Onboard Processing Metric Update for CHAI V640 / Intelligent Payload Module Flights

Vuong Ly
et al. (see end of slides)

HysplRI Symposium
Intelligent Payload Module Session
June 3, 2014

Objectives

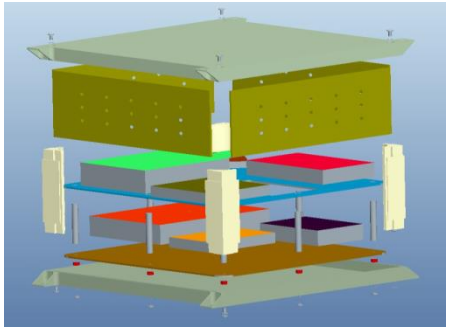
- Investigate next generation flight processors, leverage existing effort
  - Tilera Multicore Processor, Maestro (Rad-hardened TILE64)
  - SpaceCube (Xilinx Virtex),
  - Center for High-Performance Reconfigurable Computer - CHREC (CHREC Space Processor Xilinx Zynq SOC)
    - National research center and consortium led by University of Florida
  - NASA High Performance Space Computing (HPSC)
    - Next generation space processor selected by HPSC

- Develop/optimize end-to-end hyperspectral image processing software

- Demonstration of the IPM operating in realistic environments (Airborne Platforms)

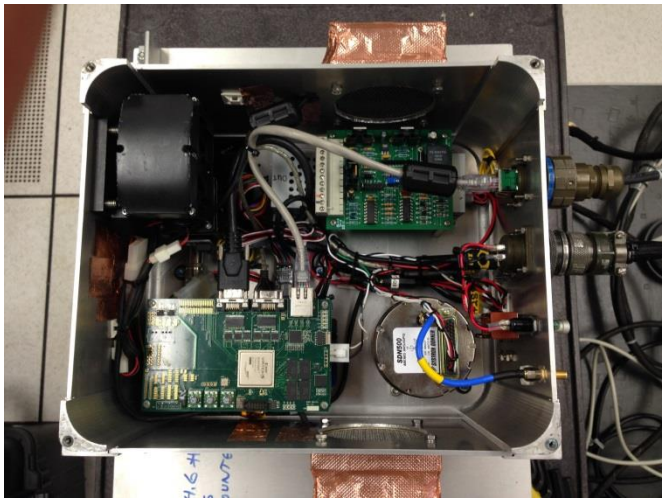
Hardware - Intelligent Payload Module Box v1

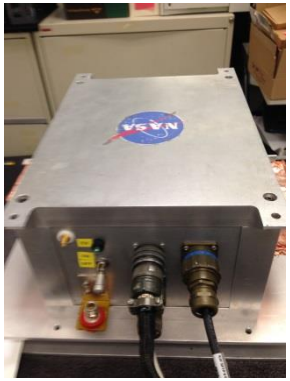
- 14.5 x 14.5 x 7 inches
- Wide-Input-Range DC voltage (6V-30V)
- Made of strong durable aluminum alloy
- Dual mounting brackets
- Flush design
- Removable side panels
- Mounting racks are electrically isolated from the box
- Electronic components
  - Tilera development board (TILEPro64)
  - Xilinx Zynq development board (MicroZed)
  - Single board computer (Dreamplug)
  - 600GB SSD
  - Gigabit Ethernet switch
  - Transceiver radio
  - Power board

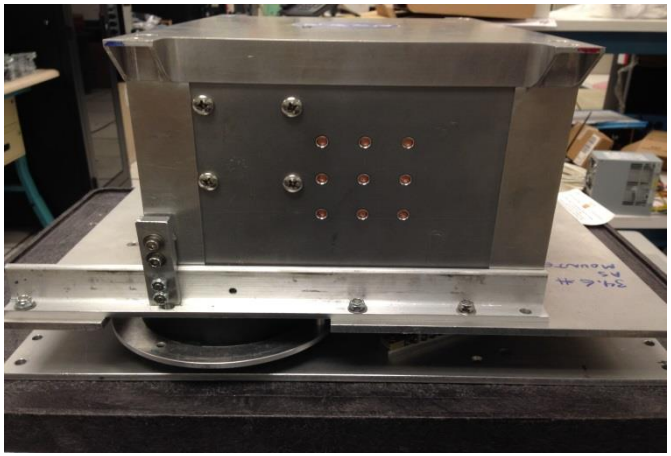


CHAI V640 Instrument Box

- 12 x 10 x 7 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
- Electronic components
  - CHAI V640
  - Frame Grabber
  - Systron SDN500
  - UNIBLITZ Shutter Driver
  - USB Hub
  - Phidgets Temperature Sensor







Brandywine Compact Hyperspectral Advanced Imager (CHAI V640)

SPECIFICATIONS

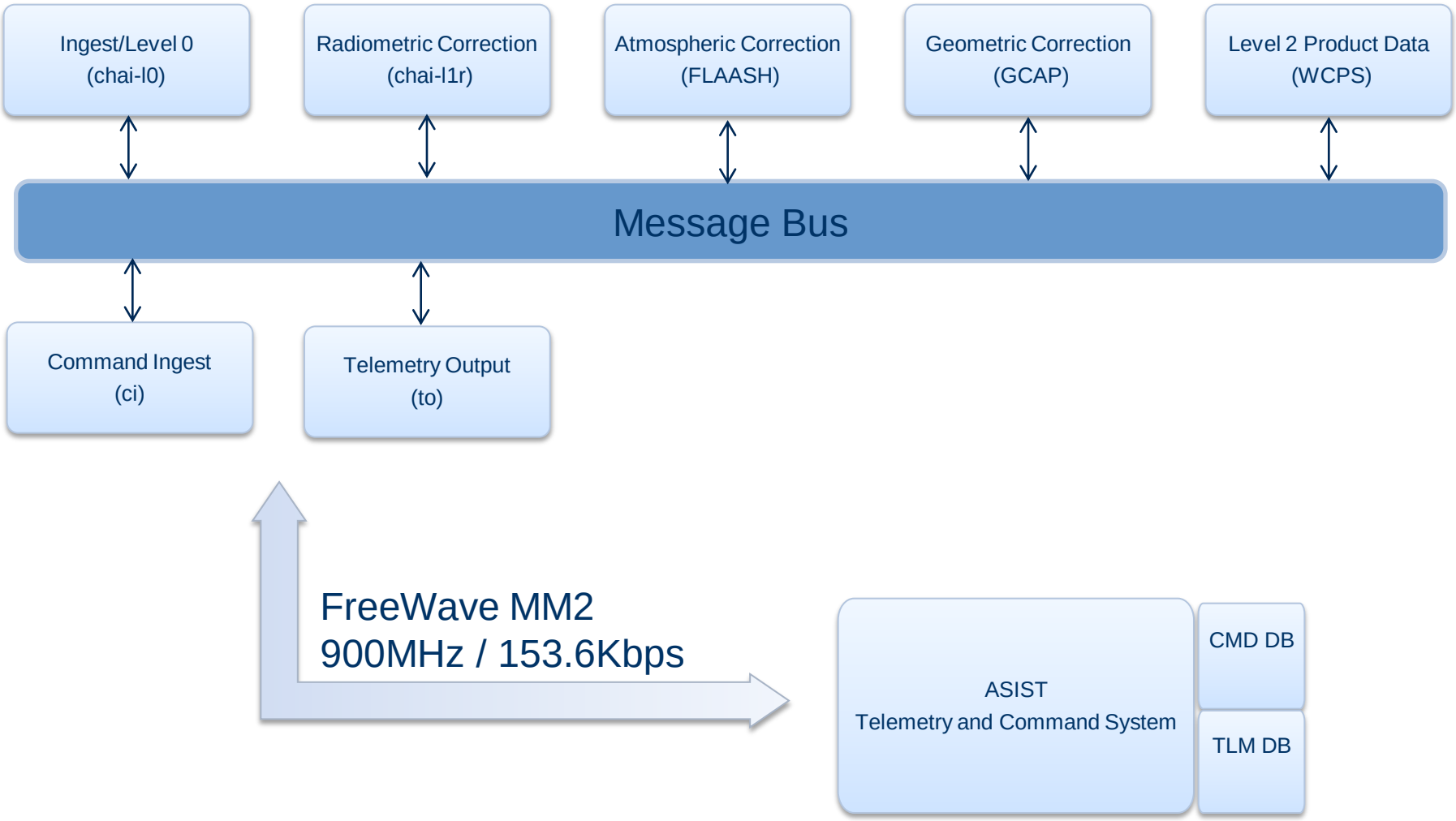
MECHANICALS	ESTIMATE
Size (with lens) Size (with telescope)	125 x 101 x 75 mm 200 x 101 x 75 mm
Weight	.48 kg [.99 lbs]
Power	20 watts
Temperature Range	-20 to +50 C
Size does not include NS/GPS	

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

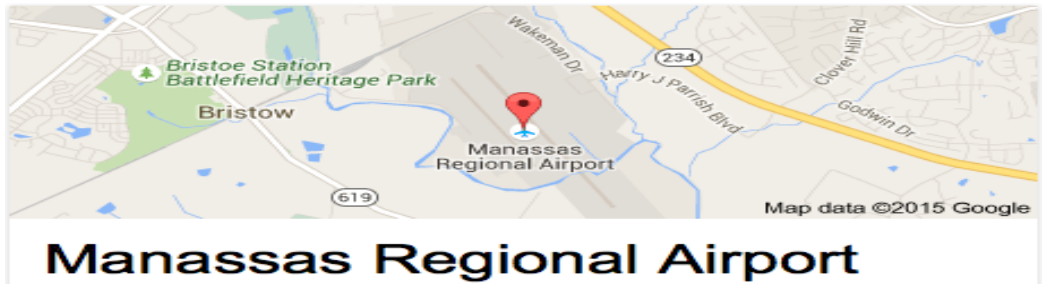
IMAGE SENSOR	
Image Sensor	640 x 512, with 15 μm pixels
Full Well Capacity	Gain 0: 500,000 Gain 1: 60,000 Gain 2: 10,000
Read Noise	Gain 0: < 63 electrons Gain 1: < 42 electrons Gain 1: < 10 electrons
Maximum Frame Rate	1000 frames/second
Quantum Efficiency	> 50% @ 380 nm 80% @ 400-900 nm > 30% @ 1000 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™

Software – Hyperspectral Data Processing



Bussmann Helicopter Integration



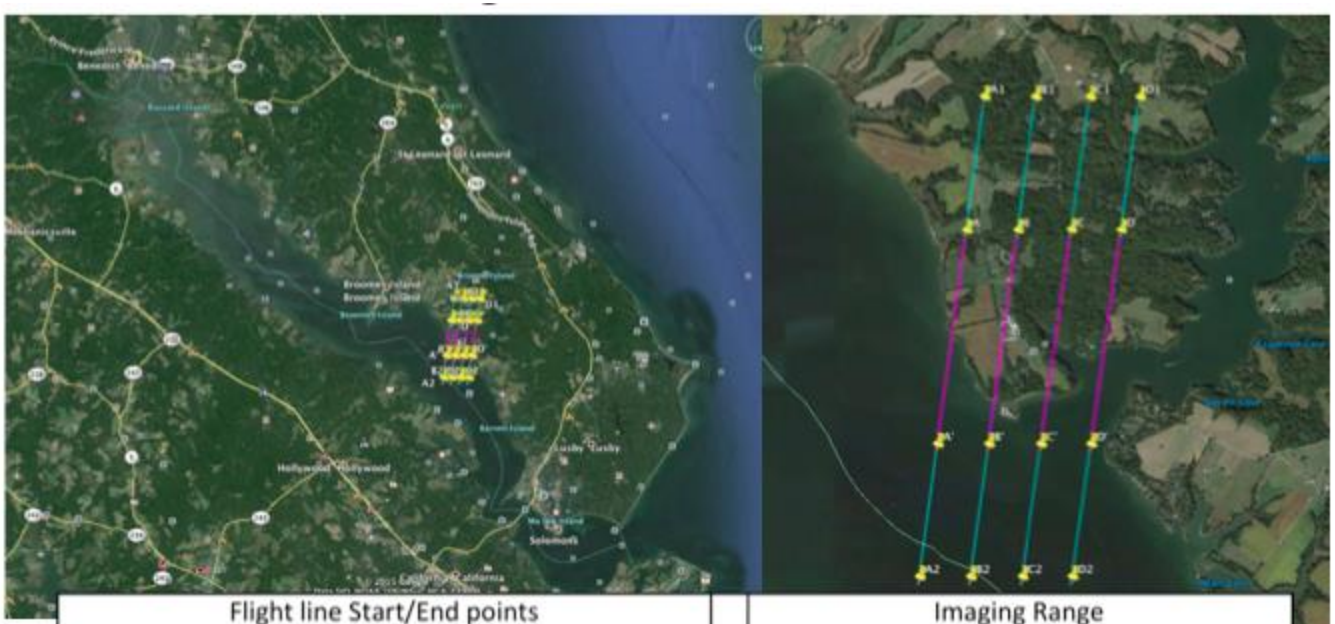
Manassas Regional Airport

Bussmann Helicopter Flights

- 7/16/2014 – Manassas Airport Area – Test flight
  - Had EMI problems, interfering with Pilot Aviation Bands 118 MHz to 137MHz
  - Had imaging problems due to software bug
- 7/23/2014 – Manassas Airport Area – Test flight
  - Had EMI problems – Tilera CPU is leaking 125MHz signal
- 9/24/2014 – Manassas Airport Area – Test flight
  - Had imaging problems due to the shutter
- 1/20/2015 – Manassas Airport Area
  - Successful Flight
- 4/13/2014 – Patuxent Environmental & Aquatic Research Laboratory (PEARL) Center Flight from Manassas (Leaf Off)
  - Successful Flight

CS65 65mm Uni-stable Shutter

IPM Test Flight Plan
Patuxent Environmental & Aquatic Research Laboratory (PEARL)
St. Leonard, MD

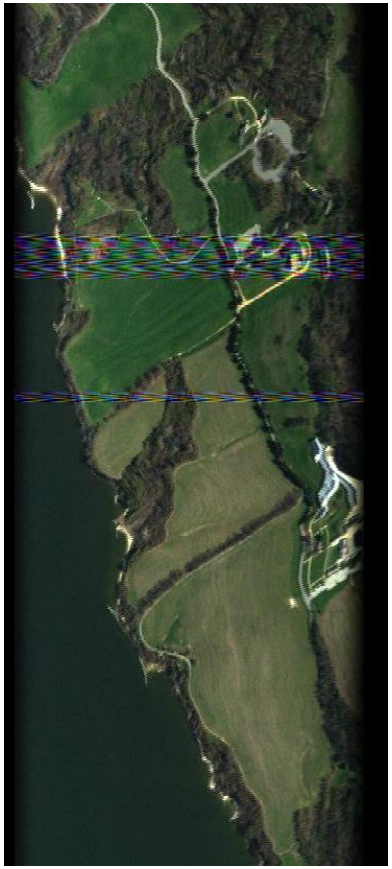


Flight line Start/End points							Imaging Range				
Waypoint	Lat		Lon		Bearing		Waypoint	Lat		Lon	
	Degrees	Minutes	Degrees	Minutes				Degrees	Minutes	Degrees	Minutes
A1	38	24.607	-76	30.555	187.75		A	38	24.072	-76	30.648
A2	38	22.673	-76	30.891	7.75		A'	38	23.208	-76	30.798
B1	38	24.607	-76	30.291	187.75		B	38	24.072	-76	30.384
B2	38	22.673	-76	30.627	7.75		B'	38	23.208	-76	30.534
C1	38	24.607	-76	30.011	188.06		C	38	24.072	-76	30.108
C2	38	22.673	-76	30.360	8.05		C'	38	23.208	-76	30.264
D1	38	24.607	-76	29.753	188.06		D	38	24.072	-76	29.85
D2	38	22.673	-76	30.102	8.05		D'	38	23.208	-76	30.006

3/31/15 2

IPM Test Flight Bussmann Helicopter
April 13th 2015 / St. Leonard, MD

20150413_A1



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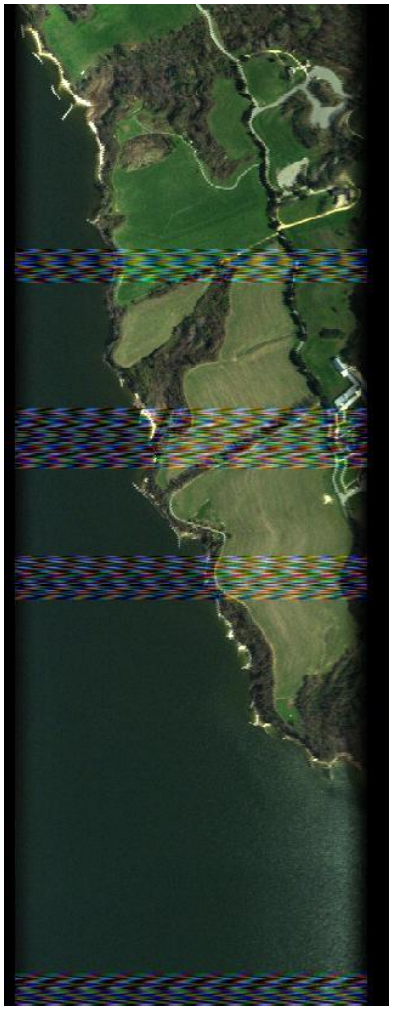
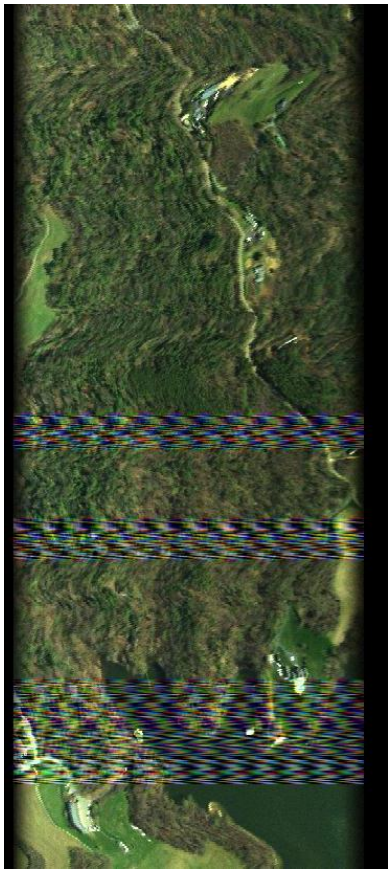


20150413_B1

20150413_B2

IPM Test Flight Bussmann Helicopter
April 13th 2015 / St. Leonard, MD

20150413_C1



20150413_C2

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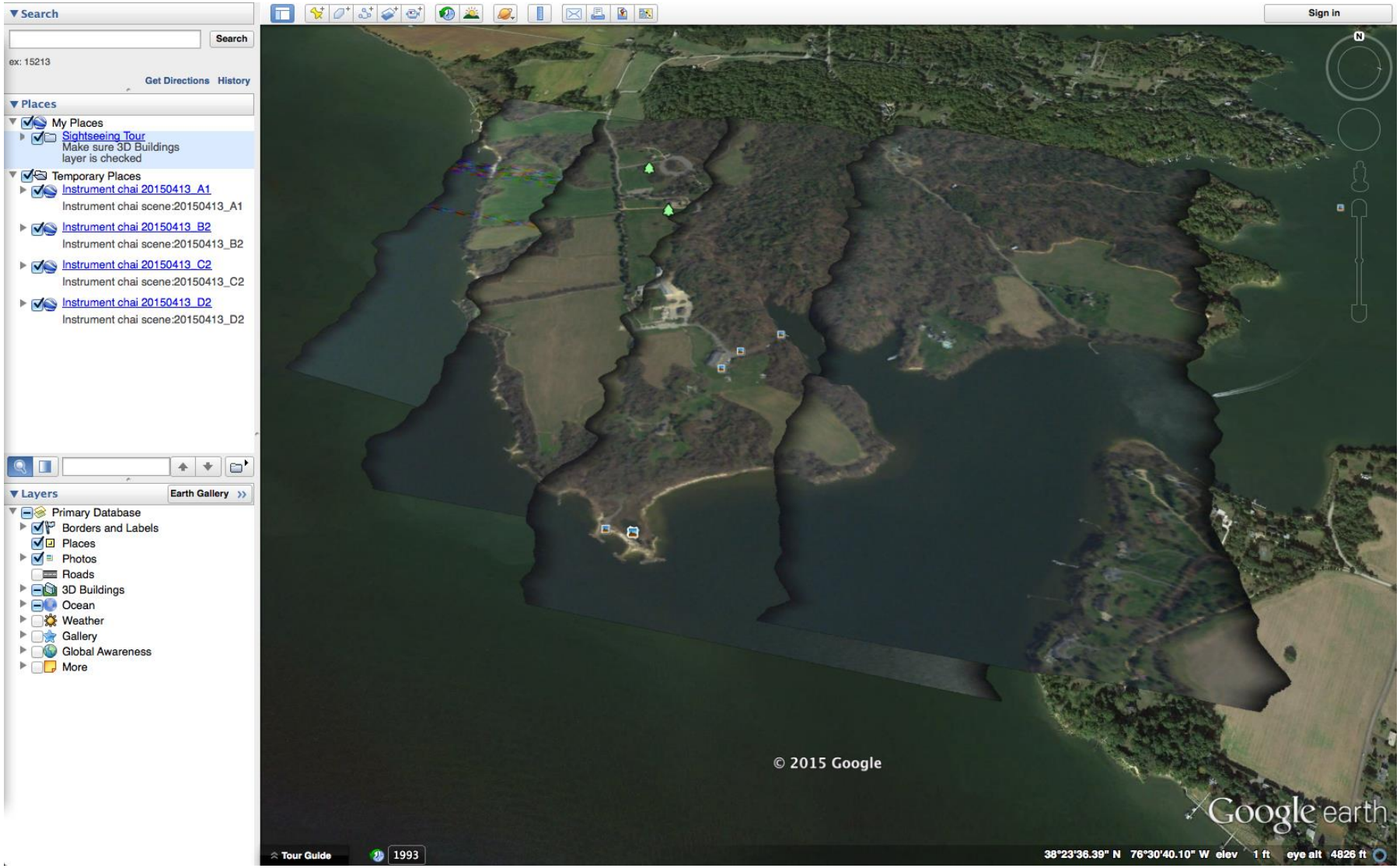
20150413_D2

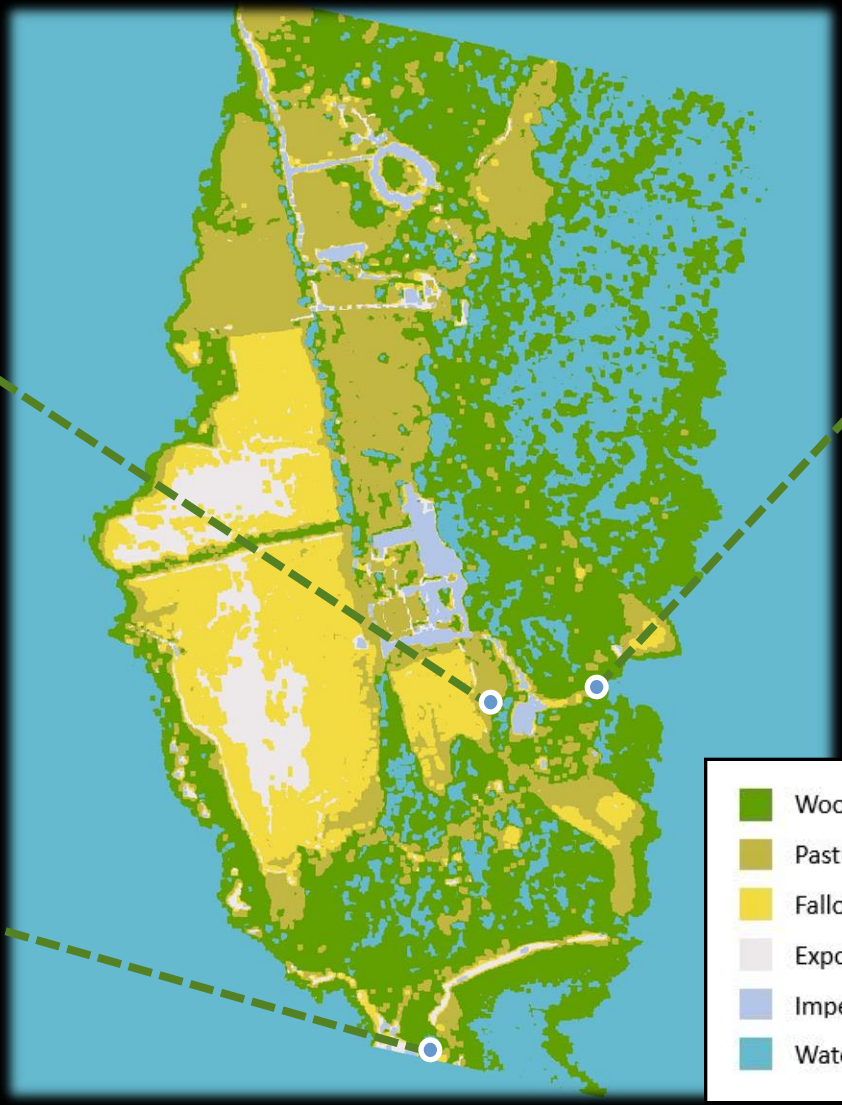
IPM Test Flight Bussmann Helicopter
April 13th 2015 / St. Leonard, MD



IPM Test Flight Bussmann Helicopter
April 13th 2015 / St. Leonard, MD

Maureen Kelly
Faculty Research Assistant UMD
mkelly17@umd.edu

IPM Test Flight Bussmann Helicopter
April 13th 2015 / St. Leonard, MD



Maureen Kelly
Faculty Research Assistant UMD
mkelly17@umd.edu

IPM Test Flight Cessna 206
May 5th 2015 / St. Leonard, MD

20150505_A1

20150505_B2

20150505_C1

20150505_D1

IPM Test Flight Cessna 206
May 27th 2015 / St. Leonard, MD

20150527_A2_2

20150527_B2_2

20150527_C2_2

20150527_D2_2

IPM Test Flight Cessna 206
May 27th 2015 / St. Leonard, MD

Preliminary Metrics for Hyperspectral Image Processing using Multicore CPU and FPGA	Radiometric Correction (chai-l1r)	*Atmospheric Correction (FLAASH)	Geometric Correction (chai-l1g)	Product Data (WCPS - vis_composite)	Co-registration (ureg)
864 MHz TILEPro64 (1 core)	59.217	1298.600	185.249	44.21	33.18
864 MHz TILEPro64 (49 cores)	10.195	906.440	4.953	-	-
1.0 GHz TILE-Gx36 (1 core)	30.053	505.102	31.229	12.41	6.78
1.0GHz TILE-Gx36 (36 cores)	2.166	381.620	1.017	-	-
667MHz ARM ZC702 (1 core)	17.827	323.550	10.861	5.12	3.44
667MHz ARM ZC702 (2 cores)	10.077	283.880	5.442		-
2.2GHz Intel Core I7 (1 core)	0.723	32.161	0.643	0.514	0.386
2.2GHz Intel Core I7 (4 cores)	0.472	28.700	0.139	-	-
FPGA (Zynq 7Z020)	Implemented		Optimizing fit		

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

Compiled with "-g -O2 -funroll-loops -fomit-frame-pointer -march=native -fopenmp"

CHAI V640
Samples: 696
Lines: 1800
Bands: 283
Data Type: 12 (UINT16)
Data Rate: 174 Mbps

Raw Data:	1305.5184 MB
Level 0:	1304.5248 MB
Level 1R:	709.0848 MB

What's Next?

- Continue flight demonstration of the CHAI v640 and the IPM onboard the Bussmann Helicopter and NASA Langley Cessna 206 aircraft for algal bloom detection over the Patuxent River

- Continue to examine a variety of methods to speed up onboard processing chain to meet needs of low latency users
  - Utilizing Xillybus and Vivado HLS to synthesize C code into VHDL
  - Working with James Coole (CHREC) to utilize OpenCL and CLIF automatically optimize code for FPGA

- Ensure IPM data processing effort applied to multiple future mission needs

Team

PI :
Dan Mandl NASA/GSFC Code 581 – daniel.j.mandl@nasa.gov (301)286-4323

Co-I's:

Robert Sohlberg, sohlberg@umd.edu, (301) 405-4292, Univ. of Md/Dept. of Geography
- Lead scientist

Pat Cappelaere, pat@cappelaere.com, (410) 340-4868, Vightel Inc.
- System architectect

Stuart Frye, stuart.frye@nasa.gov, (301) 614-5477, SGT Inc.
- System engineer

Vuong Ly, vuong.l.ly@nasa.gov, (301)286-2421, NASA/GSFC
- Programmer, system engineer

Matthew Handy, matthew.handy@nasa.gov, (301)286-2106, NASA/GSFC
- Programmer system engineer

Donald Sullivan, donald.v.sullivan@nasa.gov, (650) 714-9742, NASA/ARC
- Airborne software systems expert/programmer

Geoff Bland, geoffrey.l.bland@nasa.gov, (757)824.2866, NASA/GSFC-Wallops
- Airborne Systems expert

Vince Ambrosia, vincent.g.ambrosia@nasa.gov, (650)604-6565. NASA Ames
- Ikhana/Autonomous Modular Sensor lead

Enric Pastor, enric@ac.upc.edu, Univ. of Cataluña, Barcelona, Spain c/o Univ. of California Monterrey Bay
- Lead for UAV helicopter

Steve Crago, crago@isi.edu, Univ. of Southern Cal/ISI
- Expert in Maestro architecture

Team

Collaborators:

Lawrence Ong, lawrence.ong@nasa.gov , SSAI (301)614-6679
- expertise in instrument validation and operations

Michael Flick, michael.r.flick@nasa.gov, Columbus SES Contract (301)286-8609
- expertise in mechical design/ProE

Michael Yang, michael.a.yang@nasa.gov, Columbus SES Contract (301)286-0990
- expertise software programming

Juan Lopez Rubio/581 visiting researcher from Univ. of Catalunya, Barcelona – Phd in Computer Science received in 2012
- expertise in middleware and embedded computing

Chunlei Fan, Morgan State University
- biology and spectroscopy

Dr. Steve Ungar, NASA/GSFC scientist Emeritus
- Remote sensing and imaging spectroscopy

Tim Perkins, Spectral Science Inc
- Atmospheric Corrections, FLAASH

Team

Student participation:

James Coole/581 Co-op (University of Florida)
- expertise in FPGA acceleration and optimization

Joshua Bronston/581 Co-op (Navajo Technical College-seeking Master Computer Eng)
- expertise in Geographical Information Systems

Tim Creech/581 NASA Space Technology Research Fellow (Univ. of Md seeking Phd in Computer Science)
- expertise in automated parallelizing of

Chris Flatley/581 summer intern (Virginia Tech – seeking BS in Computer Engineering
- expertise in generalized computer engineering skills

Neil Shah/581 summer intern (Univ. of Md –seeking BS in Aerospace Engineering)
- expertise in generalized computer engineering skills, on team at Univ. of Md for man powered helicopter project - Gamera

Patricia Sazama/580 spring 2013 intern (Univ of Md –seeking BS in Computer Science
graduating in May 2013, will attend Univ. of Md for Phd in Computer Science)
- expertise in co-registration of satellite images

Andrew Overton/581 summer 2013 intern (Jackson State Univ.- seeking Phd Computer Science
- expertise in embedded system software

Jason Schiedermayer/581 summer intern (San Diego State Univ – Seeking BSEE)
- expertise software but will use Xilinx experience for FPGA work (novice but will build experience)