An Electronically Steerable Flash Lidar Update

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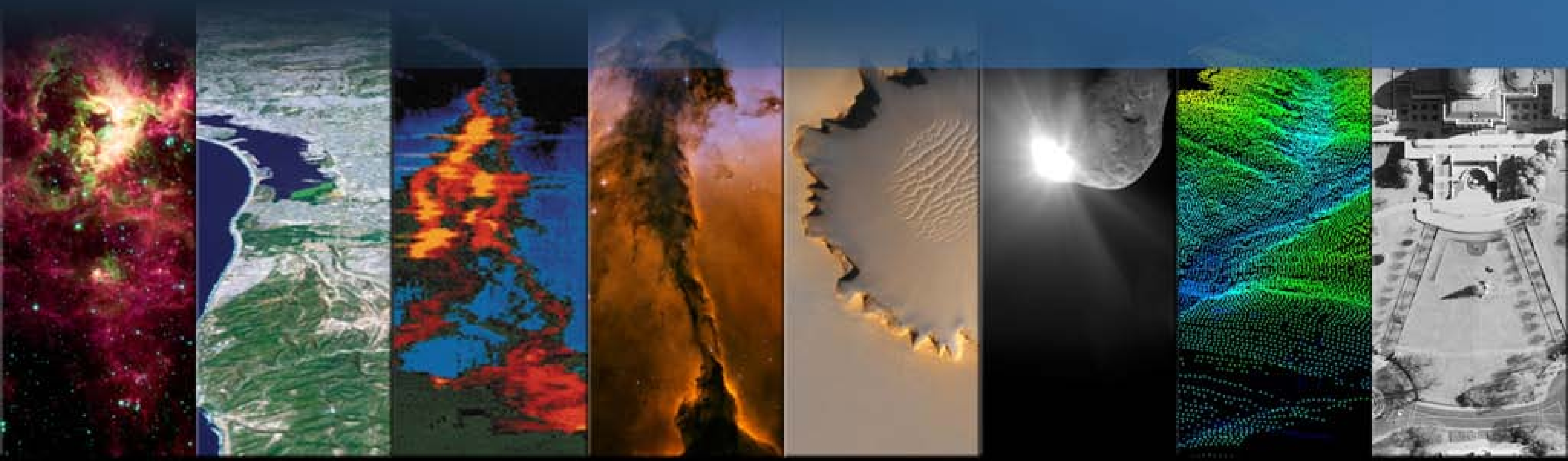
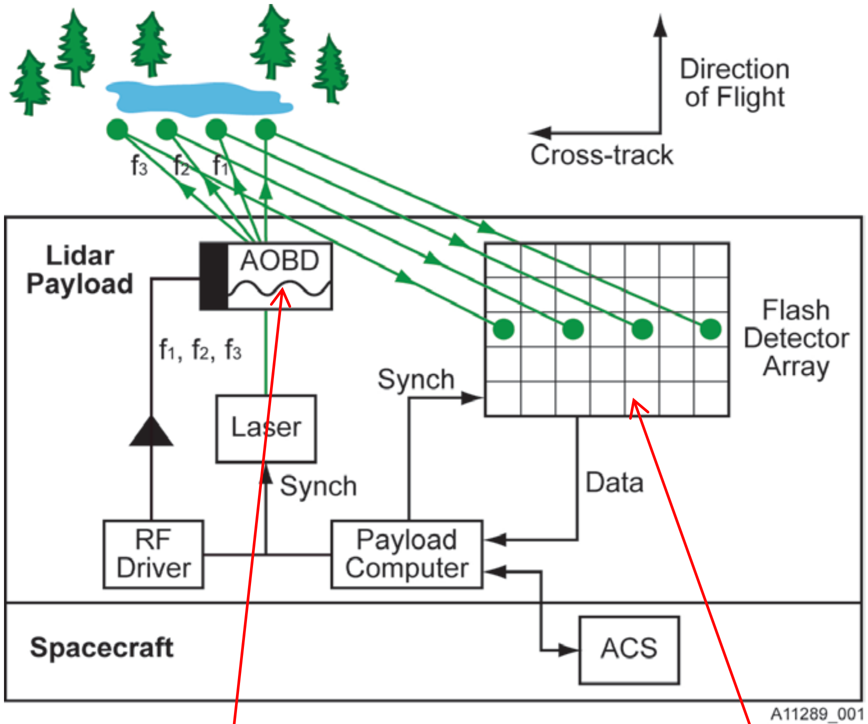
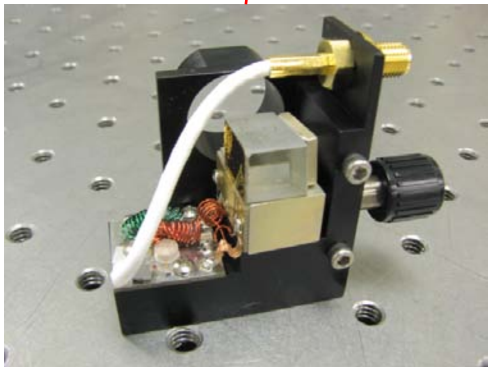
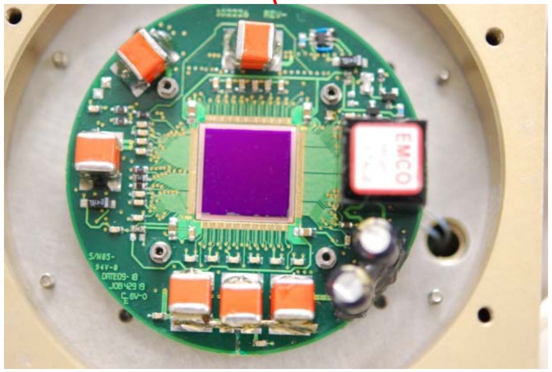


Background – ESFL

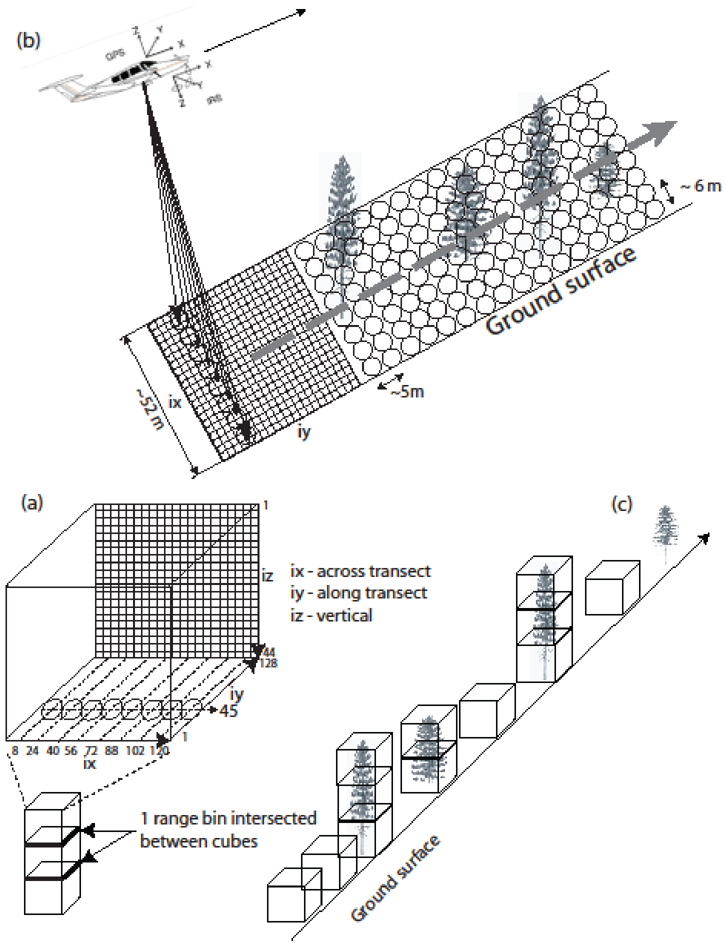




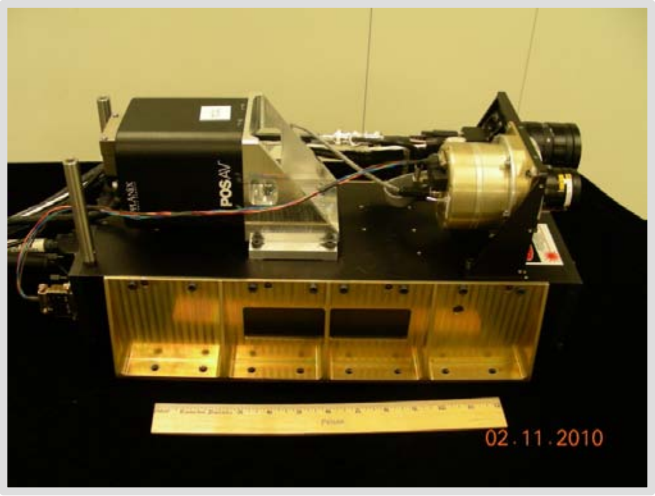


- Extend capability of future space-based lidars by using imaging lidar focal planes and laser multi-beam steering without a mechanism
- Provide multiple cross-track beams (up to ten) that can be re-configured in real-time (<< 30 Hz frame rate)
- Image and range resolve scattered laser light – full waveform!
- Adapt beam configuration to match scene – transmissions, albedo, science goals, etc
- Use separate cloud camera to identify approaching clouds and steer around
- Perform airborne testing over different forest types and prove out science

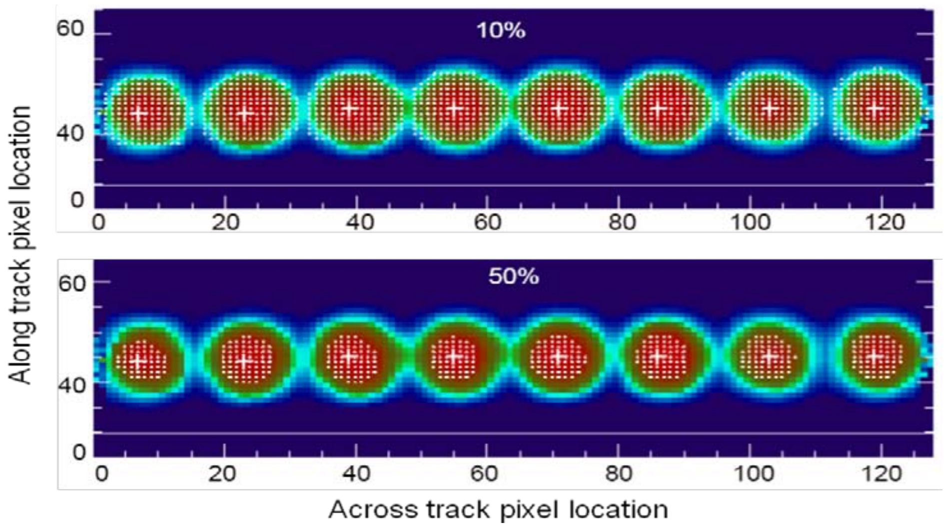
Project Status

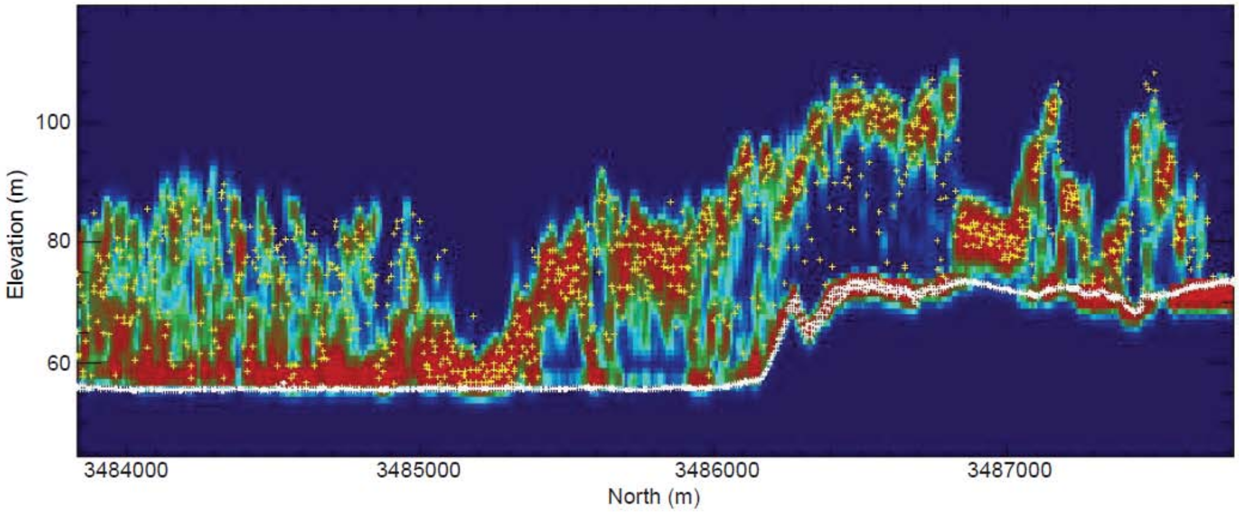


- 2007 Instrument Incubator
  - Completed program in two years
  - Three weeks of flight testing
  - Analyses and papers in process
  - Exit TRL 5
- 2009 Airborne Instrument Technology Transition Program
  - Completed first year
- 2010 SPIE Finalist for Prism Award for Photonics Innovation



Data analysis of forest scenes taken from aircraft





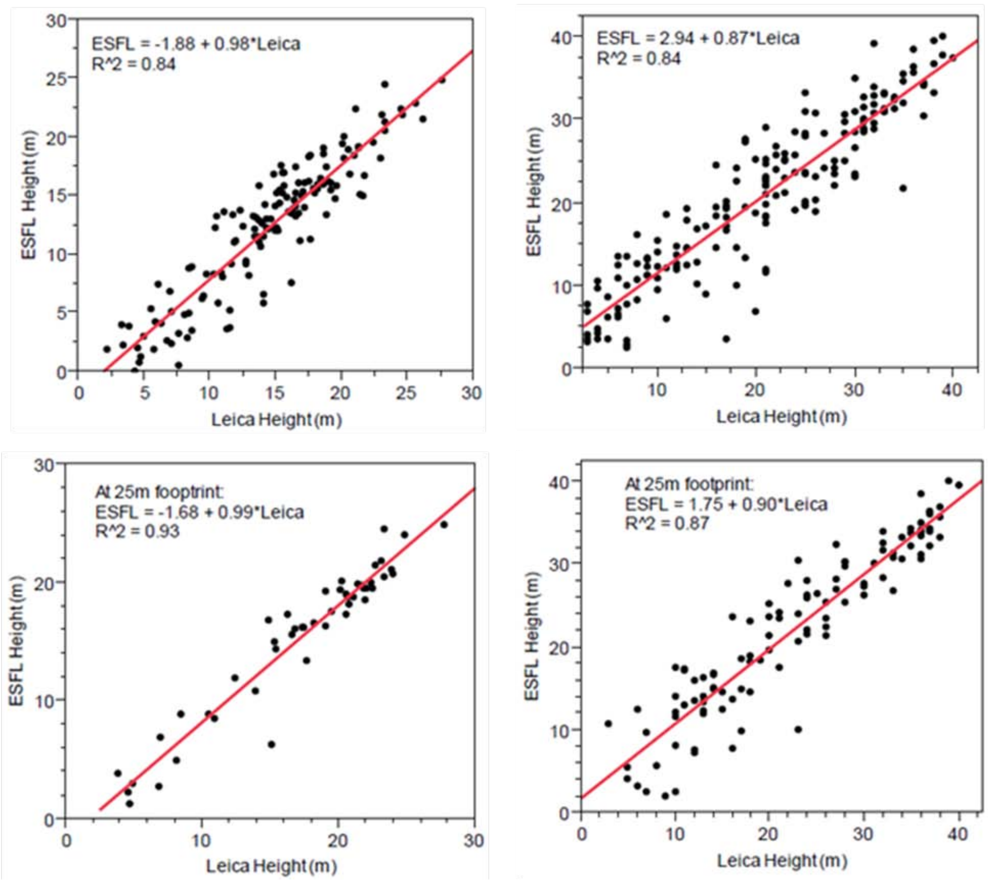
- Each laser spot was imaged onto a 12 pixel diameter spot
  - Gaussian laser beam profile gave variable SNR across a beam
- Co-located commercial scanning lidar data collected for comparison
  - Leica “4 hit” type system
- Three forest types studied – Ponderosa Pine (<80% canopy closure), and mixed deciduous in Texas and Maryland (>95% canopy closure)

Preliminary Comparison between ESFL and Conventional Lidar

Manitou | Austin

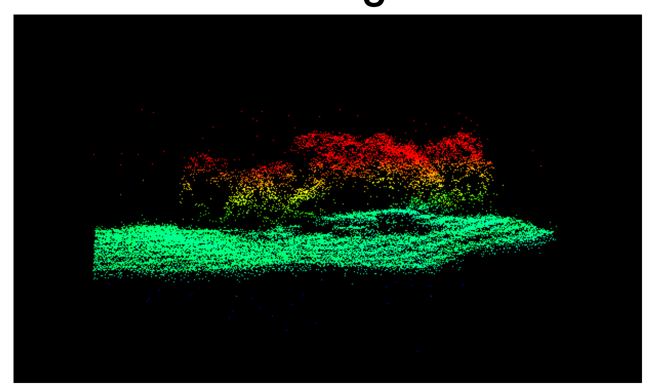
10%

50%

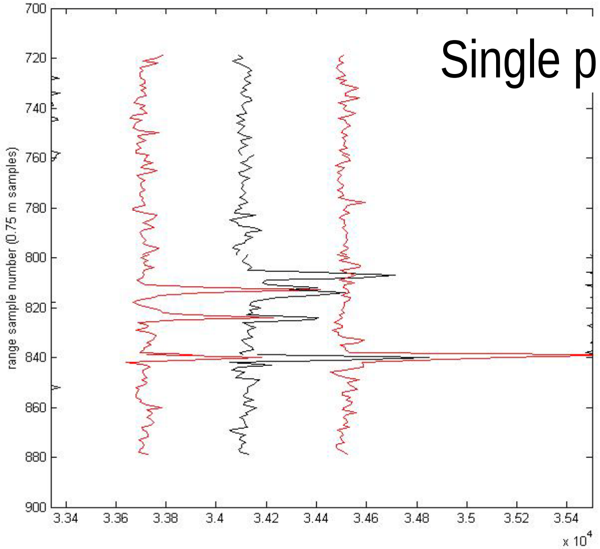


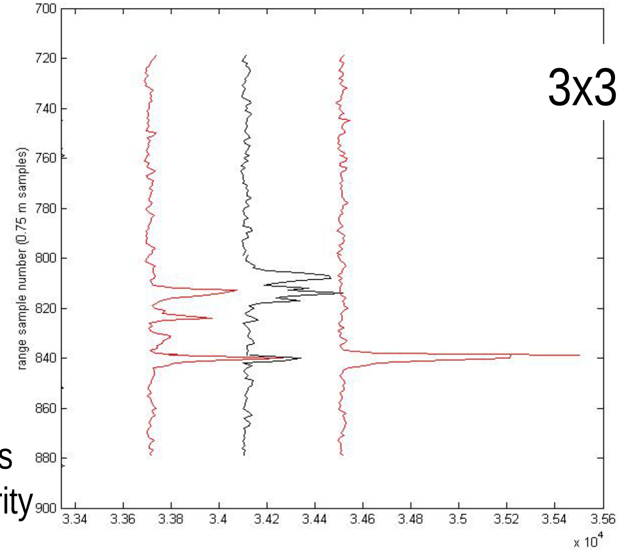
Duong et al –in preparation

- Compared tree height, mean height, ground altitude, and canopy penetration
- Excellent agreement throughout with no indication of saturation at higher canopy cover
- ESFL showed better canopy penetration since full waveform, especially where there is dense ground cover

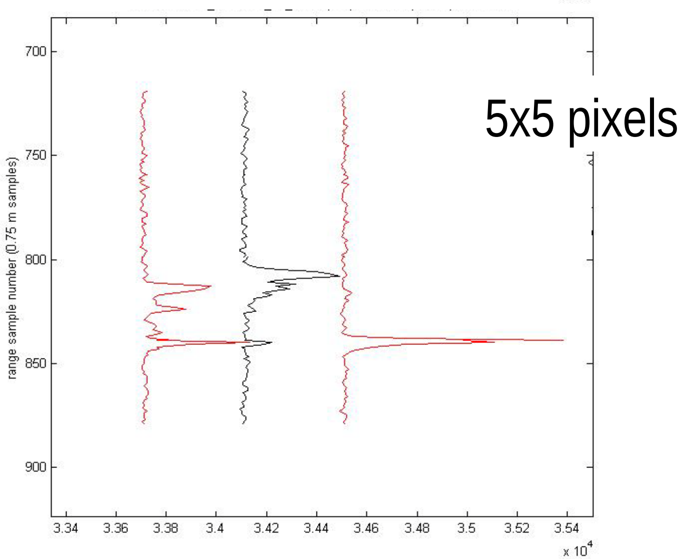


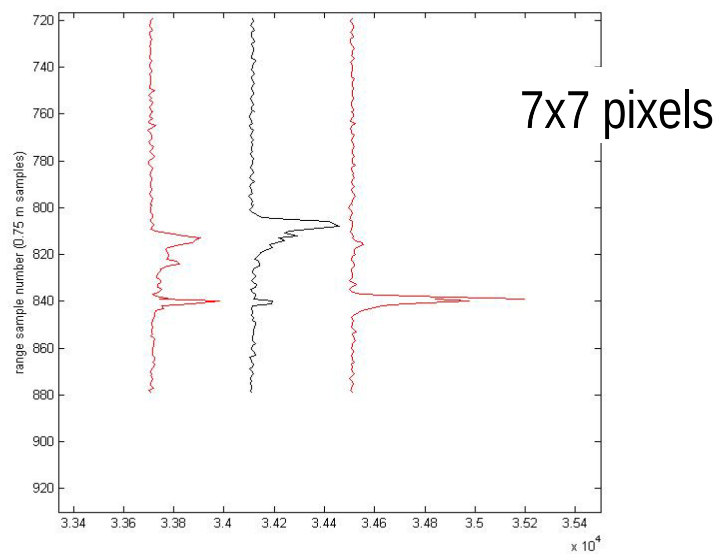
SF Austin three waveforms close-up





Waveform colors alternated for clarity





Illustrates trade-off between spatial resolution and SNR

ESFL Modeling Results - Forest Biomass Example

- Radiometric modeling completed giving estimates of number of ESFL spots that can be used for a conceptual space-based system and different forest coverage
  - For 98% canopy cover 36 beams could be generated that would provide sufficient canopy penetration
  - Assumes a 750 mJ laser, 40 Hz, 1 meter telescope, 400 km orbit, InGaAs APD array, 1 degree FOV, 25 m beam footprint
- For global biomass estimates, increased ESFL cross-track coverage would decrease mission time from 220 to 75 weeks at equator (compared with 5 beam transect sampler)
- Improved knowledge of slope would increase forest height precision by a factor of 2

<u>ESFL approach has the potential to significantly improve the science and achieve the mission in a third of the time, significantly reducing mission risk and therefore cost!</u>

Lefsky et al Remote Sensing of the Environment 115 p 1361 (2011)

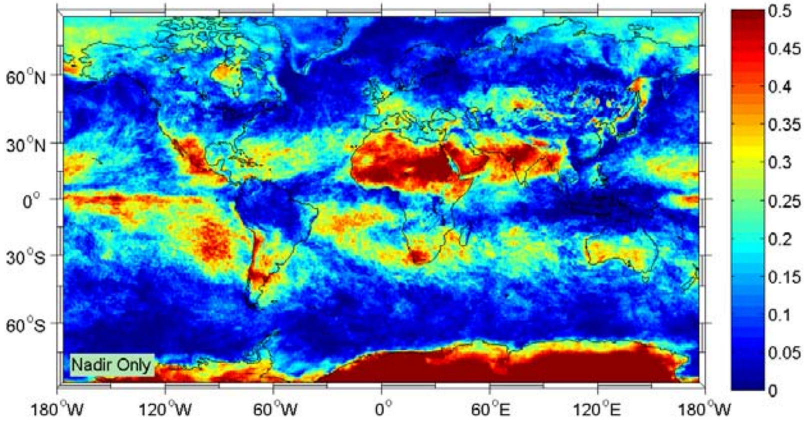
ESFL Modeling Results –Global Cloud Avoidance

- ESFL cloud avoidance mode (see last year's meeting) demonstrated in laboratory, would decrease cloud obscuration loss by allowing beams to be steered around clouds
- Simplest approach would use a forward viewing multi-spectral low-light imager
  - Better approach would be to use forward viewing pushbroom lidar.
- Impact of ESFL cloud avoidance at regional and global level calculated at LaRC using MODIS data
  - 5 km cross track swath assumed, Modis 1 km bins
  - Studied as a function of season and region using monthly averages
  - Example of result – Coverage over Amazon in February could be increased by a factor of 2 to 3

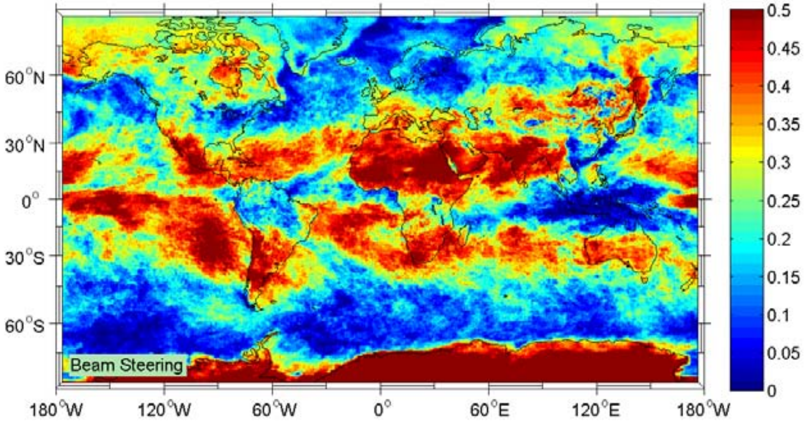
Yong Hu, Sharon Rodier – in preparation

ESFL Cloud Avoidance Model Results

Nadir-looking only

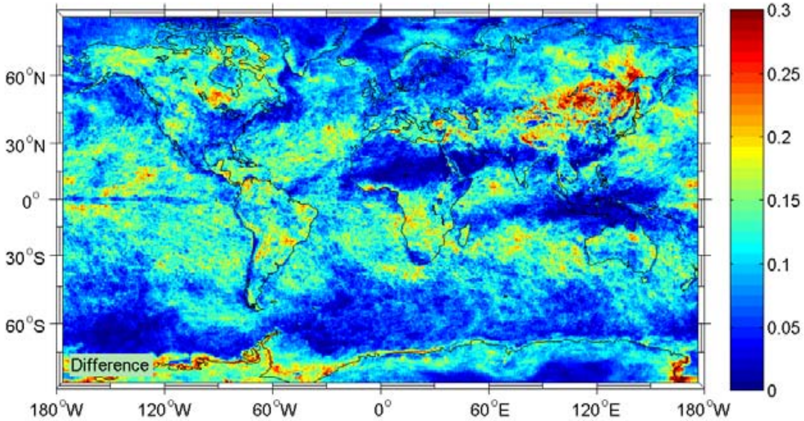


Adding in ESFL beam-steering capability

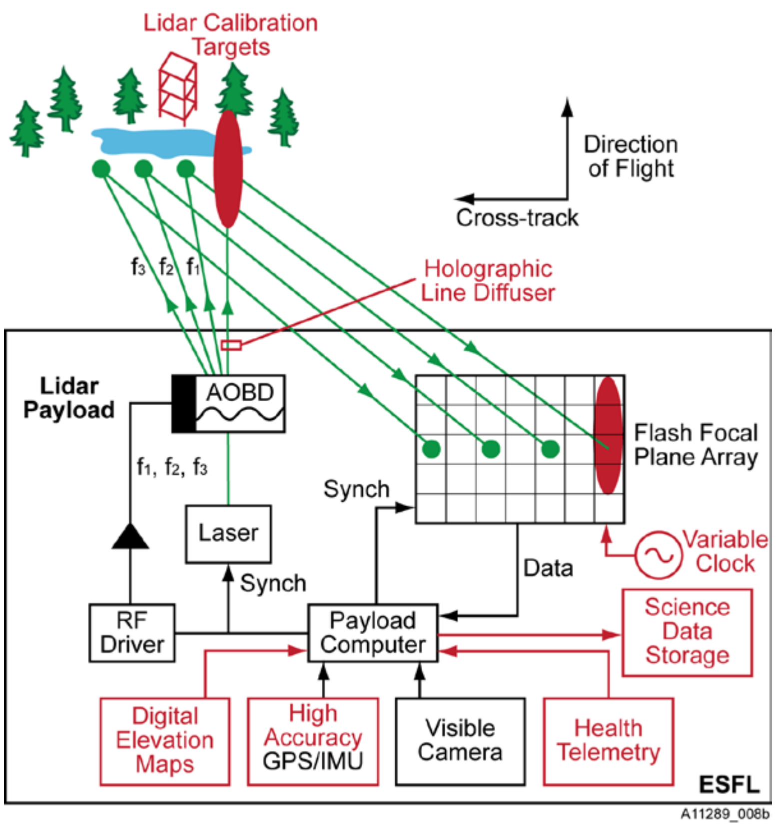


Color scale gives the fraction of lidar shots that penetrate to ground– Feb 2007

Difference



ESFL Airborne Instrument Technology Transition



- Numerous performance and reliability upgrades being made to enable use as a NASA “facility instrument”
- Added in contiguous along-track beam so dense coverage (for biodiversity studies) or sparse coverage (for biomass estimates) can be chosen
- Altitude increased (1000 ft to 5000 ft) so ground footprint of each beam is 25 m (size planned for DESDynI)
- Tightly coupled digital elevation maps allow beam configuration to be matched to the scene
- New ground validation methods developed by USGS (Jason Stoker, co-I) to be tested
- Technology upgrades to realtime processing, beam deflector crystal, adaptive control

Related Technology Advancements Beyond ESTO: ESFL

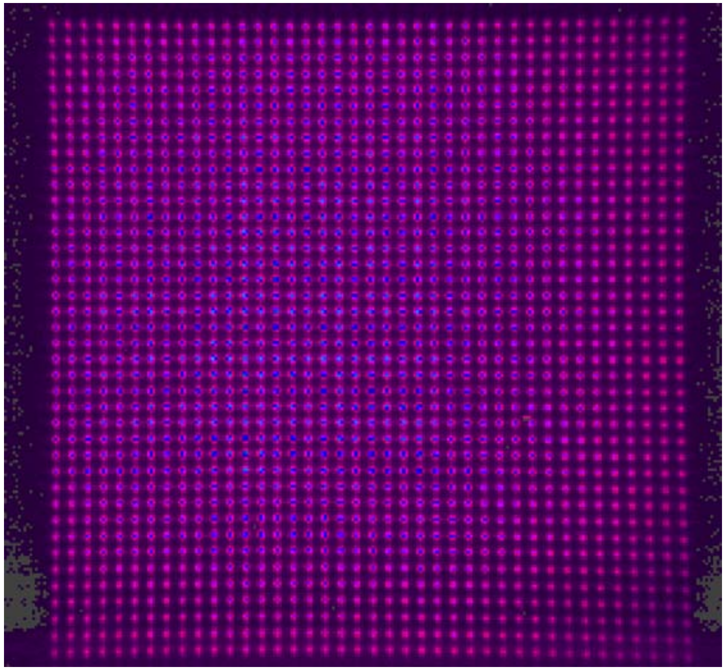
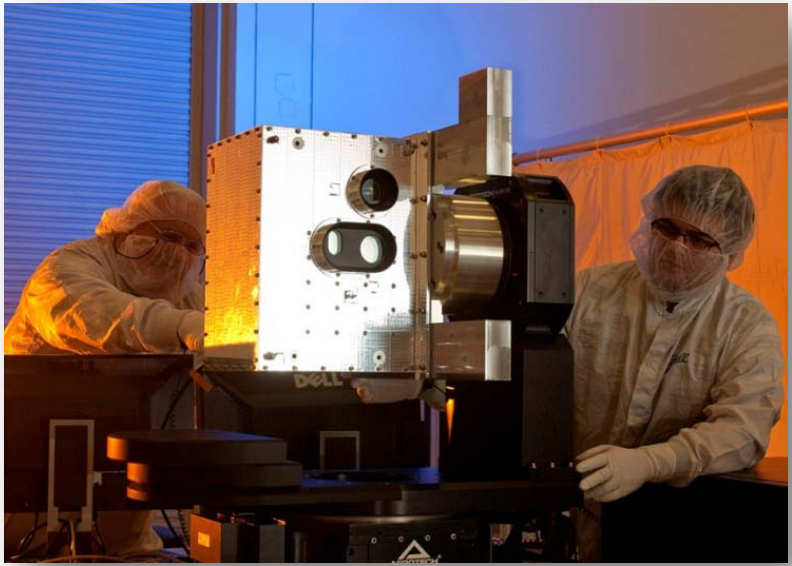


Image of a 40 × 40 laser beam pattern produced by AOBD

- Extended Beam Controller Capability
  - Two dimensional beam steering
  - Extending number of beams – number set by fpga size and laser beam quality
- Radiation analysis shows pointing subsystem good for LEO
- Completed new electrical design for power amp (< 4 W total)

Related Technology Advancements Beyond ESTO: VNS

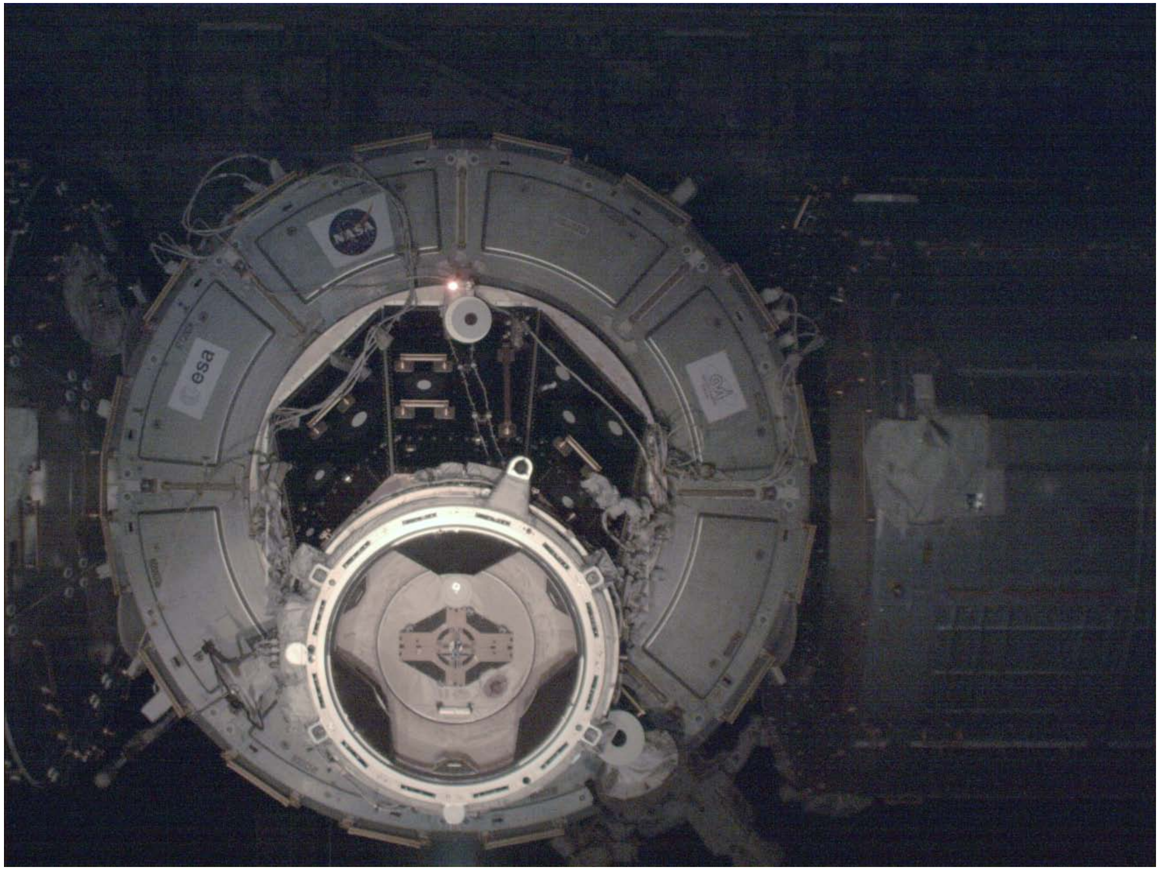
- Vision Navigation System (for ORION)
  - Flash Lidar plus docking camera
  - Used for relative navigation – range, pose, bearing
- First Flash Focal Plane Array fully space-qualified (others have flown)
  - 256 ×256 pixels
  - First Hit only (non-waveform-not good for forests)
  - Built by Raytheon Vision System
- First Unit (STORRM) mounted on Endeavour and used at ISS in May
  - Started ranging at 5.6 km off ISS cubes
  - Collected additional data during a fly-around
- Being evaluated for other navigation applications



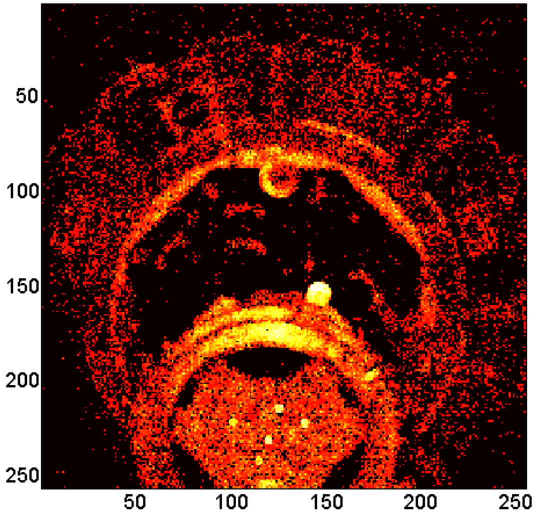
Collaboration between NASA, Lockheed Martin and Ball

STORRM Lidar Images: Shuttle to ISS Range = 8.3 m

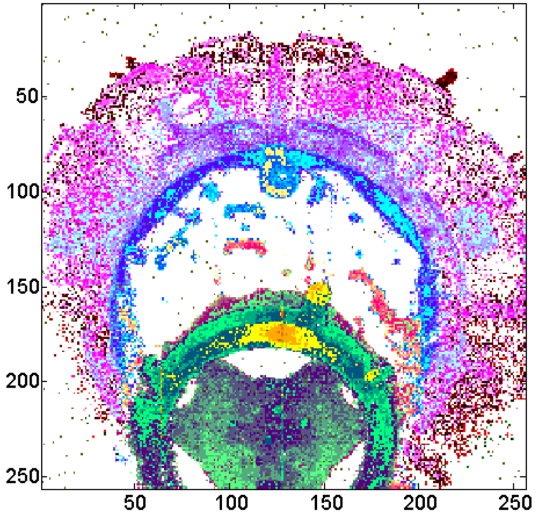
Docking Camera Image



VNS Intensity Image



VNS Range Image



At this distance, the individual reflectors on the docking target are resolved by the VNS, which can be seen as 5 bright spots in the middle of the docking ring in the VNS intensity image.

Acknowledgements

- Thanks to:
  - NASA ESTO for IIP grant (Keith Murray COTR)
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  - Warren Seale, Gooch & Housego
  - Ball Team: Jeff Applegate, Eric Coppock, Jeremy Craner, Tom Delker, Brian Donley, Bill Good, Paul Kaptchen, Lyle Ruppert

Thanks for Listening!

Play STK Movie