The fifth planet in our solar system, Jupiter, has always fascinated astronomers and space agencies. And rightly so – with its massive size (almost twice as much as all the other planets put together), its light and dark bands, the auroras at the poles, its four distinct moons and the enigmatic gaseous state – all make it worth the watch.

NASA’s mission to explore the planet in depth has been massive too. While Pioneer and Voyager, on their interstellar missions, skimmed the planet and sent back spectacular images, the spacecraft Galileo was exclusively commissioned in 1989 to reach Jupiter and study its moons. A probe was released to the surface in 1995 from Galileo. Flying by close to Io and Europa, two of the four moons of Jupiter, it sent amazing information about them and the existence of sub-surface oceans on them. Its mission completed, the spacecraft disintegrated in Jupiter’s atmosphere.

The world looks forward to Juno’s communication to unravel and demystify the hidden secrets of our solar system.

All images courtesy NASA
On 5 August 2011, another spacecraft was launched from NASA’s base in Florida, USA. Called Juno, the Jupiter-bound spacecraft was carried aboard the Atlas–V 551 rocket. The Juno mission is part of the New Frontiers Program managed at NASA’s Marshall Space Flight Centre in Huntsville, Alabama. Its mission was to reach the bright, big planet and study it in much more detail. The target distance: around 588 million kilometres (588,000,000 km at its closest to earth).

The spacecraft manufactured by Lockheed Martin at an approximate cost of 1.1 billion dollars (2011), is managed by JPL – Jet Propulsion Laboratory at the California Institute of Technology – for NASA. JPL also supervises NASA’s Deep Space Network, a worldwide system of transmitters and receivers that communicate with interplanetary spacecraft.

There was jubilation all around in the tracking centre on 4 July 2016. The monitors in the tracking centre recorded the successful locking of Juno into the orbit of Jupiter. NASA released a video consisting of time lapse images that clearly show the four moons of Jupiter in tandem as recorded by Juno.

A Special Mission

Jupiter has been studied earlier too. In the previous eight missions, only Galileo was an exclusive spacecraft sent to the planet, while all others were flyby operations – that is, flying past and returning or, gravity assists that is, taking Jupiter’s gravity to propel further to the target planets. Galileo was designed to study the moons in detail. Moreover, it could not approach the planet nearer to record the studies;

In what way is the Juno probe different from the earlier ones? Why is this mission so special and significant? Well, Juno scores brownie points on several accounts.

Firstly, most spacecrafts are designed to be powered by radioactive energy to accommodate the continuity of power supply in the absence of sunlight. However, Juno deviates from this in that it is a completely solar-powered spacecraft.

Secondly, Juno’s aim is to study Jupiter’s core, presence of water in its atmosphere and the formation of the magnetosphere. These studies will throw light on various theories. Juno will study in detail the evolution of the planet and other mysteries hidden in its core. This will help us gain more insight into the way our solar system was formed; it will give us clues as to how this planet has changed in the duration of 4.6 billion years – the life of our solar system so far.

Thirdly, Juno will take a deep look at the fascinating auroras of Jupiter. This is a highly risky endeavour as it involves intense magnetic fields and currents. Juno’s technology has to withstand this extreme environment for around 20 exposures before degrading.

Fourthly, Juno is fitted with a special camera called JunoCam, made as an interactive module and available to the public. NASA has provided the means to track JunoCam’s positioning in such
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**Great Challenges**

As Juno embarks on a mission to record the various aspects of Jupiter, it is fraught with extreme conditions to be overcome. Being gaseous in nature, Jupiter offers no solid base for probes to land on it. This is a big hurdle as any probe sent...
deep into its atmosphere will be crushed and destroyed due to the intense pressure of the atmosphere surrounding it.

Travelling into deep space and close to Jupiter, which no other spacecraft has done before, causes the spacecraft to be exposed to intense radiations. The radiations encountered are in three different positions:

- **Earth radiation:** Caused due to the magnetosphere of the earth as the spacecraft vaults into outer space. Many of these conditions are well studied and simulated for Juno to withstand. Juno overcame these.

- **Inter space radiation:** The solar particles, random space objects and cosmic rays from outside the solar system are all travelling at high speeds, acting as projectiles and cause the interstellar radiations. Juno’s protective shield has to withstand these radiations too.

- **Jupiter’s magnetosphere:** The sheer size of this gigantic planet has contributed to a strong magnetosphere that covers a distance equal to nearly 100 times the radius of the planet. In addition, its moon Io is primarily volcanic in nature spewing gaseous matter into the planet’s magnetosphere. These high intensity expulsions cause ionization adding to the intensity of the magnetosphere.

  Jupiter’s radiation belt is so strong that many particles trapped in it spiral at the speed of light travelling from top to bottom within a few seconds. These projectiles can pose a severe challenge to the spacecraft.

  The radiations on Jupiter are so intense that they can cause severe damage to the rotating parts of the spacecraft and probes. Electrical arcing often occurs between rotating and non-rotating parts causing system failure. Earlier probes faced these radiations and a lot of data was lost.

  All these hurdles can cause severe damage to Juno by making it highly electrically charged. This affects the functioning of the spacecraft, disrupting the working of the electronics and recording equipment. Additionally the noise generated by the hitting particles rapidly degrades the functioning of the equipment.

**Built to Withstand**

To overcome this situation, Juno has been fitted with a specially designed electronic armour – a vault to protect its main computer and recording instrument. A 181 kilogram, half inch thick, titanium radiation shield, known as the electronic radiation shield, is employed to protect the system from the inevitable radiations. The radiation shield adds to the bulk and weight of the spacecraft so much so that the external camera, called the star tracker camera of the spacecraft, is four times heavier than the conventional tracker camera.

Moreover the detectors and electronics are upgraded and of superior
Mission Requirements

Despite the earlier missions, Jupiter still remains enigmatic. Due to its gaseous state, and a probable liquid core, a lot has to be revealed about this giant planet. As Juno approaches the clouds over Jupiter it will peer into the gaseous atmosphere. The studies will also reveal if Jupiter has a solid core. Jupiter is such a huge ball of raging gases, that it can easily be misunderstood for another Sun. The great red spot on its surface is blazing a gas which is big enough to gobble up the earth. A critical and close up view of the planet will reveal a lot of mysteries about the formation of the solar system.

While probing deep into the core of Jupiter, it may reveal the way the intense magnetic field is created. This magnetosphere concentrates at the poles causing the famous Jovian Auroras. One critical and important responsibility of Juno is the study of the Aurora. Unlike Earth’s Auroras (called northern and southern lights as seen in Alaska), Jovian Auroras generate nearly 10 million volts! These are occurring continuously. However, Juno will make further intense studies from a much closer position.

Mostly made up of Hydrogen and Helium, another interesting aspect of Jupiter are the impressive light and dark bands, created by strong east-to-west winds of its atmosphere. The light white clouds comprise of crystalline frozen ammonia. Juno is programmed to make an extensive study of the bands while orbiting Jupiter.

Juno’s information and recordings, especially of the water content in the atmosphere will throw light on the composition of the planet. Knowing about the original form of water will help us understand better how planets were originally formed. In addition it may throw more light on the evolution of the solar system.

We look to Juno to answer all these questions.

Juno – Exploring Jupiter

The Juno mission is divided into 13 phases from launch to end-of-mission. This covers the pre-launch, deep space manoeuvres, gravity assist, in-orbit duration and recording phases.

The trajectory: Deciding a direct path for spacecrafts to reach their target distances is a highly fuel consuming affair. If a craft has to be propelled into space directly, it consumes as much fuel as it would consume to launch it from the earth into space. Hence, to reduce this energy requirement, astrophysicists use the gravitational pull of a nearby planet as a slingshot to put the spacecraft into outer regions. This is called a gravity assist flyby.

Juno too required a gravity assist to put it into the path of the outer solar system. Following a helio-centric orbit, using Earth’s gravity assist, it was launched towards Jupiter. This entire exercise however added miles to the path to be travelled. In all Juno traversed 2.7 billion kilometres to reach Jupiter.

The 66-foot diameter by 15-foot height spacecraft, hexagonally shaped, three-winged solar panelled spacecraft, employed the stable spinning elliptical orbit. This mode of operation allows for accurate and stable control of the spacecraft.

PAYLOAD INSTRUMENTS ABOARD JUNO

Gravity Science: This set of instruments fitted at the mouth of the hexagonal body will record and study the gravity fields and deep core analysis of the planet.

MAG: A vector magnetometer fitted to the tip of the wing spans, it will record the magnetic field structure of Jupiter.

MWR: A six-wavelength microwave radiometer will be used to record for atmospheric sounding and composition.

JADE, JEDI and Waves: These plasma and energetic particle detectors will especially come to use in the study of Auroras. Along with that they will also sample and study the way the magnetosphere is connected to the atmosphere on Jupiter by sampling the electric fields, plasma waves and surrounding particles.

UVS and JIRAM: These Ultra violet and Infra-red range Spectrometers will be used for imagery.

JunoCam: This colour camera is the first of its kind fitted to give an interactive experience to the public.
Earlier Missions Exploring Jupiter

1. Pioneer 10 – 1973: The first spacecraft to cross the asteroid belt and skim the atmosphere of Jupiter. It sent visuals of Jupiter’s moons, existence of the radiation belt and presence of magnetosphere. However, the intense and unexpected radiation belt that it encountered gave rise to functional errors and erroneous readings.

2. Pioneer 11 – 1974: This was principally launched with Saturn as the target; 12 months after the first craft, Pioneer 11 reached Jupiter. This too was a flyby mission and it sent back visuals of the moons, fluid nature of the interior of the planet, magnetosphere and atmosphere. Both Pioneers paved way for further advancements in the construction of spacecraft.

3. Voyager 1 – 1979: Another flyby mission sent images of the moons, rings and magnetic fields. This was a very short flyby of 48 hours and hence not many details obtained. However, at a closed distance of 349000 km from the centre, it gave spectacular imagery.

4. Voyager 2 – 1979: On its way to Saturn and Pluto, Voyager 2 reached the cloud tops of Jupiter closer than the previous probe. This flyby mission sent clear images of volcanic activity on Io, tectonic plates of Ganymede and craters of Callisto. These visuals helped scientists to further improve the technology of space crafts.

5. Ulysses – 1992: Ulysses, a solar probe, used Jupiter as gravity assist to proceed further in its journey. During this, it recorded the magnetosphere. The gravity of Jupiter deviated its path from the calculated value and hence again, Ulysses visited the planet, this time farther away and made more recordings. Since the probe had no cameras, no images were taken.

6. Galileo orbiter – 1995 to 2003: This was the first spacecraft designed as an exclusive mission to Jupiter. As an orbiter probe it orbited Jupiter 34 times in the span of seven years. Detail visuals and data were received about the moons. Galileo released a probe into the atmosphere which parachuted down to 150 km, recording 57 minutes of imagery, before disintegrating. This was a major milestone and set a benchmark for further missions.

7. Cassini Huygens – 2000: Another flyby mission to Saturn, Cassini sent the best colour visual images of the planet. At a height of around 26000 km, the smallest recorded picture was of detail 60 km across.

8. New Horizons – 2007: En-route to Pluto, this spacecraft stopped by Jupiter for gravity assist. During this period it recorded further details of the moons. Due to irretrievable memory error of the data handling computer, some recordings were lost. However, the system was rebooted in two days and New Horizons continued to stream readings.

Adopting a helio-centric orbit, it flew past the orbit of Mars, cruised inwards again towards the Earth for gravity assist and then entered the outer solar system. Cruising silently for two years, the final stage of approach to Jupiter was encountered. This lasted for 178 days.

The path of its orbit around Jupiter was to enter at the north, drop to a level lower than the inner radiation belt and exit from the south. This helped Juno avoid intense radiation regions.

As per the design, the field of view of the instruments on Juno will be exposed to the orbit once every rotation. In all, at three rotations per minute the instruments will make 400 sweeps during its flight from pole to pole. The path is so calculated that Juno does not enter the night cycle of Jupiter.

**Drawing solar power:** Jupiter being farther away from the Sun receives nearly 25 per cent lesser solar energy than the Earth. However, specially designed solar panels atop Juno employ advanced solar cells which are 50 per cent more efficient and radiation tolerant than the silicon cell hitherto used in earlier missions. The span of the panels runs to 66 feet, which fold neatly at the time of pre-launch and open up in such a way that they constantly face the Sun throughout the entire expedition. Overall they have a surface area of 256 square feet absorbing the sunrays and providing a continuous stream of energy to the instruments.

In addition, the mission duration is so well timed in design that it avoids any eclipses and the instruments draw modest power making use of the available technology.

**Leaving no traces:** Despite all the measures there will be progressive degradation of the equipment due to harsh environments encountered on the planet and Juno has to make quick and timed readings to send back before it is time to end the mission.

Keeping the tradition of deep-space missions, Juno has time only till February 2018 before which it has to destroy itself by deorbiting. This is in order to prevent any contamination from Earth (in the form of hidden bacteria or microbes on the spacecraft) that may unintentionally be present and carried into space by a defunct spacecraft.

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