An Electronically Steerable Flash Lidar (ESFL)

Carl Weimer
Ball Aerospace & Technologies Corporation

Advanced Scientific Concepts Inc.

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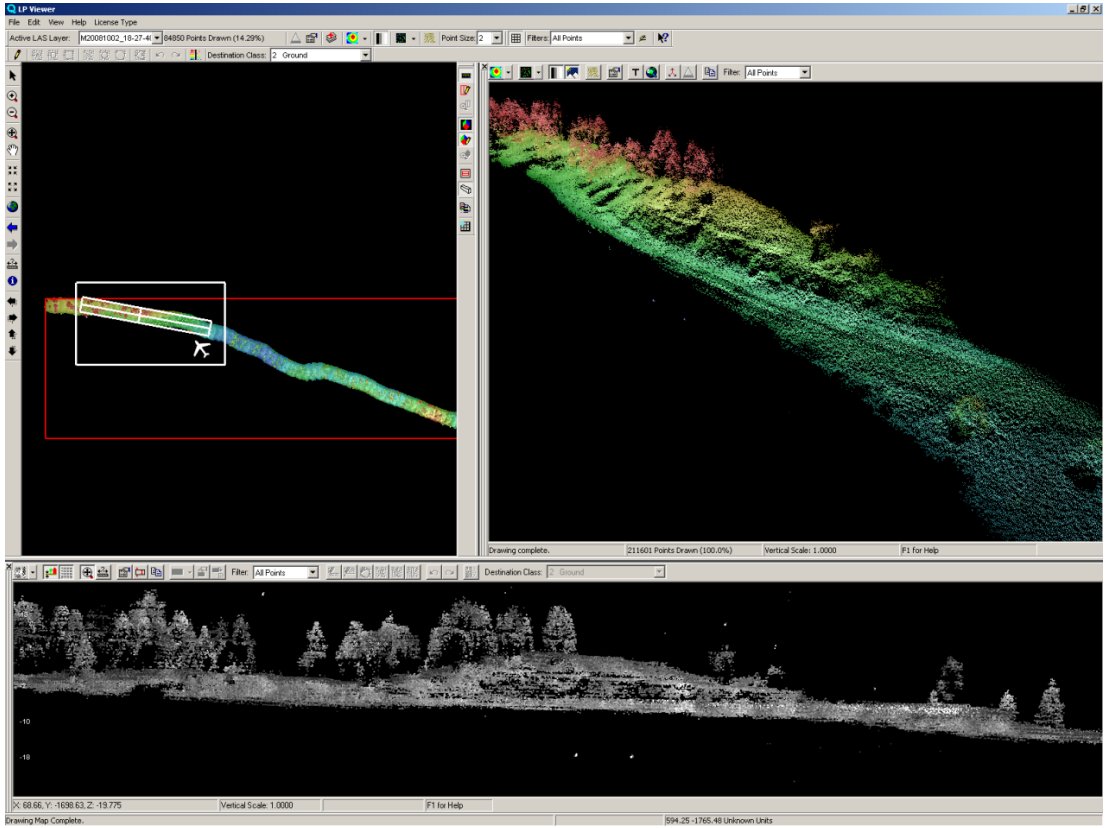
Outline

- Motivation
- ESFL Concept
- Results from Demonstration Unit
  - Lab (cloud avoidance)
  - Flight Test
- Advantages for Space-based Forest mapping
- Summary and Plans



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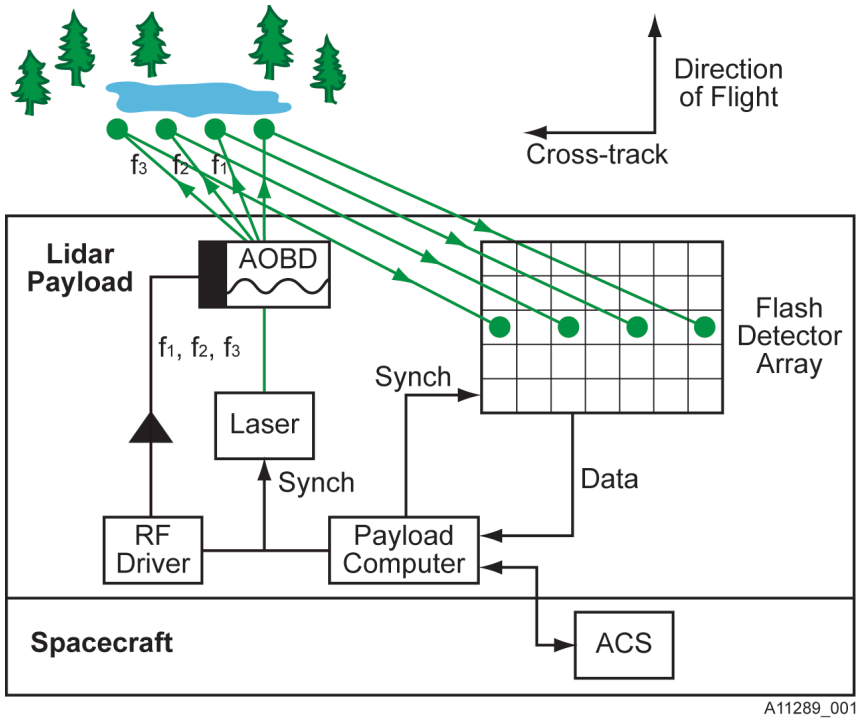
Team: Tanya Ramond (Ball); Michael Lefsky (Colorado State U.); Ingrid Burke (U. of Wyo.); Yongxiang Hu (NASA LaRC); ESFL Engineering Team (Ball); Advanced Scientific Concepts, Inc. (ASC)

Electronically Steerable Flash Lidar (ESFL) – ESTO IIP

- Goal : Look to new technologies to overcome limitations of existing and proposed lidar forest measurements from space such as for the Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI) Mission:
  - **Add crosstrack coverage to address slope induced errors in forest canopy height**
  - Provide variable spatial sampling to match type of forest and measurement goal (e.g. biomass vs biodiversity)
  - Improve lidar transmitter/receiver boresight alignment performance
  - **Decrease data loss due to cloud cover**
  - Improve ground track control of laser
  - Utilize waveform lidar to leverage off of heritage ground work
  - Leverage current space qualified laser technology AND provide contiguous sampling
  - **Increase mission reliability by decreasing the required number of laser shots required to meet mission accuracy requirements**
  - **Work with scientists to match technology and design to their needs and have them evaluate results**

ESFL Approach



- Utilize Acousto-Optic Crystal to split single laser into multiple beams
  - All beams are from first order diffraction
- Each beam individually steerable with precise control
- Spots on ground imaged through large telescope onto an imaging array
- Beam locations and number can be changed for every laser pulse
- Requires low rep rate laser (e.g. 40 Hz) with high pulse energy
  - Leverages from CALIPSO and ESTO funded laser heritage
  - Three year mission requires < 4 Billion shots
- System is adaptable to scene
- Radiometric model predicts up to 40 pixels from orbit can be utilized in forest scenes
- Patent Pending

One Example of Lidar Imaging Technology

- Traditional Methods:
  - Mechanically scan a single pixel – problems for space qualifying
  - Build up an array of individual pixels (LOLA - 5 pixels)
- New Technologies based on CMOS "Smart Pixels"
  - Photolithographically produce detector arrays and "read out integrated circuits (ROICs) and bond them together
  - Detectors can be p/n photodiodes or avalanche photodiodes in linear or geiger (photon counting) mode
  - For each detector pixel, create a "unit cell" in the ROIC that contains amplifiers, high speed timing network, and temporary data storage
  - Can create full profiles of transparent materials (clouds, water, aerosols) or just surface topography (ground)

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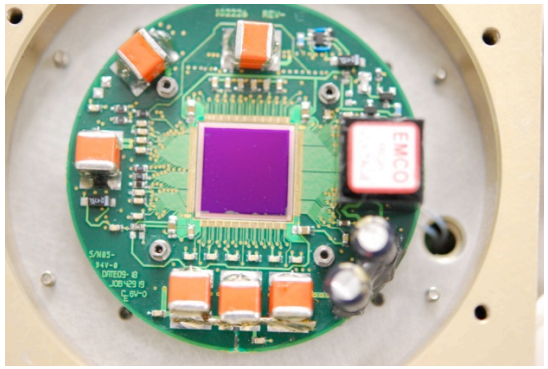
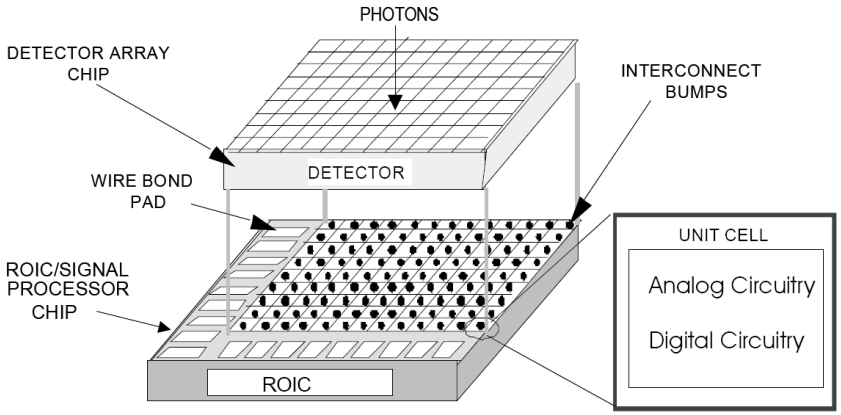
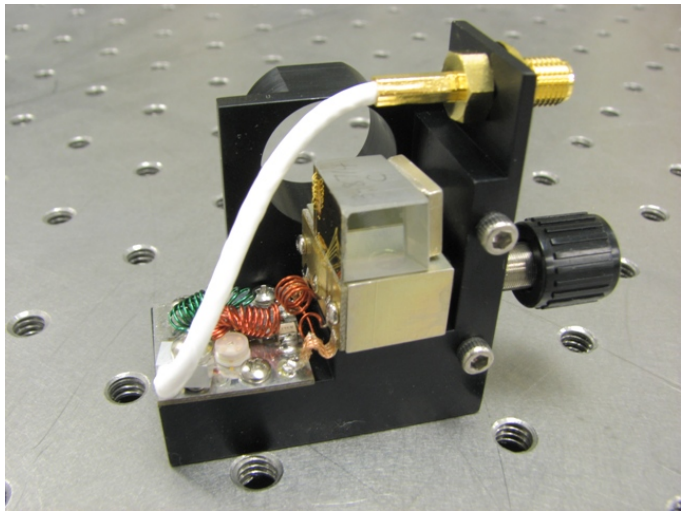
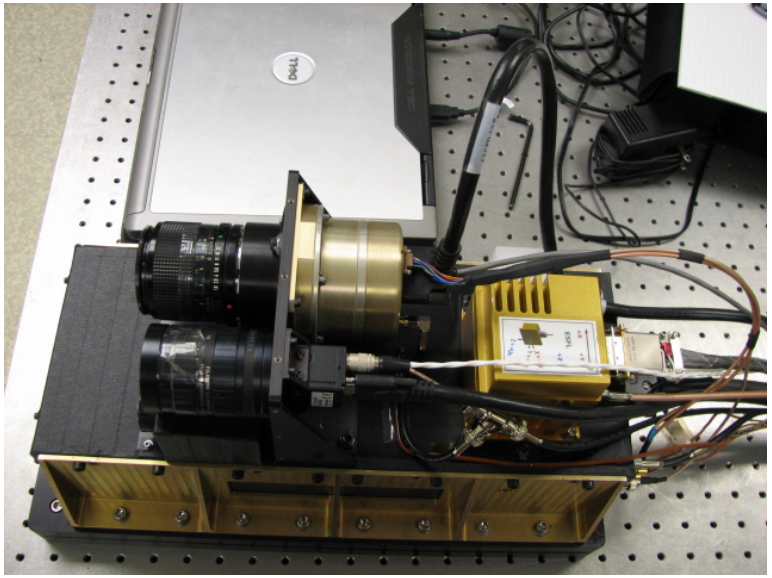




ESFL Hardware Highlights

- Tellurium Oxide Acousto-Optic Beam Deflector
  - Custom 10 tone RF driver with “path-to-space” design
- ASC 128 by 128 pixel focal plane array
  - 44 time slices (full waveform), 300 MHz
  - InGaAs APD array operating in linear mode
    - Funded by Ball NRE
- COTs Nd:YAG laser
  - 30 Hz and 40 mJ
  - 1064 nm
  - 4 meter laser ground footprint with 40 cm pixel footprint
- Integrated co-boresighted visible camera
- Integrated GPS/IMU
- System calibrated using Ball test stations
  - Intensity, Plate scale, Ranging, Geolocation
  - Level 1 data done in automated post-processing





Aircraft Flight Testing of ESFL

- Dacono, Colorado
  - Engineering testing of modes over flat, bare regions
    - Multi-beam realtime patterns, dynamic pointing
    - Terrain Following algorithms - sets range gates
    - Geolocation Mode – beam tracks GPS transect
- Roosevelt National Forest, Colorado
  - Prescribed Burnsites - Ponderosa Pine
- Manitou Forest, Colorado
  - Experimental forest – Ponderosa Pine
- Stephen F. Austin Experimental Forest, Texas
  - Dense Canopy, Hardwood deciduous plus pines

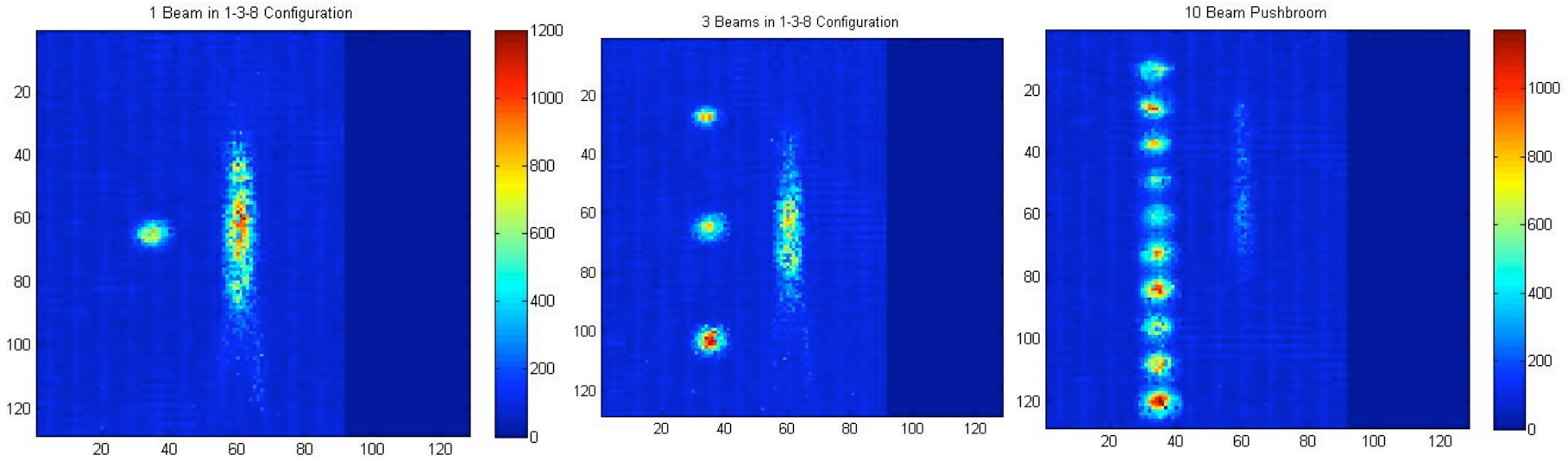
Last Flights in July:

- Smithsonian Environmental Research Center, MD

- Ground Validation being performed by students
- Commercial scanning lidar data collected for comparison at forest sites

Aircraft Demonstration of ESFL – Engineering Modes

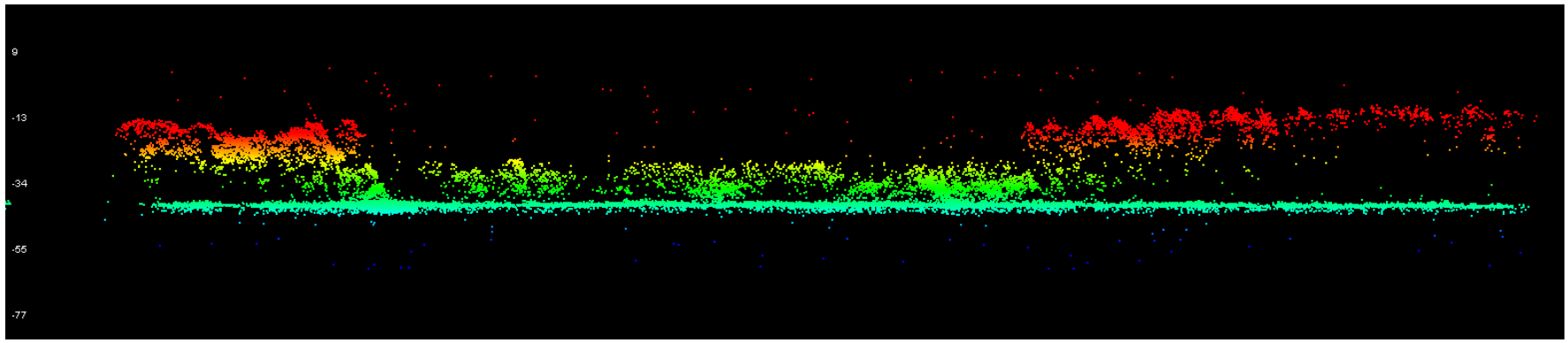
Laser light scattered from the ground from three consecutive laser shots.

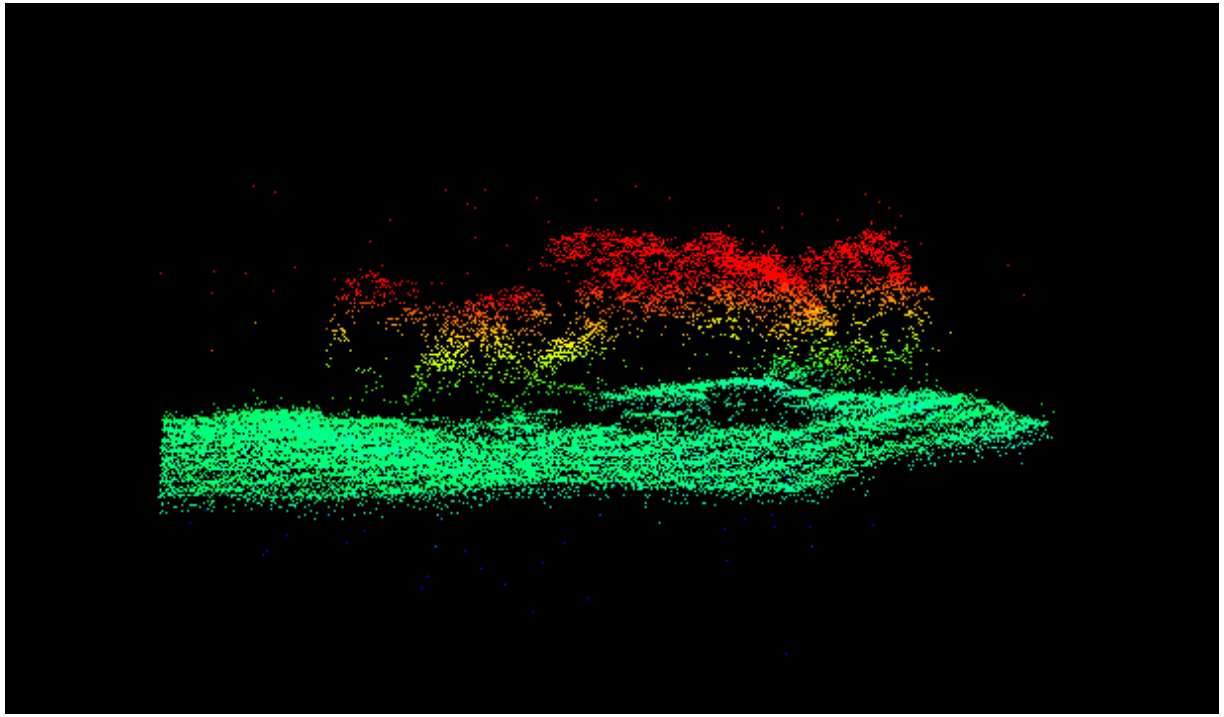


Along Track

See 1-3-8 Movie

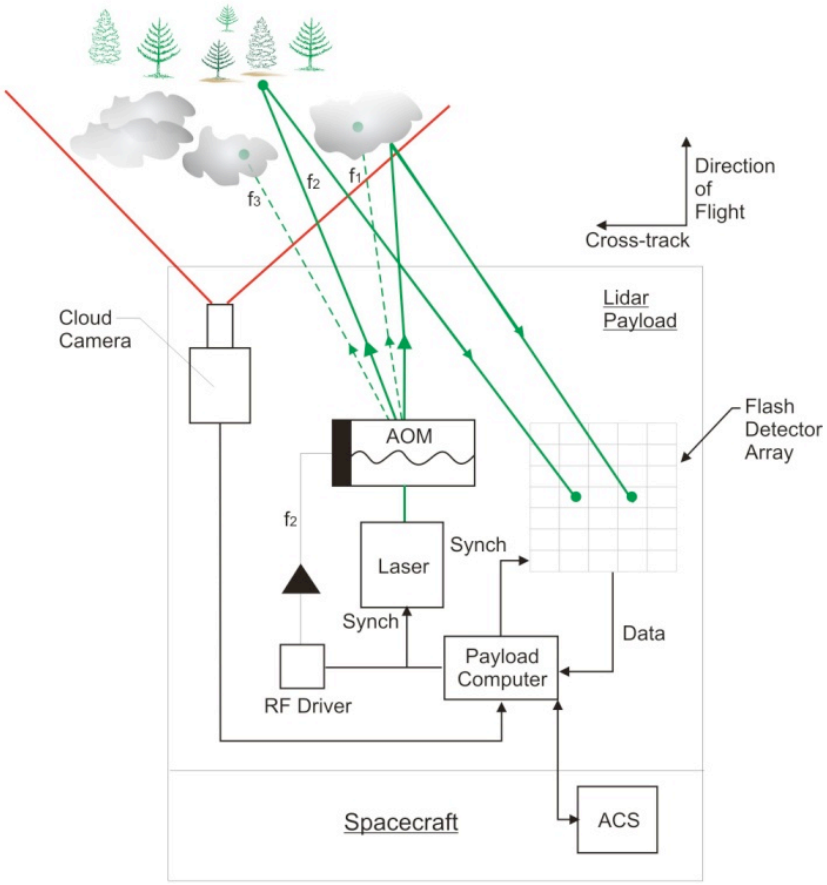
Examples of Forest Data from ESFL





- Stephen. F. Austin Forest
- Eight beam fixed “pushbroom” used
- Biomass estimates are in-process

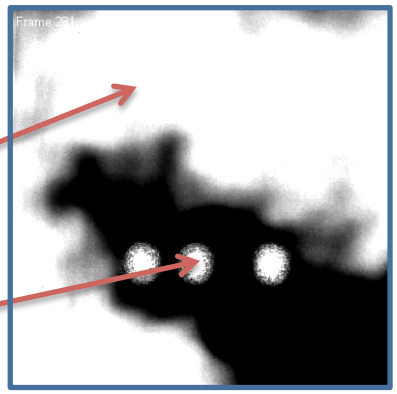
Cloud Avoidance Demonstration with ESFL



Ahead –looking camera identifies clouds which lidar then steers beams to avoid

Cloud Movie

Laser spots



See Cloud Avoidance Movie

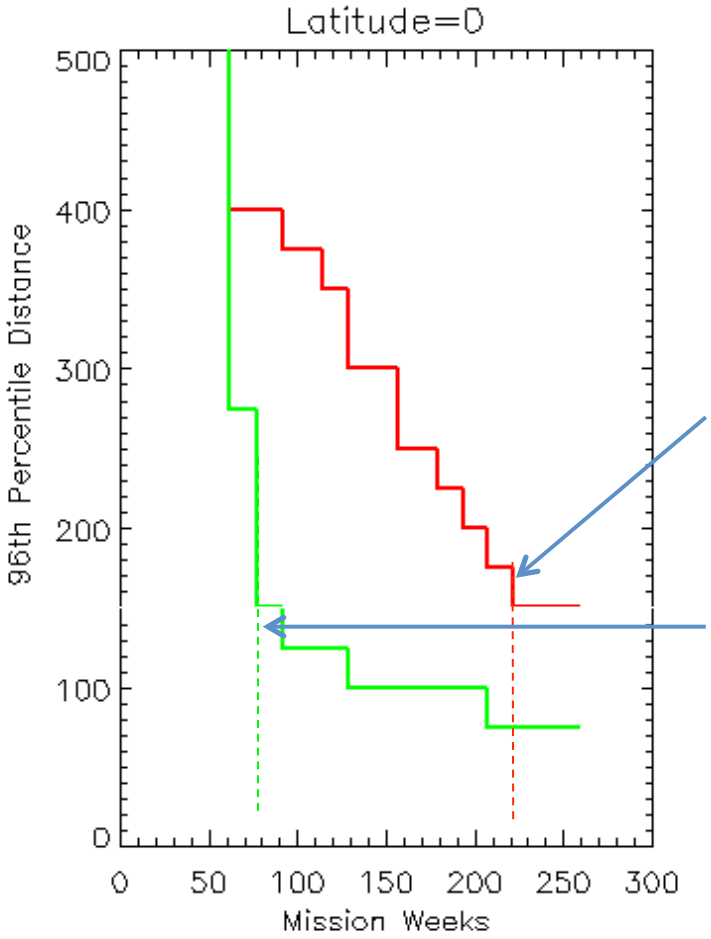
Modeling Activities – Ongoing

- Dr Hu:
  - Estimate of data enhancement by the use of Cloud Avoidance
  - Predictions of the impact of multiple scattering within forest canopy

- Ball:
  - Radiometric Modeling of different scene types by scaling to space actual system performance

- Dr. Lefsky
  - Advantages to the DESDynI mission of ESFL type spatial sampling compared with baseline transect:

How would an ESFL capability change the collection of spaceborne lidar?



At the equator, transect sampling, takes 220 weeks to reach a 96thpd of 150m

Hybrid sampling, requires 75 weeks to reach a 96thpd of 150m

The 96th percentile distance is the distance such that 96% of observations are that close to another point, or closer.

From Dr Lefsky: AGU 2009 Poster

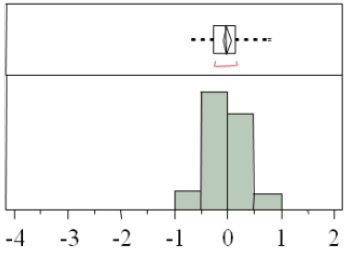
Number of weeks needed to reach a sampling density at which 96% of the area is less than 150 m from an observation

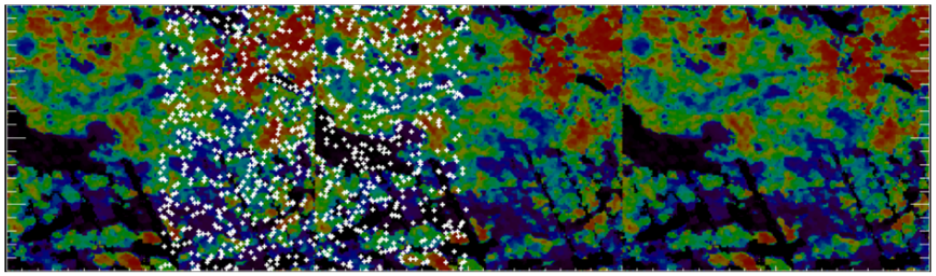
Latitude	Hybrid	Transect
0	75	220
33	65	200
60	30	110
75	30	80

How would an ESFL capability change our confidence in biomass estimates?

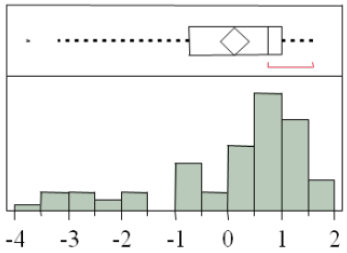
Residual heights for 100 iterations within a single subset

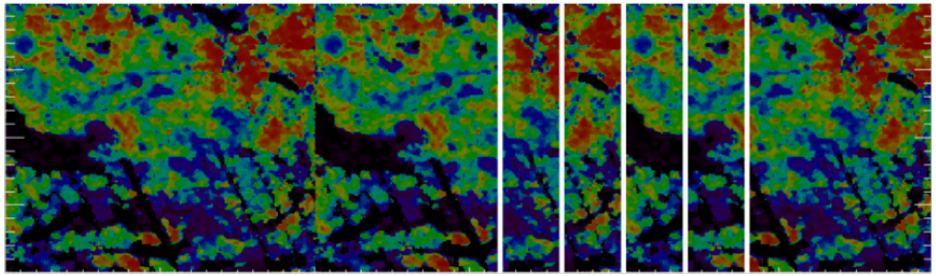
Random Sampling



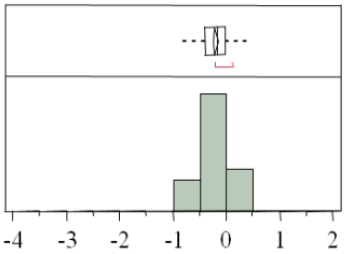


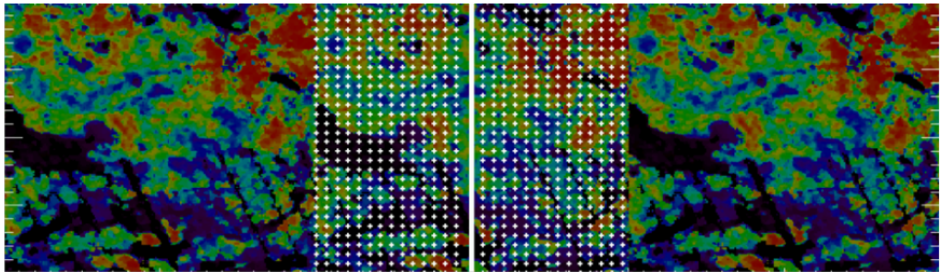
Transect Sampling





Hybrid Sampling





From Dr Lefsky: AGU 2009 Poster

Summary of ESFL – IIP

- We've developed a new approach to space-based lidars that utilizes an adaptive laser transmitter

- A demonstration unit has proven out the concept with a "path-to-flight" design in a two year timeframe

- Modeling and science analysis of data collected from aircraft is being actively worked to demonstrate the advantages to the DESDynI program

Thank you for your time!