**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
  - Fluid plume monitoring and predictions
  - Ice sheet thickness, (global warming)
  - Bismark ice (ice margin and sub-canopy heights)
  - Sea/land 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 craters 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 height, biomass, forest, oceanic fluorescence
  - Ocean health (plankton populations) via laser-induced florescence

**Technical Approach**
- The instrument uses an onboard GPS receiver and a GPS ground receiver network to obtain precise differential positioning of the aircraft.
- The laser output comes from an internal Navigation System (INS), supplemented by a digital compass, 3-axis fibertropic gyn, and two accelerometers 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 detection.
- The ground scene is imaged onto a pixellated photon-counting detector, i.e. a high efficiency, 2-D pixel array coupled to a fast timing discriminator.
- 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 "scatterer pixel" which transmitted the photon event.
- A GPS-synchronized Digital Imaging System (DIS), collocated with the microlaser, records the ground scene on one or more archival film or laser tape/computer images with 3-D laser range data. In order to correct for atmospheric delays and other biases, the DIS collects simultaneously high-speed video images and images four well-located (using differential GPS) "dowel sets" which provide a relative light-time-of-flight measurement.
- An optical wedge spinning at 20 Hz superimposes a circular scan pattern on the target to allow differential delay of the linear aircraft motion and permit topographic mapping.
- A Correlation Range Receiver (CRR) is used to extract the signal returns from the solar background noise during daytime operations.

**Advantages of Photonic-Counting Altimeters**
- **High Efficiency**
  - Since only one detected photon per detector pixel is required for range measurements, low energy lasers and smaller telescopes can be used.
  - Major reductions in weight, cost, prime power for space missions.
  - Lower radiation flux improves 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 modulation measurements.
- **Improved vertical (range) resolution and sampling**
  - Subnanosecond microlaser pulses and fast receivers with low deadtimes provide excellent range resolution and quick recovery for mapping distributed targets (e.g., tree canopies).

**Acknowledgements**
- PI: John Degnan, Tom Zagwodzki, Phil Dabney, Andy Chu
- HTS: Dick Chabot, Charles Steggerda
- SREC: Joe Marzouk, Andy Chu
- RSTX: Sam Ohring, Jorge Santana
- Goddard Telecommunications, April 2001

**Sample Raw Data (Before Signal Extraction)**
- Sample Data From 1st Engineering Flight, Jan 4, 2001

**Ground Scene Raw Data**
- Aerial scene of suburban (0.75° off nadir @ 20 Hz)
- Diode array "ground stars" which provide a well-located (using differential GPS) "dowel set" to reduce attitude errors due to gyroscope drift.
- The DIS periodically overflies and images four well-located "dowel sets" which provide a relative light-time-of-flight measurement.
- The CRR extracts the signal returns from the solar background noise.
- The "fine" receiver measures individual photon times-of-flight and also identifies the scatterer pixel which transmitted the photon event.
- The DIS collects simultaneously high-speed video images and images four well-located "dowel sets" which provide a relative light-time-of-flight measurement.
- An optical wedge spinning at 20 Hz superimposes a circular scan pattern on the target to allow differential delay of the linear aircraft motion and permit topographic mapping.
- A Correlation Range Receiver (CRR) is used to extract the signal returns from the solar background noise during daytime operations.

**Technical Approach**
- How a Correlation Range Receiver (CRR) Works
- **Remote Sensing Applications**
- **Advantages of Photonic-Counting Altimeters**
- **Acknowledgements**

**Image Descriptions**
- Earth Science Technology Office (ESTO)
- IIP AIRBORNE MICROLASER ALTIMETER
- Photon-Counting Airborne Multi-kHz Microlaser Altimeters

**Image Captions**
- How a Correlation Range Receiver (CRR) Works
- A Correlation Range Receiver (CRR)
- Sample Raw Data (Before Signal Extraction)