

Chapter 2

Remote Sensing Sources for State Forestry Organizations

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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.

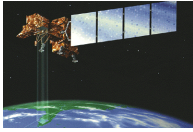
The practical and economic considerations of acquiring and processing this amount of data limits the selection of remotely sensed imagery sources to those that best meet the original information requirements. Reviewing resource information requirements in the context of planning and analysis scale helps 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



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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.

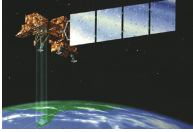
Some agencies, in particular, the USFS, participate with other government agencies to access additional aerial photography, such as the NASA Airborne Instrumentation Research Program (AIRP) to acquire special aerial photography and digital remote sensing data. AIRP is intended to provide special high 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



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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 cameras. These 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.

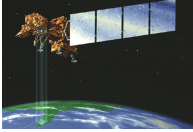
LIDAR systems are increasingly being used for forestry applications, such as measuring the elevation of tree canopies and mapping forest structure. The report cover image from the University of Washington shows how LIDAR is being used for forestry applications. Airborne laser mapping is a leading-edge 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)



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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.

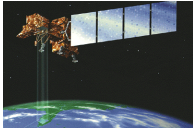
Several efforts have been made by the federal government to increase commercial involvement in satellite imagery. NASA was responsible for operating LANDSAT satellites until the early 1980s. Congress commercialized the system in 1984 and exclusive sales rights were granted to the Earth Observation Satellite 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)



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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)

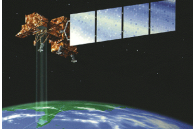
AVHRR data are also available through the USGS EROS Data Center from NOAA weather satellites. AVHRR imagery has a spatial resolution of 1.1 x 1.1 kilometer pixel size with five spectral bands. Broad area coverage is obtained with a swath width of 2,700 kilometers. Temporal resolution is excellent, with 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



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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)

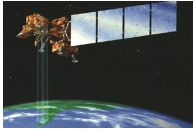
IRS-1C and IRS-1D were launched in 1995 and 1996 and have specific applications for vegetation and land cover mapping. Three sensors carried aboard the IRS satellites include the Linear Imaging Scanning Sensor (LISS), Wide Field Sensor (WiFS) and a panchromatic sensor. The LISS and panchromatic imagery 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-



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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.

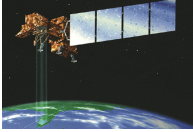
Quickbird

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



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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*.

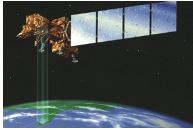
These technical investigations have focused on the northeastern U.S. There are many challenges to the use of remote sensing for forestry applications in this region. Different forest types in the Northeast are often composed of mixes of similar tree species in subtle variations under closed canopy. The 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



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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.