Draft Plan for Characterizing Commercial Data Products in Support of Earth Science Research

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NASA Science Mission Directorate
FY05 JACIE Performance Metric

Integrated Budget Performance Document Metric

5ESA1: Work with the Joint Agency Commercial Imagery Evaluation (JACIE) team and the Commercial Remote Sensing Policy Working Group through partnerships with NIMA (NGA), USGS, NOAA, and USDA to verify / validate at least two commercial remote sensing sources / products for Earth science research, specifically with respect to land use / land cover observations for carbon cycle and water cycle research.

Commercial Product V&V Plan General Approach

- Select products
  - Readily available commercial remote sensing product that supports Earth science research
  - Common interest with other JACIE members and with other Federal agencies, such as USDA and NOAA
- Verification/product characterization
  - Does product meet specification (initial science requirements)?
  - What are the fundamental properties (FY 2005) and potential/limitations of higher level products (FY 2005/ FY 2006)?
- Validation (FY 2005 planning, FY 2006 activity)
  - Evaluate products for specific science research and applications

Remote Sensing Data for Carbon and Water Cycles

- Water cycle
  - Surface radiance, reflectance, surface temperature, and vegetation measures for the soil, vegetation, and atmospheric models
  - Aerodynamic surface roughness and topography
- Carbon cycle
  - Vegetation measures, biomass, land cover, land use

Earth Science Research Literature Searches (Relevant Trends)

- Recent significant increase in use of multiple data sources
  - High-spatial-resolution datasets for studying many vegetative and manmade features occurring at 10 m scale or finer
  - Research into resolving observation differences between coarse-, moderate-, and high-spatial-resolution datasets (e.g., generation of reflectance maps for scaling studies)
  - Data fusion of LIDAR and high-spatial-resolution imagery
- Active Sources (LIDAR)
  - Biomass estimates based on derived tree height and knowledge of species' forest parameters
  - Relatively large literature base for biomass determination
  - Sophisticated lidar canopy radiative codes are in development
    - LIDAR radiometry

LIDAR Biomass Estimation

- Biomass estimates are based on derived tree height and knowledge of species' forest parameters (such as species type, diameter at breast height, basal area)
- Biomass estimation and canopy structure studies have been conducted with multiple-return and waveform LIDARs:
  - Lefsky et al., 1999
  - Rodriguez et al., 2004
  - Harding et al., 2000
  - Blair et al., 1999

JACIE Team Member Interests

- USGS and NGA share common interests with NASA Earth science research
  - Higher level products derived from high-spatial commercial satellite imaging systems
    - Reflectance maps
    - Land cover/land use, biomass, topography, evapotranspiration, and other biophysical parameters
  - Aerial LIDAR
    - Multiple-return LIDARs
    - Waveform LIDAR
    - Intensity images

High-Spatial-Resolution Multispectral (HSMS) Imagery Products V&V

Commercial HSMS Satellite Data Products

- Potential commercial vendors
  - Space Imaging IKONOS (1 m Pan, 4 m MS)
  - DigitalGlobe QuickBird (0.6 m Pan, 2.4 m MS)
  - ORBIMAGE OrbView-3 (1 m Pan, 4 m MS)

- Standard products
  - Address large class of problems that require finer scale than government-owned Earth observation systems

HSMS Image Product V&V

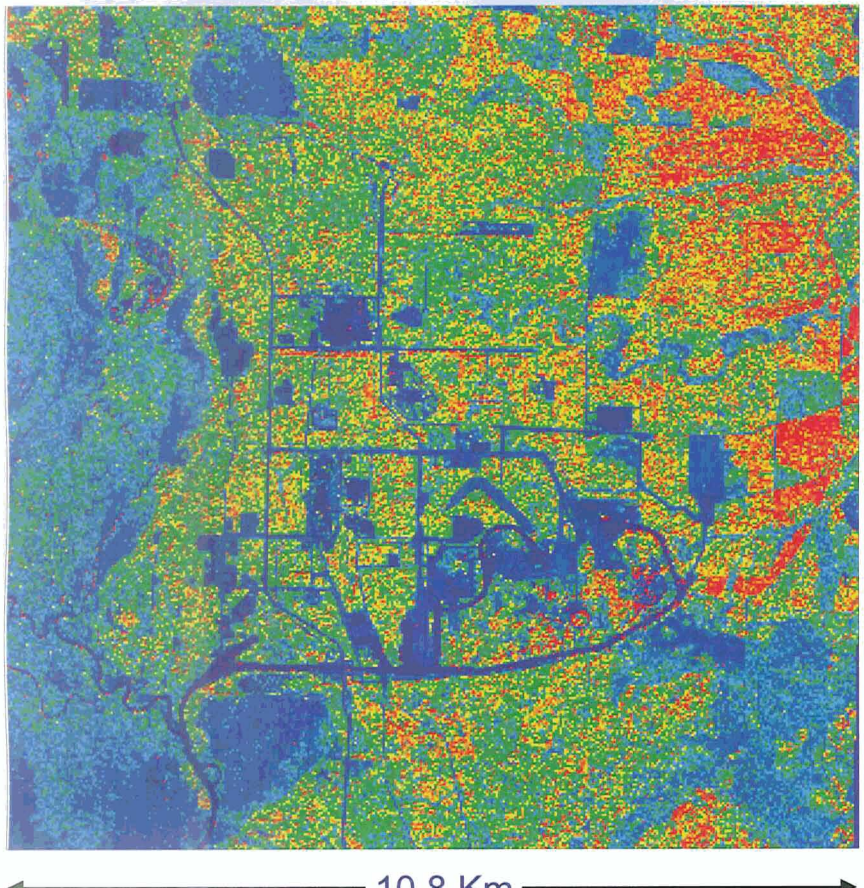
- Continue data product characterization as part of the JACIE team
  - Spatial
  - Geopositional
  - Radiometric

- Explore atmospherically corrected product generation techniques using commercial products
  - JACIE team members (NASA, NGA, USGS) interested in these types of products
  - No definitive studies have compared the accuracies and limitations of each method under a wide range of conditions
  - JACIE team holds the largest set of imagery with ground truthing to perform this assessment

Atmospherically Corrected HSMS Image Products

- Benefit of atmospherically corrected image products (NDVI and reflectance maps)
  - Change detection with reduced influence of atmosphere and solar illumination variations
  - Spectral library-based classifiers
  - Improved intercomparisons between different instruments and acquisitions
  - Scaling studies

MODIS/Atmospherically Corrected IKONOS NDVI



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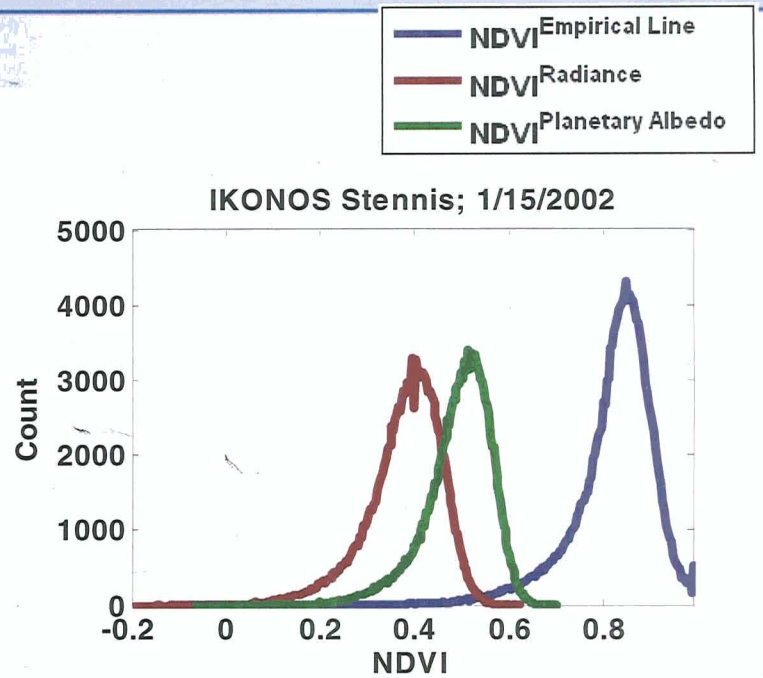
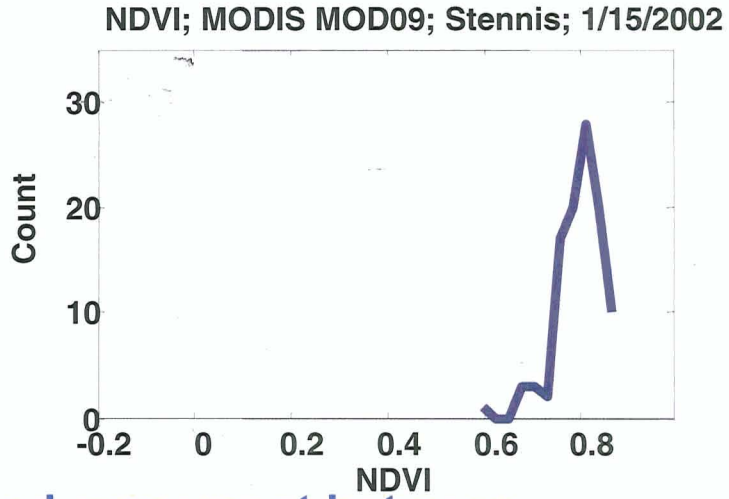


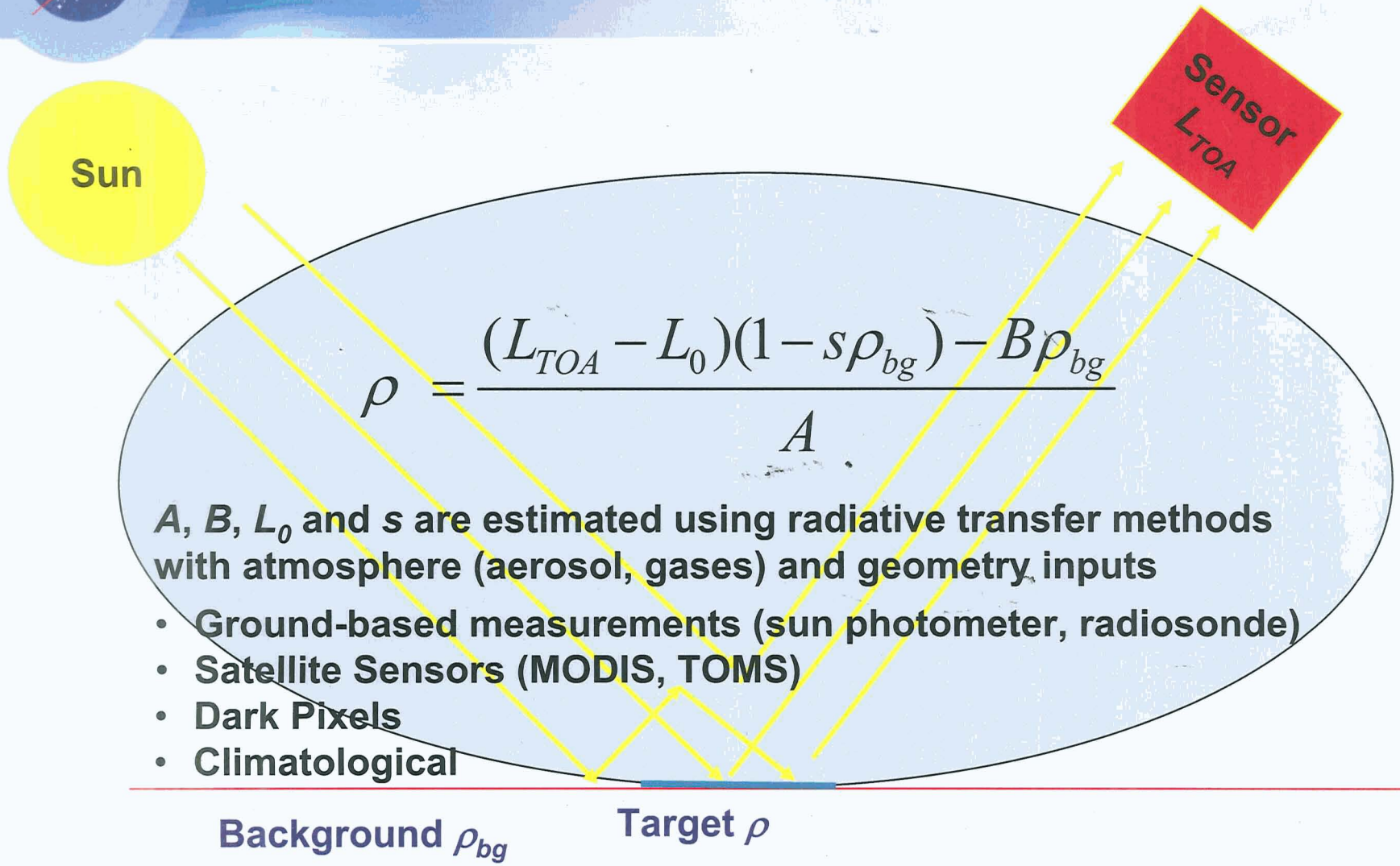


Atmospheric correction is needed to obtain good agreement between MODIS NDVI and IKONOS

Atmospherically Corrected HSMS Image Product Techniques

- Physics-based radiative transfer techniques
  - Climatological atmosphere
  - Ground-based atmospheric measurements
  - Satellite-derived atmospheric measurements
  - Dark pixel methods
- Empirical line methods
  - Ground-based reflectance measurements
  - Pseudo-invariant targets

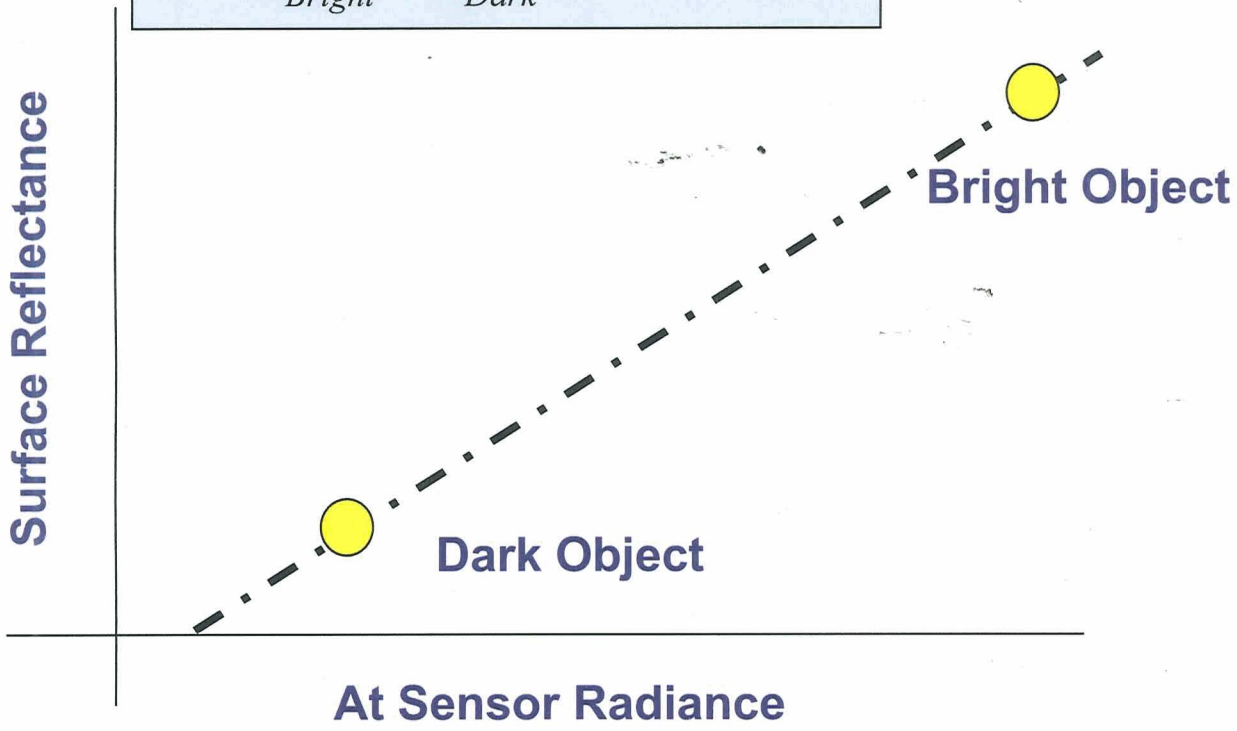
Radiative Transfer Methods



Empirical Line Method

Radiance and reflectance data are "linearly" related

$$\rho = \left(\frac{\rho_{Bright} - \rho_{Dark}}{L_{Bright} - L_{Dark}}\right) L_{TOA} + Offset$$



Atmospheric Correction Methods

Method	Advantages	Disadvantages
Radiative Transfer Ground-based Atm. Measurements	Excellent local aerosol and water vapor knowledge.	Works well only near ground truthing location.
Radiative Transfer Satellite-derived Atm.	No ground truthing with some objective knowledge of atmosphere.	Coarseness of atmospheric measurements (need near-coincident collects).
Radiative Transfer Climatological Atm.	Simple to run. No ground truthing.	Not necessarily correlated with conditions.
Radiative Transfer Dark Pixel	No ground truthing. Handles atmospheric inhomogeneities.	Need good knowledge of dark pixel reflectances.
Empirical line method	Simple to implement. Can be very accurate.	Need ground truthing reflectances. Adjacency effects can be an issue. Reference targets should be at least five pixels.

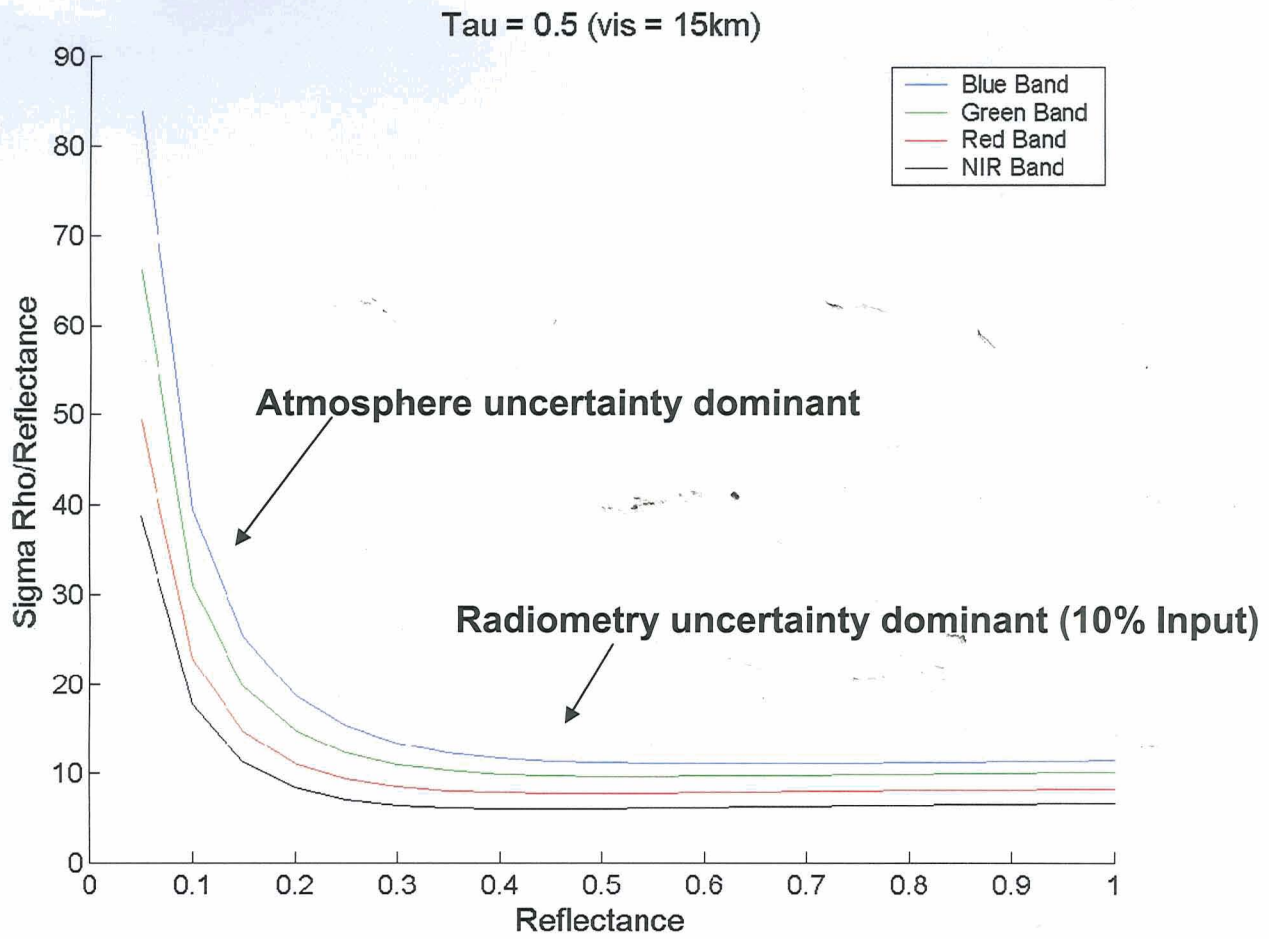
Atmospherically Corrected Product V&V Plan

- Develop reflectance maps (FY 2005)
  - Generate commercial product reflectance maps with several methods (e.g., FLAASH, ACORN, ATCOR)
  - To date, approximately 12 scenes (total) of IKONOS, QuickBird and OV-3 datasets with excellent ground truthing exist (~50 known targets)
- Verification/Characterization
  - Compare results with ground truthing reflectance data and atmospheric data
  - Compare results with MODIS and other sensor reflectance and Vegetation Index products
  - Develop an overall accuracy assessment
- Validation (FY 2005 Planning and FY 2006)
  - Work with science community to determine whether reflectance maps are sufficiently accurate for various science research/ applications

Reflectance Map Accuracy (Tarps & Natural Targets)

- Reflectance measurements are made at time of satellite overpass (BRDF); reflectance measurements are then compared with reflectance values derived from atmospheric correction algorithms
- Four 20 m x 20 m tarps with reflectance values of approximately 3.5%, 22%, 34%, and 52%
- Natural grass and concrete targets are typically measured

Atmospheric Uncertainty Analysis Example

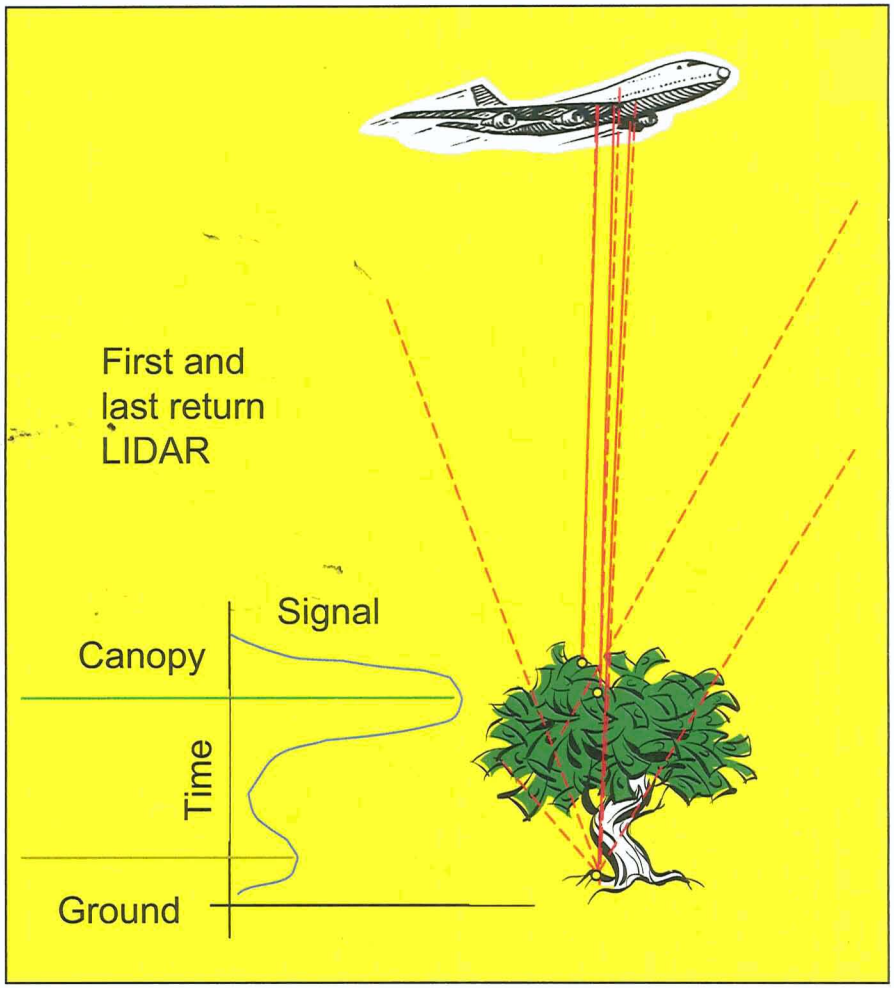


Reflectance uncertainty at low reflectance is dominated by atmosphere uncertainty
Radiometry is important at high reflectances

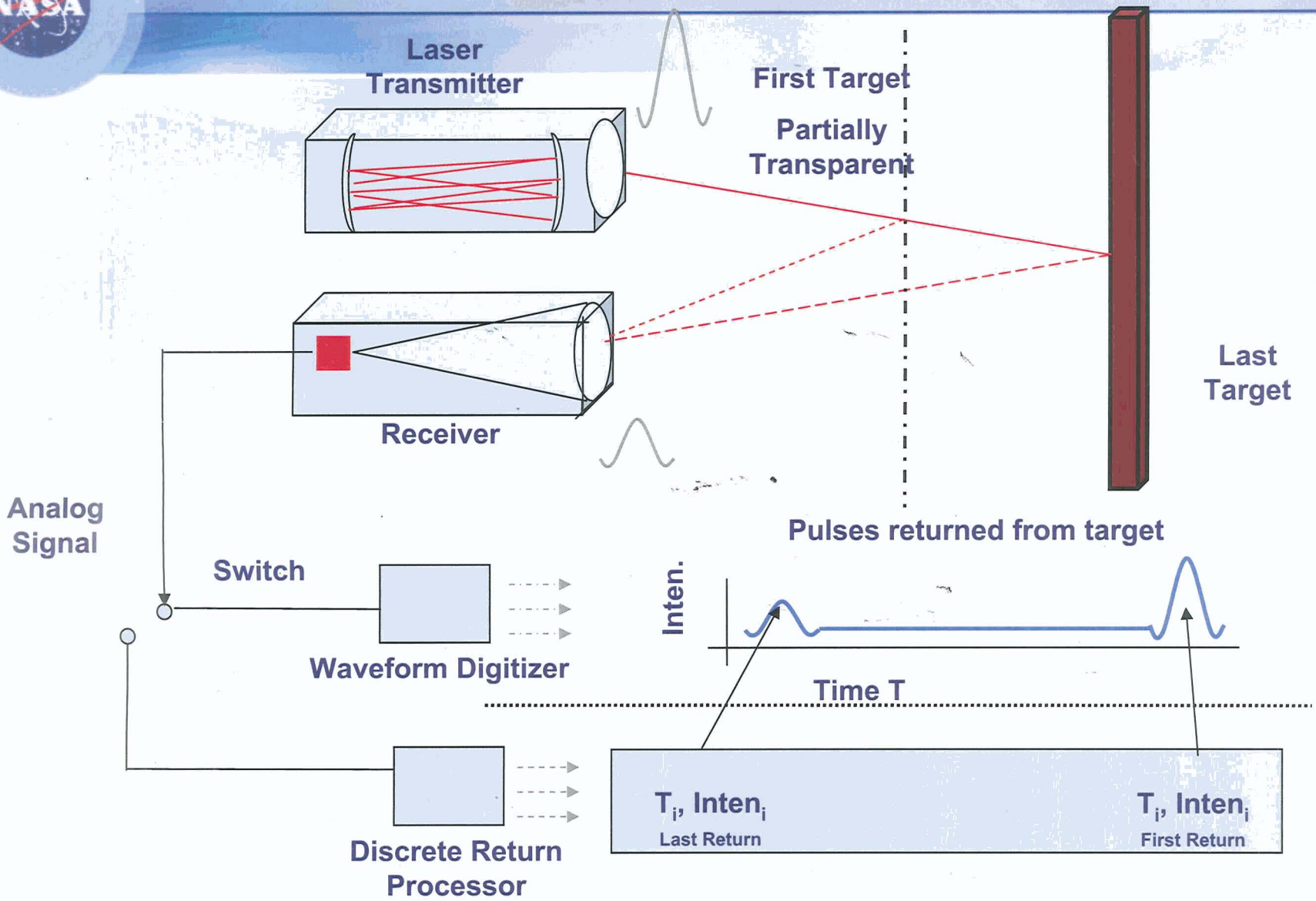
LIDAR Data Product V&V

Multiple Return and Waveform LIDAR Systems

- Discrete or multiple-return systems record finite set of returns (~2-5)
  - Most common type of system
  - Largest available set of commercial algorithms
  - Intensity assigned to return
  - Small footprint
- Waveform systems record all (or nearly all) of the return signal
  - Type of system NASA is considering for vegetation studies from space
  - SLICER and LVIS are airborne analogues (large footprint), commercial systems (small footprint)



Discrete Return/Waveform LIDARS



Discrete and waveform LIDAR are the same except for the recording electronics

In principle both products can be recorded simultaneously

Typical Discrete Return LIDAR System Characteristics Equivalents

- Wavelength
  - Monochromatic 1064 nm
- Image Quality
  - Posting: 0.2–2 m *(GSD equivalent)*
  - Footprint: 0.20–2 m (Point Spread Function *equivalent*)
  - Intensity: First and last return or more
- Geopositional
  - Accuracy (elevation): 15 cm (5–75 cm, 15 cm typical)
  - Accuracy (planimetric): 10–100 cm
- Number of returns: 2–5

Topographic LIDAR Data Providers

- Potential sources of topographic multiple-return LIDAR data products
  - Nine (9) system manufacturers worldwide
    - Most of the systems used by service providers in the United States are manufactured by Optech International, Inc., or by Leica Geosystems (LH Systems), or they are developed by the individual company (proprietary).
  - More than 22 service providers in United States; 61+ worldwide.
- Only one known commercial source of topographic waveform LIDAR data products
  - Optech International, Inc.

Digitized Waveform Systems

- Optech, Inc.
- Upgraded waveform digitizer available for current ALTM product line (50 kHz/100 kHz)
  - 256+ bins @ 1 ns sampling (~ 30 cm resolution)
  - 0.2-2 m footprint (depends on aircraft altitude)
  - Recently developed; currently undergoing testing/evaluation (four systems in existence)

LIDAR Data Derived Products

- Derived products from multiple-return and waveform LIDAR data that address Carbon and Water Cycle science requirements:
  - Land topography (all-points and bare-Earth/filtered products)
  - Canopy and subcanopy biomass
  - Vegetation cover

- To determine whether these derived products meet science requirements (in terms of accuracy, etc.), various aspects of the data must first be characterized from multiple-return and waveform LIDAR systems.

LIDAR Data V&V Plan

- The relationships between both multiple return and full waveform LIDARS has not been fully explored
- Fly single LIDAR system and record both multiple-return and waveform data
  - Develop better understanding of both types of systems

LIDAR Intrinsic Data V&V

- Intrinsic product characterization (FY 2005):
  - Vertical (z) accuracy
    - Reflectance dependencies or effects
  - Height discrimination
    - Minimum resolvable height separation for multiple-return systems
  - Planimetric or horizontal (x,y) accuracy
  - Image quality of intensity-based imaging systems
    - Edge response (footprint shape)
    - Radiometry
    - Signal-to-noise
    - Sampling

LIDAR Data V&V (Continued)

- Explore methods to characterize higher level products (FY 2006):
  - Bare Earth digital terrain model (needed for canopy height determination)
  - Canopy height and structure
  - Biomass estimation

LIDAR Data V&V Plan

- Test site: SSC V&V range
  - Infrastructure in place to support this activity
    - Significant number of points surveyed
    - Edge targets in place for image quality and SNR studies
  - Evaluating Draft National Digital Elevation Program (NDEP) Guidelines for Digital Elevation Data
    - Vertical accuracy validation of bare Earth product
  - Various land cover features and types present on the site
    - Buildings, roads, canals, pine forests, wetlands, open grass
  - Forest parameter database is available for the SSC Fee Area
    - Canopy height and biomass validation
  - Deploy specific manmade targets for height discrimination, intensity characterization, and planimetric accuracy assessment

Next Steps

- Brief NASA HQ
  - Modify plan based on feedback
- Further engage science community and refine details
  - Coordinate with industry, academia, and government scientists
- Coordinate with commercial vendors and JACIE for HSMS satellite acquisitions
- Acquire waveform LIDAR data
- Perform V&V

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