AIST Program
Space Based NRA
Technologies

Earth Science Technology Conference
2003

Real-Time Data Processing Onboard Remote Sensor Platforms

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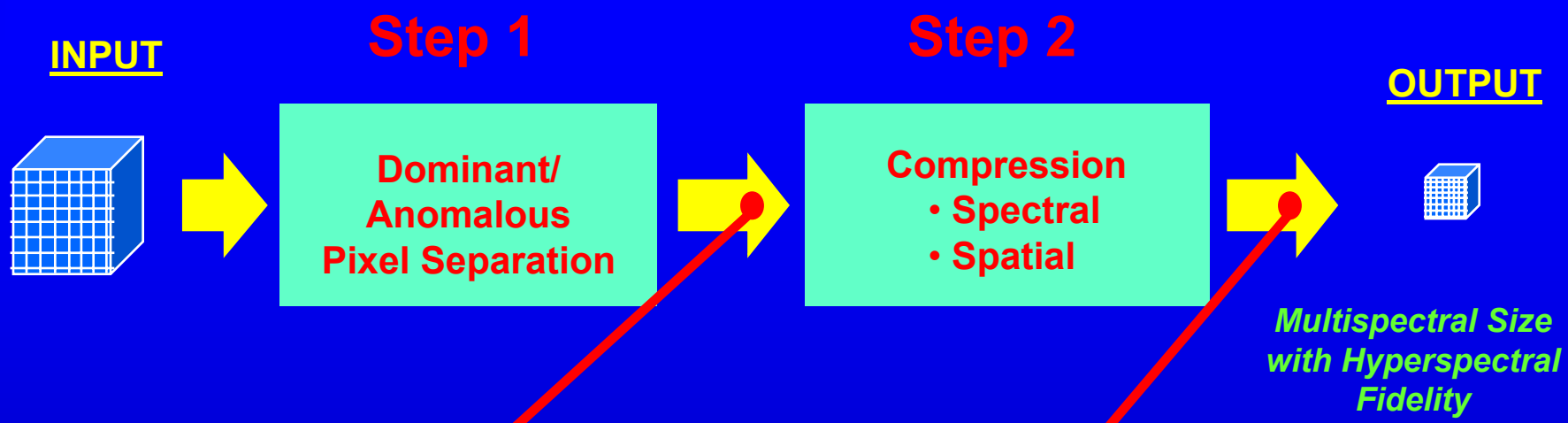
Agenda

- Describe Algorithms
- Hyperion Compression Results
- Onboard Processing Requirements
- Onboard Processor Design

Directed Data Compression Approach



Step 1:

1. Identifies anomaly locations
2. Determines pixel model order
3. Produces Dominant Subspace Model
4. Anomalous Subspace Endmembers & Classes
5. Produces Full Endmember Description

Step 2:

A. Compressed Hypercube
B. Endmember Fractions
C. Dominant Subspace Fractions

HSI Compression Evaluation

- Analytical Analysis
- EO-1 Science Team Evaluations
  - Dr. Steve Unger / Dr. Lawrence Ong – NASA GSFC
  - Dr. Jay Pearlman – TRW/Boeing
  - Dr. David Goodenough – Canadian Forest Service
  - Dr. Seth Orloff – MIT Lincoln Labs

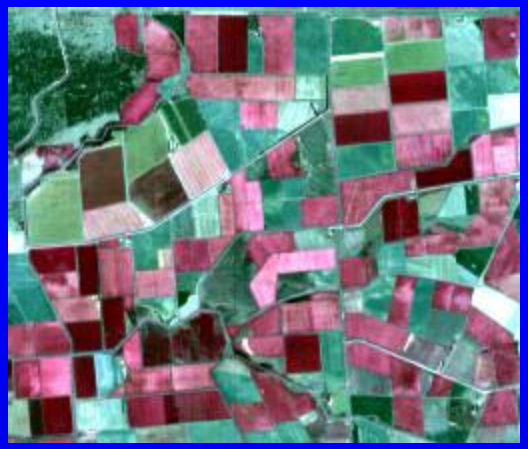
Definitions

- Spectral Angle (SA) Error
  - Pixel Vector (V) = $v_1 + v_2 + \ldots v_{\#bands}$
  - SA = arccos(Vo·Vc/(mag(Vo) x mag(Vc)))
- Root Mean Squared Error (RMSE)
  - RMSE = $\sqrt{\sum \frac{(Po-Pc)^2}{\#\,Pixels}}$
- Signal-to-Noise Ratio (SNR)
  - SNR = $10\log_{10}\left[\frac{\sum (Po)^2}{\sum (Po-Pc)^2}\right]$
- Spearman's Correlation Coefficient (CC)
  - CC = $\frac{\#\,Pixels \sum PoPc - \left(\sum Po\right)\left(\sum Pc\right)}{\sqrt{\left[\#Pixels \sum Po^2 - \left(\sum Po\right)^2\right]\left[\#Pixels \sum Pc^2 - \left(\sum Pc\right)^2\right]}}$

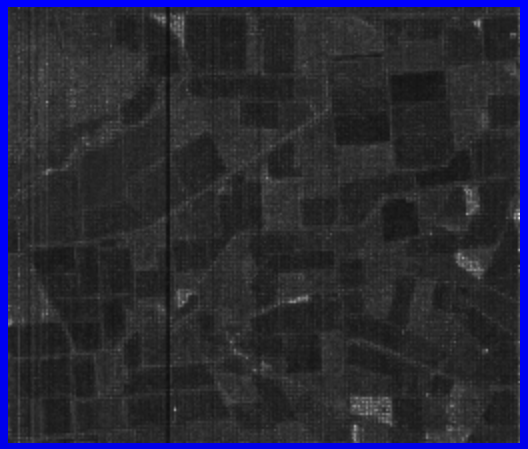
"P" Denotes Pixel Within a Band
$\sum$ Denotes Sum Over Pixels within Band

Subscript "O" Denotes Original Data Cube
Subscript "C" Denotes Compressed Data Cube

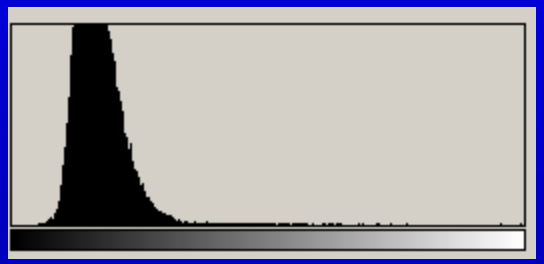
99:1 Compression



Coleambally Scene – Hyperion



Spectral Angle Error Map
Large Image Compression = 99:1

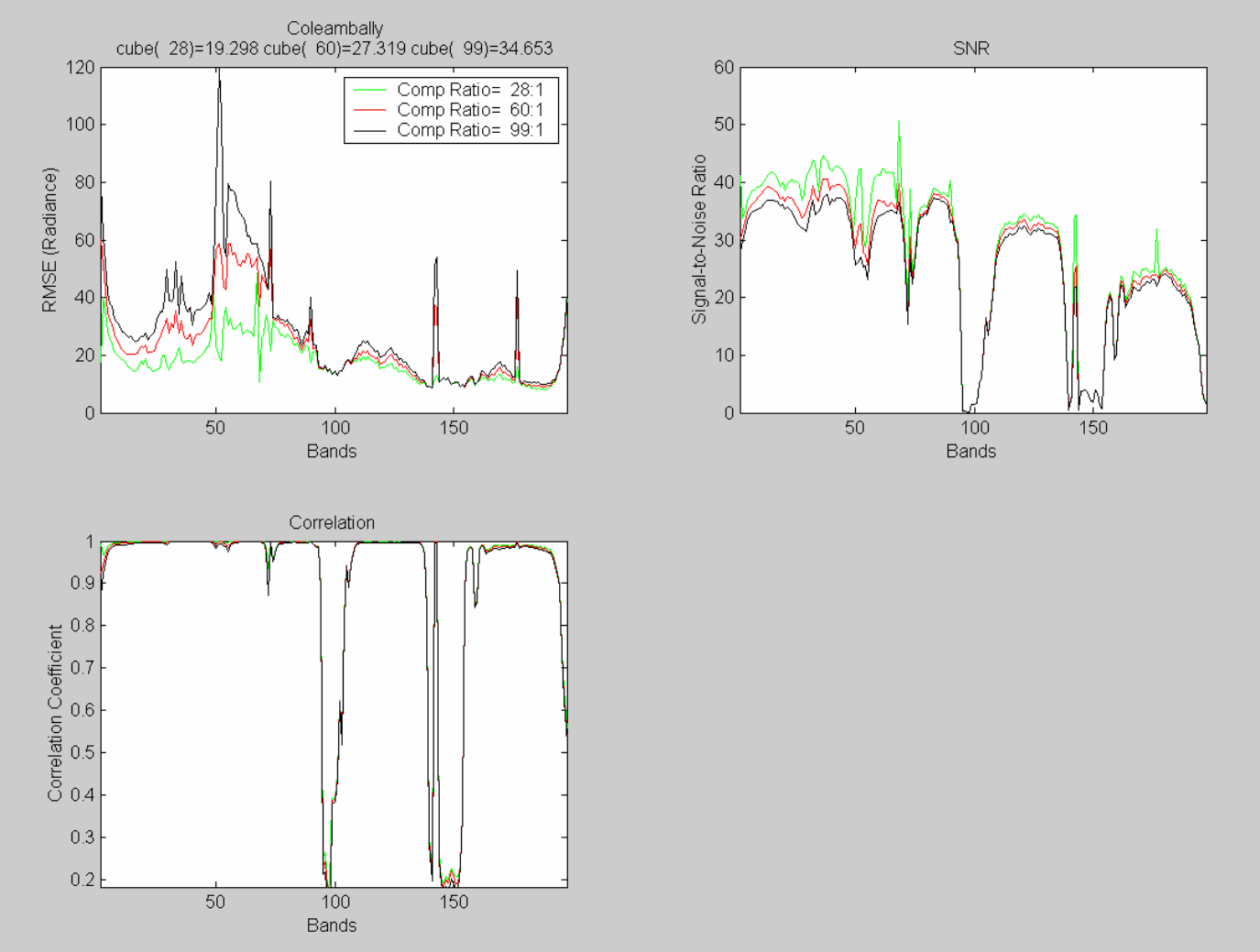


0 Degrees 7.9

Average = 1.37 Degrees
Sigma = 0.403 Degrees

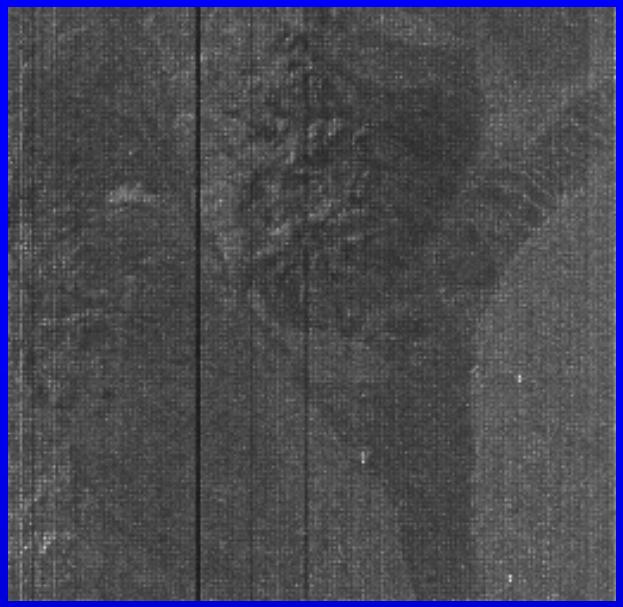
Spectral Angle Error Histogram

Coleambally Error Analysis

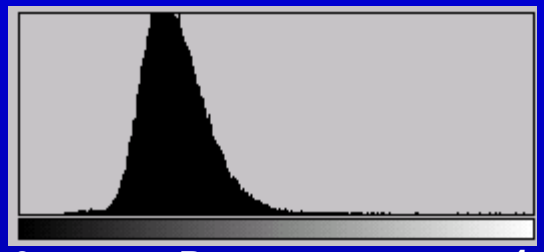


105:1 Compression

Cuprite Scene - Hyperion



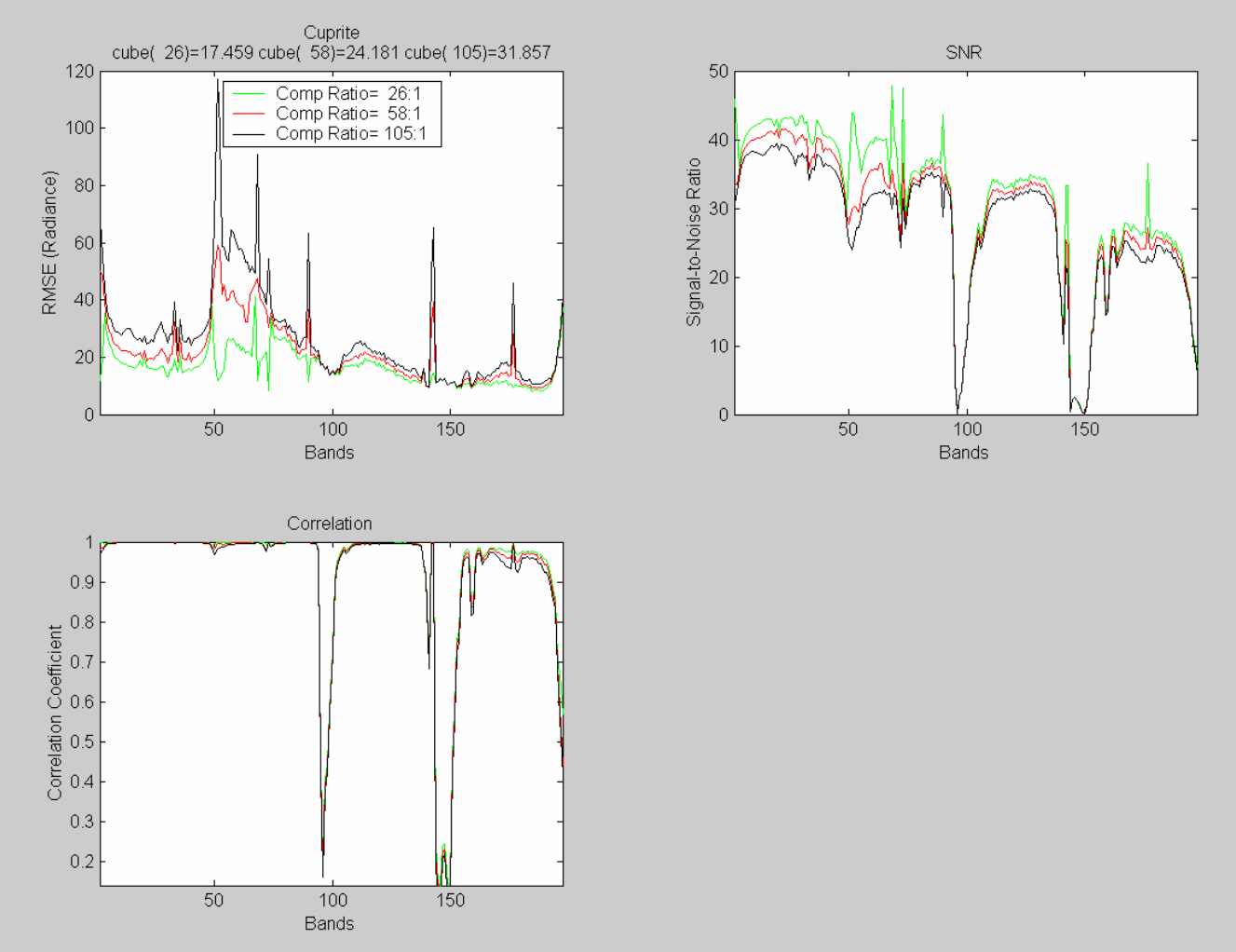
Spectral Angle Error Map
Large Image Compression = 105:1



Average = 1.37 Degrees
Sigma = 0.29 Degrees

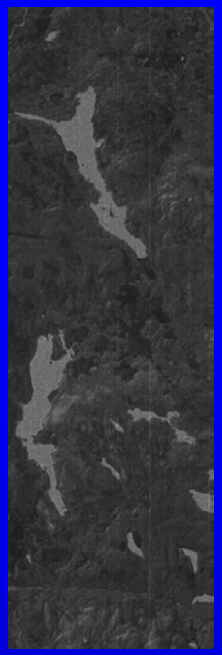
Spectral Angle Error Histogram

Cuprite Error Analysis

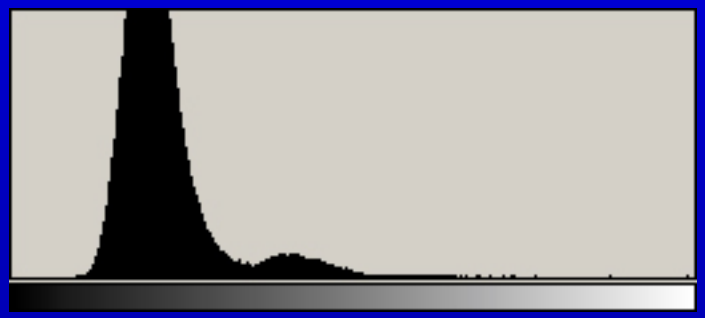


10:1 Greater Victoria Watershed (GVWD) Compression

GVWD - Hyperion



Spectral Angle Error Map
Large Image Compression = 10:1

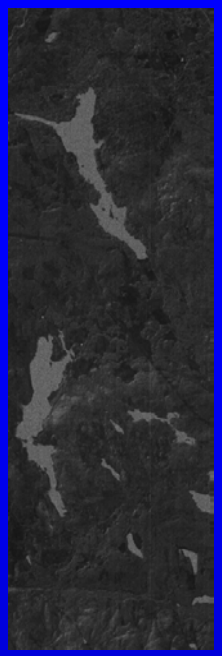


Spectral Angle Error Histogram

Average = 0.53 Degrees
Sigma = 0.17 Degrees

22:1 Greater Victoria Watershed (GVWD) Compression

GVWD - Hyperion



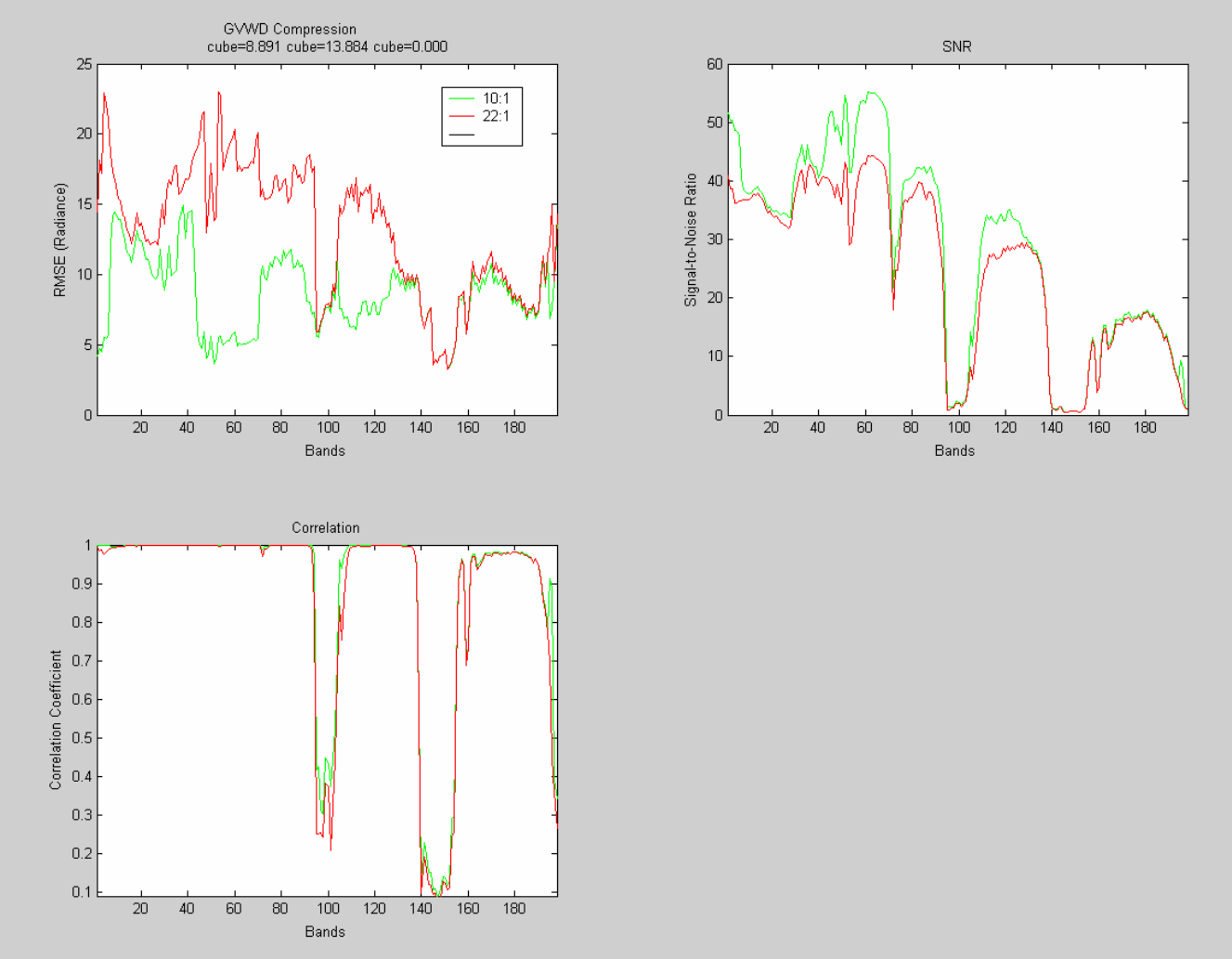
Spectral Angle Error Map
Large Image Compression = 22:1

0 Degrees 4.61

Spectral Angle Error Histogram

Average = 0.84 Degrees
Sigma = 0.30 Degrees

GVWD Error analysis



EO-1 Scientists Evaluation Results

Comp Ratio	Evaluation Observations for the Coleambally Scene
99:1	Some Classification Error (<1%)
60:1	No Classification Error Some Minimum Noise Fraction (MNF) Analysis Error
28:1	No Observed Error

Analyzed by Dr. Jay Pearlman– EO-1 Science Team

Comp Ratio	Evaluation Observations for the GVWD Scene
22:1	No Observed Error

Analyzed by Dr. David Goodenough – EO-1 Science Team

OBP Data Throughput Requirements

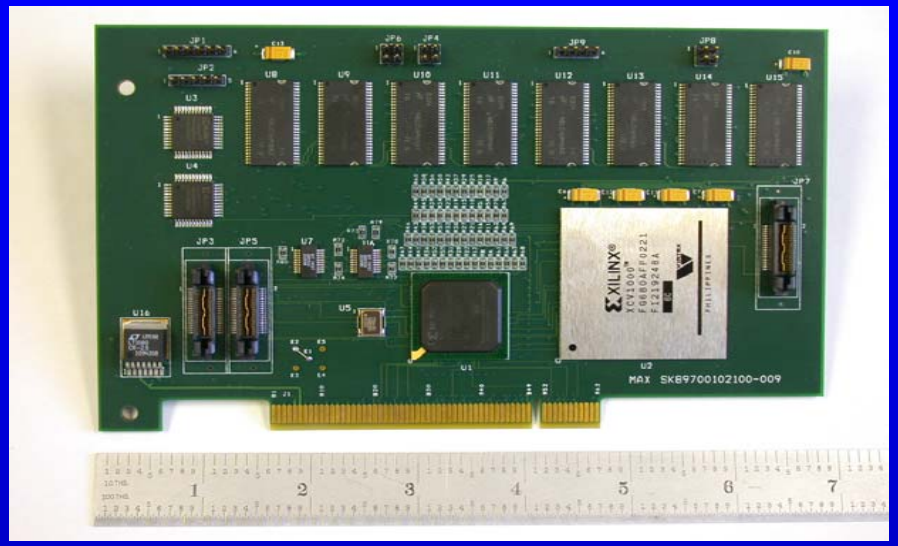
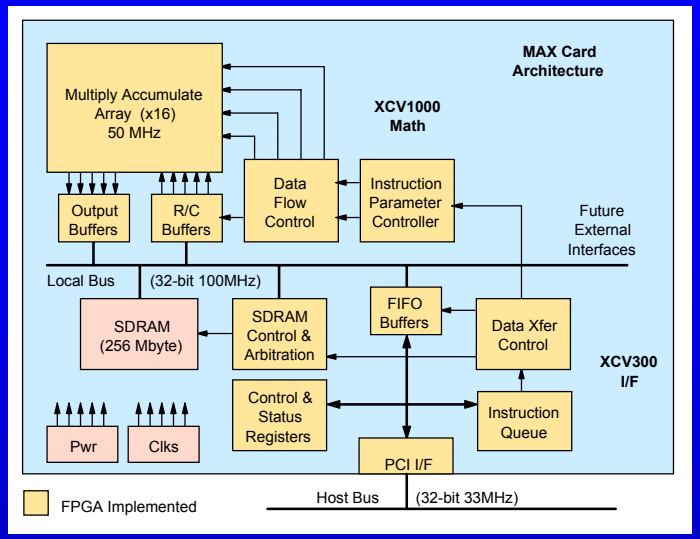
	Current Hyperion	OBP Enhanced Hyperion	Continuous / Real-time Hyperion	Future*
Area Coverage Per Day (KM^2/day)	14.7 K	1.5 M	4.5 M	117 M
OBP Rate Requirement (GFLOPS)	0.02	2	6	160
Data Transmission Req. (Gigabits/day)	67	67	201	5360

Sensor Characteristics:
- Pixel Spatial Resolution – 30m
- # Spectral Bands – 220
- Sensor Data Generation Rate – 150 mbps

Current Hyperion Operational Characteristics
- 6 Downlinks/day
- 2 Image Swaths per Downlink
- Image Swath Width – 7.65 KM
- Image Swath Length – 160 KM

* "Earth Science Enterprise Technology Planning Workshop on High Performance Spectrometry" May 12, 2000 (Hyperion Sensor with 250 KM Swath Width and SNR = 1000:1 VNIR and 500:1 NIR)

Area Coverage Per Day

Special Purpose Hardware

- Custom FPGA Hyperspectral Compression PCI Card