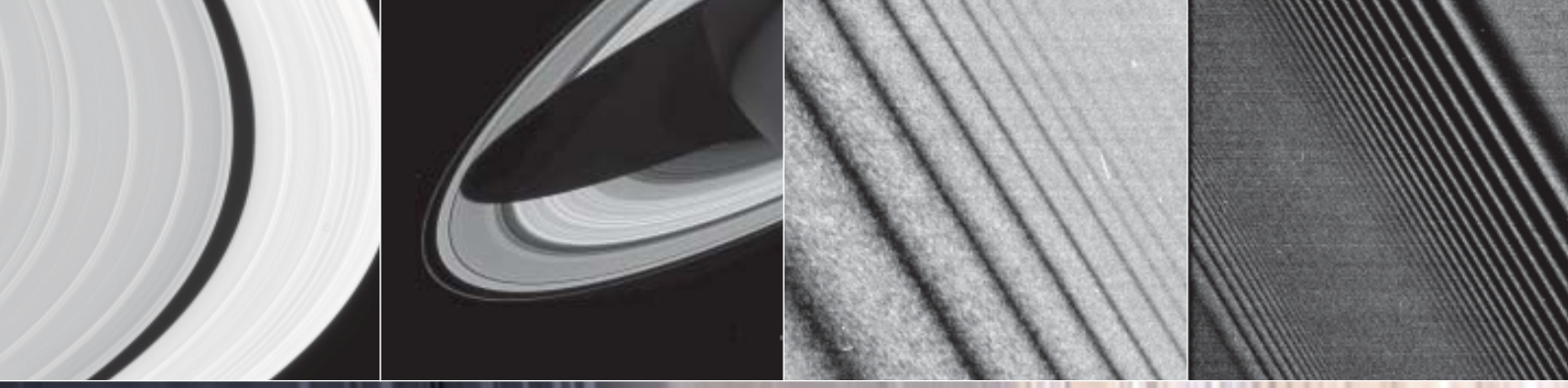


Four of the 61 images beamed back to Earth shortly after Cassini made its closest ever approach to Saturn, the first two from the sunlight side of the rings and the second two from the unlit side. *NASA/JPL*

The new Lord of the rings

by Clive Simpson

Spaceflight editor, Clive Simpson, had a ringside seat when he joined journalists at NASA's Jet Propulsion Laboratory in Pasadena, California, for the arrival at Saturn of the Cassini-Huygens probe, a joint mission between NASA, ESA and the Italian Space Agency.

It was a defining moment in the history of space exploration. After a two billion mile journey from Earth spanning seven years, a £2 billion spacecraft the size of a small bus slotted safely into orbit around the giant planet Saturn, sending back the first close-up pictures of the rings which have tantalised scientists for four centuries.

Cassini joins rings and moons of Saturn

Cassini began the final and dramatic stage of its voyage to Saturn in the early hours of 1 July 2004 by firing its main rocket engine for 95 minutes, slowing the craft sufficiently for it to be dragged into orbit.

Mission controllers waited nervously during the burn which they knew would accelerate Cassini to a top speed of 68,700 mph as it plunged towards Saturn and passed twice through the ring plane. It came closer to the planet than it ever will again before passing out through the rings and beginning its orbital tour for a prime mission that is scheduled to last four years.

"This was an unprecedented opportunity, closer to the rings than we've ever been before," said imaging team scientist, Carolyn Porco, just a few hours after glimpsing the first images. "The beauty and clarity of these images are so shocking that at first I thought my team were playing tricks and showing me simulations. We had a long time to plan these images. I am truly surprised at their clarity and beauty."

During the orbital insertion manoeuvre – which engineers decided was so accurate they would not need to perform any tidying up adjustments the next day – Cassini's cameras were aimed at the rings rather than the planet because the rocket engine had to be aligned in a fixed direction during the braking burn.

The ring images are at least five times more detailed than those from the 1980-81 Voyager fly-bys and scientists were also able to collect 75 minutes of radio data from the far side of the rings, hoping to learn more about their composition through the analysis of distorting effects.

This was a unique opportunity to attempt to discriminate individual components within the rings and the orbiter's instruments also took advantage of its proximity to the planet to make an in-depth study of its atmosphere and environment.

Cassini will never be as close to the rings again so the 61 images beamed back to Earth offer a treasure trove of information about their origin, structure and dynamics that will occupy scientists for years to come.

Astronomers are eager to study the ring system because it is believed to be a nearly perfect model of the processes that created the solar system and can be seen producing similar systems around distant stars. Understanding how Saturn's rings formed and are maintained will provide insights into our own celestial history.

Cassini – launched on 15 October 1997 by a Titan 4B/Centaur, the most powerful expendable launch vehicle in the US fleet at the time – behaved perfectly during the orbital insertion, according to project manager Robert Mitchell, who briefed journalists within minutes of its successful outcome.

"There was not a single red alarm, not a single indication of any faults. Cassini is in perfect shape," he said.

For a tense 95 minutes engineers listened to a warble of a tiny radio signal from Cassini indicating that its rocket was firing and allowing the craft to be pulled towards Saturn. The signal finally stabilised precisely on schedule, a sign that the rocket had fired for its full allotted time.

More cheers and handshakes erupted from mission control minutes later when Cassini pointed its large antenna towards Earth and sent back a blast of data indicating that all was well. The craft then turned the antenna away once more to snap a hurried series of images of Saturn's rings.

During the burn Cassini consumed some 2000 pounds of fuel – about one third of the total amount on board. The remainder will be reserved for changing or modifying the orbit during its mission.

A delighted mission communicator, Todd Barber, announced: "We've got it. There is a 32nd moon gracing the Saturnian skies tonight."

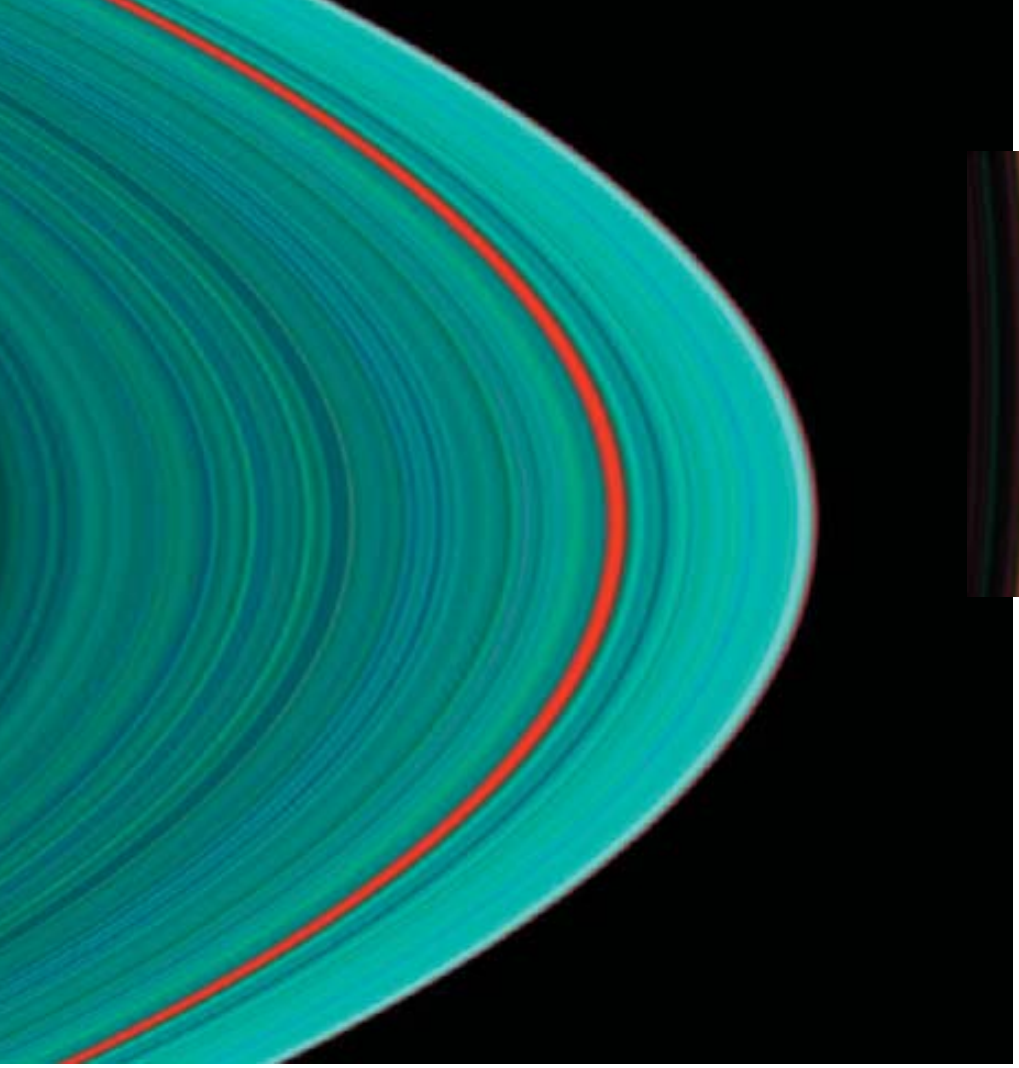
The craft – which had to operate automatically because radio signals take 83 minutes to travel the 900 million mile distance between Saturn and Earth – first hurtled through the gap between Saturn's F and G rings before the engine fired.

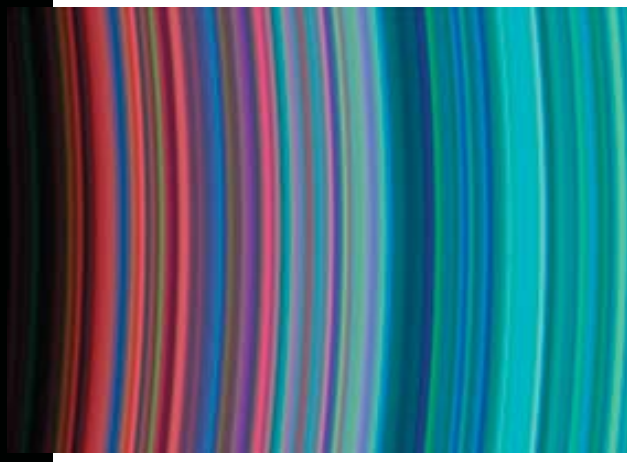
The burn knocked some 1400 mph off Cassini's speed but because the craft was falling into Saturn's massive gravity well it actually more than doubled its speed from below 30,000 mph to 68,700 mph.

The craft has initially entered a broad, looping orbit that will take it 116 days to complete – on its second orbit the craft will fly closer to Titan this autumn where it will get a gravitation tug that will tighten its orbit and reduce its length to 60 days. A second

After becoming the first spacecraft to enter Saturn's orbit, Cassini sent back this image of a portion of the planet's rings. It was taken by the spacecraft's narrow angle camera and shows the dark, or unlit, side of the rings. *NASA/JPL*

A view of Saturn's rings in the ultraviolet indicates there is more ice toward the outer part, hinting at the origins of the rings and their evolution. From the inside out, the 'Cassini Division' in faint red at left is followed by the A ring in its entirety. The Cassini Division at left contains thinner, dirtier rings than the turquoise A ring, indicating a more icy composition. The red band roughly three-fourths of the way outward in the A ring is known as the Encke gap. The red in the image indicates sparser ringlets likely made of "dirty," and possibly smaller, particles than in the icier turquoise ringlets. This image was taken with the Ultraviolet Imaging Spectrograph instrument, which is capable of resolving the rings to show features up to 60 miles (97 km) across, roughly 100 times the resolution of ultraviolet data obtained by the Voyager 2 spacecraft. ***NASA/JPL***





This image shows definite compositional variation within the rings the outer portion of the C ring and inner portion of the B ring (from left to right). The B ring begins a little more than halfway across the image. The general pattern is from 'dirty' particles indicated by red to cleaner ice particles shown in turquoise in the outer parts of the rings. The ring system begins from the inside out with the D, C, B and A rings followed by the F, G and E rings. It was taken with the Ultraviolet Imaging Spectrograph instrument, which is capable of resolving the rings to show features up to 60 miles (97 km) across. *NASA/JPL*

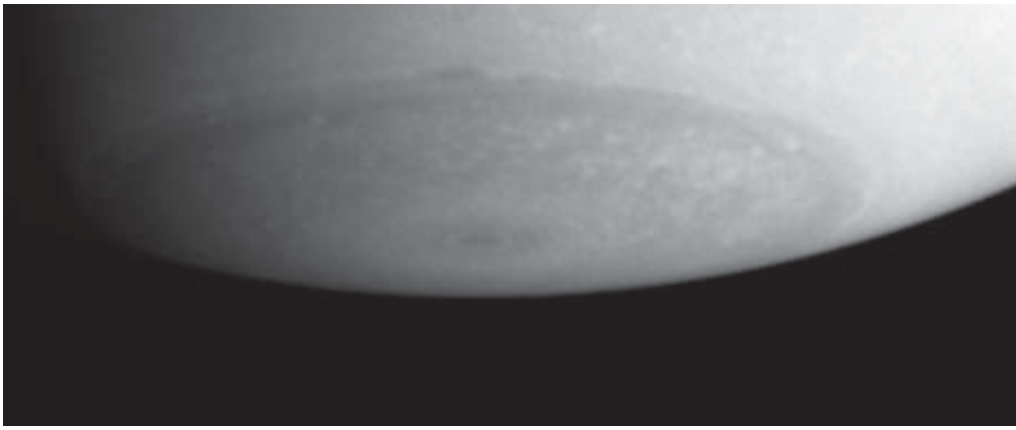
passage will reduce it to 32 days, eventually putting Cassini into an orbit that will repeatedly fly by Titan, which is required to release the Huygens probe.

In some ways Cassini-Huygens' arrival at Saturn represents the end of an era for planetary exploration. The craft's huge cost, massive size and payload of 18 scientific instruments set it apart from the recent interplanetary missions launched under the 'faster, better, cheaper' slogan.

With the new emphasis at NASA on a return to the Moon and a manned mission to Mars, it seems unlikely that such a mission will be repeated in the foreseeable future – and almost certainly none that would be so complex.

But Cassini promises much in its four year nominal lifetime as a satellite of the solar system's most enigmatic planet. On Christmas day it will release Europe's Huygens probe which, if all goes to plan, will plunge to the surface of Titan – the only moon in the solar system known to possess a dense atmosphere – three week's later.

"This shows international space co-operation at its best," ESA's Director of Science, Prof David Southwood, told journalists after confirmation of the orbit insertion. "Few deep space planetary missions have carried the hopes of such a large community of scientists and space enthusiasts around the world and our congratulations go to the teams in the US and Europe who made this possible and to all participants in the programme who have much to do over the years ahead."



Details observed in Saturn's south polar region demonstrate that this area is far from featureless. Lighter coloured clouds dot the entire region, which is dominated by a central, sharply-defined circular feature. Movie sequences in which these features are captured and followed will allow wind speeds in the polar region to be measured. This image was taken with the Cassini spacecraft's narrow angle camera on 20 May 2004, from a distance of 13.7 million miles (22 million km) from Saturn. The image scale is 81 miles (131 km) per pixel. *NASA/JPL*

The Saturn orbit insertion was the last and most critical manoeuvre performed by the spacecraft to achieve its operational orbit. If it had failed, the spacecraft would have just flown past Saturn and been lost forever in the outer Solar System.

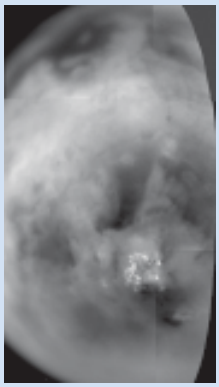
During the coming months, ESA scientists and engineers will prepare for the release of their main contribution to the mission, the Huygens probe, which will be released on 25 December to enter the atmosphere of Titan on 14 January 2005.

Built for ESA by an industrial team led by Alcatel Space, the 320 kg probe carries six science instruments to analyse and characterise the atmosphere and its dynamics during descent. If the probe survives the impact on reaching the surface, it will also analyse the physical properties of its

Enigmatic Titan begins to reveal its secrets

Cassini's visual and infrared mapping spectrometer captured never-before-seen details on Titan's surface in this false-colour image. The yellow areas indicate hydrocarbon-rich regions. The green areas reveal icier regions. The methane cloud appears white. Scientists expected to see oceans or lakes reflecting like mirrors from Titan's surface. Instead, Cassini sent back murky pictures obscured by moon clouds. "All of this is very mystifying," said Cassini's imaging team leader, Carolyn Porco. "We are trying to piece together a picture with really scant evidence." NASA/JPL

Shown here is a mosaic of Titan's south polar region acquired as Cassini passed by at a range of 210,600 miles (339,000 km) on 2 July. These images were acquired through special filters designed to see through the thick haze and atmosphere. The bright spots near the bottom represent a field of clouds at the south pole. There are many strange dark and bright patterns on Titan's surface – linear, sinuous and circular – whose origins are not yet understood. The smallest features detected on the surface are about six miles (10 km) wide. NASA/JPL



environment after landing for a short time.

Titan – actually bigger than the planet Mercury – features a hazy, nitrogen-rich atmosphere containing carbon-based compounds. The chemical environment on Titan is thought to be similar to that of Earth before life, although colder (-180 C) and

Michele Dougherty.

lacking liquid water.

The in situ results from Huygens, combined with global observations from repeated fly-bys of Titan by the Cassini orbiter, are expected to help scientists understand the evolution of the early Earth's atmosphere and provide clues about the mechanisms that led to the dawn of life on our planet.

The Cassini orbiter itself, the largest and most complex deep-space vehicle ever launched, carries 18 science instruments developed by US and international teams to conduct in-depth studies of Saturn, Titan, the icy moons, the ring system and the magnetospheric environment. Two of the orbiter's instruments were provided by Europe.

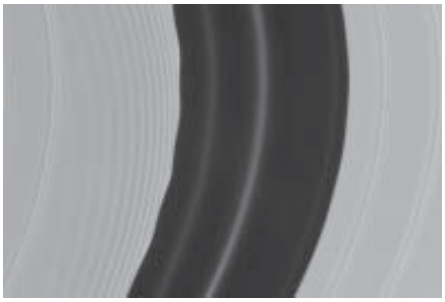
"More than 20 years have passed since Pioneer 11 and the Voyagers gave us a first glimpse of Saturn, as they crossed this complex system in only a few days," explained Prof Southwood, who is also principal investigator for Cassini's magnetometer.

"Now, with Cassini, we are here to stay, watch and investigate. And with Huygens we will go even deeper and further, not only plunging into an extraterrestrial atmosphere but also an atmosphere like the early Earth's. This means we are travelling billions of years back into our own past to investigate one of the universe's best kept secrets – where we came from.

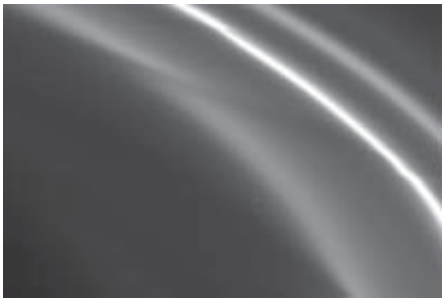
"Titan is probably the most mysterious moon, if not the most mysterious object in the solar system. Its atmosphere bears a strong resemblance to that of the Earth just one billion years ago so this is not just some obscure activity but is right at the heart of science of the solar system."

The UK has a lead role in the magnetometer instrument on Cassini (Imperial College) and the Science Surface Package on Huygens (Open University) – and a number of UK-based scientists involved in the mission at JPL expressed both delight and relief after the spacecraft's white knuckle ride into orbit courtesy of Saturn's gravity.

The region in Saturn's rings known as the Encke Gap, taken by the narrow angle camera on Cassini. It shows the sunlit side of the rings. NASA/JPL



One of the first images taken of Saturn's F ring by Cassini's narrow angle camera. NASA/JPL



John Zarnecki.

"I've waited 15 years for this moment," said Dr Andrew Coates of the Mullard Space Science Laboratory and Co-Investigator on the Cassini spacecraft's Plasma Electron Spectrometer. "Now our four year tour of discovery can really begin."

Dr Michele Dougherty of Imperial College London and Principal Investigator for the magnetometer instrument on Cassini, said: "The spacecraft performed superbly tonight and critical data was taken during the 95 minute engine burn period.

Prof Carl Murray from Queen Mary, University of London, involved on the Cassini cameras, was equally ecstatic. "This is a remarkable achievement and a wonderful example of a successful, international collaboration. The arrival of the Cassini-Huygens spacecraft at Saturn heralds a new age in our understanding of this majestic planet and its retinue of moons and rings.

"I have no doubt that the wealth of data to be returned will also provide unique insights into the origin and evolution of planetary systems. The next four years will be tremendously exciting for everybody."

A jubilant and relieved Prof John Zarnecki, of the UK's Open University, said: "For me its been seven years in the planning, seven years of travel and 95 minutes of purgatory – but now we've made it and the next stop is Titan.

"Its atmosphere is similar to Earth's primitive atmosphere four billion years ago so examining Titan is our chance to go back in time and see some aspects of the Earth's origins."