

Following the successes of single-beam and swath classification technology, Quester Tangent in partnership with Tenix LADS and the Geological Survey of Ireland has introduced Lidar Seabed Classification. This new capability will significantly enhance the Lidar data product in support of large-scale, shallow-water mapping for bathymetric and habitat studies.

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Lidar Seabed Classification

New Process for Generation of Seabed Classes

It is well known that the statistical characteristics of a sonar backscatter image depend on bottom type. Even to the novice user, textural differences between images of rocks, sand and mud are readily apparent. Statistical processing captures many of the pertinent details of the interaction between sound and bottom and of its vertical relief. Multivariate statistics can then isolate these details rich in information about the bottom, producing features containing the necessary information for accurate and reliable bottom classification. With the advance of airborne laser bathymetry technology it is now possible to reflectivity along with depth from each seabed footprint. Using a method very similar to sonar-image classification, reflectivity data can be transformed into bottom-type. In 2006 Tenix LADS collected Lidar data from three embay-

ments on Ireland's West Coast. This article presents class maps from one of those surveys.

Laser Bathymetry

Airborne Laser Bathymetry (ALB) or Airborne Lidar (Light Detection and Ranging) is a remote-sensing technique that became commercially available in the late 1990's after years of research and public-sector operation. These systems are well suited for surveying shallow, clear coastal waters, and in the right environmental conditions show significant efficiency and safety advantages over survey by surface vessels. The original use of these systems was for the collection of bathymetric data for nautical charting applications. This remains the dominant commercial requirement for ALB surveys. However, as with all remote-sensing

technologies, there has been a trend towards enhancing bathymetry data with complementary datasets, such as reflectivity. The reflectivity of an ALB pulse is a measure of the amount of energy reflected from the seabed for each individual laser pulse at the wavelength of the laser, 532nm (green/blue). The basic difference between processing an ALB waveform for depth and for reflectivity is that depth processing focuses on the leading edge of the return waveform, whereas reflectivity requires integration of the entire return pulse (see Figure 1).

Assessment

Each sounding is assessed for suitability. Drying soundings and soundings in very shallow water are not processed for reflectivity. The entire waveform from only the most suit-

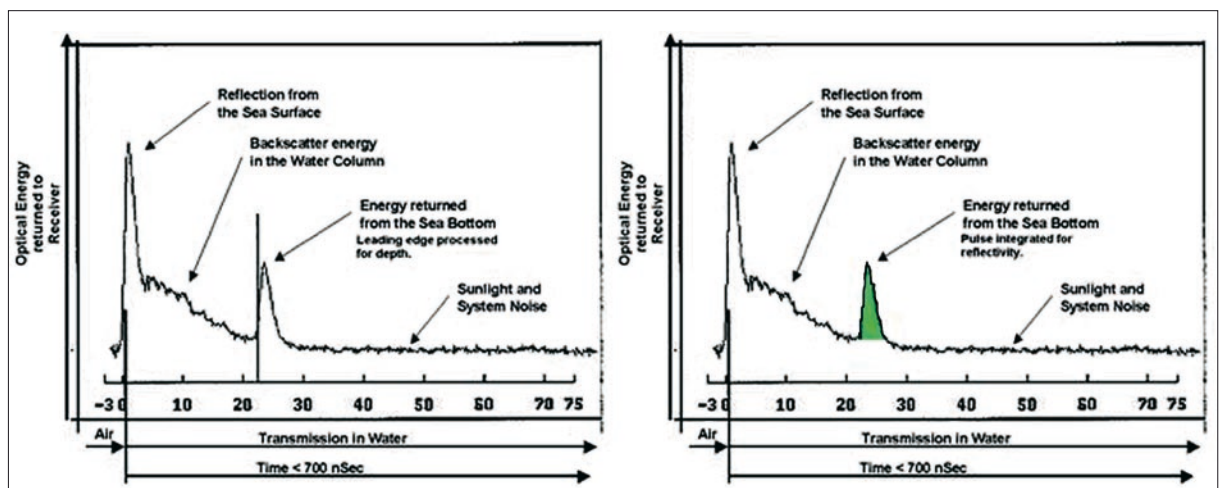


Figure 1: Time series of optical energy returned to receiver; note spike representing sea surface and seabed surface. Also shown (green) is the energy on which estimation of reflectivity for classification is based.

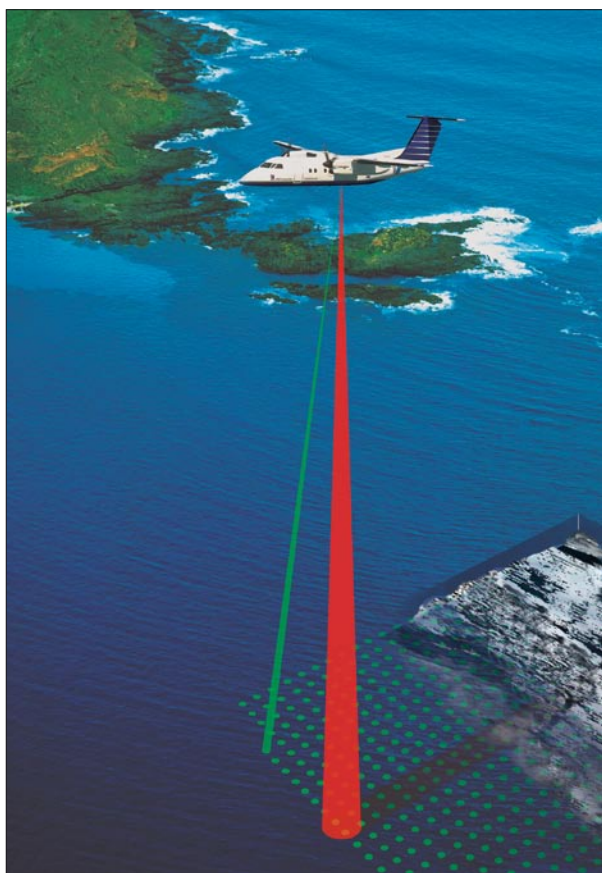


Figure 2: Cartoon of Lidar survey by Tenix LADS Dash-8 aircraft showing seabed reflectivity.

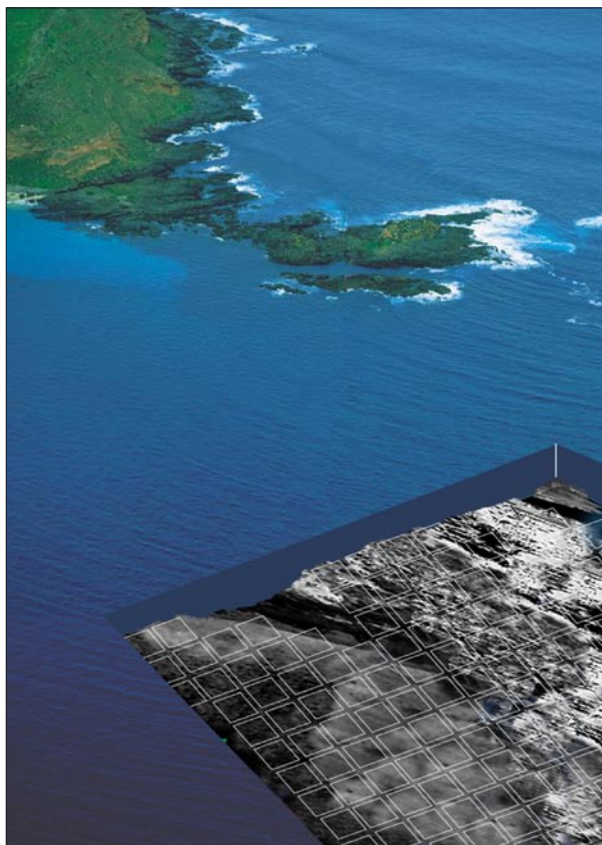


Figure 3: Reflectivity mosaic with squares representing 9 x 9 pixel arrays from which features will be extracted.

able Lidar returns need to be compensated for the electronic gain of the receiver system. The gain-control algorithms of the LADS system are complex and not detailed here. This step is straightforward, each sounding being normalised for the electronic gain applied to the photo multiplier tube to which the received laser energy is optically routed.

The gain-normalised return waveform is then analysed to determine energy returning from the seabed. As previously indicated, this is just a simple integration of the appropriate segment of the reflected waveform. Integration of the waveform from the seabed will produce a numerical value of reflectivity. To ensure that this value accurately and meaningfully describes variation in seabed reflectivity several parameters must be taken into consideration. Energy is lost from the pulses transmitted from the aircraft. These losses include the air/water interface and those through the water column, and any system-specific losses such as optical filtering and receiver field of view.

Reflectivity value, calculated for each pulse, is the ratio between the received energy normalised for the losses described and the transmitted energy. In LADS algorithms reflectance is treated as a relative value. This is considered a more robust solution given the complexity in modelling losses through the water-column and at the water/air interface. Indeed, this solution comprises a similar “phenomenological” approach to that of many swath- and single-beam classification systems. Once a relative reflectivity value has been calculated, further statistical cleaning to remove outliers is completed. Because the dataset is of relative reflectivity rather than an absolute value for each point, the entire dataset is scaled to ensure the full dynamic range is used over the dataset. This scaling is applied over an entire survey area to ensure dataset consistency.

Classification

Reflectivity values for each line are assembled into images, one pixel per footprint (see Figure 2). Each image is divided into small squares, nine pixels to a side. The squares are placed only where reflectivity values are present and meet quality standards (see Fig-

ure 3). These reflectivity images are analysed using features that capture amplitude (or reflectivity), its distribution and texture. Texture is an important property of images and may be visualised as the roughness and pattern differences between real surfaces. Texture is a second-order statistic of a matrix, meaning that it is based on relationships between a pixel and its neighbours; that is, order is important. In addition to image features, depth information is used to generate features based on seafloor relief. A total of 137 features are used to describe each image patch.

Classification of the sea-bottom from which these features arise is done using an automated clustering method adapted to the characteristics of the dataset. Each cluster represents a bottom-type that can be labelled based on ground truth; for example, photographs, grain-size analysis, or other local data. If knowledge of the bottom-type exists, it can be used to build a catalogue for classification of new or archived data. This is called “supervised classification”. The alternative, “unsupervised classification”, forms the data into logical clusters that can then be identified based on ground truth. The effectiveness of unsupervised classification in uncovering practical and valuable information from imagery has been demonstrated in many projects.

Typical deliverables include a point dataset, each record of which contains georeferenced attributes including seabed class with associated confidence and probability values. The point data can be taken into GIS or surface modelling software to present the data as classification maps overlaying bathymetric terrain models.

Irish Offshore Mapping

In the summer of 2006 Tenix LADS Corporation was contracted to fly Lidar bathymetry over three bays on the West Coast of Ireland. The mission was in support of the Irish INFOMAR programme, successor to the Irish National Seabed Survey. INFOMAR goals are to map the highest priority areas of coastal Ireland using a variety of mapping techniques, including Lidar, sonar and direct investigative methods. INFO-

MAR directed Tenix LADS to generate seabed classification data as part of the Lidar project deliverables.

Sorties were flown over Dunmanus, Bantry and Galway Bays. Approximately 150,000 seabed class data points were generated from the three embayments. The results were variable due to unseasonably poor weather, and thus water conditions. The laser gathered data down to about 20 metres water depth. Bathymetry and classification results from Galway Bay are shown in Figures 4 and 5. The data was categorically interpolated using QTC CLAMS to reduce variability and produce images. The images were draped on a digital terrain model for presentation and quality control.

Future Research

Quester Tangent and the Irish Geological Survey in partnership with the Irish Marine Institute have an ongoing programme of research into Lidar Classification within the INFOMAR Programme. The research goal is to improve the classification process by identifying algorithms and features better suited to Lidar reflectivity imagery, including bathymetry-related algorithms. The research will also investigate seabed properties to which Lidar reflectivity responds, including sediments and their biological constituents. One of the most challenging research areas for 2007 will be validation of the classification by means of direct sampling, video and aerial photography. The results will also be compared to acoustic seabed classification for these areas. ■

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Biographies of the Authors

Bill Collins is a marine geologist. He is a vice president of Quester Tangent, having been with the company for more than ten years. He was pre-

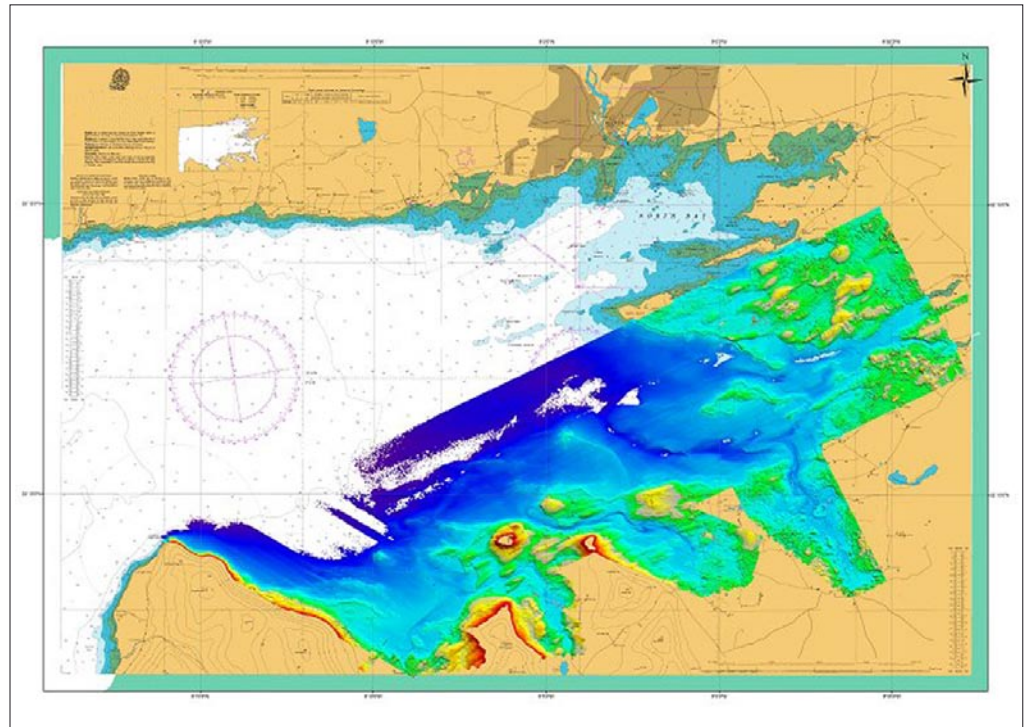


Figure 4: Lidar bathymetry of Galway Bay (source INFOMAR 2006).

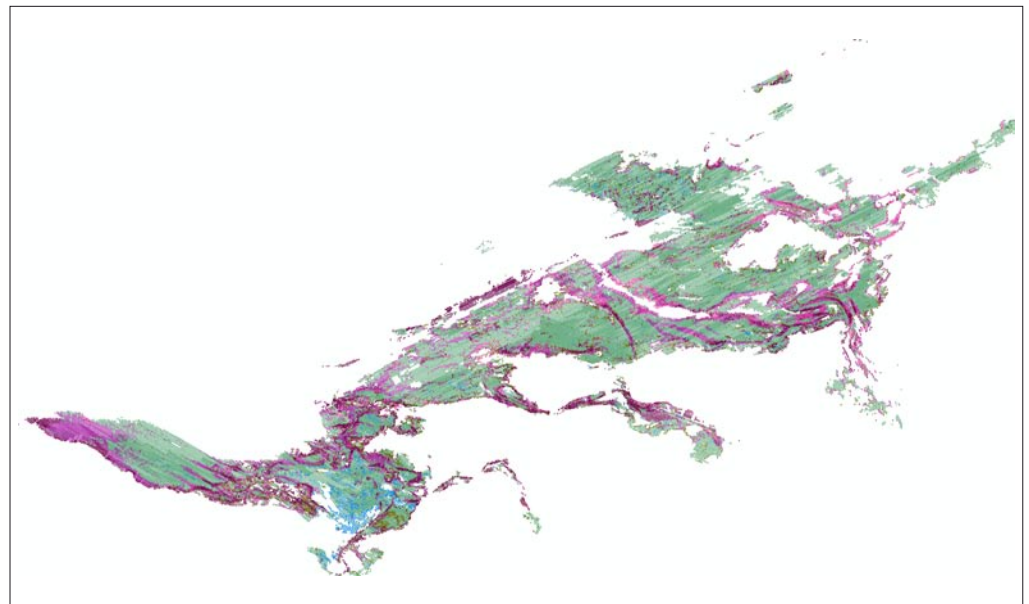


Figure 5: Seabed Classification of Galway Bay using Lidar reflectivity; ten classes with optically similar classes are assigned similar colours.

viously with the Ocean Drilling Program at the University of Washington in Seattle, and SOPAC in Fiji. Bill has published extensively in the field of seabed mapping.

Mark Penley is the technical manager for Tenix LADS Corporation. He has over twenty years of industry experience and has been with Tenix LADS Corporation for the last twelve years. Mark holds a BSc in Electronic Engineering, with specific

experience in electro-optic design, analogue and digital control systems, and system engineering integration.

Xavier Montey is a marine geologist with the Geological Survey of Ireland. Over the last six years he has been involved in mapping Irish offshore waters using different platforms.

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