Unclassified

Undersea Search and Sensors

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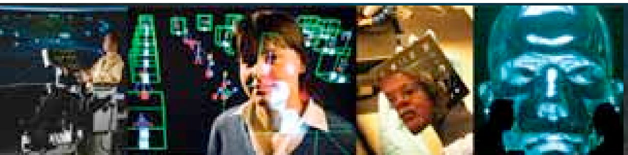
EDTAS Symposium

July 2015

- MH370 – The problem
  - The search area
  - The deep ocean environment
- Tools for the job
  - Deep tow vs autonomous underwater vehicle (AUV)
  - Side scan vs synthetic aperture sonar (SAS)
  - Low frequency SAS
- The role for autonomy
  - Adaptive survey
  - Automatic target recognition
  - Collaborative search



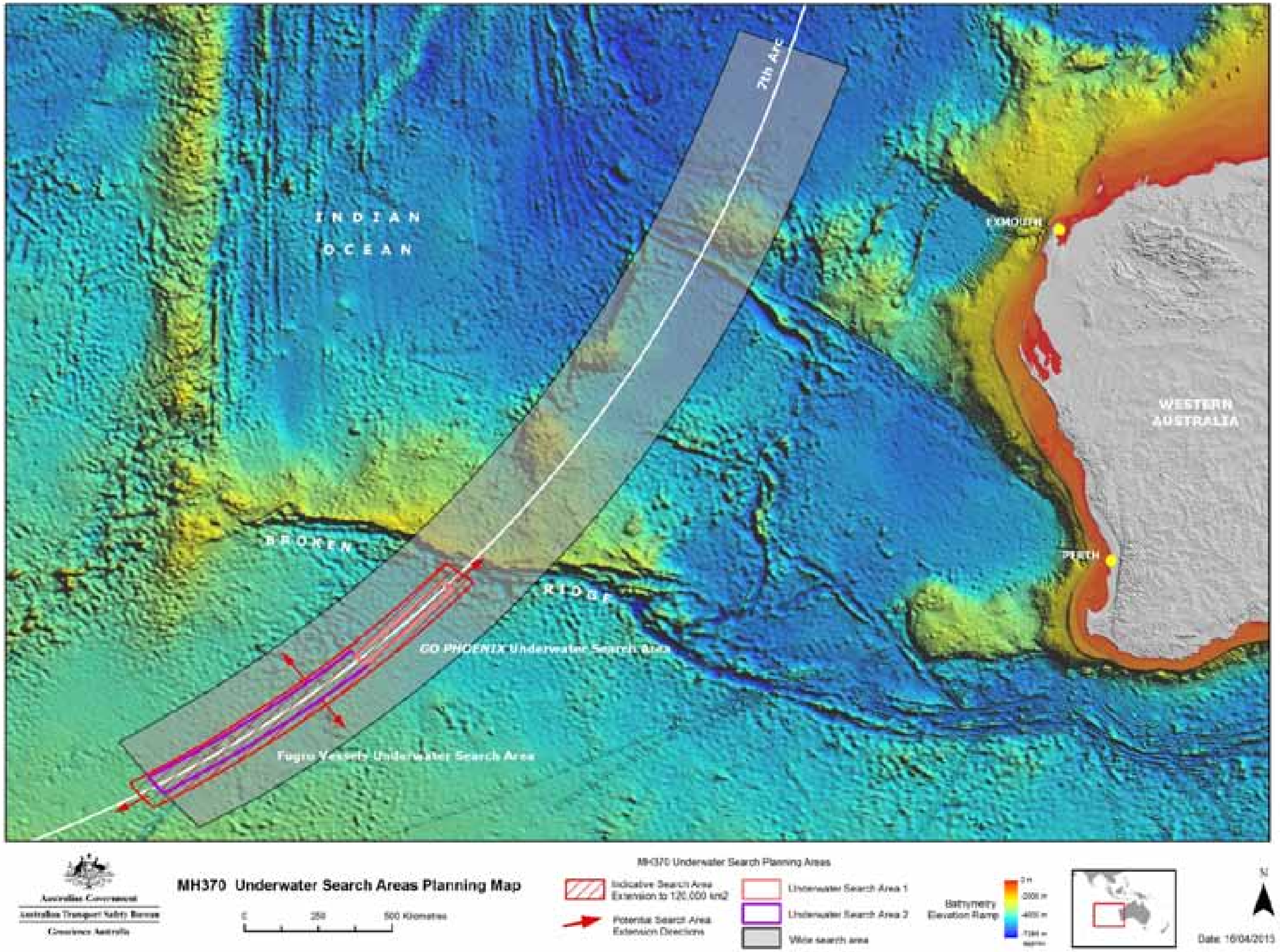
Australia's search and rescue zone

52.8 million square km

One tenth of the earth's surface

The MH370 search area

Recently doubled to 120,000 square kms



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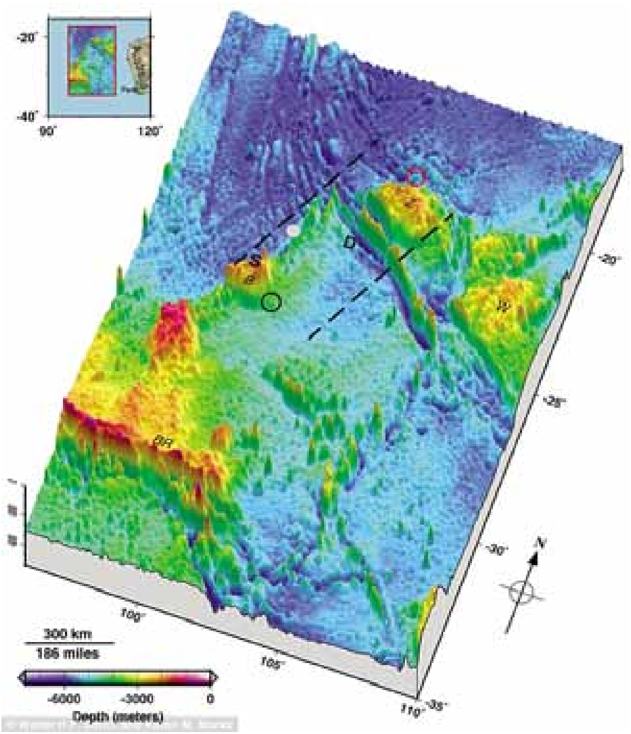
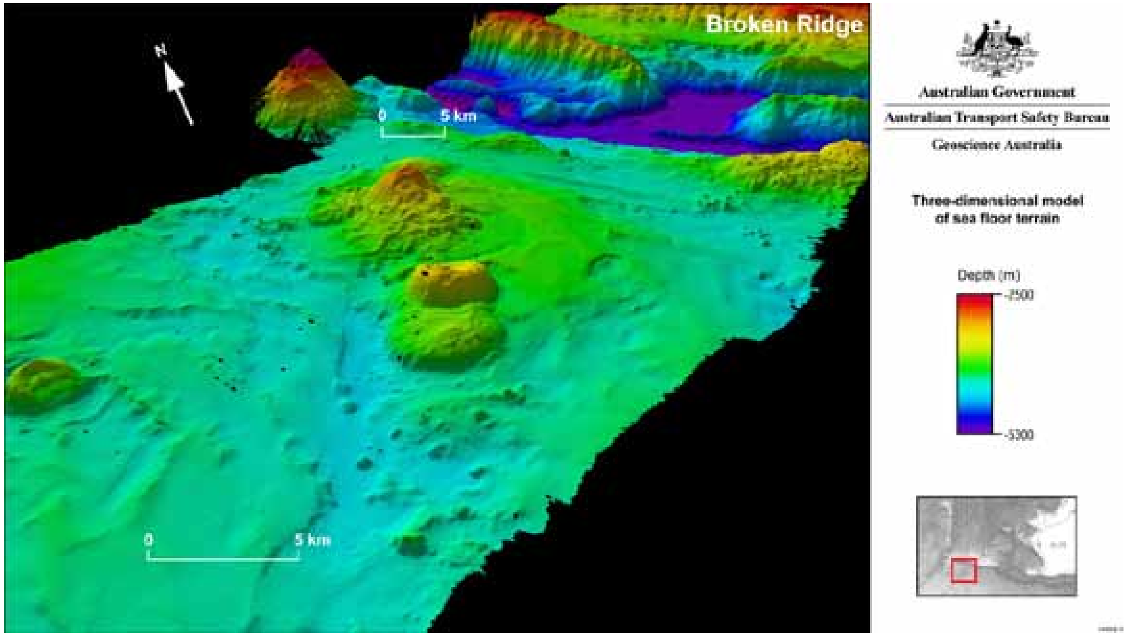
DSTO

Like looking for a needle in a haystack

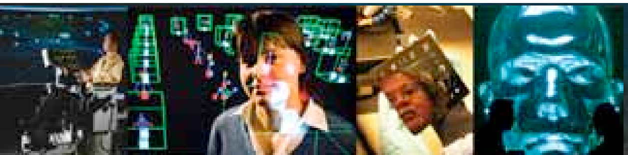
but where's the haystack?...

- Search area includes massive undersea remnant volcanoes
- Ridges 6 km wide 15 km long standing 1.5km above previously known seabed, volcanoes 14 km wide and 2.2 km-tall.
- Pockmarks up to 800m deeper than surrounding seabed.



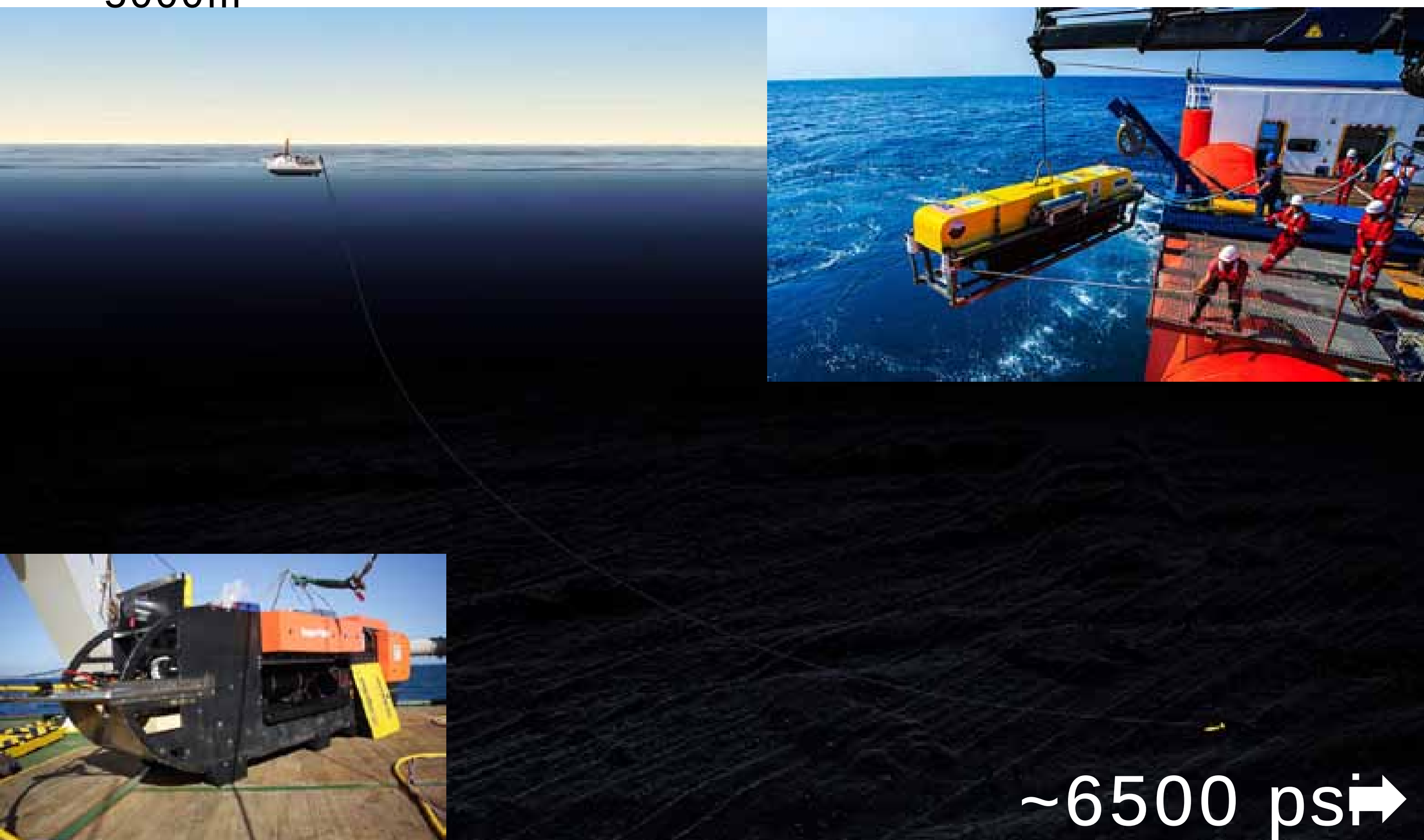


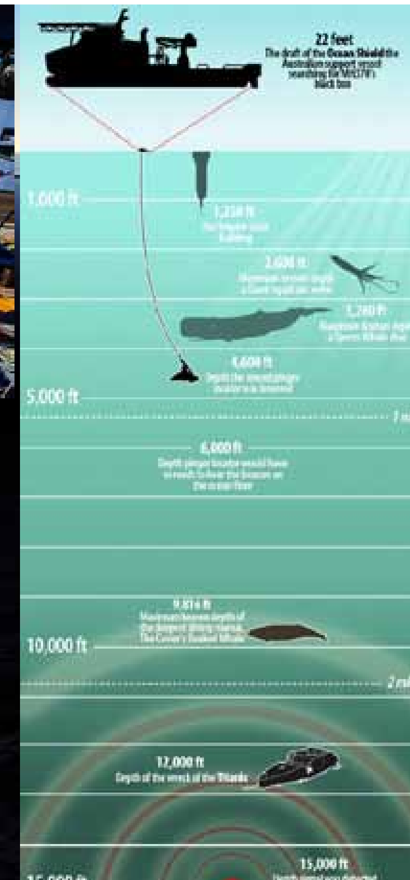
Tools for the job



Conventional deep- tow search

- Cable length is usually 2-3 times the water depth!
- Up to eight hours to execute a turn at the end of a line!
- Tow body would take approximately four hours to deploy to 5000m





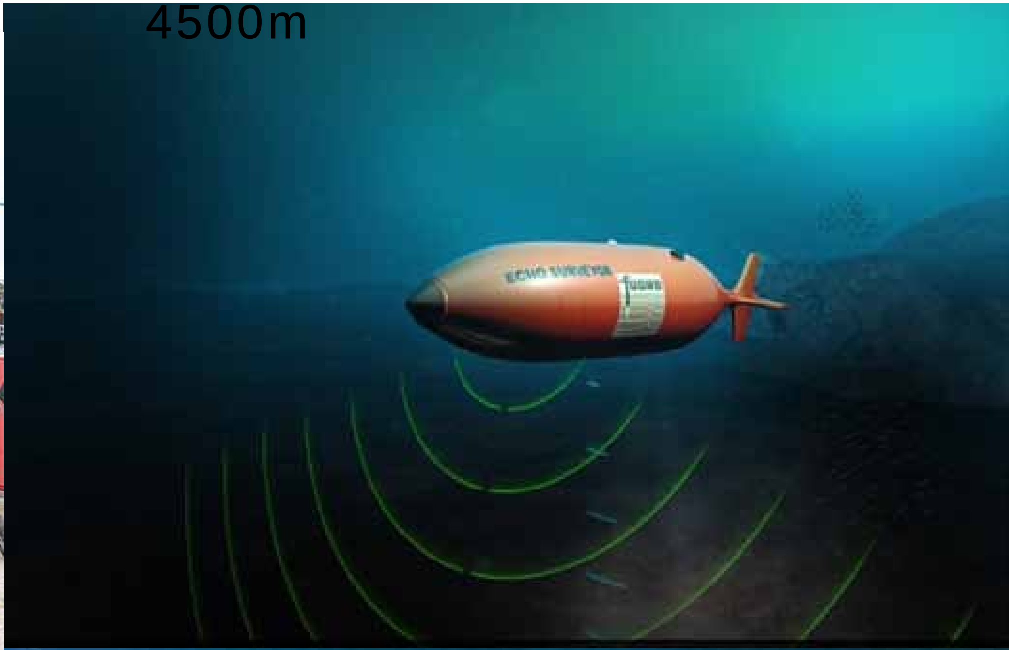
DSTO

Autonomous underwater vehicles (AUVs) so far used in the MH370 search

- AUVs can follow varying terrain to obtain the best possible images
- Time between survey lines is short (AUVs can turn on a dime)
- 2 hrs to deploy and recover from 5000 m
- Battery recharge time is significant (unless spare batteries are used)
- Total mission endurance usually around 20 hrs
- Mission cycle dominated by deploy/recover/recharge/download times

Bluefin 21: Depth rating = 5000m

Hugin 4500: Depth rating = 4500m



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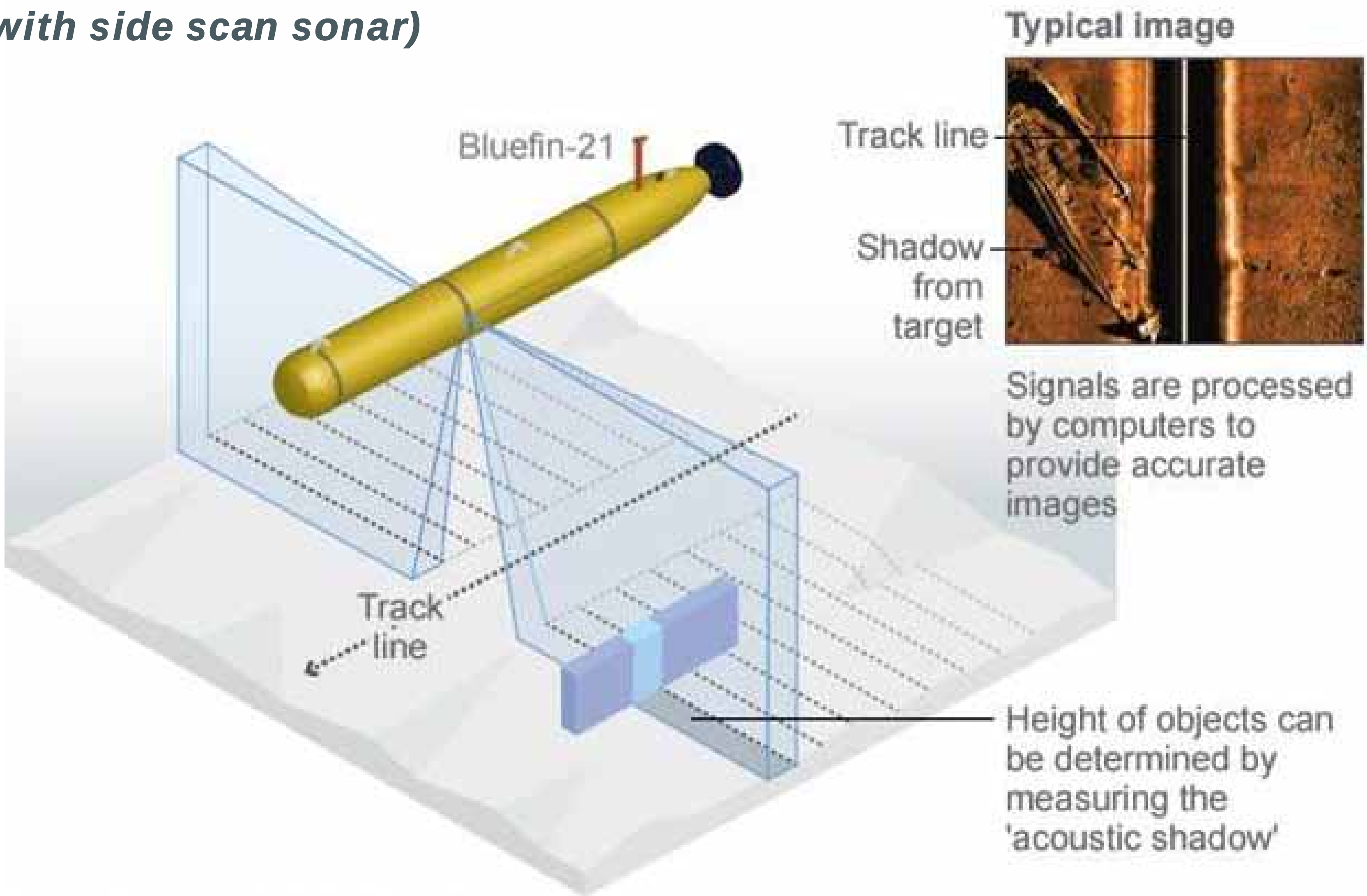
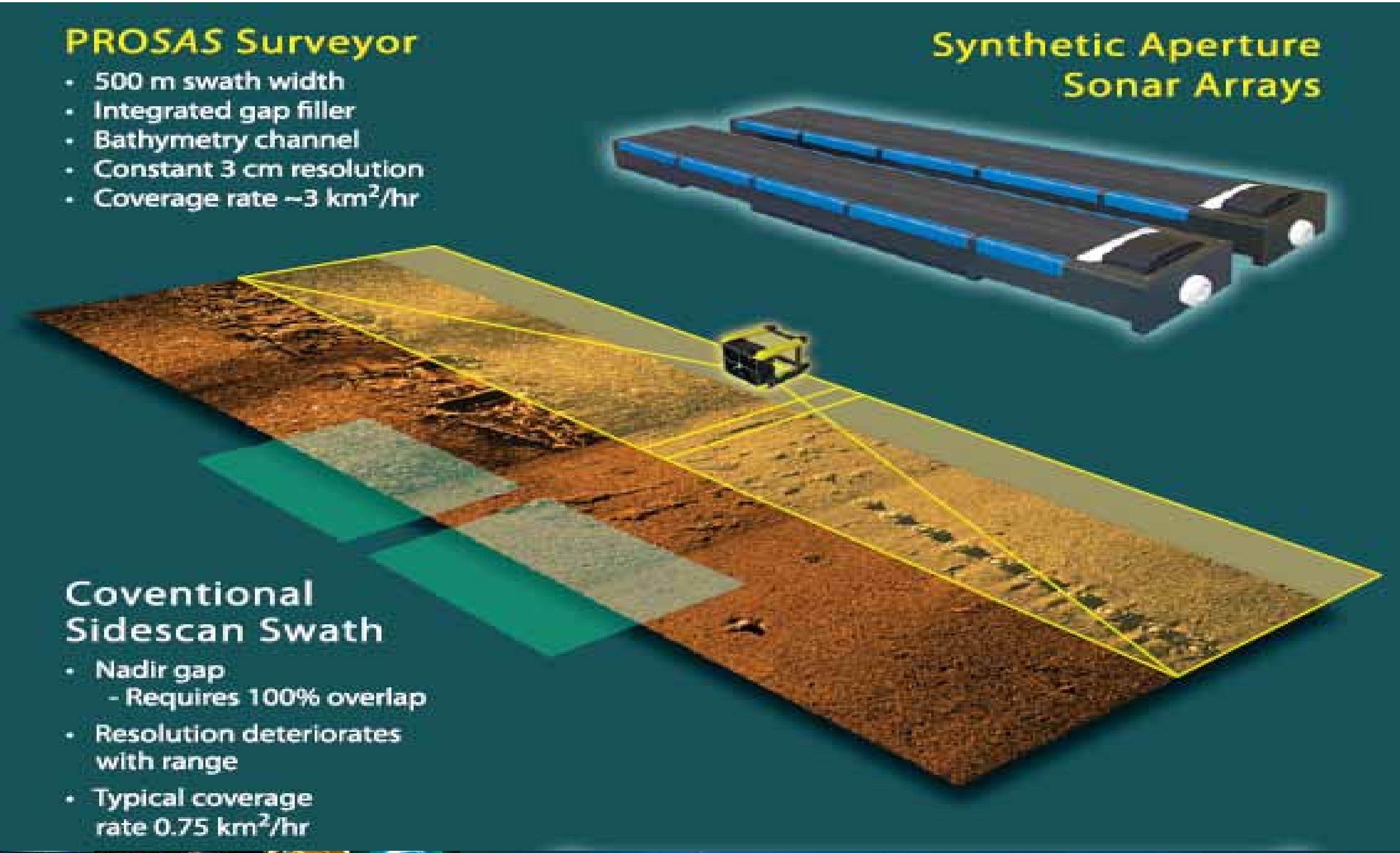
Conventional AUV search
(with side scan sonar)

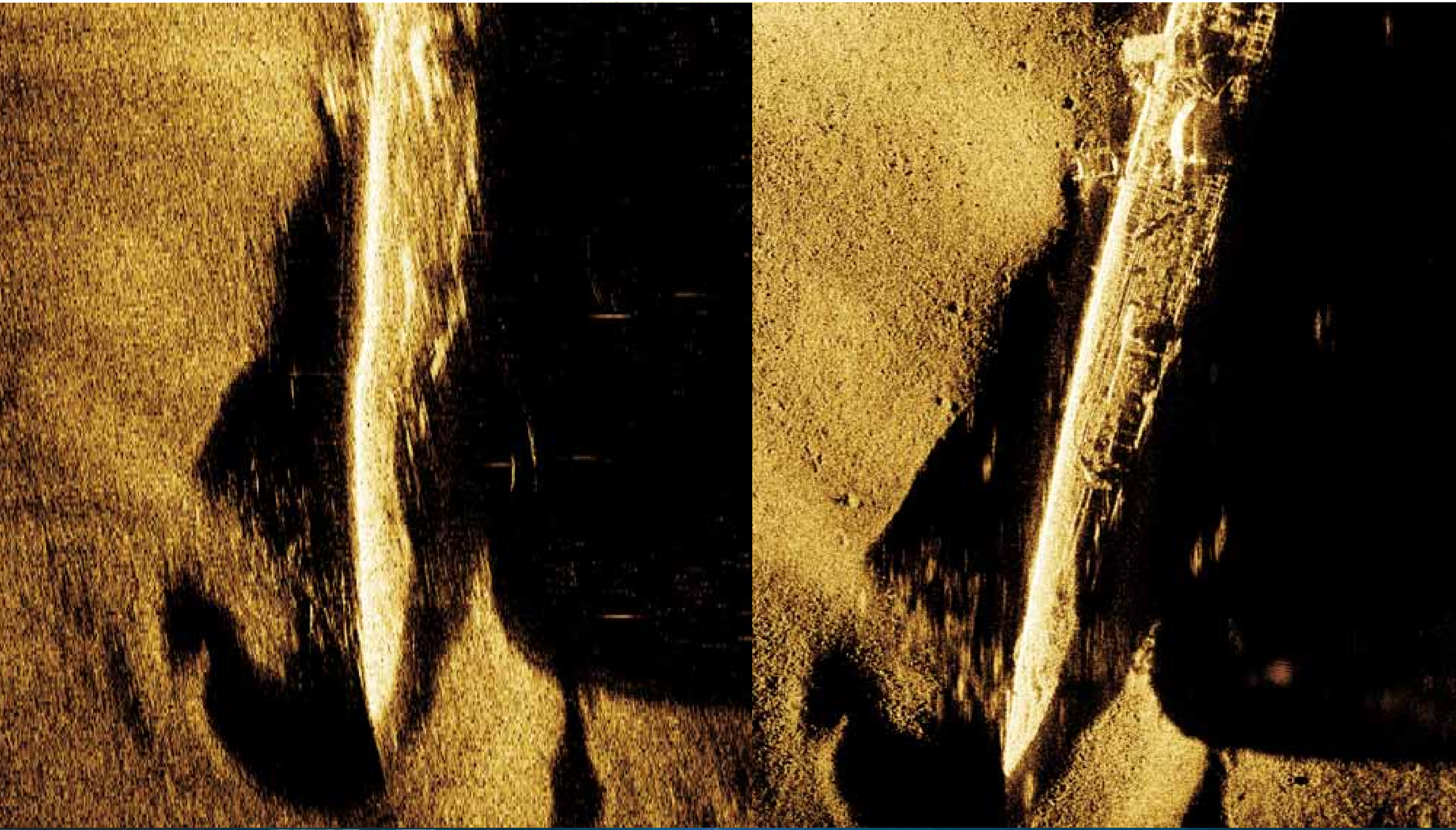


Sidescan vs synthetic aperture sonar (SAS)

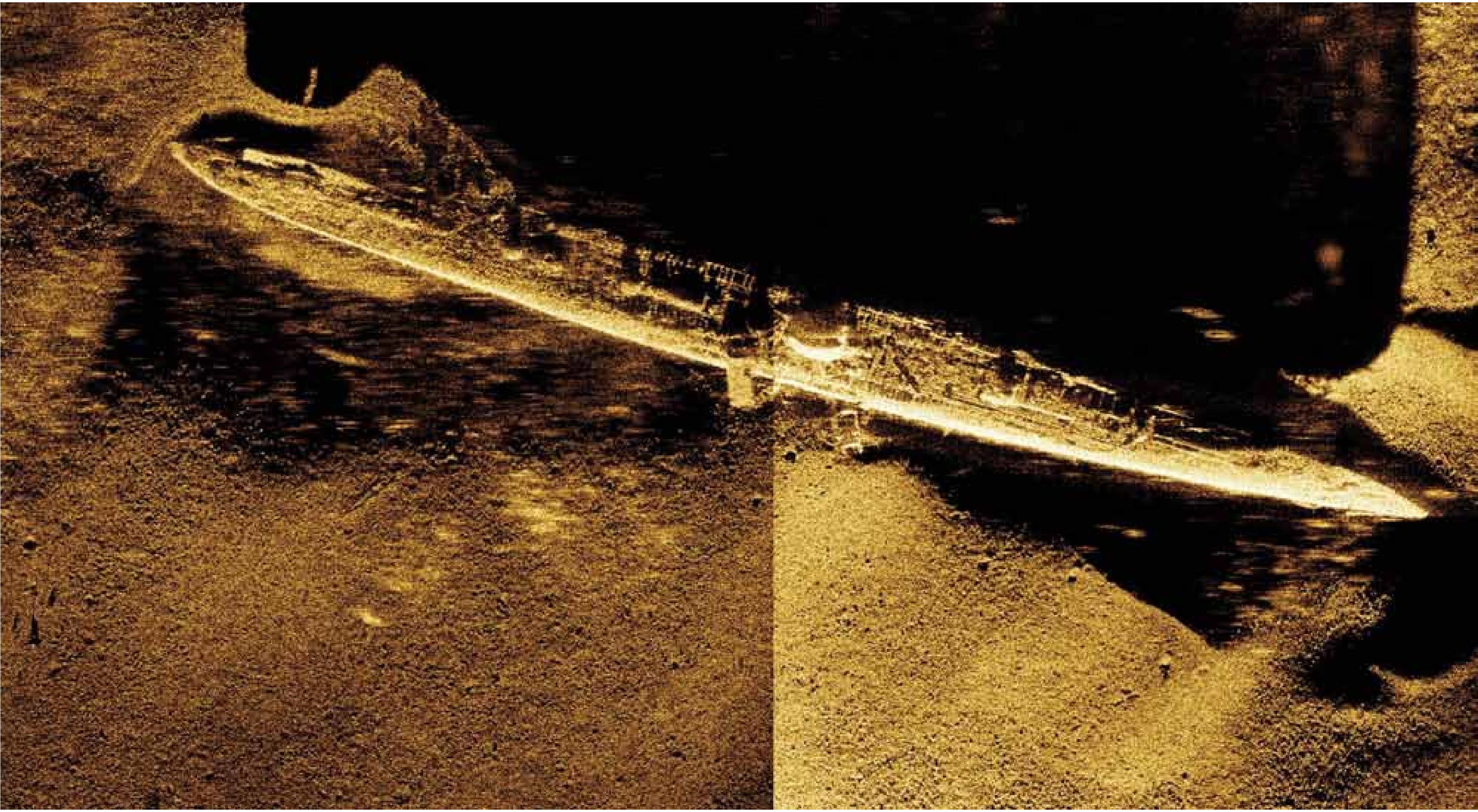


DSTO SAS trial in Northern Australia – May 2015

Side- scan vs SAS: I- 124 “*Darwin’s Submarine*”



I- 124 Full image from single pass



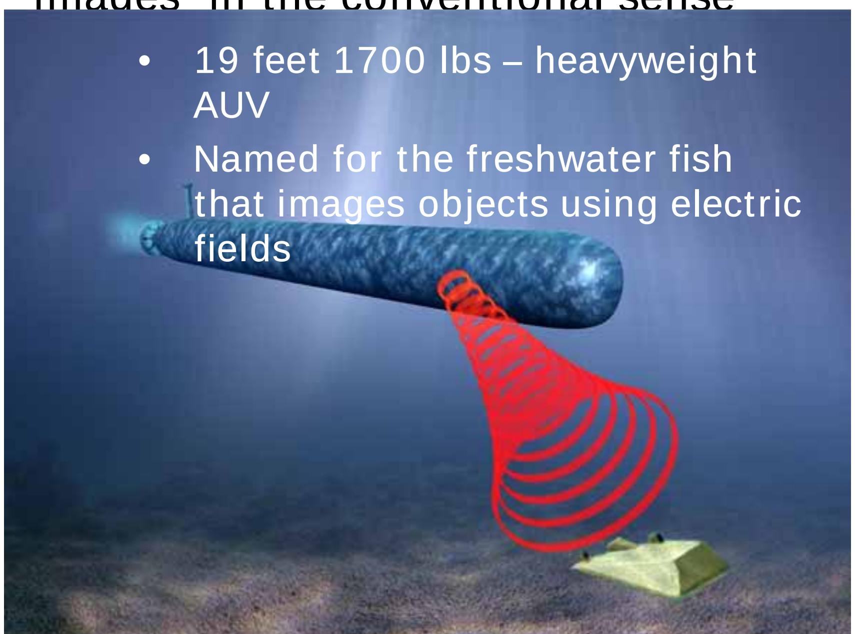
DSTO

Low frequency SAS: Knifefish

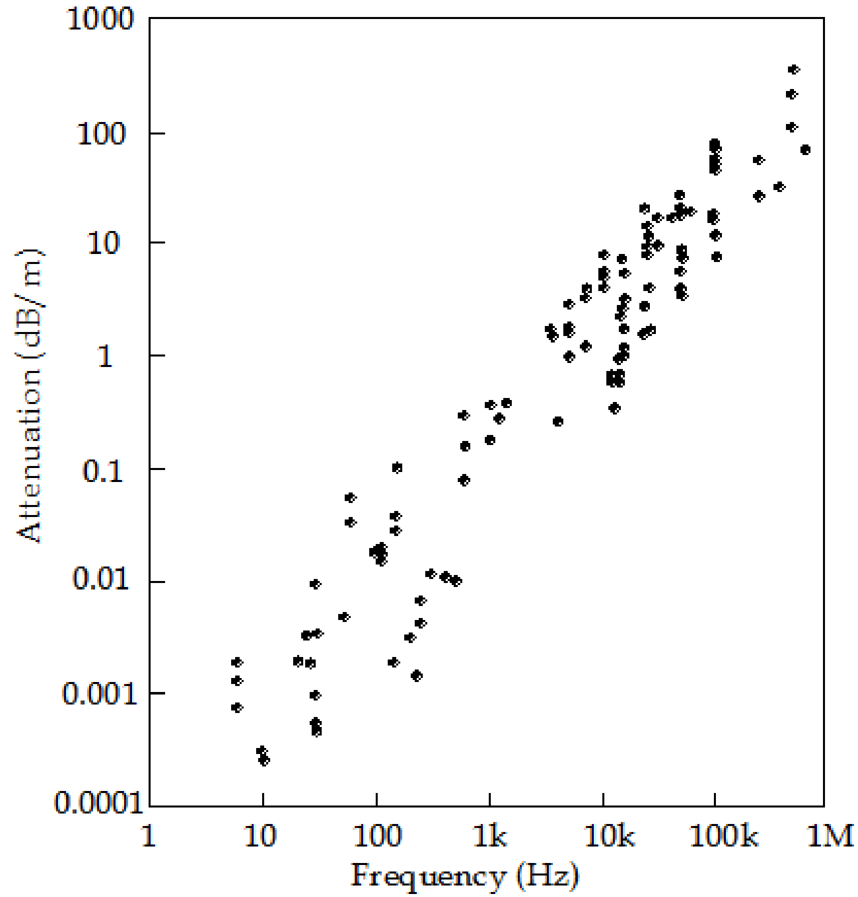
"The wreckage of MH370 is also likely buried in silt up to 30m deep…"

Prof Charitha Pattriaratchi, UWA.

- At typical sonar frequencies above 100 kHz, attenuation in sediments is severe
- At low frequencies where the attenuation is low, the resolution is poor.
- The Knifefish LF SAS does not produce 'images' in the conventional sense

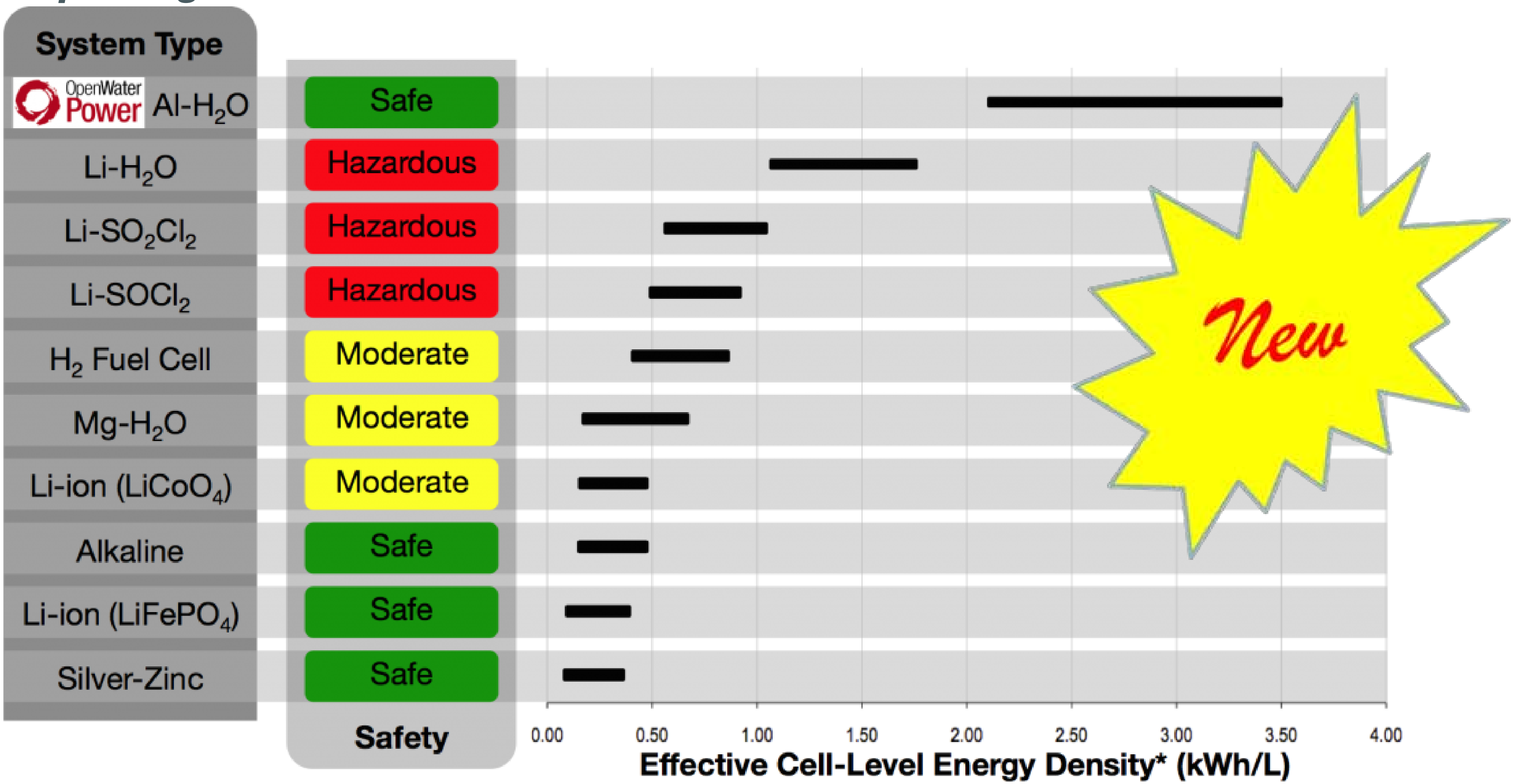


- 19 feet 1700 lbs – heavyweight AUV
- Named for the freshwater fish that images objects using electric fields



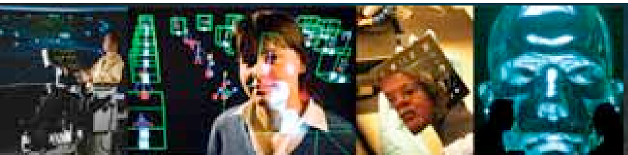
Better underwater batteries may be on the way

The case for using AUVs in deep sea search will be even more compelling



*The ranges of energy densities represent various formulations of each chemistry. Typically, for a given chemistry, power density and energy density can be traded off against each other, with higher energy densities being achievable when power requirements are low.

The role of autonomy



Why we need better autonomy…

RTSAS / Autonomy Module – 2015

Heavy dependence on GPUs for real- time SAS processing

The DSTO RTSAS trial in 2014 achieved a world first in demonstrating *real-time* reconstruction of full-resolution, full-swath imagery and bathymetry, enabling sophisticated autonomous search behaviours.

FASTEST, MOST EFFICIENT HPC ARCHITECTURE

With the launch of Fermi GPU in 2009, NVIDIA ushered in a new era in the high performance computing (HPC) industry based on a hybrid computing model where CPUs and GPUs work together to solve computationally-intensive workloads. And in just a couple of years, NVIDIA Fermi GPUs powers some of the fastest supercomputers in the world as well as tens of thousands of research clusters globally. Now, with the new Kepler GK110 GPU, NVIDIA raises the bar for the HPC industry, yet again.

Comprised of 7.1 billion transistors, the Kepler GK110 GPU is an engineering marvel created to address the most daunting challenges in HPC. Kepler is designed from the ground up to maximize computational performance with superior power efficiency. The architecture has innovations that make hybrid computing dramatically easier, applicable to a broader set of applications, and more accessible.

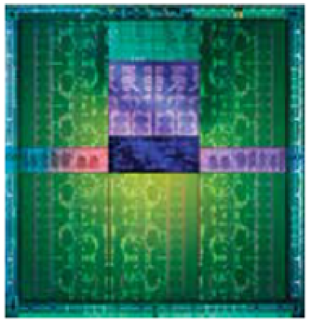
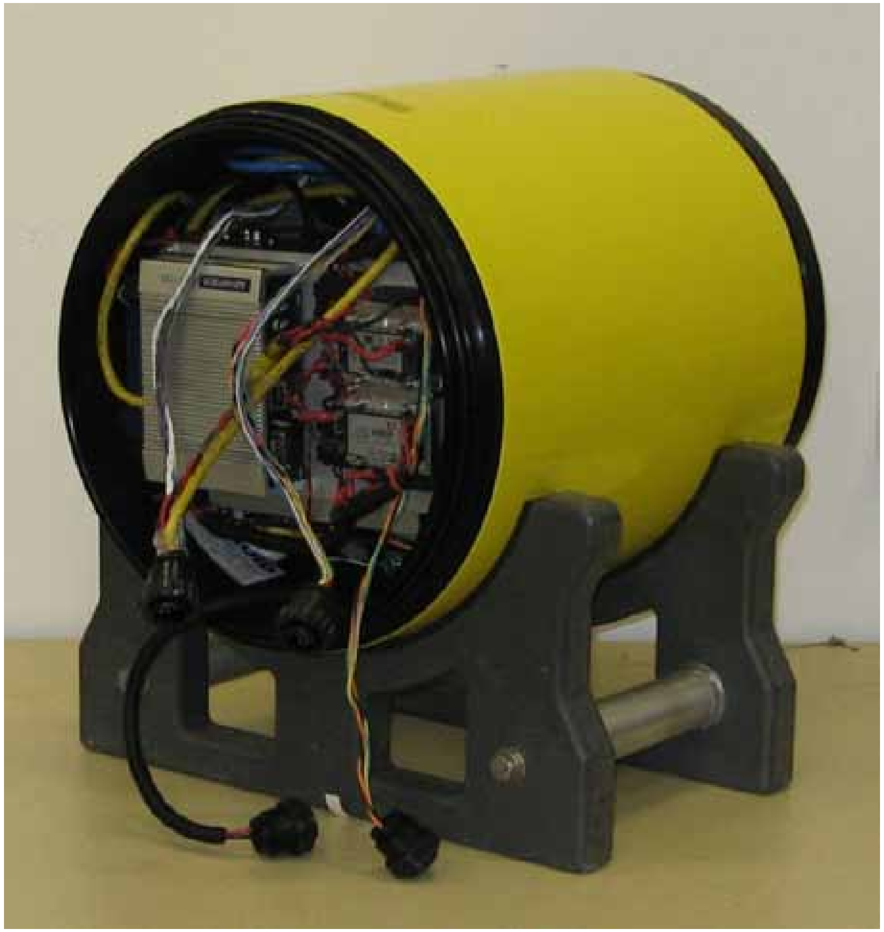


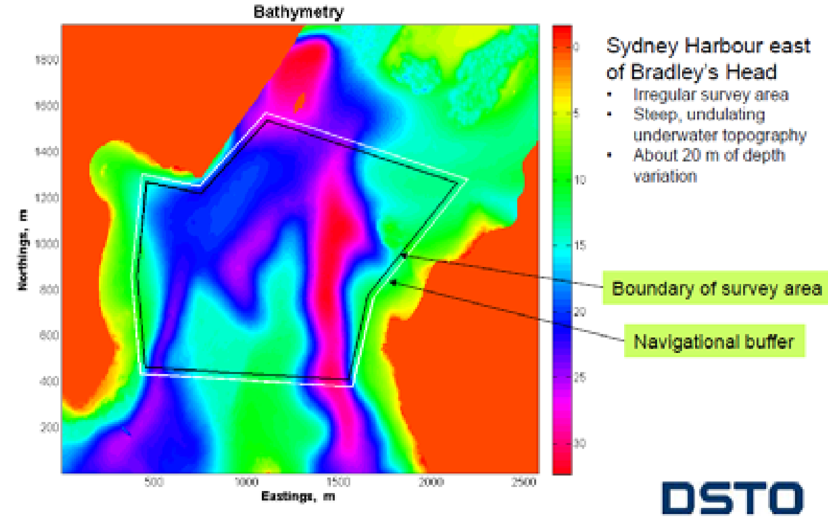
Figure 1: Kepler GK110 GPU- World's fastest and most power efficient x86 accelerator

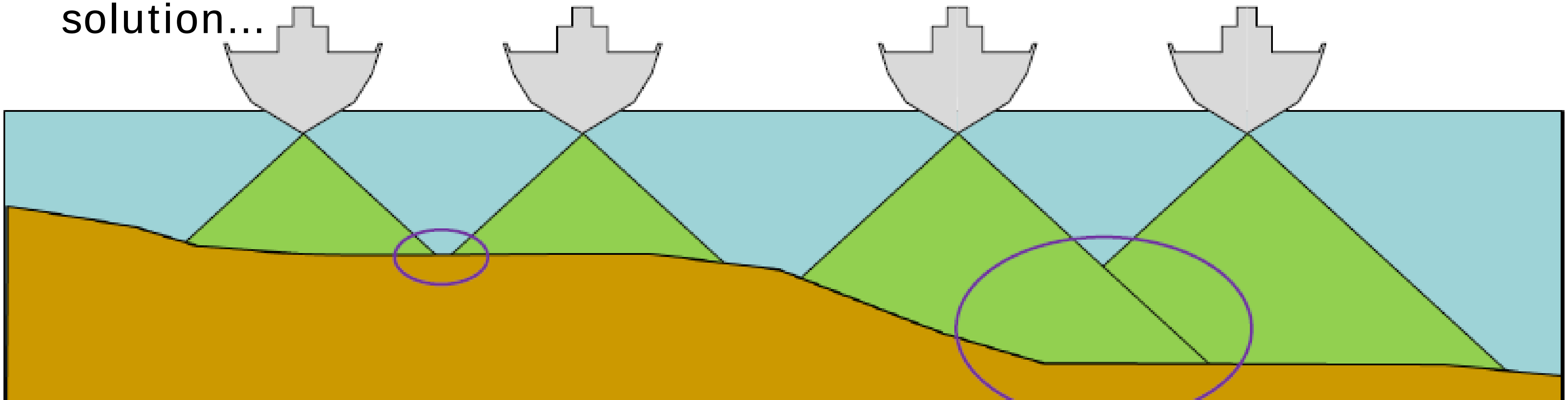


Adaptive Survey 1: Problem definition

- For swath sonar, side scan or SAS, we want 100 % coverage in minimum time while minimising repeated coverage

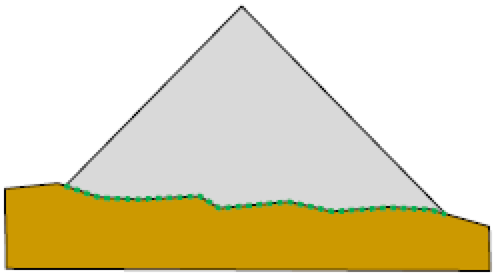
- This represents a difficult, though general problem in path planning, which may not have a unique solution...



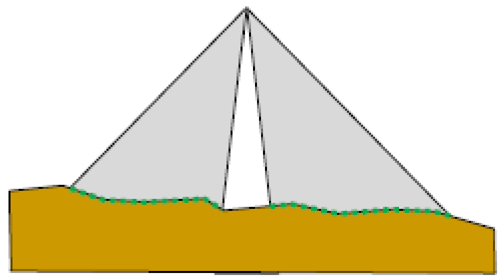


Diagrams courtesy of Dr Stuart Anstee

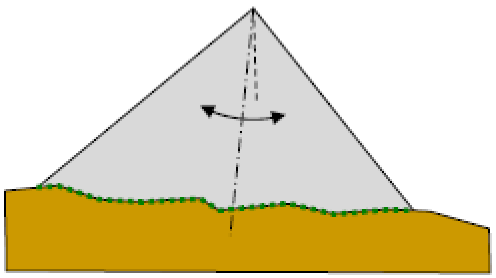
Adaptive Survey 2: Factors impacting coverage



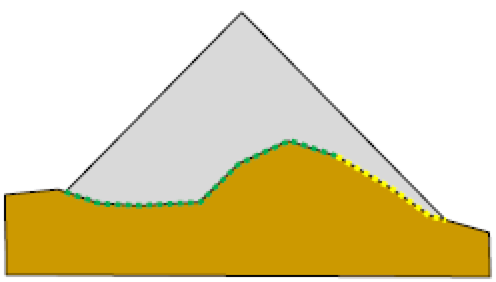
Basic multibeam



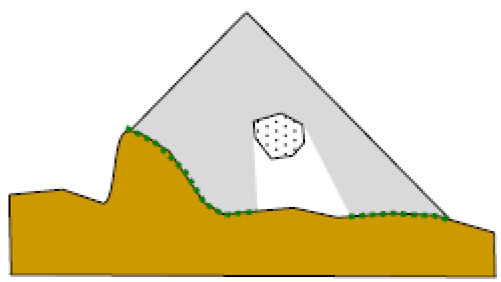
Interferometric sidescan



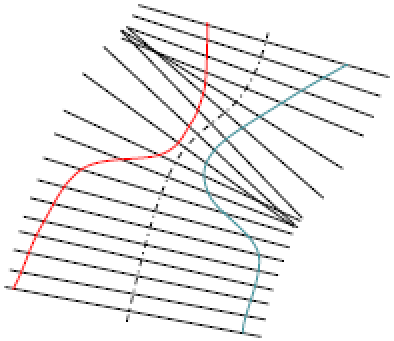
Platform motions…



Shallow grazing angles



Obstructions

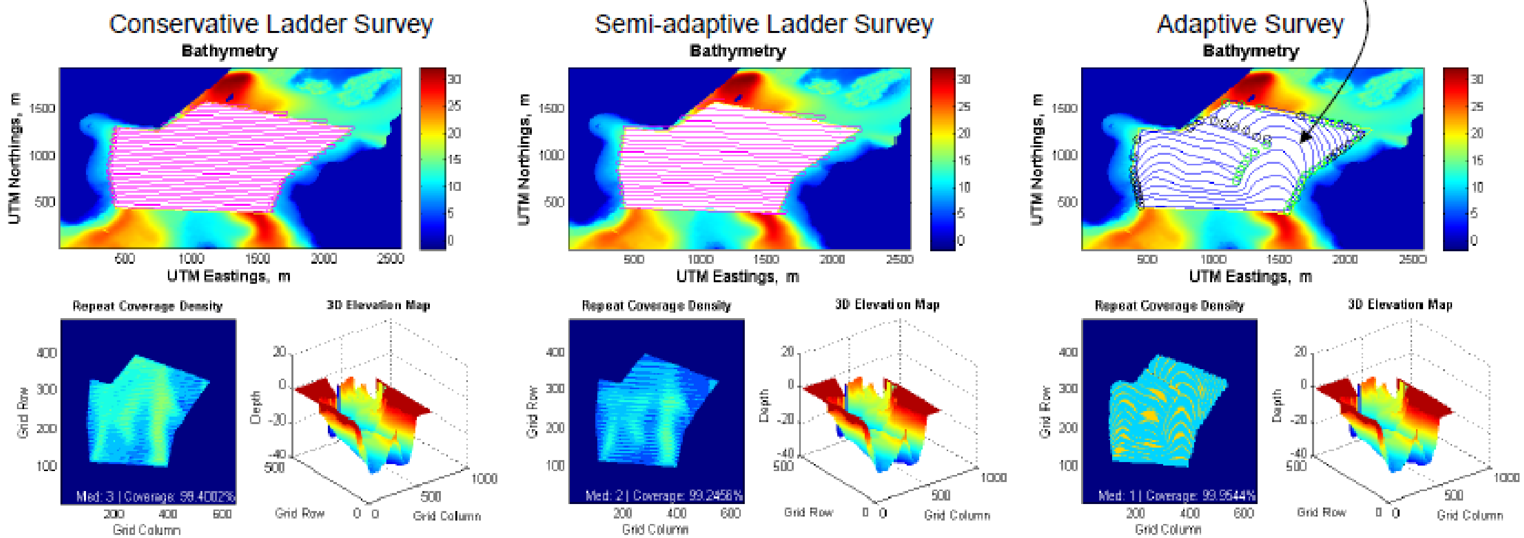


Path Curvature

Diagrams courtesy of Dr Stuart Anst

Adaptive Survey 3: Results

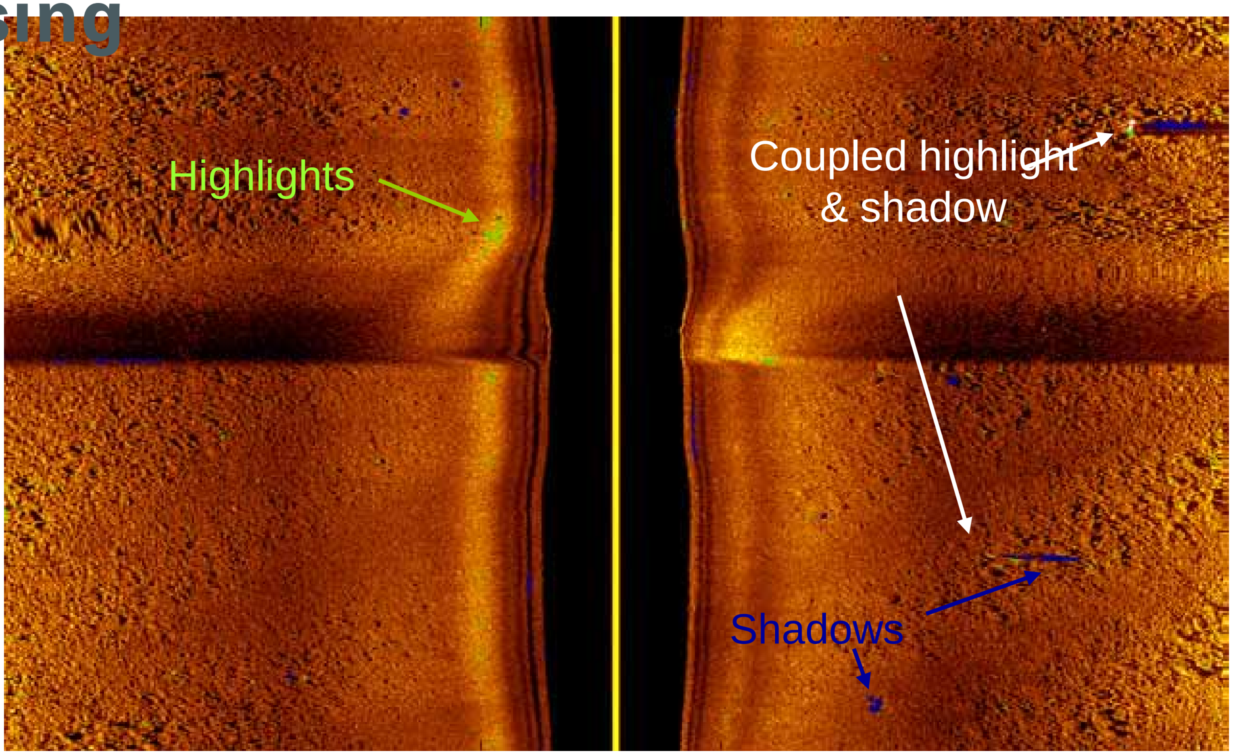
Note: a different run gave a different survey plan



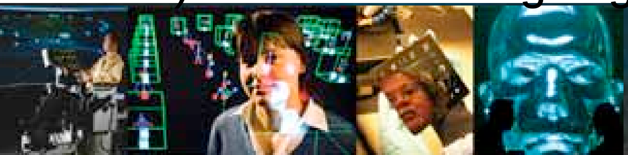
	Ladder	Adaptive Ladder	Fully Adaptive
Coverage	100%	100%	100%
Efficiency	35.7%	51.7%	83.3%
Path length	51.4 km	35.4 km	23.9 km
Curvature ok	100%	100%	96%

Courtesy of Dr Stuart Anste

Automatic target recognition 1: Image processing

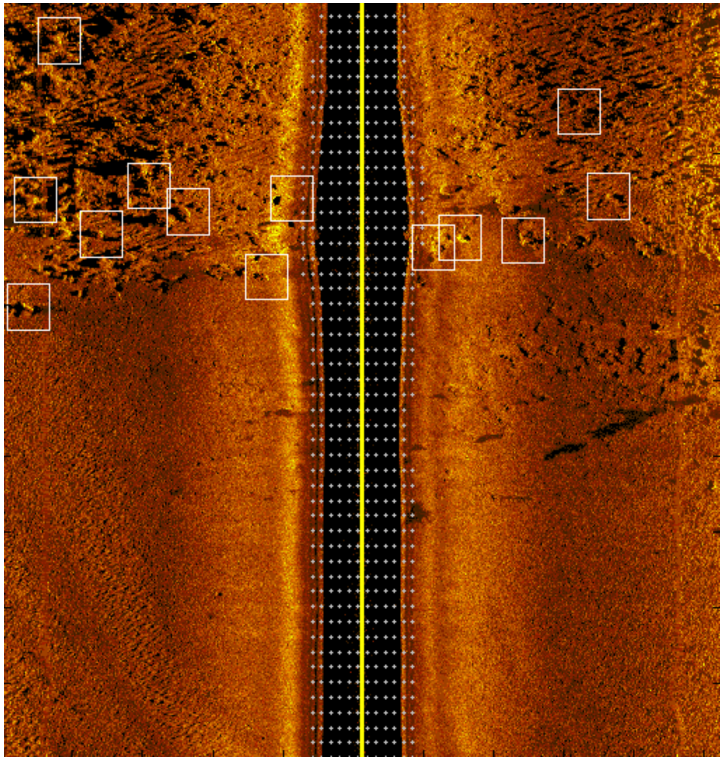


a) Retain only highlights and shadows matching size criteria
b) Retain only shadows indicating objects within a certain height of the seabed
c) Exclude shadows that are irregular in shape …
d) Find matching highlight-shadow pairs

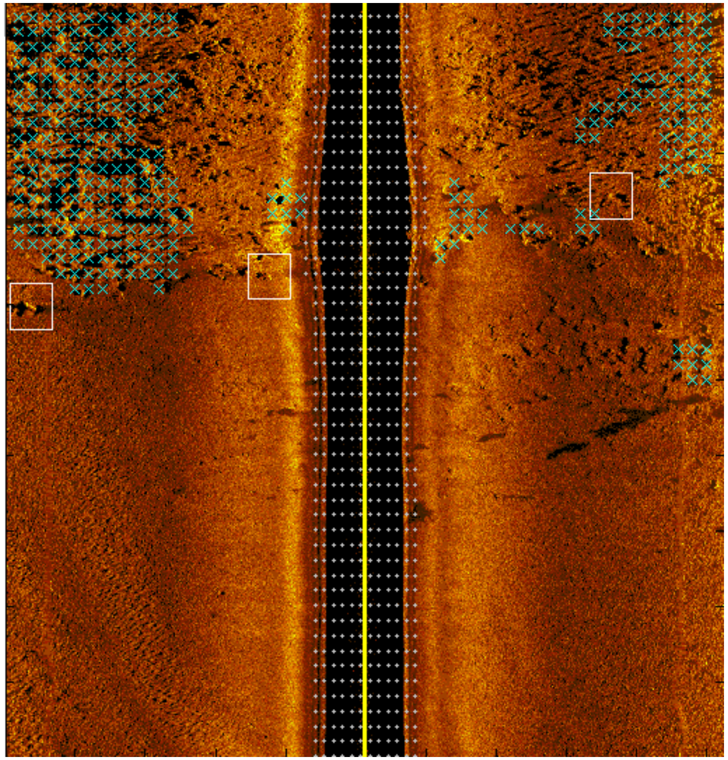


Automatic target recognition 2: Clutter rejection

- If the autonomy sub-system is intended to respond to ATR detections automatically, it's critical to have a low false alarm rate.
- This is challenging in a cluttered environment



- 13 false alarms

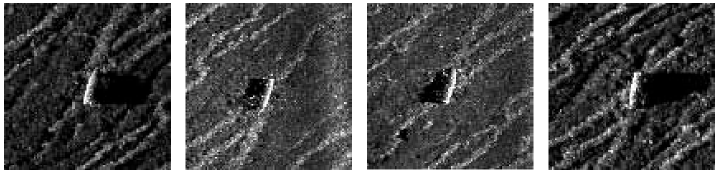


- 3 false alarms

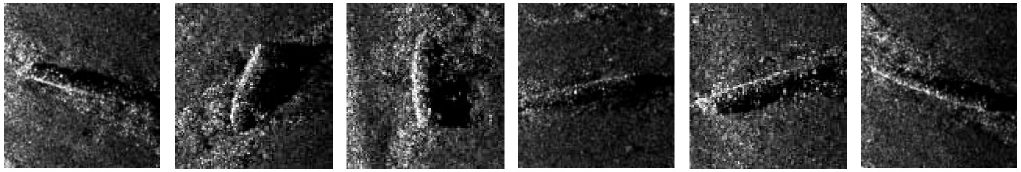
Automatic target recognition 3: Results

- Contact 1: MK41

ATR detections (900 kHz)

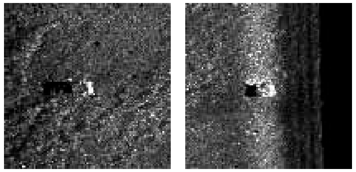


Multi-view reacquire (1800 kHz)

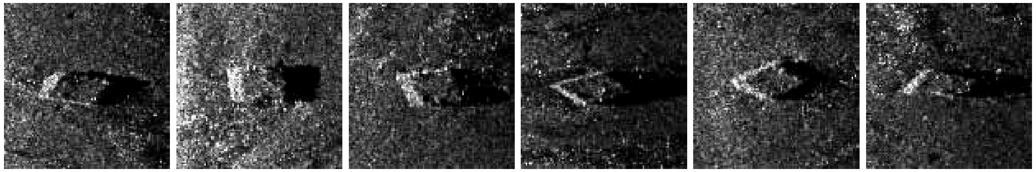


- Contact 2: Box #1

ATR detections (900 kHz)

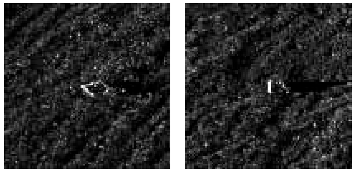


Multi-view reacquire (1800 kHz)



- Contact 3: Box #2

ATR detections (900 kHz)



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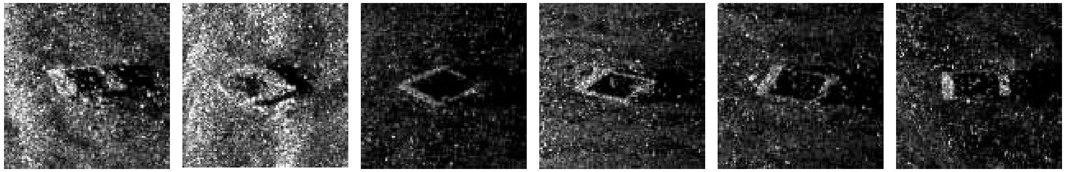
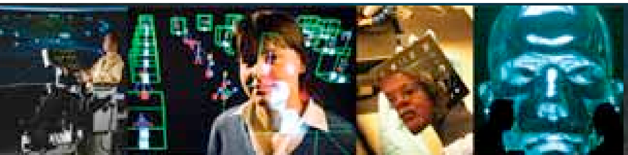




Autonomous collaboration

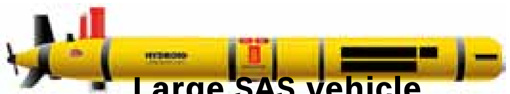
- In focussing on the automatic target recognition (ATR) problem, DSTO is developing the concept of cooperation between complementary robotic sensors.
- Despite the higher resolution of SAS, the vagaries of acoustic imaging still require views from multiple aspects to enable robust autonomous classification.
- Squads of smaller side-scan equipped 'slave' vehicles can accept hand-off requests from the SAS vehicle to execute multi-aspect classification of seafloor objects.

Slaves

Small side- scan AUVs

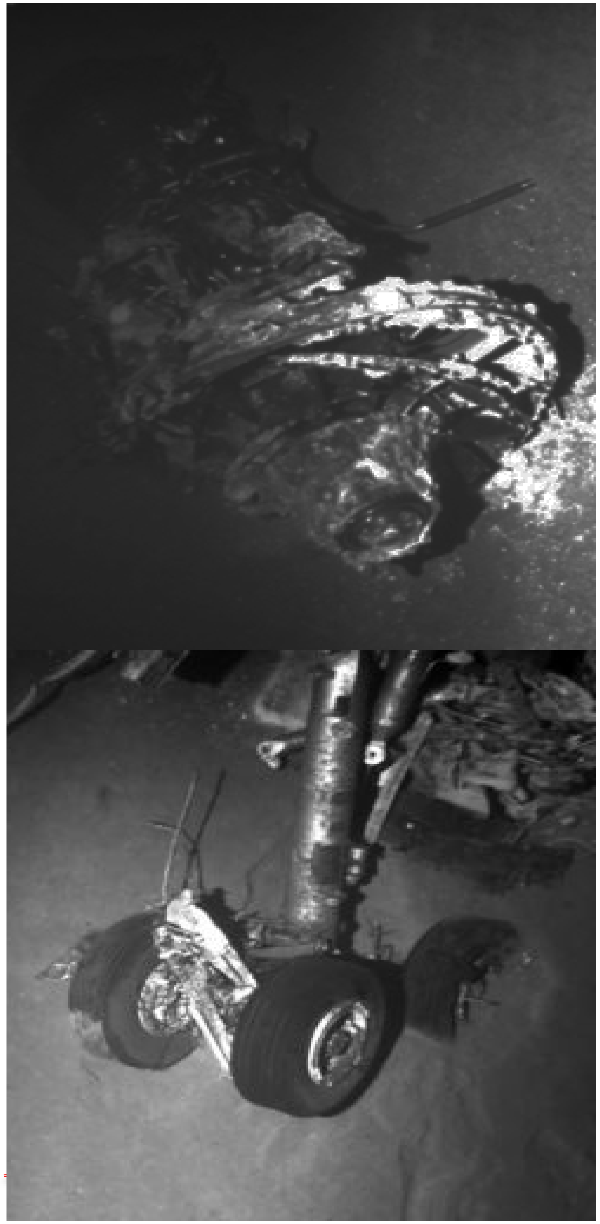
- Short range sensor
- Highly manoeuvrable
- Multi-aspect classification

Master



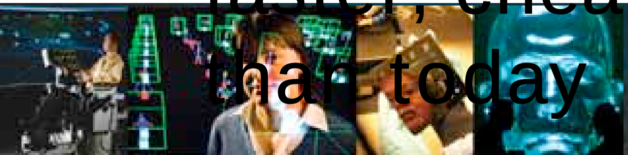
Large SAS vehicle

- Long-range sensor
- Not very manoeuvrable
- Single aspect detection
- Hands off re-acquisition tasks to available slaves



Conclusion

- Autonomous underwater vehicles are *already* the tools of choice for deep sea search
- Real-time synthetic aperture sonar technology, combined with greater endurance make their case even more compelling
- Improved autonomy is the final ingredient to ensure that future search operations are faster, cheaper, safer and more effective than today



Australian Government

Department of Defence

Defence Science and Technology Organisation