Prototype and Metrics for Data Processing Chain Components of IPM

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HyspIRI Symposium

Intelligent Payload Module Session

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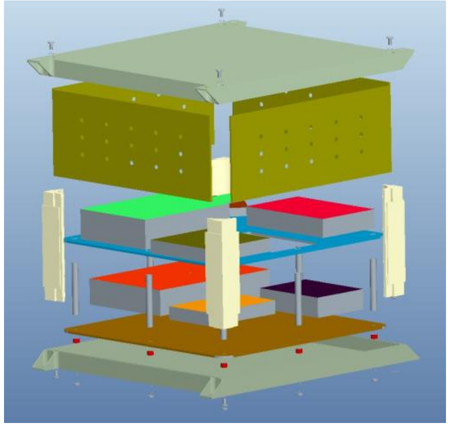
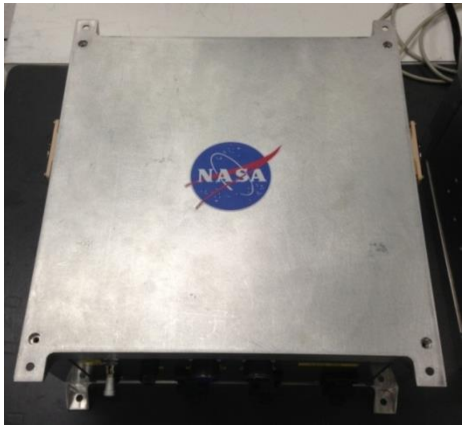
Objectives

- Investigate next generation flight processors, leverage existing effort Tilera Multicore Processor, Maestro (Rad-hardened TILE64), SpaceCube (Xilinx Virtex), and High Performance Space Computing (HPSC)
- Develop/optimize end-to-end hyperspectral image processing software
- Demonstration of the IPM operating in realistic environments (Airborne Platforms)

IPM – v1

- 14 x 14 x 6 inches
- Wide-Input-Range DC voltage (6V-30V)
- Made of strong durable aluminum alloy
- Dual mounting brackets
- Flush design
- Removable side panels
- Mounting racks are electrically isolated from the box
- Appropriate space allocation for interchangeable Tilera
- and Spacecube boards
- Electronic components
  - Tilera development board
  - SpaceCube development board
  - Single board computer
  - 600GB SSD
  - Gigabit Ethernet switch
  - Transceiver radio
  - Power board





Compact Hyperspectral Advanced Imager (CHAI V640)

SPECIFICATIONS

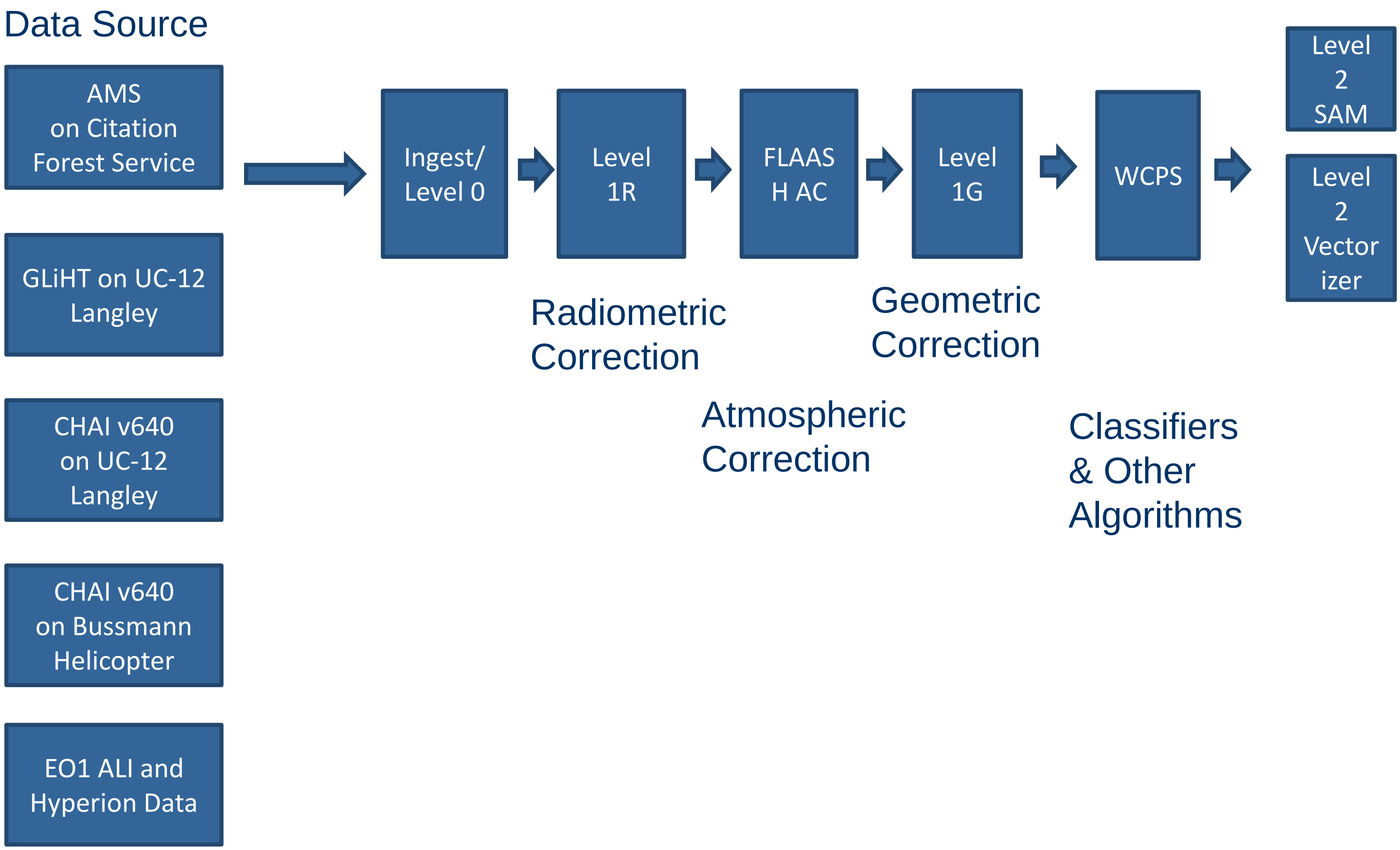
MECHANICALS	ESTIMATE
Size (with lens) Size (with telescope)	125 x 101 x 75 mm 200 x 101 x 75 mm
Weight	.48 kg [.99 lbs]
Power	20 watts
Temperature Range	-20 to +50 C
Size does not include NS/GPS	

OPTICS	SPECIFICATION
Spectrometer Type	Dyson
Telescope	All-reflective telescope
Field of View	40 degrees
Cross Track Pixels	640
F-Number	f/2
Spectral Range	350-1080 nm (Reflective) 400-1000 nm (Refractive)
Smile Distortion	< 0.1 pixels
Keystone Distortion	< 0.1 pixels
Stray Light	< 1e-4 Point Source Transmission
Spectral Bands	256
Spectral Sampling	2.5, 5, 10 nm
Peak Grating Efficiency	88%
Slit Size	9.6 x .015 mm

IMAGE SENSOR	
Image Sensor	640 x 512, with 15 µm pixels
Full Well Capacity	Gain 0: 500,000 Gain 1: 60,000 Gain 2: 10,000
Read Noise	Gain 0: < 63 electrons Gain 1: < 42 electrons Gain 1: < 10 electrons
Maximum Frame Rate	1000 frames/second
Quantum Efficiency	> 50% @ 380 nm 80% @ 400-900 nm > 30% @ 1000 nm
Camera Interface	USB-3
Data Acquisition	500 MB Solid State Recorder Serial Interface for GPS/INS

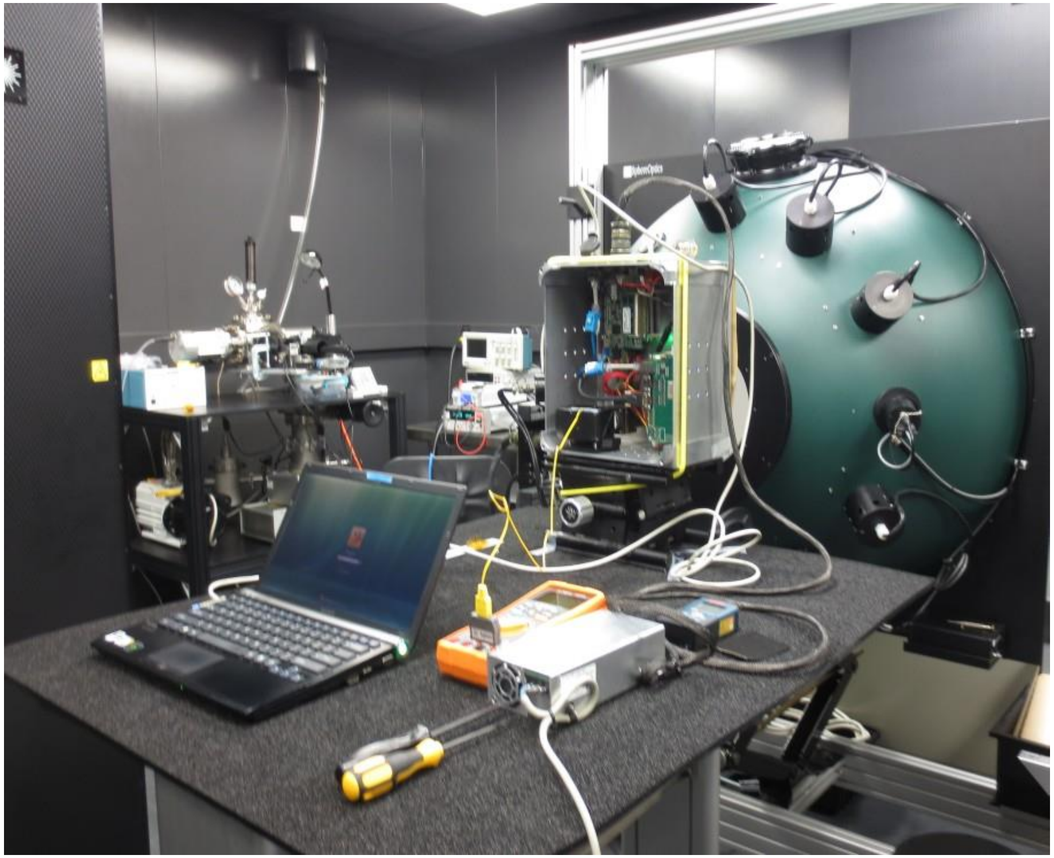
CHAI SOFTWARE	
Trigger Modes	Pilot, GUI, electronic, and Lat/Long triggered acquisition
Visualization	3-band RGB waterfall display of real-time and recorded data
Metadata	Temperature, pressure, and humidity
Data Format	RAW, ENVI BIL, or Processed
Processing	EXPRESSO™

Representative Data Processing Chain



Radiometric Correction

- Calibrated the instrument in the lab
- Developed software to process the raw data and applying calibration parameters to get the radiance values



Atmospheric Correction

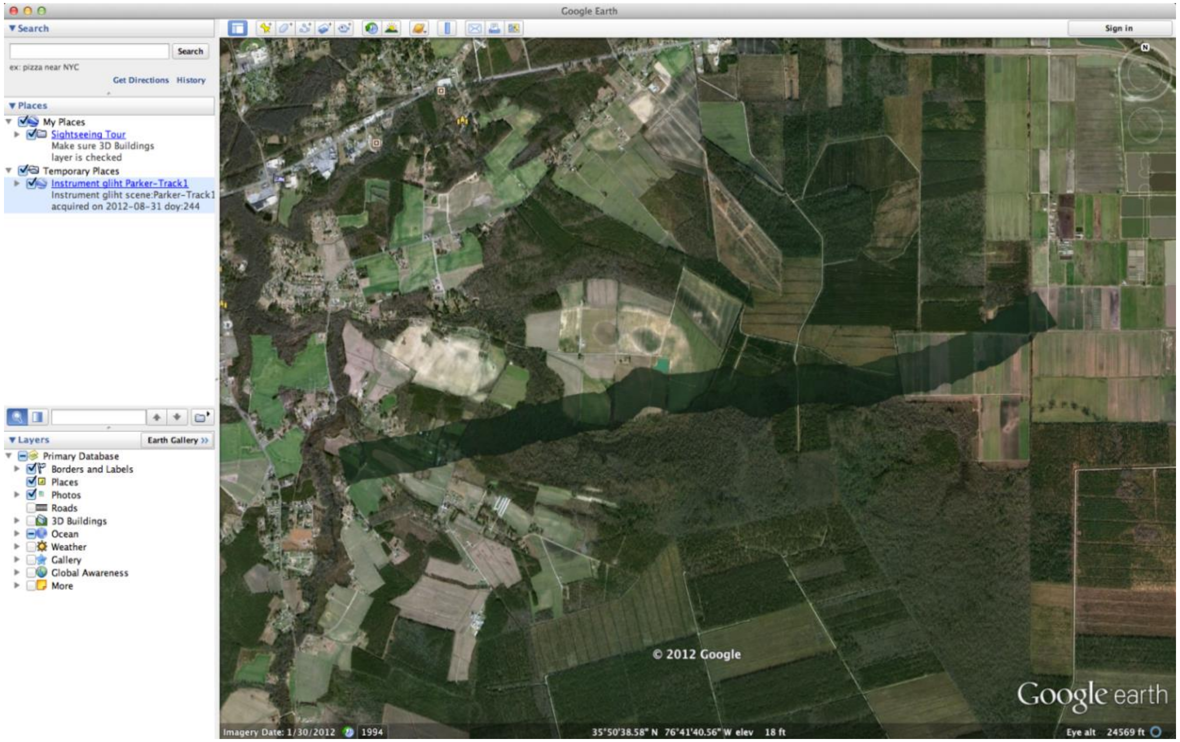
- Worked with Spectral Sciences to modify FLAASH GLUT version to support airborne atmospheric correction.
- Optimized FLAASH to run on the multicore Tilera processor.
- Processed CHAI v640 data with FLAASH to create reflectance values

FLAASH Parallelization Effort

	wall	system	user	notes	Parallelized?	Original Walltime	Parallel Speedup
Surf reflectance	32.7952	5.1398	27.6554	Reflect:: RadtoRef	YES	197.317	6.016642679
Cube smoothing	145.741	18.1373	127.6037	mini_cube->Smooth; FFT			
Cube reduction	112.363	13.9834	98.3796	mini_cube->Condense			
Cube load & distrib	89.0128	11.0775	77.9353				
Cube gather & write	83.2988	10.3664	72.9324				
Aerosol Retrieval	52.6236	6.54892	46.07468				
Water col retrieval	34.7984	4.3306	30.4678				
Spectral Polishing	33.5795	4.17891	29.40059				
Sensor calibration	28.5097	3.54799	24.96171				
Images and Masks	17.1781	2.13779	15.04031				
Spectral Resampling	8.72743	1.08611	7.64132	Smile_Resampler::Cube_Copy	YES	241.669	27.69074057
Cloud Masking	5.93287	0.738336	5.194534				
Sensor slit function	0.764612	0.0951547	0.6694573				
Modtran Tables	0.416416	0.0518223	0.3645937				
un-categorized	0.0397966	0.00495262	0.03484398				
Flaash setup	0.000163794	2.04E-05	1.43E-04				
total time	645.7813884	81.425006	564.3563824				1.641422344
total time (h:m:s)	0:10:46	0:01:21	0:09:24				
Original Wall time:	1060						
							36
	0:17:40						

Geometric Correction

- Acquired Systron SDN500 Inertial Navigational System
- Developed GCAP (Geo-Correction for Airborne Platform)
  - DEM to be implemented
- Validated the GCAP software by collaborating with the GLiHT project (Bruce Cook and Lawrence Corp)
- Optimized GCAP for multicore



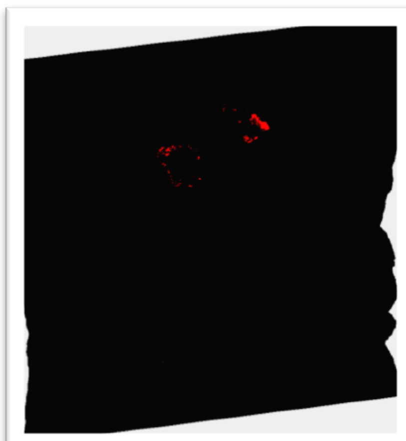
Level 2 Data Product Generation (using WCPS)

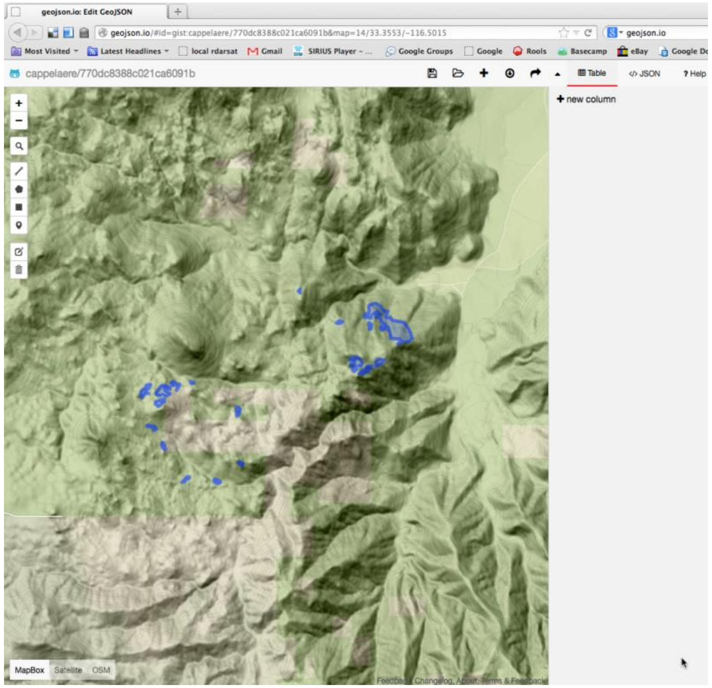
- Added capability to process AMS, GLiHT, CHAI v640 data
- Added new algorithms spectral angle mapper, vectorized hot pixels.

Burn Area Emergency Rehabilitation Imagery

Bands:
10 – 7 - 9
Linear Stretched 2%

CCRS (Hot Pixels Algorithm)





Vectorized Hot Pixels to
Topojson format (50% simplification)
File Size: 6KB (2KB .tgz)

Displayed on MapBox TopoMap

http://geojson.io/#id=gist:cappelaere/770dc8388c021ca6091b&map=14/33.3553/-116.5015

Hyperspectral Image Processing

	Radiometric Correction (CHAI data)	*Atmospheric Correction (FLAASH) (EO1 Hyperion data)	Geometric Correction (GCAP) (GLiHT data)	*WCPS (vis_composite) (EO1 Hyperion data)
864 MHz TILEPro64 (1 core)	121.95	2477.74	183.42	72.39
864 MHz TILEPro64 (49 cores)	23.83	1744.13	4.59	21.63
1.0 GHz TILE-Gx36 (1 core)	57.22	897.71	28.51	19.93
1.0GHz TILE-Gx36 (36 cores)	9.21	588.71	1.41	8.72
2.2GHz Intel Core I7	2.09	58.29	0.169	2.26
Virtex 5 FPGA	TBD	TBD	TBD	TBD

Image data:
GLiHT 1004 x 1028 x 402 (829,818,048 bytes)
Hyperion (EO1H1740732001151111K3)
256 x 6702 x 242 (830,404,608 bytes)
Chai640 696 x 2103 x 283 (828,447,408 bytes)

Notes: Unit is in seconds
TILEPro64 – No floating point support
TILEGx36 – Partial floating point support
* Indicates time includes file I/O

Key Methods to Accelerate Onboard Computing for a Space Environment

- Intelligent onboard data reduction
- Parallel processing, multicore processors
- Use of FPGA as co-processor to accelerate portion of algorithms

What’s Next?

- Flight demonstration of the CHAI v640 and the IPM aboard the Bussmann Helicopter
- Continue to examine a variety of methods to speed up onboard processing chain to meet needs of low latency users
- Dovetailing efforts and metrics with High Performance Space Computing (HPSC) effort sponsored by NASA Office Chief Technologist
- Ensure IPM data processing effort applied to multiple future mission needs

Acronyms

AMS	Autonomous Modular Sensor
GLiHT	Goddard's Lidar, Hyperspectral, and Thermal
IPM	Intelligent Payload Module
FLAASH	Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes
WCPS	Web Coverage Processing Service