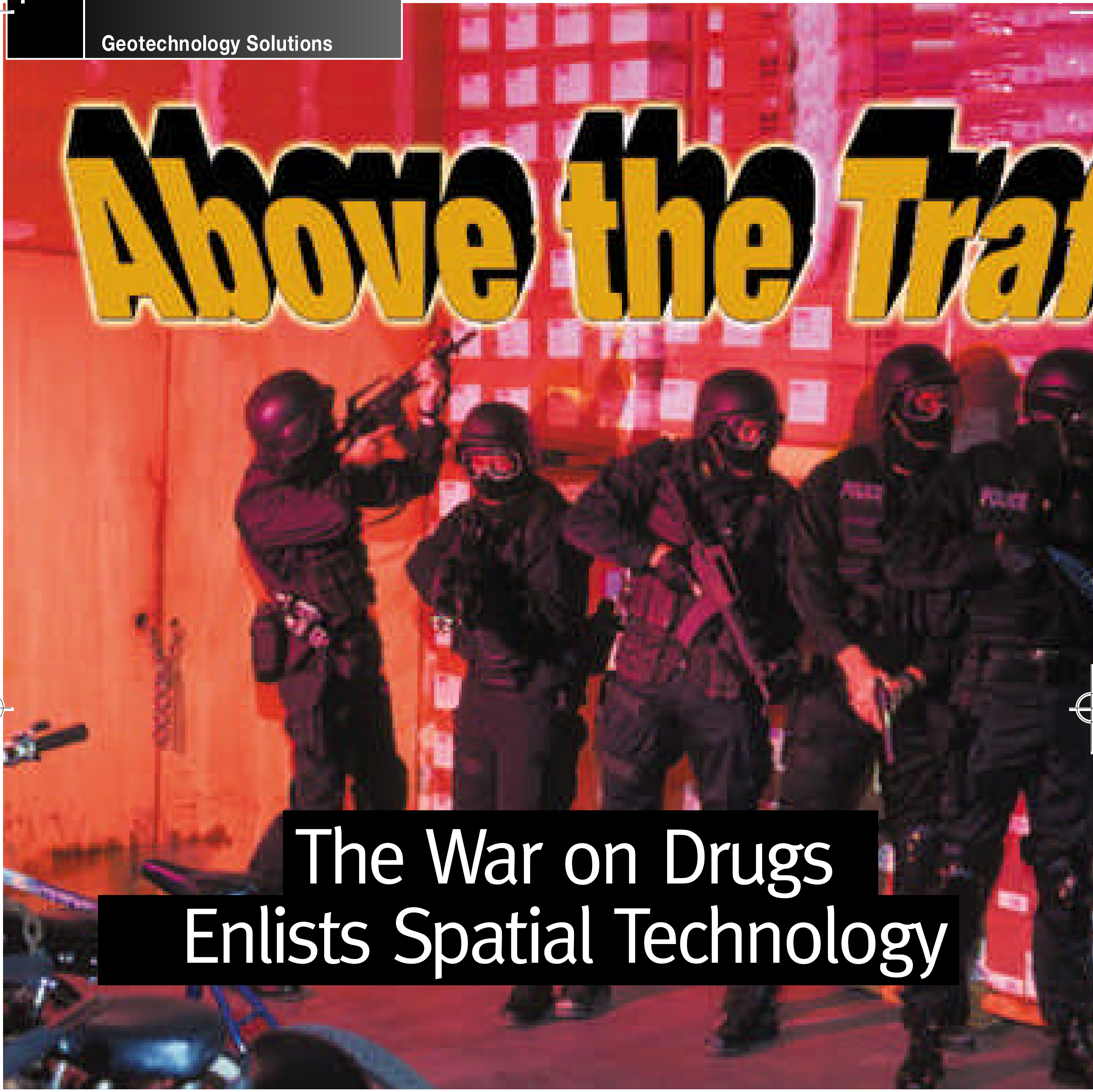


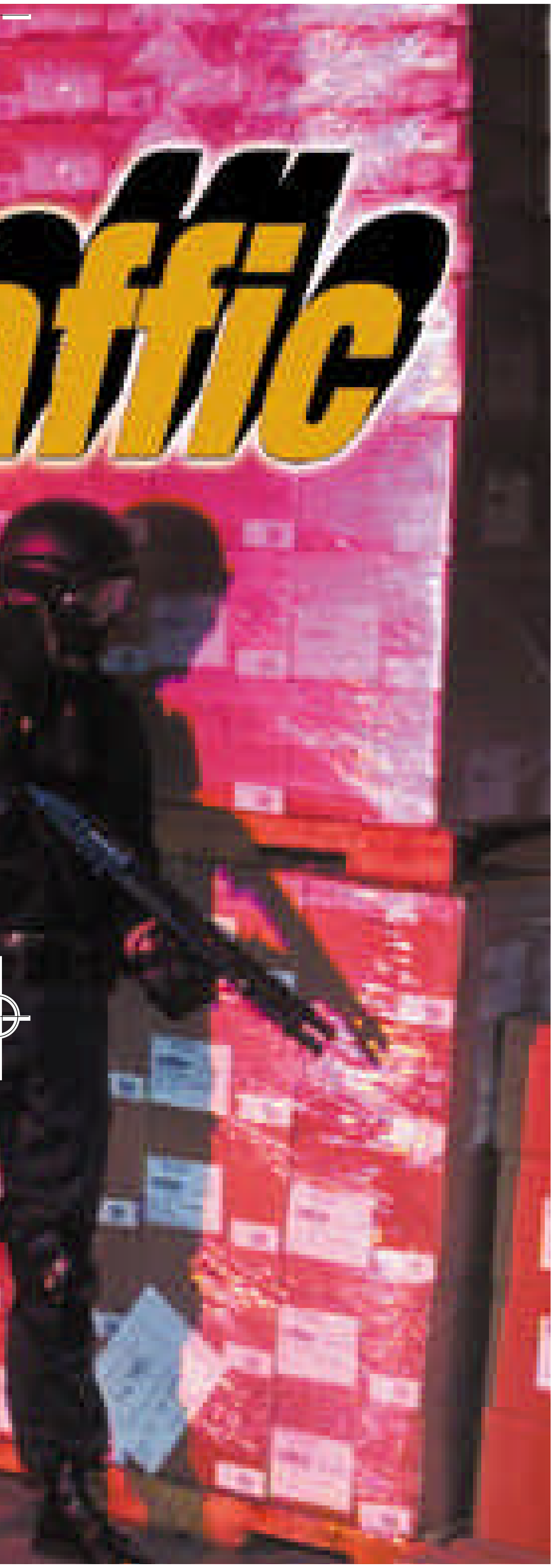
Above the Tra

The War on Drugs Enlists Spatial Technology

By **Kenneth Lee, Gary Tao** *and* **Nelson J. Mora***. Lee is a GIS analyst with BTG Inc. and currently is with GIS Services of the 56th Range Management Office at Luke Air Force Base in Arizona; e-mail:* kenneth.lee@luke.af.mil. *Tao currently is with BTG's Applied Engineering Services in Cape Canaveral, Fla., as a remote sensing analyst and project manager; e-mail:* gtao@deltabtg.com. *Mora is a BTG GIS program manager at Cape Canaveral; e-mail:* nmora@deltabtg.com.

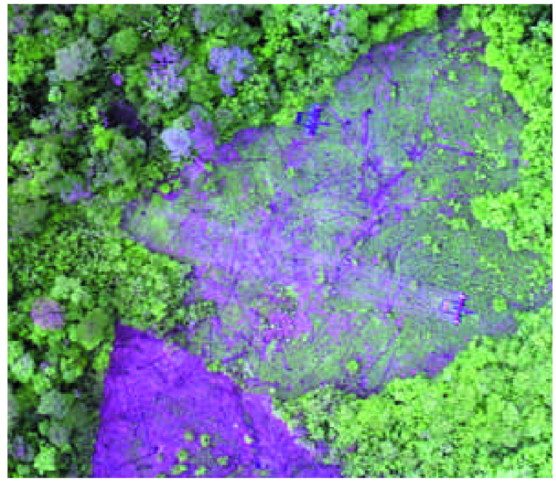
Illicit drug production and use have been growing worldwide for decades. As a result, drug enforcement agencies are always searching for effective ways to combat such operations. Now spatial technology, a tool not frequently associated with drug enforcement, is proving to be an effective weapon in the "war on drugs."

Although there has been explosive growth in the techniques and technologies used to create and distribute illicit drugs, the last few decades also have seen tremendous growth in GIS and new generations of high-resolution satellites and



other high-altitude sensor systems, which have fostered a heightened global demand for remotely sensed data. Such widespread data availability has fostered growth and competition among the commercial satellite imagery vendors, resulting in superior imagery products, lowered consumer costs and reduced turnaround times.

In the drug-enforcement arena, the new datasets and sensors have helped create innovative applications for wide-area surveillance of, among other things, illicit crop detection and monitoring. One such tool, a remote-sensing and GIS application designed by BTG Inc. for the U.S Department of State Counter Drug Enforcement Program, helps to locate poppy and coca plants, which are the basis for illegal drugs such as heroin and cocaine. Located crops then are targeted for herbicidal spraying and eradication. Remote sensing data then can determine if the crops were destroyed. Results of more than two years' work on the current coca and poppy eradication program validate the application's success.



An overhead view from an MDIS aircraft captures a pair of OV-10 planes spraying a coca field. The spray planes operate at an altitude that often draws small-arms fire.

Elevating the War

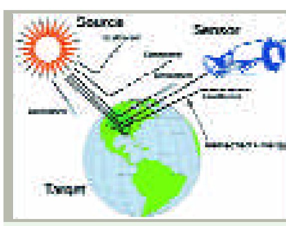
Prior to 1997, the Department of State's Counter Narcotic Eradication Program in Central and South America relied on visual aerial reconnaissance to find illicit crop fields. After locating the fields, hand-drawn maps were made, field coordinates were extracted from the maps, and this information was passed to herbicide spray pilots for subsequent aerial eradication missions. The pilots also relied on estimates and random sampling techniques to quantify the amounts of illicit crops destroyed.

In March 1998, BTG was awarded a 60-day contract to develop a multispectral digital imaging system (MDIS) that could locate, analyze and map coca-growing areas. The test required systems to identify mature, sprayed and dead coca as well as distinguish among several types of cash crops. The validation phase mandated an 80-85 percent success rate. The system developed by BTG was able to locate coca and distinguish among crops and jungle with 94 percent accuracy.

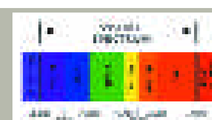
Key to the system's success was the merging of multispectral imaging technology with GIS. The techniques and processes created to find coca and opium poppy are easily adaptable to a variety of other crops, allowing users to detect and monitor illicit crops on a near-global scale.

Behind the Technology

Multispectral digital imaging is based on the physics of reflected and emitted electromagnetic energy that result from the interaction of an energy source, such as the sun, with objects and materials on



A passive sensor system measures electromagnetic energy scattering and returns.



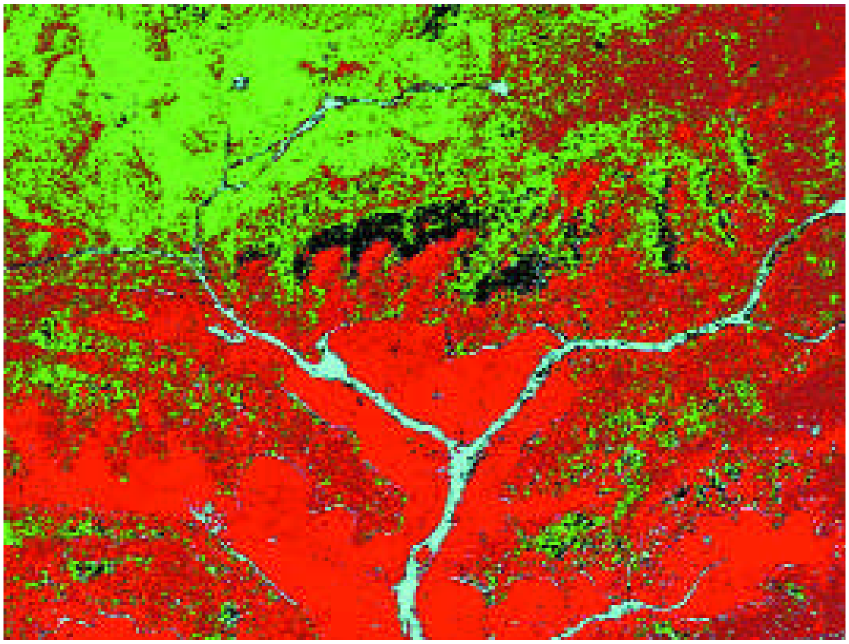
The MDIS process ranges into the infrared wavelengths as well as the visible spectrum.

Bands in the Visible and Near-Infrared Spectrums

Band	Wavelength(microns)	Description	Characteristics and Notes
1	0.45-0 .52	Visible blue	Maximum water penetration, distinguishes vegetation vs. soil and deciduous vs. conifers
2	0.52-0.60	Visible green	Good indicator of plant vigor
3	0.63-0.69	Visible red	Good indicator of chlorophyll absorption, allows vegetation discrimination
4	0.76-0.90	Near infrared	Good for biomass and shoreline mapping

Earth's surface. A variety of sensors can detect this energy, including human eyes, film cameras and imaging satellites. The term "remote sensing" encompasses the combination of techniques used to gather and process information about an object without direct physical contact.

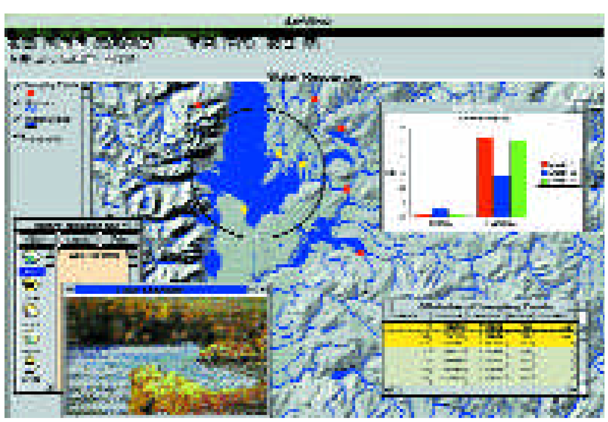
Remotely sensed data may be recorded on photographic or digital media. Remote sensors record electromagnetic radiation (EMR), which is transmitted through space in the form of electric and magnetic waves. Remote sensors are simply detectors that record specific wavelengths of the electromagnetic spectrum. The human eye is actually a three-band sensor, sensitive to light in the visible red, green and blue spectrums. All natural and man-made features (e.g., rocks, water, buildings, etc.) absorb a portion of the electromagnetic spectrum and, in return, reflect a distinguishable EMR "signature."



An aerial photograph shows a suspected marijuana "farm" in the United States, along with forests, licit row crops, upland crops and roads. MDIS allows investigators to differentiate among the crop types present in the area, showing marijuana plants in black .

Digital multispectral imagery typically is captured at an altitude of about 4,000 feet, providing an average ground resolution of about one foot while keeping the aircraft a relatively safe distance away from hostile small-arms ground fire.

By knowing which wavelengths are absorbed by natural and man-made features as well as the intensity of the reflected energy (reflectance), analysts can make accurate assessments about a given object or feature. Vegetation is highly reflective, thus highly distinguishable, from approximately 0.75 microns to 1.3 microns. This corresponds to the electromagnetic spectrum's visible and near-infrared region. In terms of drug crops, for example, marijuana can easily be discriminated in the green (550 nanometers), red (670 nanometers) and near-infrared (800 nanometers) spectral bands.



GIS software such as ESRI's ArcView and ArcInfo products were combined with ERDAS IMAGINE geographic imaging software to process raw imagery and analyze Department of State data.

Commercial satellite imagery and multispectral digital aerial imagery, when combined with commercial off-the-shelf software and hardware, provide the ability to request, receive, analyze and generate various data products. Blue, green and red filters capture wavelengths in the visible spectrum of light—near infrared is just outside the human eye's visible range. As shown in the table on page 47, each band provides specific information about the object(s) of interest.

Acquiring Imagery

A three-phased process is used to acquire multispectral imagery and get the data into a suitable format for delivery to customers: 1) image capture, 2) post-processing 3) and data delivery. On the Department of State's project, digital multispectral imagery typically is captured at an altitude of about 4,000 feet, providing an average ground resolution of about one foot while keeping the aircraft a relatively safe distance away from hostile small-arms ground fire. As the mission is flown, the image data are stored on removable hard drives. After a 100 square-nautical-mile area is flown, the data are transferred to an eight-millimeter tape. Depending on how many flight lines are required to capture the area, as many as 300 square nautical miles of imagery can be stored on one tape. After the mission is over, tapes then are forwarded to a main office for post-processing, or the processing may be performed in the field using laptop computers.

During post-processing, image data are converted into a compatible file format, and Global Positioning System coverage is extracted. The individual scenes then are mosaicked as well as color and contrast balanced. A new, single scene then is ready for classification and analysis. The classification process results in all possible occurrences of illicit crop fields being identified and delineated by colored polygons. The polygons symbolize the fields into categories by type (e.g., pasture, stressed (sprayed) coca, eradicated coca, etc.). After a mosaic has been classified into appropriate categories, analysts assess the quality of the data to ensure accuracy and that it presents the information required by the customer. Finally, the image map layout is produced, printed and then recorded (pressed) onto a CD-ROM for delivery.

Every year coca fields such as this are cleared, planted and harvested in South America.

GIS Integration

By itself, a remotely sensed multispectral picture isn't "worth a thousand words." Analysis is required to extract, make sense of and display the desired information. A GIS is used to perform analysis at the landscape level. The system is a cartographic and a terrain analysis tool that also can be used to make a line map or a color-coded thematic map using computerized, automated plotting machines. This allows cartographers to revise maps quickly, based on new digital information, and reprint them rapidly.

GIS provides the means to integrate point-sampled field data with imagery data along with previously developed map data. The advantages of using field and remotely sensed data are optimized, thus avoiding most of the drawbacks of either method alone. Today's GIS packages include powerful database software for recording, organizing and querying data electronically. When such databases incorporate the "relational model" of database design, significant gains are made in data storage and analysis.

In the GIS, database records are tied to a geographic location, allowing users to query by geographic area. In addition, users can geographically compare spatial information by displaying multiple themes. The crop detection and eradication application uses ESRI Inc.'s ArcView and ArcInfo GIS products as well as ERDAS Inc.'s IMAGINE geographic imaging software.

System Costs

A good, high-resolution digital multispectral camera system can be purchased for about $450,000 (the market ranges from $150,000 to $1.2 million). A system in this price range includes the digital camera system, standard multispectral filters (for a four- or five-band camera system), proprietary post-processing software, operating computer and data storage, inertial measuring unit/differential Global Position System receiver, and a power supply/converter. Of course, the aerial platform is extra. The BGT system uses a Cessna Caravan as the flight platform for its ADAR 5500 camera system, but the use of unmanned aerial vehicles has been suggested as a possible future platform.

Typically, the longer the lease, the better the rate. Leases usually include the costs of the aerial platform, post-processing of the imagery and soft-copy data delivery, but not data analysis.

Experience with the Department of State's MDIS shows that combined costs for aerial camera missions and image map production (post-processing and analysis) run between $2,800 to $4,800 per 100 square miles. The higher the image resolution and level of quality desired on the final product, the higher the operating costs. Such costs also reflect a contract period greater than one year. Not included in these costs is the aircraft; the airplane used on the MDIS project is owned by the Department of State.

Overall, the current MDIS project for the counter-drug effort in Central and South America costs about $2 million per year. The bulk of that effort involves the labor required to process and analyze the data collected, considering the technical limitations of the system acquired by the Department of State. A reconfigured system for a U.S.-based drug enforcement project could drastically reduce annual costs.

The procedures developed for this application have been reviewed and/or considered by various law-enforcement agencies and counter-narcotics officials, including the International Bureau of Narcotics, the Florida State Department, and the Space and Naval Warfare Systems Center in support of the Office of National Drug Control Policy Counterdrug Technology Assessment Center. Potential applications include detecting and monitoring cannabis growth in the United States as well as illicit opium poppy crops in Afghanistan's "Golden Triangle" region.