All is not lost

Even if there is not a great deal of water, it looks like there is material for jewelry in the solar system, says **S Ananthanarayanan**

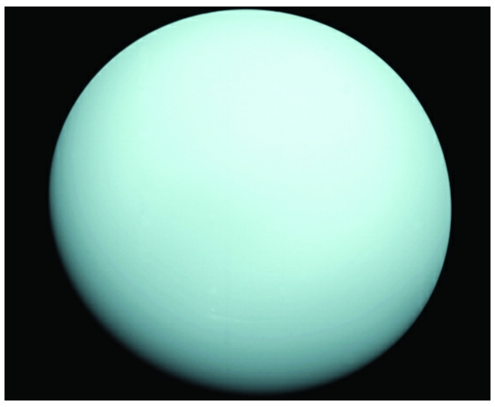
A GROUP of scientists in California reports the possibility of icebergs of diamonds afloat in oceans of carbon on Neptune and Uranus. Natural diamonds are believed to have formed when carbon solidified under great pressure, sometime in the violent geological past of the earth's history. Attempts to reproduce these conditions in the laboratory have not completely failed and there is a thriving industry of synthetic diamonds, with a market for both jewellery and industry.

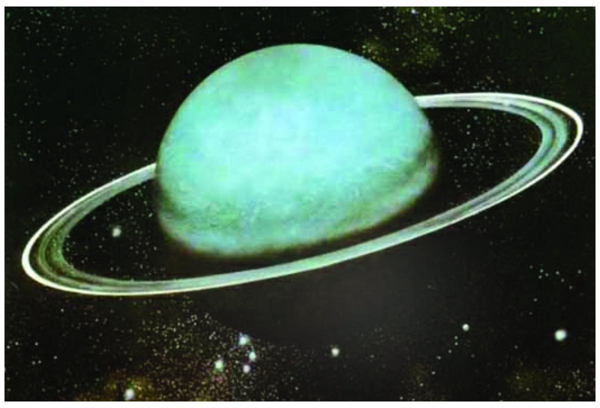
A diamond, of course, is pure carbon, the same as a piece of coal, or the graphite in our "lead" pencils. Now carbon has an atomic structure that makes it versatile both in combination with other elements to form compounds as well as with other carbon atoms to form crystals.

The atoms of all elements consist of a massive, positively charged core surrounded by tiny, negatively charged electrons equal in number to the charge of the core. These electrons, which keep from falling into the core by whirling round — like planets around a sun — are arranged in "shells" which become the most stable when they consist of eight electrons. All elements then have a few extra electrons in the last shell, which then tries, through a combination with other atoms, to achieve the numbers of two or eight.

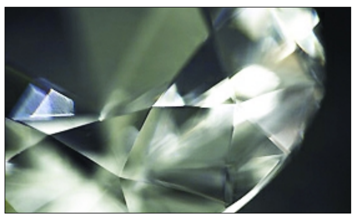
Thus, atoms which are just short of eight and can "accept" a loan of an electron from another atom are the non-metals, like oxygen, while atoms that can "lend" an electron, to drop to two, or zero, are the metals. But carbon, and a few others like silicon, is halfway to both ends, with four outer shell electrons. Carbon is thus able to *mix and match*, and can form versatile chemical forms, including the "ring" and the "chain" forms of organic chemistry when it combines with other elements, or the different crystal forms, in the pure state.

These different crystalline forms are called allotropes and in carbon we have eight different forms — the structureless, amorphous carbon like coal; the 2D structure in sheets, which is graphite and is easily deformed; the very hard 3D structure of diamond: a hexagonal structure that we find in meteorites; the structures of spheres and cylinders; and the Buckyballs and Buckytubes.





Voyager's view of Uranus (left). Does an ocean of diamonds lurk beneath these clouds or in Uranus' (right) orbit? "Diamond is a relatively common material on earth, but its melting point has never been measured," said Jon Eggert. "You can't just raise the temperature and have it melt, you have to also go to high pressures, which makes it very difficult to measure the temperature."



When scientists melted a diamond under high temperatures and pressure and then resolidified, the solid diamond chunks floated on top of liquid diamond.

The diamond structure, of course, the rarest of the natural forms, is the iridescent, very hard form used as a gem stone, as an industrial abrasive and also in electronics for its special heat conducting and electric properties. So valuable is this allotrope of carbon that anybody who strikes a source of mining diamonds has, well, discovered a diamond mine!

Synthetic diamond

Which allotropic form carbon will take when it solidifies depends on the conditions. When soot forms, it is usually the amorphous form. For graphite, we need high temperatures when the carbon atoms form into sheets. Depositing from the vapour can result in balls and tubes, the Bucky Fullerenes. But for the 3D "cubic" form of diamond, we need tremendous pressures which may have existed when the rocks condensed and formed on earth or may have existed in meteorites, which also contain diamonds. But meteorites more often contain carbon in the hexagonal lattice form, which can form with lesser pressure.

Normal crystals are produced by melting the substance and allowing it to cool slowly, usually in the form of a cone, where the vertex provides a *pole* from which the crystal can begin to form. This cannot work with a diamond, because when a diamond is heated, we do not get a melted diamond but melted graphite, and when it cools what forms is just graphite. For diamonds, we need melting under tremendous pressure, which also implies very high temperatures.

Attempts to create these conditions have been made since 1797, when it was discovered that a diamond was nothing but carbon. A number of well-known attempts are on record of dissolving carbon in molten metals and then rapidly freezing the solvent. The pressure created by the solidification was expected to squeeze the carbon into a diamond.

Similar innovative methods were tried, with success reported, but not replicated, right till the 1940s and '50s, when the GE, Norton and Carborundum companies got together. They were able to reach temperatures of 3,500? Celsius and pressures of about 35,000 atmospheres. But they were able to actually create diamond grains only in 1954, with an arrangement to reach more than 100,000 atmospheres and a temperature over 2,000? Celsius.

The first gem-quality diamonds were created only in 1971 by GE and these were found to be "nitrogen doped", which gave them the yellow tint of natural yellow diamonds. It was possible to limit the nitrogen and achieve colourless diamonds, but the effort was too costly to be worth it. The methods have been refined into a series of *High Pressure, High Temperature* methods with steadily better results. But for all the success, the diamonds are not the "same" as natural diamonds, although the difference shows only under UV or X-Ray scanners. Anyway, synthetic diamonds have a high value in industry for making cutting edges and drillbits, as also for the substrate of electronic microcircuits.

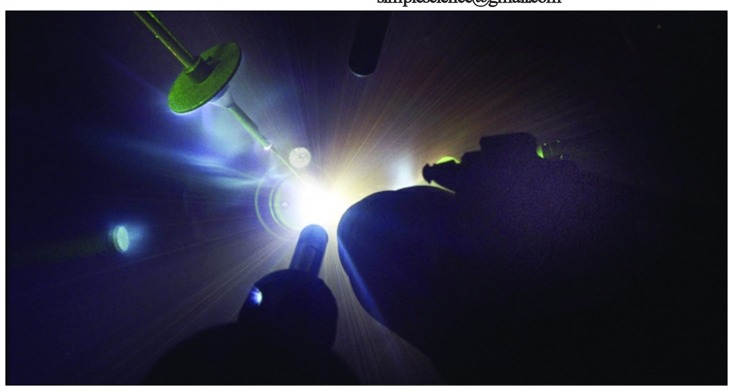
Diamonds in the solar system

Dr Jon Eggert of the Lawrence Livermore National Laboratory in California, and colleagues placed a small diamond, a tenth of a carat, under intense lasers and subjected it to pressures of millions of atmospheres and temperatures above 50,000? Celsius. The result was a drop of melted diamond, kept liquid because of the pressure. When the pressure dropped to about 11 atmospheres, diamond crystals formed and floated on the surface of the melt. As the pressure dropped, the temperature remained the same but the diamond condensate became larger, and did not sink but stayed afloat. A diamond, hence, forms under these pressures and shows anomalous expansion when it freezes, like water and even like iron.

These kinds of pressures and temperatures are considered to exist within the core of the giant planets Neptune and Uranus. These planets also consist of carbon to about 10 per cent. In the core, the carbon would be in liquid state and at a pressure of millions of earth atmospheres. The carbon that condenses in these conditions would crystallise as a diamond and float like an iceberg on the ocean of molten carbon, under pressure.

The earth also has a molten core, mostly of iron, and it is the motion of this core that is considered the reason for earth's magnetic north being away from the geographic north and also being variable. In the case of Neptune and Uranus, the mismatch is much greater and is found to be highly variable. This is consistent with the possibility of a carbon-rich, molten core much closer to the surface than in the case of earth!

The writer can be contacted at simplescience@gmail.com



A time-integrated photograph of an Omega laser shot to measure high-pressure diamond strength. The diamond target is at the centre, surrounded by various diagnostics. The bright white light is ablated plasma, and radial yellow lines are tracks of a hot target.

Farewell to the glory days

If President Obama has his way, the National Aeronautics and Space Administration will be taken out of rocket development for manned space flight altogether, says **Saswato R Das**

OUTSOURCING will soon hit the National Aeronautics and Space Administration hard, if President Barak Obama has his way. The new Nasa budget unveiled in February calls for the US space agency to outsource rocket development for manned space flights — historically a Nasa strength — to commercial companies. If Congress approves it, Nasa astronauts will be stuck riding in commercial space taxis, a sorry state of affairs for the organisation that won the race to the moon.

While some of the changes in the new budget, like the cancellation of the Bush Administration's Constellation programme (which would have sent humans back to the moon by 2020), were not unexpected, the abandonment of rocket development for manned space flight in favour of privatisation came as a shock.

Nasa's rocket programme for putting humans into orbit evolved out of the Redstone programme in Huntsville, Alabama, under rocket pioneer Wernher von Braun. In its lifetime, the programme had many firsts, none more spectacular than the Apollo moon landing, which made Nasa a US icon around the world.

The space agency was created in July 1958 by President Eisenhower after the Soviets launched the first satellite, Sputnik 1, into orbit a few months earlier. Nasa's early years were characterised by Cold-War competition and posturing between America and the Soviet Union as the two superpowers vied for supremacy in space exploration. Under the Kennedy Administration, the agency took on the challenge to be the first to set foot on the moon. The Soviets — who had sent the first man into orbit, Yuri Gagarin, in Vostok I — were equally determined. The race became a symbol not only of technological prowess but of the battle for the hearts and minds of the world. Money flowed into Nasa; at its peak, the agency's budget was almost one per cent of America's gross domestic product.

On 20 July 1969, America won the race. Television channels around the world broadcast images of the Apollo 11 astronauts Neil Armstrong and Buzz Aldrin taking man's first steps on the moon. An estimated 500 million people watched. Forty years later, it is still amazing that Nasa pulled it off. The Apollo missions were a triumph of American engineering and teamwork, employing some 400,000 people. The Apollo 11 lunar modules, Columbia and Eagle, and all their different systems, were subjected to almost 600,000 inspections, tests that exposed the communications, electrical and rocket subsystems to a battery of shocks, vibrations, heat, fire and ice.

Nasa sent astronauts to the moon five more times. No other space agency has managed to achieve that feat. Its efforts led to a continuous flow of scientific discoveries of great benefit to people. From air-cushioned sneakers to safer runways, from blankets for accident victims to better sunglasses, from satellite television to solar panels, all these innovations owe something to Nasa.

Now in its sixth decade, the space agency is very different from what it was in its youth. The unfettered funding it enjoyed during the Cold War has long since dried up. For years, Congress has kept its spending in check. Its budget today stands at $18.7 billion, less than one per cent of US government spending.

As a consequence, Nasa's missions have grown modest. Its astronauts have not returned to the moon in more than 30 years. It has suffered disasters with the space shuttle and other missions. It is no longer the destination of choice for America's best and brightest scientists. The fiery pioneering spirit seems to have given way to a more day-to-day ethos of survival: It has become another government agency.

In recent years, about a third of Nasa's budget has been spent on scientific missions, while the rest was consumed by manned efforts — the space shuttle and the international space station, both of which have grossly exceeded cost projections. Most scientists think that the most valuable knowledge comes from the scientific missions. Yet the manned missions are very much part of Nasa's history, and the US public has always been supportive of them.

All that will change if the Obama Administration prevails. Nasa will hand over rocket development to commercial companies like Space Exploration Technologies Corporation, a startup company which has yet to launch its first space-faring rocket capable of sending humans into orbit; the United Launch Alliance, a collaboration between Lockheed Martin and Boeing; and other emerging companies.

The Obama Administration's decision will get Nasa out of rocket development for manned space flight altogether. Nasa has amassed a singular competence in the field, which will be hard to replicate by private companies. What will happen if they can't deliver? One of the most important attributes of a manned space programme is its ability to inspire young people to pursue careers in science. As someone who came to power on a platform of inspiration, President Obama knows about the importance of rekindling hope. Killing Nasa's storied manned space programme and doing away with a timeline for space travel will snuff out much of inspiration and awe that has come to be associated with Nasa's endeavors.

The writer is based in NewYork and can be contacted at saswatodas@gmail.com. **This article first appeared in the *International Herald Tribune*.**