Prototyping Science As A Service with Intelligent Payload Module

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Team

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Objectives

• Develop methods to provide low latency users of HyspIRI with quick look data products
• Augment concept of Science As A Service by providing an interface for non-programmer users to define new algorithms and select data sets and data feeds to run the algorithms against
• Virtualize the interface to various environments with adapters that take into account the resources and methods to expose key data and data products
• Experiment with high performance multicore space computing architectures in order to meet the future significantly higher data rates.
• Develop increasingly realistic operational architectures that emulate the target satellite architecture for HyspIRI and other Decadal missions
Funding for IPM Effort

ESTO AIST-11 Award beginning May 2011
“A High Performance Onboard Multicore Intelligent Payload Module for Orbital and Suborbital Remote Sensing Missions”

GSFC IRAD FY 12:
“Optimization of Onboard Processing Using the Maestro Multicore Processor for Decadal Missions” (Stepping stone to AIST award)
Original HyspIRI Low Latency Data Flow Operations Concept

- **TIR**: 130.2 Mbps
- **VSWIR**: 804 Mbps
- **IPM**
- **Command & Data Handling Solid State Recorder**
- **Direct Broadcast Module**
- **To/From Alaska and Norway Ground Stations**
- **S-band command**
- **S-band Housekeeping data**
- **X-band 800 Mbps Science data**
- **Direct Broadcast Antennas**

**Spacecraft**

- **20 Mbps**
Experimental IPM Quick Load/Quick Look Ops Con

Enhanced Ops Con from Baseline IPM Ops Con

Web Coverage Processing Service (WCPS)-Client

Uploads to Various Environments

Create Custom Algorithm

WEKA to WCPS Translator

Quick algorithm upload

HyspIRI

GlobalHawk, Ikhana, ER-2 …

NASA Cloud Infrastructure As A Service

WCPS-Runtime Executes Algorithm Against Selected Sensor Data

Cloud

Quick look data products

Custom Data Product (KMZ, PNG…)

Cloud Computing

Quick algorithm upload

Machine Learning
Supervised Classifier
(Regression Tree)
Refined Offline

SCIENCE USER

Notify to user

Custom Algorithm

Parse tree

Cloud

Quick look data products

Custom Data Product (KMZ, PNG…)

Cloud Computing

Quick algorithm upload

Machine Learning
Supervised Classifier
(Regression Tree)
Refined Offline

SCIENCE USER

Notify to user

Custom Algorithm

Parse tree

Cloud
IPM Tilera Flight Testbed Ops Con
(Tilera board is proxy for Maestro and Maestro-lite)

SCIENCE USER

Create algorithm

Select algorithm to run

High speed instrument data source

Cloud

Parse tree

WCPS-Client Algorithm Builder Service

Tilera Flight Testbed

Onboard Planner & Scheduler

Onboard Algorithm Buffer

WCPS-Run Service

Algorithm

Run
Chai640 Specs

Compact Hyperspectral Advanced Imager UV-VNIR

CHAI V-640
Compact and economical, ideal for UV and field use.

CHAI V-640 Instrument* (prototype shown)

OPTICS
- Spectrometer Type: Offner
- Field of View: 40 degrees (other upon request)
- Cross Track Pixels: 640 (with BIN x3)
- F-Number: f/2.8
- Data Rate: 78 Mbps
- Spectral Range: 380-1000 nm
- Smile: <0.1 pixels
- Keystone: <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: 1920 x 1080, 8.5 μm pixels
- Well Depth: 30,000 electrons
- Read Noise: 2 electrons
- Maximum Frame Rate: 60 frames/second
- Quantum Efficiency: 22% at 400 nm
- Peak 57% at 600 nm
- 15% at 900 nm
- Camera Interface: CameraLink
- 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*

APPLICATIONS
Earth Science, Aerial Survey, Machine Vision, Medical Imaging, Microscopy

ADVANTAGES
High Sensitivity, Lower Cost, Compact, Low Power

MECHANICALS
- Minimum Size: 127 x 101 x 51 mm
- Weight: 1 kg sensor head
- Power: 40 watts
- Temperature Range: -20 to +50°C

*Final product may differ from image shown.

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IPM Testbed with Tilera Acting as Proxy for Maestro & Maestro-lite Board (building 23)

Above: Vuong Ly/583 (Ground System SW Branch) standing in front of IPM testbed holding a SpaceCube board. Right: Tawanda Jacobs/582 (Flight SW Branch) working on integration of cFE onto IPM testbed.
First Flight Opportunity Summer 2012

- Use Skycomp helicopter originating out Clarksville Maryland
- Land at GSFC
- Mount IPM
- Test on ground
- Test at various altitudes
Hayesfield Airstrip in Clarksville, Md.
Target Hybrid Architecture

- Ethernet Switch
- FPGA (SpaceCube)
- Multicore Processor (Tilera)
- General Purpose CPU
  - WIFI
  - SSD
  - UART
- Available Ethernet (Front Plate)
- Internal ethernet
- Camera Link
- Available Ethernet (Front Plate)
- Available Ethernet (Front Plate)
- Immarsat Low Cost TDRSS Transponder (LCTT)
- Chai 640

ASIST Workstation
Preliminary Flight Architecture

CASPER - Continuous Activity Scheduling Planning Execution and Replanning system
CFDP - CCSDS File Delivery Protocol
cFE - Core Flight Executive

- **CASPER**
- **WCPS** – Web Coverage Processing Service
- **CmdIn** – Command Ingest
- **TlmOut** – Telemetry Output
- **CFDP**

- cFE and CFDF are operational flight software on LRO and MMS
- CASPER is operational onboard planning and scheduling SW on EO-1
- WCPS is presently TRL 6
Benchmarks for Use of Parallelization

- Tim Creech, Univ. of Maryland, Phd student
  - NASA Science and Technology Research Fellowship (NSTRF) 3 year grant awardee
- Investigating methods to automatically transform algorithms into parallel processes that can be applied to multicore architectures
  - AESOP is software research area
  - Used algorithms running against EO-1 ALI data on Tilera testbed
- Working towards integrating automatic parallelization into WCPS
AESOP Parallelization Test Results (1 of 2)

AESOP — Speedups in Parallelized Spectral Angle Mapping on Tile64
As compared to unmodified source compiled directly by Tilera’s compiler. Input data: ALI (10 bands).

Transformation sequences:
- None
- Loop fission, interchange, and fusion
- Loop fission, interchange, fusion, and data decomposition

Speedup

Threads
AESOP Parallelization Test Results (2 of 2)

AESOP - Speedups in Parallelized Spectral Angle Mapping on Tile64

As compared to unmodified source compiled directly by Tilera's compiler. Input data: Hyperion (220 bands).

Transformation sequences:
- None
- Loop fission, interchange, and fusion
- Loop fission, interchange, fusion, and data decomposition

![Graph showing speedup vs. threads for different transformation sequences.](image-url)
Conclusion

• Develop methods to provide low latency users of HyspIRI with quick look data products
  - Showed efforts with Maestro/Tilera, SpaceCube, WCPS

• Augment concept of Science As A Service by providing infrastructure, interfaces and services for non-programmer users to define new algorithms and select data sets and data feeds to run the algorithms against selected data
  - Showed WCPS client to build algorithms in realtime and WCPS runtime to use as adapters in various environments to enable algorithms to run against selected data

• Virtualize the interface to various environments with adapters that take into account the resources and methods to expose key data and data products
  • Showed WCPS runtime

• Experiment with high performance multicore space computing architectures in order to meet the future significantly higher data rates.
  • Showed a little of benchmarking to see how much performance can be enhanced with a multicore space computing architecture while designing in low power