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Introduction and Problem

Cairns City Council needed a cost-effective solution to acquiring high-resolution spatial imagery over their entire shire. The Cairns Local Government Authority (LGA) is located in tropical north Queensland and is home to approximately 123,708 people. The LGA contains environmental and national treasures including the Great Barrier Reef and the Wet Tropics Rainforest. So Council required good quality spatial data for sustainable management of these and other assets. Council were previously using 2m orthorectified aerial photography captured in 1997 in their Geographic Information Systems (GIS) and required more recent imagery preferably at a higher resolution.

The Methodology

The imagery was captured in 6 swaths, each 11 km wide of which 4 swaths were captured on the 14 August 2004 and the remaining 2 swaths captured 5 days later on 19 August 2004. Using ERMapper and PCI Geomatica software, GEOIMAGE orthorectified each image swath from ground control points supplied by Council which were GPS points captured at specific locations on the raw imagery. A portion of the Shuttle Radar Topographic Mission (SRTM) DEM was clipped out and used to supply the height control. After the orthorectification process, accuracies of between 0.2m in urban and flat areas and up to 10m in the steep and rugged mountains surrounding the city and agricultural valleys were achieved. The image tiles were then seamlessly mosaiced and colour balanced using GEOIMAGE’s inhouse software reformatted reprojected and delivered in both ECW compressed and ER Mapper BIL formats.

The Benefits

According to Council’s GIS staff the majority of the non-GIS users use the imagery to give an overall perspective of location to their vector datasets. For example if there are reports of a dangerous animal in a location, the imagery gives context to vector information such as flood zones outlines, areas of high crime and road accident hotspots. Staff are able to save time in on-ground checks. The management of sporting and recreation facilities including botanical precincts, parks and gardens is also facilitated by the imagery as all departments involved in natural resource management benefit from having current, detailed imagery to assess areas of drought and manage hard to reach remote or rugged terrain. In addition because the imagery is integrated within Council’s GIS police and emergency services derive benefit as the imagery gives context to vector information such as flood zones outlines areas of high crime and road accident hotspots.

GEOIMAGE thanks Ms Nola Strawbridge, GIS Support Officer for her help in the preparation of this article.
Introduction
QuickBird data over the greater Brisbane area was purchased for the Fire Ant Control Centre by the Queensland Department of Natural Resources and Mines. The imagery is to be used for the control and eradication of fire ants in south-east Queensland.

The Problem
The Queensland State Government had already purchased 0.6m panchromatic Colour QuickBird imagery when they approached GEOIMAGE. The imagery had been supplied to them as many separate 16-bit GeoTiff files which were not colour balanced and had not been orthorectified. This raw unprocessed dataset was proving very cumbersome for State government users to use. The good quality imagery covered an area of over 4500 sq km and was captured on 10 different dates ranging from 22 June 2003 to 29 May 2004. Not only were different image swaths captured during different times of the year but also at many different capture angles making orthorectification essential in order to seamlessly join images between different image swaths. The extremely large file sizes were also proving a problem for users within government as the individual images took a very long time to download into individual GIS's. Therefore it was very important that the imagery was processed to particular specifications to allow government to get value for money from their imagery purchase.

The Solution
The required end product was one manageable, seamless GIS dataset reprojected, orthorectified and accurate to match the DCDB database that would allow many users from basic backdrop users to experienced remote sensing users get the most use from the imagery. GEOIMAGE quality checked the imagery and discovered that several gaps were evident between some of the swaths. Where possible, the original suppliers provided imagery to cover the gaps although one sliver could not be patched. GEOIMAGE spatially corrected the imagery to match the Digital Cadastre Database (DCDB) vectors as the majority of users would be overlaying the cadastral vectors over the imagery. GEOIMAGE used the global SRTM DEM to provide height information as government were not able to supply a DEM to cover the entire area of interest. Using PCI Geomatica and ERMapper software GEOIMAGE orthorectified the QuickBird swaths and then colour-balanced and matched each image swathe to ensure that when mosaiced, the imagery joins would be seamless. The final image mosaic was supplied as a single ECW compressed image file. The accuracies obtained were less than 2m where the DCDB was accurate but in localised areas where the DCDB was inaccurate the imagery did not match perfectly.

Benefits
Besides having a stable and consistent dataset of relatively small file size which is now used as a backdrop within a myriad of different state government GIS’s for many different applications mismatches between the DCDB and the imagery pinpoint localised areas of the DCDB that require correction. The DPI uses the dataset in their fire ant eradication program while the Department of Public Works plans to produce hard copy maps for members of the general public. Other government department are first-time users of high resolution satellite imagery and are finding the ease of use and versatility of the data to be a huge advantage in their decision making and day to day activities.

QuickBird Processing – Greater Brisbane Area

Brisbane pseudo natural colour
QuickBird mosaic with a 10km grid
Insert over South Bank at 1:3000 scale
Introduction
Centamin Egypt Limited is a mineral exploration company listed on both the Australian Stock Exchange and the Alternative Investment Market of the London Stock Exchange. The Company is the title holder to a 160km² mining lease with a tenure of 30 years plus 30 year extension. Contained within the lease is the huge tonnage Sukari Gold Project which has a current resource of around 3 million ounces. Drilling is currently ongoing at Sukari with the feasibility work focused on upgrading the throughput of the current 2 million tonne per annum study.

The Problem
Centamin required base maps for the planning of detailed exploration and development work and also to enable the engineers to plan infrastructure for the proposed gold treatment plant. Existing information is dated and not available in digital format.

The Solution
The client decided to order a new capture of panchromatic stereo IKONOS imagery over a 100 sq km area and to also obtain the 4m multispectral imagery for the most vertical panchromatic image.

The Methodology
The order for capture of the stereo IKONOS imagery was submitted to Space Imaging on July 1, 2005 and the imagery was captured on 26 July. The images were completely cloud free and were collected on the same overpass at azimuths of 303° and 220° degrees and at vertical angles of 75° and 61° degrees respectively. Ground control was supplied by the client as a table of points with E, N and Z values corresponding to a series of white crosses that had been marked on the ground prior to the capture of the images. These points produced errors in the photogrammetric model of less than a metre and the maximum error in z between the control points and the final 1m DEM was 2 metres.

The stereo pair were used to produce a 1m resolution DEM in PCI OrthoEngine and this DEM was used to orthorectify the pansharpened multispectral imagery. 2m and 5m tagged contours in DXF and MapInfo format were also produced for the client.

The Benefits
This imagery is a good example of the detail obtained by the IKONOS satellite over areas in the world where it is difficult to obtain spatial information. In parts of the world that are either very remote or difficult to access; dangerous due to existing political factors or inherent natural features; or lacking in the infrastructure to allow aerial photography or detailed surveying 1m IKONOS DEMs and imagery offer a reasonably inexpensive, accurate, convenient and timely source of spatial data.
A Phu Bia (Laos) Case Study

Introduction

Pan Australian Resources Limited is an international emerging gold and copper producer listed on the Australian and Frankfurt Stock Exchanges and is committed to an aggressive organic growth strategy based on its unique pipeline of copper and gold projects and substantial resource base in Southeast Asia. The company has placed a priority on the initial two phase development of its resource assets in Laos. The first phase of this plan is the development of the Phu Bia Copper-Gold Project subject to the outcome of a feasibility study. The second phase of the plan is the development of the much larger Phu Kham Copper-Gold Project following the successful completion of the feasibility study on that project. The second phase of this project is the development of the much larger Phu Kham Copper-Gold Project subject to the outcome of a feasibility study. The Phu Bia Copper-Gold Project comprises three deposits: Phu Kham gold-copper-iron deposit, Phu Houayxai with most of the ore reserve areas, and Phu Houayxai with most of the ore reserve areas. The Phu Bia Mining tenement covers over 2500 sq. km of terrain in northern Laos. Although some parts of the contract area where access is good, some have been explored to the stage where copper and gold resources have been defined much of the contract area remains poorly explored. Landsat 2m multi-spectral GeoCover imagery and Shuttle Radar Topography Mission (SRTM) 90m Digital Elevation Model (DEM) data had been previously used by Phu Bia Mining Ltd in their exploration program. They now required higher resolution imagery as well as a more detailed DEM over the area for their activities such as planning access roads for drilling and targeting areas for exploration based on topographical features.

The Problem

The Phu Bia Mining tenement covers over 2500 sq. km of terrain in northern Laos. Although some parts of the contract area where access is good, some have been explored to the stage where copper and gold resources have been defined much of the contract area remains poorly explored. Landsat 2m multi-spectral GeoCover imagery and Shuttle Radar Topography Mission (SRTM) 90m Digital Elevation Model (DEM) data had been previously used by Phu Bia Mining Ltd in their exploration program. They now required higher resolution imagery as well as a more detailed DEM over the area for their activities such as planning access roads for drilling and targeting areas for exploration based on topographical features. A programming request for QuickBird imagery was placed in October 2004 and the imagery over the first AOI successfully captured in two swaths on 20 November 2004 and 11 December 2004. While awaiting capture GEOIMAGE processed an ASTER DEM over the area made up of 14 ASTER scenes captured during early 2002. As there was no available ground control over this area GEOIMAGE used the 90m SRTM DEM and orthorectified Landsat TM GeoCover imagery for the processing of the ASTER DEM. Whilst these datasets do not yield preferable resolutions for the high resolution nature of this project this information was the best and only information available. PCI Geomatica software was used to produce the ASTER DEM and any holes in the resulting DEM were filled in with SRTM DEM data or by GEOIMAGE's in house programs. The average error of the height values was ±4m. The ASTER DEM was then used to orthorectify the ASTER imagery. The QuickBird imagery was delivered in OrthoReady Standard format which means that the imagery was already radiometrically and systematically corrected and projected into a cartographic datum and projection. The average accuracy of the imagery before processing was 2m plus terrain effects. The two overlapping date swaths were supplied in either three or four tiles per swath with each tile further subdivided into sub-tiles. The tiles/sub-tiles were joined back into the original date swaths to simplify the orthorectification. Approximately 46 ground control points from the orthorectified ASTER imagery were used as ground control on the eastern QuickBird swathe and points from the orthorectified eastern swath were used to orthorectify the western swath. Again whilst this is not the most accurate method for processing the data the lack of available accurate ground control made it the only methodology that could be used. Accuracies of about 2m including all terrain effects are believed to have been obtained using the method. If higher accuracies are required in the future the data will be reprocessed using highly accurate ground control. The resulting orthorectified image tiles were colour-balanced to each other using GEOIMAGE's in house software and a single mosaic over the entire AOI was created. Even though the swaths were captured only 3 weeks apart changes in cropping areas fire scars and vegetation were evident. The final mosaic was reformatted and ECW compressed for use in MapInfo and supplied on DVD. The ASTER DEM was supplied in Bil and ASCII format and 2m contours were generated for MapInfo.

Benefits

The main benefit of the high resolution QuickBird imagery in combination with the topographic information will be to help Phu Bia Mining Ltd evaluate the areas within the tenement in a timely and cost-effective manner. The imagery will be used in geological mapping programmes in planning geochemical programmes and to target areas for exploration. As mentioned above the imagery will also be used when planning the infrastructure around the mine sites and in management decision making.

GEOIMAGE thanks Mr. James Patterson of Phu Bia Mining Ltd for permission to use this case study.
Introduction

Matrix Metals Limited is a mining company focused on the discovery, development and exploitation of copper deposits in the Mt Isa base metal province of North West Queensland. The company has an extensive exploration tenement holding in the Mt Cuthbert and White Range areas and has a well advanced business plan to become a low cost copper cathode producer based on the development and exploitation of the 100% owned oxide copper assets.

The Problem

The company required a digital elevation model (DEM) for the Mine and Infrastructure planning in the White Range area. The area was only small and required detailed height measurements. The best topographic mapping available was the unpublished AUSLIG 1:100K mapping for the Mt Angelay Sheet which has 20m contours and the best DEMs were the AUSLIG 9sec and the SRTM.

The Solution

An IKONOS DEM was suggested to the client based on new capture imagery and on the basis that minimum area of purchase was 100sq km and that less than 20% cloud cover represented a successful capture.

The Methodology

The order for the DEM was received from the client in late December 2004 and the stereo pair were captured by Space Imaging on 15th January 2005. Although captured in the middle of the “Wet” season the imagery was cloud free apart from a small wisp of cloud which was only recognised as such because it resulted in small holes in the DEM. The stereo images were captured on the one IKONOS overpass at azimuths of 225 and 1deg and at vertical angles of 82 and 65deg respectively. On receipt of the data the image collected closest to vertical was orthorectified using the SRTM and output as an ECW compressed file for display in MapInfo. This file was sent to a surveying contractor who collected 11 points evenly spread over the image using a helicopter. All the points surveyed were small isolated bushes in large clearings and were supplied as a table in Mapinfo with the points marked on the ECW image. When these points were marked on the stereo images and input into the IKONOS model in PCI OrthoEngine the errors were less than a metre and the DEM generation was carried out at a 1m spacing and resulted in 98% correlation success. There were several small holes mainly corresponding to the cloud previously mentioned and its shadow. These holes were successively filled using DEMs generated at coarser pixel spacings until they were all filled. Products supplied to the client included the 1m resolution DEM image, the orthorectified panchromatic IKONOS images and 2m and 5m tagged DXF contours.

The Benefits

DEMs generated from IKONOS cost approximately $A100 per sq km and there is a minimum purchase of 100sq km. The imagery is collected on the one overpass at a good base to height ratio and depending on the weather is usually captured within a month of the initial request. There is no mobilisation cost and they can be captured anywhere in the world although some of the reception cones have higher pricing than the price quoted above. The main disadvantage is that cloud cover of 20% and below is seen as a successful capture and as the cloud and shadow are displaced in the stereo images this results in a greater percentage of holes in the DEM than the original cloud percentage. The DEM has been used by the client for mine site planning, environmental management and hydrological studies.
**SPOT5 DEM Generation – Yemen**

**The Problem**
A Petroleum company recently contracted GEOIMAGE to provide high resolution satellite imagery and elevation data over their exploration lease in the Middle East. The client required accurate and consistent spatial datasets for fieldwork and mapping and stereo imagery was the preferred source. The area of interest was approximately 46km EW by 46km NS and was often cloud-free. This allowed for many options and stereo SPOT 5 5m panchromatic imagery was chosen based on resolution and cost.

**The Solution**
The SPOT satellites can capture off nadir to provide stereo imagery for digital elevation modelling. Suitable 5m stereo imagery of the target area did not exist in archive so the satellite was priority programmed. Given the application and geographic location, SPOT Image were able to offer a cloud-free warranty. Taking the terrain and DEM generation requirements into account, a minimum B/H ratio of 0.6 was specified. Two stereo pairs were ordered for complete coverage and imagery with capture angles ranging from 15-23 degrees was successfully acquired within two months.

**The Method**
The raw imagery needed to be pre-processed for use in the field. GEOIMAGE rectified the imagery using system parameters which formed the basis of a series of 1:25,000 scale hardcopy imagemaps. The client collected DGPS points which were annotated on the hardcopy and returned to GEOIMAGE together with coordinate files and sketch maps. Digital image chips were also supplied for the more difficult control points.

PCI OrthoEngine was employed for the DEM generation. The four SPOT images were ingested together with orbital parameters and a single model was produced for the two overlapping stereo pairs. The DGPS points were identified on the corresponding imagery and tie points were added to reinforce the stereo model. Raster map data was used to reconcile any control points with high errors and a subset of the DGPS points were retained as check points.

Owing to the quality of the control, SPOT satellite stability and OrthoEngine accuracy, GEOIMAGE was able to generate the DEM datasets with combined RMS errors of 4.6m for the control and 8.7m for the check points. The resulting DEM datasets were mosaiced and subsequently used to orthorectify one image from each of the stereo pairs. The orthoimages were then mosaiced and supplied to the client together with the DEM mosaic and a number of derivative products.

A large part of the project involved a detailed interpretation study for which GEOIMAGE supplied custom SPOT 5 digital and hardcopy products as soon as they could be generated. In parallel, GEOIMAGE provided Landsat and ASTER imagery to the client for use in their regional exploration programs and interpretation studies in the same area.

**Benefits**
The SPOT 5 5m panchromatic imagery and DEM products have exceeded expectations. The acquisition of high quality imagery to specification was instrumental in being able to satisfy client requirements in a timely manner. The DEM data has been used to plan the location of seismic lines so as to minimise the elevation changes along the lines and both imagery and DEM have been used for structural and geological mapping.

The client has since purchased SPOT 5 imagery for other exploration programs and plans to continue this in the future.
SPOT5 Processing for the NSW Government

Introduction
The Department of Infrastructure, Planning and Natural Resources (DIPNR) drives, coordinates and streamlines land use and transport planning, infrastructure development and natural resource management in New South Wales. More information can be found at: http://www.dipnr.nsw.gov.au/

The Problem
In 2004, DIPNR began a program to proactively monitor vegetation clearing across the state. Historically, DIPNR had mainly used Landsat TM and ETM+ imagery for regional and statewide remote sensing programs; however, to better detect and identify the illegal clearing of native vegetation, DIPNR required a more flexible and higher resolution platform.

The Solution
A pilot project based on SPOT 5 imagery was developed, and GEOIMAGE were subcontracted to process the imagery to DIPNR specifications. The SPOT 5 has a 60km x 60km footprint and can be programmed to capture imagery on demand. The SPOT 5 satellite captures 10m multispectral and 2.5m panchromatic imagery, which can be combined to produce 2.5m colour imagery. Whilst the objective of the pilot project was to assist in vegetation compliance campaigns, DIPNR were also able to use this opportunity to investigate SPOT 5 imagery for a range of remote sensing applications.

The Method
The pilot project was confined to ‘hotspot’ regions based on previous clearing pressures and where there were numerous cases of illegal clearing. Thirty-five SPOT 5 10m multispectral/2.5m panchromatic scene pairs were acquired over the hotspot locations. The imagery was captured between December 2003 and April 2004, with view angles ranging from near vertical to 30 degrees off nadir. This imagery was supplied to GEOIMAGE, together with aerial orthophotos, GPS points and mapping vectors for ground control. The NSW Department of Lands 25m DEM was supplied for the height control, which was supplemented by GEOIMAGE elevation datasets wherever required.

Orthorectification of the SPOT 5 imagery was performed using PCI OrthoEngine, which employs a satellite orbital math model based on rigorous principles that take into account all of the geometric distortions generated during image capture. For each hotspot region, same date datasets were joined into continuous image strips. This was performed in a manner that retained the orbital model and preserved the interior geometry. Adjacent scenes and strips were geocoded to the best available control and subsequently tied and block adjusted to optimize both exterior and interior accuracy.

Using a combination of PCI and GEOIMAGE software, each pair of orthorectified multispectral/panchromatic datasets was combined to produce a single 2.5m multispectral image. The coarser resolution multispectral data is reconstructed at the higher resolution panchromatic resolution resulting in a product that contains the optimal spectral and spatial properties of the component datasets. SPOT 5 multispectral imagery consists of visible green, visible red, near infrared and shortwave infrared bands. As a visible blue band is required for true colour composites, GEOIMAGE used in-house software to produce pseudo natural colour products from the pansharpened 4-band multispectral imagery.

Benefits
The processed SPOT 5 imagery has been well received by DIPNR. The availability of quality imagery and control data made for a successful pilot project which has shown the benefits of using high resolution satellite imagery for vegetation compliance as well as for a range of monitoring, planning and mapping applications. The ability of SPOT 5 to capture large areas at 2.5m resolution is important for NSW regional programs and there is currently a state-wide program of SPOT 5 capture underway. GEOIMAGE has contracted to supply the same image processing services as was performed during the ‘hotspot’ pilot programs.
Introduction

Enertrade is the trading name of the Queensland Power Trading Corporation, a wholesale energy trader owned by the Queensland Government in Australia. The Corporation was originally established as part of the restructuring of Queensland’s electricity industry. It has since developed to be an active participant in Australia’s competitive energy market. Enertrade has just completed construction of a 369.4 km pipeline from Moranbah in Central Queensland to Townsville and Yabulu to carry gas between the gas field in the Bowen Basin to electricity generating facilities in the Townsville region.

The Problem

The GIS contractor to Enertrade, Mipela (GIS), approached GEOIMAGE with the task of providing high resolution but cost-effective imagery which could be used as a backdrop in a GIS for the new pipeline that was being constructed. The imagery was required to be used during the planning and construction phase of the pipeline and would replace aerial photos that were historically used in such applications. The imagery was to be provided as a natural colour geometrically accurate seamless mosaic with a 1m pixel size over the entire length of the pipeline route, with a buffer of 2.5 km either side of the proposed line.

The Solution

GEOIMAGE advised that archive IKONOS imagery would provide imagery of sufficient resolution at the cheapest price. The entire length of the proposed route except for a small section of approximately 23 km near the northern end near Townsville was covered by nearly cloud-free imagery in the IKONOS archive. In total, 1815 sq. km of archive IKONOS was purchased and an area of 166 sq. km was tasked for new capture by the satellite. The new capture imagery was captured in early 2003, with a restricted off-nadir angle of less than 18 degrees. Because some of the archived image had been captured at high off-nadir angles, a DEM of higher accuracy than the AUSLIG 9 dec DEM was required to orthorectify the IKONOS imagery. Approximately 11 ASTER images were obtained and were used to produce a 1 m DEM along the pipeline route to orthorectify the IKONOS data.

The Methodology

The IKONOS data was ordered as bundled 1 m panchromatic and 1 m multispectral imagery. As soon as the imagery was received by GEOIMAGE, the Pan images were mosaiced and 1:50 k scale hardcopy prints were produced in 13 sheets along the pipeline route. These prints were marked with suggested ground control points (GCPs) and these GCPs were used by surveyors contracted to Enertrade to obtain accurate ground control that were supplied to GEOIMAGE. These accurate GCPs were used in conjunction with the 1 m DEMs produced from the ASTER data to orthorectify the individual IKONOS tiles. The panchromatic and multispectral imagery from each tile were pansharpened in PCI Geomatics to produce 1 m colour imagery. The individual tiles were then colour matched to produce a seamless mosaic along the complete pipeline route. The spatially accurate and balanced imagery was tiled for ease of use and supplied to the client as both ECW compressed files to reduce file sizes and uncompressed geotiff files which would allow further image manipulation if required.

Benefits

The purchase of the IKONOS imagery has allowed the establishment of an archive of cloud-free imagery covering the whole project area. This has enabled an environmental baseline to be established prior to the commencement of construction. The provision of this high resolution visualisation tool is being used for route selection, risk assessment and pipeline design, and for alignment sheet generation. Because work can be completed from the users desktop, a reduction in the number of site visits has also been achieved. Access issues associated with landholder cultural heritage and environmental management can also be addressed. Because the area, being remote, had changed little in the past 10 years, using archive imagery that was 1-2 years old did not pose a problem to the Enertrade and Mipela team. The cost-effectiveness of using archive imagery when compared to other methods of image acquisition proved an added bonus.

This image is an example of the 1:50 000 scale hardcopy prints supplied to Mipela for the surveyors to use during the accurate survey of ground control for the imagery. The imagery was also supplied in digital form as ECW compressed files and the proposed GCPs in MapInfo format. Although the IKONOS data used was as supplied by the satellite operator the accuracy of the raw data was generally better than 1 m.
Introduction

Mackay Sugar is amongst Australia’s largest sugar cane producing and sugar manufacturing companies owned by 1100 canegrower shareholders and operating four highly efficient sugar factories located in the central sugar growing district of Queensland. The four mill areas have a total cane production area of 98,000 hectares and the 1100 growers are capable (in good seasons) of supplying up to 8 million tonnes of cane to the factories for processing. The co-operative produces on average about 1 million tonnes of raw sugar and 225,000 tonnes of the by-product molasses. The Mackay Sugar raw sugar output represents about 20 per cent of Australia’s raw sugar production.

The Problem

Mackay Sugar uses satellite imagery to manage the logistics of crop harvesting and monitor the growth of the cane within the mill areas. At the stage that GEOIMAGE became involved, Mackay Sugar was using a manual method of information collection using a large number of personnel who visited the farms and interacted with each individual farmer to establish a harvesting schedule. This method was inefficient in a number of ways as it is very time-intensive and not very cost-effective.

The Solution

Mackay Sugar contracted GEOIMAGE, together with Robert Crossley and Associates, to custom develop a farm mapping web application based on Earth Resources Mapping’s Image Web Server and the Open Source (University of Minnesota) MapServer which would serve recent satellite imagery and farm information to sugar farmers in the Mackay Region. The system needed to provide up-to-date satellite imagery over a grower’s farm and allow him to interact and advise Mackay Sugar on the status of his farm during the growth and harvesting period.

The Methodology

The application was implemented in three conceptual stages: Proof of Concept; System Design and Development; and Maintenance and Support. The Proof of Concept stage required that the clients needs were analysed and the core software components identified. From these a test server was built by installing Image Web Server and MapServer which allowed assessment of how the raster and vector processing methodologies suited the clients’ application. Once these core components had been tested the custom Mackay Sugar webmapping application was designed which was then further tested, refined and reviewed. Once the testing phase was complete the production server was built and the system deployed. User and system manuals were written by GEOIMAGE in collaboration with Robert Crossley and Associates and provided to Mackay Sugar along with training and support.

Applications

The web based Farm Mapping System allows growers to display current maps and satellite images of their farms; incorporate a number of different feature layers and optionally print these maps. The system also allows farmers to display information about paddocks and other features stored in backend databases as well as enter changed information for their paddocks in terms of cane variety, class, yield estimate, area planted and area harvested during the current year and for the next year. Mackay Sugar now uses up to date information to schedule scarce resources during the period leading up to and during harvesting. The eventual aim is for the vast majority of information passed from farmer-to-mill and mill-to-farmer relating to farm layouts and harvest progress to be processed through the web mapping interface.

Example of 20m resolution SPOT 4 data which has been image processed to a pseudo natural colour image with vegetation in green. Fallow fields are magenta in colour. The bottom image shows the field boundaries in red ©CNES 2002.

GEOIMAGE thanks Mr John Markley, GIS Officer for Mackay Sugar Co-operative Association Limited for his help in the preparation of this article.
Processing of QuickBird and ASTER Imagery – Peru

The Problem
The client Hampton Resources Pty Ltd had just obtained the rights to the Torrecilla Gold Mine in central Peru and required a suitable set of maps/data to establish an epithermal gold exploration platform. The best published geological mapping in the area was the Ingemet 1:100k geological series and Mr Gavin Daneel was retained to provide a lithological, structural and alteration interpretation over the tenement areas.

The Solution
A search of the archive of high resolution satellite imagery showed that the area of interest, which was approximately 11km by 11km, was covered by one swath of QuickBird imagery collected on 21 May 2004. This imagery was cloud free however it was collected at an off Nadir View Angle of 16.1 degrees. This view angle equates to a 30m horizontal displacement per 100m of altitude. In the area of interest the altitude range was 2065m to 3129m and in the area of immediate interest there was approximately 150m of elevation. Errors in location due to height displacement of 150m in the area of interest and 300m in the image area could be expected.

The various DEMs available for orthorectifying the imagery were the SRTM 3sec data with a 90m cell size or a 15m cell size DEM from ASTER data. It was decided to generate the ASTER DEM which would be also used to produce pseudo stereo imagery. The ASTER data was also used for spectral processing.

The Methodology
An ASTER L1A scene collected on 18 August 2000 was obtained and a 15m DEM produced in PCI OrthoEngine. The Landsat GeoCover 2000 15m panchromatic band was used for X and Y control and the SRTM for Z control. The graphic right which compares part of this ASTER DEM with the 90m SRTM shows the increased detail available in the ASTER DEM.

GEOIMAGE ordered the QuickBird data as 0.6m resolution pansharpened natural colour. As the client did not have any ground control information the orthorectified ASTER VNIR imagery was used for locational control. The QuickBird data was then orthorectified using the ASTER DEM. Pseudo stereo pairs consisting of a vertical and a left stereo image of the QuickBird imagery were prepared for the client at 1:10 000 scale. At this scale a print to cover the area would have been 110cm by 70cm and so to keep the prints at a manageable size for interpretation under a mirror stereoscope the area was subdivided into 4 subareas. An example of the north west stereo pair is shown at the bottom of this page.

The Benefits
This project is a good example of the amount of high quality spatial data that can be accessed out of archive and interpreted prior to visiting an area on the ground. This can include geological, structural and spectral studies.
Introduction

The Condamine Alliance is a regional body with the lead responsibility for enabling the community to achieve sustainable natural resource management. This occurs through facilitation, coordination, and management of assets and investments in the Condamine River catchment. The catchment is at the very headwaters of Australia's biggest river system: the Murray Darling Basin. The Condamine Alliance aim to secure the long term future of land and water resources and the viability of rural and regional industries and communities in the Condamine Catchment. They also provide advice to property owners in the Condamine Catchment on land care issues as well as assist with property planning and management [www.condaminealliance.com.au].

The Problem

In order to operate effectively the Condamine Alliance need good quality, accurate and high resolution spatial imagery over their entire area of interest (AOI). The imagery is also required to be very recent and supplied in a format that is accessible to a wide range of users including GIS operators, managers and decision makers. The Condamine Catchment comprises several local government authority areas and the data is of interest to other large organisations such as Geoscience Australia who are currently updating their 1:250,000 mapsheets over the area. In addition, there are a number of groups who would be able to use the imagery to improve their current management or mapping. An option where the imagery could be purchased under a multi-agency licence would allow each group to contribute to the financial cost of acquiring the imagery and thus reduce the individual cost to each party.

The Solution

The Condamine Alliance approached GEOIMAGE to help them assess which type of imagery would best suit their application and budget. It was decided that orthorectified SPOT5 panchromatic imagery and multispectral imagery would be the best choice. The imagery is to be supplied with the orthorectified 10m multispectral and 2.5m panchromatic imagery of each scene before pansharpening the datasets to produce 2.5m multispectral imagery. The orthorectified scenes will then be mosaiced ensuring that the joins are all seamless. Because SPOT imagery does not contain the blue band, a natural colour enhancement has to be synthesised, which is achieved by GEOIMAGE’s in-house programs. This natural colour enhancement is applied to the resulting mosaic which includes optimal contrast stretching to provide the most aesthetically pleasing imagery possible. The mosaic will then be tiled into manageable pieces, and reformatted to the clients specifications.

The Method

In a similar manner to the NSW hot spot case study, GEOIMAGE will work closely with Raytheon Australia to program the SPOT5 satellite to capture the imagery over the Condamine Catchment AOI. At the time of going to press, the satellite is just beginning the capture attempts, and it is estimated that 14 full scenes will cover the AOI. The capture angle has been restricted to less than 18 degrees and a capture window of 40 days has been allowed for. Once the imagery is captured, GEOIMAGE will quality assess the imagery to ensure that the cloud coverage is less than 10% per scene and no saturation of the imagery has occurred. The ground control will be supplied by a number of sources mainly the Dept of Natural Resources and Mines and Condamine Alliance. A DEM supplied by the Condamine Alliance and supplemented by the SRTM and ASTER DEMs will be used for the height control. GEOIMAGE will orthorectify the 10m multispectral and 2.5m panchromatic imagery of each scene before pansharpening the datasets to produce 2.5m multispectral imagery. The orthorectified scenes will then be mosaiced ensuring that the joins are all seamless. Because SPOT imagery does not contain the blue band, a natural colour enhancement has to be synthesised, which is achieved by GEOIMAGE’s in-house programs. This natural colour enhancement is applied to the resulting mosaic which includes optimal contrast stretching to provide the most aesthetically pleasing imagery possible. The mosaic will then be tiled into manageable pieces, and reformatted to the clients specifications.

Benefits

This project is a great example of the benefits of collaborating with other potential users of the same imagery. By engaging the support of state and local government, as well as Geoscience Australia, the Condamine Alliance have reduced their individual costs of purchasing this imagery by up to 50%. The Condamine Alliance will be using the imagery for all their mapping applications, mostly as a backdrop to provide context to their existing vector layers. Because the Condamine Alliance will have a consistent and accurate mapbase of their entire AOI, management decisions across the entire catchment area can be properly achieved instead of just the regions near towns and more urban areas. The Queensland state government has a myriad of uses for the imagery and in particular the imagery will be used to update the existing DCDB cadastral database in this region as well as replace the traditional aerial photography that is routinely flown over the area. The cost savings to the government in this area alone are substantial. The local governments will be using the imagery for all their planning and maintenance activities while Geoscience Australia will be using the imagery to update their 1:250,000 maphsheets of the area.
Landsat and the National Carbon Accounting System

An Australian Greenhouse Office (AGO) Case Study

The Problem
There has been no historical vegetation mapping on a large scale carried out in Australia making it very difficult to monitor trends in deforestation and regrowth or to assist with predicting the consequences of tree clearing with respect to salinity problems and even climate change. In addition the federal government is required to provide data on carbon sink modelling as land based sources and sinks are of key interest to Australia forming around 30% of the national emissions profile from activities such as land clearing, cropping grazing and forestry. Accurate emission data is needed to plan for optimal greenhouse and natural resource management outcomes.

The Solution
The National Carbon Accounting System (NCAS) formed by the Australian Greenhouse Office (AGO) tracks greenhouse gas emissions ‘sources’ and removals ‘sinks’ from the land. The system underpins National Greenhouse Gas Inventory reporting and provides a basis for emissions projections to assess progress towards meeting Australia’s emissions target. Developed through extensive collaboration with scientists, policy makers and industry professionals the NCAS combines satellite imagery with models and data to provide a 30-year dynamic account across the Australian continent. The system is also used to inform policies and programs in vegetation and land management.

The Methodology
The main thrust of this project is to optimally identify woody vegetation defined as greater than 2 metres tall and 20% canopy cover, and change to woody vegetation via land clearing and regrowth over the entire continent of Australia i.e. identify woody versus non-woody cover. This is achieved through the use of Landsat imagery which spans the era from 1972 to 2004 for this project. GEOIMAGE has been heavily involved in the technical aspects of this project from its inception in 2000, working closely with the AGO and CSIRO and a range of other private sector groups. Thirteen different years or epochs were identified for the mapping. These range from 1972, through 1977 to 2000, 2002 and 2004. Landsat imagery covering the entire continent of Australia was chosen for each epoch. Landsat MSS imagery with 80m pixels was used for epochs before 1984 and Landsat TM and ETM+ imagery has been used for more recent epochs. Areas of cloud and fire scars were clipped out and the imagery orthorectified to a base set which was decided as the 2000 epoch. Accuracy was very important when orthorectifying as each pixel needed to be compared to its corresponding pixel from each different epoch. The imagery was then calibrated to a base year (2000) to ensure consistent pixel index values as images captured at different times such as in different seasons would produce different pixel reflectance values. To calibrate the data, invariant targets such as high reflectance salt plains or beaches or low reflectance oceans or rocky outcrops were selected as seasonal changes will make no difference to such features. CSIRO created a conditional probability method using Landsat imagery which predicts the probability of a set vegetation type occurring for each pixel. This is achieved by calculating the best Landsat band combination for a certain zone for a certain vegetation type. This is then plotted against the second best combination for each scene and a threshold value is calculated. These threshold values or indices for each vegetation type in each zone within Australia are the probability of each pixel being classed as woody vegetation. Therefore, each pixel from each year is classed as a percentage of being either woody or non-woody vegetation. A computer interpolation program predicts the probabilities for the years in between the epochs used. For example, if a pixel has a high (90%) probability of being woody vegetation during the 1972, 1975 and 1977 epochs but in 1974 the probability is classed as 50%, the interpretation is that clearing occurred between 1972 and 1975.

Benefits
The final products are a series of Landsat mosaics covering Australia which show areas of regrowth and deforestation and which map the trends of woody and non-woody cover over the continent. The data produced is invaluable for carbon sink modelling and for monitoring greenhouse gas emissions and can be combined with other types of data such as salinity maps and elevation models to predict the consequences of vegetation clearing in different areas. GEOIMAGE has been intimately involved in the highly technical aspects of this project such as the world class orthorectification and processing of the Landsat imagery and the statistical analysis and final product generation in this major federal government project whilst working to extremely tight time scales.

GEOIMAGE – Satellite applications for the real world

Example of raw Landsat 741 image – 1991 epoch, a forest probability image (0 to 100%) out of 17.

Image 2

Schematic methodology to map clearing and revegetation over time using Landsat data.

GEOIMAGE
Image Applications – GEOMAGE Case Studies

13
Why Should You Use Satellite Imagery?

Using satellite imagery can often seem daunting to the uninitiated user however as the previous case studies have shown a satellite image is often the most practical way to acquire usable geographic data. In many instances it is advantageous to use satellite imagery over some of the more conventional and traditional methods of mapping such as aerial photography, field surveys and paper maps. This section aims to introduce the concept of remote sensing and satellite imagery and begins with the advantages of using satellite imagery. These are detailed below:

**DIGITAL**
Because satellite imagery is acquired digitally there is no need for expensive data conversion, scanning or digitizing. With minimal preparation, imagery is ready to load directly into your GIS, image processing or desktop mapping system for immediate use. In addition, because it’s digital, satellite imagery can be processed, manipulated and enhanced to extract subtle details and information that other sources would miss.

**FAST**
In the time it takes a field crew to unload its equipment or a pilot to preflight his aircraft a remote sensing satellite can map a vast forest or an entire city. Because the satellites are in constant orbits they are rarely more than a week or two away from acquiring imagery of your project area. There is very little planning required. Place an order today and it can be acquired tomorrow, next week or in three months depending on your schedule.

**GLOBAL**
Satellites are not limited by political or geographic boundaries. Commercial remote sensing satellites are in polar orbits that take them over every location on Earth. Regardless of whether your project area is on the top of a mountain or the middle of the ocean a remote sensing satellite can collect an image of it. In a single image remote sensing satellites can capture the details of land cover, transportation routes and major infrastructure spread over hundreds or even thousands of square kilometres.

**UP-TO-DATE**
In today’s rapidly changing world you need current information to make critical business decisions. Maps are months or years old by the time they are printed but you can have a satellite image in your hands a couple of days after it is acquired. An image is the most up-to-date map available.

**ACCURATE**
Because there is minimal human involvement in the creation of a raw satellite image the information it contains is an accurate and objective representation of objects and features on the Earth’s surface.

**FLEXIBLE**
Processing and extracting information from satellite imagery can be as complicated or simple as you want to make it. By looking at a satellite image and identifying a house with a rain-swollen river nearby it is often easy to understand the relationship between them. Just about anyone can derive more complicated information and learn to combine imagery with the myriad of other easily available geographic information in just a few hours of training on today’s user-friendly geographical information software packages.

**INEXPENSIVE**
For large areas satellite images are usually less expensive than aerial photography or field surveys.

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**LARGE AREA COVERAGE WITH THE ABILITY TO FOCUS IN ON THE DETAILS**

© DigitalGlobe 2004
An Introduction to Remote Sensing

There are currently dozens of remote sensing satellites circling the Earth with each acquiring very specific and different types of imagery. This large selection of imagery is beneficial to you the end user because it increases the likelihood that you can obtain just the right image that provides the specific information you need for successful completion of your project. However, more choices also make it more difficult to determine which type of image to buy. At GEOIMAGE, we specialize in keeping abreast of the most current information about all types of satellite imagery and can advise you of the best type of imagery for your application. It is often helpful to have some background information which is where this section can help you.

This section introduces you to the basic remote sensing concepts and jargon that will help in choosing the imagery that’s right for your needs.

**Raster and Vector Datasets**

The terms raster and vector are often used to describe geospatial data but sometimes there is confusion between them. Raster simply means an image which is comprised of numerous small units or pixels (picture elements) which cover the entire scene area. Digital satellite images are raster data sets. Vector data sets on the other hand are composed of points, lines, and polygons. Cadastral data is a good example of a vector dataset.

The most important remote sensing concepts are what a satellite image actually is and how it is acquired. An image is not a photograph taken by a camera with film in it. Nearly all commercial remote sensing satellites acquire images with digital sensors. These sensors operate on the same principles of digital cameras which we are all familiar with.

The sensor has thousands of tiny detectors that measure the amount of electromagnetic radiation (e.g., energy) reflecting from the Earth’s surface and objects on it. These are called spectral measurements. These areas have a dimension which corresponds to the pixel size or spatial resolution. For example, if a sensor has a 10 metre pixel, that means it measures reflectance for every 10 metre by 10 metre surface area in its imaging swath. A pixel is the smallest unit of the image created from these measurements and each pixel is assigned a value or digital number based on the reflectance measurements. Each spectral reflectance value is recorded as a digital number. These numbers are transmitted back to Earth where they are converted by computer into colours or greyscale brightness levels to create an image that looks like a photograph.

Depending on the designed sensitivity of the detector’s sensors, they can measure reflectance of energy in the visible, near-infrared, short wave infrared, thermal infrared, and microwave radar portions of the electromagnetic spectrum. Most remote sensing satellites measure energy in very specific well-defined wavelengths of the spectrum.

**Spectral Resolution**

Reflectance measurements can help reveal the mineral content of rocks, the moisture of soil, the health of vegetation, the physical composition of buildings, and thousands of other invisible details. This is known as the spectral content of a satellite image.

This spectral information is visible to the digital sensor because of the energy reflectance it measures. The density, water content, chemical make-up, and other unseen conditions and characteristics of a particular surface feature all influence how energy in various wavelengths or spectra interact with that feature and reflect off it. In effect, the digital sensor measures this spectral interaction which in turn provides insight to those invisible conditions and characteristics.

When viewing imagery on a colour monitor, three separate continuous tone “black/white” images are displayed in the red, green and blue colour guns of the colour monitor to display a colour image. When a greyscale image is to be displayed, the same black/white image is displayed in all three colour guns.

**SPOT Multispectral Image Redlands, Qld © CNES 1998.**

This image demonstrates the preparation of a false colour infrared composite from SPOT data. Since there is no visible blue band, the colour scheme used is the visible green band in blue, the visible red band in green, and the near-infrared band in red. Note the dominance of the vegetation response with cultivation/grasslands in light reddish-pink and the native eucalypt forest in dark red. Urban areas with only minor vegetation are coloured blue or cyan.

**Spectral reflectance curves with SPOT XS Bands.**

The reflectance of natural objects at various wavelengths can be plotted to give spectral reflectance curves which in the diagram above are compared with the bandwidths of the sensors on the SPOT 1-4 satellites. In this diagram, the bands are displayed in the colours used to represent them in a false colour infrared composite (FCIC). If we examine the curve for vegetation, we note that in the visible part of the spectrum the highest reflectance is in the visible green and that is why the human eye sees vegetation as green. However, vegetation reflectance in the near infrared is much higher. This band is coloured red in a FCIC so vegetation is viewed coloured red. The wide range of reflectances in the infrared reflects the health of the vegetation with higher reflectances usually denoting more healthy vegetation.

In the case of water, the reflectivity decreases with increased wavelength and the result is that the shorter wavelengths will travel through progressively deeper water to give reflectances off the sea bed. Under ideal conditions reflectances can be used to gauge water depths.
Spatial Resolution

Reflectance measurements and the images created from them provide an extremely accurate representation of what surface features and objects on the ground look like to the naked eye—shape, size, colour, and overall visual appearance. This is known as the spatial content of the image.

The spatial resolution you choose depends on the smallest object that you would like to see. An important factor to consider is the tradeoff between scene size and spatial resolution. Imagine a camera with a zoom lens. As the camera zooms in on small features, the field of view shrinks. The same is true of satellite imagery. Very high spatial resolution—such as one metre—corresponds with a small coverage area and large digital file sizes. In choosing your image, you should balance these two features so that spatial resolution is just high enough to distinguish the objects you need to identify. Yet, the scene size should be broad enough to put those objects in their proper perspective.

The smallest feature that can be identified by a sensor depends on the characteristics of the object. Characteristics such as the size, shape, and spectral contrast with the background are important in defining how small an object or feature can be identified. In some instances, features with one dimension smaller than the spatial resolution of the sensor, such as road markings, can be defined if they contrast vividly to the background.

Some of the most common spatial resolutions and their applications are:

1m
- Identifying and mapping human-scale features larger than one square metre such as cars, houses, highway lanes, utility equipment such as powerlines, fence lines, and free-standing trees.
- Detecting small areas of stress in farm fields or tree stands.
- Locating and mapping house additions and pools, roads, and small farm fields.
- Differentiating among types of buildings and houses for urban planning.

10m
- Locating and mapping roads, property boundaries, athletic fields, pastures, and side streets.
- Differentiating cropping areas and tree stands by relative vegetative health.
- Making small-area land-cover classifications.

25m
- Locating airports, city centres, suburbs, shopping malls, sports complexes, large factories, extensive forest stands, and large agricultural areas.
- Making generalized land-cover classifications.

1km
- Assessing vegetative indices for states and entire countries.
- Tracking regional events such as insect infestation, drought, and desertification.

Images:
- IKONOS image in natural colour © Space Imaging 2003
- ASTER image
- SPOT 5 © CNES 2004
- Pansharpened Landsat ETM+ Bands 741 in RGB
SAR imagery conveys feature information that is different from the spatial and spectral details of electro-optical imagery. Because SAR is active and operates in longer wavelengths than electro-optical systems, it can acquire images through clouds, fog, haze, and darkness.

Different Sensor Applications

Optical and SAR sensors are used for many different applications with some of the most common being:

Panchromatic Applications
- locating identifying and measuring surface features and objects primarily by their physical appearance i.e. shape-size orientation
- identifying and accurately mapping locations of man-made features such as buildings, roads, sidewalks, houses, utility equipment, urban infrastructure airports and vehicles
- updating physical features on existing maps
- delineating land-water boundaries
- identifying and quantifying urban growth and development
- deriving highly accurate digital elevation models
- classifying land use types such as urban and forest

Multispectral Applications
- providing a colour backdrop to Geographic Information Systems ‘GIS’ to give context to vector lines for example allowing for visual differentiation between a gravel road and a bitumen road
- locating, differentiating and identifying surface features by less obvious characteristics such as mineral content, moisture level, vegetative species, chlorophyll content or chemical properties
- detecting stress in vegetation, crops or trees
- delineating and measuring changes in natural habitats and ecosystems such as wetlands
- estimating water depth in coastal zones
- classifying land cover types such as grazing, cropping and bare soil

SAR Applications
- acquiring images in areas frequently covered by clouds or fog or obscured by constant darkness
- locating icebergs and sea ice and mapping other ocean surface conditions
- mapping very subtle terrain features such as faults and folds

Electro-optical sensors are passive imaging instruments that measure electromagnetic energy which is emitted primarily from the sun and bounces off the Earth’s surface. They are called passive instruments because they do not emit their own source of energy. This means they can only operate in daylight. The one exception is an electro-optical sensor measuring thermal infrared radiation which is not reflected from the sun but rather emitted from the earth’s surface.

Panchromatic or black-and-white imagery is acquired by a digital sensor that measures energy reflectance in one wide portion of the electromagnetic spectrum otherwise known as a band. For most current panchromatic sensors, this single band usually spans the visible to near-infrared part of the spectrum.

Multispectral imagery is acquired by a digital sensor that measures reflectance in many smaller bands. For instance, one set of detectors may measure reflected visible red energy while another set measures green energy. These multiple reflectance values are combined to create colour images. Current multispectral remote sensing satellites can measure reflectance in three to seven different bands at once.

A special type of multispectral imagery referred to as hyperspectral involves many, often hundreds of individual bands. The theory behind hyperspectral sensing is that measurement of reflectance in numerous narrow portions of the spectrum can detect very subtle characteristics and differences among surface features such as vegetation, soil and rocks.

Radar Imagery

All of our discussions so far refer to electro-optical sensors. The most common type carried aboard remote sensing satellites but there is another sensorcalled synthetic aperture radar (SAR) gaining popularity among users. SAR sensors are active imaging systems which means they transmit a radar signal in the microwave portion of the spectrum and measure the strength and other characteristics of the return signal after it reflects off the Earth’s surface.

How Do I Choose the Correct Satellite Sensor?

At GEOIMAGE we are happy to discuss your particular application with you and recommend the best type of satellite imagery for your needs.

Introduction to Satellite Imagery

Overview of Existing and Future Systems

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Operator</th>
<th>Launch Year</th>
<th>Optical or Radar</th>
<th>Pan/Multi</th>
<th>Pointable Sensor Y/N</th>
<th>Stereo Y/N</th>
<th>Resolution (Metres)</th>
<th>Swath (km)</th>
<th>Revisit (Days)</th>
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<tbody>
<tr>
<td>SPOT 1/2/3</td>
<td>CNES/SPOT</td>
<td>1986/90/93</td>
<td>Optical</td>
<td>Panchromatic</td>
<td>Y</td>
<td>Y</td>
<td>10</td>
<td>60</td>
<td>1-4</td>
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<td>CNES/SPOT</td>
<td>1998/2002</td>
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<td>Panchromatic</td>
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<td>Y</td>
<td>105</td>
<td>60</td>
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<td>JAPAN</td>
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<td>Panchromatic</td>
<td>N</td>
<td>N</td>
<td>1000</td>
<td>2200</td>
<td>1</td>
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<td>U.S.</td>
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<td>N</td>
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<td>16</td>
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<td>ISRO-India</td>
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<td>N</td>
<td>23/188</td>
<td>150/281</td>
<td>24/3-5</td>
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<td>16</td>
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<td>Y</td>
<td>20-100</td>
<td>50-500</td>
<td>3-35</td>
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<td>Canadian Space Agency</td>
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<td>Radar</td>
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<td>Y</td>
<td>3-100</td>
<td>20-500</td>
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<td>16</td>
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<td>ORBIMAGE</td>
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<td>N</td>
<td>1.1 km</td>
<td>2800</td>
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<td>OrbView 4</td>
<td>ORBIMAGE</td>
<td>2002</td>
<td>Optical</td>
<td>Panchromatic</td>
<td>Y</td>
<td>Y</td>
<td>1</td>
<td>8</td>
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### Processing of Satellite Imagery

#### Product Processing Levels

Satellite imagery can be processed so that its visual appearance and spatial accuracy are improved. Many processing options are available from GEOIMAGE when you order your images. It is very important for you to consider which processing level you will need. You should make this choice based primarily on what type of software you will be using to work with the imagery and what you want to use the imagery for. The most common processing levels that you will come across are:

- **Raw** - This is the lowest level of processing. For most satellite images raw data will have some degree of geometric and radiometric correction, which simply means that distortions caused by the sensor itself have been removed. This will be the most spatially inaccurate type of imagery.

- **Geometric Correction** - The imagery has been resampled to correct for geometric errors caused by rotation of the Earth and incidence angle of the sensor.

- **Projected** - The imagery is put into map coordinates using location information recorded by the satellite when the image was acquired.

- **Rectified** - The data is corrected or warped using ground control points (GCPs) either from maps or GPS measurements to pull the features of known coordinates into the correct space. For imagery over some areas of the world, GEOIMAGE may require you to supply the maps or GCPs. This process only corrects for horizontal measurements and does not take the vertical terrain into account.

- **Orthorectified** - Orthorectification is a process by which horizontal and vertical distortions are removed from the image. This process dramatically improves the quality and usability of the image because it gives the image the same qualities as an accurate map.

- **Enhanced** - Computerised algorithms are applied to increase the quality of the imagery and highlight certain features. The most common enhancement is Contrast Stretching, in which the reflectance values of pixels are reassigned to cover the full 256 greyscale range. This process is similar to adjusting the contrast on your TV.

#### Archived Imagery

Previously collected satellite images are stored in archives and are applied extensively in change detection studies. In change detection studies, older images are compared with new images to detect areas that have changed over time, such as land use/land cover, habitat, farm land, real estate, and wetlands. GEOIMAGE can advise you regarding costs and availability of archived imagery. Archive imagery is usually cheaper than new capture imagery but this is not the case with all satellites.

You could purchase archived imagery if:

- you are conducting a change detection analysis with a newly acquired image
- recent changes in vegetation cover or urban development are unimportant to your project
- your project focuses on studying geologic structure or another physical feature that does not change appreciably with time
- you need an image immediately and cannot wait for the next scheduled satellite pass over your project area

You should order a new acquisition for:

- any kind of urban mapping that requires up-to-date information on road locations, highway conditions, urban development, and land use changes
- updating scanned or digitised maps
- comparison with an archived image in a change analysis or growth trend project
- monitoring current crop or forest health

#### Image Interpretation and Derived Products

Image interpretation can range from simple visual inspection of the image to the use of image processing systems which analyse and classify ground features based on the digital value of the spectral signatures. Image processing and some mapping software can do the analysis and classification of ground features much more accurately than the human eye. GEOIMAGE specializes in producing derived products from satellite imagery for their clients. Some common types of derived products are:

- **Classification Maps** - In these maps, also called clutter thematic or morphology maps, land areas have been classified and clustered into groups of similar land cover or land use. The classifications may be broad such as urban, forested, open fields, and water or they may be very specific - differentiating corn, wheat, soybean, and beet fields.

- **Digital Elevation Models (DEMs)** - These are also referred to as digital terrain models. These data sets contain terrain elevation measurements derived by applying photogrammetric processes to overlapping stereo image pairs. DEMs are used extensively in three-dimensional modelling and visualization software packages and also for the orthorectification or spatial correction of imagery by taking the height of features into account.

- **Merges** - Two different types of satellite images can be fused to create a hybrid product with the benefits of both images. The most common is to merge a high-resolution panchromatic such as SPOT 5 2.5m with a lower resolution multispectral SPOT 10m to create a 2.5m Colour image. This results in an image with the spatial detail of the panchromatic image and the spectral content of the multispectral data.

- **Mosaics** - Often one satellite image scene does not cover an entire project area. Two or more adjacent scenes can be ordered and GEOIMAGE stitches them together using complex computer algorithms that match the edges of the scenes exactly and balance colours to create a large area seamless dataset.

- **Change Detection** - A change detection image is created by comparing two images captured at different times over the same area. These are often used to monitor trends in urban sprawl or the extent of vegetation clearing in catchment areas. Specialised algorithms are usually applied by GEOIMAGE to produce such maps.

### Other Points To Consider

#### Pricing

Image prices will vary with spatial resolution, scene size, processing level and age. The best way to compare the costs of two different images is to divide the cost into dollars per square kilometre. Costs generally increase with higher levels of processing and higher resolution. Costs usually drop with older images.

#### Sizes

System operators offer images in sizes matching common map products or on a per sq km basis.

#### Formats

There are dozens of file formats for digital image data. GEOIMAGE will advise you which is the correct format for your image processing or GIS package.

#### Scale

Digital satellite imagery has no inherent scale, however there is a limit to the scale of maps and hardcopy images that can be printed from a digital image. The map scale depends on the quality of the image data and relates to the spatial resolution or pixel size. Generally, a higher spatial resolution data set yields a larger map scale. The table below gives you some idea of the best map scale you can achieve for various spatial resolutions without losing clarity and quality.

<table>
<thead>
<tr>
<th>Image Resolution</th>
<th>Typical Map Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 metres</td>
<td>1:2,000,000</td>
</tr>
<tr>
<td>100 metres</td>
<td>1:200,000</td>
</tr>
<tr>
<td>10 metres</td>
<td>1:20,000</td>
</tr>
<tr>
<td>1 metre</td>
<td>1:3,000</td>
</tr>
</tbody>
</table>

Introduction
South East Queensland continues to attract people from the southern states looking for more affordable housing and a better quality of life. Consequently the Gold Coast just passed the 300,000 population threshold with around 90,000 individuals per year settling in this area alone. Clearly this rapid and ongoing growth which is mainly urban-based places enormous pressure on a range of resources such as water which is a key commodity in short supply. It is important to have proper planning frameworks in place to guide this urban growth and the financial capability to create the necessary infrastructure.

Council Requirements
The October 2004 Draft SEQ Regional Plan offers a framework for guiding urban growth. This plan combined with the Integrated Planning Act (IPA) 1997 means that local councils now have to manage development projects and land use much more carefully than in the past to cope with rapid urbanisation. To do this they need accurate information on what individual properties are used for; that is land use mapping. Yet few councils have basic land use maps—let alone detailed up to date land use maps upon which to base decisions on managing urban growth and protecting open space areas including remnant bushland and other habitats.

Mapping
Gold Coast City Council (GCCC) has recognised that it requires detailed land use information to assist in its decision making and implementation of its strategic planning objectives. Originally in 1999, the land use mapping was compiled on a property-by-property level using the cadastre to assist in basic hydrological modelling. TriMap Pty Ltd was commissioned by GCCC to update and upgrade its digital land use mapping in late 2004. QuickBird satellite imagery, captured in March 2003, and selected ground checking was used to systematically update the mapping. Particular attention was given to areas designated as ‘highly disturbed and under development’ on previous mapping as well as areas where land subdivisions had taken place as these are areas where growth and land use change can be expected. Originally 24 land use types across four main categories (rural, urban, commercial/industrial and undeveloped) were defined in the GCCC classification scheme of 1999. The 2004 mapping update added two more land use types in the form of ‘vacant land’ and ‘open land’ the former being self-explanatory and the latter comprising open mainly grass covered areas typically in the form of buffer strips within residential areas or alongside open stormwater drains.

The GIS fields created for each property polygon on the 2004 landuse mapping contains information such as land use, land cover, area, lot and plan numbers and addresses amongst others, ensuring that everything is referenced to an individual property. The initial compilation in 1999 was ‘broad brush’ paying little attention to detail and in some areas incorrect classification was made of properties. Consequently TriMap had the task of both updating and correcting the land use mapping. Although the GCCC cadastre now includes over 191,000 land parcels the use of georeferenced QuickBird satellite imagery with a pixel size of around 0.65m enables relatively speedy revision of the digital land use mapping. The task is assisted by occasional reference to large-scale (pixel size 0.15m) digital georeferenced aerial photography. Experience in interpretation combined with good local knowledge of the region from previous TriMap projects also assisted in the land use mapping revision.

Looking to the Future
Given the relevance and value of a detailed digital cadastral based land use maps across various sections within the council the GCCC has determined that annual satellite imagery updates are now required especially to track what is happening to vacant lots and ‘developing’ lots. Aside from providing council officers with up to date information about what given parcels of land are actually used for the land use mapping will also enable councillors to be more aware of what is happening on the ground in their constituencies. Land use information can and should be made available to the public as well so that they are aware of what is happening in their own neighbourhoods as well as citywide. A good quality land use map must result in better informed decision makers to guide the growth of our cities for the benefit of all.

GEOIMAGE and Dr Whitlow wish to thank the Gold Coast City Council for their kind permission to use this article.

An Example of a Land Use Classification Map over Coomera derived from QuickBird Imagery
An Example of 0.6m Pansharpened Natural Colour QuickBird Imagery
© DigitalGlobe 2004

Contact
Dr Richard Whitlow
TriMap Pty Ltd
Tel: (07) 5574 7972
Email: trimap@bizyweb.com.au
Property plans are used by landholders to document property resources and management practices and to design property changes. They function as a strategy to meet financial production and personal goals—a management tool for developing a property sustainably and profitably and a record demonstrating that a landholder is meeting his/her environmental obligations in natural resource management.

To date, property plans exist for:
- land management
- water conservation
- vegetation
- biodiversity
- cane production
- pest control

Property plans may be either voluntary, a regulatory requirement, or needed to support an application for financial assistance. Further details of property planning can be found at https://www.nrm.qld.gov.au/land-management/property_planning.html

The recent availability of high resolution satellite imagery has contributed greatly to the preparation of property plans. Mr Tim Neale of CTF Solutions, who specialises in the preparation of such plans, has been using satellite imagery for properties throughout Australia.

The success of farming relies heavily on managing many variables, including natural resources—crops, climate, money, human resources and farming machinery. Controlled Traffic Farming (CTF) Solutions is an enterprise that aims to improve effectiveness and sustainability of farming by managing all of these variables in a single system.

The first step in the CTF process is to gain an overall view of the property's current resources and in turn use this software for the future goals of the farmer. The use of satellite imagery plays an important role in this step. CTF Solutions have mapped over 100,000 ha of properties across Queensland, New South Wales, and Victoria using satellite imagery of all types, including Landsat, SPOT, ASTER, QuickBird, and IKONOS.

Farmers and graziers require a map that is relatively recent as properties can change dramatically over time. Maps need to be accurate spatially and resemble photographs, and not be pixelated or show false colour. Farmers also need imagery which works easily in farm management software. CTF have found IKONOS imagery to be most suitable for this purpose.

Property maps produced by CTF with IKONOS imagery are used in locating natural features such as soil types, vegetation, hills, gullies, and erosion patterns. They also use imagery for locating infrastructure such as roads, fences, pipelines, buildings, and yards, and naming this infrastructure, e.g., paddock names.

It is simple to calculate areas of paddocks and record activities through time once the image is used as a backdrop within the GIS software. Farmers and agronomists can better manage soils, water use, and vegetation as well as crop health. Crop stress, growth, and yield variations can all be recorded with the help of satellite imagery. The GIS mapping software allows for the adding of features and other data layers such as crop yield to the satellite imagery, which produces a dynamic diagram of what’s happening on the property.

With information from satellite imagery in conjunction with records of farming activities and current conditions, CTF Solutions can continue the process of developing sustainable farm management plans to help achieve farmers’ goals.

Examples of the use of satellite imagery to supplement yield monitoring data

Many farmers have taken steps towards precision agriculture adoption through the implementation of yield monitoring within their farming system. Yield monitoring is a relatively easy method of identifying variability across paddocks and provides farmers with an opportunity to ask themselves questions about those results. For example, why did certain areas within the paddocks perform worse than others? And more importantly, what can be done to ensure it doesn’t occur next season?

Often important clues to this variability can be determined by examining the health of the crop during the growing season using satellite imagery. The health of the crop can be measured using a formula called the Normalised Difference Vegetation Index (NDVI) which measures the absorption of sunlight to produce chlorophyll in the actively growing plants. This index can be measured for each square metre in a paddock using the IKONOS satellite.

Using the NDVI images, it is possible to show changes due to poor drainage areas, paddock history, problem weed, pest, or disease areas, trials, and areas that had run on water. CTF Solutions believe that combining satellite images with yield maps can increase the understanding of causes and clarify the best response to make. Once these changes have been made, it is a simple job to check the results during the next growing season using new imagery.

For more information contact:
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CTF Solutions
Ph 0428 157 208
spotonag@bigpond.com
www.ctfsolutions.com.au

An example of a natural colour pansharpened IKONOS image with vectors produced for a property plan. Scale approximately 1:12,000 © Space Imaging 2003

As Company director Tim Neale says, “we have tried the rest, so now we go for the best.” IKONOS is the most cost-effective, good-quality reliable image product for rural property planning available at the moment. CTF Solutions find true colour imagery useful as a backdrop for farm planning and also utilize the near-infrared band. Tim has found that “it is important to have the near infrared band as well as the visible bands for analysing and monitoring crops and vegetation. We can then do further analysis using vegetation indices such as NDVI.”
**Introduction**

In an effort to monitor major fluctuations in vegetation and understand how they affect the environment, Earth scientists began using satellite remote sensors 20 years ago to measure and map the density of green vegetation over the Earth. Using NOAA’s Advanced Very High Resolution Radiometer (AVHRR), scientists have been collecting images of our planet’s surface at a resolution of 1 km. By carefully measuring the wavelengths and intensity of visible and near-infrared light reflected by the land surface, scientists use an algorithm called a “Vegetation Index” to quantify the concentrations of green leaf vegetation around the globe. By combining the daily Vegetation Indices into 8-, 16-, or 32-day composites, scientists create detailed maps of vegetation on a patch of land, and where they are under stress (i.e., due to lack of water).

**NDVI**

**Normalized Difference Vegetation Index (NDVI)**

To determine the density of vegetation on a patch of land, researchers must observe the distinct wavelengths of visible and near-infrared sunlight reflected by the plants. When sunlight strikes objects—certain wavelengths of the spectrum are absorbed and other wavelengths are reflected. The pigment in plant leaves—chlorophyll strongly absorbs visible light (from 0.4 to 0.7 micrometers) for use in photosynthesis. On the other hand, the cell structure of the leaves strongly reflects near infrared light (from 0.7 to 1.1 micrometers). The more leaves a plant has, the more these wavelengths of light are affected. Nearly all satellite Vegetation Indices employ this difference formula to quantify the density of plant growth on a global scale over the Earth: near-infrared radiation plus visible radiation. The result of this formula is called the Normalized Difference Vegetation Index (NDVI). Written mathematically, the formula is: $NDVI = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}}$. Calculations of NDVI for a given pixel always result in a number that ranges from minus one ($-1$) to plus one ($+1$). A value of zero or lower means no vegetation and close to $0.1 - 0.5$ indicates the highest possible density of green leaves. Higher NDVI values can be calculated from most satellites that capture reflectance in the red and near infrared portions of the spectrum. Thus, as well as the broad scale NDVIs from MODIS and NOAA sensors, we can also obtain more detailed NDVIs for rangelands from the Landsat, SPOT, and ASTER sensors down to the smallest paddocks from the IKONOS and QuickBird satellites.

**MODIS**

In December 1999, NASA launched the Terra spacecraft—the flagship in the agency’s Earth Observing System (EOS) program. Aboard Terra is a sensor called the Moderate Resolution Imaging Spectroradiometer (MODIS) that greatly improves scientists’ ability to measure plant growth on a global scale. MODIS provides much higher spatial resolution (up to 250-meter) while also matching AVHRR’s almost daily global cover and exceeding its spectral resolution. In other words, MODIS will provide images over a given area of land just as often as AVHRR—but in much finer detail with measurements in a greater number of wavelengths using detectors that were specifically designed for measurements of land surface dynamics.

The MODIS Science Team has prepared a new data product called the Enhanced Vegetation Index (EVI) that improves upon the quality of the NDVI product. The EVI will take full advantage of MODIS’ new state of the art measurement capabilities. While the EVI is calculated similarly to NDVI, it corrects for some distortions in the reflected light caused by the particles in the air as well as the ground cover below the vegetation. Also the EVI data product does not become saturated as easily as the NDVI when viewing rainforests and other areas of the Earth with large amounts of chlorophyll.

**Other Satellite Sources**

NDVI values can be calculated from most satellites that capture reflectance in the red and near infrared portions of the spectrum. Thus, as well as the broad scale NDVIs from MODIS and NOAA sensors, we can obtain more detailed NDVIs for rangelands from the Landsat, SPOT, and ASTER sensors down to the smallest paddocks from the IKONOS and QuickBird satellites.
On 24 September 1999, a new era in commercial satellite remote sensing started with the successful launch of Space Imaging’s IKONOS satellite from Vandenberg Air Force Base, California. IKONOS was the world’s first high resolution satellite to offer one metre commercially available Earth imagery. This was soon followed by the launch on 18 October 2001 of the QuickBird satellite by DigitalGlobe and on 26 June 2003 of OrbView-3 by ORBIMAGE.

Space Imaging and DigitalGlobe have gradually been building up an archive of imagery over the world. However, there is not a program for the regular capture as with Landsat data over Australia. Data over Australia is captured and stored by on-board recorders and then down linked to ground receiving stations in the USA. Both IKONOS and QuickBird data may be purchased from the existing archive where imagery is available or captured as required.

## CHARACTERISTICS OF THE HIGH RESOLUTION SATELLITES

Many of the characteristics of the three main <=1 metre resolution satellite sensors are similar however some of the differences are important and are detailed below. The information used here has been gathered mainly from documentation on the Space Imaging [http://www.spaceimaging.com/], DigitalGlobe [http://www.digitalglobe.com/], and ORBIMAGE [http://www.orbimage.com/] web sites and is current at July 2005.

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Technical Details</th>
<th>IKONOS</th>
<th>QuickBird</th>
<th>OrbView-3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Satellite</strong></td>
<td><strong>Sensor</strong></td>
<td>Orbit</td>
<td>Imaging Details</td>
<td>Orbit</td>
</tr>
<tr>
<td>Sun-synchronous orbit with equatorial crossing 10:30 a.m.</td>
<td>Panchromatic 0.62m GSD ‘Ground Sample Distance’ at nadir</td>
<td>680 km</td>
<td>Sun-synchronous orbit with equatorial crossing 10:30 a.m.</td>
<td>Panchromatic 0.62m GSD ‘Ground Sample Distance’ at nadir</td>
</tr>
<tr>
<td>In track and cross track pointing viewing angle</td>
<td>Black and White 445 to 900 nanometres</td>
<td>1050 km</td>
<td>In track and cross track pointing viewing angle</td>
<td>Black and White 450 to 900 nanometres</td>
</tr>
<tr>
<td>Maximum off-nadir angle 90°</td>
<td>Multispectral 3.8m GSD ‘Ground Sample Distance’ at nadir</td>
<td>1050 km</td>
<td>Maximum off-nadir angle 60°</td>
<td>Multispectral 2.4m GSD ‘Ground Sample Distance’ at nadir</td>
</tr>
<tr>
<td>Accessible ground swath 490km centred on the satellite ground track</td>
<td>Band1:Visible Blue 450-520 nanometres</td>
<td>1050 km</td>
<td>Accessible ground swath 440km centred on the satellite ground track</td>
<td>Band1:Visible Blue 450-520 nanometres</td>
</tr>
<tr>
<td>Satellite orbit repeats every 1050 days</td>
<td>Band2:Visible Green 520-600 nanometres</td>
<td>1050 km</td>
<td>Revisit 1 - 3.5 days depending on latitude at 0.7m resolution</td>
<td>Band2:Visible Green 520-600 nanometres</td>
</tr>
<tr>
<td>1 day at 1° resolution at 60° latitude</td>
<td>Band3:Visible Red 625-695 nanometres</td>
<td>1050 km</td>
<td>1 day at 1° resolution at 40° latitude</td>
<td>Band3:Visible Red 625-695 nanometres</td>
</tr>
<tr>
<td>1 day at 1° resolution at Equator</td>
<td>Band4:Near Infrared 760-900 nanometres</td>
<td>1050 km</td>
<td>1 day at 1° resolution at Equator</td>
<td>Band4:Near Infrared 760-900 nanometres</td>
</tr>
<tr>
<td>Data collected at 11bit</td>
<td></td>
<td></td>
<td>Data collected at 11bit</td>
<td></td>
</tr>
</tbody>
</table>

### Swath Width and Area Size

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Technical Details</th>
<th>IKONOS</th>
<th>QuickBird</th>
<th>OrbView-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal swath width is 110km at nadir</td>
<td>Nominal swath width is 96.3 km at nadir</td>
<td>Nominal swath width is 8 km at nadir</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Nominal single image is 18.5 km by 18.5 km</td>
<td>Nominal single image is 15 km by 15 km</td>
<td>Nominal single image is 8 km by 8 km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Image Area: The area of Interest ‘AOI’ is a customer specified geographic area. The AOI may be:</td>
<td>Image Area: The area of Interest ‘AOI’ is a customer specified geographic area. The AOI may be:</td>
<td>Image Area: The area of Interest ‘AOI’ is a customer specified geographic area. The AOI may be:</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>1. a rectangle in geographic coordinates</td>
<td>1. a rectangle in geographic coordinates</td>
<td>1. a rectangle in geographic coordinates</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>2. an ESRI shape file supplied by the customer or reseller</td>
<td>2. an ESRI shape file supplied by the customer or reseller</td>
<td>2. an ESRI shape file supplied by the customer or reseller</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Minimum dimension is 4km by 4km</td>
<td>Minimum dimension is 4km by 4km</td>
<td>Minimum dimension is 4km by 4km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Areas wider than 15 km East-West or longer than 100 km North-South may be collected as separate satellite images but are processed and delivered together Areas of Interest larger than 100 x 100 km are collected processed shipped and invoiced as separate orders</td>
<td>Areas wider than 15 km East-West or longer than 100 km North-South may be collected as separate satellite images but are processed and delivered together</td>
<td>Areas wider than 15 km East-West or longer than 100 km North-South may be collected as separate satellite images but are processed and delivered together</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Minimum purchase from archive is 25 sq km</td>
<td>Minimum purchase from archive is 25 sq km</td>
<td>Minimum purchase from archive is 25 sq km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
<tr>
<td>Minimum area for new capture is 384 sq km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td>Minimum area for new capture is 384 sq km</td>
<td></td>
</tr>
</tbody>
</table>
**IKONOS Imagery Products**

Product levels: options, ordering, delivery and licensing of the IKONOS data are described below as representative of the <=1m satellite imagery.

**Product Levels**

Space Imaging categorizes the imagery products gathered from IKONOS according to positional accuracy which is determined by the reliability of an object in the image to be within the specified accuracy of the actual location of the object on the ground.

Within each IKONOS-derived product, location error is defined by a circular error at 95% confidence (CE95), which means that locations of objects are represented on the image within the stated accuracy 95% of the time. This CE95 accuracy level can be related to Root Mean Square Error (RMSE) as well as the US National Map Accuracy Standards (NMAS).

There are six levels of IKONOS imagery products determined by the level of positional accuracy: Geo, Standard Ortho, Reference, Pro, Precision and PrecisionPlus. The table below summarises the product details.

**Geo Product Suite**

Geo products are geometrically corrected to a map projection. The correction process removes image distortions introduced by the collection geometry and re-samples the imagery to a uniform ground sample distance (GSD) and a specified map projection. Geo images comprising an order are not mosaiced, and tonal variations may be evident between images.

**Geo Ortho Kit**

Geo Ortho Kit image products are tailored for sophisticated users requiring high positional accuracy. The data is tailored for users such as photogrammetrists who want to control the orthorectification process. Geo Ortho Kit images include the camera geometry obtained at the time of the image collection. With the Geo Ortho Kit, users can produce their own highly accurate orthorectified products by utilizing commercial off the shelf (COTS) software.

Digital elevation models and optional ground control are included in the camera model data to popular software packages for photogrammetric processing. Space Imaging provides the stereo imagery pairs with a rational polynomial coefficient (RPC) camera model file. The RPC file provides camera model data to popular software packages for photogrammetric extraction of 3D feature coordinates and digital elevation models (DEMs) and orthorectified imagery. Each stereo pair contains an image collected at a lower elevation angle between 72 and 90 degrees and an image collected at a higher elevation angle (above 72 degrees) with 30°-45° convergence.

To increase the positional accuracy of the final orthorectified imagery, users can upgrade IKONOS’ elevation angle to be between 72 and 90 degrees.

**IKONOS Product Levels at a Glance**

<table>
<thead>
<tr>
<th>Product Suite</th>
<th>CE95 (m)</th>
<th>RMS (m)</th>
<th>NMAS</th>
<th>Ortho Corrected</th>
<th>Target Elevation Angle</th>
<th>Mosaiced</th>
<th>Stereo Option</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geo</td>
<td>15.6</td>
<td>N/A</td>
<td>N/A</td>
<td>No</td>
<td>90° to 95°</td>
<td>No</td>
<td>No</td>
<td>Visual &amp; interpretive applications</td>
</tr>
<tr>
<td>Standard Ortho</td>
<td>20.3</td>
<td>2.5</td>
<td>1:25,000</td>
<td>Yes</td>
<td>90° to 95°</td>
<td>No</td>
<td>No</td>
<td>Basic mapping projects</td>
</tr>
<tr>
<td>Reference</td>
<td>25.4</td>
<td>1.8</td>
<td>1:50,000</td>
<td>Yes</td>
<td>90° to 95°</td>
<td>Yes</td>
<td>Yes</td>
<td>Regional large area mapping and general GIS applications</td>
</tr>
<tr>
<td>Pro</td>
<td>18.2</td>
<td>4.4</td>
<td>1:12,000</td>
<td>Yes</td>
<td>90° to 95°</td>
<td>Yes</td>
<td>No</td>
<td>Transportation infrastructure utilities planning economic development</td>
</tr>
<tr>
<td>Precision</td>
<td>4.1</td>
<td>1.9</td>
<td>1:3,000</td>
<td>Yes</td>
<td>75° to 90°</td>
<td>Yes</td>
<td>Yes</td>
<td>High positional accuracy for urban applications</td>
</tr>
<tr>
<td>PrecisionPlus</td>
<td>2.0</td>
<td>0.9</td>
<td>1:1,000</td>
<td>Yes</td>
<td>75° to 90°</td>
<td>No</td>
<td>No</td>
<td>Detailed urban analysis-cadastral &amp; infrastructure mapping</td>
</tr>
</tbody>
</table>

* Exclusive of terrain effects
** May be up to 75 metres CE95 in undeveloped areas with high terrain relief e.g. Andes or Himalayan mountain ranges


**Band Combinations**

All IKONOS data is resampled to either 1m or 4m 'multispectral' irrespective of the actual ground resolution of the original capture. Data is available as:

- **Black and White** 1m panchromatic imagery delivered as a single band.
- **Multispectral** 4m IKONOS imagery delivered as one file with three bands in true colour 'red, green, blue' or false colour 'near infrared, red, green'; or four files of one band each 'near infrared, red, green, blue'.

**Colour** IKONOS imagery created using a pansharpening process that combines the one metre spatial resolution of the panchromatic image with the spectral resolution of the multispectral bands to create a one-metre colour product. One-metre colour imagery is delivered as either one file with three bands in true colour 'red, green, blue' or false colour 'near infrared, red, green'; or four files of one band each 'near infrared, red, green, blue'.

**Bundle** When the bundle order option is selected customers receive both one-metre black and white and four-metre multispectral IKONOS imagery as per the descriptions of these products above. IKONOS collects the images for a bundle order simultaneously to ensure radiometric and temporal consistency.

**Ordering and Delivery**

GEOIMAGE can look after all your IKONOS orders. Orders for existing images from the IKONOS archive must have a minimum area of 100 square km and be captured over 4 months previously to qualify for the discount rate. New capture imagery must have a minimum area of 250 sq km. The following table of delivery times should be seen as a guide only. New image captures with 99% or less cloud are seen as successful acquisitions and must be purchased. Customers can designate a single coordinate within the image that must be cloud-free.

Areas of interest can be irregular in shape however any area must be at least five kilometres in any direction. Areas are usually defined by rectangular limits of a shape file.

**Product**

<table>
<thead>
<tr>
<th>Product</th>
<th>Size</th>
<th>Delivery Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Imaging North America Archive</td>
<td>1m business days</td>
<td></td>
</tr>
<tr>
<td>Space Imaging Regional Affiliate Archive</td>
<td>1m business days</td>
<td></td>
</tr>
<tr>
<td>Less than 1000 square kilometres 'New Collection'</td>
<td>10 days</td>
<td></td>
</tr>
<tr>
<td>1000 - 5000 square kilometres 'New Collection'</td>
<td>20 days</td>
<td></td>
</tr>
<tr>
<td>5000 - 10000 square kilometres 'New Collection'</td>
<td>30 days</td>
<td></td>
</tr>
<tr>
<td>More than 10000 square kilometres 'New Collection'</td>
<td>Custom quote</td>
<td></td>
</tr>
</tbody>
</table>

**Licensing**

Upon sale of an image product Space Imaging retains copyright and ownership of all images collected and produced. In effect customers are not purchasing the image itself; rather they are purchasing the non-exclusive right to use the image. Space Imaging defines how a customer may use the image through a licensing agreement. The licence that is purchased by the customer also determines how much they are charged for the right to use the image. For example a company that purchases a 'Single Organization' licence that only allows internal use of the data is charged less than a company that purchases a 'Multiple Organization' licence because they intend to share the data with another company.

<table>
<thead>
<tr>
<th>License</th>
<th>Price Uplift</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Organization</td>
<td>95%</td>
</tr>
<tr>
<td>Multiple Organization</td>
<td>10%</td>
</tr>
<tr>
<td>Tier 1</td>
<td>30%</td>
</tr>
<tr>
<td>Tier 2</td>
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For full details of the Space Imaging licences including the permitted activities and prohibited activities please contact GEOIMAGE or check: http://www.spaceimaging.com/aboutus/Licensing1.htm

Space Imaging’s licence structure allows the customer to choose from different licence levels. The Single Organization licence allows one customer to use the data from a listing which includes:

- one private individual
- one company but not subsidiaries
- one state Government department etc.

The Multiple organization licence allows two such groups to use the data.

A “Tier 1” licence allows the data to be used by one company or a single organisation. A “Tier 2” allows data to be shared by two of the following customer groups: A “Tier 3” licence allows data to be used by all customer groups. Some of these groups are ‘see the web site for more details’:

- Multiple private companies and/or corporations to include subsidiaries
- All Federal Government Agencies of a single country
- All state government departments of a single state
- All local municipal government agencies
- Multiple Non Governmental Organizations (NGO) and/or Non Profit Organizations (NPO)
- All departments within a single educational organisation within a single country
- Multiple international agencies such as the UN and host nations

**Regional Affiliates**

Space Imaging maintains a network of Regional Affiliates (RA) who are involved in the collection, processing, marketing and distribution of imagery products from Space Imaging’s IKONOS satellite.

The Regional Affiliate network provides the operating framework for streamlining commercial operations and procedures on a worldwide basis. It also standardizes order management processes across all RAs to ensure the best customer service experience in the industry. The Regional Affiliate program maximizes direct access to the IKONOS satellite thereby increasing commercial order fulfillment capacity.

Pansharpening is the process of transforming an image of low spatial resolution multispectral imagery to a high spatial resolution colour image by fusing it with a coregistered high spatial resolution panchromatic image. In this example of pansharpening an IKONOS natural colour multispectral image at 1m resolution has been fused with a 1m resolution IKONOS panchromatic image to produce a 1m resolution colour image. Images © Space Imaging 2005.

The current Regional Affiliates Communication cones where local reception of the IKONOS satellite data is possible.
The SPOT Satellites

SPOT launched in May 2002, continues the line of successful satellites which commenced with the launch of SPOT 1 in February 1986. The SPOT Satellite Earth Observation System was designed by the CNES ‘Centre National d’Etudes Spatiales’ in France and developed with the participation of Sweden and Belgium. The system comprises a series of spacecrafts plus ground facilities for satellite control and programming, image production and distribution. SPOT’s unique combination of features including high resolution stereo imaging and revisit capability have kept it in the forefront of successful “earth observation” systems.

SPOT Orbit

The SPOT orbit is polar circular sun synchronous phased and has the following characteristics:
- Altitude: 822 km
- Inclination: 98.7 degrees
- Near polar orbit
- Revolutions per day: 14 ± ½
- Period: 101 minutes
- Westward drift between successive ground tracks: 2823 km
- Cycle duration: 26 days
- Orbital revolutions per cycle: 369

SPOT 1, 2, 3

The SPOT 1, 2, and 3 payloads are the same and comprise two identical HRV (High Resolution Visible) imaging instruments which scan in either the panchromatic or multispectral modes. The position of each HRV entrance mirror can be commanded by ground control to observe a region of interest not necessarily vertically beneath the satellite. Thus each HRV offers an oblique viewing capability with the viewing angle being adjustable through ±27 degrees relative to the vertical. Two spectral modes of acquisition are employed: panchromatic (P) and multispectral (XS). Both HRVs can operate in either mode either simultaneously or individually.

SPOT 4

Improvements to the instrumentation on SPOT 4 include:
- Addition of a new band in the Short Wave Infrared (1.58-1.75 µm).
- Onboard registration of all spectral bands. This has been achieved by replacing the panchromatic band (0.51-0.73 µm) by band B2 (0.61-0.68 µm) operating in both a 10 m and 20 m resolution mode.
- Improved knowledge of ground reflectance acquired by SPOT 1 and 2 is used to introduce electronic sensor gains matching according to landscape type and season thus ensuring greater dynamic range. The imaging instruments are no longer susceptible to glare and they are unaffected by the polarization of the incident light.
- The two HRV imaging instruments are programmable for independent image acquisition significantly increasing the total number of imaging opportunities. In particular it is possible to change the viewing direction of one instrument without affecting the quality of the images acquired at the same time by the other instrument.
- The recording capacity of each of the two onboard recorders is increased from 22 to 48 minutes. A solid state memory of about 15 Gbits has been included to increase the overall reliability of onboard recording and extend the design life while ensuring a greater storage capacity.

SPOT 5

Changes to the instrumentation on SPOT 5 include:
- An increase in the ground resolution of the three multispectral bands visible and near infrared to 10 metres.
- The panchromatic band has been changed back to a visible green-red bandwidth similar to the band on the earlier SPOT satellites.
- An increase in the ground resolution of the panchromatic band to 10 metres coupled with a second panchromatic band. These bands are acquired by two dedicated arrays of CCD detectors that are vertically and horizontally offset by one half pixel (2.5 m) in the focal plane. These two images are downlinked separately and CNES has patented a process it refers to as Supermode which is a three step process to “merge” the two 10 m images and produce a 2.5 m resolution image.

The prime SPOT 4-5 mission is supplemented by a second imaging payload referred to as the VEGETATION instrument. This sensor has a very wide angle 400 km wide swath earth observation instrument offering a spatial resolution of about 1 km and high radiometric resolution. It uses the same spectral bands as the HRVIR instruments (B1, B2 and mid-IR) plus an additional band known as B0 (0.43-0.47 µm) for oceanographic applications and for atmospheric corrections. The VEGETATION instrument has been developed as a European cooperative project including the European Community.

High Resolution Instruments onboard SPOT 1 to 5

|                  | SPOT1 | SPOT4 | SPOT5
|------------------|-------|-------|-------
| Instruments      | 2HRGs | 2HRVIRs | 2HRV
| Spectral bands and resolution |                   |
| Combined to generate a 2 m product | 1 panchromatic (4m) |
| Panchromatic (10m) | 1 multispectral (10m) |
| Short wave infrared (10m) | 1 short wave infrared (10m) |
| Spectral Range | P: 0.48 - 0.57 µm | B1: 0.50 - 0.65 µm | B2: 0.61 - 0.68 µm |
| Imaging swath | 60 km x 60 km to 1 km | 60 km x 60 km to 1 km | 60 km x 60 km to 1 km |
| Image dynamics | 8 bits | 8 bits | 8 bits |
| Angle of incidence | 43.06 | 43.06 | 43.06 |
| Revisit interval | 1 to 4 days | 1 to 4 days | 1 to 4 days |

Operation of the HRS instrument aboard the SPOT 1 Satellite
The SPOT 5 payload also includes the HRS Imaging instrument developed by Astrium for DTM generation. This instrument uses cameras looking at 20° fore and aft to image stereo pairs over a surface area of 600 km across track and 106 km along track. The spatial resolution of the instrument is 2.5 m and sampling cross track is 2.5 m and along track is 2 m. The elevation accuracy of DTMs generated from HRS images is:
- Relative accuracy: ±1 m
- Absolute accuracy: ±2.5 m

**Image Acquisition**

SPOT’s oblique viewing capacity allows it to image any area within a 500 km swath. Oblique viewing can be used to increase the viewing frequency for a given point during a given cycle. The frequency varies with latitude: at the equator a given area can be imaged 2 times during the same 26-day orbital cycle while at a latitude of 40° degrees a given area can be imaged 14 times during the orbital cycle. The constellation of 6 SPOT satellites (SPOT 1 and 2) dramatically increases this revisit capability: any point on 99% of the earth’s surface may be imaged any day by one of the three satellites. This ability is restricted to areas where direct ground reception is possible.

SPOT’s oblique viewing capacity makes it possible to produce stereo pairs by combining two images of the same area acquired on different dates and at different angles. This is due to the parallax thus created. A Base/Height (B/H) ratio of 1 can be obtained for a viewing angle of 40° degrees to the East and to the West. For a stereo pair comprising a vertical view and one acquired at 72° degrees to the West, a B/H of 1 is obtained. Stereo pairs are mainly used for stereoplotting topographic mapping and automatic stereocorrelation from which Digital Terrain Models (DTMs) can be directly derived without the need for maps. Across track stereo is reliant on obtaining stereo images that are close enough in time to produce good correlation. The new HRS instrument on SPOT produces stereo pairs with a B/H ratio of approximately 0.84 and since the images are obtained almost simultaneously has less problems with correlation.

**SPOT Programming**

The SPOT satellites offer unique advantages for acquiring images on demand by virtue of the ability to capture imagery within a 900 km swath on each overpass of the multi satellite constellation and the high-resolution imaging instruments on each satellite. To provide the most flexible response to users’ requests, SPOT IMAGE offers two programming services based on levels of urgency and specific acquisition requirements.

The **Standard Programming Service** is best suited for applications that do not require images to be acquired within specific time windows or at extreme viewing angles. The price of programmed products includes programming service fees and applies to images acquired with less than 10% cloud cover.

The **Priority Programming Service** is particularly suited for applications that are subject to urgent time constraints or require full coverage of an area under specific conditions. This option guarantees high priority image acquisition after analysis of available satellite capacity and previous commitments. Priority programming fees are charged on top of the price of programmed products acquired with less than 10% cloud.

**SPOT Receiving Stations**

The network comprises two main stations at Toulouse (France) and Kiruna (Sweden). These stations are capable of receiving the telemetry recorded on the on-board recorders or directly within their visibility circle of approximately 2500 km radius centred on the stations. Hence they have access to imagery of any part of the globe.

There are 22 direct receiving stations (‘DRS’) which can only receive telemetry within their visibility circle. Each DRS effectively manages its own visibility zone according to the satellite resources allocated by SPOT IMAGE. Data within the Australian area is captured by Raytheon Australia Pty Ltd using a receiving station located in Adelaide.

**SPOT Catalogue**

SIRIUS is the on-line electronic catalogue for the full range of SPOT Image products and services. The service is available from the SPOT Image web site at www.spotimage.fr

With SIRIUS you can:
- Search for and select SPOT scenes from SPOT Image’s global archive of over 1 million scenes.
- Use a map browser to identify available products i.e. SPOT View Archive Coverage: General Public Image
- Save your most frequently used requests and automatically receive new results.
- View product information relevant to your business through an automatic news service giving you the latest information on your business and regions of interest.

**Resolution and Spectral Modes**

By combining imagery from all SPOT satellites it is possible to generate data at 4 levels of resolution between 2.5 m and 20 m in black and white and colour across the same 500 km swath. This multi-resolution approach offers users the geospatial information they need at different scales.

**SPOT 5 - 2.5m black and white products**

A 2.5 m black and white product is obtained from two 5 metre panchromatic images acquired simultaneously by the same HRG instrument. Each HRG instrument has a dedicated detector for this purpose. The 2.5 m image generated by ground processing is therefore panchromatic and has the same viewing geometry as the two 5 metre images. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT 5 - 2.5m colour products**

2.5 m colour products are derived from images acquired by SPOT 5. A 2.5 m image is obtained from two 5 m panchromatic images acquired simultaneously by the same HRG instrument. Each HRG instrument has a dedicated detector for this purpose. The 2.5 m image generated by ground processing is therefore panchromatic and has the same viewing geometry as the two 5 m images. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT 5 - 2.5m colour products**

2.5 m colour products are derived from images acquired by SPOT 5. They are obtained by merging two separate images: one in panchromatic mode at 2.5 m resolution and the other in four band multispectral mode at 20 m resolution. Because the 2.5 m panchromatic image is itself generated by merging two 5 m images, one of the HRG instruments has to acquire three images simultaneously to produce a 2.5 m colour image. Thus obtained images are like a four band multispectral image with a resolution of 2.5 m and panchromatic viewing geometry. The multispectral bands can be combined to produce a three band natural colour image.

**SPOT 5 - 1m black and white products**

1 m black and white products are derived from images acquired by SPOT 5. They are obtained by merging two separate images acquired simultaneously by the same HRG instrument: one in panchromatic mode at 1 m resolution and the other in four band multispectral mode at 10 m resolution images. These images are acquired in a single panchromatic band. In this mode the ground pixel size is 1 m. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT 5 - 1m colour products**

1 m colour products are derived from images acquired by SPOT 5. They are obtained by merging two separate images acquired simultaneously by the same HRG instrument: one in panchromatic mode at 1 m resolution and the other in four band multispectral mode at 10 m resolution images. These images are acquired in a single panchromatic band. In this mode the ground pixel size is 1 m. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT Programming**

The SPOT satellites offer unique advantages for acquiring images on demand by virtue of the ability to capture imagery within a 900 km swath on each overpass of the multi satellite constellation and the two high-resolution imaging instruments on each satellite. To provide the most flexible response to users’ requests, SPOT IMAGE offers two programming services based on levels of urgency and specific acquisition requirements.

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- Save your most frequently used requests and automatically receive new results.
- View product information relevant to your business through an automatic news service giving you the latest information on your business and regions of interest.

**Resolution and Spectral Modes**

By combining imagery from all SPOT satellites it is possible to generate data at 4 levels of resolution between 2.5 m and 20 m in black and white and colour across the same 500 km swath. This multi-resolution approach offers users the geospatial information they need at different scales.

**SPOT 5 - 2.5m black and white products**

A 2.5 m black and white product is obtained from two 5 metre panchromatic images acquired simultaneously by the same HRG instrument. Each HRG instrument has a dedicated detector for this purpose. The 2.5 m image generated by ground processing is therefore panchromatic and has the same viewing geometry as the two 5 metre images. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT 5 - 2.5m colour products**

2.5 m colour products are derived from images acquired by SPOT 5. A 2.5 m image is obtained from two 5 m panchromatic images acquired simultaneously by the same HRG instrument. Each HRG instrument has a dedicated detector for this purpose. The 2.5 m image generated by ground processing is therefore panchromatic and has the same viewing geometry as the two 5 m images. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.

**SPOT 5 - 1m black and white products**

1 m black and white products are derived from images acquired by SPOT 5. They are obtained by merging two separate images: one in panchromatic mode at 2.5 m resolution and the other in four band multispectral mode at 20 m resolution. Because the 2.5 m panchromatic image is itself generated by merging two 5 m images, one of the HRG instruments has to acquire three images simultaneously to produce a 2.5 m colour image. Thus obtained images are like a four band multispectral image with a resolution of 2.5 m and panchromatic viewing geometry.

**SPOT 5 - 1m colour products**

1 m colour products are derived from images acquired by SPOT 5. They are obtained by merging two separate images acquired simultaneously by the same HRG instrument: one in panchromatic mode at 1 m resolution and the other in four band multispectral mode at 10 m resolution images. These images are acquired in a single panchromatic band. In this mode the ground pixel size is 1 m. SPOT’s 5 m panchromatic band covers wavelengths between 0.48 and 0.77 μm.
SPOT 4 - 10m colour products
10 metre colour products are obtained by merging two separate images acquired simultaneously by the HRV/IR instrument: one in panchromatic mode at 10 metre resolution and the other in multispectral mode at 20 metre resolution. Because the camera is designed so that the two images register directly generating a 10 metre colour image is relatively easy. The single image thus obtained is a four band-10 metre colour product.

SPOT 5 - 2.5m resolution
2.5 metre colour products are derived from multispectral images acquired simultaneously in the same four spectral bands as SPOT 4 Bands B1, B2 and B3 yield images at a resolution of 10 metres and the SWIR band yields 20 metre images which are then resampled to obtain a 10 metre image. Only one image therefore needs to be acquired.

Levels of Processing
SPOT IMAGE offers a wide choice of preprocessing levels to meet clients GIS needs. These are described below.

**Level A**
Corrected by normalizing detector response to compensate for radiometric variations due to detector sensitivity. No geometric corrections.

- Location accuracy: better than 36 metres due to the new star tracker on SPOT 5 which provides more accurate satellite altitude data.
- Better than 86 metres for SPOT 1 to SPOT 4.

Use: Designed primarily for mapping applications and used for geometric processing—to orthorectify images and generate digital terrain models (DTMs) — and for precise radiometric processing.

**Level B**
The same radiometric corrections as level A. Geometric corrections compensate for systematic effects including panoramic distortion, the Earth’s rotation and curvature and variations in the satellite’s orbital attitude.

- Location accuracy: equivalent to level A.
- Use: Well suited for geometric measurements (distances, angles and areas), photo-interpretation and thematic studies. Thematic analysis may be visual-computer assisted or fully digital.

**Level C**
The same radiometric corrections as level A and B. Geometric corrections to match a standard map projection—UTM WGS 84—without using ground control points. For SPOT 5, a global DEM with a post spacing of one kilometre is used while for SPOT 1 to SPOT 4, the mean rectification elevation is constant across the scene.

- Location accuracy: same as for levels A and B.
- Use: For users who want to combine different kinds of geographic information from different sources and apply their own colour processing in order to extract specific information.

While allowing for location error, level A images register directly with other layers of geographic information — vector data, raster maps or other satellite images — in the same map projection.

**Level D**
Georeferenced product.

SPOT View Precision scenes are framed in a given map projection and tied to ground control points (GCPs) obtained from a map or topographic survey for even better location accuracy.

- At the rectification elevation or on flat terrain, the location error is generally lower than 30 metres.
- Use: SPOT View Precision is designed for use as digital maps providing up to date geographic information and global coverage. Can be used whenever relief distortions are not a major concern.

**Level **
Georeferenced like SPOT View Precision.

SPOT View Ortho is preprocessed using a digital elevation model (DEM) from the Reference4D database to correct residual parallax errors due to relief. Reference4D makes it possible to reduce the location error to less than 36 metres per pixel.

- If Reference4D has no data for the area of interest, other DEMs can be used. In such cases, location accuracy depends directly on the quality of the DEMs.

- Use: SPOT View Ortho is ideal for mapping relief. Such a sophisticated level of preprocessing is designed to offer maximum accuracy for producing and updating maps. It also allows images to be registered with other known GIS data from different sources.

*Reference4D is a global georeferenced database derived from stereopair images acquired by SPOT 5’s HRS instrument. This database contains a DEM layer and an orthoimage layer with accompanying image quality data giving excellent geometric accuracy. It was developed by SPOT Image and IGN France’s national survey and mapping agency.*
Applications of High Resolution Satellite Imagery

For certain applications high resolution satellite imagery offers a cheaper alternative to or has a number of advantages over aerial photography. The reasons for this are based on the following attributes of the satellite imagery:

- four spectral bands from visible blue to near infrared providing the equivalent of both colour and colour infrared photography
- digital radiometric data which provides the ability to undertake spectral processing e.g. spectral classification and modelling e.g. crop yield estimating
- imagery captured on a stable platform therefore no distortion will occur around the edge of a scene as with an aerial photograph
- a 1-3 day repeat revisit time allowing regular updates and multi-temporal analysis of the same area
- can be calibrated or matched so that large area seamless mosaics can be compiled
- captured as 16bit rather than 8bit giving better dynamic range than aerial photography and airborne scanners
- does not have the variable brightness within a single image that is usually associated with photos
- satellite operators may already have data in archive over your area
- image capture can commence within 3 days of placing an order

Local and State Government Applications

High resolution imagery provides powerful tools for urban and regional government planning and management applications including image base cadastral and map updates, transportation analysis, asset management, environmental planning, crime mapping and analysis, stormwater management, public safety and disaster management, validating vegetation maps produced at coarser scales, and enabling Internet based property information access.

Vegetation Clearing

Local governments use high resolution satellite imagery to monitor vegetation clearing in remote or difficult to access areas. By using simple subtraction techniques, local governments can pin-point areas where clearing has occurred and cross check this against the permits issued to identify illegal clearing. State governments have used IKONOS imagery in court cases to win successful prosecutions by proving that clearing has taken place before the date that the permit was issued or after the property was purchased by the current owner. State governments have used IKONOS imagery in court cases to win successful prosecutions by proving that clearing has taken place before the date that the permit was issued or after the property was purchased by the current owner. Some private businesses are now realising the benefits of being able to instantly examine an area on the desk top to make informed business decisions without the necessity of visiting a site. For example surveying engineering firms that in the past would have visited a site before quoting to provide services are able to quickly assess the job context without leaving the office. For any job where a geographical context is required high resolution imagery can be a great help and time saver. In this age where time equals money the investment in imagery will quickly pay for itself.

Example imagery 'above' is 1m pansharpened natural colour IKONOS of Cairns captured in August 2004 overlaid with cadastral boundaries in yellow Image © Space Imaging 2004.

Monitoring Progress of Development

Most local government areas along the coastal sections of Australia are undergoing rapid urban development. Using multi date high resolution imagery, local governments are able to monitor development and enable better management and town planning practices. Some private businesses are now realising the benefits of being able to instantly examine an area on the desk top to make informed business decisions without the necessity of visiting a site. For example surveying engineering firms that in the past would have visited a site before quoting to provide services are able to quickly assess the job context without leaving the office. For any job where a geographical context is required high resolution imagery can be a great help and time saver. In this age where time equals money the investment in imagery will quickly pay for itself.

Example imagery 'above' is 1m pansharpened natural colour IKONOS of Cairns captured in August 2004 overlaid with cadastral boundaries in yellow Image © Space Imaging 2004.

Water Resources

The quick revisit capabilities of the high resolution satellites makes them ideal for managing disasters such as flooding. On the Gold Coast more than 400mm of rain fell in 24 hours on 29-30 June 2005. Coolangatta Airport was closed, with water waist deep outside the terminal. The SPOT5 colour imagery above was obtained just one day after tasking the satellite to capture the flood ravaged areas of Lismore in Northern NSW and the Gold Coast SE Queensland. By comparing the imagery to that captured 4 weeks earlier the exact flood extents can be determined. Imagery © CNES 2005.
Applications of High Resolution Satellite Imagery

Real Estate Applications
The high resolution colour imagery from IKONOS and QuickBird is ideal as a tool in the sales and promotion of real estate. Imagine being able to show a potential client all the available houses for sale from the comfort of your own office. During the process you would be able to highlight the advantages of each property, showing the site’s proximity to beaches, golf courses, schools and shopping centres, as well as main roads, busways and railway tracks. Similarly for the promotion of a new housing development, the ability to put the new area into its geographical context showing all the existing development and services would be an ideal selling strategy.

Example image (above) is approximately 1:5000 scale over Sovereign Island, Gold Coast. IKONOS image collected 31 May 2005. © Space Imaging 2005.

Mine Site Monitoring
Aerial photography is often flown over mine sites to provide a base map for the mining operation and for monitoring and planning purposes. Imagery is also used for environmental assessment of the site before, during and after mining activities have commenced. Where mine sites are developed in remote areas, it is difficult to obtain aerial photography. IKONOS or QuickBird imagery offers an ideal substitute. The ability to produce 1m DEMs from IKONOS imagery is also ideally suited to mining applications.

Example image (above) is 1m pansharpened natural colour IKONOS over the Super Pit, Kalgoorlie. Date 26 April 2001. © Space Imaging 2001.

Utility Corridors
High resolution IKONOS and QuickBird imagery is often used to provide spatial information along powerline or pipeline corridors. This is because the imagery can be purchased in a 5km swathe along the corridor following the exact routing. This saves costs as only imagery over the area directly affected by the route is purchased. GEOIMAGE has provided imagery to be used during the construction phase of pipelines and to monitor existing electricity powerline corridors. This imagery has been used for access planning, community consultation, environmental monitoring and as a backdrop to GIS vectors.

Example image is 0.6m resolution natural colour QuickBird data collected over the Logan area in Queensland on 27 December 2003. © DigitalGlobe 2003.

Mapping and Monitoring Crops
The application of high resolution satellite imagery in the agricultural arena is only limited by the imagination. This case study kindly provided by CTF Solutions (See Page 20) shows the application of IKONOS data when identifying problems with farming practices in agricultural crops.

Image 1 is an IKONOS NDVI image of a barley crop. Blue areas show high NDVI and healthy crops while the green-yellow areas are lower values of NDVI and less healthy crops or sparser croppings. The red areas are non-crop areas. Investigations into the striping pattern in the field eventually led to the conclusion that it was caused by an unequal distribution of fertiliser by the fertiliser spreader. When the spreader was fixed, the problem disappeared. Images 2a, 2b and 2c show the same paddock sampled at different resolutions and indicates that to solve cropping problems of this nature requires high resolution 1 metre or less imagery. © Space Imaging 2003.
Applications of High Resolution Satellite Imagery

Flight Simulations
High resolution satellite imagery provides realistic backdrop information for visualisation in both civilian and defence simulation programs. Accurate and naturally-coloured 3D terrain visualisations for flight training mission rehearsal and battlefield management over any location on Earth can now be created by combining satellite imagery and terrain elevation datasets. In addition, the accurate and up-to-date portrayal of the surface terrain is invaluable for safety and training when simulating civilian and military air flight and ground operations. Previous to the availability of this high resolution satellite imagery, simulation graphics were often characterised by poorly mosaiced and less than realistic estimations of land cover with no practical capability for frequent updating.

Shallow Water Mapping
Both IKONOS and QuickBird capture imagery in the blue portion of the visible spectrum which allows both these satellites to have shallow water penetrating capabilities. The shallow water penetration depth is dependent on a number of factors including off-nadir angle of capture, collection azimuth and turbidity of the water.

This QuickBird example is representative of the high resolution satellite imagery being used for shallow water mapping in coastal estuaries and coral reefs in Australia, the Pacific Islands and the Caribbean by the Centre for Remote Sensing and Spatial Information Science at the University of Queensland. The spatial resolution, spectral band placement and radiometric sensitivity of this imagery are suited for producing maps of benthic cover types (e.g. seagrass, sand, macroalgae) and their level of cover and condition. Maps containing this information are commonly required by coastal resource management agencies for baseline inventory, design of marine protected areas and monitoring the effects of extractive industries, natural disasters (cyclones, tsunami) and human activities. The QuickBird image above showing the eastern banks of Moreton Bay in Queensland Australia was captured at 09h56 on 31 July 2004 which was 59min after a 1.7m high tide. The imagery was purchased by the ARC Linkage Project "Integrating Natural Vision and Remote Sensing" and Coastal CRC and was processed by Prof. Stuart Phinn from the University of Queensland.
Bush Fire Mapping - Canberra January 2003

The worst fires ever to hit the Australian capital of Canberra occurred on Saturday 18 January 2003. Four people were killed from the gust-driven wild fires while hospitals treated around 200 others for burns and smoke inhalation. Over 400 homes were destroyed as bush fires burning out of control in forests south of the city raced into Canberra on Saturday afternoon overwhelming firefighters who were not able to get to the worst-hit areas.

The SPOT5 satellite captured imagery over the worst affected areas of Canberra on 15 February 2003, approximately 1 month after the bush fires and then again on 13 January 2004, approximately 1 year after the bush fires took place.

The SPOT5 10m pixel Multispectral imagery is shown in pseudo natural colour which depicts photosynthesising or unburnt vegetation in red. New firescar is visible on the 2003 image ‘right top’ as blackened patches ringing the suburb while the areas where the fires encroached into the suburb around the western and northern sections are visible as there is no photosynthesising vegetation ‘red’ around the buildings. These burnt and cleared areas are characterised by the pale blue colour representing bare earth.

One year on ‘right bottom’ the fire scarred plantation areas are characterised by the blue colour describing the low vegetation regrowth in that area. The western and northern portions of the Canberra suburb that were ravaged by fire are even more prominently marked by bare soil which are property lots where the destroyed buildings have been demolished and the bare lots are awaiting redevelopment.

Assessment of Changes to Wetlands Using IKONOS Imagery - North Stradbroke Island

Consolidated Rutile Limited (CRL) is one of the world’s major producers of natural rutile and is a significant producer of natural zircon. The company commenced mining of mineral sand deposits on North Stradbroke Island in 1963. CRL currently has two operating mines being the Enterprise Mine (a continuation of the Ibis Mine into a new ore body) and the Yarraman Mine.

CRL seeks to monitor the vegetation in 18 Mile Swamp on the escarpment and the Ibis Lagoon wetlands during the life of the Enterprise and Yarraman mines as part of its management of these environmental values. IKONOS imagery was considered appropriate due to the small features associated with the eastern escarpment adjacent to 18 Mile Swamp and as there was an archive image for 2000. Imagery over the study area was acquired in 2005 and will be subsequently captured annually during the mine life.

The study will monitor change through differences between image bands and vegetation indices Changes will be mapped both spectrally and by context (a form of texture classification) and validated by sampling at representative sites located by the imagery.

Example used courtesy of CRL and Mark Evans of ESys Consulting Pty Ltd.

brisbane@esysconsulting.com.au

IKONOS natural colour imagery over the study area collected April 2005. © Space Imaging 2005.
ASTER 'Advanced Spaceborne Thermal Emission and Reflectance Radiometer' is an imaging instrument on board Terra - the first Earth Observing System 'EOS' satellite. Terra was launched on December 18, 1999 from the Vandenberg Air Force Base in California and flies in a sun-synchronous polar orbit crossing the equator in the morning at 10:30. ASTER is one of the five state-of-the-art instrument sensor systems on board Terra with a unique combination of wide spectral coverage and medium spatial resolution in the visible near infrared through shortwave infrared to the thermal infrared regions. It was built by a consortium of Japanese government industry and research groups. ASTER data contributes to a wide array of global change-related application areas including vegetation and ecosystem dynamics, hazard monitoring, geology and soils, land surface climatology, hydrology and land cover change.

ASTER consists of three different subsystems; the Visible and Near Infrared (VNIR)- the Shortwave Infrared (SWIR) and the Thermal Infrared (TIR). The VNIR subsystem consists of two independent telescope assemblies. One is vertical looking and has three detector arrays collecting data in the visible green visible red and near infrared wavelengths while a backward looking telescope has one detector array in the same spectral band as the near infrared of the vertical array. These infrared arrays 3N and 3B generate an along-track stereo image pair with a base-to-height ratio of 1:4 and an intersection angle of 2 degrees and can be used to generate digital elevation models.

### ASTER Sensor Systems

<table>
<thead>
<tr>
<th>Sub-system</th>
<th>Band No.</th>
<th>Spectral Range (µm)</th>
<th>Spatial Resolution</th>
<th>Bits</th>
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<td>1</td>
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<td>1m</td>
<td>16</td>
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<tr>
<td></td>
<td>2</td>
<td>0.63 – 0.69</td>
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<td>3</td>
<td>0.69 – 0.76</td>
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<tr>
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<td>4</td>
<td>2.295 – 2.365</td>
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<td></td>
<td>5</td>
<td>2.235 – 2.285</td>
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</tr>
<tr>
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<td>6</td>
<td>2.215 – 2.245</td>
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</tr>
<tr>
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<td>2.305 – 2.385</td>
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<td></td>
<td>8</td>
<td>2.385 – 2.493</td>
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<td>SWIR</td>
<td>9</td>
<td>0.63 – 0.71</td>
<td>1m</td>
<td>16</td>
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<td>14</td>
<td>0.8825 – 0.9145</td>
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<td>TIR</td>
<td>15</td>
<td>8.125 – 8.475</td>
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<td>12</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>8.825 – 8.925</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comparison of ASTER and Landsat bandwidths and pixel sizes**

### Advantages/Disadvantages of ASTER imagery

1. The ASTER VNIR data at 1m resolution is a good medium resolution multispectral dataset and at a price of approximately US$100 per ASTER scene is a bargain. Comparison of the ASTER data on a single band basis with the Panchromatic 1m band on the Landsat EMT+ shows that the ASTER data is better both spectrally and spatially.

2. The SWIR data consists of 6 bands designated bands 4 to 9. Band 4 has a similar wavelength to Landsat band 6 and is located where most cover types have maximum reflectivity. Bands 5 to 8 cover an area of the shortwave infrared where many OH bearing minerals and carbonate minerals have absorption features. Bands 5 to 8 approximately cover the wavelength limits of Landsat band 7. Minerals which may be of interest to exploration geologists and which will produce absorption features in this region are:

   - Alunite / pyrophyllite; significant for mineral exploration. Landsat TM has no capability and mine site rehabilitation/environmental studies defines low pH/acid environments ie advanced argillic style alteration
   - Illite muscovite smectite; common minerals in the surficial environment and useful for geological mapping. Components of phyllic and argillic style alteration
   - Mg OH / carbonate; significant because Landsat TM is incapable of detecting these minerals directly. Major components of geological units and ore systems.

3. ASTER VNIR/SWIR/TIR scenes are 50km square and can be collected at angles up to 6 degrees to the vertical VNIR data can be collected at up to +/- 8 degrees but the SWIR is limited to 4 degrees. If large area mosaics are required the Landsat TM with its 185x185km footprint will provide better geometrical accuracy and much less processing.

4. ASTER data could be obtained for free from EROS prior to the 17th August 2002. On that date a nominal charge was applied. Although the low cost is an advantage the time taken to do searches and process the data must be taken into account when comparing it with the much easier to order and process Landsat TM. The Japanese suppliers charge approximately US$70 per scene.

5. From November 2004, it has been possible to submit observation requests to obtain ASTER data and this is of interest to users who:
   - Want to obtain the latest ASTER data of a specific area
   - Cannot find any data of interest from a data search of archived data
   - Want to obtain data observed in a specific season

This service is significant in mind of the problems with the current Landsat satellites.

6. Only a limited number of ASTER scenes that have been collected have been processed to Level A scenes and this conversion can not be ordered from the Japanese suppliers. GEOIMAGE have written a conversion program to carry out this processing.

### ASTER Problems

SWIR Crosstalk Crosstalk refers to an unwanted signal from either an optical or electrical source that affects acquired bands of an image. ASTER SWIR bands have optical crosstalk where the signal from one spectral band bleeds into a different spatial position in the same band and signal from one spectral band bleeds into one or more different spectral bands. The result is that ASTER spectra of known material may not match ground or other remotely sensed spectra. Artifacts appear in SWIR images especially those with large contrast such as coastlines and islands. Bands 5 to 9 most prominently depict the problem.

SWIR Bad Detectors The SWIR sensor has several areas on the detector array which often produce anomalous data. The reason for this is not known and the phenomena is only visible on processed imagery. The edges of the main band are shown on the graphic (right) but other less obvious parallel bands are also visible on this image.

Kaolinitic group; significant for mineral exploration. Useful in defining argillic style alteration and mapping regolith deposits.

Illite muscovite smectite; common minerals in the surficial environment and useful for geological mapping. Components of phyllic and argillic style alteration.

Mg OH / carbonate; significant because Landsat TM is incapable of detecting these minerals directly. Major components of geological units and ore systems.

The ASTER VNIR and SWIR data therefore promise enhanced discrimination of mineral assemblages relative to existing Landsat Thematic Mapper data.

ASTER TIR data is the only available multispectral thermal imaging satellite data available and although it only has a resolution of 10m should be useful for defining surface silicification.

The along-track 3N and 3B stereo images allow the calculation of digital elevation models and although the baseheight ratio is not as large as for the SPOT satellite data this is compensated for by the fact that only one date imagery is required. SPOT is a side looking sensor and thus two dates of imagery in opposing directions are required for stereo viewing. SPOT now has along track stereo capability however the imagery is not commercially available.

ASTER VNIR/SWIR/TIR scenes are 50km square and can be collected at angles up to 4 degrees to the vertical VNIR data can be collected at up to +/- 8 degrees but the SWIR is limited to 4 degrees. If large area mosaics are required the Landsat TM with its 185x185km footprint will provide better geometrical accuracy and much less processing.
ASTER imagery can be used in mineral and petroleum exploration for lithological information and geological mapping for structural mapping and for spectral processing and the identification of alteration minerals associated with gold and mineral deposits. GEOIMAGE has a standard fee structure for:

- acquiring the ASTER imagery over your area of interest
- producing an ASTER DEM if required
- rectifying or orthorectifying the data depending on your requirements
- GEOIMAGE uses either a DEM created from the ASTER or the SRTM 30m DEM for the orthorectification
- producing a standard set of lithological images in ERMapper and ECW compressed format for display in MapInfo or ArcView
- a set of predicted alteration mineral layers in MapInfo TAB or ArcView Shape format and
- a report describing the processing

GEOIMAGE also carries out non-standard processing including spectral unmixing. For structural studies, we recommend pseudo-stereo hard copy imagery.

Please check with one of our offices for details of costings or a quote for your area of interest.

**Lithological Information**

Imagery from the three ASTER wavelength subsystems can be used to give complementary information on ground cover and lithological information. Examples of the images commonly used are shown here for an ASTER scene collected on July 25, 2001 over the Sar Cheshmeh Copper Mine, Iran.

**Image A.** VNIR bands 321 in RGB. Visible green in blue, visible red in green and near infrared in red. Vegetation is in red. This band combination uses the bands with the smallest pixel size and is most useful for cartographic applications. **Image B.** Bands 4, 3, 2 in RGB. This band combination uses three spectrally separate areas and maximises the information content in the image. The image is similar spectrally to a Landsat Band 742 colour composite in vegetation is green and is pseudo natural colour.

**Image A** ASTER SWIR bands 7 6 5 colour composite. Note that there is little colour information in the image because of the high correlation between the bands. **Image B.** ASTER SWIR bands 7 6 5 decorrelation stretched image (DS765). Decorrelation stretching is a method of enhancing multispectral image data by forcing the variance between the bands to be maximised to better discriminate between features. The image is prepared by calculating the principal components of a three band image rescaling or contrast stretching by normalizing the variances of the vectors and rotating back into RGB colour space. Any combination of three bands can be used and GEOIMAGE usually prepares decorrelation stretched images of bands 765, 876 and 987.
Alteration Minerals

Minerals of exploration interest that produce recognizable spectral patterns in ASTER SWIR imagery are the epithermal clay minerals groups - kaolinite, alunite-pyrophyllite and illite, and the propylitic minerals.

Propylitic alteration is characterized by episode chlorite-actinolite and carbonate minerals all of which produce absorption in band 8 of the ASTER SWIR data. Definition of this absorption is not helped by the cross-talk problem however the best estimator of the absorption is the Relative Band Depth estimator. The example above shows the RBD estimator with a 99% clip with the top % of the predicted RBD estimator in blue. This top % is converted to a vector file and output as an ArcView shape file or as a MapInfo TAB file.

Note: The following limitations of ASTER imagery should be kept in mind when interpreting processed spectral images:
1. ASTER is not a hyperspectral instrument so the ability to map individual minerals is limited. The best that can be expected is to define groups of minerals with the same spectral pattern.
2. The pixel size of the ASTER SWIR data is 30m and pixels with the spectral pattern from one individual mineral cannot be expected i.e. all pixels are admixtures.
3. Crosstalk problems affect B4 and B9 and to a lesser amount all the other SWIR bands. The result is that interpretations based on absorptions in B8 are problematic.
4. The spectral interpretations of the alunite-kaolinite and illite group minerals are based on theoretic spectra in the ASTER bandwidths that are least affected by crosstalk. The identification of spectra of individual pixels from the anomalous regions are usually confirmed by comparison with the USGS spectral library resampled to ASTER bandwidths.
5. The vegetation in an image can theoretically be removed by subtracting the vegetation signature using unmixing techniques however in some areas this signature may comprise the majority of the signal. Healthy vegetation can cause absorption in the same bands as the clay minerals.
ASTER Data Levels

Searches for ASTER data can be carried out on either the ERSDAC or EOS sites and enable the user to define the particular level of data required a geographical window of interest and restrictions on the cloud cover etc. The search engines are not particularly user friendly and the searches are very time consuming if the quick look images are required.

The main ASTER processing levels are:

**ASTER Level 1A Data Set - Reconstructed, Unprocessed Instrument Data**

The ASTER Level 1A product contains reconstructed, unprocessed instrument digital data derived from the telemetry streams of the 3 telescopes and their respective ground resolutions: Visible Near Infrared (VNIR), 15 m; Shortwave Infrared (SWIR), 30 m; and Thermal Infrared (TIR), 90 m. These depacketized demultiplexed and realigned instrument image data have their geometric correction coefficients and radiometric calibration coefficients calculated and appended but not applied. It also includes corrections for the SWIR parallax and intra- and inter-telescope registration information.

This level of data is required to generate accurate digital elevation models but is no use spectrally because the bands are not registered.

**ASTER Level 1B Data Set - Registered Radiance at Sensor**

The ASTER Level 1B product contains radiometrically calibrated and geometrically coregistered data for all the channels acquired previously through the telemetry streams of the 3 different telescopes in Level 1A. This product is created by applying the radiometric calibration and geometric correction coefficients to the Level 1A data. Both intra-telescope and inter-telescope registration correction for all the bands has been accomplished relative to the reference band of each subsystem. The Level 1B radiance product offers the same number of bands at the same resolution as the Level 1A product. Level 1B data provide the input for generating higher Level 2 geophysical products.

Only approximately 20% of the data collected as Level 1A has been processed to Level 1B.

**GEOIMAGE L'A to L'B conversion**

GEOIMAGE have developed their own Level 1A to 1B conversion program that carries out all the destriping interband registration and geometrical correction as detailed above. It also goes one step further and corrects the data to a map registration. The map accuracy is of the order of less than 20m although in some instances errors of up to 320m have been found. Higher accuracies are obtained by orthorectifying the data using X and Y control from the GeoCover 2000 Panchromatic imagery and the SRTM DTED 1 as the DEM. Locational accuracies using this method are believed to be generally of the order of 2m with maximum errors of 20m.

**Log Residuals**

The ASTER L'B data requires conversion to reflectance data before it can be used for spectral studies and without knowledge of the atmospheric effects during capture of the data the easiest way of doing this is by using Log Residuals. Log Residuals is a technique introduced by the CSIRO for processing Landsat TM and airborne scanner data in the 1980s. The transformation removes the solar irradiance atmospheric transmittance instrument gain and topographical/albedo effects from image data to produce a pseudo reflectance image. This is achieved by first calculating the spectral and spatial geometric means from the data. Geometric means are calculated using logarithms of the data values and are used because the transmittance and other effects are considered multiplicative. The spectral mean is the mean of all bands for each pixel and removes topographic effects while the spatial mean is the mean of all pixels for each band and accounts for the solar irradiance atmospheric transmittance and instrument gain. Each image data value is then divided first by the spectral and then by the spatial mean. Make sure to test this using a pancromatic scene and the SRTM DTED 1 DEM data. The results are the log residuals which are a good substitute for the Reflectance data.

**ASTER Level 2 Surface Emissivity TIR (AST 05)**

The ASTER Level 2 Surface Emissivity product is an on-demand product and provides an estimate of the thermal emissivity for each of the five ASTER TIR bands. The accuracy of the product is dependent on the accuracy of the surface leaving radiance TIR product (AST02T) which in turn is dependent on the accuracy of the atmospheric profiles used in the correction procedure.

**ASTER Level 2 Surface Reflectance Product (VNIR) (AST 07)**

The ASTER Level 2 Surface Reflectance Product is an on-demand product that contains atmospherically corrected Visible and Near Infrared data. It is generated using the 4 VNIR bands between 0.52 and 0.68 μm from an ASTER Level 1B image. Atmospheric correction involves deriving a relationship between the surface radiance/reflectance and the top of the atmosphere (TOA) radiance from information on the scattering and absorbing characteristics of the atmosphere. A digital elevation model provides the slope and elevation information for the accurate modelling of surface reflectance. Further details of the methodology are obtainable from http://edcdaac.usgs.gov/aster/asterdataprod.html.

**ASTER Level 2 Surface Reflectance Product (SWIR) (AST 07)**

The ASTER Level 2 Surface Reflectance Product is an on-demand product that contains atmospherically corrected short-wave infrared data. It is generated using the 4 SWIR bands between 1.56 and 2.25 μm from an ASTER Level 1B image. The methodology is similar to that for the VNIR.

**ASTER Level 2 Surface Kinetic Temperature Product (TIR) (AST 08)**

The ASTER Level 2 Surface Kinetic Temperature Product is an on-demand product that provides an estimate of the surface temperature for each of the five ASTER TIR bands. The accuracy of the product is dependent on the accuracy of the surface leaving radiance TIR product (AST02T) which in turn is dependent on the accuracy of the atmospheric profiles used in the correction procedure.

**Geometrical processing of Level 2 data**

The ASTER Level 2 imagery is in a similar orientation to the Level 1B data. Top Image and GEOIMAGE routinely processes this by expanding the 15m SWIR data to 30m resolution and merging the VNIR and SWIR data into the same file. Using ground control from the GeoCover 2000 EMT+. Panchromatic scenes and the SRTM DTED 1 DEM data, the data is orthorectified into a map-orientated image Bottom Image using Rational Functions in PCI Orthoengine. Locational accuracies using this method are believed to be generally of the order of 15m with maximum errors of 50m.
The Advanced Land Observing Satellite (ALOS) has been developed by the Japan Aerospace Exploration Agency (JAXA) as a follow-on to the Japanese Earth Resources Satellite (JERS) and the Advanced Earth Observing Satellite (ADEOS) to upgrade satellite based land observation technology. The satellite is due to launch in early 1999. Its main improvement over ADEOS is its instantaneous field of view IFoV. The AVNIR-2 provides 4m spatial resolution images when compared with the 16m resolution of the AVNIR in the multispectral region. The higher resolution was realized by improving the CCD detectors (AVNIR: 5,000 pixels per CCD; AVNIR-2: 7,000 pixels per CCD) and their electronics. Another improvement is a cross track pointing function for prompt observation of disaster areas. The pointing angle of AVNIR-2 is ± 44 degrees.

**ALOS Observation Strategy**

The ALOS mission features a systematic observation strategy which comprises multi-seasonal global coverage, on a repetitive basis, with all three sensors, a short revisit capability so that in cases of natural disasters, ALOS will be able to capture images of the disaster area with any of its instruments within a few days. ALOS has three mission instruments i.e. two optical imagers and an L-band Synthetic Aperture Radar. The optical imagers are the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) that consists of three telescopes of forward/nadir and backward viewing with 2.5m spatial resolution and the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) that has a 4m spatial resolution multispectral imaging and cross track viewing capabilities. The radar is the Phased Array Synthetic Aperture Radar (PALSAR) that has up to 10m spatial resolution variable off nadir angle beaming and full polarimetric capabilities.

The weight of the satellite is approximately four tons and the design life is three to five years. ALOS will be in a sun synchronous orbit with an inclination angle of 98.16 degrees orbit at an altitude of 691.65 km at the equator and have a 46 day repeat cycle. Considering the very high speed data produced from each instrument ALOS is designed to use a 240 Mbps inter-satellite link to JAXA’s Data Relay Test Satellite (DRTS) for its major data downlink. ALOS also has an X-band direct downlink capability to the local ground stations however this downlink data rate is only 120 Mbps.

**AVNIR-2 Characteristics**

- **Number of Bands**: 4 bands
- **Wavelength**: 0.4 to 1.65 micrometers
- **Number of Optics**: 3 (Nadir, Forward, Backward)
- **Base to Height ratio**: 1/8 between Forward and Backward looking
- **Spatial Resolution**: 2m
- **Swath Width**: 70km (Nadir) / 35km (Triplet mode)
- **SNR**: > 30
- **MTF**: > 0.05
- **Number of Detectors**: 2000 / band / Swath Width 16km
- **Band**: Band 1 = 0.52 - 0.6 - 0.68 - 0.77
- **Band**: Band 2 = 0.77 - 1.1 - 1.65 - 2.5
- **Band**: Band 3 = 0.4 - 0.5 - 0.6
- **Band**: Band 4 = 0.9 - 1.7 - 2.3 - 3.9
- **Polarization**: HH or VV, HH+HV, HH+VV, HH+HV+VV
- **Incident angle**: 4 to 70 degrees
- **Range Resolution**: 70m
- **Observation Swath**: 40 km
- **Bit Length**: 8 bits
- **Data rate**: 320 Mbps

**PALSAR Characteristics**

- **Mode**: Fine, ScanSAR, Polarimetric
- **Centre Frequency**: 1270 MHz
- **Bandwidth**: 14 MHz
- **Polarization**: HH, HV, VH, HH+VH, HH+HV+VH
- **Incident angle**: 4 to 83 degrees
- **Range Resolution**: 30m
- **Observation Swath**: 35km
- **Bit Length**: 3, 5 bits
- **Data rate**: 120 Mbps

**PRISM Characteristics**

- **Number of Bands**: 3 bands
- **Wavelength**: 0.52 - 0.67 micrometers
- **Number of Optics**: 3 (Nadir, Forward, Backward)
- **Base to Height ratio**: 1/8 between Forward and Backward looking
- **Spatial Resolution**: 2m
- **Swath Width**: 70km (Nadir) / 35km (Triplet mode)
- **SNR**: > 30
- **MTF**: > 0.05
- **Number of Detectors**: 2000 / band / Swath Width 16km
- **Number of Optics**: 3 (Nadir, Forward, Backward)
- **Base to Height ratio**: 1/8 between Forward and Backward looking
- **Spatial Resolution**: 2m
- **Swath Width**: 70km (Nadir) / 35km (Triplet mode)
- **SNR**: > 30
- **MTF**: > 0.05
- **Number of Detectors**: 2000 / band / Swath Width 16km
- **Pointing Angle**: 15 to 15 degrees
- **Bit Length**: 12 bits
Landsat Satellites - Historical

The Landsat Project is the longest-running enterprise for acquisition of moderate resolution imagery of the Earth from space. The Landsat 1 satellite was launched in 1972 and the most recent Landsat 7 was launched in 1999. The instruments on the Landsat satellites have acquired millions of images. These images form a unique resource for applications in agriculture, geology, forestry, regional planning, education, mapping and global change research.

The data presented here on the historical aspects of the Landsat Program is a summary only and more details can be found on the web sites:

Landsat Platforms

Six Landsat satellites have now been successfully launched commencing with Landsat 1 in July 1972. All platforms have operated from a repetitive circular sun synchronous near-polar orbit and on each day-side pass scan a ground swath 185km wide beneath the satellite. The first three satellites carried the Multispectral Scanner (MSS) as the main imaging instrument with a Return Beam Vidicon (RBV) as a subsidiary. The paths of these satellites were inclined 98 degrees with an 18 day repeat cycle and an equatorial crossing of between 5.10° and 3.35° local time. Landsats 4 and 5 have the Thematic Mapper (TM) as the main sensor together with an MSS. They were inclined 99 degrees and have a repeat cycle of 16 days and an equatorial crossing between 4.90° and 4.49° local time.

Landsat 6 was unfortunately lost on launch in 1984 however Landsat 7 continued to provide good imagery even after the launch of Landsat 7 in April 1984. The Enhanced Thematic Mapper ETM+ sensor on Landsat 7 developed a Scan Line Corrector (SLC) problem in May 2003 and this has severely limited the usefulness of the current ETM+ data.

Landsat 1 is still producing useable TM data.

Data Reception

Data from Landsats 1-3 was either directly transmitted to ground stations or recorded onto onboard magnetic tapes for later transmission to ground stations in the US. Landsats 4-7 did not have onboard magnetic storage and were restricted to direct download or uplink via the Tracking and Data Relay Satellites (TDRSS). Landsat 7 has sufficient onboard solid state memory to store 300 scenes for playback over a US ground station as well as the capability for direct transmission to ground stations.

Landsat Program Summary

<table>
<thead>
<tr>
<th>System</th>
<th>Launch End</th>
<th>Sensors</th>
<th>Resolution</th>
<th>Communication</th>
<th>Altitude (km)</th>
<th>revisit Days</th>
<th>Equatorial Crossing</th>
</tr>
</thead>
<tbody>
<tr>
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<td>13 Jul '72</td>
<td>RBV</td>
<td>60</td>
<td>Direct Downlink with Recorders</td>
<td>707</td>
<td>8</td>
<td>8.01 at 20m</td>
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<tr>
<td>Landsat 2</td>
<td>1 Aug '73</td>
<td>MSS</td>
<td>60</td>
<td>Direct Downlink with Recorders</td>
<td>707</td>
<td>8</td>
<td>8.01 at 20m</td>
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<tr>
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<td>RBV</td>
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<td>Direct Downlink with Recorders</td>
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<td>2 Mar '84</td>
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<td>Direct Downlink</td>
<td>707</td>
<td>10</td>
<td>10.97 at 20m</td>
</tr>
</tbody>
</table>

Worldwide Reference System

Data from the Landsat satellites is collected in a continuous stream along a near vertical path as the satellite moves from north to south in a descending pass. Some thermal imagery has been collected in ascending nighttime passes. The data is arbitrarily divided into nominal scenes which are about 28 seconds of spacecraft time apart corresponding to a spacing of approximately 185km. The pathrow designation is referred to as the Landsat Worldwide Reference System (WRS). The rows have been positioned in such a way that Row 0 coincides with the equator. This reference system is different for Landsats 1-3 and Landsats 4-7 because of the different altitudes and inclination angles of the satellites. This affects the spacing of the paths so Landsats 1-3 have 185 paths worldwide while Landsats 4-7 have 218 paths. An ArcView shapefile which allows the user to display pathrow boundary lines of the Landsat TM scenes and geographic coordinates and overlay an overlay that can be used in conjunction with other GIS layers is available from http://landsat.usgs.gov/wrs地形shape.php

Landsat path numbers increase from east to west while SPO is the reverse. The standard MSS and TM scenes from all the Landsat satellites have the same nominal ground coverage of 185km by 170km. Since the Landsats 1-3 had 251 paths compared to the 303 of the later satellites there is considerably more overlap between adjacent paths on the earlier satellites. For example there was 10% overlap at the equator on Landsats 1-3 and 0% on Landsats 4-7. At higher latitudes sidelap increases and when sidelap is greater than 56 degrees for Landsats 1-3 and 58 degrees for Landsats 4-7 alternate scenes are required for complete ground coverage.

It is possible to view Landsat images stereoscopically in the overlay region and at latitudes greater than 45 degrees there is complete stereoscopic coverage. The quality of the viewing will be dependent on relief but the angle of capture varies from zero at the centre to a maximum of 8 degrees at the edges of the scenes.

Landsat 7 SLC Problem

An instrument malfunction occurred onboard Landsat 7 on May 31, 2003. The cause of the problem was failure of the SLC which compensates for the forward motion of the satellite. Subsequent efforts to recover the SLC were not successful and the problem appears to be permanent. Without an operating SLC the ETM+ line of sight now traces a zig-zag pattern along the satellite ground track. Landsat 7 ETM+ is still capable of acquiring useful image data with the SLC turned off particularly within the central portion of any given scene. Landsat 7 ETM+ therefore continues to acquire image data in the "SLC off" mode. The SLC off impacts are most pronounced along the edge of the scene and gradually diminish toward the centre of the scene. The middle of the scene (approximately 25 kilometres with a L1G product) contains matched data values derived from one or more alternative acquisition dates. Several different Level 1G (L1G) product options have been developed by EROS in order to increase the utility of the L1G SLC off product. These options reflect the three different methods by which the original duplicated data may be replaced during L1G processing.

Level 'G' Standard - This product includes the original data gaps. Duplicated pixels have been replaced with null values. The image will therefore contain alternating "stripes" of missing data.

Level 'G' Gapfilled - This product provides a fully populated image in which all of the missing image pixels in the original SLC off image have been replaced with histogram-matched data values derived from one or more alternative acquisition dates.

Level 'G' Interpolated - Maximum 16 pixel interpolation provides a fully populated image in which all missing pixels have been filled with DN values interpolated from neighboring scan lines.

Details of the Australian SLC off products offered by ACRES can be obtained by contacting GEOIMAGE or from http://www.ga.gov.au/acres/referenc/SLCoff_composite.jsp

Medium Resolution Satellite Imagery

GEOIMAGE – Satellite applications for the real world
The Thematic Mapper (TM) scanner which first appeared on Landsat 4 in 1982 was designed to provide improved spectral and spatial resolution over the MSS instrument. The basic mode of operation is similar to MSS except that the use of more sensitive detectors better optics and a lower orbit has enabled the collection of data from individual spectral bands with improved ground resolution and with data quantised to 256 grey levels. Data is collected using banks of 16 detectors in each band and 16 lines of data are collected during both the forward and backward sweeps of the oscillating mirror system.

The geometry of TM scenes is similar to MSS. Each full scene covers an area of approximately 185 km x 185 km and is designated by the same Worldwide Reference System (WRS) as MSS data from the Landsats 1-5. Scene centres may be moved along the satellite path to better cover an area of interest but cannot be moved across track edges. Allowing for the differences in orbit parameters and optimizing our processing such as unsupervised and supervised classification, change images and Point of Interest processing, many applications of TM data are documented in geological literature. Image processing techniques for the enhancement of Landsat Thematic TM imagery for geological applications can be divided into spatial and spectral. Spatial filtering to enhance directional and edge information in imagery is a valid technique in the visualisation and interpretation of structural features. Spectral processing involves the enhancing of interrelationships between the different spectral bands in an image. The major types of processing are contrast enhancement: principal component images and band ratios as well as the LSFIT technique.

Image processing techniques for the enhancement of Landsat Thematic TM images are the result of the interaction of naturally occurring illumination of all the materials on the surface within a 30m square area. This includes the vegetation, leaf litter, varying soils and rocks, varying moisture contents and a shadow component. What is represented in an image is a summation over a large number of pixels of all these effects and will be dominated by the major surface components. Thus for geologists trying to differentiate rock units vegetation can be considered as interference and its effects are often poorly documented in geological literature.

Image processing techniques for natural resource assessment usually involve processing such as unsupervised and supervised classification to change images and calculation of indices such as the NDVI vegetation index.
Contrast Enhancement

With six reflectance spectral bands it is possible to make a total of 120 different band colour composite images from a TM image. From a practical viewpoint however the first three visible bands are very highly correlated as are bands 5 and 7 so the number of significantly different band combinations reduces to only a few. The main ones being:

- Bands 147 or 247 in BGR simulated natural colour with the visible blue in blue vegetation in green and iron oxides in red. This band combination usually has the least correlation between bands.
- Bands 345 in BGR is usually preferred for vegetation studies.
- Bands 123 in BGR is a natural colour image and although the bands are very highly correlated often shows a remarkable amount of detail.
- Bands 457 in BGR incorporates all the infrared bands and is useful in areas affected by haze.

Of course the selection of the bands is only the first step and the selection of the type of histogram modification is just as important. This is especially so in the case of a bimodal histogram where separate enhancements may be necessary to give maximum information e.g. in a greenstone terrain with very bright granitic and very dark greenstone areas. Region of interest contrast stretching may be required where the image area used in the histogram generation is restricted to the immediate area of interest e.g. over a particular rocktype so that the resulting contrast modification is maximised to show that particular rocktype.

Principal Component (PC) Images

Principal component analysis has been used in several ways to enhance imagery. For example the first three principal components can be displayed as an RGB composite. This shows the majority of the information content of a six band image as three bands and is of limited usefulness because the resulting colours cannot easily be related to the original bands. The first principal component can be regarded as the albedo and is often displayed in grayscale either by itself or as a backdrop for mineral or thematic maps. A variation on PC enhancement is the decorrelation stretch where an original three band image is taken into PC space the variance of these bands increased and then transformed back into normal colour space. This has the effect of saturating or increasing the colour information in a normal three band colour composite. This shows the majority of the information content of a six band image as three bands and is of limited usefulness because the resulting colours cannot easily be related to the original bands.

Band Ratios

Ratios of spectral bands are commonly used because they highlight the spectral differences between materials at the same time decreasing the variations in surface brightness due to topography. For example the ratio of bands 1/3 is often used to highlight iron oxide and 3/7 is used to highlight clays. Before ratios are calculated it is important to remove the effects caused by scattering of light in the atmosphere from each band. This effect which is highest in band 1 decreases to almost negligible values in bands 4 and 7. Theoretically the atmospheric effect would be the reflectance value in the image from a black body reflector on the earth’s surface. This might be expected to be the minimum value in any band however there may be noise in the image well below this value. The best method of estimating the value is to examine the histogram and select the value where the back slope of the band's histogram intersects the zero reflectance. Use these values in the ratio and examine the image produced. If there is still topographic detail visible in the image slightly modify the subtraction values until it disappears. When there is minimal slope information visible in the image you will know that the atmospheric corrections are correct. Ratios tend to highlight the noise in an image and this can be minimised using a median filter.

LSFIT

Most clay minerals have an absorption feature in the area covered by Landsat TM Band 7. Many techniques have been developed to highlight this effect and thus enable identification of areas of clay alteration indicative of mineralisation. The LSFIT technique developed by the Australian CSIRO is a linear regression technique that compares the predicted band 7 with the actual band 7 to identify areas of anomalously high absorption and hence infer the presence of clays.

Summary

The above techniques are generally very important in providing information on the rock types and possible alteration from TM imagery prior to field visits. It is however important that the spectral techniques be applied properly and that common sense is used in their interpretation. For example techniques that try to predict clays may also highlight water and snow as well as defining all playas with thin coatings of clay. For this reason it is important to interpret such images in conjunction with a standard colour composite image of the same area.

Image A Bands 3 2 1 Image B Band 1/3 ratio without atmospheric correction. Note the image is like a greyscale albedo representation of Image A Image C Band 1/3 ratio with atmospheric correction. Note the loss of topographic shading. Image D Bands 4/1 in RGB Vegetation is now in green. Image E LSFIT of Band 4 with predicted clay in white. Image F Band 1/3 ratio which highlights clays in white but also highlights vegetation.
During the 33 year history of the Landsat program, the MSS, TM and ETM+ imagery has been used for innumerable applications and only a brief summary is presented here. ASTER applications are very similar for the VNIR and SWIR sensors. Web sites with good reviews of application are:
http://landsat.usgs.gov/using.html
http://landsat.gsfc.nasa.gov/images/Landsat_Applications.html
http://asterweb.jpl.nasa.gov/science.asp

Several of the most common applications for medium resolution imagery include:

**Agriculture, Forestry and Range Resources**
- Discrimination of vegetative, crop, and timber types
- Measurement of crop and timber acreage
- Estimating crop yields
- Forest harvest monitoring
- Determination of range readiness and biomass
- Assessment of grass & forest fire damage
- Wildlife habitat assessment

**Land Use and Mapping**
- Classification of land uses
- Cartographic mapping and map updating
- Categorization of land capability
- Monitoring urban growth
- Regional planning
- Mapping of transportation
- Mapping of land water boundaries
- Siting for transportation/transmission routes
- Flood plain management

**Geology**
- Mapping of major geologic units
- Revising geologic maps
- Recognition of certain rock types
- Delineation of unconsolidated rocks and soils
- Mapping recent volcanic surface deposits
- Mapping landforms
- Searching for surface guides to mineralization
- Determination of regional structures

**Water Resources**
- Determination of water boundaries and surface water areas
- Mapping of floods and flood plains

**Coastal Resources**
- Determination of turbidity patterns
- Mapping shoreline changes
- Mapping of shoals & shallow areas
- Mapping of ice for shipping
- Tracing beach erosion
- Tracing oil spills and pollutants

**Environment**
- Monitoring environmental effects of man’s activities (deforestation, etc.)
- Monitoring water pollution
- Determining effects of natural disasters
- Monitoring surface mining and reclamation
- Assessing drought impact
- Siting for solid waste disposal
- Siting for power plants

**Fire Scar Mapping**
GEOIMAGE has been mapping fire scars over Uluru-Kata Tjuta National Park over many years. Determining where areas have burnt over time is important for monitoring and managing the National Park as well as for researching why some areas did not burn. This enables Park management to better understand the habitats of native fauna and flora. Temporal Landsat TM and ETM+ imagery, captured at different times over the years, was used. The imagery was orthorectified to a base image to ensure that the resulting vectors were all accurately co-registered. Techniques such as supervised and unsupervised classification were then used to distinguish burnt areas from unburnt areas. The resulting classification images were vectorised to produce a GIS map of the fire scars and the fire scar vectors from different time periods were combined to produce a map showing the age of the different burn scars. The resulting draft map was ground truthed by staff on the ground and final corrections and edits made. The final data was supplied by GEOIMAGE as ArcView shapefiles and raster images and is used in day-to-day management of the Park.

**Landcover Classification**
GEOIMAGE used Landsat imagery to map different landcover types in Asia. Some of these landcover types included forestry; oil palm plantations; failed oil palm plantations; cropping; subsistence farming and rural villages; and refineries. This landcover mapping was commissioned by groups looking for areas in which they could expand their plantations. Of particular interest were areas where previous plantations had failed. Landsat imagery was obtained and various supervised and unsupervised classifications performed to distinguish between different land cover types. The classified raster image was vectorised to produce a GIS map of the different landcover types and vectors were exported as shapefiles. Extensive ground truthing of the resulting landcover maps was performed to check the accuracies of the land cover classes produced. The maps produced are now used as base maps on which all future plantation development and planning is based.
Applications of Medium Resolution Satellite Imagery

Using Satellite Imagery For Monitoring Revegetation After Open Cut Mining In Central Queensland

The coal industry funded an ACARP study conducted by ESys to investigate the benefit of using satellite imagery to reduce the field effort and cost for revegetation surveys. The project was limited to commercially available satellite imagery and focused on five mines in central Queensland. Imagery comprised Landsat ETM+, SPOT IKONOS and a digital orthophoto. The accuracy by which different imagery types differ. Preprocessing methods and in particular texture mapping could separate different vegetation types was evaluated. A full copy of the ACARP Report is available at http://www.acarp.com.au/Completed/abstractsC10030abstract.htm

Context mapping

ESys has developed and uses a context classifier that incorporates the context of surrounding spectral classes within the classification of a pixel. Context mapping produces a more map-like classification. Settings conform to conventional survey guidelines allowing identification of objects appropriate with the survey scale. In this study, the identification of both vegetation types ‘unique floristic and structure characteristics’ and vegetation groups ‘assemblages of similar vegetation types and representing objects generally mapped’ was assessed.

Study Findings

- Texture classification consistently improved agreements with vegetation by 10% or more over spectral classification alone.
- Image processing using both spectral and texture information identified groups of similar vegetation types at an accuracy commensurate with published guidelines.
- The number of field sample sites could be reduced to between a quartern and a half of that recommended by survey guidelines while still identifying more than 90% of vegetation types present thus focusing and reducing the field effort and cost.
- ETM+ and SPOT imagery performed similarly; ETM+ produced slightly better agreements with vegetation while SPOT performed slightly better than IKONOS in some circumstances.
- Both ETM+ and SPOT were found to separate vegetation types substantially better than aerial photography.

Application

Satellite imagery is routinely used by ESys to assess revegetation after mining at mapping scales of 1:25,000. The analysis proceeds by mapping cover both spectrally and contextually at a preselected mapping scale. The resulting cover units are considered subunits that form the building blocks of the final map. Current sample sites are assessed to confirm that they remain representative of dominant cover in a map unit. If not, they are either included in the survey for resampling or removed from the database. Additional sample sites representative of the different cover present are selected for field sampling. Sample sites can be optimised to maximise the area sampled or to sample the widest range of cover present or both with the least number of sample points.

After field sampling, the subunits are combined into map units derived from field data and image analysis. Finally, an assessment of reliability of the final map units is then made based on quantitative differences between cover units derived from the imagery and the sites sampled.

Image A. TM imagery of part of an open cut coal mine (area of 7.5 km x 10 km). Image B. Context mapping of the revegetation. Image C. Reliability of resulting map; blue areas are highly reliable, cyan and green areas are of moderate reliability while yellow and red are poor (such areas would be targeted for sampling during next year’s monitoring). Example used courtesy of ACARP and Mark Evans of ESys Consulting Pty Ltd. brisbane@esysconsulting.com.au

Geological Interpretation - Regolith landform mapping using ASTER imagery

A regolith landform map has been produced from pseudo-stereo ASTER imagery of a partly sand covered area of southern Botswana. Interpretation of left hand and vertical images using a conventional mirror stereoscope enables mapping of the regolith profile including differentiation of duricrusts developed on weathered granitic bedrock and transported Kalahari cover sediments. Additional information is drawn from regolith ratios derived from Landsat data. Regolith landform elements mapped from the ASTER imagery include Cainozoic ferruginous duricrust developed on strongly jointed granite (CzfG), weathered Archean granite beneath the duricrust (Gm), topographic ‘breakaways’ produced by erosion of duricrusted basal Kalahari sediments (Czf) partly consolidated Kalahari sediments (Czk) sporadic Archean greenstone and bif outcrops (Vm). Recent pans (p) and fluvial sediments formed in a dry valley drainage system.
GeoCover are a global set of orthorectified Landsat scenes compiled by Earthsat Corp under the NASA Commercial Remote Sensing program. The scenes span three epochs; 1970s using Multi Spectral Scanner (MSS) data, 1990 using Landsat 4 and 5 Thematic Mapper (TM) data and 2000 with Landsat 7 Enhanced Thematic Mapper (ETM+). The dataset is unique as it provides a geographically accurate record of the earth’s surface spanning 30 years at pixel resolutions from 14.25m to 80m and is ideally suited to scientific research and educational activities. Full details of date selection, orthorectification, accuracy, access and other aspects are described in Photogrammetric Engineering & Remote Sensing Vol 70, No 3, March 2004, pp 313-322.

Approximately 5,500 Landsat TM images were selected from each of the 1990 and 2000 epochs. The acquisition dates of these images were relative to a 1990 and 2000 acquisition baseline and the images were either cloud-free or contained minimal cloud cover. In addition, only TM images with a high quality ranking in regards to the possible presence of errors such as missing scans or saturated bands were selected. It was important to collect data during periods of peak greenness so NASA adopted an approach for image selection that was based upon global 1-kilometre Advanced Very High Resolution Radiometer (AVHRR) NDVI data. It was sometimes difficult for NASA to obtain clear images during times frames of peak greenness; therefore there was some image substitution from other times of the year.

The Landsat data were orthorectified using geodetic and elevation control data to correct for positional accuracy and relief displacement. Large blocks of Landsat data were adjusted through a patented procedure that uses pixel correlation to acquire tie points within the overlap area between adjacent Landsat images. Ground control points were fixed and images projected to the Universal Transverse Mercator map projection using the World Geodetic System 1984 (WGS84) datum. All bands are individually resampled, using a nearest neighbour algorithm. The result is a final product with a Root Mean Square (RMS) Error of better than 50 metres in positional accuracy.

GEOIMAGE is a reseller of the GeoCover data and offers the following products. Please check with your local office for pricing.

**GeoCover-Ortho Single Scenes**

The stock scenes are “off-the-shelf” orthorectified full scene TM images for the 1990 epoch and ETM+ images for the 2000 epoch with the following product specifications:

- Worldwide coverage of the Earth’s landmass
- Data set size based on Landsat WRS (Path/Row) Reference system
- UTM projection – WGS84 datum
- 30 metre RMS positional accuracy
- 28.5 metre pixel size for 7 spectral bands: Landsat 4
- 28.5 metre pixel size for 6 multi bands, 14.25 metre for the pan band and 57m for the thermal bands: Landsat 7
- Interpolated with Cubic Convolution
- GeoTIFF file format: Load&Go GIS compatible
- ERMapper format: provided by GEOIMAGE

The stock scenes can be reprojected into any customer selected projection and/or datum. While the GeoCover scenes are a very cost effective dataset it should be noted that for certain applications they may not be ideal. For example, because the data were preferentially selected when the vegetation growth was at a maximum, some scenes may not be suitable for applications such as mineral exploration where it is important to get maximum soil/rock exposure. In such cases, there may be better scenes available from the EROS archive.

**GeoCover Ortho Mosaics**

GeoCover Ortho Landsat mosaics are created by digitally suturing a group of juxtaposed Landsat scenes into a single seamless digital image. Mosaics are colour (3 band) products with Bands 2, 4 and 7 in blue, green, red ‘BGR’. The stock mosaics have been prepared from both the 1990 and 2000 epoch GeoCover stock scenes and are “off-the-shelf” products with the following specifications:

- Worldwide coverage of the Earth’s landmass
- Data set size based on 3 degree ‘N/S’ segments of standard UTM
- UTM projection – WGS84 datum
- 30 metre RMS positional accuracy
- 28.5 metre pixel size: 1990 epoch
- 14.25 metre pixel size: 2000 epoch
- Contrast adjusted colour composite of TM bands 2, 4, 7 in BGR
- Cubic Convolution interpolation
- Compressed using MrSID data compression or uncompressed GeoTIFF
- GEOIMAGE has compressed with ERMapper ECW compression
- Load&Go GIS compatible
Radar imagery utilizes remote sensing of microwave radiation. Airborne and spaceborne radar imagery is produced by data from active microwave sensors that provide their own source of microwave radiation to illuminate the target. The sensor transmits a microwave ‘radio’ signal towards the target and detects the backscattered portion of the signal. The strength of the backscattered signal measures the difference in targets and the time delay between transmission and reflection determines the distance or range to the target. The wavelengths of microwaves range from 1 cm to 1 m and the benefit of these long wavelengths is their capacity to penetrate cloud, haze, dust and all but the heaviest rainfall making radar essentially weather independent.

Similarly to optical systems, the radar platform travels forward along the flight direction ‘A’ with the nadir ‘B’ directly below the platform. However, unlike optical systems, the microwave beam is transmitted obliquely at right angles to the flight direction illuminating a swath ‘C’ which is offset from nadir. The range ‘D’ refers to the across-track dimension perpendicular to the flight direction and azimuth ‘E’ refers to the along-track dimension parallel to the flight direction. This side-looking viewing geometry is typical of imaging radar systems.

The polarization of the radar beam which is the orientation of transmission or reception of the radar beam and also backscatter with respect to the sensor may be either horizontal ‘H’ or vertical ‘V’. Some radars can transmit and receive in both directions, so the options from different sensors are:

- **HH** - transmit and receive horizontally ‘like-polarized’
- **VV** - transmit and receive vertically ‘like-polarized’
- **HV** - transmit horizontally and receive vertically ‘cross-polarized’
- **VH** - transmit vertically and receive horizontally ‘cross-polarized’

The brightness of features in a radar image is dependent on the portion of transmitted energy that is returned back to the sensor from targets on the surface. The surface roughness and dielectric properties of a feature control how the microwave energy interacts with the target and are the dominant factors in determining the tones seen on a radar image. A surface is considered to be smooth if the surface height variations are much smaller than the radar wavelength. Hence, the resultant radar image will look dark for this feature as most of the microwave energy is bounced away from the sensor. A surface is considered rough if the surface height variations approach or exceed the radar wavelength. This will scatter the microwave energy in different directions returning a significant portion of the radar energy back to the sensor and therefore the target will appear lighter in tone on the image. The local incidence angle and look direction also contribute to the brightness targets in an image. In areas of strong relief, slopes facing towards the sensor will cause relatively strong backscattering and result in a brightened appearance on an image. The reflectivity and image brightness of a target will also change with the moisture content due to variations in dielectric properties. This is a useful feature for assessing biophysical parameters such as soil moisture.

### Introduction to Radar Imagery

<table>
<thead>
<tr>
<th>Name</th>
<th>Platform</th>
<th>Vintage</th>
<th>Frequencies &amp; Bands</th>
<th>Polarisations</th>
<th>More Details</th>
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</thead>
<tbody>
<tr>
<td>SIR C/X SAR</td>
<td>Satellite</td>
<td>1994</td>
<td>X; C, L</td>
<td>HH; HV; VH</td>
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<td>RADARSAT 1</td>
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<td>HH</td>
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<tr>
<td>RADARSAT 2</td>
<td>Satellite</td>
<td>Future</td>
<td>X</td>
<td>HH; HV; VH</td>
<td><a href="http://www.nasa.gov/">http://www.nasa.gov/</a></td>
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<tr>
<td>JERS 1</td>
<td>Satellite</td>
<td>1992-98</td>
<td>C</td>
<td>HH; HV; VH</td>
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<tr>
<td>ENVISAT-ASAR</td>
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<td>2002</td>
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<td>C</td>
<td>VV</td>
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<td>C</td>
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<tr>
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</tbody>
</table>

The table above describes most of the radar satellites whose imagery is in common usage.
RADARSAT

The RADARSAT satellite was launched on November 4, 1995 and has been providing imagery for operational monitoring services on a global basis since that time. It is equipped with a state-of-the-art Synthetic Aperture Radar (SAR) that can be steered to collect data over a 1750 km wide area using 7 beam modes. This provides users with superb flexibility in acquiring images with a range of resolutions, incidence angles, and coverage areas and offers the following key benefits:

- C-band synthetic aperture radar SAR
- Cloud-free images of the Earth
- Frequent revisits for monitoring and emergency response
- Programming for emergencies and priorities
- Near-Real Time processing of data
- Direct downlink and onboard recorder storage capacity
- Data calibration for change detection studies
- 7 beam modes for a wide range of imaging options
- Varying Resolutions: 50 x 500 m, 300 x 3000 m
- Swath Widths of 50 - 500 km
- Incidence Angles from 10 - 59 degrees

Within each RADARSAT beam mode a number of incidence angle positions are available. These are called beam positions. For example, Standard beam mode, which covers a 100 x 100 km area has seven beam positions. By specifying a beam position one of seven 100 x 100 km images within a 500 km accessible swath will be collected.

### RADARSAT Beam Modes and Resolutions

<table>
<thead>
<tr>
<th>Beam Mode</th>
<th>Nominal Area Covered (km)</th>
<th>Nominal Resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ScanSAR Wide</td>
<td>500 x 500</td>
<td>100 m</td>
</tr>
<tr>
<td>ScanSAR Narrow</td>
<td>300 x 300</td>
<td>50 m</td>
</tr>
<tr>
<td>Extended Low</td>
<td>170 x 170</td>
<td>30 m</td>
</tr>
<tr>
<td>Standard</td>
<td>100 x 100</td>
<td>25 m</td>
</tr>
<tr>
<td>Extended High</td>
<td>75 x 75</td>
<td>20 m</td>
</tr>
<tr>
<td>Fine</td>
<td>50 x 50</td>
<td>8 m</td>
</tr>
</tbody>
</table>

RADARSAT is due for launch in 2006. This satellite will have the same orbit repeat cycle and ground track as RADARSAT and will be providing continuity of the RADARSAT mission. Several improvements will be a 3 m Ultra Fine resolution mode for more frequent revisits and faster response to user requests for full polarimetric imaging modes and selective polarization HH/HV/VH/VV and GPS receivers on board for real-time position knowledge ± 60 m.

ERS

ERS was placed in a near-polar orbit in July 1991 at a mean altitude of about 780 km with an instrument payload comprising active and passive microwave sensors and a thermal infrared radiometer. ERS is currently the nominal mission as ERS was retired after nine years of service in March 2000. ERS has basically the same instrumentation as ERS1 with the main instruments onboard being:

- The Radar Altimeter which is an active microwave sensor designed to measure the time return echoes from ocean and ice surfaces. The Radar Altimeter provides information on significant wave height; surface wind speed; sea surface elevation; which relates to ocean currents; the surface geoid and tides; and various parameters over sea ice and ice sheets.

ERS1 was launched in February 1995 and carried a SAR L-band instrument and an optical sensor (OPS) OPS collected spectral bands from visible to SWIR while the SAR operated at HH polarization. The swath width of the SAR was approximately 5 km and spatial resolution was approximately 10 m. The longer L-band allowed some penetration of vegetation and other surface types. Although this satellite was lost in October 1998 the JERS1 archive provides a good source of historical information in Equatorial areas particularly for mapping rain forests where clouds are prevalent.
The applications for radar imagery are many and varied with the main advantage being that radar image collection is not hampered by cloudy weather conditions. This makes image acquisition in tropical areas such as northern Australia equatorial Africa and middle America and over the polar regions possible and repeatable. Some of the more common applications for radar imagery include:

1. Environmental Monitoring: discerning soil characteristics such as moisture and salinity crop monitoring such as assessing areas of harvested and non-harvested sugar cane for logistical planning and locating ice flows.
2. Disaster Response: Mapping particularly of oil spills and bush fires as smoke in the atmosphere will not affect image capture.
3. Ground Deformation Mapping: such as measuring earthquakes, mapping land slips and land slides and assessing mining effects.
5. Marine Mapping: such as measuring surface and internal waves, determining current boundaries such as mean low water mark, shallow water bathymetry and describing sea ice forms.
6. Land Mine Detection and
7. Reconnaissance Surveillance and Targeting which is day/night independent.

**Mean Low Water Mark Mapping**

Accurate boundary maps are required for many reasons, especially during disputes over land ownership and legal applications. In tropical areas where land boundaries need to be accurately determined for survey plans and legislative decision making SAR imagery is particularly useful. In the case of mean low water mark mapping where the timeframe to capture the imagery offers only a narrow window when the tide is out, airborne SAR offers the advantages of rapid acquisition and production of accurate and high resolution (2m pixel) imagery. This imagery is specific to the area under investigation and is captured in a cost-effective manner when compared to on-ground surveying while producing imagery independent of weather and atmospheric conditions unlike aerial photography or optical satellite imagery. The SAR imagery is flown following the coastline during low tide and the resulting images are georectified and mosaiced. The landwater boundary can then be extracted using image classification and GIS techniques to define the mean low water mark which is then incorporated into the final survey plan. Accuracy assessment can be performed using corrected high resolution satellite imagery.

**Biomass Mapping**

Biomass assessment is usually measured in tonnes per hectare and is important for reporting for the Kyoto Protocol and assessing carbon stock sequestrian. The advantage of using SAR is that it is cloud and smoke penetrating and provides consistent illumination responses which are not influenced by atmospheric conditions. In cases where the vegetation biomass in regions in the Northern Territory needs to be quantified SAR is used as it is not hampered by the tropical cloud cover. Different vegetation communities are able to be distinguished based on their different structures and moisture content and areas of forest that have been cleared can be accurately mapped.

**Harvest vs Non-Harvest Sugar Cane Mapping**

Sugar cane is mostly grown in the northern coastal reaches of Queensland which is often characterised by cloudy weather conditions, particularly during the Spring and Summer months. This is the time of year that sugar cane is usually harvested and when the logistics of sending cut cane to the sugar mills needs to be planned. This process requires an ongoing assessment of which cane fields have been harvested and which not. By using satellite imagery to capture repeat images over these large cane growing tracts the need for on-ground assessment is greatly reduced. However, collection of cloud-free optical satellite imagery is often difficult at this time of the year and requires many capture attempts to obtain a suitable image. By using radar imagery captured on a fortnightly or monthly cycle the frustration of high cloud cover is avoided and since radar has been shown to be statistically valid in determining the difference between harvested and non-harvested sugar cane fields the logistical planning for each sugar mill is able to be done accurately and in a timely manner.

GEOIMAGE would like to thank Dr. Darren Bell, GecOz Pty Ltd for his assistance in preparing this section and for the use of his radar application case studies. For more details please contact GecOz at www.gecoz.com.
GEOIMAGE are distributors and suppliers of all the major satellite imagery including IKONOS, QuickBird, SPOT, ASTER, Landsat, RADARSAT-1, ENVISAT, JERS, etc. We can offer advice on the data best suited to your application and have extensive experience in specialist image processing including:

- Geometric correction and orthorectification
- Image matching and mosaicing
- Image calibration
- Contrast enhancements
- Hardcopy and digital output in client specific formats
- DEM generation

**Geometric Correction and Orthorectification**

Most types of raw satellite imagery require some type of geometric correction or rectification so that the image corresponds to real world map projections and coordinate systems. Geometric rectification improves the horizontal positional accuracy of the imagery by warping the imagery to match the client's vectors or accurate ground control and is suitable where the area is largely flat and the imagery has been acquired from nadir (near vertical) viewing. For areas where there is undulating topography or the imagery has been acquired at a high angle to the vertical or very high accuracy is required orthorectification is necessary. Orthorectification is basically rectification that incorporates a digital elevation model (DEM) to compensate for topographic relief by allowing the vertical aspect to also be taken into account. GEOIMAGE uses PCI OrthoEngine which has specific satellite sensor math models to generate very precise orthoimages. Orthorectification is also usually required if several images or scenes need to be mosaiced in order to ensure that the joins are seamless. For both rectification and orthorectification, accurate ground control is essential to produce geometrically accurate imagery.

**Colour-Balancing, Mosaicing and Tiling**

Colour-balancing, mosaicing and tiling are all services that make satellite imagery easier to use, integrate into GISs or more aesthetically pleasing. GEOIMAGE has many years of experience in processing satellite imagery to integrate seamlessly into our client's existing systems and is able to custom produce imagery formats and products to our clients' unique requirements.

Colour-balancing is the process of matching two adjacent and joining satellite images usually captured on different days so that there is no discernable difference in the colour between them. This process is vital to the process of mosaicing images so that no join or seam is noticeable. Mosaicing requires that the imagery is not only colour balanced but also spatially co-registered to each other so that the two or more images can be joined seamlessly. Once the images are mosaiced together, GEOIMAGE often 'cookie-cuts' the resulting large mosaic into a series of user-defined tiles usually based on 1:50,000 map sheet boundaries. This allows the client to use one smaller tile or file when working in a smaller discrete area to avoid manipulating a large and often cumbersome file.

GEOIMAGE often performs colour-balancing, mosaicing and tiling after orthorectification of satellite imagery, particularly the higher resolution imagery such as IKONOS, QuickBird and SPOT. This is because IKONOS and QuickBird image swatches are relatively narrow so many separate files are often required to cover a large area of interest, but the resulting mosaic of the imagery creates a file of several gigabytes in size which is difficult to use and must be cut up in smaller and more manageable pieces.

**Pansharpening**

Often imagery is captured at a higher resolution in panchromatic or black and white mode while multispectral or colour imagery is captured at a lower resolution. GEOIMAGE has perfected the technique of merging a higher resolution panchromatic image with lower resolution multispectral imagery to produce a colour image showing the better detail of the panchromatic image. The client therefore receives a colour image which is better suited to a range of applications such as vegetation mapping or simply as a backdrop to vectors with the higher spatial resolution allowing the client to see more detail.

Some satellites such as the IKONOS satellite capture 1m panchromatic imagery at the same time as 2m multispectral imagery. Because this imagery is captured simultaneously and is co-registered the imagery can be pansharpened or merged without prior orthorectification. In cases where imagery from different satellites are to be pansharpened such as merging the 2m multispectral Landsat imagery with 1m panchromatic SPOT imagery the images first need to be orthorectified to ensure that they exactly co-register with each other. GEOIMAGE will recommend which datasets can be pansharpened to ensure you get the best spatial and spectral resolution possible.
Introduction

GEOIMAGE specialises in processing airborne and ground geophysical surveys of all vintages. We use quality software including Intrepid Geosoft, ERMapper, Geomatica, ArcGIS, and MapInfo, and our staff have extensive experience in handling the good and the not-so-good digital data. Examples of some of the surveys we have worked on include re-processing and mosaicing the extensive publicly-released surveys from Australia, Canada, and west and southern Africa.

GEOIMAGE can also write the specifications for your surveys, oversee the capture, and provide quality assurance of the acquired data. In addition to processing of geophysical data, we also supply geophysical survey data from:

- The Queensland OpenFile Survey Database
- MAGNet Database, an extensive principally WA and NT database of private company geophysical surveys available for resale to the exploration industry.
- Queensland Department of Natural Resources and Mines airborne surveys.

Data Reprocessing

Data acquired by airborne geophysical surveys have been routinely stored on digital media and processed digitally since the late 1980s. However, in comparison to more recent surveys, these data are commonly seen to be inferior due to:

- Lower specification survey parameters like broader line spacing, increased terrain clearance, and smaller volume crystals for spectrometer surveys.
- Inaccuracies in the survey location data due to poor navigation and recovery.
- Difficulties in the digital processing due to lack of computing power and by today’s standards’ unsophisticated software and computing techniques.

Gridded representations of these earlier surveys are commonly characterized by: corrugations and “busts” due to poor tie-line levelling; crossing flightlines and terrain clearance variation along lines; spikes due to inadequate diurnal corrections and poor processing; parallax and heading errors or introduced errors due to excessive filtering and smoothing of flight line data by contractors.

The lack of separation between potassium, thorium, and uranium channels in spectrometer surveys is sometimes also a problem.

In reality, though this earlier data is an invaluable resource, careful re-processing can make any survey more interpretable and allow easier extraction of relevant information. A re-processed survey with lesser specifications, or better still a careful mosaic of a number of these surveys, can provide a regional overview that facilitates interpretation of a structural setting, as well as providing the basis for better defining the parameters and location of high-resolution surveys over potential target areas. Possibly suggesting airborne EM or airborne gravity as preferred or ancillary acquisitions. The re-processed survey may even serve in its own right ‘depending upon survey specifications’ as a basis for detailed interpretation and information extraction.

The above graphic depicts an example of geophysical processing and mosaicing of multiple aeromagnetic surveys. Individual surveys were edited to correct obvious problems due to elevation errors, reflights, and noise spikes in the original data. Surveys were then microlevelled to a common base and grid “stitched” at optimum cell size. This preserves high frequency information from surveys flown at closer line spacing. Data shown here is provided by the Northern Territory Geological Survey.
Introduction

Digital elevation models (DEMs) are an integral part of any GIS. They are required both for the description of the three-dimensional surface and are also required to orthorectify imagery which is used both as a backdrop and to provide information for a GIS. In the past, the best available world-wide DEM has been the GTOPO30 with its 1 km spacing. The recent availability of SRTM DTED2 between ±48° and ±60° has produced a virtual world-wide DEM that is several orders of magnitude better. The original specifications on the absolute accuracy of the SRTM DEM was ±20 m horizontal and ±4 m vertical. These figures appear to have been very conservative based on results of accuracy assessments presented at a workshop. The Shuttle Radar Topography Mission Data Validation and Applications held in June 2005. See http://edc.usgs.gov/conferences/SRTM/. For example, Ernesto Rodriguez of JPL presented the results of an extensive ground campaign conducted by NGA and NASA to collect ground truth to validate the SRTM result. The results are summarised in the table below with all quantities representing ±95% errors in meters.

<table>
<thead>
<tr>
<th>Continent</th>
<th>Accuracy (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>11.9</td>
</tr>
<tr>
<td>Australia</td>
<td>7.2</td>
</tr>
<tr>
<td>Eurasia</td>
<td>3.8</td>
</tr>
<tr>
<td>Islands</td>
<td>9.8</td>
</tr>
<tr>
<td>N America</td>
<td>12.6</td>
</tr>
<tr>
<td>S America</td>
<td>9.0</td>
</tr>
</tbody>
</table>

DEMs at finer resolution than the ±20 m of the SRTM are required for many applications e.g. infrastructure planning, flooding studies, orthorectification of high resolution imagery, erosion control, 3D viewing, and many others. At the very extreme detailed level this demand for DEMs is met with aircraft-based LIDAR systems which typically have ±1 m spatial resolution with accuracies of about ±0.5 cm. However for large area DEM coverage in non-urban areas optical satellites with stereo image capability are a cost effective option.

Most of the current push-broom satellite sensors have a stereo capability whether it is in track stereo such as the ASTER sensor cross-track stereo such as the SPOT satellites or a combination of in-track and cross-track stereo as is the case with the agile IKONOS and QuickBird sensors. Whatever the source of the stereo pairs the methodology of creating the DEM is similar and is described in detail by Toutin http://www.ipi.uni-hannover.de/html/publikationen/ssw/Workshop/psu_toutin.pdf. The method involves selection of several accurate GCPs in the stereo pairs computation of the structural autocorrelation between the stereo pairs on a pixel by pixel basis and computation of XYZ cartographic coordinates from the sensor parameters and refined using the GCPs. The base to height ratio (B/H) is a measure of resolution and detail of the resultant DEM. The finer the resolution of the sensor obviously the higher resolution and detail of the resultant DEM.

<table>
<thead>
<tr>
<th>Base to Height Ratio of Stereo Pair</th>
<th>B/H Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1:1</td>
</tr>
<tr>
<td>0.07</td>
<td>1:2</td>
</tr>
<tr>
<td>0.09</td>
<td>1:3</td>
</tr>
<tr>
<td>0.11</td>
<td>1:4</td>
</tr>
</tbody>
</table>

DEMs from Satellite Imagery

The Digital Terrain Elevation Data (DTED) format was developed for the distribution of gridded elevation data by the US Defence Mapping Agency (DMA) now the National Imagery and Mapping Agency (NIMA). The format was developed as a data source for military activities and systems that require landform/slope elevation and/or terrain roughness in a digital format. For more information on the format see http://www.fas.org/irp/program/core/dted.htm.

- **Radiometric quality of the imagery**: Since the panchromatic band used in the stereo pairs is invariably a combination of the visible spectra the imagery is subject to haze problems in tropical areas.
- **Ground cover**: Large areas of no texture - examples are playa lakes, ocean rivers and lakes; areas of low albedo - examples are forested areas or imagery with low sun angles; and repetitive textured areas e.g. stripped paddocks - all produce problems during the image correlation.
- **Relief in the area**: Very steep areas such as coastal cliffs, edges of tablelands; incised river valleys; benches in open pits etc will often be missing in one of the stereo pair images because the slope is steeper than the angle of capture.
- **Quality of the ground control points**: GEOIMAGE provides a guide to its clients on how to collect the GCPs needed for accurate control.
- **Time difference between stereo images**: For cross-track stereo pairs the greater the time difference between images the higher the probability of spectral and spatial differences in the images. Changes in cloud cover - fires vegetation glints on water bodies etc will all contribute to correlation problems.

**IKONOS**

The agile pointing capability of IKONOS with its ability to collect imagery up to ±48° off nadir in any direction makes it ideal to collect same pass stereo pairs. In fact the height of the satellite and therefore the time it has over a target area often allows it to capture adjacent stereo pairs on the same overpass. Space Imaging will capture between ±42 degrees latitude in track stereo pairs. In fact stereo pair acquisitions are almost invariably new acquisitions and areas of interest must meet the normal IKONOS ordering criteria i.e. minimum area of 100 sq km and minimum 3 km wide in any dimension. GEOIMAGE usually orders the Reference Image at 2048 x 2048 pixels so it can not be carried over to the subsequent stereo pair.

**SPOT**

The SPOT stereo pair is after orthorectification Scale approximately 1:30 000. Left image collected 31 Jan 2005 Incidence angle L±64° Right image collected 11 Feb 2005 Incidence angle R±45° CNES 2005.

The two white areas annotated A are water bodies that have caught a sun glint on the left image and are black on the right image. All the water bodies in the image regardless of size including a wide river had the same glint and were much brighter than the surrounding land while in the right image they were very low albedo and darker than the surrounding land. The paddock marked B is best seen in the right image where it is much darker than the surrounding paddocks and the change can only be attributed to a fire.

The areas marked C are wisps of cloud on the right and the associated cloud shadow on the left. Such cloud is difficult to see in such a busy image.

This image also produced correlation problems in some of the paddocks with contour plowing which had variable visibility in the two images based on the particular aspect of the paddock.
DEM from Satellite Imagery

Stereo products and our normal experience has been that the imagery has been collected within 2 weeks of the order except in one case where the order was cancelled because of continuous cloud cover northern Peru. Space Imaging provides the stereo imagery pairs with a rational polynomial coefficient. RPC camera model file. The RPC file provides camera model data to popular software packages for photogrammetric extraction of 3D feature coordinates and orthorectified imagery. Each stereo pair contains an image collected at a low elevation angle (above 40 degrees) as well as an image collected at a higher elevation angle (above 30 degrees) with 0.5° to 1.0° base to height ratio. Space Imaging can also provide a Digital Terrain Model defined as product ITM. See http://www.spacescience.com/products/srtmtechnical_overview.htm. This product is extracted from the IKONOS stereo pairs and has a 1 arc second (90m) cell size and vertical accuracy of ±1m LE90 and approximately 1m RMSE. The data are terrain edited to ground elevation by removal of buildings and canopy height except where the buildings are lower than the accuracy specification. In areas where the ground cannot be seen due to dense canopy the elevation is not edited to the ground and will remain at canopy height.

GEOIMAGE uses PCI OrthoEngine to create IKONOS DEMs at 1 or 2 m cell size and with 1-2m accurate ground control points have been able to generate DEMs with accuracies of ±1m.

QuickBird

The maximum pointing capability of the QuickBird sensor is 30 degrees off nadir and stereo capture is believed to be restricted to one stereo pair per overpass however this image may be up to 46km wide.

SPOT HRS

The SPOT HRS payload includes the HRS imaging instrument developed by Astrium for DEM generation. This instrument uses cameras looking at 20deg fore and aft to image stereo pairs over a surface area of 496km along track and 190km across track centered on the satellite track. The spatial resolution of the instrument is 1m and sampling cross track is 1m and along track is 1m. SPOT IMAGE offers two DEM products from the HRS data which are referred to as SPOT DEM and Reference3D. Full descriptions of these products are available at http://www.spotimage.fr/html/1_20_200_2.png. The SPOT DEM product comprises a raster DEM in 16bit GeoTiff format (‘DTED0’ or 32bit BIL as an option) as well as metadata in XML format. The data is sold by the square kilometre according to the framing provided by the customer. In some areas due to cloud cover stereo pair correlation problems or inherent limits of the sensor when imaging very mountainous terrains the DEM may be filled locally by interpolation or with other available data such as GTOP0 or SRTM 4m data. The data in the vertical datum EGMA and either in geographical coordinates with respect to WGS84 or cartographic coordinates in UTM WGS84. Pixel sizes are 1 arcsecond (about 1m at the equator) in Geographical coordinates and 9m resampled in cartographic coordinates. The absolute planimetric and elevation accuracies depend on the dimension of the area of interest and on the availability of Reference3D for the area. If Reference3D is not available then the accuracies are ±1m @ 90% confidence for planimetric accuracy ±2m @ 90% confidence for elevation accuracy. For larger areas 4° to 10° HRS stereoscopic strips the accuracies are ±1m @ 90% confidence for planimetric accuracy ±2m @ 90% confidence for elevation accuracy. SPOT DEM production systematically includes automatic filtering to eliminate correlation artifacts and flattening of non running water bodies exceeding 0.5 sq km.

Reference3D is co produced by SPOT Image and IGN France’s national survey and mapping agency. It comprises three registerable layers of data:

- DTED level 1 DEM
- An HRS orthoimage with a resolution of near five metres
- A full layer of quality and traceability data

Reference3D stores data as tiles of one square degree (about 100 km x 100 km) covering the Earth’s landmasses and aligned along parallels and meridians. The DEM has a higher level of accuracy than the SPOT DEM.

SPOT HRG Cross track Stereo

SPOT’s oblique viewing capacity makes it possible to produce stereo pairs by combining two images of the same area acquired on different dates and usually at different look angles i.e. an image looking left from the satellite track and a right looking image. A Base Height (BH) ratio of 1 can be obtained for a viewing angle of 24 degrees to the East and to the West. For a stereo pair comprising a vertical view and one acquired at 37 degrees a BH of 0.3 is obtained. Across track stereo is reliant on obtaining stereo images that are close enough in time to produce good correlation.

ASTER

The ASTER sensor has a vertical looking infrared detector array while a backward looking telescope has a detector array in the same spectral band. These infrared arrays (N and B) generate an along-track stereo image pair with a base to height ratio of 0.4 and an intersection angle of 277 degrees and can be used to generate DEMs. Good archived ASTER data which can be used to generate DEMs now exists for most areas in the world with the exception of the equatorial belt, and is available at relatively low cost. GEOIMAGE regularly generates DEMs from ASTER data for orthorectification of the high resolution satellite images and to produce pseudo stereo images.

Aerial Photos

GEOIMAGE is able to produce high quality air photo DEMs using the clients aerial photography over their given AOI. Any number of digital or hardcopy aerial photographs can be processed to provide one seamless high resolution and high quality DEM over a large AOI.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Image resolution (m)</th>
<th>DEM Spatial resolution (m)</th>
<th>DEM Accuracy Absolute</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKONOS</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>QuickBird</td>
<td>6.4</td>
<td>12</td>
<td>1.2</td>
</tr>
<tr>
<td>SPOT HRG</td>
<td>5</td>
<td>10</td>
<td>9.10</td>
</tr>
<tr>
<td>cross track stereo</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPOT HRG:DEM</td>
<td>10</td>
<td>30</td>
<td>10.30</td>
</tr>
<tr>
<td>SPOT HRG:REF-ID</td>
<td>10</td>
<td>30</td>
<td>10.30</td>
</tr>
<tr>
<td>ASTER</td>
<td>15</td>
<td>10-15</td>
<td>15</td>
</tr>
<tr>
<td>SRTM DTED</td>
<td>30</td>
<td>90</td>
<td>15</td>
</tr>
</tbody>
</table>

Note: DEM accuracies are dependent on many factors as discussed on Page 48 and the figures for IKONOS QuickBird SPOT HRG and ASTER are for high quality imagery in relatively low slope areas. Several authors suggest that the DEM cell size from stereo imagery should be 1 to 2 times the pixel size of the source image. GEOIMAGE generally produces DEMs at 2 times the pixel size.

Above left: GEOIMAGE derived 3m SPOT DEM from cross track stereo pair
Above right: SPOT s orthoimage (1:100 000 scale © CNES 2005)

GEOIMAGE derived 3m DEM from the ASTER image (underneath)

An example of an airphoto DEM mosaic created by GEOIMAGE
Introduction
Most geologists and geographers are familiar with air photos and the increased information that can be obtained from viewing them in three dimensions using a stereoscope. This information mainly relates to the ability to estimate dip angles and to interpret structural information. However, it is also important in understanding the development of the physical landscape, e.g., for geochemical sampling. With the arrival of two-dimensional satellite imagery, scientists have learned to rely more heavily on spectral information in their interpretations. It is now possible to integrate two-dimensional satellite imagery with readily available digital elevation data from the ASTER satellite or the SRTM digital elevation model (DEM) to produce pseudo-stereo imagery.

GEOIMAGE has been producing stereo imagery and DEMs for clients, particularly in the mining and exploration industry, for many years and has coined the name **STEREO-SATMAP** for the product.

DEMs
The ability to create pseudo-stereo imagery at any scale anywhere in the world at least to 60° of latitude has only been possible since the ready availability of good quality DEMs. DEMs which offer large area coverage such as the SRTM DTED® data are useful down to scales of 1:100k while DEMs derived from SPOT, ASTER, and IKONOS stereo imagery are useful at larger scales.

Stereo Pairs
**STEREO-SATMAPs** are prepared by GEOIMAGE using inhouse developed software. Although modeled on the stereo viewing of air photos, the stereo imagery produced is slightly different. Air photos have radially oriented stereo or height-induced distortion by virtue of the instantaneous capture of a single airphoto using a lens system. In the pseudo stereo, the input is an orthorectified three-band color image (or a black and white single band image) and the height offset is introduced into the data in the east-west direction. It is normal to make a left and right stereo pair where the height offsets are made in equal amounts but in opposite directions as is the case in air photos. The amount of height offset is usually made in a linear relationship to the range of DEM values in the image and will be dependent on the scale of the images. The type of stereoscope used and the viewing needs of the interpreter. The amount of the stereo offset can be fine-tuned for an individual. The normal maximum offset is 20 pixels; i.e., a pixel at maximum height is offset 20 pixels while a point at minimum height is not offset.

One of the problems of a stereo left-right combination is that each image is height distorted so that neither image will produce an undistorted interpretation. This can be overcome by preparing a left-vertical stereo pair with double the height offset on the left stereo image i.e., a maximum of a 40-pixel offset and a vertical or undistorted image containing the coordinate information. A second problem relates to the size of the image prints and trying to position them under a stereoscope. This problem is best handled by cutting the left stereo print into vertical strips and interpreting a strip at a time. The vertical print can be left intact.

The digital stereo images can also be examined on a computer screen. This is most easily performed in ERMapper with the images displayed in adjacent geolinked windows. If the windows are set up with a spacing similar to the viewers' eye separation distance, it is possible to view the stereo without a stereoscope.

Any single band ‘black and white’ or three-band color composite imagery can be used to produce the pseudo-stereo imagery. The optimum scale for hardcopy output will depend on the pixel size of the input imagery. For example, ASTER imagery can be enlarged to 1:25,000 scale although it looks sharper at 1:50,000 scale. Landsat ETM+ imagery which has been pansharpened can be enlarged to 1:50,000 scale but is sharper at 1:100,000 scale. The optimum scales for various image/DEM combinations are shown in a table on the next page.

**CHUQUICAMATA MINE, CHILE**: Approximate scale = 1:75,000.
Images are ASTER bands B8+B7+B6+B5, B3, B1 in RGB which gives a similar spectral response to a Landsat Band 742. A 15m ASTER derived DEM produced from the same Level L1A dataset has been used to produce the pseudo-stereo. The left hand image is the left stereo pair, and right hand image is the vertical image. Maximum height offset is 40 pixels at maximum elevation. The grid on the vertical image is at a 1-km spacing.
POSSIBLE SCALES FOR STEREO SATMAP PRINTS

<table>
<thead>
<tr>
<th>IMAGE TYPE</th>
<th>IMAGE RESOLUTION (metres)</th>
<th>DEM</th>
<th>BEST SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GeoCover Mosaics</td>
<td>28.5</td>
<td>SRTM</td>
<td>1:000 000</td>
</tr>
<tr>
<td>Landsat TM/ETM+</td>
<td>14.25/28.5</td>
<td>SRTM</td>
<td>1:250 000</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>14.25</td>
<td>SRTM</td>
<td>1:500 000</td>
</tr>
<tr>
<td>ASTER</td>
<td>15</td>
<td>ASTER</td>
<td>1:50 000</td>
</tr>
<tr>
<td>SPOT</td>
<td>5-10</td>
<td>ASTER/SPOT</td>
<td>1:20 000</td>
</tr>
<tr>
<td>IKONOS/QuickBird</td>
<td>0.6 - 10</td>
<td>ASTER/SPOT/IKONOS</td>
<td>1:5 000</td>
</tr>
</tbody>
</table>

This table sets out some examples of image/DEM combinations that can be used in the preparation of pseudo stereo pairs but is by no means exhaustive and should be used as a guide only.

1:50 000 SCALE STEREO-SATMAP

Prepared from ASTER bands 731 in RGB and using a 15m DEM derived from the same ASTER data for the pseudo stereo. The print covers 30km by 30km.

1:250 000 SCALE STEREO-SATMAP

Prepared from Landsat bands 741 in RGB and using the SRTM DTED for the pseudo stereo. The print covers a 1°deg by 1°deg area.

1:1 000 000 SCALE STEREO-SATMAP

Prepared from a GeoCover Mosaic with bands 742 in RGB and using the SRTM DTED for the pseudo stereo. The print covers a standard 6°deg by 5°deg area.
South American Multiclient Interpretation

1st Generation Studies

Since 2000, Colin Nash and Associates Pty Ltd and GEOIMAGE have completed ten individual Landsat Multiclient Interpretation studies (see accompanying figure) based on interpretation of 1:100,000 scale images over the highly prospective Central Andean region of Peru and northern Chile. These studies have revealed important patterns of Cenozoic structure in the region which form major controls of hydrothermal mineralization. Our studies have been acquired by the majority of the principal exploration groups active in the region.

The aim of these studies has been to map new structures and selected stratigraphic information from high-resolution Landsat data and to display these data in attributed GIS format suitable for targeting of metallic deposits. The studies have also included the identification of geomorphic and spectral features indicative of hydrothermal activity.

The original studies have now been merged into more regional groupings and are presently offered at a substantially reduced cost. Please check the GEOIMAGE website for details of costings [www.geoimage.com.au](http://www.geoimage.com.au).

The multiclient data packages include the following components:

- Digital Landsat data for the relevant standard 1:100,000 scale sheets
- Fully attributed digitised interpretation data for viewing in GIS (ArcView or MapInfo)
- Hardcopy 1:250,000 overview interpretation maps
- Reports for each study area as pdf files

**Digital Landsat Data**
The Landsat TM data used in the studies is supplied on CD ROM/DVD. The Landsat data are in the form of discrete image sets corresponding to the full areas of the 1:100,000 sheets covered by each of the studies. Each image set has been georectified to the appropriate Ingemmet 1:100,000 sheet and topographic maps where appropriate. The following image sets are provided:

- **Greyscale Band 4 image** which is suitable for structural interpretation
- **Colour Composite** (741=RGB) image - Decorrelation stretched colour composite images were used in some of the central Peru studies where it was considered that this enhancement was more suitable for interpretation of lithology and alteration. For the studies completed in 2003 and later, Landsat ETM+ imagery was used and copies of the full Landsat scenes are included in the package. In these studies, pansharpened bands 741 were used.

For some studies, alteration type images including Abrams ratios and Lizfit clay prediction images were prepared and are included in the package.

**Digital Interpretation Data**
Photogeological interpretations over the multiclient study areas have been carried out at 1:500,000 scale by Dr Colin Nash using a consistent photogeological methodology based on worldwide experience. Hardcopy 1:100,000 scale and digital GIS-based images were used to interpret lithological and structural information which were subsequently captured as fully attributed MapInfo and ArcView GIS map objects (vectors and polygons). The following types of geological interpretation data have been routinely collected:

- All high frequency structural data required to visualise regional structure (bedding traces, dips, fracture traces).

**1:250,000 Scale Overview Maps**
Digitally drafted overview maps have been prepared by a professional cartographer from the digital map data and are included in the data packages as hardcopy products and as plotfiles.

**Reports**
A report in ACROBAT pdf format will be supplied for each of the original studies. The reports describe the methodology, regional geological setting and results of each study on a sheet-by-sheet basis. An Appendix to each report contains a summary of photogeological structural and spectral anomalies on each sheet.

**Copyright and Reproduction of Data**
The maps, images and reports forming part of this study are copyright to GEOIMAGE Pty Ltd and Colin Nash and Associates Pty Ltd.
Colin Nash and Associates and GEOIMAGE are currently preparing a second generation of Multiclient Interpretation Studies over prospective portions of the Central Andes region of South America. These studies have commenced over portions of the Miocene mineral belt of southern Peru and the Maricunga-El Indio belt of northern Chile. The approximate areas are marked on the attached diagram.

The basis for the new interpretations will be orthorectified ASTER VNIR-SWIR reflectance imagery that has been mosaiced into standard 1:100,000 scale Half Degree Sheets. Dr Colin Nash will stereoscopically interpret structure and lithology from pseudo stereo ASTER images similar to the example at the bottom of this page. For each sheet we will also be preparing a standard set of ASTER alteration images.

The digital interpretation maps will contain the following information:

- All high frequency structural data required to visualise regional structure (bedding traces, dips, fracture traces)
- Interpreted locations of structures and their vergences (folds, reverse, normal, and strike slip faults; inferred faults, domes, basins, etc)
- Interpreted and inferred lithological boundaries and interpreted lithological polygons based on stereoscopic ASTER interpretation and existing geological maps
- Interpreted geomorphic/structural and spectral anomalies possibly associated with clay/Fe oxide alteration and hydrothermal activity

The studies will be available per 1:100,000 scale Half Degree Sheet and will include:

- Coregistered 15m VNIR-SWIR ASTER reflectance imagery that has been orthorectified and mosaiced.
- ASTER spectral images of highest predicted alunite group, kaolinite group and illite group minerals.
- Fully attributed digitized interpretation data for viewing in ArcView or MapInfo.
- A report in PDF format describing the methodology, regional geological setting and results of the study.

Images below: Example ASTER images of the Rio de Montosa 100K Sheet from the 2nd generation study in Chile/Argentina. From left to right the images are: Left Stereo image, Vertical image and Alunite group - kaolinite group - illite group colour composite spectral image.
GEOIMAGE IKONOS Product – Gold Coast Coastal Strip

GEOIMAGE is offering a special price for 1m Colour high resolution IKONOS satellite imagery over the Gold Coast coastal strip covering an area of 831 sq km. This satellite imagery was captured by the IKONOS satellite on 31 May 2005 and has been orthorectified and seamlessly mosaiced to create one complete and accurate dataset over this entire area.

This satellite imagery can be used for a multitude of applications for anyone requiring detailed and accurate information about the Gold Coast area. For example, real estate agencies can use this imagery to show potential buyers various properties in a specific suburb or area. By looking at this imagery, buyers can determine how close the property is to the beach, the golf course, shopping centres and schools, as well as get an overall impression of the suburb. Surveyors use this imagery when preparing quotes for developers and in describing plans without having to purchase individual aerial photographs over specific sites. Anybody wishing to add context to their GIS vectors in this area will find this imagery useful, such as for the management of powerline corridors or for attracting retailers to a shopping centre by illustrating urban growth of an area. Tourism agencies and travel agents can use the imagery to show visitors the location of hotels, theme parks, boating marinas and train stations. Any vegetation mapping in the area or landuse mapping would benefit from this imagery and this imagery is also ideal for shallow water mapping. The imagery is so accurate that you can even measure distances from it.

The IKONOS satellite imagery was captured in 3 swaths on 31 May 2005. The imagery was orthorectified using the SRTM DEM and accurate cadastral boundaries to ensure the accuracy of the imagery. This imagery allows zooming in to 1:3,500 scale and is displayed in an aesthetically pleasing natural colour. The imagery is supplied in GDA94, MGA56 datum and projection and is available in a number of different file formats.

GEOIMAGE will also be offering similar products for other areas around Australia in the near future.
Worldwide SRTM Elevation Data

The Shuttle Radar Topography Mission (SRTM) collected interferometric Synthetic Aperture Radar (IFSAR) data over land between 80 degrees North and 80 degrees South latitudes in February 2000 from the space shuttle Endeavour. The mission was co-sponsored by the National Aeronautics and Space Administration (NASA) and the National Geospatial Intelligence Agency (NGA). NASA’s Jet Propulsion Laboratory (JPL) processed the raw C band radar data into a preliminary partially finished version of terrain elevations and related products. These were subsequently finished by NGA contractors and conform to the NGA SRTM Data Products Specification and the NGA Digital Terrain Elevation Data (DTED) Specification.

SRTM DTED is a uniform matrix of elevation values indexed to specific points on the ground. The horizontal datum is the World Geodetic System 1984 (WGS 1984) and the vertical datum is mean sea level as determined by the WGS Earth Gravitational Model (EGM 1996). The elevation values represent the reflective surface which may be vegetation, man-made features or bare earth.

SRTM DTED elevation values are spaced one arc second apart (nominally 30 metres post spacing) between 6 degrees and 90 degrees latitude and spaced one arc second apart in latitude and two arc seconds apart in longitude between 90 degrees and 180 degrees latitude.

SRTM DTED values are derived from the SRTM DTED values by decimating the DTED. The SRTM DTED values are spaced 3 arc seconds apart (nominally 30 metres post spacing) between 6 degrees and 90 degrees latitude and spaced 6 arc seconds apart in latitude and 6 arc seconds apart in longitude between 90 degrees and 180 degrees latitude.

SRTM DTED values are identical at coincident 30 metres spaced points.

The finished SRTM DTED has also been edited. Spikes and wells in the data were detected and voided out if they exceed 100 m compared to surrounding elevations. Small voids (16 contiguous posts or less) were filled by interpolation of surrounding elevations. Large voids which are left in the data may be due to shadows layover poor reflective properties of the Earth’s surface or excessive noise in the data. Water bodies are depicted in the SRTM DTED and ocean elevations are set to 0 metres. Lakes of 600 m or more in length are flattened and set to a constant elevation. Rivers that exceed 183 m in width are delineated and monotonically stepped down in height. Islands are depicted if they have a major axis exceeding 300 m or the relief is greater than 15 m. The data are processed in one degree by one degree “cells.” The edges of each cell are matched with the edges of adjacent cells to ensure continuity. There may also be occasional small floating islands of data that are completely surrounded by void present in the DTED unregistered vertically due to phase unwrapping errors during the JPL processing.

Regional and continental SRTM DTED have been compared to other independent sources of elevation data to evaluate the accuracy of the SRTM data. The SRTM DTED absolute height accuracy appears to be significantly better than the 30 metre 95% confidence specification for the mission and the horizontal accuracy meets the corresponding 30 metre specification.

SRTM DTED 1 over US territory and all SRTM DTED 1 are public domain and unrestricted. Copies of the world wide SRTM DTED 1 are available on a 13 DVD set from EROS GEOIMAGE has obtained this data and for a nominal cost offers the data in user friendly formats.

The GEOIMAGE SRTM product

GEOIMAGE has located the 1deg by 1deg raw data tiles by writing a header file for each tile and then mosaicing them. The holes in the data have been filled using a minimum curvature algorithm except where they were considered too large. The 16bit signed integer ERMapper tiles were mosaiced and warped into the relevant UTM zone creating 1deg longitude by 1deg latitude tiles on the same index pattern as the GeoCover mosaics.

A colour enhanced image of each individual tile is also provided in ECW Compressed format. Each ECW colour tile has been contrast stretched to maximize the information content of the file therefore when adjacent tiles are displayed together marked edge effects are apparent. ECW files are a maximum of 100 Mb in size and are readable in MapInfo, TAB files supplied, ArcView and most other GIS programs.

SRTM-OZ

The data over Australia is available in GDA 94 datum in either lat/long or in UTM and covers the area bounded by 9 deg South to 44 deg South and 112 deg East to 154 deg East. The lat/long data is provided subdivided into the different states. File sizes vary from 133 Mb for Western Australia to 465 Mb for the Northern Territory and fit on one DVD. A coloured ECW file of the data which also includes the islands to the north of Australia is also supplied.

The area is covered by 1 deg full and part UTM tiles and the file name denotes the area covered by the mosaic eg the tile S925_srtm2.ers is in Zone 52 and covers latitudes from 1 deg to 10 deg S Individual ERMapper tiles have a maximum size of ~100 Mb.

WORLD WIDE DATA

World wide data is available in 1deg by 1deg UTM tiles in WGS 84 or by special request in lat/long projection. An ECW coloured file of the whole world at full resolution is also available (image below).

For further information please visit our Web Site or contact one of the GEOIMAGE offices.
GEOIMAGE specialize in the gridding, levelling (‘including microlevelling’), filtering both spatial and spectral of aeromagnetic radiometric and gravity data as well as the production of image quality hardcopy contour plots stacked profiles and flight line plots. Old and incomplete surveys are a specialty—we use state of the art software such as Intrepid, ER Mapper, Geosoft OASIS and a considerable amount of in-house software to address specific problems. GEOIMAGE can supply digital and/or hardcopy data from the following sources and custom process it for you at competitive prices.

**MAGNet**

MAGNet: The Multiclient Airborne Geophysics Network is a database of company funded airborne geophysical surveys. It was jointly established by GEOIMAGE Pty Ltd and Pitt Research Pty Ltd but is now controlled exclusively by GEOIMAGE.

MAGNet aims to provide:
- A centralised current and consistent database of airborne geophysical surveys ‘complementing open file surveys where appropriate’ available for resale to the exploration community.
- A mechanism which will relieve contributor companies of much of the day-to-day distractions of managing, negotiating and effecting geophysical data swaps and sales.
- A repository that meets the requirements of the current guidelines for WA Dept of Mines and Energy for the lodgment of ‘multi-client’ surveys.

The MAGNet database currently contains airborne geophysical surveys collected by BHP Billiton Rio Tinto, Newcrest Mining, De Beers Australia, and many more companies within Western Australia and the Northern Territory. The extent of these surveys is shown above.

For contributor companies, the benefits of belonging to MAGNet are:
- recoup part or all of the costs of their airborne surveying programme
- outsource the task of managing their archive of airborne geophysical data
- leave non-core activities such as geophysical data sales to an agent
- A contract agreement covering conditions of data contribution, confidentiality, sales and royalties is required to be signed by contributors.

The benefits to the purchasers are:
- improved access to existing data from a centralised, current and consistent database
- data at a cost of around 1/5th the cost of new surveys
- access to reprocessing that will offer substantial improvement to the utility of the data
- Please check with your nearest GEOIMAGE office for further details including survey coverage, costs etc or if you would like to contribute data.

**Queensland Openfile Airborne Geophysical Data**

Company airborne geophysical survey data submitted to the Queensland Mines Department is routinely processed by GEOIMAGE and added to the Queensland Openfile Database. Since 1983, companies have been obligated to submit digital data which becomes open file upon unconditional surrender of their tenement. From 1995, data becomes open file five years from the date of flying or on surrender of their ground whichever is sooner. The MIM Open Range Airborne Survey was flown in 1990 to 1992 and the total survey has now been released to open file. The data was released in 5 stages in 1992, 1993, 1994, 1995 and 1996. The image below shows the order of openfile release. The located, ‘Winzipped ASCII format’ and gridded ‘ER Mapper BIL format’ data for each release can be purchased. The data is also available for each 1:100k sheet. Check with your local GEOIMAGE office or our web site for pricing details.

The open range MIM survey was flown in 1990 to 1992 and the total survey has now been released to open file. The data was released in 5 stages in June of 1997, 1998, 1999, 2000 and 2001. The located and gridded magnetics and radiometrics, and in some cases DEM data are available for re-sale to the exploration community.

From 1995, data becomes open file upon unconditional surrender of their tenement. The located (Winzipped ASCII format) and gridded (ER Mapper BIL format) data for each release can be purchased. The data is also available for each 1:100k sheet. Check with your local GEOIMAGE office or our web site for pricing details.
Introduction
In the last decade there has been a rapid research effort into the applications of high resolution spectral remote sensing to environmental and natural resource applications. This new field of imaging spectrometry is commonly referred to as hyperspectral remote sensing to differentiate it from the multispectral data from earlier sensors such as Landsat. The multispectral sensors commonly collected data from four to seven broad wavelength bands while the hyperspectral sensors collect data from many tens to hundreds of narrow bands. This gives the ability to identify materials based on their reflectance signatures.

During the late 1980's De Beers Remote Sensing geologists discovered that reflectance spectroscopy could be applied to exploration. Attempts to use satellite and aircraft borne imaging spectrometer data to exploit this discovery were frustrated as existing instruments lacked sufficient image bands and/or signal to noise ratio. An investigation into various imaging spectrometer manufacturers worldwide was conducted. This indicated that an Australian consortium consisting of Integrated Spectronics Ltd, CSIRO Division of Materials Science and Auspace could produce an airborne instrument of original design that would overcome the limitations of existing or planned systems. De Beers commissioned a scanner from this consortium. This instrument, called the AMS, was the first in a series of instruments produced by Integrated Spectronics that are now referred to as HyMap scanners.

De Beers no longer fly the AMS scanner however an Australian archive of over 80,000 sq km of imagery is available for purchase from GEOIMAGE.

AMS Instrument
The AMS was the first of the HYMAP series of scanners and was delivered in 1996. Since that time it has been used for proprietary surveys covering 250,000 sq km in various countries.

The main features of the system are:
- Three spectrometers covering wavelength regions:
  - 500nm - 1100nm Visible to near infra red
  - 1450nm - 1800nm shortwave infra red 1
  - 1950nm - 2450nm shortwave infra red 2
- Each spectrometer images 32 bands with approx 15nm bandwidth
- IFOV 2.08mrad cross track and 2.5mrad along track
- Mounted in a Zeiss stabilised platform to minimize distortions during data collection
- Fully calibrated system: Data can be supplied in formats ranging from raw data to radiance or atmospherically corrected. All ancillary information such as dark current is also provided
- GPS and inertial navigation gyros are attached to the system to provide data for automated geometrical correction
- Signal to noise ratios are approximately 500:1 for a 100% reflector across all spectrometers

Archived Data
The archived data over Australia is available as raw data or GEOIMAGE can arrange to have the data geometrically and spectrally processed. Hyperspectral remote sensing data requires significantly more processing than multispectral data. The six processing stages for HYMAP MK1 data are:

SYSTEM CALIBRATION Completed prior to and post survey. Produce calibration files containing band centre wavelengths and gains for use in converting data to radiance
PREPROCESSING Convert raw data to an image cube suitable for further processing. Apply system corrections and convert data to radiance
ATMOSPHERIC CORRECTION Convert radiance data to reflectance
SPECTRAL CLASSIFICATION Identification of end member spectra and their distribution within the image. The result of this process is a mixed image comprised of bands that map the distribution of each end member.
SPECTRAL COMPONENTS MAPPING Production of colour composite and index images that highlight the distribution of spectrally interesting components.
GEOMETRICAL RECTIFICATION Warp output images to required map projection production of mosaics and thematic maps

ALTERATION MINERAL MAPPING
Distribution of minerals in red, green and blue on a greyscale background

Phengite
Nontronite
Fe Oxide

Spectra of the end member minerals mapped. The red, green and blue spectra match the colours in the image.
GEOIMAGE has produced a digital, georeferenced 1:100,000 map sheet dataset that can be incorporated directly into your GIS and used as a backdrop to your mapping applications. The Raster 100K dataset has been produced by scanning both published and unpublished 1:100,000 topographic scale maps over mainland Australia, rectifying them to standard map datums and projections and reformatting them to 2m resolution JPEG or ECW files. The map sheets were also border trimmed and mosaiced into seamless map tiles which are provided with both ArcView and MapInfo header files for integration into your GIS.

Only the AUSLIG and Department of Defence 1:100,000 topographic map sheets are available as Raster 100K products. The Raster 100K dataset is unavailable over Tasmania and some parts of western NSW and over the Tarcoola 1:250,000 map sheet in South Australia. The rest of Australia is covered by this georectified and digital dataset.

The Raster 100K dataset can be purchased as:
1. Standard 1:1 million map sheet areas
2. Australia, States and Northern Territory coverages, and
3. Individually listed sheets (with a minimum of 10 sheets)

Some of the applications of the Raster 100K dataset include providing a backdrop for mapping flight lines for aerial surveys; utilities, infrastructure and corridor planning; and locating roads, water courses and urban reaches within known co-ordinates or polygons. Many of the clients who have already purchased the Raster 100K product include the Queensland State government, most of the private mining and exploration companies in Australia, many local governments and most other organisations that specialise in spatial information.

Prior to the supply of Raster100K, a License Agreement must be completed and returned with the order form. For further information and copies of order forms, please visit our web site or contact one of the GEOIMAGE offices.

### Published Maps

Clean published paper map sheets were scanned at 200dpi and 8bit colour and were rectified using a network of control points over each individual map sheet.

The published/unpublished map sheets were reprojected into lat/long, border trimmed and joined into a seamless mosaic. The individual map sheets were then generated as JPEG and ECW UTM files in AGD66 and GDA94 projections with headers for MapInfo and ArcView.

### Unpublished Maps

Unpublished map sheets have been scanned off films containing the original plotted information compiled from aerial photography. In most instances the unpublished sheets had two layers available:
- Height Information includes 20 metre interval contours (in some instances 10m contours) and spot heights.
- Planimetry Information includes roads, rail fences, sand dunes, drainage and other topographic information. In some instances, the sand dunes and drainage were also available as a separate film and were scanned separately.

The individually scanned sheets were processed independently and then combined as a colour image raster. The colour scheme for the unpublished RASTER 100K sheets is as follows:
- Where height and planimetry were available: contours in brown and planimetry in blue
- Where height planimetry and sand dunes were available: contours in brown, planimetry in blue, and sand dunes in dark red
- Where height drainage and planimetry were available: contours in brown, drainage in blue, and planimetry in dark red
ER Mapper

Helping people manage the earth  
http://www.ermapper.com/

ER Mapper is proud to be the leading desktop image processing software developer. The ER Mapper product family provides your imaging solution for any application.

- Prepare your imagery for use in any application with ER Mapper. The latest release of the No. 1 image processing software package features orthorectification, automatic mosaicing and colour balancing.
- ECW JPEG 2000 Compression Wizard
- Lossless and Lossy Compression Wizard
- Reprojection Images on the Fly
- Geocoding and Orthorectification Wizards
- Spatial Analysis and Image Enhancement
- Map Production and Annotation Tool
- ID and Multi Surface Transparency Views
- Use your imagery in any application with Enhanced Compressed Wavelet ECW compression technology. This fundamental breakthrough in image compression allows all your desktop imaging applications such as ArcView®, MapInfo®, AutoCAD Map® and Microsoft® Office to incorporate large imagery.
- Serve your imagery to any application via the Web with the latest addition to our product family: the Image Web Server V1®. Based on the patented ECW technology, the Image Web Server allows users to view and work with imagery over the Internet or an intranet. Examples of this technology can be found on the following site: http://www.earthetc.com/

MapInfo

http://www.mapinfo.com/

MapInfo is a global software company that integrates software data and services to help customers realise greater value from location-based information and drive more insightful decisions. We help our customers in government and business meet a diverse set of needs - from asset management and network planning to site selection. MapInfo Professional V8® was released in Australia in June 2005.

MapInfo Professional is a powerful Microsoft Windows-based mapping application that enables business analysts and GIS professionals to easily visualize the relationships between data and geography. With MapInfo Professional you can perform sophisticated and detailed data analysis by leveraging the power of location, including location in your decision making and daily operations. It can help you increase revenue, lower costs, boost efficiency and improve services. Use MapInfo Professional to:
- Create highly detailed maps to enhance presentations and aid in decision making.
- Analyze and visualize data in spreadsheets and charts.
- Perform sophisticated and extensive data analysis.
- Understand customer and marketplace demographics.
- Manage geographically based assets such as stores, people and property.
- Plan logistics and prepare for emergency response.

The award-winning MapInfo Professional package includes a built-in geocoder over 100 MB of data and an extensive collection of pre-designed maps. It’s simple to use, powerful and easily integrates with other mapping applications.

PCI Geomatics

http://pcigeomatics.com/

PCI Geomatics is a world leading developer of Geomatics software ‘geographic modelling, measurement analysis and output’ solutions based on its remote sensing digital photogrammetry, spatial analysis and cartographic editing programs. The company is privately held Canadian Corporation headquartered in the Toronto area with another large facility in Ottawa. Since its founding in 1982 PCI Geomatics has continued to grow as a result of innovative thinking, active involvement in the geomatics community and alignment with other companies with innovative solutions. PCI Geomatics has world-wide agreements to resell the Xvelco Corporation’s EarthView® software, Definients Imaging GmbH’s eCognition software and GeoTango’s SilverEye software.

The starting software core is Geomatica Fundamentals which includes solutions for geometrical correction, data visualization and editing image classification and cartographic map production. Highlights of Geomatica Fundamentals include Focus, a complete data visualization and processing environment, and OrthoEngine technology designed to perform basic geometric correction and mosaicing. An upgrade to Geomatica Prime gives full access to the advanced ensemble of integrated tools for your higher geospatial processing needs. Geomatica Prime offers all of the advantages of Geomatica Fundamentals plus full access to over 300 geospatial processing algorithms. You can also access the entire image and vector processing power through easy to use command line or visual modelling environments.

Specialized image processing modules can be added to Geomatica Prime and these include the Advanced Optical Advanced Radar and Advanced Hyperspectral packages, and you can improve the quality of your images with the Advanced Pan-sharpening and ATCOR add-on modules.

The OrthoEngine interface is a powerful photogrammetric tool which can be added to Geomatica Fundamentals and is designed to perform basic and advanced geometric corrections as well as geospatially mosaic remotely sensed imagery. OrthoEngine Add-On Modules Airphoto-Satellite High Resolution Satellite and Generic and RPC modules contain advanced models designed for efficient and accurate processing of these data types. Models are included that will allow for easy precise orthorectification of the full image and vector processing power through easy to use command line or visual modelling environments.

OrthoEngine image processing can also be enhanced with additional OrthoEngine Advanced Add-On packages. The Productivity Tools package includes a set of functions designed to improve your image processing efficiency. For accurate DEM extraction there is a module which works with both optical imagery: the Automatic DEM Extraction and a module for radar images: RADARSAT DEM Extraction. The ID Stereo package makes stereo viewing of images from any sensor model easier and more affordable than ever.

Able Software Corp. is a leading software developer for raster-to-vector conversion. ID image processing and rendering applications including RVT
http://www.ablesw.com/RVTindex.html

RVT for Windows (9X/NT/2000/ME/XP) is an automated raster to vector conversion software for automated map digitizing. GIS data capture and CAD conversion applications. The software supports full automatic vectorization and interactive line tracing from scanned maps and drawings. RVT inputs bit level greyscale and colour images in TIFF, GeoTIFF, GEC JPEG, RLC, PNG or BMP formats; it exports vector data to ArcView Shapefiles, Arc/Info Generate, MapInfo .MIF/.MID, AutoCAD DXP, IGES, STL, VRML and MapGuide SDL formats. RVT supports support on-screen image and vector editing and georeferencing using GeoTIFF or user specified control points. Image rubber sheeting, colour image classification and separation, text symbol detection and recognition “OCR” automatic polygon layer creation “ID” DEM and Grid creation and “ID” display and image editing. RVT is currently being used in more than 40 countries for mapping and GIS database creation applications.
Why GEOIMAGE?

There are many reasons to consider talking to GEOIMAGE when you are thinking about spatial information. Besides our friendly and efficient service, below are some of the main reasons why our loyal client base extends across Australia, and throughout Asia, Africa, North and South America:

Independent – GEOIMAGE is independent of all satellite operators, and therefore not restricted to providing only one or two types of imagery. GEOIMAGE can thus source and supply any type of satellite imagery to suit your specific application. Because GEOIMAGE is an independent reseller of all available commercial satellite imagery, you can be sure that our advice is unbiased and offers the best solution to your problem.

Flexible – GEOIMAGE not only provides the best satellite imagery to suit your needs, we can also process the imagery to make sure that it seamlessly integrates into your GIS or other applications. We will listen to you and make sure that you receive the data in the correct format to suit you and your resources.

Reliable – GEOIMAGE has been in the business of providing and processing spatial information for over 16 years, and has expanded over the years with three offices servicing our clients from many differing backgrounds. You can be assured that when you need to come back to us, we will be here to assist you into the future.

Knowledgeable – You will have the same person working with you from the start of your job to the end. The person who firsts advises you on what imagery will best suit your application is the person who also processes your imagery and makes sure that it arrives in the format that you need. This means that the person you are speaking to on the phone has first hand knowledge of what is required for your job and you can be assured that the information you receive is up to date and accurate. Our staff have experience in geology and geophysics, natural resources, mathematics and IT, government applications, mapping and GIS.

Global – GEOIMAGE has access to imagery from around the globe, so if you have a mining application in China, a utilities application in Zimbabwe or require imagery over Antarctica, we can provide the spatial imagery that you need. Don’t let your location restrict you in your choice.