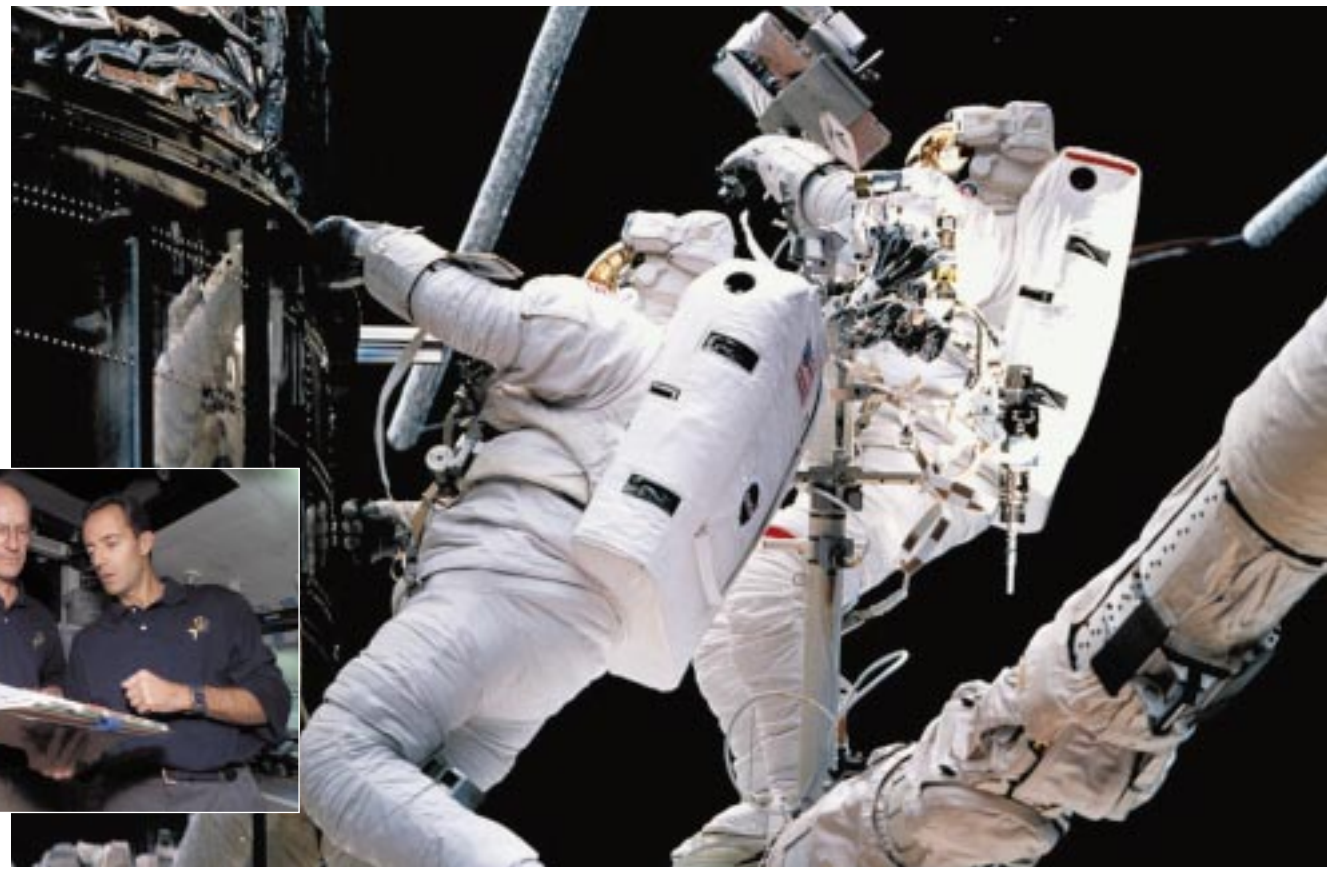
esa **STS-103**

European Space Agency's role in space telescope servicing mission

Astronauts set for Hubble challenge



European Space Agency astronauts Claude Nicollier and Jean-François Clervoy are key members of the crew of the Space Shuttle Discovery that will carry out a new round of repairs and maintenance on the Hubble Space Telescope. The mission's main objective is to replace Hubble's failing pointing system, which allows astronomers to aim precisely at stars, planets and other celestial targets.

Claude Nicollier (left) and Jean-François Clervoy of ESA (inset picture) discuss the Hubble servicing mission

Shuttle mission will keep Hubble on target for astronomers

Hubble, a joint NASA-ESA project, is one of the most successful orbiting observatories ever, having provided a wealth of new scientific data about hundreds of astronomical objects. It continues to conduct scientific observations but its pointing system has begun to fail so the Space Shuttle is being launched on an earlier than planned mission to repair it.

Two of ESA's most experienced astronauts will assume crucial roles as part of a highly qualified astronaut team.

Claude Nicollier will help fit a new computer and insulation material during two spacewalks. He will also become the first European to walk in space from the Space Shuttle.

Jean-François Clervoy will operate the Shuttle's robotic arm during demanding phases of the mission, including initial capture of the satellite and during the spacewalks.

Nicollier is on his fourth flight into space. Among them he took part in the first Hubble servicing mission in 1993, controlling the Shuttle's robotic arm while astronauts outside performed repairs to the telescope. This time Clervoy, on his third flight, will have the lead role in the operation of the robotic arm.

Hubble was launched in 1990 with an expected orbital lifetime of 20 years. ESA contributed a 15 percent share to its development and in return European astronomers receive a guaranteed 15 percent share of observing time. In reality this has averaged 20 percent because of the high quality of proposals from scientists in Europe.

A third servicing mission had been scheduled for June 2000 but after three of the telescope's six gyroscopes failed NASA officials decided not to risk waiting because three gyroscopes must be working to meet the telescope's very precise pointing requirements. NASA rules also dictate that a servicing mission should be considered before a fourth gyroscope fails.

With less than three working gyroscopes Hubble would remain safely in orbit but could not continue with science observations. So, to ensure astronomers receive an uninterrupted service, the third servicing mission has been split into two – the first part now and the second in mid-2001.

As well as replacing all the telescope's gyros the crew will also install other equipment that has either degraded in the harsh space environment or can now be replaced with more up-to-date technology.

Discovery is scheduled for launch from the Kennedy Space Center in December.

The Hubble Space Telescope in the cargo bay of the Space Shuttle during the last servicing mission

European astronomers on voyage of discovery

A joint NASA and ESA project, the Hubble Space Telescope has already made some of the most dramatic discoveries in the history of astronomy.

At its heart is a 2.4 m primary mirror and a collection of five science instruments that work across the entire light spectrum, including ESA's Faint Object Camera.

Manned servicing missions, to replace faulty and obsolete parts with new or improved instruments, are crucial to fulfilling its objective of probing the farthest and faintest reaches of the cosmos for up to two decades.

The telescope, equivalent in size to a double-decker bus, is roughly cylindrical in shape and measures 15.9 m end-to-end and 4.3 m in diameter at its widest point.

For European astronomers, and scientists throughout the world, it is providing a rich cosmic harvest of stunning pictures and new information – from the relatively near planets in our own Solar System to the most distant and unknown parts of the Universe.

Mission facts

Flight	STS-103
Orbiter	Discovery
Launch	6 December 1999 02.37 EST (08.37 CET)
Launch site	Pad 39a, Kennedy Space Center, Florida
Landing	15 December 1999 23.57 EST 16 December 1999 05.57 CET
Landing site	Kennedy Space Center, Florida
Duration	10 days
Altitude	512 km
Inclination	28 degrees

Crew members

Curtis Brown
Commander (NASA)

Scott Kelly
Pilot (NASA)

Steven Smith
Mission Specialist (NASA)

Michael Foale
Mission Specialist (NASA)

John Grunsfeld
Mission Specialist (NASA)

Claude Nicollier
Mission Specialist (ESA)

Jean-François Clervoy
Mission Specialist (ESA)

STS-103 websites

http://www.estec.esa.int/spaceflight

http://spaceflight.nasa.gov/shuttle

http://sci.esa.int/hubble

http://www.stsci.edu

http://hubble.gsfc.nasa.gov

Sharp eyes above the atmosphere

Light from distant astronomical objects speeds through the Universe on journeys taking billions of years.

But on reaching Earth it has to pass through the atmosphere before being received by ground-based telescopes.

As a result the fine cosmic details become less clear because, to light, our atmosphere is like a dirty lens.

So astronomers have always dreamt of avoiding the problem by placing a telescope in orbit. Hubble is the answer to those dreams – it can detect light before it is distorted by the atmosphere with 'eyes' 10 times sharper than the largest ground-based telescopes.

As a result Hubble, a joint NASA and ESA project, has already made some of the most dramatic discoveries in the history of astronomy.

A future space telescope

Europe could play a significant role in the development of a new space telescope to replace Hubble. A decision will be taken next year on whether Europe, through ESA, will participate in NASA's proposed Next Generation Space Telescope (NGST).

NGST's observing capabilities will far surpass the reach of existing ground or space-based telescopes, providing the opportunity for the first time to look back through eons of time to the very first stars and galaxies in the Universe.

With an aperture of eight metres, NGST could also provide European astronomers with a crucial complement to some of ESA's planned future space projects, like FIRST (the Far InfraRed Submillimetre Telescope) and Planck, a mission to study the cosmic background radiation field.

NASA and ESA are already involved in NGST studies and technology development activities, and the potential contribution of ESA will be decided upon in the Spring of 2000. NASA wants to start formal development in 2003, with a launch in 2008.

What is being replaced

Gyroscopes

The Hubble Space Telescope's gyros are the most accurate in the world, extraordinarily stable and capable of detecting extremely small movements of the telescope – they have to be to keep HST precisely on target for long periods to collect the spectacular images.

As well as keeping Hubble stable, the gyros measure attitude when the telescope is changing its pointing from one celestial target to another.

There are six gyros on board and to provide enough information to control Hubble accurately three must operate simultaneously.

But they have limited lifetimes. Only three of the six are working properly and on this mission astronauts will replace all three double units leaving Hubble with six fresh gyros.

Fine Guidance Sensor

This is the second in a series of refurbishments of Hubble's three fine guidance sensors which allow fine pointing and help keep the telescope stable. The astronauts will be taking with them a renovated Fine Guidance Sensor – the same unit that was returned on the last servicing mission. The unit removed on this mission will be refurbished and upgraded for re-use on the fourth servicing mission.

New computer

A radiation-rugged computer will replace Hubble's now outdated main computer, dramatically increasing operational capabilities, reducing the burden of flight software maintenance and significantly cutting operational costs. The more advanced computer will run 20 times faster and provide six times as much onboard memory.

Voltage/temperature improvement kits

With age Hubble's batteries become more susceptible to overheating if they are overcharged. This kit will compensate by lowering the battery's charge termination voltage. One kit will be installed for each of Hubble's six batteries.

Spare S-band single access transmitter

This will replace an aged and failed unit which will be removed, returned to Earth and refurbished for a later flight.

Spare Solid State Recorder (SSR)

The second of three tape recorders is being replaced by a high-capacity solid state recorder, as was the first during the previous servicing mission. SSRs are essential for efficiently handling the high volumes of data from Hubble's newest instruments and for maintaining high science productivity.

New Outer Blanket Layer

Stainless steel sheets, covered with a protective thermal coating, will be installed at various locations on telescope to help control the internal temperature. They will fit over existing insulation that has degraded.

Shell/Shield replacement fabric

Flexible aluminised Teflon sheets will be added to the outside of Hubble's forward shell and light shield to provide additional protection and insulation against the harsh space environment.

Handrail covers and shroud latches

Fibreglass cloth, called beta cloth, will be fitted like sleeves around the handrails above the Fine Guidance Sensor bay to prevent contamination of the area after flaking paint was observed on these handrails during the previous servicing mission. Astronauts will also replace latches on Hubble's bay door.

European astron

Credit: HST (NASA & ESA), WFPC2. Bruce Balick (University of Washington), Vincent Icke (Leiden University) and Garrelt Mellema (Stockholm University).

Cosmic collisions

Observations carried out by Pieter van Dokkum (Groningen and Leiden Universities, The Netherlands) and Marijn Franx (Leiden University) show the first direct images of collisions between galaxies. The colliding galaxies reside in a so-called cluster of galaxies. Though collisions have been observed in other clusters, this particular cluster displays by far the largest number ever seen.

To astronomers, the finding indicates that, at least in some cases, massive galaxies form through collisions between smaller ones. "It has been a real surprise," said team leader Pieter van Dokkum. "Collisions had never been observed before at this frequency. Many involve very massive galaxies and the end result will be even more massive galaxies."

Previously, the evidence for the theories of galaxy formation through collisions has been strong but circumstantial. Thanks to Hubble a large number of galaxies have been caught in the act.

Credit: HST (NASA & ESA), WFPC2. Pieter van Dokkum (University of Groningen/Leiden), Marijn Franx (University of Leiden).

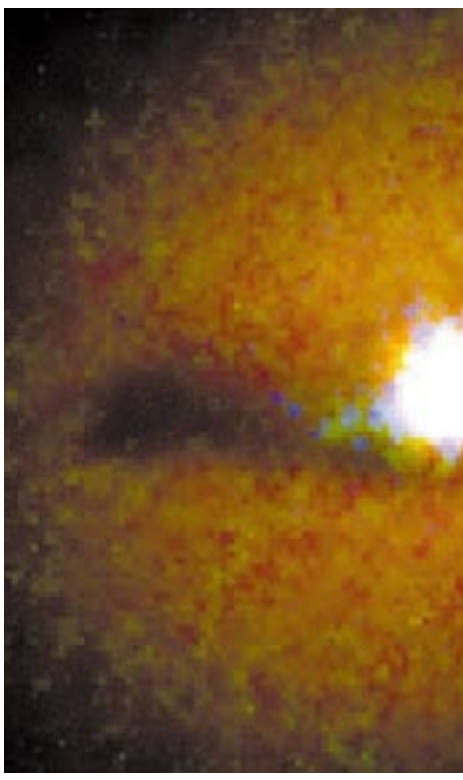
Interesting facts

- Hubble has taken about 259,000 different pictures of astronomical objects
- Hubble has observed nearly 13,000 astronomical targets
- Astronomers using Hubble have published over 2,400 scientific papers
- Hubble, circling the Earth every 97 minutes, has travelled the equivalent of the distance between the Earth and Uranus – around 2.293 billion km

Discovery of a "naked" black hole

In 1997 Philippe Crane from the European Southern Observatory (ESO) at Garching, Germany discovered a black hole peeping out over the edge of a swirling dusty disk. "It was astounding," Crane commented. "Thanks to the extremely high resolution from ESA's Faint Object Camera we saw a completely new phenomenon. Before HST you could never do this kind of research."

The galaxy in which the black hole resides is some 300 million light-years away in the constellation Ursa Minor. At the centre of the galaxy all kinds of material – dust, gas and even stars – are steadily falling into the violent black hole and creating a blaze of energetic ultraviolet light (coloured blue in the picture).



Credit: HST (NASA & ESA), FOC. P. Crane (European Southern Observatory).

nomy and the Hubble Space Telescope

Some 2,100 light-years away in the constellation Ophiucus a planetary nebula called M2-9 helps astronomers to cast new light on the final stage of our own Sun's life. Around five billion years from now, the Sun will eject its own beautiful nebula and then fade away as a white dwarf star.

Since the launch of HST in April 1990 and its initial repair in orbit astronomers have had access to an astronomical instrument with unsurpassed sharpness and imaging capability. HST has been able to deliver new views on most of the many different objects in the cosmos. For European astronomers it has meant a world of difference to have access to the most famous space telescope of them all, developed jointly by ESA and NASA.

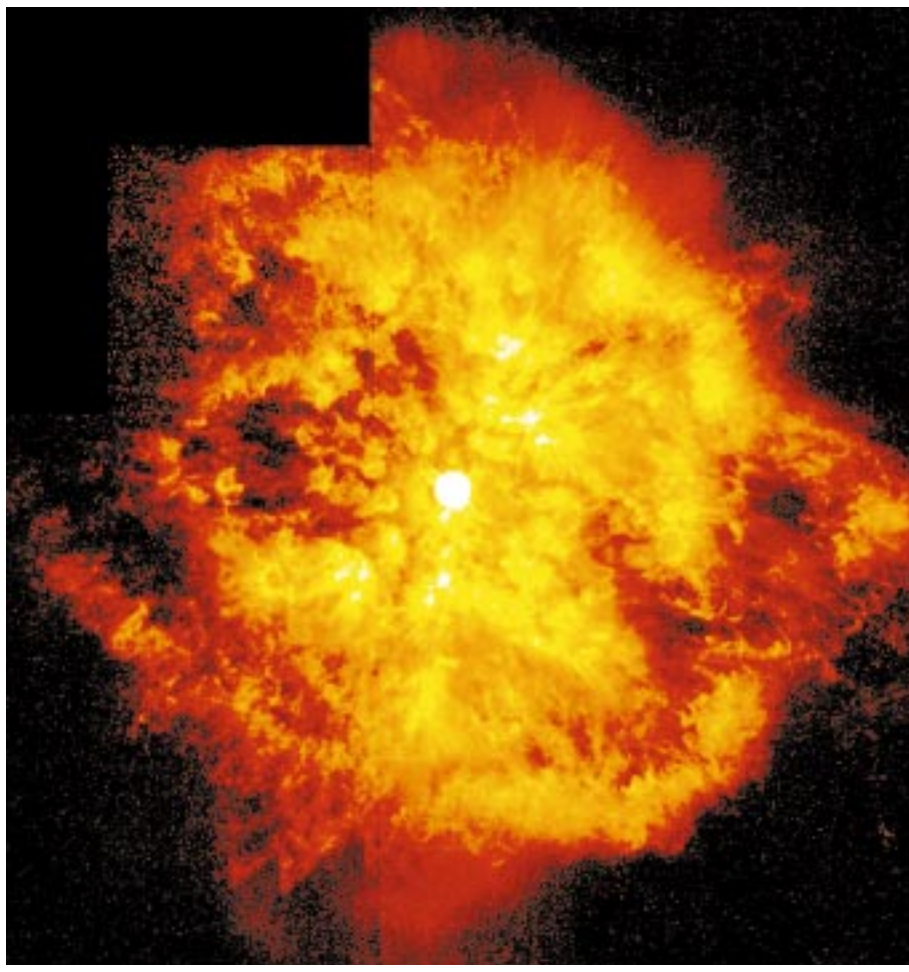
For Europe, as well as for the United States, HST has so far been a success beyond comparison. Astounding results are pouring out of the telescope on a daily basis and hundreds of scientific publications based on HST data are published every year.

With the third HST servicing mission, it is a good time to take a look at some of the spectacular results that European astronomers have achieved using Hubble.

By submitting excellent observing proposals European astronomers have been able to get substantially more observing time than their original quota of 15 percent. Around 20 percent of HST's total number of observations have been carried out by Europeans.

In the third period of HST's operation – between 1997 and 1999 – some of the most interesting, as well as visually compelling, results from the European astronomers have included discovery of a naked "black" hole in a galaxy, the first direct image of aurora on Jupiter, observations of stellar "fireworks" and the first direct images of collisions between galaxies. These examples represent only a small fraction of the hundreds of discoveries that HST has been able to deliver to the European science community.

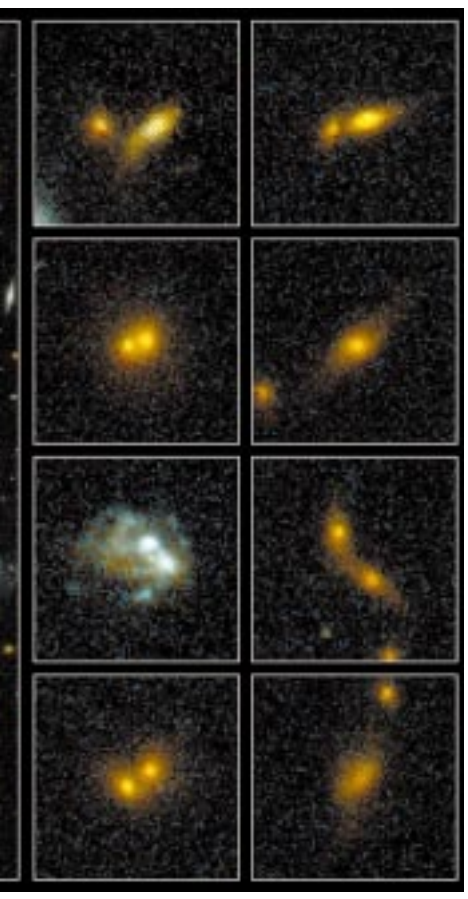
Credit: HST (NASA & ESA), WFPC2. Yves Grosdidier (University of Montreal and Observatoire de Strasbourg), Anthony Moffat (University of Montreal), Gilles Joncas (Universite Laval), Agnes Acker (Observatoire de Strasbourg).



Stellar fireworks

Resembling a gigantic fireworks display the nebula M1-67 surrounds a warm and energetic star. The gasses have been ejected from the star in the middle at speeds of more than 150,000 km per hour and the image may show the direct existence of a powerful stellar wind around the star.

The nebula extends over more than 100 billion km and the observations were carried out by Yves Grosdidier of Strasbourg Observatory and University of Montreal, Canada.

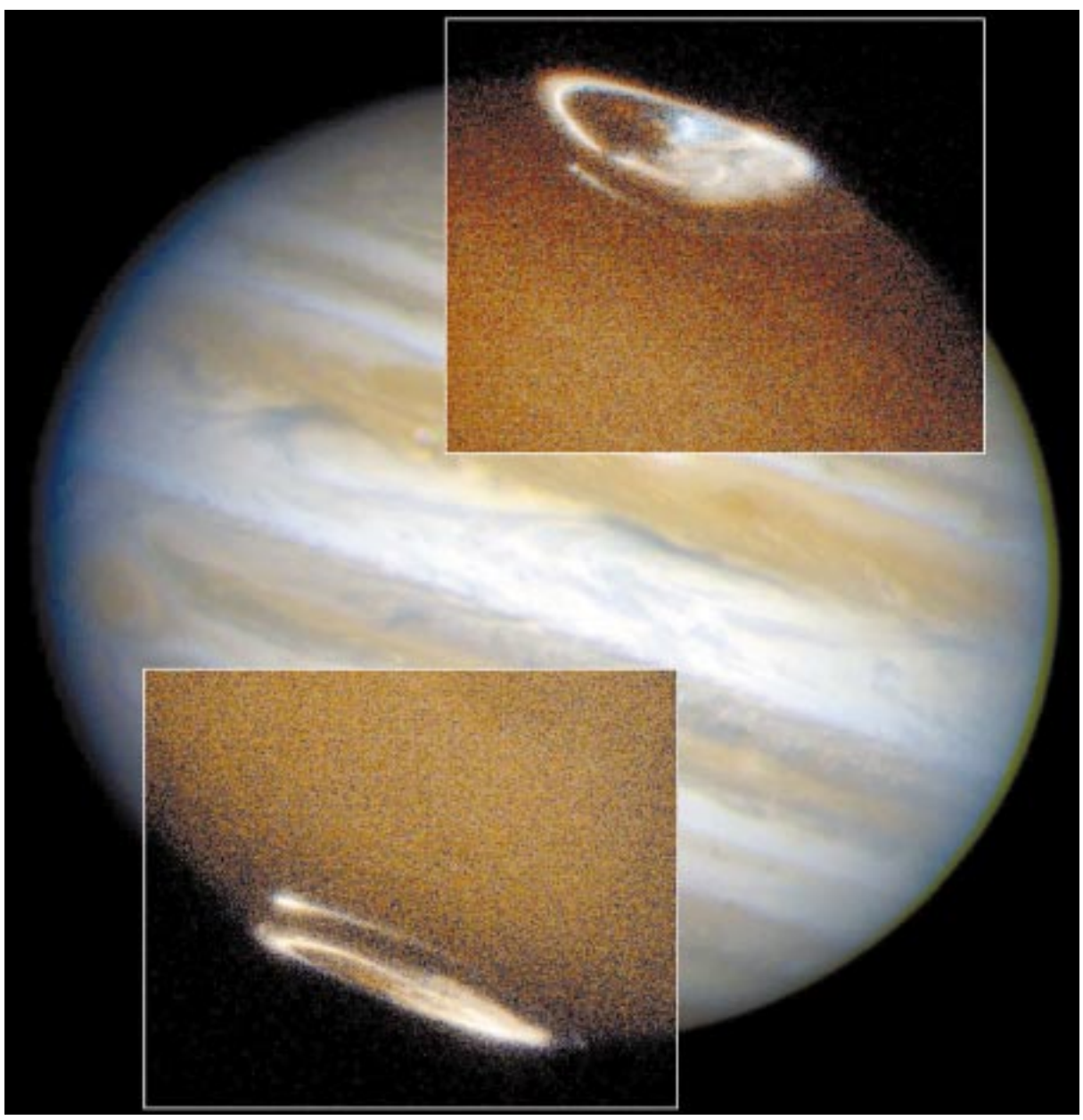


Aurora on Jupiter

Jean-Claude Gerard, from the Laboratory of Atmospheric and Planetary Physics in Belgium, has shown how the giant planet Jupiter is lit up by beautiful aurora – also known as northern lights. "Our work was really not possible without Hubble. We knew that aurora existed on Jupiter ever since the Voyager probes flew by, but it has not been possible to take pictures of them. Hubble was a unique opportunity to finally achieve this."

The aurora on Jupiter are brilliant curtains of light in the upper atmosphere. They resemble the aurora we see on Earth, but the story behind their creation is quite different. Particles spewed out by volcanoes on the Jovian moon, Io, spiral down into Jupiter's atmosphere where they hit atoms and molecules and cause them to glow.

Credit: HST (NASA & ESA), STIS and WFPC2. John Clarke, Joe Ajello, Kent Tobiska, John Trauger, Gilda Ballester, Lotfi Ben Jaffel, Jack Connerney, Jean-Claude Gérard, Randy Gladstone, Hunter Waite, Wayne Pryor and Daniel Rego.



European astronaut will control robotic arm

Tense moments during the mission will come immediately after the Shuttle has made its rendezvous with Hubble. ESA astronaut Jean-François Clervoy has the responsibility of gently attaching the Shuttle's robotic arm to the Hubble Space Telescope as the two hurtle round the Earth in tandem at speeds of 27,000 km an hour.

Clervoy is the mission's flight engineer. He flew in space for the first time on the Space Shuttle Atlantis in November 1994 and the experience gained on that flight – when he controlled the robotic arm to deploy an atmospheric research satellite for the German space agency DLR – will be invaluable.

Discovery's rendezvous with Hubble will occur in orbit during the second day of the mission some 600 km above the Earth. Unlike on previous occasions, the Shuttle will move vertically towards the Telescope, gradually reducing the closing speed from about 1 m/sec at a distance of 600 m to 0.02 m/sec at 36 m. Approaching in this way is more fuel efficient if everything goes according to plan.

"During rendezvous with Hubble I will be monitoring a laptop Windows '95 program that reads data from the orbiter systems, displaying graphically the relative motions of the orbiter and telescope and providing us with a better awareness of what is going on," said Clervoy.

Once they achieve the proper relative positions Clervoy will switch to the controls of the robotic arm. There will be no room for mistakes as he performs a task in real time that he has practised for many hours in simulations on the ground. After attaching the arm he gently guides the 12-ton telescope to its repair berth at the rear of the Shuttle's payload bay.

Speaking during the final stages of his training at Houston, Clervoy said: "I think everyone has a great sense of responsibility. Compared to my previous flights STS-103 will be a challenge of a very different kind – it is totally focussed on Hubble."

Clervoy also represented ESA in 1997 among the international crew of STS-84 which docked with the Mir space station – an important mission in Europe's preparation for work on the Space Station.

His career as an astronaut started in 1985 when he was selected by CNES (the French space agency) to join the second team of French astronauts. He also supported European manned space activities through the Hermes Space Vehicle Crew Office in Toulouse before joining ESA's astronaut corps in 1992.

"Space Shuttle crews are chosen according to the best ability and experience for the job in hand so it is really great that NASA decided to put two European astronauts on this high profile mission," said Clervoy, who has trained at Star City, Moscow, as well as at NASA's Johnson Space Center in Houston.

Jean-François Clervoy

"Everyone on the crew is looking forward to this mission. The work will be demanding for us all – I may be spending eight hours a day flying the robotic arm," he added.

By the time the servicing flight blasts off Clervoy will have completed more than 150 hours of mission specific training on the robotic arm alone. As the ultimate in high-tech repair jobs this third trip into orbit will be highly spectacular but a very different one for Clervoy.

First European set to make spacewalk from Shuttle

ESA astronaut Claude Nicollier will achieve the ambition of a lifetime when he exits the airlock at the beginning of the mission's second major spacewalk.

Before him will be the two-storey high Hubble Telescope like an orbiting high-rise set against the backdrop of the Earth below. It will be his first stint of six hours in a space suit carrying out repairs.

A veteran of three space flights, Nicollier is no stranger to Hubble – he operated the robotic arm on STS-61 in 1993, the first HST servicing mission.

Altogether he has logged more than 828 hours in space, participating in the deployment of the European Retrievable Carrier science platform on STS-46 in 1992 and serving as mission specialist on STS-75 in 1996 – the reflight of the Italian Tethered Satellite System.

The opportunity for one of its astronaut to make two spacewalks during the mission is important for ESA. "It is a question of building up experience. We have had EVAs from Mir but this will be the first time a European has had the opportunity to go from the Shuttle," said Nicollier.

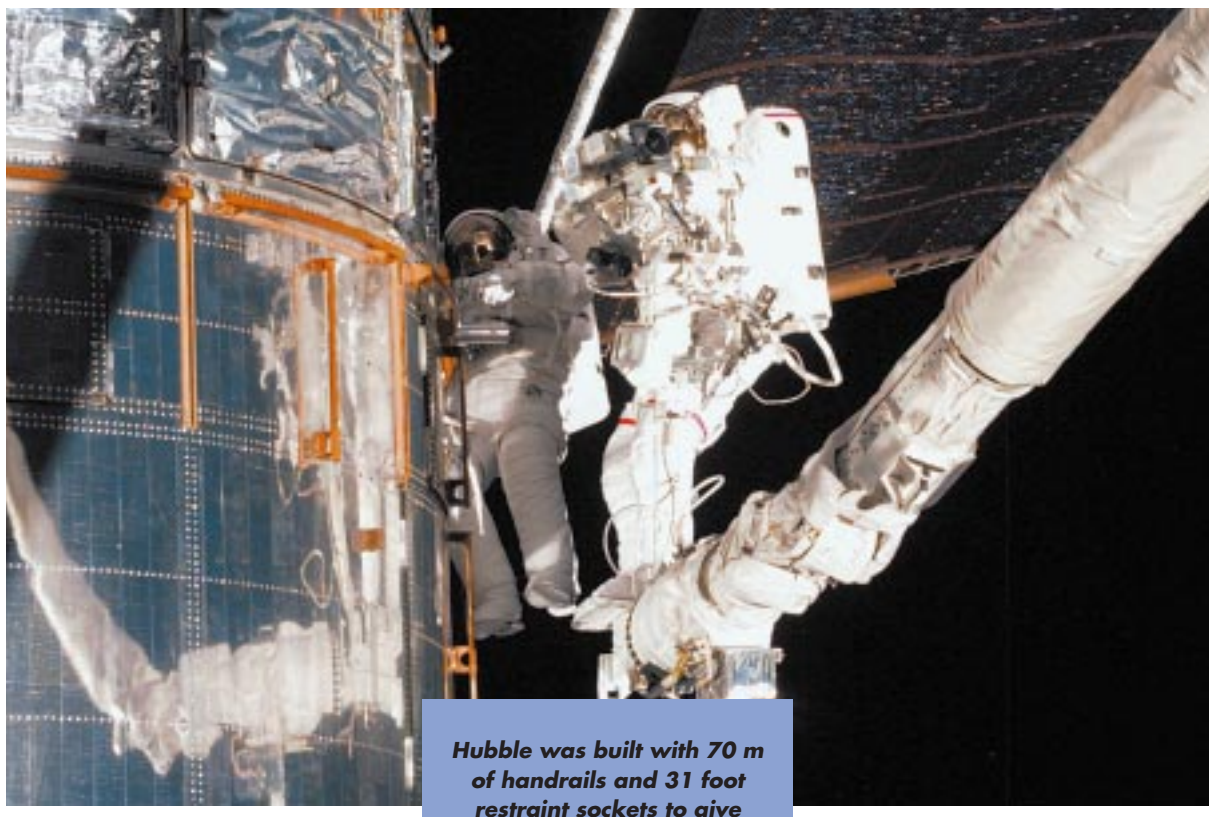
"The fact that it has two astronauts on this flight is a source of pride for ESA, especially as NASA had no agreement for the presence of Europeans. We are part of a large group of astronauts and people are picked for the job."

A native of Vevey, Switzerland, Nicollier has logged more than 100 hours of underwater training in the Neutral Bouyancy Laboratory, a giant, 12-metre deep water tank used by NASA to familiarise astronauts with working in space.

He joined ESA in 1978 as a member of the first group of European astronauts and is now one of the agency's most experienced astronauts.

Four EVA mission specialists will work in two-person teams on alternate days. Claude Nicollier will be with Mike Foale, a British-born American citizen.

Claude Nicollier



Astronauts working on Hubble during the second servicing mission in 1997

During each EVA one astronaut (known as EVA1) accomplishes primarily the free-floating portions of the EVA tasks while the other astronaut (EVA2) works from a special platform attached to the Shuttle's robotic arm.

To reduce crew fatigue during the spacewalks, which are scheduled to last six hours each, crew members exchange places once during each EVA.

On EVA Day 2, Nicollier and Foale are scheduled to replace the telescope's computer.

"One of the big issues for all the EVAs is preventing debris from getting inside the telescope," said Nicollier. "At various points the guts of the telescope will be exposed to the outside. We are all very aware of the potential damage and presence of debris and we don't want any of the debris to get inside."

The final scheduled EVA for Nicollier and Foale is devoted to reinsulating the telescope and installing new thermal blankets to the middle and upper parts.

Hubble was built with 70 m of handrails and 31 foot restraint sockets to give astronauts safe and convenient work sites as they hurtle around the Earth at 27,000 km an hour. On the ground that would be like travelling between two villages 7 km apart in a single second.

One side of Hubble is continually facing the sun and as a result has suffered serious degradation and damage from solar radiation. The original protective blanket is quite brittle so new ones will be installed over the top. The seven 1.5 m wide strips of insulation will be in 3 m rolls.

"It will be like hanging wallpaper. We'll start at the top and gradually unroll the insulation, attaching it with wires and clips," said Nicollier.

One unique aspect of Hubble servicing missions is that the Shuttle goes to a higher altitude than on other flights – 600 km compared to an average 300 km. "It means we get to see a larger panorama of the Earth below and that's pretty spectacular. A spacewalk is something I have always wanted to do. For me it is a dream about to come true," said Nicollier.

Like regular repairmen, the astronauts will carry more than 150 aids and special tools on this service call. These range from carrying aids to sophisticated, computer-operated power tools. Some are standard items from the Shuttle's toolbox and others are unique to the mission. All are designed to accommodate and compensate for the astronauts' bulky pressurised gloves and space suits.

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