CHPS: The Compact Hyperspectral Prism Spectrometer for Sustainable Land Imaging

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Sustainable Land Imaging Program

Sustainable Land Imaging-Technology Program

- Reduce the risk, cost, size, volume, mass, and development time for the next generation Sustainable Land Imaging (SLI) instruments while meeting or exceeding the current Landsat land imaging capabilities;

- Improve temporal, spatial, and spectral resolution of SLI measurements; and

- Enable new SLI measurements that can improve operational efficiency and reduce overall costs

- Maintain continuity with heritage Landsat instrument to continue 40+ year data series
SLI-T Compact Hyperspectral Prism Spectrometer (CHPS)

- Airborne instrument developed to demonstrate technology for potential insertion in spaceborne mission
- Prism-based pushbroom spectrometer
- Continuous VSWIR Spectral coverage (400-nm to 2500-nm)
- Maintain data continuity with heritage SLI bands of legacy Landsat instruments while enabling additional science from spectroscopic data
SLI-T Compact Hyperspectral Prism Spectrometer (CHPS)

- Continuous high spectral resolution from 400 to 2500 nm provides spectroscopic information to support wide range of emerging land science products:
  - Plant functional types and distribution
  - Intelligent agriculture (crop selection, water use practices, drought mitigation, etc.)
  - Ecological disturbances (invasive species, wild fires, forest thinning and dieback, insect infestation, etc.)
  - Near-shore Coastal Water Science (chlorophyll concentrations, algae blooms, water pollution)
Airborne CHPS Optical Subsystem

- F/3.0 Pushbroom system
- 20 degree Field of View
- Spectral range: 400 – 2500 nm
- 2.5 m GSD @ 4000 m Altitude

- 4-Mirror Telescope coupled with prism spectrometer
- Fused Silica refractive elements
- Protected silver coated mirrors
- Each major optical subsystem assembled and tested independently and then brought together to form full system
CHPS offers advantages for SLI

- **Small Size/Cost:** Compact form factor utilizing dual purpose optical elements for efficient space-saving design

- **Low stray-light:** Prism-based design eliminating multiple orders and scattering common in grating-based instruments

- **High SNR:** Capability for spectral binning to match Landsat bands while also providing additional bands

- **Low polarization:** Increased utility for inland and coastal water studies
Current CHPS Hardware Status

CHPS and REMI Integrated on Flight Mount

Integrated CHPS Sensor
CHPS On Board Calibration Sequence

- CHPS performance during flight is monitored using:
  - Broad-band Source
  - Shutter for dark collects
  - OLI filters
  - NIST 2035b Wavelength standard

- Calibration collects conducted for each flight line for sensor trending
Spectral Calibration of CHPS

- NIST 2035b Wavelength Standard included in On-Board Calibration system
- Utilized to verify CHPS Spectral calibration for every collect
Spectral Calibration of CHPS

- Tunable Laser utilized to illuminate CHPS at select wavelengths
  - Spectral Mapping
  - Instrument Line Shape and Spectral Response Function
- Excellent correlation between measured Spectral Mapping and the designed Dispersion Model
Radiometric Calibration of CHPS

- CHPS radiometrically calibrated in the Ball Radiometric Calibration Laboratory
- Utilized the “Death Star Source” (DSS) used in the OLI and OLI-2 radiometric calibration
- Ball Custom Transfer Radiometer (CXR) used to transfer calibration to DSS
- CXR is traceable to NIST and was also used for OLI and OLI-2
Radiometric Calibration of CHPS

- DSS Radiance levels selected to span expected dynamic range
- DSS includes feedback loop for stable operation
Polarization Characterization of CHPS
Polarization Characterization of CHPS

- Generally low Polarization sensitivity (<3%)
- Polarizer had a decreasing contrast ratio at short wavelengths
CHPS Engineering Flights

- Engineering flights conducted in March of 2019
- CHPS and REMI integrated into leased Twin Otter DHC-6 in Grand Junction, CO
- Flight plans were designed to test the instrumentation
  - Instrumentation Checkout
  - Geolocation
    - Timing
    - Pixel Pointing
    - Edge-shear
  - Sensor Comparison
    - CHPS
    - REMI
    - OLI
  - Heterogenous scenes
CHPS Engineering Flights
Weather prevented co-incident CHPS and Landsat 8 OLI collect

Co-incident collect with off-nadir Landsat-7 collect

CHPS collect conducted over vegetated community park in Grand Junction
CHPS Engineering Flights

- CHPS Laboratory Calibration being applied to Engineering flight data
- CHPS Spectral Calibration trended using NIST 2035b wavelength standard
- Development of CHPS Radiance data enables comparison to Landsat data

CHPS FPA Frame from Flight
CHPS Geolocation

- Geolocation Flights
  - “Wiggle” Test over Grand Junction Airport to verify system timing
  - Series of flight lines over Fruita, CO for geolocation
  - Initial CHPS “Camera Model” is in development
Remaining Activities

- Preparations for Science flights
  - Further Laboratory verification
  - Minor Software enhancements
  - Additional Radiometric and Spectral Calibration
  - Further analysis of sensor performance

- 2019 Science flights

- Produce sample L1 data from engineering or science flights

- Spaceborne Instrument Concept underway
2019 CHPS Science Flights

- Science flight are expected to occur in late summer 2019 due to aircraft availability

- Calibration Flights
  - Landsat/Sentinel-2 under flight
  - Table Mountain – vicarious calibration collect

- NEON Sites
  - Niwot Ridge – Alpine ecology site west of Boulder
  - Central Plains Experimental Range – managed Prairie site

- Other potential Science sites
  - High Park burn scar subset - Previously burned area undergoing regeneration
  - Horsetooth Reservoir – Inland open water
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