Coastal Engineering Technical Note

EMERGING HYDROGRAPHIC SURVEY TECHNOLOGY: THE SCANNING HYDROGRAPHIC OPERATIONAL AIRBORNE LIDAR SURVEY SYSTEM

PURPOSE: This technical note describes a new hydrographic survey system being developed to provide quick and accurate condition and reconnaissance surveys to augment existing techniques. The development program consists of an international effort to define, design, construct, and field test the Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) system.

BACKGROUND: The U.S. Army Corps of Engineers (USACE) invests over $30 million in hydrographic surveys annually in support of the planning, design, construction, and maintenance of Federal projects. The USACE surveying program covers a broad range of project types including flood control, navigation, and erosion control. This translates into thousands of miles of projects and navigation channels including both large scale regional projects and channels such as the Intracoastal Waterway to small scale projects such as a single harbor. The most resource demanding survey requirement is the need for quick and accurate bathymetric surveys.

Present USACE hydrographic surveys are performed by small launch-type vessels (20 to 70 ft) with acoustic fathometers. The USACE owns and operates approximately 50 vessels and contracts for another estimated 30 for bathymetric surveying. Horizontal control for both is usually provided by a microwave range/range or range/azimuth system, and vertical control depends on standard fathometer calibrations such as bar checks coupled with tide or river gages and associated water surface elevation interpolation/extrapolation techniques.

The USACE needs technology that can augment existing survey methods at comparable costs without requiring significant additional manpower to operate or administer. An airborne system that can achieve orders of magnitude increases in survey speed has the potential to meet this requirement. In March 1988, the USACE began a cost-shared program with the Canadian government to design, construct and field verify an airborne lidar hydrographic surveying system. The program is intended to build on experience gained by the Canadian Hydrographic Service in operating a similar system from a fixed-wing aircraft. The program is implemented through a joint Memorandum of Understanding under the U.S./Canadian Defense Development Sharing Program. Optech, Inc., of Toronto, Canada is the contractor developing the system.

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SYSTEM DESIGN: The primary operating element of SHOALS is the LIDAR, which is an acronym for LIght Detection And Ranging. The technology utilizes a laser to generate an optical pulse that is transmitted downward from an aircraft (Fig. 1). An optical receiver detects the laser pulse reflections from both the water surface and the sea bottom. The water depth is determined from the elapsed time between the surface and bottom returns. In order to meet the USACE accuracy requirements, this resultant depth is corrected for various bias errors and water surface wave effects and matched with its corresponding horizontal position. The horizontal coordinates of the soundings are determined from the aircraft's position determined by the Navstar Global Positioning System, the calibrated laser beam exit angles, aircraft altitude, and the water depth.

The SHOALS system will operate out of a Bell 212 helicopter and measure water depth at a rate of 200 soundings per second. The laser pulses will be scanned across the water surface to produce a uniform distribution of soundings as the aircraft is in flight. At a nominal operating altitude of 200 meters, the system will generate a swath of soundings whose width is about 120 meters. The average spacing between soundings will normally be in the 3-10 meter range. Trade-offs between area coverage rate and sounding spacing can be made by proper selection of aircraft speed, altitude and scanner rate. Depth accuracy specifications are +/- 30 cm, which is the requirement for Class 2 & 3 surveys by the draft Hydrographic Surveying Engineer Manual (EM 1110-2-1003).

The main limitations of the system are its maximum and minimum depth capability, weather-related operational abilities, and bottom structure sensitivities. Water clarity will typically limit the system's maximum depth penetration capability to less than 50 meters in very clear water, and 20-30 meters in moderately clear waters. The system will not be appropriate for use in highly turbid waters. The minimum depth measurement capability of the system will be approximately 1.5 meters, limited primarily by the system hardware. Weather-related phenomena such as high surface waves, heavy fog and precipitation, and surface sun glint can degrade system performance by decreasing depth penetration and/or depth measurement accuracy. Bottom reflectance will vary depending on bottom materials, which can range from highly reflective material such as sand to highly absorptive material such as organic mud.

The airborne portion of the SHOALS system consists of six primary components: a) a laser transmitter/receiver with scanning device; b) an onboard system to acquire, initially process, and store all sensed data such as time, depth, and position; c) a system to provide the pilot with real-time navigation guidance; d) an aircraft attitude recorder for removing aircraft pitch and roll; e) a real-time differential horizontal GPS positioning system; and f) an operator status panel for monitoring system parameters and confirming that valid data are being collected. A ground-based system which post-processes the collected data will produce as the final system product a fully corrected and quality-checked file of position and water depth referenced to standard survey control.

SYSTEM USE: The SHOALS system should offer an effective augmentation to conventional hydrographic surveying. By providing a high coverage rate, daily survey capabilities may be greatly expanded. Cost savings can be realized by utilizing the aircraft's mobility and ability to rapidly complete a project survey. This can allow the grouping of several projects to reduce a crew's field time, travel expenses, and system mobilization and demobilization costs.

It is estimated that a crew of two would be required to carry out a survey operation, exclusive of the aircraft pilot and copilot. The crew members would carry out the unpacking, installation and pre-flight calibration of the SHOALS system. Installation and calibration time is estimated to be six hours.

Once the SHOALS system is installed and calibrated, the survey mission plan is entered into the onboard computer and the survey mission begun. The mission plan consists of a computerized small-scale display of the area to be surveyed showing survey flight-lines and selection of the aircraft altitude, speed, and laser scan rate required to achieve the desired survey performance and sounding density. During the survey, one SHOALS operator monitors and adjusts system performance parameters, while the other monitors data quality. Upon landing, one of two data tapes is shipped to the ground-based data processing facility for immediate processing. The second, duplicate, tape is used as a backup.

The ground-based data processing facility houses the hardware and software necessary to reduce the lidar data to corrected depths with corresponding horizontal locations. An operator loads the recorded data into the computer, inputs supplemental data such as tide elevations and initiates the automated data processing software. After data validation and editing, the processed data can be used to prepare field sheets, charts and maps, or be used in conventional hydrographic software packages to compute quantities such as dredging volumes.

THE SHOALS DEVELOPMENT PROGRAM: Program organization includes the U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center (CERC) as the study manager with funds and program monitoring provided by both the Operations and Readiness Division, HQUSACE Headquarters and the Canadian Department of Industry, Science and Technology. CERC is responsible for overseeing all technical aspects of the program including development of the performance requirements, review of design specifications and ultimate design approval as well as managing all contractual elements.

The program includes a Field Working Group composed of representatives from USACE Field Offices. Their role is to review, from an operational perspective, the system design and implementation plan. The FWG has provided assistance defining field needs in terms of performance and accuracy requirements, potential projects that the system may be used on, and the approaches to implementing the SHOALS system following program completion. Table 1 lists the members of the Field Working Group.

Table 1
Field Working Group

Member	Organization
Mr. Glenn Boone	Wilmington District
Mr. George Domurat	South Pacific Division
Mr. Bob Hopman	North Pacific Division
Mr. Juris Jurisons	Portland District
Mr. Herbie Maurer	Galveston District
Mr. Bob Neal	North Central Division
Mr. Doug Pirie	South Pacific Division
Mr. Jim Pruett	Jacksonville District
Mr. Jerry Ptak	Buffalo District
Mr. Jimmy Reaves	Mobile District

Individual technical specialists from sources such as academia, the National Ocean Service and the U.S. Army Engineer Topographic Laboratories are periodically asked to review technical reports, tests, and products provided to WES from the contractor. Such specialists have provided design reviews and recommendations on key system elements such as the horizontal positioning system, software development, laser receiver design, scanner design, data post processing algorithms and general system design specifications.

The SHOALS development program is two-phased. Phase I was to develop a conceptual design to assess whether USACE performance and accuracy requirements were obtainable and to conduct an evaluation into the economic feasibility of such a system. This phase was initiated in March 1988 and completed in March 1989. Products included the system's performance specifications and expected operational restrictions, the system conceptual design (Optech, Inc., 1990), and an economic feasibility analysis (Golaszewski, et.al., 1990). All products were reviewed by the FWG and technical specialists and based on their recommendations, initiation of Phase II was approved by HQUSACE and the Canadian Department of Science, Industry and Technology.

Phase II started 1 March 1990 and will require approximately 36 months to complete. It consists of the detailed design, construction, and field testing of an operational prototype system. Field tests are tentatively scheduled to begin August 1992 at Duck NC. This location was selected because the CERC Field Research Facility there offers the required logistic support such as ground truth equipment and offshore wave gages. The site also offers a variety of physical conditions because of its proximity to both the Atlantic Ocean and Currituck Sound, a shallow sound with diverse bottom conditions including mud, sand, and vegetation which would allow a controlled but varied test program. Additional operational test sites are also being reviewed.

FOR FURTHER INFORMATION: Contact the U.S. Army Engineer, Waterways Experiment Station, Coastal Engineering Research Center, (ATTN: CEWES-CD-SE, Mr. Jeff Lillycrop), 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, or telephone 601/634-4212.

REFERENCES:

OPTECH, INC., "Helicopter Lidar Bathymeter System Conceptual Design", U.S. Army Engineer, Waterways Experiment Station, Contractor Report CERC-90-__, September 1990.

Golaszewski, R., Barol, D., Phillips, J., Zyskowski, W., Maillett, E., "Economic Evaluation of Proposed Helicopter Lidar Bathymeter System", U.S. Army Engineer, Waterways Experiment Station, Contractor Report CERC-90-1, February 1990.

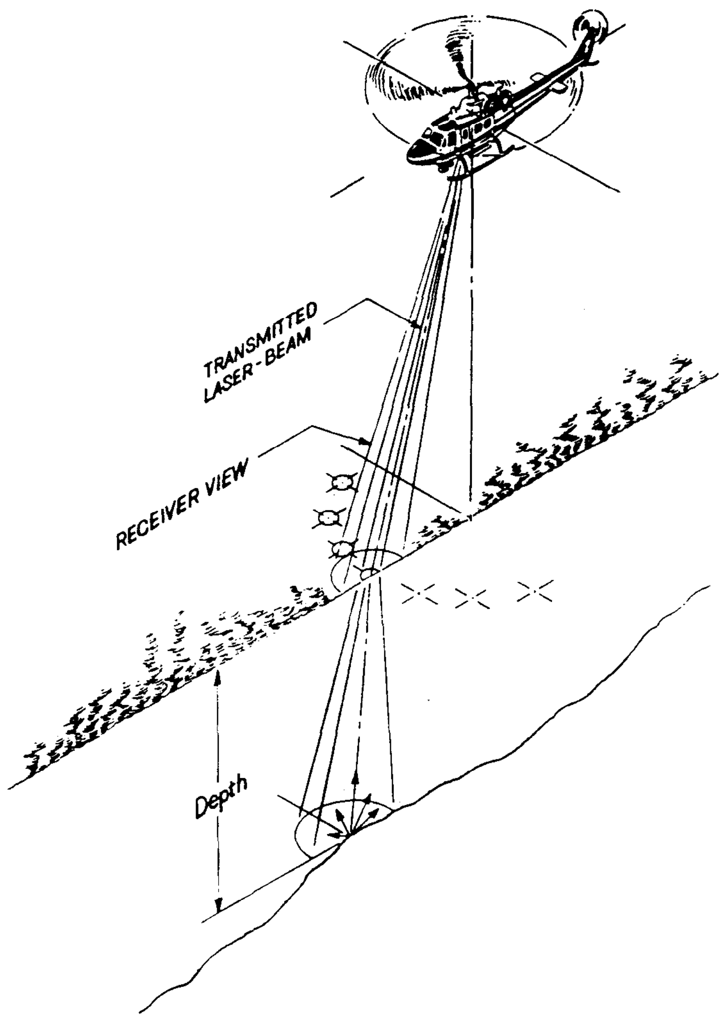

Fig. 1 System Operating Principle