The following is the text of the speech delivered by Len Fisk at the COSPAR General Assembly in Montreal, Canada, on July 14, 2008, on the occasion of the 50th anniversary of COSPAR.

The Impact of Space on Society

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I have two tasks before me today. This is first of all a celebratory event. This year marks the 50th anniversary of the International Geophysical Year, which occurred in 1957-58, during which the Soviet Union launched the first satellite, Sputnik, followed closely by the American Explorer 1, and the space age began. As we heard from Peter Wilmore, in 1958 the International Council of Scientific Unions established the Committee on Space Research, our own COSPAR, as a vehicle where international scientists could meet and discuss, and cooperatively plan the exploration of space on behalf of all humankind.

The celebration is of course not just about those seminal events when it all began, but rather it is about all that we have collectively accomplished to change forever our understanding of space and the opportunities it holds for all of our societies. We have changed forever our perception of the universe in which we live and our place as humans in it.

This, however, should also be a contemplative event. As with all anniversaries, it is worthwhile to pause amid the celebration of what we have accomplished and ask where we are going in the years ahead. What do the next 50 years in space hold for us?

The title of this talk is the Impact of Space on Society. This title needs also to be considered in the reverse. Over the last 50 years, space has inexorably altered our societies. Over the next 50 years, our societies -- their desires, their expectations, their goals -- will determine our future in space.

We all know the history. To get to space you need a rocket, and the basic rocket technology on which we still rely today was developed by the Germans in the cauldrons of World War II. In the spoils of that war, the Americans did well, acquiring the leader of the German rocket program, Werner von Braun and 525 of his leading engineers and technicians, as well as 13 years of documented research and 100s of V2 rockets to play with. The Soviets did less well, acquiring only one major rocket designer but many lesser engineers and technicians.

In the U.S., after the war, relatively little rocket development took place. Rockets were viewed as military weapons, and from its location and with the Soviets as the enemy, the U.S. needed an Intercontinental Ballistic Missile that could carry an atomic warhead. But atomic warheads were heavy, and U.S. senior advisors concluded that an ICBM would never be possible. That situation changed in the early 1950s with the development of the hydrogen bomb, which required much smaller warheads. And so in 1954, the United States Air Force declared the Atlas program to develop an ICBM its highest priority.

Interestingly enough, the Soviets began their ICBM program that same year, 1954. Their deciding event seems to have been the ascension of Khrushchev, following the death of Stalin, to lead the Soviet Union. Khrushchev recognized the importance of rockets and space for modernizing the Soviet military and economy, and for projecting the image of the Soviet Union and its form of government, as a world power and a technologically advanced society.

In the late 1950s the U.S. was interested in satellites, not for science, but as reconnaissance satellites for observing the Soviet Union. This was a time in the U.S. of much fear of the Soviets, and much ignorance of what they were capable of. It was a time when the U.S. flew U-2 planes over the Soviet Union, one of which was shot down causing an international incident for the Eisenhower administration. Satellites would not have the problem of being shot down. But it was unclear how the Soviets would react to over-flights of satellites. Would it be considered a destabilizing threat?

In 1950, in the living room of James van Allen in Silver Spring Maryland, the International Geophysical Year was conceived, and then realized in 1957-58. As part of this worldwide effort to understand Earth, the founders of the IGY thought that launching a satellite would be a good contribution. The U.S. government was supportive, not because of the science it would accomplish, but because a scientific satellite would legitimize over-flights of satellites in general.

The U.S. assigned the development of its rocket and satellite to the Naval Research Laboratory – the Vanguard program --because NRL was considered to be essentially a civilian organization, and the U.S. wanted only indirect ties to the military. Unfortunately, NRL was not very successful at developing the Vanguard rocket and the Soviets launched first, with Sputnik on October 4, 1957. Vanguard blew up in December, and the U.S. turned to Werner von Braun, now with the Army in Huntsville, for the rocket, and to JPL for the satellite, and the first American satellite, Explorer 1, was launched on January 31, 1958.

There is probably no single event in American history that has had more positive impact on American society than Sputnik. We had our Pearl Harbor. We had a Civil War. The final outcome of Pearl Harbor and our Civil War was a stronger, more advanced America. But the initial consequence was death and destruction. The American response to Sputnik, and the Soviet launches of satellites and humans that followed, was all positive, and has transformed American society.

The American response came quickly. Shortly after the launch of Explorer 1, the American Congress passed the Space Act, the bill authorizing the establishment of NASA. If you are a student of American legislation, it is worthwhile reading the Space Act for the high-minded purposes it empowers NASA to pursue, and how comprehensive a mission NASA is charged with.

And there was more. In 1958, the National Defense Education Act was passed, which altered forever scientific education in the United States. The American research universities came into their prominence, in recognition that the pursuit of technology in defense of the nation requires that the vast science and engineering resources available in American universities needed to be fully deployed.

I was 14 years old when Sputnik was launched, early in my high school years. Guidance councilors all across America were telling students if they could add and subtract they needed to be engineers – their country needed them. I told my councilor that I wanted to be a scientist. He wasn't sure exactly what the difference was, but being a scientist was probably just as good.

The transformation of American society continued with President John Kennedy's remarkable pledge in 1961 committing the United States to place a man on the Moon and return him safely to Earth before the decade was out. Perhaps the most revealing statements of Kennedy's intentions appeared later in the speech when he said "a Moon landing would demand sacrifice, discipline, and organization: the nation could no longer afford work stoppages, inflated costs, wasteful interagency rivalries, or high turnover of key personnel". He stated also: "every scientist, every engineer, every technician, contractor and civil servant must give his personal pledge that this nation will move forward, with the full speed of freedom, in the exciting adventure of space".

Kennedy viewed the Apollo program as an event that would transform the nation. And transform us it did. At the peak of the Apollo program, NASA consumed 4% of the Federal budget; some 400,000 Americans worked on Apollo; some 20,000 American industrial firms of all sizes. From Apollo, and all the other aspects of space that developed concurrently, we vastly improved the American technical workforce, and our sense of what technology can accomplish for us.

Perhaps the most remarkable aspect of this brief recital of space history is how a program that had its origins strictly in the military – the German rocket program of World War II, ICBMs, the need for military reconnaissance satellites – evolved into a highly visible, aggressive, and comprehensive civilian space program of human exploration, of science, and of the utilization of space for society. To be sure, throughout the history of the space age, the development of military space has continued unabated – better ICBMs, more capable military reconnaissance satellites – to now where a modern military is completely dependent on the space assets it can deploy. But most of the military work has been classified, invisible to the public. The public side of space, which society is most aware of and which it most benefits from, is the part of space that we pursue for strictly peaceful purposes.

The reason this evolution occurred is straightforward. In the Cold War between two superpowers that were capable of destroying each other, real war was not possible. And so space became a proxy for war. If our rockets could hit the Moon with precision, surely they could hit Moscow. If a Soviet rocket could lift large objects into space, surely it could carry nuclear warheads, and no one had to die in the demonstration.

Space as a demonstration of a nation's technological capabilities was wonderful cover for developing all possible space capabilities. The more you could do, the more you demonstrated your nation's technological prowess. In addition to Sputnik I and II in 1957, the Soviets orbited the Moon and took pictures of the far side in 1959, a testimony to the precision of Soviet rockets. They launched the first human into space in 1961. On the American side, in addition to pursuing Mercury, Gemini and Apollo, the first weather satellite, Tiros I, was launched in 1961. Also in the early 1960s, the first active communication satellites were launched, in time to provide television coverage of the Tokyo Olympics in 1964. The first mission to another planet, Mariner 2 to Venus, was launched in 1962. The human space flight program may have dominated the American budget in the 1960s, but the idea was to be very good about all aspects of space, and to do it in the most visible way possible.

Other nations, beside the Americans and Soviets, soon joined the space age. The Europeans, through ESRO, the predecessor to the European Space Agency, ESA, launched their first satellite in 1968. The first Japanese and the first Chinese satellites were launched in 1970. The Indian space program launched its first satellite in 1975.

And now many nations have highly developed space capabilities. Indeed, the development just since the turn of the century has been dramatic. Chinese astronauts. Europe with the ability to autonomously dock with the International Space Station. India with a highly developed launch capability. Israel with sophisticated reconnaissance satellites. To cite just a few examples.

We talked about the impact of the early space program on American society. In each country that has developed a space program, and used it to exhibit its technological capabilities, that same transformation has occurred. The improvement in the technical workforce and capability, and the public demonstration of it, provides a sense of national pride, a statement to the world that the nation, or nations, is entitled to a position of respect on the world stage.

Over the years since the beginning of the space age, we have also seen space become part of the underlying infrastructure of our civilization. We have weather satellites that provide data for sophisticated weather 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, available now from Google-Earth for all to see.

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.

When considering the impact of space on society, we have to look no further than the global interconnections that have flourished in the last few decades. We live in a global economy. Corporations are multi-national. Manufacturing and trade are worldwide. Countries who in previous generations might have been suspicious enemies now are dependent upon each other for resources, and as marketplaces for their manufactured goods. This has had a stabilizing effect on world peace. And it has been greatly facilitated by satellite observations and communications. Detailed knowledge of what is happening everywhere in the world, and the ability to share that knowledge, reduces fear and makes the full engagement among societies possible and routine.

There is, however, a subtler but far more profound impact of the space age on society. And that is how we view ourselves as humans, how we relate to each other, what is our place in the cosmos. For most people, I suspect, the change in attitude, the penetrating new insight, followed from the historical 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.

And then 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 space-faring 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 16th 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.

We have also explored our own solar system, revealing the wonders and the opportunities it contains. Prior to 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 than 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 for which 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 America and perhaps 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. Indeed, the younger generation would say what is so impressive about sending people into space? The technology, much of which is not new, is primarily to keep the astronaut alive. The rovers, however, 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?

Indeed, if one of the purposes of the space program is to demonstrate a nation's technological prowess, which is more impressive? Human space flight, which uses the technology of the

1960s, and may in time make it back to the Moon. Or to invoke the full power of the revolution in technology that has occurred over the past few decades – in materials, in electronics – and robotically colonize our solar system.

Consider also how much we have learned during the space age about our Sun and the space environment it creates, and in which we live. This year is another 50^{th} anniversary. The 50^{th} anniversary of Gene Parker's seminal paper, 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 settle definitively that indeed Parker was correct. The atmosphere of the Sun expands to fill a large region of space, to carve out a heliosphere from the local interstellar medium. And we now know from Voyager that the supersonic flow continues to around 100 times the distance from the Sun to Earth.

The solar wind impacts the magnetic fields of the planets. It creates dynamic magnetospheres around each of the planets that has a strong magnetic field. The solar wind creates the conditions where Earth's radiation belts can form, which was the first space science discovery, by van Allen on Explorer 1.

The engine of the space environment of the solar system is of course the Sun itself. Prior to 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 impact 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 to 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.

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 the unfulfilled promise results from the lack of flight opportunities. Missions have been few and of relatively short duration. The International Space

Station, which is designed to provide the opportunities to pursue this research, is just 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 the 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, this still remains to be determined.

Perhaps the most impressive feature to date of the International Space Station is that it has been built. A cooperation among many space-faring 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 space faring nations to achieve an impressive accomplishment.

The Americans are racing to retire the Shuttle, which has become a much-maligned vehicle. Its safety is a concern. Its cost far exceeds what was expected by its designers. But what a marvelous vehicle for learning to live and work in space. Maneuverable; a large payload capacity; a large down mass. It made the assembly and utilization of the International Space Station possible.

The Shuttle is to be replaced by rockets that strongly resemble the Saturn rocket and crew capsule of Apollo. Necessary I am sure if we are to return to the Moon. Of less obvious utility if we were to remain in low-Earth orbit.

And 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 last 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 due to 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 have treated the human influence on the climate as an uncertainty. The perceived economic consequences of any meaningful response is 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 so cavalierly.

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.

What then does our future hold? It depends upon what our societies want. The space programs of the world were established to serve the needs of our governments and our societies. In the 1960s, the American and the Soviet space programs were established to fight the Cold War, by proxy. To demonstrate our technological prowess, and by doing so to win the hearts and minds of the world in support of our different forms of government. Other nations have established space programs to demonstrate their technological prowess, to foster national pride, to stimulate their economies, to make their nations players on the world stage.

Today, however, we are all an underutilized resource. The American space program was sized to be supported by 4% of the U.S. Federal budget. We now receive about 0.7%. All other nations with space programs, even those currently in a growth phase, have more capabilities than are currently being called upon. And yet there are so many problems to which we could be significant contributors to the solution.

Global climate change. Our governments and our societies need facts on which to base sound policy decisions to ensure the sustainability of Earth. Those facts will come from space observations, and the interpretation and analysis of data that space observations provide. We need to be set loose and supported to provide the most comprehensive and complete information possible on how Earth works, what we as humans are doing to it, and to do so as soon as possible before irrevocable damage has occurred.

We need to increase the economic opportunities that are available to our societies. We need to consider whether expanding the economic sphere of the world to include the near space environment, the Moon, and asteroids, is an appropriate investment in our collective future, and be set loose and supported to extend the human presence throughout these regions.

We need to recognize that in time our economic sphere will need to expand throughout our solar system. Why not start now?

We live in a global, highly interdependent world. This is no longer a time to pursue space strictly for national pride. We need to bring to bear all of our capabilities in space to determine the future of our planet and to increase the economic opportunities that are available for all of our societies.

There are compelling tasks that need to be undertaken in specific scientific disciplines. If we extend the human presence into space, we no longer have the luxury of treating the conditions and the hazards of space as an interesting scientific problem, to be solved at our leisure. We need instead to be set loose and supported to develop a true predictive capability of the space environment through which humans will fly. And to do so as soon as possible.

Perhaps we will decide that the future of fundamental physics is in understanding dark energy, which is not understood, but appears to be powering the expansion of the universe. We should be set loose and supported to mount a worldwide effort to use our capabilities in space to understand this fundamental force of nature. With anticipation, as with all previous discoveries in fundamental physics, that future societies will depend upon and profit from the discoveries we make.

It cannot be that we occupy this vast universe alone. Where does everybody else live? What are they like? We need to be set loose and supported to determine how common life is, even within our own solar system. We need to find life elsewhere in the universe, and if possible to communicate with it. Such an event would alter the course of human history as no other.

Asteroids can hit Earth and destroy us. An unlikely event, but not an impossible one. We need to be set loose and supported to fully understand our risks, and to be prepared to defend ourselves.

There is a worldwide need for technically competent workforces, to solve the many problems facing our societies, and to ensure our economic future. Space has a proven record of creating technically competent workforces. The Apollo program in America inspired a generation to pursue careers in math, science, and engineering. We can all do this again.

There is a worldwide need to believe that the future can be better than the present, and to collectively work to secure that brighter future. Space is all about the future. We envision a time when our planet is safe from ourselves. When our economies grow without bound. When our knowledge of the wonders of the universe has become true understanding. When we are a true space faring civilization. We need to be set loose and supported to pursue that brighter future for all of us.

During the last fifty years, space has had a profound impact on our societies. It has facilitated the globally interdependent world in which we live. It has altered our sense of our place in the universe. It has created technically competent workforces, stimulated our economies, enhanced our lives, vastly increased our knowledge of Earth, our solar system and the universe beyond.

It is my fervent hope that in the years ahead we will be called upon to do so much more. We can make it a much better world for all of our societies, if only we are set loose and supported to do so.

Thank you very much.