NASA's Origins Program

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For more than two millennia, ancient philosophers and medieval scientists have pondered the existence of worlds beyond the Earth and ultimately whether life, possibly intelligent life, might exist on those other worlds. But we who are about enter the Third Millennium are privileged to live in a time when humanity has developed the technical prowess to move beyond philosophical speculation into direct the realm of direct scientific measurement. NASA's Origins Program seeks to trace our human origins back to the creation of the first stars and galaxies soon after the Big Bang, and to seek out habitable worlds and even life, if it exists, either within our solar system or around the nearest stars.

Even in the absence of knowledge about the true nature of the solar system the Greek philosopher Epicurius argued in 300 B.C. that there must be "infinite worlds both like and unlike this world of ours...We must believe that in all worlds there are living creatures and planets and other things we see in this world." In the Middle Ages and through the Renaissance in Europe, our knowledge of the Universe grew. Copernicus, Kepler, and Galileo moved the Earth from its central position in the cosmos, presenting a solar system with the sun at its center with planets in orbit around it. The debate about life on those worlds was tinged with religious overtones and the fear of Papal censure. Giordano Bruno was an enthusiastic believer in the existence of other planets as abodes of life, "There are countless suns and countless Earth's all rotating around their suns in exactly the same way as the seven planets of our system. We see only the suns because they are the largest bodies and are luminous, but their planets remain invisible to us because they are smaller and non-luminous. The countless worlds in the universe are no worse and no less inhabited than our Earth." For his belief in other worlds and other heresies Bruno was burned at the stake in 1600. For his scientific discoveries supporting a heliocentric universe Galileo was convicted by the Catholic church as a heretic in 1633, a conviction which was not overturned until 1992.

But despite centuries of progress in understanding the universe and increasing confidence that there should be planets orbiting other stars, there were no hard scientific facts until 1996 when Michel Mayor and Dedier Queloz working from an observatory in Europe discovered an object with roughly the mass of Jupiter orbiting close around the star 51 Pegasus. The European observations were quickly confirmed and expanded upon by American scientists Geoff Marcy and Paul Butler. These scientists used a technique of measuring the velocity of a parent star to search for small oscillations due to the gravitational tug of a companion star. Approximately 20 objects of roughly Jovian mass are known to orbit nearby stars. One star, Upsilon Andromedae appears to be a true planetary system, with not one planet, but three with masses 0.5-5 Jupiter masses and orbital distances of 0.2-2 Astronomical Units[1].

NASA plans a number of ground- and space-based telescopes to advance our knowledge of other solar systems and to search for signs of life itself. NASA will launch the Space Interferometer Mission (SIM) in 2006 to search for the small wobbles in the position of a star induced by the gravitational tug of an orbiting planet. This change in position for a star 10 light years away is 1 millionth of an arcsecond for an planet the size of the Earth, or roughly the angle an bicycle on Mars would subtend if it were observed from here. To make such fine measurements, scientists will use a special kind of telescope called an interferometer that uses two or more relatively small telescopes (0.4 m) by a large distance (10 m) to make possible observations of very small angles. SIM will conduct a census of hundreds of nearby stars looking for planetary systems like our own with planets as small as a few times the mass of the Earth. SIM will be the first major space observatory to use the technique of interferometry.

A few years after launching SIM, NASA will launch a successor to the Hubble Space Telescope (HST) called the Next Generation Space Telescope (NGST) . With an 8 m deployable mirror compared with the 2.4 m mirror of HST, NGST will be thousands of times more powerful than HST in making key discoveries about the origins of the first elements suitable for the creation of planets and ultimately of life. Additionally, NGST will pioneer the development of light-weight mirrors more than ten times lighter than the mirrors used on Hubble or ground based telescopes.

The technologies developed by SIM and NGST of interferometry and lightweight telescopes will culminate in a mission called the Terrestrial Planet Finder (TPF) which could be launched around 2011. The goal of TPF is to detect directly the light of planets like the Earth against the glare of their parent stars and to analyze that light to look for evidence of an atmosphere capable of supporting life or even of an atmosphere showing the presence of primitive life. TPF uses an interferometer to "null" or reject the light of a parent star while still passing the light of the closely adjacent planet. Looking in the infrared band[2] where the contrast between the star and planet is most favorable, TPF will be able to see the planets and to detect signatures of gases in the atmospheres of the planets, such as carbon dioxide, water vapor, and ozone. Finding the first two gases would indicate that the planet had a warm, wet, dense atmosphere suitable for the development of life like our own. Finding in addition ozone on such a planet would be a strong indicator for the presence of photosynthetic primitive life that has produced a large amount of oxygen in the atmosphere of that planet. In the absence of life, oxygen and ozone would soon disappear from a planet's atmosphere due to normal chemical reactions. At the end of its 5 year mission, sometime around 2016, TPF will have

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[1] An Astronomical Unit (or AU) is the distance of or Sun to the Earth. It is a useful scale for measuring distances within our own and other solar systems. An AU is approximately 150 million km.

[2] Visible and infrared light are parts of the electromagnetic spectrum We see "visible" light with our eyes, while we experience infrared radiation as "heat". Infrared light waves have longer wavelength than visible light, roughly 10 microns for the infrared compared with 0.5 micron for visible.

surveyed some 200 stars within about 50 light years of our solar system for habitable planets.

In searching for habitable planets and even for life itself, we are building on the great progress biologists have made in understanding the fundamentals of life here on Earth. Biologists have learned that life on Earth is remarkably hardy and able to occupy ecological niches that would appear very hostile to us, such as the near boiling waters of deepsea volcanic vents and within rocks located kilometers beneath the surface. Life, many scientists believe, will form anywhere the chemical elements such as Carbon, Oxygen, Nitrogen, Sulfur, and Phosphorus are located in the presence of liquid water and with some freely available source of energy like sunlight or geothermal heat. On the Earth, primitive life has been traced back as far as 3.8 billion years ago, or just 700 million years after the formation of the solar system. Since astronomers know that the water and the elements of life are seen almost everywhere in universe --- in the in the material out of which stars form, in the disks of newly forming stars, and in the comets of our solar system--- scientists have an expectation that life, at least primitive life, should be present elsewhere in the Universe, and that a mission like TPF has a good chance of detecting it.

The realization that life is much hardier than previously thought gives rise to another theme within NASA Space Science program, the search for life on other bodies within our own solar system. At roughly the same time as the first planets beyond the Sun were being discovered, a remarkable discovery was being made much closer to home. NASA scientists that their examinations of a meteorite that had been recovered from the Allen Hills ice field in Antarctica showed plausible evidence of having been ejected from Mars and carried to earth. Most remarkably these scientists claimed that the Allen Hills meteorite showed fossil remnants of microbial life. While the reality of microbial fossils has been called into question by other researchers in subsequent years, the excitement about possibly finding life on Mars continues to mount as a number of spacecraft are planned to land on the Martian surface over the next decade. The Mars Polar Lander will touchdown at the southern polar cap on December 1999 close to the boundary of the polar ice cap. The Lander will search for surface ices of either of carbon dioxide or water, look for effects climate change, and characterize physical processes controlling the seasonal cycles of water, carbon dioxide and dust.

Subsequent missions include the Mars Surveyor 2001 Lander, scheduled to land on Mars on Jan. 22, 2002. The Lander will carry an imager for geological studies and to assist in planning rover operations. In addition to characterizing the Martian soil properties, the 2001 Lander carry out experiments designed to assess the possibility of human missions to Mars, such as a demonstration of producing rocket propellant using gases in the Martian atmosphere. A rover similar to the successful Mars Pathfinder rover than landed on Mars in 1997 will also explore the Martian terrain in the vicinity of the Lander. The Orbiter will carry instruments to map the mineralogy and elemental composition of the Martian surface and to characterize of radiation environment which might pose a risk to eventual human explorers.

Beyond the 2001 mission are plans for missions in 2003 and 2005. In addition to more studies of the Martian surface these missions will focus on returning samples of Martian soil back to Earth for examination in chemical and biological labs back on Earth. Samples will be put into orbit in both 2003 and 2005 and returned to Earth by the 2005 mission.. Samples could be back in Earth-based labs by 2010 for examination. Stringent precautions will be taken to prevent contamination of the Earth's environment by possibly life-bearing Martian material as well as to protect the Martian samples from terrestrial environment to ensure a meaningful search for possible Martian life.

These robotic missions to Mars take place within the context of a long term vision for an human expedition to Mars. While no such mission is officially under consideration, there is considerable interest in conducting manned exploration of Mars when the technology to carry such a program in a safe and cost effective manner becomes available. The robotic orbiters, landers, and rovers will tell us where to land astronauts safely and where the particular skills of humans can be brought to bear on the key questions of searching for signs of life beyond the Earth.

There is one additional solar system body that might be a possible refuge for life in the solar system. Images from the Voyager spacecraft in the 1970s and most recently from the Galileo spacecraft suggest that Europa, one of the four major moons of Jupiter, is probably covered in a sheet of ice some 10 km thick that covers a subsurface ocean of liquid water. Galileo images show evidence for giant ice bergs the size of Manhattan island frozen in channels of what may once have been open water but which is now frozen over. Liquid water might still exist on Europa because Jupiter would raise tides on Europa just as the sun and moon raise tides in the oceans of the Earth. These tides might be as high as 30 m and the constant rising and falling of these tides, reaching some 30 m in amplitude, could prevent the water from freezing solid. Preliminary examination of the Galileo data suggests that this ocean may be full of minerals. Thus Europa might have water, the elements of life, and a source of energy in the form of tidal friction.

NASA is currently studying a mission to Europa to measure the thickness of the surface ice and to detect an underlying liquid ocean if it exists by bouncing radio waves through the ice. Other instruments would reveal details of the surface and interior processes. This mission could arrive at Europa by 2008 and would be a precursor to sending a lander which could launch a remote controlled submarine that could melt through the ice and explore the undersea realm.

The search for our cosmic origins will take us from Mars and Europa in our own solar system, to nearby stars where we might find other habitable, or even inhabited worlds, and ultimately to the creation of the earliest stars in galaxies where the elements of life were first forged. Why do we undertake this search and what will we learn? Neither the Terrestrial Planet Finder, the Mars Sample Return mission, nor the Europa Lander are end-points of the Origins program. Rather these missions like those before and after them will be vital way-stations in humanity's long quest to discover the origins of life, to learn whether or not the Universe teems with life, and ultimately to deepen and broaden our understanding of ourselves and of our place in the Universe.

In the words of T.S. Eliot:

"We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And to know the place for the first time.
Through the unknown, remembered gate
When the last of earth left to discover
Is that which was the beginning "
'Four Quartets' 1942