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SEE ALSO *National Institutes of Health; National Science Foundation; Royal Society.*


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# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) is the principal civilian space agency in the United States, and the leading space science agency in the world. Its scientific and technological activities pose a variety of ethical issues, from setting program priorities to environmental impacts and risk–safety tradeoffs. NASA decisions, however, rarely turn on explicitly ethical considerations (see, for example CAIB 2003, PCSSCA 1986). Common influences on NASA decisions include interest-group lobbying, Congressional politics, and intra-agency competition for resources.

## NASA's Mission and Other Space Activities

Legislation created NASA in 1958, building on existing civilian aviation research activities of the National Advisory Committee for Aeronautics (NACA). The core of NASA's mission is space exploration, divisible into human exploration and space science. Human exploration includes, for example, the space shuttle and the International Space Station (ISS) in Earth orbit and the Apollo missions to the Moon. Space science includes astronomy and robotic planetary exploration missions; the Hubble Space Telescope (HST) is the most visible example of the former, while the Mars rover missions of 2004 exemplify the latter. Exploration and science overlap: Astronauts installed instruments on the Moon, and scientific experiments are conducted on the ISS and shuttle. Other NASA programs include earth science (satellites that look down at the earth) and practical applications such as communication satellites. In 2004 President George W. Bush called for human planetary exploration.

Other U.S. agencies with space activities include the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense. NOAA operates satellites to gather data in support of its missions (weather forecasting, for example). The Defense Department and intelligence agencies support their missions with satellites for surveillance, communication, and navigation. Private commercial activities, some virtually independent of NASA, include launch services and satellites for communications and Earth observation.

As an independent agency, NASA reports directly to the U.S. president. Although managed from a Washington, DC, headquarters its operations are decentralized in two ways: First, the great majority of NASA employees work at eight field centers such as the Johnson Space Center near Houston, Texas. Second, private-sector contractors do most of NASA's work, and most of its scientific research is conducted through grants to universities. In 2002 the NASA budget was around $15 billion, supporting 18,000 civil service employees and a contractor workforce several times as large.

NASA's involvement with science and technology is extensive: Virtually all its missions embody advanced technology (although some long-lived missions use yesterday's state-of-the-art technology). It developed the Saturn launch vehicle for Apollo, and the shuttle as a general-purpose, reusable launch vehicle. It created the HST, perhaps the most productive scientific instrument ever, and its series of missions to other planets were the basis for the new field of planetary science.

## Ethical Issues

Broadly speaking, many justify space exploration primarily in terms of human adventure and scientific knowledge. A strong version of this position is that humans have an innate need to explore and learn about the world around them. In this view, humans leaving Earth is a straightforward extension of the species' past spread across Earth. Further in this vein, certain images from space, such as Earth seen from *Apollo 11* and the violent galaxies captured by HST, show how fragile and lonely this beautiful planet is, inspiring efforts to preserve it. A somewhat more modest justification holds that, regardless of human history, today humans want to go into space essentially because they can.

Against this background, and to some extent because of it, NASA activities raise a diverse set of ethical issues. These run from whether space exploration can or need be justified in terms of human history, anthropology, and psychology, to the dangers of planetary cross-contamination, risks to astronauts, and honesty in justifying and describing particular programs.

The possibility of life on other planets has animated reflection across much of human history. Search for evidence of life is an important aspect of many planetary missions. But if missions that land on Mars carry with them microbes from Earth, the Earth microbes may confuse the results. Future generations may be misled. Humankind may have "polluted" another planet. (Against this possibility NASA sterilizes spacecraft before launch.)

Further, many scientists want to bring back to Earth a Mars sample for study more complete than can be done remotely on Mars. If life exists there, a returned sample or dust on the returning spacecraft might contain organisms threatening to life on Earth. The threat is remote because NASA will take steps to isolate any returned spacecraft and sample, but given human ignorance it still raises the issue of whether NASA programs might cross-contaminate planetary life-forms. NASA recognizes the issue and therefore ended the Galileo mission in 2001 by crashing it into the atmosphere of Jupiter, which was intended to extinguish all Earth-life aboard it. If humans "colonize" Mars, however, cross-contamination is probably inevitable.

Another form of contamination is the debris missions leave in orbit. A collision with even a small object can disable a spacecraft. Thus early missions leave risks for following ones. Debris in low Earth orbit will slowly reenter because of residual atmospheric drag, but debris in higher orbits remains for centuries. The vastness of space dilutes the risks, but they remain real. Recognizing this, NASA and the world's other space agencies are working to minimize debris from future missions.

## Risks to Life

The loss of life in space transportation accidents dramatically raises questions of risks. For example, what purposes justify risking astronaut lives in space missions? In the *Challenger* and *Columbia* space shuttle disasters risk became loss.

In the past NASA dismissed the risks of shuttle flight, claiming at one time that the accident rate would be one shuttle lost in 100,000 flights. Empirically it is roughly 2 in 100. Reliability of 98 percent is good for a launch vehicle—perhaps the best possible, and perhaps acceptable for professional astronauts on valuable missions. What about amateurs: a "teacher in space," members of Congress, scientists? Do the experiments done on the ISS justify the risk to astronauts tending them? Is returning the HST to the Smithsonian Institution at the end of its life worth the risk of a shuttle mission to retrieve it? Do seven astronauts have to be sent up for this mission? Perhaps the science done by the HST justifies the risk of the missions flown to keep it operating, but a mission to retrieve it for the Smithsonian seems questionable.

The death of seven astronauts in each of two shuttle accidents makes clear that one way to reduce the potential loss is to reduce the number of crew on each mission. The first accident involved a "teacher in space" who was to inspire young students. In order to decide if the risk she took was appropriate, one would have to ask hard-to-answer questions such as whether inspiration was likely, and whether students most needing inspiration would be positively affected. Another dimension is whether an amateur could give adequately informed consent to the risk.

Risk issues become entangled: The HST will eventually reenter Earth's atmosphere. Being massive, it will not burn up; large pieces are expected to reach the ground, presenting an involuntary risk to people on Earth. Guiding the HST down to a remote ocean area would greatly reduce that risk, but it has no capability for a guided reentry because NASA originally planned for shuttle retrieval. A mission to install a reentry package could also service HST to lengthen its scientifically productive life. Several incommensurate considerations are thus involved: The risk to professional astronauts, the risk to bystanders on Earth, and the value of HST science. Balancing these risks calls for ethical discussion. One proposed solution involves the use of robots to service HST.

## Promoting and Justifying Programs

A different ethical problem arises in the description and justification of programs. NASA began as a geopolitical response to the Soviet Union's launch of *Sputnik I*, to demonstrate that U.S. technical capability was superior to that of the USSR. The program, however, was promoted as space exploration—as the realization of humanity's drive to explore and gain knowledge. In reality space exploration was the means for the end of demonstrating U.S. prowess. From the beginning there has been a mix of motives, of ends and means. The ISS is variously justified and described as space exploration and as a science laboratory in space. But these are both problematic: As the station goes around and around Earth, the incremental exploration on additional orbits becomes vanishingly small, while the risk to astronauts remains the same. Second, there are questions as to whether the science on the ISS is worth what it costs. That is, if the justification is scientific, one must ask whether the same funds could support better science, for example in space astronomy (SSB 2003).

Similarly, NASA's justification of a program to develop a nuclear power reactor in space is questionable. The public justifications are that nuclear power would enable new activities, including scientific missions. Nuclear power is probably necessary for missions outside the solar system, and perhaps for extended human exploration missions within the solar system. Nevertheless, to justify the nuclear program a scientific mission to study Jupiter's moons, which had been endorsed by the scientific community and which could be done without nuclear power, has been adopted as the nuclear program's first mission, to give the technology development a clear target. The adopted mission had to be redesigned to require nuclear power; a scientific mission became a nuclear mission. That is, from the time of adoption forward the criteria for making decisions about the mission became nuclear first, science second. Scientific questions no longer drive the mission; rather the driver is developing and demonstrating nuclear power in space—science is a stalking horse. It would be more honest to call this a nuclear program using a science mission to demonstrate possibilities.

Of course a program to put a nuclear reactor into space faces all the ethical problems of nuclear programs on Earth, if in a different form. First are the hazards in the development program and the hazards of launching fissile material. Further, when its fuel is exhausted the reactor will become both another bit of nuclear waste and another bit of space debris. Where and how will it be "disposed of"? Typically, such questions are considered technical, not ethical.

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**SEE ALSO** *Apollo Program; Space Exploration; Space Shuttle Challenger and Columbia Accidents; Space Telescopes.*

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