A CubeSat and SPA Compatible Hyperspectral Imager

CubeSat Summer Workshop 2010

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Outline

• Space Plug-n-play Avionics (SPA) Overview

• Spatial Heterodyne Spectrometer (SHS) Background

• Combining SPA with the SHS Instrument
Motivation

• Can we develop an optical instrument that can be reconfigured rapidly when a mission opportunity arises?

• Scenario narrative:
  – A number of different Space Plug-n-Play Spectrometers (SPnPS) instruments sit on the shelf. Additionally, a set of Spatial Heterodyne Spectrometer (SHS) monoliths sit on the shelf. When a launch opportunity arises, a particular SHS monolith is selected for a particular wavelength and spectral resolution.

• This could support both Operationally Responsive Space (ORS) missions and/or late breaking CubeSat launch opportunities.
Space Plug-n-play Avionics (SPA) Overview

Different data buses:

• SPA-S (SpaceWire)

• SPA-U (USB)

• SPA-1 (I²C)

(Reference: McNutt 2009)
Space Plug-n-play Avionics (SPA) Overview

Appliqué Sensor Interface Module (ASIM)

eXtended Transducer Electronic Datasheet (xTEDS):
- XML based
- Device functions
- Data produced
- Required data

(Reference: Lyke 2009)
Space Plug-n-play Avionics (SPA) Overview

(Reference: Lyke 2009)
The Spatial Heterodyne Spectrometer (SHS)
Monolithic SHS

- Extremely robust
- No moving parts
- Resistant to, and largely self-correcting for, thermal stress
Space Plug-n-Play Spectrometer (SPnPS) Overview

SPnPS Optics Train

SPnPS Prototype Unit
Middle Atmosphere Remote Sensing Target Species

- OH, Atomic Metals (Na & K), O, and O2

<table>
<thead>
<tr>
<th>Lower State</th>
<th>Upper State</th>
<th>Wavelength (nm)</th>
<th>Characteristic Luminosity</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO ($X^3\Sigma$)</td>
<td>NO ($A^3\Sigma^*$)</td>
<td>200 – 300</td>
<td>5 R/nm</td>
<td>Gamma Bands</td>
</tr>
<tr>
<td>$N_2$ ($X^1\Sigma_g^+$)</td>
<td>$N_2$ ($A^3\Sigma_g^*$)</td>
<td>200 – 400</td>
<td>5 R/nm</td>
<td>Vegard–Kaplan Bands</td>
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<tr>
<td>$O_2$ ($X^3\Sigma_g^+$)</td>
<td>$O_2$ ($A^3\Sigma_g^*$)</td>
<td>260 – 380</td>
<td>8 R/nm</td>
<td>Herzberg Bands</td>
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<tr>
<td>OH ($X^2\Pi_{1/2,3/2}$)</td>
<td>OH ($X^2\Pi_{1/2,3/2}$)</td>
<td>382 – 4470</td>
<td>100 – 2000 R/nm</td>
<td>Meinel Bands</td>
</tr>
<tr>
<td>O ($,^3\Pi$)</td>
<td>O ($,^3\Sigma^+$)</td>
<td>557.7</td>
<td>250 R</td>
<td>Green Line</td>
</tr>
<tr>
<td>Na ($,^2S$)</td>
<td>Na($,^3P$)</td>
<td>589</td>
<td>50 – 200 R</td>
<td>Sodium D1/D2 Lines</td>
</tr>
<tr>
<td>O ($,^3P$)</td>
<td>O ($,^3\Pi$)</td>
<td>630.0</td>
<td>50 – 100 R</td>
<td>Red Line</td>
</tr>
<tr>
<td>$O_2$ ($X^3\Sigma_g^+$)</td>
<td>$O_2$ ($B^1\Sigma_u^+$)</td>
<td>750 – 770</td>
<td>250 – 2000 R/nm</td>
<td>Atmospheric Band 0-0</td>
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<tr>
<td>$O_2$ ($X^3\Sigma_g^+$)</td>
<td>$O_2$ ($,^1\Delta_g$)</td>
<td>1260 – 1280</td>
<td>5000 R/nm</td>
<td>IR Atmospheric Band</td>
</tr>
</tbody>
</table>
Middle Atmosphere Remote Sensing Target Species

- OH, Atomic Metals (Na & K), O, and O2

We will now consider the Sodium D1/D2 lines and the Atmospheric Band O-O for example implementations
Mesospheric Temperature Sensing: Na vs. O$_2$

Different missions will require different SHS monoliths and encoded information to complete the mission-specific spectral analysis techniques.
SHS Monolith Sizes for Various Missions

- 37.807 mm
- 18.000 mm
- 557.7 nm (oxygen green line)

- 38.260 mm
- 589 nm (sodium yellow lines)

- 38.892 mm
- 41.010 mm
- 630 nm (oxygen red line)

- 764 nm (potassium lines and oxygen A-band)
Tradespace Plots for SHS Monolith Parameters

- Littrow Angle Constraints
  - Graph showing Littrow angle (deg) vs. Wavelength (nm)
  - Different colors and markers represent different Grating Groove Densities (100,000, 300,000, 600,000, 1200,000, 1800,000, 2400,000)

- Resolution Constraints
  - Graph showing Resolution (nm) vs. Wavelength (nm)
  - Different colors and markers represent different Grating Groove Densities (100,000, 300,000, 600,000, 1200,000, 1800,000, 2400,000)

- Field-Widening Prism Wedge Angle Constraint
  - Graph showing Prism Wedge Angle (deg) vs. Wavelength (nm)
  - Different colors and markers represent different Grating Groove Densities (100,000, 300,000, 600,000, 1200,000, 1800,000, 2400,000)

- Grating Center Distance Plot
  - Graph showing Grating Position from BS (nm) vs. Wavelength (nm)
  - Different colors and markers represent different Grating Groove Densities (100,000, 300,000, 600,000, 1200,000, 1800,000, 2400,000)
Prototype Na Field Test

[Image showing a diagram of a field test setup with labels for Field Lens, CCD, Aperture, Output Optics, Collimating Lens, and SHS Monolith.]

[Graph showing Na spectrum with peaks at 589.0 nm and 589.6 nm.]
Combining SHS with SPA

• By swapping out SHS monoliths the SPnPnPS instrument can support a wide range of missions.

• Build-in an ARM based processor with the SPnPnPS instrument that can both interface with the detector and process the mission-specific spectra.

• To the best of our knowledge this is an additional level of flexibility than currently implemented under other SPA projects (including the larger spacecraft – not just CubeSats).
Challenges

- How best to expose interfaces via the xTED when different missions need to be accounted for?
  - Pre-load xTEDs for all potential missions
  - Load xTED at time of SHS monolith insertion

- Should all processing be done on the payload processor, or do some missions require exposure of lower level interfaces to the detector so processing can be done on the main computer?

- Support both SPA-U (USB) and SPA-1 (I2C)?
  - Right now primarily targeting SPA-U

- When can we fly?
References


