CURRENT SITUATION AND VIEW TO THE FUTURE OF REMOTE SENSING IN THE USDA FOREST SERVICE

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Before looking at the current situation or future of remote sensing in the USDA Forest Service, let's reflect upon the past Forest Service Remote Sensing Conferences. This is our seventh Remote Sensing Applications Conference. The fact that we have such good participation and continued interest is a testament to the hard work that so many have devoted to the conference over the years. Yesterday we had a wonderful fieldtrip to the Johnson Space Center, continuing a close cooperative relationship with NASA at these conferences. This is the fourth time we have had the privilege to visit a NASA facility during this conference. First at Ames in 1986, then Stennis in 1988, Kennedy Space Center in FL in 1992, and this year in Texas. I'm also very happy the conference has returned to Region 8, host of two previous conferences.

Over the past 12 years of these conferences, we have seen many marvelous new developments in the field of remote sensing and related technologies that each of us work so hard to development and utilize in support our business or agency. It is truly amazing to see how far we have come. But, there is more we can do. It's easy to get overwhelmed with the complexities of our business, using advanced geo-spatial data technologies to support the complex business of ecosystem management. But don't feel like you stand-alone.

There have been truly great minds that have backed away from working in this field. I'm sure Albert Einstein never heard the term "geo-spatial" generally used in the context of discussing or describing digital geographic data. What would Mr. Einstein think of our industry today? He once wrote in a letter, "As a young man, my fondest dream was to become a geographer. However while working in the customs office I thought deeply about the matter and concluded that it was far too difficult a subject. With some reluctance, I then turned to physics as a substitute." I don't know how many of use would turn to physics as a substitute, but I do find this a fascinating field, especially at this time.
Before we discuss the current situation and future outlook of remote sensing in the Forest Service, I’d like to review how the Forest Service has allocated financial and human resources in the areas of geo-spatial data collection and management.

GEO-SPATIAL DATA RESOURCES

Financial Expenditures

Expenditures for geo-spatial data within the Forest Service have varied by program and year. Last year the Forest Service, Bureau of Land Management, United States Geological Survey, and National Ocean Survey sponsored a National Academy of Public Administration (NAPA) study of Geographic Information (GI) to better determine and balance the role and functions between the government and the private sector. As part of this study, each sponsoring agency provided data on resources expended to support Geographic Information (GI) related activities. This was a significant undertaking, as many people at all levels of government, the private sector, and academia devoted countless hours providing information, insights and ideas to the panel and NAPA staff.

![Figure 1. Geo-spatial data collection expenditures by the USDA Forest Service.](image-url)
One of the more difficult activities of this study was providing a coherent report on expenditures, as most Forest Service expenditures are derived from natural resource budgets to accomplish natural resource management goals, and not related to appropriations for geo-spatial data product development and dissemination. As you can see from Figure 1, budgets for survey and boundary management activities have been significantly reduced, while remote sensing and mapping has been flat. GIS expenditures have increased significantly. After 1994, accounting methods associated with the IBM contract, to modernize office automation and implement GIS, made it impossible to distinguish GIS costs from other related office automation improvements.

Personnel numbers (FTE's) in remote sensing and GIS have increased slightly from 1992 to 1998 (Figure 2). However, in Geometronics and boundary management, there have been significant decreases, with a 38% reduction in surveyors and 20% overall reduction in geometronics. Impacts on individual regions have been even more significant. The percentage of total expenditures contracted to the private sector has increased in all areas of GI functions.

Figure 2. Personnel numbers associated with geo-spatial data activities in the USDA Forest Service.

**AERIAL PHOTOGRAPHY**

With all the speculation on high-resolution satellite systems making the headlines, the Forest Service continues to rely heavily on aerial photography for information collected on the national forests. Five primary programs are used for aerial photography acquisition: 1) resource aerial photography contracted to the private sector by the USDA Aerial Photography Field Office (APFO); 2) the
National Aerial Photography Program (NAPP); 3) in house (force account) operations in Atlanta, Ft Collins, Ogden, and Portland; 4) special project contracts administered by regional offices; and 5) liaison with NASA for ER2 and U2 flights over selected areas for special emergency response, forest health and resource management initiatives.

Resource Aerial Photography

In 1997, 39 contracts were administered to fly over 60,000 square miles at a cost of just over $1 million (Table 1). Over the past five years we have seen a significant increase in the completion rates of these contracts because of improved communication and coordination between APFO, the contractors, and the Regional Offices.

<table>
<thead>
<tr>
<th>Contracts Administered</th>
<th>1997</th>
<th>1996</th>
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<tbody>
<tr>
<td>New Contracts</td>
<td>39</td>
<td>42</td>
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<tr>
<td>Linear Miles</td>
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<td>Square Miles</td>
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<td>Total cost</td>
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<td>$691,980</td>
</tr>
<tr>
<td>Completion Rate (flying only)</td>
<td>88%</td>
<td>99%</td>
</tr>
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</table>

Table 1. Resource aerial photography activity in 1996 and 1997.

The National Aerial Photography Program

The NAPP continues and is healthy. Established in 1987 to provide high-resolution CIR or B&W photography of the conterminous United States, quarter quad centered at a scale of 1:40,000. It is a multi-agency activity coordinated by a steering committee made up of the USGS (chair), Farm Services Agency (FSA), Natural Resource Conservation Service (NRCS), and Forest Service. The National Agricultural Statistics Service (NASS) and Tennessee Valley Authority (TVA) also participate. The primary objective is to reduce cost and eliminate duplication of effort obtaining complete, uniform aerial photo coverage of the United States. The USDA contributes approximately 65% of the overall cost, while the USGS is the largest single contributor.

We are currently in the third cycle of the NAPP. In this third cycle, we have gone to a seven-year rotation (Figure 3) to allow all states to be completed in a dependable schedule, as the previous NAPP cycles were never fully funded. Nine states are up for procurement consideration in 1999. Pennsylvania was skipped in 1998 and is up for reconsideration. Due to problems in the previous cycle to acquire Colorado, this state has been moved up for consideration in 1999.
Figure 3. Seven year schedule for the third cycle of the NAPP.

It is uncertain what will happen after the third cycle of the NAPP. With high-resolution satellite systems anticipated, the steering committee will be evaluating other options for supporting a digital Orthophoto (DOQ) like digital image product in the future.

NATIONAL DIGITAL ORTHO PHOTOGRAPHY PROGRAM

The National Digital Orthophotography Program (NDOP) uses the NAPP as the source to support one of the fastest growing geo-spatial data products in the country. DOQ's combine imagery with map accuracy and scale, with displacements removed. The goal is to complete coverage of the United States by 2002, contracting to the private sector to produce the product at a scale of 1:12,000, with 1m resolution, quarter quad centered. Cooperative funding and production agreements are encouraged. The NDOP is also operated by a steering committee for oversight and guidance.

We are on tract to meet the year 2002 goal with 70% of the country already completed or in work. The Forest Service Geometronics Service Center (GSC) has entered into production agreements with the United States Geological Survey (USGS) and also has DOQ contract and in-house production capabilities to support DOQ production on approximately 20% of the United States on which national forest occur by quad, or about 10,500 quad sheets.
SUPPORT TO WILDLAND FIRE SUPPRESSION

During the conference in Denver in 1996, we were beginning one of the most damaging and worst fire seasons in the history of the United States. Fires were raging in New Mexico and Texas in April. During this extended fire season, over 6 million acres burned and at one time over 21,000 men and women were actively engaged in fire suppression activities. $721 million were spent in suppression activities alone.

Remote sensing continues to play a major role in all phases of emergency management. The Forest Service and BLM, along with other federal land management agencies, with state and local fire officials, are viewed as world leaders for applying wildland fire suppression technologies. Remotely sensed data is the best source for accurate and timely information to help in all phases (preparation, mitigation, response, and recovery) of wildland fire activities. Remote sensing is used to help protect fire fighters and natural resources by identifying critical information needs of the incident command.

The Remote Sensing Applications Center (RSAC), working with the National Interagency Fire Center (NIFC), has made major improvement in our air borne detection and suppression support capabilities. Airborne infrared (IR) scanners produce digital images which are geo-referenced using the Global Positioning System (GPS) Precise Positioning Service (PPS) capabilities, which are electronically transmitted to the incident command and field locations. RSAC and NIFC continue to improve these products to provide increased electronic delivery speeds over larger areas, with digital images displaying better information on fuels, terrain and infrastructure. Providing this information in a geo-reference and terrain corrected format is not a trivial task, and will require further developments in order to operate in near real time, available by 5 or 6am for morning planning briefings.

In addition to the advances made in remote sensing support to domestic fire suppression, the Forest Service has been active in support of international wildland fire suppression. The El Nino has caused extended droughts in many tropical areas of the world, creating one of the worst environmental disasters in the history of Southeast Asia. In Indonesia, several million hectares have burned, causing loss of lives and property on a monumental scale. Human health concerns from smoke and haze, transportation accidents, loss of endangered wildlife habitat (especially affecting the orangutan and Sumatra tiger) have lead to a large international fire suppression and assessment effort.

The Forest Service, working with the National Imagery and Mapping Agency (NIMA), has provided maps displaying areas of actively burning and intense fires to provide tactical support and post fire assessment information in Java, Kalimantan, and Sumatra. These maps are installed on the Forest Service home
page and made available to the world via the Internet. These maps may be found at the following URL address: http://www.fs.fed.us/eng/indofire/.

GLOBAL POSITIONING SYSTEM APPLICATIONS

Advances in Global Positioning System (GPS) applications are another area in which the resource conservation and land management community can be very proud of their contributions. GPS has become truly pervasive within the Forest Service, supporting all resource staff functions. The Forest Service has invested over $10 million in GPS receivers alone. Approximately 1000 professional resource grade receivers are in use, over 350 P(Y) code receivers are actively used, and a multitude of low cost receivers are used which have not been accounted for in our national procurements. Seventy-five survey grade receivers support boundary management functions. With approximately 276,000 miles of property and boundary lines to mark and administer (that's equivalent to about 55 round trips between New York City and Los Angles) GPS has allowed Forest Service surveyors to accomplish more in their overwhelming responsibility to survey and mark national forest boundaries.

GPS is broadly used in inventory and monitoring to help navigate to inventory plots and record their location. Geodetic control acquired from GPS for mapping and DOQ production has allowed greater advancement in these areas, traditionally a major bottleneck in our Geometronics production flow of work. An increasing larger segment of society is using GPS for recreational purposes on national forest lands, so we are seeing increased usage within the Forest Service and by our publics.

The Forest Service GPS steering committee continues to address issues which have broad national importance. The Forest Service has the distinction of developing the first national differential base station network. Most of these stations continue to operate and the data from many are now provided over the Internet from a Forest Service web page free of charge. We will continue to cooperate with other federal agencies to support the development of continuous operating base station networks.

We will continue to support the evaluation of receivers at the four Forest Service test sites to determine the effectiveness and efficiently of equipment, demonstrated in the working environment of most Forest Service applications. Coordination with industry on user requirements is essential. Continued training and support is also necessary to maximize our use of GPS. The proper integration of GPS collected data into our information management systems is critical.

There have been many new developments within the GPS industry and community. On March 30, 1998 Vice President Gore announced that a second civilian signal would be provided by the GPS system. The addition of a second
frequency will enhance the accuracy, reliability and robustness of civilian GPS receivers by enabling them to make more effective corrections for the distorting effects of the earth's atmosphere on the signals from space. On March 26, the Interagency GPS Executive Board selected the L2 signal after months of deliberation. Most of the new survey grade GPS receivers use radio communications, which require dedicated frequency allocation. Some resource grade units have real-time differential GPS capabilities using beacons or satellites. Most of the United States will be covered with real-time differential broadcasts soon. We will need dedicated frequency to avoid interference from other applications, such as voice communications. We have also been successful in gaining the authority to allow contractors and cooperators to use the encrypted P(Y) code receivers.

REMOTE SENSING AND LARGE AREA ASSESSMENTS

Environmental awareness has been increasing in all areas of the country for the past three decades. Natural resources are now recognized to be scarce and fragile, and environmental protection remains an important societal concern. Commodity production is also a major concern, with increasing demands placed on the Forest Service to produce more revenues to support local and national initiatives. The significance of biodiversity and ecosystems information for helping to understand, manage, and protect natural resources and the environment is experiencing growing acceptance. At the same time, traditional jurisdictional boundaries are not as relevant to environmental conditions and concerns because the actions of individual landowners increasingly impact lands in other political jurisdictions. Accordingly, there is a growing desire to understand and manage ecosystems regardless of administrative and ownership boundaries. There is an increasing governmental emphasis on regional and broad area approaches to planning land management activities (Figure 4).

![Figure 4. Large area assessments in the United States.](image-url)
While only a handful of broad area assessments have been conducted, over 800 watershed councils and groups have been initiated at regional and local levels in both rural and urban areas. Remote sensing and GI has played a prominent role in supporting broad area planning to reduce the cost and impact of the forest plan revision process. We are currently in the middle of the forest plan revision process for the majority of national forests. Remote sensing and GI are essential tools to allow for better public understanding and input to support adaptive management during the plan revision process.

**EARTH OBSERVATION SATELLITE SYSTEMS**

Most of the data sources used by the Forest Service have remained relatively constant over the past 12 years. We still use most of the same types of data to support our programs. However, we are on the verge of realizing significant changes within our industry.

In the near future, we can expect to acquire imagery from multiple new high-resolution platforms, operated by many governments and private sector providers. Systems will be multi and hyper spectral, radar, panchromatic, and thermal. Resolutions will vary from 1m to 5k. Swath width will vary from small area coverage to global coverage. Some acquiring imagery twice daily, while others on only a monthly basis looking at the earth from various angles and ranging in cost from free to the mega budget busters. Let's take a look at what the current situation and outlook is for remote sensing in the next three years.

Landsat 5 continues to provide uninterrupted converge of the earth. SPOT 1 and 2 continue to operate and India has successfully operated two earth observation satellites during this period. The NOAA polar orbiters continue to provide AVHRR data, and the Canadian RadarSat system is providing the first commercially available radar data (Figure 5).

![Figure 5. Pre-1997 earth observation systems.](image-url)
Launching and operating earth observation satellites is a risky business and several failures were notable in 1997. The NASA funded small-sat Lewis was lost. The first high-resolution commercial remote sensing satellite Earlybird, built and launched by Earthwatch was lost. Spot 3 stopped sending imagery to receiving stations. However OrbView 2, a system providing imagery similar to AVHRR but at higher resolutions was the first commercial system to achieve orbit and operational status. India was again successful in launching a system with 6m Pan and a 4 band multi-spectral system (Figure 6).

1998 will be a busy year if launches go as scheduled. SPOT 4 was successfully launched on March 23. SPOT 4 will have a new SWIR band and an instrument called the vegetation mapper. Land management agencies have high hopes of using this system in vegetation mapping activities. The first of 4 planned SPIN-2 satellites was successfully launched. Clarke the second of the NASA small-sats, planned to acquire hyperspectral imagery, has been cancelled. The Space Imaging EOSAT satellite, Ikonos 1 is scheduled for launch this year and will provide 1m Pan and 4m multi-spectral data. OrbView 3 is scheduled to provide 1m Pan and 8m multi-spectral data. In 1998, the first in a series of Earth Observation Satellites (EOS) will be launched. Landsat 7 is now scheduled for launch in early 1999, will provide 15m Pan and 30m multi-spectral data to support the continuity of Landsat imagery into the future. Landsat 7 imagery will be provided at the cost of fulfilling a user request (Figure 7).

As we enter the new millenium, the skies will be filled with new earth observation systems. The United States is taking a wait-and-see attitude for a follow-on Landsat system (possibly called Landsat 8). However, if plans to
design and launch a follow-on Landsat system are not initiated soon, there are concerns about the ability to design, build and launch a successor to Landsat 7. Another SPOT, Indian, and Quickbird are planned. A constellation of four Resource 21 satellites will have the temporal resolution to meet many of the agricultural requirements of the USDA (Figure 8).

Figure 7. New or proposed earth observations systems in 1998.

One of the newest systems has been proposed by Vice President Gore. This new system will allow 24 hour, continuous observation of the sunlit surface of the earth, and broadcast imagery over television networks and will be available on the Internet. The Vice President suggests this will increase public awareness of the fragility of the earth and allow observation of major meteorological and other events such as large wildland fires, at a 5k resolution. The proposed name for the new system is Triana, after the lookout on watch that discovered the New World during the voyage of Christopher Columbus.

Over the next ten years, approximately 1700 satellites will be built and launched. Most of these will be for communications, others for military and civil applications. Only a fraction of these systems will be for earth observation purposes. However, keep in mind that many space vehicles will be platforms for multiple sensors and applications.

Most commercial imagery providers have indicated they will follow a flexible pricing schedule. In the United States, aerial photography will compete with the new high-resolution systems. In denied areas pricing will be whatever the market will bear. Our ability to share information and the restrictions on data licenses will have serious consequences to many organizations. The increasing
availability of wide band communications and the spread of the Internet have served to accelerate the communication and exchange of ever-larger volumes of data. There is strong consensus within the communications industry that the current bandwidth limitations on data transfer constraining dissemination will soon be a thing of the past.

Figure 8. Post-1998 earth observation systems.

LOOK TO THE FUTURE

Recently I had the opportunity to visit the largest visitor center in the national forest system on the Caribbean National Forest. This was a beautiful learning and demonstration center on tropical forestry issues. Sustainability and protection of forests on a global basis, not just the tropics, is a growing societal concern. As I was leaving the visitor's center, there was an inscription on the wall that stated, "We do not inherit the earth from our parents, we borrow it from our children." I will keep this in my mind and hope you will consider this philosophy, as we provide land managers with the critical information needed to support ecosystem management and forest planning processes. The decisions made today on natural resources will have lasting impacts on future generations and will be viewed by the global community as a framework for global sustainable forestry.