THE HYPERSPECTRAL IMAGER ABOARD THE SSTI's LEWIS SPACECRAFT: A COMPARISON WITH AVIRIS

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1. INTRODUCTION

This paper compares the performance and operational parameters of the Hyperspectral Imager (HSI), scheduled for launch aboard the Lewis spacecraft in July 1996, with those of the Airborne Visible/Infrared imaging Spectrometer (AVIRIS). The HSI is a pushbroom, imaging spectrometer with 30 meter spatial resolution, generating 384 spectral channels over the range 400 to 25(K) nm at 5.0 to 6.4 nm resolution for each of its 256 crosstrack pixels. The Lewis spacecraft and the HSI are being hill by TRW, Incorporated as part of the Small Spacecraft Technology initiative (SSTI) initiated by NASA's Office of Space Access and Technology to advance the state of technology and reduce program costs associated with the development and operation of small satellites. The SSTI is also producing the Clark spacecraft being built by CTA, Incorporated, which is scheduled for launch late in the summer of 1996. Clark will carry the high spatial resolution WorldView imager, having 3m panchromatic and 15m multispectral capability, as its primary payload.

Because the SSTI was intended to demonstrate new design and space system qualification methods as well as to promote commercial applications for remotely sensed data, both Lewis and Clark will carry a number of additional payloads and experimental technology demonstrations. Among these payloads are two other imaging spectrometers: the Linear Etalon imaging Spectrometer Array (LEISA) and the Ultraviolet Cosmic Background (UCB) instrument aboard Lewis. The LEISA is an earth-observing sensor providing 256 spectral bands in the 1000 to 2500 nm region, with roughly 300 meter spatial resolution. The UCB is designed to map the diffuse, ultraviolet cosmic background in the 11.8 to 22.5 eV range. Additional Clark payloads include the Atmospheric Tomography (ATOMS) instrument for determining 3-D atmospheric molecular profiles, the Measurement of Air Pollution from Satellites (µMAPS) sensor for mapping and monitoring atmospheric carbon monoxide profiles, and the X-Ray Spectrometer (XRS) for observing solar flares and cosmic gamma ray bursts over the 1 to 100 keV region.

To augment the list of sensor performance metrits, this paper presents the signal to noise ratios of both the HSI and the AVIRIS for typical observing conditions, outlines plans for standard processing of HSI data, and discusses both data availability and satellite tasking.

2. 11S1 PERFORMANCE ANI) OPERATIONAL PARAMETERS

Table 1 compares the performance and operational parameters of the AVIRIS with [hose of the 11S1, which is composed of two focal plain assemblies: the Visible- to Near-lnfralcd (VNIR) and SIImt-Wave Infrared (SWJR) spectrometers.

'l'able 1. Comparison of 11S1 and AVIRIS System Parameters

Parameter	Lewis/11Sl	AVIRIS
Operational **Altitude**	Circular orbit of **S'23** ∄10km altitude, **San Synchronous** (97.5° **inclination**) 10:50 **AM** ∄0:20 ascending **node,**	**Nominal ?()** km operational altitude.
Positional Accuracy	≈∄ **100** m in **x,** Y, and **z**	≈∄ **1(K)** m **in X, Y, and** Z.
Imaging Attitude	• ∄ 22° **in Roll**	Nadir pointing **only.**
	• ∄ ().25° in Pitch	
	• ∄ 3.8° **in Yaw**	
Attitude Uncertainties	• ∄ 8" **in Roll** (≈2/3 **pixel)**	• ∄ 21" in Roll (≈1/10 pixel)
	• ∄ 25" in Pitch (≈2 **pixels)**	• ∄ 21" **in Pitch** (≈ **1/10 pixel)**
	• ∄ 30" **in** Yaw (≈1/60 pixel)	• ∄ 2]" in Yaw (≈1/100 pixel)
Data Collection Rate	One imaging **event pcr** working day. Approximately **250** image cubes **in** the first **year of** operation.	≈80 cubes per flight day or ≈3,000 cubes per **year. This** includes 33% downtime **for** scheduled maintenance.
Radiometric Calibration Plan	• Pre-launch laboratory calibrations	• A pre-image sequence **of darks, white.s,** and line frames
	• 8 pre-image **dark** frames	• A post-image sequence of darks, whites. Lyots, and Line frames
	• 8 **post-** image dark **frames**	• Yearly laboratory **calibration**
	• 8 post-image white frames at low lamp current	• Three operational calibration experiments annually
	• 8 post-image white frames at **high** lamp current	
	• **1** set of solar frames per week	
	• Periodic, on-orbit calibration verification experiments	
Radiometric Calibration Accuracy	• ∄ 5% absolute	• ∄ 4% **absolute**
	• ∄ 2% relative	• ∄ 2% relative
Data Quantization	12-bit digitization, padded to a two **byte** integer	12-bit digitization, **padded 10** a two-byte .E!!L?%—
Spectral Calibration Plan	• Pre-launch calibration	• **Annually in** laboratory
	• On-orbit **verification**	• ∄ **1** nm **band** centers
	• Periodic on-orbit monitoring	• ∄ 1 nm band widths full width **half** max (FWHM)
Spatial Resolution	30m by 30m pixels	20m by 20m nominal pixels
Spatial Size of Data Sets	• 256 cross track **pixels**	• 614 cross track **pixels**
	• ~ **1000** along track lines but more **in** proportion to the fraction **Of** bands *not* acquired	• **512** along track lines
Spectral Resolution	"* VNIR - > 5.0 nm FWHM	=**10** nm **for** all spectrometers **(A,** B, C, and **1))**
	• SWIR -) **6.4** nm FWHM	
Spectral Sampling	• VNIR -) **5.01111)**	≈ 10 nm for all spectrometers **(A,** B, C, and **1))**
	• SWIR - > **6.4** nm	
Number of Bands	• VNIR -) **128 (400- 1000** nm)	• **A** - > 32 **(370 - 680** nm)
	• SWIR - > '**256 (900 - 2500** nm)	• B - > 64 **(670 1?70** nm)
		• **C** - > **64** (1250 - 1880 nm)
		• I) - > 64 (1880 - **2500** nm)

3.   SIGNAL-TO-NOISE RA"T1OS

Figure 1 compares the signal-to-noise ratios expected from both the }1S1 and the AVIRIS for a target at **45°N latitude,** having a gray albedo of 0.3, an observing geometry with 60° solar zenith angle, using a standard, MODTRAN spring season atmosphere. The signal-to-noise ratios for both VNIR and SWIR are plotted in the 900 nm to 1000 nm region where they overlap.

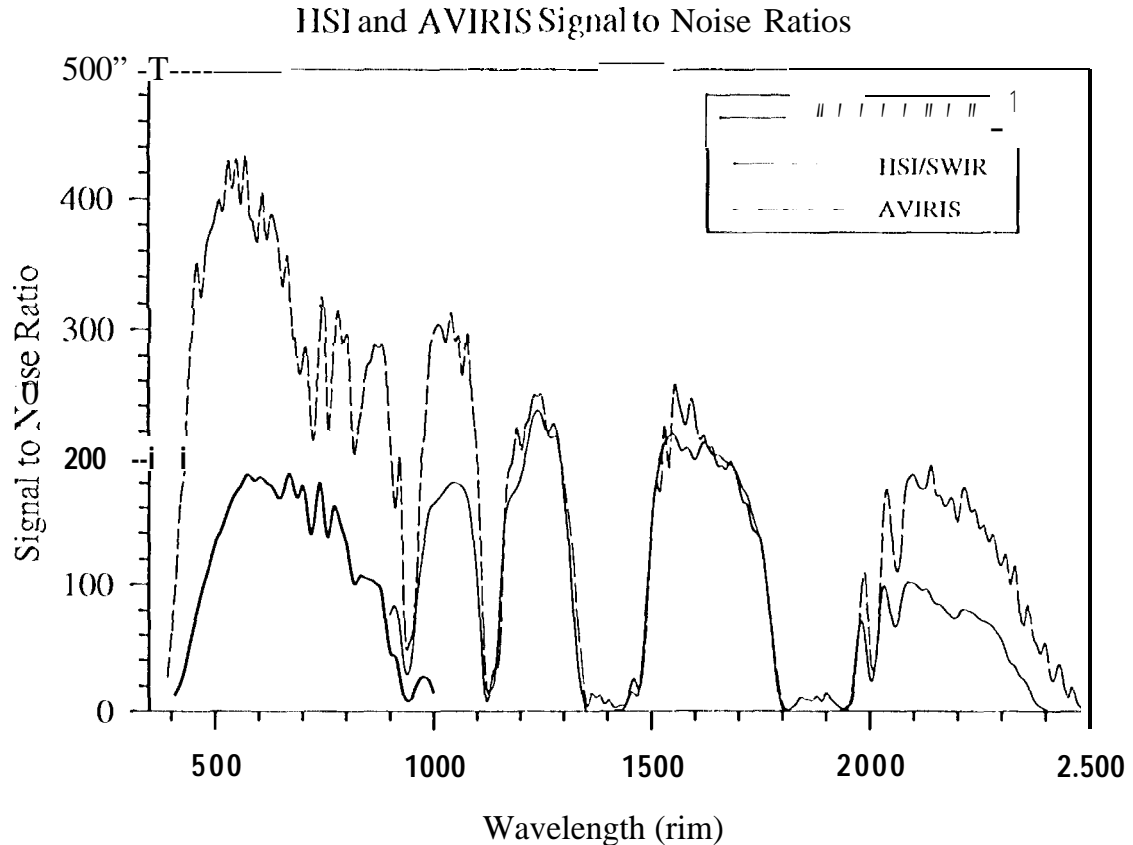## HSI and AVIRIS Signal to Noise Ratios

Figure 1.   The signal-to-noise ratios expected from both HSI and the AVIRIS for a target at 45° N latitude, having a gray albedo of 0.3, an observing geometry with 60° solar zenith angle, using a standard, MODTRAN spring season atmosphere. The VNIR and SWIR spectral channels have been binned in twos to produce resolutions of 10 nm and 12.8 nm for VNIR and SWIR respectively, comparable with that of the AVIRIS. Both VNIR and SWIR spectra are plotted in the 900 nm to 1000 nm region where they overlap.

4.   DATA PROCESSING

The Commercial Remote **Sensing** Program (CRSP) **base.(i** at Stennis **Space** Center (SSC), Mississippi, **is** developing the Data Processing System (DPS) to dc.rive }Iigllcl-level data products from level O HSI data acquired al the spacecraft. The purpose of' the DPS is to optimize the commercial and scientific viability of the Lewis and Clark missions by offering the entire user community standard data products, appropriate to their requirements, for further processing and analysis. The data processing outline of the DPS **is 1)** radiometric calibration, where signal DNs are converted to units of radiance at the space.claf(; 2) atmospheric removal, where molecular absorptions as well as

molecular and aerosol scattering effects are removed, thus converting pixel units to apparent ground reflectance; 3) georeferencing of both VNIR and SWIR spectrometers, where the latitude and longitude of each image pixel center are determined relative to a featureless Earth model (NOTE: (here is no data resampling here); 4) the SWIR data are spatially resample.d, producing a footprint on step 3's model Earth equivalent to that of VNIR; and 5) the region of spectral overlap between VNIR and S WI R is removed, yielding one complete, apparent reflectance spectrum for each image pixel. The DPS will also perform a number of automated quality assurance (QA) steps and allow for manual QA at every level. All DPS processing will be performed using C++ and IDL code.s running in the Windows-NT opci'sting system on INTEL,-based machines. Processing to level 2 data products and beyond will be accomplished manually by SSC staff for Lewis team members on an as-requested basis.

5. DATA AVAILABILITY

Appropriate data products from the 1)1'S described in section 4 will be made available to all Lewis team partners via the Wo[]d-Wide-Web-1~ascd Mission Data Management System (MDMS). This system will allow team partners to examine all data sets and to download chosen image cubes and associated data structures (i. e., data headers, metadata, parameter blocks, and calibration data structures) directly. Copies of appropriate data within the MDMS will be stored at the EROS Data Center (EDC), where they will be made available to the public following EDC and NASA established pricing guidelines. Generally, there will be no period of exclusivity for SS'1'1 data products, and all SSTI data will be made available immediately following DPS processing. However, data collected in response 10 national emergencies and for code. S sponsored investigations will retain a one-year period of exclusivity for government use and the Code S experiment team, respectively.

Although subject to change, it appears that the MDMS will contain the following data generated by the DPS for each imaging c.vent: I) an unprocessed, level l **A cube** (prior to step 1 above); 2) a 1G1 cube, which has been converted to georeferenced d, apparent reflectances on the ground (processed through step 3 above, NOTE: having undergone no irreversible processing); anti 3) a 1R? cube, containing one complete spectrum per image pixel (processed through step 5 above, NOTE: resulting from both spatial and spectral irreversible processing). Higher-level (data levels 2 and beyond) information products will *not* be made available from within the MDMS environment or at the EDC.

6. LEWIS/HSI TASKING

Current NASA/SSTI data policy is to establish an Experiment Tasking Oversite Group (ETOG), which will review all satellite tasking requests in each of the four basic experiment areas: commercial, science, education, and technology demonstrations. Proposals from current Lewis team partners will be given precedence over those from non-members, who will be required to enter into a Space Act Agree.rIIcm with NASA, including appropriate experimental results reporting, in order to submit tasking proposals for ETOG consideration. In cooperation with NASA, CRSP, and TRW personnel, the ETOG will generate the tasking priorities among the four general experiment types and establish a coordinated tasking and observation plan. This plan wiii conform with all existing NASA data policies, including contingencies for national emergencies and natural disasters.

7. ACKNOWLEDGMENTS