Earth Science Technology Office (*ESTO)*

IIP AIRBORNE MICROLASER ALTIMETER

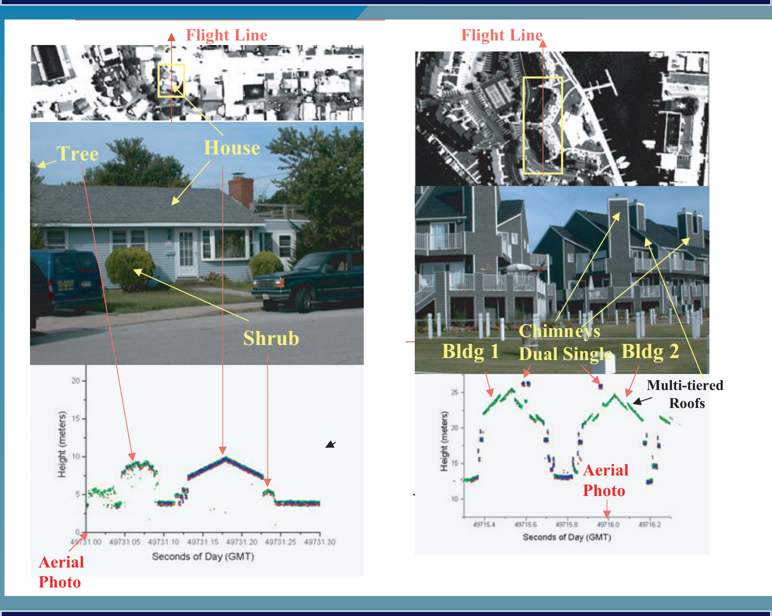
Photon-Counting Airborne Multi-kHz Microlaser Altimeters

OBJECTIVE

- Develop the necessary enabling technologies, algorithms, and software and demonstrate single photon laser ranging and 3D imaging of a variety of surfaces (land, ice, water, vegetation, clouds, etc.) from aircraft cruise altitudes under night and day conditions.

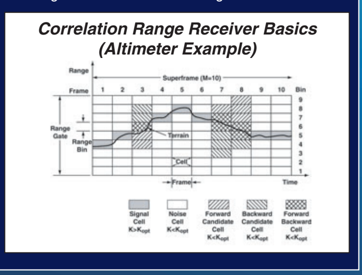
REMOTE SENSING APPLICATIONS

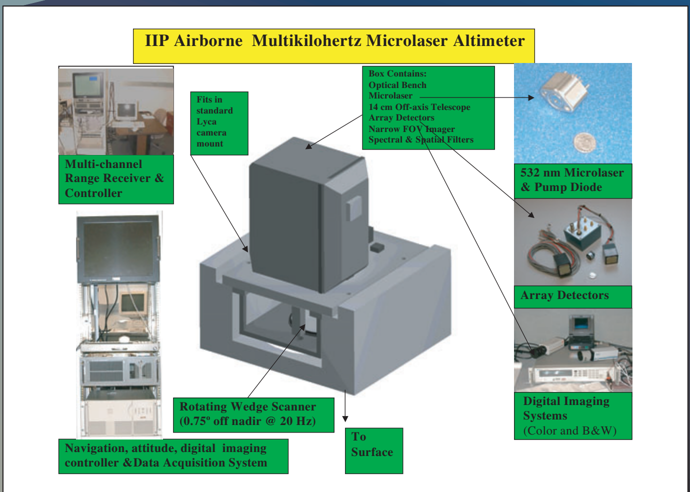
- Earth Science Applications
  - High spatial resolution terrestrial 3D mapping from space
  - Flood plain monitoring and predictions
  - Ice sheet thickness, global warming
  - Biomass estimates (e.g. tree canopy and sub-canopy heights)
  - Sea/lake levels, wave heights, eddies, ocean currents, bathymetry
  - Cloud heights, planetary boundary layer, radiation balance
  - Commercial aircraft surveying applications
- Space Science Applications
  - High spatial resolution global surface topography of extraterrestrial bodies (planets, moons, asteroids, etc.)
  - High resolution crater profiles, age of the Solar System
  - Locating "safe" landing sites (e.g. Mars)
- Signal extraction technique may have application to other low signal strength applications, e.g.
  - Crop health via laser-induced fluorescence
  - Ocean health (plankton populations) via laser-induced flourescence



How a Correlation Range Receiver (CRR) Works

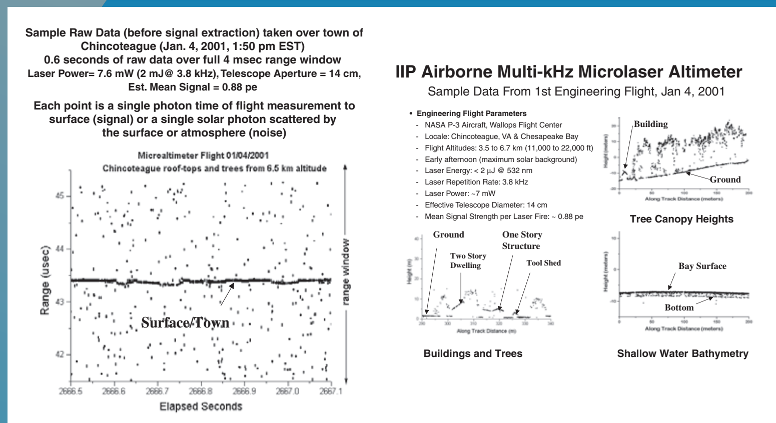
- The vertical axis (range window) is divided up into optimally sized range bins.
- The single photon returns are collected over an optimally chosen number of laser fires called a "frame".
- The 2D areas defined by the range bin and frame boundaries are called "cells". The bin and frame sizes are chosen so that there is high probability that all of the signal counts fall within a single cell.
- The number of photon returns in each cell is recorded by the CRR and compared to a threshold, which is optimally chosen according to Poisson statistical theory.
- Cells which exceed the threshold are tentatively identified as "signal cells" and the data is retained. Cells which have fewer counts are tentatively identified as "noise cells" and rejected. Under most conditions, this data extraction can be done with a high confidence level.
- Under weaker signal conditions or extreme conditions such as steep slopes, one can use multiple frames ("superframe") and apply the additional condition that in subsequent frames the signal cannot move by more than one range bin in the "up" or down direction. Applying this constraint in both the forward and backward directions from clearly identified signal cells identifies additional cells which probably contain data.





TECHNICAL APPROACH

- The instrument uses an onboard GPS receiver and a GPS ground receiver network to obtain precise differential positioning of the aircraft. Real time instrument attitude is provided by an onboard Inertial Navigation System (INS), supplemented by a digital compass, 3-axis fiberoptic gyro, and two inclinometers mounted to the optical bench.
- A small passively Q-switched Nd:YAG microlaser transmitter provides a multi-kHz train of low energy (few microjoule), sub-nanosecond green (532 nm) pulses for precise ranging.
- The ground scene is imaged onto a pixellated photon-counting detector, i.e. a segmented anode photomultiplier, which provides a quasi "point-to-point" ranging and 3D imaging capability within a single laser fire.
- The outputs of the various detector pixels are "OR'ed" together and input to a Multi-Channel Scalar (MCS) to produce a record of all the scatterers (clouds, etc.) between the aircraft and the ground. The ground return is used to center the 4 msec timing window of the "fine" receiver.
- The "fine" receiver measures individual photon times-of-flight and also identifies the detector pixel which recorded the photon event.
- A GPS-synchronized Digital Imaging System (DIS), collocated with the microaltimeter, records the ground scene at one second intervals for later correlations of 2-D camera images with 3D lidar range data. In order to correct for attitude errors due to gyroscope drift , the DIS periodically overflies and images four well-located (using differential GPS) diode array "ground stars" which provide a pulsed light output synchronized with GPS .
- An optical wedge spinning at 20 Hz superimposes a circular scan pattern on the transmit and receive fields-of-view on the linear aircraft motion and permits topographic mapping.
- A Correlation Range Receiver (CRR) is used to extract the signal returns from the solar background noise during daylight operations.



ADVANTAGES OF PHOTON-COUNTING ALTIMETERS

- High Efficiency
  - Since only one detected photon per detector pixel is required for range measurement, low energy lasers and smaller telescopes can be used
  - Major reductions in weight, cost, prime power for space missions
  - Lower radiation fluxes improve eye safety margins for ground observers and reduces risk of internal optical damage to the instrument
  - Use of smaller telescope increases scanning options for 3D measurements over wide swath widths
- Improved horizontal resolution and registration
  - Imaging of the ground scene onto a pixellated detector allows the source of the photon reflection to be identified
  - Single photon time-of-flight removes ambiguities associated with conventional multiphoton measurements
- Improved vertical (range) resolution and sampling
  - Subnanosecond microlaser pulses and fast receivers with low deadtimes provide several cm resolution and quick recovery for mapping distributed targets (e.g. tree canopies)

ACKNOWLEDGEMENTS

IIP Microaltimeter Instrument Team

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- SREC: Joe Marzouk, Andy Chu
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- Geoscience Technology Office, April 2001 Code 920.3, GSFC/NASA

GSFC = Goddard Space Flight Center
HTSI = Honeywell Technology Solutions Inc.
SREC = Sigma Research & Engineering Corporation
RSTX = Raytheon STX

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