSC runway after a successful mission. Two more flights followed in April and October when Mission 41G carried seven, the largest crew to be launched at the time.

In May, 1985 Challenger carried Spacelab for its first mission and in July it became the first orbiter to "abort to orbit" when No. 1 main engine failed prematurely. In October, 1985 the orbiter carried the first mission for another country, the West German sponsored Spacelab. And its final launch was the first from remodeled Complex 39B, last used for Apollo-Soyuz in 1975.

The mishap could not have occurred at a worse time for NASA. Its administrator is on leave to defend himself against government charges related to his employment at General Dynamics before joining the agency. Jesse Moore, nominal chief of the Shuttle programme, who gave the "go" signal for Challenger's launch, has been chosen to head Johnson Space Center and is now in the midst of the official inquiry. What's more, NASA had begun to justify its new budget request to Congress.

There were strong indications from Washington that despite brave talk of "we won't quit" by Mr. Reagan and others, Congress will insist upon a thorough, time consuming inquiry that may question the continuation of Shuttle flights.

Will NASA try to replace Challenger with a fifth Shuttle? Jesse Moore said the Rockwell plant is still turning out Shuttle spares and could be turned into production but no one was ready to step forward and commit more than $1 billion.

Two satellites built for Shuttle launch are too heavy for Delta vehicles and would require Atlas Centaur. General Dynamics, the builder, has three vehicles that will carry Navy navigation satellites. No one has yet bought such a vehicle for commercial launch. Two more satellites supposed to be launched in 1986 can only be handled within Shuttles.

Air Force Under Secretary Edward Aldridge told Congress in July, 1985 that a four Shuttle fleet would satisfy defence needs. Ten missions per year, he said, will be required for these missions – any other flights essential to the Strategic Defence Initiative would be additional Shuttle missions. When he testified Aldridge said a fifth Shuttle could be justified only by commercial usage. Rockwell international estimated four years would be needed to construct another orbiter.

PLANNING FOR AN EMERGENCY

By Keith T. Wilson

One of the most dangerous phases of a Space Shuttle mission is the launch when a serious malfunction is most likely to occur. Crews are well trained in four available abort options, which can be initiated after booster separation to enable both Orbiter and crew to return safely to Earth. Should an emergency occur before normal booster separation, no abort procedure is immediately available. Unfortunately the explosive nature of the malfunction with mission 51L offered no hope of survival for the crew.


Challenger lifts off from pad 39A on its maiden flight in April 1983.

Introduction

During early Shuttle flights Orbiter Columbia was fitted with ejection seats for emergency use by the two-man crews during the launch phase. However from STS-5, the first operational mission, ejection seats were no longer viable due to the enlarged number of crewmembers.

Four launch abort modes are currently available and selection depends on the altitude that the Shuttle has reached when the emergency occurs. They are (from the earliest possible abort to the last): Return to launch site (RTLS), Trans-Atlantic or Trans-Pacific landing (TAL, TPL), Abort once around (AOA) and Abort to orbit (ATO).

Abort 1

Return to launch site is put into operation if there is loss of thrust on a main engine or some other serious systems failure during the first four minutes of flight which might require an immediate return. Although an abort might be indicated as soon as the Shuttle clears the tower it is not initiated until the Solid Rocket Boosters separate and the Orbiter and External Tank reach an altitude of 107 km at which point a pitcharound manoeuvre is possible. Pitcharound brings the Orbiter from the inverted position it adopts during ascent to an upright one in which it is pointing back towards the launch site. Those main engines remaining operational would assist in the return flight, as would the two Orbital Manoeuvering System engines and a number of thrusters. Following depletion of fuel the Orbiter would pitch down, release the External Tank and glide back to the landing site,

Mission 51F

Challenger Aborts to Orbit

by Roelof L. Shuiling

Challenger's ninth flight (51F), the nineteenth Shuttle mission and the fiftieth US manned spaceflight, came about as close to a launch without actually launching as is possible. On July 12, 1985 the Shuttle aborted its launch three seconds before liftoff after a sensor indicted a malfunction in a coolant valve on main engine number two.

All three main liquid fueled engines had begun operation at that point but the Solid Rocket Boosters had not ignited. Subsequent analysis indicated that the engine did not actually malfunction but the sensor itself did.

The mission finally lifted off on July 29, 1985.

Even after liftoff, however, the Orbiter was not free of problems. At five minutes and 45 seconds into the flight the centre main engine suddenly shut down. Challenger was forced to abort its planned flight parameters and enter an "abort to orbit" mode.

In abort to orbit the Shuttle has enough energy to reach an orbit but not the planned orbit. An abort to orbit leaves open the possibility of completing much of the mission and then landing at a planned landing site.

Gordon Fullerton, Challenger's commander, switched the on-board computers to abort to orbit mode and preplanned abort procedures were begun, which included igniting the Orbital Manoeuvering System engines to burn off 4,400 pounds of fuel. The two remaining main engines fired for about one minute longer than had been planned for the normal flight. Again, a sensor rather than the engine was later determined to be the problem.

Following a burn of the manoeuvring engines, Challenger eventually reached an orbital altitude of 170 nautical miles. The planned altitude had been 206 nautical miles but this lower altitude allowed the flight to be completed with some effect to the sensors on some of the Spacelab 2 experiments.

touchdown occurring between 20 and 30 minutes after lift-off.

Abort 2

The second launch abort option available, a Trans-Atlantic or Trans-Pacific landing, would be used if main engine failure occurred after the four minute mark and before enough energy had been built up to achieve the third abort mode. Once this abort mode had been initiated the Orbiter would turn itself upright, release the External Tank and glide to a contingency landing site. For launches from the Kennedy Space Center a number of Trans-Atlantic abort landing sites exist, selection depending on the inclination to the equator flown by the Shuttle. For 28 degree launches Dakar International airport in Senegal, West Africa would be used, 40 degree launches, as in the case of STS-1, would use Rota in Southern Spain and for 57 degree launches as flown by most Spacelab missions the landing site would be in Northern Spain at Zaragoza. When the Shuttle is launched from Vandenberg Air Force base in 1986 a Trans-Pacific abort landing site will become available at Mataveri airfield on Isla de Pascua, better known as Easter Island, where the runway is at present being modified for emergency Shuttle landings.

Abort 3

The Abort once around phase could also begin at four minutes into the launch provided enough energy was available to allow the Space Shuttle to gain sufficient altitude to reach the US mainland following one orbit. A semi-ballistic trajectory, just short of orbital insertion, would be flown taking the Orbiter around the planet before routine re-entry and landing some 90 minutes after launch. Such an abort would require extra firings of the Orbital Manoeuvering System and attitude control thrusters before and after main engine shutdown to maintain altitude for the circuit.

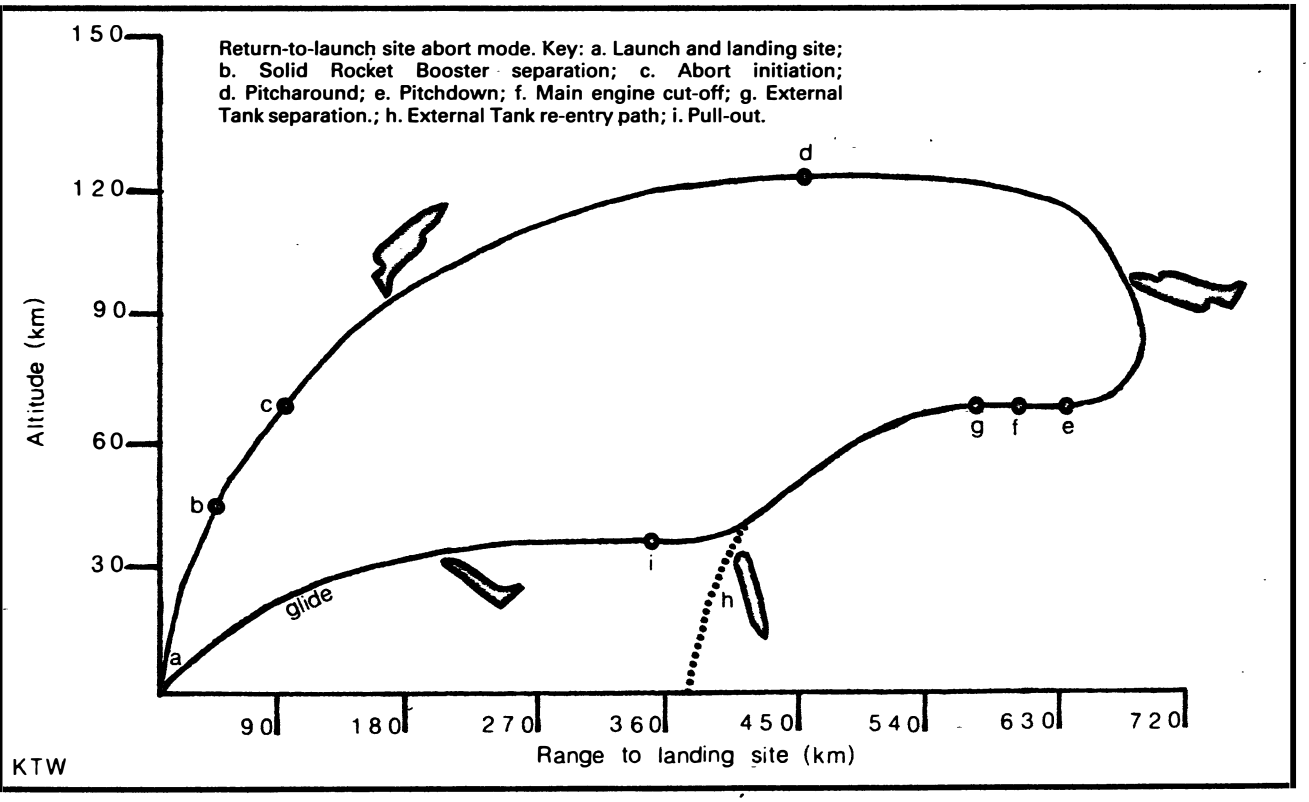
Abort 4

The final launch abort, Abort to orbit, would be used following a main engine failure late in the ascent phase where enough energy existed for the Orbiter to reach a minimal 194 km orbit using remaining engines and Orbital Manoeuvering System engines. This abort mode might also be used if a systems failure occurred during ascent but was not serious enough to require immediate return to Earth. This option allows the Orbiter to reach orbit and remain in space until the future of the mission is decided. This could lead to an immediate landing or to an adapted full-length mission as happened on mission 51F. On that mission one main engine was shut down nearly six minutes into the launch following a faulty engine temperature sensor reading. As all other systems were functioning normally and enough energy existed to reach orbit, ground controllers decided correctly to proceed to orbit. This, the first Shuttle launch abort, resulted in a slightly modified, but successful, mission being flown. The term Abort to orbit tends to be misleading as such an option might not be an abort at all. Following the 51F incident NASA referred to this particular abort as a 'positive two-engine to orbit'.

Launch Emergency

The Challenger accident has focussed attention on the consequences of other kinds of emergency during ascent which might not be immediately catastrophic. If the emergency could be contained until after the Solid Rocket Boosters had burnt out and been jettisoned, one of the above abort procedures may be entered. On the other hand, if the emergency could not be contained, the survivability of the crews becomes conditional on actual circumstances. Resort might be made to separating the Orbiter from the External Tank and SRB's by explosive charges. Circumstances might then permit the Orbiter to ditch in the ocean, where surviving crew members would be recovered by air-sea rescue.

Return-to-launch site abort mode. Key: a. Launch and landing site; b. Solid Rocket Booster separation; c. Abort initiation; d. Pitcharound; e. Pitchdown; f. Main engine cut-off; g. External Tank separation.; h. External Tank re-entry path; i. Pull-out.



KENNEDY SPACE CENTER LANDINGS

By Keith T. Wilson

Before the era of the Space Shuttle all US manned spacecraft returned to Earth by splashing down in the Atlantic or Pacific Oceans. Recovery was a very costly operation. For the Shuttle, the 'space-plane' returns to dry land. And what better than landing at the launch site, the Kennedy Space Center in Florida.

Introduction

The landing speed of a returning Orbiter under normal conditions is 354 km/hr, compared with 209 km/hr for a commercial aircraft such as the DC-9. This high speed necessitates a lengthy runway. The Orbiter also returns unpowered, like a giant glider — the Shuttle pilots have to get it right first time. It was with these two main points in mind that construction of the Shuttle Landing Facility at KSC began in 1974, ten years before the first Orbiter returned from space to the Florida site.

The Landing Facility

The Shuttle Landing Facility, built at a cost of more than $27 million, is located some 3 km to the northwest of the Vehicle Assembly Building and lies on a northwest-southwest alignment. The runway is only part of the facility, which was built in three stages. The runway, towway, parking apron and associated facilities were started in 1974 and work was completed by late 1976. The second construction phase, which centred on the landing aids control building, navigation and instrumentation shelters, communications cabling and mate-demate device foundations, was started in April 1975 and also completed in 1976. The final stage was the installation of navigation, instrumentation and communications systems and ground support equipment; this was completed during 1978.

The Runway

The main feature of the Shuttle Landing Facility is the runway, one of the most impressive in the world. At 4,572 m long and 91.4 m wide, it is twice the length and width of commercial airport runways. It required over 500 hectares of land to build, land that was at one time used for agriculture before being taken over by NASA in the early 1960's. It is not flat but has a camber of 61 cm from the centreline to the edge. A series of grooves each 0.63 cm wide and deep have been cut into the concrete every 2.85 cm across the runway (a total length of 13,600 km of grooves!). Together with the camber they provide rapid drain-off of rain as well as a more skid-resistant surface. A large ditch borders the runway to help cope with water run-off during heavy rains. The 'sandpaper-like roughness' of the grooves, it is thought, could be a factor contributing to excesssive tyre-wear during landings. The concrete used to pave the runway needed 1,000 truckloads of cement and 10,000 of crushed limestone and sand aggregate. 193,000 m^3 of concrete were used in paving the runway and at its centre it is more than 40 cm thick.

Landings can be made from either direction. From the northwest it is designated as Runway 15; from the southeast it is Runway 33. Approach lights point to the centreline, and the threshold and edge lights outline the field as on a commercial runway. Safety overruns of 305 m are provided at each end. One serious hazard common at many commercial airports is the presence of birds. At KSC the hazard came from alligators — they enjoyed wallowing in the drainage ditch, followed by basking on the warm concrete. It was not unusual for KSC employees to have to chase them off before a landing. Recently, however, a low fence has been erected to discourage such intrusions.

Shuttle landings

Orbiters are guided down by the Microwave Scanning Beam Landing System (MSBLS — pronounced 'Miss Bliss') which is accurate to within 99 per cent in bringing an Orbiter to the designated point on the runway. Landing system equipment is duplicated to permit approaches from either direction. The MSBLS azimuth (left-right) measuring equipment

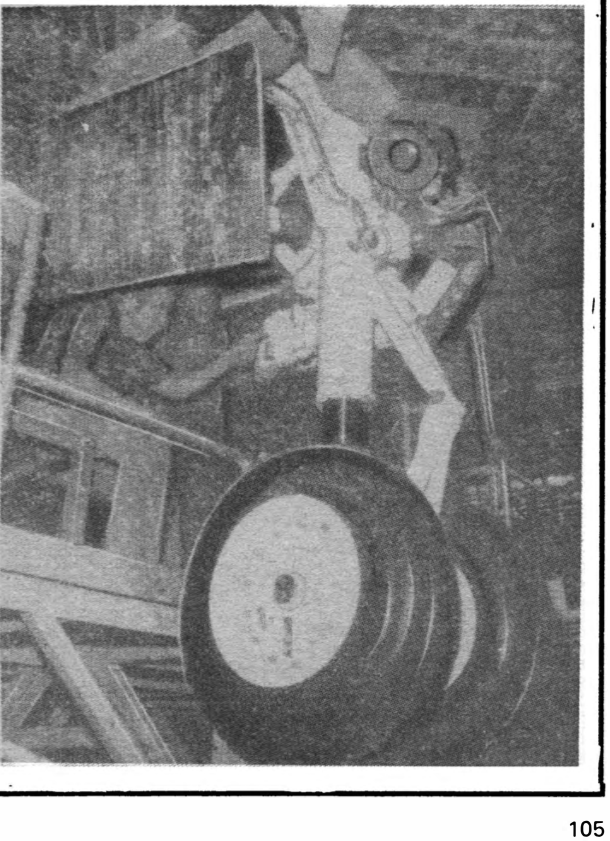
NOSE WHEEL STEERING

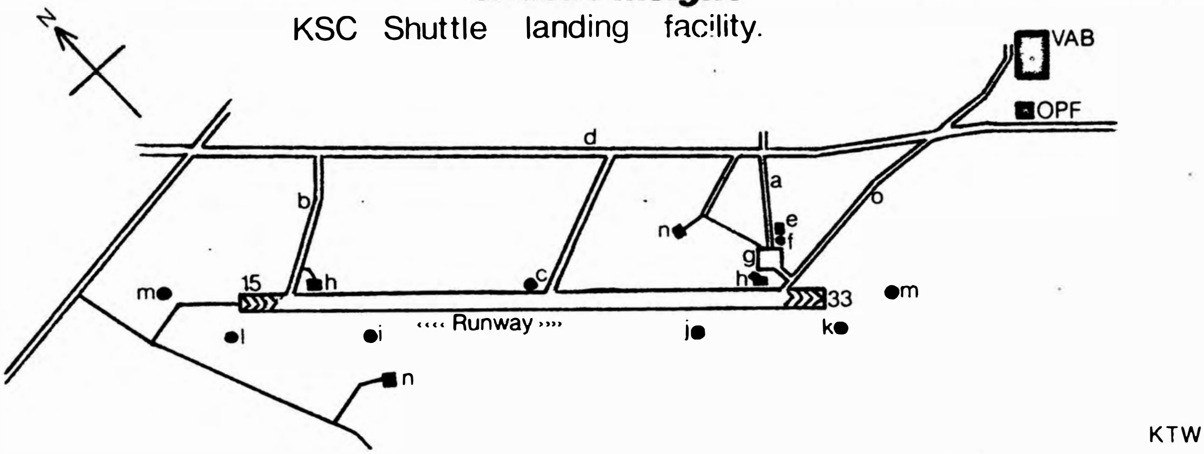
Nose Wheel Steering box and actuator (pictured below) were successfully installed and tested on the Challenger spacecraft during the mission 61A landing at Edwards Airforce Base in early November 1985.

As Challenger touched down and began to slow mission commander Henry Hartsfield put the orbiter through a series of steering manoeuvres to test the steering system.

Success of the test was a key factor in the decision to resume landings at the Kennedy Space Center which were halted following mission 51D when Discovery's brakes locked near the end of its 10,500 foot roll at Kennedy causing a tyre blow out. Prior to the Challenger test all steering during the landing roll had been accomplished by differential braking, particularly demanding in strong cross winds.

Hartsfield, who steered the orbiter 30 feet from the centreline and then back again, reported that the system "performed well"





KSC Shuttle Landing Facility. Key: a. Access Road A; b. Access Road B; c. Crash, Fire, Rescue; d. Kennedy Parkway; e. Landing Aids Control Building; f. Ground Support Equipment Power Panel g. Parking Apron; h. Meteorological Equipment Pad (2); i. MSBLS — Elevation Station Runway 15; j. MSBLS — Elevation Station Runway 33; k. MSBLS — Azimuth/Distance Measuring Equipment Station Runway 15; l. MSBLS — Azimuth/Distance Measuring Equipment Station Runway 33; m. Orbiter Target Aim Point (2); n. Television Tower and Equipment (2); o. Tow-way to Vehicle Assembly Building

is contained in two shelters, one at each end. They send out signals that sweep 15 degrees on each side of the landing path with directional data. Distance data are also provided. MSBLS elevation stations are located at the side of the runway close to the touchdown point. A vertical beam sweeps the landing path to provide elevation data up to 30 degrees. The MSBLS systems aboard the Orbiter receive these data and the craft adjusts to the correct glide path. In an emergency the Orbiter could be landed safely without intervention by the flight crew. The MSBLS could, in theory, guide the Orbiter's nose-wheel down within the width of the paint stripe on the centre line.

As of October 1985, KSC had seen five landings: missions 41B, 41G, 51A, 51C and 51D. Following braking problems during the cross-wind landing of 51D in April 1985, all future KSC landings were postponed and Edwards Air Force Base in California was used instead. The intention was that KSC landings would be resumed in 1986, depending on the introduction of nose-wheel steering, tested for the first time on mission 61A at Edwards. This elimiates differential braking, which caused the problems on 51D. The 51D crosswind landing at KSC emphasised a problem that had been mentioned in a 1983 report to the US Congress by a committee of the National Research Council. They made the following recommendation: "The crosswind limitations of the Shuttle Orbiter suggest that an additional runway should be considered at KSC to avoid diversions". It is an unlikely prospect because of the high cost involved.

Weather Hampers Mission Scheduling

Shuttle Columbia's night landing at Edwards Airforce Base on January 18 again highlighted the susceptibility of Shuttle missions to poor weather conditions

The first night landing of the Shuttle programme for Challenger at Edwards Airforce Base in September 1983.

Mission 61C astronauts Robert Gibson and Charles Bolden piloted the orbiter to a pre-dawn touchdown – only the second night landing of the programme – after a final opportunity to land at the Kennedy Space Center was reluctantly rejected.

Attempts to land on the Kennedy runway previously, on January 16 (which would have ended the mission a day early to help preserve orbiter processing time) and the following day also had to be called off because of bad weather.

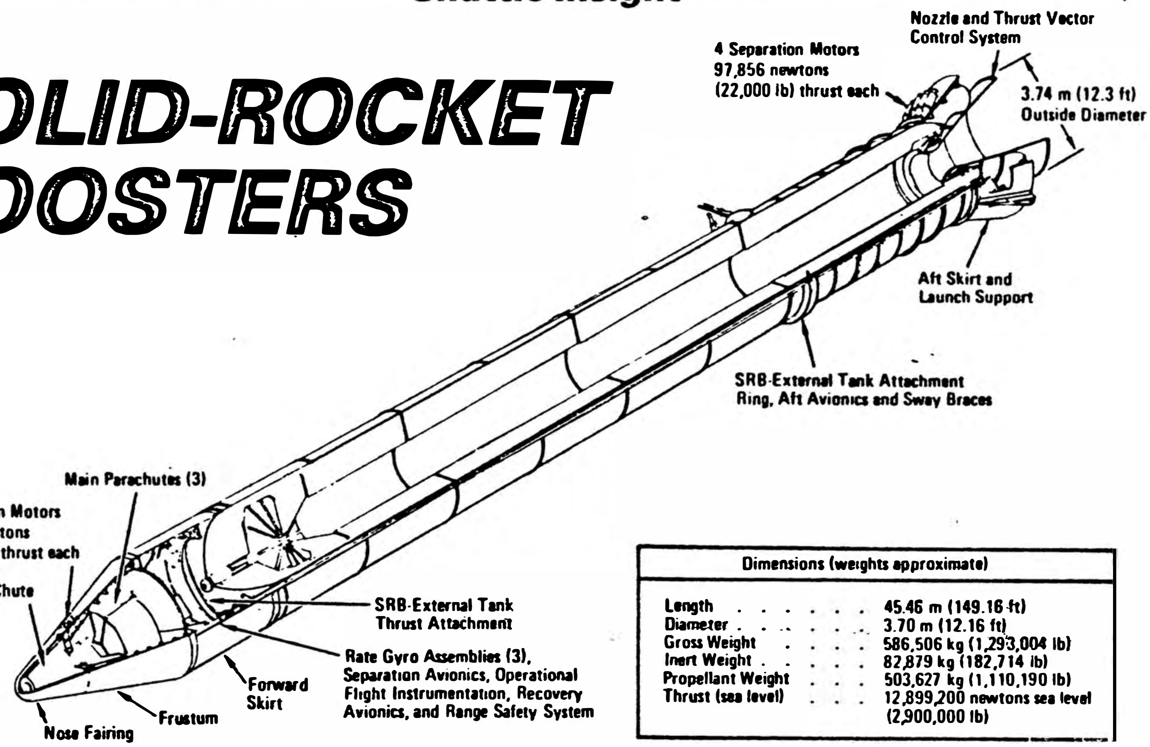
Columbia – the first Shuttle to fly – had not flown for almost two years and during this time had undergone extensive modernisation. Lift-off of mission 61C, which finally occurred on January 12, was the seventh flight for Columbia.

Once again the weather and minor technical problems had delayed this launch seven times – it was originally scheduled for lift-off on December 19 – and the flight was dubbed by the media at large "mission impossible".

Gibson and Bolden piloted Columbia through an ascent profile that placed greater stresses on the vehicle than any previous launch in order to provide additional data on the actual loads encountered during launch compared with projections and earlier flights.

Data from previous Shuttle flights has revealed greater stresses on the vehicle than predicted by wind tunnel and other experiments.

SOLID-ROCKET BOOSTERS



Dimensions (weights approximate)	
Length	45.46 m (149.16 ft)
Diameter	3.70 m (12.16 ft)
Gross Weight	586,506 kg (1,293,004 lb)
Inert Weight	82,879 kg (182,714 lb)
Propellant Weight	503,627 kg (1,110,190 lb)
Thrust (sea level)	12,899,200 newtons sea level (2,900,000 lb)

Close-up pictures of the Challenger 51L launch sequence showed a small flash around the lower third of the external tank and left Solid Rocket Booster (SRB). This appeared to be the trigger for the devastating explosion and NASA investigators are now looking closely at the potential for failure within a joint between segments of the Morton Thiokol/ United Space Booster-built SRB's.

The two SRB's provide the main thrust to lift the Space Shuttle off the pad and up to an altitude of about 45,720 metres (150,000 feet), 24 nautical miles (28 statute miles). In addition, the two SRB's carry the entire weight of the External Tank and Orbiter and transmit the weight load through their structure to the mobile launch platform.

Each booster has a thrust (sea level) of 2.9 million pounds at launch. They are ignited after the three Shuttle main engine thrust level is verified. The two SRB's provide 71.4 per cent of the thrust at lift-off and during first stage ascent.

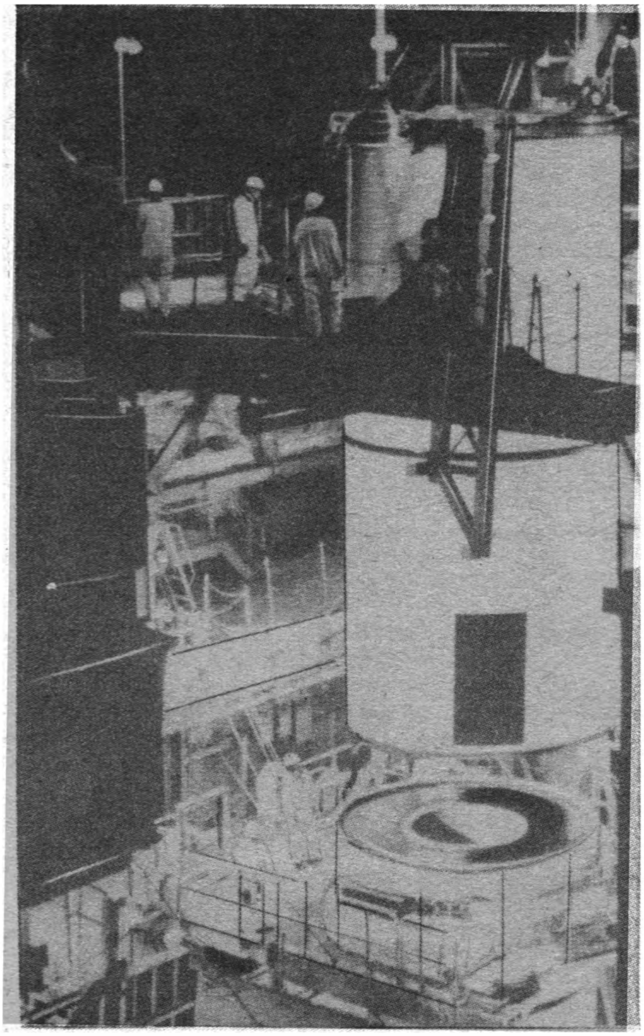
The SRB's are the largest solid-propellant motors ever flown and the first designed for reuse. Each is 45.46 metres long and 3.70 metres in diameter. At launch each weighs 586,506 kilograms, of which 85 per cent, 503,627 kilograms, is propellant.

Primary elements of each booster are the motor (including case, propellant, igniter, and nozzle), structure, separation systems, operational flight instrumentation, recovery avionics, pyrotechnics, deceleration system, thrust vector control system and range safety destruct system.

The interchangeable SRB's are used as matched pairs and each is made up of four solid rocket motor segments. The pairs are matched by loading each of the four motor segments in pairs from the same batches of propellant ingredients to minimise any thrust imbalance. The segmented casing design gives maximum flexibility in fabrication and ease of transportation and handling.

Solid rocket motor ignition commands are sent by the Orbiter computers through the MEC's (Master Event Controllers) to the safe and arm device NSI's

A large crane is used to lower the second booster section onto the aft section in the Vehicle Assembly Building. It is at the junction between the two segments where the leak in Challenger's right SRB is thought to have occurred.



(NASA Standard Initiators) in each SRB.

Three signals must be present simultaneously for the PIC to generate the pyro firing output. These signals – Arm, Fire 1, and Fire 2 – originate in the orbiter computers and are transmitted to the MEC's.

The "arm" signal causes a barrier rotor to move into a position from which redundant NSI's fire through a thin barrier seal down a flame tunnel. This ignites a pyro booster charge, which is retained in the safe arm device behind a perforated plate. The booster charge ignites the propellant in the igniter initiator, and combustion products of this propellant ignite the solid rocket motor initiator, which fires down the length of the solid rocket motor igniting the solid rocket motor propellant.

The computer launch sequence also controls certain critical main propulsion system valves and monitors the engine-ready indications from the main engines. The MPS start commands are issued by the onboard computers at T minus 6.6 seconds (staggered start – engine three, engine two, engine one – all approximately within one-fourth of a second) and the sequence monitors the thrust buildup of each engine.

Normal thrust build-up to the required 90 per cent thrust level will result in the engines being commanded to the liftoff position at T minus 3 seconds as well as the Fire 1 command being issued to arm the SRB's.

At T-0, the two SRB's are ignited, under command of the four onboard computers, separation of the four explosive bolts on each SRB is initiated (each bolt is 711 millimeters – 28 inches – long and 88 millimeters – 3.5 inches – in diameter); the two T-0 umbilicals (one on each side of the spacecraft) are retracted; the onboard master timing unit, event timer, and mission event timers are started; the three main engines are at 100 per cent and the ground launch sequence is terminated.

The solid rocket motor thrust profile is tailored to reduce thrust during the maximum dynamic pressure (max q) region.

The NASA accident review board investigating the cause of the Challenger explosion believes it most likely to have been triggered by a rupture in the right SRB at one of the segment joints.

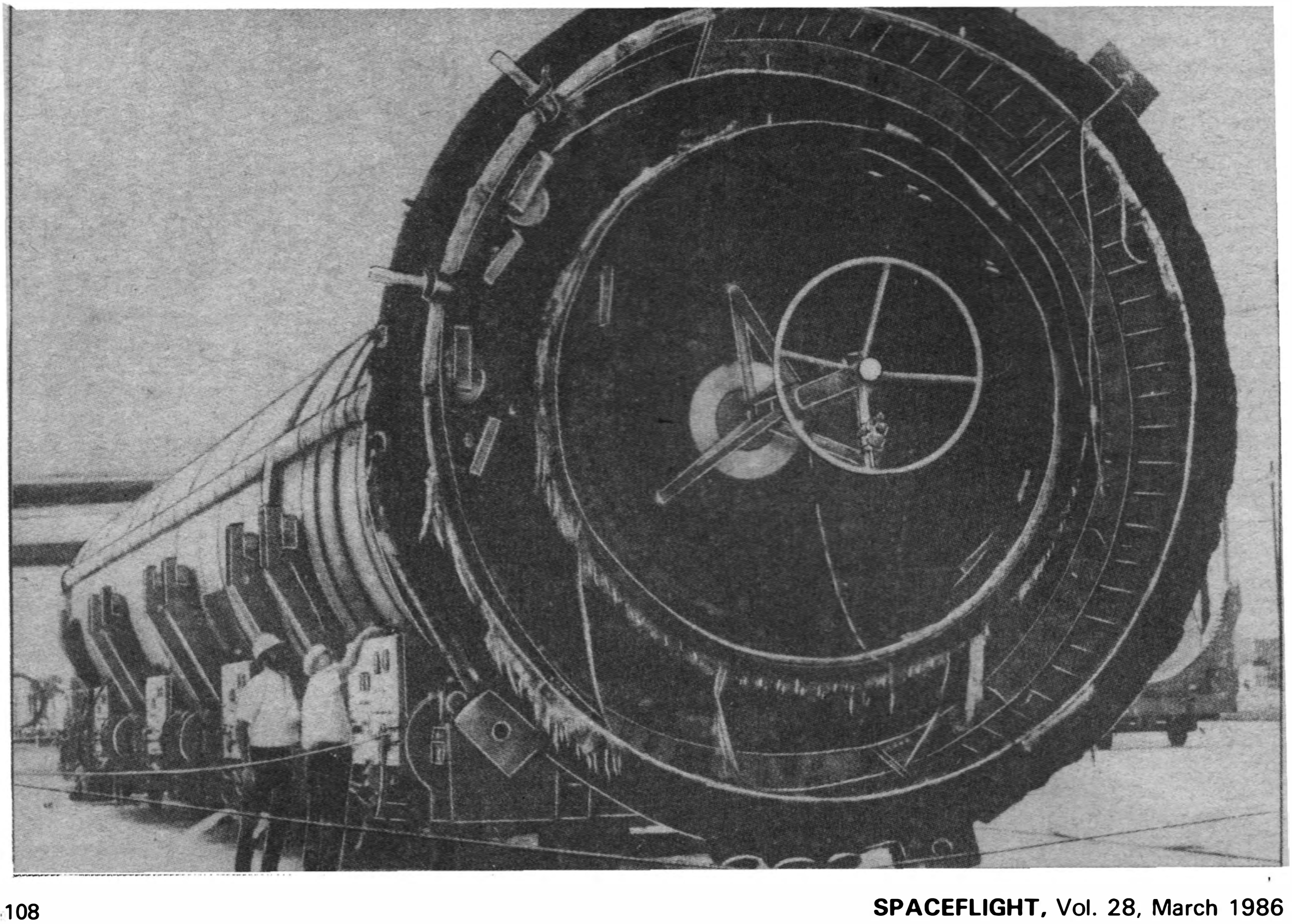
An exhaust plume and flame seen emitting from the side of the booster are thought to have caused the bottom part of the SRB to separate from the external tank, pushing it away from the climbing orbiter.

In response, the top half is believed to have pivoted into the external tank, rupturing the oxygen and hydrogen section which resulted in the massive explosion.

However, finding a reason for the rupture may be less easy. Tests on the structural design of the booster joints together with the seals and lubricants are being performed to establish if the unusually cold pre-launch weather had any adverse effect.

Although the seals are designed to prevent the kind of leak that resulted in the explosion, NASA engineers have recorded on some previous flights slight leakage on the first seal.

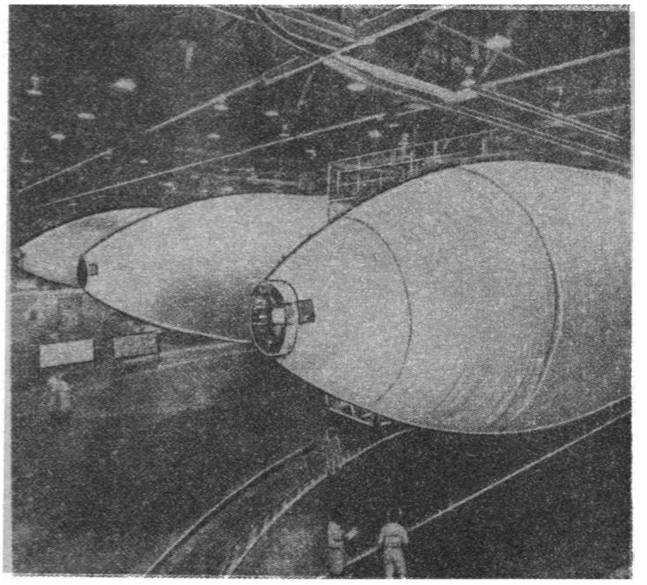
One of the two SRBs used during the launch of Columbia on its third flight in 1982. The booster is at the disassembly facility after being picked up from the ocean about 164 miles north east of the launch site. After being "safed" it is disassembled and shipped out for reprocessing.



EXTERNAL TANK

by Frank Sietzen

The Space Shuttle External Tank is a vital element of the reuseable space transportation system. It not only holds the super-cold liquid propellants for the Orbiter's three main engines but also acts as the backbone of the vehicle in flight. The recent Shuttle explosion in flight has focussed attention on the design and role of the External Tank. The author describes this element of the Shuttle system and how it involves a new technology – that of the very large.



Three External Tanks complete with their layers of insulation - only the first two carried the white finish. *Martin Marietta*

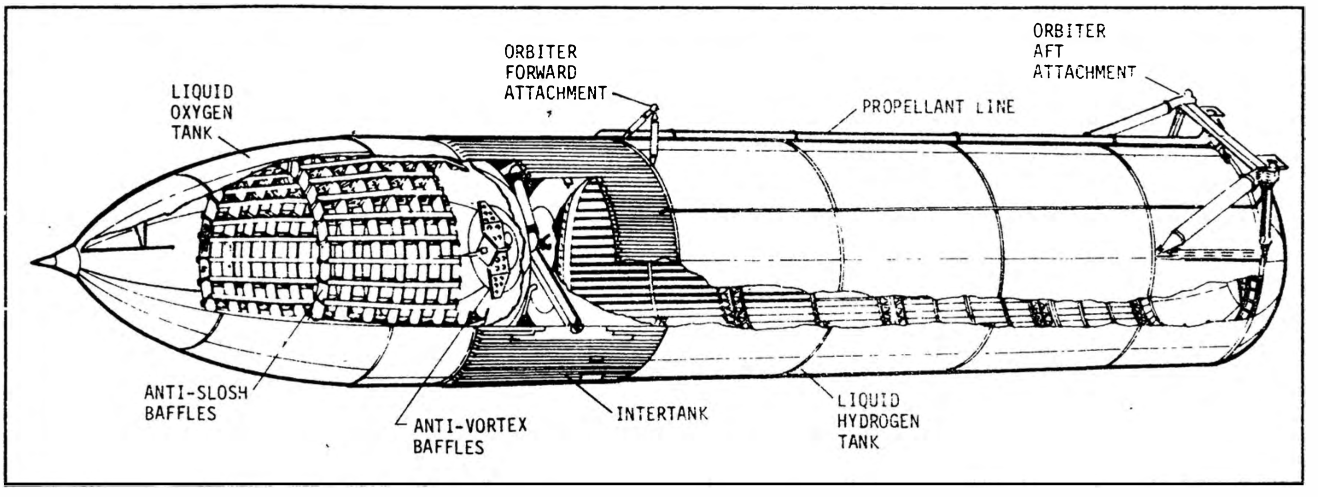
Introduction

The 3500 acre cypress swamp east of New Orleans was made into a permanent plantation home as a result of the labours of Baron Antoine Michoud, the son of a French Cabinet Minister and the third Frenchman to own a tract once infested with alligators and dotted with hunting camps for the Choctaw Indians. Michoud purchased the estate and buildings from a bankrupt civil engineer and sought to make it an appropriate reflection of his lifestyle. Alas, Michoud's personal eccentricities alienated him from the crescent city's business community and he eventually retreated to the confines of the plantation, which he converted to sugar growing and refining. Two smokestacks from those days still stand in front of the assembly plant that bears his name, a silent testimony to the past. Most of Michoud's estate was gradually divided into parcels, with the US government buying a 1,000 acre tract in 1940 to build Liberty ships. Just two years later, when the huge 43 acre plant was finished, it was decided to switch to the manufacture of wooden cargo aircraft. Only two 'planes of an estimated 200 were actually built before that plan, too, was abandoned. Years of inactivity followed.

The coming of the Saturn rocket programme in 1961 finally brought it back to life. It was at Michoud, now a part of the Marshall Space Flight Center, that the Apollo astronauts' journeys to the Moon truly began. The first stages of the Saturn family (Saturn 1, 1B, and the massive 5) were built there from 1961 to 1968, when the assembly lines were stilled and the excess vehicles stored. A Saturn 5 first stage still sits on the lawn at the entrance today, a silent reminder of America's retreat from the Moon of the 1970's. The year after the assembly lines were closed, Congress approved the Space Shuttle programme and in 1973 Martin Marietta was chosen to build the only major expendable Shuttle component, the External (propellant) Tank, at the Michoud site. A prime reason for the decision, as was the case with the Saturn decision a decade before, was the site's access to canals for water transport of the aerospace products that were too large for air travel to their launching sites.

ET Basics

The largest of the several Shuttle elements, the External Tank is 8.4 m in diameter and 47 m long. It is designed to hold more than two million litres of propellants for the Orbiter's three main engines and to be jettisoned from the speeding Shuttle just before orbital insertion. In its pointed, ogive-shaped nose is a liquid oxygen tank that holds 540,000 litres of the oxidizer, with waffle-shaped structures, called baffles, on the inner surface to keep the super-cold liquid from sloshing about during the trek to space. Below that is perhaps the most important part of the overall ET: an intertank connection linking the upper liquid oxygen tank with the liquid hydrogen tank below. Its most important function is to absorb the heavy loads imposed during launch - the ET is the strong backbone of the Space Shuttle.



The liquid hydrogen tank, at 29.5 m long, is the largest part of the ET. Like the oxygen portion, it is made of aluminium segments fusion welded together in the 'TIG' or Tungston Inert Gas welding process. The hydrogen fuel, more than 1½ million litres of it, is kept at -253°C, a supercold but high energy fuel.

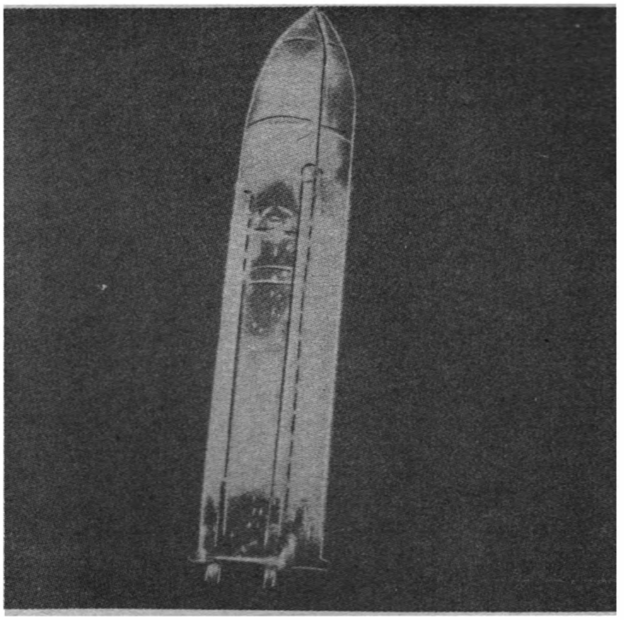
The exterior of the ET contains propellant feed lines, mounting struts to hold the Orbiter, vents for the use of gaseous hydrogen as an attitude control device during separation, antennae for transmission of destruct commands should things go awry and a Thermal Protection System that covers the entire external surface. Now omitted is the final coat of white paint - at 270 kg and costing $15,000, it was decided that the weight could better be used in the payload bay as cargo. Thus all tanks since the third launch in March 1982 have the natural colour of the thermal insulation. This spray-on protection is an important element: the polyurethane-like foam keeps the liquids at their proper temperature, while preventing ice and frost from forming on the outside. Such material falling off during launch and striking the delicate tiles on the Orbiter is a problem for the reusable ship. Averaging about 2 cm thick, the composition varies at different places. A CPR 488 foam is sprayed over the entire tank, except for the nose and other areas that are subjected to high aerodynamic heating during launch - those are treated with a superlight ablator, sealed with a fire-resistant latex coating that prevents moisture from being absorbed. The insulation is a beige or amber when first sprayed on (the entire tank rotates on a huge turntable while nozzles spray the material in even strokes) but as it is exposed to the ultraviolet rays of the Sun, it cures to a brown-maroon colour. Now that ETs are stored several missions ahead at the Kennedy Space Center in Florida, they will have cured by the time the Shuttle stack rolls out to the pad. For the first use of the lighter, unpainted tank on the third mission the tank cured while on the pad, which aroused the interest of observers who saw a beige tank leave the Vehicle Assembly Building and a brown one on the launch pad!

How the ET Works

The tanks are shipped to Cape Canaveral *via* barge, on a water journey that takes about five days in the Gulf of Mexico. When the Shuttle begins polar ascents from California's Vandenberg Air Force Base in 1986, the water trip for the ET will cross the Panama Canal and take two weeks.

Once at the launch site, the tank is raised to the launch platform and stacked with the pair of Solid Rocket Motors. Then the Orbiter itself is attached to the ET and the entire stack readied for the trip to the pad (at Vandenberg, the system will be assembled on the pad itself). Once there, electrical and liquid or gas connections are made and the interior tanks purged of contaminants. Several hours before launch, fuel and oxidizer are loaded simultaneously, at various rates of flow as the tanks are filled. With computers watching carefully, the tanks are topped off and any collected gas vapours vented through the nose cap. At 6.6 seconds before lift-off, the propellants are fed to the Orbiter engine cluster at a combined 400 litres/sec through 43 cm wide lines. The ground support umbilical linking the intertank with the launch tower falls away at solid motor ignition and the Shuttle begins an 8½ minute ascent through the atmosphere. At main engine shut-down, pyrotechnic devices separate the ET from the belly of the Orbiter and residual gases in the nose are vented through a valve, beginning a slow pitch-over as a result. This action ensures that it will tumble as it moves below and away from the sub-orbital Shuttle, which then climbs to orbit using the two orbital Maneuvering Engines. The ET plunges back into the atmosphere and breaks up about 55 km above the Indian Ocean. The imparted tumble also helps to assure a small area of impact for surviving fragments. The Orbiter's General Purpose Computers are in control through the short powered flight, reducing the amount of hardware the tank itself requires.

The STS-1 tank separates from *Columbia*, captured by cameras in the umbilical bays underneath the Orbiter. Note the scorching. *NASA*



Diets for the ET

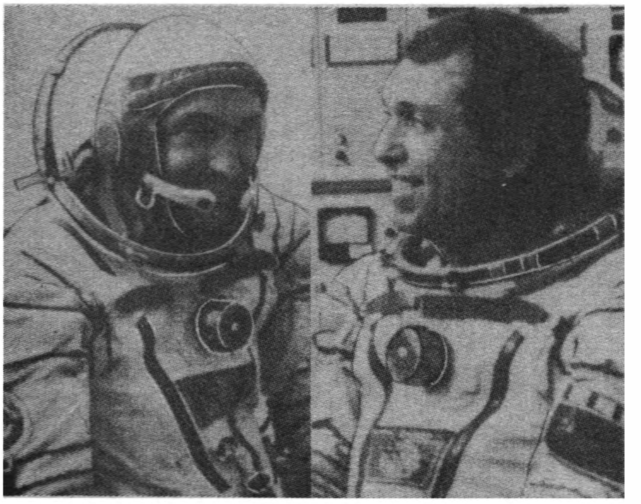
The External Tank is not a static design but is evolving as the Shuttle programme matures. A programme, started in 1979, continues to work at making the ET cheaper and more efficient. The lightweight tank programme set up by NASA called for reducing the weight of the ET by 2720 kg - Martin Marietta was able to deliver a 4500 kg saving, beginning with the tank for *Challenger's* maiden flight in April 1983.

Future ETs may be made more efficient by removing cable trays and baffles and substituting composite material for heavier metals. The challenge is complicated by the slowly increasing demand for ETs: the production rate is presently 14 tanks in various stages of construction at all times. In the not-so-distant future, when a full fleet of Shuttle Orbiters is in service with three launch pads on two coasts, the rate of assembly must gear up to match the rate of growth. Plans currently call for an increase of the current rate to 24 tanks per year by 1988. To support this goal, the Michoud plant itself must be nearly remade from the inside out. This process involves the substitution of new, more efficient manufacturing techniques, such as welding two quarter sections of the liquid hydrogen dome together on a smaller machine and then welding the halves on the original larger machine. The plant is undergoing a facelift of sorts, with an aisle being added that runs the length from east to west, allowing for a more efficient flow of constructed parts, much as in an automobile assembly plant. Martin Marietta representatives in New Orleans refer to this as the '60 minus 36 plan,' meaning that the changes will allow the plant, now gearing up for 24 tanks per year, to grow to support 60 tanks if the rate of Shuttle flights ever require such production levels.

NEW SALYUT SPACE STATION

by Neville Kidger

It is now increasingly likely that the next Soviet cosmonauts to spend a lengthy period in space will do so aboard a new Salyut space station. Meanwhile, further details have also emerged on the sudden return to Earth of the Salyut 7 crew in late November 1985.



Vasyutin (left) and Volkov.

Speculation about the launch of Salyut 8, a replacement space station for Salyut 7, has arisen from revelations of Soviet officials at the IAF conference in Sweden last October. It was reported that the main component of the station would be a central core with multiple docking ports to allow four to six modules to be docked to the station.

A picture, from the US Defence Department publication "Soviet Military Power" shows an enlarged Salyut with two Cosmos Modules docked radially at the rear of the complex. The publication says this is the design of the enlarged Salyut. It has already been noted that the Cosmos modules bear a strong resemblence to the 1960s McDonnel Douglas "Big G" study for a space station but a picture which was published in 1969 (AW&ST 22 September 1969, pp 103) shows "Big G" modules docking laterally with the large cylindrical station. If the DoD drawing is representative of the Salyut 8 design then comparison with the McDonnel Douglas study is unavoidable. The 1969 US study featured an architecture similar to that employed in Skylab (ie with several cylindrical 'rooms' along the length of the station). It will be interesting to see if the Soviets have built their large station interior similar to the US design.

Salyut Mission Report – Working In Orbit

October began for the 'Chegets' – cosmonauts Vasyutin, Savinykh and Volkov – with a series of medical tests. These showed that the men remained in good health, the Soviets said.

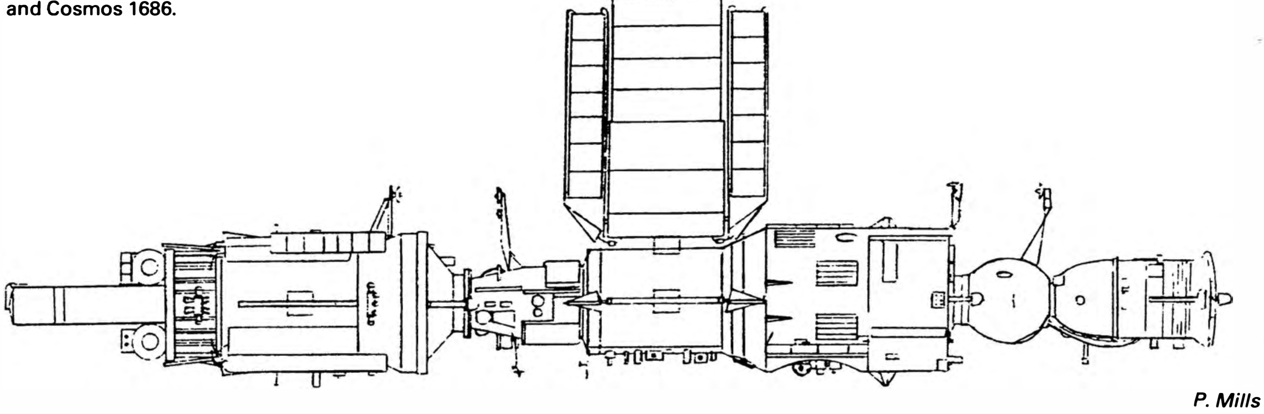
The men were also heavily involved in photography and other data gathering over the USSR. Areas studied included the Black and Caspian seas and areas of the Central Asian Republics.

The cosmonauts monitored the performance of the COMET experiment, a French-Soviet experiment which had been mounted on the exterior of Salyut by Dzhanibekov and Savinykh during their EVA on August 2. The experiment used deployable 'arms' to trap dust particles in the vicinity of the complex and the first collections were timed to coincide with the near passage of Comet Giacobini-Zinner. Studies would allow scientists to determine the chemical composition of the dust particles and by October 10, the Soviets claimed that the first stages of work with the detector had been accomplished.

Another astrophysical experiment conducted extensively by the Chegets involved an improved gamma spectrometer, called 'Mariya', which was placed at various locations in the station to study the mechanism of the generation of currents of high-energy particles such as electrons and positrons in near-Earth space. Work also continued with the 'Pion' technological installation to study the behaviour of materials in weightlessness and the cosmonauts regularly monitored the progress of plants, such as cotton and flax, which they had planted in biological installations.

By October 12 it was reported that the Cosmos module was still not fully unloaded and that the men

Salyut 7 docked with Soyuz T14 and Cosmos 1686.



P. Mills

were having to unload it in their spare time. Two days later the cosmonauts took part in a TV session with US astronauts Slayton and Stafford as part of a goodwill exchange. It also involved Congressman Bill Nelson (who flew on Shuttle mission 61C). Nelson was told that the three cosmonauts would still be in orbit during his flight, which was then scheduled for a December 18 launch.

As October passed the men continued their cycle of work of Earth observations, materials studies and astrophysical observations. Special attention was also paid to the cosmonauts health. In an interesting experiment the cosmonauts were used as guinea pigs to study how an increase in the intensity of physical exercise could be used to decrease the length of time the men had to spend on it (typical time per day spent on physical exercises was between two and two-and-a-half hours).

By October 20 the men had begun another series of dust collections with the COMET experiment and had spent time studying the phenomena of noctilucent clouds at an altitude of 80 km over the Pacific. During the studies, under the codename 'Aerosol' the attitude of the complex was controlled by the Cosmos satellite.

TASS reported on October 25 that the complex was orbiting at a height of 375 x 357 km at an inclination of 51.6 degress and a period of 91.6 minutes.

During the first ten days of November the cosmonauts continued the cycles of work with TASS reports being issued every four to five days summarising the work. Special photographs were taken of areas around Tajikistan which had recenlty been the epicentre of a severe earthquake. On November 13 the cosmonauts completed more Earth studies but later at 19.11 GMT the same day it was reported by observers that the cosmonauts had suddenly begun to scramble radio transmissions to Earth. However, routine reports of normal working on the station continued.

Subsequent analysis of TASS reports revealed that the last report that the crew were "in good health and feeling well" – a fairly standard phrase in TASS announcements – was issued October 25. Four days later, the agency said that the systems of the complex were functioning normally and the cosmonauts were implementing the flight programme.

TASS stated on November 15 that the men were continuing work aboard the complex and were engaged in astrophysical, biological, geophysical and medical activities. The 'Chibis' suit was used in "an examination of the state of their cardiovascular systems both at rest and under hydrostatic pressure." It was the last offical report from the agency before the dramatic events of November 21, although Soviet radio reports on the flight, describing the work programme, continued up to 0900 GMT November 18. Once again, the omission of any reference to the men's health was significant.

Emergency Return to Earth

At 1136 GMT on November 21 TASS made a short announcement which said that, at 1031 GMT that day, the crew of Soyuz T-14 had landed some 180 km southeast of the city of Dzhezkazgan in Kazakhstan. The agency stated that the men had conducted studies of the Earth's surface, atmosphere and also astrophysical, technological and technical experiments as well as biological and medical studies.

Only in the final paragraph did TASS give the reasons for the termination of the flight: "The cosmonauts' long flight . . . was terminated due to Vladimir Vasyutin's sickness and the need for hospital treatment for him."

Subsequently, TASS reported that the commander was "satisfactory" but that he was being flown to Moscow for urgent treatment. Western observers confirmed that the return had occurred after four days of scrambled radio transmissions. No further details were released about Vasyutin's illness immediately although a later report spoke of "some inner inflamation" which led some western analysts to suspect an attack of appendicitis.

Vasyutin's illness had caused the Soviets to gather another, certainly unwanted, "first" in space – the first time that a manned flight had been terminated early due to the sickness of a crew member.

The next day, at the Baikonur cosmodrome, Maj. Gen. Aleksei Leonov introduced Savinykh and Volkov to the press. The two men praised Vasyutin for his conduct during the descent to Earth. The Soviets played up the achievements of the flight saying that the Earth photography had covered some 16 million sq km of the USSR and over 400 sessions of scientific research had been accomplished.

There were no new reports of the conditon of Vasyutin released in the following days and one western source claimed that the illness had been so sudden that the cosmonauts had been unable to "mothball" the complex. There was some expectation that another flight would follow quickly to man the operational complex. But there was also expectation that the Soviets would launch a new, larger Salyut (number 8) which would have modules docked to it.

Revelations About The Illness

In 'Pravda' on December 29 the Soviets published an abridged version of the diary Savinykh had kept during the flight which revealed the 'illness' suffered by Vasyutin. The publication continued the series of startlingly frank Soviet accounts of their problems which had begun with the Soyuz T-8 failure in 1983.

The Soviets acknowledged that the crew should have been in space over the New Year period at least and said that the cosmonauts had begun to observe "a slight uneasiness" in Vasyutin's behaviour at some point. He was not sleeping and suffered loss of appetite. Savinykh said that he put that down to his mood and they attempted to help him by cracking jokes and offering advice but Vayutin "became ill" and although the commander wished to ride the illness out the situation became worse.

Savinykh said, graphically, that Vasyutin became "a bundle of nerves". After consultations with FCC it was decided to return to Earth to treat Vasyutin and the decision to return was taken on November 17. During preparations for the return Savinykh wrote: "it seemed . . . that he was improving. But still we made the right decision."

Savinykh said that the men were able to screw and unscrew "dozens of bolts" in the complex and cover the portholes. The crew left a note for those who would follow them and Savinykh said that he had also left some things behind "so if I come back again (to Salyut 7) I'll have something to climb into".

PHOBOS LANDER MARS PROJECT

by Brian Harvey

A 460 day unmanned mission to Mars and its moon Phobos during 1988/9 is now in the final stages of design. Landers will be deployed on the Phobos surface and scientists in the Soviet Union hope to receive signals from these and spacecraft left in orbit for up to 12 months.

Phobos is the prime target for two probes to be launched by Dle Proton boosters in July 1988. First spotted by Asaph Hall in 1877, Phobos measures an irregular 27 x 21 x 19 km. It has a cratered, shapeless surface and always keeps the same aspect turned towards the mother planet Mars.

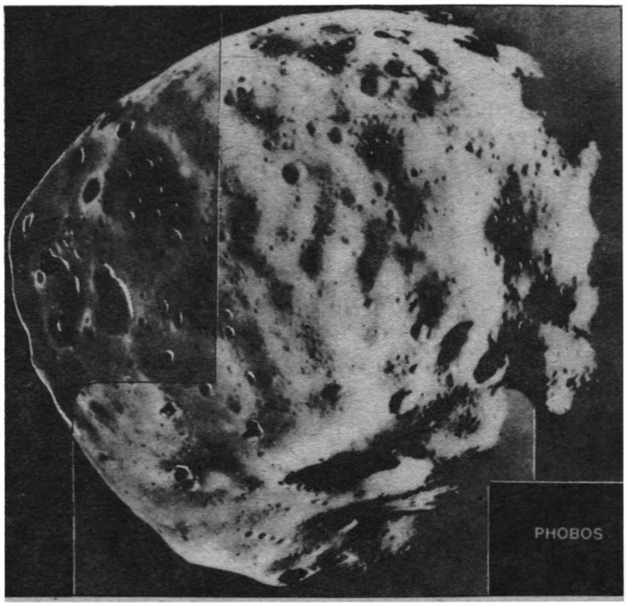
Detailed photographs of the moon were obtained by the American Viking orbiters in 1976-7 confirming earlier predictions that it could possibly be a captured asteroid. Phobos' terrain is dominated by a large 8 km crater, Stickney.

It is not clear from Soviet sources as to whether the second of the two probes to be launched in 1988 will also rendezvous with Phobos, or intercept Mars' other moon Deimos. This smaller moon, measuring 15 x 12 x 11 km is in a much higher orbit of 20,000 km, period 30.3 hrs. In contrast to Phobos, tidal forces are pushing Deimos away from Mars.

Mars-Phobos – mission timetable.

Date	Event
July 15, 1988	Launch of Mars-Phobos 1.*
Feb 2, 1989	Mars orbit insertion. Orbit 4200 by 60,000 km. Period 72 hrs.
Feb 27	Transfer to orbit of 9700 by 60,000 km, period 7070 hrs.
Mar 29	Rendezvous orbit. 9700 km circular. Period 8 hrs. Propulsion unit jettison.
May 3	Encounter phase (125 min) – deployment of landers; close to 50 m at 2 - 5 m/sec; surface remote analysis.
May 3	Post-encounter phase: return to 9700 km circular orbit.
Sep 20	Final Mars orbit of 9400 km by 9700 km. Period 7.6 hrs.
Oct 20	Conclusion of mission.

*This will depend at what exact moment the launching takes advantage of the 10-day window. Subsequent dates will alter accordingly as the launch goes before or after this date



Spacecraft coast to Mars will last 200 days. Mars Orbit Insertion will place the spacecraft in a highly elliptical orbit of 4200 by 60,000 km. A burn of 25 days will raise the periapsis to 9700 km, closer to Phobos' own altitude. A second burn will then lower the apoapsis. A third short burn will place the spacecraft on an interception course to Phobos. At this stage, its work done, the propulsion unit will be dropped.

The main spacecreaft will approach Phobos to a distance of 50 m. During the approach, there are two main events. First, the two surface landers are deployed and second, the main spacecraft will carry out laser and ion analysis of the surface. This phase of the mission will be fully televised.

After interception, the main spacecraft will remain in close proximity to Phobos for 140 days before transferring to a final 7.6 hrs orbit for 30 days.

Each main spacecraft will carry two landers, not one as originally envisaged. The larger of the two will weigh 35 kg and transmit for a year. The landers will carry six experiments, including television, seismic detectors, spectrometers, penetrator, and telephotometer. By the end of the year-long experiment, Soviet scientists hope to have precise measurements of Phobos' orbit and tidal effects. They hope to discover the chemical, thermal, physical and magnetic composition of the rocks. No lander designs have yet been released.

Experiments at interception

Two principal experiments will operate at interception : the remote laser mass spectrometer; and the remote mass analyser of secondary ions. The laser will evaporate and ionise surface material at 50 m range and analyse the free scattered ions in a reflectron. The experiment is being built by scientists from the USSR, Bulgaria, West Germany, the GDR and Czechoslovakia. Afterwards, it should be possible to know in detail the chemical, elemental and isotopic composition of the surface.

The remote mass analyser of secondary ions will identify the degree and manner in which Phobos' surface has absorbed the solar wind. An ion beam will be fired for one second from a distance of 100 m, and

a foil reflectron will analyse the outcome. This is a joint Franco-Soviet experiment.

A number of major experiments are to be directed towards both Phobos and Mars. In one, a radar will be used to scan the surface, structure and relief of Phobos down to a resolution of 35 cm. The same instrument will be used for radio-sounding of the Martian atmosphere. It is hoped to identify the boundaries of the Martian ionosphere and ionopause. and the nature of the Martian magnetic field. This experiment is operated at an altitude of 6300 km and is Soviet-built.

A complete video set will be carried by Mars-Phobos, including three stereo TV cameras and a memory unit able to store 1100 complete frames. The video unit will be used first in Mars orbit, where its resolution will be 7 km, each frame covering 3000 by 2300 km. It will also be used during the encounter with Phobos where its resolution will be 6 cm. It will be used to compile a detailed surface and geological map of the moon.

An infrared spectrometer, made by France and the USSR, will compile thermal maps of Mars and Phobos, identifying the mineral composition of the two bodies. It will be specifically designed to locate heat sources and permafrost.

The gamma spectrometer will study the nature and extent of galactic cosmic rays and related matter on the surface of both Mars and Phobos. It will help identify the chemical composition of the rocks and their radioactivity. This is a Soviet-only experiment.

Mars-only experiments

Two instruments will be carried which will be turned only towards Mars and will not be used in connection with Phobos. These are a neutron moisture meter which will search for water or moisture on the Martian surface and an atmosphere spectrometer. The latter will carry out a detailed analysis of the Mars atmosphere – its ozone, water vapour, oxygen, dust, carbon dioxide – over a sufficient period of time to identify any seasonal changes.

In-flight and solar experiments

Eight inflight instruments will be carried. These include a scanning analyser to study the magnetosphere of Mars and the solar wind; a low energy electron and ion spectrometer; a solar wind spectrometer (similar to that scheduled to fly aboard the ESA spacecraft "Ulysses" in May); a proton/solar wind spectrometer; a low energy solar X-ray spectrometer; two magnetometers; and a plasma-wave analyser.

As Mars-Phobos moves away from the Earth and towards the far side of the Sun, experimental packages will also study the Sun and its radiation. Nine instruments are being carried – an X-ray photometer; a solar ultraviolet radiometer; a gamma-ray spectrometer; a solar cosmic ray detector; and three solar photometers. Mars-Phobos will also carry an X-ray telescope.

The Mars-Phobos missions represent a quantum jump forward in terms of Mars exploration, just as Viking did in the 1970s and Mariner in the 1960s. A total of 31 experiments are planned, a record, and they should lay the firm basis for surface exploration by robots in the 1990s, and the precision required for Mars orbit rendezvous with Phobos will be similar to that ultimately needed on the first manned expedition.

SPECULATIONS ON A MANNED MISSION

The relatively close approach to Earth of Mars in August 2003, when the two planets will be within 56 million km of each other, provides the opportunity for a comparatively short duration manned mission to Mars.

Mohammed Q. Hassan, of the Scientific Research Foundation in Baghdad, evaluates the possibility of a Soviet manned landing during the early part of the 21st Century.

He writes: According to Soviet Scientist Rukavisnikov, speaking in a workshop on "Mars Landing Missions" in 1973, the shortest path to Mars gives a total trip time of 456 days.

Such a mission would allow 210 days for the outward trip, a three week landing period, and the remainder for the return journey. Spaceships for such missions could weigh between 900 and 3000 tons.

Why not then make use of the period between the years 2000 and 2006? Note that in August 2003 the distance between Earth and Mars will be only 56 million km.

Nuclear propulsion could also be considered. For example Soviet expert Prof. Sternfeld stated (1978) that a return trip could be made in less than a year with a stay at the vicinity of Mars of more than a week. This would require a starting velocity of 16 km/s obtained using nuclear propulsion.

It seems likely that the Soviets would send a Manned Mars Exploration Mission using the shortest possible time for such a Mission even if it required much higher delta velocity (DV) in order to reduce the problems of long term weightlessness without artificial gravity.

It will take the Russians no less than five years to reach a one year endurance stay in space, if we base our calculations on extrapolation from the previous long duration missions. (An increment of one month for each new successful endurance mission).

In terms of propulsion one could conclude that there is an active nuclear power propulsion programme going on.

The HLLV could place in orbit a 150-200 ton nuclear powered third stage either of the liquid core or a closed cycle gas reactor type. At least five HLLV launches would be required to assemble the big parts together in Earth's orbit.

One or more Landers could be incorporated and perhaps a small shuttle type spaceplane for skimming in Mars' atmosphere with refuelling capability. Experience with the planned 100 ton space station would provide the basis for the kind of habitable space for a Mars mission.

EUROPEAN RENDEZVOUS

BNSC Cash Boost for Hotol

The British National Space Centre is to provide cash support for proof-of-concept studies on Hotol, the horizontal take-off and landing space plane by British Aerospace and Rolls-Royce.

Studies on Hotol, and its revolutionary propulsion system, Swallow, will last for up to two years and cost £3 million. The contracts placed with the two companies contain a break point after the first six months when the position will be reviewed. The cost of the studies up to that point will be about £750,000 which will be shared equally by the BNSC and industry.

Geoffrey Pattie, Minister of State for Industry and Information Technology, said: "These studies will build on work already funded by the two firms and in particular establish if there are any insuperable difficulties with the concept and to provide credible design, performance and cost data on which to explore the technology with our partners in the European Space Agency.

"Many of the uses we might make of space are ruled out at present by our not having routine and cheap access to space. Even with the vigorous competition between Europe's Ariane launcher and the Space Shuttle, which I hope will soon overcome last week's sad event, getting spacecraft into orbit is still a very expensive business."

The studies on Hotol and Swallow will look at the feasibility of a spaceplane able to carry a load direct to space from a runway, without the need for expensive rocket launch facilities or major preparation lasting many weeks before launches. It would, for example, launch a satellite into an equatorial orbit and return direct to Europe. As it will not need booster rockets it will use less fuel compared with present launchers.

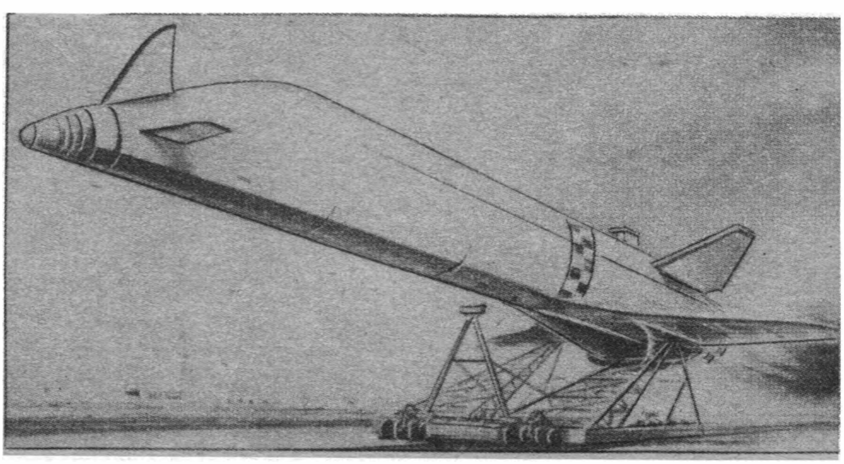
Its goal is to achieve launch costs to low Earth orbit for, say, a seven tonne payload at about one-fifth of those of current launch systems. Hotol's ability to recover satellites and to dock with Europe's Columbus and the American Space Station will also be investigated.

"The studies to be supported are essentially to prove the engine and other technologies involved, prior to considering whether to move into a traditional development programme. If Hotol is confirmed to be a technically and economically viable project, it will need to be considered alongside other long-term European plans, and I will ensure that the opportunity to develop Hotol with European partners remains open," said Mr. Pattie.

Hotol is an advanced concept for a horizontal take-off and landing launch vehicle for satellites based on a new power plant – Swallow – proposed by Rolls Royce. The novel propulsion system reduces the need for Hotol to carry large quantities of liquid fuel by utilising a hybrid engine arrangement which combines air-breathing and rocket propulsion.

In the first instance, Hotol would be developed as an unmanned automatic vehicle but it would be capable of being adapted for manned operations at a later date. Initial studies have already shown that it should have a good cross range capability and be able therefore to return direct to Europe after launching satellites into equatorial orbits. On present forecasts of its weight and volume Hotol will not need thermally insulating tiles like the Space Shuttle for its re-entry into the atmosphere.

In its characteristics and time-scale, Hotol is likely to be complementary to the projects of Ariane 5 already being undertaken by the European Space Agency with a planned in-service date of 1995 and to Hermes, a vehicle designed to be carried into space on Ariane 5 and able to stay in-orbit for periods of up to 30 days. With a crew from two to six astronauts, Hermes has been proposed by the French national space agency, CNES, to follow shortly after Ariane 5.



Hotol would carry a payload of 7-11 tonnes into low Earth orbit. It would use a liquid hydrogen fuel air-breathing engine during the early stages of flight and then draw on liquid oxygen carried on board for the remainder of the flight to low Earth orbit.

The Swallow propulsion system would allow Hotol to take off from a conventional Concorde-length standard runway from a re-useable trolley.

Hotol would climb rapidly clearing commercial airlines after 4-5 minutes and reaching Mach-5 and 26km altitude about 9 minutes after launch.

At this point the engine would cease to air-breath and the vehicle would climb on a higher, rocket-like trajectory.

EUROPEAN RENDEZVOUS

GIOTTO CLOSES IN

Europe's Giotto spacecraft is expected to meet Comet Halley around midnight on March 13 and make a close approach to the dust shrouded and never-before-seen nucleus.

At encounter the spacecraft, with its precious payload of 10 scientific experiments (two from the United Kingdom), will have a closing speed of a fantastic 68 kilometres per second. As it nears its intended 500 kilometre close approach there is a distinct possibility that Giotto will be destroyed or lost through collision with streams of icy dust particles being ejected from the nucleus.

Now visible only in the Southern Hemisphere, recent telescopic observations from both Earth and space show the comet has developed a bright and dust laden head and tail, so coming up to astronomers expectations.

The Comet will return to Northern skies in April and will probably be visible to the naked eye for several weeks before gradually fading as it heads away from the Sun into the cold depths of the Solar System.

Observations of the comet's head show the presence of dense jets of dust which Giotto must avoid if it is to survive long enough in its brief four hour encounter to make worthwhile scientific observations and take the first-ever pictures of the central nucleus.

HEALTHY ORDER BOOK

The number of launch service contracts held by Arianespace now stands at 40 (of which 28 are still to be fulfilled) following the latest contract from Intelsat for the launch of an Intelsat V1 F4 satellite in early 1990.

The satellite, which will be the fifth to be launched by Arianespace for the 110 member country Intelsat, will have the capability to provide more than 30,000 simultaneous telephone calls and three television channels.

Backlog orders secured by Arianespace are now worth more than 7.9 billion French Francs.

SATELLITES IN EDUCATION

An exciting new initiative is being launched that will involve the use of satellites in British schools. Already many enthusiasts, schools and colleges are receiving data directly from radio amateur satellites, University of Surrey satellites and weather satellites.

The use of this data will have a significant impact in the secondary school curriculum. It will:

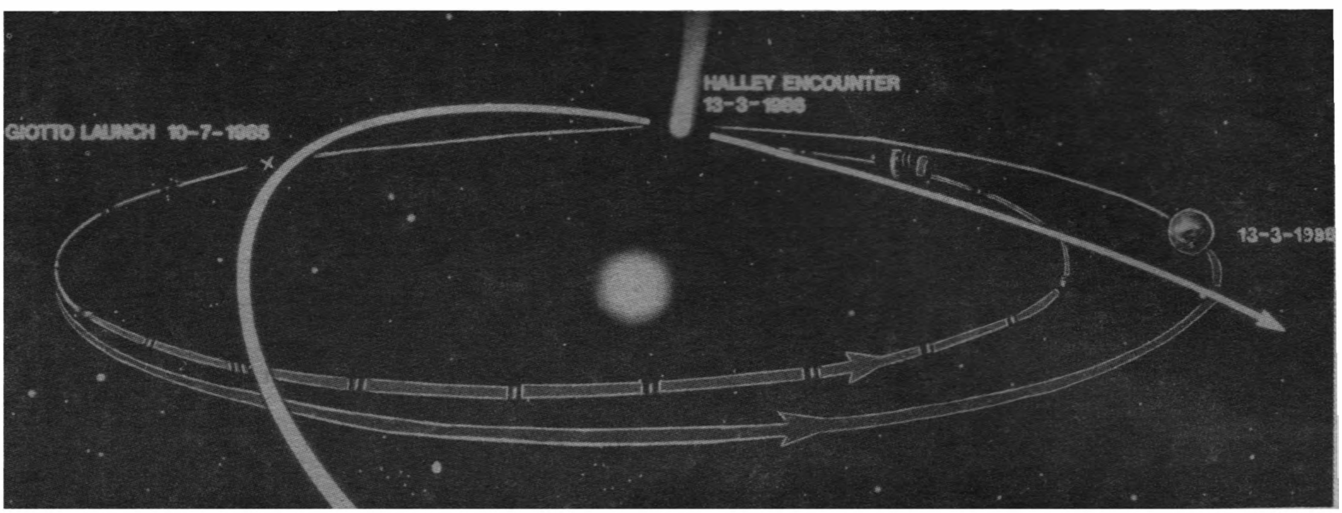
- Provide the opportunity for technological projects such as constructing detecting apparatus and creating computer models.
- Allow experimentation which reflects many aspects of large-scale research, that is collecting, processing and interpreting considerable amounts of live data.
- Promote cross-curricular activities linking mathematics, science and technology with the humanities, particularly geography.

Other education applications currently under way include the use of direct broadcasting satellites as an aid in modern language teaching.

A large number of interested organisations have joined forces to form the UK National Coordinating Committee for Satellites in Education. The group will assist and liaise with teachers who wish to become involved in using satellite data in education; individuals, or institutions who wish to conduct research on the educational use of satellites; and agencies that may fund projects.

Immediate tasks to be tackled by the group include identifying the roles of satellites and satellite data in education; ascertaining what information and equipment teachers need in order to make the best use of the resource and ensuring its development; assessing what software is needed and ensuring its development; and identifying how funds can be used to promote the use of satellites in education.

As part of the initiative a 40-page booklet *Satellites in Education – a guide for teachers* is now available. It is distributed for and on behalf of the National Coordinating Committee by AMSAT (UK), 94 Herongate Road, Wanstead Park, London E12 5EQ, price £3.50 (inc p&p). Cheques should be payable to S.E.U.K.



INTERNATIONAL SPACE REPORT

A monthly review of space news and events

REMOTE SENSING AGREEMENT

NASA and the European Space Agency (ESA), have signed a memorandum of understanding on cooperation in connection with the first ESA Remote Sensing Satellite (ERS-1).

Under the memorandum, ESA has agreed to permit direct readout of ERS-1 Synthetic Aperture Radar (SAR) data, for US government research purposes, at the Fairbanks, Alaska station that NASA is developing in connection with its Navy Remote Ocean Sensing Satellite System Scatterometer (NROSS) programme. In addition to the C-band SAR, ERS-1 will have a C-band scatterometer, a radar altimeter, an infrared radiometer, a microwave sounder and a precise positioning system.

ERS-1 is planned for launch in 1989 and will have a three year projected lifetime, with a possibility for a second flight unit to be launched in 1992/93.

Under the agreement, NASA also will exchange NASA scatterometer and radar imagery for other ERS-1 data of interest. The data received from ERS-1 should enhance NASA and ESA supported polar ice research and complement NASA experimental activities related to NROSS, the ocean Topography Experiment (TOPEX) and Shuttle Imaging Radar-C, all of which are projected to operate in the same time frame as ERS-1.

DELTA LAUNCH DATES

An up-dated launch schedule for the remaining four Delta launch vehicles has been released by NASA. All will lift off from the Eastern Space and Missile Center in Florida and the dates are: Delta 178 (model 3914) carrying the GOES-G satellite, May 1, 1986; Delta 179 (3914) carrying GOES-H, July 17,1986; Delta 180 (3920) DoD payload, August 14,1986; and Delta 181 (3920) DoD payload, August 1987.

SATELLITE MANOEUVRES

Inmarsat has carried out a complex series of satellite manoeuvres to enable it to make maximum use of its in-orbit resources in providing communications services for maritime and other mobile applications.

The process began on January 14 when the Inmarsat Pacific Ocean region traffic was transferred from the Marecs B2 satellite to MCS-D, the Maritime Communications Subsystem aboard the Intelsat V (F8) spacecraft.

This meant that the three coast Earth stations operating in the Inmarsat Pacific region – Ibaraki, Japan; Santa Paula, USA; and Singapore – had to realign their parabolic dish antennas to the new satellite's location at 180 degrees East in geostationary orbit.

Following its activation, engineers at the European Space Agency's satellite operations centre in Darmstadt, Germany, placed the Marecs B2 satellite, which is leased from ESA, in standby mode.

On January 15 ESOC issued a telemetry command through the telemetry, tracking and command station at Ibaraki, Japan, which caused the firing of hydrazine thrusters aboard Marecs B2, nudging it into a five degrees a day drift around the world in a westerly direction. It was due to arrive at its new station, at 26 degrees west over the Atlantic Ocean, on February 25 when it will take over as Inmarsat's Atlantic operational satellite from Marecs A.

Both Marecs satellites are capable of carrying the equivalent of 60 simultaneous telephone calls, but Marecs A has suffered a number of anomolies in its performance.

"Marecs B2 is the newest, and most powerful, of the satellites Inmarsat has in orbit," Inmarsat Director (Technical and Operations) Ahmad Ghais said. "These moves should enable us to use our resources to maximum advantage and to cope with growing demand until the launch of the first Inmarsat-2 satellites in 1988.

"The availability of MCS-D presented Inmarsat with the opportunity to deploy Marecs A in a less sensitive, less heavily loaded, standby role over the Pacific Ocean, and it will be drifted easterly to 177.5 degrees east," he added.

When the manoeuvres are completed Inmarsat system will be configured as follows:

Atlantic	India	Pacific
MARECS B2 26W	INTELSAT MCS-A 63E	INTELSAT MCS-D 180E
INTELSAT MCS-B 18.5W (Spare)	INTELSAT MCS-C 66E (Spare)	MARECS A 177.5E (Spare)

BAHRAIN JOINS INMARSAT

The State of Bahrain has become the 45th member country of Inmarsat – the International Maritime Satellite Organisation.

Inmarsat is the international cooperative organisation that operates a satellite system for the provision of satellite communications services to the world's shipping and offshore industries. It is also planning to offer services for aircraft in the near future (see ***Spaceflight***, January 1986). Currently more than 4,000 vessels and other units are equipped to operate with the Inmarsat satellites.

Bahrain is the seventh country in the Gulf area to join Inmarsat, others being Iran, Iraq, Kuwait, Oman, Saudi Arabia and the United Arab Emirates.

SATELLITE DIGEST – 190

Robert D. Christy

Continued from the February 1986 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources.

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

COSMOS 1702, 1985-106A, 16247.

Launched: 1225, 13 November 1985 from Plesetsk by A-2.
Spacecraft date: Possibly based on the Vostok manned spacecraft, with spherical re-entry module, instrument unit and a supplementary package of instruments at the forward end. Length about 6 m, diameter (max) 2.4 m, and mass around 6000 kg.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 414 km, 92.30 min, 72.88 deg.

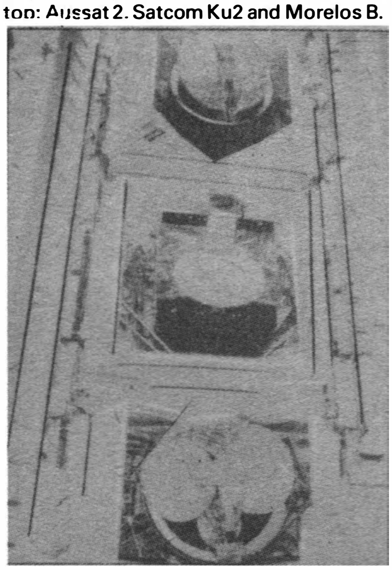
RADUGA 17, 1985-107A,16250

Launched: 1429, 15 November 1985 from Tyuratam by D-1-E.
Spacecraft data: Cylinder with a pair of solar panels, and a multi-dish aerial array at one end. Length 5 m, diameter 2 m, and mass around 2000 kg.
Mission: To provide round the clock radio, television and telegraphic communications within the Soviet Union through the 'Orbita' system.
Orbit: Geosynchronous above 35 deg east longitude.

COSMOS 1703, 1985-108A, 16262

Launched: 2219, 22 November 1985 from Plesetsk by F. vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 635 x 666 km, 97.79 min, 82.51 deg.

Cargo for mission 61B is loaded into the payload bay of Atlantis. From bottom to top: Aussat 2. Satcom Ku2 and Morelos B.



STS-61B, 1985-109A, 16273.

Launched: 0029*, 27 November 1985 from the Kennedy Space Center.
Spacecraft data: Shuttle Orbiter 'Atlantis'.
Mission: Carried crew of Shaw, O'Connor, Cleave, Ross, Spring, Walker and Neri (Mexican astronaut). Events included the launchings of three satellites, station keeping experiments with a small visual target vehicle, and testing space construction techniques during two space eva's by Ross and Spring. Atlantis landed at 2123, 3 December at Edwards AFB.
Orbit: Initially 357 x 366 km, 91.59 min, 28.46 deg, then manoeuvered several times.

MORELOS 2, 1985-109B, 16274

Launched: 0747*, 27 November 1985 from the payload bay of 'Atlantis' by PAM-D.
Spacecraft data: Hughes HS-376 type, spin stabilised satellite, cylindrical in shape and covered with solar cells. Diameter 2.16 m, and length 2.84 m, extending to 6.6 m on full deployment of the solar panel. The mass (excluding fuel) is 512 kg.
Mission: Mexican domestic communications satellite placed in orbital storage for up to two years.
Orbit: Geosynchronous above 116 deg west longitude.

AUSSAT 2, 1985-109C, 16275

Launched: 0120*, 28 November 1985 from the payload bay of 'Atlantis' by PAM-D.
Spacecraft data: similar to Morelos 3, except that the mass is 655 kg.
Mission: Australian domestic communications satellite.
Orbit: Geosynchronous above 156 deg east longitude.

RCA AMERICOM K2, 1985-109D, 16276.

Launched: 2150, 28 November 1985 from the payload bay of 'Atlantis' by PAM-D2.
Spacecraft data: Three axis stabilised, box shaped body, 1.7 x 2.1 x 1.5 m, with a 15 m span solar array and mass around 1100 kg.
Mission: Commercial communications satellite.
Orbit: Geosynchronous above 81 deg west longitude.

OEX, 1985-109E, 16277.

Launched: 0300, 30 November 1985 from the payload bay of 'Atlantis'.
Spacecraft data: 1 m diameter, circular cross section assembly, put together by the crew from three discs.
Mission: Visual target for station-keeping practice.
Orbit: 368 x 382 km, 91.87 min, 28.48 deg.

Australia's Aussat communications satellite prior to installation in the Shuttle cargo bay for launch during mission 61B.

COSMOS 1704, 1985-110A, 16291.

Launched: 1312, 28 November 1985 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a drum-shaped solar array with length and diameter both about 2 m. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 965 x 1009 km, 104.91 min, 82.94 deg.

COSMOS 1705, 1095-111A, 16296.

Launched: 1215, 3 December 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1702.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 415 km, 92.31 min, 72.87 deg.

COSMOS 1706, 1985-112A, 16306.

Launched: 1440, 11 Dec 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1702.
Mission: Military photo-reconnaissance.
Orbit: 162 x 340 km, 89.55 min, 67.16 deg.

COSMOS 1707, 1985-113A, 16326.

Launched: 1552, 12 Dec 1985 from Plesetsk by F Vehicle.
Spacecraft data: not available.
Mission: Electronic intelligence gathering.
Orbit: 634 x 655 km, 97.79 min, 82.54 deg.

USA 13 & USA 14, 1985-114A & 114B, 16328 & 16329.

Launched: 0055, 13 Dec 1985 from Wallops Island by Scout.
Spacecraft description: Uninflated balloon in cylindrical container.
Mission: Two targets for future anti-satellite tests by the USAF. The balloons can be inflated to 2 m diameter.
Orbit: 313 x 774 km, 95.38 min, 37.07 deg.

COSMOS 1708, 1985-115A, 16331

Launched: 0745, 13 Dec 1985 from Plesetsk by A-2.
Spacecraft data: as Cosmos 1703.
Mission: Photo-reconnaissance, all or part of the payload was an Earth resources package, recovered after 14 days.
Orbit: 257 x 273 km, 89.87 min, 82.28 deg.

COSMOS 1709, 1985-116A, 16368.

Launched: 0847, 19 Dec 1985 from Plesetsk by C-1
Spacecraft data: as Cosmos 1704.
Mission: Navigation satellite.
Orbit: 963 x 1013 km, 104.92 min, 82.95 deg.

MOLNIYA-3 (27), 1985-117A, 16393.

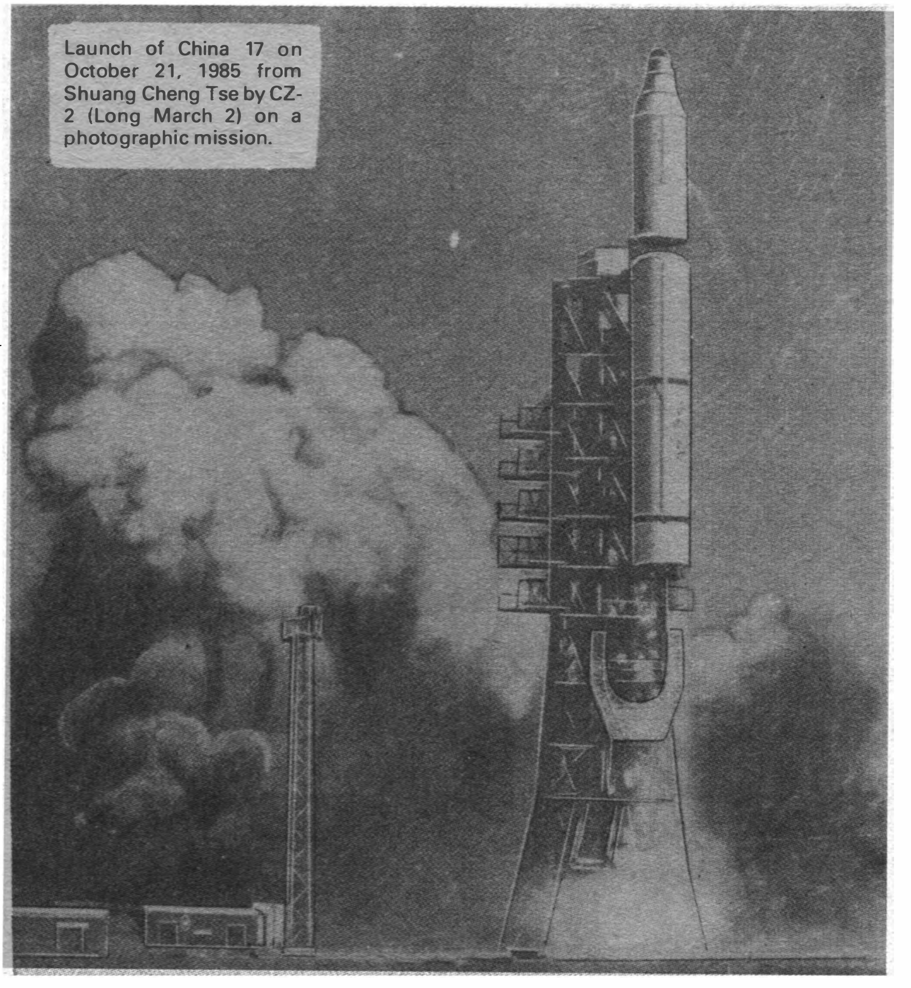
Launched: 1856, 24 Dec 1985 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with conical motor section at one end, deriving power from a 'windmill' of six solar panels. Length 4 m, diameter 1.6 m and mass around 2000 kg.
Orbit: 487 x 39904 km, 718.51 min, 62.85 deg.

COSMOS 1710-1712, 1985-118A-C, 16396-16398.

Launched: 2145, 24 Dec 1985 from Tyuratam, possibly by a version of the D vehicle.
Spacecraft data: not available.
Mission: Navigation satellites in the GLONASS system.
Orbit: 19133 x 19156 km, 676.33 min, 64.84 deg.

METEOR 2 (13), 1985-119A, 16408.

Launched: 0152, 26 Dec 1985 from Plesetsk.
Spacecraft data: Cylindrical body with two, sun-seeking solar panels, length 5 m, diameter 1.5 m and mass around 2000 kg.
Mission: Environmental satellite providing both cloud cover and Earth resources images.
Orbit: 939 x 962km, 104.13 min, 82.54 deg.



Launch of China 17 on October 21, 1985 from Shuang Cheng Tse by CZ-2 (Long March 2) on a photographic mission.

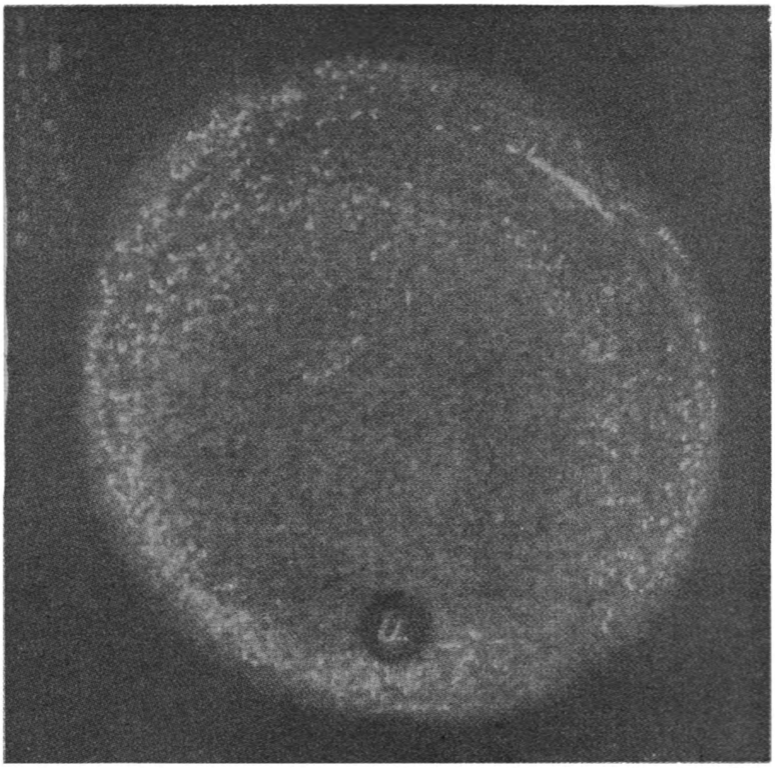
ARIANE LAUNCH MANIFEST

Flight	Month	Launch Vehicle	
		1986	
V 16	Feb	AR 1	SPOT 1 + VIKING
V 17	Feb	AR 3	G-STAR 2 + BRASILSAT S2
V 18	Mar	AR 2	INTELSAT V-F14
V 19*	May	AR 3	ECS 4 + SPACENET -F3'
V 20	Jul	AR 2 or 3	TV-SAT 1 (or AUSSAT K3 + TC 1C)
V 21	Aug	AR 4	APEX 401
V 22	Sept	AR 3 or 2	AUSSAT K3 + TC 1C (or TV-SAT 1)
V 23	Nov	AR 2	TDF 1
		1987	
V 24	Mar	AR 3	SBS 5 + ECS 5
V 25	Apr	AR 2	INTELSAT V-F13
V 26	May	AR 4	SES + F.O.
V 27	Jun	AR 2 or 3	TELE-X (or OLYMPUS)
V 28	Jul	AR 3 or 2	OLYMPUS (or TELE-X)
V 29	Sep	AR 2 or 4	INTELSAT V-F15 (or DFS 1 + MOP 1)
V 30	Nov	AR 4 or 2	DFS 1 + MOP 1 (or INTELSAT V-F15)
		1988	
V 31	Jan/Feb	AR 4	INTELSAT V1-F3
V 32	Mar/Apr	AR 2	SPOT 2
V 33	May/Jun	AR 4	DFS 2 + HIPPARCOS
V 34	Jul/Aug	AR 4	TDF 2 + F.O.
V 35	Sep/Oct	AR 4	F.O.
V 36	Oct/Nov	AR 4	MOP.2 + F.O.
V 37	Nov/Dec	AR 4	INMARSAT 2-F2 + SKYNET 4C

*Priority for AUSSAT K3 in case of unavailability of ECS 4 or SPACENET F3'

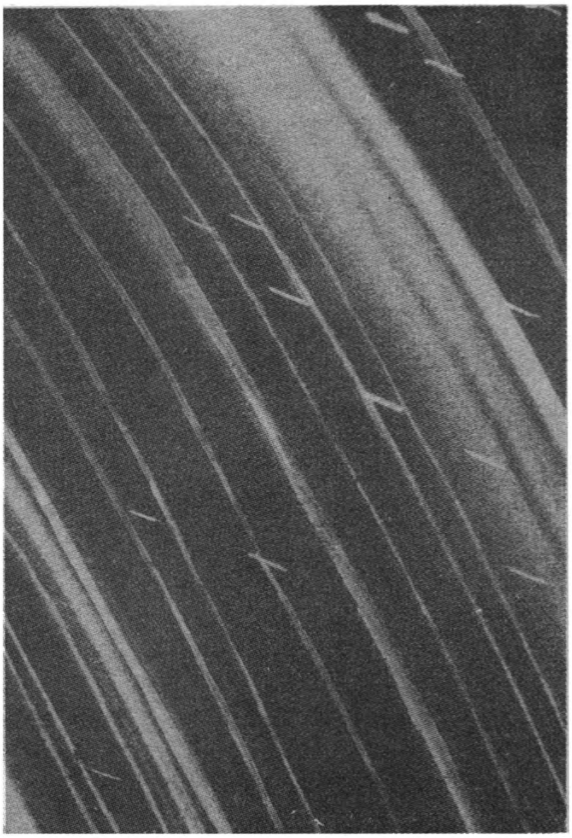
F O = Flight Opportunity

A VOYAGE OF D

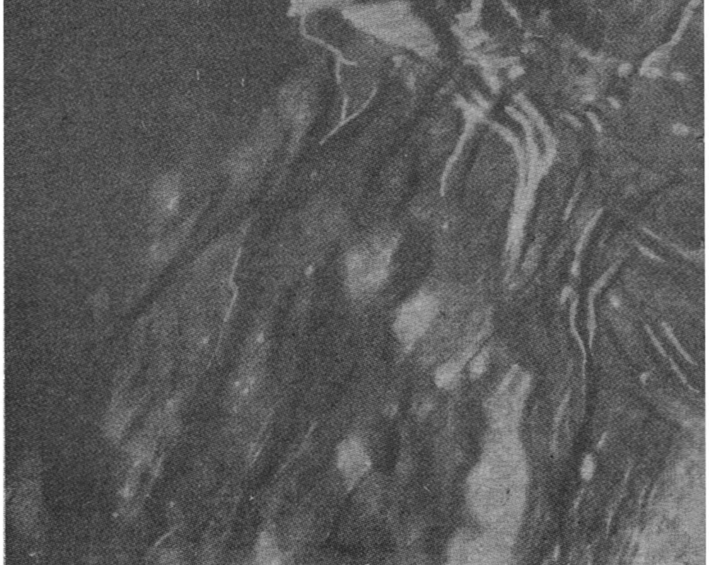


In this highly processed composite picture of Uranus a cloud form can be seen as a bright streak near the planet's limb.

Miranda from a distance of just 31,000 km. This hig
of fractures, grooves and scars. The great variety
different densities of impact craters upon them, si

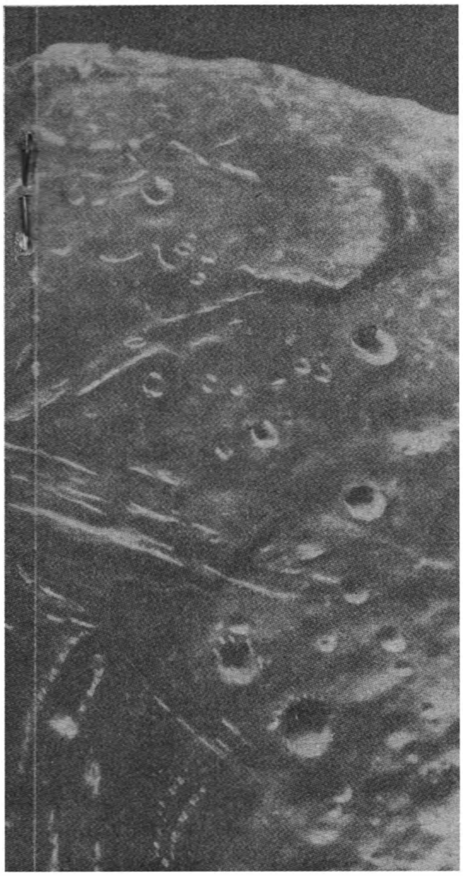


A continuous distribution of small particles throughout the Uranian ring system is revealed in this dramatic picture. This was a time exposure and the streaks are due to trailed stars.



Miranda at close range (36,000 km) displaying two distinct types of terrain –
striated terrain.

ISCOVERY

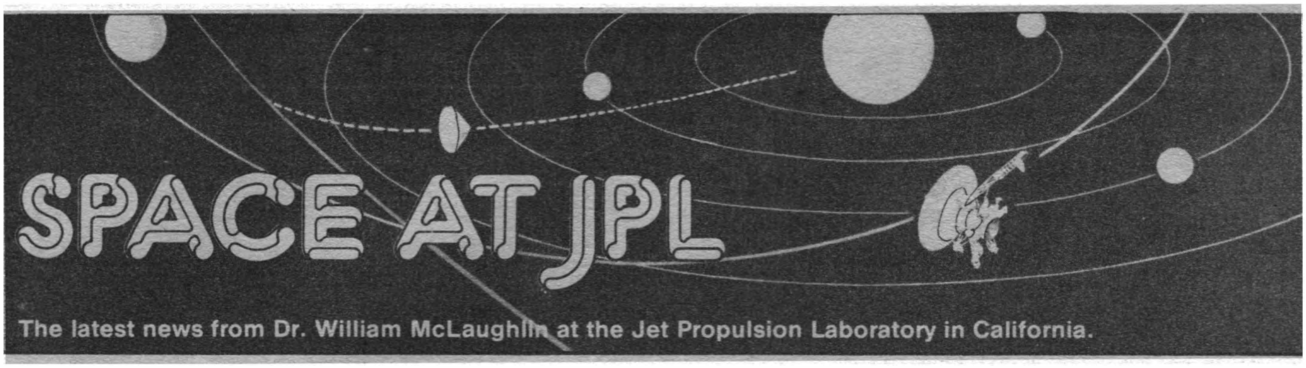


high resolution picture reveals a bewildering variety
riety of directions of fracture and troughs, and the
, signify a long, complex geologic evolution.

in – a rugged, higher-elevation terrain (right) and a lower

A mosaic of the four highest resolution images of Ariel. Numerous valleys and scarps criss-cross the highly pitted terrain.

THE FIRST CLOSE-UP PICTURES FROM URANUS



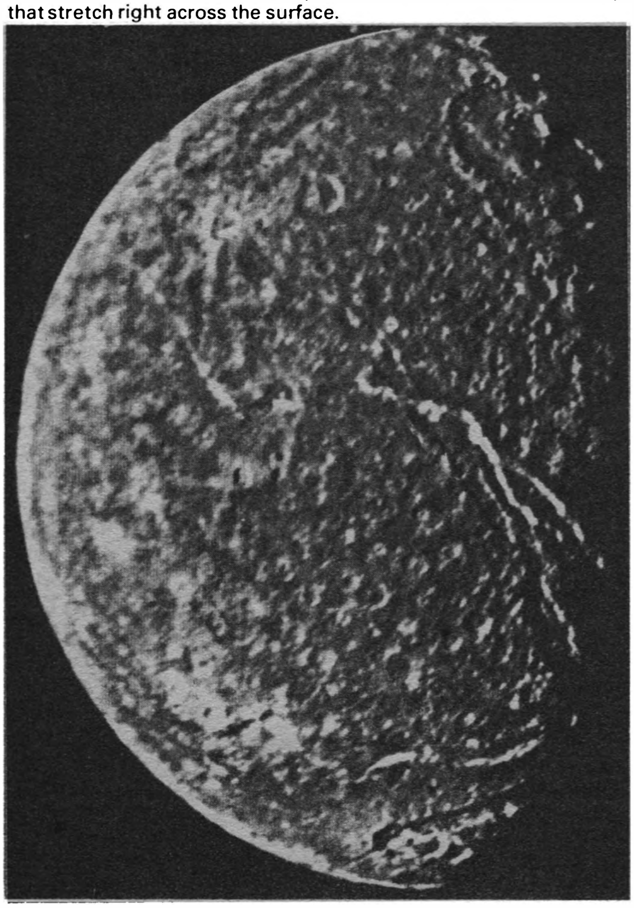
Uranus Discoveries Thrill

Not since the discovery of Uranus by William Herschel in 1781 has so much new scientific information been obtained about Uranus and its satellite system as with the Voyager 2 fly-by. At 17:58:51 GMT on January 24, 1986 the Voyager 2 spacecraft made its closest approach to Uranus, approximately 107,000 km from the centre of the planet, and our fund of planetary knowledge became further enriched.

The highly successful encounter period actually began on November 4, 1985 and extended to February 25, 1986 but the most intense and most important segment of activity occurred in the few hours centered about closest approach (see the November 1985 issue of *Spaceflight* for a Voyager flight plan).

The relative compression of the near-encounter period was due largely to the fact that Uranus lies on its side, with the south pole pointing in a sunward direction. Hence the on-rushing Voyager 2 pierced the plane defined by the planetary equator much as a projectile going through a bullseye target (but slightly off centre, where the planet lies!). Since the rings and satellites are located in the equatorial plane, the spacecraft was closest to almost everything of interest at about the same time.

This is a composite picture of Titania, largest Uranian satellite with a diameter of 1,600 km. The most prominent features are fault valleys that stretch right across the surface.



A detailed review of the scientific results is scheduled for publication in late May in the journal *Science.* A preliminary summary of some of the more important findings is given here.

The planet does possess a significant magnetic field. The most surprising feature of the field is the fact that the magnetic pole is inclined 55 degrees to the rotational pole, so that the field wobbles considerably as the planet rotates on its axis.

The discovery of new bodies included 10 satellites (five were known), one or possibly two rings (9 were known), and several partial rings or arcs. The count may increase as the data are analysed in greater detail.

The Uranian rings appear to be composed of relatively large objects, of the order of a metre or so, and have been swept clean of most small ring particles. However, a long-exposure image with the wide-angle camera, while the rings were backlit by the Sun, revealed dust structures of considerable complexity, resembling images taken at Saturn. Thus, some small particles are present, but not in as great numbers as for the Jovian and Saturnian rings.

The satellite Miranda displayed structures of great variety on its surface. The close approach to that intriguing satellite and the steadiness of the spacecraft while images were being taken yielded some of the most interesting pictures that Voyager has recorded in more than eight years of flight.

Imaging of the other four previously-known satellites also revealed geological structures such as craters, rays, valleys and scarps. Preliminary estimates for these satellites (Oberon, Titania, Umbriel and Ariel) indicate that their density may be in the range of 1.5 to 1.7 gm/cm^3 (water has a density of 1.0 gm/cm^3). Further refinements of these estimates will come when radiometric tracking data have been folded into the analysis. The first new satellite discovered by Voyager 2, 1985U1, was imaged from a distance of about 500,000 km. Features, including craters, were visble on

its surface, and its diameter was estimated to be 170 ± 30 km.

The atmosphere of Uranus showed much less in the way of features than did those of Jupiter and Saturn, but some clouds and other structural features were observed. The temperature profile of the atmosphere as a function of altitude was successfully measured, as was the planetary rotation period (approximately 16.8 ± 0.3 hours – greater accuracy should be achieved upon further analysis), and auroral activity was detected in the atmosphere. An earlier, Earth-based estimate of a very high helium content was not substantiated; the Uranian atmosphere contains 12 ± 4 per cent helium by volume.

With the planned addition of Neptune to the scientific stable in 1989, planetary theorists should have sufficient data to provide definitive models for these residents of the outer Solar System.

A VOYAGER DIARY

The following notes were synthesised from various personal and public records that pertain to the encounter of Voyager 2 with Uranus. The treatment of the encounter is, perforce, sketchy, and the perspective is skewed to my responsibilities as manager of the Flight Engineering Office for the project. Nevertheless it is hoped that some of the flavour of the event can be conveyed through a diary treatment of significant events.

Times are quoted in Pacific Standard Time (PST), which is eight hours earlier than GMT. The number inside parentheses after each date measures the distance of the spacecraft from Uranus at 9 am (PST) in millions of kilometres. Behind the welter of facts and technicalities look for the reaction of the Voyager flight team to the first encounter with Uranus – the thrill of it all!

March 7 1985 (412.1)
First meeting of the Navigational Data Working Group. Wrinkles in new software and hardware installed by the Deep Space Network (DSN) have been resulting in less tracking data with which to estimate our trajectory. I am not concerned for now, but formed the group to ensure we can monitor and influence the performance at encounter.

March 30 (382.7)
Loaded the new dual-processor computer program on Voyager 2. It was briefly tested onboard last fall but will now stay through encounter. Its function is to package the imaging data more efficiently before its transmission to the DSN stations on Earth. By this means we can send back more than twice as many pictures than with the old scheme – an important consideration with the increasing communication distance to Earth.

June 5 (297.1)
The reduced pulse width testing is going well on Voyager 1 (most engineering innovations are tested on the ground and then on this spacecraft prior to use on Voyager 2). This involves making the attitude-control thrusters on the spacecraft fire shorter bursts, by a factor of two, which will result in more gentle control of the spacecraft's orientation. This, in turn, will yield less smear (from "rocking") in the images to be taken at Uranus. It is four times darker at Uranus than Saturn, necessitating longer camera exposure times. During the time the shutter is open we are vulnerable to image smear and consequent loss of resolution.

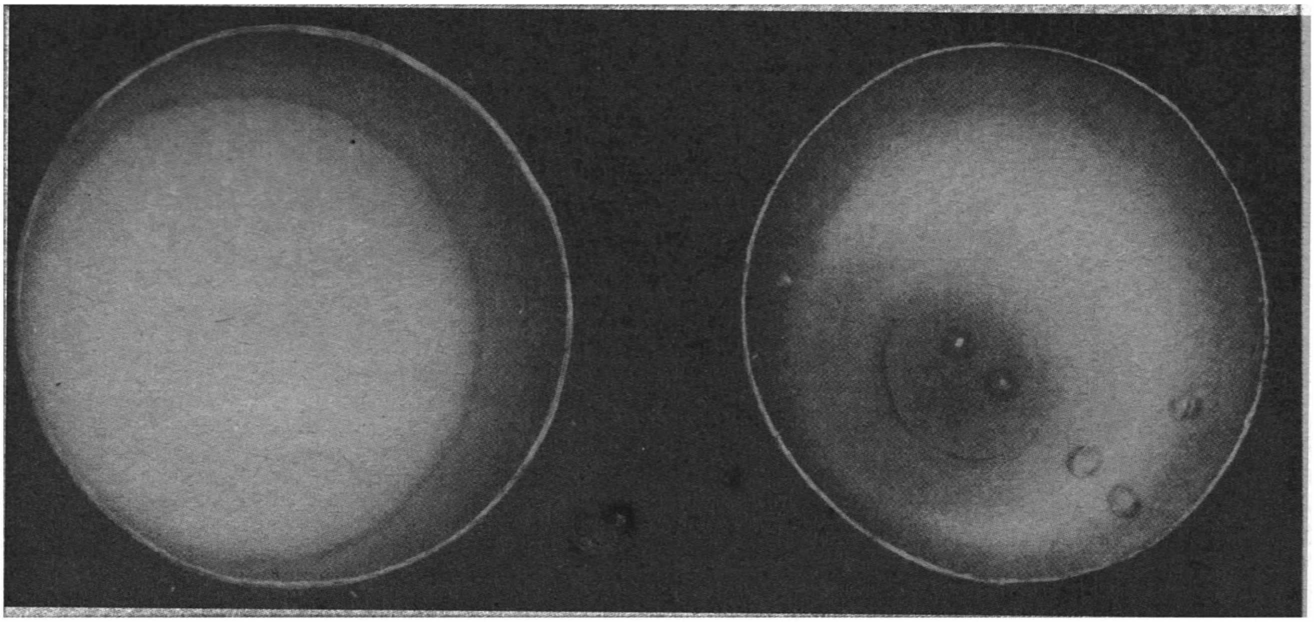
June 13 (286.9)
Looked at the first Voyager 2 optical navigation images we have taken of the Uranian satellites (on June 7). The four larger satellites are visible, but smaller Miranda is still too faint. Now we can start improving the knowledge of the orbit of Uranus and the satellites. I can smell the first wisps of methane from the planet!

July 16 (244.8)
All-day formal review of the project's test and training plan for the encounter. Ray Heacock (a former Voyager project manager) chaired the Review Board, which expressed concern about DSN readiness. I showed statistics from the Navigational Data Working Group.

July 31 (225.7)
Most critical point of testing reduced pulse width on Voyager 2. Went well.

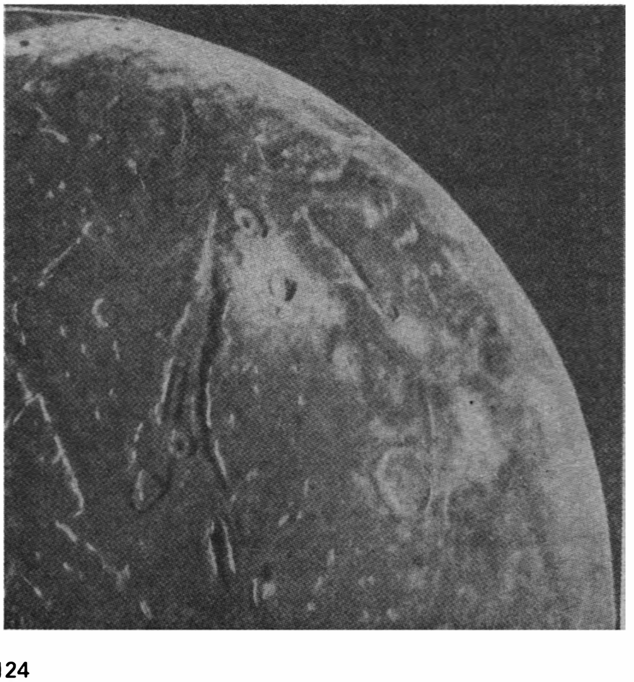
August 6 (218.0)
Dick Laeser (Voyager project manager) and I are in Washington at NASA Headquarters to brief them on Voyager. He outlined science highlights, and I covered engineering. Visited the Air and Space Museum later in the day.

The twin pictures of Uranus were compiled from images returned on January 17 from a distance of 9.1m km. The image on the left would have a green hue and is as the human eye would see the planet from a similar distance. The false colour picture (right) brings out subtle details in the polar regions.



September 9-10-11 (174.7-173.4-172-2)
First test of the all-important Late Stored Updates (LSU) procedure. This flight team activity will take place, for real, in a 30-hour period just before closest approach to Uranus. Then we will utilise the latest navigational data to calculate new pointing, timing, and other critical-parameter changes for cur observations at closest approach. After calculation the new parameters will have to be uplinked quickly to the spacecraft. This test was split into three parts, one done on each day. Fairly smooth performance. No spacecraft commanding included.
October 13 (131.4)
Dr. Charles Stembridge died today. My colleague, who was Manager of the Flight Science Office on Voyager, had fought pancreatic cancer with courage and determination since last year. His contributions at Jupiter and Saturn were great, and he will be missed.
October 24-25 (117.4-116.1)
Near Encounter Test (NET). This simulates on the ground and on Voyager 2 the activity at closest approach: first the LSU by the flight team (see September entry), then the response by the spacecraft. We did not do so well, only getting the changes up to the spacecraft with 10 minutes to spare, but it performed well. We decided to retest the ground activity on November 9.
November 4 (103.4)
The Uranus encounter offically began this morning with some ultraviolet observations.
November 5 (102.1)
Voyager Readiness Review all day. Still concerned about the DSN by the Review Board.
November 8 (98.3)
Surprise; the Epsilon ring of Uranus was seen yesterday on a long-exposure (15 second) optical navigation image. Some had thought the rings were too dark to be seen this early, but I won a dollar bet from Charley Kohlhase (Manager of the Mission Planning Office) that they would be seen this month.
November 9 (97.0)
The retest of the ground portion of the NET went very well.
November 13 (91.9)
Saw Halley's comet for the first time – with 7x35 binoculars. Good luck to Giotto and the others in the Halley fleet.
November 18 (85.6)
Meeting with the navigators to assess our status. I want to get them all together every few weeks to trade ideas. Navigation at Uranus is made more difficult by the great distance (hence less accurate *a priori* satellite and planet orbits), lack of a preceding flight by a Pioneer spacecraft (as occurred at Jupiter and Saturn), and the unusual tipped-pole geometry.
November 21 (81.7)
No emissions from Uranus have been detected by the Planetary Radio Astronomy experiment yet; one consequence is that we probably will not see a strong magnetic field at Uranus. This would also imply a low-intensity radiation environment. Good! Spacecraft computers can malfunction if the radiation levels get too high.
November 28 (72.8)
Late in the evening my wife Karen and I went to JPL to watch long-exposure images being returned from Voyager 2. We saw the Epsilon ring clearly. The Imaging Team says that our reduced pulse width effort has paid off with the ability to produce these images.
December 2 (67.7)
Meeting on advanced planning for Neptune. Even though we are nearing Uranus, the drum is starting to beat for the 1989 flyby of Neptune.
December 9 (58.8)
Voyager 2 is behind the Sun today. Relativity and solar corona experiments are being done in this period of time (few weeks), using the X-band and S-band radio systems.
December 13 (53.7)
Important milestone as flight team representatives met to discuss the changes we want to make to our closest approach observations. We were able to fit almost all desired scientific and engineering updates into these modifications. The observations will fill the few days around closest approach and will be optimised later by the LSU. The changes proposed today are conceptual ones driven by thought and Voyager 2 observations over the past few week.
December 16 (49.9)
Voyager Family Night at the Laboratory in the evening. Spouses and children saw movies and heard a talk by Ed Stone about Uranus. They also got to see the flight team Mission Support Area.
December 20 (44.8)
The Navigation Team thinks that the mass of Uranus is 0.3 per cent greater than previously expected. Consequently we will move the aim point a few hundred kilometres outward from Uranus in order to achieve the desired gravity assist to Neptune. Some relative timing changes will result in the observations of Uranus. The Science Office has been briefed.
December 23 (41.0)
Trajectory correction manoeuvre went well. The velocity change was 2.1 metres per second. The spacecraft was off Earth-point for the manoeuvre and communications were thus interrupted. A dramatic reminder of its return to Earth-point took place when all the line printers started their chorus of chatter again, recording the restoration of spacecraft telemetry.
December 25 (38.4)
Ham for Christmas dinner. Took the day off from work. The whole family looked at Halley through our 4-inch reflector. All four Galilean satellites were also visible about Jupiter.
December 31 (30.8)
The unofficial word through the project today is that a new satellite of Uranus was discovered in earlier images. Confirmation awaited.
January 3, 1986 (27.0)
The IRIS (infrared experiment) instrument returned anomalous data from its recent health check. It has a history of problems, but this seems to be a new trouble. Considerable concern exists.
January 4 (25.7)
The PPS (photopolarimeter) decided to misbehave today. It did not go to the proper-sized field of view upon command. This is an old problem with the PPS. We spent most of the day analysing the situation and started corrective action.
January 7 (21.9)
More data have been analysed concerning the IRIS problem. My impression after talking with the instrument people is that the experiment will execute satisfactorily at Uranus.

A high resolution picture of Ariel, a Uranian moon with a diameter of 1,300 km. The complexity of Ariel's surface indicates that a variety of geologic processes have occurred.



Third meeting of the navigation discussion group today (see September 18). We are seeing a slight drift in successive trajectory estimates which may indicate an unmodelled force, but generally things are going well. We know the arrival time at Uranus to within about 70 seconds now. The delivery position with regard to the Miranda flyby is now known to 500 or 600 km; by closest approach we have to have that down to 100 km for accurate pointing.

January 9 (19.3)

The new satellite discovery has been released to the press; this is the sixth satellite for Uranus. A seventh and eighth are in the process of being confirmed prior to public release. A composite image of the atmospheric features seen to date is also ready for release. With a dark area around the pole it looks like a giant eye in the sky. The drift in successive trajectory estimates continued and has become a source of worry.

January 13 (14.2)

Check of the IRIS instrument showed that it is now working well!

January 15 (11.7)

Navigational Discussion Group met in the morning. The drift in trajectory estimates has stopped, and we are just getting stochastic fluctuations in the estimates as we add more optical and radiometric date. We held an operations strategy review all afternoon. Went over the plans for next week's near encounter events. The important IRIS observation of the infrared output of Uranus seems to have gone well. This will factor into an eventual compilation of the heat balance of the planet.

January 16 (10.4)

The discovery of six new satellites was announced today. Uranus now has 12 of them. Special Nav Working Group meeting showed that the last weeks of DSN tracking data have been excellent, about 90 per cent of it is usable. Now we have to hold this performance through encounter. Reviewed our last Far Encounter sequence load before uplinking it to the spacecraft tomorrow. We are closing in!

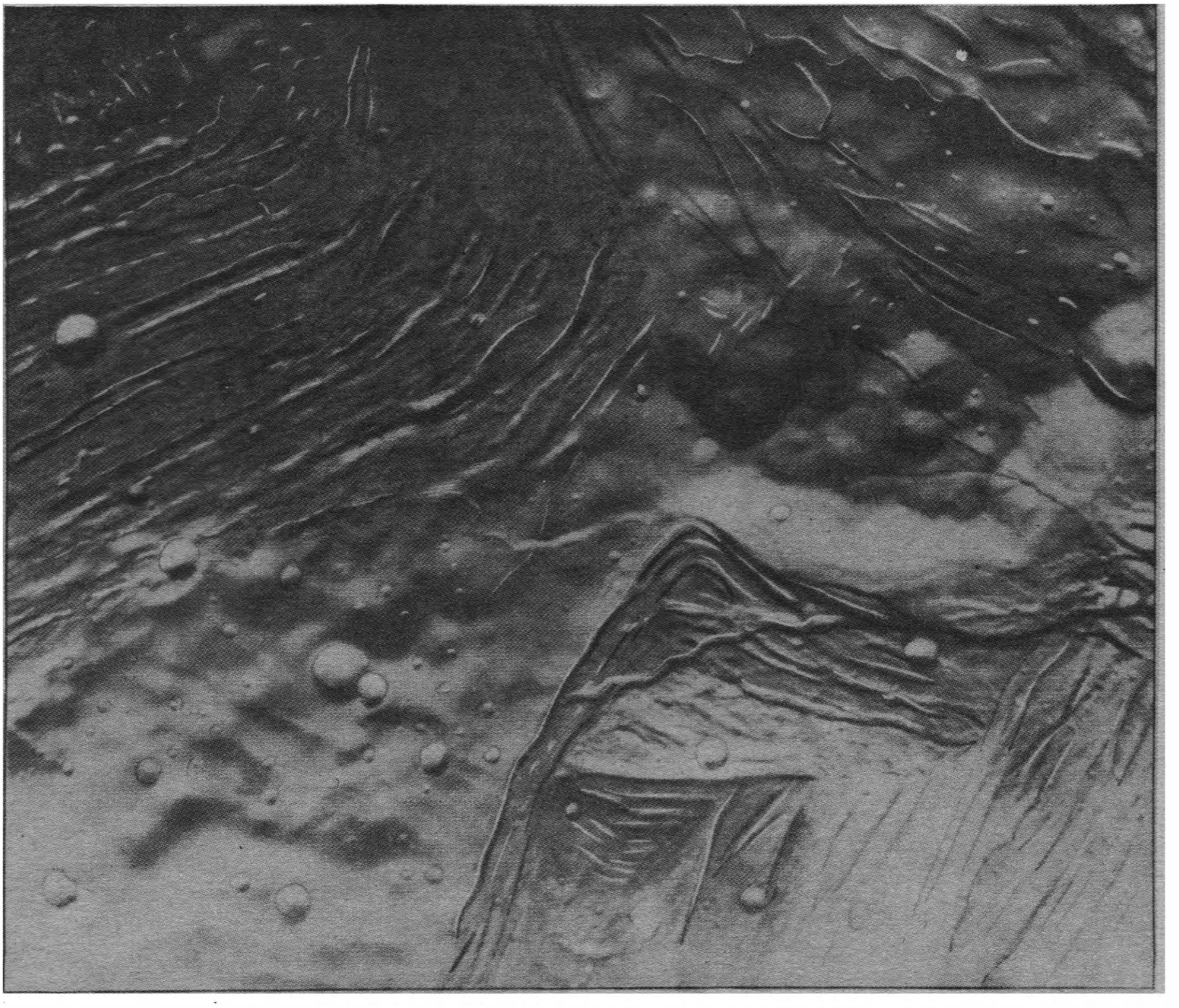
January 17 (9.1)

We cancelled the trajectory correction manoeuvre scheduled for Sunday; the first time an encounter manoeuvre has been cancelled on Voyager. The course is so close to where we want to go that there is no reason to touch it up. The benefits from not doing it up are fourfold: (1) the tracking – date blackout for a day or so after a trajectory correction manoeuvre on Voyager 2 will be avoided (the Voyager 2 receiver has a reduced bandwidth due to a failed capacitor and cannot be locked onto after certain thermal events), (2) we do not introduce a propulsive "bump" into the ongoing orbit determination process, (3) the small but always-present risk of such an event is avoided, (4) the workload for the flight team is reduced considerably.

January 18 (7.8)

White and dark lines have started appearing in many of the Voyager 2 images. We have an analysis meeting scheduled for early tomorrow.

This image of Miranda shows an unusual "chevron" figure and regions of distinctly differing terrain. Taken at a distance of 42,000 km the picture spans an area about 220 km across.



January 19 (6.6)
Analysis of the performance of the ground system has uncovered no problems, indicating that the problem is the images may be onboard the spacecraft. We spent the day generating commands to send the Voyager 2 to read out one of its computer memories which, from the symptoms, is suspect. About midnight the read out came to Earth (5½ hour round trip light time to Uranus) and showed that one bit in one word in the memory was "1" when it should be "0". We will fix it tomorrow. At 3 am my Deputy Manager (Donna Wolff) and I watched the last diagnostic test of the scan platform gear mechanism on Voyager 2. That gear mechanism malfunctioned just after the closest approach at Saturn, and we have been using it carefully and monitoring it closely ever since. If the diagnostic test failed, we would use an already-prepared alternative sequence load at Uranus closest approach, one which would not employ the once-faulty gear but use instead motion of the entire spacecraft to help point the remote-sensing instruments. Fortunately, the mechanism worked perfectly and we endorsed the normal use of the scan platform for the next few days of crucial observations.

January 20 (5.3)
Decided to modify the onboard computer program to avoid the bad bit and, at the same time, to see if we could change it back from "1" to "0". By midnight the results were back; the correction has been made but the bit did not flip, so it is a hardware failure – no big problem for only one word of memory. The pictures should be cleared up tomorrow. Six of the nine known rings are now easily visible on the TV monitor on my desk.

Januarty 21 (4.0)
I held an Engineering Office staff meeting today to check our status before the critical activities of the next few days. The spacecraft is healthy and producing good images after yesterday's repair. Navigation looks solid; the relative uncertainty between the spacecraft and Miranda is down to about 200 km. For pointing the cameras, we need to achieve 100 km or less and appear to be on the way to accomplishing this figure. The Sequence Team has got our computer load for closest-approach observations almost done. Kelly Beatty of *Sky and Telescope* magazine dropped in to discuss the encounter. Press interviews are increasing.

January 22 (2.7)
The Uranian satellites are growing in size on my TV monitor and starting to show features. How often does one get to observe the approach of a new world? In the evening we started the all-important Late Stored Update (LSU) (see September 9). The Navigation Team will process optical and radiometric tracking data all night. Donna has the watch overnight.

January 23 (1.4)
I have the watch today. We had a well-attended meeting at 5 am to evaluate the navigational results. They look great! Our knowledge of the trajectory is turning out to be better than expected. The Spacecraft and Sequence Teams started to work processing the navigational results to modify the timing and pointing parameters in the program onboard Voyager 2. The Navigation Team continues to process tracking data for further refinements. By midnight we were done with the LSU and the modifications to Voyager 2 at 1:15 am. The Navigation Team really nailed the trajectory, with an uncertainty between the spacecraft and Miranda within 50 km. Lack of engineering excitement has never been so welcome. Got to bed at 2 am.

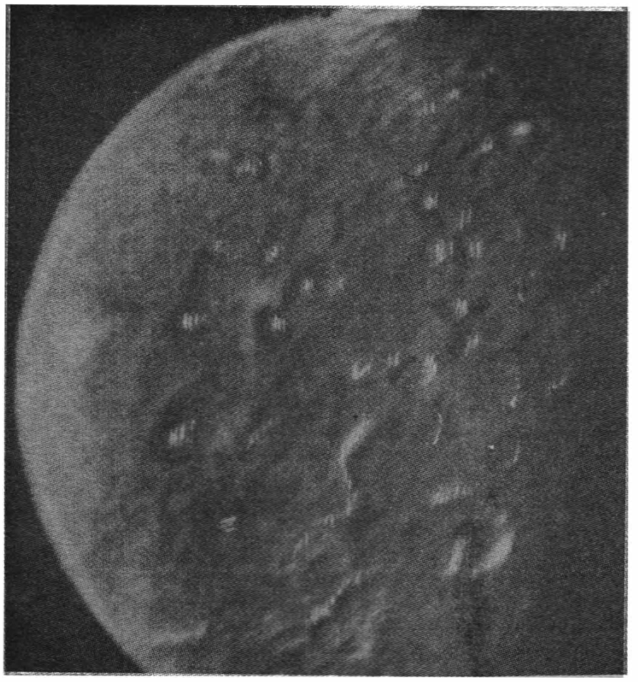
January 24 (as close as 107,000 km today)
This is it – the big day. I arrived at JPL early, and, generally, all was progressing as expected. However, Howard Marderness (Spacecraft Team Chief) reported that we had seen one cycle error in the attitude control computer. This will not have an effect but could be serious if it persists. It means the computer is overly busy. The phenomenon did not occur at the Near Encounter Test (October 24) but we have made slight changes to the observing program since then. Just before I was ready to give a TV interview at 4 pm, the "beeper" on my belt sounded. But after a quick check with the Spacecraft Team the news was good; the cycle errors (there had been four more) were benign and we should be OK. The interview was, consequently, quite a nice event for me. Voyager 2 slid behind Uranus, and continued its experiments. We could detect its existence through radio waves that it was beaming through the Uranian atmosphere to probe the structure of that entity. The DSN was performing magnificently. The spacecraft emerged from occulation about 4:30 pm. The telemetry was not turned on for another two hours (to facilitate a radio science experiment measuring ring structure). When it did come back on all systems were in excellent condition. We did it! Tomorrow the pictures will be replayed from the tape recorder and we will begin to see what the rings, satellites, and surface of the planet really look like. In the early evening, several of us sat in the project office, listening to the mission and looking at data, but mostly we had begun to relax from the tension of the last few weeks.

January 25
Today, in effect, we went through the Uranian system for a second time as the pictures were replayed. What a feast! Miranda is proving to be the real star of the show. Karen and three of our four children joined me as other visitors and guests from around the world converged on JPL.

January 26
At today's press conference, the scientists commented on how crisp and clear the images were and expressed their approval of the smear reduction measures we had taken to steady the spacecraft as an observing platform. Our pointing also turned out to be near perfect, and we captured the most difficult target of all: nearby (29,000 km) Miranda. It was certainly worth the effort, for geologist Dr. Larry Soderblom described the satellite as a "bizarre hybrid" of geological forms and one of the most interesting objects in the Solar System.

January 27
I had not been able to get with Len Carter yesterday; he was here as a guest of the Laboratory to observe the encounter. But this morning we met and went to visit Dr. Lew Allen, Laboratory Director. The sky is blue in Southern California today and the temperature is about 80 degrees, but I think the warm glow from the encounter is what I feel most.

The southern hemisphere of Umbriel displays heavy cratering in the image taken from a distance of 557,000 km. Umbriel is the darkest of Uranus' larger moons and appears to have experienced the lowest level of geological activity. The strangest feature on this image is a curious bright ring. Its nature is not known, although it may be a frost deposit, perhaps associated with a large impact crater.



COMET FLY-BY FIRST RESULTS

by L. J. Carter

The International Cometary Explorer (ICE) crossed the tail of Comet Giacobini-Zinner on September 11, 1985 becoming the first ever spacecraft to intercept a comet. The encounter produced a rich harvest of information about the interaction between the comet's atmosphere and the solar wind.

Scientific findings from the fly-by of Giacobini-Zinner by the American ICE spacecraft confirmed the traditional portrait of a comet and yielded much new information.

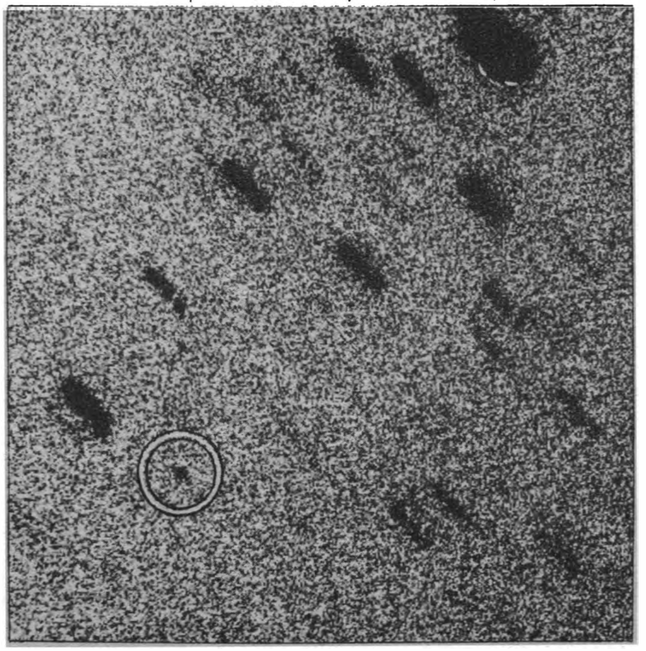
Among unexpected measurements were the spatial extent and intensities of the energetic cometary ions found by the Energetic Particle Instrument. Signs of these were detected much further out than expected at a distance of more than one million km before closest approach.

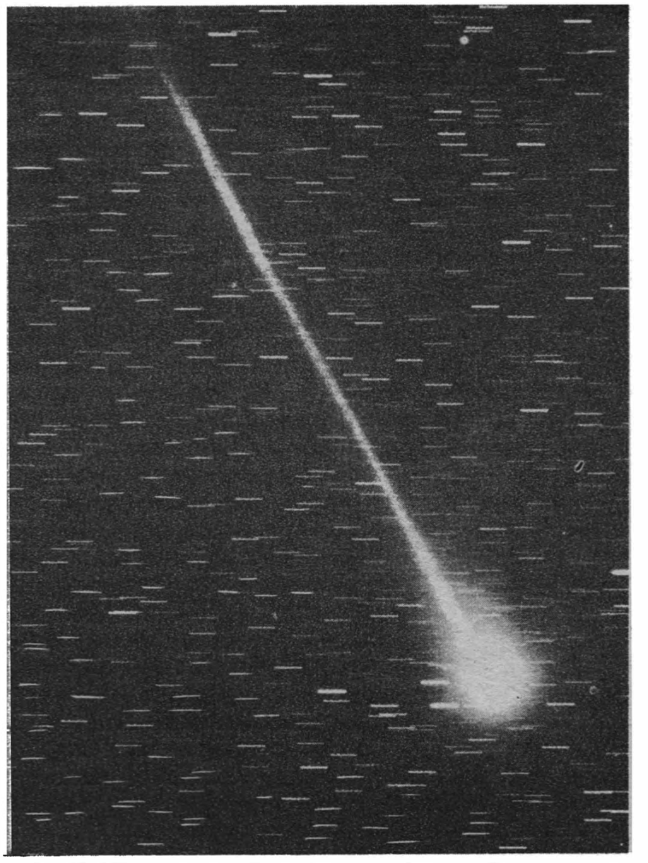
The spacecraft payload had originally been designed to measure the solar wind, solar X-rays, energetic charged particles and the composition of galactic cosmic rays.

So, of the 13 instruments onboard, seven were selected on the basis of returning the most useful data during the cometary encounter and these were: Electron plasma, Magnetometer, Plasma waves, Radio waves, Plasma composition, Low-energy cosmic rays, and Energetic particles.

Prior to encounter it had to be decided on the exact trajectory through the comet's plasma tail.

The recovery of Giacobini-Zinner on 3 April 1984, from the Kitt Peak National Observatory by S. Djovgovski and H. Spinrad (University of California, Berkeley), and G. Will and M.J.S. Belton (Kitt Peak National Observatory). The elongated images are stars smeared out as the telescope tracks the predicted motion of the comet.
National Optical Astronomy Observatories





Comet Giacobini-Zinner, with its ion tail, is shown in this 26 October 1959 photograph by Elizabeth Roemer. *US Naval Observatory*

An aiming point far down the tail carried the risk of missing it altogether due to the 'wagging' effect in response to variations in the velocity of the solar wind.

And aiming too close to the nucleus would have created a potentially serious dust hazard. As a compromise interception of the tail was planned at 10,000 km from the nucleus but a minor orbital trim manoeuvre on September 8 to take account of the latest information on the comet's position reduced the actual flyby distance to around 8,000 km.

The cometary presence was first noticed in the energetic ion data about 24 hours prior to closest approach and some kind of 'bow shock' wave was detected early on September 11. However, the characteristics were quite different from the bow shock observed in front of planets like the Earth and Venus.

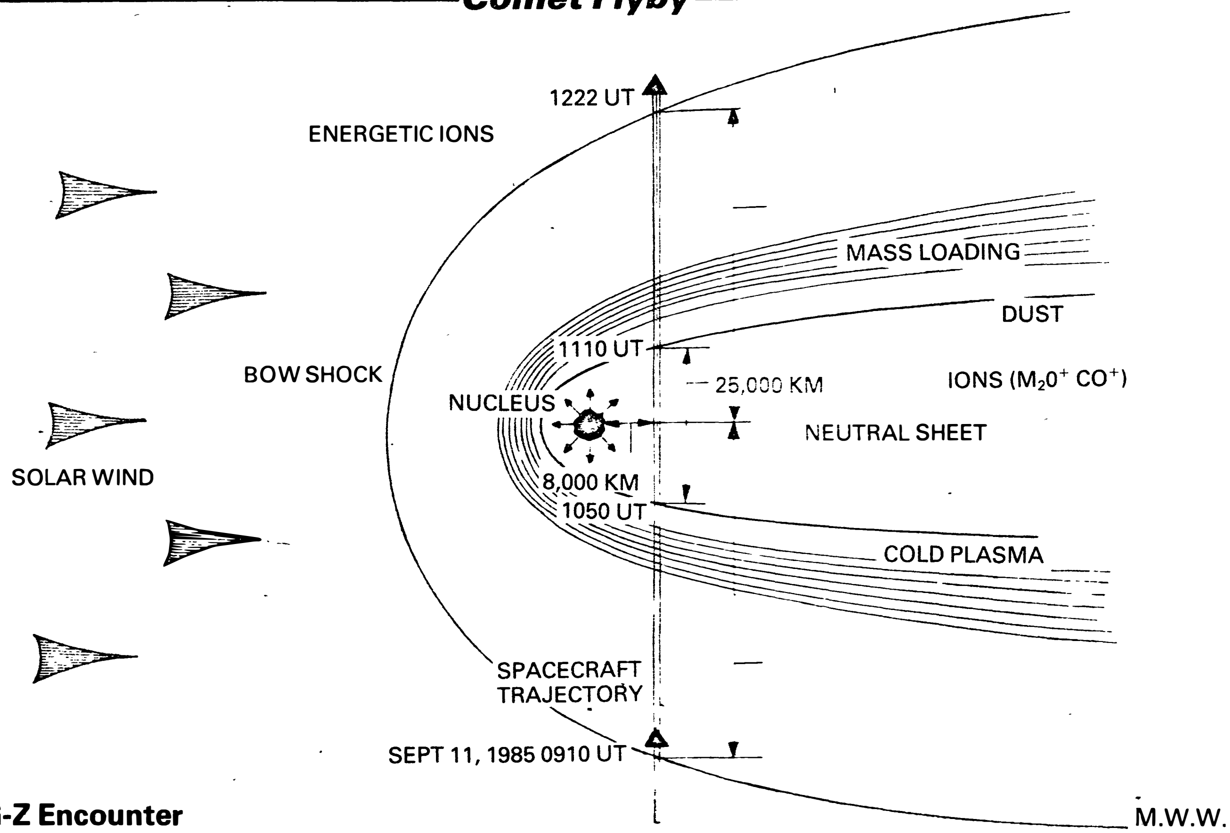
Sudden changes in the magnetgic field were not clearly detected and no distinct point was found where the plasma density rose to higher values inside than outside. The high mass density of cometary heavy ions may cause this unexpected structure but the true nature of the cometary 'bow shock' remains open.

As the time of closest approach drew closer the ICE spacecraft traversed a region of turbulence (known as the "interaction region") where assimilation between cometary ions and solar wind plasma takes place.

The turbulence decreased before ICE entered the cold plasma tail where cometary plasma of high density and low energy dominated.

The outward pass revealed similar characteristics to the inward one, including the 'bow shock' structure. Total width of the cometary interaction region between the shock boundaries was found to be 250,000 km, 140,000 km on the inward pass and 100,000 km on the outward.

A major prediction confirmed by the ICE data was



ICE G-Z Encounter

that the magnetic structure of the comet's plasma tail consisted of two parallel lobes, each threaded by a magnetic field of opposite polarity – a structure suggested by Dr. Hannes Alfven in 1957.

One of the most unexpected results was that neither the spacecraft nor its instrument payload suffered damage as a result of impact with cometary dust.

ICE did not carry a specific dust experiment but it was possible to deduce information on dust impacts from the plasma wave detector data. Micron-sized particles were recorded during the crossing of the plasma tail, with a peak in the impact rate near the point of closest approach.

Comet Giacobini-Zinner, with a short period of 6.5 years, is a member of the Jupiter family of comets. It was discovered by M. Giacobini at Nice, France, in 1900 and rediscovered by E. Zinner at Bamberg, Germany, 13 years later.

By 1985 it was at its 11th observed apparition, reaching eighth magnitude at its brightest. The comet has a fairly stable orbit inclined at about 30 degress to the ecliptic, though discontinuities in its orbital motion, probably caused by outgassing (jets), qualify it as an "erratic" comet.

Studies suggest that it has a highly flattened nucleus with an equatorialdiameter of 2.5 km, which is some eight times larger than its polar diameter.

This flattened nucleus seems to be spinning rapidly, making a complete rotation every 1.66 hours – close to the critical rate at which an oddly-shaped iceball could, literally, break into pieces.

The success of ICE's encounter with Comet Giacobini-Zinner has given officials at NASA cause for optimism that the spacecraft will be able to collect useful scientific data about Halley's comet.

Scientists say there is now a good chance that the spacecraft will be able to measure particles from Halley's comet at the end of March and during the first week of April.

Sun Explorer Turns to ICE

When the International Sun-Earth Explorer 3 (ISEE-3) was launched in August 1978 there were no plans for cometary encounters – its mission was to collect scientific data about the solar wind and study the Earth's magnetosphere.

However, the spacecraft remained in good operational condition on completion of its three year mission and in June 1982 was diverted by NASA controllers to study the Earth's magnetotail.

Then, in March 1983, began a series of spectacular orbital manoeuvres for ISEE-3 computed by Dr. Robert Furquhar and his team of engineers at NASA's Goddard Flight Center.

The spacecraft traced a series of complex curves, diving from deep outer space to within a mere 120 km of the Moon's surface on the final occasion before being catapulted out towards Comet Giacobini-Zinner. It was at this point the probe's name was formally changed to International Cometary Explorer (ICE).

But the historic 'first' may not be the end for this remarkable spacecraft. After passing within 32 million miles of Comet Halley at the end of March it will continue out on an elliptical orbit.

That orbit will return ICE to the vicinity of the Earth in the year 2012 and Furquhar predicts, with some excitement, that a gravity assist manoeuvre using the Moon could place it into an Earth orbit.

From here, the Space Station complex and an Orbital Transfer Vehicle might then be able to retrieve it and return it to the Earth for examination and display!

Compiled by L. J. Carter

COMET STAMP COLLECTION GROWS

Stamps commemorating the return of Halley's comet are currently being released by more than 20 different countries from around the world.

The British Post Office set were released on February 18 and the four stamps feature paintings of the comet at various stages of its return to the vicinity of the Sun (see ***Spaceflight,*** February 1986).

Other countries which have already released commemorative stamps include Ascension Island, Bermuda, British Antarctic Territory, Hong Kong, Jersey, Malawi, Mauritius, Seychelles and Swaziland.

Those countries still to publish their special stamps include Australia (April 9), Botswana (March 28), Fiji (July), Micronesia (March), Norfolk Island (March 11), Papua New Guinea (May) Samoa (April), St Helena (May), Sri Lanka (March), Tristan da Cunha (March), and Solomon Islands, Trinidad and Tobago, Vanuatu and Zambia (dates to be announced).

Books Galore

The number of books on comets (many specifically on Halley's comet) which have appeared over the past year is now approaching 50.

It is impossible to keep pace with all these but a further batch of reviews of some of the more important works appears below.

Mankind's Comet

G. Ottewell and F. Schaaf, Astronomical Workshop, Furman University Greenville, S.C. 29613, USA, 15 x 11 in. 1985, 193pp $22.00.

This is a good addition to any collection on Halley's comet for it contains several unusual features both in presentation and content.

Sub-titled "Halley's Comet, in the past, the future and especially the present", this is probably the largest-sized book devoted solely to the comet which has yet appeared. Although directed to the layman, it contains much historical material not covered elsewhere, e.g. references to events contemporary to the non-observed appearances of the comet between 315 BC and 140 BC. All the subsequent recorded appearances are dealt with in turn, and most interesting they are. This digest is followed by descriptive text of comets in general, drawing attention to many characteristics both of comets and meteors.

Considerable information is given about the 1910 return and the authors also describe the current "space fleet" of cometary probes.

Particularly interesting is one of the appendices which is an Atlas of the 48 visits computed for the comet from 140 BC to AD 2133. Charts show the movements of the comet at each return against the stellar background, as seen from Earth, though only the charts for 1404 BC and 1986 are fully labelled.

Comet

G. Walz-Chojnacki, AstroMedia, a division of Kalmbach Publishing Co., 625 East St. Paul Ave, P.O.Box 92788, Milwaukee, WI 53202, 64pp. $9.75.

Sub-titled "The Story behind Halley's Comet" this book sets out to provide, for the younger reader, a simple explanation of comets and their effects on mankind, ending with a series of star maps, tips on observation and several projects on comets and meteors.

The book, beautifully illustrated and very easy to read, should meet the needs of its potential readers admirably.

Comet Watch: The Return of Halley's Comet

Frank H. Winter, Lerner Publications Company, 241 First Avenue North, Minneapolis, Minnesota 55401 USA, 1985, 64pp, U.S.$9.95.

This is a book on Halley's comet which a young reader will not fail to find interesting. It explores the fascinating characteristics of the famous fiery, mysterious object that has played such an important role in human history beginning with an account of early beliefs that comets were warnings of impending disasters and going on to explain how the work of Halley marked a turning point in comet history. The author also describes preparations being made around the world for the 1985-6 return.

The book is well illustrated, easy to read and, as one might expect from such an author, very well researched.

Some of the recently introduced stamps commemorating the return of Comet Halley.

Halley's Comet

M.E. Bailey, Department of Astronomy, The University, Manchester, M13 9PL, 1985, 90pp, £1.50.

The author set himself the task of finding a reliable yet non-wordy guide to Halley's comet. Finding none suitable, he prepared this short introduction to comets generally and to the 1985-6 sighting of Halley's comet in particular, including finding charts and hints on how best to observe the comet.

Oberserver's Guide to Halley's Comet

J. Muirden, George Phillip, 12-14 Long Acre, London WC2E 9LP, 73pp, 1985, £2.95.

This handy paperback is an easy guide for anyone interested in observing Halley's comet. It includes advice on finding the Comet with the naked eye, bionoculars or telescopes. It is illustrated with month-by-month star maps while tables for each month give details of the comet's rising and setting times and altitudes.

Halley's Comet: Memories of 1910

R. Etter and S. Schneider, Abbeville Press Inc, 505 Park Avenue, New York, N.Y. 10022, USA, 1985, 96pp, $19.65.

The authors spent years accumulating what they call a whimsical collection of Halley's comet memorabilia, all dating back to 1910 and a collection which has now grown to the point that it is acknowledged to be the largest in the world.

This is amply borne out by the present volume, containing 200 illustrations in colour and which amounts to a fabulous potpourri of artefacts to do with the comet from bracelets, buttons, telegrams and compacts to cartoons, newspaper clippings, advertising, souvenirs, song sheets and a marvellous collection of over a hundred post-cards. It even includes childrens' games, silver pieces and the first Delft commemorative plate!

Comets, Meteors and Asteroids: How they affect Earth

S. Gibilisco, John Wiley & Sons, Shripney, Bognor Regis, West Sussex, PO22 9SA, 1985, 208pp, £11.45.

Impact craters on many worlds show that meteors, and possibly comets, must have also affected the Earth in bygone years. From this it is only a short step to consider how such events could have altered the Earth's climate and even the evolution of life.

The author pays particular attention to the latter and considers whether such impacts could have caused the demise of the dinosaurs or changed the geographical orientation of the Earth's axis.

He traces events from the big bang theory of the origin of the Universe to the leftovers from the formation of the Solar System. Considerable space is given to the treatment of comets, such as their possible origins, lifetimes and probable ends.

A further chapter discusses Halley's comet, while another introduces the topic of comet-hunting for amateurs. This is followed by a similar chapter on meteors/meteorites before ending on such speculataive matters as whether and how comets contributed to the origin of life on Earth.

KEEP UP TO DATE

The Halley Comet "Hotline" is concentrating on the progress of Giotto. Regular reports can be obtained from dialing the following numbers:

Belfast	**0232-230-505**	**Birmingham**	**021-355-6144**
Bristol	**0272-279-494**	**Cardiff**	**0222-399855**
Glasgow	**041-552-6300**	**Leeds**	**0532-8013**
Liverpool	**051-236-8474**	**London**	**01-790-3400**
Manchester	**061-246-8061**		

TELESCOPE DETECTS ICE

Solid ice particles have been detected in Halley's comet, confirming for the first time the theory that comets consist largely of ice.

The idea that comets are "dirty snowballs" was first presented in the 1950's but direct evidence for the existence of ice has always been missing.

Observations made at the Lick Observatory allowed astronomers to penetrate the gas cloud surrounding Halley's comet to a region where ice grains exist intact. There they detected a characteristic infrared signature from the ice grains.

The observations were made with the Observatory's 3-meter Shane Telescope on the nights of November 5 and 6, 1985. Discovery proved possible because of good timing and the use of a special spectrometer recently developed at Ames Research Center. A spectrum was made by passing sunlight reflected by the comet through this spectrometer – ice grains in the comet absorbed some of the Sun's infrared energy, leaving a tell-tale feature in the spectrum.

"We were able to see down to where snowflakes were coming off the comet," said David Rank, Lick Observatory astronomer and UC Santa Cruz professor of astronomy.

Timing of the observation was critical. Had the comet been too far from the Sun there would not have been enough reflected sunlight to give a strong signal: had it been too near, its own infrared emission would have completely masked the absorption feature of the ice grains in the spectrum.

Astronomers had long supposed that ice was present in comets because they observed gaseous hydrogen and oxygen compounds – presumed to be by-products from the breakdown of the ice in the cloud, or coma, surrounding and hiding the comet's nucleus.

In 1983, observations of Comet Cernis by Martha Hanner of JPL indicated the presence of ice grains but her work involved measuring the brightness of the comet in three regions around the ice grain absorption feature and discovering decreased brightness in one of the regions. The Lick-Ames group is the first to reveal a spectrum that clearly shows the absorption feature at the wavelength at which ice grains are known to absorb infrared light.

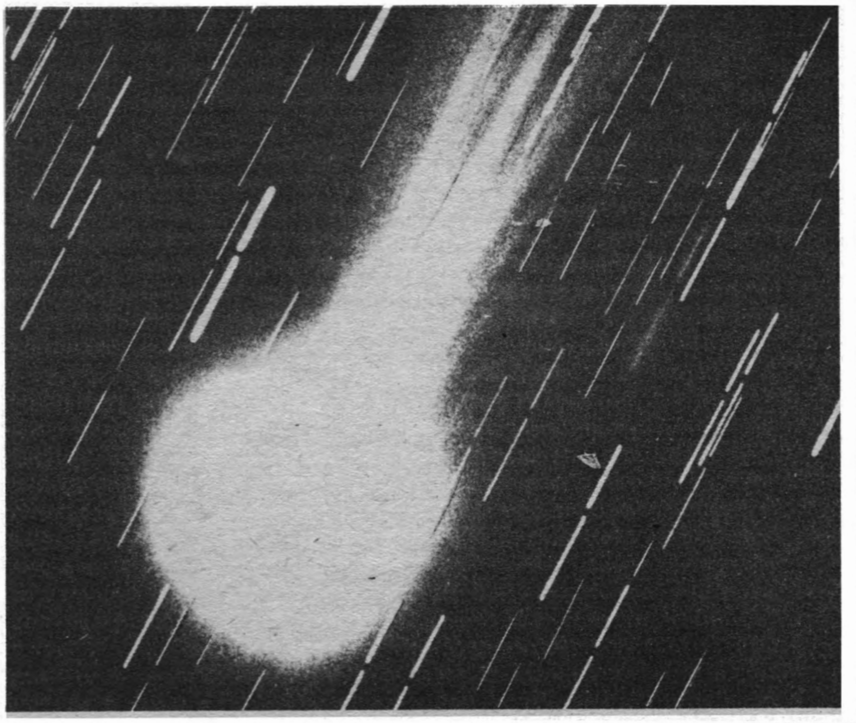
Attempts will be made to observe this absorption feature, called an "ice band" in other comets as well so that its exact shape can be pinned down and deductions made on the exact composition of the ice. Since comets are thought to be primordial material left over from the Solar System's formation period, their exact composition is of great interest.

NEW TASK FOR GIOTTO

Giotto, with only 12 per cent of its onboard stock of hydrazine used and now likely to survive the Halley's comet encounter undamaged, seems in good shape to accomplish a second mission.

No studies have yet been made for a second mission but there is plenty of time for these to be done. A suitable candidate could be Comet Schwassman-Wachman 3, a very faint object discovered photographically in 1930 and with a period of six years.

HALLEY'S COMET STARTS A TAIL



Halley's comet photographed on December 9, 1985 with the Anglo-Australian Telescope at Coonabarabran, New South Wales, Australia. The telescope followed the comet's motion during the exposure, so that all stars appear as lines.

As the comet approached the Sun, gas and dust were freed from the icy nucleus to form the bright head and tail which now appear to an observer on Earth.

The pressure of radiation from the Sun on the tenuous head sweeps some of the material, away to form the tail, which is seen stretching to the right.

Individual streamers in the tail are believed to originate from different spots on the nucleus.

PIONEER OBSERVATIONS

NASA's Pioneer spacecraft, still orbiting the planet Venus, began six weeks of observations of Halley's comet during the comet's most active period closest to the Sun (perihelion).

Observations in the ultraviolet spectrum began on December 26, 1985 the first phase ending on January 4 when both Venus and Pioneer passed behind the Sun for almost a month, cutting off effective communictions between the spacecraft and ground controllers at NASA's Ames Research Center, Mountain View, California. Observations resumed on February 3, six days before perihelion, and continues until March 6.

Near the time of perihelion, the comet, Venus and Pioneer were all located on the opposite side of the Sun, some 160 million miles away from Earth. Pioneer was the only spacecraft close to Halley's comet at this time.

It is hoped that Pioneer's observations will reveal the rate of change of comet outbursts and evaporation with time, the composition of the coma (gas and dust cloud around the comet nucleus), and the extent of the hydrogen cloud. Other data may show the shape of the coma and its gas/dust ratio.

This was Pioneer's third look at a comet. It viewed Comet Encke in mid-1984 and Comet Giacobini-Zinner in September 1985. Somewhat surprising data showed that Comet Encke was losing water at a rate of three times greater than expected for its distance from the Sun.

Pioneer spins on its axis five times a minute as it journeys in orbit around Venus. By choosing the number, length and direction of thruster pulses, engineers can tilt this axis to any desired position. For the Halley's comet observation, the spin axis was moved in small increments by firing some 1,000 pulses, each of half-second in duration. The entire manoeuvre consumed nearly half of the spacecraft's usable fuel reserve.

Because the spectrometer has a small field of view and is always rotating, it "saw" only a strip of Halley's comet during each spin. However, by tipping Pioneer so the spectrometer could view another area, a two-dimensional image of the entire comet was developed, strip by strip.

ULTRAVIOLET INVESTIGATIONS

The first observations from space of Comet Halley were made with the International Ultraviolet Explorer spacecraft (IUE) back in April 1985 and in December a further, more intensive cycle of observations started which will last until the comet has returned to the outer regions of the Solar System.

In total more than 150 hours of observing time will be dedicated tc observations of Comet Halley with the IUE Observatory satellite.

Spectra taken with IUE in the Ultraviolet on December 15, 1985 when the comet was at a distance of 115 million km from the Earth showed clear evidence of a considerable increase in activity in the comet caused by the enhanced solar radiation.

The results obtained showed that in this relatively young periodic comet the gas composition is similar to that found in other older comets observed earlier with the IUE spacecraft. The characteristic emission of the elements hydrogen, carbon, oxygen and sulphur as well as the emission of molecules such as carbon-sulphide and the possible decomposition product of water, hydroxyl, were identified.

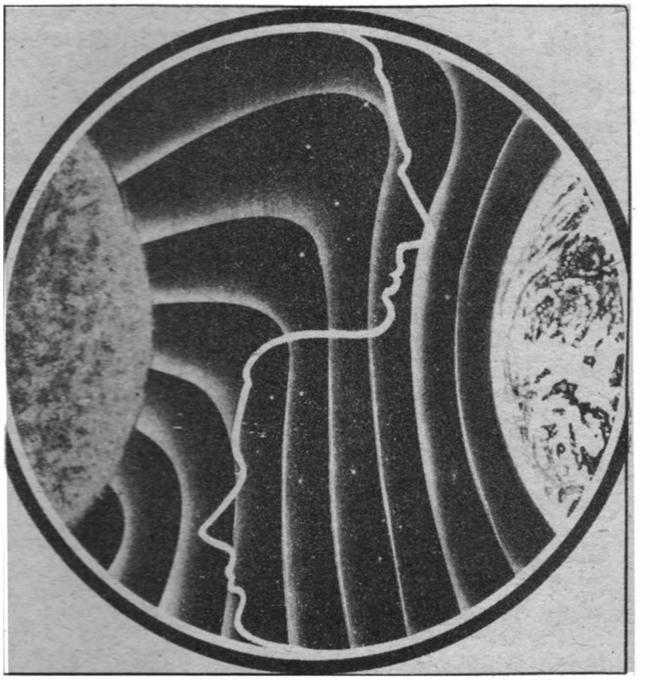
The production of gaseous material increased substantially as Halley approached the Sun – in December the gas production rate was more than five times higher than that observed in September.

The comet has a significant dust cloud (dust Coma) with it. The dust coma is rather compact (20 000 km; this is only one tenth of its gas coma) and appears quite dense. This could be of importance to the success of ESA's Giotto mission which is coming very close to the cometary nucleus and will pass through this dust cloud to obtain pictures of the cometary nucleus.

THE GEOSPACE SCIENCE MISSION

By John Bird

Over the next few decades, scientists studying the near-Earth space environment will be attempting to develop a comprehensive understanding of its interactive regions, including the magnetosphere and the ionosphere. These regions around the Earth are known collectively as 'geospace'.



The International Solar Terrestrial Physics programme will study the Earth's environment in unprecedented detail. *NASA*

Introduction

The ambitious goal of understanding geospace in detail can be realised only by using a large network of observation stations on the ground and in space. By taking simultaneous complementary observations in many locations, it will be possible to piece together the puzzle of this complex system. The International Solar Terrestrial Physics programme is being developed by NASA, the European Space Agency, and the Institute of Space and Astronautical Science (ISAS) of Japan to commence in 1989. A comprehensive study of geospace as a whole has not been previously attempted.

A key element is the Global Geospace Science (GGS) mission, involving four complementary satellites. They will be in different orbits and will be capable of making large changes to move to new paths. The scientific objectives include tracking of particle and energy flows from the solar wind to our atmosphere, determination of the influence of plasma processes and investigation of the origin and loss of plasma near the Earth. Plasma is a gas in which the atoms are electrically charged, or ionized. In addition, theoretical work will involve the synthesis of mathematical models to simulate geospace.

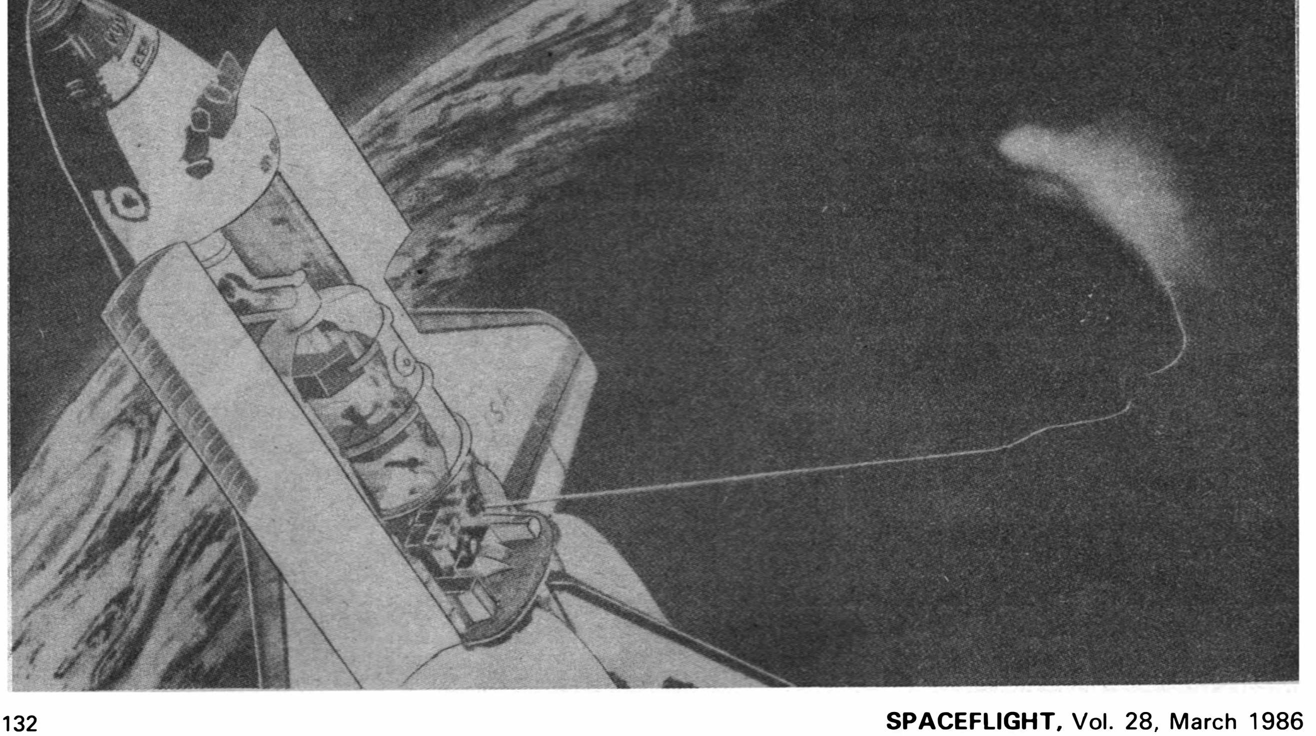
The Satellites

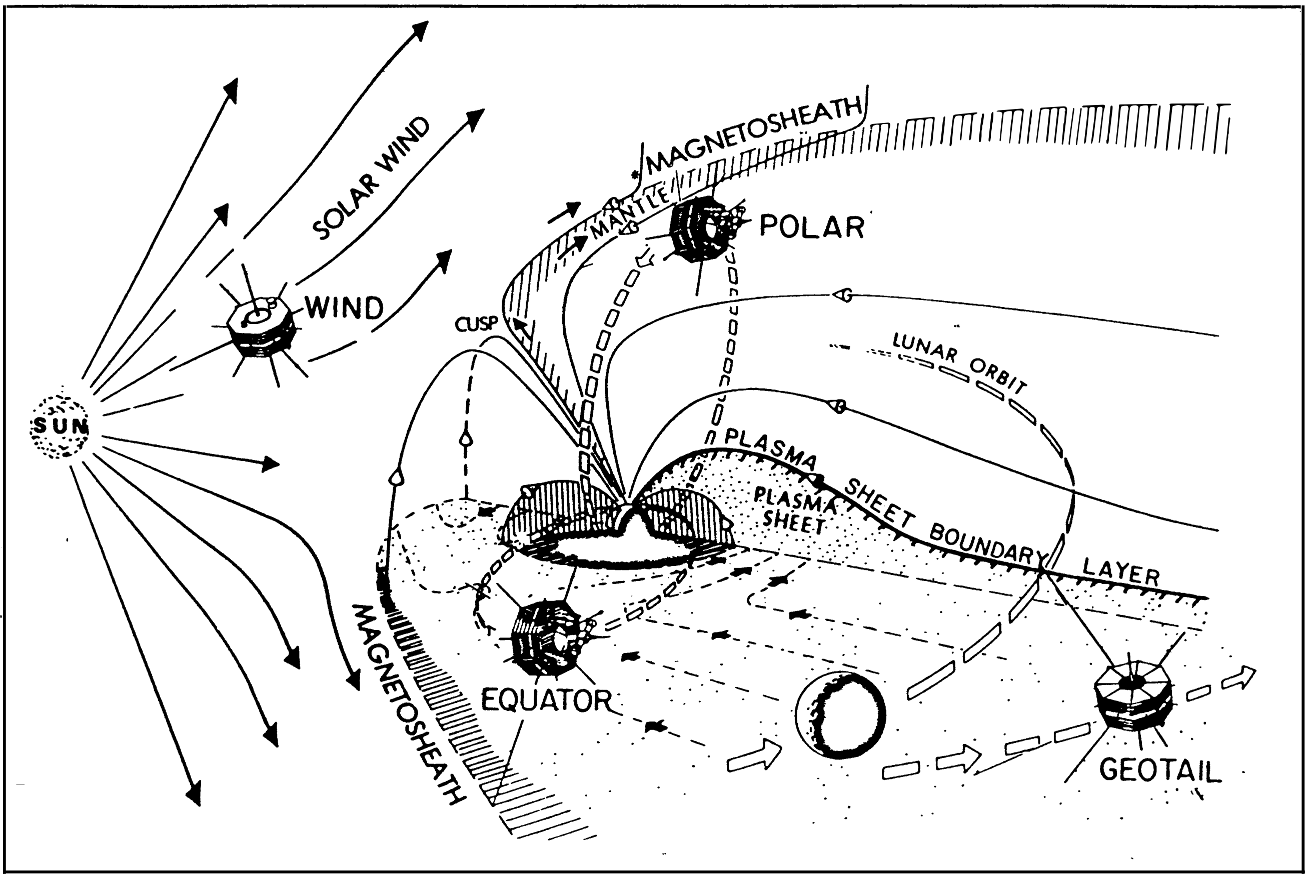
Four satellites are required in order to monitor the plasma source and storage regions simultaneously. The primary sources of plasma in geospace are the solar wind (a continual flow of material from the Sun) and the ionosphere (a region in the upper atmosphere). Primary storage regions are the tail of the magnetosphere (the region of magnetic fields surrounding the Earth) and the electric currents that surround our planet. To cover these four regions the four satellites are:

Wind will monitor the solar wind upstream from Earth at a distance of 6-250 Earth radii.

Polar will measure plasma flows from the ionosphere and flows into high latitude regions from space. It will be in a polar orbit of 6 by 250 Earth radii to provide good views

Scientists can now direct charged particles into the Earth's magnetic field lines to study their behaviour. *NASA*



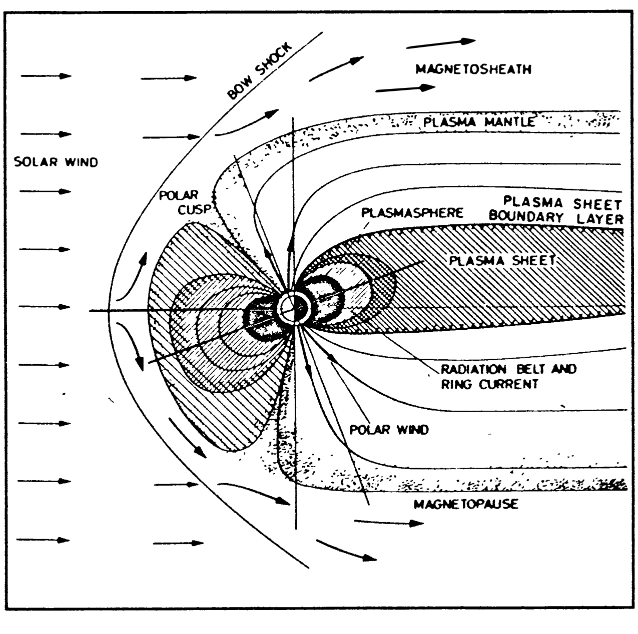


Geospace regions.

of the aurorae. Images of the aurorae from the X-ray to visible bands will be recorded every minute, so the data transmission rate for this spacecraft (42 kbps) will be much higher than for the others.

Equator will monitor the ring current that surrounds the Earth and acts as an energy and particle storage region. 'Equator' will be in an equatorial orbit of 2 by 12 Earth radii.

Geotail will orbit from a lunar flyby back to a distance of a few Earth radii to monitor energy and particle storage mechanisms in the geomagnetic tail. This craft will be built by ISAS whereas the others will be constructed by NASA with some European instruments.



All of these satellites will be launched from the Shuttle using Payload Assist Modules to move them into their required orbits. Basically, the satellites will be similar, weighing between 600 and 900 kg and using spin stabilisation at 10 to 20 rpm. Some 100 to 300 W of power from solar arrays will be consumed; data will be stored on tape recorders and played back through the telemetry system. Instruments will monitor magnetic fields, electric fields, plasma waves, plasma composition and energetic particle velocities.

A tentative schedule has already been put forward. Wind will be launched in 1989 to supplement measurements made by ESA's Ulysses solar polar mission. Polar will be launched in 1990, followed by Equator and Geotail in 1991.

In addition to these satellite observations at key points in geospace, complementary ground-based observations will be made, concentrating on the mechanisms of upper atmospheric heating by electric currents. Radar, magnetometer and photometer sites will be used around the world. 'Darn' will use a network of radar facilities in the northern latitudes to detect back-scattered radio waves from the ionosphere to reveal details on the structure. 'Mainstep' will study the ionosphere from Halley Station in Antarctica. 'Canopus' will study the aurorae and ionosphere from sites throughout northern Canada.

Numerous orbital geometry configurations will be employed. For example, the Wind satellite will fly in two different types of orbits. One involves a double lunar swingby where the spacecraft passes by the Moon on the way out to a distance of 200 Earth radii. The other is the 'L1 halo' which it will orbit the L1 libration point. At this position in space, 240 Earth radii away, a satellite can maintain its position with respect to the Earth with negligible fuel consumption.

SPACE RADAR FOR REMOTE SENSING

By Dr. Harry Joyce*

A number of radar remote sensing instruments have been flown in low Earth orbit with considerable success. With interest in these all-weather high-resolution remote sensing systems increasing within the space and remote sensing communities, there are plans for a number of future radar remote sensing missions.

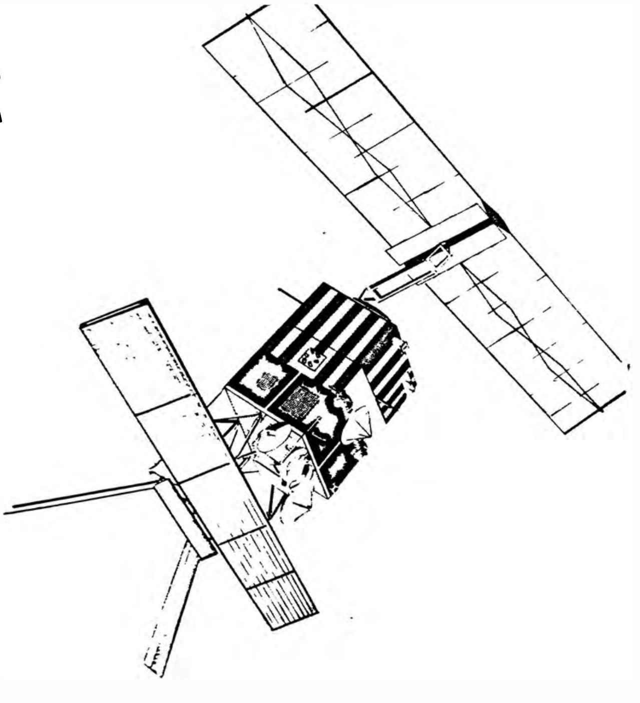


Fig. 2. The ERS-1 spacecraft; carrying a Synthetic Aperture Radar (SAR), a Microwave Wind Scatterometer and a Radar Altimeter.

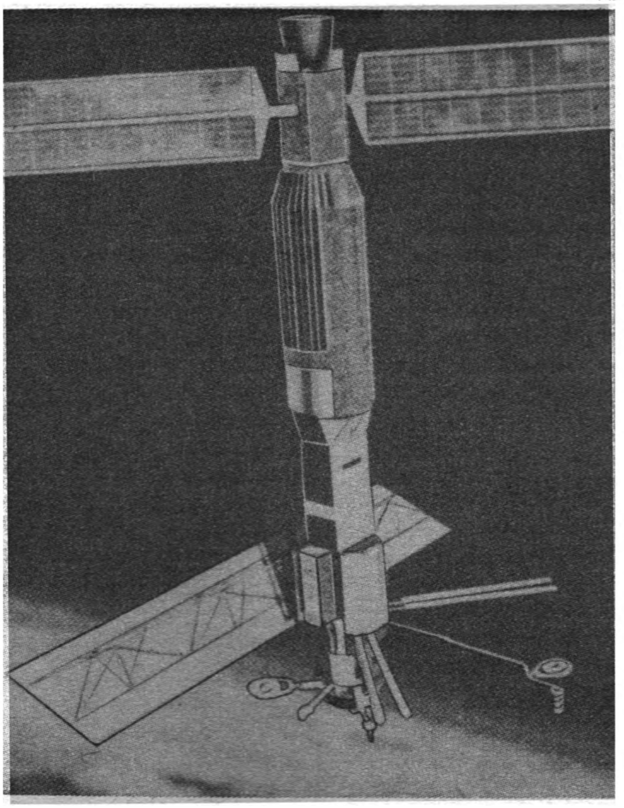
Introduction

Radar instruments observing the Earth from space can carry out a number of valuable remote sensing measurements over land and sea, including high-resolution altimetry, sea surface wind field and surface wave measurement, and high resolution radar imaging of land, sea and icefield regions. Because of their ability to make high resolution observations under virtually all weather conditions, radar systems complement optical, infra-red and passive microwave sensors to provide an 'all-round' remote sensing capability.

The history of spaceborne radar systems effectively began in 1974 when Skylab astronauts first used experimental microwave sensors to gather ocean surface data. The instruments included a Microwave Radar Scatterometer for ocean surface observations and a low-resolution Radar Altimeter.

The GEOS-3 satellite carried a high-resolution microwave radar altimeter and demonstrated the potential for radar altimetry for sea-state and surface level measurements.

Fig. 1. The Seasat experimental oceanographic research satellite.
NASA



The successful NASA Seasat of 1978 carried a full complement of microwave sensors dedicated to ocean remote sensing research, including a scatterometer for ocean wind field measurements, an altimeter and an Imaging Synthetic Aperture Radar (SAR). The resulting data, examples of which are included here as illustrations, stimulated a great deal of interest in remote sensing circles and has clearly demonstrated the value of radar remote sensing instruments on space platforms.

Particular attention is drawn to two major remote sensing missions: the successful, though short-lived, Seasat experimental oceanographic spacecraft, shown in Fig. 1, and the European Space Agency's ERS-1 remote sensing satellite (Fig. 2), scheduled for launch in 1989 [1,2].

Spaceborne Radar Instruments

State-of-the-art radar instruments for space remote sensing applications fall into three broad classes *viz* the Radar Altimeter, Syntheic Aperture Radar and the Microwave Wind Scatterometer.

The Radar Altimeter

The radar altimeter measures its height above the surface of the Earth by timing the delay between the transmission of a radar pulse and the reception of the reflected echo [3]. This measurement, in principle very simple, can be made with great precision and can produce a great deal of information about the topography of the target area.

Modern radar altimeters enhance their altitude resolution by using 'pulse encoding,' or pulse chirping. By encoding each portion of the transmitted pulse with its own characteristic signature, the radar altimeter can use a long-duration pulse (typically 20 microseconds) to give a good signal-to-noise ratio while simultaneously achieving a very fine time resolution and thus a high resolution in altitude.

The high accuracies allow some very rewarding global observations to be made. As well as the obvious precise

* Manager, ERS-1 Systems Group, Marconi Space Systems, Portsmouth, England.

measurement of the geoid (the Earth's shape), sea surface levels can be plotted, showing wave patterns and allowing ocean currents to be deduced - matters of great interest to oceanographers and meteorologists. As an example, Fig. 3 shows the results of a Seasat radar altimeter survey of the oceanic western hemisphere. By making a number of precise sea level measurements over each area and combining the resulting data, the on-ground data processor has built up a picture that shows not only evidence of extensive ocean currents but also sea floor topography. This latter observation is possible since gravity causes sea bed irregularities to result in corresponding irregularities in the sea surface height above them. The sea surface height varies by 2-3 m for every kilometre change in sea-bed depth.

Altimeter data can also be used for plotting ice coverage in polar regions, including the deduction of ice thickness from the 'spreading' of the returned echo.

To achieve very high measurement accuracies, a number of sources of error must be tackled. The most serious are those associated with uncertainties in the precise position of the spacecraft at the time of measurement. However, using a combination of orbit modelling, periodic position location and precise altitude calibration (ERS 1 will employ a laser reflector mounted on it) these errors can be largely eliminated. There is room for improvement and efforts are under way to produce enhanced performance.

Synthetic Aperture Radar (SAR)

The Synthetic Aperture Radar employs sophisticated resolution-enhancing techniques to produce high quality images. SAR is one of the most fundamental performance enhancing techniques developed in the field of radar [4]. First conceived during the 1940's, it improves the spatial resolution of a moving radar system parallel to the direction of motion.

The ground resolution is a function of the antenna size: a space radar with a useful resolution would require an impracticably large antenna if SAR were not used. For example, a typical remote sensing mission operating in low orbit (i.e. at round 750 km) could achieve the 30 m resolution required for the ERS-1 imaging radar with a real aperture antenna more than 4 km long.

Aperture Synthesis takes a number of independent 'looks' at the same area as the spacecraft moves over it. The data are then summed by processing algorithms to produce a final image. In this way the satellite's motion synthesises a large antenna from the much smaller real one. The antenna can be quite modestly-sized but the data processor must work much harder - a classical hardware/software tradeoff. The technique allows ERS-1 to achieve a 30 m resolution with an antenna only 10 m long [5,6].

Spaceborne SARs also use the pulse coding technique, described earlier for the radar altimeter, to give a fine range resolution in the direction parallel to the radar beam.

An example of a SAR image obtained using these techniques is given in Fig. 4, which shows a Seasat image of the Chesapeake Bay Bridge area in Maryland, USA. The bridge itself is clearly evident in this 25 m resolution radar picture, as are long-wavelength surface waves in the bay.

The SAR imaging principle has a wide range of remote sensing applications including sea wave mapping, icefield plotting, pollution monitoring and ship tracking, as well as a host of land applications including geological surveying and crop monitoring.

The ERS-1 SAR uses the large 10 m antenna at the top of the spacecraft (Fig. 2) to transmit and receive, at a carrier frequency of 5.3 GHz. The transmit pulse length is 37.1 microseconds and the mean DC power requirement is approximately 1300 W.

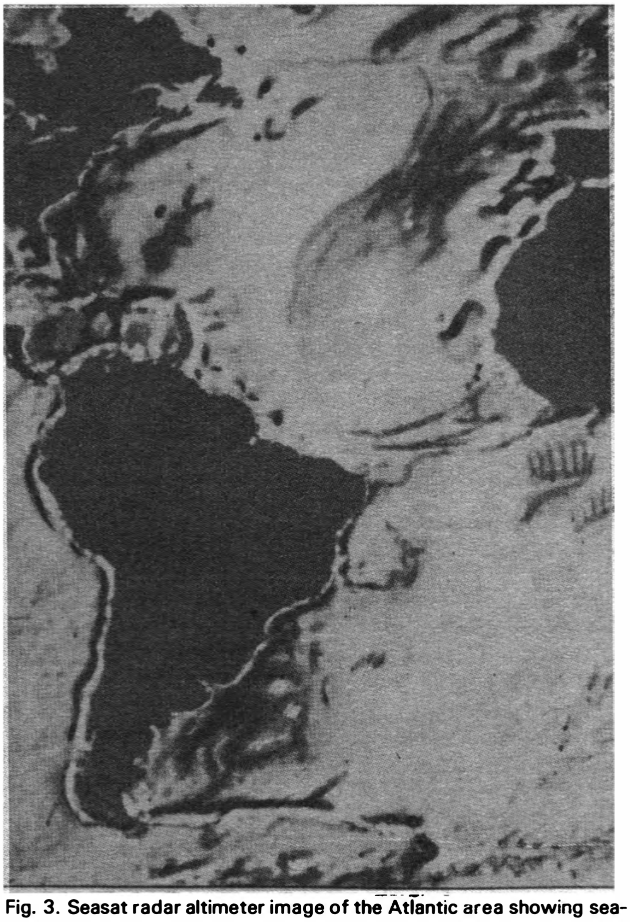


Fig. 3. Seasat radar altimeter image of the Atlantic area showing sea-bed topography.

The Microwave Wind Scatterometer

The Wind Scatterometer is designed to measure the speed and direction of ocean surface winds. This cannot be done directly but by measuring the strength of the radar signal reflected from the sea surface from a number of different look angles are used the nature of the small wind-induced waves on the surface can be deduced. A complex mathematical model within the on-ground data processor takes these values of reflected energy and derives the wind velocity [1,5].

A stretch of water subjected to windy conditions shows just how dependent the surface roughness is on the wind and how this affects the surface reflectivity to visible light. The same effect pertains at radar frequencies and empirical models have been derived relating wind velocity to radar reflectivity from measurements with tower-mounted and airborne radars over the sea. Many useful wind field products have been obtained from Seasat Scatterometer data.

An impression of the wind field product required from the ERS-1 Scatterometer is shown in Fig. 5. A single wind velocity value is computed for each node on a 50 km grid within a 500 km wide swath along the ocean surface. In the final product vector arrows representing wind direction can also be numerically or colour-coded to give wind velocity information.

In order to resolve ambiguities in the wind direction data satisfactorily it has been found necessary to take independent measurements of the reflectivity at each sea surface point from a least three different directions. Hence the ERS-1 scatterometer system will have three indepen-

dent antennae (Fig. 2) with different pointing directions. ERS will be oriented so that all three scatterometer antennae, as well as the much larger SAR antenna, point Earthwards. One antenna, known as the Mid antenna, will point directly broadside to the direction of flight while two others will point independently at 45° to the velocity vector. AS ERS moves over the target area, the reflectivity at each point on the sea surface will thus be measured in turn by the three independent radar beams. Each of the three scatterometer channels will use a single antenna for both transmission of radar pulses and the reception of their echoes from the surface. The three resulting reflectivity values from each point within the target will be relayed to the on-ground data processor for conversion into a wind map similar to that shown in Fig. 5.

Radar Remote Sensing Missions

As well as the Skylab, GEOS and Seasat missions already mentioned, two Shuttle flights have carried successful Synthetic Aperture Radar remote sensing experiments and Japan is planning to use an Earth-resources SAR in 1988. Europe's ERS-1 Ocean Remote Sensing Satellite should begin operations in 1989.

The Canadian Government's Radarsat, currently scheduled for launch in 1990, will be an ERS-1 type mission including an altimeter, an SAR and a Wind Scatterometer. A major objective will be the monitoring of ice fields off northern Canada and elsewhere.

NASA's Topex satellite, due for launch in 1988, will carry a precision radar altimeter for Earth-surface topography surveying. Also of considerable interest is the US Navy's N-ROSS mission, which will include a Microwave Scatterometer for meteorological and oceanographic remote sensing.

The European Space Agency has plans for follow-on missions from ERS-1. ERS-2 will probably have ocean remote sensing objectives similar to those of its predecessor, while ERS-3 might well be a land-oriented remote sensing mission with a strong Synthetic Apeture Radar content.

In addition, there are a number of other possible applications of radar remote sensors in the pipeline, including NASA's Free-Flying Radar Experiment (Firex) and Space Station Imaging Radar (Spirex).

Future Development

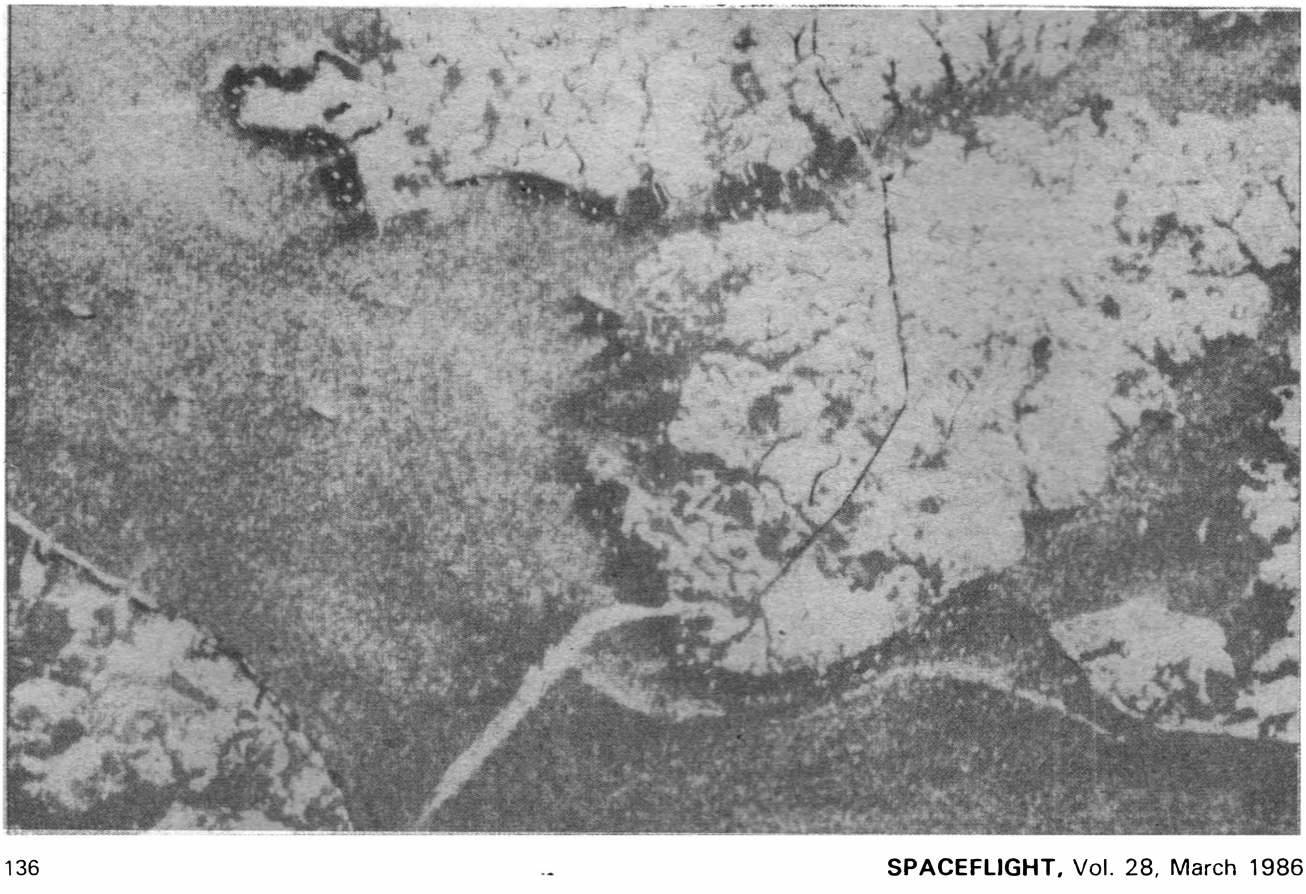
Remote sensing has produced valuable data, particularly over ocean areas, and the potential for these state-of-the-art instruments is enormous. Development efforts during the coming decade will centre largely on two areas that now present significant, though by no means insurmountable, constraints.

Owing to system constraints, mainly instrument power, mass and data output rate, the ERS-1 Synthetic Aperture Radar is usable over only about 10% of each 100 minute orbit. Although the Radar Altimeter and Scatterometer are both usable over large portions of each orbit, the widths of their coverage areas, or 'swaths,' will have to be greatly increased to meet the needs of meteorologists and others in the future. In addition to the actual ground coverage, the use of multispectral instruments will also increase. A number of important features of the radar echoes received, especially from land targets, vary significantly with the precise radar frequency used and also with the polarisation mode. Future sensors will use a number of different frequencies and polarisations to maximise the information content of received data.

A number of promising technological developments currently receiving attention are each expected to make contributions to the alleviation of mass, power, data rate and other constraints.

Mass reductions will be achieved by constructing

Fig. 4. A Seasat SAR image of the Chesapeake Bay Bridge Area. The spatial resolution is about 25 m.



antennae of carbon fibre materials instead of aluminium alloys, using lighter constructions for improved-efficiency amplifier tubes and, ultimately, by the use of semiconductor high-power amplification devices. The development of higher reliability components might, in some cases, reduce the requirement to provide fully-redundant equipment. On-board instrument controllers using microprocessor technology, as specified for ERS-1, will become universally applied. Improvements in high power amplifier efficiency, (typically 35-40% in high power systems at present), will bring significant mass benefits in conductors, power conditioners and amplification devices. New, lighter radio frequency devices will also yield some mass reductions.

Contributions to reduced instrument on-board power requirements will come mainly from increased high-power amplifier efficiency, improvements in component noise figures and associated performance improvements, allowing reductions in required transmit power. Another important power-saving area is in more selective sensor operation. An example would be a Scatterometer switching to a reduced performance mode over large expanses of ocean for which the wind velocity is fairly constant. Transmitters might be blanked out over target areas known to be of lesser interest, so conserving power. For the SAR there is also the possibility of operating at reduced transmission power over regions for which full performance is not required.

As mentioned earlier, there is the need to improve data communication with the ground. Since a satellite in low orbit can remain in contact with each ground station for a maximum of only about 15 minutes, clearly either a large number of stations are required - a very costly solution - or some other means of handling the generated data must be found. On-board storage of data (currently on high-density tape recorders) for oportunistic transmission to ground, and satellite data relay sytems are possible solutions. Present storage techniques cannot accommodate the very large data sets generated by SAR systems but a relay system could allow transmission to the ground *via* a communications satellite in geostationary orbit.

Data reduction procedures, similar to those used in digital TV broadcast systems, are also very promising for data handling. On-board data processing algorithms act to decide on the 'uniqueness' of each piece of data. If a significant period of largely unvarying data is detected then the total data set required to be transmitted can be reduced using some code defining the set length. Other criteria for data reduction, including auto-selection of image quality requirements, can also be implemented.

The second broad area in which significant improvements will be required is in the processing of the gathered data to derive the image products required by the user. In Radar Altimeter terms this means a detailed spatial map of land or sea surface height above some specified datum, such as that in Fig. 3, and other derived products. For the Scatterometer, wind field maps of required ocean area are necessary and, for the SAR, precision images or pictures of chosen target areas.

With current technological capabilities almost all image processing is done on the ground. The required complex error-correcting and compensating algorithms, the image-derivation algorithms and the sheer volume of data generated, particularly for SAR systems, dictate processing times that limit the usefulness in applications requiring near real-time data. For example, meteorologists would like a complete wind and wave map of the world's oceans renewed every six hours. To achieve this, increases in computing power and more efficient data processing

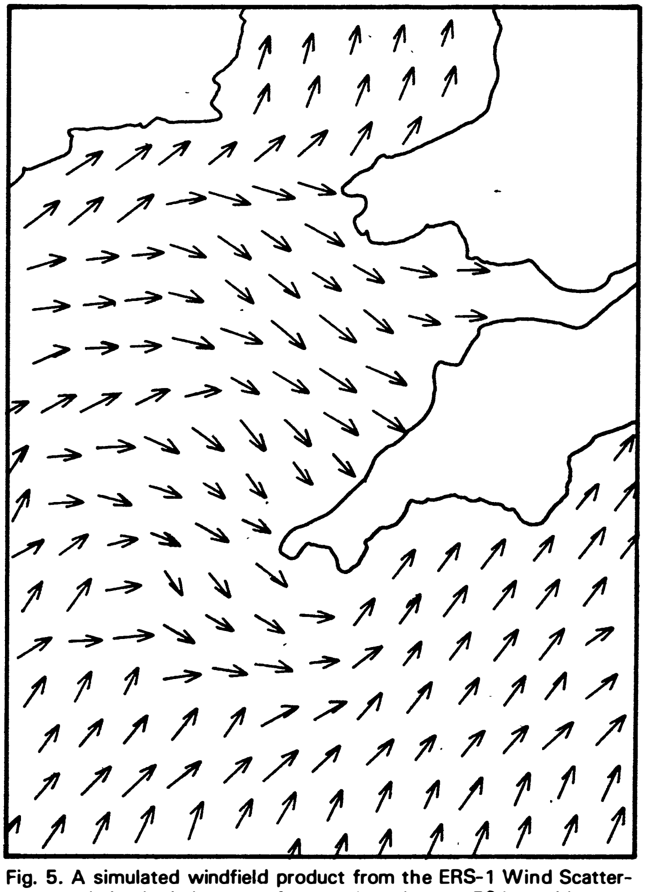


Fig. 5. A simulated windfield product from the ERS-1 Wind Scatterometer; derived wind vectors from each node on a 50 km grid.

algorithms will be required. Such on-ground data processing capabilities should be available within a few years.

There will also be a gradual shift of data processing from the ground to the satellite itself whereby final or near-final image products will be generated before transmission to ground. The benefits here will be profound. The amount of data for transmission will be reduced but, more importantly, the complexity (re cost) of the on-ground processor will be greatly reduced. The received data will be suitable for users with limited financial and technical resources. Since developing countries stand to benefit considerably from remote sensing, real benefits can be foreseen here.

Spaceborne radar instruments are a powerful tool in remote sensing applications. The potential for their application for the benefit of Mankind is enormous and we can expect to see many exciting developments within the near future.

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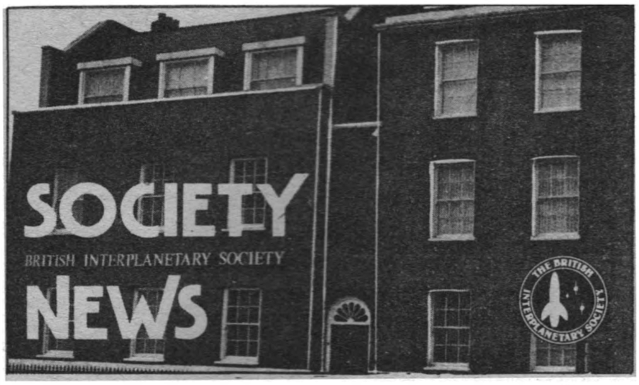


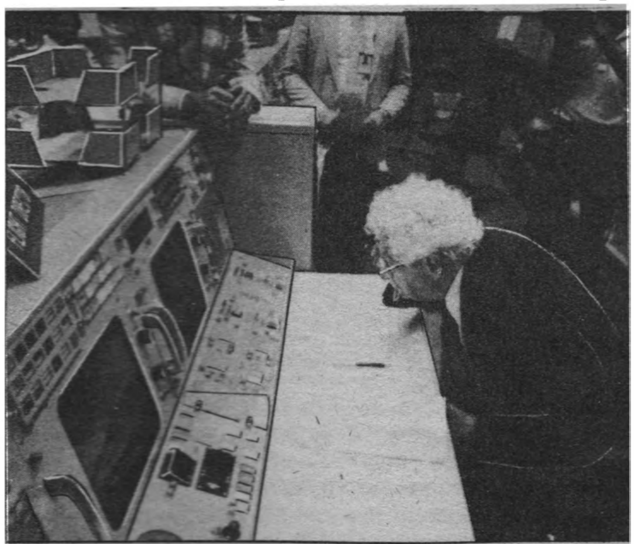
OBERTH AT SHUTTLE LAUNCH

BIS Honorary Fellow Professor Hermann Oberth, who is considered by many to be the father of modern rocketry, was a guest at the Kennedy Spaceflight Center to witness the launch of the German D-1 Spacelab aboard the STS 61A Shuttle mission on October 30, 1985. The 91-year-old rocket pioneer watched the Shuttle launch from a guest viewing area only a few miles from the launch site. He had previously been to the Kennedy Spaceflight Center to watch the Apollo 11 launch with Wernher Von Braun in July of 1969.

Prior to watching the launch Professor Oberth reiterated his life long goal "To make available for life every place where life is possible; to make inhabitable all worlds as yet uninhabitable and all life purposeful." Professor Oberth said that he wished the crew Godspeed and a safe journey and added that it is not important, in the end, who became the first to chart where mankind could fly in orbit around the world; what is vital is to have our world's peoples and leaders pulling together in peaceful coexistence, respecting one another's rights, so there will never be the day in history when someone becomes the last to fly beyond our planet. Following the launch Oberth said that he considered it to be perfect and he enjoyed it very much.

BIS writer Roelof Schuiling was also at the launch and interviewed Herman Oberth about developments in space flight (via an interpreter). Schuiling writes: "It was a great experience for me to actually talk to a man who has seen so much and been involved for so long in this field."

Hermann Oberth and his daughter are shown round the astronaut training centre by Bob Crippen.



Oberth takes a keen interest in the workings of the Mission Control Center.

When asked to predict the future of space flight over the next 50 years Oberth indicated that technological problems would have less of a space flight impact while political concerns could become greater. Professor Oberth spoke also of the probability of mining on the Moon and of the use of solar energy on space stations by the year 2005. He predicted that by the year 2030 orbiting mirrors could be used to focus energy on the Earth to mitigate cold winters and maintain clear shipping lanes in the icebound seasons. By adding to such mirrors, he predicted the possibility of weather modification so bringing rain to droubt-ravaged areas of the world by creating artificial low pressure weather systems.

ORDER NOW

A brochure describing the unique nature of the Society's copy of "Uranometria" and advertising the availability of facsimile copies has been distributed to all members. Publication is scheduled for March 31, 1986. Those who place an order for a copy before that date will receive a 10 per cent discount, so this is worth remembering. Additionally, only a very small number are being bound in calf and hence there is a need to order early if this is the binding desired. Furthermore, only 500 copies of the facsimile are being printed for this strictly limited edition..

Prices are £250 ($375) for the calf bound Uranometria and £160 ($240) for buckram binding. Payment can be by sterling or dollar cheque, GIRO (account No. 53 330 4008) or by VISA or ACCESS. Send your order with name, address and payment to the BIS, 27/29 South Lambeth Road, London, SW8 1SZ.

The Society's research into Bayer's "Uranometria" has already been reported in two articles published in ***Spaceflight*** in 1985 (p.117 and P.275). A third article has now been prepared and is scheduled to appear in the April issue of ***JBIS***. We had intended to publish this third article also in ***Spaceflight,*** but current Space events would have delayed its appearance. Readers of ***Spaceflight*** who do not regularly see ***JBIS*** may be interested to know that the April issue is devoted to the theme of "Pioneering Space". Single copies may be ordered from the Society at £2.00 ($4.00) post free.

A CLOSE ENCOUNTER AT JPL

Beautiful weather, playing fountains and flowers in full bloom greeted those invited to the Jet Propulsion Laboratory at the California Institute of Technology on January 24 to witness the arrival of the close encounter pictures of the Uranus flyby. BIS Executive Secretary, Mr. Len Carter, was among the guests.

It was both a privilege and a pleasure to attend the JPL activities to highlight the Voyager Uranus Encounter and which reflected so well upon both NASA and JPL personnel who not only made the enterprise possible but who so ably carried it out. Results achieved were of the highest calibre. May good fortune go with Voyager on its further flight to Neptune, culminating in a flyby of the planet – a new first – in August 1989.

Events at JPL moved at a hectic pace. Not only had a number of VIPs, officials and press representatives to be accommodated but teams of scientists, too, moved hot-foot between various ports of call as the total of around 6,000 images flooded back.

For those not directly involved frequent TV updates were provided with Donna Piviratto acting (very ably) as the "anchor man" – not only in providing comment, playback and update but also interviewing a host of those directly involved.

News briefings were provided on a regular basis, supplemented by a variety of lecturettes on a variety of space missions currently under study or of interest to JPL.

Dr. Burt Edelson (Associate Administrator, Space Science and Applications) one of those interviewed, said that, as a scientific achievement, we had gained new knowledge about a very obscure planet. Discoveries included ten more moons and a new ring, with the probability of further rings to come.

It was a superb engineering accomplishment. An 1800 pound spacecraft, launched eight and a half years ago, had passed Uranus within one minute of a scheduled time fixed five years ago. Navigation had been so flawless that the need for one of the final corrections had been avoided, thus saving fuel. The time in building the spacecraft, with the flight time, added up to about 20 years altogether.

Press Conferences were relayed to other areas eg to the VIPs gathered in a different conference room. The Press corps, representing a well-informed group, not only pressed home questions of a most searching character but were constantly pressing for an even more vigorous US space programme. When some regret was expressed over the absence of a US Halley mission it was pointed out in reply that science is basically international in character; the fact that Halley probes were *not* a wholly-US dominated activity represented not only a great plus for America but also one for the rest of the world.

Principal Investigators reported that magnetic measurements of Uranus were about the same as those for Saturn, with both just below that of the Earth. The conclusion was that, within Uranus, there must be an electrically-conducting region which is being mechanically stirred continuously.

Initial interest centred on the satellite, Umbriel, which appeared so bland as to be something of an enigma, impact craters on the other three large satellites appearing normal by comparison. It was Miranda, however, which stole the show, looking like a weird concoction from parts of the Solar System simply stuck together in a most incogruous fashion.

Although scientists had been looking at Uranus continuously since November 4, the planet held back its ultraviolet signatures until Voyager was right on its doorstep. It appears to have an extended hydrogen corona, similar to those of Jupiter and Saturn, extended mainly because of its lower escape velocity. This was only 2.5 electron volts, far below those of both Jupiter and Saturn.

Not all the new moons were discovered immediately. One new satellite (1986 U9) appeared for nearly a week before its nature was recognised.

The rings were not so bright as expected, doubtless because the quantity of fine material is scanty. This suggested that some sweeping-up process is in action.

All the Principal Investigators gave individual reports and responded to questions, though not always happily. An example of difficulty in reaching the public occurred when one speaker was asked to re-phase his reply and put it in lay terms. He responded "There is an axis of symmetry for a magnetic dipole . .

The welcome everywhere was friendly and cordial. There was only one notice which quelled even the stoutest heart. It read *"No Admission Without Cookies"*.

SPACEFLIGHT BY AIR MAIL

The Society is pleased to be able to offer an Air Mail delivery of Spaceflight to overseas readers in non-European countries. The advantages are considerable for readers in the US, Canada, the Far East and Australasia who experience delivery times of four to six weeks by surface mail.

The service starts with the April issue and costs US$16.00 (£10.00 sterling) for the remaining seven issues of 1986. Requests for this serice with remittance enclosed should reach the Society's office by March 16. After this date the charge for air mailing later 1986 issues is US$2.50 (£1.50 sterling) per issue.

OBITUARY

It is with deep regret that we record the death at Grobming, Germany, at the age of 74 years of Hans Karl Kaiser, a Fellow of the Society since 1949 and a prolific author of books on space.

Hans attended the Universities of Breslau and Kiel and for a number of years was an assistant astronomer before moving on to be a physicist with several German chemical companies.

In 1962 he was awarded the Golden Badge of the Herman Oberth-Gesellschaft and was elected Honorary Member of the HOG a year later.

CHALLENGER ASTRONAUTS

Members attending the meeting at the Society's HQ on the evening of January 29 observed one minute's silence in memory of the seven astronauts who had perished in the previous day's launch of the Challenger Orbiter.

MEETINGS DIARY

All meetings unless otherwise stated are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ.

9 April 1986, 7-9 pm **Lecture**

AN ENCOUNTER WITH COMET HALLEY – dust impacts on-board Giotto

by Professor Tony McDonnell

Exploring a cometary nucleus at the closest distance ever, dust impact sensors of the DIDSY experiment on Giotto recorded the bombardment by the comet's dust grains of the meteroid shield.

Admission by ticket only. Members should apply in good time enclosing stamped addressed envelope.

14 May 1986, 7-9 pm **Lecture**

ARTISTS IN SPACE

by David A. Hardy

Chesley Bonestell is without doubt the 'Old Master' of astronomical art. But there were artists painting the landscapes of other worlds many years earlier – some very accurately. David Hardy shows examples of these, and of the many space artists at work today, and explains how our view of the universe has changed since the turn of the century.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed evelope.

21-22 May 1986 **Symposium**

SPACE STATION EXPLOITATION

A two-day Symposium on the above theme considering the scientific and industrial opportunities offered by the Space Station and free-flying platforms and the problems of management and buisiness planning to ensure both technical and economic success.

Registration details available on request.

7 June 1986, 10 am – 5 pm **Forum**

THE SOVIET SPACE PROGRAMME

Offers of papers are invited. Members with a special interest in the Soviet space programme are invited to attend. A registration fee of £5.00 is payable. Forms are available from the Executive Secretary on request, enclosing a stamped addressed envelope.

11 June 1986, 7-9 pm **Lecture**

PROSPECTS OF A MANNED MARS MISSION BY THE YEAR 2010

by J. Daniels, *University of Leicester*

After completion of the Space Station in the mid 1990's one possible goal of the US and its partners is a manned mission to Mars. This lecture will examine the why's, how's and prospects of an actual mission by 2010.

Admission is by ticket only. Members should apply in good time enclosing a stamped addressed envelope.

26-28 September 1986 **Conference**

SPACE '86 – PROFILES OF THE FUTURE

A weekend conference at the Brighton Centre including Civic Reception and banquet. Programme includes:
Advancing Frontiers
Space probes
Deep Space Astronomy
The Space Station
Living in Space
Details from: The Executive Secretry, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

19 November 1986 **Symposium**

SPACE TRANSPORTATION

A one-day symposium on the above theme. Offers of papers invited. Potential authors should contact the executive Secretary. Registation details available on request.

LIBRARY

The Society Library will be open to members from 5.30 to 7 p.m. on the following dates:

9 April 1986
14 May 1986
11 June 1986

Whilst every effort will be made to adhere to the published programme, the Society cannot be held responsible for any changes made necessary for reasons outside its control.

ELECTIONS TO COUNCIL

The Report of the Scrutineers on the Ballot Papers counted up to and including 31 January 1986 is as follows:

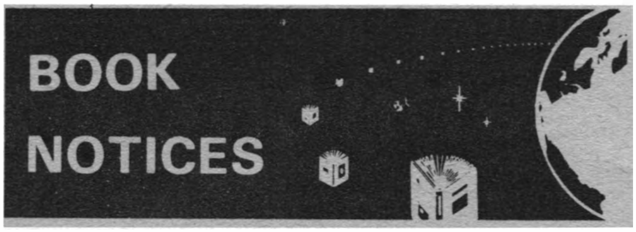
Number of Papers received	902
Number of spoilt Papers	1

The votes cast in favour of each Candidate are as follows:

Order of Voting	Name of Candidate	No. of Votes Received
1	Leslie R. Shepherd	648
2	Cyril R. Hume	581
3	Gillies W. Childs	547
4	Gerald M. Webb	528
5	Timothy J. Grant	515
6	Bede J. Alcock	303
7	Alexander G. Smith	262
8	Frank R. Smith	136

The four Candidates who received the highest number of votes and who are accordingly declared elected are as follows:

L. R. Shepherd, C. R. Hume, G. W. Childs, G. M. Webb.



Interstellar Migration and the Human Experience

Ed. B. R. Finney and M. Jones, University of California Press, Berkeley, Calif., 94720, USA. (or 37 Dover Street, London, W.1.) 1985. 354pp. £21.25

Several million years ago our earliest human ancestors took the first "giant leap" for mankind when they left the dwindling forests of Africa for a new life on the Savannahs. Further biological evolution as well as social and technological innovations led eventually to Neil Armstrong's first "small step" on the Moon and the prospect of human settlements in space. How far will human migration eventually reach? Will our descendants go to the stars and, if they do, what will motivate them and how will they live?

This book weaves together essays by 25 contributors from the social and space sciences to examine the potential human as well technological sides of man's future beyond the Earth. Questions posed concern the character of our species, social institutions, past migration and the resources and technologies needed to support human communities in space.

Schemes for reaching distant stars, the dangers facing pioneer settlements and the implications of potential human interstellar migration are also considered.

In general, this is a compilation of a number of short essays on various aspects of the interstellar puzzle, all receiving a rather broad-brush treatment. Technical content is relatively small.

Astronomy with a Small Telescope

J. Muirden, George Philip, 1214 Long Acre, London, WC2E 9LP, 1985, 224pp £9.95

This is a handbook for those with absolutely no knowledge of astronomy whatsoever, intended to introduce the various celestial objects which can be seen with the naked eye, binoculars or with a small astronomical telescope, together with further text explaining how one can select and use a telescope in order to obtain the maximum satisfaction.

After a brief introduction to such items of equipment, the volume examines various celestial objects in turn; the Sun, Moon, planets, meteors and comets, followed by a further chapter on observing the stars themselves.

The core of the book is chapter six. This gives information on the range of interesting objects to look for on a month by month basis throughout the year, all of which can be located by using the detailed star maps provided.

The final chapter introduces the subject of astronomical photography and shows how this can be carried out even with modest equipment.

Supernovae as Distance Indicators

Ed. N. Bartel, Springer-Verlag, Heidelberger Platz 3, Postfach, D-1000 Berlin 33, Germany, 226pp, 1985, DM 30.

This work, Vol. 224 in the series entitled "Lecture Notes in Physics," reproduces the proceedings of a workshop held at the Harvard-Smithsonian Centre for Astrophysics in 1984.

Supernovae, apart from the one in 1572 associated with Tycho Brahe, always appear to be events which happen to other galaxies, beginning first with that in M31 in 1885 and which, to date, now total about 574.

The idea to organise a meeting on the topic emerged as progress in angularly resolving expanding radio-supernovae with VLBI techniques shed light on the prospect of determining extragalactic distances. The purpose of the workshop was both to discuss these new methods and to compare them with existing optical methods, besides looking at the extent of uncertainties to see if theoretical models of supernovae and supernova remnants could help reduce them.

The book begins with a review of traditional methods of determining the distances of remote galaxies, followed by observational reports of supernovae and supernova remnants. This includes an exciting report on 40 discrete radio sources in the visually-obscured nucleus of the galaxy M82, sources comparable to those of the half-dozen radio supernovae found in other nearby galaxies. Presumably their physical characteristics are similar, in which case it suggest that M82 contains an entire population of radio-supernovae!

The second part of the book discusses radio and optical supernovae with a view to determining extragalactic distances.

Double Stars, Physical Properties and Generic Relations

Ed. B. Hidayat, Z. Kopal and J. Rahe. D. Reidel Publishing Co., P.O. Box 989, 3300 AZ Dordrecht, The Netherlands, 1984, 410pp, £58.50.

There must be a huge reservoir of binary configurations in our galaxy, representing, probably, the major part of the stellar population.

Studies of the evolution of binary and multiple systems began to emerge as a central feature of astrophysics in the late 1940's, stimulated by the discovery of a whole group of close binaries (including Algol) where the secondary, less massive component, just about fills its Roche limit, leading to the hypothesis of mass transfer between the components of such systems.

This compendium of papers presented to IAU Colloquium no. 80 held in 1983 covers the physical properties of visual as well as close binary (i.e. interacting) systems, and their generic relations in the broadest possible sense. There were nearly 40 contributions, all relatively short, covering such areas as (a) Physical properties of double and multiple systems; (b) Wide systems; (c) Close binaries; (d) Generic relationship between wide and close systems.

The Human Role in Space: Technology, Economics and Optimization.

S. B. Hall, Noyes Publications, Mill Road at Grand Ave., Park Ridge, NJ 07656, USA. 1985, 386pp. $45.

The human role in space and man-machine interactions are explored in detail in this book. Systems design, far too often, creates an artificial dichotomy which attempts to classify systems as manned or unmanned. In reality, there is no such thing as an unmanned space system: everything created by the systems designer involves man in one way or another, for everything in human existence is done by, for, or against man. The real point is to establish, in every systems context, the optimal role of each man-machine component.

The purpose of this volume is to:

(1) investigate the role and degree of direct human involvement required in future space missions;

(2) establish valid criteria for allocating functional activities between humans and machines; and

(3) provide an insight into the technological requirements, economics, and benefits, stemming from a human presence in space.

Six basic categories of man-machine interaction are considered: manual, supported, augmented, teleoperated, supervised and independent.

The results detailed are intended to provide information and guidelines in a form which will enable programme managers and decision-makers to establish, early in the design process, the most cost-effective design approach to future space programmes, through the optimal application of unique human skills and capabilities in space.

Milestones

December 1985

15 An intensive series of observations of Comet Halley by the International Ultraviolet Explorer (IUE) began. Spectra taken with the comet at a distance of 115 million km from Earth showed clear evidence of increased activity in the comet caused by the enhanced solar radiation.

18 Space Shuttle Columbia's first mission (61C) for 18 months was postponed for 24 hours after checkout schedules fell behind.

19 Mission 61C halted just 14 seconds before liftoff when reading from hydraulic power unit in one of the solid rocket boosters indicated excess heating.

21 Second Centaur Upper Stage arrived at Kennedy Space Center a month later than planned ready for mounting on support structure that holds it in the Shuttle's payload bay.

27 Intelsat signed contract with Arianespace for the launch of Intelsat VI F4 to geostationary orbit in 1990. The order brought Arianespace launch service contracts to a total of 40 satellites, of which 28 remain to be launched.

January 1986

6 Columbia's launch is again called off, this time 31 seconds before liftoff, after 1,500 gallons of liquid oxygen were accidentally drained from the external tank.

8 Voyager 2 discovered a sixth moon in orbit around Uranus. It was spotted in long exposure images taken by the spacecraft's narrow angle camera at a distance of 19 million miles.

10 The National Oceanic and Atmospheric Administration (NOAA) turned off its NOAA-8 polar orbiting meteorological satellite following the malfunction of the master clock's crystal oscillator which provides timing for attitude stabilisation.

11 Launch of the Hubble Space Telescope is slipped by two months from August 18, 1986 to October 27 in order to allow more time for pre-launch checking.

11 Ariane V16 launch postponed for a further five days for precautionary checks' on turbopump roller bearings in the Viking engine.

12 Columbia finally gets off the pad at Kennedy Space Center and whilst in orbit achieved all of its objectives including deployment of RCA's communication satellite and support of the new Hitchhiker and Getaway Special payloads.

14 Ariane V16 launch postponed until February 21.

19 Bad weather at the Cape forced a pre-dawn landing of Columbia at Edwards Airforce Base – the second night landing of the programme. Earlier attempts to land at Cape Kennedy on January 16, 17 and 18 were thwarted by poor weather.

24 Voyager 2 returns spectacular pictures from the Uranian system during the first-every flyby of the giant outer planet.

28 Seven American astronauts were killed when Space Shuttle Challenger exploded 90 seconds after launch. Immediate Board of Inquiry is set up to discover the cause of the worst ever in-the-air tragedy of the American space programme.

Engineering and Configurations of Space Stations and Platforms

Staff of NASA Lyndon B. Johnson Space Center, Noyes Data Corporation, Mill Road at Grand Avenue, Park Ridge, New Jersey 07656, USA, 1985, $64.00 pp.773.

This book serves as a detailed overview of current thoughts on Space Station and platform design. The original text was prepared by a team of 80 scientists and engineers from a number of establishments over a period of four months. The aim was to provide a focal point for the definition and assessment of the programme, a reference configuration in fair detail and a basis for establishing appropriate costs.

It documents the engineering and configurations of both manned Space Stations and unmanned space platforms.

Various configurations were considered for the purposes of this study and, for each of these, mission functional requirements were converted to design requirements. A functional evaluation was made of the configuration's ability to handle payloads, support crew and logistics operations, accommodate integrated systems requirements and be assembled efficiently. Systems and subsystems were sized accordingly. Detailed subsystem descriptions with options were considered and the rationales used to select specific subsystems are given. Data developed in the study are intended as possibilities for potential space station and platform design.

The final assessment is of a long thin-shaped Space Station, which leads naturally towards a gravity-gradient attitude control system, with gimballed solar array rings to provide power at any relative alignment.

DO YOU REMEMBER?

25 Years Ago...
9 March 1961. The dog Chernushka is launched aboard Sputnik 9 in a Vostok-type spacecraft test. Capsule and dog are recovered safely.

20 Years Ago...
1 March 1966. The Soviet Venera 3 spacecraft crashes on Venus, thus becoming the first man-made device to reach the surface of another planet. It failed to return any data.

15 Years Ago...
4 March 1971. NASA devises a plan to rescue Skylab astronauts in the event they become stranded because of a failed command-service module (CSM). A two-man CSM would be launched to return five men to Earth.

10 Years Ago...
24 February 1976. Crew members for the Space Shuttle Approach and Landing Tests are announded by NASA. The two-man crews to fly *Enterprise* from a modified Boeing 747 are Haise/Fullerton and Engle/Truly.

5 Years Ago...
12 March 1981. Viktor Savinykh becomes the 100th person to enter space following the successful launch of Soyuz T-4 from Tyuratam. Savinykh and Soyuz commander Valdimir Kovalyonok dock with the Salyut 6/Progress 12 complex the following day.

K.T. WILSON

SPACE '86

September 26-28, 1986

PROFILES OF THE FUTURE

A unique opportunity to meet a host of space experts and space scientists from around the world at Britain's premier Space event.

Space '86 is your chance to learn first hand about the space projects of today and the future from those directly involved.

Individual sessions will cover:

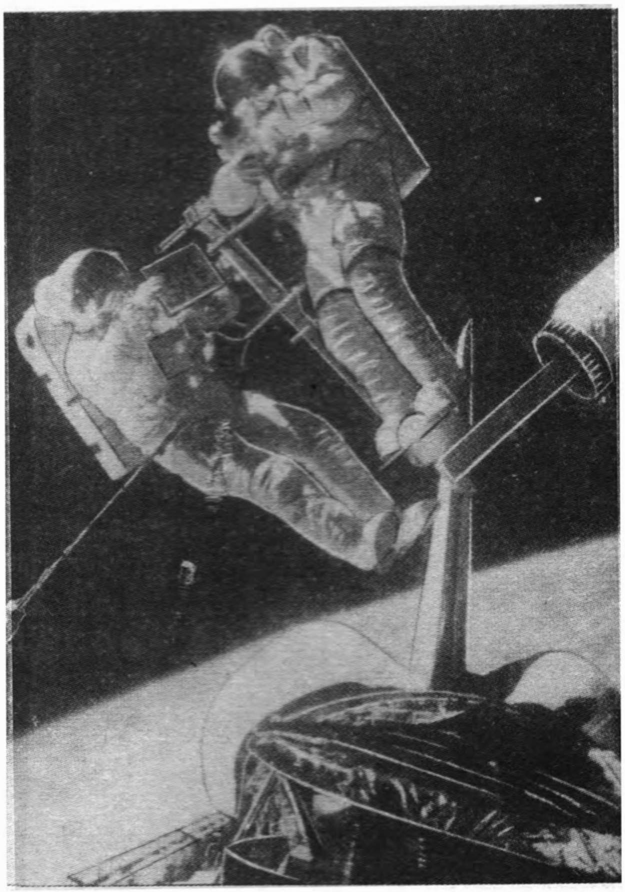
Advancing Frontiers

Space Probes

Deep Space Astronomy

The Space Station

Living in Space



APPLY NOW FOR YOUR PLACE AT SPACE '86

The Brighton Centre, set in an attractive seaside location, is the venue for this two-day, weekend conference which includes a Civic Reception and buffet dance, and an evening banquet. For accompanying persons there is the chance to tour Brighton Pavilion and sample the delights of the excellent shopping centre.

To reserve your place at Space '86 write now for a registration form and FREE guide to accommodation in Brighton.

Numbers will be strictly limited to 250 to keep the atmosphere as friendly and intimate as possible, so do not delay, apply now!

Space '86
British Interplanetary Society,
27/29 South Lambeth Road,
London. SW8 1SZ.

ORGANISED BY THE BRITISH INTERPLANETARY SOCIETY