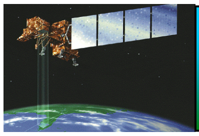


Chapter 1
Introduction and Background

Many sectors of society now use geographic, geospatial or spatial information (GI) and related information technology (GIT) to more effectively make decisions and manage operations to meet their missions. The continuing expansion, convergence and widespread availability of GIT capabilities in geographic information systems (GIS), remote sensing, the global positioning system (GPS) and related technology promise to accelerate applicability and benefits to an ever greater array of applications and policy needs. However, research and anecdotal evidence show that policy and institutional matters have a growing influence on the implementation and use of GIT.

1.1 Project Need and Description

State Forestry Organizations (SFOs) have a unique and critical role in the nation's governance. They serve in public land management, private land regulation, wildland fire management, and additional roles to address many of society's fastest growing concerns and needs. While their significance is growing due to these roles and the increasing impact of forestry on other matters of societal importance, the nation's SFOs also have a rich heritage of working with and learning from each other to better direct and manage their operations. At the same time, SFOs share one of the strongest and longest term relationships with the federal government of any state government function.

Many SFOs have a long track record of innovation, particularly regarding data management and technology adoption to meet their missions. Some SFOs were among the earliest state government GIT users (Warnecke and Decker 2002). Today, some SFOs are among the most extensive GIT users of any agency in some state governments. However, like many other governmental entities, SFOs are challenged by expanding technological capabilities and several policy, institutional and technological issues and financial constraints. This situation extends to all GIT, but is particularly evident and pervasive given many new and future remote sensing capabilities and opportunities.

State foresters, as the leaders of SFOs, must work with elected officials, state policy makers, internal staff, other agency directors and staff, federal counterparts and other stakeholders to best accomplish their missions. Several state foresters indicate that GI/GIT is an invaluable resource to understand, communicate, work with others and make effective decisions about conditions on the ground. They indicate that the unique capability to integrate otherwise often disparate information is particularly helpful. However, several challenges remain to make the best use of and realize the greatest benefits from these investments.

This context led to the establishment of a project, entitled ***Technology and Policy Aspects of Applying Remote Sensing in State Forestry Organizations***, to help state foresters and others learn more about opportunities and from each other to address growing needs concerning GIT, and particularly remote sensing. Funded by the National Aeronautics and Space Administration (NASA), the project is headquartered at the State University of New York's College of Environmental Science and Forestry (SUNY-ESF). The project is comprised of two separate but interconnected parts, the first addressing important technical issues associated with the application and accuracy of remotely sensed data, and the second focused on policy and institutional matters associated with remote sensing and other GIT adoption. This report is an intermediate product of the project, particularly the initial investigation into institutional and policy aspects of the use of remote sensing and other GIT by SFOs. The terminology used throughout the report is defined in **Figures 1-1a and 1-1b**.

Figure 1-1a. Report Terminology

Aerial photography – A form of photography taken from an aircraft using specialized cameras and mounts. Infrared aerial photography uses special film sensitive to invisible wavelengths of electromagnetic energy that are slightly longer than but very similar to visible wavelengths. These infrared wavelengths are very indicative of the presence and condition of vegetation, but have no direct relationship with heat or thermal characteristics.

Digital aerial data – A computer representation of imagery acquired from an aircraft. This type of data is produced either by digitizing aerial photographs or through direct acquisition by electronic sensors such as digital cameras or Forward Looking Infrared (FLIR) thermal imaging sensors. Common examples include digital orthophotos, digital ortho quadrangles (DOQs), and quarter quadrangles (DOQQs).

Digital elevation model (DEM) – A computer representation of terrain that provides elevation values for a series of features, usually points or cells.

Digital orthophoto, digital ortho quadrangle (DOQ) or quarter quadrangle (DOQQ) – A computer representation of an aerial or satellite image that has been processed to remove displacements of points caused by sensor tilt, topographic relief, or perspective geometry. These processed images have a consistent scale and can be used much like a map. A common example is the digital ortho quarter quads (DOQQs) produced in the U.S. for each quarter of a standard 7.5 minute U.S. Geological Survey quadrangle map.

Geographic or geospatial information (GI) – Information about a phenomenon that can be referenced to a specific location relative to the earth's surface.

Geographic information system (GIS) – A computer system that is capable of assembling, storing, manipulating, analyzing, and displaying geographic or geospatial information. GIS also can be considered to encompass the broader resources required for these activities, including computer software, hardware, data and personnel.

Geographic or geospatial information technology (GIT) – A broad term encompassing all forms of technology to gather, display, sample and process geographic or geospatial information, in particular including GIS, remote sensing and use of the global positioning system.

Global positioning system (GPS) – A system operated and maintained by the U.S. Department of Defense that is based on a constellation of satellites maintained in precisely known orbits about the earth. Ground-based electronic receivers determine locations (coordinates) on the earth's surface using information radioed from multiple satellites that are in view of the receiver.

Figure 1-1b. Report Terminology

Light Detection and Ranging (LIDAR) System – An instrument capable of measuring distance and direction to an object by emitting timed pulses of light in a measured direction based on the time between when a pulse is emitted and when its echo is received. Three-dimensional information is computed by relating these distance and direction measurements to the location and orientation of the instrument. Airborne LIDAR instruments are used to develop three-dimensional data such as digital elevation models (DEMs), tree and building heights, and feature geometry.

National Digital Orthophoto Program (NDOP) – A program jointly proposed in 1990 by the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service and Farm Service Agency and the U.S. Geological Survey (USGS) to ensure the availability to the public domain of photography, imagery and digital orthoimagery data. NDOP coordinates with the National Aerial Photography Program (NAPP) to provide imagery such as digital orthophoto quadrangles (DOQs) data that meet national requirements.

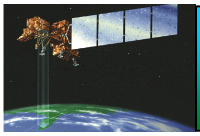
Radio Detection and Ranging (RADAR) – An instrument that emits a narrow beam of electromagnetic pulses (radio waves) in a specific direction and measures the time, intensity, or other characteristics of the energy that returns from targets or objects. RADAR imagery can be obtained at night or through clouds and smoke. RADAR images provide a very unique visual impression and advanced analysis of RADAR imagery usually requires specific experience, knowledge, and facilities.

Raster – An approach for representing and organizing space by subdividing a region into a regular pattern of cells (or pixels) that completely cover the region. Usually, square cells provide a grid of values for the condition or variable of interest. Digital imagery is a common example of raster data where cells contain values that represent different shades. See also Vector.

Remote sensing (RS) – Process of determining properties of objects without contact, usually by measuring and recording images based on electromagnetic energy that has interacted with the objects. Remote sensing also involves the manipulation of images to derive useful information. Remote sensing traditionally involves aerial photography but now includes many electronic sensors on both airborne and space-based platforms.

Satellite sensor – A remote sensing device that measures, images, receives, and transmits data from an orbital path above the earth.

Vector – An approach for representing and organizing space by subdividing a region based on points, lines, and polygons that delineate where conditions change. The points, lines, and polygons are defined using ordered lists of coordinate pairs. See also Raster.



Overall project direction is provided by Dr. Paul Hopkins, Professor at SUNY-ESF, who also manages the technical investigation. Additional project guidance is provided by the National Association of State Foresters (NASF), its member state foresters, and particularly its Research Committee chaired by Mr. Gerald Thiede, State Forester of Michigan. The policy and institutional component of the project is managed by GeoManagement Associates, Inc. and primarily conducted by Dr. Lisa Warnecke. Important assistance is provided by Dr. Zorica Nedovic-Budic, an Associate Professor at the University of Illinois at Urbana-Champaign, and Mr. Ronald Nanni and Mr. William Stiteler IV, SUNY-ESF graduate students.

The policy and institutional part of the project includes complementary research and outreach focused on the following goals:

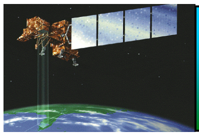
1. Establish working relationships with and gather continuing input from NASF, state foresters and their staffs, and other related organizations;
2. Gather, synthesize and analyze information about remote sensing and other GIT approaches and use in the 50 SFOs; and
3. Understand and communicate key policy and institutional issues concerning remote sensing and other GIT in SFOs and related organizations.

This document serves as an interim report for the policy and institutional part of the project. It provides an initial baseline understanding about how the nation's SFOs approach and apply remote sensing and other GIT, and begins to identify associated policy and institutional issues and challenges. The information and analysis provided in this report are designed to be informative for state foresters, their staff and others working with them. However, the results are also useful for others addressing policy and institutional issues related to remote sensing and GI/GIT adoption as implications are relevant for many other organizations. The results of this analysis will also be used in the second portion of the project's policy and institutional work. It will be used to help design and implement a follow up survey instrument to refine findings and further investigate conditions to identify issues, benefits, pitfalls, needs and lessons learned. This work will be used to generate suggestions and recommendations for future actions to address these concerns.

1.2 Forestry Characteristics Among the 50 States

Forestry has long been and will likely always be a worldwide, societal concern - with appropriate attention by government policy makers. Early focus concentrated on meeting demand for forest resources to meet societal building needs balanced with conservation values. Today and future challenges add recognition of the unique and high importance of forested lands to maintain and improve many aspects of conditions on the Earth. For example, much of the world's potable water (two thirds of the supply in the United States) originates in forests, and diminishing water quality is of growing concern. Increasing trends, such as forest fragmentation, can exacerbate problems and increase the urgency for attention and action.

The challenges and associated tradeoffs facing forestry and other policy leaders and interests are growing as never before. For example, the U.S. Forest Service (USFS) located in the Department of Agriculture, which is the largest forest land management organization in the country, operates with more and sometimes conflicting Congressional directives than any other federal land management agency (National Academy of Public Administration. 1998). Recent extensive changes in the ownership of industrial forested lands, growing pressures on the nation's many non-industrial land owners, and the growing activism of various



stakeholders in the U.S. also reflect the importance of forestry and associated challenges.

States, and their governments, vary considerably in terms of forestry, as for many functions of government. The overall land mass of the states and the relative amount of forested land within their borders differs dramatically. The most recent data available from NASF, the report entitled ***State Forestry Statistics - Fiscal Year 1998 Report****,* provides detailed data about conditions in each of the 50 states and SFOs except Alaska (Dupree 1998). For example, summarization of these data as shown in **Figure 1-2** reveal that forested land ranges from just over 300,000 acres in Delaware to over 39 million acres in California, and from 1.17% of a state's land mass in North Dakota to 89.67% in Maine.

Figure 1-2. Total and Forested Land Mass by State - Descriptive Statistics (in millions of acres)

	N	Range	Minimum	Maximum	Sum	Mean
Total	**49**	**171.12**	**0.68**	**171.80**	**1891.38**	**38.60**
Forest	**49**	**39.30**	**0.37**	**39.67**	**608.00**	**12.41**
% Forested	**49**	**88.50**	**1.17**	**89.67**	**-**	**42.03**

Source: State Forestry Statistics - Fiscal Year 1998 Report (Dupree 1998)

As shown in **Figure 1-3**, state foresters reported that ownership of forested land is about one-fifth of federal ownership (36.96 million acres and 165.1 million acres respectively). Correlation analyses reveal that the greater the acreage of forested land, the greater the forested acreage under state ownership. State land management is one of the most critical roles of SFOs, especially in states with large land holdings.

1.3 Characterizing State Forestry Organizations

While forestry is the top mission of many public and private organizations in the U.S., State Forestry Organizations (SFOs) likely have the widest range of roles, responsibilities, and activities of any type of forestry organization in the country. Approximately one third of the total

Figure 1-3. Land Ownership by State - Descriptive Statistics (in millions of acres)

	N	Range	Minimum	Maximum	Sum	Mean
State	**49**	**4.00**	**0.00**	**4.00**	**36.96**	**0.75**
Industrial	**49**	**10.66**	**0.00**	**10.66**	**92.76**	**1.89**
Non-industrial	**49**	**17.09**	**0.07**	**17.16**	**306.84**	**6.26**
Federal	**49**	**22.80**	**0.00**	**22.80**	**165.10**	**3.37**
Other	**49**	**2.80**	**0.00**	**2.80**	**13.05**	**0.27**

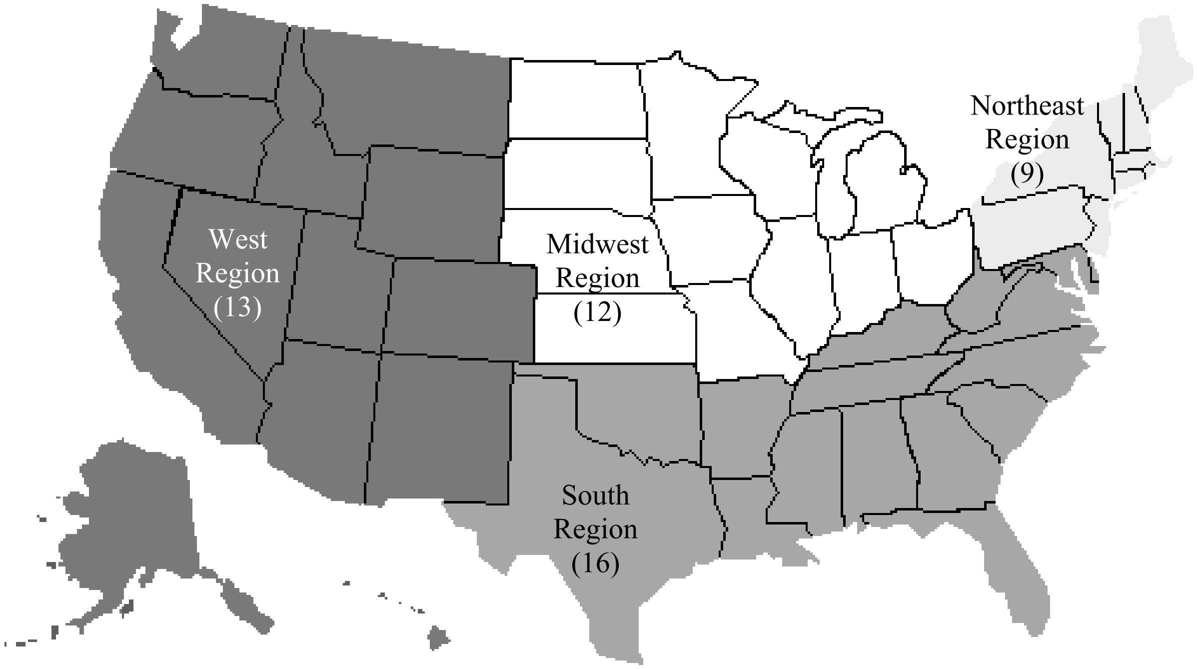
Source: State Forestry Statistics - Fiscal Year 1998 Report (Dupree 1998) land area of the U.S. is forested, but the federal government only has direct authority over lands under its management. As explained below, SFOs similarly have responsibility for lands management, but also have authority over private forested lands and manage several other forestry related programs. SFOs must balance many competing and often conflicting interests and needs in order to best direct, manage and plan for the best interest of their state's forest resources.

1.3.1 State Forestry Organization Responsibilities

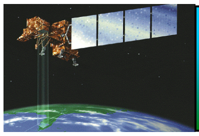
While most SFOs are responsible for managing forested lands under state ownership, land management responsibilities sometimes extend beyond forested lands in some states. Analysis of state government structures and primary state land management organizations reveals that 12 (or 24%) of the SFOs also are responsible for managing non-forested state-owned lands. Moreover, almost all 48 (or 96%) of the SFOs are responsible for wildland fire management, which also extends beyond forested areas.

Efforts are made in this project to compare regional conditions and determine any relevant differences. The standard four U.S. Census Bureau regions as shown in **Figure 1-4** are used in these evaluations.

Figure 1-4. U.S. Census Bureau Regions*



* Alaska and Hawaii in West Region not drawn to scale.



Regional differences were observed in terms of SFO roles. For example, the only two SFOs without fire responsibilities are located in the Northeast (Massachusetts and New York). However, as shown in **Figure 1-5**, two thirds of the SFOs in this region (six of nine) have responsibility for non-forested state lands in addition to forested lands (which represents half of the SFOs nationally). The Western region has the second largest number of SFOs (3) with non-forested state land management responsibilities.

Figure 1-5. SFOs with Non Forest Land Management Responsibilities by Region

	NE	MW	South	West	Total States
No	**3**	**10**	**15**	**10**	**38**
Yes	**6**	**2**	**1**	**3**	**12**
Total	**9**	**12**	**16**	**13**	**50**

In addition to responsibilities for state owned forest land, other state lands and wildland fire management, many SFOs also have authority over forested lands owned by the private sector. State foresters indicated that almost 400 million acres are owned by the private sector, approximately ten times more than state owned and twice the number of acres of federally owned forested land (Dupree 1998). State programs directing private forest practices have increased both in number and intensity in recent decades (Ellefson, Cheng and Moulton 1995). SFOs also work with public and private forest land owners in a variety of non-regulatory programs in addition to regulatory practices. SFOs also are key participants in forest assessments and other natural resources management practices and assessments. SFOs are also becoming active in urban forestry, recreation, and economic and rural development efforts due to changing societal relationships with and needs concerning forest resources. The functions and activities of SFOs are determined by state directives and programming, but also to respond to federal directives and funding for specific functions.

1.3.2 Organizational Placement of SFOs

The organizational placement and reporting relationship of SFOs also vary by state. Within this report, the identity of organizations within which SFOs are located is referred to as "parent" to help clearly identify these entities and reporting relationships. An organizational typology of state government natural resources and environmental organizations developed for a previous study (Warnecke 1994) was used to understand the organizational placement of the nation's 50 SFOs. As shown in **Figure 1-6**, almost half of all SFOs are located in a Natural Resources Department (21). An additional six SFOs exist under an environmental and natural resources (ENR) department or agency. These departments or agencies combine natural resources functions with environmental roles similar to the U.S. Environmental Protection Agency. Ten SFOs do not report to another state department, and exist as their own department (5) or serve under a Forestry Commission (5). The remaining less than a third of the SFOs exist as separate units within state government under either Agriculture (6), Lands (1), or Commerce (1) departments, or operate under their state's public university system (5).

Some regional differences can be observed when considering the organizational placement of SFOs. For example, all five of the Forestry Commissions are located in the south. Four of the other five independent SFOs, which exist as separate departments, are located in the west where omnibus ENR organizations are less

Figure 1-6. Organizational Placement of SFOs by Region

	Northeast	Midwest	South	West	Total
Agriculture		1	5		6
Independent			1	4	5
Commission			5		5
Commerce			1		1
Omnibus ENR	5		1		6
Lands				1	1
Natural Resources	4	8	2	7	21
University		3	1	1	5
Total	9	12	16	13	50

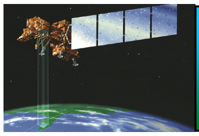
likely to occur than in eastern regions (Warnecke 1994). As shown in Figure 1-6, five of the six SFOs located in ENR organizations are in the northeast. Five of the six SFOs are located in Agriculture Departments similar to the U.S. Forest Service. The organizational placement of the remaining 28 SFOs seem to be more distributed across the regions. Overall, the organizational placement of most SFOs in the south differ from that of other regions. At least ten of the 16 southern SFOs are located in organizations that are separate from other natural resources functions, which is in contrast with the majority of states (28). Otherwise, the organizational placement of SFOs is generally spread across the regions.

1.3.3 General Resource Commitments in SFOs

Given that SFOs differ significantly in their sizes, amounts of forested and state lands, responsibilities, and organizational placement, SFOs also vary in terms of the size of their operations and their corresponding resource commitments. For example, as shown in **Figure 1-7**, expenditures by state vary from almost $1.5 million to $450 million, with average spending per state of about $30 million (Dupree 1998). Total expenditures are significantly correlated with the acreage of forested land (Pearson correlation coefficient of 0.638). The findings from the NASF survey also indicate that expenditures for management are significantly

Figure 1-7. SFO Expenditures and Personnel Levels
($1000s)

	N	Range	Minimum	Maximum	Sum	Mean
Total expenditures	49	446600	1404	448004	1447772	29546.37
Personnel w/o Temps	48	4336	19	4355	15562	324.21
Personnel w/ Temps	48	5829	26	5855	21721	452.52



correlated with the acreage of forested land owned by the state, but the total expenditures are not, which reflects the many roles of SFOs.

The findings also reveal a great variation in the number of employees in SFOs, ranging from 19 to almost 4400 without considering temporary employees, and with an average of almost 325. As can be expected, the total expenditures are also highly correlated with the number of employees.

This information about forestry in the states and general characteristics of the SFOs is useful to help understand GIT conditions within these organizations as described in subsequent chapters.

1.4 Statewide GI/GIT Approaches

While this report focuses on the nation's 50 SFOs, most state governments have responded to the accelerating growth in GIT use by institutionalizing statewide coordination approaches for GI/GIT. While not all states have done so, these approaches typically include directives for statewide GI/GIT coordinating entities, staff and/or groups. A description of statewide GI/GIT coordination conditions in the 50 states is contained in a recent report prepared for the National States Geographic Information Council (NSGIC), an association of state GI/GIT coordinators similar to NASF for state foresters (Warnecke, et.al. 2002). The information and figures in this section are reproduced with permission from this NISGIC report.

SFOs may have direct or indirect linkages with these offices and/or groups as described later in this report. SFOs can achieve several benefits by working with corresponding statewide GI/GIT coordination efforts. As explained in Chapter 6, relationships with these statewide efforts can have important impacts on GIT results in SFOs.

1.4.1 State GI/GIT Coordination Entities

State GI/GIT coordination entities typically include small offices or one or a few individuals. However, these entities can have as many as 36 staff, as in Michigan. Known in the following discussion as "coordinators" regardless of their size, specific criteria are used to determine their incidence.

Figure 1-8 reveals that 46 states had at least one state GI/GIT coordinator in 2001. Identities of these coordinators are included in each Section 3 of the profiles in Appendix C. With evaluation at several points in the past, the trend is clearly toward the existence of more statewide GI/GIT coordinators over time. An important phenomena revealed in the most recent investigation is the growing existence of secondary state GI/GIT coordinators. States with secondary coordinators are those in which statewide coordination roles are clearly shared by two separate organizational entities. Details about the 17 states with these entities were not investigated. However, most of these entities are natural resources departments (which may be SFO parents) or state-sponsored universities. Many early statewide coordinators originated in natural resources departments and some continue to serve in primary or secondary statewide GI/GIT coordinating roles today. This is likely because these departments were among the earliest users of GIT, but also because some states experienced strong efforts in the 1980s to integrate natural resources data, which often is needed by other agencies as well (Warnecke 1998).

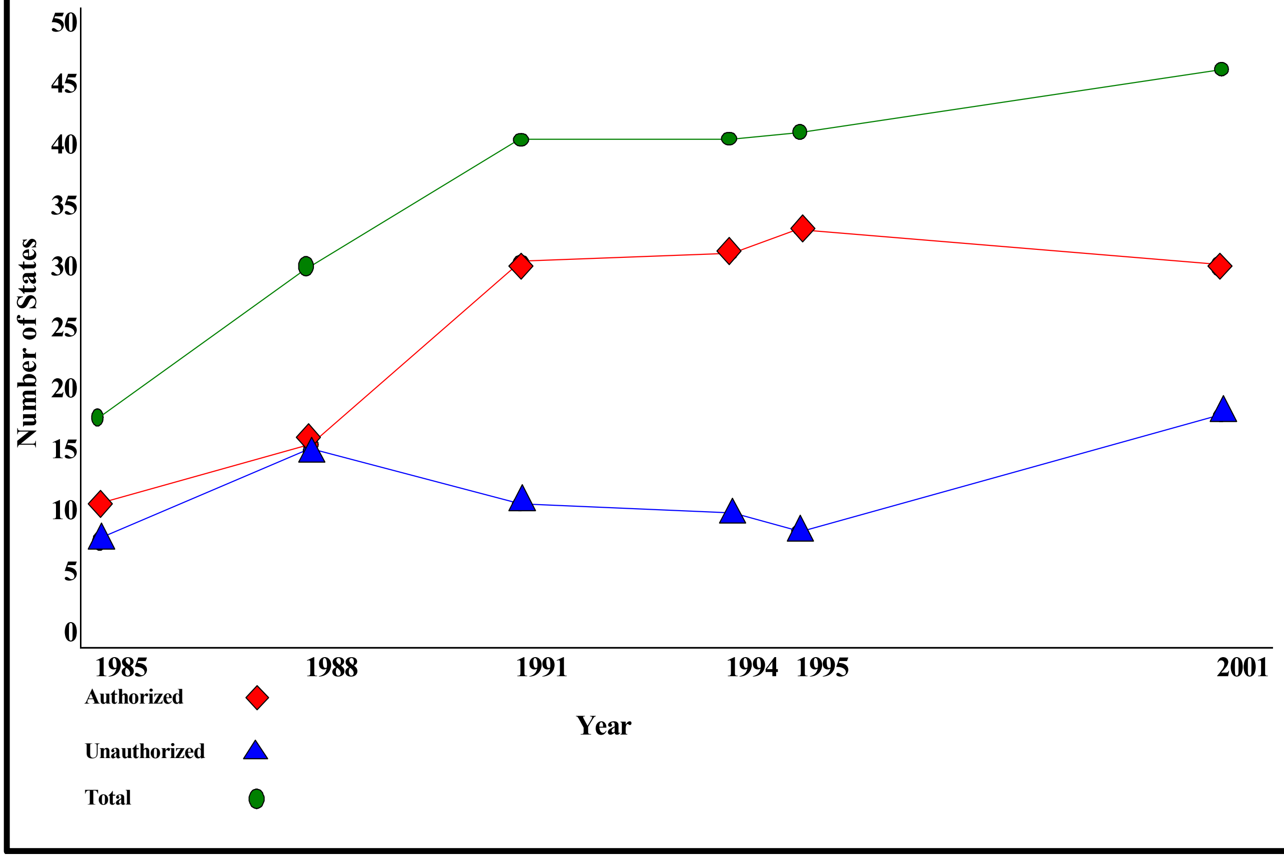
This figure also indicates whether state GI/GIT coordinators are recognized as either official and "authorized," or more informal and "unauthorized." Over half of the states have had authorized coordinators in place for over a decade. In comparison, using a similar definition, the National Association of State

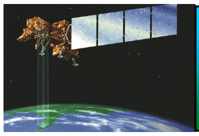
Chief Information Officers (NASCIO) found in its recent survey that 47 states have authorized general information technology (IT) management or organizations (NASCIO 2002). The number of states with authorized GI/GIT coordinators more than tripled between 1985 and 1994, revealing a trend toward increasing authorization of state GI/GIT coordinators that was even stronger over this time period than the increase in their incidence.

Despite continued growth in GIT use in states, the trend toward a growing number of authorized coordinators has diminished in recent years. These findings likely indicate the continuing challenges of institutionalizing and maintaining policy-level support for statewide GI/GIT approaches, and at the same time, growing financial constraints shared by SFOs and others in state governments.

The findings about authorization are particularly important at this time because the majority of the states have Gubernatorial elections in 2002. Legislative authorization exists in about half the states, and another six states exist with Executive direction. Authorization and support can be important when encouraging state

Figure 1-8. Incidence and Authorization of State GI/GIT Coordinators





agencies to cooperate with others, or to secure and maintain resources for GI/GIT when competing with other state government functions. Legislative direction can be viewed as the most preferred and permanent form of authorization because Governors change regularly. Examples of states with Legislative direction include Virginia, Utah, Kentucky, Wisconsin, Arkansas and Arizona. The American Planning Association recently prepared a "Growing Smart Legislative Guidebook" including many examples of model legislation. Prepared with input from this lead author, the model provisions in Chapter 15 include establishment of a Division of Geographic Information and a Geographic Information Advisory Board. (http://www.planning.org/guidebookhtm/chapter_fifteen.htm) This model is not necessarily endorsed by this author or others associated with this project, but it is informative for states developing authorization language.

1.4.2 State GI/GIT Coordination Groups

State GI/GIT coordination groups have existed for over a decade in virtually all 50 states. These groups share a primary or dedicated purpose to address and improve inter-organizational conditions concerning GI/GIT among state agencies, but increasingly also with other sectors operating in their states. Some states have multiple coordinating groups that work with each other but may focus on differing technology or sectors. Other state groups and entities may impact the need for and/or complement the activities of GI/GIT groups. For example, states with omnibus or large natural resources and environmental departments may have internal data coordination groups that may obviate the need for some roles and activities of statewide groups. Some states have inter-organizational mission-driven groups (such as for homeland security, growth management, environment and natural resources, or otherwise) which may include data coordination as an important aspect of their work and thus also conduct GI/GIT coordination activities. **Figure 1-9** reveals the incidence and authorization of all known statewide GI/GIT coordination groups as of the end of 2001.

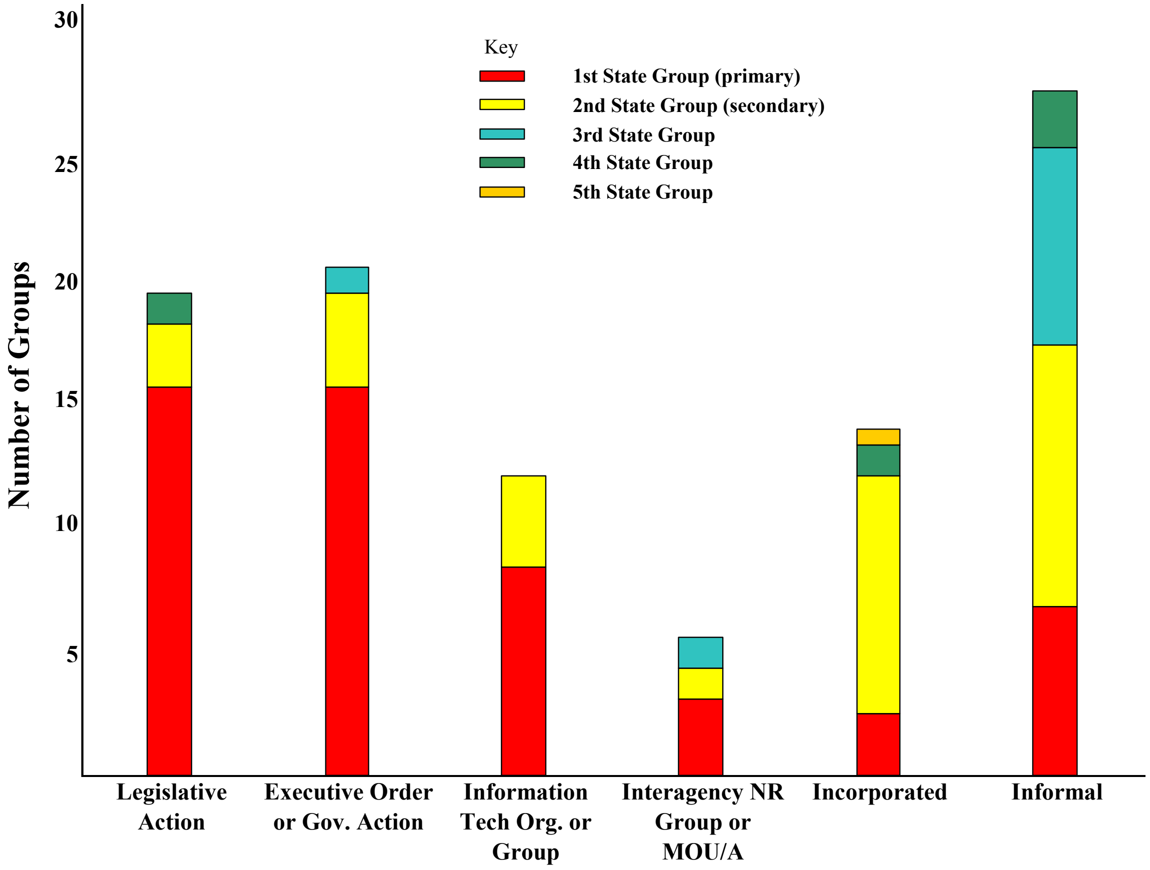
Leading state GI/GIT groups are identified in Section 3 of each profile in Appendix C. A total of 95 dedicated GI/GIT groups were identified to exist within 49 states. SFOs may participate in leading or other state GI/GIT groups as indicated in the state profiles in Appendix C and discussed in Chapter 6. Florida was the only state without a group (it also was one of the four without a coordinator) because it recently experienced some changes in Information Technology (IT) management that impacted GI/GIT coordination.

The remaining 49 states each had from one to four groups. Various reasons exist for states to have multiple groups. In some states, there is a clear distinction between policy level groups and those with technical focus. Both groups may exist officially, but there is a clear distinction and reporting relationship between them. Some GI/GIT groups formally or informally report to broader IT groups that also exist in most (if not all) states, while in other states there appears to be little relationship between these groups.

State GI/GIT groups are classified using various authorization categories. Thirty states have their leading GI/GIT coordination group authorized via Legislative or Gubernatorial action. Some state groups are classified as unauthorized, but some may be legally incorporated.

The existence of GI/GIT groups is an important component, and may serve as a critical "first step" to further institutionalization of statewide GI/GIT coordination. They have differing authorization, participants, objectives, resources and activities, but they typically share the goal of greater GI/GIT coordination and

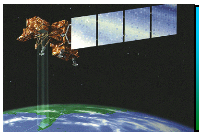
Figure 1-9. Number and Authorization of State GI/GIT Coordination Groups



associated data sharing. Participation by SFOs and other state agencies can reap internal benefits. Groups frequently build momentum and demand for data, services and specific coordination mechanisms. They also seem to increasingly have formal and informal influence over the direction of GI/GIT in their states even though their authorization varies. The increasing incidence and authorization of state GI/GIT groups reveals an overall trend toward formalization of roles and responsibilities, and generally reflect increasing maturation and institutionalization of GI/GIT in states.

1.4.3 Statewide GI/GIT Roles, Functionality and Level of Effort

Statewide GI/GIT coordination roles, responsibilities, resources, and level of effort vary significantly among the states. A state GI/GIT coordination entity can range from a portion of one employee's time to several staff. Functionality usually depends upon available and type of financial sources, with some GI/GIT coordinators concentrating on coordination roles, while others primarily operating as service centers to conduct specific work charged to others, particularly state agencies.



Comparing states concerning the functions they perform and associated resource commitments is even more difficult for GI/GIT coordination than for forestry. Differing definitions are pervasive and many state GI/GIT activities, such as by SFOs and their parents, are funded as part of program missions. Moreover, each agency differs in how GI/GIT costs are categorized. Some states have appropriated general fund or other resources for data, clearinghouses or coordinating staffs while others are financed through charge backs to users. **Figure 1-10a** provides a list of 15 statewide GI/GIT coordination functions that can be grouped into four categories, including data, coordination, assistance and other. These categories are defined

Figure 1-10a. Statewide GI/GIT Roles and Functionality

A. Data Function	
A-1	Provide data clearinghouse, access and dissemination functions for data indexed and possibly maintained in a state GI/GIT database, including customized data searches, manipulation and interpretation to meet user needs.
A-2	Develop and implement data and metadata policies, guidelines, standards and procedures to encourage data commonality and sharing, including accuracy and scale requirements to meet overall state needs.
A-3	Develop data (framework and otherwise), sometimes with general appropriation or collaborative interagency funding to ensure data is useful for more than one purpose, project or agency.
A-4	Gather information about and/or prioritize state level data needs independently or collaboratively.
A-5	Perform quality assurance, quality control, validation and arbitration of statewide data sets.

B. Coordination Function	
B-1	Serve as a clearinghouse concerning activities, projects and plans about GI/GIT in state agencies and possibly other entities, including providing directories, guides, annual reports, newsletters and other materials with current information.
B-2	Promote collaborative planning for future data development and other work, including helping prioritize and coordinate data work conducted by multiple organizations.
B-3	Provide staff support for GI/GIT coordination and users groups.
B-4	Sponsor GI/GIT events, including conferences, workshops and meetings to facilitate information exchange.
B-5	Coordinate GI/GIT with CIO and the state's IT organization(s).

C. Assistance Function	
C-1	Provide GI/GIT education or training services for state agencies and others.
C-2	Provide GIT assistance and facilitate interlocal coordination to local governments.
C-3	Provide GIT assistance and facilitate coordination to others.
C-4	Provide financial resources and/or assistance, e.g., funding, in-kind services, etc. to local governments.

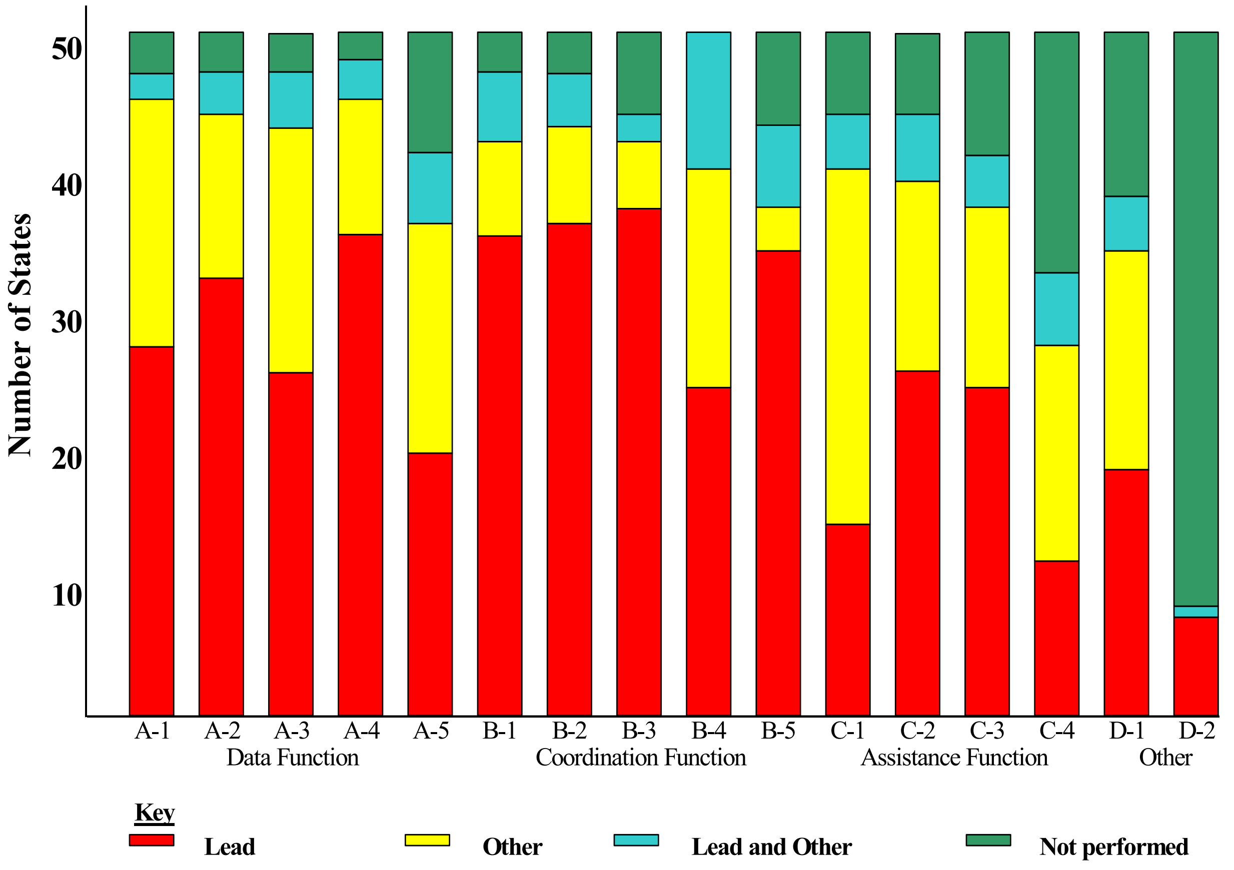
D. Other Functions	
D-1	Provide contract GI/GIT services for state agencies and others.
D-2	Other.

to differentiate general coordination activities, such as educational, planning and group support work, with that of efforts specifically focused on data access and development. Assistance is considered a third distinct function, as is work conducted under contract or otherwise for a fee, such as applications projects in individual agencies. This list was provided to leading GI/GIT coordinators in the 50 states and they were asked to indicate which functions they perform. The responses are shown in **Figure 1-10b**. Important for SFOs and other agencies, these results clearly indicate that most states conduct general coordination efforts.

However, on average, only slightly more than 30 of the 50 lead coordinators conduct the data functions listed in Figure 11a. Of the three categories, the fewest number of states and lead coordinators conduct specific assistance efforts, though some states have grant programs to facilitate GI/GIT in local governments.

Financial resource commitments for statewide GI/GIT have not been measured for all 50 states. A comparative study of such commitments for 12 states is available from work conducted for the State of Ohio (Warnecke, et.al. 2001). Personnel commitments are easier to measure and provide a

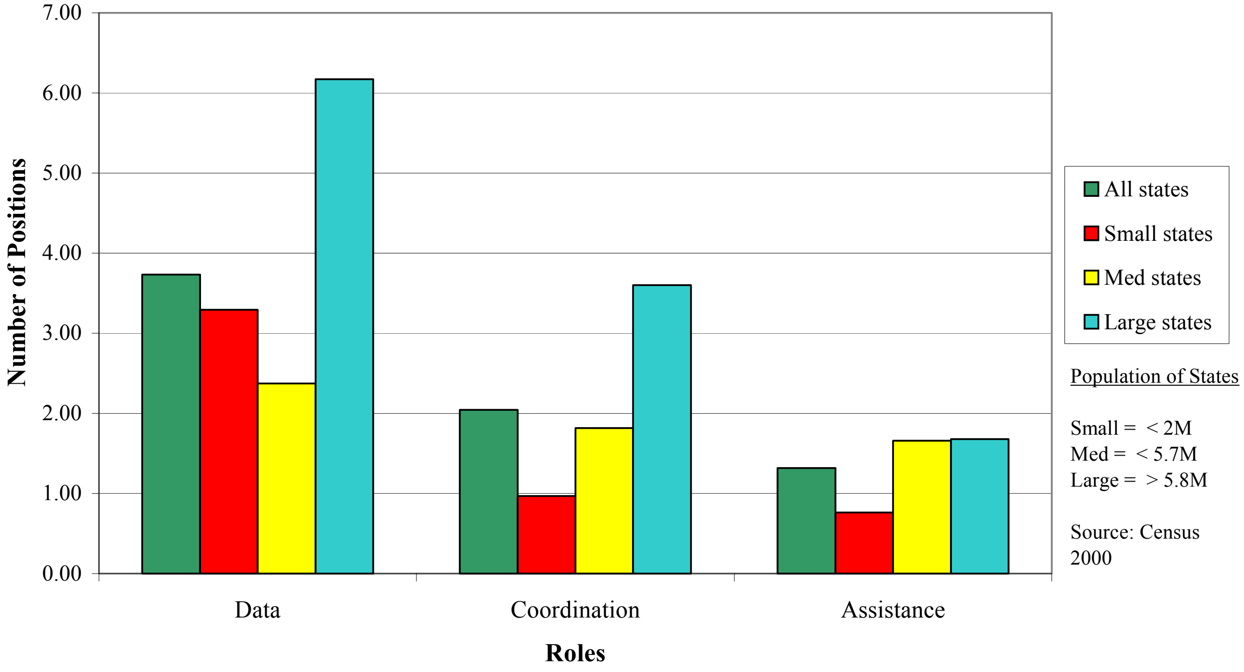
Figure 1-10b. Statewide Functionality of Lead and Other GI/GIT Organizations



valid approach to understand general and relative resource commitments across the states. These comparisons, while less difficult than for finances, are also challenging to measure and compare because similar work can be done by individuals in a combination of different entities in one state or by a single office or individual in another. GI/GIT coordinating work can be conducted through a combination of paid and volunteer time, on the part of state employees within the GI/GIT coordination entity or other state agencies, or by others outside state government, making quantification even more difficult. Moreover, many different job classifications and descriptions are used for GI/GIT work, even within the same state and agency, such as also exists in some SFOs. This situation compounds the difficulty of distinguishing between statewide and agency level GI/GIT efforts. Some states seem to be establishing statewide classification series for GI/GIT, but in many cases, engineers in a transportation department and resource analysts in SFOs or natural resources departments may do similar work. Some employees may not use GI/GIT directly, but coordinate, direct or support its use, so they may have another set of job titles.

Information about staffing commitments is available for all 50 states in **Figure 1-11**. Results are shown according to the same GI/GIT functions described above (data, coordination and assistance). The level of personnel resource commitments are measured in terms of Full Time Equivalent (FTE) positions. FTEs are often used to quantify staffing because one FTE may be one full time individual or the combination of two or more part time staff. Vast differences are revealed, ranging from less than one person in a few states to 36 in Michigan. An average of 8.29 FTEs per state work on all statewide GI/GIT coordination

Figure 1-11. Statewide GI/GIT Level of Effort in Full Time Equivalent (FTE) Positions



Population of States

Small = < 2M
Med = < 5.7M
Large = > 5.8M

Source: Census 2000

efforts. FTE commitments for specific data, coordination, assistance and other functions reveal that the greatest number of FTEs is devoted to data efforts, and particularly in more populous states with an average of over six FTEs.

These results about statewide GI/GIT functionality and resource commitments complement the findings about coordinating entities and groups. While significant differences are highlighted among the states, these findings provide clear evidence that states are devoting resources for statewide GI/GIT coordination, and particularly to meet data needs. Increasing institutionalization and maturation of statewide GI/GIT coordination is clearly evidenced and provides many opportunities for SFOs and other agencies. Many benefits and savings can be realized in internal approaches by learning from and accessing data from others, and working with others to help finance and develop data needed to meet SFO and other agency needs.

1.5 Report Overview

This report characterizes remote sensing and other GIT conditions in each of the 50 SFOs based on information gathered from the 50 state foresters and their staff, and augmenting materials as described in the following chapters. Most of the findings presented in this report are based on "State Profiles" that are located in Appendix C of the report. State participants providing information in the project are listed in Appendix B.

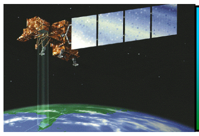
Chapter 2 provides an overview about remote sensing resources available for SFOs, including airborne and satellite products. It also includes an important description about ground reference data that is required in remote sensing, with highlights about the technical component of this overall project headquartered at SUNY-ESF.

Chapter 3 reviews the methodology of the project resulting in this report. It includes summary descriptions about related research and literature. It also describes project involvement with NASF and individual state foresters in order to ensure accurate and useful results. The chapter also includes a description of the development and content of the profiles in Appendix C and the methods employed to analyze the results.

Chapter 4 provides a summary about the growth and current presence of remote sensing and GIT in SFOs based on analysis of the state profiles. General summary statistics are provided and analyzed based on some external factors. Another important focus of the chapter is on remote sensing and other GIT applications. Information about GIT usage from the SFO profiles was classified according to 14 applications categories. The frequency of each of these applications is provided and compared for each form of GIT and type of remote sensing. Chapter 5 includes a description of each of these 14 applications categories, and examples and graphics from selected SFOs about their use of remote sensing and other GIT for these applications.

Chapter 6 includes information about how the nation's SFOs incorporate, manage and deploy remote sensing and other GIT and GI within their organizations. Comparisons and analysis are provided about organizational approaches and structure; types and distribution of data and technology roles and responsibilities; types of staff and contacts; internal and external coordination and relationships; and GIT policies, plans, issues, and benefits. These findings about current approaches and issues within the nation's SFOs provide insight about future trends and opportunities.

Chapter 7 includes information to help SFOs address some of the institutional and coordination matters raised in the report.



Chapter 1
Introduction and Background

Information is provided about NASA's work with states and the U.S. Forest Service's (USFS) approach to and activities regarding remote sensing and other GIT. Conclusions are also provided, including implications of the findings for SFOs and others. Appendix D augments this chapter with examples of remote sensing applications at the USFS.

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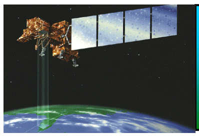


Chapter 2

Remote Sensing Sources for State Forestry Organizations

Authors' note: This chapter was prepared with the assistance of Tom Bobbe, Manager of the U.S. Forest Service's Remote Sensing Applications Center (RSAC) in Salt Lake City.

A wide variety of remotely sensed imagery sources are currently available and provide many options for SFOs. Clearly defining resource information requirements is an important initial step in selecting the proper remote sensing source for a particular set of applications. Once the information requirements are defined, the correct source of imagery or combination of imagery sources can be selected based on system capabilities. Defining resource information requirements in terms of spatial, spectral, and temporal properties is important.

Considerations include: 1) the extent of the geographic area and the desired level of detail, 2) the properties of the features that need to be delineated (do these features have unique spectral properties?), 3) how often is this information needed (does this information need to be updated on a frequent basis?), and 4) the availability of ground reference data. A final consideration is the cost of acquiring and processing imagery. Ideally, high spatial resolution imagery covering large geographic areas may be needed, with many spectral bands and frequent updates.

The practical and economic considerations of acquiring and processing this amount of data limits the selection of remotely sensed imagery sources to those that best meet the original information requirements. Reviewing resource information requirements in the context of planning and analysis scale helps resource specialists understand which remote sensing systems are most appropriate for a particular project need.

2.1 Aerial Photography

Although there are many new developments in other remote sensing systems such as satellites and airborne electro-optical sensors, aerial photography and digital aerial data continue to be a primary source of imagery used to collect resource data, perform map revisions, and update GIS databases. Aerial imagery is usually collected in panchromatic (greyscale), true color, or false-color infrared. Digital imaging systems are becoming more common and offer many advantages over traditional photography. Digital collection can be less expensive and more efficient than analog photography, and is more readily usable in digital systems such as GIS. Aerial photography can be acquired by 1) contracting with aerial survey firms, 2) participating with other government agencies that manage related programs and/or operate aerial survey aircraft, and 3) using in-house aerial photography aircraft.

Many state and federal agencies participate in the National Aerial Photography Program (NAPP) to acquire 1:40,000 scale aerial photography. NAPP is a multi-agency program that includes the U.S. Geological Survey (USGS), Bureau of Land Management (BLM), U.S. Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS), USDA Farm Service Agency, and state agencies. The objective of the NAPP program is to fly every state on a five-year cycle. Some states share in the program and pay 50% of NAPP costs for the state. Most of the NAPP aerial photography contracts now specify panchromatic aerial film.

An important aerial imagery product that is increasingly used by SFOs and other state and federal agencies are digital orthophotographs (orthophotos), especially Digital Orthophoto Quadrangles (DOQs). The USGS and the USFS Geospatial Service and Technology Center (GSTC) are working cooperatively to generate digital orthophoto products for the entire U.S. in the National Digital Orthophoto Program (NDOP). Digital orthophotos have the advantage of being orthorectified (corrected for the effects of photography to form map-like products), and being in a digital form for easy transfer and use in GIT.

Although digital orthophoto products provide critical imagery useful in creating and maintaining GIS databases, panchromatic aerial photography, as is available from NDOP, is generally not preferred by resource specialists. Natural color and color infrared aerial films are considered much more useful for interpreting and delineating vegetation types and identifying forest health problems. For example, resource specialists in the USFS obtain large scale (generally 1:12,000) resource aerial photography through contracts separate from NAPP. Natural color and color infrared aerial photography is generally specified in these contracts.

In addition to participating in this national program, several states have developed their own digital orthophoto programs to provide more current and accurate imagery for many users. The availability and quality of digital orthophotos varies from state to state. Many states are fully covered, while some are not. Some digital orthophotos are available only in panchromatic form, while others are collected in natural color or color-infrared.

Some agencies, in particular, the USFS, participate with other government agencies to access additional aerial photography, such as the NASA Airborne Instrumentation Research Program (AIRP) to acquire special aerial photography and digital remote sensing data. AIRP is intended to provide special high altitude aerial photography and other digital remote sensing imagery that cannot be obtained through contracting with private aerial survey firms or by using USFS aerial photography assets.

Several SFOs and other state and federal agencies maintain their own aircraft with the capability to collect aerial photography and other remote sensing imagery. For example, USFS manages a fleet of nine fixed wing aircraft, with six of them having 9" x 9" aerial mapping cameras. Natural color and color infrared films are normally used with these camera systems. Programs that need aerial photography to monitor riparian habitat, range condition, forest health and pest problems, and perform resource inventories can rely heavily upon such aerial photography aircraft. USFS aircraft are also used to collect remote sensing data from other sensor systems such as digital camera systems, Forward Looking Infrared (FLIR) systems and multispectral scanners. Three USFS aircraft are used solely for wildland fire mapping and are located at the National Interagency Fire Center in Boise, Idaho. These aircraft carry high resolution thermal infrared line scanners systems that are used to provide detailed active fire maps to fire suppression crews.

2.2 Airborne Electro – Optical Sensors

While electro-optical sensors have been used since the early 1970s, there is a growing interest in and experience among state and federal resource agencies concerning new airborne systems and capabilities. Airborne systems that are increasingly used by resource specialists include: airborne video, airborne digital frame cameras, multispectral scanners, thermal infrared line scanners and imagers, hyperspectral imagers, and Light Detection and Ranging (LIDAR) systems.

Airborne video systems can be linked with the Global Positioning System (GPS) and are often used for forest health protection aerial survey applications. Airborne video is used for acquiring moderate resolution imagery for forest health surveys, and high resolution imagery for small area or point sample applications. An important benefit of video imagery is that it can be viewed and processed as soon as the flight is completed.

Digital cameras offer the same advantages of airborne video systems. The equipment is relatively inexpensive, easy to operate, and provides imagery that is readily integrated with image processing and GIS. Modern digital cameras provide higher spatial and radiometric resolution than video camerasThese modern imaging systems use on-board GPS receivers and inertial measurement units that record the position and orientation of the camera at the time each image is collected. This reduces or eliminates the need for ground control targets to orient each image. The ability to fly without setting up ground control reduces the cost of collections, and allows very fast (as little as under a day) turnaround of images. This type of imagery has been used in a wide variety of studies, from determining timber volume to delineating individual tree crowns. An example of a system of this type is used by Emerge Corporation. Emerge operates a fleet of aircraft stationed throughout the country that are used to collect images used for agriculture, resource management, and disaster management applications. The report cover image was collected by Emerge over Huntington Wildlife Forest, a property in the Adirondacks managed by the State University of New York College of Environmental Science and Forestry (SUNY-ESF).

USFS has used airborne thermal infrared line scanners and Forward Looking Infrared (FLIR) systems for fire mapping since the 1960s. Three high resolution thermal infrared line scanners currently provide active fire maps to fire suppression crews. The line scanners are modified 1.25 milliradian scanners with two thermal infrared bands important for fire mapping and detection. The two thermal infrared bands sense energy in the 3-5, and 8-12 micrometer ranges. The scanners systems use a target discrimination algorithm to highlight small fire hot spots, and eliminate false fire detects.

Many hyperspectral image systems (systems that collect in a wide range of the electromagnetic spectrum) are now airborne. The most well-known example of this is the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). AVIRIS collects imagery in 224 bands and is operated by NASA. Hyperspectral imagers are currently being evaluated for forest health monitoring, post-fire burn area analysis, mapping hazardous materials, and invasive species mapping.

LIDAR systems are increasingly being used for forestry applications, such as measuring the elevation of tree canopies and mapping forest structure. The report cover image from the University of Washington shows how LIDAR is being used for forestry applications. Airborne laser mapping is a leading-edge application for helicopter platforms. However, NASA plans to launch an experimental satellite system, the Vegetation Canopy LIDAR (VCL), which will employ multiple lasers to measure the vertical distribution of vegetation canopy on a worldwide basis.

2.3 Satellite Imagery

Some of the most extensive remote sensing advances in the last decade have been in the development and use of satellite imagery. A general overview of these products and capabilities is provided below and in **Figure 2-1**. Significant developments have occurred even within the last year and others are expected in the future. A major trend in satellite sensors is the move towards higher spatial resolution, as exemplified by recent high resolution products available from IKONOS and Quickbird, as described below. Analyzing imagery from such

Figure 2-1. Satellite Remote Sensing Platforms for Forestry Applications

Sensor	**Source**	**Launch Date**	**Sensor Types**		**Ground Resolution (meters)**
			Reflected Bands	**Emitted Bands**	
LANDSAT Multispectral Scanner (MSS)	USA	1972	blue, green, red, near infrared (NIR), mid-IR	-	80
LANDSAT Thematic Mapper (TM)	USA	1982	blue, green, red, NIR, mid-IR	Thermal IR	30 (visible, NIR, mid-IR) 120 (Thermal IR)
LANDSAT Enhanced Thematic Mapper (ETM+)	USA	1999	panchromatic, blue, green, red, NIR, mid-IR,	Thermal IR	15 (pan) 30 (visible, NIR, mid-IR) 60 (Thermal IR)
Advanced Very High Resolution Radiometer (AVHRR)	USA	1986	red, NIR, mid-IR	Thermal IR	1,100
Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)	USA/Japan	1999	green, red, NIR, mid-IR	Thermal IR	15 (visible, NIR) 30 (mid-IR) 90 (Thermal IR)
SPOT 1-3	France	1986	panchromatic, green, red, NIR	-	10 (pan) 20 (visible, NIR)
SPOT 4	France	1998	panchromatic, green, red, NIR, mid-IR	-	10 (pan) 20 (visible, NIR, mid-IR)
SPOT 5	France	2002	panchromatic, blue, green, red, NIR, mid-IR	-	2.5, 5 (pan) 10 (visible, NIR, mid-IR)
IKONOS	USA (private sector)	1999	panchromatic, blue, green, red, NIR	-	1 (pan) 4 (visible, NIR)
Quickbird	USA (private sector)	2001	panchromatic, blue, green, red, NIR	-	0.6 (pan) 2.4 (visible, NIR)
MODIS	USA	1999	blue, green, red, NIR, mid-IR	Thermal IR	250 (red, NIR) 500 (visible, NIR) 1000 (visible, NIR, mid-IR, Thermal IR)
Indian Remote Sensing (IRS-1C, IRS-1D)	India	1995	panchromatic, green, red, NIR, mid-IR	-	5.8 (pan), 23 (green, red, NIR), 70 (mid-IR)
Airborne Multispectral	USA (gov't and private sector)	-	varies, often panchromatic, blue, green, red, or green, red, NIR	-	varies, often 0.5 - 1
Airborne LIDAR	USA (gov't and private sector)	-	-	laser illumination	varies
RADARSAT-1	Canada	1995	-	C-band microwave	9-100
European Radar Satellite (ERS-1,2)	ESA	1991	blue, green, red, NIR	C-band microwave	26 (radar) 1000 (visible, NIR)
Japanese Radar Satellite (JERS-1)	Japan	1992	green, red, NIR, mid-IR	L-band microwave	18 (radar) 18 (visible, NIR, mid-IR)
Environmental Satellite (ENVISAT)	ESA	2002	blue, green, red, NIR	C-band microwave	30,150 (radar) 300,1200 (visible, NIR)

sensors is difficult using methods developed for lower resolution sensors, but high resolution satellite imagery can often be used for applications that traditionally used aerial photography. The development of Synthetic Aperture RADAR (SAR) sensors is also a relatively recent trend. These sensors emit the signal they receive, and therefore do not depend on reflected sunlight.

2.3.1 U.S. Government

Perhaps the most well known and most used satellite imagery is from the series of LANDSAT satellites initiated by the federal government, with the most recent imagery available from LANDSAT 7. Early satellite data was only available from the federal government, with the first in a series of launches over thirty years ago on July 23, 1972. Originally known as the Earth Resources Technology Satellite - 1 (ERTS-1), it operated until 1978, with a second satellite in this series launched in 1975. The second satellite became named LANDSAT 2, and subsequent satellites were named sequentially.

Several efforts have been made by the federal government to increase commercial involvement in satellite imagery. NASA was responsible for operating LANDSAT satellites until the early 1980s. Congress commercialized the system in 1984 and exclusive sales rights were granted to the Earth Observation Satellite Company (EOSAT). It is generally recognized that such commercialization increased costs and limited use in states and other organizations outside the federal government (Warnecke 1997). LANDSAT 7 data is now operated through the combined efforts of NASA, the National Oceanic and Atmospheric Administration (NOAA) and USGS, with data available from USGS. Congressional passage of the Land Remote Sensing Policy Act of 1992 and subsequent Bush and Clinton Administration actions encouraged private companies to launch and operate their own satellites. While useful products have resulted, only a few private sector satellite ventures are functioning today as described below, and early market projections anticipated much stronger growth and sales than has been realized (O'Connell, et.al. 2001).

The U.S. Global Change Research Program was initiated in the 1980s and includes several federal agencies. The Earth Observing System (EOS) was established from this program and now includes other satellites in addition to LANDSAT 7, such as Terra and Aqua, as described below. These civil systems are complemented for some applications by classified imagery. For example, derived products from classified systems are used extensively in wildland fire suppression efforts. State government officials can have authorization to use these products if working with federal partners.

LANDSAT Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper+ (ETM+)

In addition to being the oldest and most commonly used satellite imagery, the LANDSAT program provides the longest running program in the collection of multispectral imagery of the earth's land surface from space. In general, these satellites cover the same geographic location every 16 days, each scene covering 185 x 170 kilometers. Many years of archived data from LANDSAT 7 and previous LANDSATs provide a rich resource to address many forestry and other resource management needs. LANDSAT MSS imagery has a spatial resolution of 80 meters with spectral resolution in four bands. The LANDSAT program gathered digital MSS data from 1972 through 1992. The result is a 20-year time span of data that can support evaluations of change in landscapes or land cover over a longer time period than any available earth observation system. MSS data is available through USGS's Earth Resource Observation System (EROS)

Data Center working in cooperation with NASA.

LANDSAT TM and ETM+ imagery has 30 meter spatial resolution with seven spectral bands. The most current sensor on LANDSAT 7, ETM+, provides inexpensive and flexible imagery with a 15 meter panchromatic band. Although ETM+ has moderate spatial resolution compared to some other satellites, it collects in eight bands from visible to thermal infrared, which can be used in various combinations for a variety of applications.

One of the most useful results of the LANDSAT series is the development of land cover data. Forestry and other government officials often identify the need for land cover as a top priority need that can be addressed with satellite imagery.

The Multi-Resolution Landscape Characterization (MRLC) Consortium, consisting of EPA, USGS, USFS, National Oceanic and Atmospheric Agency (NOAA), NASA, and BLM, was established to purchase satellite imagery covering the conterminous U.S. The program provides access to an extensive archive of TM imagery. MRLC imagery is provided for at least three dates per scene, reflecting seasonal changes, and is terrain-corrected to within one pixel. The National Land Cover Data (NLCD) project was established by the MRLC to provide land cover data for the U.S. NLCD 1992 mapped the U.S. using LANDSAT TM data, while NLCD 2000 provides the same using LANDSAT 7 ETM+ data.

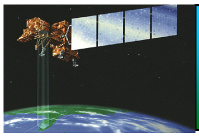
Advanced Very High Resolution Radiometer (AVHRR)

AVHRR data are also available through the USGS EROS Data Center from NOAA weather satellites. AVHRR imagery has a spatial resolution of 1.1 x 1.1 kilometer pixel size with five spectral bands. Broad area coverage is obtained with a swath width of 2,700 kilometers. Temporal resolution is excellent, with repeat coverage over a given geographic area every 12 hours. Major applications for this data include: vegetation determination, vegetation-fuel moisture indices, fire mapping, vegetation-crop stress, and geothermal mapping.

Moderate Resolution Imaging Spectroradiometer (MODIS)

MODIS data is collected by the NASA Earth Observation System (EOS) Terra satellite, and most recently by the successful launch of the Aqua satellite in May, 2002. MODIS has unique capabilities that extend the applications of other heritage sensors such as AVHRR. MODIS offers a unique combination of features: it detects a wide spectral range (36 spectral bands), it provides three levels of spatial resolution (250, 500 and 1,000 meter), has a wide field of view (2,330 kilometer swath width) with excellent repeat coverage, and has a direct broadcast capability. MODIS imagery is available to remote sensing users through the NASA EOS Data and Information System. The NASA MODIS science team has developed algorithms to produce a wide variety of land cover products. These products include: Land Cover, Vegetation Indices, Leaf Area Indices, Net Primary Production, Vegetation Continuous Fields, Vegetation Land Cover, Vegetative Cover Conversion and Active Fire.

USFS has recently made extensive use of MODIS. The Remote Sensing Applications Center (RSAC), a part of the Engineering Division of the agency, installed a MODIS direct broadcast receiving station in 2002 which allows USFS access to MODIS imagery in real-time from the sensor. RSAC uses the direct broadcast capability to prepare active fire maps for the entire country. The active fire mapping program is a collaboration between the NASA Goddard Space Flight Center, University of Maryland, and the Forest Service. Active fire maps and imagery are made available to the wildland fire fighting community and the public through the National Interagency Fire Center



web site, which is located at (www.nifc.gov/firemaps.html).

Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)

ASTER represents a cooperative venture between NASA and Japan's Ministry of Economy, Trade and Industry (METI) and flies on the EOS Terra satellite. ASTER collects in the green, red and near-infrared bands with a spatial resolution of 15 meters. It also collects six short-wave infrared bands at a spatial resolution of 30 meters, and five bands of thermal infrared at a spatial resolution of 90 meters. ASTER is an on-demand instrument, meaning that data is collected only for areas where it is requested. Once data has been collected for a given area, it is available for a small fee through the EOS data gateway (http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/plain.html).

2.3.2 International Imagery Sources

Many of the satellites sensors available for and used in forestry and other applications are operated by foreign countries. Their cost and availability varies.

SPOT

The French SPOT satellite system was the first satellite imagery venture outside the U.S. that provided data resources for widespread use. SPOT 2 and 4 provide a combination of 10 meter panchromatic and 20 meter multispectral imagery with a swath width of 60 kilometers and a 26 day revisit cycle for vertical view (nadir) imaging. SPOT 5 is the most recent system that provides 2.5, 5 and 10 meter panchromatic, and 10-20 meter multispectral imagery. SPOT 4 and 5 have a short wave infrared band that is useful for vegetation and burn area intensity mapping. Each SPOT satellite has oblique viewing capabilities which provide three day revisit capability. Forestry applications of SPOT data have largely been similar to LANDSAT TM and ETM+. SPOT's higher spatial resolution compared to LANDSAT can improve detection of smaller features but with a reduced swath width.

Indian Remote Sensing (IRS)

IRS-1C and IRS-1D were launched in 1995 and 1996 and have specific applications for vegetation and land cover mapping. Three sensors carried aboard the IRS satellites include the Linear Imaging Scanning Sensor (LISS), Wide Field Sensor (WiFS) and a panchromatic sensor. The LISS and panchromatic imagery are the most commonly used by the Forest Service. The five meter panchromatic imagery with a 70 kilometer swath provides a useful product in areas where digital orthophotos do not exist or are not current. The LISS 23 meter imagery with a 142 kilometer swath is similar to LANDSAT TM and ETM imagery but lacks a mid-wave infrared spectral band.

RADARSAT

RADARSAT-1 is a Canadian satellite that collects in microwave bands using Synthetic Aperture RADAR (SAR). SAR emits a microwave (radio) signal and collects the return from this signal, so it can collect at night and through clouds. RADARSAT-1 collects in the microwave C-band usually processed to a spatial resolution of 25 meters. This capability can be very helpful in many areas of the world and for particular needs where clouds can be a significant impediment to other forms of remote sensing. RADAR imagery is a newer technology and generally requires more specialized manipulation than sensors that collect reflected light.

European RADAR Satellite (ERS)

ERS is another RADAR sensor which is operated by the European Space Agency. ERS-

1 and ERS-2 collect C-band data usually processed to a spatial resolution of 25 meters. Both satellites orbit the earth in 100 minutes and collect nearly global coverage every 35 days. The recently launched ENVISAT continues the European activities with a few modifications.

Japanese RADAR Satellite (JERS)

The JERS-1 satellite also collects microwave data using a SAR sensor. JERS-1 collects a given scene once every 44 days, usually processed to a 20 meter ground resolution, and in the L-band.

2.3.3 Private Sector Imagery Sources

There has been a recent expansion in private sector satellite launches. These sensors often provide very timely data that is useful for specific and high resolution applications. While unsuccessful launches plagued commercial satellite imagery efforts until recently, two companies now provide products for a wide range of users. The costs associated with private sector satellite data is often considerably higher than those for data collected by government agencies.

IKONOS

The IKONOS satellite, launched in 1999, marked the start of the world's first high-resolution commercial satellite imagery operation. It is operated by Space Imaging, Inc., which was founded in 1994. It has one meter panchromatic and four meter multispectral imagery useful for small project areas where imagery is required within a very short time frame. The sensor has oblique viewing capabilities, a swath width of 11 kilometers, and a revisit capability of three days. Examples of recent applications include fire response and recovery mapping, forest health monitoring, and updating areas without recent digital orthophoto coverage. Space Imaging acquired EOSAT in 1996 and sells other products in addition to those from IKONOS. It has received approval from the federal government to develop and operate satellites with greater resolution than their existing products.

Quickbird

Quickbird is the newest commercial high resolution imaging satellite following a successful October 2001 launch. Operated by DigitalGlobe, it provides 0.6 meter panchromatic and 2.4 meter multispectral imagery within a 16.5 meter swath width. Quickbird has oblique viewing capabilities that provide a reported revisit capability of four days. Applications of Quickbird are similar to those of IKONOS though with corresponding greater resolution. DigitalGlobe also plans to develop more advanced imagery and products.

2.4 Ground Reference Data

An essential aspect of using remote sensing is the need for ground referencing. Ground reference data are used both in the training and analysis phase of remote sensing work, and for the assessment of the accuracy of finished products.

Ground reference work is often neglected or done as an afterthought despite its crucial importance and impact on the accuracy and results of imagery analysis. Good ground reference, particularly for use with data of high spatial resolution, can be expensive and time-consuming to collect. Projects using remote sensing require determination of how much ground reference work is appropriate to meet requirements of precision and accuracy. The type of ground reference required for forestry often requires extensive field work in rugged terrain and dense vegetation, rather than the aerial photo interpretation or road surveys often used to obtain reference data in flatter areas. Existing sources of ground reference data are generally localized to specific areas. One exception to this is the Forest Inventory Analysis (FIA) program operated by USFS. FIA plots cover the entire country, but their use is extremely restricted due to privacy concerns of private land owners.

2.4.1 SUNY-ESF Technical Investigation and Reference Work

Ground reference, among other remote sensing analysis issues, is a leading focus of technical investigations underway at the State University of New York's College of Environmental Science and Forestry (SUNY-ESF) in tandem with the policy and institutional work discussed in this report. Both investigations are part of the project entitled *Technology and Policy Aspects of Applying Remote Sensing in State Forestry Organizations.*

These technical investigations have focused on the northeastern U.S. There are many challenges to the use of remote sensing for forestry applications in this region. Different forest types in the Northeast are often composed of mixes of similar tree species in subtle variations under closed canopy. The northeastern U.S. also lacks the sharp gradients in elevation and other factors that can make the use of imagery easier in the Western part of the country. Success in applying remote sensing to forestry application in the Northeast has generally come only in limited regions using specific techniques.

A flexible set of ground reference data is needed for this project in order to conduct a wide variety of analyses. The project uses permanent plots located using survey-grade GPS receivers. These permanent forest plots contain detailed-tree level information about a portion of forest (approximately 1/5 acre in the case of this project), as well as plot-wide information such as slope and aspect of the land. The level of detail of the reference allows it to be used for imagery of high spatial resolution and detailed analysis. It may also be generalized for studies that use lower-resolution data. In order to facilitate generalization, the immediate surroundings of each plot are examined in the field to verify whether the plot is generally representative of a larger area. Intermediate observations between plots check for general forest information but are not located using GPS. The permanent plots are located very precisely to allow their use with a variety of image types, including those with spatial resolution of one meter or better. Plots are located in clusters to facilitate their use with what imagery is available, and these clusters are spread across the northeastern U.S. So far, over 1400 plots have been established and/or located, creating a reference set useful for a wide variety of applications in New York, Pennsylvania, New Hampshire, and Maine. These reference data are available on the Forestry Organization Remote Sensing Technology (FOReST) project web site (www.esf.edu/forest/referenceData.html).

2.4.2 Establishment of Baselines

A problem often encountered by those that might wish to apply remote sensing to their own projects is confusion about exactly what remote sensing technology can accomplish. Methods that work for one area or with one set of data may not be transferable to other users of remotely-sensed imagery. A given technology may be over-sold, and represented as a solution to a given problem, with no attendant presentation of the limitations of the technology, or the reference data that must be used with it. Therefore, one of the primary goals of the technical investigations is to establish baseline data and results that will provide the basis for consistently and systematically analyzing the acceptance, effectiveness, and efficiency of applying remote sensing to forestry. These baselines will provide potential users of the technology with information on the effectiveness of a given set of remote sensing data and techniques for their chosen application. They will be evaluated with a consistent set of methods, so that they may be compared against each other. Baselines are performed using various commonly-used imagery types as described above, such as LANDSAT ETM+, ASTER, SPOT-4, and aerial imagery. Analysis methods for baselines are also those most commonly used.

2.4.2 Novel Methods and Imagery

In addition to baselines, project personnel are analyzing other methods and imagery. These analyses will indicate useful areas for further and more advanced explorations of remote sensing for forestry applications. The results obtained through novel methods and imagery will be compared to the baselines already performed to assess their efficacy. Examples of new types of imagery include airborne and satellite sensors with high spatial resolution, hyperspectral sensors which divide the electromagnetic spectrum into a large number of bands, and sensors such as LIDAR, which can be used to precisely measure topography. Some novel analysis techniques include the fusion of imagery from several sensors, and the use of artificial intelligence methods such as neural networks.

2.4.3 Project Application Focus

As discussed throughout this report, there are a wide variety of potential applications of remote sensing to forestry. This project is focusing on two applications that SFOs indicated were important in their work: forest characterization and forest health analysis. Forest characterization mainly consists of the classification of areas of the landscape into a set of land cover or land use categories, such as hardwood versus softwood or maple-beech-birch versus spruce-fir. Other aspects of forest characterization might include timber volume classification. Forest health analysis includes both the study of catastrophic damage such as that from ice storms, and applications such as the monitoring of long-term insect damage. Baseline analysis as well as novel methods will be performed for both of these applications.