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Mr. Chairman, Members of the Committee, it is a pleasure to be here today to testify on NASA's Earth science efforts and their impact on U.S. citizens. This is an important and crucial subject in these days of increasingly tight federal budgets for science and the development of useful applications of science results. For nearly 25 years I have followed and analyzed the development of U.S. Earth science and applications capabilities, first for the Congressional Office of Technology Assessment and since 1995, as a research professor in the Space Policy Institute within The George Washington University.

During those two and a half decades, the United States has made dramatic progress in Earth science and applications. Investments in several geospatial technologies have contributed to the development of powerful methods for improving weather and climate forecasts (including advance warnings of severe weather), transportation planning and monitoring, agricultural planning, energy efficiency, and other geographically- and environmentally-influenced activities.

Whether through NASA, NOAA, the U.S. Geological Survey, or though university research funded by the National Science Foundation, the federal investment has been key to bringing the science and the resulting methods and technologies to a status that they can truly benefit not only the federal government including important defense and homeland security programs but also state and local authorities, the private sector, and especially the average citizen. Yet, despite the substantial progress over the years, a lot more can and should be done to make sure that the benefits of science research actually reach the American public.

Benefits of Earth Science Research

Mr. Chairman, among other things, your letter of invitation to testify in this hearing asked about past accomplishments from the NASA Earth science program and what future benefits can be expected. In a recent research project co-funded by NASA and NOAA, my colleagues at the Space Policy Institute and I explored the scope of social and economic benefits provided by NASA's current Earth science research and NOAA's applications of science results to weather and climate, and determined that in sum they were quite substantial. However, reliable estimates of the total of such benefits do not exist and the available socio-economic studies focus on specific examples of benefits to

particular industries, geographical areas, and types of storms or damage. All of the available studies indicate with little doubt that improved weather and climate forecasts have saved many millions of dollars in property damage, prevented the loss of life from severe storms, and contributed further millions of dollars to industrial efficiency.

Both NASA and NOAA have made substantial contributions to the development of more accurate, longer-term weather and climate forecasts. NASA has provided the lead in new instrumentation, new understanding of the basic chemistry, physics, and biology of Earth systems, and advances in modeling and data assimilation techniques. NOAA has provided long-term, routine observations focused on improving forecast models and other decision support tools directly benefiting the end user of weather and climate information. More specifically, benefits of NASA's Earth science research include, but are certainly not limited to:

1. A much deeper and broader scientific understanding of Earth systems and how they function, which in addition to contributing to general scientific knowledge, also provide the basis for applied use of this important knowledge;
2. Development of sophisticated satellite sensors capable of monitoring Earth systems for the benefit of U.S. citizens;
3. Significant scientific and technical support in the development of a $3.5 billion dollar satellite and aerial remote sensing data and applications industry that is now growing at a rate between 9 and 14 percent per annum [1];
4. Data, models, and other decision support tools for weather and climate forecasts, including forecasts of damaging storms. Data from the TRMM satellite, for example, enable forecasts to predict hurricane paths and rainfall amounts much more accurately [2].

When we examined the economics and related benefits literature related to NASA's Earth science research for quantitative economic studies or value analysis, we found relatively few in-depth studies. Further, although most studies cited sizeable benefits, each study was carried out using a different valuation methodology, or was focused on a narrow element of the industry under study. Taken together, these two factors mean that few quantitative conclusions can be drawn about the total social and economic benefits of NASA's Earth science information to U.S. industry and to federal, state, and local government applications. This means that benefits studies cannot yet be used with confidence to guide future investments in space systems.

Yet our studies show that the supportable, qualitative benefits of Earth science research are quite high to nearly all sectors of industry and to the public sector. Since NASA is at the cutting edge of Earth science research in this country, it should focus more attention on this important subject in order to assist in guiding its future research agenda. This is not to say that expected practical benefits alone should determine NASA's future research agenda, since such an approach might stifle creative, breakthrough research efforts, but such benefits should play a role in the decision process when difficult decisions are being made among projects.

The Electric Energy Industry

In order to understand the range of issues surrounding the development of benefits estimates, we focused on the potential social and economic benefits to the electric energy industry of improved weather and climate forecasts and other information derived from a combination of satellite data and other weather information. This industry, on which the United States depends as a critical part of the infrastructure of economic growth and well being, relies deeply on accurate weather and climate forecasts to estimate its customers' future demand for electricity and the company's needed future fuel supplies. Because satellites operate either globally or over very large regions, they provide synoptic views of meteorological conditions over substantial portions of the globe that cannot be monitored cost-effectively from aircraft or ground stations. In fact, some 90% percent of the data now used in weather forecasts derive from satellite measurements.

Our study shows that electric utilities derive the greatest economic benefit from weather forecasts that are accurate over 2-4 days. Improved 7-10 day weather forecasts would also provide additional economic benefit for utilities. [3] The companies use monthly and seasonal weather forecasts for scheduling maintenance and for meeting EPA-set yearly emission allotments. Longer-term forecasts assist in planning for new power generation facilities.

The industry also depends on such forecasts for severe weather warnings. As noted above, most of the data inputs for these forecasts derive from satellites. The latter data are especially important in geographic areas at risk from severe storms. Our study also shows that the industry has need of other types of satellite data. For example, some companies use NASA's MODIS data to estimate snow cover and Landsat data to assist in meeting environmental regulations on transmission line rights of way. All of these data contribute an economic benefit to the industry, which, in a competitive environment, will generally result in greater efficiencies and in lower electricity prices to customers.

Satellite information can also provide significant benefits in planning and operating electric production dependent on renewable sources of energy such as wind, sunlight, and water. At least seventeen (17) states have now mandated the use of renewable energy sources in generating electrical power; in the future, other states are likely to add similar regulatory requirements. Satellite-based remote sensing can aid in realizing the potential of exploiting renewable energy resources by helping in the optimal location of generating facilities as well as in the operational decisions of generating facilities and electric power grid management. The future growth and development of this increasingly important sector of energy generation would be significantly assisted by NASA satellite data which can provide a principal ingredient for this effort to assist in the siting and operations of these energy sources.

More accurately measuring the economic value of the contribution of satellites would help in guiding federal policy toward the electric utility industry. However, the use of weather and climate forecasts and other satellite data in this industry represents only part of the total benefit inherent in the environmental information gathered by spacecraft. Many other weather-dependent economic sectors, including water resources, agriculture, construction, recreation, and the general public would also profit from a better understanding of the benefits and mechanisms of both weather forecasting and the use of those forecasts. These economic benefits are most evident in the ability of better weather

forecasts to reduce the risks and uncertainty in planning and performing a wide variety of economic and social functions.

Global Earth Observation System of Systems (GEOS)

In July 2003, the United States invited other countries to enter into discussions regarding the establishment of an Integrated Global Earth Observation System (IEOS) that would gather as much information as possible from current Earth observation systems operating in space, the atmosphere, and on Earth, with the goal of establishing comprehensive data and information systems to guide our management of planet Earth. That initial meeting was a resounding success and led to the current 10-year Implementation Plan agreed to by more than 30 countries in July of 2004.

The Implementation Plan, which consumed considerable effort in all countries party to the agreement, is only the beginning of many years of additional effort to bring the plan to fruition. NASA plays a very important role in this effort, supplying new, more useful satellite data sets and assisting with development of models and other tools to make the data sets truly useful.

This international system can provide significant additional benefits to the United States, as well as to the rest of the world, in many ways such as reducing hunger and providing better warnings of impending natural disasters. I note, for example, that one of the chief tasks of GEOSS will be to focus on methods and means to reduce the impact to life and property from natural disasters, such as earthquakes and Tsunamis. Satellite data and methodologies have an important place in this effort through their ability to gather real-time data on a worldwide basis which is one very key element of the modeling, forecasting, and warning system.

Having established its leadership in GEOSS, the United States must now follow through on its implementation. This will require sufficient funding for the U.S. effort, the Integrated Earth Observation System (IEOS) both in continuing NASA's Earth science program at a robust level, and in supporting the involvement of other agencies in the endeavor. As noted in a recent report by the American Meteorological Society, "there will have to be a long-term robust research program designed to add value to the operation of IEOS." [4]

Such support should also include research on the expected benefits from such expenditures and sustained efforts to include the inputs of information users—the final stakeholders in the IEOS process. After all, there is only so much public money to go around, especially in an era of increasing budget deficits, and understanding the areas likely to return the greatest benefits will help NASA managers and Congress make better funding decisions among the many worthy research projects and proposals.

Bringing Benefits to Users

Despite the importance of maintaining a vigorous Earth science program at NASA, obtaining more accurate, more detailed scientific data from satellites does not automatically lead to economic benefits to users of the information. The many and complex steps between the development of forecasts and other decision support tools from satellites mean that expected benefits are not always fully realized by the end user. Hence, considerable effort must be expended to improve both the understanding of all

parties involved in the process. This especially includes the communications between the research community and the ultimate users of the information.

Second, the transfer of Earth observations information from the producing agencies of the government to the end users must occur in a timely manner and in easily used formats. At present this is not always the case. With better appreciation of the roles and needs of the research, modeling, and end user communities, economic and social benefits of weather information can improve. We need a series of efforts to improve the flow of research results to information end users. I cite as an excellent example, H.R. 426, the Remote Sensing Applications Act sponsored by Representative Mark Udall, which would institute a series of competitively awarded pilot projects to encourage public applications of Earth observations data.

Yet, such efforts to incorporate beneficial Earth science results into the wider community will not be enough. In general, NASA and the agencies that use its data to improve their operations also need to focus on more effective technology transfer, communication, and coordination among them. After all, NASA is in the research and development (R&D) business, and the user agencies as well as the private sector mold NASA's data and other research results to specific users in the transition from research to operations. It is always easier and more accurate to quantify the end-use applications than the R&D. Yet, they are so interlinked in a "but for" chain of events that benefits achieved by the end users would not and could not exist without NASA's research. NASA's Earth Science Applications Program is on the right track in centering its efforts on working with the user agencies to improve their processes. However, it will need continued support and encouragement from Congress and from within NASA itself.

Conclusions

In summary, NASA's Earth science program has provided sustained benefits to the United States. Nevertheless, in order to do more focused, cost-effective planning for the next steps in Earth science research, the United States needs a comprehensive, long-term effort to estimate both the measurable economic impacts and non-quantifiable social benefits of Earth science research and applications.

I see several ways in which this Committee could be especially helpful in assuring that the public actually reaps the benefits of Earth science research:

1. Eliminate the steady decline in the proportion of NASA's budget devoted to Earth science. NASA's Earth science program produces real benefits to the American public and should be maintained at a level that maintains strong U.S. leadership in Earth science research.
2. Provide additional resources to support U.S. leadership in GEOSS.
3. Authorize NASA to direct greater attention to the quantification of the benefits of Earth science research and applications to America's industry and public sector, and the policy implications of those benefits.
4. Include an exploration of the issue of "transition from Earth science research to useful applications" in the Committee's next hearing related to Earth science and applications.

In the eyes of many, Earth science research is not nearly as "sexy" or as cutting-edge as exploration beyond Earth orbit. It certainly doesn't command the same sort of

public attention as the astounding results from the Hubble telescope or the Cassini Mission to Saturn. Nevertheless, though it may not be as much in the public eye, earth science research truly does involve exciting new technological developments and may be vastly more important in direct and near-term impacts to the economy and the public welfare than these other examples. Modern society has come to depend on the new knowledge and technologies that NASA's Earth science program provides. Just imagine what our lives would be like if our Earth science and meteorological satellites all suddenly failed. Tomorrow's weather would again become guesswork and electricity would start to cost us more. Local and regional environmental trends would be next to impossible to determine and monitor. Ships in the North and South Atlantic would be vastly more susceptible to iceberg collisions and other hazards. Resource exploration and resource management would be much more difficult to undertake. Even the security of our homeland would be lessened and our defense efforts hindered. Finally, we would be deprived of the benefit of seeing for ourselves the satellite weather maps on the evening news or over the Internet. In short, we would stand to lose the substantial benefits that we have already gained from Earth science research and application to the detriment of society. Continued aggressive support of these R&D and operational efforts is an essential component of the future of the economy and security of our nation.

Thank you Mr. Chairman, for this opportunity to present my views on these important topics. I welcome questions or comments.

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From 1979 to 1995, he was a Senior Associate and Project Director in the Office of Technology Assessment of the U.S. Congress. While at OTA, Dr. Williamson was Project Director for more than a dozen major space policy reports on a variety of space subjects.

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Dr. Williamson received his B.A. in physics from the Johns Hopkins University and his Ph.D. in astronomy from the University of Maryland, and spent two years on the faculty of the University of Hawaii studying diffuse emission nebulae. He taught philosophy, literature, mathematics, physics and astronomy at St. John's College, Annapolis for ten years, the last five of which he also served as Assistant Dean of the College.

Dr. Williamson is a contributing editor to the journals *Space Policy*, and *Imaging Notes.* From 1998-2001 he was a member of the Aeronautics and Space Engineering Board of the National Academy of Engineering. He is also a Corresponding Member of the International Academy of Astronautics.

Published books include:

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