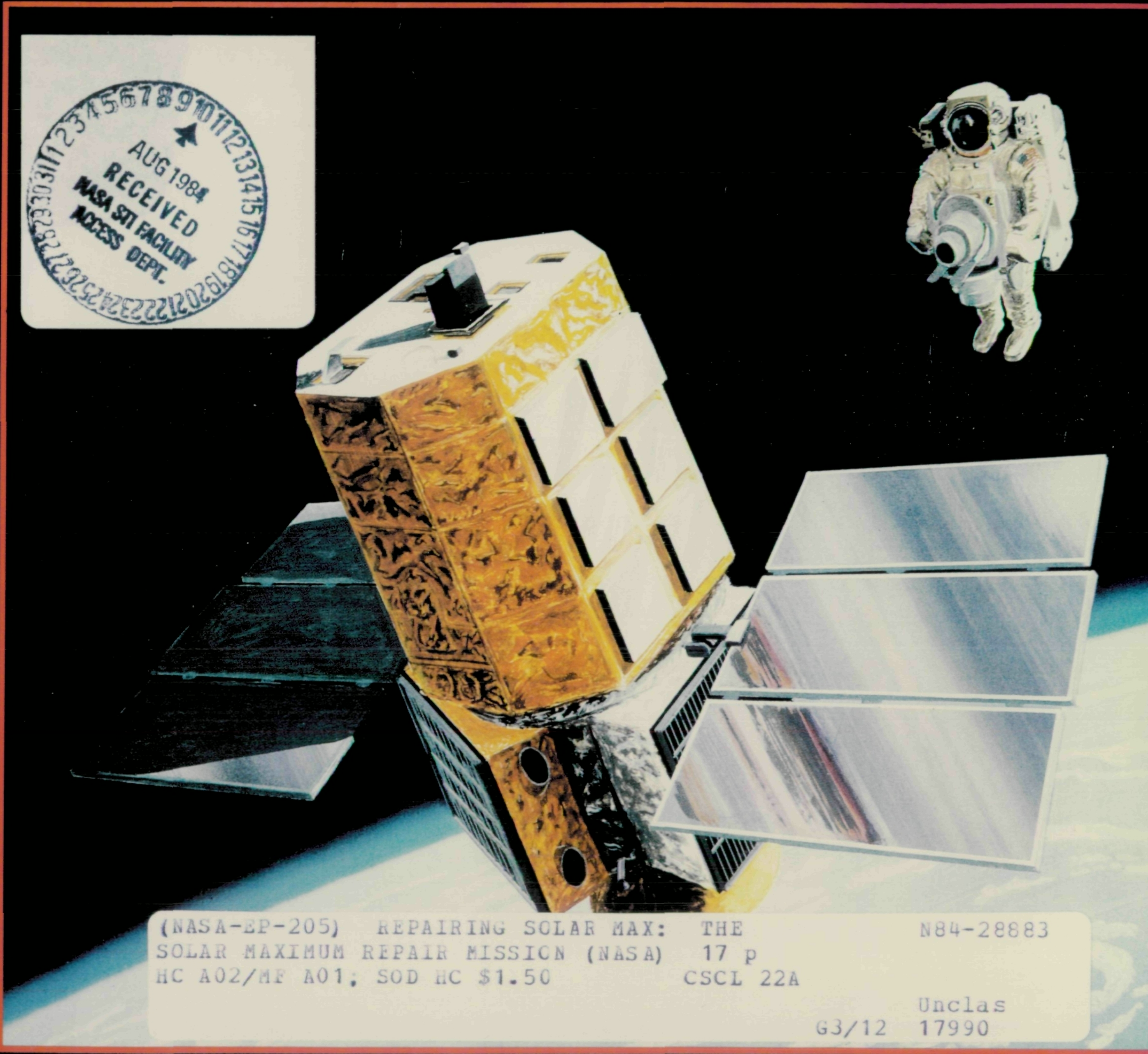
REPAIRING SOLAR MAX



THE SOLAR MAXIMUM REPAIR MISSION

REPAIRING SOLAR MAX

THE SOLAR MAXIMUM REPAIR MISSION

NASA
National Aeronautics and
Space Administration

Goddard Space Flight Center

by Tracy McMahan and Valerie Neal for the Office of Space Science and Applications, Multimission Modular Spacecraft/Flight Support System Project Office

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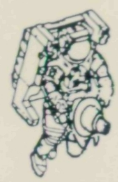
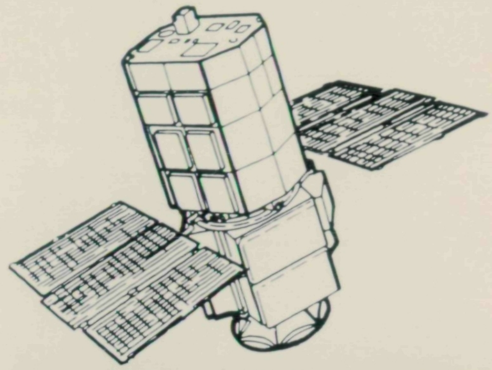
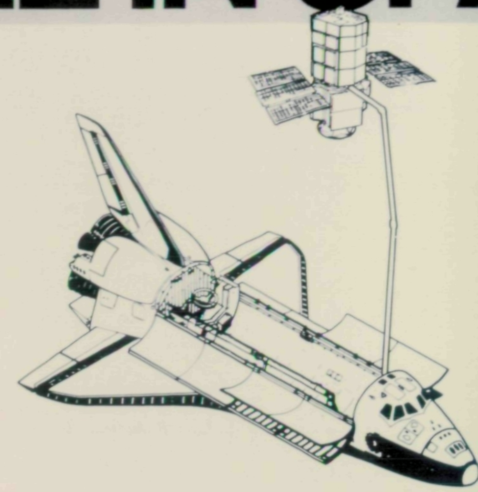
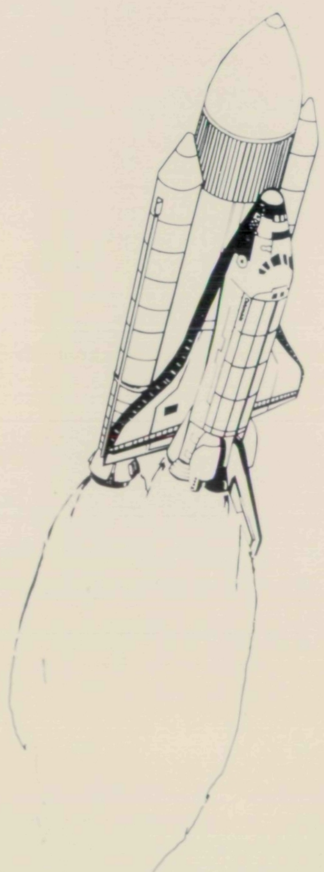
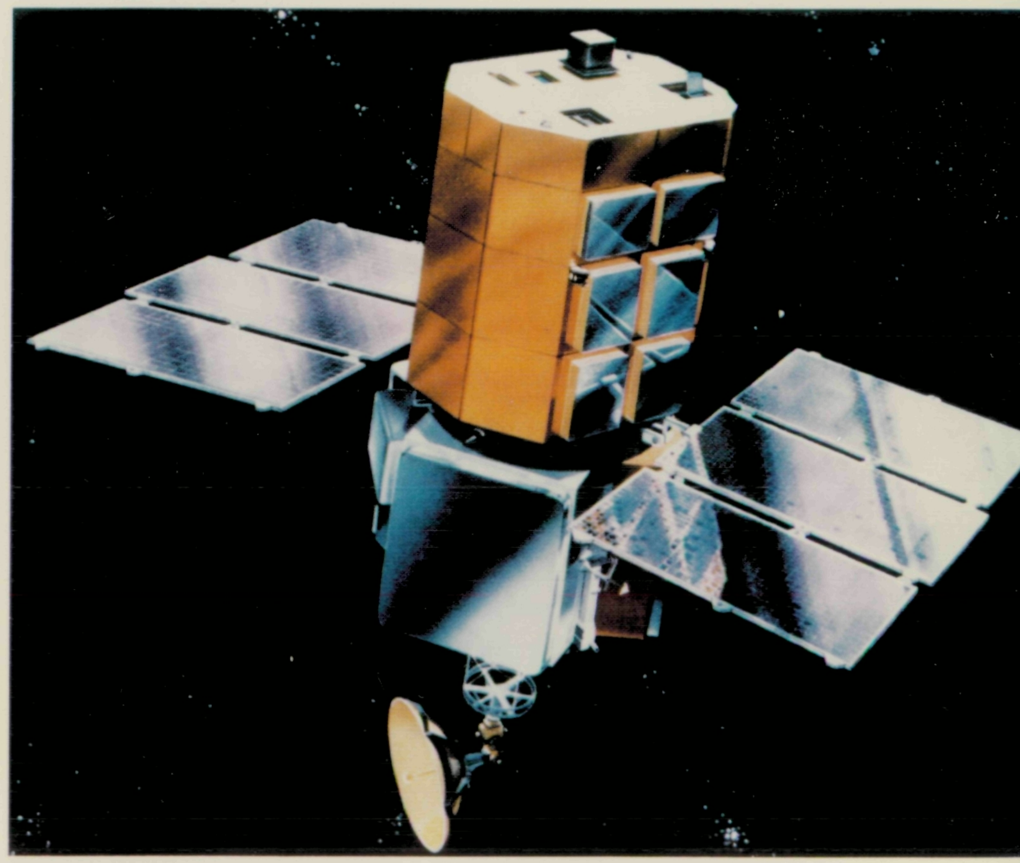
A SERVICE CALL IN SPA











Solar Max

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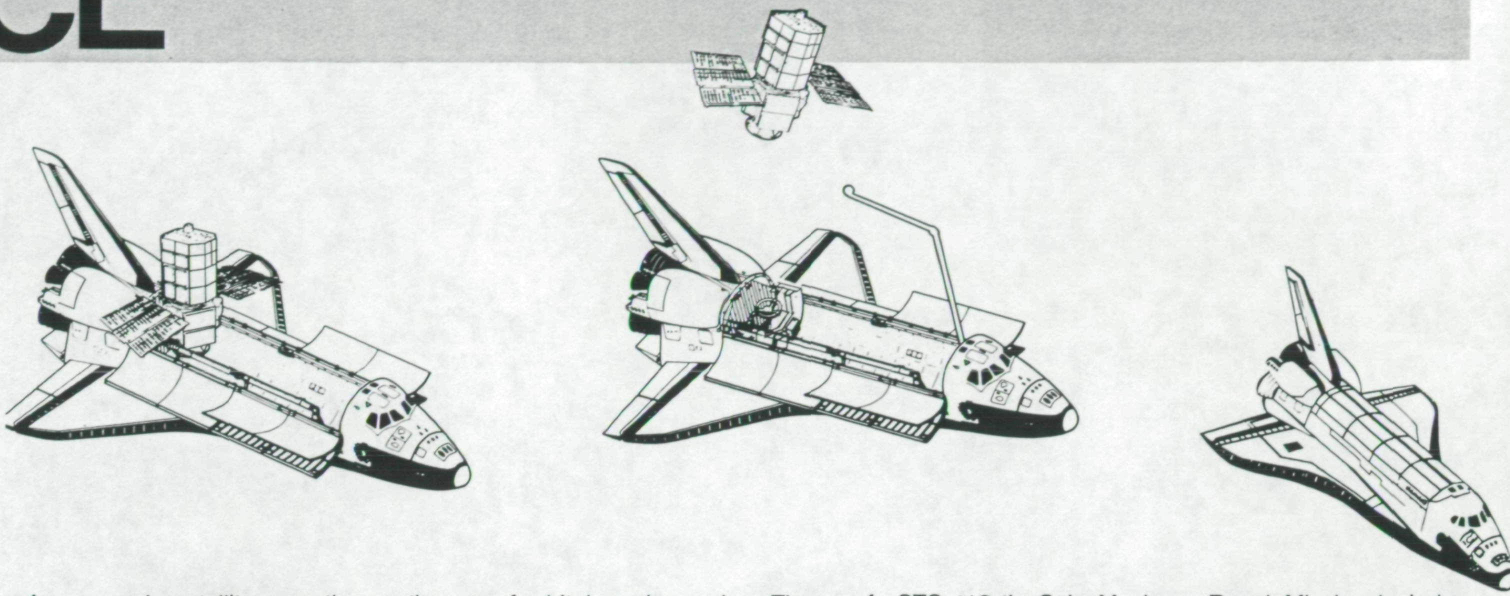


A new era in satellite operations – the era of orbital service and repair – begins in the spring of 1984 on the STS-41C Space Shuttle mission. A team of astronauts will replace a faulty module on the Solar Maximum Mission satellite, known as Solar Max. Repair is necessary because three small fuses in the attitude control system failed, leaving Solar Max unable to point its instruments precisely at targets of observation on the sun. The crew also will repair scientific instruments aboard this orbiting solar observatory.

Fortunately, Solar Max is the first of a new breed of satellites built of standardized components and designed to be repaired in space. The faulty attitude control module is one of three replaceable, box-like units that control power, commanding, and positioning of the satellite. These units are part of the multimission modular spacecraft system, which makes up the lower portion of the Solar Max satellite. The upper portion, the observatory, contains seven different instruments for solar research.

The National Aeronautics and Space Administration (NASA) will introduce daring technology and procedures to restore the satellite in a feat never before attempted in space. Using a jet-powered backpack called a manned maneuvering unit, one Shuttle crewman will fly 90 meters (100 yards) from the Shuttle cargo bay to the slowly spinning spacecraft. The astronaut will not be connected to the Shuttle by the usual tether line but will move freely through space. Although the maneuvering unit was tested by astronauts during a previous Shuttle flight, this will be its first use in regular mission operations.

When the astronaut reaches the satellite, he will capture it with an attachment device and stop its rotation by activating the maneuvering unit's thrusters. When Solar Max is stabilized, the Shuttle will move 9 meters (10 yards) below it. Then, the remote manipulator system arm will grasp the satellite and lift it onto a platform in the Shuttle's cargo bay, the "workshop" for the repair operation.

After Solar Max is securely latched to the support platform, the astronauts will begin the repair tasks. They will use a special module service tool to replace the malfunctioning module with a new one, enabling scientists once again to point the sophisticated instruments on the solar observatory toward specific areas on the sun. The astronauts also will repair two accessible scientific instruments on the satellite, but they will not attempt repair of a third malfunctioning instrument that is more difficult to reach.

The crew for STS-41C, the Solar Maximum Repair Mission, includes: Commander Robert Crippen; Pilot Francis R. (Dick) Scobee; and Mission Specialists, Terry Hart, Dr. George D. Nelson and Dr. James van Hoften. The crew rehearsed the repair mission at facilities around the country. Although they are cross-trained and can assist each other in various roles, each has been assigned specific tasks during the mission. As the commander, Crippen will be responsible for flying and maneuvering the Shuttle during rendezvous, retrieval, repair, and redeployment of the satellite. Scobee will assist Crippen, operate the flight support system and coordinate the repair mission. Hart will operate the remote manipulator system. Nelson and van Hoften will share the repair tasks during two extravehicular activities (EVA). ✸

Solar Maximum Repair Mission "Firsts"

First Shuttle rendezvous and capture operation with a free-flying spacecraft

First Shuttle era spacecraft repair

First Shuttle era instrument repair

First Shuttle reboost of a free-flying spacecraft

First direct ascent launch of the Space Transportation System

First operational use of the Manned Maneuvering Unit

First operational use of the Multimission Modular Spacecraft Flight Support System

First operational use of the Manipulator Foot Restraint

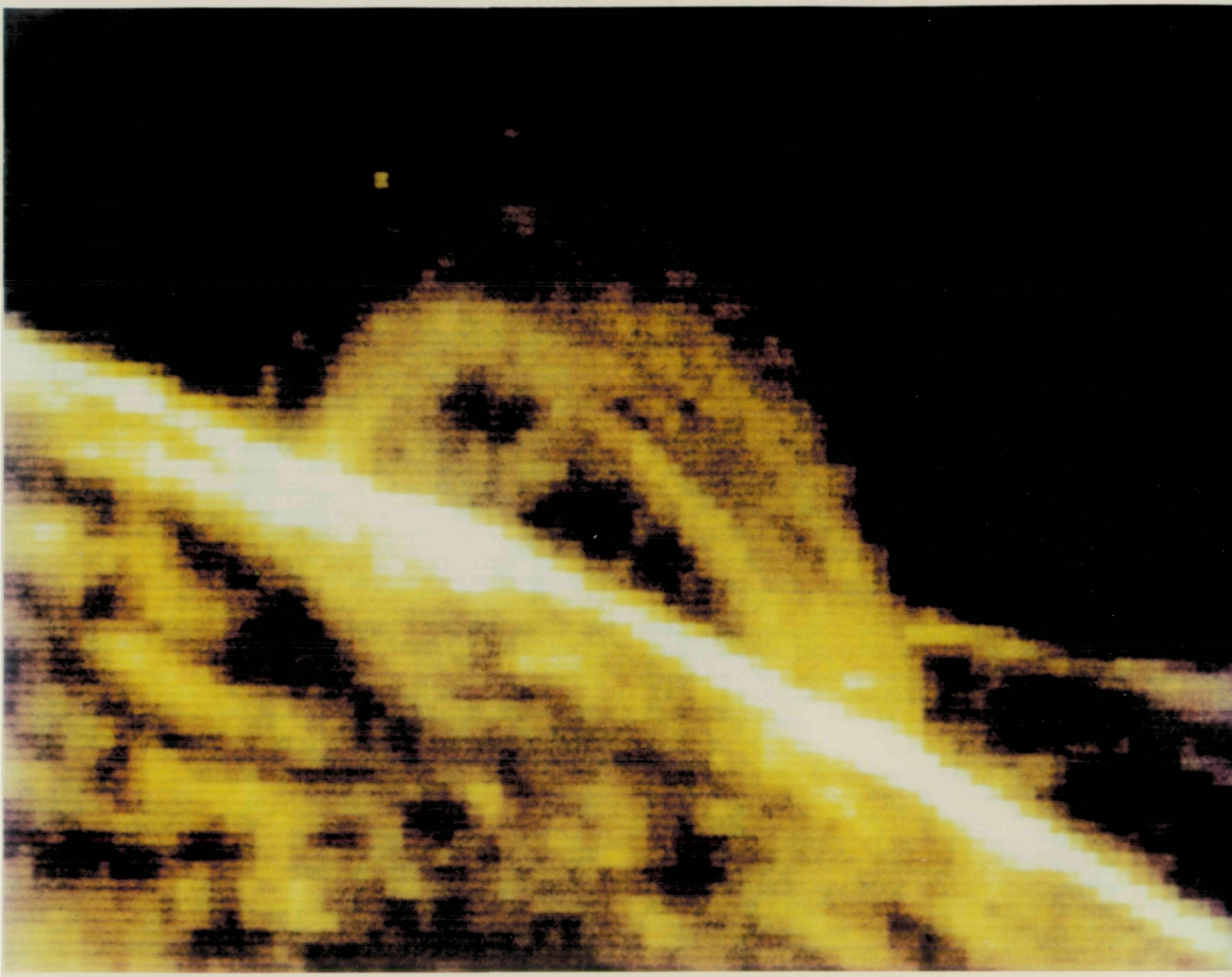
First use of the EVA power tools

First extensive checkout of a spacecraft berthed to the Shuttle

First use of a Payload Operations Control Center at a remote location from the Mission Control Center

First return of spacecraft hardware that has been in space for several years

SOLAR MAXIMUM REP



Magnetic field loops in a solar flare, as revealed by the Solar Maximum Mission Ultraviolet Spectrometer/Polarimeter

AIR MISSION

ORIGINAL PAGE
COLOR PHOTOGRAPH

Studying the Sun ☐ Launched high above the clouds and filtering atmosphere on February 14, 1980, the Solar Maximum observatory was a source of very detailed information about the sun. For the first nine months of the planned two-year mission, the satellite collected spectacular new data. Hundreds of scientists gathered at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and at ground observatories around the world to watch the sun and study solar flares.

These solar flares are tremendous explosions that rack the sun, sending radiation and matter toward Earth. Within hours after a flare erupts, solar matter bombards the Earth, often interrupting radio communications or causing brilliant auroras. Flares occur most frequently during the sun's active cycle, which peaks every 11 years. Scientists declared 1980 the Solar Maximum Year and launched Solar Max in an effort to learn more about flares and the sun during this active period.

Flares, like thunderstorms on Earth, are complex; no single instrument can monitor all their features. The Solar Max observatory carries several different instruments that can observe flare features simultaneously. Six of the instruments monitor flare radiation in parts of the electromagnetic spectrum from visible light through ultraviolet and X-ray emission to gamma rays. Scientists can use data from these instruments to understand better how flares start, how they release their energy, and how they affect the Earth. A seventh instrument on board the satellite monitors the sun's total radiation. Small changes in the sun's radiant output could dramatically affect the Earth's weather and climate. After tracking hundreds of flares before the satellite lost its fine pointing control, scientists made numerous discoveries and raised many new questions about the sun.

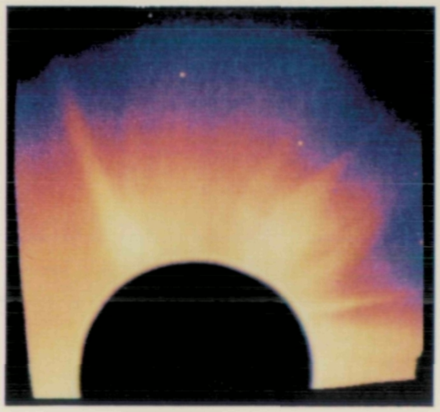
Repair Mission Rationale ☐ There are many reasons for repairing Solar Max and extending its mission. Solar Max is the only solar observatory currently in orbit. A successful repair will restore the $77-million satellite at an estimated one-fourth of its replacement cost and will extend the operational life of the observatory for several years.

Many pieces of the solar flare puzzle are still missing, and scientists need continuous and very precise measurements of flares to determine how they affect the Earth. Using the insight gained from nine months of prior Solar Max observations and three years of data analysis, scientists can pinpoint what they need to watch. Results from the earlier observations will guide plans for the renewed mission.

By the time Solar Max is restored, the solar cycle will have progressed four years to a quieter phase, punctuated by strong but less frequent flare activity. Scientists will have an unforeseen chance to focus on the quieter sun and compare different phases of solar activity. Solar scientists can renew their search for solar-terrestrial connections. As a revived Solar Max beams more information to Earth, they may understand more clearly why explosions on the sun bombard the Earth with energetic particles that disrupt communications, endanger orbiting spacecraft, damage power stations, and alter the chemistry of the atmosphere.

Solar scientists will not be the only ones to benefit if the faulty attitude control module is replaced and the solar observatory is once again working properly. The scientific community at large will no longer be virtually helpless to save equipment that malfunctions in space. The mission will demonstrate that the Shuttle can be used as a space repair vehicle supplied with crews and parts to service satellites. No longer will it be necessary to abandon multimillion dollar spacecrafts because of localized hardware problems.

During the Shuttle era of orbital repair and modular design, satellites may no longer have to rely on expensive, back-up components designed into systems to prevent their failure. Other major observatories designed with replaceable modules for orbital servicing, including Space Telescope, the Landsat series of satellites, and the Gamma Ray Observatory, can be assured of mission success. A host of future satellites can be expected to benefit from the procedures and hardware demonstrated in the Solar Maximum Repair Mission. ✷

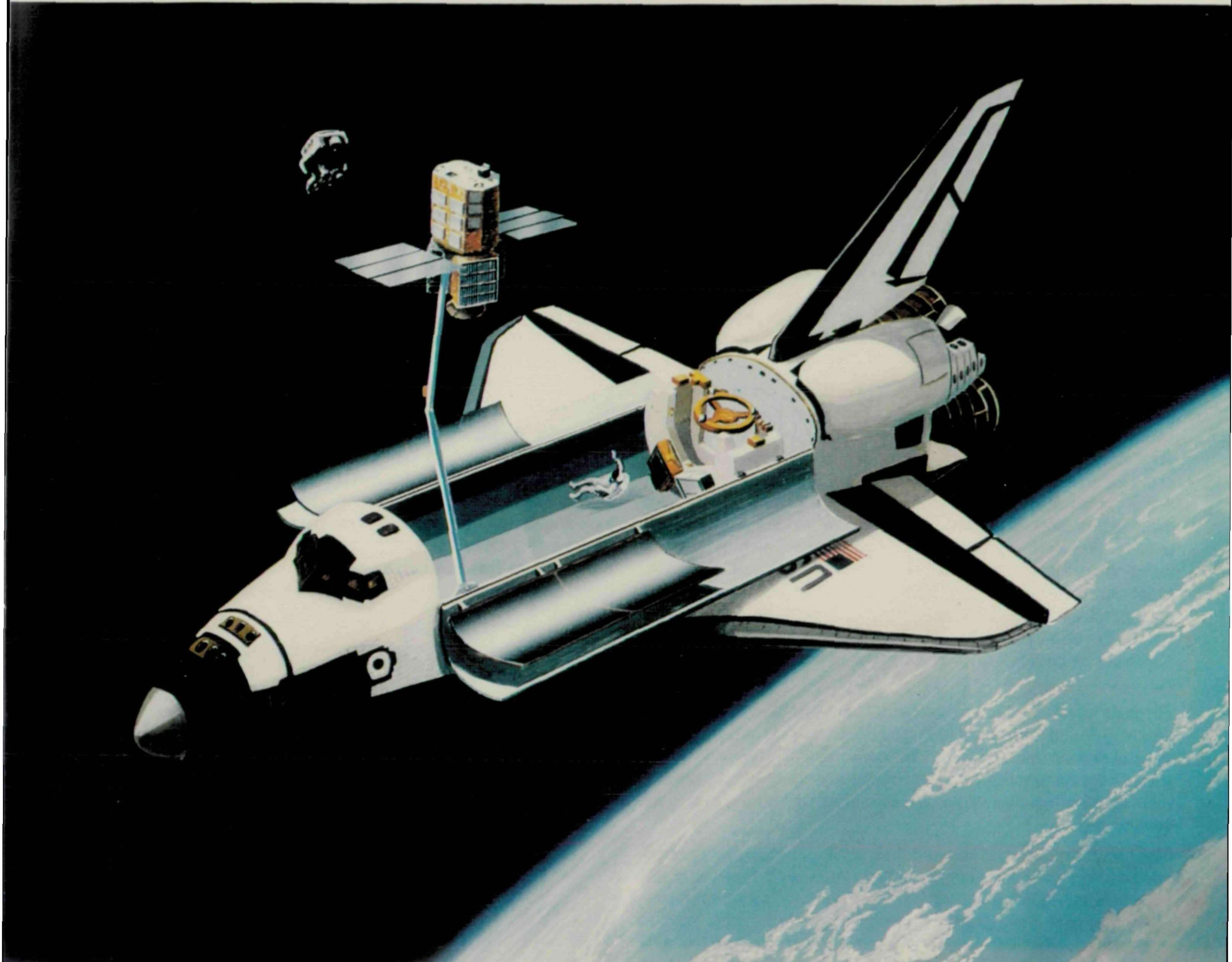


The sun's outer atmosphere, the corona, as revealed by the Solar Maximum Mission Coronagraph/Polarimeter

Left: the quiet corona, with streamers of outflowing gas

Above: an eruptive prominence of cooler, denser material from the lower atmosphere

SOLAR MAX RENDEZV



Retrieval

'OUS & RETRIEVAL

Scientists and technicians at NASA-Goddard commanded Solar Max during its nine months of successful solar study. They will play an important role in helping the Shuttle rendezvous with the satellite. Sixty days before launch, a mission team working in the NASA-Goddard control center will pinpoint the satellite's exact location and begin to prepare Solar Max for the Shuttle's approach. After the launch, they will advise the Shuttle crew of the satellite's exact rotation rate and inclination, and they will position Solar Max for rendezvous and capture.

It is predicted that Solar Max will be orbiting the Earth at approximately 500 kilometers ±37 kilometers (270 ±20 nautical miles) at an inclination of 28.5 degrees above the Earth. The Shuttle will reach this high orbit by the first direct ascent launch in the history of Shuttle operations.

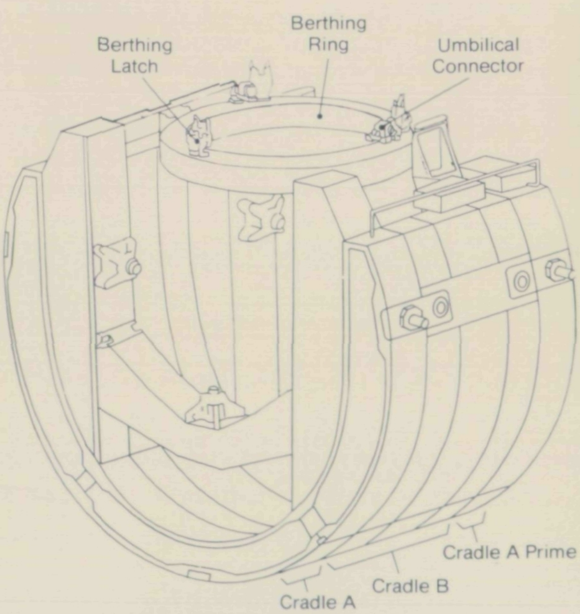
Besides a satellite payload that will be deployed during the second day of the mission, the Shuttle will carry the items needed to repair Solar Max: the flight support system, the replacement attitude control system module, instrument repair parts, the module service tool, repair tools, and the manned maneuvering unit. Before approaching the satellite, the crew will activate and perform system checks on the flight support system and the remote manipulator system. Both systems are essential to the successful retrieval and berthing of Solar Max.

Equipment Checkouts □ After launch, on the first day of the seven-day mission, the crew will checkout the equipment. An important piece of equipment is the flight support system, a mounting platform for the satellite during repairs. This support system mates with the multimission modular spacecraft base of the satellite.

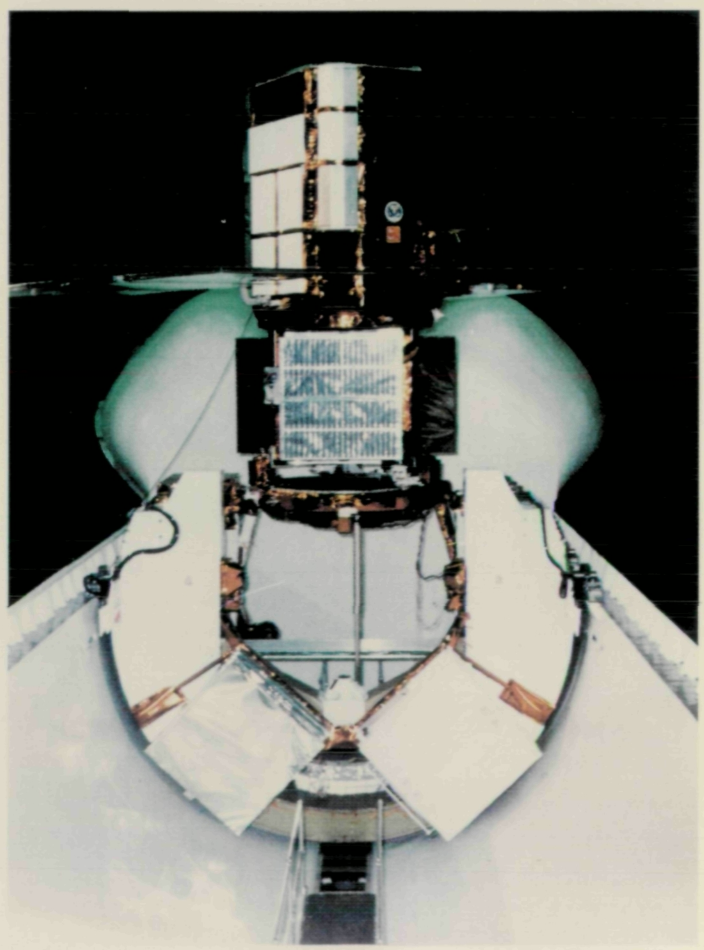
The flight support system is a U-shaped structure that fills the width of the 4.5-meter-wide (15-foot) cargo bay. It consists of three cradles (called A, B, and A-prime) and a circular berthing ring to which the satellite will be anchored. This system can be used again and again on service and repair missions. Simulations at Johnson Space Center using full-scale models of the flight support system, Solar Max, and the Shuttle proved that the satellite could be berthed to the support system successfully. During training on these models, the astronauts demonstrated that they have adequate room and maneuverability to repair the satellite.

The flight support system has 12 motor-driven mechanisms that provide mechanical and electrical connections between the satellite and the orbiter during the repairs. A berthing ring attached to cradle A-prime is stored vertically inside the cradles during launch but is pivoted into horizontal position for satellite repairs. A rotator on the ring can be used to turn the satellite, and a pivoter can be used to tilt the satellite to any position from upright (90 deg.) down to horizontal within the cargo bay (0 deg.) If the repairs to the spacecraft should fail, the solar panels can be jettisoned, and the satellite can be lowered to the horizontal stowed position and locked into the flight support system for return to Earth.

To secure the satellite to the platform ring, three jaw-like berthing latches will clamp onto pins near the bottom of Solar Max on the multimission modular spacecraft base. Nearby, two umbilicals will plug into the satellite to provide Shuttle power and heat to Solar Max during the repairs. The astronauts will turn on and check the motor-driven units in the flight support system before they rendezvous with the satellite.



Flight Support System Configuration for the Solar Maximum Repair Mission

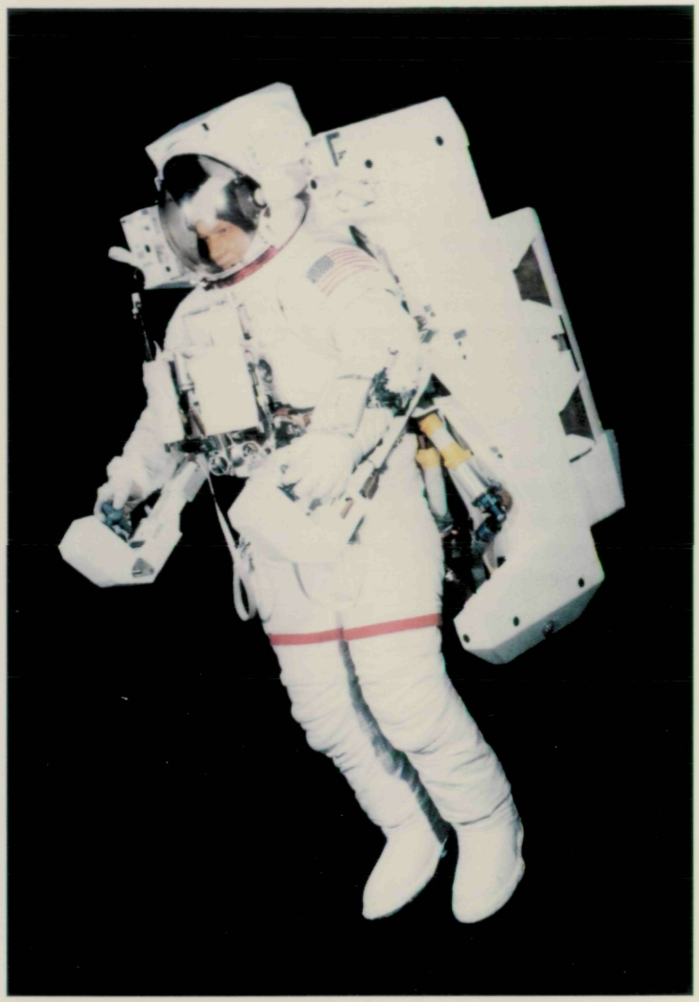


Solar Max model used in engineering evaluations and training

The remote manipulator system or robot arm, which will be used to grapple the satellite, also will be checked out. The 15.2-meter (50 foot) Canadian-built arm has been tested and used on previous Shuttle missions to deploy, grapple, and retrieve various objects. During this mission, the arm will be used to retrieve Solar Max, place it in the orbiter payload bay on the flight support system, and later redeploy it when the repairs are completed. Having performed the various equipment checkouts before beginning the rendezvous operations, the crew will complete their first day's activities.

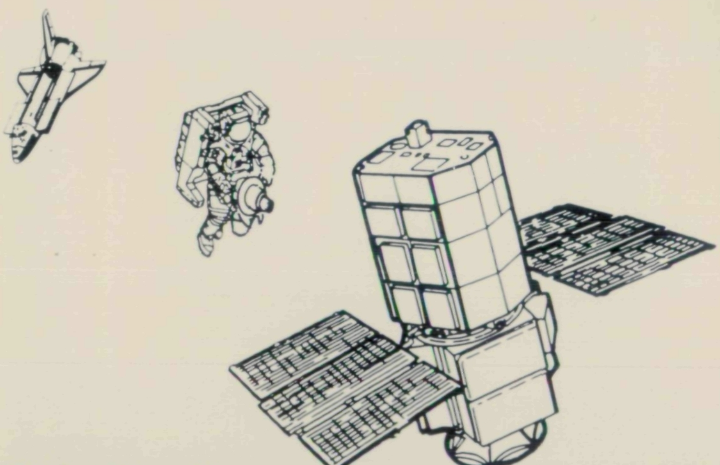
On the second day of the mission, at an altitude of 482 kilometers (260 nautical miles), the crew will deploy another satellite located in the front end of the cargo bay. Launching the additional satellite allows NASA to accomplish two tasks on one Shuttle flight. Following this operation, the Shuttle will maneuver to an altitude of 502 kilometers (270 nautical miles) to rendezvous with Solar Max. Mission teams at NASA-Goddard's control center will do a remote checkout to ensure that Solar Max is safe and ready for capture. After the astronauts sight Solar Max, they will report their observations, station the orbiter 90 meters (100 yards) away, and then begin preparing for their busy schedule the next day.

Capturing Solar Max □ After mission control informs the crew that Solar Max is ready for capture, two astronauts will prepare to leave the Shuttle crew compartment and work outside in space. They must awake earlier than usual to prepare their bodies for the extravehicular activity, during which they will breathe pure oxygen. Before suiting up, they will breathe pure oxygen for four hours to flush the nitrogen from their blood. After they don their space suits in the Shuttle's middeck airlock, they will depressurize the airlock, open the outer hatch, and use handrails to move to the manned maneuvering unit, which is stowed in the cargo bay. After one crewman dons the manned maneuvering unit, he will perform a brief checkout flight in the cargo bay.



Manned Maneuvering Unit

The manned maneuvering unit is a 149-kilogram (330 pound), self-contained mobility unit that is a spacecraft in itself. Powered by two sets of 12 gaseous nitrogen thrusters, it will move the astronaut to Solar Max at a maximum speed of .6 meters per second (1.5 miles per hour). The backpack was tested for the first time during STS-11B when an astronaut flew approximately 90 meters (100 yards) without a tether. The maneuvering unit's range is currently 303



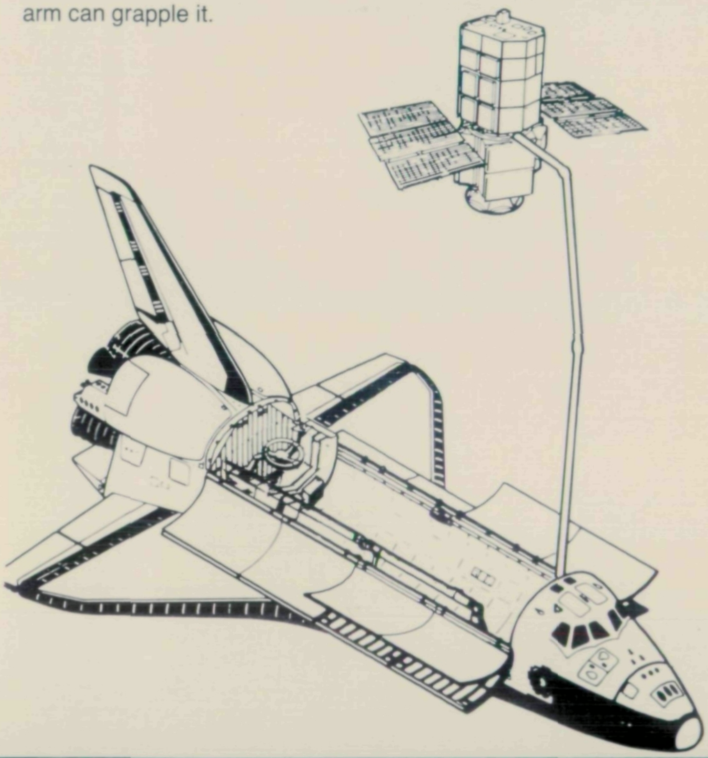
EVA I Timeline

0 HOURS	1 HOUR	2 HOURS
Astronauts enter airlock and don manned maneuvering unit	*MMU checkout flight*	*Astronaut captures Solar Max* *Manipulator arm holds satellite and berths it to flight support system in Shuttle cargo bay*

meters (1,000 feet). While the Shuttle is parked 90 meters (100 yards) from Solar Max, one astronaut will fly the distance to the satellite and use the manned maneuvering unit to stop its rotation.

In the unlikely event of a malfunction, the maneuvering unit and contingency procedures are designed to protect the astronaut's safety. The orbiter would move toward the stalled crewman and scoop him into the open cargo bay. This precision maneuvering capability has already been demonstrated in flight.

Grabbing a moving satellite is a challenge, because even a weightless satellite retains all the momentum of its spinning. Practicing in a manned maneuvering unit simulator, the crew demonstrated that the backpack's 1.7-pound thrusters can be used to stabilize objects rotating faster than Solar Max. The satellite is predicted to be rotating at 1 degree per second or 1 rotation every 6 minutes. The astronaut will match the satellite's rotation, using the manned maneuvering unit to maintain his position while he docks with the satellite. To dock, he will connect a trunnion pin attachment device, called a T-PAD, that is carried between the maneuvering unit hand controls to a trunnion pin protruding from Solar Max. The astronaut will remain docked to Solar Max, using the maneuvering unit thrusters to stabilize the satellite until the Shuttle's remote manipulator arm can grapple it.



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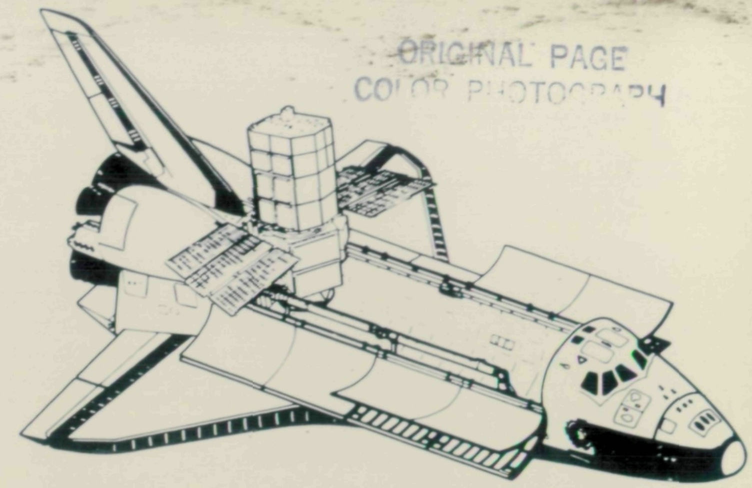


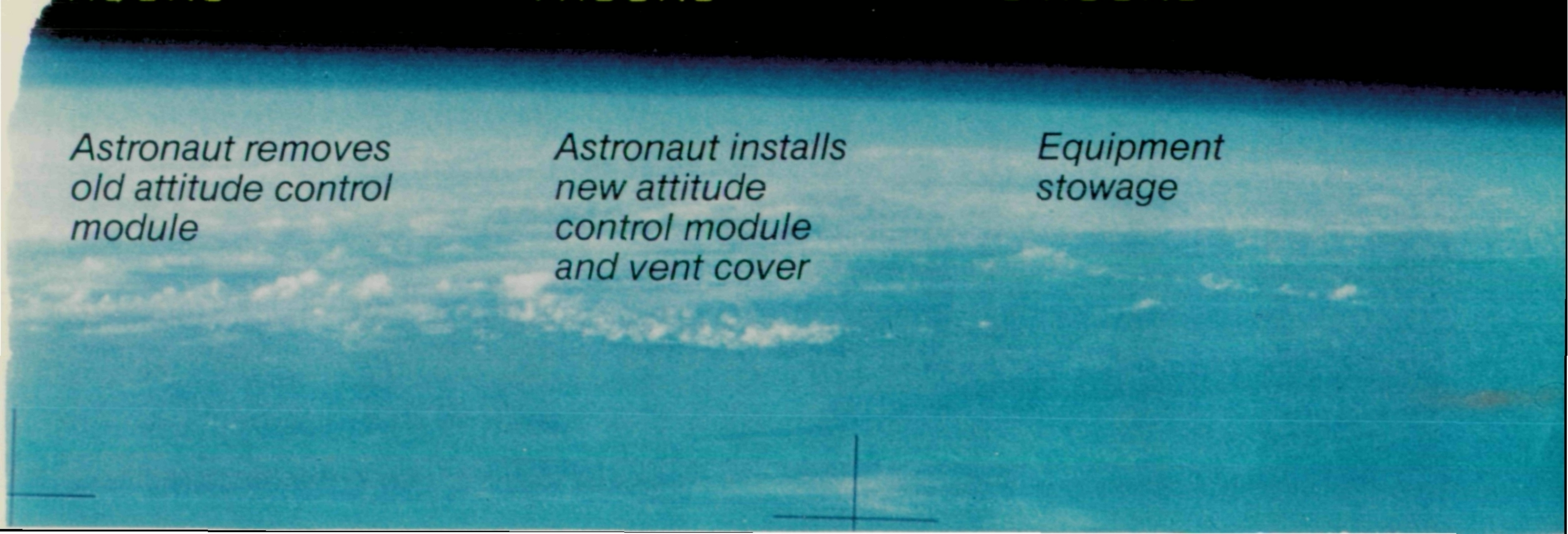
Berthing Solar Max ☐ The Shuttle will then move into position 9 meters (10 yards) below Solar Max, and the robot arm will move upward and grapple an existing fixture between the satellite's solar observatory and the multimission modular spacecraft base. During the retrieval operation, the astronaut operating the arm from inside the Shuttle must avoid hitting and damaging the delicate solar arrays that power the satellite.

When the robot arm has a secure hold on the satellite, the astronaut will remove his attachment device and move clear of Solar Max, while the arm brings the satellite to the flight support system in the rear of the Shuttle's cargo bay. The berthing ring will be in the horizontal position when the arm moves the satellite to the support platform. Crew members inside the Shuttle will close the jaw-like berthing latches located on the ring around pins on the satellite. When the latches have secured Solar Max in place, the arm will release the satellite. Then Solar Max will be rotated into the correct position for repairs. During this operation, the ring must be tilted slightly to keep the satellite's solar arrays from hitting the orbiter. Meanwhile, the astronaut who is using the manned maneuvering unit will return to the orbiter and stow the backpack in the cargo bay.

Before the repairs begin, specialists at NASA-Goddard will turn off Solar Max's power. The crew can control power flow to the satellite once it is connected with the flight support system. Space Shuttle heaters will be used to keep the satellite at the proper temperature and provide power for the satellite as needed.

NASA intends to berth the satellite during daylight, which lasts for 60 minutes during each 100-minute orbit of the Earth. Some of the repairs will be performed as the Shuttle moves through half-hour nights, but orbiter lights and astronaut helmet lights will allow repairs to continue. ✱

HOURS | 4 HOURS | 5 HOURS



RESTORING SOLAR M

Repairs

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Servicing the Spacecraft □ All extravehicular activities are performed in low Earth orbit with the Shuttle's cargo bay doors open. The two repair crewmen will be anchored to the Shuttle by 15.6 meter (50 foot) safety tethers. One astronaut will insert a work station in the end of the remote manipulator arm. This work station has handholds and foot restraints to hold the astronaut in place, tether attach points, and tool boards where various tools are mounted.

One astronaut will operate from the work station, while the other moves freely around the cargo bay. The astronauts will move to a tool locker located at the base of the horseshoe-shaped flight support system. Various tools and equipment necessary for the repair tasks are stowed in the locker. Before servicing the spacecraft, the astronauts will cover the attitude control module's sensitive star trackers, which help point the satellite.

Then, they will remove the module service tool, designed especially for exchanging modules in the multimission modular spacecraft system. The tool is controlled by two handles and two switches. Two latches on the tool fit into oblong holes on the module and hold it in place as the socket wrench on the end of the tool loosens a retention bolt. Each box-like module is attached to the multimission modular spacecraft by two bolts. If the astronaut used a regular wrench to remove these bolts, he would turn while they remained unmoved.

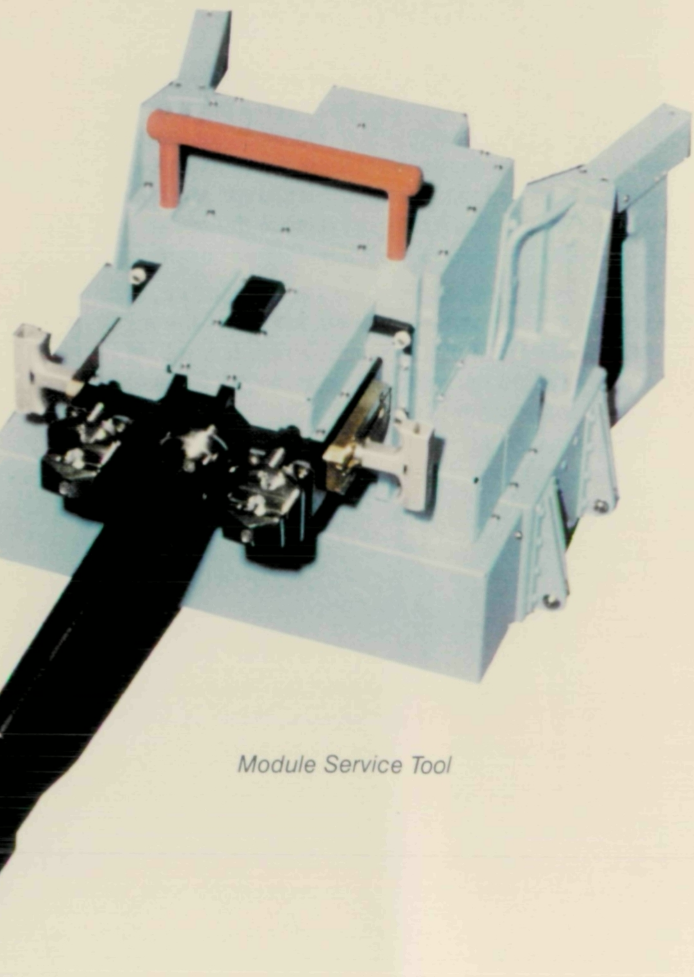
The astronaut will disengage the lower bolt of the faulty module. Then, he will disengage the upper bolt and slide the module off the satellite, using the service tool to hold the module. The manipulator arm will then move him to a temporary storage area, where he will place the old module.

The astronauts must work slowly while moving the modules around. Although they are weightless in space, the modules are 1.2 meters by 1.2 meters by .5 meters (4 feet by 4 feet by 1.7 feet) large and weigh 225 kilograms (500 pounds) on Earth. If they were set in motion, they would be hard to control.

The two astronauts will then remove the stowed replacement attitude control module by grasping it with the module service tool. The astronaut on the end of the arm will be moved up to the site of the attitude control module and will use the module service tool to secure the new module to the spacecraft. The old module will then be placed in its proper storage location for return to Earth.

The next task will be to place a baffle, or cover, on the satellite's X-ray Polychromator unit, which measures X-ray emission from solar flares and shows scientists how particles are moving and changing in the hot solar flare gases. Plasma, the electrified gas that flows through space, is leaking into the instrument and distorting the data it sends to Earth. The astronaut will remove the baffle from the tool locker and then be moved on the manipulator work station to the instrument's exhaust vent, located above a solar array on one side of the satellite. The 6.9-centimeter (2.75 inch) baffle snaps on the vent with spring clips; no extra tools are needed to attach it.

When the first repair operations are completed, the crew will store all equipment and go inside the orbiter. The mission team at the NASA-Goddard control center will turn on Solar Max's power and perform an eight-hour remote checkout of the satellite's systems. Should there be something crucially wrong with the satellite, its solar panels can be jettisoned and it can be lowered into the Shuttle's cargo bay and returned to Earth.



Module Service Tool

Repairing a Scientific Instrument ☐ *If the checkout indi*cates that the satellite's systems are functioning properly, the astronauts will repair another scientific instrument on the fifth day of the mission. The crew will spend the fourth day of the mission resting and servicing their space suits. Before the second extravehicular activity begins, the Shuttle will maneuver to a higher orbit if it has adequate fuel. Solar Max was launched into an orbit of 574 kilometers (310 nautical miles), and scientists would like for it to be redeployed at an altitude near its original orbit.

The astronauts will don their space suits again and move through the airlock into the cargo bay to repair the observatory's Coronagraph/Polarimeter. One crewman will operate from the manipulator foot restraint work station. The other crewman will move between a worksite near the tool locker and a worksite at the Coronagraph/Polarimeter, which is located near the bottom of the solar observatory. He will hand tools to the astronaut mounted on the robot arm and assist him as needed.

The astronauts will be replacing the main electronics box in the Coronagraph/Polarimeter, an instrument that is used to study the sun's outer atmosphere or corona by creating artificial eclipses. Unlike the multimission modular spacecraft units that provide the utilities for the satellite, the scientific instruments on board Solar Max were not designed to be replaced or repaired in space. The coronagraph's main electronics box is mounted inside the insulated shell of the observatory, but its location is accessible enough to make a repair attempt feasible. This repair operation is estimated to take three hours and is more complicated than the removal of the faulty attitude control module.

The tool kit for this repair includes scissors, adhesive tape strips, a ratchet tool, and a battery-operated screwdriver for use on screws and bolts. The ratchet tool will be available as a substitute for the electric screwdriver.

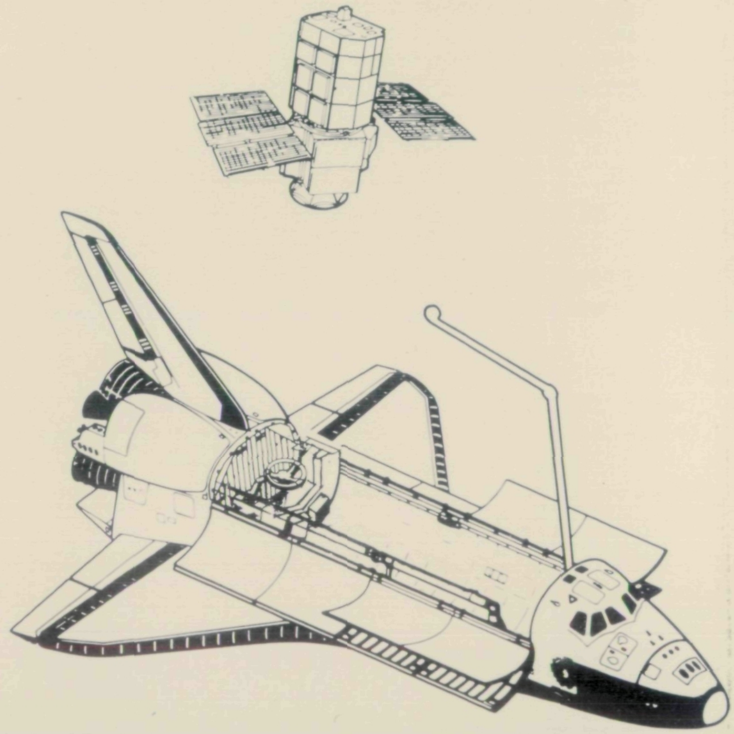
To remove the electronics box, which is about the size of a briefcase, and install a new one, the astronaut will open a panel in the observatory shell at the location of the box. He must cut through the foil insulation and remove screws that secure a protective thermal blanket over the box. After taping the thermal blanket and insulation out of the way, he will install a hinge and remove the remaining screws to open the panel that covers the main electronics box.

Next, he will unplug cables from the electronics box, remove the box and pass it to his partner, who will hand him the replacement electronics box from the tool locker. The new box will be installed, all connectors will be remated, the door closed and secured, and the protective insulation reattached.

Deploying Solar Max ☐ *When the astronauts have com*pleted this repair, they will stow all equipment. Specialists at the NASA-Goddard control center will turn on Solar Max's power and perform a remote systems check for.the last time. The manipulator arm will grapple Solar Max and move it outside the cargo bay, pointing it toward the sun.

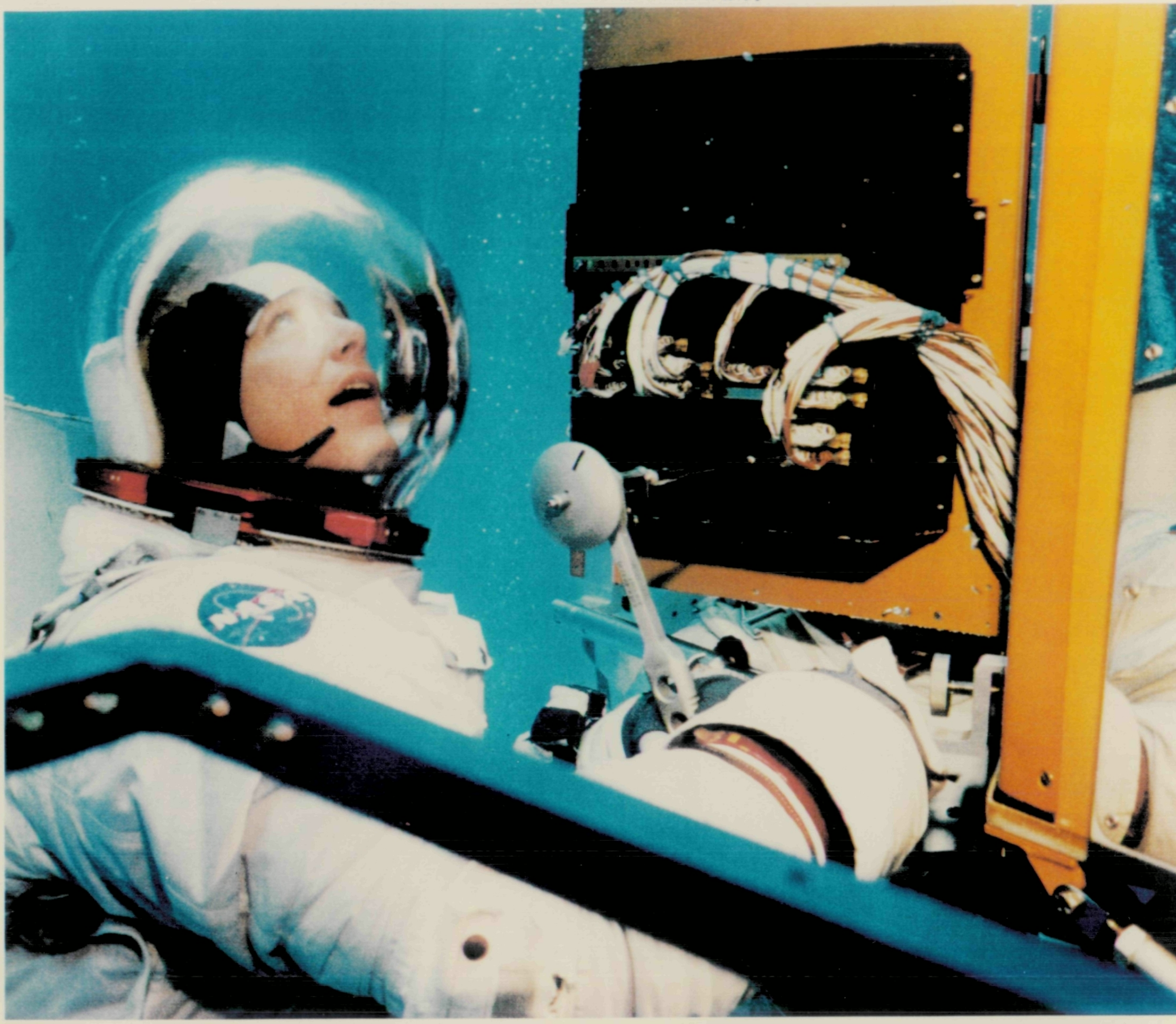
While it is on the arm outside the Shuttle, mission teams at NASA-Goddard will remotely deploy the satellite's high gain antenna. This antenna will allow the satellite to send data to Earth through NASA's new Tracking and Data Relay Satellite System. The two extravehicular activity crewmen will watch the antenna deployment from the forward bulkhead of the cargo bay and then return inside through the airlock.

While the crew rests overnight, Solar Max will remain attached to the arm outside the cargo bay. On day six, the arm will release the satellite, and the Shuttle will back away. The crew will spend the rest of this day performing checks on the flight support system and preparing to deorbit. On the seventh day, the Shuttle will land at Kennedy Space Center with Solar Max's failed parts, which will be returned to NASA-Goddard for engineering analysis. ✷



EVA II Timeline

0 HOURS	1 HOUR	2 HOURS
Astronauts enter airlock and prepare for repair	*Replace electronics box*	*Replace electronics box*



Mission Specialist Dr. George Nelson practices removing the main electronics box of the Coronagraph/Polarimeter underwater in the Neutral Buoyancy Simulator at NASA-Marshall Space Flight Center.

3 HOURS	4 HOURS	5 HOURS
Replace electronics box	*Checkout satellite for deployment*	*Checkout satellite for deployment*

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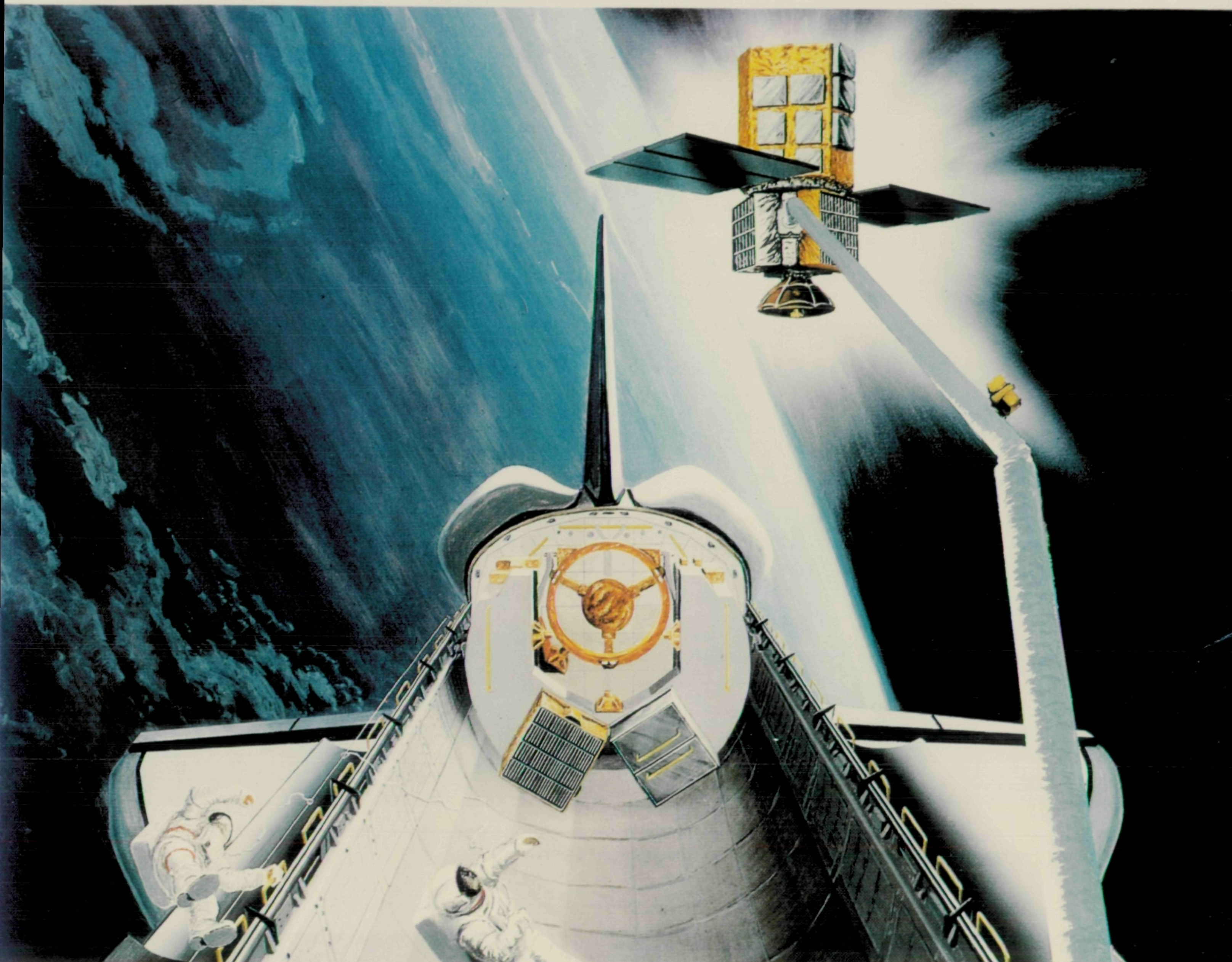
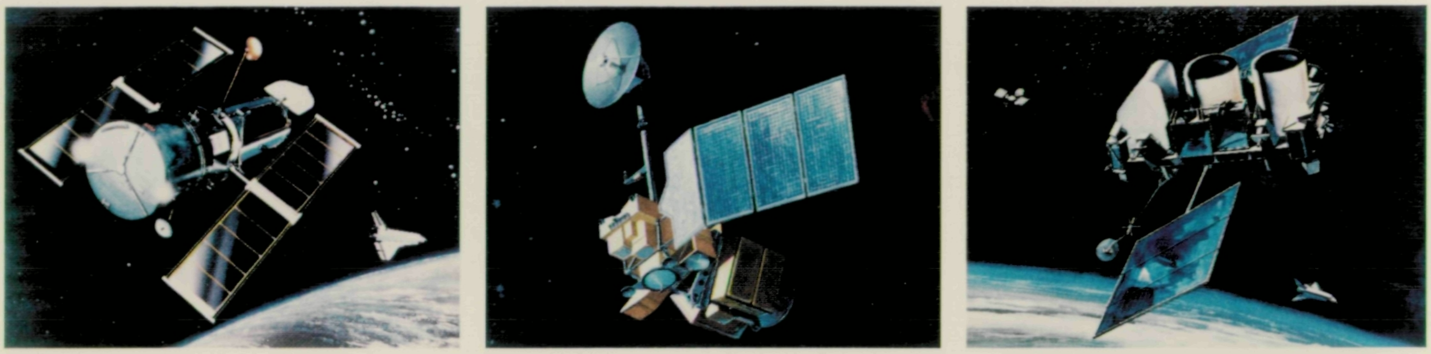


Deployment

LAR MAX REPAIR



Space Telescope, Landsat-4 and the Gamma Ray Observatory belong to a new family of satellites designed for orbital repair.

When the Shuttle lands at NASA-Kennedy, the Solar Maximum Mission will begin a new phase. A revived Solar Max will be monitoring activity on the sun and returning new data to Earth. Meanwhile, the first astronauts to repair a satellite in space will return home with practical information about servicing satellites.

Renewing Solar Science ☐ Besides learning many practical lessons in servicing satellites, NASA will extend the life of Solar Max and enable scientists to continue their studies of the sun from a sophisticated orbital observatory. Major advances in ground-based microwave and optical instrumentation will make new collaborative observations possible. Answers may be found to some of the questions raised by Solar Max data collected previously.

The renewal of the Solar Maximum Mission offers several major benefits to solar physics and solar-terrestrial studies. Continued observations should help to solve the flare puzzle and give us new insight into the processes of energy build-up and release on the sun and other stars. Better understanding of the flare process should enable better prediction of flare events and the disruptive radiation that may affect spacecraft or vulnerable electronic equipment on the ground. An extended mission will enable longer-term measurements of total solar output, which are necessary for correlating changes in Earth's weather and climate with changes in solar radiation. Finally, coordinated observations of the atmosphere will reveal how ozone and other constituent gases vary with solar activity.

The Era of Orbital Repair ☐ If the Solar Maximum Repair Mission is successful, investigators on future projects need not worry about missions being cut short before they have met planned scientific objectives. A blown fuse or a short circuit in a satellite no longer will end its life. With modular design and replaceable parts, scientists will be able not only to repair malfunctions but also to take advantage of new technology to replace instruments and to improve their observations. The life of the satellite may be lengthened and its operation enhanced because it can receive new state-of-the-art components, subsystems, and experiments.

Some new observatories, such as the Advanced X-Ray Astrophysics Facility and the Space Telescope, will have modular instruments designed to be replaced or repaired in space. These new designs will make tasks similar to replacing the electronics box in Solar Max as easy as changing the modules on the satellite's base. Modular design will also allow scientists to use instruments which require special coolants or fluids that must be replenished for continued operation.

Because the Shuttle will carry the used attitude control module and electronics box home in the cargo bay, scientists can check these old parts for contamination and determine the effects of long-term space exposure on hardware. The attitude control module from Solar Max will be refurbished for reuse on a Landsat satellite. Scientists will learn what kinds of equipment and resources are needed to refurbish used satellite parts. The magnitude and cost of reworking the Solar Max parts will help to establish guidelines for designing and building future spacecraft parts.

As repair missions help perfect the modular concept of standardized spacecraft, parts may be mass-produced and bulk-purchased to create an inventory of available spare parts. Then money and design efforts can be focused on the scientific instruments required for the different missions instead of on building the entire satellite from scratch.

The cost-effective use of the Shuttle as a repair vehicle for satellites will become a reality. The Solar Maximum Repair Mission will give NASA practical information about designing satellites more effectively for retrieval and repairs by Shuttle crews. New hardware items, such as the manned maneuvering unit, the flight support system, and the module service tool, will prove their usefulness and will be available for other missions using the multimission modular spacecraft system.

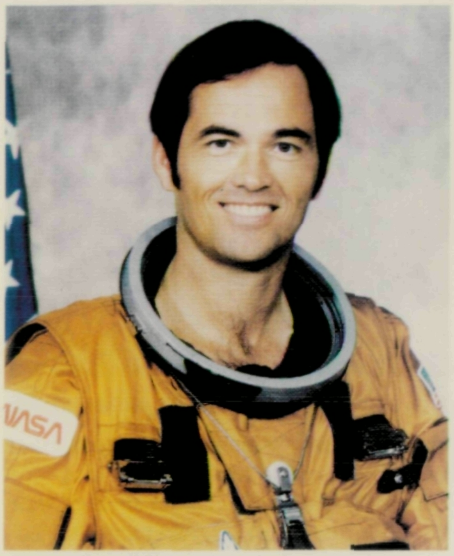
Solar Max is only the first of the new breed of satellites. NASA plans to build many satellites with modular, replaceable components. Other satellites that may be repairable in space include the Landsat series, the Space Telescope, the Upper Atmosphere Research Satellite, the Gamma Ray Observatory, and the Advanced X-Ray Astrophysics Facility.

A successful Solar Maximum Repair Mission not only will restore the world's only orbiting solar observatory but also will open a brand new era in the practical utilization of space. This mission blazes the trail for a promising new venture – commercial manufacturing in space – by demonstrating the use of America's Space Transportation System for scheduled servicing of orbital facilities.

Through the confidence established by this pioneering mission in satellite rendezvous, capture, repair, redeployment, and hardware retrieval, companies will be encouraged to assume the high risks of commercial manufacturing in space. Pharmaceutical companies, for example, should be able to manufacture better medicines economically in space in the very near future.

As the Solar Maximum Repair Mission opens this new opportunity, citizens can look forward to manifold benefits from their investment in space. ✸

REPAIR MISSION CREW



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C

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D

E

A. Robert L. Crippen,
STS-41C Commander
Veteran of two previous Shuttle missions, as Pilot for STS-1 and Commander for STS-7.

B. Francis R. (Dick) Scobee,
STS-41C Pilot
Aerospace Engineer and instructor pilot for the NASA/Boeing 747 Shuttle carrier plane.

C. Dr. George D. Nelson,
STS-41C Mission Specialist
Astronomer with experience in astronomical research, development of the Shuttle-era space suit, and mission support for the STS-3 and STS-4 missions.

D. Dr. James D. van Hoften,
STS-41C Mission Specialist
Hydraulic Engineer and leader of the Astronaut Support Team responsible for Space Shuttle testing and flight preparations, with experience in Shuttle guidance, navigation, and flight control.

E. Terry J. Hart,
STS-41C Mission Specialist
Mechanical and Electrical Engineer with experience as a support crewman for the STS-1, STS-2, STS-3 and STS-7 missions.

Modular Spacecraft
- The New Generation

Solar Maximum Mission

Space Telescope

Gamma Ray Observatory

Advanced X-Ray Astrophysics Facility

Shuttle Infrared Telescope Facility

Large Deployable Reflector

Advanced Solar Observatory

System-Z

Landsat series

Upper Atmosphere Research Satellite

Leasecraft and other commercial spacecraft

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