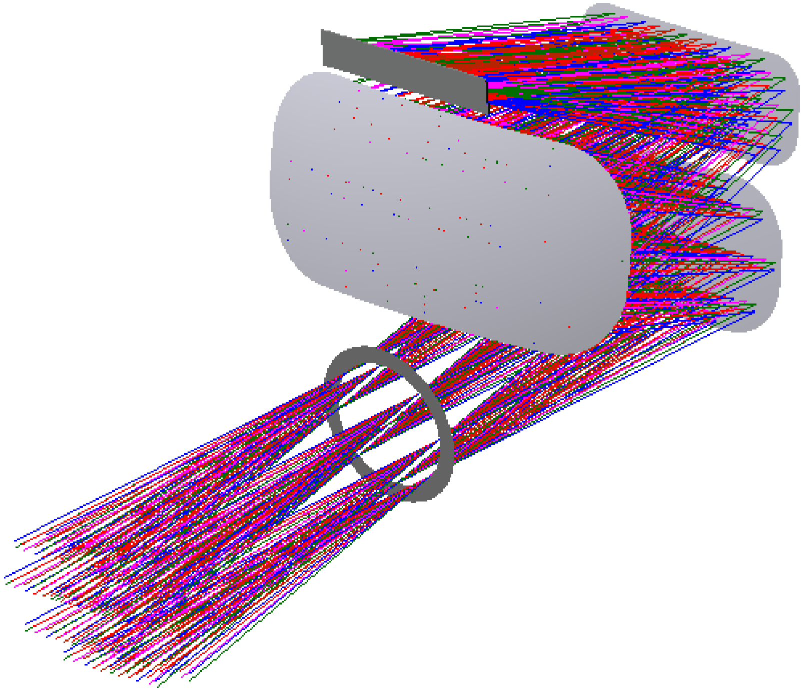


Advanced Technology Land Imaging Spectroradiometer (ATLIS)

Grant Number: NNX16AP64G

Dr. Jeff Puschell
Principal Investigator

2017 June 14

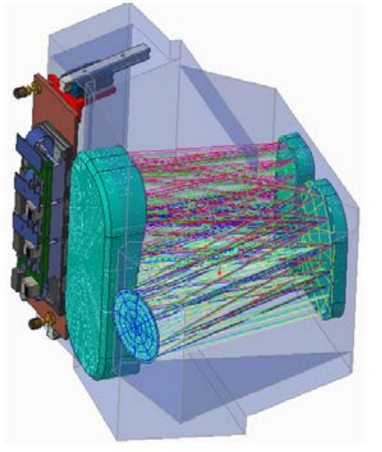
Advanced Technology Land Imaging Spectroradiometer (ATLIS)

PI: Jeff Puschell, Raytheon

Objective

Demonstrate whether compact, low mass ATLIS design approach with wide field of view (WFOV), compact telescope, large format, small detector digital FPA and on-chip processing meets or exceeds SLI-T VSWIR requirements

Technologies include WFOV nearly telecentric RT telescope with free form optics; production digital FPA with on-chip processing; full aperture calibration approach, detailed instrument system ATLIS Performance Model.



ATLIS-Prototype showing WFOV Reflective Triplet (RT) telescope with digital Focal Plane Assembly (FPA)

Approach:

Design, build, test and demonstrate a multispectral ATLIS-Prototype (ATLIS-P) by:

1. Designing an ATLIS-P system scaled to meet SLI-T Reference Mission Architecture (RMA) VSWIR reqts
2. Procuring, integrating and testing ATLIS-P elements
3. Planning and completing demonstration of ATLIS-P performance with respect to SLI-T RMA requirements
4. Comparing demonstrated ATLIS-P performance with model predictions, updating and documenting model and using verified model to extend predictions to other SLI-T RMA VSWIR bands

CoIs: Lynn Mears, Raytheon

Key Milestones

• Kickoff	10/16
• Interim Review	04/17
• All ATLIS-P parts in house	12/17
• ATLIS-P integrated and ready for test	02/18
• Initial ATLIS-P test/analysis (TRL 5)	02/18
• ATLIS-P testing	03/18
• Data analysis/model verification/scaling (TRL 6)	04/18
• Final report	05/18

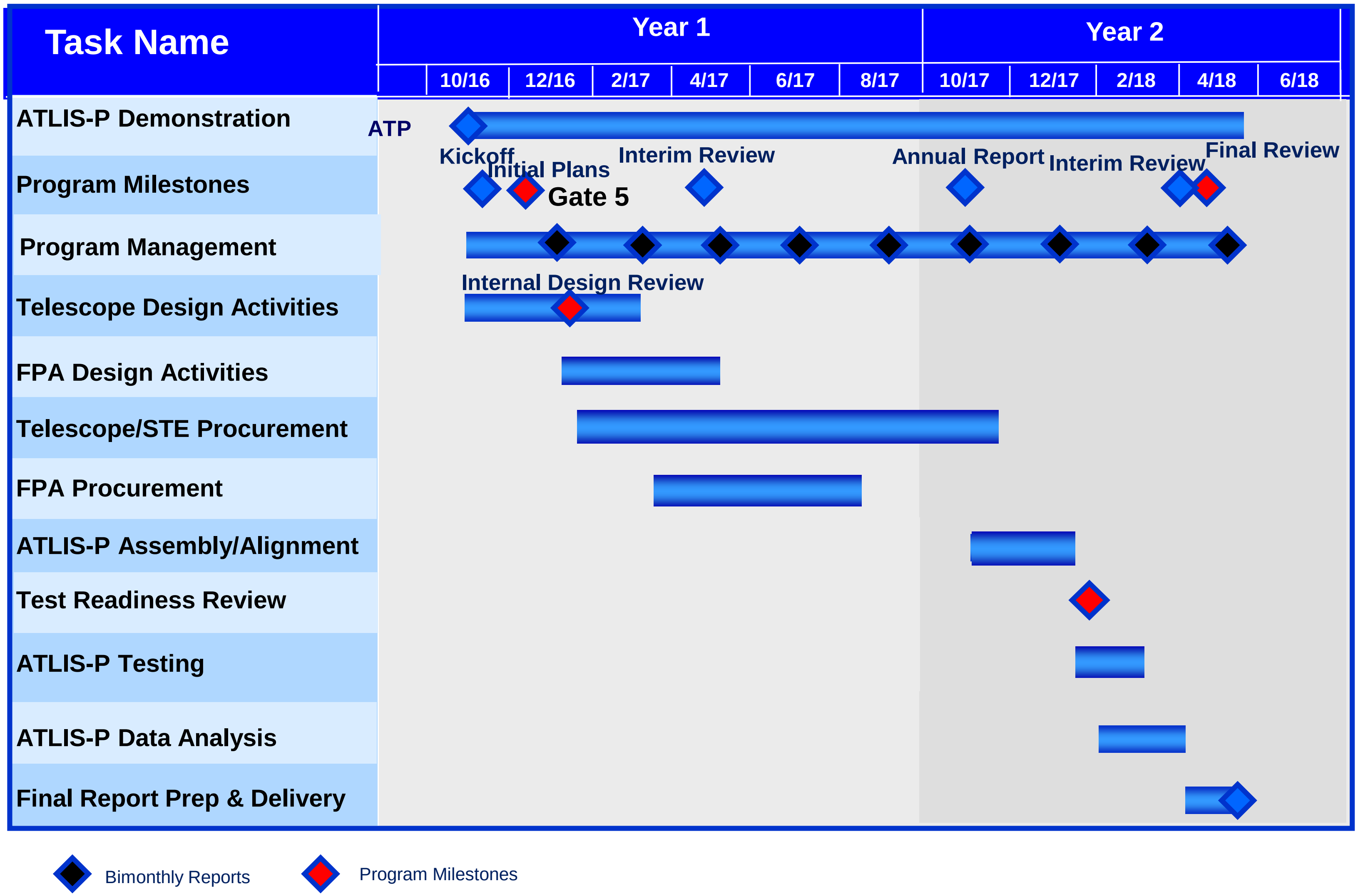
TRL_{in} = 3

Earth Science Technology Office

ATLIS-P supports Sustainable Land Imaging (SLI) architectures

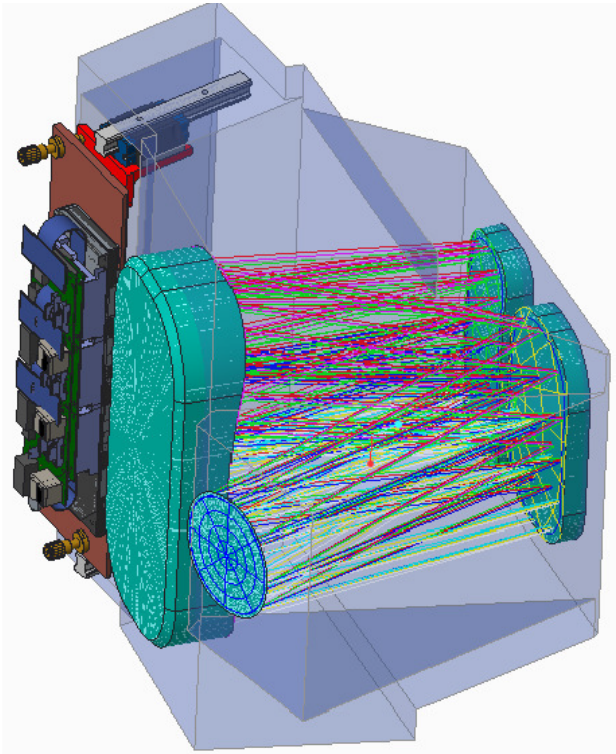
- ATLIS-P supports future SLI architectures by providing a direct path to a disaggregated architecture using an ATLIS-like approach for the VSWIR and a separate instrument for the TIR – similar to the current architecture
  - Other work at Raytheon with WFOV emissive infrared refractive systems has already reduced risk for the emissive infrared element of this architecture – prompting us to develop the free form Zernike polynomial described mirror reflective telescope for SLI-T
- ATLIS-P also supports a full spectrum instrument by demonstrating a scalable design approach that could be built with the larger aperture size required to deliver high quality 60 m TIR pixels
  - Improved understanding of free form telescope captured in ATLIS combined with improved system engineering tools improves technology readiness for a larger aperture ATLIS-like approach

ATLIS Schedule



ATLIS-Prototype (ATLIS-P)

- SLI-T project involves designing, building, testing and demonstrating a six spectral band Advanced Technology Land Imaging Spectroradiometer Prototype (ATLIS-P)
  - ATLIS-P uses a VIIRS Integrated Filter Assembly (IFA) to provide spectral separation
  - In addition, 865 nm and 443 nm spectral filters covering entire FPA are available
- Key elements of the technology to be demonstrated include:
  - Wide FOV nearly telecentric free form RT telescope with real entrance pupil
  - Production digital Si:PIN FPA based on the Raytheon space-qualified SB501 ROIC
  - On chip processing
  - Full aperture calibration approach
  - ATLIS system engineered and optimized for SLI-T requirements by means of integrated imager system performance models
- ATLIS-P telescope and FPA design characteristics were selected to reduce cost, while enabling a valid demonstration of system performance



ATLIS-P is a testbed for future NASA and Raytheon funded demonstrations of calibration, VNIR and SWIR focal plane technology and any other technologies that support NASA and USGS SLI-T goals

Comparison of RMA and ATLIS-P spectral bands

RMA Center Wavelength (nm)	RMA Spectral Bandwidth (nm)	ATLIS-P Center Wavelength (nm)	ATLIS-P Spectral Bandwidth (nm)
443	20	445	18
482	65	488	20
562	75	555	20
590	180	640	80
655	50	672	20
865	40	865	40
1375	30	1378*	15*
1610	100	1610*	6*
2200	200	2250*	50*

*VIIRS SWIR bands that could be incorporated into enhanced demo

Predicted SNRs for ATLIS-P at L_{typ}

Center Wavelength (nm)	Spectral Bandwidth (nm)	Cross Track GSD (m)	L_{typ} (W m^{-2} sr^{-1} μm^{-1})	Predicted SNR	Required SNR	Margin (percent)
445	18	23.4	40	253	130	95
488	20	23.4	40	344	130	164
555	20	23.4	30	305	100	205
640*	80	11.7	23	159	80	99
672	20	23.4	22	261	90	190
865	40	23.4	14	304	90	238

*Panchromatic band with 2x smaller GSD

ATLIS-P Relative Edge Response (RER)

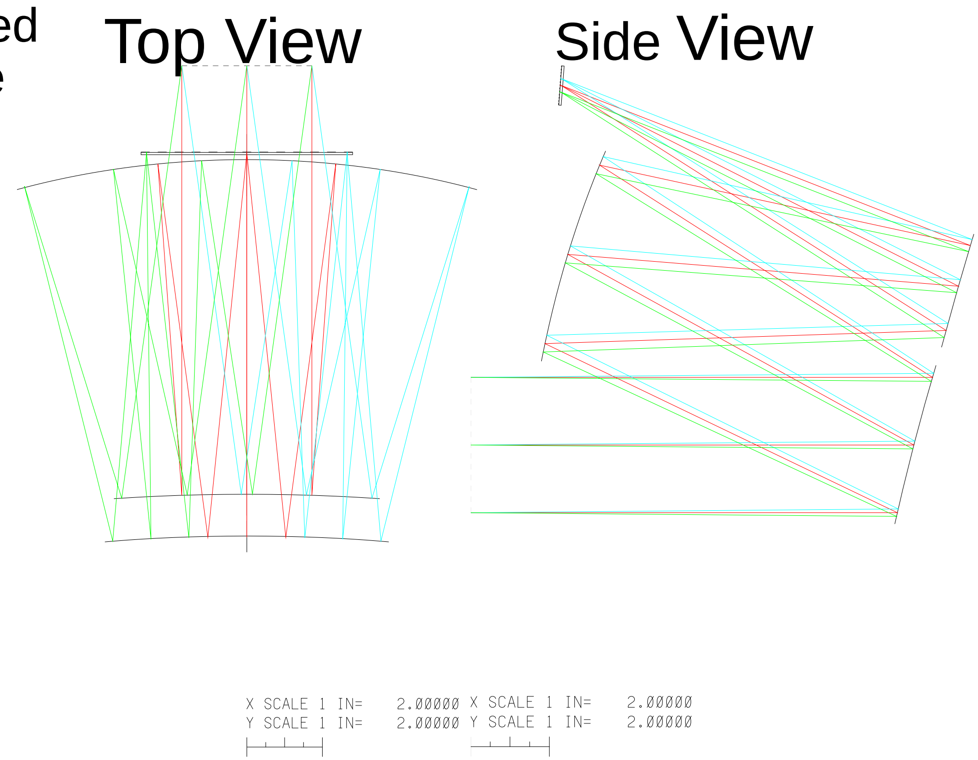
Center wavelength (nm)	RER Slope along track (m^{-1})	RER Slope cross track (m^{-1})	Edge response uniformity along track (m^{-1})	Edge response uniformity cross track (m^{-1})	Aliasing along track	Aliasing cross track
445	0.0434	0.0421	1.013	1.008	0.983	0.986
488	0.0430	0.0420	1.004	1.006	0.975	0.982
555	0.0423	0.0416	0.987	0.996	0.958	0.973
640	0.0591	0.0723	0.690	0.866	0.767	0.938
672	0.0432	0.0421	1.008	1.008	0.980	0.984
865	0.0423	0.0410	0.987	0.982	0.958	0.959

ATLIS-P meets nominal SLI-T RMA requirements for RER Slope of 0.027 m^{-1} for the multispectral bands and 0.054 m^{-1} for the PAN band with no aliasing in all bands

Wide field of view, RT telescope with real entrance pupil

Raytheon
Space and Airborne Systems

- Free form Zernike polynomial described mirror RT telescope with real entrance pupil
- Nearly Telecentric
  - Maximum angle over FOV: 1.21 mrad
  - Image AOI: 22.56°
- EPD: 8.75 cm
  - Circular External Pupil
- FOV: 1 x 16 deg
- EFL: 48.11 cm (f/5.5)



Reference: Lacy Cook, “All Reflective Real Pupil Telecentric Imager”, US Patent 8,714,760 (2014)

ATLIS Performance Model (APM) verification is at the heart of this study

Raytheon
Space and Airborne Systems

- Measured performance of ATLIS-P will be compared with predictions made by a detailed instrument system performance model that combines industry-standard analysis techniques for SNR, MTF and many other related parameters with measured ATLIS-P telescope, FPA, electronics and test equipment characteristics to predict measured ATLIS-P system performance
  - Differences between predictions and measured performance will be investigated in detail to determine the source of any anomaly
- APM is derived from similar imaging spectroradiometer system performance models used at Raytheon to successfully predict performance of many recent instruments including VIIRS, JAMI and earlier Landsat instruments
- APM simulates the image and signal processing chain step-by-step to account for impact of all system elements on ATLIS data products, while accounting for all known sources of noise and signal degradation in predicting quality of sensor products
- AMA performance predictions made with APM indicate this conceptual system meets all SLI-T requirements considered to date with margin, including SNR and RER Slope
- APM has been tested by putting in design characteristics for existing systems like OLI and comparing performance predictions with measured performance – results look good for predicted and measured MTF, SNR and RER slope

Closing remarks

- New and emerging optical and focal plane technology enables much smaller land imagers than current systems
- Innovative signal processing methods not discussed in this presentation improve RER slope and SNR and lead to further reductions in land imager size, mass and power
- ATLIS-P supports both a disaggregated architecture and a full spectrum instrument and provides a testbed that can be used in future technology demonstrations
- Key ATLIS-P technology (free form reflective telescope, digital FPA) benefits many other NASA Earth Science missions, especially those involving small satellite systems

Thanks to NASA ESTO for supporting this project!