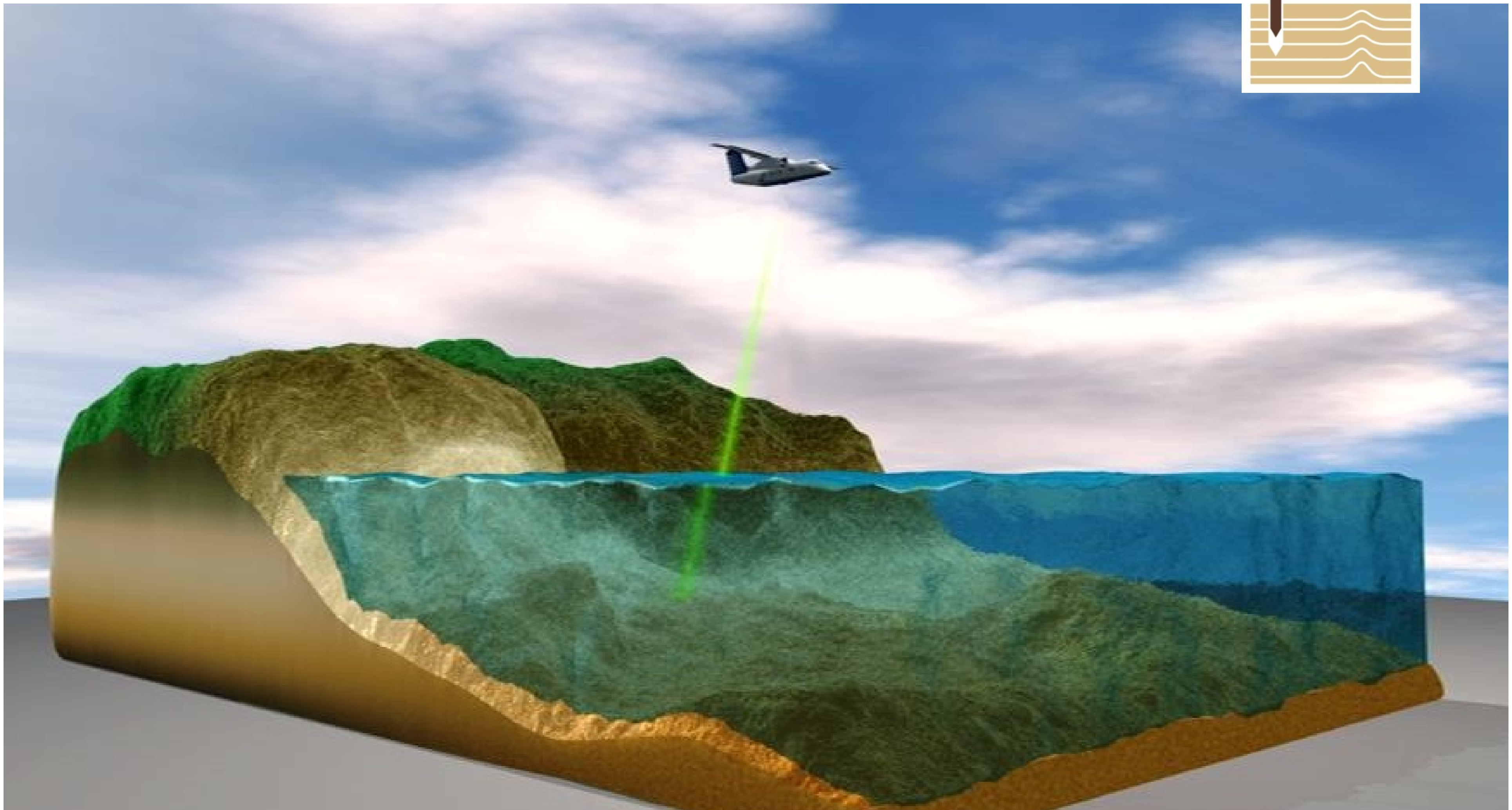
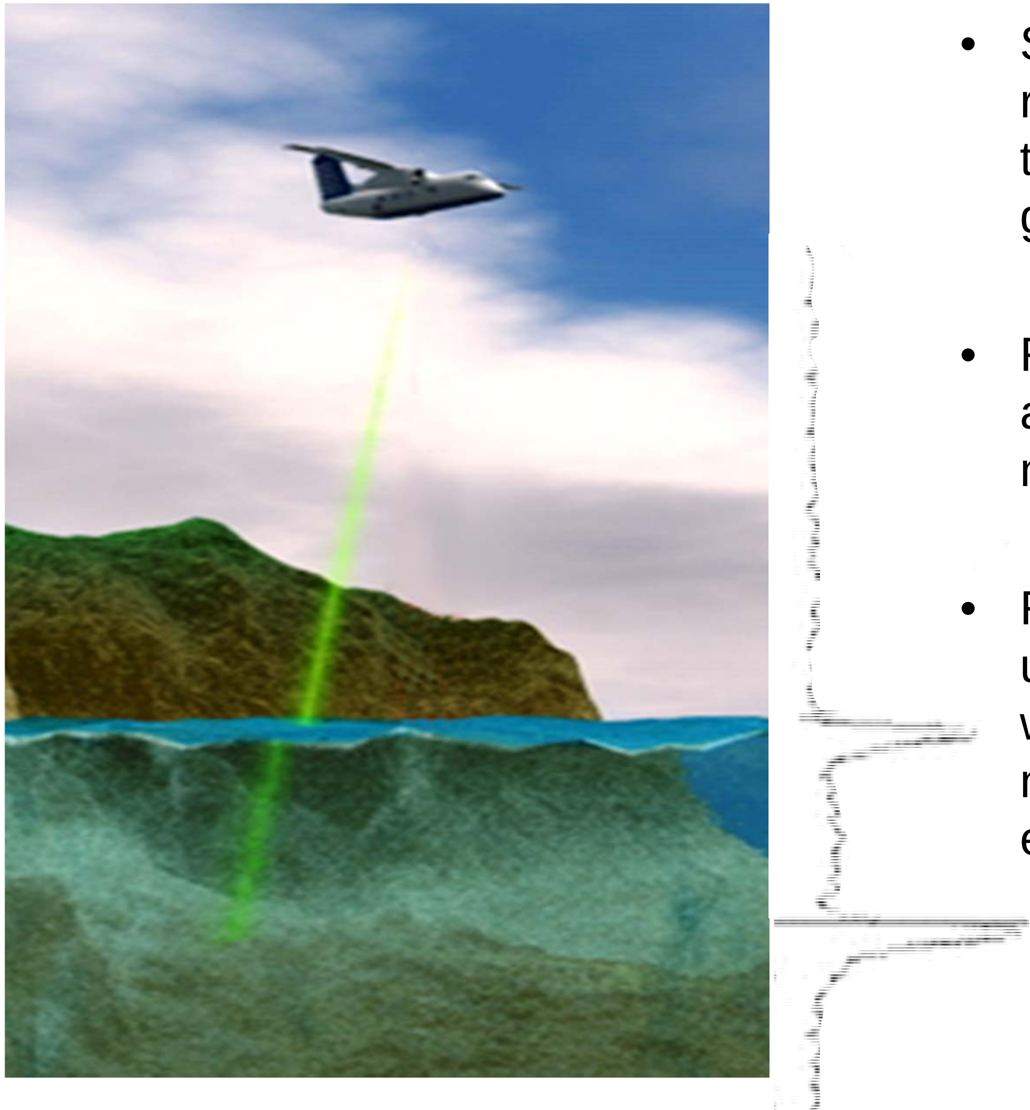


Airborne LiDAR Bathymetry Technology and Sensors

Hugh Parker, Fugro, 20 June 2017

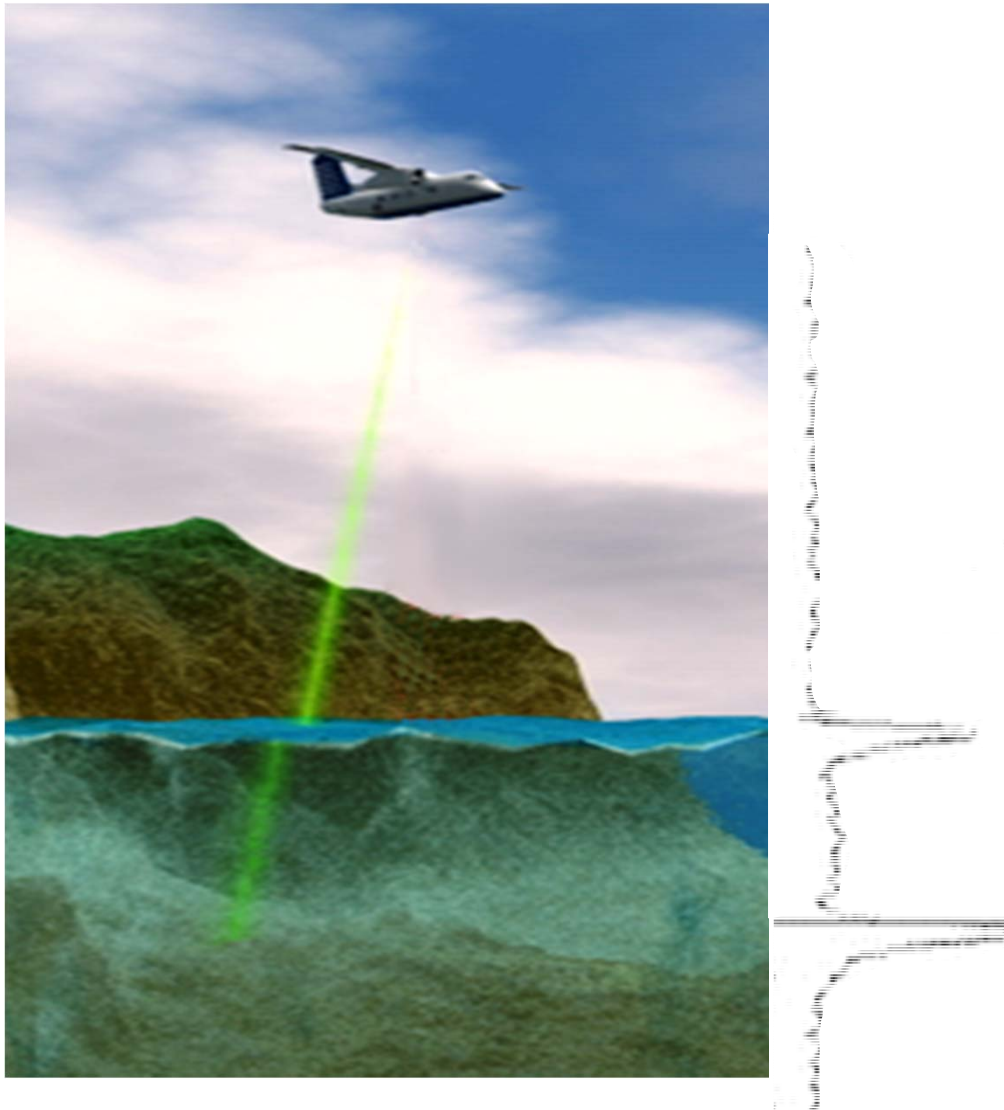
Introduction

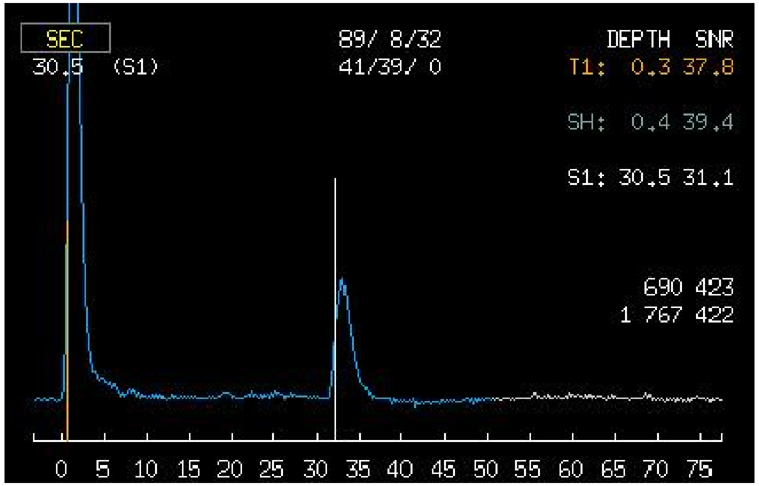
Overview of Technology

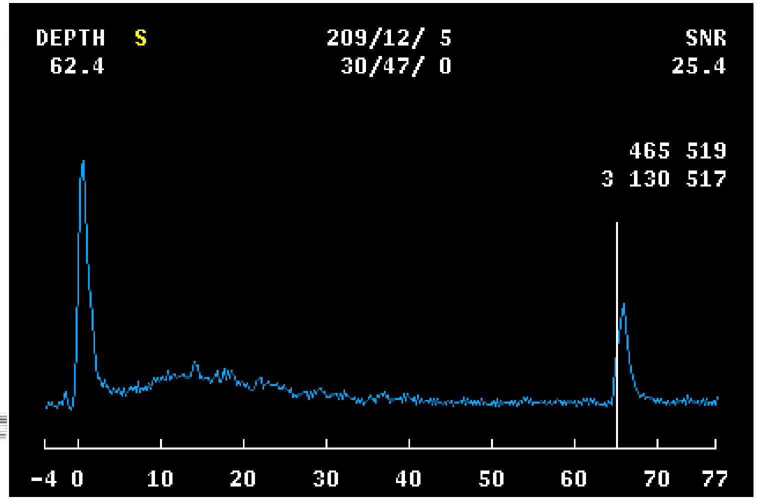


- Scanned green beam (532mn), reflects from the sea surface and the seabed, and is detected by the green receiver.
- Reflections from the sea surface are used to create a sea surface model
- Reflections from the seabed, are used to determine the depth of water, relative to the sea surface model or measured from the ellipsoid

Overview of Technology







Brief History of ALB

1960s – Concepts for defence applications (submarine detection)

1970s – First tests (US, Australia, Sweden, Canada, Soviet Union)

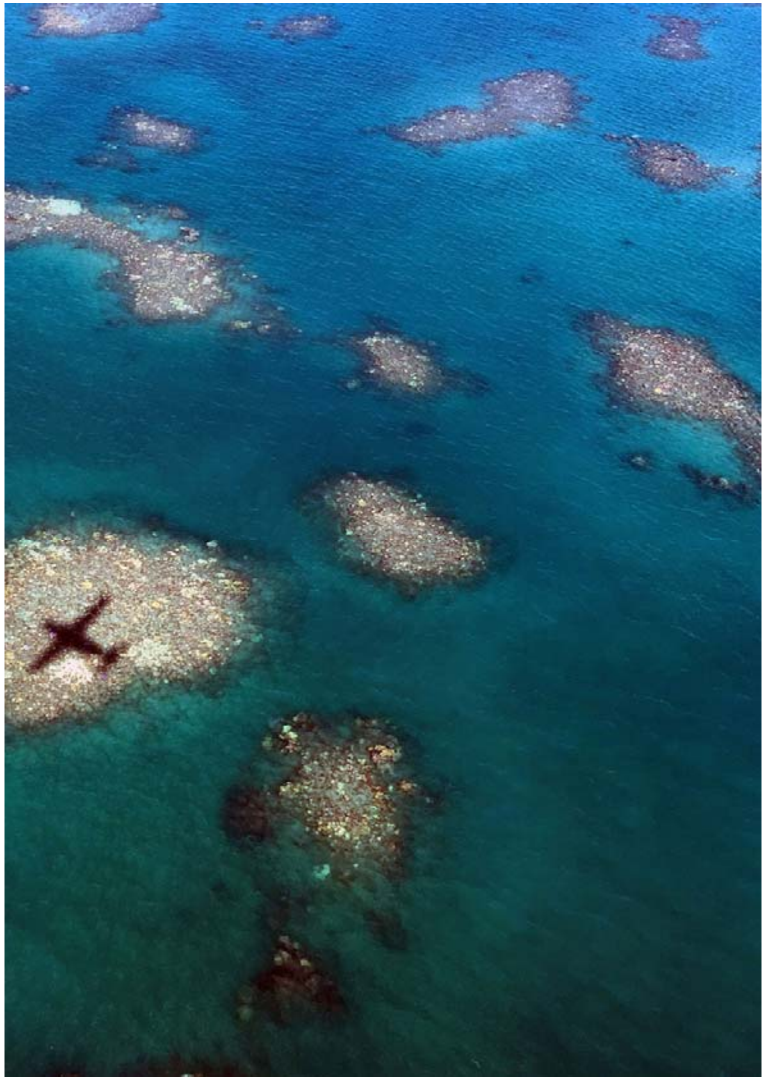
1980s – First developed systems

1990s – Operations commence for charting utilising first generation sensors…

(late 1990s) – Commercial operations start

2000s – greater use of commercial operations, further sensor developments

2010s – Development of new (smaller, low power sensors



Overview of sensors

There are now 2 types of ALB systems in production/operation:

1. **Traditional "Deep Water" Bathymetric LiDAR Sensors with High Power / Lower PRF**

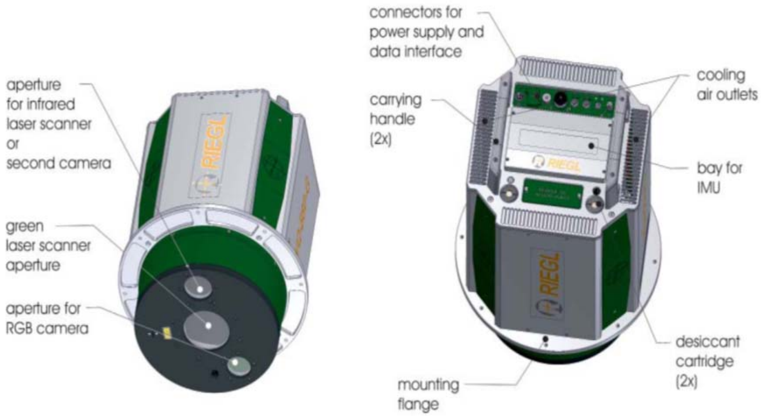
Examples: Fugro LADS HD (Mk 3 / Mk 2 / Mk 1)
Teledyne Optech CZMIL Nova, deep channel (SHOALS)
Leica Hawkeye III (HE II / HE I)

2. **Topo / Bathy "Shallow Water" Sensors with Low Power / Higher PRF**

Examples: Leica Chiroptera II
Riegl VQ-820-G and VQ-880-G
Teledyne CZMIL Nova, shallow channel
USGS EAARL-B

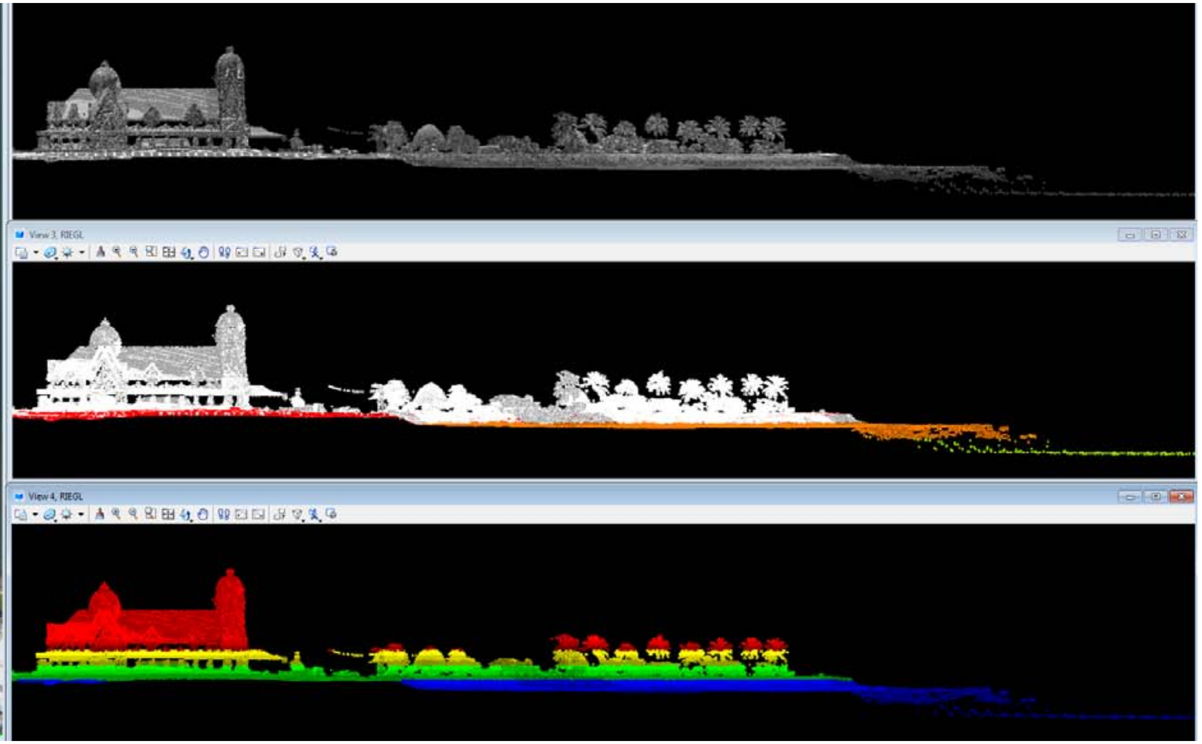
Reference: Quadros, N., 2013, LiDAR Magazine • Vol. 3 No. 6, "Unlocking the Characteristics of Bathymetric LiDAR Sensors"

Fugro's "LADS HD" High Powered ALB system



Riegl "VQ-880-G" Low Powered ALB System

Overview of sensors – Shallow Water Systems



Topo/Bathy (Shallow Water) ALB Sensors

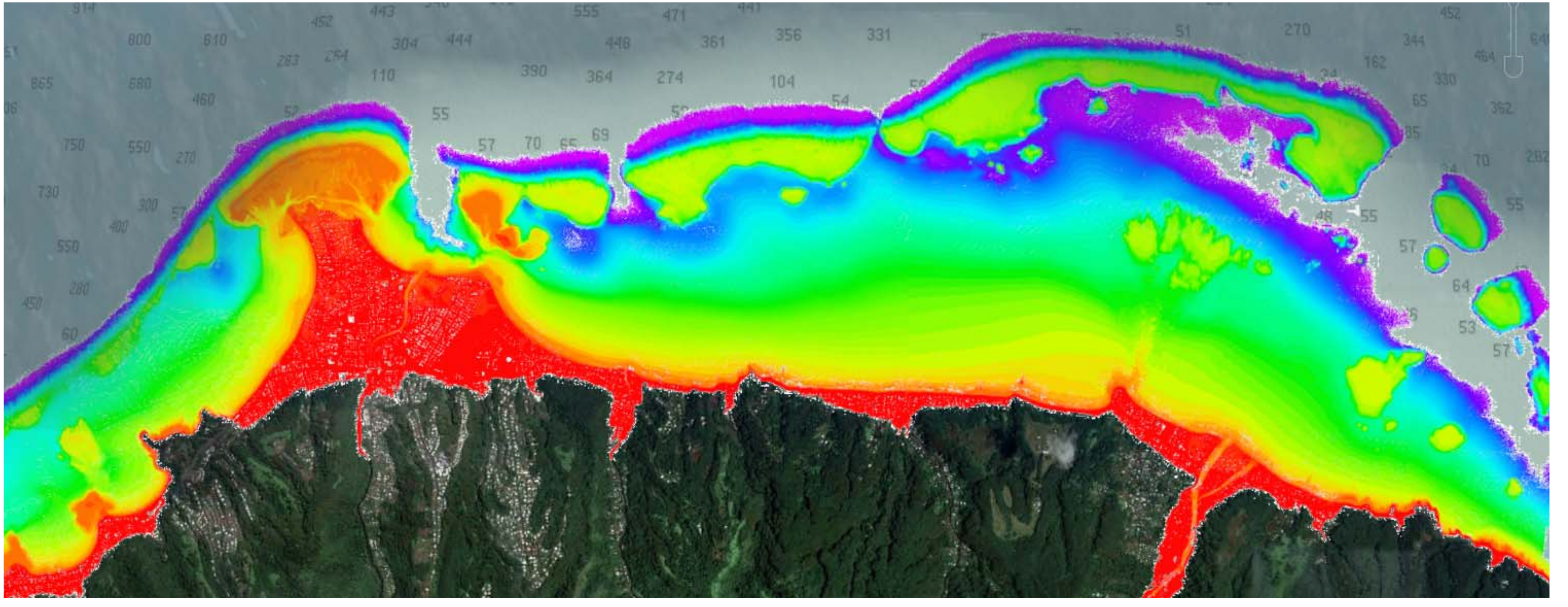
1. <u>Pros</u>:

   High Frequency/High resolution/small footprint, smaller units for installation

2. <u>Cons</u>:

   Lower power, Limited depth performance, 1 – 1.5 x Secchi Depth

Overview of sensors – Deep Water Systems



Deep Water Bathymetric LiDAR Sensors

1. <u>Pros</u>:

   High power, Greater depth performance, 2 – 3 x Secchi Depth

2. <u>Cons</u>:

   Low Frequency/lower resolution/larger footprint, Larger units for installation

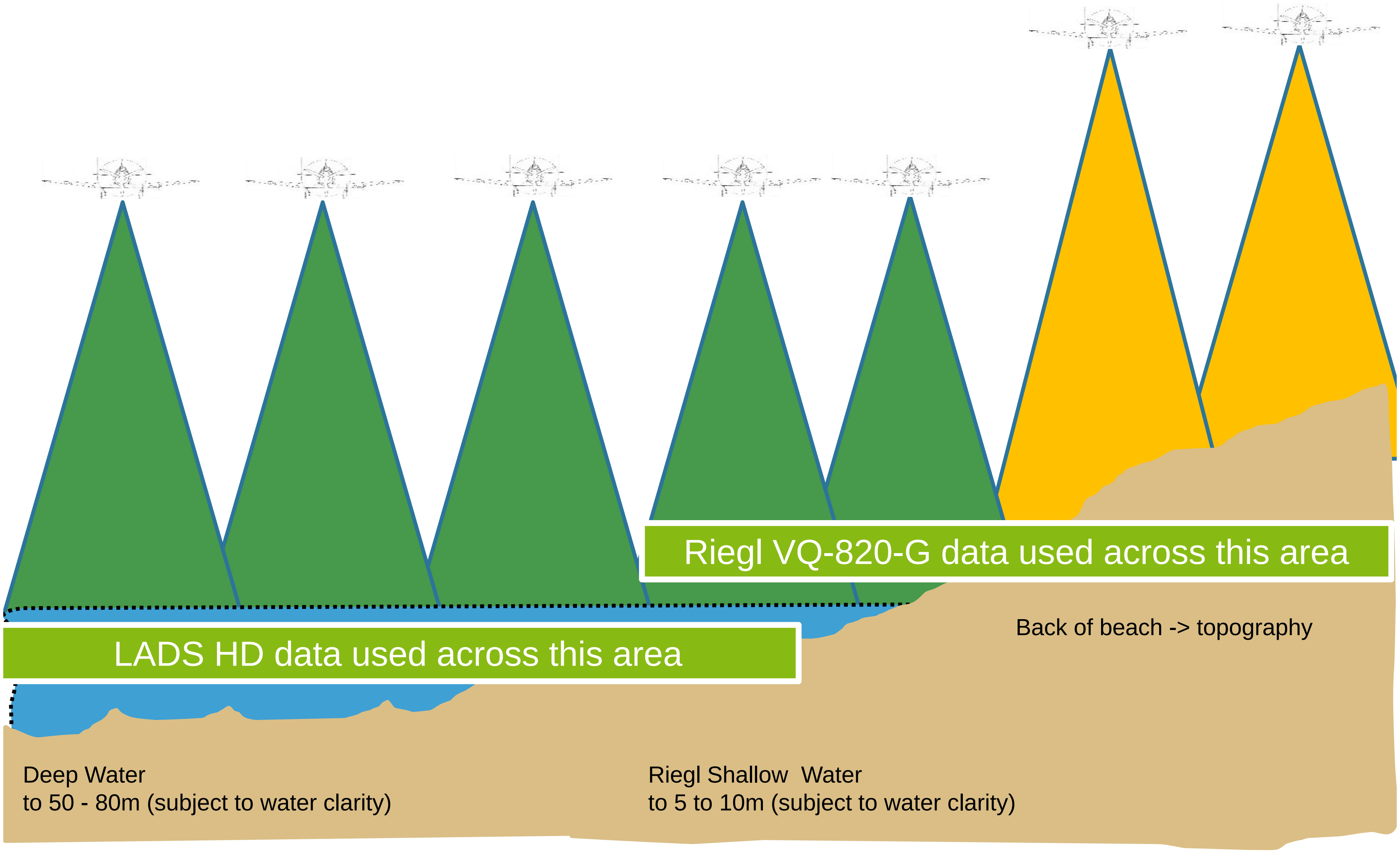
Multi-sensor operations

Common practice is to nowadays undertake ALB surveys using both type of sensors, for example:

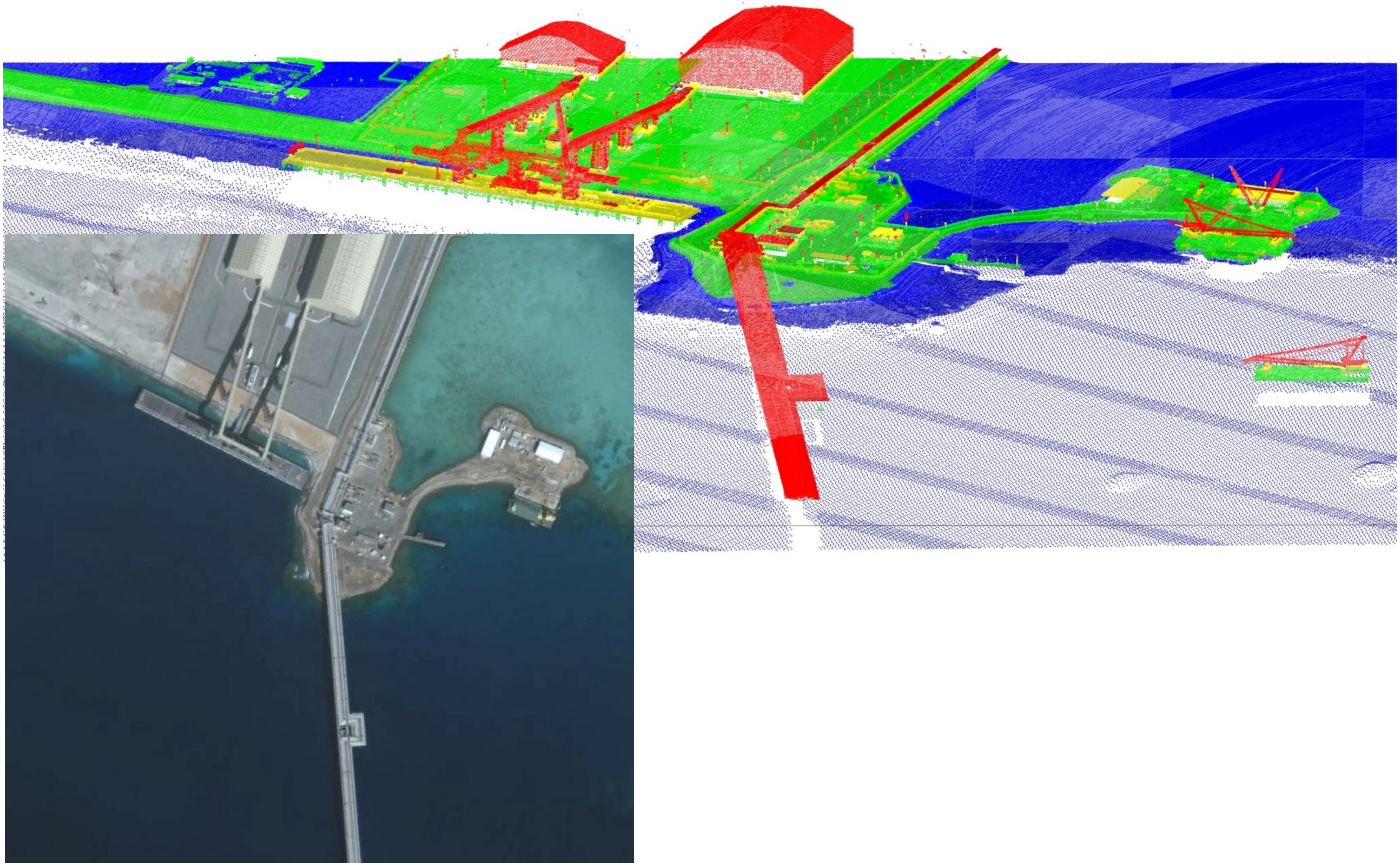
1. **LADS HD**
   - 7mj Laser Power
     - Depth performance to 80m in best conditions (3 x Secchi disk)
   - High Data Quality
     - Wide Aperture Receiver
     - Automatic Gain Control - for optimised signal return
   - Efficient data collection
     - Operating heights from 1200 – 3000 feet
     - 2x2 to 3.5x3.5 m spot spacing;
     - Roll and off-track compensation

2. **RIEGL VQ-820-G**
   - High spatial resolution
     - Variable resolution up to ~8 points / m^2
   - Depth performance to 5-15m in best conditions (1 x Secchi disk)

Multi-sensor operations

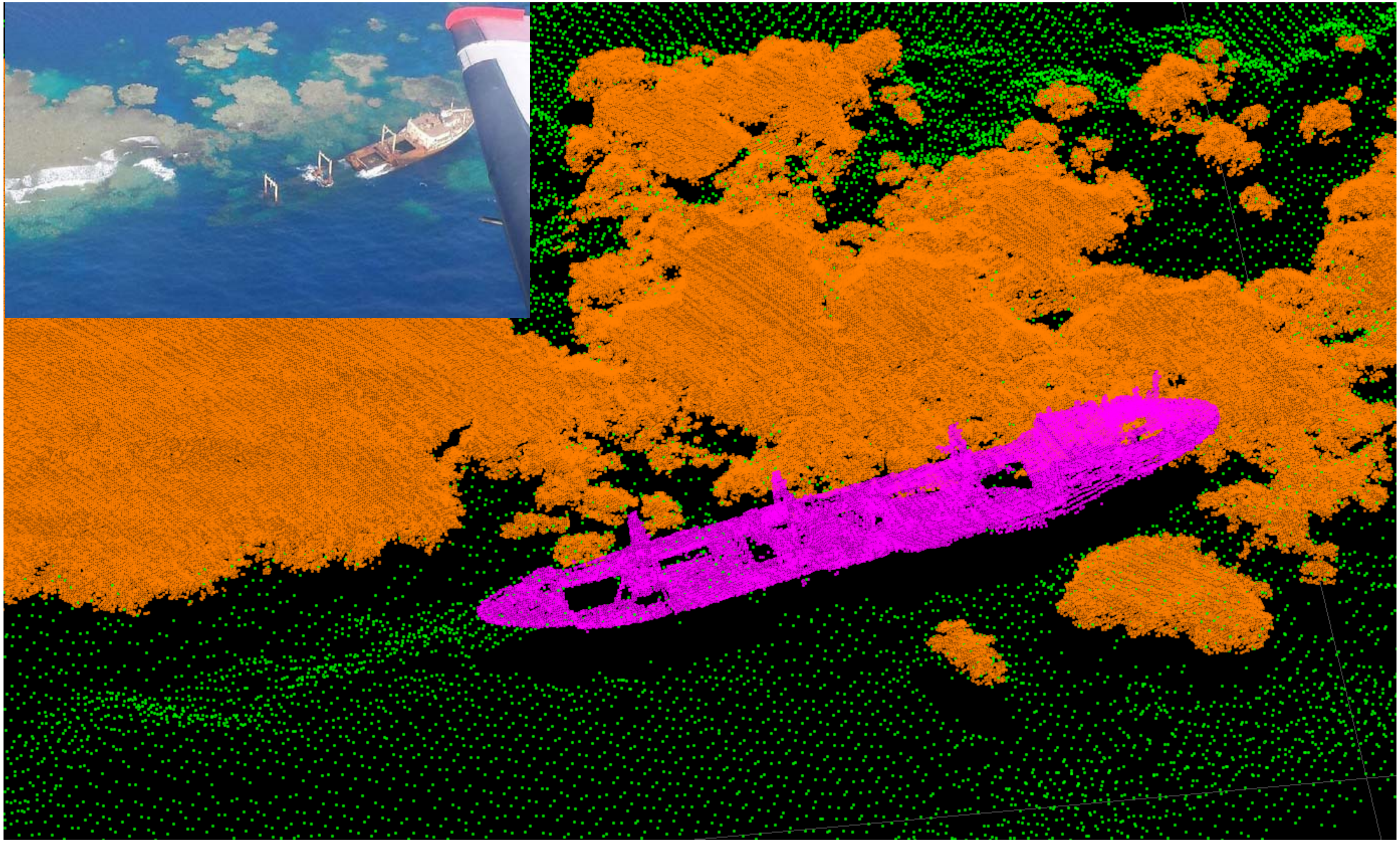


Example of Merged Deep and Shallow Water Sensors Data



Example of Merged Deep and Shallow Water Sensors Data

Example of Merged Deep and Shallow Water Sensors Data



Current IHO S-44 Specifications for LiDAR

S-44 - Table 1:
Minimum spot spacing for bathymetric LIDAR is included in Table 1 for Order 1b surveys where *full sea floor search* is not required. (5x5m resolution)

Guidelines for Quality Control (Annex A):
Section A.3.4 - Bathymetric LIDAR: Hazards to navigation detected by bathymetric LIDAR should be examined using a bathymetric system capable of determining the shallowest point according to the standards set out in this document.

Side note: ***C-13 (Manual for Hydrography) References***

Chapter 3: Depth Determination

- *Incl. Section 6.1 (Non-acoustic systems)*

Chapter 4: Seafloor Classification and Feature Detection

- *Incl. Section 2.3.15.1 (Other methods for Feature Detection)*

"ALB systems such as LADS Mk.2 and CHARTS are capable of a full area search and of detecting features two metres square. This means they can meet IHO standards in clear waters suitable for ALB operations"

IHO Standards – Feature Detection

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS (S-44)
5th Edition February 2008

TABLE 1
Minimum Standards for Hydrographic Surveys
(To be read in conjunction with the full text set out in this document.)

Reference	Order	Special	1a	1b	2
Chapter 1	**Description of areas.**	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but *features* of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	**Maximum allowable THU 95% *Confidence level***	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	**Maximum allowable TVU 95% *Confidence level***	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	***Full Sea floor Search***	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	***Feature Detection***	Cubic *features* > 1 metre	Cubic *features* > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	**Recommended maximum Line Spacing**	Not defined as *full sea floor search* is required	Not defined as *full sea floor search* is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	**Positioning of fixed aids to navigation and topography significant to navigation. (95% *Confidence level*)**	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	**Positioning of the Coastline and topography less significant to navigation (95% *Confidence level*)**	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	**Mean position of floating aids to navigation (95% *Confidence level*)**	10 metres	10 metres	10 metres	20 metres

Reference: IHO, 2008, IHO Standards for Hydrographic Surveys, 5th Edition

Challenges using ALB - Ensuring data quality

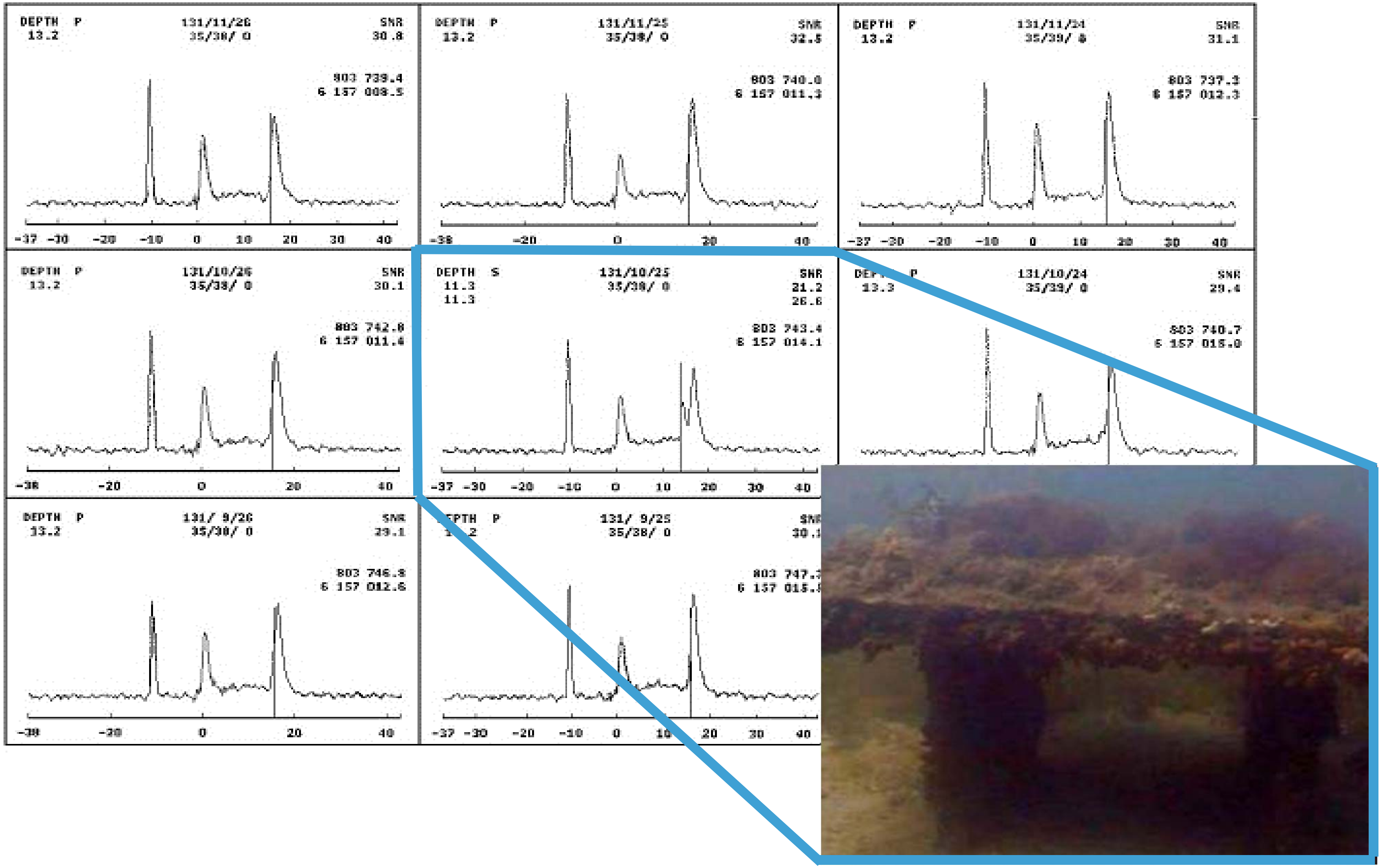
LiDAR Bathymetry data is only as good as the quality of the data collected (reflection of the seabed), and the processing of the raw laser waveforms. Data quality is affected by the following environmental and technical variables:

- Environmental
  - water clarity
  - seabed reflectivity
  - Depth of water
  - Time of day
  - Operating altitude

- Technical
  - laser power and receiver aperture
  - gain applied to the return signal
  - Data processing algorithms

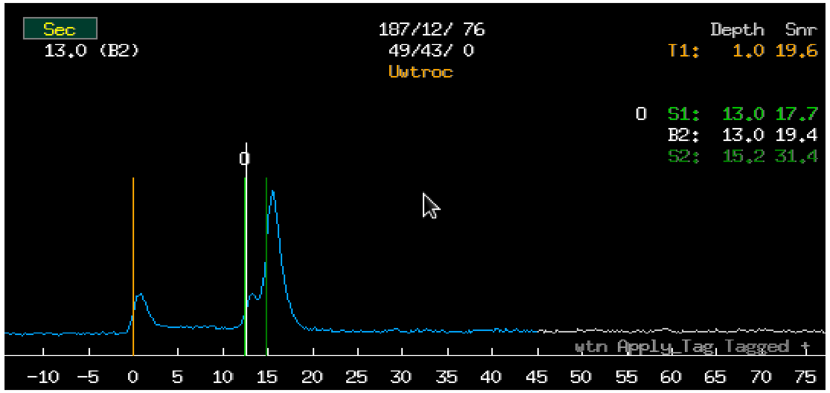
The ability to detect targets using ALB is also therefore affected by all of these factors.

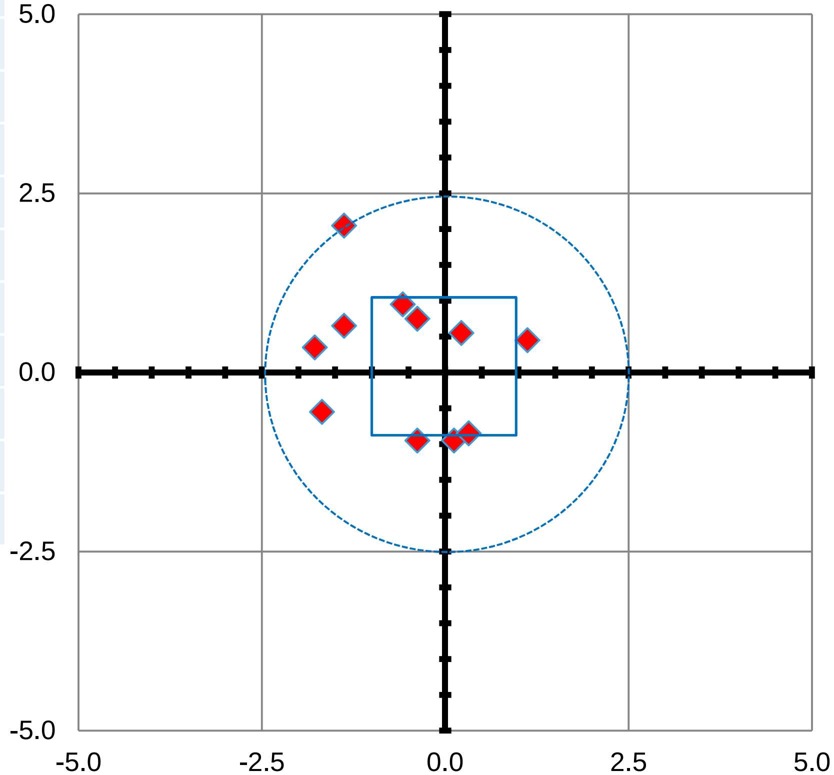
Results from trials – Target detection



Results from trials – Target detection

	Easting	Northing	ΔE	ΔN
Absolute Position	**423728.82**	**2857523.75**		
Line 1	423728.6	2857523.2	0.22	0.55
Line 2	423727.7	2857523.3	1.12	0.45
Line 3	423730.5	2857524.3	-1.68	-0.55
Line 4	423730.6	2857523.4	-1.78	0.35
Line 5	423730.2	2857523.1	-1.38	0.65
Line 6	423728.7	2857524.7	0.12	-0.95
Line 7	423729.4	2857522.8	-0.58	0.95
Line 8	423730.2	2857521.7	-1.38	2.05
Line 9	423728.5	2857524.6	0.32	-0.85
Line 10	423729.2	2857523	-0.38	0.75
Line 11	423729.2	2857524.7	-0.38	-0.95
Mean			**-0.53**	**0.22**
Std. Dev.			**0.94**	**0.95**





ALB Error Sources

Accuracy requirements for IHO Order 1 hydrographic surveys utilising ALB can simplified as follows:

- <u>Vertical</u>: total of ±0.50 m (95%) from all sources,
  - Sensor, tides or GNSS heighting (post processing) + separation model, swell and sea state…

- <u>Horizontal</u>: total of ±5.0 m (95%) from all sources
  - Sensor: including platform, optical alignment, sensor mounts, laser footprint; sea state, , lever arm offsets, GNSS positioning (post processing), IMU error sources…

Though it is the sensors technology and the settings/parameters of the sensor (and how it is used) that has most impact on the final accuracy of a survey. Considerations as follows:

- Laser frequency
- Sounding resolution
- Processing parameters
- Water clarity
- Laser power
- Laser beam footprint
- Signal to noise ratio
- Seabed reflectivity

Considerations for LiDAR Specifications

Sensor specifics

Higher laser power =	greater depth performance (2-3 secchi disc) lower frequency and resolution larger laser footprint (low fidelity)
Lower laser power =	lower depth performance (1 secchi disc) higher laser frequency and resolution smaller laser footprint (high fidelity)
Feature Detection:	Need to ensure full seafloor illumination with consideration of laser beam width and resolution of the survey
Water Clarity and Seabed reflectivity…	Lower powered sensors are affected as much, or perhaps more so by these environmental conditions due to their lower laser power Results in noisier data with gaps in shallow water in poorer conditions.

Thankyou

Questions?

Hugh Parker
Hydrographic Survey Business Development Manager
Email: h.parker@fugro.com