Major hydrographic and seabed habitat mapping projects in the Caribbean using ALB and hyperspectral imagery

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Abstract

Major hydrographic and habitat mapping projects have been conducted by Fugro ALB in the Caribbean in Puerto Rico, Martinique, St Thomas, St John, St Croix and Guadeloupe. These projects have included the measurement of depth by Airborne Lidar Bathymetry (ALB) and seabed habitat using reflectivity data calculated from the ALB waveforms. These projects have been conducted for and in collaboration with a number of agencies including National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey, NOAA Center for Coastal Monitoring and Assessment, National Parks Service, University of New Hampshire and Service Hydrographique et Océanographique de la Marine, the French Hydrographic Service for the Litto3D® project. In addition, digital geo-referenced mosaiced imagery and hyperspectral data in the visible to near infrared spectral range have also been collected. The airborne data has been supplemented with ground truth data including seabed sampling, spectroscopy measurements made within the water column and on the seabed and the collection of long term tide data. The data from these projects have been used to improve the nautical charting coverage and support a number of environmental and research projects. This paper discusses the data capture, processing and the products created and makes recommendations regarding future requirements and initiatives.

Biography

Mark Sinclair is the Managing Director Fugro LADS Corporation (Adelaide, South Australia) and President Fugro LADS Incorporated (Ocean Springs, Mississippi). He is a mariner, hydrographic surveyor, completed IHO Category A course and certified to Level 1 (SSSI). He previously served as a Commander and seaman officer in the RAN Hydrographic Service.

General

Major hydrographic and habitat mapping projects have been conducted by Fugro ALB in the Caribbean in Puerto Rico, Martinique, St Thomas, St John, St Croix and Guadeloupe. These projects were conducted using the LADS Mk II system.

The projects were conducted for a number of customers including the National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey (OCS) and Service Hydrographique et Océanographique de la Marine (SHOM), the French Hydrographic Service for the Litto3D® project. A minor research project at St Croix also was conducted for a number of interested parties including NOAA Center for Coastal Monitoring and Assessment, National Parks Service and the University of New Hampshire.

The first of these projects was conducted in 2006 and the remainder in 2010 and 2011. Data collection for the latter projects has now been completed and the data is currently being processed.

A summary of the projects, customer and requirements is provided in Table 1.

Table 1: Project Summary

Survey	Dates	Customers	Primary requirement	Secondary requirement
Puerto Rico	2006	NOAA	Nautical charting	Habitat mapping
Martinique	2010 – 2011	SHOM	Coastal zone management for the Litto3D® project	Nautical charting
St Thomas and St John	2011	NOAA	Nautical charting	Habitat mapping
St Croix	2011	UNH , NPS and NOAA CCMA.	Hyperspectral research	Reflectivity research
Guadeloupe	2011	SHOM	Coastal zone management for the Litto3D® project	Nautical charting

For the first project in Puerto Rico data was collected using the Fugro LADS Mk II system fitted inside a Dash 8 aircraft. For the subsequent projects the Fugro LADS Mk II system was fitted into a Fokker F27 aircraft. The Dash 8 was transferred to the Royal Australian Navy LADS program in late 2009, and the Fokker F27 aircraft has been adopted as a temporary platform for contract survey services, while the LADS system is being redesigned to fit into other aircraft. This will provide additional operational flexibility and is planned to occur in May 2011 with the launch of the Fugro LADS Mk 3 system.

Operating Sites, Schedule and Environmental Conditions

For the Puerto Rico survey, operations were conducted from San Juan. This was ideal because it was relatively close to the survey area and environmental conditions were predominantly good. It was found that conditions were more favorable at this end of the Caribbean island chain, compared with the southeast end of the Caribbean in the vicinity of Martinique. The islands get progressively more tropical as one travels to the southeast, with higher rainfalls creating more turbid run off from rivers and more low cloud. At the Martinique end of the Caribbean a more flexible approach had to be adopted.

Operations in Martinique were initially conducted from Fort de France. Commencement of survey operations was delayed by a combination of the ash cloud from the Icelandic volcano, which prevented air operations in certain parts of Europe and closed air routes across the north Atlantic, and unscheduled aircraft maintenance. The first flight in Martinique was conducted on 31 May 2010 and good conditions were initially experienced, however from 15 June weather conditions deteriorated due to the onset of the wet season and operations were consequently suspended. Operations recommenced in December 2010 however conditions were still marginal and did not significantly improve until mid March 2011.

This required a flexible approach of using alternative areas in different parts of the Caribbean in order to manage these conditions. This can be seen in the planning of the completion of Martinique survey and conduct of the work in the US Virgin Islands and Guadeloupe. These survey areas, operating sites and dates are described in Table 2.

Table 2: Survey areas and operating sites

Survey	Operating site	Dates	General location	Comment
Puerto Rico	San Juan	7 Apr – 15 May 2006	NW Caribbean	Ideal conditions
Martinique	Fort de France	26 May – 26 June 2010	French Antilles (far SE Caribbean)	Wet season commenced from 15 June 2010; operations suspended
Martinique	Fort de France	14 Dec 2010 – 30 Jan 2011	French Antilles (far SE Caribbean)	Poor conditions, little progress
Martinique	Guadeloupe	5 March, 11 March, 17 March – 26 March 2011	French Antilles (far SE Caribbean)	Poor conditions 5 March, marginal 11 March and good from 17 March
St Thomas and St John	Martinique	29 Jan – 3 Feb 2011	US Virgin Islands (NW Caribbean)	Ideal conditions
St Thomas and	San Juan	4 Feb – 15	US Virgin	Ideal conditions

Survey	Operating site	Dates	General location	Comment
St John		Feb 2011	Islands (NW Caribbean)	
St Thomas and St John	Guadeloupe	28 Feb 2011	US Virgin Islands (NW Caribbean)	Strong winds degraded conditions temporarily
St Croix	Guadeloupe	22 and 28 Feb 2011	US Virgin Islands (NW Caribbean)	Ideal conditions
Guadeloupe	Guadeloupe	23 Feb – 26 Mar 2010	French Antilles (SE Caribbean)	Initially conditions were mixed, good offshore and poor in certain places inshore; conditions improved from early March

Additional environmental data was also collected as follows. In early August 2010 a reconnaissance was conducted to St Thomas and St John. Some 63 Secchi disc readings were taken around the islands from a vessel, and the mean depth of 42 feet was recorded, with maximum Secchi depths of 60 feet. Generally ALB can measure depths to 2.5 times the Secchi disk depth. This indicates that these areas remained clear even during the wet season.

From this it can be concluded that the window of suitable environmental conditions for ALB in the Caribbean reduces as one heads southeast. The window is virtually all year in the US Virgin Islands, from the start of March to possibly the end of June in Guadeloupe and from mid March to mid June in Martinique.

This also demonstrates the flexibility of an ALB system, able to conduct numerous projects in a similar geographic area concurrently. This enables each area to be flown when environmental conditions are most suitable.

Horizontal and Vertical Control

The horizontal and vertical control for each survey is provided in Table 3:

Table 3: Horizontal and Vertical Control

Survey	Real time horizontal control	Post processed horizontal control	Vertical control datum	Vertical Control Stations
Puerto Rico	WGS 84	NAD 83	MLLW	Observed tides at two National Water Level Observation Network (NWLON) sites applied through tide zones and subordinate gauge(s) installed by John Oswald and Associates
Martinique	WGS 84	WGS 84	IGN 1987	Observed tides at one Permanent SHOM site, one additional administration gauge and four temporary Fugro established stations.
St Thomas and St John	WGS84	NAD83	MLLW	Observed tides at one NWLON site and three JOA established subordinate stations, applied through tide zones
St Croix	WGS84	WGS84	MLLW	Observed tides at one National Water Level Observation Network (NWLON) site applied through tide zones
Guadeloupe	WGS84	WGS84	MSL / GRS80	Observed tides at two SHOM sites, one additional administration gauge and five temporary Fugro established stations.

For all surveys real-time positions were determined using an Ashtech GG24 GPS receiver aided by Wide Area Differential GPS (WADGPS) service. In addition, a local GPS base station was established in each survey area and government operated continuously logging GPS services were also utilized, including NGS CORS. These local logging stations enabled post-processed KGPS positions to be determined relative to the local GPS base station and then applied to all soundings. This provided increased sounding position accuracy and horizontal redundancy.

For all surveys a number of position checks were conducted including DGPS site certifications of local reference stations for obstructions and multipath, static position checks of all positioning systems on the tarmac, dynamic positioning checks between real time WADGPS positions and post processed KGPS positions during sounding operations and navigation checks by overflying visible objects of accurately known position. For each survey, IHO Order 1 position accuracy was achieved.

For all surveys vertical control was established relative to the tide datum through observed tides from existing tide gauges or tide gauges established for the survey. A number of checks were conducted of the tide gauges and datums including leveling to benchmarks, 25 hour pole gauge comparisons and smoothing of the data. The reduction of soundings for tides throughout the survey area was then conducted through tide models, including linear and planar interpolations and establishing tide zones (polygons) where factors were applied to the to the height of tide and +/- offsets to the time within each individual zone.

For all surveys, vertical control of soundings was checked by surveying the same area of seabed on each flight and conducting cross lines throughout the survey areas. Mean depth differences and standard deviations between the data sets were determined. These checks demonstrated that the data was consistent with IHO Order 1 depth accuracy.

Survey Results - Case Study

The survey of the western end of Puerto Rico was completed in 2006 and the results of the survey have been analyzed, whereas data collection for the remaining surveys was not completed until February and March 2011, and this data is still being processed and the results are yet to be finalized. To provide an example, some of the key attributes and results of the Puerto Rico survey are discussed below.

To recap, the primary requirement of the Puerto Rico survey was to provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area. A secondary requirement was to provide relative seabed reflectivity for habitat mapping.

During this data collection phase of the project twenty-one survey sorties of nominal 7-hours duration were flown. The survey was divided into 10 areas, corresponding to 1:10,000 scale sheets, named H11557 to H11567. During the survey the area was extended to the north-west as indicated in red in Figure 1 (page 7).

The water clarity in the survey area was ideal for laser bathymetry. Maximum depths to 55 meters were measured before the reef dropped off quickly. Consistent depths of 35-40 meters were achieved throughout the survey area.

The survey operations were conducted in wind strengths of up to 20 knots, the sea state ranged from 1 to 3 and long period swell was not experienced. Cloud levels would build up over land and move offshore during the early afternoon which increased towards the end of the survey. However these environmental effects did not affect the data quality.

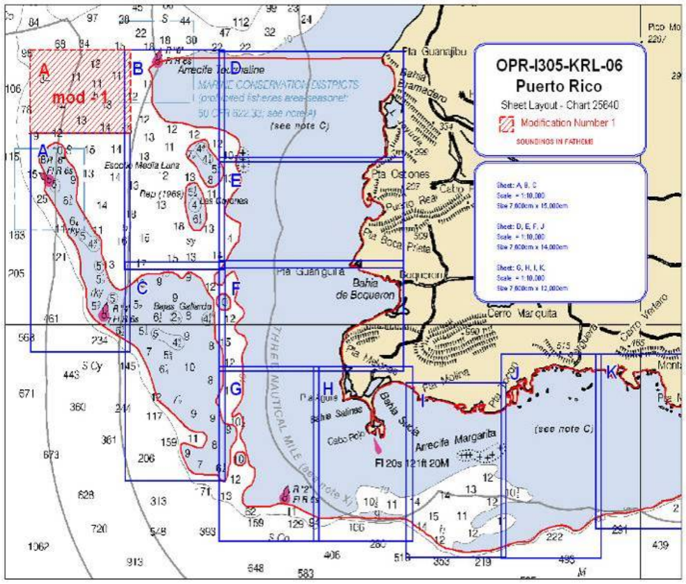

Figure 1: Puerto Rico area and extension

The survey area was sounded at 4x4 meter laser spot spacing with main lines of sounding spaced at 80 meters, which provided 200% coverage.

As with many surveys, a significant number of new dangers were found and differences between the survey and the existing charts identified. The survey area was previously surveyed by NOS surveys, partly between 1900 and 1939 by lead-line, and partly between 1940 and 1989 by single beam echo sounder.

Of significance, some 47 Dangers to Navigation were reported. NOAA OCS defines Dangers to Navigation as follows:

Dangers to navigation are inadequately charted natural and cultural features that a field hydrographer identifies as potentially dangerous to navigation. Submerged features with depths less than 11 fathoms (66 feet) in navigable waters are considered dangers to navigation as are items found to be significantly shoaler than charted, incorrect or uncharted clearances on bridges or overhead cables, and floating or fixed aids off position or incorrectly labeled. Hydrographers must also take into account the general vessel traffic including fishing and tour activities and largest scale chart produced for the area when making determinations regarding the potential danger of an identified item.

The Dangers to Navigation identified during the Puerto Rico Survey are summarized below. The list has been provided in full, in order to give the reader with non hydrographic surveying background an understanding of the importance of typical survey projects in these types of areas.

Table 4: Dangers to Navigation Reported for Survey in Puerto Rico

Survey area	Item number	Surveyed depth	Charted depth	Comment
H11559	1	6.8	14.6	0.5 nm west of a deep channel running north
H11560	1	3.9m	6m	adjacent to a deeper 6-7m channel
H11560	2	2.2m	5.7m	shoaler soundings may exist in the vicinity due to the turbid nature of the water at the time of data acquisition
H11560	3	4.6m	6 – 7m	
H11560	4	9.0m		Directly to the SW of the feature is a 23m channel, which gives marine access from the sea through the shallow reefs
H11560	5	5.6m		Shoalest point on a 200m x 60m feature protruding from the seabed in 25m of water. This feature lies in a 25m channel between the shallow reefs
H11560	6	3.2m		Directly to the E of the feature is a 23m channel
H11560	7	10.4m	16.4m	
H11560	8	12.6m		Coral feature with dimensions of 40m x 40m in 20m of water
H11560	9	11.2m		Coral feature with dimensions of 80m x 60m in 20m of water
H11560	10	11.7m	21.9m	
H11561	1	13.8m		This feature is in the middle of a 20m channel and could be a potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	2	2.6m		In 8m, is a potential hazard for marine traffic along the coast
H11561	3	15.9m		In 20m, and could be a potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	4	8.4m	12.8m	A potential hazard to marine traffic approaching the southwest coast of Puerto Rico
H11561	5	11.2m		In 20m, a potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	6	7.9m		In 20m, located in the middle of the entrance to a channel
H11561	7	4.1m		In 10m, at the entrance to a bay
H11561	8	11.6m		In 22m, at the entrance to a bay which leads to a possible passage.
H11561	9	13.0m		In 20m, a potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	10	14.8m		In 20m, a potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	11	9.6m	23.7m	A potential hazard to marine traffic approaching the southwest coast of Puerto Rico.
H11561	12	0.7m		In 6m, may be a hazard for local marine traffic.
H11561	13	2.8m		In 8m

Survey area	Item number	Surveyed depth	Charted depth	Comment
H11561	14	12.8m		In 22m, located at the southern side of a channel.
H11561	15	7.1m		In 22m
H11561	16	7.9m		In 22m, between charted 3.6m and 9.5m
H11561	17	7.1m		In 20m
H11561	18	10.6m		Protruding S from reef structure into a more significant channel, giving marine access to the SW coast of Puerto Rico.
H11561	19	9.7m		In 20m, at the head of a bay and at the southern side of a significant channel, giving marine access to the SW coast of Puerto Rico.
H11561	20	12.1m		SE extent of a shallow reef at the northern extent of a channel, thus giving marine access to the SW coast of Puerto.
H11562	1	14.6m		In 22m, located in a channel south of a charted 13.3m and north of a shoal coral outcrop, and would be a hazard for marine traffic approaching the SW coast of Puerto Rico.
H11562	2	13.9m	16.4m	In 22m, and would be a hazard for marine traffic approaching the SW coast of Puerto Rico.
H11562	3	13.2m		In 18m, 350m NW of a charted 12.9m.
H11562	4	14.2m		In 22m, at the entrance to a channel giving access to the SW coast of Puerto Rico.
H11562	5	11.5m		In 18m, would be a hazard for marine traffic approaching the SW coast of Puerto Rico.
H11562	6	2.9m		In 5 – 6 m, located seaward of a charted 5.4m
H11562	7	0.6m		150m W of the coast
H11562	8	1.9m	3.9m	
H11562	9	1.8m		In 4 – 5m, a hazard for marine traffic approaching the nearby township.
H11562	10	2.1m	4.5m	In 4 – 5m, a hazard for marine traffic approaching the nearby township.
H11562	11	2.2m	5.4m	In 4 – 5m, a hazard for marine traffic approaching the nearby township.
H11562	12	3.4m	5.4m	In 4 – 5m, a hazard for marine traffic approaching the nearby township, following the north coast of the bay.
H11562	13	2.8m	6.7m	In 7 – 8m, a hazard for marine traffic coming through the southern entrance.
H11566	1	3.4m		Located between a charted 9.1 and 18.2m soundings, in an approach channel
H11566	2	4.5m	18.2m	At the approaches to the channels
H11567	1	12.9m	20.1m	
Total	47			

Although this list is extensive, it has been provided in full in order to demonstrate the importance of the project and the value of the results. Knowledge of the list of significant Dangers to Navigation listed above, has subsequently reduced the risks to surface vessels operating in this area.

In addition to the specific Dangers to Navigation above, a large number of other Significant Differences between the survey and charts were also identified and reported, for each of the survey areas, as follows:

Table 5: Significant Differences between Survey and Chart

Survey area	**Number of DTONS**	**Number of Significant Differences to the chart**	**Total DTONs and Significant Differences**
H11557	0	66	66
H11558	0	78	78
H11559	1	88	89
H11560	10	106	116
H11561	20	113	133
H11562	13	101	114
H11563	0	22	22
H11564	0	54	54
H11565	0	217	217
H11566	2	122	124
H11567	1	85	86
Total	47	1052	1099

Although not as significant as the Dangers to Navigation listed in Table 4, these items of Significant Difference also demonstrate the importance of conducting modern surveys to improve the knowledge of the area and enhance navigational safety. Interestingly, the total number of Dangers to Navigation and Significant Differences totaled almost 1100 items, an average of 100 items per 1:10,000 scale sheet.

In addition to DTONs and Significant Differences, the following General Recommendations regarding differences between the survey and chart were also made:

Table 6: Other Differences between the Survey and Chart

Coastline	The charted coastline was highly generalized and differences with the survey by up to 150 m existed in some areas.
Artificial coastline	Cultural features such as buildings, wharfs and seawalls exist close to the water line which were not shown on the chart, and the MHW line differs by up to 50 meters in places.
Islets	Differ in position by up to 50 meters
Cultural features	A large number of small recreational jetties and

	some larger commercial jetties were surveyed along the coastline and were not shown, extending up to 80 meters from the coast.
Pontoon	A number of small pontoons were detected which appear to be moored permanently.
Rocks	A number of shallow ledges with drying rocks and rocks awash extend from the shore seaward. Many coral outcrops and rocks awash have been surveyed in the exposed and shallow reefs, which were not shown on the chart
Bridge	The surveyed position of a bridge differs by 30m
Wrecks	A wreck was identified in the lidar data and from imagery and it is located in very shallow water between two jetties

Some of these differences between the survey and the chart are more or less important. However they serve to demonstrate the huge amount of detail which has been surveyed which was not previously shown on the chart.

Areas Surveyed

A summary of the areas surveyed is provided below:

Table 7: Size of Areas Surveyed

Survey	**Area (sqkm)**
Puerto Rico	Nominally 675
Martinique	516
St Thomas and St John	205
St Croix	40
Guadeloupe	1,578
TOTAL	3,014

Images of the survey areas are provided below:

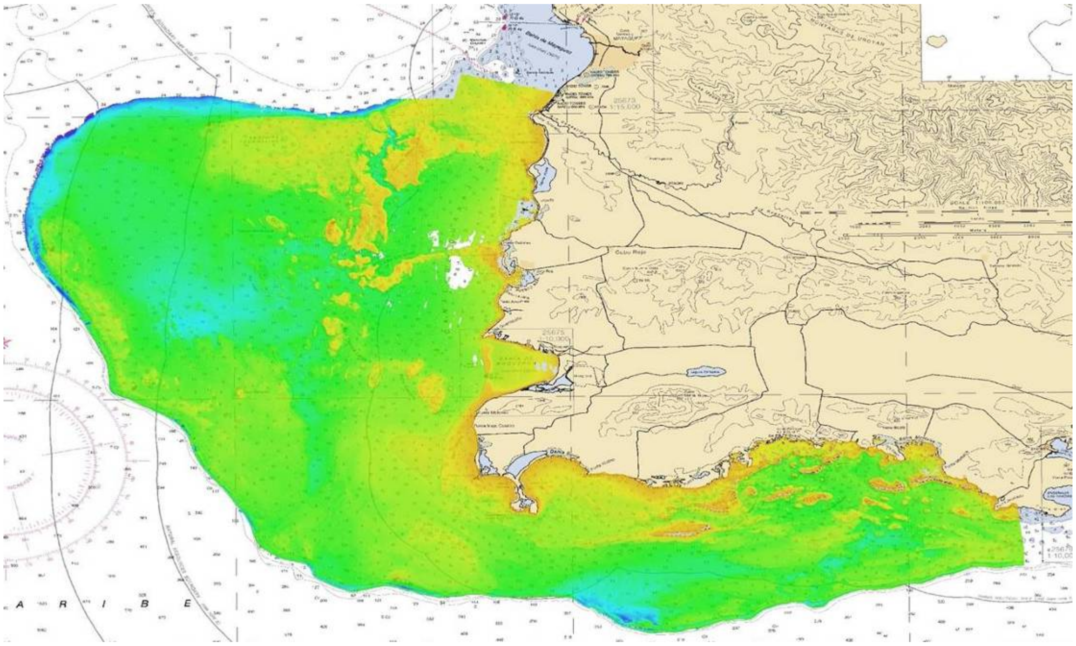

Figure 2: Puerto Rico Final Coverage

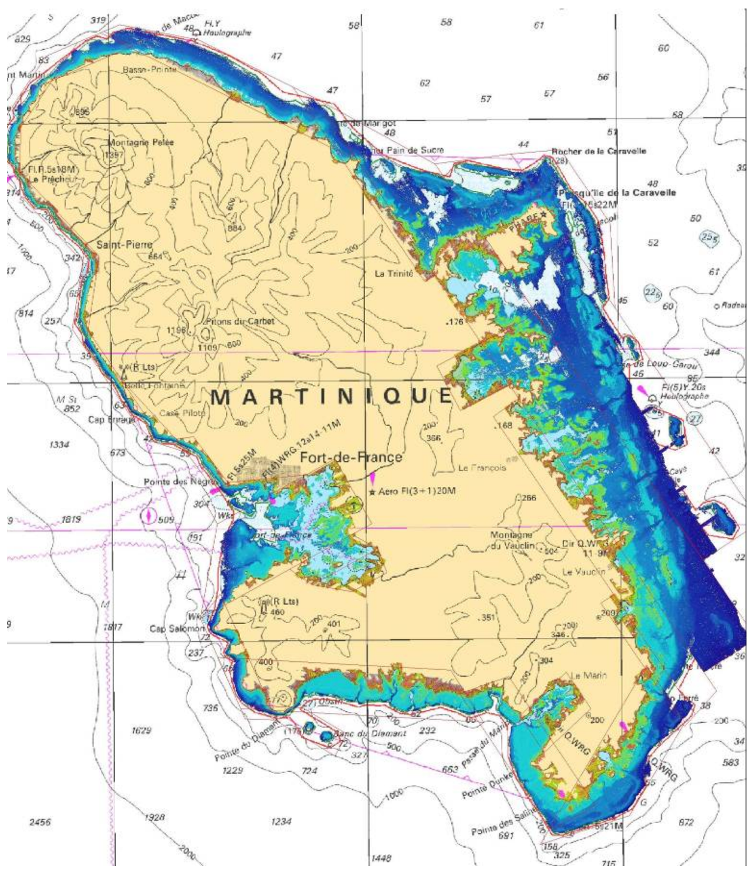

Figure 3: Martinique Interim Coverage

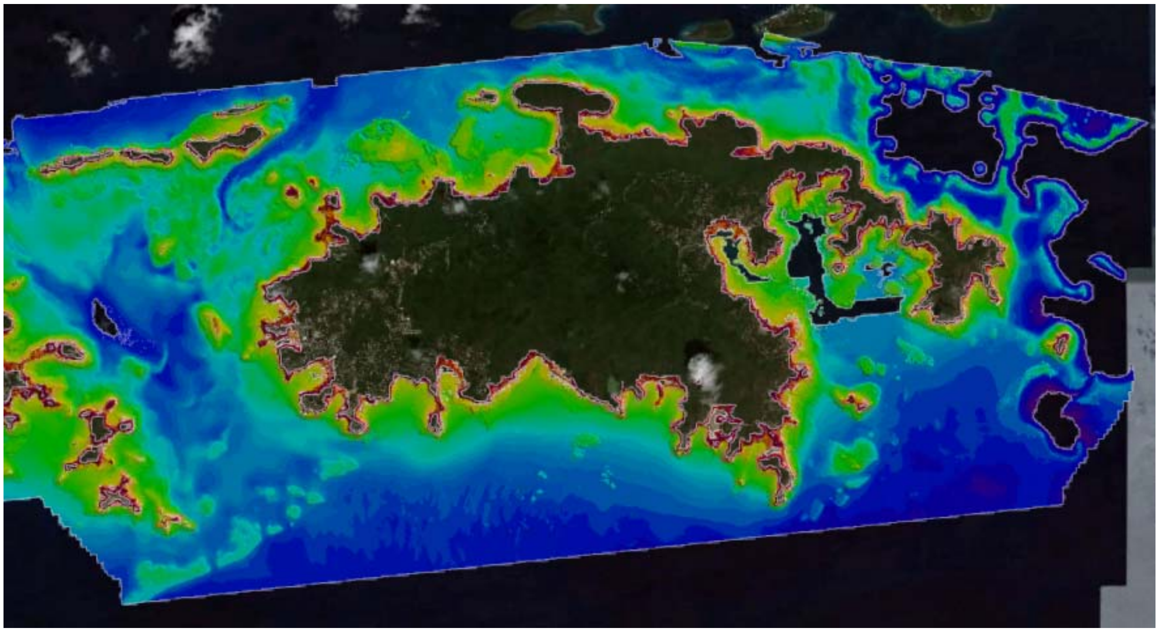

Figure 4: US Virgin Islands (St John) Interim Coverage

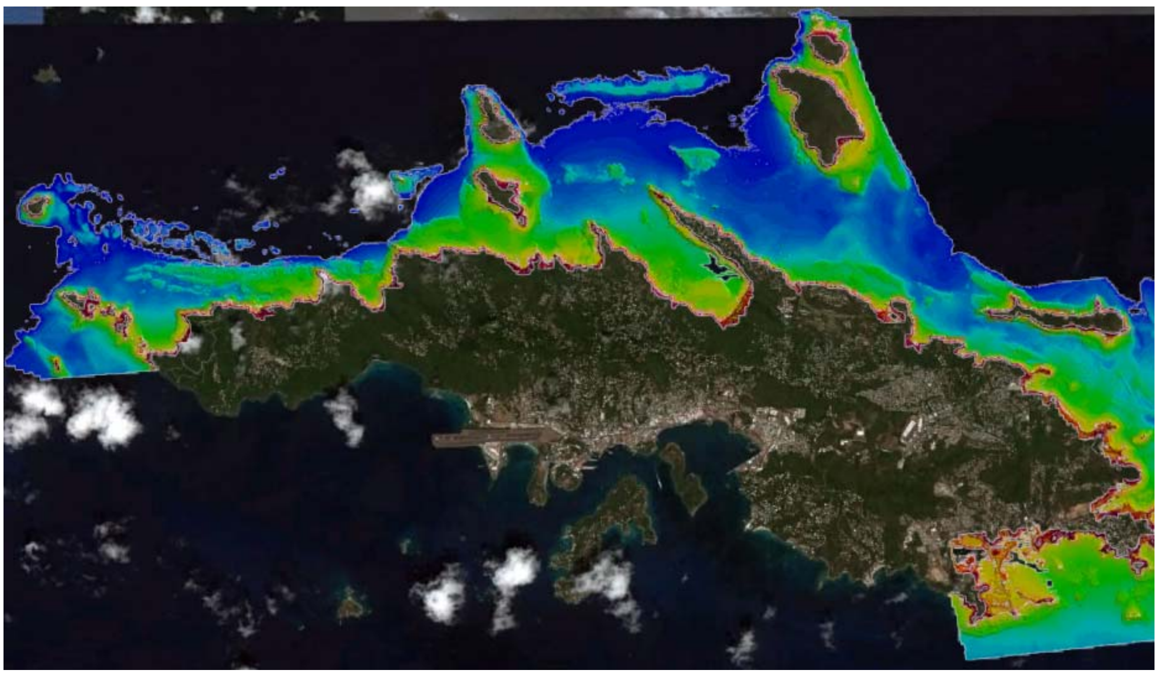

Figure 5: US Virgin Islands (St Thomas) Interim Coverage

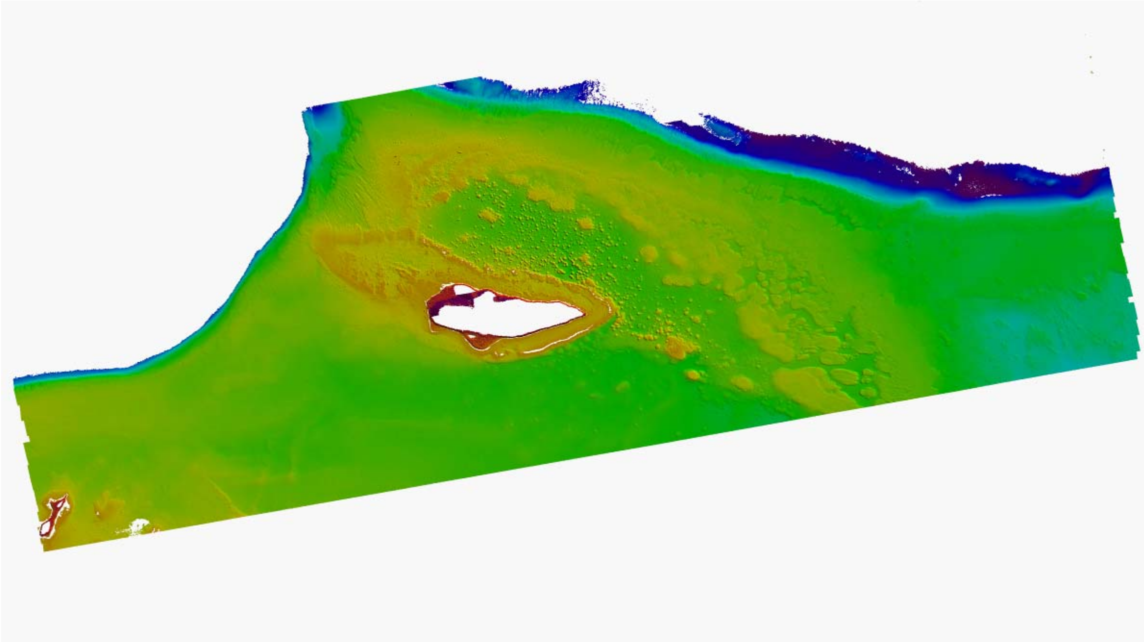

Figure 6: St Croix Interim Coverage

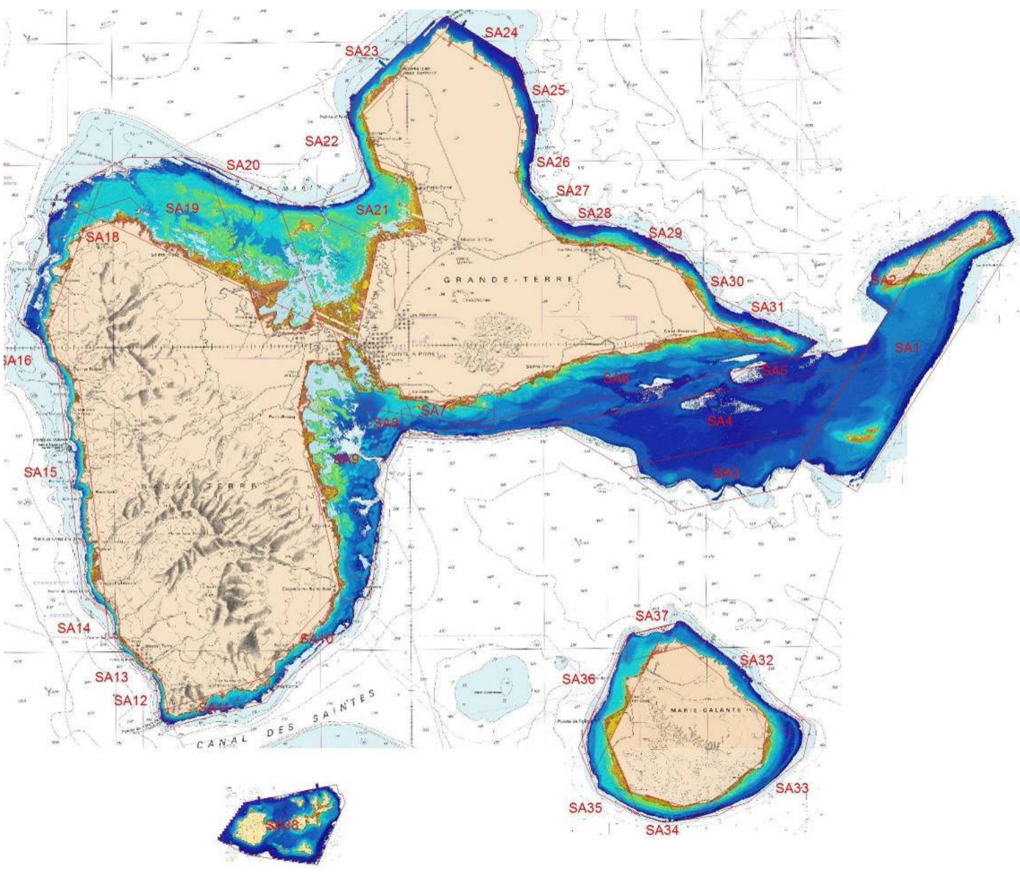

Figure 7: Guadeloupe Interim Coverage

Other data types provided from the surveys

In addition to the ALB depth data, relative reflectivity data calculated from the ALB waveforms, digital geo-referenced imagery was produced and hyperspectral data collected in the visible to near infrared spectral range.

<u>Relative Reflectivity</u>

The reflectivity of an ALB pulse represents a measure of the amount of energy reflected from the seabed for each individual laser pulse at the wavelength of the laser, 532 nm (green/blue).

The basic difference between processing an ALB waveform for depth and reflectivity is that depth processing focuses on the leading edge of the return waveform and reflectivity requires the entire return pulse from the seabed to be integrated. The two figures below show the time domain calculation required for depth calculations between the waveform returned from the sea surface and seabed and, secondly, the integration of the waveform from the seabed to calculate the energy reflected from the seabed

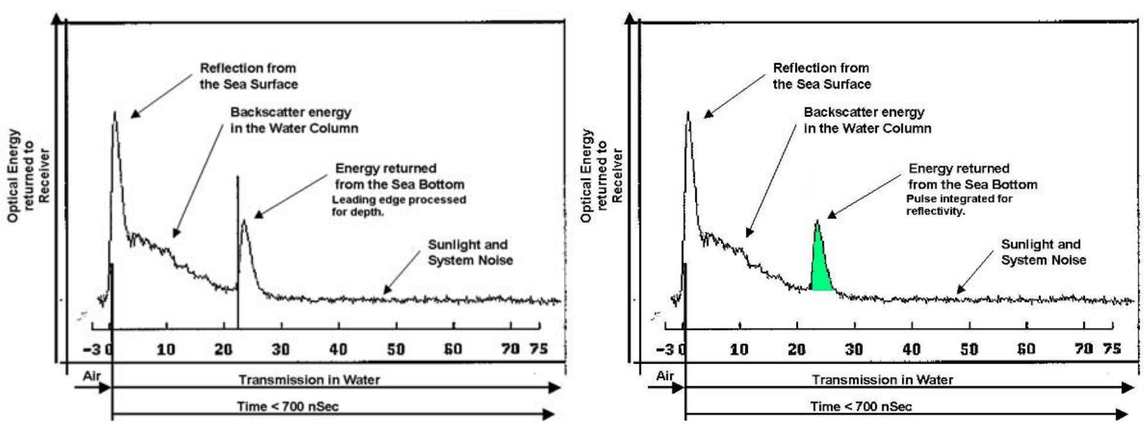

Figure 8: An example of the methodology for processing ALB waveforms for depth (left) and reflectivity (right)

There has been a growing trend in recent years to enhance ALB data with complimentary datasets such as reflectivity. This reflectivity data can then be analyzed to determine a map of optical diversity that identifies seabeds of similar optical response. This data can then be supplemented with an additional seabed sampling campaign, to produce a classified map of the seabed identifying different bottom types that are useful for habitat mapping applications (Collins, Penley and Xavier, 2007).

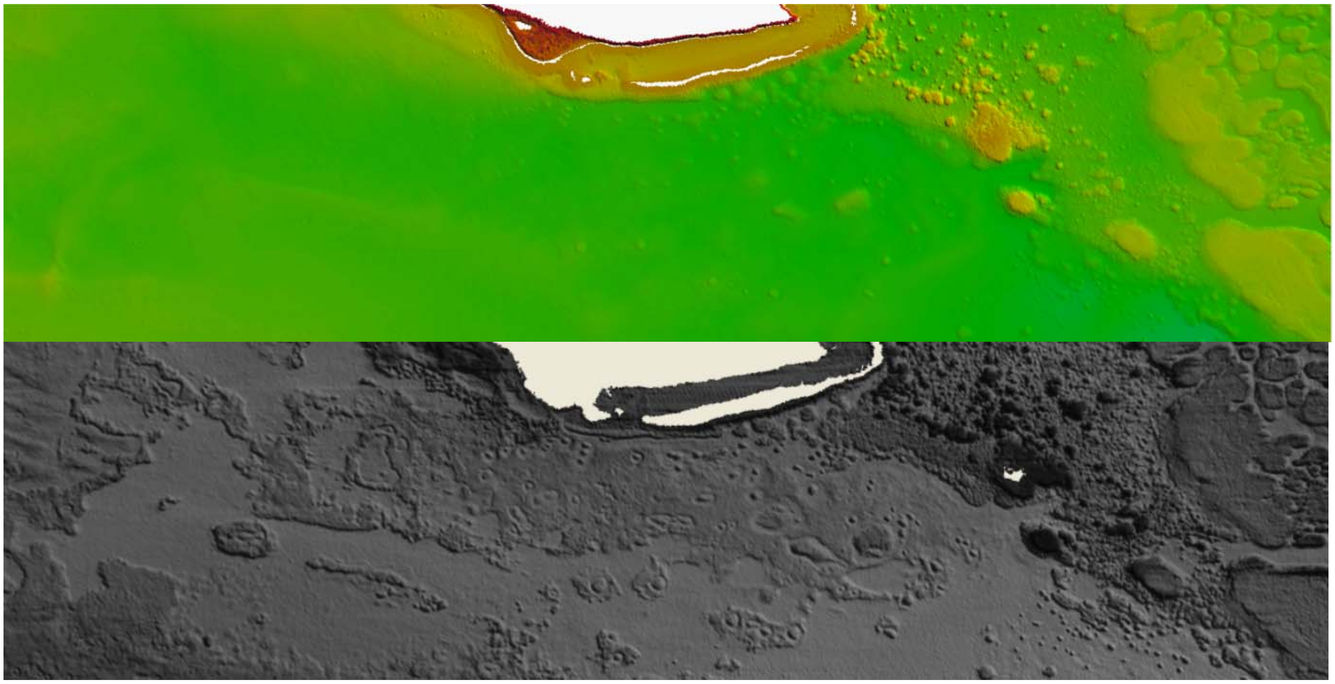

Figure 9: An example of the Relative Reflectivity from the St Croix Survey (Bottom) and corresponding bathymetry (Top)

Georeferenced Imagery

Digital still photographs are captured via a camera system integrated with the ALB sensor which is bore-sighted with the laser sensor. Images are generally captured at 1-second intervals with the actual geographic extent of the image related to aircraft height. These individual are georeferenced and can be mosaicked together to create a continuous georeferenced image of the survey area. The final resolution is nominally 25-40cm per pixel (though this varies dependant on survey height) and an accuracy of 5m CEP. These images are used during quality control for the bathymetric survey, and have also been provided to the customer in order to provide imagery to delineate cultural features.

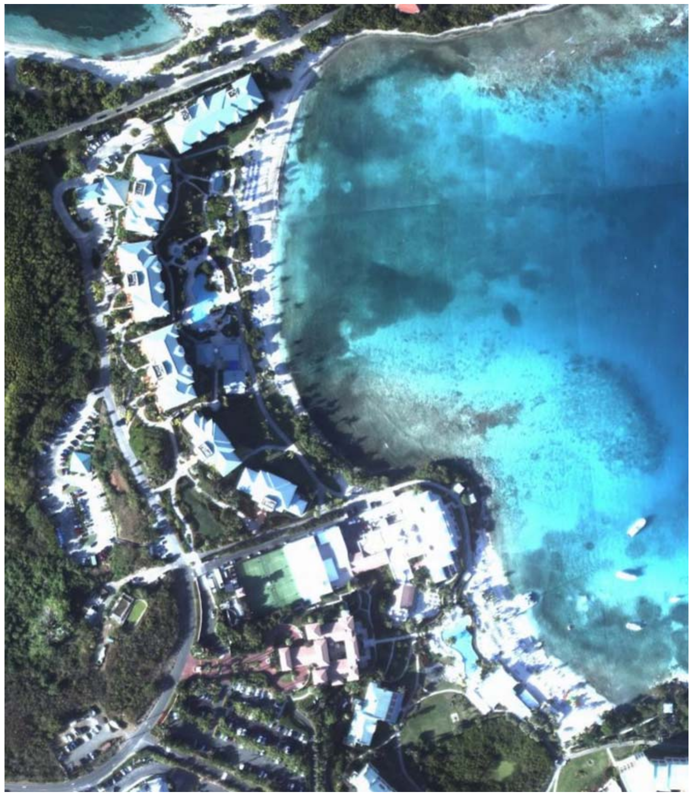

Figure 10: Example of the Mosaicked Georeferenced Imagery generated from multiple flight lines from the US Virgin Islands survey

Hyperspectral Data

Hyperspectral data was collected during the Martinique, Guadeloupe and St Croix surveys. The imagery was collected using a NEO Hyspex VNIR-1600 sensor which has a wavelength range from 400 to 1000 nm. For the three surveys the imagery was collected using an 80 band configuration resulting in 7 nm spectral resolution approximately. As the hyperspectral was collected simultaneously to lidar operations, lidar survey altitude and speed was the controlling factor in regards to hyperspectral spectral resolution and swath width. At lidar survey altitude and speed the HS imagery spatial resolution was approximately 1m with a swath width of 300m.

For the Martinique survey only HS data was also collected at a higher altitude. The imagery acquired at 2500m was collected in the 160 band configuration resulting in spectral resolution of 3.5nm. At 2500m survey altitude the resulting spatial resolution and swath width are 2m and 1500m respectively.

As procurement of the HS sensor occurred immediately before the Martinique survey, there were some growing pains with the implementation of the new sensor. One issue of note was observed a few flights into the survey where stripes were observed in the collected imagery. The positioning of the stripes was dynamic and would migrate from one survey flight to the next. The sensor was returned to NEO for inspection where it was discovered that the glass grating inside the camera had cracked and glass shards had fallen into the imaging field of view. Replacing the grating and cleaning the sensor's internal components temporarily resolved this issue. After subsequent flights additional stripes were observed in the imagery which were related to dust particles that had also settled on the slit. The solution was an additional visit to the NEO office where the sensor underwent a thorough cleaning.

Issues were also experienced relating to the positioning and inertial reference unit that was used for positioning the HS system. The IMAR ITrace IMU used in the recommended configuration relied on OmniSTAR for both positioning and inertial measurements as the inertial solution was GPS integrated. Unfortunately, in the standard configuration, a consistent lock on the OmniSTAR L-band signal could not be achieved resulting in correction dropouts that affected the positioning and attitude accuracy. After being unable to resolve the dropout issue a move to a post processed GPS and inertial solution was made that has resulted in a better accuracy and stable positioning solution.

Operating in the Caribbean with a passive imaging sensor such as HS is made difficult most of the year by prevailing weather patterns. The surveys conducted by Fugro in the Caribbean suffered several periods of unsuitable weather for HS acquisition because of widespread cloud cover that would start to build early in the day in close proximity to the shoreline. Appropriate acquisition windows were made shorter by considerations of sun angle and tide regime.

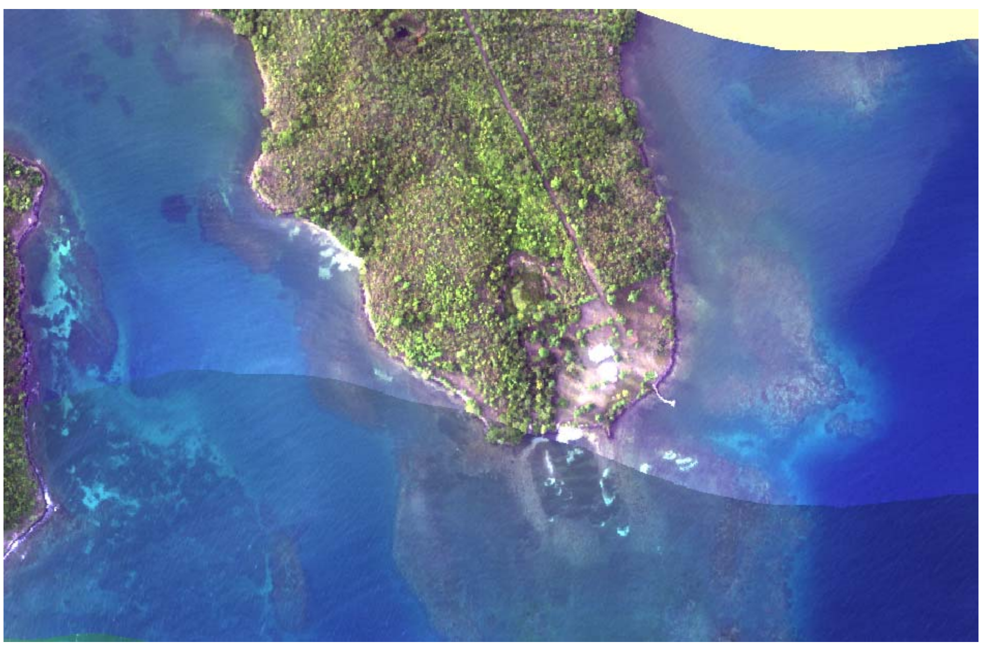

Figure 11: An example of the hyperspectral data from two adjacent lines collected over Martinique, only a composite RGB image is presented above; however a continuous sample of the spectrum from 400 to 1000 nm has been captured and stored within the image file structure.

Future Requirements and Initiatives

Requirements of airborne lidar bathymetry technology during its early development were to provide a safe and efficient means of mapping the seabed, primarily for nautical charting. Whilst this requirement has remained, other user requirements have emerged, especially in coastal zone management and habitat mapping domains. The surveys Fugro have completed in the Caribbean thus far are a testament to this as they demonstrate the initiative of the customer to utilize ALB data to its full potential and multiple applications.

As coastal areas throughout the world are faced with an increasing number of challenges, international funding agencies such as the World Bank and the UN Development Program are taking notice and currently developing mapping programs that require ALB technology to map coastal zones for disaster risk management and costal resources management.

Another initiative of agencies that are responsible for managing coastal environments is the combined use of airborne topographic and bathymetric lidar to develop accurate, seamless models of the coastal zone across the land-sea interface. This approach has been pioneered in landmark projects in both Australia where the entire Victorian coastline was mapped (Sinclair and Quadros, 2010), and in America where the entire West coast of the United States was mapped. Similar mapping programs are also being replicated in other countries. Combined with high-resolution airborne imaging sensors, this unique and comprehensive geospatial dataset supports research and policy decisions for a variety of needs, including: coastal and marine spatial planning, land use management, coastal erosion, marine fisheries management, transportation and shipping coordination, and modeling of sea-level rise, storm surges and tsunami for risk mitigation.

These current trends in the market also indicate a wider adoption of the technology, and have ensured that ALB systems continue to be developed in order to meet these broadening requirements and uses. Examples of this are the simultaneous collection of georeferenced imagery and hyperspectral data, along with the development of seabed reflectivity for habitat mapping applications. These initiatives have all been implemented from user requirements.

Conclusion

Through the surveys and case study described above, it can be demonstrated there are many applications for ALB surveys within the coastal environment that benefit a wide range of users in the Caribbean.

The benefits and advantages of ALB technology for nautical charting applications in the Caribbean near-shore/coastal environment are highlighted here by the number of Dangers to Navigation that were identified in Puerto Rico which have subsequently reduced the risks to surface vessels operating in the area, enhancing navigational safety and demonstrating the detail that can be surveyed using ALB. Additionally, initiatives made by coastal management agencies for using airborne topographic and bathymetric lidar to develop accurate, seamless models of the coastal zone have also helped these agencies understand and manage the coastal zone.

However ALB systems are no longer just tools for measuring ocean depth, but also capable of collecting additional datasets including reflectance, georeferenced imagery and hyperspectral data that allows more applications to be considered including habitat mapping. Fugro's ALB systems have been continually developed to provide these broadening user requirements, which are particularly suited to meet the inshore survey requirements in the Caribbean.

The majority of the Caribbean projects described here have been managed almost as one large data collection campaign whereby these large coastal surveys in a similar geographic region were conducted concurrently through the flexibility that ALB technology allows. Fugro's understanding of the environmental conditions in the area was essential in managing these projects and highlights the benefits of utilizing alternative areas that are in close proximity of each other.

References

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