

SPACE SCIENCE: IS IT WORTH IT?

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Just a year ago the Galileo spacecraft sent a probe into Jupiter's atmosphere, where it operated flawlessly for an hour, sending back information through a relay link with the orbiter flying overhead. Scientists earlier this year translated these data into a puzzling new picture of the giant gas planet's atmosphere which suggests that Jupiter is much drier than expected, and that its high-altitude winds are much faster than previously thought. These findings may force planetary scientists to revise their models of how Jupiter and the rest of the solar system formed some 4.5 billion years ago, and of what drives the 400 mile-per-hour winds measured by the probe. But do Earth-bound taxpayers get over a billion dollars of value by knowing this, and should they pay for university and federal laboratory scientists to build computer models of a planet a half-billion miles away and far too hostile for anyone to visit (Stanley Kubrick and his Jovian Louis XV salons notwithstanding)?

Similarly, since 1992 the Topex/Poseidon Earth-orbiting, ocean-monitoring spacecraft has found that sea level is rising about one-eighth of an inch per year, raising the possibility that this is another indication that human production of "greenhouse" gases (carbon dioxide from fossil fuel combustion, and methane) is warming the planet, thereby melting glaciers and the polar ice caps and increasing the volume of water in the oceans. But should taxpayers who believe that global warming is a fanciful theory of liberal environmentalist scientists, and whose oil, gas, coal, or power businesses depend on the production and use of fossil fuels, be required to pay hundreds of millions of dollars in taxes for space science which could threaten their very livelihoods?

National financial support for science has been a bipartisan cornerstone of federal policy since at least the end of World War II when Vannevar Bush sent President Truman his study *Science: The Endless Frontier*. But at the end of the century, as pressure mounts to reduce taxes, reduce federal spending and shrink the federal deficit, and as society is faced at the same time with exploding demands for health care and retirement benefits for aging baby boomers, science is squeezed into the discretionary portion of the federal budget, which might be sacrificed to provide funds for deficit reduction and health and retirement entitlements. In addition, some blame science for many of the problems facing humanity, or fear the outcome of the technologies science spawns. For example, science has been blamed for the threat of nuclear war and the possibility of nuclear terrorism or blackmail. Others find that energy and agricultural pesticide technologies pollute our air and water, drive some plant and animal species to extinction, and compromise the health of humans. Philosophers of science point out, however, that the knowledge produced by science is value-free, while the application of that knowledge in technology is full of value and can be beneficial or destructive, or some of both. Others argue that a value-free activity such

as the scientific search for knowledge is inherently insupportable because of the absence of positive values in its pursuit.

Space science can be justified for several reasons, depending on the enthusiasms of the voter or taxpayer. Fundamentally, space science is about satisfying human curiosity and satisfying our desire to know and understand our life, our world and our place in that world. Much of space science produces absolutely no practical, useful consequences except that it provides us with increasingly detailed knowledge of the physics and chemistry of local planets and moons and of more distant stars and galaxies. Of course, practitioners in the field write papers and books, obtain tenure and increased research support, and enhance their professional reputations by discovering new features of space objects. But, when reported in the lay press, this work is also exciting to many non-scientists, often provides aesthetic pleasure when unusual visual effects are part of the science (such as the recent striking images of star formation through giant cosmic dust clouds and of violent stellar explosions from the Hubble Space Telescope), and enriches our lives by enlarging our understanding of our place in the solar system and universe. The great eighteenth century writer and natural philosopher Johann Wolfgang von Goethe, in arguing against using only subjective and introspective thinking as a means of understanding human existence, suggested that "man knows himself only insofar as he knows the world." Of course, our curiosity may be a less noble human characteristic than Goethe envisioned. Modern evolutionary psychologists since Darwin, and sociobiologists such as Harvard's E. O. Wilson, have pointed out that all our emotions and psychological traits have evolved merely to improve the reproductive success of our genes. Space science may therefore only be a modern Holoocene--the modern geological time period since the end of the last ice age ten thousand years ago--manifestation of our animal ancestors' successful curiosity tens of millions of years ago which enabled them to find more food or a healthier mate; but, as Goethe argued, it certainly adds to our solid, empirical knowledge of our near and distant neighborhood.

The excitement of space science products provides a second intangible but real benefit in the form of an incentive and encouragement for students to study science and mathematics. To the extent that they are exposed to the results of recent space missions and the instruments or spacecraft that obtained the data, students get excited about the wide variety of objects in the universe, the enormous distances involved, and the science and mathematics that is required to conduct space science.

Another important return from space science, perhaps more significant than the pure knowledge gained and the incentive to education, is the practical knowledge about our own planet that can be obtained only from the distant perspective of space. This return is also pure science, but it is science that can be used to affect and benefit human life--in fact, it may be critical to the future of life on Earth. These contributions from space science are similar to those from many of today's biological sciences which provide knowledge that can lead to new diagnostic or therapeutic tools for agriculture or human health. For example, Earth-orbiting satellites can measure detailed changes over long periods of time in the Earth's forests and water resources to detect natural or human-made changes that may threaten agricultural,

economic, or human cultural patterns. JPL-developed instruments measure stratospheric ozone, which protects the Earth from harmful high-energy ultraviolet energy from the sun, and study contamination plumes from old toxic waste dumps so that cleanup can be done with greater accuracy. And, as mentioned in the introduction above, JPL's four-year-old Topex/Poseidon mission is continuing its studies of long-term changes in ocean currents and elevations. But a significant number of scientific, business, religious and political leaders are opposed to Earth science studies which might suggest that there are limits to human numbers or economic activities--which could be a conclusion if Topex/Poseidon and future NASA "Mission to Planet Earth" studies show that rising ocean levels are caused by global warming from human-generated greenhouse gases, and are not merely short-term natural variations. Whether or not one agrees that there is cause to be concerned about the increasing scale of human activities, space science can be justified, at least partially, as one of the more effective techniques for getting definitive answers to these questions. Along similar lines, space science can support and complement other sciences, whether or not the benefiting science is, itself, useful, or whether it also enriches human existence just by the accumulation of knowledge about our natural or man-made world. An example of this support to other sciences is JPL's Shuttle imaging Radar-C/X-band Synthetic Aperture Radar (SIR-C/X-SAR) missions which have helped geologists find ancient riverbeds under sand, and have helped archeologists locate long-buried roads and the lost city of Ubar in modern Oman.

A final, if tangential, reason that space science is valuable is the technology that it produces, which provides immediate and long-lasting economic, health, safety, and convenience benefits to all who are able to use the spinoffs. Some may feel that they want to grab their wallet when they hear space enthusiasts talk about all the gadgets space science has produced. This is a reasonable reaction, since it is not space science that has produced the spinoff, but space technology spending, or space technology investment, depending on whether you believe that money spent on space technology (which certainly may be essential to generate new space science knowledge) is short-term consumption or current capital expenditure with the expectation of a future return on that investment. And many of the technologies usually touted as hi-products of the space program were really developed for military purposes, rather than for civilian uses, or were just bright ideas by enterprising scientists, engineers or entrepreneurs in industrial laboratories. Whether you believe that space spending is for consumption (like social security payments, cleaning the national parks, policing our borders, or paying for heart bypass surgery) or for investment (such as educational expenditures to develop a more productive workforce and a more fulfilled and conscientiously participative citizenry in the future), space spending has produced an impressive array of technology from which many Americans benefit. Some of it is very intentional and direct, such as communication satellites and the global positioning system (GPS) which millions now use for very accurate position location when they travel. Other space technology spinoffs are more indirect and are fortuitous applications of space techniques to terrestrial needs. Examples of these can be found in NASA's annual report of space technology benefits, a publication called *Spinoff*, and include such items

as heat pipes to cool computer electronics, small inexpensive antennas to receive satellite signals, a tornado detector which senses lightning within thunderclouds, flight computer software which detects wind shear so that aircraft pilots could have a half minute of warning before encountering potentially dangerous downdraft microbursts as they take off or land. Even the cloud of spectacular space technology failures can have a silver lining of beneficial side-effects. Software developed to enhance the images from the faulty Hubble Space Telescope before its lenses were replaced can now be used to detect breast microcalcifications in mammograms.

Twenty-three centuries ago Aristotle pointed out in his *Nicomachean Ethics* that: "Every science and every inquiry, and similarly every activity and pursuit, is thought to aim at some good," perhaps suggesting that even worthless activities are entered into with good intentions. But space science lives up to the higher expectation of enriching our lives with pure insight into our larger environment (and usually raising more questions in the process), encouraging our children to study the sciences, improving our own planet's physical environment, providing warnings of natural or man-made hazards to that environment, and providing the incentive for technology investments that generate current health, safety, and convenience benefits along with future economic growth.