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## Meeting State and Local Needs for Space-based Data and Information

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Mr. Chairman and Members of the Subcommittee on Aeronautics and Space of the House Science Committee. I am delighted to be here to testify about the benefits of Federal investments in Earth observations from space for state and local governments. For the last 20 years I have followed and analyzed the development of U.S. remote sensing and geographic information 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 decades, the United States has made astounding progress. 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. Geospatial technologies are a diverse collection of software and hardware that allow one to link a precise location and time with objects on the surface of the Earth (table 1). Geospatial technologies, particularly remote sensing coupled with geographic information systems (GIS), also have enormous potential for improving the security of the nation's critical infrastructure (box A).

The federal investment has been key to bringing these technologies to a status where they can truly benefit state and local authorities. Whether through NASA and NOAA, or through the innovative use of these technologies by other federal agencies, the federal investment has provided basic research in support of applications for the public benefit. Nevertheless, a lot needs to be done to ensure that the promise of these powerful technologies benefits individuals at the state and local level.

## *Table 1.—Illustrative Geospatial Technologies*

- Geographic Information Systems (GIS)
  - Map making
  - Geographic decision analysis
- Position, Navigation, and Timing (PNT)
  - U.S. Global Positioning System (GPS)
  - Russian GLONASS
  - European Galileo (in development)
- Remote Sensing
  - Imaging, e.g.,
    - Landsat Thematic Mapper
    - Ikonos, Quickbird, high resolution commercial satellites
    - Aerial photography, radar imaging
  - Non-imaging, e.g.,
    - LiDAR (laser ranging)
    - Atmospheric sounders
    - Chemical, biological atmospheric sensors

## *Box A. Remote Sensing in Support of Critical Infrastructure Protection*

Remote sensing technologies include both imaging sensors and non-imaging sensors (table 1). Remote sensing and other geospatial information technologies provide a vital spatial and temporal foundation for all phases of the U.S. response to terrorist threats:

- **Detection:** New digital techniques allow for "data mining," the rapid spatial and temporal comparison of both imaging and non-imaging sensor data, to craft effective and efficient threat analysis. By linking and analyzing information related both temporally and spatially, it is possible to detect potential threat patterns and likely terrorist targets.
- **Preparedness:** Emergency response planners require current, accurate, geospatial information that is readily available in interoperable databases. Up-to-date remotely sensed imagery aids planners in their planning process for responding to terrorist attacks, natural disasters, and other emergencies.
- **Prevention:** Patterns discovered through analysis of geospatial information provides a means to respond to terrorist threats and deter attacks. This information, when fused with additional information about borders, waters, and airspace, can help disrupt and interdict attacks.
- **Protection:** Remotely sensed data are particularly important for analyzing the vulnerabilities of critical infrastructure. Decision support technologies such as scene visualization and incident simulation assist in anticipating the direction and form of potential attacks and in designing protective tactics and strategies. Such technologies make it possible to view the interaction of transportation lifelines with other geographically related critical infrastructure, such as power plants, population centers, and financial centers.
- **Response and Recovery:** Effective response to natural and human induced disasters requires the rapid analysis of imagery and other sensor data acquired both before and after the event. Such information will enable emergency response services to clear blocked transportation routes rapidly and to reroute traffic efficiently. Likewise, recovery efforts depend on the acquisition and analysis of timely imagery and other remotely sensed data that might indicate the presence of toxic or noxious chemicals. Compatible, interoperable geospatial databases containing base information that can be rapidly updates will assist in saving lives and reducing costs.

SOURCE: Federal Geographic Data Committee and Space Policy Institute

**Remote Sensing and Transportation**

My own remote sensing research has focused recently on two areas: developing methods to increase safety and reduce risk to hazards on rural roads; and developing a research agenda for applying remote sensing to the security of U.S. transportation lifelines. The projects I direct are part of a broad based research consortium, funded by the U.S. Department of Transportation in partnership with NASA. The National Consortium for Remote Sensing in Transportation (NCRST) is focused on developing software products for state and local communities, because that is where many of the crucial transportation, as well as development and environmental decisions, are being made.[1] State and local agencies generally do not have the funding to conduct research into new ways of using the results of Earth science research, but they are very open to partnerships with NASA, NOAA, the Department of Transportation, and other federal agencies that would improve their operations and further their ability to serve the citizens of their state.

The particular consortium to which George Washington University belongs, NCRST-H,[2] centers its research on remote sensing technologies for transportation safety, hazards, and disaster assessment. Our consortium is developing a series of tools to assist state and local communities with applying the tools of remote sensing to transportation. It has projects for such important transportation issues as: operating safer local airports; increasing pipeline safety; improving E-911 systems and emergency evacuation, and increasing the safety of rural roads. All of these issues are of considerable interest to state and local communities. Two projects with which I am involved provide examples:

- ***Improving safety on rural roads.*** Rural roads often do not receive the design attention that the larger, more expensive projects receive. Yet, they are critical to the rural economy. Dr. Douglas Fuller of GW's Department of Geography and I are developing inexpensive software to analyze the risks that drivers face while traveling rural roads. This software will give state and local transportation analysts a new analytic tool to examine potential hazards and reduce the risks they pose to motorists.
- ***Improving transportation security***. The nation's transportation networks function as the lifelines of commerce, security, and recreation. They are also vulnerable to attack and severe disruption. As transportation officials have discovered since September 11, protecting and preserving the extensive U.S. transportation networks against terrorist attacks remains a daunting task. Our consortium is also developing methods to improve the security and reliability of the nation's transportation infrastructure using remote sensing tools. To assist that effort, the Space Policy Institute recently held a workshop to develop a research agenda for transportation security. That workshop not only drafted a research plan, but also underlined the need for much more effective sharing of crucial geospatial information among federal, state, and local offices. Without better coordination and a willingness to make geospatial databases more interactive, any new remote sensing technologies developed will be much less effective than they could and should be. The rescue and cleanup efforts at the World Trade Center last year demonstrated both the best and the worst of data

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[1] See http://www.NCRST.org/

[2] See http://www.trans-dash.org/

sharing among the participants. Lessons learned in that effort, if heeded, will go a long way toward improving the security of transportation lifelines.

**Social and Economic Benefits**

In addition to this remote sensing research, with GW economist Dr. Henry Hertzfeld, I have been leading a NASA-sponsored study to assess the socioeconomic benefits of NASA's Earth science research. The first phase of that study focused on the benefits to the nation of developing improved predictions of impending natural disasters—floods, drought, wildfires, hurricanes, tornadoes, earthquakes and so forth. That study was largely retrospective, as it examined the gains that have already been made. Future research will focus on additional benefits that can be gained by continuing investments in Earth science research. I have made copies of the first report, *The Socioeconomic Benefits of Earth Science and Applications Research: Reducing the Risks and Costs of Natural Disasters in the United States* available to the Committee.

The preliminary conclusions of this study are highly relevant to today's hearing:

1. ***Natural disasters cost the United States over $14 billion each year.*** Within the United States and its territories alone, between 1980 and 2001, major weather and climate disasters costing over $1 billion per event created losses of more than $248 Billion (1998 dollars) and led to the loss of some 690 human lives.[3] The estimates of loss of life do not include several thousand people whose death can be attributed in part to heat stress from prolonged periods of heat. In that same period, earthquakes and volcanoes cost the United States an additional $41 billion and 193 lives. Thus, the United States suffered measurable economic losses during that 21-year period of nearly $14 billion per year. Damages from the smaller destructive storms such as the tornados that have struck throughout the country this spring add even more to the bill. Most of the economic and social costs are borne directly by individuals and authorities at the local and state level, although federal aid is also substantial.
2. ***The costs of natural disasters are increasing yearly***. The number of great natural catastrophes[4] worldwide increased fourfold from the 1950s to the 1990s, for the most part because of increasing population concentrations, especially along the coasts and river drainages. These disasters also carry a higher price tag than in the past; the economic losses from natural catastrophes, after adjusting for inflation, increased by an astonishing factor of fourteen within the same timeframe.[5]
3. ***The risk to property and human life is directly related to uncertainties regarding the onset and severity of impending destructive events.*** Reducing these uncertainties

[3] Tom Ross and Neal Lott *A Climatology of Recent Extreme Weather and Climate Events*, National Climate Data Center Technical Report 2000-02., October, 2000 [http://www.ncdc.noaa.gov/ol/reports/billionz.html].

[4] Munich reinsurance defines a natural as *great* "if the ability of the region to help itself is distinctly overtaxed, making interregional or international assistance necessary. This is usually the case when thousands of people are killed, hundreds of thousands are made homeless, or when a country suffers substantial economic losses, depending on the economic circumstances generally prevailing in that country."

[5] http://www.munichre.com/pdf/topics_2000_a5_e.pdf

for severe weather conditions such as hurricanes, tornadoes, harsh winter storms, and flooding would allow local officials and individuals to prepare ahead, reducing economic losses and human suffering. Thus, better information can be translated into direct economic value. If Earth science research could help reduce future losses by as much as 10 percent, the U.S. economy alone would benefit by over $1.4 billion per year.

4. ***Some of these costs can be reduced with improved predictive techniques made possible by investments in Earth science research.*** Beyond reducing the costs and loss of human life resulting from natural disasters, greater accuracy in predicting future weather and climate patterns, coupled with effective planning, would enable farmers, developers, energy producers, land managers, and a host of other occupations to mitigate some of the harmful effects of weather and climate, thereby reducing resulting future economic losses. Lengthening the warning time for the onset of major earthquakes could sharply reduce losses of human life. In short, information has economic value; the practical applications of improved predictive capabilities will, if realized, result in considerable benefit to the U.S. and global economy.

Our report cites a few specific examples in which remote sensing technology has assisted communities to reduce the costs and suffering from severe storms, at home and abroad. The development of these technologies also presents a business opportunity for U.S. companies:

- ***LiDAR topographic studies***. LiDAR systems, which employ a rapidly firing low-intensity laser flown over the landscape, were developed originally with funding from NASA and other federal laboratories. Flown on an aircraft, they can be used to create detailed topographic maps of the Earth. Broward County, Florida, which is often on the path of late summer hurricanes, has reduced its evacuation costs for these damaging storms by creating a highly detailed map of the county's topography using LiDAR technology. In the past, this low-lying county routinely evacuated some 450,000 residents when faced with the threat of particularly severe hurricane strikes because county officials had only a low quality map of the topography and therefore never had a clear idea of which areas of the low-lying county were likely to be flooded. The LiDAR study has enabled the county to reduce the number of evacuees for the most damaging hurricanes dramatically, to about 250,000, sharply reducing evacuation costs for the county and its residents.

  In the aftermath of the incredibly damaging Hurricane Floyd in 1999, the state of North Carolina is conducting a similar study for the entire state, enabling North Carolina officials to predict more accurately the extent of future flooding. Similar studies of topography along Kansas drainages would greatly improve flood predictions in this state, thereby reducing the costs of flood damage and enabling residents to escape particularly dangerous floods in a timely manner.
- ***Increasing warning times for severe storms***. Satellite data from NOAA's Geostationary Observational Environmental Satellite (GOES) System, along with ground based radar have sharply improved the National Weather Services' ability to track the development and growth of severe storms, such as hurricanes and tornados. Warning times for both classes of storms has increased, which has resulted in fewer lives lost. Future improvements in the GOES satellites will add to this capability.

**Bringing Greater Benefits to the States and Local Communities**

Recently, the Space Policy Institute held a workshop devoted to understanding how future NASA investments in Earth science research directed toward improving weather and climate prediction would benefit the nation economically. Our participants, which included economists and policy analysts as well as scientists, concluded that continued investments in Earth science research would be beneficial, not only for the economy, but also in terms of quality of life. However, workshop participants also noted that conducting business as usual will not result in substantially greater benefits to the end users of the Earth science data and information unless NASA, NOAA, and other federal agencies devote significantly more attention to the *process* of gaining benefit from investments in Earth science.

Moving from research to applications to benefits for an end user of information (e.g., the farmer, transportation planner, resource manager, energy supplier, or a family planning for vacation) has generally been thought of as a linear, or pipeline, process where one puts federal dollars into basic research, which later through applied research, is developed into a technology that eventually turns out useful products or information (figure 1). However, the reality is much more complex than that, with feedback loops throughout (figure 2). The particular case of weather and climate information is even more complex (figure 3). Because of the complexity of the process, it is also much harder to accomplish than is often perceived. Further, workshop participants noted that a number of unrelated impediments may undercut the process. Hence, it is important to focus much greater effort than previously expended on understanding the process and improving how it works in practice.

The following points will illustrate some of the more notable impediments to better utilization of scientific information for applications:

- ***Data analysis is often underfunded***. Typically, mission budgets contain a certain amount for data analysis and detailed science research after the satellite is successfully launched. However, if, in the development process, the satellite budget becomes squeezed, either because the development team encounters unexpected technical difficulties or because Congress limits the funds after construction starts, resources necessary to complete the satellite and launch it are often taken from the science budget, leaving too little to utilize the data adequately.
- ***Collected data are often unused.*** Once the satellite is flying it generally makes sense to collect as much data as possible because the major expense is in developing and launching the satellite. However, that means that often, large quantities of potentially useful data go un-analyzed for a variety of reasons, including lack of funding. Often it is because the applications community hasn't yet learned how to use the available data. Hence, if NASA and NOAA were to put greater effort into making the transfer to applications occur more efficiently, the data would not only contribute to the solution of important scientific problems but also find utility at the state and local level. One possible mechanism for making this transfer is to require each funded research project to identify, if possible, one or more applications of the scientific results and an outline of how to accomplish the application.
- ***Lack of exposure, lack of training***. Two of the major impediments to wider use of remotely sensed data and information are the lack of exposure to remote sensing

technologies and the lack of training in using them. The first involves a public relations effort with the mid-level managers who make the state, local, and private sector funding decisions in a wide variety of disciplines. These managers need to understand better how the data and information generated by NASA's and NOAA's programs would benefit the broad community of applied data users. The second, training, involves direct hands-on training of the workforce who will actually turn the raw data into useful information. This is not a simple problem because the potential user community is very broad and diffuse, so the agencies have to become smart about a range of potential applications, each of which has special needs for data products. Nevertheless, targeting a few important communities, such as the transportation or land planning communities would go a long way toward bridging the gap.

It is clear that if we can do a better job in removing the barriers to utilizing the data, state and local governments, as well as private data users will benefit enormously. NASA's current efforts to improve the applications focus of the Earth Science Enterprise will go a long way toward addressing these systemic problems, some which have been with us in one form or another since the launch of the first Landsat satellite 30 years ago this July. The potential benefits are great, not only for the United States, but also for other countries.

Two other points can be made regarding the potential benefits of Earth observations from space. 1) They could play a central role in assisting the economies of other countries and reducing social costs; and 2) U.S. businesses could benefit substantially by developing information tools that can be marketed abroad.

- ***Reducing costs and human suffering from storm damage in developing countries***. Over the long term, the U.S. investment in earth science research will also accrue to the developing countries, which are sadly lacking in the capacity to acquire and analyze the data NASA and NOAA produce, and which are available globally at relatively low cost. However, these countries often suffer staggering losses of human life, property, and future income as a result of natural disasters. These losses can often destabilize the economy of these nations, leaving them open to political forces that are unfriendly to the United States. Reducing losses in these countries also helps to alleviate the support these nations receive in the form of disaster relief and aid, and enables them to participate more readily in the global marketplace.
- ***Business opportunities***. The United States leads the world in the development of remote sensing and other geospatial information products. What technology developers learn about transfer of remote sensing technologies to the state and local level will also help U.S. companies to develop appropriate technologies to market at home and also abroad. The primary engine for developing these new products is the university community working in conjunction with the private sector. For example, the high resolution data provided by the U.S. satellite imagery companies Space Imaging and DigitalGlobe have proved to be of great value where sharp, multispectral imagery of urban environments are needed for planning purposes, whether for businesses or the local government. They also assist in recovery and reconstruction from storm damage. Other companies can assist by generating software and hardware to make use of these remarkable images. The global market

for U.S. geospatial technologies represents a remarkable opportunity for companies in Kansas and other states to contribute to the growth of the information economy.

In summary, state and local entities have benefited substantially over the years by the federal investment in space technologies. However, greater federal effort is needed to reap the maximum benefits from the gains that have been made. This does not necessarily involve more funding, but rather, detailed attention to the process of turning science investments into practical solutions to today's challenges.

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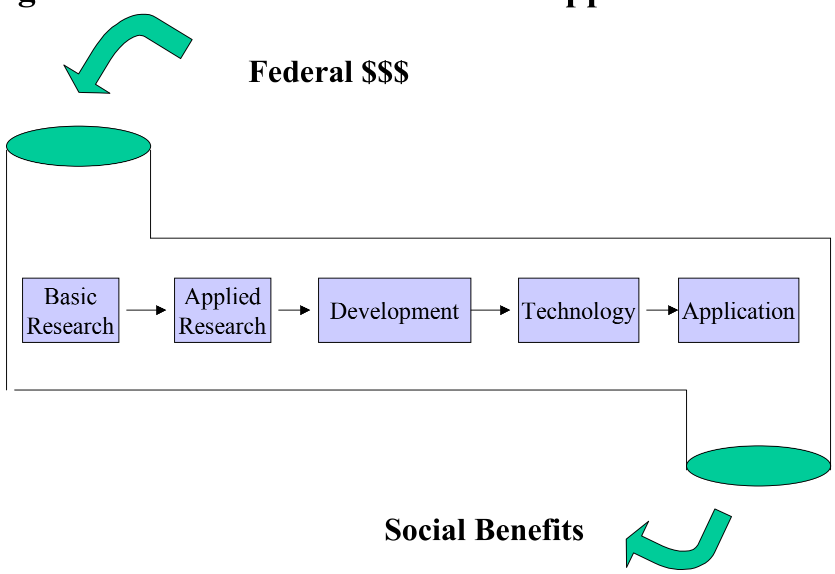
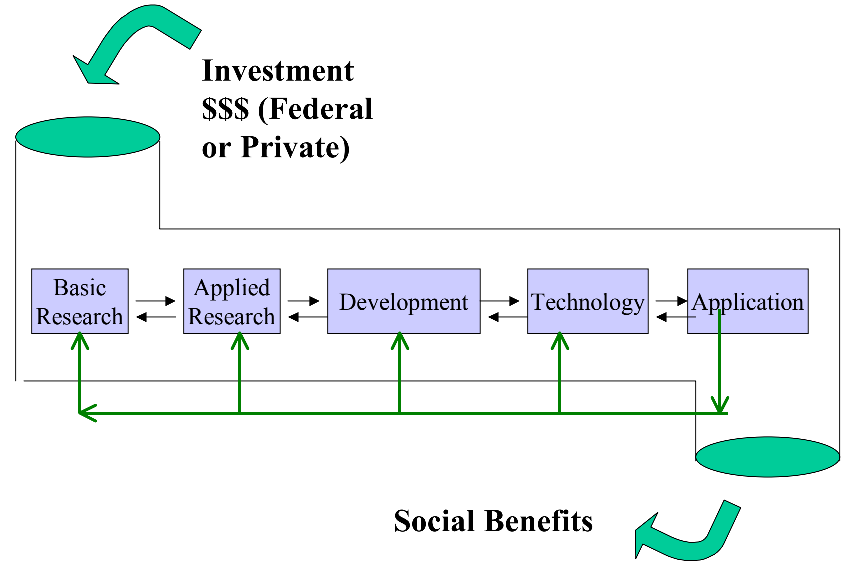
**Fig. 1: Common Model of R&D to Applications**



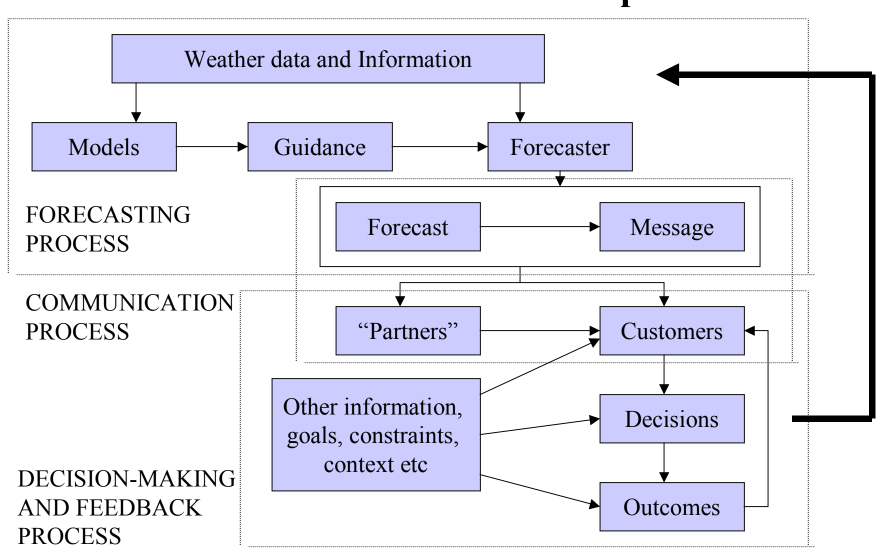

Source: Roger Pilke, Jr.

## Fig. 2: The Actual R&D Pipeline is Interactive




Source: Henry R. Hertzfeld

## Fig. 3: Reality in the weather forecasting process is also interactive and complex




Source: Roger A. Pielke, Jr.