TESTIMONY BEFORE THE HOUSE COMMITTEE ON APPROPRIATIONS
SUBCOMMITTEE ON COMMERCE, STATE, JUSTICE AND RELATED AGENCIES

# THE PLACE OF NASA SCIENCE IN THE OVERALL SCIENCE ENTERPRISE

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Mr. Chairman, members of the subcommittee, thank you for inviting me here to testify today. My name is Lennard Fisk, and I am the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan. I also served from 1987 to 1993 as the NASA Associate Administrator for Space Science and Applications, and until last July as the Chair of the National Research Council Space Studies Board. The testimony I am giving today is on behalf of myself.

There have been several legislative initiatives recently that have treated science in NASA as less important to the nation than our other scientific pursuits. The highly acclaimed National Research Council report, Rising Above the Gathering Storm, which called for substantial investments in the physical sciences, was effectively silent on NASA. The legislative initiatives that followed from this report, e.g., the America Competes Act, did not focus on NASA science. The recent American Recovery and Reinvestment Act of 2009 was appropriately supportive of the National Science Foundation and the DoE Office of Science, yet in NASA the only science discipline that received substantial funding was Earth science, and then it provides only a partial recovery from a disastrous decline in funding that occurred during the previous decade.

As a practicing space scientist, and someone who throughout much of my career has been concerned with science policy, I can find no logic in the judgment that NASA science is less important. In later sections of this testimony, I discuss the impact that each of the disciplines in NASA science has had on society, and its importance to our nation's future. These arguments can be repeated for many different science disciplines, and they are no less compelling for NASA science.

NASA science asks and is attempting to answer the most fundamental human questions: What is our place in the cosmos; are we alone? NASA science is revealing the wonders of our own solar system, and the resources it may hold for us. NASA science is attempting to understand the controlling body of our solar system, the Sun, and the space environment through which we fly our satellites and send our human explorers. NASA science is attempting to make it possible for humans to live and work in space. NASA science is attempting to answer the single most important question of our age, what is the future of the climate of the Earth, and what impact are humans having upon it.

We need to recognize that space has become part of the underlying infrastructure of our civilization. We have satellites that provide data for sophisticated forecasting models to predict the weather throughout the world. We communicate through satellites, particularly the visible images of television that bring to each of us an awareness, unprecedented in human history, of what is happening everywhere in the world at all times. We have direct broadcasting that brings the television signals directly into our homes. We have global positioning satellites, which help us fly our airplanes, let us find our way in automobiles. We have remote sensing satellites that provide high-resolution images from around the world. All this is now part of our basic infrastructure as a civilization. We don't particularly marvel that it is available. We assume it will be and think no further about it.

Indeed, when we consider the impact of space on our society, we have to look no further than the global interconnections that have flourished in the past few decades. We live in a global economy. Corporations are multinational. Manufacturing and trade are worldwide. Countries that in previous generations might have been suspicious enemies are now dependent upon each other for resources, and as marketplaces for their manufactured goods. This has had a stabilizing effect on world peace. Detailed knowledge of what is happening everywhere in the world, and the ability to share that knowledge, reduces fear and makes full engagement among societies possible and routine.

We need to recognize also that space is an integral component of our nation's foreign policy. Our activities in space have a profound impact on our image as a nation, and provide extraordinary opportunities for us to be strategic leaders in world that is increasingly judging space to be important. The peoples of the world are increasingly dependent on space for basic activities in their everyday lives. There are space races developing in Asia, and every nation that wishes to gain respect as an important player on the world stage has concluded that they need to acquire a recognized space capability. The United States has an opportunity to be a strategic leader in this worldwide effort to become a true spacefaring civilization, and provided that we lead, not by dominance, but rather by example and in cooperation, we will realize our destiny as a great nation, capable of making a better world for all of the world's peoples.

At the foundation of all our space activities is science in NASA. Science often provides the initial reason for why we explore a new region in space, or even a new region of the electromagnetic spectrum. The technology developed for scientific exploration enhances our other space activities, and finds its way into our economy. The youth of our nation are inspired by the brilliance of our scientific achievements in space, and encouraged to pursue careers in science and engineering. The people of the world ask the same fundamental questions that we do about our place in the cosmos, and they expect the United States, as a great nation, to use its capabilities in space to enlighten. The people of the world are frightened by the pending changes in our climate, and they expect the United States, as a strategic leader, to ensure that we create the capabilities in space to observe and to understand the climate, and predict its future.

We invest in scientific research because it provides the foundation of knowledge on which we depend to advance our civilization. We invest in space because it is essential to the future of our nation, for the stewardship of our planet, for the growth in our economy, for our position as a world leader. It follows, therefore, that the science of space, space and Earth science in NASA, is as important to our nation as any other scientific discipline.

The following sections discuss each of the science disciplines of NASA –Astrophysics, Planetary Exploration, Heliophysics, Life & Microgravity Science, and Earth science –and the contributions that it has made, why each is important to our nation, and some of the challenges they are facing.

## *Astrophysics*

The Space Age has had a profound impact on our society and how we view ourselves as humans, how we relate to each other, how we reflect on our place in the cosmos. For most people, I suspect, the change in attitude, the penetrating new insight, followed from the historic picture of Earth taken by the crew of Apollo 8 en route for the first time to the Moon. Earth is beautiful, isolated in the cold darkness of space. We look fragile. Who would not conclude that we have a responsibility to protect our home, to ensure that it remains a safe haven for us in the inhospitable cosmos?

For others there was a profound awakening when Voyager, leaving the Solar System, turned its cameras to look back and see the planets, including Earth, as mere dots of light. How vast space is; how alone we are, at least in our local neighborhood.

Of most importance, there has been the steady drumbeat of astronomical discoveries. Space is the ideal location from which to observe the universe. Our atmosphere shields us from many forms of radiation, and even in visible light, which does penetrate through the atmosphere, it can be distorting. And so from virtually the beginning of the Space Age, the spacefaring nations of the world have launched ever more sophisticated astronomical observatories, and greatly expanded our knowledge of the universe, and greatly expanded the questions we can ask, and can expect eventually to answer.

We have observed the remnant radiation from the Big Bang that began our universe. We have found that the universe is continuing to expand, driven by a force that we don't yet understand. We have discovered that there is matter in the universe, a lot of it, which we can't yet observe. We have seen galaxies forming at the beginning of the universe, and stars forming in our own galaxy. We have discovered planets around other stars, many of them, so many that it is ever more likely that there are other earths and perhaps other civilizations comparable to our own.

We have generated marvelous images from our great observatories peering into the universe in all the different wavelengths of light. The public, in many cases, cannot fully understand the scientific discoveries enabled by these images. But they have no difficulty in marveling at the beauty and the majesty of the universe, and its unfathomable vastness. The Copernican revolution of the early 16$^{th}$ century displaced Earth and thus humans from the center of the universe, showing that we are just another planet orbiting the Sun. I doubt the public of that time paid a great deal of attention, but the Copernican revolution ultimately affected society and its attitudes, even religion.

We are in the midst of another such revolution, which in time will have equally profound consequences. As the vastness of the universe becomes known and appreciated by all, and how common are our planetary circumstances, we become ever more insignificant. But perhaps we will view that insignificance in the most positive light—that our tensions and conflicts, which are our constant, everyday concern, are truly insignificant in the grand scheme of the cosmos.

### *Planetary Exploration*

We have also explored our own solar system, revealing the wonders and the opportunities it contains. Before the Space Age the planets were observed, with only very limited resolution, by telescopes. Now we have been to them all. Depending upon where you stand on whether Pluto is a planet, we will be there shortly also. It has been a systematic process. First fly-bys that produced many surprises. Then orbiters about many of the planets—Venus, Mars, Jupiter and Saturn, with a Mercury orbiter currently underway. And in the case of Mars, there have been landers with their rovers that roam the surface, and look for water and maybe life.

The epic journey of exploration of the Space Age has been the Voyager spacecraft, which visited Jupiter, Saturn, Uranus, and Neptune, and now the two Voyagers are en route out of the Solar System, both having crossed the termination shock of the solar wind, where the supersonic expansion of the solar atmosphere, the solar wind, goes subsonic and begins the process of merging into the local interstellar medium.

There has been unprecedented excitement in the discoveries of each planetary mission. The fly-bys were events that the public stayed up and watched. The rovers on Mars have been adopted by the public, and followed on the internet with each new canyon and rock formation that is explored.

In the United States and elsewhere in the world we are witnessing a fascinating difference among the generations as to what is impressive. To the older generations who witnessed Apollo, human space flight is impressive. The astronauts were true heroes. However, to the younger generation, who are steeped in technology, who vicariously participate in all sorts of adventures through their computers, rovers on Mars are more impressive. The rovers are based on the latest technology. They are doing something we have never done before. And wouldn't it be better still if the younger generation could drive them themselves?

### *Heliophysics*

We have also learned much during the Space Age about our Sun and the space environment it creates, and in which we live. Last year was the 50$^{th}$ anniversary of the seminal paper by Gene Parker, which predicted that the outer atmosphere of the Sun, a million-degree plasma, would expand supersonically into space creating a solar wind. Parker's paper was highly controversial at the time, nearly rejected by the journal. It took the first interplanetary mission, Mariner 2, in 1962 to prove definitively that Parker was indeed correct. The atmosphere of the Sun expands to fill a large region of space, to carve out a heliosphere from the local interstellar medium. We now know from Voyager that the supersonic flow of the solar wind extends to 100 times the distance from the Sun to Earth. Along the way, the solar wind impacts the magnetic fields of the planets and creates dynamic magnetospheres around each of the planets that has a strong magnetic field.

The engine of the space environment of the Solar System is of course the Sun itself. Before the Space Age, the Sun was viewed as a relatively benign object, a constant source of light and energy, on which we depend for life. With the advent of space observations in many different wavelengths of light, the true character of the Sun has been revealed. Its surface and lower atmosphere are a cauldron of dynamic processes, driven by strong magnetic forces that can eject large amounts of high-energy particles, and at times large amounts of matter, which can affect Earth and other planets.

This is the space environment through which we fly our satellites, and hope some day to fly humans. It is not a friendly place. It is a place where damage can be inflicted on our technologies, and if we are not careful, death inflicted on our human explorers. We have made much progress in documenting the range of conditions that can occur in our immediate space environment. We have made only limited progress in predicting the conditions in space. Yet, if our societies wish to make maximum use of the opportunities that space provides, we will indeed need a reliable predictive capability.

The Sun is a cyclic object. It has an 11-year cycle in its activity. Its magnetic polarity flips every 11 years, for a 22-year magnetic cycle. The causes of the cycles, their length, the strength of the activity, all these are only primitively understood, and not reliably predicted. Yet there is evidence of the imprint of these cycles on life on Earth, through means we do not understand. As we sort through the undeniable impact of humans on the climate of Earth, we need to make sure that we understand all the natural forcing functions, and can predict their occurrence and their impact.

### *Life and Microgravity Science*

During the 50 years of the Space Age, we have also taken the first feeble steps in learning to live and work in space. The efforts to use the space environment, particularly the microgravity environment, to do research that has application on Earth, has for the most part been an unfulfilled promise. It can be argued that this unfulfilled promise results from the lack of flight opportunities. Missions have been few and of relatively short duration. The ISS, which is designed to provide the opportunities to pursue this research, is only now being completed.

What we have done, however, over these 50 years, is learned to live in space and to construct things there, which has established the usefulness of humans in space. We have demonstrated that humans can remain in weightlessness for extended periods. Since this experience has been within the protective shielding of Earth's magnetic field, and thus relatively free of radiation, the radiation hazard of space and its consequence for humans, and whether weightlessness and radiation together are a serious complication still remain to be determined.

Perhaps the most impressive feature to date of the ISS is that it has been built. It is the fruit of cooperation among many spacefaring nations; an extraordinary construction project in which many different pieces of hardware had to come together and be assembled on orbit. We have certainly proven that we can work together as spacefaring nations to achieve an impressive accomplishment.

### *Earth Science*

Finally there is Earth science. No other science discipline has had more direct impact on society than Earth science. And space has made that impact possible. We have passed through a tipping point in the past 50 years, to where now our everyday activities, our use of natural resources, are having a global impact on the future of the planet. The sustainability of Earth to support human life is in question. This is a global problem. And the global perspective of observations from space is required to understand what is happening to Earth; what our future holds.

We have also learned, strongly influenced by the global perspective provided by space observations, that Earth is a highly coupled system. The atmosphere, the oceans, the cryosphere, the land surfaces, the biosphere are all coupled, in an intertwined system, in which complex feedback mechanisms are possible. Understanding Earth, and what we as humans are doing to it, is not an easy problem. It does not do any good simply to say that Earth is warming as a result of fossil fuel emissions. That is certainly so. But the knowledge that is required is: what are the regional consequences? How will precipitation patterns change, or growing seasons? Exactly how much will sea levels rise? A foot makes a big difference.

It will take many observations from space, and much of the world's scientific talent to understand exactly how Earth works, and to predict exactly what we as humans are doing to it; and to monitor and evaluate our efforts to protect the future of the planet, should we ever be so wise as to engage in a serious effort to avoid the pending catastrophe.

In the late 1980s NASA made a serious effort to embark on a major program to make comprehensive observations of Earth, and to support the science needed to understand the observations, with its multi-billion dollar Mission to Planet Earth. That program has been largely abandoned under the same government policies that treated the human influence on the climate as an uncertainty. The perceived economic consequences of any meaningful response was considered to be so overwhelmingly negative that ignorance of what our future holds is a preferred state. Generations to come will not be kind to us that we treated the future sustainability of the planet in so cavalier a fashion.

At least we can say that one of the most important impacts of space on society is that space has provided the basis for our growing human awareness that we are highly interdependent. What China does to the atmosphere affects the United States. What the United States does to the atmosphere affects Europe. What we all do to heat Earth affects the polar regions. And so on. Most of us know this. Most of us came to this realization because of the global perspective of Earth that has been provided by space observations. Most of us would like to see wise decisions being made to protect that fragile globe that we saw from Apollo 8, and be sure that it remains our hospitable home in the hostile and lonely environment of space.

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Lennard A. Fisk is the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan, where he is the current Henry Russel Lecturer, the highest honor the University bestows upon a senior member of its faculty. Prior to joining the University in July 1993, Dr. Fisk was the Associate Administrator for Space Science and Applications of the National Aeronautics and Space Administration. In this position he was responsible for the planning and direction of all NASA programs concerned with space science and applications and for the institutional management of the Goddard Space Flight Center in Greenbelt, Maryland and the Jet Propulsion Laboratory in Pasadena, California.

Prior to becoming Associate Administrator in April 1987, Dr. Fisk served as Vice President for Research and Financial Affairs and Professor of Physics at the University of New Hampshire. In his administrative position, he was responsible for overseeing the University's research activities and was the chief financial officer of the University. Dr. Fisk joined the faculty of the Department of Physics at the University of New Hampshire in 1977, and founded the Solar-Terrestrial Theory Group in 1980. He was an astrophysicist at the NASA Goddard Space Flight Center from 1971 to 1977, and a National Academy of Sciences Postdoctoral Research Fellow at Goddard from 1969 to 1971.

Dr. Fisk is the author of 200 publications on energetic particle and plasma phenomena in space. He is a Member of the National Academy of Sciences (NAS) and the International Academy of Astronautics (IAA); he is a Foreign Member of Academia Europaea and a Fellow of the American Geophysical Union. He served as Chair of the NAS Space Studies Board from 2003-2008; he is a co-founder of the Michigan Aerospace Corporation and a Director of the Orbital Sciences Corporation. He is the recipient of the NASA Distinguished Service Medal in 1992, the AIAA Space Science Award in 1994, and the IAA Basic Science Award in 1997 and 2007.

He is a graduate of Cornell University. In 1969, he received his doctorate degree in Applied Physics from the University of California, San Diego.