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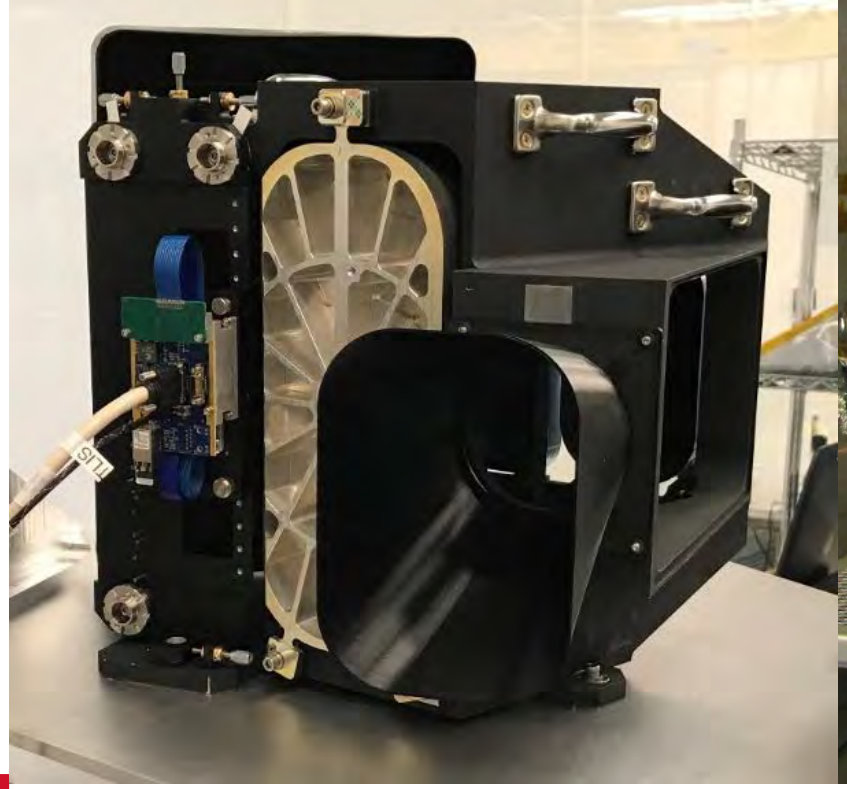

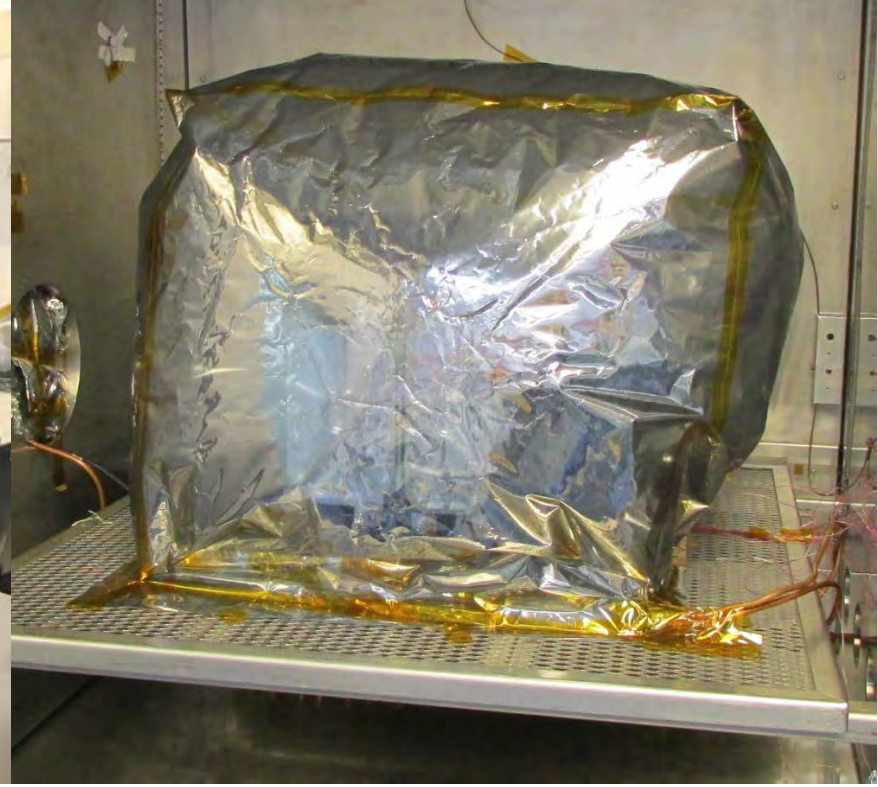

Advanced Technology Land Imaging Spectroradiometer (ATLIS)

Grant Number: NNX16AP64G/80NSSC18K0103

2020 June 25

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Acknowledgements

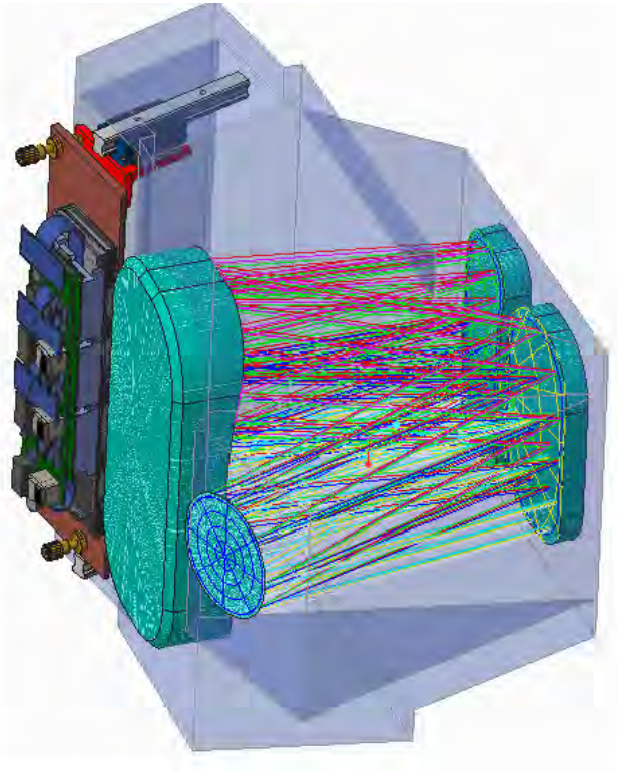
- Sustained efforts of this ATLIS Engineering Team enabled project success:
  - Principal Investigator: Dr. Jeff Puschell
  - Lead System Engineer: Dr. Jeff Puschell
  - Chief Engineer: John Schlaerth
  - Lead Test Engineers: Dr. Joe Choi, Dr. Kushal Mehta
  - Telescope Manufacturing: Dr. John Schaefer
  - Optical Design Leads: Lacy Cook, Neil Nelson
  - Opto-mechanical Design Leads: Christina Arlow, Austin Semmelroth
  - Calibration Engineers: Dr. Stephen Schiller, Chris Koontz
  - Focal Plane Assembly Leads: Michael Halter, Neil Malone, Tom Yengst
  - Software Lead: Dr. Kushal Mehta
  - Environmental Test Engineers: Ryan Sipos, Michael Zarella, Carl Ginnow, Dr. Kyle Heidemann, Ryan Butt-Yoshioka and Duncan Campbell, Dr. Joe Choi, Dr. Kushal Mehta, Hans Naepflin, Malinee Krailas, Nicholas A. Patterson
- Many thanks to NASA ESTO for funding this work

ATLIS-Prototype (ATLIS-P)

- SLI-T project involves designing, building, testing and demonstrating an Advanced Technology Land Imaging Spectroradiometer Prototype (ATLIS-P)
  - Interchangable spectral filters at 865 nm and 443 nm cover entire FPA
  - VIIRS Integrated Filter Assembly (IFA) provides additional VNIR bands
- Key elements of the technology demonstration include:
  - Wide FOV nearly telecentric Freeform Reflective Triplet (FFRT) telescope with real entrance pupil
  - Production digital Si:PIN FPA based on Raytheon space-qualified SB501
  - ATLIS system engineered and optimized for SLI-T 2015 Reference Mission Architecture (RMA) requirements by means of integrated imager system performance models
  - Compact, end-to-end onboard calibration system
- ATLIS-P telescope and FPA design characteristics were selected to reduce cost, while enabling a valid demonstration of system performance

Basic question posed by ATLIS-P: Can a small aperture Freeform Reflective Telescope imaging system meet SLI-T RMA 2015 requirements?

ATLIS-P Entrance Pupil Diameter (EPD): 8.74 cm



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

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 freeform Zernike polynomial described three 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 freeform telescope captured in ATLIS combined with improved system engineering tools improves technology readiness for a larger aperture ATLIS-like approach

ATLIS-P telescope extends US industrial capabilities

- ATLIS-P telescope is the first Freeform Reflective Triplet (FFRT) telescope manufactured by US industry and the first known FFRT for the VNIR
  - Earlier telescopes with all free form mirrors developed by University of Rochester and TNO for Tropomi among others are not RTs and do not address SLI-T RMA requirements for aperture size, FOV and IFOV
- New freeform metrology methods were created and demonstrated with successful Magnetorheological (MRF) figure correction
- Lessons learned include:
  - Freeform mirrors require more processing time to achieve figure
  - Freeform Zernike mirror alignment sensitivities differ from rotationally symmetric aspheres, requiring models that account for Zernike sensitivities

Thanks to NASA's investment in this technology, ATLIS-P reduced risk and inspired design and fabrication of multiple FFRTs for a wide variety of Earth observation systems

ATLIS-P test results combined with model predictions confirm this innovative imager meets SLIT-15 RMA performance requirements

- Spatial and temporal coverage – performance across full FOV meets RMA requirements, enabling credit for spatial and temporal coverage
- Radiometric SNR – measurements agree with predictions to within 5%
- Saturation radiance – no saturation for maximum spectral radiance in all bands
- Relative Edge Response (RER) – meets requirements across the full field of view, except in the PAN band, which can be met with low fill detectors
- Edge Extents – measurements and predictions meet edge extent requirements
- Pixel-to-pixel uniformity – 0.04% or better following non-uniformity correction
- Radiometric stability - 0.0997±0.184% meaning each pixel varied by less than 0.1% over both short duration (one minute collects over 99 mins/day) and over 16 days, meeting both parts of the RMA radiometric stability requirement

ATLIS-P moves toward successful project completion

- Completed ruggedization and testing of ATLIS-P against flight qualification like thermal and mechanical disturbance to assess telescope's thermal and opto-mechanical stability
  - Thermal Cycling Environmental Testing completed with no appreciable change to WFE across the FOV
  - Vibration Testing completed, but with an anomaly caused by a well-understood assembly error that resulted in secondary mirror shift due to pin ejection during vibration – repairs restored telescope to pre-vibe test performance with 0.103 wave RMS averaged across the FOV with values ranging from 0.065 wave to 0.135 wave
- Completed proof-of-concept demonstration of LED-based Jones source placed near ATLIS-P entrance pupil – measured uniform irradiance across the ATLIS-P FOV with signal levels within a few percent of model predictions
- Incorporated ATLIS-P results into RMA19 system performance analyses

Closing remarks

- New and emerging optical and focal plane technology enables much smaller land imagers than current systems
- ATLIS-P telescope achieved performance required to meet SLI-T requirements - advanced key technology from TRL 3 to TRL 5
- Lessons learned in ATLIS-P telescope build and test reduce risk for future imaging system developments
- Comparison between measurements and model predictions looks good
- ATLIS-P supports both disaggregated architectures and full spectrum single instrument land imaging systems
- Key ATLIS-P technology benefits many other NASA Earth Science missions, especially those involving small satellite systems

Thanks to NASA ESTO for this investment in advanced land imager technology!