Space Science for the I'bird Millennium

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As NASA approaches the beginning go its fifth decade in 1998, and as the calendar approaches the beginning of its third millennium, America's civilian space agency is changing its historic ideas about conducting, space science so that it will still bc able to perform the desired scientific studies in an era of const rai ned NASA budgets. The agency began in a t imc of intense political competit ion with the Soviet Union, when military priorities, and military-sized budgets, carried over into civilian space science programs. We competed to bc the first nation to launch an unmanned satellite, to put an astronaut on the moon, and to rendezvous with, orbit, and land on another planet. Budgets were determined by whatever it took to do the job. We developed the reusable shuttle 10 bc able to make frequent human flights to space, and wc will soon bc using it to build a permanently occupied Earth-orbiting space station. The human space program has always consumed the larger portion of NASA's budget, but space science has also, until recently, enjoyed a growing program.

But the international world, the nation's priorities, and NASA's programs have all changed since the days of intense political compet it ion in space. Space technology must now support the nat ion's industrial competitiveness in a world without economic, transportation, or communication borders. Space science must compete for budget priorities with the popular demand to bring the federal budget into balance, while not slowing the growth of federal payments to citizens. NASA's funds arc in the easily controlled discretionary portion of the federal budget, so, when popular payments squeeze popular spending limits required by unpopular taxation, NASA's budget is vulnerable. To bc relevant to its historical space science mission of conducting difficult, first-ever space science research, NASA must therefore figure out a way to continue its programs with shrinking budgets, which arc reduced even faster when adjusted for inflation,

An imaginative way to meet this challenge was started early last year at Caltech's and NASA's Jet Propulsion Laboratory in La Canada Flintridge. JPL is a university-operated contractor to NASA, and one of several major NASA centers for solar system, space physics, astrophysics, and Earth observation studies. JPL is now in the second year of its "New Millennium" program aimed at developing, testing, and validating the technologies that will bc needed to carry out exciting space science missions at lower cost, This will require flying many more spacecraft, each of which must bc only onc tenth to onc one-hundredth the size of today's giant spacecraft such as Galileo, which went into orbit around Jupiter last fall. New Millennium is therefore trying to get the technology ready for the science missions of NASA's fifth decade and beyond. Initially, it plans six technology validation flights: three to planets and other objects in the solar system such as asteroids and comets, and three Earth-orbiting missions. The first mission to bc launched in a year and a half, will study an asteroid and comet. The second, planned for a

January 1999 launch, will send two small penetrators into the soil of Mars. The third launch will bc three spacecraft flying in very accurate formation around the Earth to form an "interferometer," an instrument which collects visible light, infrared (heat), or radio waves at receivers separated by ten or twenty miles, combines the signals, and produces the much more accurate image of a telescope with a ten or twenty mile diameter.

These first three missions will produce exciting science, but their primary goal is to validate the technologies that will be needed for even more ambitious subsequent missions. If Ncw Millennium is to meet its goal of enabling ten to fifteen affordable launches pcr year, each flight must have only limited, very sharply focused science objectives, instead of the over two dozen investigations on JPL's Cassini Saturn orbiting spacecraft and its 1 luygens Titan atmospheric probe which will bc launched next year. To reduce the costs of operating the spacecraft in flight, each must be autonomous to the greatest extent possible so that fewer costly humans arc needed on the ground to operate it. Autonomy can take such forms as the spacecraft monitoring its own health and correcting errors, or performing its own navigation by determining where it is and where it's headed, and then pointing and firing its rocket thrusters to correct its flight path. Because of its importance to the future of American space science, the New Millennium program is also making major efforts to reach out to the public through its education and public information program, and to produce products useful to our economy through its technology transfer and commercialization program The education program will usc interactive computer networks (including the capabilities of the Internet and the Worldwide Web) for students and the public so that they feel they have immediate access to the science generated by twenty-firsl century spacecraft, The technology transfer effort will work to get the technologies that permit increased performance, smaller size, and lower cost into commercial products to support American competitiveness.

What kinds of scientific questions is Ncw Millennium developing and validating technology to answer, and what sort of strategy dots NASA and JPL have to answer those questions if Ncw Millennium technology can enable the construction of spacecraft to answer them? NASA hopes to emphasize four major areas of study in the early years of the third millennium. First, it wants to support the experimental effort to validate or refute the cosmologists' and theoretical physicists' ideas about the origin and evolution of the universe. Theoret icians have developed increasingly detailed models of the early years (and even of the earliest small fractions of a second) of the universe, and of the "standard model" of particles that populated those early times. They have predicted and found the remaining glow from the universe's initial "big bang" ten to fifteen billion years ago. They have predicted black holes, with gravity so strong that not even light can escape them, so that they arc invisible to us. They have modeled the formation and death of stars and their planets, and of galaxies containing billions of stars like our sun, NASA plans to usc Ncw Millennium technology to build spacecraft that will explore the observable results of these theoretical models on the origin and evolut ion of the universe, its galaxies, stars and planets.

Second, within the last year wc have already seen the signature of planets orbiting other nearby stars (say, within 500 trillion miles, or a few dozen light years). Using infrared sensing telescopes on spacecraft, wc have actually observed planetary disks around stars. But planets have only been inferred from the variation in the frequency of the light from stars that arc pulled slightly by their planets' gravity. We hope Ncw Millennium technology will permit constellations of several spacecraft to form interferometers in space (such as the third mission described above) which will permit observat ions of these stars and their planets with unprecedented accuracy.

Third, wc arc far from exhausting the possibilities for studying our own solar system. We have not been to Pluto, our most distant planet from the sun, wc have performed only preliminary studies of comets and asteroids, and wc have done only limited analyses on the surface or interior of three planets: Viking 1975's two landers on Mars, the former Soviet Union's Venera spacecraft's brief visit to Venus, and the Galileo atmospheric probe's rapid descent through Jupiter's atmosphere. Ncw Millennium technology may enable a great increase in the number of less costly but more capable microspacecraft that can carry out detailed studies of many bodies in our solar system.

Fourth, and probably most importantly, wc must continue to study our own planet in great detail over time to keep track of changes caused by natural and human activities. Large numbers of inexpensive spacecraft with very specific science goals, built using Ncw Millennium-developed technology, could study the effects of small changes in the sun on Earth, they could cent inuc to assess the effects of human-generated refrigerants and carbon dioxide on Earth's atmosphere, they could generate detailed topographic maps of the entire planet, or they could improve our warnings and analyses of natural bawds such as storms and earthquakes.

Because Ncw Millennium will enable greatly increased numbers of small spacecraft with very specific science capabilities, NASA's strategy for carrying out these four major areas of study will be threefold. First, "armadas" of several small spacecraft will be assigned to a specific scientific objective such as the study of Mars' surface or of comets. Second, constellations of a few spacecraft, flying in ultra-precise formation enabled by Ncw Millennium-developed guidance and control technology capable of controlling the spacecrafts' separations to an accuracy of less than an inch and of knowing their separation distances to an accuracy of a fcw hundred millionths of and inch, will form telescopes in space capable of observing stars, galaxies and other astronomical objects, or of mapping our own planet with great accuracy. Finally, networks of microspacecraft will be sent to the surface or into orbit around other planets in our own solar system so wc can continue to understand more deeply our own immediate planetary neighbors, and, by analogy, our own plane{.

Ncw Millennium plans to develop specific new technologies recommended by interdisciplinary teams comprising NASA, JPL, other government agency, university, and industry experts. But it also expects to improve the processes of conceiving, designing, developing, and manufacturing spacecraft so that the seemingly incompatible goals of improving quality, lowering cost, and dramatically augmenting scientific performance can be met. It is only through such efforts that our space science program can continue into the third millennium in the presence of the. expected economic realities.