Appropriate Geomatic Technology for Local Earth Observation

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ABSTRACT
Geomatics is a useful new term for the use of advanced information technologies for the recording, storage, manipulation and analysis of geographical imagery. It includes remote sensing, global positioning systems and computer-based image manipulation and analysis. While high technology geomatics has tended to concentrate analytical power, recently developed, affordable systems now permit land-based peoples to use geomatics in pursuing land claims and environmental monitoring. New, off-the-shelf information technology makes it possible to mimic satellite-sensing capabilities in light-aircraft based systems that are more appropriate for local applications. The Local Earth Observation Project has adopted an applications-driven approach and built a complete system that can act as an alternative or complement to satellite systems. Its capabilities are consistent with expressed needs of many land-based communities and with the implementation priorities of the Biodiversity Convention.

The idea for this project, Local Earth Observation, came to mind after meeting with NASA officials working on the Earth Observing System (EOS), a constellation of satellites to be launched in 1996 as an instrument for planetary management. Data streams from these satellites will flow into computer models designed to mimic vital earth processes and reveal significant trends. Ultimately these will be converted into options, or justifications, for political decisions.

This is not a comforting prospect. The track record for international environmental negotiations is discouraging and it is difficult to believe that the self-serving nationalism so conspicuous in the debate over ozone and climate change will be suspended when it comes to selecting among likely options. Delegations at the 1992 Earth Summit consistently championed national interests rather than commit to the cooperative actions needed to address global environmental issues.

Satellite systems concentrate vast arrays of sensitive data in the hands of institutions supported by the industrialized nations. Since first introduced in the 1970s, their output has been monopolized by organizations with the technical capacity to analyze complex data: land management agencies, resource corporations and academic researchers. The prices for satellite imagery, initially subsidized, have risen to as much as $5000 for a single frame. Plans to privatize processing and distribution of satellite information are likely to restrict access by increasing prices further.

Remote sensing is often referred to as a "technology in search of an application." During its brief history, it has always been technology-driven — a hangover from its military origins. Although justified in terms of potential applications, academic research reinforces this tendency by focusing upon sophisticated and subtle technical operations invariably unsuitable for operationalization. This has generated an enormous literature but virtually no action.

TECHNICAL ALTERNATIVES FOR LOCAL EARTH OBSERVATION

Technological imperatives, military origins, institutional research and political convenience have combined to advance remote sensing as a technology that concentrates rather than diffuses the power that comes with the possession of global information. This has been widely presented as inevitable but this is no longer the case. New information technologies from a variety of sources can be integrated to make cheap and credible alternatives to space-based systems.

The LEO Project is an effort to explore and demonstrate this alternative, to counter these concentrating tendencies with one that is dispersive, to shift from technology-driven to applications-driven systems, to localize geomatic technology so as to empower land-based people and environmental NGOs in remote areas, and to democratize access to environmental information that is becoming increasingly significant and occasionally proprietary. In deciding what technologies to mobilize in taking this direction, we took account of global and local trends from an applications perspective.

With virtually no technical resources at their disposal, the communities scattered throughout these lands are faced with a huge double task: to protect their territory from intrusive settlement and industrial resource exploitation, and to adapt and reinforce traditions of sustainable resource utilization in a contemporary context.

APPLICATIONS FRAMEWORK: GLOBAL SCALE

On a global or continental scale, three current trends set a framework for developing local capacities to collect and apply environmental information: 1) Negotiations between Indigenous Peoples and national governments. 2) An increasing focus upon community-based or people-centered conservation. 3) The emergence of global conservation agreements which call upon governments to recognize the historical contribution of land-based peoples to biodiversity conservation and support them as exponents of sustainable resource development.

REGAINING INDIGENOUS LANDS IN THE AMERICAS

It has been estimated that the current round of negotiations will lead to Indigenous Peoples regaining various degrees of control over a third of the Amazon Basin, and to about 13% of the Americas in total. With virtually no technical resources at their disposal, the communities scattered throughout these lands are faced with a huge double task: to protect their territory from intrusive settlement and industrial resource exploitation, and to adapt and reinforce traditions of sustainable resource utilization in a contemporary context.

It is self-evident that traditional knowledge and practice has proven sufficient to care for these lands in the absence of external pressures. Such traditions remain at the core of many current projects to reinforce local resource economies. But this knowledge does not necessarily equip local groups to deal with the manifold effects of distant industrial economies in remote areas: the impacts of roads, mines and dams, trans-boundary pollution, deforestation, and colonization. Geomatic technology, if localized, has the potential to amplify the capacities of small, scattered communities to monitor and protect large territories.

COMMUNITY BASED CONSERVATION

The principles and practices of environmental conservation have evolved within the western scientific community, with a strategic focus upon protected areas and species. It is now widely acknowledged that a protected area system must often be combined with the active engagement of land-based people in the management of the resources upon which they directly depend. The idea of community-based conservation has taken hold within the environmental community, and mainstream NGOs have launched programs designed to involve peoples living close to protected areas. But concrete accomplishments are rare, and this idea is in danger of becoming an empty slogan, prompting deference rather than action — compulsory rhetoric found only in the Vision Statement of project proposals.

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While initiatives taken by conservation groups are producing ambiguous results, another set of historical circumstances is prompting land-based peoples to assume a more assertive role in conservation; to seize the conservation agenda. They are realizing the negotiating advantage that comes with a better data base and are adapting advanced mapping and information technologies in imaginative ways: to gather and record traditional local knowledge, to demarcate and protect recovered lands, to restore degraded habitats, and to manage traditional resources under sustained use regimes.

These experiences demonstrate that "owning" the information about land and resources can be as important as owning the land itself. This idea is gaining currency in Indigenous strategies to regain, confirm, and exercise authority over traditional lands. Arguably, these activities also qualify as virtual implementation of the Biodiversity Convention.

THE BIODIVERSITY CONVENTION AND AGENDA 21

The global conventions emerging from the 1992 Earth Summit are essentially designed to repair the damage inflicted by incoherent industrial resource exploitation, much of it on lands appropriated from Indigenous peoples. Although this is not explicitly stated, it is clearly implied in language which calls upon national governments to respect the unique contribution of Indigenous knowledge and practice and to support its application in implementing these agreements. Scientific advisory groups are now discussing structures and methodologies for implementing the Biodiversity Convention. A recent Open-Ended Intergovernmental Meeting of Scientific Experts on Biological Diversity (UNEP 1994) was charged with the "identification of innovative, efficient, and state-of-the-art technologies [on] conservation and sustainable use of biological diversity..." Six technologies were prioritized:

- habitat, vegetation, and gene-variation mapping
- regional mapping technologies
- remote sensing for spatial heterogeneity and complexity
- geographic information systems
- aerial survey, patrol, and photography
- traditional knowledge of territories and habitats

These priorities correspond to the goals of the LEO Project and to the expressed interests of many land-based communities.

APPLICATIONS FRAMEWORK: LOCAL SCALE

SURVEYS OF LOCAL NEEDS FOR ENVIRONMENTAL INFORMATION

Simple photo and video technology is sufficient to meet most current local needs.

Technical development was based on surveys of over 200 conservation projects initiated by Indigenous or land-based communities (Poole 1994, 1995), about half of them involving some aspect of geomatics. This led to a first approximation of the needs and interests in locally-acquired environmental information. The main conclusion was that simple photo and video technology is sufficient to meet most current local needs. On the basis of these surveys, applications fall within five general categories:

- Mapping Land Use and Occupancy: In support of negotiations over land, high-resolution and geocoded photography of traditional sites provide irrefutable evidence of occupancy.

- Demarcating Traditional Territories: GPS units have been used very effectively in self-demarcation projects. In some cases, aerial imagery has been used to plan demarcations.
- Protecting Demarcated Lands: The kinds of boundary markers that meet the regulations have little effect upon incursions and some groups in the Amazon are looking into GPS/video monitoring systems adaptable to light or ultralight aircraft. High resolution is not necessary — ordinary video is quite sufficient to detect changes near boundaries.
- Biodiversity Conservation and Management: The wide range of local applications using both photo and video includes habitat mapping, animal census-taking, water quality monitoring, and forest management.
- Ecological Damage Assessment and Restoration: Assessing impacts of industrial forestry, mining, water pollution, and monitoring the progress of landscape restoration projects.

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APPROPRIATE TECHNOLOGY FOR LOCAL EARTH OBSERVATION

The most critical decisions in designing the LEO system were about which technologies to exclude, on the grounds of cost or unnecessary complexity. Among the lessons learned from these surveys is that many users do not need photogrammetric accuracies of a few centimeters, nor do they need acute and specific spectral data. To detect and monitor incursions on protected lands, video is adequate. To make inventories of the biodiversity of small sites, high resolution photography is sufficient. A combination of video and photo is adequate for general or detailed monitoring of habitat regeneration.

Advances in the development of light aircraft remote sensing systems has followed two main paths. One is in refining imaging systems by increasing spectral sensitivity. The other is in improving the positional accuracy of the acquired imagery.

The first path has yielded a generation of video-based "multi-spectral scanners" capable of capturing data in narrow spectral bands, or "windows." Such scanners are excluded from the LEO system on the grounds that these are more suitable for basic scientific research than routine mapping and monitoring operations. Sophisticating the LEO technology in this direction would yield diminishing returns in terms of the expressed needs of land-based communities.

GLOBAL POSITIONING SYSTEM (GPS)

The second path of development is in the technology used to guide survey missions and record the position of the images. This uses the Global Positioning System (GPS), originally designed to enable submarines to locate themselves more accurately. It comprises a net of 24 satellites that emit signals that can be picked up by a GPS receiver. When three signals are received, the GPS unit automatically computes and displays its geographic position as a "waypoint." Users can enter their own waypoints into the GPS unit and then use it to navigate between any series of waypoints. The GPS unit can also compute ground speed, time of arrival, and so on.

In the world of mapping, GPS technology is exerting an impact equivalent to that of the transistor in the world of communications. Coupling GPS units with cameras generates a powerful system for environmental monitoring. This union has two attributes. First, all images are "geocoded" — that is, the center point of the image is recorded to an accuracy of 100m or better. Once geocoded, these images can be compared with any other kind of geocoded data, including maps, aerial photographs, and satellite images. It facilitates local-global data trade. Geocoded information is also acquiring a degree of legal acceptance, useful in responding to incursions on Indigenous lands.

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The second attribute is that air survey missions can be flown without using maps. The GPS satellite net literally guides the aircraft along a predetermined mission track and fires the cameras at appropriate intervals. All mission tracks are stored in the notebook computer which integrates the imaging and guidance systems. These flight patterns can be recalled and reflown at any time, making this a useful system for monitoring environmental change.

Geocoding also equips local groups to engage in direct data transactions with satellite systems such as EOS. They can amplify satellite imagery by gathering highly detailed data from specific sites through the same spectral window. This "ground-truthing" of satellite information is a service continually needed by such systems. This is recognized by NASA, which runs an informal Light Aircraft Research Program, exploring real-time linkages between light aircraft and EOS.

THE LEO ENVIRONMENTAL MONITORING AND MAPPING SYSTEM

The LEO Project develops technology to enable local groups, communities, and agencies to acquire, analyze, and apply the information needed for biodiversity conservation and the sustainable development of renewable resources. Following a strategy of demonstrating rather than debating the merits of this approach, we have constructed a mapping and monitoring light aircraft, equipped with an integrated mission guidance and imaging system using the most simple technology consistent with operational utility and safety. It has these elements:

Aircraft

The aircraft used is a Murphy Rebel, in the experimental category. It has been substantially modified for remote area operations with the addition of long-range tanks, reinforced landing gear, a three-bladed propeller, and numerous reinforcements to the fuselage. Two camera hatches and equipment racks that will accept 70kg of equipment have been installed behind the two seats.

Mission Guidance System

This is based upon an SEL 2000 GPS unit connected to the imaging system via a notebook computer. The computer display can be used interactively with local users when planning missions and provides an image to guide the pilot along the predetermined survey track. This image can also be transferred to a navigation screen on the panel.

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Gyro-Stabilized Mount

The GPS records the position of the aircraft in space at the moment of camera exposure, but this position can only be projected to the image center on the ground if the camera plane is level at that instant. A low-cost stabilized mount has been developed, using auto-pilot gyros and a second computer. This uses fast servo motors to correct for aircraft movement on three axes.

Photo Cameras

The camera being used for the current air trials is a 35mm Contax RTS, which has been calibrated and equipped with the fiducial plate required for stereoscopic image analysis. The Contax contains a unique film-flattening vacuum system, producing images of high quality for these applications. There are also mounts for 70mm cameras.

Video

Some researchers have developed sophisticated video-based multi-spectral scanning systems. For the LEO system, we have decided to rely on straightforward color video.

Digital Frame Cameras

These closely resemble photographic cameras and often share the same optics, but the photo emulsion is replaced by a CD array of a million or more pixels. They directly capture still images in digital form and promise to eventually replace video-based scanners. There is an advantage to acquiring direct digital imagery if it is to be subjected to computer analysis. Although spatial resolution is inferior to that of conventional photography, it is superior to the still images derived from video. For use in light aircraft, the current limiting factor is storage — single images occupy a minimum of one megabyte. We expect to incorporate a digital frame camera within a year or so.

CURRENT STATUS AND FUTURE PLANS

The LEO aircraft is now undergoing trials in the Pacific Northwest. These are being conducted in collaboration with Indigenous resource groups and environmental organizations. The ultimate objective is to transfer this capacity overseas and a proposal has been developed to establish a self-contained local earth observation center in Central America.

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PETER POOLE

Dr. Poole began his career as a Glaciologist and an Arctic Parks Planner. For the last 18 years he has worked as a freelance consultant on community-based renewable resource development, environment, land use, occupancy, and mapping projects with Indigenous Peoples in the Arctic, the Pacific Northwest, and Central and South America. Dr. Poole has also been conducting policy research for NGOs in Africa and Southern Asia.

Peter Poole Working Group

Among the most urgent threats facing Indigenous cultures is how to get governments to respect their land claims, how to demarcate these claims, and how to monitor and protect these lands. Aerial imagery works well in helping Indigenous peoples respond to external threats, as it amplifies local capabilities to monitor and protect traditional lands in such a way that the relevant government agencies cannot readily dismiss the Indigenous claims.

The discussion was oriented primarily around the technical difficulties involved in Dr. Poole's work, although a few questions were directed at the impacts of technology on Indigenous cultures. Dr. Poole opened the session with a brief discussion of the technical difficulties involved in the one-year building of his specially designed plane, and how he got his projects with Indigenous cultures in Canada going while the plane was being designed, built, and tested. While the plane was being built, Dr. Poole went around to various groups, told them what his plane could do and what his imagery could be used for, and asked them if they had any use for such information (which he would provide at cost during the testing phase). The following text picks up at the end of the opening monologue.

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Peter Poole: In British Columbia alone there are currently 27 separate Indigenous land claims in Canadian courts. Because there is a great deal of merchantable timber in these areas, timber industries are pressing hard for their own uses of the land. Local Earth Observation (LEO) was used in a few cases where the areal extent and a general bioassessment of the land claims needed to be done. A smaller part of this project was in the assessment of timber cutting boundaries, in order to determine whether or not the timber industries involved were following the law. In many cases, however, the imagery obtained from LEO's flights showed that timber companies were blatantly violating most conservation laws involving harvesting practices on these lands. This information is practically impossible to obtain on the ground, due to restricted access or difficult terrain. An additional advantage to LEO's work is that the imagery and flight path can be stored on computer, which allows for easy monitoring in the future.

Conrad Reining, Conservation International: Can you produce your own maps?

PP: Yes. There are dozens of software packages available that can do mapping from imagery quite easily.

Jim Murphy, Tufts University: How much memory does digitized information require?

PP: Quite a bit. Computers are keeping pace with memory requirements quite nicely, although sometimes it is the computer limitations that hinder work. Also, photo companies can digitize photos now, cheaply and quickly, although fiducial marks are sometimes cut off.

Ramzy Kanaan, Clark University: What do you do with video imagery?

PP: Not much right now. It is primarily used for basic mapping, that is, "what's going on here?" We've used it to find point pollution sources in the Queen Charlotte Islands, and to update old maps for things like buildings.

Emily Harwell, Yale F&ES: Why would you want a moving image?

PP: Well, for example, you could fly the perimeter of an area to see what there is along this boundary without taking hundreds of still photos.

Mathilde Snel, Clark University: Are there cheaper alternatives to building a plane?

PP: Fixing cameras to a plane's wings is not practical over 400ft above the ground, because beyond that you are unable to get stereoscopic photos. In any case, it is very dangerous to fly that low. There is a group in Arizona that is designing something that clips on to the side of an aircraft to mount cameras on, but it is still in the design stage.

Lisa Beaudoin, Worldview Ltd.: How manipulable is the digital data?

PP: Once it is in the computer, you can do anything you wish. However, being credible is far more important, and these scenes are meant to be ground-truthed.

Austin Troy, Yale F&ES: Can remote imagery be used in court, and if so, what are the standards for admissibility?

PP: Yes it can be, but I don't. I pass on imagery to those for whom I work, and sometimes they use it for legal purposes. For example, the Sierra Club Legal Defense Fund used it when looking for timber companies' compliance to stream buffer-strip laws. GPS can place your imagery to an accuracy of 2 to 5 meters when ground base stations are available nearby to calibrate to, and so the images can be placed very precisely. It can be used in court because it is easily replicated, and if the evidence is questioned, you can go there in person to prove it.

[Geocoded imagery] can be used in court because it is easily replicated, and if the evidence is questioned, you can go there in person to prove it.

EH: Does the mapping of territorial boundaries change the spatial orientation of Indigenous people?

PP: An Indigenous group in Venezuela contacted me to do a project, and they have always told me what they want to do. And when I present the photos I take, they have no trouble connecting their terrestrial experience with views from above.

One interesting example is that the First Nation on Vancouver Island has an interactive CD-ROM database, where you can click on a map and have an audio-visual presentation of information relevant to that place. They've included oral histories and their creation myth sequence into the database. Basically, they've put Indigenous knowledge into a different context — Indigenous legends on maps. Legally, this helps with land claims, and it also helps preserve some of their heritage.

Laura Appell: How much does your system cost?

PP: It is much cheaper than most methods or approaches; you can buy a plane like mine for what it takes to fly the Canadian government's remote sensing plane for 10 hours. It will get even cheaper — right now the biggest cost is the geostabilizer mount for the camera, which allows it to point directly downward even when the plane's pitch is not oriented with the ground.

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Payal Sampat, Tufts University: What are the laws relating to aerial photography?

PP: There's no consistency. In Canada, I classify my plane as experimental (since it was home-built), which does not allow me to do full commercial work. However, it does allow me to have a hole in my plane for the cameras without having to go through all of the bureaucracy involved in having a hole in a "normal" plane.