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CNR LARA PROJECT, ITALY: AIRBORNE LABORATORY FOR ENVIRONMENTAL RESEARCH

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The increasing interest for the environmental problems and the study of the impact on the environment due to antropic activity produced an enhancement of remote sensing applications. The Italian National Research Council (CNR) established a new laboratory for airborne hyperspectral imaging, the LARA Project (Laboratorio Aereo per Ricerche Ambientali - Airborne Laboratory for Environmental Research), equipping its airborne laboratory, a CASA-212, mainly with the Daedalus AA5000 MIVIS (Multispectral Infrared and Visible Imaging Spectrometer) instrument. MIVIS's channels spectral bandwidths and locations are chosen to meet the needs of scientific research for advanced applications of remote sensing data. MIVIS can make significant contributions to solving problems in many diverse areas such as geologic exploration, land use studies, mineralogy, agricultural crop studies, energy loss analysis, pollution assessment, vulcanology, forest fire management and others. The broad spectral range and the many discrete narrow channels of MIVIS provide a fine quantization of spectral information that permits accurate definition of absorption features from a variety of materials, allowing the extraction of chemical and physical information of our environment. The availability of a such hyperspectral imager, that will operate mainly in the Mediterranean area, at the present represents a unique opportunity for those who are involved on environmental studies and land-management to collect systematically large-scale and high spectral/spatial resolution data of this part of the world. Nevertheless, MIVIS deployments will touch other parts of the world, where a major interest from the international scientific community is present.

MIVIS is a sensor with 4 spectrometers, that simultaneously sample and record 102 spectral bands. It is designed to collect radiation from the earth's surface in the Visible/Near-IR (20 channels from 0.43 - 0.83 μm), Near-IR (8 channels from 1.15 - 1.55 μm), Mid-IR (64 channels from 1.985 - 2.479 μm), and Thermal-IR (10 channels from 8.21 - 12.7 μm).

The MIVIS technical characteristics are (Daedalus Ent., 1994):

- *Two built in reference sources thermally controlled in the range 15°C below and 45°C above ambient temperature*
- *Spatial registration of all spectral bands due to a common field stop optical design (2.0 mrad IFOV)*
- *Sample rate (angular step): 1.64 mrad*
- *Digitized Field of View (FOV): 71.059°*
- *12 bits data quantization*
- *Pixels per scan line: 755*
- *Scan rotational speeds: 25, 16.7, 12.5, 8.3 and 6.25 scans/sec*
- *Computer aided data quality check for all 102 channels in real time*
- *Thermally compensated optical-mechanical design*
- *Large dynamic range: 1200°C maximum scene temperature*
- *Computer interfaced data recording system. VHS cassette media (10.2 Gbytes capacity)*
- *Built in aircraft Position and Attitude System (PAS) using a GPS receiver, a roll/pitch gyro and a flux gate compass for aircraft heading. Real time aircraft roll correction ($\pm 15^\circ$)*
- *Simple operator interface using a touch screen display and menu system*
- *Built in system monitors: Moving Window Display on CRT, and oscilloscope*
- *Automatic built in subsystems testing*

The complete scanner system consists of an electro-optical sensor assembly (Scan Head/Spectrometer) and four electronics chassis interconnected by electrical cables. The Scan Head/Spectrometer component is mounted to have a clear opening through the aircraft skin to the ground below. Data from the sensors is amplified in the spectrometer and passed to the electronics where it is digitized, combined with ancillary data and recorded. The electronics chassis contains the operator interface, the GPS receiver and other supporting subsystems. The principle MIVIS subsystem components are: Scan Head and Spectrometer, Moving Window Display and Monitor, Digitizer, VLDS (Very Large Data Store) Tape Recorder and the Power Distributor.

Three of the MIVIS subsystems contain embedded control computers that supervise and monitor operations for which that subsystem is responsible. Commands and status information is passed between these three subsystems through a local communication network. System startup automatically initiates a series of self tests to verify that the system is ready for use.

The Scan Head consists of the optical elements comprising the primary collecting telescope, a rotating scan mirror, the motor-encoder assembly, two controlled thermal references, and an Invar^R steel and aluminum structure. The scene energy collected by the scan mirror is focused by a paraboloid and directed onto the IFOV defining aperture. Energy passing through the aperture is collimated and reflected out of the scan head to the spectrometer. The two reference sources contained within the scan head are viewed once per scan mirror revolution.

The Spectrometer accepts the collimated energy from the Scan Head and divides it into 4 optical ports. Each port contains a diffraction grating, imaging lens, detector array and preamplifier electronics. Each spectrometer port uses optical materials, coatings and detectors that are optimized for its specific wavelength region of operation. Selectable electronic gains and/or optical attenuations are implemented in the spectrometer to maximize SNR for a wide range of input radiance levels. The output of the spectrometer is 102 electrical signals, each from a different detector, representing, as already seen, a segment of the spectrum between 0.43 and 12.7 μm .

The Moving Window Display (MWD) contains a CRT display monitor assembly, a wave-form monitoring oscilloscope, and a DC to AC power inverter. The principal function of this unit is to provide a visual real time image of the scene being recorded to the operator. This function serves to assess areal coverage, monitor the system integrity and provide an estimate of data quality. The MWD is capable of operating in either real time during the data collection, or after flight in data playback. Display functions are controlled by touch screen menu selections from digitizer system component.

The principle Digitizer function is to provide 102 channels of analog to 12 bit digital conversion, format this data and write it to tape. This process is synchronized to the scan mirror rotation by signals from the optical encoder on the motor. All Digitizer functions are supervised by an embedded computer and control software. The Digitizer contains the Touch Screen which is the principal interface to the instrument. The touch screen and display menu concept makes the control and monitoring of a such complex instrument relatively simple. Menus are presented on the screen to the operator, identifying what action will occur when a designed area on the screen is touched.

During recording time the operator through the MWD monitor continuously check the Dynamic Range status of each channel in the form of a matrix of 102 numbers (one for each channel). The channel number will be illuminated when any of the above mentioned dynamic range errors occur.

The MIVIS system records all data for post flight production and analysis by means of an image processing system (MIDAS). The VLDS recorder is a digital magnetic tape drive using helical scan technology and tape cassettes similar to the home VCR. It enables MIVIS to store a large quantity of data (10.2 Gbytes per cassette) at high speed.

The MIDAS (Multispectral Interactive Data Analysis System) system has been developed to efficiently preprocess, analyze and visualize MIVIS data, and is written for portability to a large number of computer platforms. It has been designed for use on a wide variety of UNIX workstations that support X-Window System and the Application Visualization System (AVS) graphical programming environment. LARA project hosted MIDAS software on a UNIX Silicon Graphics SGI 4D/420VGXT based in Pomezia, a town close to Rome, in a configuration that is synthetically listed below:

- *Two 40 MHz CPUs*
- *128 Mbytes main memory*
- *Four 1.1 Gbytes IPI high-speed disks*
- *Two 1.2 Gbytes SCSI disks*
- *VLDS helical scan cartridge tape system*
- *Two 8 mm Exabyte tape drives (5 Gbytes capacity each)*
- *One 8 mm Exabyte tape drive (10 Gbytes capacity)*
- *1/4 inch cartridge tape drive (150 Mbytes capacity)*
- *Kodak Model XL-7700 film recorder*

A MIDAS Production Processor handles data ingestion, standardized processing (which include radiometric, geometric or atmospheric calibration), reformatting, archiving and dissemination. Raw data from MIVIS are ingested with the VLDS helical scan cartridge tape system and backed up on the 10 Gbytes 8mm Exabyte tape, while preprocessing, archiving, dissemination, and alternative data ingestion is via the two 5 Gbytes 8 mm Exabyte tape drives and the 1/4 inch cartridge tape drive.

The big capacity of this particular hardware and software configuration is the use of a flexible three-dimensional data structure that allows to rapidly move information from high speed disks to memory, so that arbitrarily large data volumes may be processed or interactively visualized (30 frames/sec) without regard to memory limitations. This allows a sensitive compression of times for ingestion, reformatting, validation and preprocessing of MIVIS data before their distribution. In fact, all modules in MIDAS handle hyperspectral data in the Volume Image Management System (VIMS) format greatly improving the system performance. MIDAS organizes data into volume elements (voxels), and uses the voxel bricking (an extension of the planar processing pixel tiling) reducing the disk thrashing problem (TASC, 1993).

Besides MIVIS data production, MIDAS offers to users a very powerful system for hyperspectral image processing. MIDAS provide all the standard functions of a software dedicated to image processing, but more, offer software tools to analyze data in the spectral domain and allow the possibility to develop new algorithms for particular user's analysis.

During the second half of last July 1994 LARA Project, in the framework of the final MIVIS/MIDAS testing and tuning, held a MIVIS test deployment in Sicily. The deployment was successful and more than 56 Gbytes of MIVIS data were collected in almost 5 hours of VLDS recording time.

This first MIVIS deployment has been carried out in Sicily in cooperation with national and international institutions on a variety of sites, including active volcanoes (Mt. Etna and Eolian Islands), coastlines (Gela, Acireale, Taormina), ocean (Messina Straits and Marsala lagoon), vegetated areas (Mt. Etna slopes), waste discharges (Acireale), and archeological sites (Selinunte, Alesa and Acireale).

During MIVIS data acquisition a contemporaneous ground data acquisition campaign has been carried out for most sites. For the surveys on volcanic areas CNR/IIV offered its ground support logistics in making measurements of plume SO₂ with its portable COSPEC instruments, while JPL, CNR/CSGDSA, ING, OGUM, and the University of Palermo people launched radiosondes to measure H₂O profiles, used anemometers for wind speeds, a GER portable spectrometer to measure ground radiances, radiation thermometers and thermocouples for measurements of ground temperatures. CNR/IROE deployed by helicopter its FLIDAR instrument contemporaneously with MIVIS on Gela's coastline and on Mt. Etna's beech-woods. CNR/CST and the University

of Palermo made sea truths measurements with scientific boats on the Straits of Messina and inside/outside the Lagoon of Marsala.

After the Sicily 1994 MIVIS deployment an evaluation of MIVIS inflight performances has been done for thermal channels making statistics on a portion of the ocean West of Stromboli Island (6771 pixels). In Figure 1 the inflight NEAT is shown.

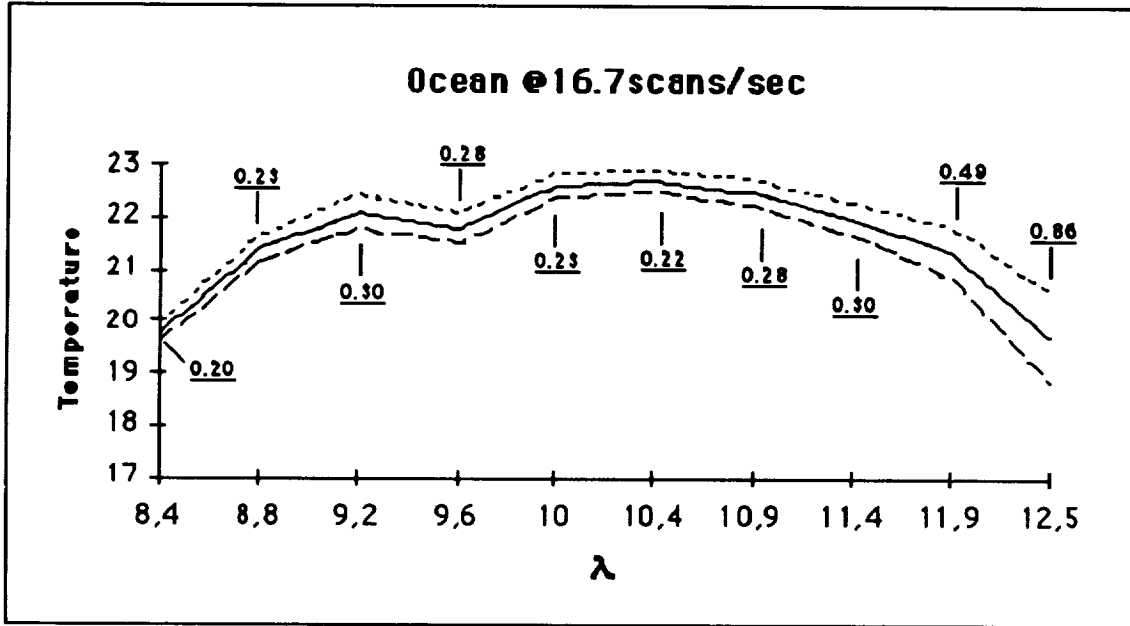


Figure 1 - Inflight NEAT (underlined numbers on the plot) computed for the 10 MIVIS thermal channels on a portion of ocean target (6771 pixels), West of Stromboli Island.

Selected scenes of the Sicily 1994 MIVIS data will be extracted for general distribution under request starting from 1995.

REFERENCES

- DAEDALUS Enterprises, 1994, *AA5000 MIVIS Operator Manual*, 6 volumes.
- TASC Company, 1993, *MIDAS Data Center User's Manual*, 2 volumes.