SRI International

Scientific Solutions, Inc.
Spectroscopic Devices & Consulting

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?

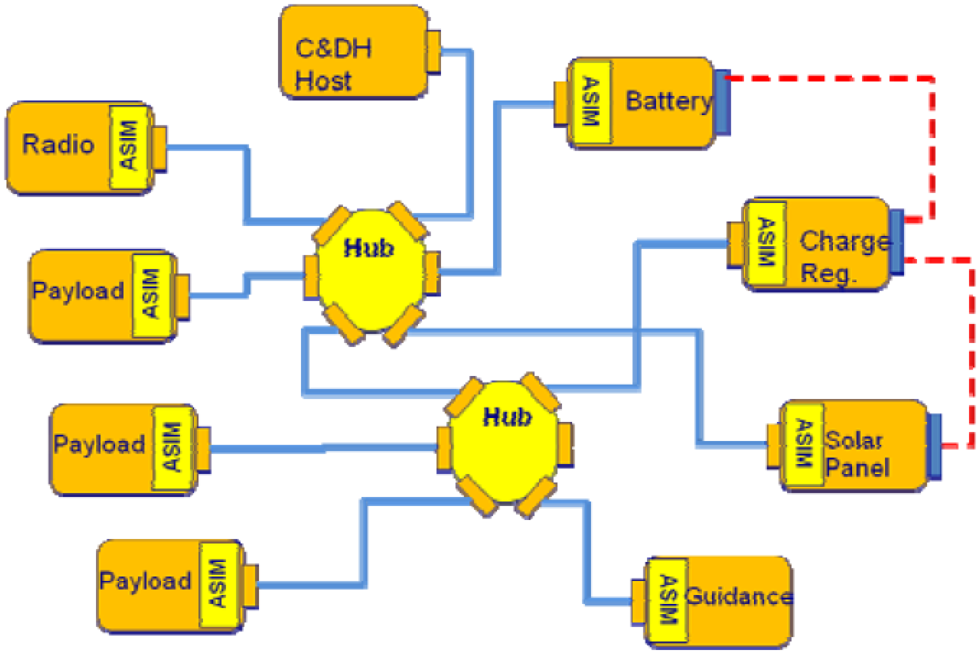
- Scenario narrative:
  - A number of different Space Plug-n-Play Spectrometers (SPnPS) instruments sit on the shelf. Additionally, a set of Spatial Heterodyne Spectrometer (SHS) monoliths sit on the shelf. When a launch opportunity arises, a particular SHS monolith is selected for a particular wavelength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

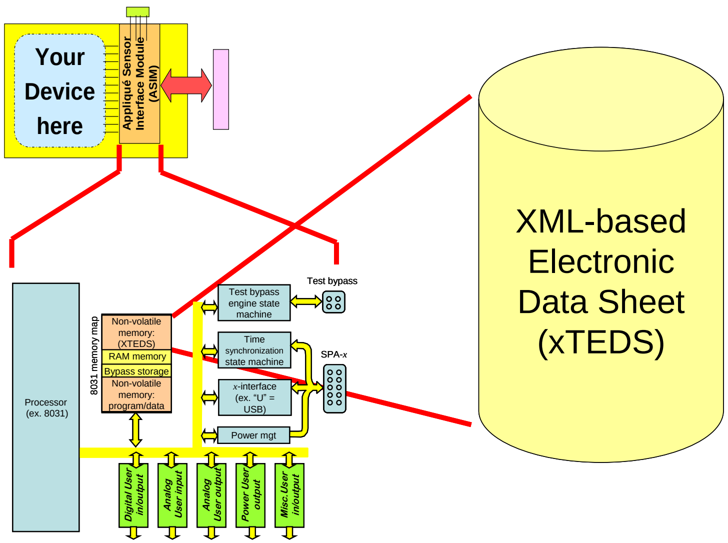
- SPA-S (SpaceWire)
- SPA-U (USB)
- SPA-1 (I^2C)



(Reference: McNutt 2009)

Space Plug-n-play Avionics (SPA) Overview

Appliqué Sensor Interface Module (ASIM)

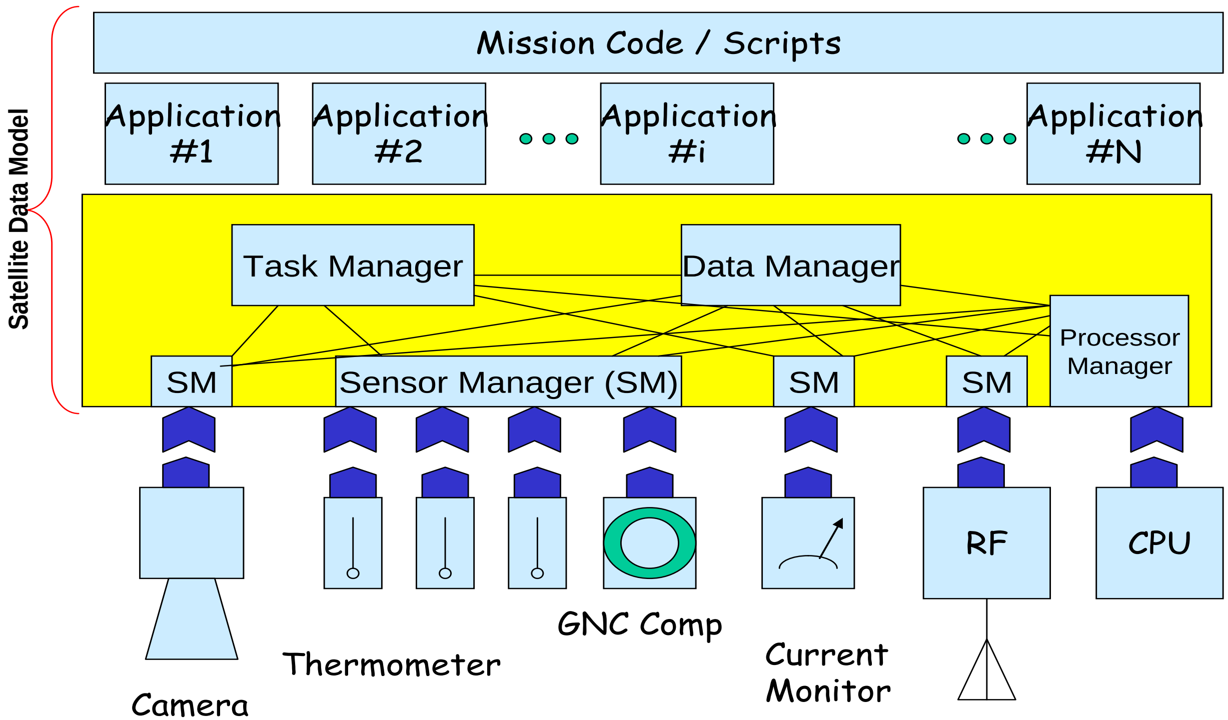


eXtended Transducer Electronic Datasheet (xTEDS):

- XML based
- Device functions
- Data produced
- Required data

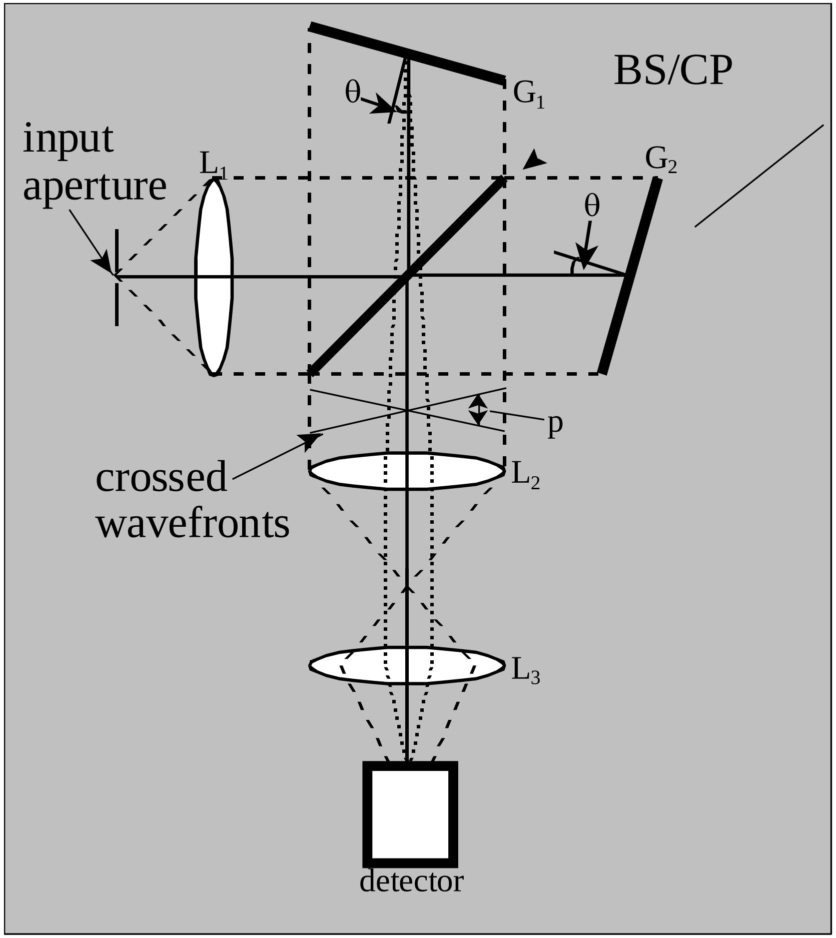
(Reference: Lyke 2009)

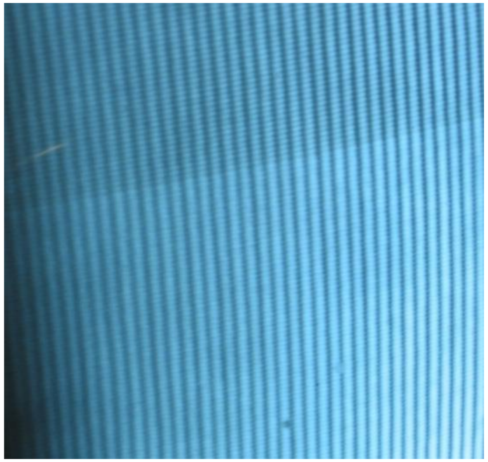
Space Plug-n-play Avionics (SPA) Overview



(Reference: Lyke 2009)

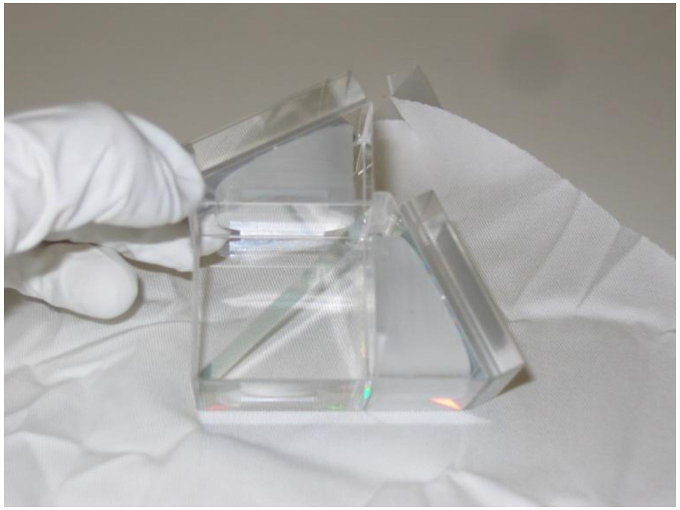
The Spatial Heterodyne Spectrometer (SHS)





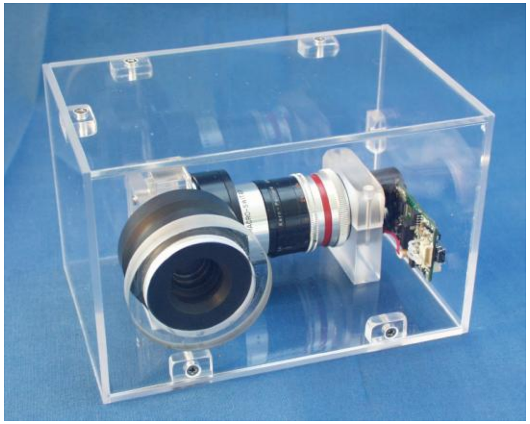
Fringe Pattern

Monolithic SHS

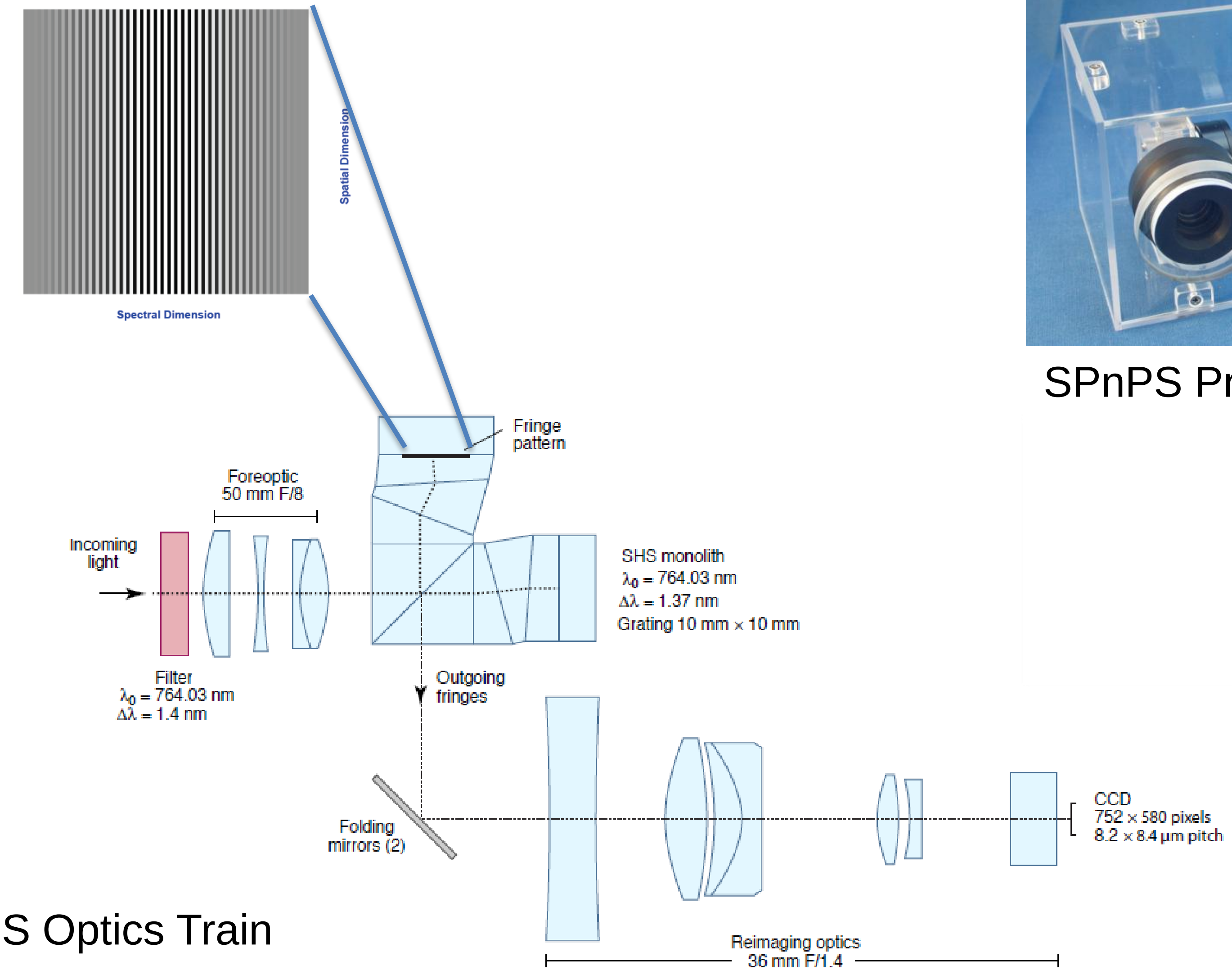


- *Extremely robust*
- *No moving parts*
- *Resistant to, and largely self-correcting for, thermal stress*

Space Plug-n-Play Spectrometer (SPnPS) Overview



SPnPS Prototype Unit



SPnPS Optics Train

Middle Atmosphere Remote Sensing Target Species

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

Lower State	Upper State	Wavelength (nm)	Characteristic Luminosity	Name
NO ($X^2\Pi$)	NO ($A^2\Sigma^+$)	200 – 300	5 R/nm	Gamma Bands
N_2 ($X^1\Sigma_g^+$)	N_2 ($A^3\Sigma_u^+$)	200 – 400	5 R/nm	Vegard–Kaplan Bands
O_2 ($X^3\Sigma_g^-$)	O_2 ($A^3\Sigma_u^+$)	260-380	8 R/nm	Herzberg Bands
OH $(X^2\Pi)_{v=0,1}$	OH $(X^2\Pi)_{v=9,8}$	382- 4470	100 – 2000 R/nm	Meinel Bands
O (^{1}D)	O (^{1}S)	557.7	250 R	Green Line
Na (^{2}S)	Na(^{2}P)	589	50 – 200 R	Sodium D1/D2 Lines
O (^{3}P)	O (^{1}D)	630.0	50 – 100 R	Red Line
O_2 ($X^3\Sigma_g^-$)	O_2 ($b^1\Sigma_g^+$)	759 - 770	250 – 2000 R/nm	Atmospheric Band 0-0
O_2 ($X^3\Sigma_g^-$)	O_2 ($a^1\Delta_g$)	1260 – 1280	5000 R/nm	IR Atmospheric Band

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

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N_2 ($X^1\Sigma_g^+$)	N_2 ($A^3\Sigma_u^+$)	200 – 400	5 R/nm	Vegard–Kaplan Bands
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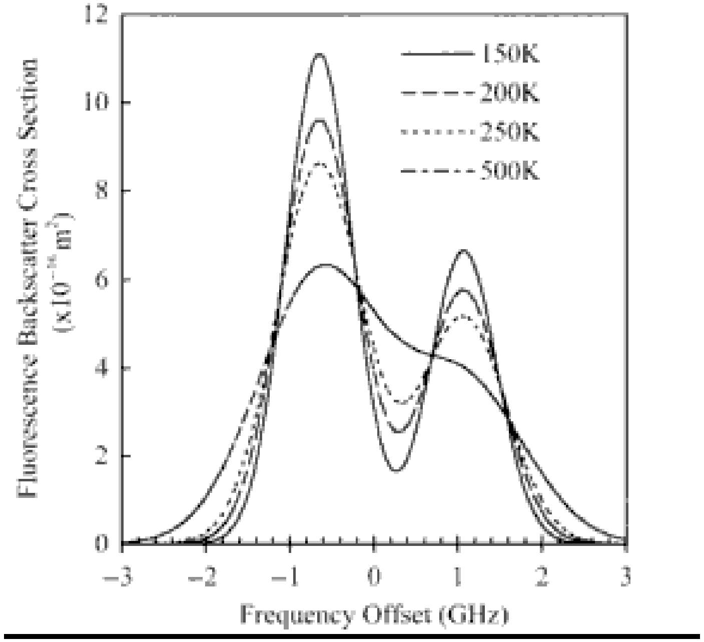
Mesospheric Temperature Sensing: Na vs. O_2



Sodium Synthetic Spectra

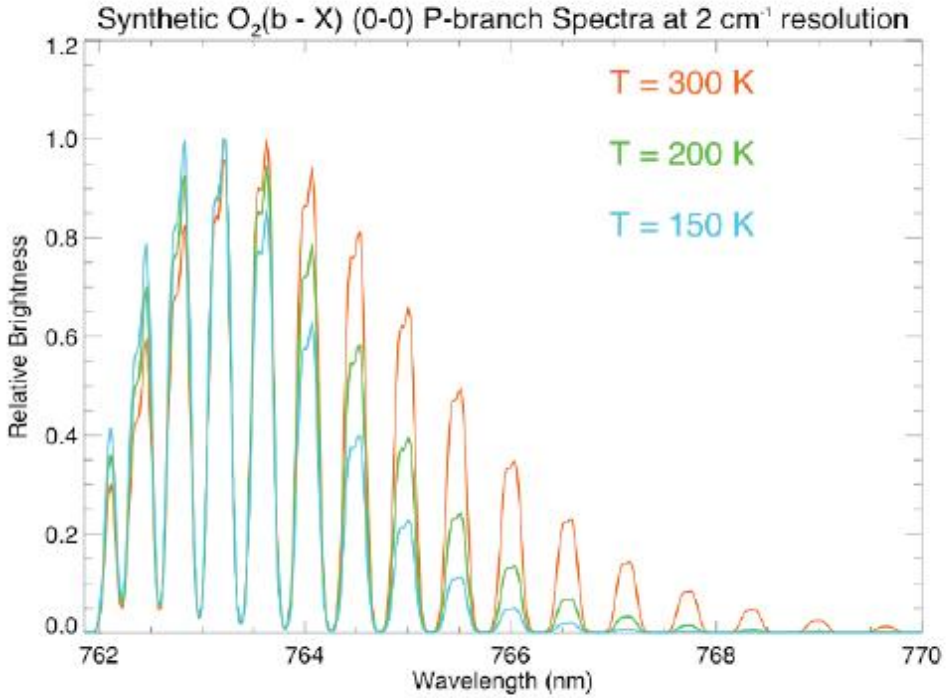
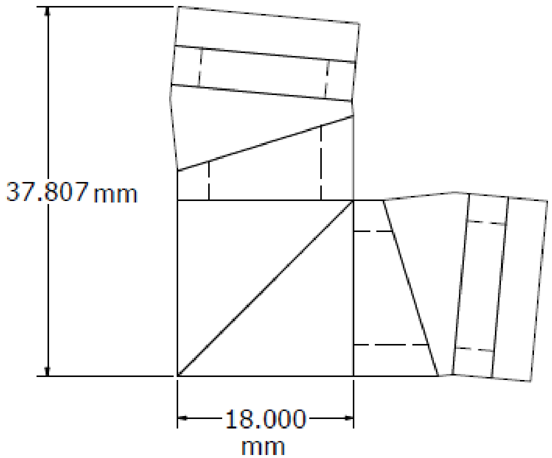


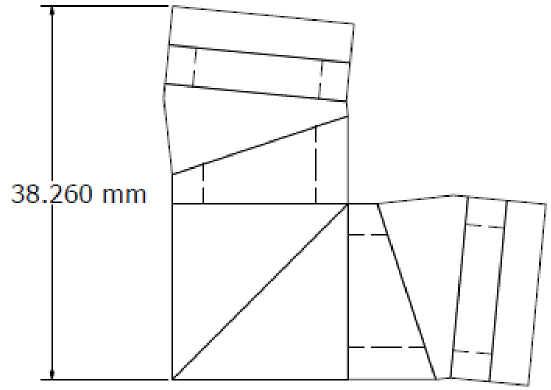
Figure 5. Synthetic O_2 A-band (0-0) P-branch spectra (0.12 nm resolution) for three mesopause temperature values.

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

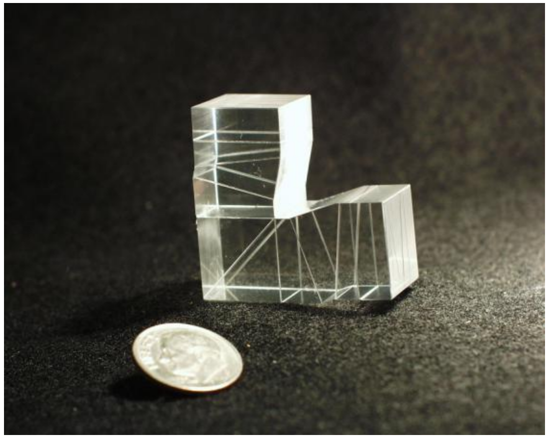
SHS Monolith Sizes for Various Missions

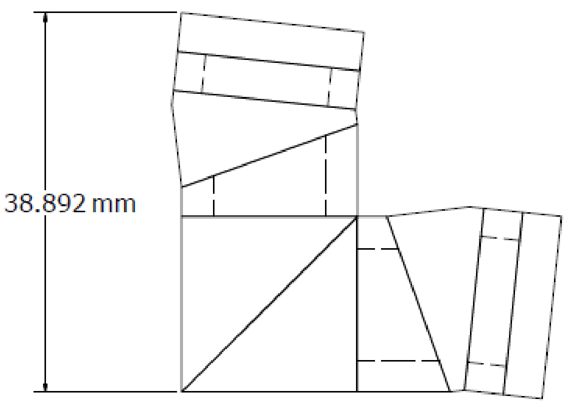


557.7 nm
(oxygen green line)

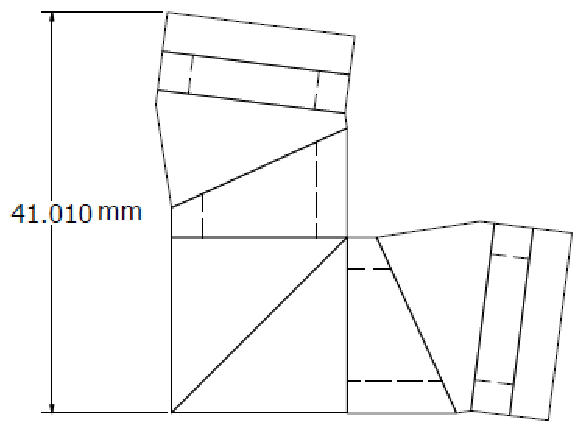


589 nm
(sodium yellow lines)



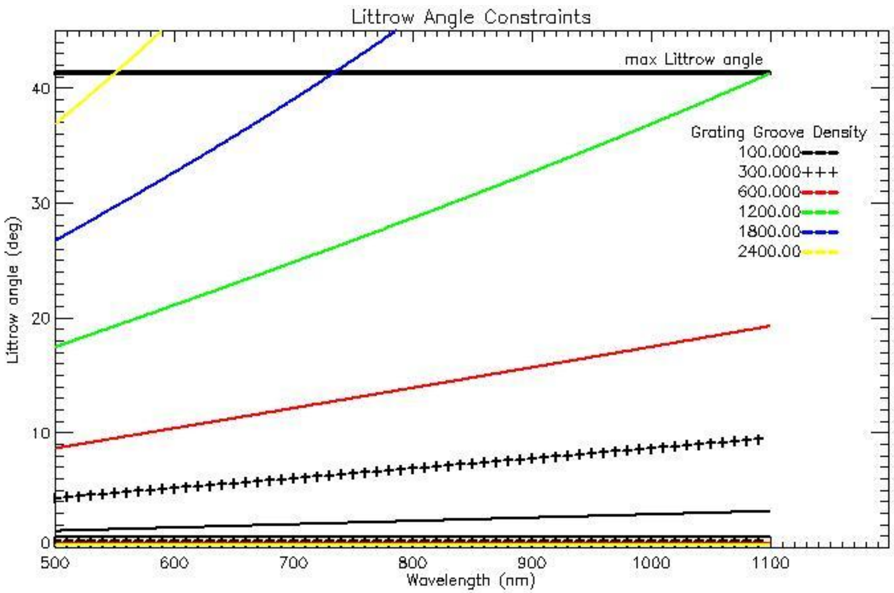


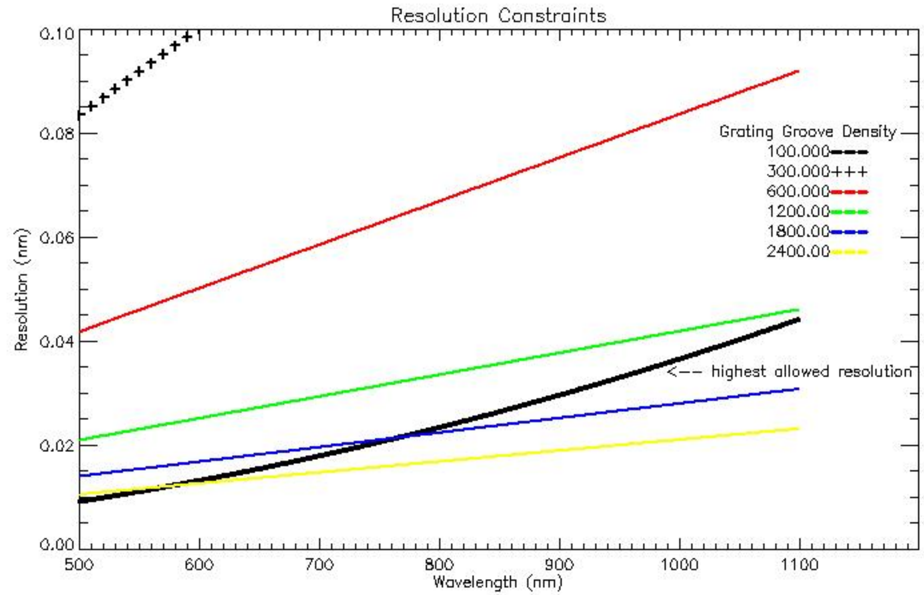
630 nm
(oxygen red line)

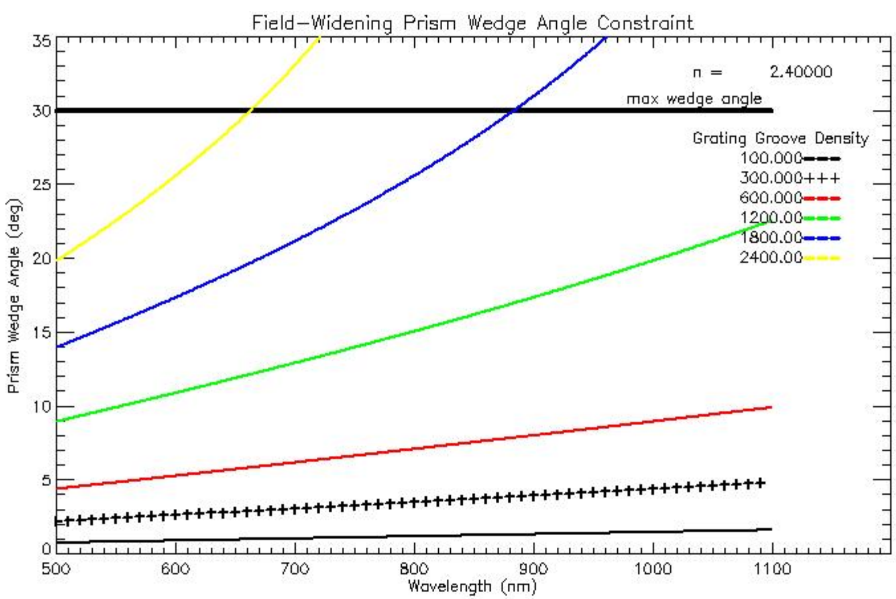


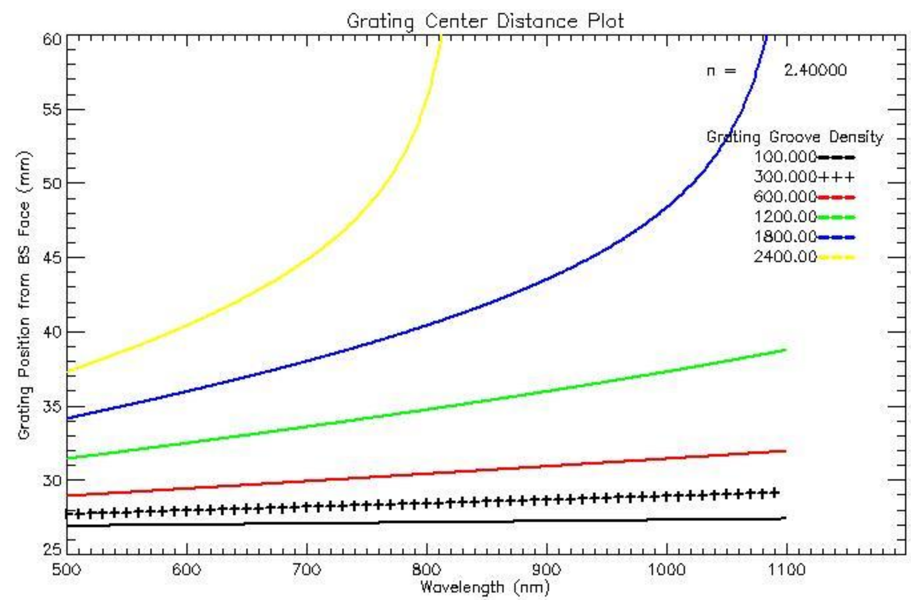
764 nm
(potassium lines and oxygen A-band)

Tradespace Plots for SHS Monolith Parameters

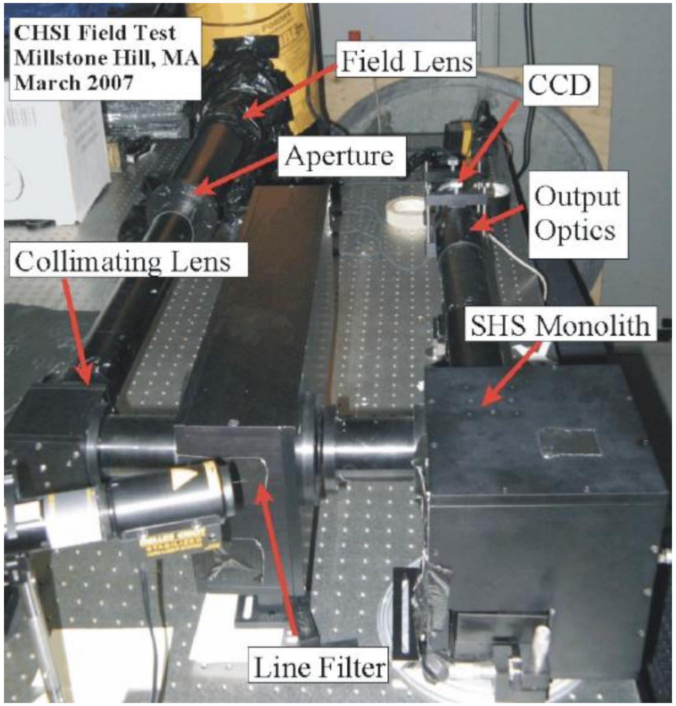


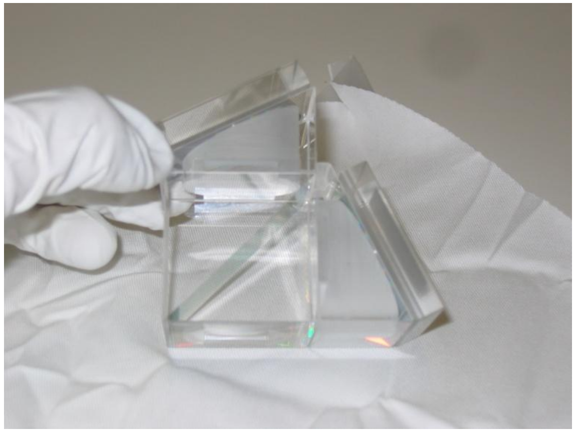


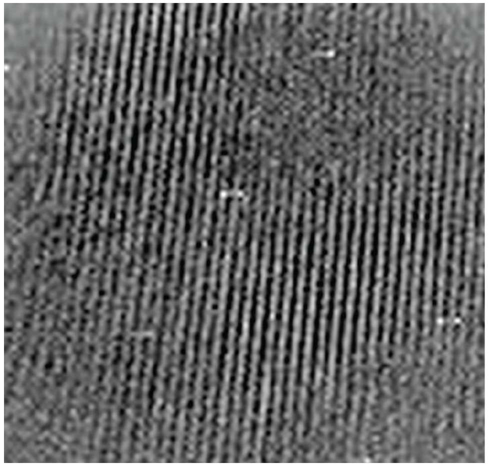


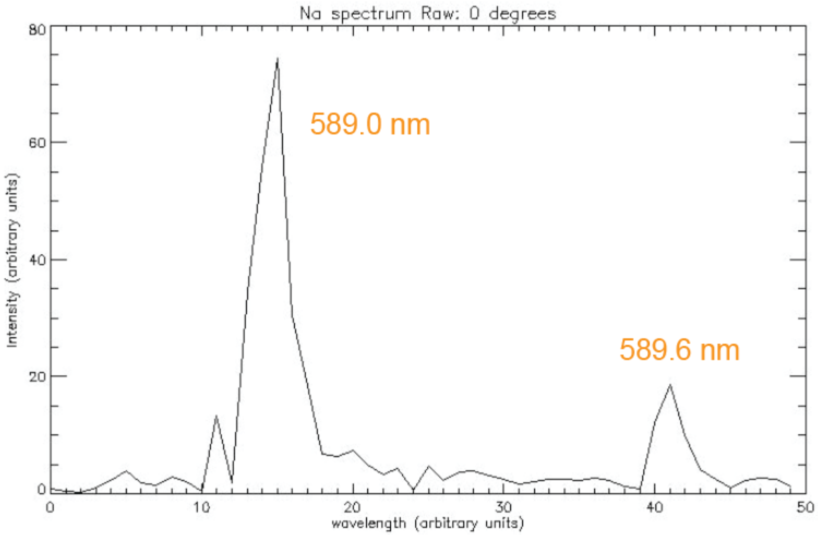


Prototype Na Field Test









Combining SHS with SPA

- By swapping out SHS monoliths the SPnPS instrument can support a wide range of missions
- Build-in an ARM based processor with the SPnPS 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

- McNutt, C. et al. "*Modular Nanosatellites – (Plug-and-Play) PnP CubeSat*", 7th Responsive Space Conference, April 2009.

- Lyke, J. "*Bringing the Vision of Plug-and-play to High-Performance Computing on Orbit*", HPEC 2009 Workshop, September 2009.

- Doe, R. et al. "*CubeSat-Scale Hyperspectral Imager for Middle Atmosphere Investigations*", CubeSat Developers Workshop, April 2009.

- Doe, R. et al. "*CubeSat-Scale O2 Atmospheric Band (o-o) Imaging Spectrograph*", Poster Session - American Geophysical Union Fall Meeting, December 2009.