An Electronically Steerable Flash Lidar (ESFL)

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

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

Hybrid sampling, requires 75 weeks to reach a 96th percent of 150m.

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

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From Dr Lefsky: AGU 2009 Poster
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!