

*James N. Levitt*

## Conservation via Satellite

### Leveraging Remote Sensing to Monitor the Pingree Easement

Despite increasing human population pressures around the world, and the unprecedented environmental impacts that come in their wake, conservationists have made remarkable headway since the mid-twentieth century in extending protection to landscapes on every continent. For instance, in the four decades between 1962 and 2003, the IUCN/World Conservation Union reports that the number of protected areas it tracks worldwide increased more than ten-fold, from 9,214 to 102,102.<sup>1</sup> This represents nearly an eight-fold increase in area, from 2.4 million square kilometers in 1962 to 18.8 million square kilometers (about 4.6 billion acres) in 2003. To get a sense of this scale, consider that the lands in the 2003 inventory, though distributed across the globe, are equivalent to about 96% of the area covered by the United States and Canada, combined.<sup>2</sup>

This impressive tally is the result of countless conservationists employing a wide range of conservation strategies. Worldwide, national parks have been created in nearly every country that is represented at the United Nations. Augmenting more traditional conservation strategies, such as the creation of national parks, national forests, and national wildlife refuges, are more novel methods for protecting land, such as multi-party working forest conservation easements (WFCEs) that legally prevent commercial and residential development on actively-timbered, privately-owned forestland. Landscape-scale WFCEs are emerging as significant land protection devices that governments and non-profit entities can use to protect privately-owned forestland in such places as the Northern Forest, a multi-jurisdictional region that stretches from New York State to Maine in the United States, and into the provinces of Atlantic Canada. To cite one outstanding example, the New England Forestry Foundation's 762,000-acre Pingree project in Maine has set a new standard for conservation on private lands in the area (see Figure 1).

Notwithstanding this remarkable achievement, conservation practitioners face daunting challenges. Just as considerable expanses of open space have been protected, immense swaths of previously undeveloped land are being converted to intensive agriculture and building sites, from South Carolina to South Africa. This

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44

## Conservation via Satellite



**Figure 1. An aerial view of Chandler Lake, one of the many natural features protected by the Pingree Easement**

Photograph courtesy of the New England Forestry Foundation.<sup>3</sup>

development often has devastating effects on a diverse array of biological communities (collectively referred to as “biodiversity”) and negative impacts on an increasingly well-understood array of ecosystem services provided by the natural environment itself.

Even as they meet ambitious goals for land protection, practitioners face complex new challenges. One of the most difficult is the perpetual task of efficiently and effectively monitoring the physical changes that occur on protected landscapes—changes induced both by nature and by humankind. Such monitoring is essential if public, private, and non-profit organizations are to be good stewards of the land, enforcing legal protections and preventing disruptive human activities, such as illegal hunting of endangered species and poaching of timber, from degrading the quality of the protected landscapes.

Over the past several decades an inventive and potentially effective method has emerged for detecting changes on protected landscapes. That method is the use of satellite-based remote sensing technology, in combination with more detailed aerial photography and traditional on-the-ground patrols and inspections, to observe changes in the condition of a particular territory. In recent decades, several organizations, including the U.S. National Aeronautics and Space Administration (NASA), WinRock International, and the World Resources Institute’s Global Forest

*James Levitt*

Watch,<sup>4</sup> have employed satellite and aerial remote sensing technology to advance our understanding of human and natural change in forested landscapes, in both the developing and the developed world. Only recently, however, have such tools been applied by organizations such as land trusts that have legal and ongoing responsibility to enforce working forest conservation easements and similar multi-party land protection agreements. The bulk of this essay focuses on a highly ambitious effort spearheaded by researchers at the University of Maine and conservationists associated with the New England Forestry Foundation (NEFF) to employ this rapidly evolving technology to monitor a WFCE. Before I discuss NEFF's initiative, however, I offer a little historical perspective.

“THESE REFUGES ... ARE WORTHLESS UNLESS THEY ARE PROTECTED”

Less than two years into his presidency, Theodore Roosevelt had already scored a few successes in his storied effort to expand the nation's inventory of conserved landscapes. Following precedents set by earlier presidents, he had created a new national park at Crater Lake in Oregon and a new forest reserve at Luquillo, in Puerto Rico.<sup>5</sup> By early 1903, his focus turned to the creation of two new species of federal lands: the first of several dozen Bureau of Reclamation projects in the West, and the nation's first federal bird reservation at Pelican Island, on Florida's Atlantic coast.

Between March 14, 1903, when Pelican Island was created, and the day in 1909 when he turned over the White House to William Howard Taft, Roosevelt managed to establish a total of 51 federal bird reservations, the first units of what is today the Federal Wildlife Refuge System, a vast collection of protected landscapes covering more than 96 million acres in the United States.<sup>6</sup> Roosevelt was justly proud of what he had done to “preserve from destruction beautiful and wonderfully wild creatures whose existence was threatened by greed and wantonness.” He boasted in his autobiography that “the creation of these reservations at once placed the United States in the front rank of the world work of bird protection.”<sup>7</sup>

As the nation's chief executive, Roosevelt had the authority to set aside land for conservation—but not to allocate funds to pay the wardens who would monitor the new bird sanctuaries. To fill the gap, he turned to his friends in the growing Audubon movement for philanthropic support. They were happy to help. With funds provided by philanthropists associated with the Audubon movement and the American Ornithological Union, Paul Kroegel was hired to oversee Pelican Island, a somewhat solitary and occasionally dangerous job. Likewise, Guy Bradley and C.G. McLeod were paid modestly to monitor and protect other sites in South Florida. Tragically, Bradley and McLeod were killed in the line of duty by poachers who sought to kill the resident wild birds for their plumage, which they could sell for high prices to milliners seeking to decorate fashionable ladies' headwear.

The national outrage that followed the deaths of Bradley and McLeod helped build passionate nationwide support for the cause of conservation, and respect for the essential work done by wardens. Retrospectively praising the Audubon move-

*Conservation via Satellite*

ment for its help, Roosevelt underscored the importance of constant vigilance over protected lands: “It was the Audubon Society which started the movement for the establishment of bird refuges. The society now protects and polices about one hundred of these refuges, which, of course, are worthless unless they are protected.”<sup>8</sup>

Today, more than a century after Theodore Roosevelt famously championed land and habitat conservation, the oversight and monitoring of protected lands in both developing and developed nations around the world remains a costly, difficult, and sometimes dangerous task.

For example, in the world’s less developed regions, wardens of land typically protected by regional and national governments often face the task of protecting landscapes from gangs of poachers who seek to profit from the sale of illicitly captured wildlife and stolen timber. As noted by one warden responsible for overseeing nature preserves on the Andaman and Nicobar Islands off the coast of mainland India, “we must always be prepared for encounters with criminals who are better armed and equipped than we are.”<sup>9</sup> Similarly, WWF, the international conservation group, started a project in 2003 to deploy an “anti-timber-poaching brigade in Siberia” to halt “widespread illegal and semi-legal logging activities” in a region of the Burea Mountains “that hosts a unique mixture of temperate, boreal and endemic Daurian species, including the last remaining Korean pine (cedar) forests.”<sup>10</sup> Similar conservation monitoring and enforcement measures are underway around the globe from Malaysia to the Congo Basin.<sup>11</sup> Such anti-poaching initiatives involve serious law enforcement measures, at considerable expense. Given that many such warden operations depend largely upon on-the-ground patrols over vast territories populated by precious few citizens, the personnel costs of such operations alone can be considerable.

In nations with more developed economies, such as the United States and Canada, the protected-land stewardship challenges are in some ways similar to those found in the developing world, and in some ways quite different. Like their counterparts in India, wardens of government-owned and managed-forest and wildlife refuges in the U.S. must remain vigilant against a wide variety of encroachments, including the threat of aggressive timber and wildlife poachers. In a recent publication, the Vermont Fish and Wildlife Department, an agency of the state of

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*James Levitt*

Vermont, reported that “due to the firearm-related link to game law violations, game wardens are seven times more likely than other types of law enforcement officers to be seriously injured or killed in an assault.”<sup>12</sup>

A distinctive complication faces conservationists working in the United States: legally protected lands are often owned by a vast multiplicity of public, private, and non-profit entities. As a consequence, the protection and stewardship of the land is not principally confined to local, state, and federal government agencies, or even to non-profits that are assisting such governmental entities. Even on very large parcels of land, that responsibility now also falls to combinations of organizations that have acquired various conservation easements (alternatively called “conservation restrictions”) on their own land, or who are contractually responsible to the public for enforcing such restrictions on land owned by a third party.

Consider, for example, a substantial challenge now facing the New England Forestry Foundation (NEFF), a small, Massachusetts-based non-profit organization focused on the conservation of working forests. To understand the challenge, let us step back to a meeting that took place in the late 1990s at Harvard University’s Kennedy School of Government in Cambridge, Massachusetts.

#### A TRULY BIG DEAL

In the spring of 1999, Keith Ross, Frank Reed, Jerry Bertrand, and Bill King made a trip to Cambridge for a brainstorming session with several Kennedy School faculty and staff about the Pingree project, a private forest conservation effort of unprecedented scale and novel design being launched by the New England Forestry Foundation.<sup>13</sup> The proposed project aimed to buy a Working Forest Conservation Easement on more than 750,000 acres (more than 300,000 hectares) of private forestland owned by the Pingree family in northern Maine. By buying the easement from the family, NEFF would effectively extinguish any rights to develop the land for residential, commercial, or industrial purposes, assuring that it would remain as working forestland owned by the Pingrees, as well as a resource providing wildlife habitat and recreational opportunities, in perpetuity.

Ross, a stout, friendly bear of a man with a curly blond beard, was the group’s leader and the project’s visionary. He was also the only one of the four actually employed by the New England Forestry Foundation. The other three were either NEFF board members or consultants to the Pingree project. As Ross and his team began describing the project, the exceptional nature of their enterprise became apparent.

Measured in acres protected, the project that Ross and his associates described would be more than one hundred times larger than any land deal the NEFF had ever consummated in its fifty-five year history. Indeed, if it succeeded, the effort would be the largest conservation easement project in American history, covering a land area larger than the state of Rhode Island. Furthermore, the project, as it was described, intended to set sev-

### *Conservation via Satellite*

eral important precedents in the field of land conservation.

First, in part because of its scale and the limited bundle of development rights that the easement agreement was putting under restriction, the project was being marketed to potential donors with a remarkably modest price of \$37.10 per acre protected. Second, at the request of the Pingree family, the effort was designed to raise from non-government sources all or most of the \$28 million that would be used to purchase the easement itself, plus several million dollars to cover campaign expenses and to set up a permanent endowment for easement stewardship. Third, because NEFF was a very small and relatively entrepreneurial organization (it then had six full-time employees), it planned to have a “virtual organization” run the fundraising campaign, and also design and implement a novel stewardship monitoring program. The dozen or so individuals in the virtual “Pingree Forest Partnership” included only one or two full-time NEFF employees at any given time, along with Pingree family interests. Finally, the whole fundraising effort to underwrite this historic WFCE had to be completed by December 31, 2000—less than two years hence.

As if that wasn’t ambitious enough, Ross also mentioned that NEFF would have to figure out a novel technical method so it could monitor the vast, widely dispersed easement on a limited endowment. NEFF had to be able to assure project donors that the project could manage such monitoring in perpetuity in accordance with the stipulations in the conservation easement.

The meeting at the Kennedy School was cordial, lively, and wide-ranging, but the group had no “Eureka!” suggestions regarding fund-raising, organizing, or monitoring protocols. After more than two hours of exchange, the meeting adjourned. Afterwards, conversations among Kennedy School participants were colored with both hope and a fair amount of skepticism. In response to a hopeful comment by a colleague, one participant commented: “Yes, the Pingree Project would be a ‘big deal’—literally and figuratively—*if* it gets done by the deadline. But that’s a huge ‘*if*’. They’ve got to raise a lot of money in a very short time, and NEFF has never done anything even close to this scale, in terms of dollars or acres, in its entire history. We’ll see.”

And so we did see. Over the succeeding year and three-quarters, Ross and his team employed an inventive communications strategy and worked at an intense pace to raise sufficient pledges to cover the cost of the deal. They did so in the context of considerable political controversy and public debate. But the entrepreneurial team persevered, and got their pledges by the deadline. With the help of bridge financing, NEFF exercised the option to purchase the easement in December 2000. The following spring they completed the largest private easement deal in American history.

*James Levitt*

RECOGNIZING THE NEED FOR A NOVEL APPROACH  
TO MONITORING PROTECTED LAND

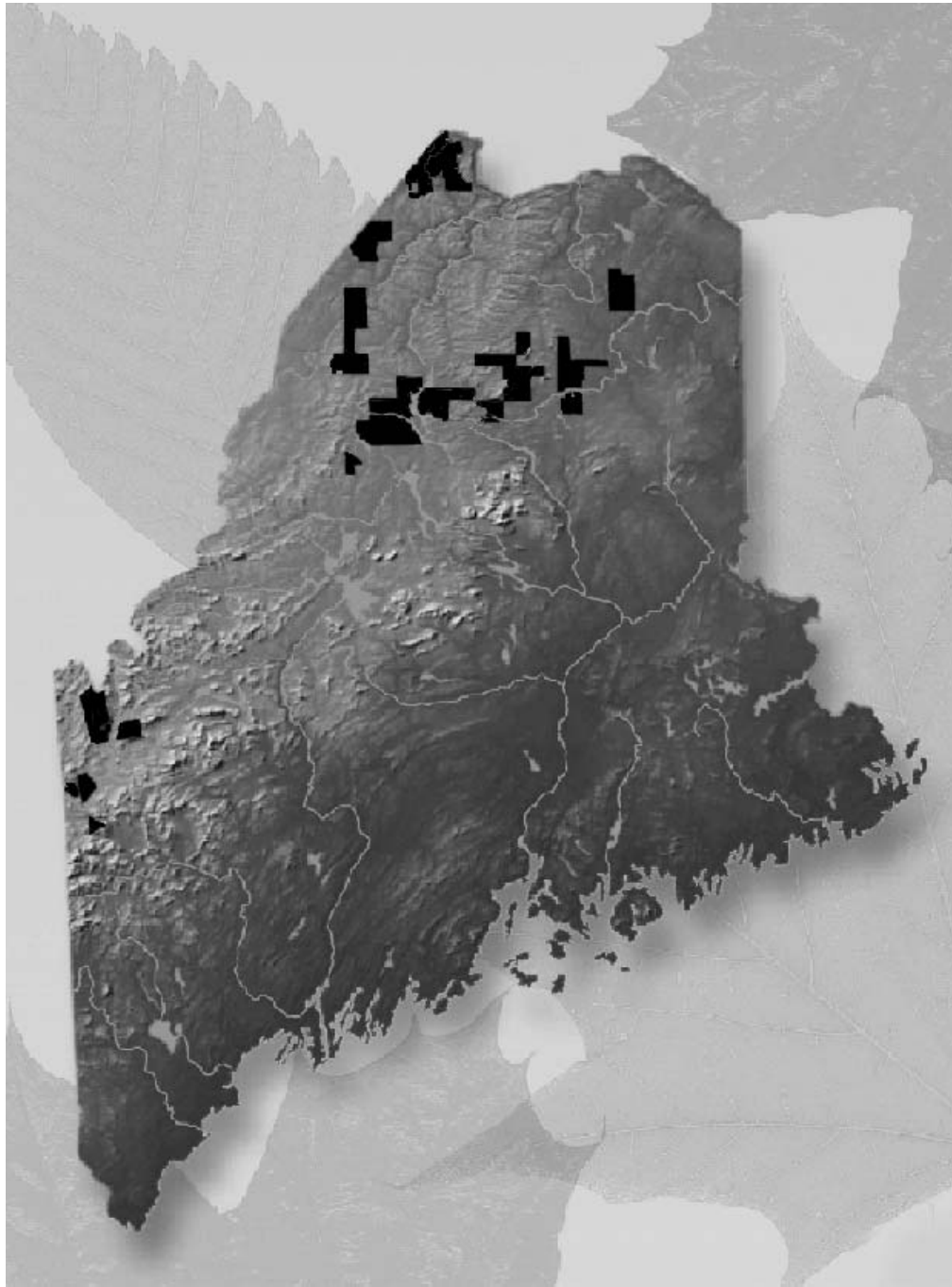
But even with progress on the financial aspects of the Pingree project, the task was far from complete. As early as the middle of 1999, Keith Ross began working in earnest with two of his Pingree Forest Partnership colleagues to devise an easement stewardship and monitoring methodology that would be efficient, effective, and economically sustainable over many decades. Frank Reed was a forestry consultant based in Randolph Center, Vermont, who later became a NEFF employee; Peter Stein was a director of Lyme Timber Company's Conservation Advisory Services. Stein was particularly keen to develop new easement monitoring methods; he realized that traditional methods, typically an individual forester riding around a property in a truck, would not be economically or physically feasible given the very large scale and wide geographic distribution of the Pingree easement.

The team was quite clear about the importance of this work. From NEFF's point of view, ongoing easement monitoring was—and is—essential to achieving the organization's conservation objectives. Catherine Hahn, a NEFF Land Protection Specialist, put it emphatically: "the strength of any conservation easement program lies in the diligence of the conservation organization's monitoring and enforcement activities."<sup>14</sup> Rather than using ongoing monitoring simply as an enforcement tool, NEFF saw the implementation of the monitoring program as an opportunity to build a lasting, conservation-oriented bond with the landowner: "to work with the landowner to ensure that activities on the land conform with the terms of the easement and to develop a partnership with the landowner in promoting sustainable forestry practices."<sup>15</sup>

As it worked to complete the easement deal and set up monitoring systems for the Pingree forest, NEFF had the great good fortune to be working with a land owner and land management organization that has maintained an outstanding record for stewardship and accountability for many generations. The Pingree family, which has owned and managed Maine forestland since the early 1840s, has worked to extend that record into the future through an ownership entity formed in 1974, known as Pingree Associates, led by Stephen Schley. Schley is a sixth-generation descendant of David Pingree, the entrepreneur who began assembling the family forestland holdings. Reporting to Pingree Associates is a second entity, the Seven Islands Land Management Company. That group, set up by the Pingree family in 1963, now manages forestland owned both by the family and by others in New England.<sup>16</sup>

Given the Pingree family's motivation to be responsible land owners and good corporate citizens, Seven Islands took a leadership role in promoting sustainable forestry practices in Maine. In the early 1990s, Seven Islands decided to become a pioneer in the field, seeking and gaining Forest Stewardship Council (FSC) certification. To do so, it agreed to undergo extensive, ongoing reviews by an independent certification organization, Scientific Certification Systems (SCS). Having become the largest land manager in the Northern Hemisphere to be FSC certified

*Conservation via Satellite*



**Figure 2: The area protected by the 762,192-acre Pingree Easement (in black), dispersed throughout Northern Maine**

Graphic courtesy of the New England Forestry Foundation and Virtual Design.



*James Levitt*

as “well-managed” in 1994, Seven Islands has gone on to maintain its FSC certification (as well as Sustainable Forestry Institute certification) into the 21<sup>st</sup> century. The careful SCS reviews provided both experience with and extensive documentation for the monitoring efforts that NEFF launched when it completed the Pingree easement deal.<sup>17</sup>

It is important to note that NEFF’s dedication to high-quality, consistent easement monitoring is not universal among its peer-group of government or non-profit organizations that hold conservation easements. As explained by Amos Eno,

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who became active in the Pingree project as a consultant in the 1999-2000 period and served as NEFF’s executive director from 2002 to 2005. According to Eno, “the Pingree Forest Partnership sets a precedent for monitoring and enforcing its conservation easement. Many conservation easements are rarely or cavalierly monitored. According to a 1998 report, none of the State of Maine’s 93 easements, which cover about 28,000 acres, are ‘regularly’ monitored.”<sup>18</sup> Eno is a great-nephew of Gifford Pinchot, Theodore Roosevelt’s brother-in-arms in the fight to make conservation a national priority in the early 1900s; he echoes a sentiment Roosevelt had expressed almost a century earlier: “Enforcement and monitoring are

the cornerstones to the effective management of a conservation easement; without monitoring the easement is of little value.”<sup>19</sup>

NEFF’s enthusiasm for monitoring was reflected in the energy it put into raising an endowment to underwrite ongoing Pingree easement monitoring efforts. In total, NEFF raised \$1 million over the course of the Pingree project to support this work.<sup>20</sup> This money, now held by a separate community foundation for NEFF’s benefit, will yield approximately \$50,000 per year to cover the costs of monitoring development activities, forestry activities, and forest ecosystem attributes over the mosaic of Pingree forestlands in Northern Maine (see Figure 2 for an overview map of the 762,000 acres of forestland protected by the Pingree easement).

With that amount in hand, the challenge facing NEFF was—and is—to use that endowment to maintain a highly effective monitoring program for many decades into the future. Beyond meeting its own needs, the organization was aware that if it successfully developed and implemented a cost-effective monitoring pro-

### *Conservation via Satellite*

tocol, it would set a new and significant precedent for forest management organizations throughout New England, and eventually, the nation and the world.

Given the potential significance of this work, NEFF ultimately raised additional funds (beyond the endowment to support long-term monitoring) in order to support the development of the novel three-tiered monitoring methodology and its dissemination to the forestry community. Funders of this pioneering work included the Kendall Foundation, NASA, the Ford Foundation, and the Bradley Fund for the Environment.<sup>21</sup>

#### DEVISING A MONITORING PROTOCOL WITH THE BENEFIT OF PEER REVIEW

In mid-2000, Ross, Reed and Stein interviewed several private companies and not-for-profit organizations that were interested in the challenge of designing such a methodology. Each offered a variation on the theme of employing satellite-based remote sensing technologies, which had been used for more than a decade to conduct surveys of forest conditions around the world, to monitor the Pingree family's industrial forestry operations and so assure compliance with the NEFF conservation easement.

The most interesting of the potential service providers was a team led by Dr. Steven A. Sader, a professor in the Department of Forest Management at the University of Maine in Orono. Sader had been recommended to Peter Stein by Conrad Reining, who was at that time working with Conservation International (CI). Reining described to Stein the work that Sader had done for CI in helping to design a remote sensing protocol for use in CI's Rapid Assessment Program, a program that quickly maps out the biodiversity potential of promising sites such as the Guatemalan rainforest.

Since the early 1980s, Sader had been experimenting with the application of remote sensing technologies to forestry related analytical and management issues.<sup>22</sup> Despite his teaching load—he also directs the University's Maine Image Analysis Laboratory (MIAL)—Sader relished the opportunity to work with Reed, Ross and Stein. He quickly understood that by engaging with the Pingree project, his team at the University of Maine could use its expertise in practical and near-term applications with working foresters.

In 2001, NEFF awarded Sader's team a contract to put together a monitoring protocol for the Pingree forest, and they got right to work on a three-tiered, "multiscale" scheme. It employs medium-resolution Landsat Thematic Mapper (TM) satellite-based remote sensing for the first, highest-level, pass at reviewing changes in forest conditions. Then, aerial photography (or high-resolution satellite-based imagery) allows closer-in, second-pass inspections of potential trouble spots identified by the Level 1 analysis. Finally, a forester makes on-the-ground inspections, generally only in those places identified in levels 1 and 2 analysis as meriting further inspection, and for those attributes, such as the quality of forest diversity or of wildlife habitat, that might not be effectively monitored from above.

*James Levitt*

As the protocol has evolved since 2001, it has been repeatedly peer-reviewed and discussed in several venues. For example, it was the subject of a day-long meeting that NEFF convened at its offices in Orange, Massachusetts in the spring of 2002. That meeting brought together practitioners in information science and forestry to consider and propose improvements to the methodology. In addition, the methodology has been described in peer-reviewed and practitioner-oriented journals several times since the spring of 2002, when it was described in the *Journal of Forestry*,<sup>23</sup> the professional publication of the Society of American Foresters, the world's largest society of professional foresters. Finally, the remote sensing scheme was presented for more diverse audiences interested in the stewardship of protected landscapes at Land Trust Rally meetings (gatherings of more than 1,500 land conservationists) in Austin, Texas and Sacramento, California in 2002 and 2003.<sup>24</sup> According to Frank Reed, these many reviews and public presentations helped the innovators become increasingly adept at packaging the protocol so that it could be transferred to other organizations and applications.

#### IMPLEMENTATION

The first step in implementing the monitoring protocol was to establish baseline conditions. To assemble a comprehensive record of the Pingree forestland, Keith Ross and his associates at NEFF began to collect documentation even before they wrapped up the deal's financial details in March 2001. Pingree Associates and Seven Islands helped them greatly in this effort by providing extensive information. To build on that base, in August 2001 NEFF retained a forester long affiliated with NEFF: Sherman Small, of New England Forestry Consultants, Inc. Based in Bethel, Maine, Sherm Small tackled the task diligently. In addition to assembling the necessary documentation and physically visiting key sites on the landscape, he identified and mapped landscape features into a complex Geographic Information System (GIS) database that allows the user to record written information and assemble time series of graphic images supplied by satellite, aerial, and ground-level digital cameras.

Generally, the inventory of baseline conditions on the Pingree property had to accurately reflect the presence of its impressive number of natural attributes, including "1,180 square miles of protected forestland protected from development; over 2,000 miles of river frontage; 72,000 acres of wetlands; 110 remote ponds and lakes larger than 3 acres; 215 miles of lake and pond frontage; 67 rare and endangered plant sites; 24,800 acres of managed deer yards; 12,264 acres of fragile high mountain areas over 2,700 feet in elevation; five federally listed endangered plant sites; peregrine falcon nesting sites; and a 3,000 acre limited harvest management zone along the St. John River."<sup>25</sup>

Specifically, the technology for collecting the baseline documentation had to enable present and future NEFF employees and agents to assure compliance with a carefully negotiated easement agreement. The stated purpose of that agreement is to maintain "the property forever in its present and historic primarily undevel-

### Conservation via Satellite

oped condition as a working forest, and to conserve and/or enhance forest and wildlife habitats, shoreline protection, and historic public recreation opportunities of the Property for present and future generations.”<sup>26</sup> To achieve this purpose, NEFF has the ongoing responsibility to track changes in *specific landscape features* (including leases, structures used in forestry activities, roads, gravel pits, riparian habitat, clearcuts, wetlands, and recreational use), as well as *landscape level attributes* (including forest diversity, ecosystem health, and disturbance). Should variations from the terms of the WFCE be detected, then NEFF is responsible for working with the landowner to assure compliance.

Sader, Reed, Ross, and their team set up monitoring protocols that could be performed year after year, providing a detailed, cumulative record of changes over time in both specific landscape features and landscape-level attributes. Consider, for example, how they are set up to track changes in one *specific landscape feature*—gravel pits—on the Pingree property.

The Pingree conservation easement document has detailed provisions regarding gravel pits,<sup>27</sup> and prohibits any excavation of minerals, geothermal resources, or hydrocarbons, except that rock, gravel, sand, peat, or sod may be removed in connection with forestry activities—for forestry-related road-building purposes. Gravel pits, which are permitted, cannot exceed 1% of the property at any given time, or be greater than 10 acres in area at any given location. If a planned expansion of a gravel pit would make it larger than 10 acres, then an unused portion of the pit must be reclaimed using a seeding procedure recommended by the USDA Natural Resource Conservation Service (the NRCS), or the NRCS’ appropriate successor agency.

To monitor compliance with these agreement provisions for this particular landscape attribute, Sader, Reed, and Ross, in consultation with Pingree Associates and the land managers at Seven Islands, set up a detailed monitoring protocol. They first determined baseline conditions by using Global Positioning System (GPS) technology to “locate each active excavation and unreclaimed excavation on [a] GPS map of each township.”<sup>28</sup> Such

GPS positioning can be accomplished by carefully reading recent satellite or aerial photos; or, for larger, active pits, a forester can conduct an on-site inspection using a handheld GPS device. Second, using the same technology, they determined the acreage for each excavation. Third, they set up a schedule for visiting a sample of active excavations each year to verify acreage estimates and site conditions. Fourth, they set up a schedule for communicating with the land manager to learn the schedule for reclaiming those excavations that are in a position to be reclaimed. And, fifth, they prepared to use remote sensing (both Level 1 medium spatial resolution satellite change detection and Level 2 high-resolution satellite or aerial photography sampling) to look for expansions of excavation sites and to conduct ground visits if the size of any excavation were to approach 10 acres.



James Levitt

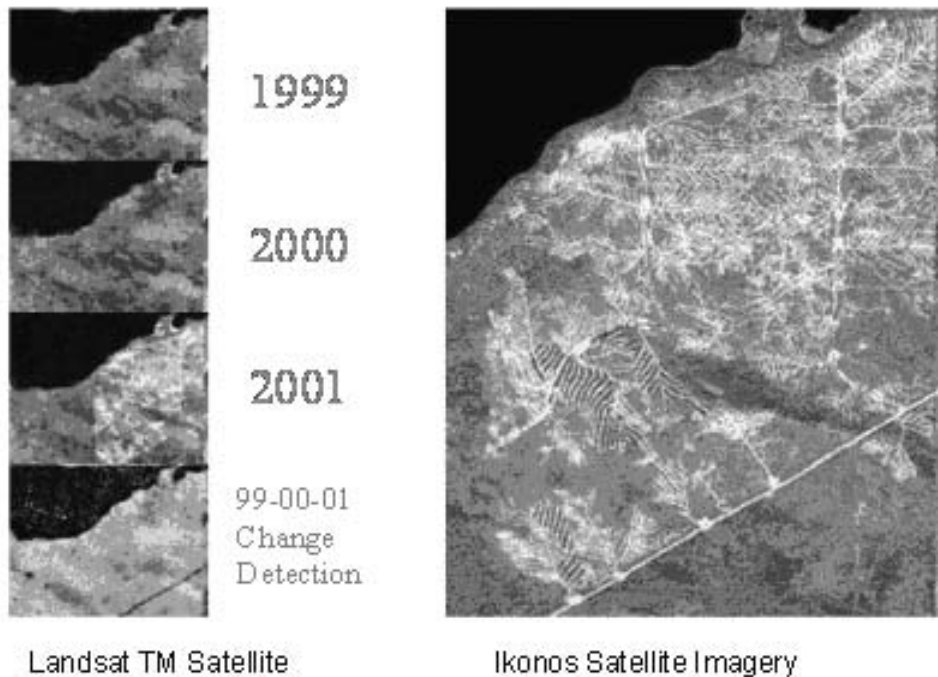
Level 1 remote sensing, as used in this application, depends on two important components. The first component is imagery from Landsat and comparable satellite sources provided, in this case, by NASA. Landsat Thematic Mapper information provides medium-resolution data at a scale of about 30 x 30 meters. That lets them distinguish and track specific landscape features such as gravel pits that are approximately one-quarter acre or larger, using images collected each year in the spring and early summer (mid-May to late June). For the Pingree project, the entire easement can be monitored with two Landsat images that cover 13,225 square miles.<sup>29</sup>

The second component is a change detection algorithm developed by Sader and his associates at the Maine Image Analysis Laboratory (MIAL). The algorithm allows the user to identify changes in the landscape by comparing an earlier image with a later one. The science behind the algorithms builds on a foundation laid by several decades of research sponsored by organizations such as NASA<sup>30</sup> that employed analog and digital images to track landscape change. The MIAL algorithms, in part based on NASA-sponsored research that Sader led in Central America,<sup>31</sup> have been demonstrated to be quite accurate in detecting expected and unexpected changes on the ground.

The same technological underpinnings are employed in the protocol for monitoring *landscape-level attributes* on the Pingree forest protected by the NEFF conservation easement. As with specific landscape features, tracking landscape-level attributes requires combined efforts at all three levels. Consider, for instance, how the project monitors disturbances in the forest over time, both natural ones and those caused by human intervention.

Using Level 1 monitoring techniques, Sader and his associates can track forest harvesting and regrowth patterns that appear on satellite images taken each spring. That is, they can use the MIAL algorithms to analyze data from Landsat images. Over time, at medium (30-meter) resolutions, they can detect various changes in forest cover, such as the location and amount of harvest areas created in clearcuts. Based on such analyses,<sup>32</sup> they can confirm whether or not such clearcuts conform to the restrictions detailed in the Pingree easement (i.e., that “grantor will strive to maintain no more than 3% of the Property in clear-cut condition”).<sup>33</sup> Similarly, they can use this type of information to compare actual cutting patterns with the planned cutting patterns described in the forest management plans (FMPs) prepared by the land manager (in this case, Seven Islands) and discussed at the annual-information sharing meetings required by the easement agreement.

Level 2 analysis allows Sader and his associates to gain further insights, for example, when a new or unexpected forest cover disturbance pattern occurs, or when they must analyze areas of the forest too small to be easily interpreted using Level 1 information. They have several options for obtaining more detailed imagery. In the Pingree case, the best source may often be the landowner, which “collects aerial photography over one-third of the ownership every year and has agreed to make the photos available for purchase by NEFF.”<sup>34</sup> If they cannot get suitable Level 2 imagery through that source, NEFF can acquire it using small-for-

*Conservation via Satellite*

**Figure 3: A comparison of Level 1 medium-resolution imagery from Landsat (1999-2001) on the left and Level 2 high-resolution (4 meters) imagery from Ikonos on the right. Note the appearance of equipment trails showing harvesting patterns in the right-hand photo**

Graphic courtesy of the New England Forestry Foundation.

mat cameras in aircraft overflights, or from commercial satellites that can provide images at a 4 meter resolution (see Figure 3 for an illustration of the detail provided by 4 meter Ikonos satellite imagery provided by Space Imaging Corporation). Such Level 2 imagery can often clarify the on-the-ground situation, for example differentiating between mechanical harvests (characteristically marked by logging trails left by heavy equipment) and large blow-downs of trees caused by such natural causes as heavy storms or hurricanes.

On-the-ground field visits can be scheduled when the easement monitoring staff needs finer detail than it can get using Level 1 and Level 2 imagery. For example, when the diversity of forest stands or the quality of wildlife habitat must be inspected in a recently disturbed area, there may well be no acceptable substitute for an on-site visit by a forester. Because such visits are relatively expensive, they must be carefully planned to achieve an optimal use of the forester's time.

According to Frank Reed and Steve Sader, monitoring using medium-resolution satellite imagery has gone largely according to expectations, with no significant known failure to detect forestry operation patterns on the ground.

*James Levitt*

Coordination between the imagery lab and the field staff has also gone well. For example, an image analyst detected an unexpected cutting pattern in a field, but Sherm Small was able to show the analyst where that cutting was anticipated, both in the easement language and in the harvesting plan. With that feedback from Small, the analyst then determined that the cutting had been carried out according to plan and in adherence with the easement language.

## ENFORCEMENT

According to verbal reports by Reed in the first quarter of 2006, discussions between the NEFF team and Pingree Associates regarding monitoring and easement enforcement issues have been cordial and cooperative. While the three-tiered monitoring protocol was under development, one of the Seven Islands managers wryly characterized it as “Star Wars proctology,” but now both NEFF and Pingree Associates/Seven Islands representatives see the findings of the annual monitoring efforts as valuable and interesting. The annual meetings called for in the easement agreement have included detailed discussions of actual versus planned forest management practices on a township-by-township basis. Minor issues have been discussed from time to time, such as the fact that a lessee in the Pingree forest had stored a canoe outside of the lease boundary. However, no significant disagreements over easement violations have arisen during the first five years of monitoring. Furthermore, in the first five years of easement monitoring on the Pingree site, the NEFF team has not observed any significant wildlife or timber poaching activities that would have required intervention by Seven Islands or law enforcement personnel.

As title to ownership of the Pingree forestlands changes, dialogue between the easement grantor (the Pingree Associates group) and the easement grantee (NEFF) may present new challenges to NEFF management. For example, in 2005, Pingree Associates sold “a significant parcel of forest land in Northern Maine,”<sup>35</sup> including lands that are protected by the NEFF easement, to a third party. Because Seven Islands continues to manage that land for the new owners, the easement monitoring has changed very little. Should this land, or other lands under the easement, come to be managed by a new set of players, then the resulting multi-party monitoring dialogue will likely become more complex and time consuming for NEFF easement monitoring and enforcement teams.

## IMPROVING ECONOMIC EFFICIENCIES

As noted above, annually monitoring the Pingree project using conventional ground-based methods would have been prohibitively expensive. Consider, for example, that the ground-based monitoring of a 20,000+-acre easement in New England requires several person-days per week, year round.<sup>36</sup> At more than thirty times the size of that easement, the Pingree project might have required a dozen or more staff foresters, at a cost of hundreds of thousands of dollars per year, to pro-

### *Conservation via Satellite*

vide similar coverage.

By contrast, Steve Sader carries out the bulk of remote monitoring work for the Pingree easement, with assistance from the staff and graduate students in his lab (the MIAL). When field visits are required, Sherm Small typically drives over. According to reports by Frank Reed, the cost per acre of the monitoring program continues to decline over time, from a level of 10 cents to 15 cents per acre in 2001-2003 (approximately \$75,000 to \$100,000 per year for the more than three-quarter million acre easement area), to approximately 9 cents per acre per year (between \$60,000 and \$70,000) in 2005. This welcome decline in monitoring expenses brought annual costs closer to the target \$50,000 (about 6 cents per acre per year) that can be sustained with funds from the monitoring endowment. The annual decline in costs so far, as well as the anticipated future decline, is likely related to at least three inter-related factors: so-called “experience curve” economies, economies of scale, and economies of scope.

The experience curve effect is likely to continue as NEFF accumulates organizational experience with the three-tiered monitoring protocol. First observed in manufacturing industries in the mid-20<sup>th</sup> century by analysts associated with the Boston Consulting Group, such experience curves are now well understood to take hold in both manufacturing and professional operations where on-the-job learning can be passed along, on the job, from one individual to another.

Economies of scale are likely to occur as the Maine Image Analysis Lab staff takes responsibility for easement monitoring on nearby tracts of land, such as the Downeast Lakes and Sunrise easements. This tract in Downeast Maine, in combination with adjacent protected forestlands in Maine and across the Canadian border in New Brunswick, accounts for more than a million acres of protected landscapes. Costs of computer equipment, imagery acquisition, and software are likely to be distributed across multiple projects, reducing the cost of monitoring any given acre. Similarly, economies of scope are likely to occur as monitoring staff become more practiced at monitoring a variety of specific landscape features and landscape-level attributes. The image analysts expect they will be able to apply learning from monitoring one specific attribute to related challenges that arise while they monitor a second attribute.

#### USING THE TECHNOLOGY IN NEW APPLICATIONS

Since it was first implemented for the Pingree easement, the three-tiered monitoring protocol has caught the attention of many organizations charged with monitoring large working forest conservation easements, as well as other large-scale protected landscapes. In 2003, NEFF received funding from the United States Forest Service (USFS) to prepare easement monitoring protocols for two large easements that had been financed in part by the USFS Forest Legacy program. The purpose of the grant, in part, was to “see if remote monitoring techniques (applied by NEFF to the Pingree conservation easement) could be applied to other landscape scale easements to improve on the effectiveness and efficiency of ongoing



*James Levitt*

monitoring requirements.”<sup>37</sup> The first of the two easement properties, located in Coos County in northern New Hampshire, is known as the Connecticut Lakes project. The second easement property, in the nearby “Northeast Kingdom” in the state of Vermont, is called the Hancock Forest Legacy Conservation project. Given their close proximity to one another, both tracts of land are covered by a single Landsat image, so the two legacy programs will be able to share the costs of acquiring images.

As the Forest Legacy WFCEs prepared their monitoring protocols, they followed a path very like that used to prepare the Pingree monitoring protocol. First, detailed baseline conditions for each of the tracts were collected. Based in part on experience the Pingree group gained while developing its monitoring protocol, a

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checklist of baseline documents was collected for the Connecticut Lakes and Hancock Forest Legacy projects. This list included Landsat images of the tracts, taken both shortly before and shortly after the respective easements were initiated; aerial photos or digital orthophoto quadrangles of the areas at easement initiation; digital elevation information; maps showing lease locations and boundaries;

copies of forest lease documents; and forest management plans, if available. Relevant forest attributes detailing each easement restriction for each site were identified and recorded. Next, four years (1999 to 2003) of Level 1 imagery were used to assess which attributes could best be tracked using medium-resolution satellite images. For the Hancock Forest Legacy property, the exercise showed that 11 of 16 attributes restricted by the easement could be monitored, at least in part, using Level 1 imagery. The remaining attributes, including billboard placement, waste disposal, topographical change, utility placement, and subdivision, would have to be monitored through site visits. While the ongoing effectiveness of the three-tiered monitoring protocol for the Connecticut Lakes and Hancock Forest Legacy projects is still being investigated, project managers report that the protocols developed will likely be implemented for long-term easement monitoring purposes.

As noted above, NEFF and a group of conservation partners (a local land trust, state and federal agencies, and an Indian tribe) have recently protected a second landscape-scale conservation area in Maine. That property, known as the Downeast Lakes project, forms the core of a nearly one-million-acre protected landscape that stretches from Washington County, Maine into New Brunswick,

### *Conservation via Satellite*

Canada. NEFF is currently preparing a protocol to use the three-tiered monitoring technology to monitor the Downeast Lakes tracts. Early reports are that the application of the technology to this multi-owner landscape is going smoothly. Experience with this multi-owner situation should give staff at NEFF and MIAL additional expertise they can apply to additional easement monitoring opportunities that are being considered.

#### OPPORTUNITIES AND CHALLENGES AHEAD

In 2004 and 2005, Steve Sader and Kenton Williams at MIAI, along with Chris Pryor and Frank Reed at NEFF, developed new capabilities for the three-tiered monitoring system, in conjunction with their work on the Connecticut Lakes and Hancock Legacy Forest easement monitoring protocols. These new capabilities make the technology more accessible to a wider range of users, including managers of small land trusts and comparable organizations that have limited access to information technology expertise.<sup>38</sup> For example, field-based monitoring staff can now use handheld GPS and Personal Digital Assistant (PDA) technologies to access from the field baseline GPS information for a given easement property, and enter new information into a GPS system based on new field observations. Even novice users unfamiliar with more complex GIS software (for example, ArcGIS and ArcView from ESRI) can use free GIS software to enter and analyze field observations. With modest technical assistance from local commercial service providers, non-profit GIS service providers, or universities, such novice users can layer their field-based observations onto Layer 1 and Layer 2 information to gain a more comprehensive view of easement property conditions over time. Such capabilities will only make the three-tiered system even more useful for those administering large-scale WFCEs.

Beyond the opportunities to serve WFCEs, the three-tiered protocol has many other potential applications, including large easements that protect lands other than working forests. This has become particularly relevant in recent years, when United States Senate Finance Committee hearings on the regulation of easements and land trusts have led the land trust movement to adopt a new set of recommended standards and practices. These call for careful baseline documentation and systematic monitoring programs for all easements held by member organizations of the Land Trust Alliance.<sup>39</sup>

In addition, in both the developed and the developing world, the monitoring technology may well prove to be of considerable value to those who are operating and regulating the increasing numbers of ecosystem service projects. These projects provide valuable services, in exchange for payments from qualified buyers (such as governments, NGOs, or private sector developers operating within cap-and-trade regulatory systems) to qualified sellers (such as quality-certified landowners and managers). Among the many services are wildlife conservation banks (reclaimed or unspoiled habitat for endangered or threatened wildlife species at an assured quality level); wetland mitigation banks (reclaimed or

*James Levitt*

unspoiled wetlands at an assured quality level); carbon sequestration banks (sustainable managed forest or grassland ecosystems that store carbon that might otherwise be released into the atmosphere); and watershed protection districts. In Costa Rica, for example, hillside farmers in districts surrounding hydroelectric projects are paid to keep steeply-sloped forested landscapes planted with trees, to prevent soil erosion that would ultimately impair the hydroelectric facility operating in the valley below their farms. Such an application would be very fitting, given

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that before he worked on the Pingree project, MIAL's Sader had paid particular attention to designing Rapid Assessment Program protocols for biodiversity-focused organizations such as Conservation International.

Likewise, the monitoring protocols developed for the Pingree easement could also be quite valuable to those overseeing and enforcing land protection agreements for vast and remote national parks, national forests, and wildlife refuges that suffer from timber and

wildlife poaching. From the islands off the coast of India to the Siberian boreal forests I mentioned at the beginning, comprehensive monitoring technologies could help thinly stretched enforcement teams pinpoint ongoing poaching activities in widely-dispersed trouble spots and allocate on-site personnel accordingly.

Importantly, the longitudinal records established by digitally recorded remote-sensing protocols could serve as strong and effective evidence in any legal proceedings where the history of change on the landscape is in some way disputed or uncertain. In this type of application, the use of such technologies could strengthen the efforts of organizations such as World Forest Watch to reduce graft and corruption in the administration of timber concessions in regions where such practices delay the emergence of fair and efficient market economies.

Both NEFF and MIAL face a challenge in taking advantage of these myriad opportunities: how to sustain what largely remains a research and development oriented effort rooted in a university and a small non-profit. As the demand grows for Pingree-like monitoring services, it may be necessary to transfer some of the monitoring operations to an independent non-profit service bureau or a commercial enterprise that is organized and financed to pursue market opportunities.

But such a transition has not yet proven practical. Amos Eno, executive director of NEFF from 2002 to 2005, enthusiastically supported such a transition. With

### *Conservation via Satellite*

Eno's recent departure from NEFF, and with NEFF now engaged in a search for a new executive director, the monitoring efforts are likely to continue to grow within their current organizational context for some time to come.

#### KEY FACTORS FOR SUCCESS

From the perspective of the protocol's principal advocates and developers, as well as third parties that have evaluated a variety of WFCE monitoring protocols, the one developed by NEFF and MIAL for the Pingree project appears to have unique design, considerable utility, and genuine promise.<sup>40</sup> At least three distinctive factors appear to be related to the success of the Pingree monitoring effort.

First, the Pingree project's efforts to develop a monitoring protocol, along with those by the Connecticut Lakes and Hancock Forest Legacy projects, have benefited from the close professional attention of an uncommon mix of professionals from the non-profit, academic, private, and public sectors. Experienced professionals from well-respected organizations—NEFF, the University of Maine, Seven Islands and the U.S. Forest Service—collaborated on the specification of required baseline documents and methods to monitor change over time, allowing the monitoring protocol to benefit both from years of experience and a cross-cutting perspective. Similarly, the protocol has benefited from being submitted in a variety of forums to peer review.

Second, the protocol benefits from relatively generous amounts of funding provided for technical development, professional review, and information dissemination. Without the non-profit and public sector grants that funded the early protocol development, MIAL and NEFF would not have been able to complete preliminary and full-scale testing of the protocol. Similarly, the relatively generous funding of the stewardship fund itself will allow NEFF to continue monitoring and process improvement for many years into the future. This is in stark contrast to the monitoring budgets set aside for many other conservation easements, which are typically modest in comparison to the Pingree easement monitoring budget, or—all too often—non-existent.

Third, the Pingree easement monitoring effort benefited from the persistence of conservationists who have worked at overall project fundraising and development for more than a decade. Their persistence was fueled in part by the knowledge that if they reached their goals for fundraising and technology development, they would be setting a nationally (and perhaps internationally) important precedent both for the size of a WFCE, and for the way in which that WFCE was stewarded over time.

#### IS THIS AN IMPORTANT INNOVATION IN CONSERVATION STEWARDSHIP?

Now that the Pingree project has made impressive progress towards successfully implementing the three-tiered monitoring protocol, a critical question remains: is



James Levitt

this an innovation of lasting importance for conservation stewardship practitioners around the globe, or will it have only a modest and transitory impact? Five criteria, discussed in greater depth in recent publications on conservation innovation,<sup>41</sup> can be usefully applied to weigh the question. Specifically, is this initiative: *novel*, showing a spark of creativity in conception; *significant* from a policy or organizational strategy point of view; *measurably effective*, using an objective, independently applied metric; and *transferable*, from one jurisdiction, city, state or nation to another? And, perhaps most important for conservationists, does it show the promise of *enduring* over the course of decades and human lifetimes?

The Pingree protocol monitoring effort is indeed novel. The protocol developed for monitoring the Pingree easement, while based on substantial work regarding the use of remote sensing to track land use change, is the first application of its kind used on a landscape-scale Working Forest Conservation Easement, or any other very large scale private land protection initiative in the U.S.

Is the initiative significant? It clearly proved to be significant for NEFF, which found it to be a unique way for a very small land conservation organization to monitor landscape change over a very broad, dispersed territory. The willingness of the USFS to invest in the technology on a Forest Legacy project further argues for its significance.

The measurable effectiveness of the protocol is demonstrated by its reported accuracy in tracking changes in the landscape without major errors, in an increasingly cost-effective way. It is important to note that the protocol has not yet achieved targets for annual costs per acre. It will not be entirely successful, in the context of the Pingree project, until it brings annual monitoring costs down to about 6 cents per acre, or the total of about \$50,000 per year that the project can support over the long term with its million-dollar stewardship endowment.

As for transferability, the protocol has already been deployed by NEFF for the Connecticut Lakes and Hancock Forest Legacy projects, as well as the Downeast Lakes project. The big unanswered question here is whether or not the protocol will be used by other organizations outside of New England to annually monitor large easement tracts.

The three-tiered monitoring developed for the Pingree project has a good chance of enduring over time if it can continue to reduce its costs per acre, and successfully transfer its technology to a wide variety of large and small land conservation organizations. While components of the protocol may change, it is likely to remain an attractive monitoring scheme for many years to come, given its combination of satellite/aerial based scans and well-planned field visits linked to high-capacity GIS systems. Indeed, as developing conservation community standards call for frequent monitoring of easement requirements, there may be few, if any, practical alternatives for monitoring easements of greater than 50,000 acres in the future.

In sum, the three-tiered monitoring protocol developed for the Pingree project shows good promise of qualifying as an important conservation innovation, but to do so it must continue to make progress on costs and technology transfer to

## *Conservation via Satellite*

outside organizations.

As Teddy Roosevelt indicated nearly a century ago, conserved lands that are not actively monitored and protected are likely to be greatly diminished in value. In contrast, competent, accurate, and efficient stewardship can go a long way toward assuring that such lands can continue to provide vital ecosystem services long into the future. They can continue to provide wildlife habitat, filter drinking water, sequester carbon, and supply beauty for us, our children, and our children's children. Roosevelt would likely have high praise for the developers of the monitoring protocol described here. They have shown at least one pathway for applying modern information technology to the considerable conservation challenges of our age, bringing conservation practice into the 21<sup>st</sup> century.

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*We invite reader comments. Email <editors@innovationsjournal.net>.*

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*James Levitt*

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### *Conservation via Satellite*

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