AIRBORNE IMAGING SPECTROMETRY: A NEW APPROACH TO ENVIRONMENTAL PROBLEMS

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ABSTRACT

The CNR (Italian National Research Council) Airborne Laboratory for Environmental Researches (LARA Project), since summer 1994 acquired and its has been intensively operating the MIVIS AA5000 (Multispectral Infrared and Visible Imaging Spectrometer). A large number of MIVIS deployments have been carried out in Italy and Europe in cooperation with national and international institutions (France, Germany and USA) on several test sites, including active volcanoes, coastlines, lagoons and ocean, vegetated and cultivated areas, oil polluted soils, waste discharges, and archeological sites. The 1994-1996 two years of activity has shown the high system efficiency and the utility of the MIVIS airborne imaging spectrometry for the study of environmental problems. The purpose of this work is to present and to comment the results of the past campaigns and, in the meantime, to illustrate present and future programs of deployment in Europe and worldwide.

1. INTRODUCTION

CNR established a laboratory for airborne hyperspectral imaging devoted to environmental applications since June 1994. The project (LARA Project) is fully operative to provide hyperspectral data to the national and international scientific community. A large number of deployments of the Daedalus AA5000 MIVIS system have been performed using a CASA-212 aircraft platform.

MIVIS is a modular instrument constituted by 102 spectral channels that uses independent optical sensors simultaneously sampled and recorded. The complete scanner system (Figure 1) consists of an electro-optical sensor assembly (Scan Head/Spectrometer) and four electronics chassis (Moving Window Display and Monitor, Digitizer, VLDS Tape Recorder, Power Distributor) interconnected by electrical cables.

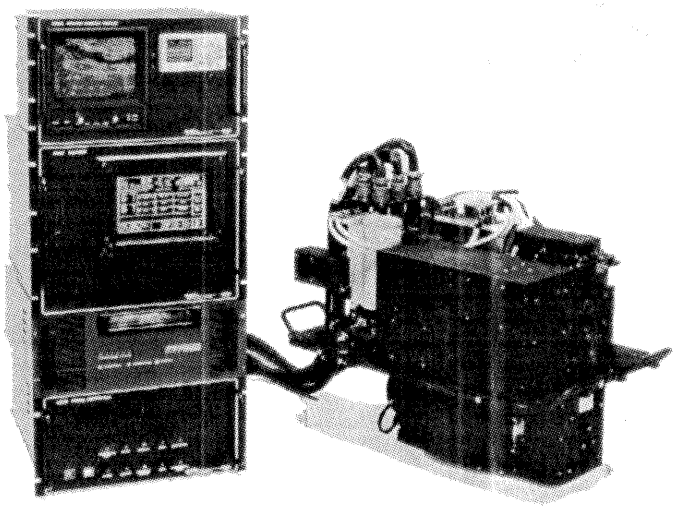

Figure 1 - The MIVIS instrument

Three of these components contain embedded control computers that supervise and monitor operations. Commands and status information is passed between these three subsystems through a local communication network.
MIVIS, with its 4 spectrometers designed to collect radiation from the earth's surface in the Visible (20 channels), Near-IR (8 channels), Mid-IR (64 channels), and Thermal-IR (10 channels), represents a second generation imaging spectrometer developped for its use in Environmental Remote Sensing studies across a broad spectrum of scientific disciplines.

2. MIVIS CHARACTERISTICS

2.1 Technical characteristics

The MIVIS technical characteristics are:

102 spectral bands: simultaneously sampled and recorded

Bands #	Lower edge mm	Upper edge mm	Bandwidth mm
1-20	0.43	0.83	0.02
21-28	1.15	1.55	0.05
29-92	1.983	2.478	0.009
93-102	8.18	12.7	0.34-0.54

- Two built in reference sources thermally controlled in the range 15°C below and 45°C above ambient temperature
- Field of view : Instantaneous 2.0 mrad, Total 71.059°
- Sample rate (angular step): 1.64 mrad
- 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 Sensor (PAS) using a GPS receiver, a roll/pitch gyro and a flux gate compass for aircraft heading sensor.
- Real time aircraft roll correction: ±15°
- Simple operator interface using a touch screen display and menu system
- Built in system monitors: Moving Window image on CRT, and oscilloscope
- Automatic built in subsystem testing
- Total Power: 28 ±3V DC, 80 Amp Continuous.

2.2 MIVIS test bench calibration

In order to calibrate and maintain the MIVIS scanner system performances a test bench is used to quantify the system sensitivity. The calculation of system sensitivity is determined by measuring the signal-to-noise ratio (SNR) produced by a known radiance input. The radiance source for visible and near-infrared bands is a calibrated reflectance panel, illuminated by calibrated lamps, while the radiance source for thermal infrared is the self-contained thermal reference sources on the scan head. To facilitate the collection of signal and noise data, the bench contains a data collection module that allows separate noise measurements for each channel at each scan speed.

The used test bench provides:

- A source of 28 VDC power of sufficient capacity to operate all the MIVIS subsystems.
- A calibrated spectral radiance source, composed by a calibrated "white" panel illuminated by two 200 watt tungsten-halogen lamps operated at 2900° K, for scanner radiometric testing and calibration in the 0.4-2.5 micrometers.
- A collimator/target projector for scanner spatial resolution tests and focusing.
- A thermal reference source composed by a flat aluminum plate painted flat black (the same paint used on the scanner blackbodies), operating at 40°C, to be used in aligning the thermal detectors.

All the scanner's sensitivity measurements can be stored on the MIVIS hard disk to be recorded on VLDS tape together with data during deployments. In Figure 2 is reported signal to noise ratio (SNR) values for the 4 spectrometers at the minimum and maximum scan speed.

In May 1995 monochromator spectral calibration curves for all the 102 MIVIS channels have been obtained for distribution to users.

2.3 MIVIS deployment

For every MIVIS deployment, in order to assure data quality, the following operations are performed:
- Test bench scanner calibration and recording of calibration data on the MIVIS hard disk
- Check of the signal level for each of the four spectrometers
- MIVIS installation on board the CASA 212
- Functionality check of the five MIVIS subsystems and signal level check for all the 102 channels
- MIVIS deployment execution (Daily functionality checks are performed for multi-days campaigns)

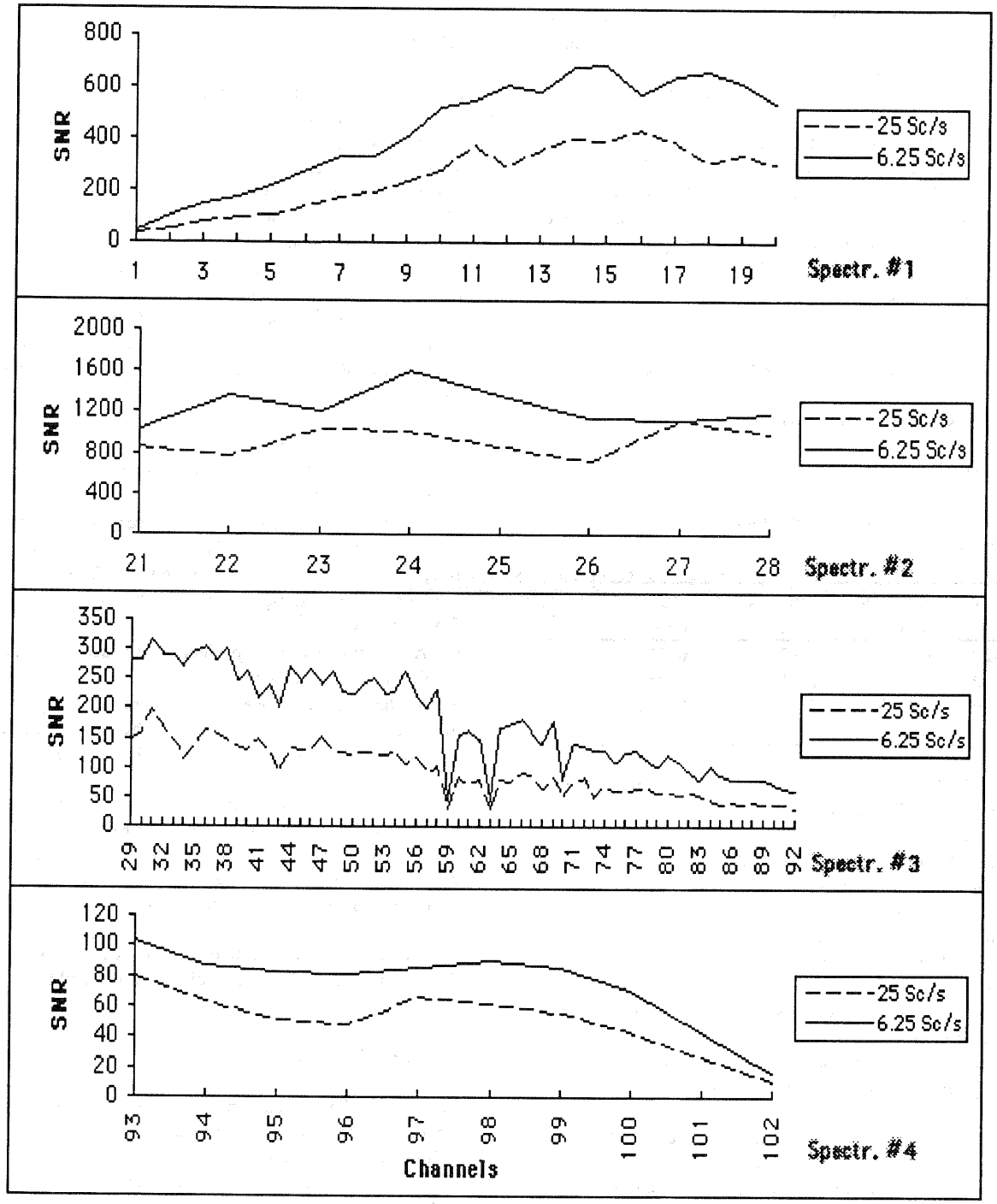

Figure 2. Signal to Noise Ratio (SNR) values for the 4 MIVIS spectrometers at the minimum and maximum scan rate

- MIVIS deinstallation from the airborne platform and repetition of test bench scanner calibration to check the MIVIS performance level after the deployment.

3. HYPERSPECTRAL DATA PRODUCTION

The production (preprocessing and analysis) of these large hyperspectral data sets is performed in the LARA Project headquarter of Pomezia,a small town close to Rome, where a computer system with a software designed to handle MIVIS data has been established.

The MIDAS production software (MIDAS: Multispectral Interactive Data Analysis System), besides the data production management, offers a powerful and highly extensible hyperspectral analysis capability. The Pomezia ground station is designed to maintain and check the MIVIS performance through the evaluation of data quality (like spectral accuracy, signal to noise performance, signal variations, etc.), and to produce, archive, and diffuse MIVIS data in the form of geometrically and radiometrically corrected data sets on low cost and easy access CC media.

3.1 Avaiable products

The MIDAS production pipeline is structured as follows:

-MIVIS data ingestion into MIDAS system for extraction of all ancillary info and backups.
-Production of 512 lines scenes in four different levels of preprocessing, as function of data owners request. The 4 different preprocessing levels are:
- Level 0: Raw data + ancillary info for radiometric calibration and geometric corrections.
- Level 1: Data radiometrically calibrated at the sensor, by using MIVIS internal references and the scanner's sensitivity measurements recorded from test bench.
- Level 2: Data corrected by atmospheric effects and radiometrically corrected as in Level 1. In this case data owners are requested to supply all the paameters for path radiance and solar irradiance corrections.
- Level 3: Level 1 or 2 data geometrically corrected from panorama distortions and the effects due to roll, pitch and yaw platform variations. The corrections are performed by using info gathered by MIVIS PAS system.
- Level 4: Level 1 or 2 data geocoded images obtained integrating with a digital elevation model the MIVIS ancillary position and navigation sensors, allowing an exact positioning of pixels on the ground in no flat areas.

Distribution of preprocessed data by using exabyte 8mm tapes in tar UNIX format as support.

4. MIVIS CAMPAIGNS

MIVIS data were recorded over different types of sites

A large area, near the town of Trecate (Northern Italy), has been interested by a huge oil blow-out from oil rig belonging to AGIP (Italian Petroleum Agency).
MIVIS has flown at an altitude of about 2000 m a.s.l. offering good quality data for the estimation of the level of oil pollution over cultivated and urban areas.
MIVIS data over Garda Lake, Venice and Orbetello Lagoon and Po river delta, gave the possibility of a preliminary new insight in the field of specific applications of hyperspectral remote sensing to water quality, shallow and algal bloom analysis.
MIVIS survey was carried out in Sicily for geological mapping and to investigate active volcanic phenomena (Mt. Etna and Eolian Islands), coastline pullution (Gela, Acireale, Taormina), ocean currents dynamics and algae bloom (Messina Straits and Marsala lagoon), beech-wood canopy (Mt. Etna slopes), waste discharges (Acireale), and archeological sites (Selinunte, Alesa and Acireale).
In the summer of 1995 MIVIS has been deployed over the whole Italian Molise region for landslides and vegetational studies, in test sites located in Germany for enviromental investigations,and in Southern France for agricoltural studies.
In the fall of 1995 a further deployment interested the Campania Region for the study of several specific targets, i.e: urban areas (Napoli), vulcanology (Vesuvius and Solfatara in Pozzuoli), coastal pollution, archeology (Pompei) and other enviromental and monumental sites (Caserta Royal palace and gardens.

Two year of activity has shown as CNR/LARA Project has been and is operative according to the guidelines that represented the main tasks for the Project institution. The flight and data requests from the scientific national and international community has been far more above the initial forecast, and Lara Project is still working to improve its own capability to assure the most opportune reaction towards the future flight requests and shortest time for data production and diffusion amongst the users.

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