Stuart Clark

Voyage to the ringed planet

Since the world's first glimpse of Saturn through a telescope, this far-flung planet has enchanted mankind with its beauty. The rings of Saturn are spectacular enough when seen in photographs. When seen with the naked eye through a telescope of any size, they almost defy belief. Yet, since the Voyager 2 flyby of 1981, spacecraft have neglected the planet. Now the twenty-three-year wait is over. After a seven-year voyage through deep space, the joint NASA-ESA Cassini-Huygens mission is due to arrive. It promises to revolutionise our understanding of the giant planet.

The Cassini-Huygens spacecraft is the most ambitious space mission ever launched and, at 5.6 tonnes, the largest scientific spacecraft ever built. In the four years it is expected to operate at Saturn, it will complete more than seventy orbits of the giant. Each orbit will be different, so that the spacecraft can see Saturn from new points of view and rendezvous with a number of Saturn's retinue of icy moons.

The forebear of the Cassini mission is NASA's previous giant-planet-orbiter, the Galileo mission. Between December 1995 and September 2003, Galileo toured the Jupiter system, surveying the giant planet and its collection of moons.

"It you want to think of the Galileo mission to Jupiter as a template then that's okay, but we are doing a modernised mission with newer technology. Even though some of the instruments have the same names, they are generally much more capable," says Dennis Matson from the Jet Propulsion Laboratory, Pasadena. He is Cassini's Project Scientist, the man where the buck stops. He's been filling this role since 1989 but describes himself as the 'new boy' since some of the scientists and engineers have been involved in the project since earlier in the 1980s.

Cassini will rocket to its closest approach with Saturn on 1 July 2004 and that will involve it having to pass through the rings. Thankfully, it only has to pass through a gap between the most tenuous rings. Even so, scientists are taking no chances and will point the spacecraft so that the 4-metre high-gain antenna acts as a battering ram, to soak up any stray particles that do get in its way.

"We expect that the hole we are shooting for will be essentially empty. It's between the F and the G rings and the greatest number of particles there will be cigar smoke-sized particles and perhaps a little bigger. Nevertheless, we're going in

antenna first, as that will be capable of absorbing impacts from dust grains up to 1-mm in size," says Matson.

Once through the ring plane, Cassini will fire its main engine to slow it down enough for the gravity of Saturn to capture it. The Saturn Orbit Insertion, or SOI as the scientists all refer to it, will not just be a manoeuvre; the spacecraft's instruments will be collecting invaluable data because this will actually be the closest approach that the spacecraft will make to the planet.

One person who is interested in the results is Michelle Dougherty, Imperial College, London. She will be using the Cassini magnetometer to investigate the planet's somewhat peculiar magnetic field. The magnetic bubble that surrounds Saturn is huge, extending over one and a quarter million kilometres into space, but it sits bolt upright, pointing in the same direction as the rotation pole and that's peculiar. "According to the theories of magnetic field generation, there has to be an asymmetry between the rotation pole and magnetic pole," says Dougherty.

It either means that the magnetometers on Voyager were too imprecise to properly measure the orientation of the field or maybe something much more exciting: the interior of Saturn is very different from that of Jupiter. Traditionally, astronomers had assumed that their interiors were very similar with a gradually thickening atmosphere that finally gave way to peculiar states of matter in which hydrogen gas began behaving like a liquid metal, rather like the element mercury. If the Saturnian magnetic field is indeed upright, however, Saturn's interior must be different than previously suspected. "Perhaps there is a weak conductive layer somewhere inside Saturn where the magnetic field is generated," suggests Dougherty.

So Cassini will dip close and hope to detect the messy magnetic details that become averaged out far away from the planet. Those details will betray where and how the magnetic field is generated within Saturn, revealing the secrets of the planet's interior.

It may also solve a problem that the Voyagers brought to light during their flybys: the ring spokes. These are dark markings that stretch across the rings like spokes on a wheel, hence the name. The only clue that scientists have is that the spokes appear to rotate at the same speed as the planet and some people wonder if they are being caused by the way the magnetic field interacts with the rings. Cassini will hopefully tell.

Cassini will also use an arsenal of cameras and other instruments to fully characterise the weather patterns on Saturn. Already, during its approach, it has watched two 1000-kilometre-diameter storms approach and eventually merge into a single whirling maelstrom. It may also have detected its first lightning from the giant planet too. If so, these are no ordinary storms, rather they are giant discharges of electricity that could be a sizeable fraction of the Earth's diameter!

The mission is not just focused on Saturn. Right from its inception, the mission was designed to investigate both Saturn and its large moon, Titan. Titan was the surprise 'star' of the Voyager flybys. Voyager 1 was purposely directed to investigate this world. In fact, Voyager 1 had to forfeit its chance to perform flybys of Uranus and Neptune in order to investigate Titan. Although the large moon proved itself to be rather shy, hidden below a permanent hazy cloud layer, the Voyager instruments showed a wealth of carbon-based chemistry taking place in its atmosphere.

The atmosphere reminded scientists of what they think the Earth's should have looked like, over four billion years ago, before life began. The principal instrument for investigating Titan is the European built lander, Huygens. This will parachute to the surface of the mysterious moon on 14 January 2005. It will be backed up by observations using all of the instruments on the Cassini mothership. During its stay in the Saturn system, Cassini will return to Titan 44 times. The aim of these investigations is to understand this totally unexplored world, its weather and climate and, particularly, its chemistry in the hopes that it might offer a clue about the origin of life on Earth.

Saturn has a whole family of other moons too. These range from icy worlds to captured asteroid-like rocky bodies and all are virtually unknown beyond the images that the Voyagers returned. The trick here for Cassini is to find the similarities and differences between these globes.

Related to the moons are the famous rings of the planet. These are a collection of dust and small pebble-sized particles that orbit the planet. The planet's moons seem to act as shepherds, keeping the rings in place and opening gaps within them. It is all a highly complex system that must change with time. So, Cassini will try to investigate how much dust falls into the ring system and how much falls out, possibly into the planet's atmosphere.

Cassini is a wide-ranging mission with ambitious, exciting goals. "I think the most exciting thing about this mission is the diversity of science that we are planning to do," says Matson.

It has certainly been a long time coming. Shortly after the tantalising hints of Saturn and Titan offered by the Voyagers, both NASA and ESA began working on ideas for this mission. Right from the start it was viewed as a mission of international cooperation with enmeshed European and American science teams. The fifteen or so years of development finally came to an end when the spacecraft was launched on 15 October 1997.

To reduce the already lengthy wait, the probe was actually launched incomplete. Although the hardware obviously had to be in place, the software was not all written and loaded. Cassini-Huygens was launched a moron, its reasoning and intelligence later supplied via radio uploads as the mission cruised through space. "If Cassini had plunged into the Caribbean during the launch, we would have saved a lot of money on software development," says Matson, with a mischievous smile. By the time Cassini-Huygens flew past Jupiter in December 2000, everything was running and the encounter gave scientists and engineers a full dress rehearsal for the Saturn rendezvous.

Surprisingly, it is these final few months that are proving the hardest for the scientists. "We are tired of saying what we will do at Saturn," says John Zarnecki from the Open University, Milton Keynes, who is in charge of the Surface Science Package on the Huygens lander, "I look forward to this time next year, when I will be able to talk about what we have done!"

Once at Saturn, the mission has guaranteed funding for the next four years but no one seriously thinks that NASA will pull the plug if there is more science to be had and the spacecraft is in good health. In fact, the lobby for an extended mission has already started. "At the end of the mission, Cassini will have cranked its orbit up and be passing over the poles. So we are asking for another year, to use the spacecraft in that orientation and then to move it back down towards the equator," says Dougherty.

However long the eventual mission, the flood of data and the subsequent understanding about the ringed planet are expected to be stunning. "Voyager raised

profound questions about Saturn and Titan. We are going to try our hardest to answer them," concludes Matson.

UPDATE: Check out the mission's progress at:
Cassini Web Page: saturn.jpl.nasa.gov/index.cfm
Huygens Web Page: www.esa.int/science/huygens

Jean Dominique Cassini 1625-1712
Born Giovanni Domenico, Cassini's early work centred on the Sun. As telescopes improved he studied the planets, computing an exact date for Easter based on lunar cycles, an almost accurate rotational period for Mars, and the positions of Jupiter's satellites. Moving from Italy in 1669, he became Director of the Paris Observatory and a French citizen. He discovered Iapetus, Rhea, Tethys and Dione, and discovered the gap in the rings now known as the Cassini division.

Christian Huygens (1629-1695)
Huygens was a gifted child who became a solitary man, seemingly assured of his own genius. After studying at the University of Leiden and the College of Breda, Huygens helped develop astronomical telescopes. Observing Saturn's rings in 1655, he discovered Titan and four years later resolved the shape of the rings, publishing *Systema Saturnium*. His interest in pendulum clocks led to *Horologium Oscillatorium* but his wave theory of light remained unrecognised for a century.

Saturn
The Sun's sixth planet is also the second largest and can be seen with the unaided eye, so has been known since pre-history. It is a gargantuan world; fully nine times the diameter of the Earth and ten times further from the Sun. The planet lacks a solid surface and is composed mainly of the same chemicals as the Sun, hydrogen and helium, but without the nuclear energy-generating processes that take place in the Sun.

In the early 1600s, Galileo was the first to study Saturn with a telescope but it was fifty years before Huygens found the moon Titan and understood that the

magnificent rings were detached from the planet itself. The rings were considered unique for three centuries until faint ones were seen around the other gas giants.

Saturn's moons

Enceladus

Its fresh, clean ice surface is the most reflective in the Solar System. Smooth plains, linear cracks and ridges suggest low melting point material rather than pure water ice with water volcanism at work. Herschel discovered this 500km diameter moon in 1789.

Hyperion

The largest non-spherical Solar System body, with an average diameter of 286 km, Hyperion rotates chaotically. Its uniform surface is dark and made of water ice and some rock. It is locked by gravity to Titan and was discovered by Bond and Lassell in 1848.

Dione

Cassini discovered this 1120 km diameter moon in 1684. Its comparatively high density suggests much rock as well as water ice. Always keeping the same face to Saturn, Dione has a bright, heavily cratered leading hemisphere and a dark but brightly streaked trailing hemisphere.

Rhea

Larger than Dione with a diameter of 1530 km and more than twice the mass, Rhea is otherwise a very similar moon in composition and reflectivity, with contrasting hemispheres and a locked rotation. Cassini found this bigger moon in 1672.

Iapetus

With an orbit tilted at 15 degrees, Iapetus is made almost entirely of water ice. In 1671, Cassini noted the contrasting hemispheres, its leading one being coal black, whilst its trailing one is much brighter. Sometimes the moon could not be seen against the velvet of space.

Phoebe

The outermost moon with a very low density and the darkest surface, Phoebe orbits round Saturn the 'wrong' way, compared to the rings and other moons. Its north pole points in the opposite direction to Saturn and it is almost certainly a captured asteroid.

Did you know?

Saturn is the least dense planet; in fact if you could find a bathtub large enough, the planet would float in the water!

Titan is the second largest moon in the Solar System and the only one with a thick atmosphere. No one knows why Titan should have an atmosphere but Jupiter's similarly sized moon, Ganymede, does not.

The length of day on Saturn is unknown by some 6 seconds. Added up, that uncertainty over the 23 years since Voyager made its measurements means that scientists have no idea what longitude they are now seeing.

Many scientists believe that there will be at least one subsurface ocean among Saturn's moons, rather like the global ocean known to exist inside Jupiter's icy moon Europa.

Landing on Titan

On Christmas day this year, scientists will be holding their breath as the 318-kg Huygens probe separates from Cassini and continues towards Titan. Things will be tense again 22 days later, as the probe begins its 137-minute descent through the orange smog surrounding the moon.

A protective shell shields the descent module against the heat caused by friction as Huygens slams into Titan's upper atmosphere. When the danger is past, the descent module is released and parachutes are deployed. The descent module contains all of the experiments and support subsystems to control the probe on the way down.

There are six instruments on Huygens. Each is a multipurpose sensor suite that will work furiously to collect data on the atmospheric composition, the nature of

the haze and cloud particles, the wind and other meteorological data. A sequence of three cameras will provide up to a thousand images of the landscape on the way down. The gently spinning probe will allow a 360-degree panorama of the landing site to be constructed.

If the probe survives the 5-metres per second landing, the six scientific instruments will continue to report until the batteries expire. In space, Cassini will be passing Titan and will be able to receive data for about four hours.

Huygens may even land in one of the liquid methane lakes thought to exist on the planet. Huygens is carrying a microphone to listen for thunder claps. These will be the first sounds ever returned from another world.

UPDATE: This all happened successfully. Check out the results at: www.esa.int/science/huygens

Jargon busters

Albedo – This is a measure of the reflectivity of a planetary surface. Surfaces with a low albedo are dark, whilst a high albedo indicates it is bright.

Gravity assist – This is a way of extracting energy from a large body's gravitational field by flying close to it. Cassini extracted the equivalent of 68,040kgs of rocket fuel energy from its two Venus and one Earth flybys.

Organics – Molecules that contain the element carbon. On Earth, these went on to form the biological molecules such as DNA. No one knows how far this sequence has progressed on Titan.

Solar wind – this is the constant blizzard of electrified particles that emanate from the Sun. They strike Saturn's giant magnetic field and sometimes penetrate the planet's atmosphere. During high solar activity, the solar wind probably strikes Titan directly as well.

Meet the Expert: Ralph Lorenz

Ralph Lorenz is a planetary scientist at University of Arizona. He is one of the world's experts on Titan.

What brought you to work on Cassini Huygens?
Originally I started as a trainee engineer, at the ESA's European Science and Technology Centre (ESTEC) in Holland. I had got a degree from Southampton in aerospace systems engineering and was interested in working on spacecraft of any sort. I was allocated to the Huygens project, which was just starting at that time. I saw it as a wonderful opportunity to get a view of the whole project because it was still in the process of being planned and formed.

If you were an engineer first, how did you then become a scientist?
The ESTEC job exposed me to a lot of the scientific problems as well as the engineering ones and I could see that, long term, the probe would get built and the thing would get launched and that would be almost the end of the engineering story but there would be a lot of exciting scientific challenges thereafter. So after my training year there, I went to do a PhD back in the UK, helping to build one of the experiments on the probe.

Which experiment?
The surface science package with John Zarnecki, the Principal Investigator as my PhD supervisor.

Where will you be when Huygens plunges into Titan's atmosphere?
I am planning on being in Darmstadt at European Space Operations Centre (ESOC) where the data will be received and we will get our first look at what is happening.

The probe will collect data for just 2 1/2hours or so. How long is it going to take you to sift through that and understand what it is telling you?
Well, the only guide I really have to that is from Voyager, which flew by in 1980 and even this year I have been working with a student analysing some of its data and finding things in there that people didn't know about before! So a scientific

generation – 25 years – is probably a conservative guess as to how long we'll still be reading insights out of the data.

What is the most exciting thing about this mission for you?
Titan is the largest single unexplored surface in the Solar System and probably the most interesting apart from the Earth because we have evidence that Titan's surface may be shaped by a hydrological cycle – rain on the motion of liquids, seas or lakes – involving liquid methane rather than water. So it's a whole new laboratory to explore meteorology and oceanography and all the other kinds of things that make the Earth so interesting.

Discovery of Titan's atmosphere
When José Comas Solà published his 1907 sketch of Titan suggesting an atmosphere, few believed him. In 1943, Gerard P Kuiper's spectrum of Titan indicated methane gas and suggested the orange hue was an atmosphere. When the spacecraft Voyager 1 arrived in 1980, the all enswathing orange smog proved mostly nitrogen and the pressure measured one and a half times Earth's. Comas Solà was right; Titan does have an atmosphere.

Cassini at Jupiter
Cassini swung by Jupiter in December 2000 to gain a final gravitational push to throw it to Saturn. Cassini paid for this free boost by collaborating with the probe Galileo that was already at Jupiter. Together they collected information about the giant planet.

Over ten days of the approach, Cassini captured a colour movie spanning 24 Jupiter rotations that produced a global map of weather patterns. The two spacecraft worked together to transmit images of Jupiter and its volcanic moon, Io, back to Earth. They also made a detailed study of Jupiter's magnetic field and the effects of the solar wind on it. They discovered atoms mysteriously escaping from Jupiter's magnetic grip that experts are still pondering.

What next?

Some scientists wonder whether the January descent of Huygens and the subsequent images may ignite a widespread global interest in this world. If so, they are already proposing ideas to follow up Huygens.

Titan is the easiest place in the Solar System to fly. Its gravitational field is similar to the light pull of our Moon and combined with its large atmospheric pressure, much less power is needed to stay aloft than around Earth or Mars.

A proposed Titan airship is currently piquing interest at NASA and ESA are preparing to open a call for mission ideas for launch in the 2015 timeframe – some of which will be Titan follow-up missions.

Find out More:

Lifting Titan's Veil by Ralph Lorenz and Jacqueline Mitton. Published by Cambridge University Press.