This special compendium of "Airborne Multispectral Applications...Worldwide" is an imagery compendium which acknowledges the accomplishments of our customers. We take pride in presenting to you this wide variety of high quality applications material.

It is not possible to include rigorous technical descriptions of the objectives, procedures, and processes used by our customers for the applications illustrated in this document. However, we have provided complete addresses for all customers whose data are included to assist you in receiving more information.

If you now own or have operated Daedalus systems in the past, the editor of Daedalus International is interested in receiving imagery and information from your organization concerning applications of these systems. Please send imagery, captions and text to:

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DAEDALUS

Special Compendium

Airborne Multispectral Applications...Worldwide

TABLE OF CONTENTS

DAEDALUS
Special Compendium

Airborne Multispectral Applications...Worldwide

The rapidly increasing population and rapidly decreasing undeveloped land and natural resources on our planet have created an urgent need for more sophisticated and comprehensive management tools in all aspects of man's endeavors. Digital geographic information systems (GIS) are being implemented by the thousands by earth science research and operational management professionals throughout the world. Moreover, GIS is rapidly becoming the basic tool for the management of distributed facilities such as power networks, pipelines, railroads, and highway systems on an international basis. In addition, the worldwide availability of Global Positioning Systems (GPS) satellite data has provided an economical solution to the problem of accurately locating earth surface features anywhere on the planet.

GIS and GPS technologies are now being combined to create an awesome capability to compile, correlate, analyze and display geographic information for almost any purpose. Floods, forest fires, severe storms and oil spills require real-time or near-real-time systems to assess damage and manage resources for mitigation efforts. Management of agriculture and forest resources require weekly or monthly data to monitor changes, predict yields, and to plan activities to maximize harvests. Monitoring and managing air and water pollution, biodiversity and global carbon and ozone conditions require vast amounts of data on monthly, annual, and decade time intervals.

These new technologies have created an exploding demand for accurate, timely, and continuous spatial data on earth surface features that can only be met by imaging systems operating from aircraft or space platforms. More and more GIS system users are realizing that their data needs can only be satisfied by aircraft imaging systems which can provide the flexible spatial resolution, spectral discrimination, and timeliness capabilities required by their particular problems.

Daedalus has recognized these emerging needs for many years and we have tailored the development of our family of airborne multispectral and hyperspectral imaging systems to meet these needs. A brief summary of the entire Daedalus product line of airborne imaging systems is presented on pages 30 and 31 of this special compendium along with a table indicating some of the special applications for which our customers are now employing the systems. All of these imaging systems are now digital with computer compatible recording systems, real-time display, built-in GIS receivers or interfaces, touch panel control systems, built-in test capabilities, and are designed to facilitate modification or upgrade to meet changing customer requirements. More importantly, they have all been designed and engineered to be operational systems with full documentation and are supported by Daedalus spare parts and engineering assistance no matter where they are operated in the world to assure our customers of many years of useful service.

The Daedalus commitment to airborne multispectral remote sensing spans more than 25 years and our programs for continuous product improvement coupled with an aggressive new product research and development program produces new and improved airborne remote sensing products on a continuing basis. We are now exploring digital camera technology which promises to produce low-cost, high spatial resolution, digital imaging systems that can meet many of the GIS needs for small projects or those that require frequent update. Our development of hyperspectral remote sensing techniques has resulted in two new systems that have expanded spectral discrimination capabilities dramatically but there is much more to come.

Daedalus is proud of its achievements as the leading developer and manufacturer of airborne multispectral imaging systems during the last 25 years. We pledge ourselves to continue to maintain the high standards for engineering design and customer support that has earned us the confidence of customers throughout the world who have purchased and are operating nearly 100 Daedalus multispectral systems - some of them still operating after 20 years.

We are even more proud of the accomplishments of our customers who have pushed the state-of-the-art in airborne multispectral remote sensing from a research curiosity to a valuable and accepted technique to assist in the solution of a myriad of environmental and resource management problems throughout the world. It is to these customers and users of Daedalus remote sensing technology that we dedicate this special applications compendium which highlights some of the work performed by our customers and friends.

VITAL ROLES FOR AIRBORNE REMOTE SENSING

CSIRO

Airborne remote sensing plays a vital role in providing data for resource management and environmental monitoring in many countries. Airborne remote sensing services do not compete with space-based services, rather they complement and extend the capability of such techniques.

Remote sensing from aircraft can include a number of active and passive techniques using lasers, altimeters, radars, and multispectral imagers. Airborne platforms provide a convenient means of obtaining high resolution data at closely spaced intervals in time, especially during times of flood, fire or other environmental disasters. Further, aircraft sensors give higher spectral and spatial resolution than most space-based systems, so that it is possible to study small-scale dynamic surface features in detail.

Use of aircraft also makes it possible to simulate the performance of space-based sensors and to develop new remote sensing technologies before the design and manufacture of the space instrument. While problems of vibration and the motion of the aircraft make airborne sensors much more difficult to design and use than space sensors, they remain essential as both "proof of concept" and operational systems.

CSIRO AIRCRAFT AND SENSORS

CSIRO has, for many years, operated a Fokker F27 aircraft to carry out a wide range of scientific research and technology development programs. In particular, the F27 has been the flying test bed for the Atmospheric Pressure Sensor (APS) and the CO_2 Infrared Laser. The APS is currently undergoing further tests, and a Phase A design for a space instrument is being carried out.

CSIRO now offers other aircraft for specific purposes. For example, CSIRO is flying the Daedalus scanner in a Learjet (Figure 1). Since it is frequently necessary to cover large distances over Australia to gather data, this is a particularly effective aircraft because it can fly faster and farther than an F27. As new CSIRO technology development programs–such as imaging spectrometry–come on-line, we shall continue to use a variety of aircraft to test sensors, collect data, and provide information to users.

The Daedalus Airborne Thematic Mapper (ATM) instrument is now commercially available in Australia for airborne thematic mapper missions. CSIRO owns the refurbished ATM scanner and the company Air Target Services P/L. Nowra, under license to CSIRO, operates the scanner in a commercial environment. The instrument is routinely engaged in environmental, geomorphological and water study programs both in Australia and overseas. In the summer period the aircraft is on standby to regional fire service organizations for infrared bushfire front detection and imaging.

AIRBORNE PLATFORM

The Learjet operates at a maximum altitude of 12,500 m, at an economical cruise altitude of 11,000 m at 700 km/hr air speed, and may travel approximately 3,600 km on maximum fuel. Access to aircraft crew and airfield is unrestricted. The aircraft is installed with a Global Positioning System (GPS) and records of start and finish of each run are logged.

The Daedalus scan head is mounted in a modified "RC-10 camera port" located in a special Learjet door fixture– the lower section of the standard split door entrance. The scan head lies outside the pressure cabin neatly below a pressure dome protruding into the cabin area. The scanner mechanically corrects for roll to ±15° by means of a gyroscope. As a requirement for imaging the 8.5-13.0 μm thermal infrared spectrum, the scanner views the ground track surface directly without the use of an intermediary glass pane.

BUSHFIRE MAPPING

The Learjet gave fire fighters of the New South Wales Department of Bushfire Services valuable information during recent bushfires. The aircraft was extensively used for fire front mapping and spot fire detection. During a 7-day period the Learjet flew most days and every night gathering data on terrain and fires over 63,000 km², and giving detailed infrared images of the bushfires. Figure 2 shows two ATM images of a bushfire near Armidale, New South Wales. The image on the left is a false color image (visible) and the image on the right is from the thermal infrared channel showing how it penetrates the smoke.

The Learjet is an ideal platform for use of the Daedalus scanner in this role. Operating from an altitude of 7,600 m at speeds near 700 km/hour, the plane performed terrain and fire imaging at a rate of about 5,000 km² per flying hour. The images were available to the fire officers on board the aircraft immediately after each overpass. This permitted immediate transfer of critical fire position information to a base map, ready for facsimile transmission to fire authorities in regional centers, and speeding the dispatch and positioning of fire fighters.

Figure 1

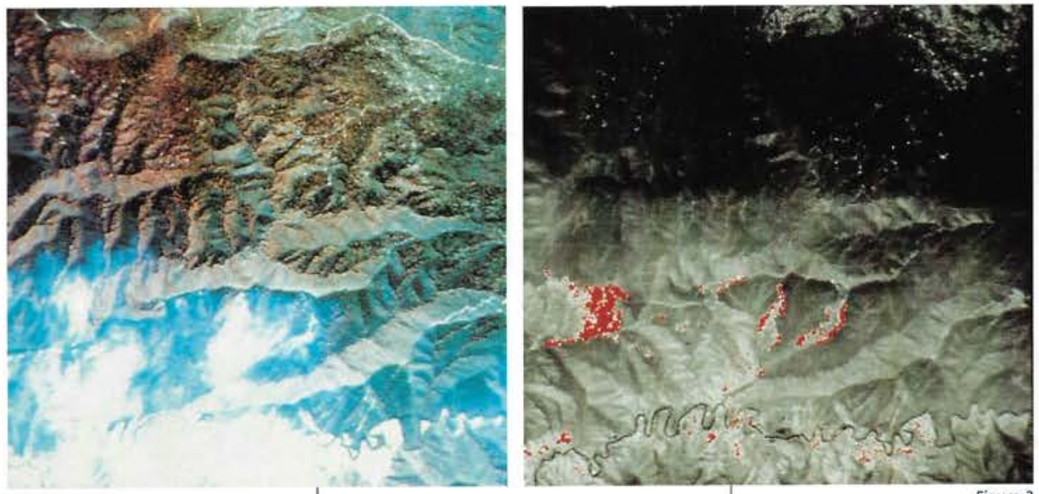

Figure 2

At an altitude of 7,600 m, the scale of the image produced is about 1:100,000, allowing rapid and reliable manual transfer of fire information to a similar scale topographical map. The on-board GPS gave accurate latitude-longitude information during flight, allowing overlapping flight segments to be easily planned.

During daytime flights, data from eleven wavelengths was collected to allow detailed analysis using image processing systems. This data will be used for research on fire behavior.

The operators of the "Airfire" service, based in Nowra, New South Wales, say it is uniquely able to gather positional information on fire fronts and spot fires through thick smoke (Figure 2), day or night, at speeds achievable only with a jet aircraft. Air Target Services will continue this service with emphasis on providing fast response during the bushfire season.

ALGAE BLOOM MAPPING

In the month of February, between 12:00 and 12:20 pm, the CSIRO Office of Space Science and Applications (COSSA) Research Aircraft Facility F27 and a Fleet Support Learjet flew over Lake Mokoan in NE Victoria, Australia. The aircraft were carrying (respectively) an airborne scanner designed to map variations in ocean chlorophyll (the "Ocean Color Scanner", or OCS, a developmental instrument package being assessed by CSIRO for its potential to study low intensity radiation from the sea) and the Daedalus ATM. A CSIRO team carried out ground based measurements of atmospheric radiation and lake reflectance spectra, and a Rural Water Commission of Victoria team took water quality samples. At the time, there were extensive patches of Microcystis spp. cyanobacteria (i.e. blue-green algae) in the north-east end of the lake. In addition to field data on atmospheric conditions, spectra of Microcystis patches were taken for later analysis.

The primary objectives of the mission were to evaluate the performance of the scanners, define the requirements for their future use and to provide advice to the Murray Darling Basin Commission on the use of the scanners for monitoring inland water quality and, in particular, the environmental conditions leading to algae blooms. Both scanners acquire multispectral imagery which may be analyzed using computer based image processing methods. With appropriate information on the atmospheric conditions during the flight, the scanners provided measurements of the spectral distribution of radiation leaving the water volume, as well as (in the case of the ATM thermal channel, 8.5-13.5 μm) the temperature of the surface. It is well known that such measurements can separate different water masses on the basis of their physical properties such as turbidity, light penetration, color and surface temperature. The images produced by the scanners provided this information over a large area within a short time interval and, therefore, captured the spatial variation and relationships among the physical properties. In this way, they work well with sparse ground-based surveys which normally sample small areas either intensively or over extended time periods.

A specific focus of the exercise was to establish the logistical and analytical requirements which would make the ATM and/or OCS data timely and useful inputs for monitoring conditions leading to algae blooms like the ones occurring at Lake Mokoan (Figure 3, Algae Bloom and the Field Site; Figure 4, Resampled ATM Data; Figure 5, Thermal Image Detail; Figure 6, Temperature/Algae Associations–*page 6*) and in other water bodies in the Murray Darling Basin during the summer months.

The Daedalus ATM provides a good overall set of spectral bands for inland water mapping and monitoring. Its calibrated thermal channel is especially useful, and allows the spatial dynamics of temperature stratification and mixing to be sensed in the same context as other water parameters such as turbidity and phytopigments. It also has well developed logistical procedures for data acquisition planning, collection and dissemination among alternatives currently available in Australia.

Dynamics are the key to understanding algae blooms and remote sensing provides a spatial time slice across the rapidly changing water surface. To successfully use remote sensing, its models and relationships need to be validated in the temporal and spatial frame appropriate for water sampling so that it can be used to extend that sampling framework

away from a sparse set of detailed measurements to the broad spatial view of the water body and its dynamics. In-water and surface radiometry at the time of field measurement can provide the link between water properties and spectral measurements. Modeling also allows surface measured spectra and airborne spectra to be related. In this way, the mismatch between the time and space scales of in-water sampling and airborne remote sensing can be removed. The possibility exists to use the tools outlined in this report extensively in coming summers provided the support, basic studies and developments are undertaken.

Through the worldwide activities of companies such as Aerodata and Geoscan PTY., Australia has a proven record of commercial success in technology development and the provision of airborne remote sensing services. CSIRO will continue to work closely with commercial operators to ensure that Australia retains its lead in world markets.

Material on algae bloom mapping was provided by David L. B. Jupp et al, CSIRO Division of Water Resources and David Parkin (COSSA). The report is entitled, "The Potential Use of Airborne Scanning for Monitoring Algal Dynamics in Australian Inland Waters".

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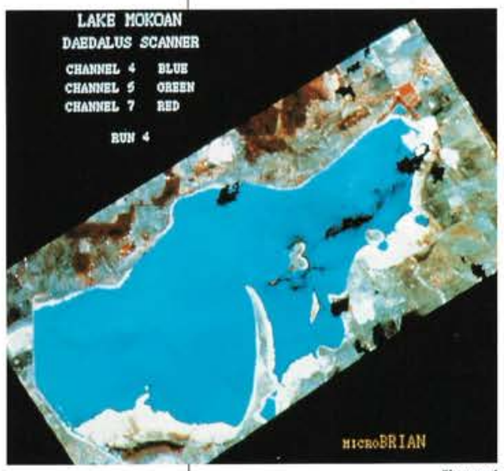
Figure 3



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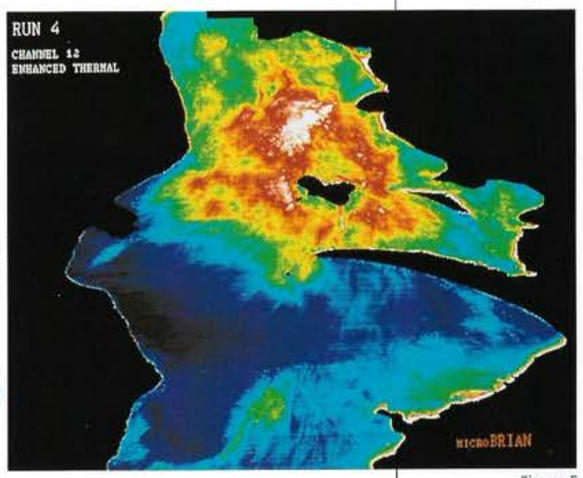

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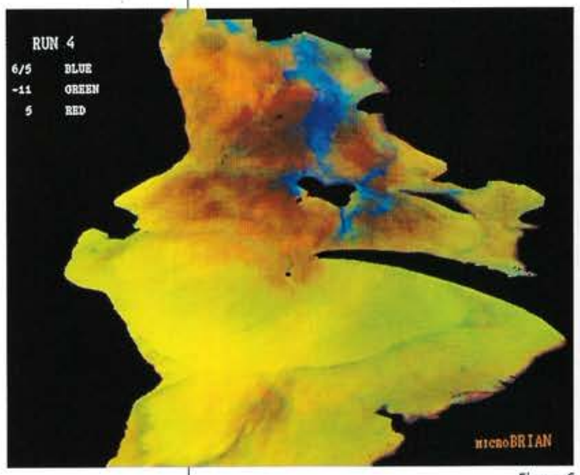

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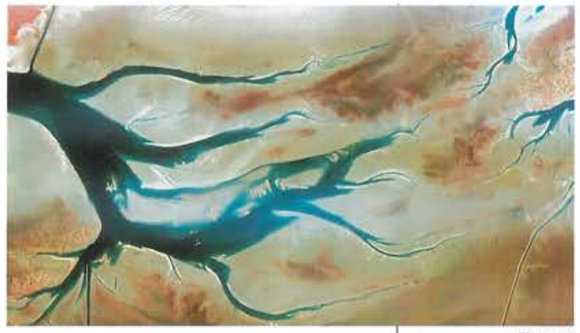

Figure 1

Figure 2

GEOSCAN GmbH performed an ESA Pilot Project (PP2-D 19), in which the Daedalus Airborne Multispectral Scanner (AMS) was used, aimed at mapping important ecosystem factors in the tidal flat area between the coastline and the island of Spiekeroog, Germany. In this pilot project diverse remote sensing instrumentation was used. The project was also conducted to show the possibilities of application of the ERS-1/SAR radar. The monitoring procedure was covered by data from micro scale (aerial photo, airborne scanner) to macro scale (LANDSAT-TM, ERS-1).

By means of on-site investigations and the use of the wadden sea data base (WADABA), data acquisition started at the lowest altitude level. The second altitude level constituted a color IR airborne survey flight and, parallel to it, a Daedalus AMS flight. Only the AMS data is presented here. The highest altitude and most comprehensive data acquisition level comprised LANDSAT TM and ERS-1 data.

The constant dynamics of the ecosystem wadden sea, caused by tidal currents, required a color IR and a synchronous scanner flight for the verification of the satellite data. The airborne sensors supplied up-to-date uncoded data. These data served as an update of the existing obsolete map of tidal flats that contained only a limited amount of information and is influenced by the cartographic processes.

The Daedalus AMS data were collected as a 6-channel data set and enabled a multidimensional classification following geocoding and radiometric correction. Furthermore, certain channels that contained information relating to soil moisture or growth of seaweed could be evaluated separately. This was possible because the reflection characteristics of the different types of tidal flats and types of shells were already available from earlier investigations. By means of unsupervised cluster analyses, a water and seaweed (green algae, diatoms) chart could be drawn in order to mark the final sediment classification which was only based upon uncovered tidal flat surfaces.

Images shown in Figures 1 and 2 are mosaics of 4 strips of Daedalus AMS data (channels 7/5/3). The organic layers, in red/red-brown colors, are changing over time (a very remarkable fact). These organic layers consist mostly of diatom algae caused by the high nitrogen inputs from agriculture along the coast.

In addition to the Daedalus AMS data of 0.42 µm-1.05 µm, the thermal channels of 3.0 µm-5.5 µm and 8 µm-12.5 µm were used. Especially during nighttime, temperature differences could be observed because of different moisture of the sediments. Due to the heat capacity of the water, dry areas showed up colder than wet areas with higher temperatures.

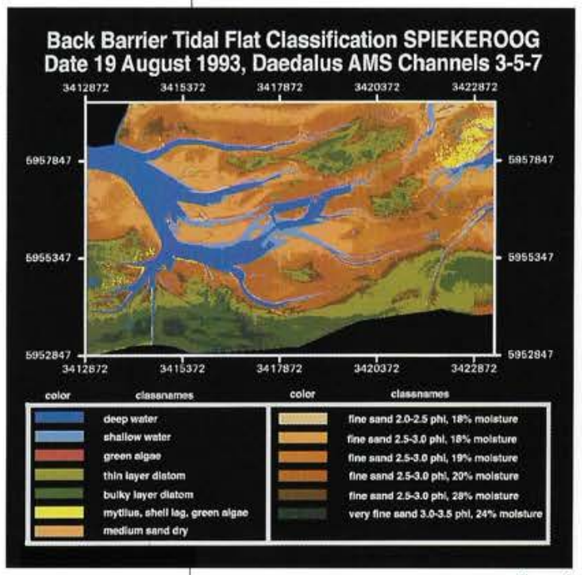

Figure 3

The high spatial resolution of the Daedalus AMS provided precise classification and mapping of the temperature of the tidal flats as well as an assignment to the moisture and grain size classes (Figure 3).

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Figure 1

Figure 2

NASA/Ames Research Center located at Moffett Field near San Francisco, California, has operated a high altitude aircraft program since 1971. Three ER-2 (Figure 1) and one C-130 earth resources survey aircraft are flown from various deployment sites in support of scientific projects sponsored by NASA and other federal, state, and university investigators.

The NASA ASAP uses the ER-2's as readily deployable, high altitude sensor platforms for the collection of remote sensing and in situ data on earth resources, celestial phenomena, atmospheric dynamics, and oceanic processes. Additionally, these aircraft are used for electronic sensor research and development at sites in Kansas, Texas, Virginia, Florida, and Alaska. ER-2's have also been used in cooperative international projects flown from deployment sites in Great Britain, Australia, Chile, New Zealand and the Azores. The C-130 has also conducted numerous foreign and domestic deployments with the TIMS instrument.

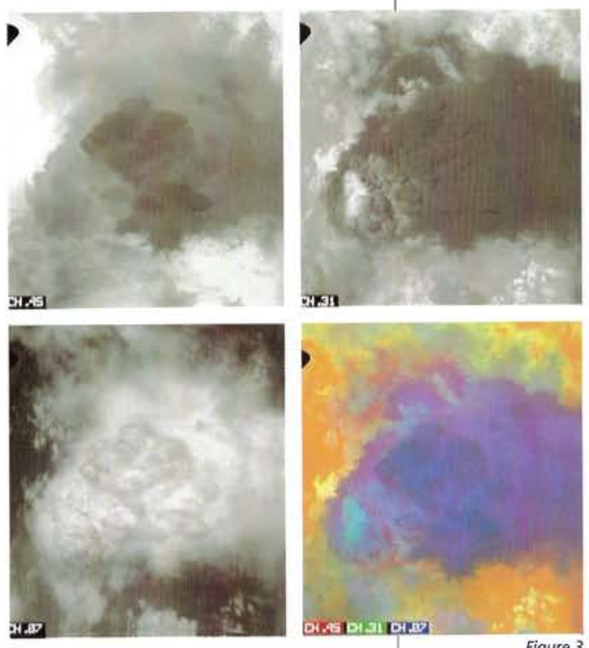

Figure 3

NASA/Ames ER-2 aircraft platforms can accommodate a variety of sensors; since 1975, the list has included a number of Daedalus airborne scanners. Many satellite simulation studies have been accomplished by NASA using Daedalus scanners specially designed to meet their specifications for wavelengths and channel configuration. Several Daedalus airborne scanners have been developed as a result of these simulation studies including the Multispectral Scanner (MSS), the Airborne Thematic Mapper (ATM), the Thermal Infrared Multispectral Scanner (TIMS), the Airborne Ocean Color Imager (AOCI), and the MODIS Airborne Simulator (MAS) systems. NASA/Ames owns and operates each of these systems, which are commercially available from Daedalus.

The four images displayed on these pages are examples of some of the types of data acquired by NASA using Daedalus airborne sensors:

Figure 2. Mississippi River Flood. Acquired by the ER-2 from 65,000 ft. with the MAS sensor. The resolution is 50 m, using bands (7=R, 2=G, 1=B) approximate a color infrared composite. It shows the swollen confluence of the Mississippi, Missouri, and Illinois Rivers at St. Louis.

Figure 3. MAS image of a large cumulonimbus cloud over the Solomon Sea. Acquired at 65,000 ft., bands 7 (0.875 μm), 31 (3.725 μm) and 45 (11.002 μm) are shown individually and as a color composite. These data were collected for the international TOGA COARE experiment, investigating the interaction between ocean and atmosphere over the warm pool region in the western Pacific Ocean.

Figure 4. The Mississippi Delta employing the AOCI sensor. Bands 5, 3 and 2 show the sediment transport and deposition patterns from Breton Sound to Southeast Pass. Image resolution is 50 m.

Figure 5. San Diego, California sewage spill. Acquired with the AOCI sensor. A rupture in an offshore pipeline (lower left) caused a large quantity of untreated effluent to be released into the Pacific Ocean for several weeks, which appears as a reddish plume. Bands 6-3-2 (R-G-B) show the water color, while band 4, which was set at a lower gain, is used over land. Kelp beds, which also have a reddish signature, are masked in green using a NIR/Red ratio.

Figure 4

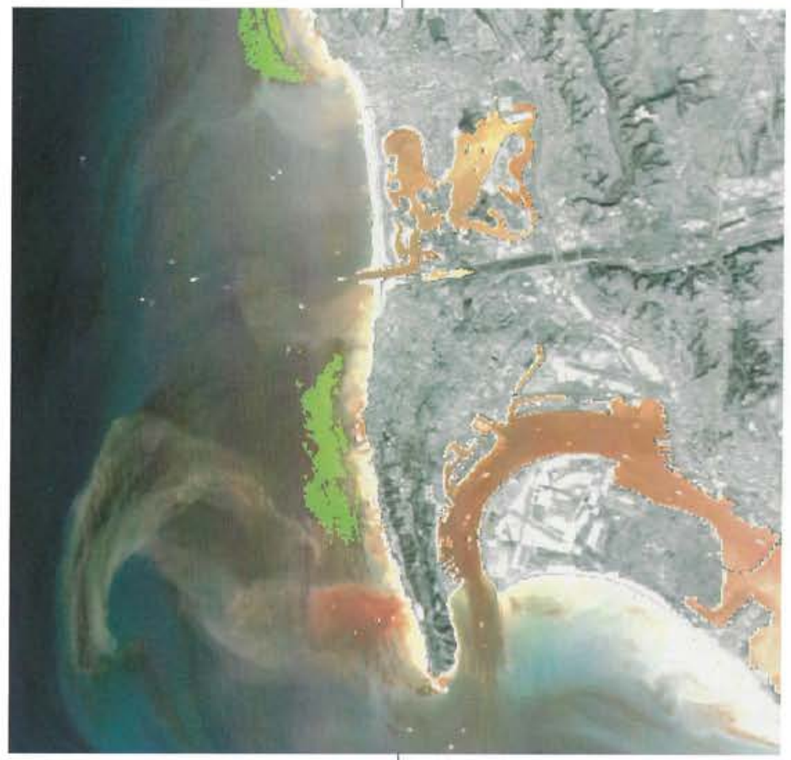

Figure 5

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AN INTRODUCTION TO HYPERSPECTRAL DATA ACQUISITION AND IMAGE PROCESSING

The Analytic Sciences Corporation (TASC)

Until now, Earth remote sensing has been highly influenced by the limitations of airborne and satellite scanners and by the computer system used to process their data. Multispectral scanners have been characterized by the large number of spatially distributed pixels they provide. The spatial resolution of these sensors has permitted large-scale scientific studies and has provided tools for various commercial enterprises. However, the spectral resolution of these sensors has been limited to a few fairly wide bands in the visible and infrared, hampering both scientific and commercial exploitation of remote sensing.

Hyperspectral instruments, such as the Daedalus Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) Figure 1, represent an important new addition to the family of airborne scanners. This new generation in remote sensing instrumentation provides both high spatial and high spectral resolution. With over 100 channels of spectral information, hyperspectral scanners enable finer discrimination of material classes and facilitate studies into the detailed physics and chemistry of the Earth's surface.

But, hyperspectral instruments produce an order of magnitude increase in the quantity of data which can be processed to meet many new and exciting challenges. And of greater importance, these scanners will provide high spectral resolution consistent with non-imaging spectrometers but not a feature of past imaging sensors. So, while traditional image processors have been designed to handle data from conventional imaging sensors, such as Landsat or SPOT, they are woefully unsuited to the requirements of hyperspectral remote sensing. Off-the-shelf image processors cannot handle either the quantity or the new type of data associated with hyperspectral scanners, but the TASC Multispectral Interactive Data Analysis System (MIDAS™) can.

The first Daedalus MIVIS and TASC MIDAS™ systems are owned and operated by Consiglio Nazionale delle Ricerche (CNR) in Italy.

The image in Figure 2 was produced using TASC MIDAS™ to process the MIVIS data acquired during the first airborne tests in Italy. The scene is in natural color and shows a portion of the City of Parma.

Figure 1

Figure 2

The Image was geometrically corrected by the TASC MIDAS™ production processor using Position and Attitude Sensor (PAS) data recorded on the MIVIS data tape. The current PAS data is available for each scan line and eliminates the need to use ground control points.

The following page describes the status of the CNR program as this compendium goes to press.

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CNR LARA PROJECT, ITALY

CNR

Figure 1

The LARA Project (Airborne Laboratory for Environmental Studies) was established within the Italian National Research Council "Strategic Project for Climate and Environment in Southern Italy".

The LARA Project provides airborne remote sensing data to the national and international scientific community utilizing its scientific instruments aircraft, the CASA C200/212 (Figure 1). The aircraft is modified to accommodate additional instruments.

MIVIS HYPERSPECTRAL IMAGING SPECTROMETER

The Project owns the hyperspectral imaging system, the Daedalus Multispectral Infrared and Visible Imaging Spectrometer (MIVIS). This instrument is considered the first of a family of new generation imaging spectrometers developed for use in environmental remote sensing. It is designed as a modular instrument and consists of four spectrometers: one in the visible region of the spectrum (20 channels), one in the near-IR (8 channels), one in the mid-IR (64 channels) and the thermal-IR (10 channels) for a total of 102 spectral channels. MIVIS permits accurate definition of absorption features from a variety of materials providing information for scientific disciplines such as agronomy, botany, geology, atmospheric science, and others.

Figure 2

MIDAS™ DATA ANALYSIS SYSTEM

The Headquarters of the LARA Project (see Figure 2) is in Pomezia, Italy (located near Rome) where the TASC Multispectral Interactive Data Analysis System (MIDAS™) is installed. MIDAS™ produces and analyzes the MIVIS image data collection. MIDAS™ software can also process data acquired with other sensors.

The LARA Project tasks are: maintain and operate the MIVIS instrument; and preprocess, distribute and archive MIVIS hyperspectral data and other remote sensing data as complementary for potential integration with hyperspectral data.

GROUND RECEIVING STATION

The city of Pomezia also has a ground receiving station for NOAA meteorological satellites series. With the Southern Italy Demonstration of Remote Sensing Applications (SIDERA) program, the Project acquired an airborne infrared false color and black & white high altitude large format camera and an airborne Synthetic Aperture Radar (SAR) for surveys of southern Italy.

The CNR LARA Project is intended to help other establishments gain stronger research cooperation between Italian and foreign scientists by means of joint scientific investigations on environmental problems.

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DLR

For over 20 years major research establishments, universities and industry in the Federal Republic of Germany have been engaged in remote sensing in a wide variety of contexts. Remote sensing methods have increasingly found their way into the fields of regional planning, cartography and, to a growing extent, early detection of environmental damage. In particular, this involves the complex relationships between atmosphere, land surfaces and oceans, requiring highly sophisticated observation techniques in order to acquire the necessary data. In this context, satellite and aircraft-based measuring systems have proven to be particularly suitable instruments for observing the Earth's surface and atmosphere because of the large areas to be covered by such research.

The DLR Research Centre in Oberpfaffenhofen develops techniques relating to optical and microwave sensors and deals with fundamentals and application-oriented research tasks in remote sensing. These activities are coordinated with national projects and integrated into international environment programs and the space flight projects of ESA and NASA.

The DLR operates a Do 228 research aircraft (Figure 1) equipped with various sensors including an aerial camera (Figure 2, right), and a Daedalus Airborne Thematic Mapper (ATM). The ATM scan head is seen mounted to the right of the camera in Figure 2.

INVENTORY OF EFFLUENTS INTO UPPER ELBE RIVER

The Upper Elbe River is part of the most polluted inland waters of eastern Germany. On its way from the Czechoslovakian border across the State of Sachsen, the river has to take on numerous waste waters of industrial and municipal origin. Particularly, effluents from large industrial settlements in and around the City of Dresden impact highly on the river water quality.

To identify and locate the individual (known and unknown) discharges into the river, the consulting DORSCH CONSULT, Munich & Dresden, commissioned DLR to carry out an inventory on the basis of aerial thermography over the entire Upper Elbe in the State of Sachsen (110 km).

Figure 1

Figure 2

The flight was conducted around solar noon under varying medium to severe haze conditions. Using the Daedalus ATM, multispectral imagery was acquired at an altitude of 600 m AGL, with resulting 1.5 m by 1.5 m pixel size. In total, 21 transects had to be flown to follow the meandering course of the river.

The collected thermal infrared imagery was radiometrically processed with the goal to derive water bulk temperatures from the remotely sensed surface brightness data. This was achieved by use of the in-house developed SENSAT model and the incorporated LOWTRAN-7 code. The modeled results were in good agreement with surface truth data that were measured at the time of aircraft overpass (0.5 K deviation).

After radiometric correction, the water surfaces were masked on the basis of the co-registered near infrared channel 8 (0.91-1.05 µm) which usually provides high contrast between land and water surfaces. On some occasions, however, the discharged water body exhibited higher reflection than the shadowed river bank. The resulting misclassification was tolerated in favor of a comprehensive assessment of the various effluents.

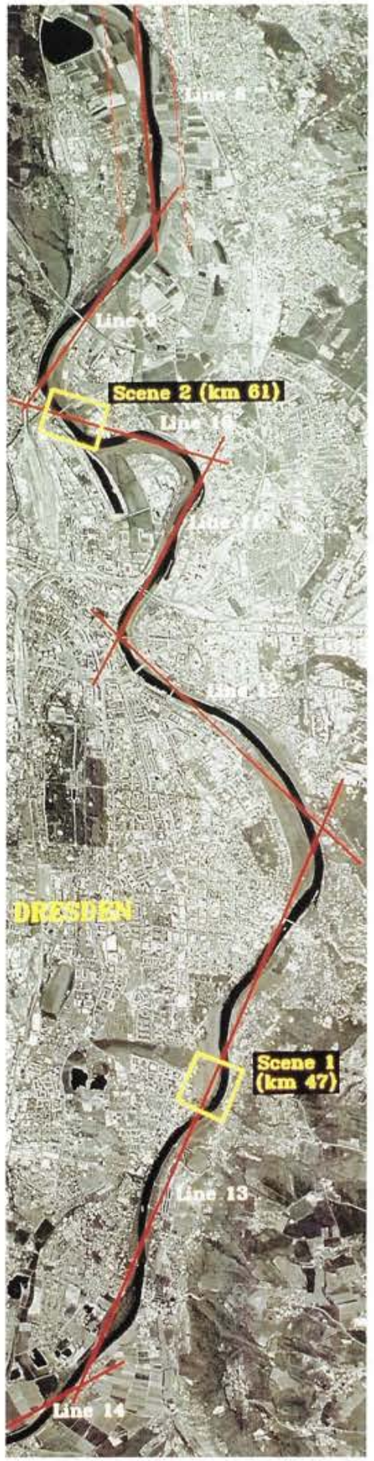

Figure 3

Figure 4

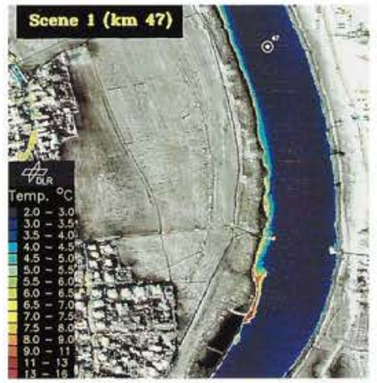

Figure 5

As a final step of the data processing, the masked thermal IR water pixels were color coded and overlaid to the original temperature scene.

The location map is a thermal infrared image from 3,000 m altitude that was obtained later in the year for a supplementary land use survey (Figure 3). Figures 4 and 5 show the locations of the described scenes along with the nadir tracks of transect no. 8-14 in the Dresden area.

Figures 4 and 5 are typical output products. Both effluents displayed stem from industrial plants. Due to the high river flow rate (6 m/s), the discharge and mixing zone pattern is tied to the river bank. This makes it difficult to identify effluents of smaller extent by their shape. The low background temperature of the river (2-3°C) offers more favorable conditions.

In conclusion, a total of 242 effluents were registered and classified as follows:

Class 1: known, i.e., documented by local authorities
Class 2: unknown, i.e., not yet documented or illegal
Class 3: suspected, i.e., not sufficiently identified

The most remarkable result of this survey was that 40% of the identified effluents fell in Class 2.

POLLUTION OF ARMAMENT SITES

In mid 1994, the Russian forces were completing their withdrawal from East German territory. What they left behind was a number of airbases, training grounds and other military installations, along with all kinds of environmental burdens that resulted from the intense use of these terrains over the past decades after World War II.

In 1991, when these facilities were still fully in operation and strictly inaccessible, the discussion about their future utilization and the desire for an initial inventory of the ecological situation became very urgent.

Thus, a study was initiated by the DLR German Remote Sensing Data Center (DFD) and other German research institutions with the goal to develop and test a methodical scheme that was solely based on remotely acquired data of different origin and allow them to: assess the overall ecological situa-

tion; and identify and locate areas with particularly severe burdens.

As a suitable test site for this type of study, the combat maneuver training center in the Colbitz-Letzlinger Heide was chosen. With an extent of around 15 by 25 km, this facility is among the largest in Europe. Figure 6 gives a synoptic view of the center. The image is a Landsat 5–Thematic Mapper (TM) scene from April 27, 1985, superimposed to multitemporal ERS 1–SAR data of 1992.

Due to the 30 m pixel size of TM, the spatial information content is restricted to the major fundamental structures of the area, such as the main thoroughfares, larger buildings, fields of fire and the way in which the grounds fit into the surroundings. It became quite obvious that the Daedalus ATM would be the appropriate means to provide the imagery at the required detail.

On request of DFD, a mapping flight was conducted on October 10, 1991, covering the entire study area with a meandering pattern of 13 strips. The ATM was operated onboard the Do 228 research aircraft at an altitude of 1200 m AGL and a resulting pixel size of 3 m by 3 m. For stereophotogrammetric evaluation purposes, simultaneous black & white photography was collected.

As a result of the airborne mission, a unique data set of high quality imagery was obtained. The ATM imagery revealed a scene of extremely high spatial and spectral heterogeneity. The data allowed mapping of the whole grid of roads and tank trails. Single objects, such as fire stands, barracks, and observation towers could be identified, as well as impact and detonation structures. Using standard algorithms, different types of vegetation and soil were discriminated;

Figure 6

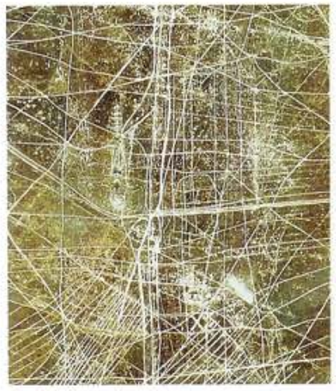

Figure 7

the degradation of soil, due to compaction and contamination by oil and fuel, showed distinct spectral features.

In the central northern part of the study site, patterns were detected with striking anomalies in the reflected radiance spectra. An example of this phenomenon is given in Figure 7 which combines 3 channel composites and the straight thermal channel from the same scene of approximately 2.5 by 3.1 km size.

While the true color composite of ATM channels # 2-3-5 (Figure 7, upper right) yields little information on these patterns, the spectral anomalies can clearly be recognized in the 5-7-9 (upper left, dark tones) and 7-9-11 (lower right, yellow-orange tones) channel composites. They coincide with the areas of elevated temperatures in the thermal image (lower left, white-colored).

Since these areas have sharp contours, it can be assumed that they have been treated deliberately by whichever means. In the study, they appear in the category of suspected damage areas. The results of the airborne inventory are currently verified by terrestrial observations and sampling. The findings will confirm the excellent role of the ATM in this field of application.

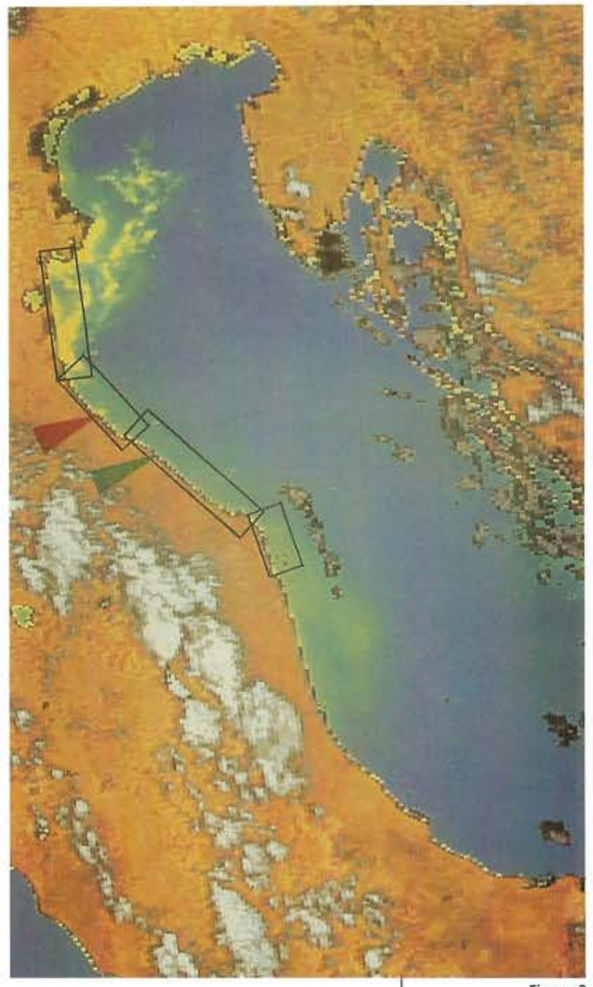

Figure 8

ALGAE BLOOM DETECTION IN THE ADRIATIC

Figure 8 is a portion of the product of NOAA AVHRR satellite data processed at DLR. The objective here was to detect algae in the northern Adriatic along the Italian coast from Trieste to Ancona. In this picture, algae differ from the clean (dark blue) water in that they are blue-green or green to yellow in color. However, these data do not permit a distinction to be made between algae and other suspended matter in the water. This would require better spectral resolution, as offered by CZCS in the past or ROSIS in the future. In the case in question, water samples taken at the same time confirmed that the Adriatic was indeed polluted by algae. Airborne coverage using the Daedalus ATM provides a more accurate picture. Figures 9 and 10 show a 5 × 5 km scene on the coast at Rimini taken from an altitude of 3000 m (see arrows on satellite image indicating airborne acquisition areas in Figures 9 and 10). What is shown is the ratio of the green to the blue spectral channel (550 nm/450 nm), this ratio reacting particularly sensitively to the presence of algae.

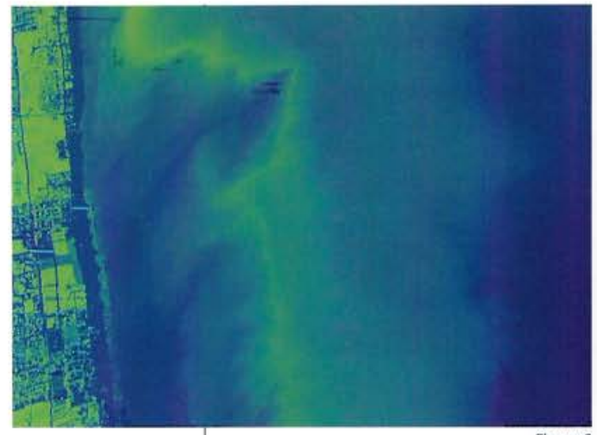

Figure 9

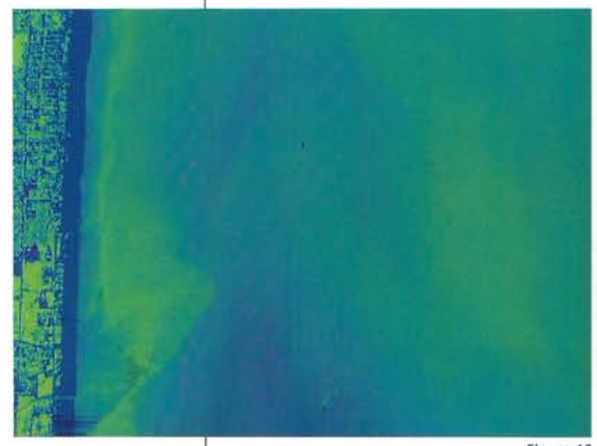

Figure 10

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Alenia

Alenia's airborne remote sensing systems entail the use of light aircraft equipped with specialized instrumentation (P68 OBS, AP68TP Viator, Learjet 35-A, Piaggio P180 Avanti) and processing centers for the remotely sensed data.

The system requires a properly equipped aircraft and a data/image processing center. Alenia, in collaboration with Enea, has developed a light twin turboprop aircraft (VIATOR, Figure 1) equipped for advanced airborne remote sensing. Remotely sensed data is acquired by the sensors mounted on the aircraft and then analyzed and interpreted in the Environment and Energy Division's processing center.

The on-board instruments comprise sensors and dedicated state of the art avionics; the system employs, in various configurations, a Daedalus Airborne Thematic Mapper (ATM), an infrared TV camera (FLIR), a color TV camera and a satellite positioning system (GPS).

The thematic maps, which are the final product of the processing and the basic elements for the creation of territorial databases, allow the data acquired to be analyzed and interpreted, thus providing the user with complete information which can be immediately understood.

Of the high technology infrastructures for airborne remote sensing, TELAER, a project which will offer an indispensable tool for integrated land management, is in an advanced stage of development with the realization of regional centers and equipped aircraft (a Viator and a Learjet). The project, financed by a three-year program for the Mezzogiorno (run by IASM), is directed by the TELAER consortium which has been set up by Alenia and Telespazio.

The airborne atmospheric pollution measurement systems are of particular interest for their market potential. Alenia has already developed, under its SNIFFER program, an aircraft equipped for measuring air pollution from high altitudes and the data processing center.

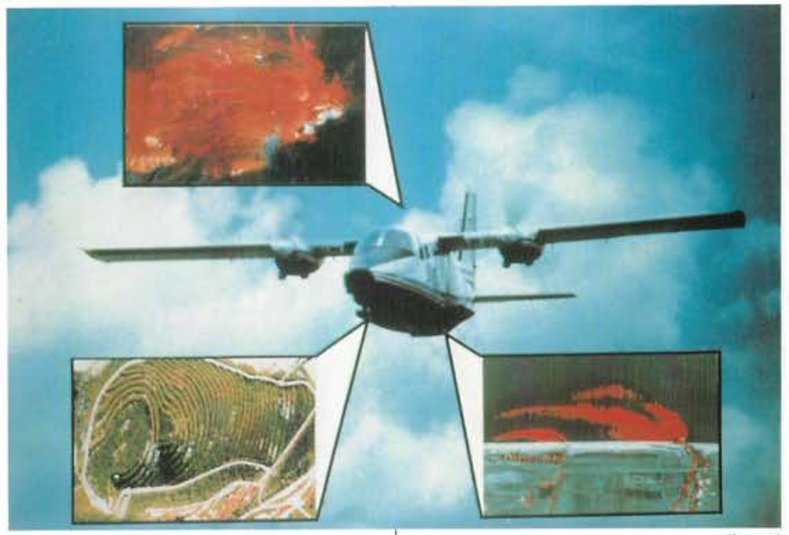

Figure 1

REMOTE SENSING SERVICES AND AIRBORNE MEASUREMENT OF ATMOSPHERIC POLLUTION

The remote sensing and measurement services carried out by airborne missions managed by SAMANTA, an Alenia-group company specializing in this field, are aimed at monitoring specific phenomena of particular public interest (identifying discharges of pollutants into the sea, monitoring of volcanoes, controlling electrical power lines, agricultural controls, early warning of forest fires, measuring of chemical and radioactive atmospheric pollution), and identification of algae and mucilaginous masses.

The principle behind remote sensing is the gathering of the electromagnetic signals from objects and acquiring information on their physical condition without any direct contact. This function requires special electronic optical sensors mounted on the aircraft which operate in the visible and infrared bands and can provide images of the terrain containing a large amount of information much of which is invisible to the human eye. Subsequent digital processing of the aircraft acquired data enables one to obtain thematic maps, i.e., interpretable computerized cartography which provides a wide range of land use information.

APPLICATIONS FOR TERRITORIAL INFORMATIONAL SYSTEMS

Alenia can provide packages of integrated software for multistandard territorial informational and related systems.

The design, which studies the software tools for developing an integrated software package for generating and managing a multistandard territorial information system, is specifically aimed at providing a regional territorial information system to support land management and planning. The system, developed by Alenia, allows one to access cartographic information of different types and formats. Paper maps and charts may be introduced into the system by digital scanning. The most interesting feature of the system is the user interface which has been studied and produced to image different Geographical Informational Systems (GIS) without changing the type of interaction.

The development of GIS applications is aimed at developing the use of thematic mapping and airborne remote sensing, integrating the information available from various sources, both off-line and in real-time, and creating land management databases.

COASTAL DISCHARGES MONITORING

The Italian Ministry of Environment requested a mapping of the coastal runoffs along the Italian coasts. In this context Alenia, an Italian aeronautical firm, conducted an aerial remote sensing survey of the Gulf of Naples aimed at establishing an expedited monitoring technique to be applied to the detection of coastal runoffs and the investigation of water quality, along the Italian coast line.

The Gulf of Naples, one of the most picturesque areas in the world, has become a receptor of many unknown discharges, mostly of anthropological origin, mainly due to unsupervised urbanization. This situation, which could modify the marine environment through the introduction of a larger amount of nutrients and promote eutrophication of the water, has not been systematically studied until now.

The aerial campaign was conducted during a period of dormancy of microalgae blooms, to avoid undesired spectral signatures in the data. At the same time, a sea truth campaign was organized and atmospheric parameters were measured to support the remotely sensed data. In order to recognize all discharges, even small discharges, a Viator AP68TP, a small aircraft configured by Alenia, was used in agreement with ENEA for environmental monitoring.

Data acquisition was performed using a Daedalus ATM configured with the Coastal Zone Color Scanner (CZCS) array. The aircraft was flown at an altitude of 1,900 m, with a resulting pixel size of about 5 m. The aircraft flew four flight lines over the coast:

1–from Lucrino Lake to Capo Miseno
2–from Naples Harbor to Nisida
3–from Posillipo to Lucrino Lake
4–from Scassata Tower to Naples Harbor.

The mission was repeated for three days to allow a more detailed analysis.

A sea truth study was carried out at the time of the overflights. Measurements of concentration of materials suspended and dissolved in sea water were performed by researchers of the Zoological Station "A. Dohrn" of Naples, while measurements of spectral signatures, incident irradiance and radiometric temperatures were performed by researchers of the National Research Council of Venezia. Measurements of atmospheric transmittance and meteorological data were performed by dott. G. Zibordi of the National Research Council of Modena.

Computer compatible reduced data were processed in order to eliminate geometric distortions and atmospheric effects. The geometric correction process takes into consideration four factors: the flight altitude, the total field of view with respect to the vertical, the line samples and the elementary area of the observed pixel. The atmospheric correction process consists essentially of two steps: application of the calibration to pass from digital numbers to physical units and subtraction of atmospheric effects from the collected data.

Figure 2

To highlight the discharges and to study the marine environment, three thematic maps were produced: (Figure 2) a chlorophyll a concentration map (Top), a sediment concentration map (Center), and a radiometric temperatures map (Bottom). In the analysis of the chlorophyll and sediment maps, the sea truth data were divided into two parts; the first part was used to retrieve the parameter values to use in the models, while the second part was saved for the final validation of the model and the acquired results.

Thermal gradients show coastal emissions and allow the study of surface runoffs. The thermal infrared band was employed to enhance coastal runoffs via their radiometric temperature, which is different from that of the sea waters. Water appearing colder than surrounding areas is usually due to urban discharges or to clean freshwater, while relatively warm water usually originates from industrial or mixed discharges. In the resulting thematic map, different temperatures are presented by discrete colors.

The water content of suspended sediments was calculated to enhance coastal runoffs and the way they disperse into the sea. Alenia used an algorithm which produced good results in a precedent study performed by Zibordi et al. Making a visual comparison between the thermal map and the sediment map, it is possible to enhance the plumes of

Alenia

the main discharges and their path of dispersion into sea waters.

The chlorophyll a content is an indicator of the water eutrophication level. To study its distribution, Alenia utilized an algorithm which has proved to be effective on Mediterranean waters for data remotely sensed either by satellite or from aerial platform (Zibordi et al.). The retrieved chlorophyll concentration values were split into seven classes, each of which was represented with a specific color on a thematic map. The map shows an amount of chlorophyll a typical of eutrophied waters, but not as much as it would seem for the large number of existing discharges and the large quantity of available nutrients. This is probably due to the natural inertia of an ecosystem to adapt itself to a rapid environment variation.

The validation of the described process was performed comparing the results with the data available at the local Administration acquired by a vessel using traditional methods. We found that our discharges were in the same position as those known, and we also discovered 56 new discharges.

ADVANCED AIRBORNE REMOTE SENSING FOR EMERGENCY ON MOUNT ETNA

Majestic and overwhelming from its 3,340 m height, Mount Etna is a volcano in continuous eruption. Its activities, more or less violent, culminate–every ten years on the average–in peaks such as that now in progress. The phenomenon has always been of great interest to scientists for study. In addition to consolidated techniques and methods, today more sophisticated technologies are available; among these, a leading role belongs to advanced airborne remote sensing.

An airborne remote sensing mission has been carried out, in particular, within the activities of the experimentation plan for the study of emergencies foreseen by the TELAER project.

The project, tasked to the TELAER Consortium between the Alenia and Telespazio companies, is within the programs foreseen by Act 64 "Organic Action 2" and has as target the setup of a technological infrastructure dedicated to the supply of advanced airborne teledetection services for the protection of the territory.

In the mission on Mount Etna an advanced teledetection system has been used, already proven due to the collaboration between Alenia and ENEA.

The image in Figure 3 shows four craters–North-West, Central, New Mount and South-East–which dominate the peak as the result of data acquisition using a Daedalus ATM with high thermal and geometric resolution operating in the thermal infrared range mounted on-board the VIATOR aircraft. The image, originally recorded in black and white, has been processed in false colors according to a scale of temperatures:

- White represents the maximum allowable temperature (approximately 900 degrees Celsius)
- Red-violet represents a lower temperature by 100 degrees Celsius
- Blue represents ambient temperature.

The image was acquired at 0700 hours from an altitude of 5,000 m or 16,500 feet.

The processed image indicates the presence of thermal hot spots which, starting from the peak of the South-East crater, form a belt around the southern border of the Ox Valley, which represents the area of the eruption which started mid December 1991 and is still in progress at the time of this writing.

The imagery is now under study by the experts of the Great Risks Commission within the Department of Civil Protection.

Airborne remote sensing, used on a time-schedule basis, can become an instrument whose relevance is evident not only during monitoring, but also as support in coping with emergencies.

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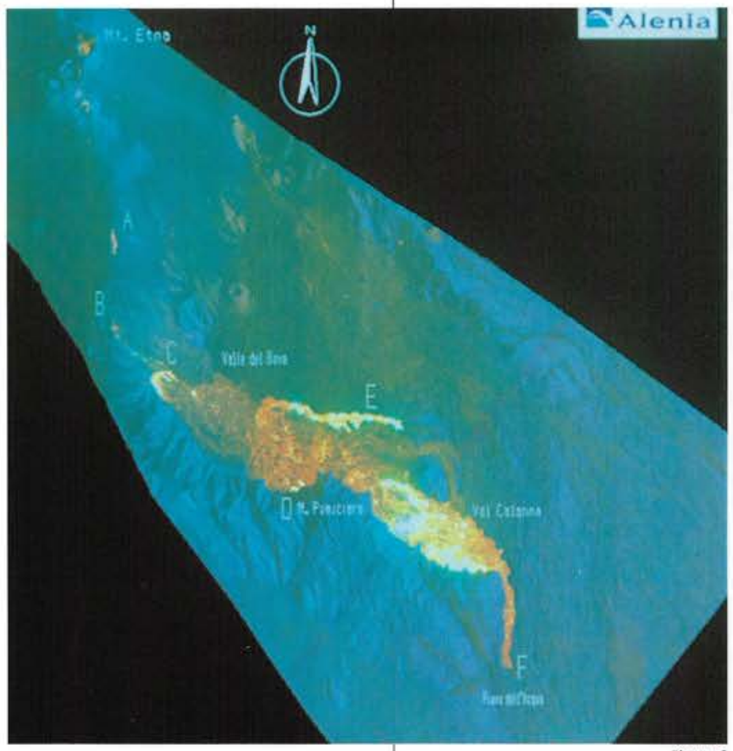

Figure 3

SPACETEC

For more than 20 years SPACETEC has been actively engaged in environmental surveys and climate-related planning procedures using terrestrial methods and the varied possibilities offered by airborne remote sensing including a Daedalus multispectral scanner. The focus is on surveys of climatic conditions and air hygiene in urban planning and locating.

When analyzing urban climate or evaluating the "climate" factor as part of environmental impact assessments, the Climatop Chart and the Climate Function Chart developed by SPACETEC play a substantial part. They show close area coverage recordings of actual status of thermal and dynamic components of the micro-climate. Model calculations are used to simulate a variety of different planning situations, allowing proposals to be submitted for concrete improvement measures or planning options. Examples include the climate-related planning of motorway routes (pollutant propagation) and large industrial complexes which affect the local climate, and the air quality through sealing effects, increased air flow resistance and emissions.

REMOTE SENSING METHODS

Both the "classical" remote sensing methods (thermal infrared and aerial photographs) and the latest multisensory techniques are used for surveying and inspecting landfills, contaminated areas, forest regions or technical installations. These techniques include airborne SAR sensors which operate independent of weather conditions and with high resolution (e.g. for charting tropical forests), and ultralong wave and magnetic sensors (e.g. for locating contaminated military sites) carried by helicopters. On-site local surveys can also be planned and carried out cost-effectively and target-specific. The method is also of great interest for locating archeological structures.

The data are analyzed using the Geographical Information System (GIS). The results of the surveys are expertly underpinned and presented clearly and graphically. As a matter of course, SPACETEC also offers extensive software (e.g. the SPACEklip program) in addition to their textual and cartographic presentations.

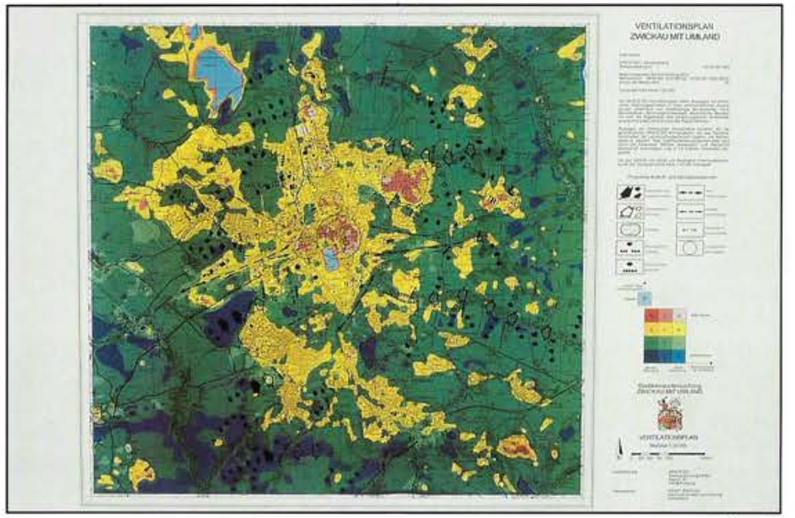

Figure 1

SPACETEC Environmental Surveys			
Operating area	Survey Variables	Survey Methods	Product
Urban climate surveys • Thermal islands • Cold air generation areas • Air currents • Flow barriers	Regional and local climate Bio-climate and air hygiene (emission, immission)	Thermal scanner fly-overs Meteorological measurements Relief, roughness and real utilization chartings, Mesoscale model calculations (temperature, humidity, wind)	Thermal charts Climatopic charts Climate function chart Planning note chart
Location planning • Residential and industrial zones • Industrial plants • Traffic areas (motorways, railroad lines)	as above, plus: odors, noise sealing effects	as above, plus: Simulations Microscale model calculations (e.g. pollutant propagation, cold air flow-off, shading)	as above, plus: Planning options (environmental impact studies, project or master plans
Structures close to surface • landfills • Contaminated land • Archeological structures • District hearing systems • Buildings	Thermal anomalies Gas escapes Water leaks	Multisensory method: Ultra-long waves (active EM, passive VI.F) Magnetism, Thermal/Multispectral scanner Aerial photos and CIR images	Close area coverage analysis chart for planning on-site surveys
Special remote sensing • Roughness • Relief • Forest crop • Vegetation damage	Urban structures (3D) Spectral features Texture	Airborne SAR Multispectral scanner Aerial photo and CIR image	Ventilation plan Forest stand charts Tree cadasters Damage reports

Figure 2

SPACEklip allows the results to be visualized and the data obtained to be edited and processed.

The imagery and chart (Figure 1) show the temporary climate conditions (thermal islands, cold air generation areas, air currents, flowing barriers) of the ventilation plan. This is the basis for different location plannings (residential and industrial zones, traffic areas). The adjacent chart shows the results of thermal scanner surveys and meteorological measurements including topography.

The table in Figure 2 shows the different operating areas of SPACETEC environmental service surveys with their specific methods and products.

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UNDERGROUND AND SURFACE COAL MINE FIRE DETECTION IN JHARIA COALFIELD, INDIA

National Remote Sensing Agency (NRSA)

Many of the coalfields around the world have the common problem of spontaneous combustion of organic matter. Incipient heating of this type occasionally gives rise to mine fires. Cases have been reported around the world; the Witbank coalfield in the Eastern Transvaal of South Africa (Baker et al., 1978), Pennsylvania coalfields of United States (Knuth and Fisher, 1967), Burning Mountain region in Australia, Baskiria region in U.S.S.R., and in China (IRS MinG, 1987).

In India, Jharia and Raniganj, the coalfields of eastern India, are well known for coal mine fires. Self-ignited coal mine fires of this kind usually originate in old mine workings either in underground or opencast mines and cause damage both to the production and the overall coal quality, not to mention polluting the environment.

Mine fires in Jharia not only burn the coal in the seam, but also block access to the proven reserves within the fire affected region and in the underlying seams as well. Additionally, mine fires pose a serious threat to surface installations and also cause a major environmental hazard specially due to the emission of noxious gases such as CO, NOx, SOx and unburnt hydrocarbons. It is, therefore, imperative that the fire affected areas be detected and mapped as early as possible.

Conventional methods of locating and monitoring mine fires are based on thermal logging and thermometric surveys at as many points as possible. However, these methods are localized and somewhat conjectural, particularly if the data points are sparse or the fire zones are inaccessible. Further, such traditional monitoring is a very slow process as compared to the dynamic nature of fire phenomena.

With the advent of remote sensing technology, airborne thermographic surveys are being conducted to measure the radiant temperature of the earth's surface features. The advantage of this technique over the conventional fire monitoring methods lies in its capability to provide a faster and continuous record of minute variations in temperature, without physically coming into contact with the fire zones. At this writing, only a few studies have been carried out utilizing

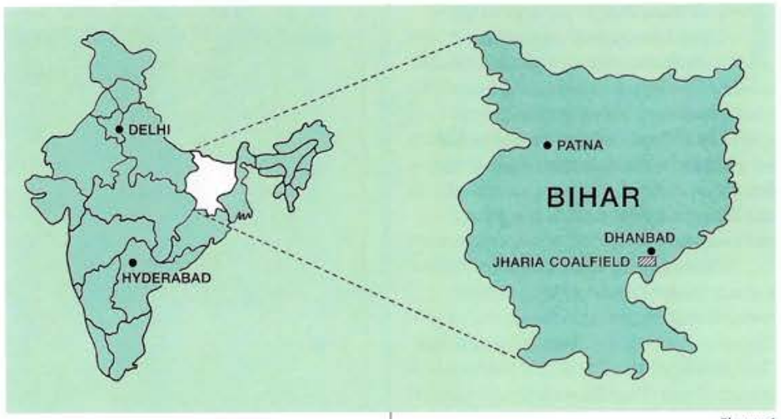

Figure 1

airborne and spaceborne thermal infrared data for mine fire delineation. The previous studies have been concerned primarily with visual interpretation of uncalibrated thermal IR imagery.

NRSA PROJECT

The National Remote Sensing Agency (NRSA), Hyderabad, carried out a project funded by Central Mine Planning and Design Institute Limited (CMPDIL), Ranchi, a subsidiary unit of Coal India Limited, to study systematically the age-old problem of coal mine fires reported from Jharia coalfield in eastern India (Figure 1), using a Daedalus Airborne Thematic Mapper (ATM).

The main objectives of this project were: develop methodology to locate and monitor mine fires at Jharia coalfield of eastern India, in the light of recent advances in infrared imaging technology and digital processing of thermal infrared data; map the surface and subsurface fires on 1:4,000 scale; prepare subsurface isotherm map of the study area; and find out the source depth.

An area of about 650 square km covering the Jharia coalfield in Bihar State was surveyed using the Daedalus ATM and an aerial camera. Simultaneous ground based thermal infrared measurements have also been made to support the airborne survey. Multispectral data collection consisted of daytime visible, near, middle and thermal IR region and predawn thermal infrared data. Black and white aerial photographs were also acquired at a scale of 1:8,000. Day and night thermal IR coverage was obtained to map the Jharia coalfield.

Data processing included conversion of magnetic tapes (HDDT to CCT), pseudo-color slicing of temperature data (Figure 2), the generation of isothermal contour maps, temperature profiles and hard copy color prints. Temperature profiles (Figure 3) obtained from predawn flights have been found to be useful in assessing the depth of the fire zones. Visual interpretation of the scanner data has also been carried out to prepare a fire map at 1:8,000 scale. Aerial photographs have been used to update the 1:4,000 and 1:8,000 scale toposheets (base maps) of the study area.

CONCLUSIONS OF STUDY

(1) Fire and non-fire areas are easily identified in predawn thermal IR scanner data; (2) predawn thermal IR scanner data are superior over the daytime data for coal fire mapping; (3) certain fire areas which are not shown on the existing CMPDIL maps, are also easily identified; (4) delineation of fire prone areas is possible on the isothermal contour maps; (5) identification and detection of thermal anomalies along the induced cracks caused due to the fires located as deep as 70 m are possible; (6) in the pilot study area of about 30 square km, an estimated area of 3.63 square km area is mapped as the total fire zone; (7) besides the accurate mapping of fire locations, the techniques developed in the present study are quite efficient to monitor the fire problem on a regional basis using multitemporal thermal IR data; (8) updated toposheets from a good database to assess the impact of mining activity on the environment; and (9) in addition to the application of remote sensing data to underground fires, the data has capabilities for other applications, particularly of interest to the coal industry, such as mapping of undocumented geological structure in Jharia coalfield area, and mapping of sand blanketed areas.

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Fax: 91 40 278 648.

COLOR NAME	COLOR	TEMP. VALUES
Lime Green		01-05
Pastel Blue		06-10
Orange Purple		11-15
Mocha		16-20
Pastel Green		21-25
Light Purple		26-30
Hot Pink		31-35
Orange		36-40
Cyan		41-45
Yellow		46-50
Blue		51-55
Red		>55

Pre-dawn Thermal Infrared (Channel No. 12; 8.5 to 13.00μm) Color sliced map of Mukunda OCP, Jharia Coalfield, Bihar.
Scale 1:5000 approximately (without geometric corrections). North is towards top of page.

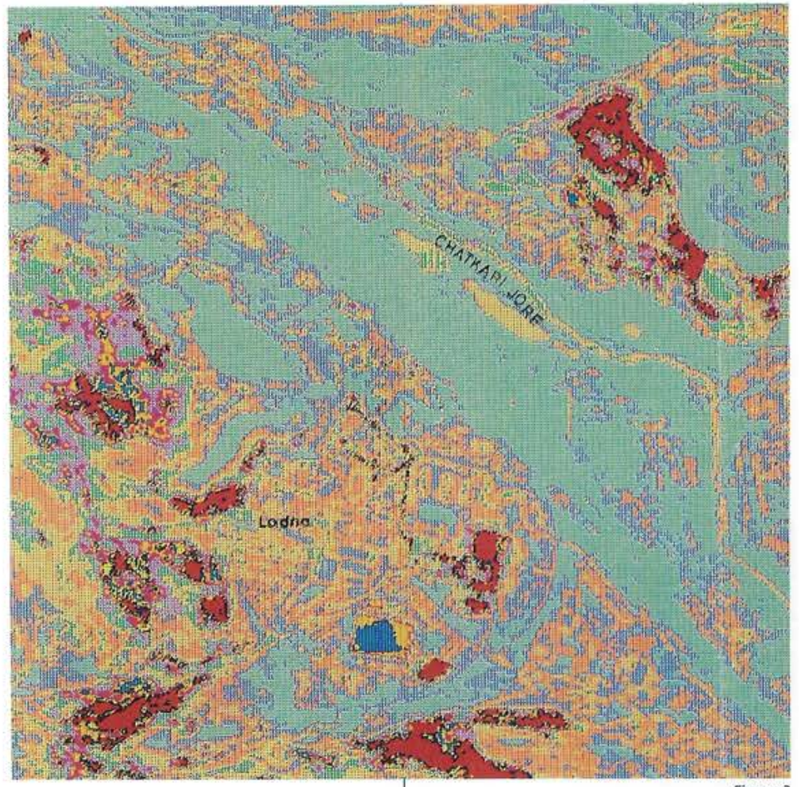

Figure 2

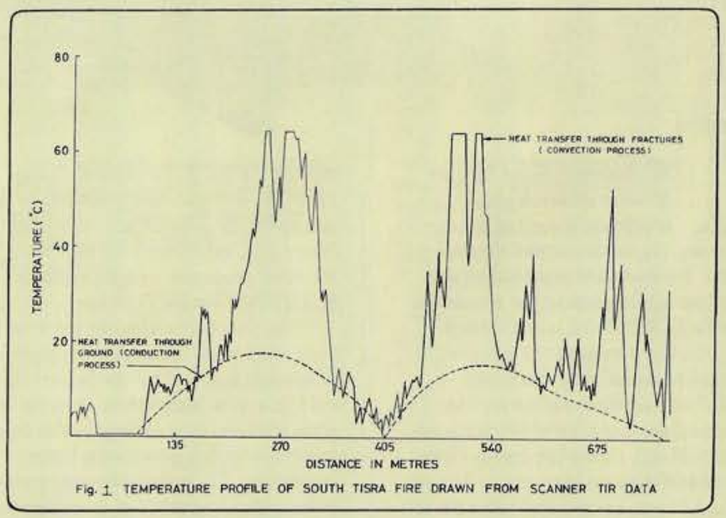

Figure 3

3D THERMOGRAPHY OF ERFURT, GERMANY AND HARBOR WATER STUDY OF ZEEBRUGGE, BELGIUM

Eurosense

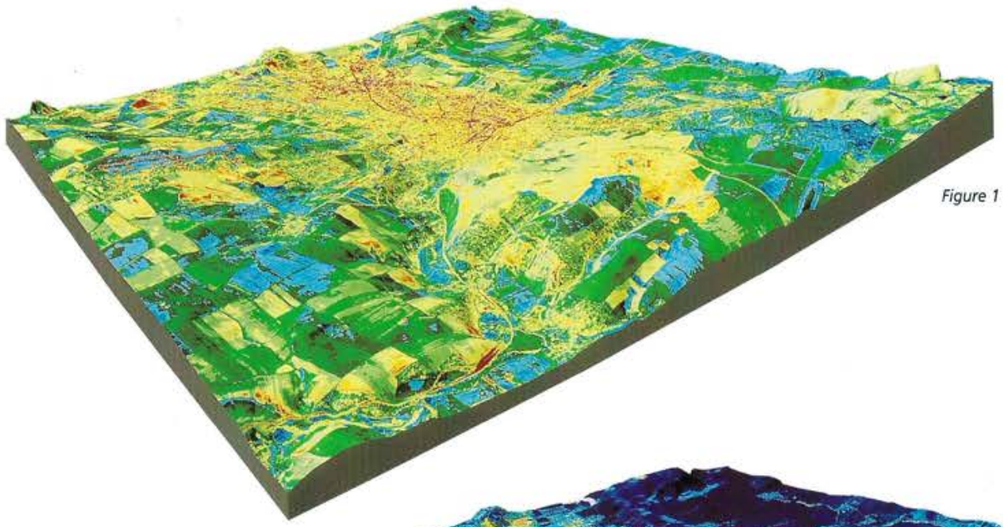

Figure 1

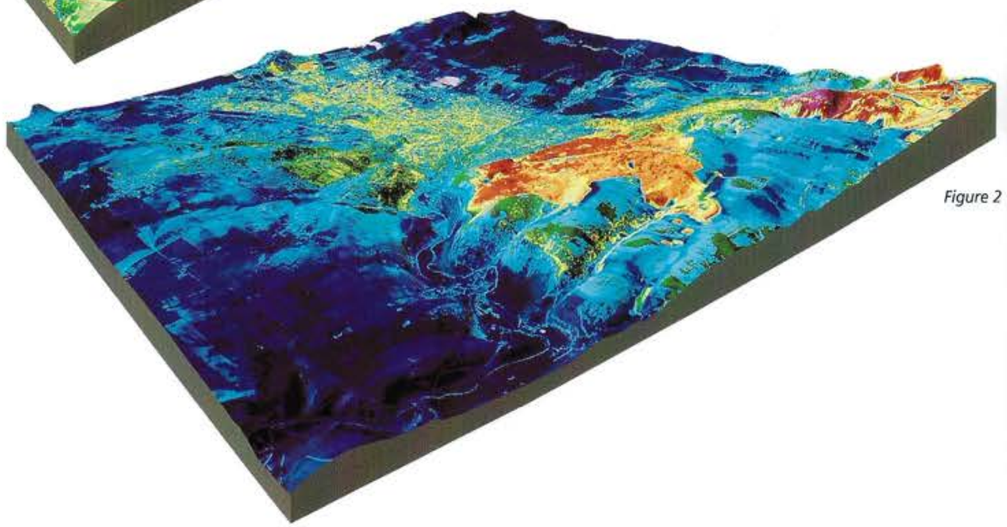

Figure 2

The two images shown here are 3D views of thermography acquired of the city of Erfurt, Germany, draped on a digital elevation model. The basic data was acquired by a Daedalus digital multispectral scanner on board a EUROSENSE survey aircraft.

The first scanner survey took place in September, immediately after sunset (6:30-7:40 pm); the second survey was conducted the next morning before sunrise (5:00-6:20 am). During both survey flights, the infrared radiation (wavelengths between 8.5 and 12 μm) was recorded with a thermal resolution of 0.2° K. To obtain the images shown, the data have been geometrically and radiometrically corrected and color-coded (blue = cold, red = warm). All steps of the 3D views' production were performed by EUROSENSE GmbH, Germany.

The city of Erfurt straddles the river Gera, which to the south of the city (on the foreground) is incised into the Steigerwald and Fahnerhöhe lime plateaus. Industrial and urban areas are clearly distinguishable from open fields by their considerably higher temperatures. The remarkably warm sections to the south and southeast of the city are the crowns of wooded areas.

Thermography is a valuable tool in urban microclimate studies, as town planning and concern for the environment become important local and regional government issues.

Figure 1 is an evening thermographic image of the city of Erfurt, Germany, recorded with a Daedalus digital multispectral scanner on board a EUROSENSE survey aircraft immediately after sunset (3D view).

Figure 2 is a morning thermographic image of the city of Erfurt, Germany, recorded with a Daedalus digital multispectral scanner on board a EUROSENSE survey aircraft just before sunrise (3D view).

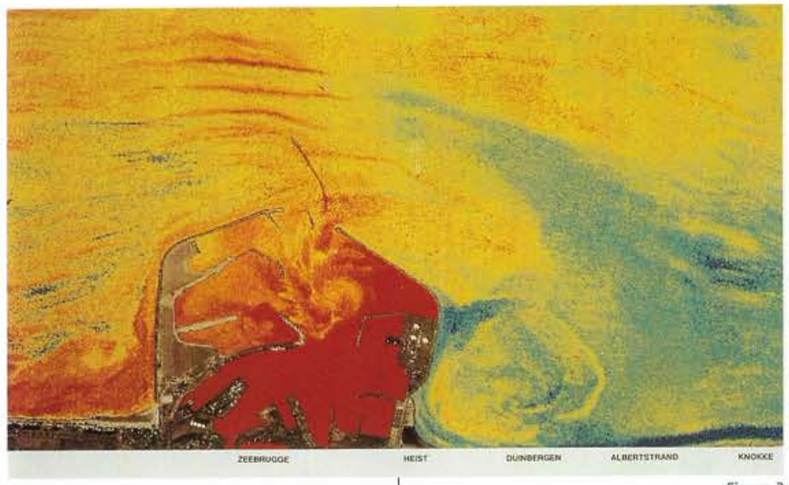

Figure 3

These views represent the suspended sediment concentrations at high and low water around the harbor of Zeebrugge (Belgium) at 1m below the water surface. The basic data were obtained with a Daedalus digital multispectral scanner on board a EUROSENSE survey aircraft, together with simultaneous ground truth data using the BEASAC®-platform. The BEASAC®-platform is a specially equipped hovercraft to perform bathymetric and hydrographic measurements.

Flights were performed during low water conditions (Figure 3) and at high water conditions (Figure 4). During both flights, the entire visible part of the spectrum as well as the near and thermal infrared were measured in 12 channels. To obtain the present images, the data has been geometrically and radiometrically corrected, statistical comparison with the ground truth data has been performed in order to obtain the proper calibration formula, and the images were color coded (red = high concentration, blue = low concentration). All steps of the production of the maps were undertaken by EUROSENSE BELFOTOP, Belgium.

The recording at low water illustrates the sediment plume which separates from the outer harbor of Zeebrugge. At high water a vortex in the lee of Zeebrugge is imminent. Both images are quantified so that when combined with water current velocities global sediment transport budgets over a tidal cycle can be compiled.

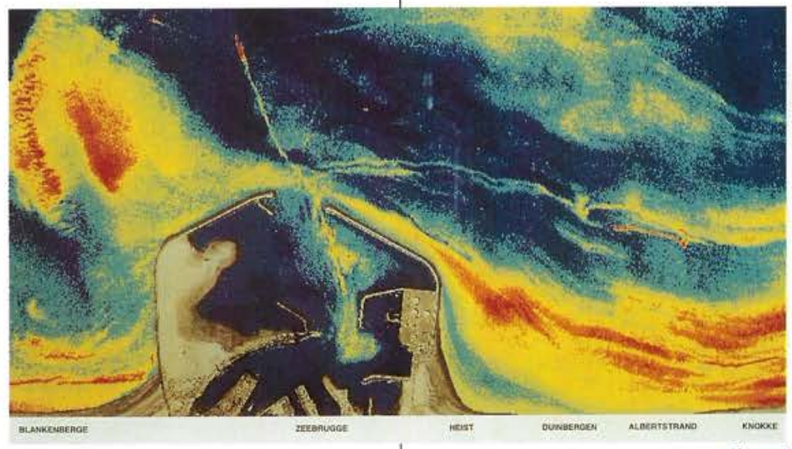

Figure 4

These measurements are valuable tools when evaluating sedimentologic processes or the impact of dredging activities on the environment or for the planning of new harbor extensions.

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SWEDISH MARITIME SURVEILLANCE SYSTEM

Swedish Space Corporation

The Swedish Space Corporation (SSC) is a state-owned limited company responsible for technical implementation of the Swedish space and remote sensing programs. SSC's activities cover the entire range of space-related work from feasibility studies to project management and operational applications of space technology and remote sensing.

Worldwide marketing of these services to international customers is now a major part of SSC's business.

SWEDISH COAST GUARD SYSTEM

The Swedish Maritime Surveillance System (MSS) was developed by SSC for the Swedish Coast Guard (see artist's concept in Figure 1). The MSS has been in operation in Sweden for over ten years. Today, the Coast Guard uses three systems of the latest version, and it is used daily in several other countries around the world.

The MSS is a field proven, user friendly system, which brings together information from several sensors, analyzes this information, and distributes relevant details to end users on the ground and the sea surface.

The MSS is used for coast guard sea surveillance tasks such as oil pollution detection and assessment, fishing activities monitoring, border patrol, etc.

The unique MSS consists of :

- SLAR (Side Looking Airborne Radar) for large patrol of small targets (80 km swatch width), oil spill detection, etc.
- Daedalus IR/UV scanner for wake inspection and oil pollution mapping
- Microwave radiometer for oil slick thickness measurements
- Photographic and video cameras for documentation and evidence to court
- Fully annotated imagery
- Image and data link for information distribution.

OIL SLICK IMAGING

The IR/UV imagery shown in Figure 2 is of a ship collision in Öresund, the strait between Sweden and Denmark. This is an example of a highly sensitive area from the standpoint of environmental protection as well as from a general sea traffic point of view. Among other applications, the Coast Guard uses the airborne system for immediate response and subsequent monitoring of accident sites in order to guide the surface activities and supply the responsible agencies with appropriate information for immediate and future use. In this specific image booms have been deployed to contain possible oil spills from the two ships. The IR image to the left shows the booms and the thicker parts of the slick, while the UV image to the right shows the total area of the slick. This combination of spectral bands is essential to guide clean-up operations and monitor the development of a spill. This type of imagery adds to the value of the documentation for further legal actions.

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Fax: 46 8 98 7069.

Figure 1

Figure 2

WILDLAND FIRE MANAGEMENT

USDA Forest Service

Figure 1

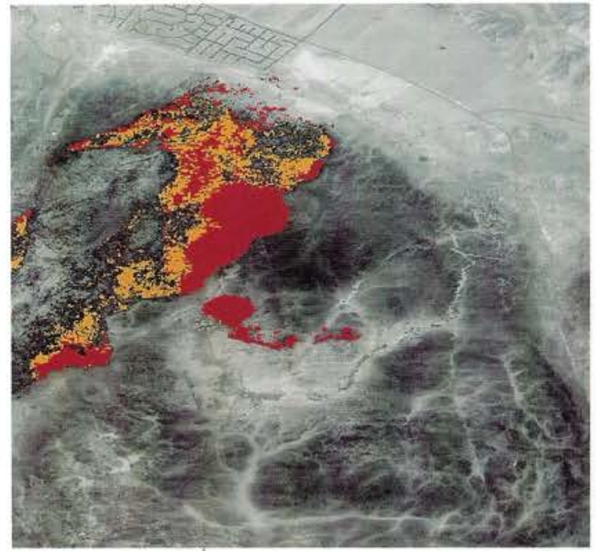

Figure 2

The USDA Forest Service (FS) is one of the world's leading fire agencies in wildland fire management. The FS has used Infrared (IR) line scanners since the mid-1960's as a reconnaissance tool for mapping large wildfires and for detection of small fire spots. The initial FS use of IR scanners was built upon military systems modified to the specific needs of FS fire mapping and detection.

In the mid-1980's the FS started investigating what should be done to take advantage of on-coming technologies such as Geographic Information Systems (GIS), image processing systems, the Global Positioning System (GPS), and, of course, computer data/image processing and storage techniques. The IR scanning system named Firefly is an outgrowth of the investigations. The Firefly product originally envisioned did not produce the required accuracy, but the basic concept and system can now be expanded to produce geo-referenced images of terrain features in gray scale, with fire spots or areas overlayed in colors representative of intensity (see Figures 1 and 2). This can now be done with several software-hardware packages available for adaptation from industry.

DAEDALUS ABS SYSTEM

The Daedalus Airborne Bispectral Scanner (ABS) using the 3-5 μm and 8-12 μm IR channels was selected for the Firefly sensor system. The Daedalus ABS was selected because of its versatility, reliable reputation, cost, spare parts availability, and maintenance considerations. Unlike the original FS systems which were designed and built as unique stand-alone IR systems, future FS IR systems will need to be capable of separating the image (or data) acquisition system from the image processing, storage, display, and transmission systems. The ABS provides a digital output which can be stored on tape, disk, or other media for subsequent processing, playback, or transmission, or can be used to produce a real-time video or hard-copy image product. As advanced or specialized image processing systems or methods develop, the ABS can continue to serve as the "front end" of the systems. Further, the scanner can be modified to provide sensing capability in other spectral areas of interest in known and proven ways available from Daedalus. The Daedalus ABS can be used in a traditional stand-alone mode and deliver a traditional image product if desired.

The digital and analog outputs make it a ready data/image acquisition source for any processing system which may be available.

The initial operational use of the ABS by the FS is expected to be during the next fire season. It will be installed on a Sabreliner jet aircraft. It has also been installed on a FS twin-engine turbo-prop (Merlin) aircraft.

ABS IMAGERY DESCRIPTION

The red portions on the images represent fire. The temperature level or range can be set to the level chosen by the operator. Multiple colors can be used for multiple temperature ranges. Example: red for hottest levels, orange for hot, yellow for warm, etc. The geographic area of the data shown was southern California's "Rainbow Fire" between San Diego and Palm Springs.

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Material supplied by Mr. John Warren, USDA Forest Service.

DETECTION OF PERCOLATING WATER AND OIL SPILLS USING THE ABS

North Sea Directorate (NSD)

Between Christmas and the New Year, the southeastern part of the Netherlands was confronted by a typical Dutch problem–high water. This time, however, it was not by the sea, but the rivers Maas, Lek, Rijn, Waal, Merwede and IJssel. In a few hours, several rivers flooded their banks due to the rising water. Not only the summer banks, but also the winter banks could not withstand the extreme high water. Many people were required to evacuate their houses during the holidays.

AIRCRAFT AND SENSORS

The North Sea Directorate was asked by the local authorities to provide, on very short notice, an overview of damage caused by the flood by means of their remote sensing aircraft, the Dornier 228-212. The aircraft is equipped with a Side Looking Airborne Radar (SLAR), thermal and visual video, photo cameras, an Ultra Low Level Night Identification camera, and the Daedalus Airborne Bispectral Scanner (ABS) IR/UV system. All images are provided with data annotation and then presented on-line in the aircraft. For processing on a ground station, all data are stored on tape. The IR detector of the ABS can be used for day or night data acquisition but cannot penetrate clouds. Two adjustable blackbodies provide temperature references for each scan.

The SLAR was used to give an overview of the total flooded area while the ABS was able to indicate certain weak spots in the dikes due to percolating water (Figure 1). The method was based on the difference in temperature radiation in the relatively warm river water, percolated ground, and the surrounding dry ground.

ABS Configuration

Spectral Bandwidth: IR channel 8.5-12.5 µm
UV channel 0.3-0.4 µm
Field of View: 86°
Sensitivity: 0.2° C (IR)

OIL SPILLS AT SEA

Pollution of the sea by oil and other harmful substances may cause a threat to the marine environment and the interests of coastal states. In order to detect pollution and, if possible, combat oil spills at sea, the North Sea Directorate operates their remote sensing aircraft about 1200 hours a year.

The system philosophy is that the SLAR is used as a main detection sensor at a distinct altitude to optimize the use of it. Targets are marked using the track ball and their coordinates are documented. After area reconnaissance, targets may be further investigated (like pollution type, size and layer thickness) by means of the ABS IR and UV channels (Figure 2) and/or video/photo cameras.

The UV-sensor indicates the difference in reflection of UV radiation between a slick and the surrounding water and, thus, provides information about the size of the slick. It can only be used during daylight and under conditions of good visibility. The IR-sensor indicates the difference in heat absorption and radiation between a slick and the surrounding water as well as within the slick itself, thus providing information on layer thickness.

Apart from the "offshore" tasks, the scanner is also used for detection sources of pollution in harbors and inland waters. New applications are being investigated by the North Sea Directorate.

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Fax: 31 703 900 691.

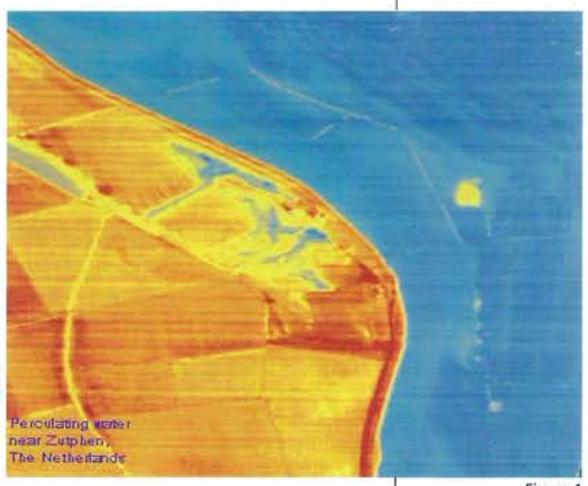

Figure 1

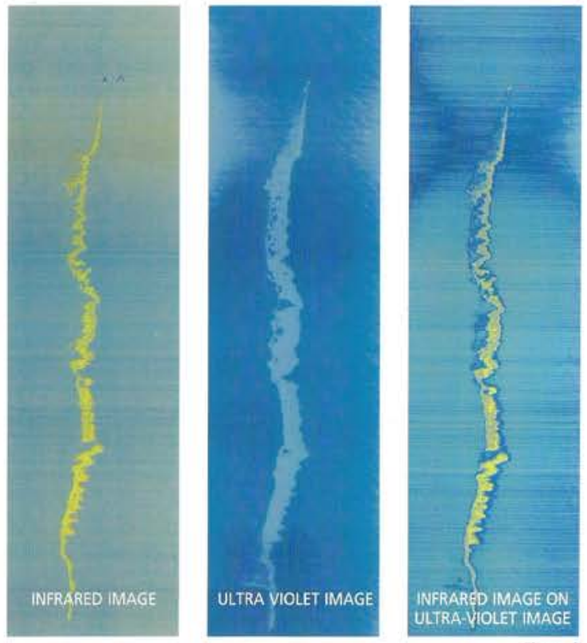

Figure 2

AIRBORNE INFRARED MAPPING AND GIS FOR URBAN ENERGY MANAGEMENT

Innotech Aviation

Figure 1

Figure 2

Dayton Power and Light required information on the relative efficiency of building insulation correlated with power usage for nearly one million clients in Montgomery County Ohio, including the city of Dayton. This demanding task was feasible by combining airborne infrared image mapping and geographic information system technology to produce the required data base.

Woolpert, with extensive expertise in both aerial mapping and GIS applications, was the prime contractor selecting Innotech Remote Sensing to provide the infrared imaging. The overall strategy called for the infrared data to be acquired during nighttime under clear cold conditions to ensure accurate thermal measurements while the buildings were being heated. The digital imagery would be processed, using photogrammetric technology, to the Ohio State Plain map projection and formatted to digital map tiles coincident with the county maps.

The flights were carried out in early January using a Daedalus 1260 Multispectral Scanner, configured with dual infrared detectors at bandpass centers of 4.7 and 10.0 µm. Flight line navigation data including position from differential GPS and sensor attitude from an inertial navigation system were recorded in parallel with the digital imagery.

To meet the mapping requirements, the imagery were processed to seamless digital orthomosaic tiles corresponding to more than two hundred county maps. Ground control points and terrain elevation were extracted from the existing digital map base. These data, combined with continuous position and attitude information recorded in flight, were input to the resampling function to generate the orthoimage products. This function employs the standard photogrammetric co-linearity and co-planarity equations to create the bundle adjustments for each flight line.

Figures 1 & 2 are two examples of the infrared image products combined with the dual line vector street map of Dayton. These illustrate the utility of the digital infrared products for the follow on GIS extraction of the management information. The smaller scale image, Figure 1 showing street boundaries overlaid in red, includes the entire county map E3434. Both infrared bands are presented in this image to illustrate the potential separation of terrain by the spectral emittance of each band. Here the asphalt streets show a higher emittance in the shorter band. The larger scale image (Figure 2) presented at 1:6,000, to compare with the paper county map, covers the north west portion of map E3434. The output pixel size for the infrared imagery was 2 m with 8 bit encoding providing radiometric temperature separation of approximately 0.2 degrees Celsius.

The complete county-wide coverage of digital infrared maps available to the utility's GIS as a digital image map overlaid onto the urban infrastructure data base, makes every possible GIS function available for information extraction.

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Dayton, Ohio 45402-1261 USA;
Telephone: 513 461 5660;
Fax: 513 461 0743.

URBAN HEAT ISLAND CHARACTERIZATION

INTA

Figure 1

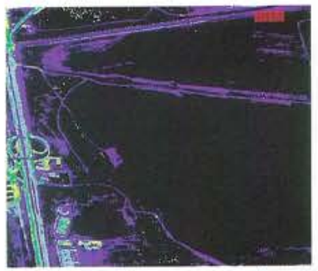

Figure 2

Figure 3

Figure 4

Figure 5

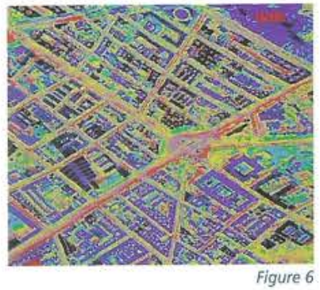

Figure 6

The expansion of urban areas gives rise to many environmental problems. The alteration of climatic parameters in the cities, leading to a specific urban microclimate, is one of the most noticeable effects of urban development.

This climatic effect of urbanization is the so called urban heat island, an increase in the air temperature in the cities. For a given city, the urban heat island varies in intensity both in time and space; the local air temperature is a function of urban materials and city structure, thus areas with similar features give rise to fairly uniform air masses with front-like limits with other areas.

This phenomenon is a complex consequence of the alteration of the energy fluxes over urbanized areas. Incoming short-wave radiation is reduced by air pollution, but the same stands for outgoing long-wave radiation; additionally, this radiation is trapped or reflected back by buildings. There is a change in the surface albedo. The great proportion of impervious surfaces leads to a decrease in evapotranspiration and the corresponding increase of sensed heat flux.

Several approaches have been made to compare the surface energy balance in rural and nearby urban areas. A primary problem for evaluating the energy balance related to the urban heat island is analyzing the diversity of surfaces involved–surfaces with different albedo, emissivity, heat capacity, and thermal inertia. Airborne thermal imagery is an important tool for this task.

CITY OF MADRID STUDY

In Spain, the Centro de Investigaciones sobre la Economia, la Sociedad y el Medio, a department of the Consejo Superior de Investigaciones Científicas is performing an integrated study of the urban heat island over Madrid. The purpose is to characterize the phenomenon and its spatial distribution under different meteorological conditions in relation with the surface fluxes.

AIRBORNE DATA

The Remote Sensing Laboratory of Instituto Nacional de Technica Aeroespacial (INTA) has performed several flight campaigns during recent years to acquire Daedalus Airborne Thematic Mapper (ATM) data for this study. Data has been acquired during day and night flights for the summer and winter seasons representing climatic conditions. Recognition and classification of different urban surfaces and "landscapes", including rural surroundings, is performed by means of the multispectral data. Additionally, thermal features associated with the different structures are analyzed using the thermal images (3-5 μm and 8.5-13 μm) from the ATM with the inclusion of air temperature measurements.

The images shown here represent the type of data used as input for the study. Three characteristic urban landscapes are displayed in color infrared (RGB channels 3-5-7) and 8.5-13 μm thermal images:

Figure 1 is a semi-rural area outside of Madrid (RGB 3-5-7).

Figure 2 is the thermal image of the scene of Figure 1.

Figure 3 is a newly-developed area with large streets and some vegetated areas (RGB 3-5-7).

Figure 4 is the thermal image of the scene of Figure 3.

Figure 5 is a densely built-up area in the center of the city (RGB 3-5-7).

Figure 6 is the thermal image of the scene of Figure 5.

The hottest surfaces in the thermal images are represented by red, followed by yellow, green, blue and black (colder surfaces).

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AIRBORNE REMOTE SENSING FOR ENVIRONMENTAL MONITORING

Korea Institute of Geology, Mining and Materials (KIGAM)

Korea Institute of Geology, Mining and Materials (KIGAM) has conducted airborne multispectral data collection and analysis for environmental monitoring. Representative imagery from two special applications is presented. The imagery was acquired using the ten channel multispectral system, the Airborne Multispectral Scanner (AMS), designed and manufactured by Daedalus.

THERMAL DISCHARGE FROM A POWER PLANT

There has been serious disagreement between the fishermen and the executive officials of YK power plant, one of the major atomic power plants in Korea, about the temperature and movement of thermal effluent produced by the plant. The fishermen did not believe the measured temperature using a thermometer because they could not see the measuring process. KIGAM has monitored the movement and temperature of this thermal effluent produced by the plant using the airborne scanner. Airborne remote sensing surveys were conducted to map the movement of thermal plume in ebb and flood tide respectively. The flight altitude was 8,000 feet (Figure 1), to produce images with a nominal ground resolution of 6 m. The data was processed using PC software developed by KIGAM. Unfortunately, the results showed that the thermal plume was not dispersed far out to sea; it was just moving up and down along the coast.

WATER QUALITY MONITORING

Hapcheon Lake is one of the major drinking water resources in Korea. AMS data was acquired to map the distribution of water quality factors such as chlorophyll a, suspended elements, and transparency of Hapcheon Lake. Water samples were collected from ten randomly chosen locations in the lake to be used as ground truth. The airborne surveys were flown from an altitude of 8,000 feet to cover the entire lake in a single strip (Figure 2). In this study, areas of high suspended sediment concentration exhibited relatively high band 7 reflectance. And the ratio of band 3 and band 7 (band 3/band 7) showed closer correlation with the concentration of chlorophyll a than the ratio of band 3/band 2 (or band 1) due to the limitation of light available for photosynthesis.

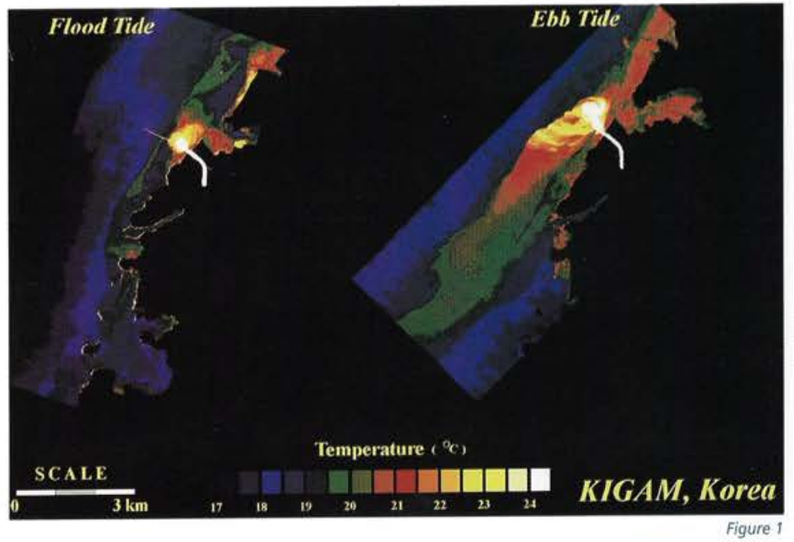

Figure 1

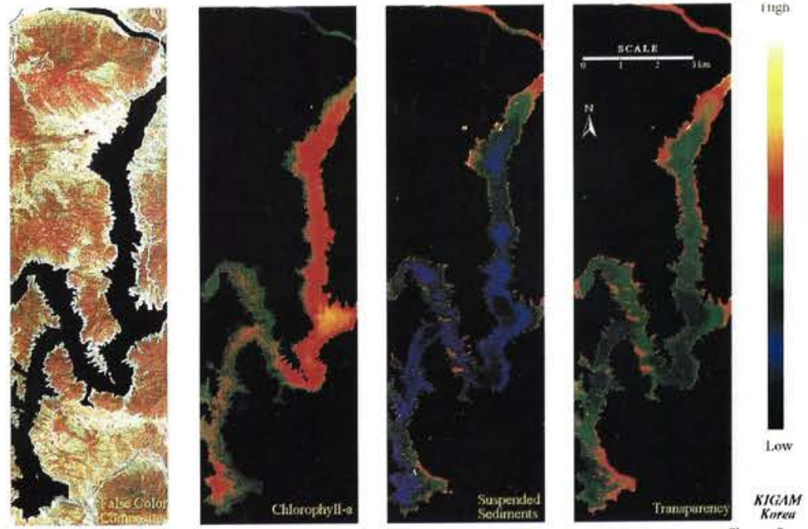

Figure 2

Therefore it is valid to use band 3/band 7 rather than band 3/band 1 for the mapping of chlorophyll a distribution. The transparency was represented by the weighted sum of band 7 and band 3/band 7. Though it was impossible to quantitatively correlate airborne MSS data with water quality factors due to the insufficient number of ground truth data, the water quality maps visually displayed the overall spatial distribution of water pollution in the lake.

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DAEDALUS
PRODUCTS & APPLICATIONS

Daedalus Enterprises, Inc. is internationally recognized as the premier supplier of airborne multispectral imagers for environmental remote sensing. Since 1968 Daedalus has placed nearly 100 major systems in over 24 countries worldwide.

Daedalus offers a complete line of digital airborne imagers and ancillary products. If you would like full details and specifications on any of the products listed, please contact Daedalus by phone, fax or mail.

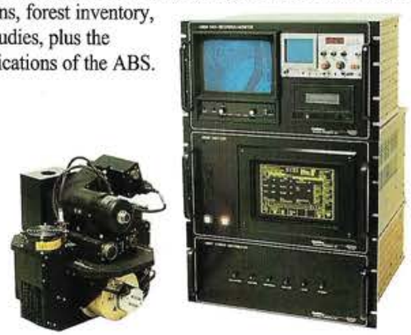
QUICK-LOOK APPLICATION CHART

APPLICATION	# OF BANDS: / SYSTEM:	2 1221	2 ABS	10 AMS	11 ATM	11 ATMX	6 TIMS	10 AOCI	48 AHS	128 MIVIS
IR/UV OIL SPILL DETECTION/MAPPING		X	X	X						
SOIL MOISTURE STUDIES			X	X	X	X	X		X	X
THERMAL DISCHARGE MONITORING			X	X	X	X	X	X	X	X
FIRE DETECTION/MAPPING			X	X	X	X			X	X
HEAT LOSS DETECTION/MAPPING			X	X	X	X			X	X
GEOLOGIC MAPPING				X	X	X	X		X	X
WATER CHLOROPHYLL				X	X	X		X	X	X
WATER SUSPENDED SEDIMENT				X	X	X		X	X	X
WATER TEMPERATURE			X	X	X	X	X	X	X	X
FOREST INVENTORY				X	X	X			X	X
CROP VIGOR STUDIES				X	X	X			X	X
THEMATIC MAPPER SATELLITE BANDS					X	X			X	X
SPOT SATELLITE BANDS					X	X			X	X
CZCS SATELLITE COMPARISONS								X	X	X
INVENTORY OCEAN BIOMASS								X	X	X
FOR COMMERCIAL FISHERIES TO PREDICT LOCATIONS FOR MAXIMUM FISH HARVEST								X	X	X
DISCRIMINATE BETWEEN SILICATE, CARBONATE AND ALTERED ROCKS							X		X	X
RESOLVE PLANT AND MINERAL SPECTRA									X	X
CONDUCT ATMOSPHERIC ABSORPTION STUDIES									X	X
GLOBAL CLIMATE CHANGE RESEARCH									X	X
HAZARDOUS WASTE SITE ASSESSMENT/MONITORING			X	X	X	X			X	X
DETECTION AND CHARACTERIZATION OF VEGETATION STRESS				X	X	X			X	X
WATER QUALITY (ALGAE, POLLUTION)				X	X	X		X	X	X
ALGAE BLOOM DETECTION				X	X	X		X	X	X
VEGETATION MAPPING				X	X	X			X	X
MINERAL MAPPING					X	X	X		X	X
URBAN MICROCLIMATE STUDIES			X	X	X	X			X	X
VOLCANOLOGY			X	X	X	X	X		X	X
SOIL CLASSIFICATION				X	X	X			X	X
LAKE EUTROPHICATION STUDIES				X	X	X		X	X	X

AIRBORNE DIGITAL IMAGERS

ABS (Airborne Bispectral Scanner) The ABS is a dual port system typically coupling a long wave (thermal) infrared channel with either an ultraviolet, visible/near infrared or short wave infrared channel – at the user's option. Typical applications include oil spill detection/mapping, fire detection/mapping, thermal discharge mapping, heat loss mapping, soil moisture studies and ground water discharge mapping.

AMS (Airborne Multispectral Scanner) The AMS is a dual port system which records up to six spectral channels simultaneously directly onto digital tape. The standard configuration offers a dual element thermal-infrared detector and an 8-channel visible/near-infrared spectrometer for choice from 10 spectral bands. Typical applications include water mapping of chlorophyll, suspended sediment and temperature conditions, forest inventory, crop vigor studies, plus the thermal applications of the ABS.



ATM & ATMX* (Enhanced Airborne Thematic Mapper) The world's most widely used airborne multispectral systems. Their spectral bands include those of the Landsat Thematic Mapper and SPOT satellite channels. These systems are used to complement and expand coverage of satellite applications and the interchangeable detector arrays and spectrometers offer further spectral flexibility.

ATM

ATMX*

(* X = Extra collecting aperture for improved SNR.)

INTERCHANGEABLE SPECTROMETERS FOR ATMX SYSTEM:

TIMS (Thermal Infrared Multispectral Scanner) Unique thermal infrared spectral bands provide specialized data for rock type discrimination, geological mapping and oil/mineral surveys.

AOCI (Airborne Ocean Color Imager) A prime tool in oceanographic research for the study of biomass, chlorophyll, fisheries, or pollution.

AHS (Airborne Hyperspectral Scanner) This system offers 48 spectral bands of data spatially co-registered and simultaneously recorded on computer compatible T-120 cartridge tape. The AHS is based on the integration of many advanced technologies developed by Daedalus under R&D contracts over the past few years. The AHS incorporates advanced components to ensure high performance while maintaining the ruggedness to provide operational reliability in a survey aircraft.

MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) A hyperspectral system with up to 128 spectral bands for advanced remote sensing research. A current configuration of MIVIS can simultaneously record up to 102 channels, spatially co-registered on computer compatible T-120 cartridge tape. Applications include mineral exploration and environmental studies.

CUSTOM SYSTEMS Daedalus' Product Development Group provides contracted engineering services for both commercial customers and government agencies.

DAEDALUS SYSTEM OWNERS

COUNTRY AND OWNER	SYSTEMS
ARGENTINA	
Argentine Air Force	AADS1260 (2)
AUSTRALIA	
CSIRO, Office of Space Science and Applications	AADS1268 (1)
AUSTRALIA	
Department of Conservation and Natural Resources	AADS1260 (1)
BELGIUM	
Eurosense-Belfotop N.V.	AADS1260 (1)
CANADA	AADS1230 (2)
Innotech Aviation Ltd.	AADS1260 (1)
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