Coastal Area Tactical-mapping System (CATS)

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LONG-TERM GOALS

The long-term goals of the CATS project are

(1) to improve detection and identification of anti-vehicle and anti-personnel obstacles and munitions in the coastal zone, and
(2) to gain a fundamental understanding of the phenomenology of the Earth’s surface and shallow coastal water under very low-energy laser probing

OBJECTIVES

The overarching objective of the CATS project is to design, build, and demonstrate a low-power scanning airborne laser altimeter capable of continuous ground coverage, superior three-dimensional (3D) sampling, and shallow-water penetration.

APPROACH

The technical approach we have taken to achieve the stated objectives and goals is to employ multi-channel photon-counting technology. This technology allows the use of low-power, low-weight micro lasers with order of magnitude shorter pulse lengths than traditional airborne laser swath mapping (ALSM) lidar systems. The short pulse length allows comparable range resolution to traditional ALSM without the need for constant-fraction based detection of the return photon packet. This in turn leads to detector electronics that are well suited for recording a large number of return events per pulse rather than just a few discrete returns, which will lead to a more nearly 3D representation of the surface, landcover, and targets. The key individuals participating in this work are listed in Table 1.

Originally, it was intended that Grady Tuell of Optech International, Inc. would make existing SHOALS (Optech’s bathymetric lidar system) data available over a suitable field test site or coordinate with UF personnel to collect SHOALS data over a suitable field test site. However, this activity is
dependent upon the results of the system-level CATS integration and ground-based field testing, and so remains tentative.

Table 1: Key individuals participating in CATS

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Roll</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramesh Shrestha</td>
<td>UF</td>
<td>Programmatic, fiscal</td>
</tr>
<tr>
<td>Clint Slatton</td>
<td>UF</td>
<td>Design, sensor modeling</td>
</tr>
<tr>
<td>Bill Carter</td>
<td>UF</td>
<td>Design, systems engineering</td>
</tr>
<tr>
<td>John Degnan</td>
<td>Sigma Space, Inc.</td>
<td>Detailed design of optical-mechanical and laser subsystems, system-level integration</td>
</tr>
<tr>
<td>Bill Gavert</td>
<td>Fibertek, Inc.</td>
<td>Detailed design and testing of receiver subsystem</td>
</tr>
<tr>
<td>Joe Foster</td>
<td>Dynetics, Inc.</td>
<td>Target phenomenology, environment simulation, field testing</td>
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WORK COMPLETED

The major components of the CATS, including the micro-laser, holographic element, and scanner subsystems are being integrated by Sigma Space Inc., while the Photomultiplier Tube (PMT) receiver and multi-channel, multi-event timer subsystems are being integrated by Fibertek, Inc. The subsystems are currently nearing the end of laboratory testing, and the initial steps of system-level integration have begun. Laboratory testing, followed by ground and airborne testing, is expected to yield the first CATS data sets by early 2006.

Subcontractors Sigma Space, Inc. and Fibertek, Inc. both experienced delays due to technical problems during the past fiscal year. The resulting delay to the overall project is estimated to be approximately three months. Details are listed below. Due to these delays, UF personnel requested and were granted a no-cost extension for the project.

1. Receiver subsystem: Fibertek, Inc.
   a. UF personnel made a site visit to Fibertek to review the progress of the final assembly and testing of the PMT and timing electronics (see Figs. 1 and 2). The unit was not fully assembled because of delays caused by errors found in the printed circuit (PC) cards. At least 2 cards had to be redesigned and remanufactured, causing several weeks of delay. Work has been further delayed by key Fibertek personnel being pulled off of the project to support higher priority classified work.
   b. In late August 2005, Fibertek personnel succeeded in getting the timing cards running reliably at 2GHz - a primary goal (previous units they developed worked at 1 GHz). They also have tested the 100 channel PMT to measure the dark noise count. The dark noise is within tolerable limits. Fibertek personnel plan to begin testing the receiver subsystem with light diode signals in early October 2005. The plan is to complete bench testing by mid October, and then deliver the unit to Sigma Space for integration with the optical-mechanical-laser components.
   c. UF personnel visited the Fibertek facility on 17 August 2005. Multiple teleconferences between personnel at Fibertek, UF, and Sigma Space have been held.
   d. CATS is a cutting-edge laser scanning system, which will require extensive laboratory and field testing to check out and characterize. We expect that it will be necessary to make adjustments and perhaps even change components to achieve the optimal performance. Our plan is to have Fibertek and Sigma Space personnel directly involved in the field tests. We have allocated funds to cover the transportation, per diem, and other costs associated with the
field testing, possible limited changes to optimize the system performance, and the support of UF staff and students to reduce and analyze the data collected in order to commission the system.

2. Optical-mechanical subsystem: Sigma Space, Inc.
   a. It was decided that an electronic pulse, rather than an optical pulse, generated from each laser fire inside the Sigma Space assembly will be used to trigger the range gate timing in the Fibertek receiver assembly. A photodiode illuminated by the laser light will generate the electrical pulse needed to trigger the interval timer.
   b. The JDS Uniphase laser (model NG-10320), like most lasers, produces a beam with a radially symmetric, nearly Gaussian distribution of energy across the beam. To distribute the laser energy more uniformly over the laser footprint, 10×10 and 21×21 hologram elements (manufactured by INO of Canada) were tested in late spring 2005. The 10×10 hologram produced the most uniform footprint (see Fig. 3) and was selected.
   c. A highly versatile Risley prism scanner allows the operator to select many different scan patterns, allowing the system to acquire data in different modes, including profiling, side-to-side raster scans, conical scans, and rosette scans. This flexibility in scan geometry will also facilitate the use of the CATS sensor for both airborne and ground-based applications.
   d. UF personnel visited Sigma Space to review their progress. The optical bench is currently being populated with optical elements (see Fig. 4). Metal mirrors were ordered by mistake for some of the optics package. The design called for glass mirrors with high-quality optical coatings to minimize attenuation. The metal mirrors would have resulted in unacceptable attenuation of the laser energy density. Glass mirrors were subsequently ordered and used, but the error imposed a delay.
   e. The angular position encoders that Sigma Space purchased for the Risley scanner assembly were delayed and then delivered with metal scales. The laser readings from these metal scales were found to be too noisy and the metal scales had to be replaced with glass scales. During the mounting and alignment process, one of the glass scales was broken and had to be replaced, causing delays. The scanner prisms are driven by belts. Noise in the electronics had caused the belts to slip and/or actually come completely off of the drive wheels, making it necessary to change certain components. The scanner electronics and the laser appear to be working well now and once the mechanical changes are made to the scanner, the system should be ready for final alignment and testing, followed by integration of the Fibertek detector and electronics.
   f. UF personnel visited the Sigma Space facility on 18 August 2005. Multiple teleconferences between personnel at Fibertek, UF, and Sigma Space have been held.

   a. During the month of August 2005, there was some discussion among UF, Fibertek and Sigma Space personnel about the potential need for some form of active cooling of the Fibertek electronics boards. It was decided that a small cooling fan would be employed to force ambient air over a small aluminum housing. The Fibertek board assembly will be heat sunked to this housing, and the air pathway will be ducted so that no air flows over the optics.
   b. Personnel from UF are currently drafting a system-level integration plan. Fibertek will deliver the receiver subsystem to Sigma Space and then work with Sigma Space personnel to integrate it with the laser and optical-mechanical subsystems. The UF integration plan will list specific verification tests to be performed and documented during the integration activities.
4. Field testing: Dynetics, Inc.
   a. Before airborne testing, the CATS sensor will be placed on one of the 100m tall observation towers at the coastal test facility at Eglin Air Force Base near Panama City, Florida. This tower overlooks a beach area containing traditional impediments to amphibious landings, such as concrete blocks, hedgehogs, and concertina wire, inside and outside of the surf. These are precisely the targets and the environment for which CATS was developed. UF and Dynetics personnel are drafting a detailed test plan.
   b. UF personnel are working with subcontractors Sigma Space and Dynetics, Inc. to generate safety documentation required by Eglin Air Force Base to operate lasers at the test facility. The safety verification procedure is anticipated to go smoothly because of the low transmit energy (4.5 µJ), short pulse lengths (450 picoseconds) and distributed beam pattern (10×10 beamlets over a 2m × 2m area).

   a. The ground based testing of CATS will be followed by airborne tests covering coastal areas in Florida, which may include areas mapped by Optech with their SHOALS bathymetric lidar system to validate CATS data in shallow water (depths less than 5 m). UF researchers are still evaluating the cost/benefit of such tests, which depends on the ability of SHOALS to produce high resolution bathymetric maps in shallow surf zones.

RESULTS

Most of the results achieved during the past year can be characterized as demonstrating the feasibility of building the CATS sensor using existing, or incrementally advanced, components. For example, demonstrating that the Fibertek time interval cards will operate at 2 GHz and that, with a special interface card, the USB will handle data flow rates that make it possible to collect multiple events from 96 channels with 8 kHz laser pulse rates. These are “new capabilities” in the sense that Fibertek had not built such a unit before, nor had Sigma Space built the optics and mechanical components to illuminate a ten by ten array of groundals, or a versatile Risley prism scanner that offers new opportunities to use the sensor for both ground based and airborne laser scanning. UF graduate students working on simulator, data reduction, and analysis computer software have investigated the advantages and disadvantages of photon counting laser scanning, including aspects that offer the possibility of achieving more nearly 3D point clouds, and extracting man-made obstructions from those point clouds. Until the subsystems are fully integrated and observations are collected, it is not possible to reach conclusions about the relative merit of the CATS design versus more traditional designs.

IMPACT/APPLICATIONS

The successful operation of the CATS sensor, especially over surfaces covered by shallow water or vegetation, will demonstrate a dramatic improvement over traditional surficial lidar mapping, while using a lower-weight, lower-power approach suitable for Unmanned Aerial Vehicles (UAVs). It thus has the potential to revolutionize the field of high-resolution topographic mapping.

TRANSITIONS

The CATS sensor will be of significant interest to researchers supported by the National Science Foundation (NSF) because of the potential for dramatically improved topographic mapping, including
mapping the bottoms of shallow streams and lakes. The ability to extend beach surveys below the water line to depths of a few meters is also of great interest to coastal engineers and agencies such as the Florida Department of Environmental Protection.

RELATED PROJECTS

1. Sponsor: National Science Foundation. Title: The National Center for Airborne Laser Mapping (NCALM). NCALM helps to maintain and improve infrastructure at UF for collecting and processing ALSM data. The CATS sensor head will be mounted into the UF Cessna 337 aircraft used for most NCALM acquisitions. The existing GPS and IMU system in that aircraft will also be used for CATS. See http://www.ncalm.ufl.edu/ for more information.


PUBLICATIONS

Selected publications over the past fiscal year only

Refereed Journal Articles


Refereed Conference Paper


FIGURES

Fig. 1: Front and back views of the receiver electronics. Photographs taken at Fibertek facility.

Fig. 2: The PMT assembly. (Left) front view and (right) back view. Photographs taken at Fibertek facility.
Fig. 3: Image of the 10×10 beam footprint generated by passing the 532nm (green) laser light through the hologram element. Image taken at Sigma Space during bench testing.

Fig. 4: (Left) Emission side of CATS system. (Right) Reception side of CATS system. Photographs taken at Sigma Space facility.