AIRBORNE VISIBLE/INFRARED IMAGING SPECTROMETER (AVIRIS): SENSOR IMPROVEMENTS FOR 1994 ANJ) 1995

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1.0 INTRODUCTION

AVIRIS is a NASA-sponsored Earth-rcmo[c-sensing imaging spectrometer designed, built and operated by the Jet Propulsion Laboratory. In the time that AVIRIS has been operational since 1989, major improvements have been completed in most of the subsystems of the, sensor during the winter maintenance cycles. As a consequence of the.sc efforts, the capabilities of AVIRIS to reliably acquire and deliver consistently high quality, calibrated imaging spectrometer data continue to improve annually, significantly over those in 1989. improvements to AVIRIS prior to 1994 have been described previously (porter et al., 1990, Chrien et al., 1991, Chrien et al., 1992, Chrien et al., 1993). This paper details recent and planned improvements to AVIRIS in the sensor task.

2.0 SENSOR IMPROVEMENTS

2.1 1994 Engineering and Maintenance Cycle

2.1.1 100 Lines of Post Cal Dark Current

A 100 line sliding dark current average has been employed in the processed data since the 1993 flight season for noise reduction, but had a ramping-off arti fact which would begin 100 lines before the end of each run. To compensate for this and also to provide an even more stable dark current value for the entire run, 100 scan lines of dark current are taken at the end of each run during the post-cal sequence.

2.1.2 Lyot Filters in and Temperature Telemetry from IFRS

The number of filter wheel positions in the in-flight reference source (IFRS) was increased from 4 to 8 to accommodate the addition four Lyot filters, onc pcr spectrometer. Because of manufacturing delays, the first three Lyot filters (A, B, and C) were installed mid-way through the 1994 flight season during a two-week hiatus in July. The fourth Lyot filter (D) was installed at the end of the flight season. A temperature sensor was added for monitoring the Lyot filters in telemetry, which change spectral characteristics with temperature.

2.1.3 Spectrometer Thermal Testing and Additional Thermal Blanketing

All four spectrometers were tested in a thermal chamber to investigate operation at simulated mission temperatures, down to -10 C. Resulting data showed that a vert ical thermal gradient existed even with the distributed, actively controlled spot heaters. Additional thermal blanketing applied to the lower part of the spectrometers was found to greatly ameliorate this condition, which was causing a spectral shift in the spectrometers.

2.1.4 Tape Recorder Thermal Testing

Both AVIRIS high densit y digital recorders (HDDR) underwent testing in a thermal chamber to further refine the performance of the JPL developed thermal control. An adjustment to the thermal controller time constant improved the thermal tracking and enhanced the bit error rate performance at mission temperatures. Onc of the HDDR's was updated to the high-performance cross-cut scanner heads, bringing it current with the other AVIRIS unit.

2,1.5 High Resolution Scan Timer

A high resolution scan timer (HRST) was installed to measure the skew between the roll-compensated start of successive cross track scans. The scan timer is a 16 bit counter driven by a crystal stabilized 94.3 kHz clock, with a 10.6 usec period. Nominally, the scan timer value rolls over every 8.33 scans (with no aircraft roll rate). One application for the HRST is in temporally registering the crosstrack scan lines in an image so that an FFT can be used to remove coherent noise from a roll-compensated image.

2,1.6 Recovered Elements in Spectrometer B, C, and D FPA's

The first element of each of the four FPA's was previously saturating due to an artifact in the analog signal chain. A simple change in the timing generator was found to delay the ADC start pulse sufficiently to bring the B, C, and D spectrometer WA'S out of saturation and make them usable. In previous years (from 1989 on), these channels (33, 97, and 161) were present in data products as blank image planes.

2.1.7 Operational Features

To accommodate a request from Ames Research Center that AVI KIS operational indicators in the ER-2 cockpit be more like other ER-2 sensors, the AVIRIS cockpit control indicators now describe the operational state of AVIRIS. The operational states are: power-on-initiation; run-initiation, pre-cal/post-cal; and science data collection. This enhancement reduces the pilot workload, facilitating data gathering. Another operational enhancement is delaying the gyro reset pulse until the. last moment before commencing science (image) data collection, to eliminate the previously required lead time for a flight line following the completion of an ER-2 turn.

2.1,8 Spares Program

The inventory of spare parts continues to grow with the. addition of a spare gym assembly. The need for spare parts is recognized especial 1 y for deployments outside the continental United States, when an unrecoverable AVIRIS breakdown in the field would mean the termination of a deployment. Spare parts from the AVIRIS inventory during the 1993 flight season afforded a recovery within 5 hours from the damage caused by a power transient in the lab (which occurred less than 24 hours before the shipping date at the start of the flight season), and a 95% fix to the Freckles and Badspots problems mid-way through the 1993 season without impacting the flight schedule.

2.2 1995 Engineering and Maintenance Plans

2.2.1 New FPA's

Development and testing continues on candidate FPA designs which will have 12 bit digitized data, lower noise, increased dynamic range, and snapshot mode readout, A minimum of two of the four spectrometers will have new WA'S installed.

2.2.2 Dark Current Summing and 12 bit Data Path

An upgraded data formatter onboard AVIRIS will have 12 bit data paths and a dark current summing on the flyback for lower noise dark current readings, The dark current summing will collect and add a fixed number of dark current samples for all 224 bands during the ftyback period of the scan. Averaging of the sums will be done in the AVIRIS data facility. The number of samples collected will be selected after characterizing the foreoptics shutter to determine the maximize time available for collecting dark current samples during the flyback. A spare foreoptics shutter module is being built for characterization and will be added to the spares inventory.

2.2.3 Calibrator lamp Stability

To improve the stability of the lamp in the IFRS, a photosensor has been added to the lamp regulator, In 1993 and 1994 a precision current regulator was used to control the lamp output, but it eventually became clear that changes in the filament over the life of the lamp and variations among lamps (if one failed between calibrations) would compromise the desired stability of the source.

2.2.4 IFRS Thermal Testing

Thermal chamber testing is planned for the IFRS to calibrate and measure the stability of the reference lamp and the Lyot filters down to -10 C. Results from this testing activity will expand the usefulness of the IFRS as an on-board spectral and radiometric calibration source during in-flight data runs.

2.3 Future Engineering and Maintenance Plans

2.3.1 C-130 Flight Demonstration Program

Plans are underway to adapt AVIRIS to the C- 130 and conduct 30 hours of demonstration flights in 1996. Special attention will be given to acoustic and vibration isolation in the C-130 airborne environment, which is more severe than the ER-2, to reduce levels below those experienced in the ER-2. Data will be collected at altitudes as low as 5 km, increasing the AVIRIS spatial resolution by a factor of 16, or reducing the, noise by a factor of 4.

3.0 CONCLUSION

Since AVIRIS first became operational in 1989 the AVIRIS system has been undergoing incremental improvements. A number of these improvements have occurred in the sensor component of the AVIRIS project. In all cases, the driver for these modifications and upgrades has been the quality of data provided to the science investigators. The important modifications in 1994 and 1995 have been described.

4.0 ACKNOWLEDGMENTS

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6.0 TABLES

Table 1. AVIRIS Data Characteristics		
SPECTRAL	Wavelength range	400 to 2500 run
	Sampling	<= 10nm
	Spectral response (fwhm)	10 nm nominal
	Calibration	<= 1nm
RAD1OMETRIC	Radiometric range	O to maximum lambertian
	Sampling	-1 dn noise rms
	Absolute calibration	<= 7%
	Intraflight calibration	<= 2%
	Precision/noise	exceeding NEdL/SNR requirement
GEOMETRIC	Field of view (FOV)	30dcgrcm(11 km)
	Instantaneous FOV	1.0 mrad (20 m)
	Calibration	<= 0.2 mrad
	Flight line length	Up to ten 100 km flight lines

'able 2. AVIRIS Operational Characteristics		
ENSOR	Imager type	Whiskbroom scanner
	Cross track samples	614 elements
	Scan rate	12 scans /second
	Dispersion	Four grating spectrometers (A ,B ,C,D)
	Detectors	224 detectors (32,64,61 ,64) Si & InSb
	Digitization	10 bits (12 bits planned for 1995)
	Data rate	2.125 Mwords/second
	Spectrum rate	7300 spectra/second
	Data capacity	>10 gigabytes (>10,000 km^2)
	Onboard calibration	Radiometric and spectral
	Position & pointing	Lat, Ion, alt, and roll, pitch, yaw
	Launches	-30 per year
ATA FACILITY (ADF)	Performance monitoring	48 hours from acquisition
	Archiving	Onc week from acquisition
	Quick-look distribution	Onc week from acquisition (anon ftp)
	Calibration	Two weeks from request
	Quality monitoring	Prior to distribution
	Distribution	Two weeks from request
	Engineering analysis	High priority as required

'able 3. AVIRIS Data Acquisitions	1992	1993	1994
Months of operations	8	7	8
ircraft bases	4	4	4
rincipal investigators supported	32	35	24
ivestigator sites flown	172	211	382
aunches	34	38	53
iflight calibration experiments	3	3	3
quart kilometers flown	114,300	138,400	250,000
'light scenes	1143	1384	2500
iigabytes processed	317	363	>600
Data scenes calibrated/distributed	1120	1212	2000
pproximate data turnaround (months)	2.5	1	1