Onboard Processing and Autonomous Operations on the IPEX Cubesat

Steve Chien, Joshua Doubleday, Kevin Ortega
Jet Propulsion Laboratory, California Institute of Technology
Tom Flatley, Gary Crum, Alessandro Geist, Michael Lin
NASA Goddard Space Flight Center
Austin Williams, John Bellardo, Jordi Puig-Suari,
Eric Stanton, Edmund Yee
Cal Poly, San Luis Obispo

Copyright 2012, All Rights Reserved.
Portions of this work were carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.
Background

• IPEX is a 1u Cubesat sponsored by NASA Earth Science Technology Office (ESTO)

• Goals
  – Flight validate high performance flight computing (Spacecube Mini / GSFC)
  – Flight validate onboard instrument data processing and product generation software (JPL for HyspIRI)
  – Flight validate autonomous operations for instrument processing (JPL)
  – Enhance NASA outreach and University ties (Cal Poly SLO)
    • Cal Poly builds, integrates, operates IPEX cubesat
  – Launch expected in late 2013 (4/2013 launch integration)
Cal Poly SLO spacecraft

- 1u cubesat
- Passively stabilized
  - fixed magnets
- Cal Poly Motherboard
  - 400 MHz Atmel
  - 128 MB RAM
  - 512 MB Flash
  - Micro SD card slot
  - Linux OS
Cameras

- 4 x Omnivision OV3642
- **Camera Specifications**
- Focal Length (f): 4mm
- Integration Time (t_int): 67ms
- Pixel Diameter (d_pixel): 1.75um
- 3 Megapixels
- Instantaneous Field of View (IFOV)
- IFOV = 2arctan(d_pixel/2f)
- IFOV = 0.025 degrees

2 of 4 Cameras

Balloon image, same sensor family, same manufacturer

Image of moon at night with flight model camera
Onboard Computing – SpaceCube Mini

- Uses Xilinx Virtex-5 FX130T
  - 2 X PPC 440 32-bit processors (non-rad hardened version)
  - Aeroflex UT6325 Eclipse FPGA (130M gates)
- 2 x 256MB DDR RAM
- 3 x 32Gb NAND Flash
- Runs scLinux

- Provided by GSFC
- ~5% duty cycle due to power (10W)
Onboard Instrument Processing on IPEX

• IPEX will utilize the SC Mini FPGA and PPC to:
  – Demonstrate onboard image correction and bad data rejection
    • image filtering while tumbling
  – Onboard product generation
    • Using both Omnivision data and Hyperspectral data loaded at launch
  – Stretch goal of processing streaming data
    • 1 image per second, tracking Earth and other objects
Autonomous Operations on IPEX

• IPEX will fly the CASPER onboard mission planning software (on Atmel) to:
  – Manage resources onboard
  – Take actions based on image analysis
    • Image based on image and product compression
    • Re-image based on detection of features/events in images
  – CASPER flown on Earth Observing One 2004-present as part of Autonomous Sciencecraft
Autonomous Operations

• Baseline Schedule created on ground using ASPEN
  – Ground-contact schedule of non-overlapping contact windows
    • prefer longest contacts, maintain schedule of alternates
  – Eclipse schedule
  – Observation Activities
  – Subsequent processing activities: quick filter, full processing,
    comparison of results, maybe reprocessing if comparison fails

• Constraints:
  – SpaceCube Mini processing occurs only during eclipse (thermal)
    • power: ~10Watt – 15Watt (!)
      • Prefer to pack these activities to minimize boot time
  – Data storage: raw images, processed images, summary products
    < flash storage capacity (e.g. 4GB)
  – Energy capacity of battery: ~50 Whr
  – Solar generation: <~1.5 Watt
Autonomous Operations for HyspIRI IPM

• HyspIRI Mission concept is a mission under study which includes a VSWIR hyperspectral imager and TIR Thermal infra-red imager

• HyspIRI is studying a heritage Direct Broadcast concept Intelligent Payload Module which will process the ~800 x 10^6 bits/second raw data stream into ~10 x 10^6 bits/second direct broadcast data stream

• IPEX will demonstrate automated planning and processing of the data as maturation of the prototype HyspIRI IPM operations system
  – Users specify regions of interest, products, and priorities in Google Earth ™
  – System automatically creates priority based plans for onboard processing and downlink
Instrument Swaths

4 x 112.5 km wide – TIR only
4 x 37.5 km wide – VSWIR + TIR
Sample Plans
Other JPL Cubesat Concepts

• Several additional cubesat concepts (not ESTO funded) that may use same cubesat bus
  – Space Situational Awareness (w. AFRL)
  – Onboard Computing Demonstration of Opera/Maestro 7x7 multicore processor
  – Onboard autonomy and instrument processing demonstrations with gumstix processors and gumstix clusters