

## **Science and Exploration**

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I'm here today to talk about what science at NASA means to U.S. leadership in space exploration, and in the world at large. I will also address specific components of our Science Mission Directorate plans, and discuss the opportunities in science that we expect to result from both our new exploration plan and our ongoing decadal research plans.

To begin, I think that some perspective on the role of science in our national life might be in order. We are all here in San Francisco this evening because we believe that what we do is important, not only to our specific disciplines, but also to society at large. It is our good fortune to live in a society that invests in and greatly values scientific achievement. Indeed, most of us have grown up in a world in which we take it for granted that the United States government will invest significant taxpayers' resources in scientific research. But this has not always been the case; prior to World War II, government investment in scientific research was miniscule.

But the contributions of science and technology to the war effort prompted President Roosevelt to request a report from Dr. Vannevar Bush, the Director of the Office of Scientific Research, on how scientific expertise could be used in the post-war world. Bush's report, *Science: The Endless Frontier*, provided the framework for much of the federal backing of scientific research of which many of us have been or currently are the beneficiaries. In his report, Bush wrote, "It is in keeping also with basic U.S. policy that the government should foster the opening of new frontiers and this is the modern way to do it." I think Dr. Bush got it exactly right.

America's space program is a prime example of a successful national investment in opening new frontiers that became possible precisely because our leaders thought about scientific advancement in this new context. Today we conduct bold and rewarding, but costly, scientific activities in space today because our leaders two generations ago viewed American preeminence in all aspects of space exploration as essential to maintaining world leadership. It was in this same spirit that, nearly two years ago, President Bush announced the Vision for Space

Exploration, noting its implementation would advance America's economic, scientific and security interests.

In this sense, science is the beneficiary of our commitment to seek out and explore new frontiers. While exploration has historically spurred technological innovation and commercial enterprise, it has also led to the flowering of scientific activity. I have high hopes for the scientific progress we will achieve as we pursue the Vision for Space Exploration.

Through space exploration and related scientific activities, we can project humankind's vantage point into space, both virtually and physically with robots and humans. From space and in space, our scientific initiatives encompass questions as practical as tomorrow's weather and as profound as the origin and nature of the Universe.

From space, we can view the Earth as a planet – one member of a solar system governed by a typical main-sequence star midway through its life cycle. We can view the Earth's relationship with the Sun, shaped not just by gravity, but by the solar wind, solar radiation, and the Earth's own magnetic field and atmosphere. And we can view the Earth in its entirety, seeing the interconnectedness of the oceans, atmosphere, continents, ice sheets and life itself. We can observe and track global-scale changes, and perceive regional changes in their global context. We can observe the role that human civilization increasingly plays as a force of change. Earth science at NASA is Earth system science, the study of Planet Earth as dynamic system of diverse components interacting in complex ways. We are learning to trace cause to effect, to connect variation with response, and vastly improve national capabilities to predict climate, weather, and natural hazards. Thus, NASA research is also an essential part of national and international efforts to employ Earth science and observation in service to society.

In space, we are extending our virtual presence via robotic missions to other planets and their moons, to asteroids and comets, and to the Kuiper Belt. We are in the midst of a full-scale investigation of Mars, with one or more missions launching every twenty-six months. We are directing more of our attention to the moons of the giant planets as we see intriguing signs of both water and dynamism on their surfaces, knowing that on Earth, where there is water and energy there is also life. We are progressing from observers to rovers to sample return missions, each step bringing us closer to our principal goals: to understand whether life does or did exist elsewhere in the Solar System, and to prepare for human expeditions to other planetary bodies.

The human exploration of space will benefit from the scientific research that we conduct in support of the Vision. The selection of lunar and Martian landing sites, the development of techniques for operations in differing radiation environments and atmospheres, and the exploitation of the Lagrange points are examples of the productive interactions we anticipate between science and exploration as each is pursued for its own purposes.

But having painted this picture, let me make a second point about the space frontier, which is that in fact we have barely entered it. To gain some historical perspective on the matter, consider that the great European voyages of maritime discovery began in the early 15<sup>th</sup> Century with the founding, by Prince Henry the Navigator, of the School of Oceanic Navigation in Sagres, Portugal in 1418. Though he never went to sea himself, Prince Henry sponsored a long series of voyages of exploration down the coast of Africa, in search of a seagoing path to the Orient.

Henry's vision for ocean exploration was "a journey, not a race." In 1420 the Madeira Islands were discovered by Joao Zarco. In 1434, after no less than *fourteen expeditions* had failed – many of them simply never returning – Henry's man Gil Eannes finally made it through the treacherous waters off Cape Bojador, on the coast of Africa south of the Canary Islands, and returned alive. Portuguese explorers rounded the western bulge of Africa in 1460, the year of Henry's death. And the southern tip of Africa, the Cape of Good Hope, was finally reached by Bartolomeu Dias in 1488. Vasco da Gama reached India in 1498. By the time Columbus sailed westward in search of a shorter, easier path to Asia, European maritime exploration had been firmly underway for almost 75 years. Yet today, we think of the 1492 voyage of the Nina, the Pinta, and the Santa Maria as the beginning of everything. That is hardly the case.

The space age, for all its achievements, is less than fifty years old, and is just getting underway. To date, twelve human beings have explored the surface of the moon for a total time of less than one man-month; it is now my job to make that number grow by leaps and bounds. Our initial scientific reconnaissance of the solar system is still incomplete, with NASA planning to launch the New Horizons mission next month to conduct the first robotic exploration of Pluto. We have also barely scratched the surface when it comes to understanding the extent and nature of extra-solar planets. In just ten years, more than 150 planets beyond our solar system have been discovered, and there are indications that at least one has the same rocky characteristics as our

home planet. And as this audience knows quite well, we have only begun to tap the potential of Earth observing, weather, and other remote sensing satellites.

Continuing on the theme that we are just at the dawn of the true space age, let me point out that in a matter of years, people around the globe will be able to look up at a new moon, and with the aid of a good telescope, be able to see the glimmering lights of a research station on the lunar surface. At this research station, pioneering astronauts will be learning how to obtain oxygen from the lunar regolith. They will be deploying antennas on the back side of the moon, linked in phase to form the largest radio telescope ever built, free of radio noise from Earth. They will be engaged in geological exploration of the moon, finally establishing the origins of our Earth-moon system. And other astronauts, in Earth orbit, will be readying a 500 ton spaceship for mankind's first voyage to Mars.

This is the direction for our space program that two successive Congresses have endorsed, and that, according to a very recent Gallup Poll, three-quarters of our citizens "support", or "strongly support". This support is found roughly in equal proportions across the political spectrum, and between the genders. This is the kind of support that will fuel many of our space science initiatives in the future. And we are just at the beginning.

Having said this, I am aware that many in the science community have questioned NASA's commitment to science, and believe their own work to be gravely threatened by the Vision for Space Exploration. Let me speak directly to this point. I have frequently stated my belief that exploration will be a boon for science in the long-term. I have also said on many occasions that it is not our desire to sacrifice present-day scientific efforts for the sake of future benefits to be derived from exploration. We who run NASA today are doing our very best to preserve these efforts in the face of, frankly, some daunting fiscal realities. But we also must avoid setting unrealistic expectations. NASA's \$5.4 billion investment in its Earth and space science portfolio is almost the size of the entire National Science Foundation, and this robust portfolio has grown at a rate significantly greater than has NASA's top line budget over the past decade. Such growth cannot logically be supported within an overall portfolio that is at best fixed in constant dollars.

But we must also acknowledge the plain fact that we cannot do everything that was on our plate when I assumed office. All of you know many reasons why this is so. NASA can only move forward on our fundamental missions of exploration, science and aeronautics at the pace

that available resources will allow, so it is important to be as efficient as possible in allocating these resources. To this end, we have made several changes in recent months, and I would like to discuss some of these changes with you tonight.

First, we are reconstituting the organization the Science Mission Directorate into separate offices for Earth science, heliophysics, planetary science and physics and astronomy.

Second, Mary is defining an executable science program across each of these portfolios in Earth and space science. She is conducting a rigorous review of each flight project now in formulation and development, and establishing gates through which each program must pass in order to proceed from formulation to development. This process requires balancing technical performance against cost, evaluating the management team that is in place, and rigorously identifying risks and defining plans to mitigate them. We very much need better cost discipline in the large assignment missions, as cost growth inhibits the future of the smaller, but incredibly prolific, competed lines.

Third, we are returning to NASA's classical approach to science management, including relying on outside bodies for strategic advice on the ranking of missions by priority. In each of the four major elements of our research portfolio, we will establish priorities through dialog with the science community, based on the budget realities we face. The decadal surveys of the National Research Council have proven essential to this process in the past, and we will continue to rely on them as authoritative sources of science community priorities. We also will engage in more frequent venues for dialog with the science community, such as professional society conferences like these. For tactical level advice we will engage the science community in workshops that help us to implement successful programs by balancing detailed technical requirements, cost and schedule. A principle source of advice at this level is the NASA Advisory Council, which has just been reconstituted. The NAC has five committees, including a five-member science committee with many subcommittees. I believe the latter group's advice will be very helpful to the agency.

Many of you are interested in our plans for Earth science. While it is true this activity does not get the media attention that human spaceflight and planetary exploration receive, I can assure you it is an important activity that we are determined to continue well beyond the completion of the Earth Observation System.

I believe most of you know that I have significantly re-emphasized Earth science since rejoining NASA earlier this year. Our Earth science programs are essential to the accomplishment of three initiatives begun by President Bush: The Climate Change Research program, the Global Earth Observation System and the Oceans Action Plan. We recognize that through our contributions to these initiatives, NASA is providing researchers around the world with unprecedented access to diverse data about the Earth system. This is being done at a time when there are huge societally relevant questions about global changes that require the view from space.

One need look no further than NASA's contributions to this season's hurricane predictions to recognize that we are getting tremendous value out of our Earth observation satellites. Indeed, as a result of NASA's development and deployment in the past decade of the Tropical Rainfall Measuring Mission (TRMM), the Aqua satellite and the Quikscat sea winds measurement instrument, our colleagues at the National Weather Service are now able to predict the formation of tropical storms nine days instead of seven days out, and predict landfall within 400 miles of coastline instead of 800. Such advances allow significant improvement in the marshalling of resources to deal with the inevitable property destruction of, and better warning to people likely to be affected by, major hurricanes.

At NASA's request, the National Research Council has undertaken its first decadal survey for Earth science and applications from space. Our colleagues at NOAA and the U.S. Geological Survey are co-sponsors of this effort, whose results should be available by the end of next year. We will use these results to create a profile with an optimal mix of systematic and exploratory missions, technology development, and research programs to implement the survey's priorities and the presidential initiatives I mentioned.

Turning to the sun, NASA's heliophysics program is helping us to gain a better understanding of the sun, and the sun's interaction with Earth, other planetary environments, and interplanetary space itself. We have used a strategy of deploying frequent, smaller missions within this vast system to form a distributed Great Observatory that is truly greater than the sum of its parts. Next year, we are poised to reap the rewards of several years of hard work.

In 2006, we will launch STEREO, a mission to track the evolution of solar disturbances from the sun's surface to Earth's orbit; the five-satellite THEMIS mission to determine the causes of space weather reconfigurations of Earth's near space environment; and the AIM small

explorer satellite that will examine the formation of the highest altitude clouds in Earth's atmosphere in response to external and internal forcing functions.

Also next year, we look forward to deployment of the NASA CINDI and TWINS instruments on two DoD missions, and to providing instrumentation for Japan's Solar-B mission that will resolve magnetic fields on the sun's surface and how they interact with the sun's outer atmosphere.

Similarly, our planetary program is guided by the decadal surveys we have in hand, and we will proceed with our planetary mission priorities as quickly as our budget will allow.

One area pinpointed for further attention is the Moon. As we plan to return to the Moon to open up the next great era of space exploration, I'd like to mention a few of the new vistas a more extensive focus on lunar exploration will provide. Paul Spudis, my former colleague at Johns Hopkins University's Applied Physics Laboratory, has written extensively on the subject, including a Scientific American article from December 2003 that I commend to your attention. In the article, Paul notes that scientists still have many unanswered questions about the Moon's history, composition and internal structure, whose understanding may also illuminate the history of all the rocky planets in the inner solar system. Paul also wrote of the importance of determining whether significant amounts water ice do in fact exist in lunar polar areas. If confirmed, such a discovery would offer the hope that a lunar base would have a source of water for life support as well as for rocket fuel.

We're looking at a number of promising lunar science targets in our Robotic Lunar Exploration Program, an activity that links our Exploration and Science Mission Directorates. Their collaboration began with the Lunar Reconnaissance Orbiter now in development for launch in 2008. The Science Mission Directorate managed the selection process for the Lunar Reconnaissance Orbiter instruments, and will play a Program and Project Scientist role in spacecraft development managed by the Exploration Systems Mission Directorate.

Of course, we're also interested in outer planet exploration which represents some of the most challenging scientific missions NASA carries out. I already mentioned the New Horizons mission set to launch next month. We're in the preliminary design phase for the Juno mission that will investigate whether an icy rock core exists at the center of Jupiter, and NASA hopes to conduct future missions to investigate the potential of life at Europa, Titan, and other compelling targets for outer planet exploration. Again, these missions represent some of the most

technically challenging science missions for NASA over the next decade. And I'm also very intrigued by Ed Lu and Rusty Schweickart's ideas about nudging large near-Earth asteroids before they can pose a threat to humanity. We will most certainly continue our work to discover large asteroids close to the Earth.

It is important to note that we cannot accomplish all our goals for science and exploration on our own. We're very fortunate to have strong partnerships with a number of spacefaring countries. Today, 29 of NASA's 53 ongoing planetary, astronomy and Earth-observing satellites and spacecraft missions include international participation, with NASA involved in 13 operating science missions led by our international partners. As I've said on numerous occasions, I am looking forward to the opportunity to enlarge and extend these partnerships.

In closing, please allow me to offer a few thoughts on what we might achieve in science if we move ahead with purpose and dispatch with our space exploration program.

By 2020 we will be surveying our portion of the galaxy to create a census of extra-solar planets, and using the next generation of space telescopes to study the origin and destiny of the universe. We will be probing the Martian surface and subsurface for resources that will enable human exploration, and to answer questions about the past and present habitability of Mars. Together with our partners we will have created a global Earth observing system that includes sentinel satellites in higher orbits communicating with active remote sensing systems in lower orbits. These systems will provide both real time information for hazard warning and management and the long term data records required to understand and predict global change.

All of these advances will come about because of the hard work and commitment of our diverse community, which I believe has its greatest successes when we allow the pursuit of exploration and scientific progress to complement each other.

I thank you for your hospitality today, and again extend my heartfelt thanks to all of you for your commitment to regaining the initiative that has driven our past successes.