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SUBSEA TECHNOLOGY

Optimising Ultra-Short BaseLine (USBL) Positioning from Research Vessels

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POSITIONING
NAVIGATION
COMMUNICATION
MONITORING
IMAGING

Optimising USBL Positioning from Research Vessels

USBL for demanding science

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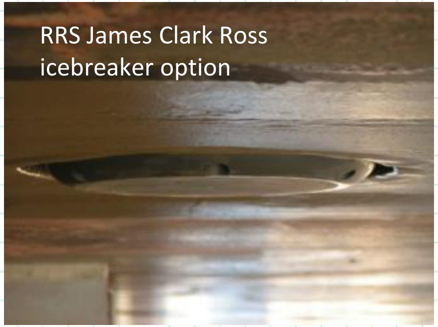
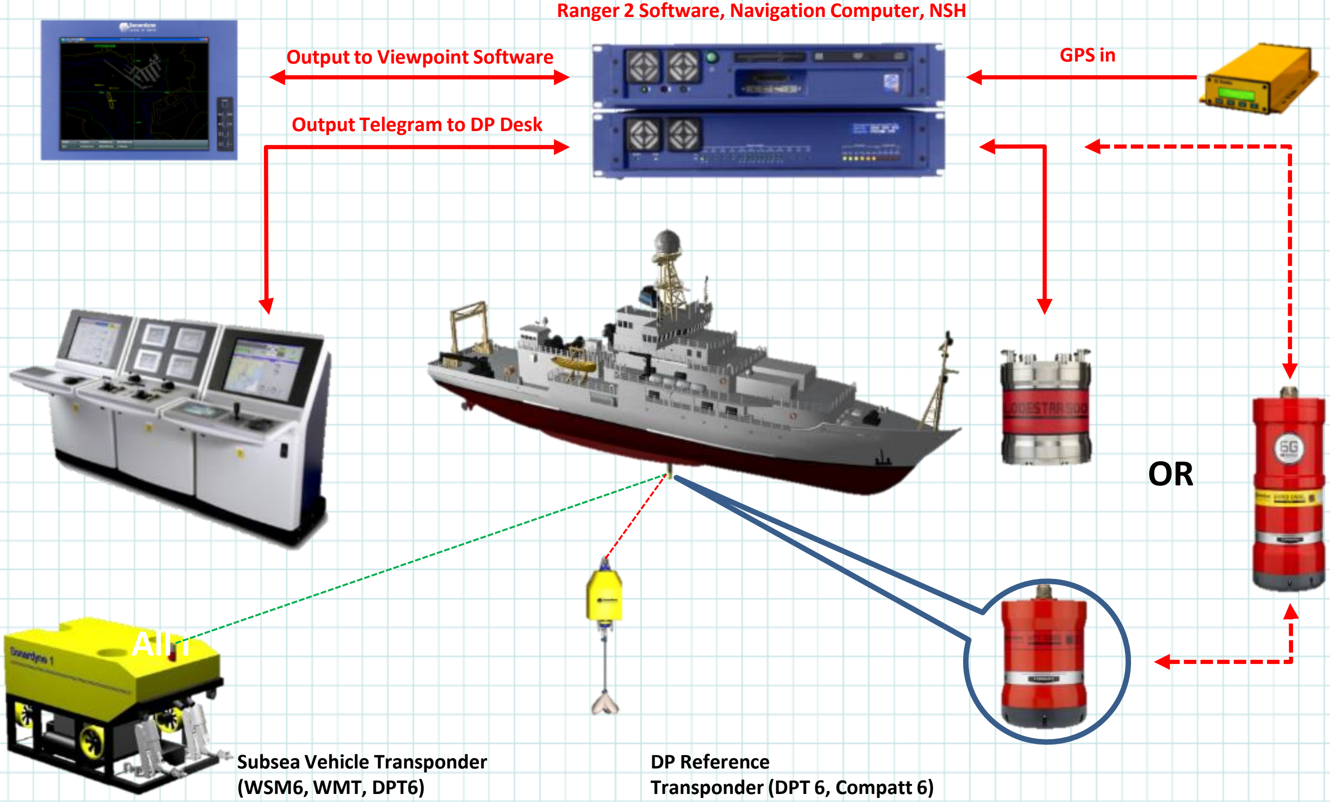
What's the right solution for my ship?



Optimising USBL Positioning from Research Vessels

USBL System Overview

- USBL is a range and bearing system - position calculated by measuring reply signals at the transceiver:
  - time (range)
  - phase (angles) of
- Requires high quality vessel motion sensors and precise timing
- Accuracy defined in relation to percentage (e.g. 0.12 – 0.5%) of Slant Range



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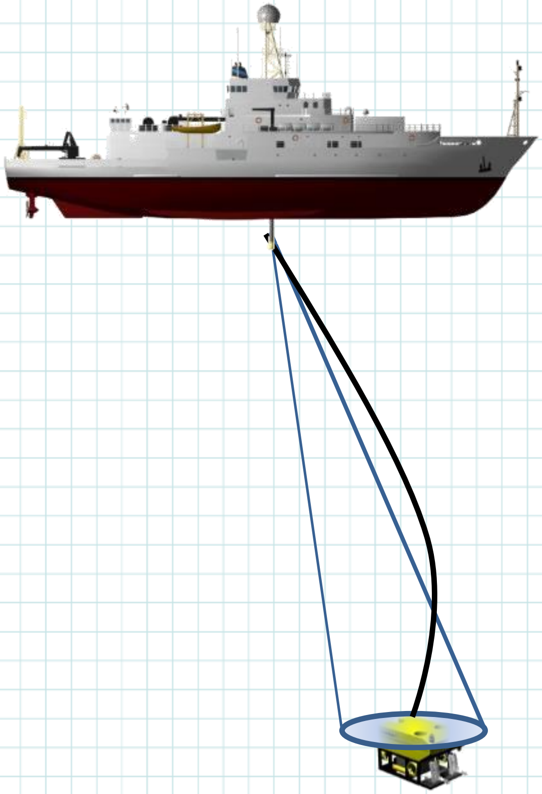
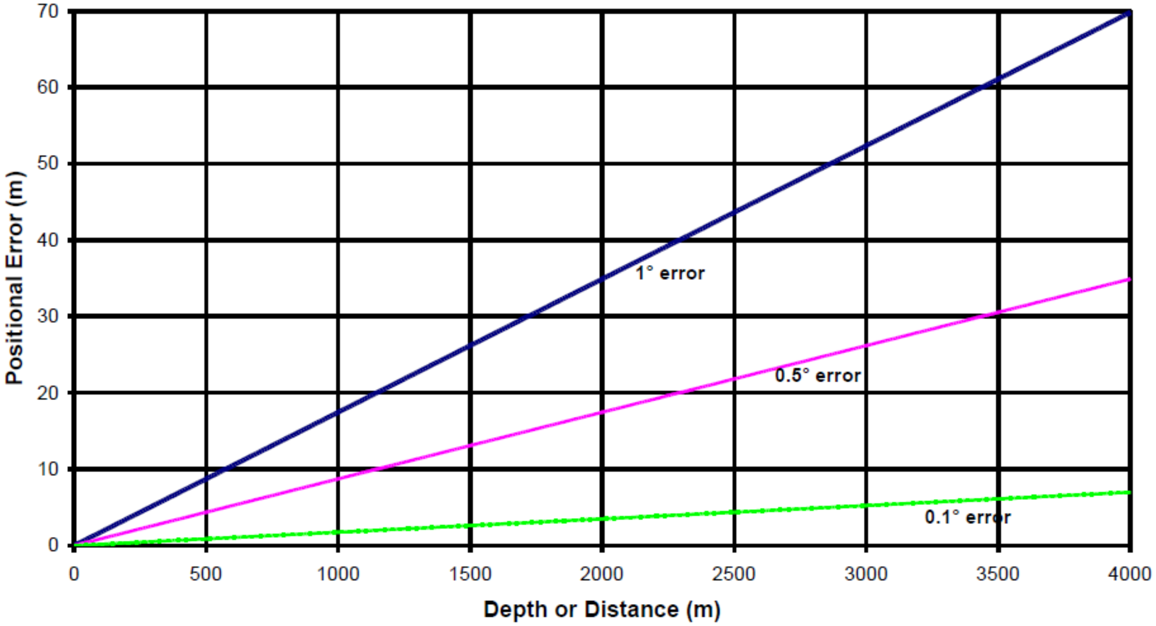
So what does an accuracy of 0.12 – 0.5% of Slant Range mean?





eg - a 0.5° error in transceiver pitch or roll would equate to 17.5 m positional error at a slant range of 2,000 m (0.88% of slant range)

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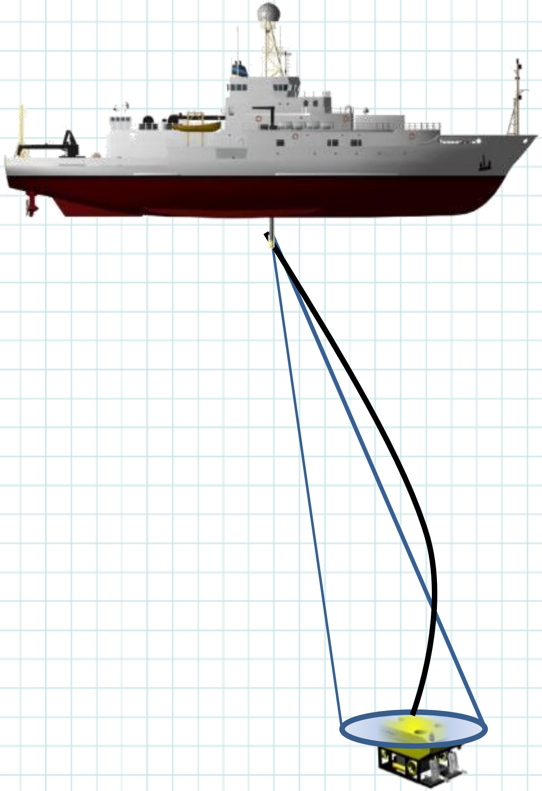
USBL System Position Error



- **GNSS**
  - **Noise -** will be directly translated into the subsea position, but only affects precision.
  - **Offset Error or Invalid GNSS Corrections** - won't affect precision, will affect accuracy
- **AHRS**
  - **Uncompensated motion**
    - Pole flex, flap
    - Hull flex
    - MRU mounting, latency or low quality
    - Predominantly affects precision…….Will affect accuracy if it causes a fixed bias.
  - **Misalignment of MRU to vessel frame or to USBL** - fixed bias that will affect accuracy
- **Sound Speed (Timing)**
  - **Scaling or TAT Error**
  - **Ray Refraction**
  - **Bad Surface SV**
- **Bad Depth (Pressure)**

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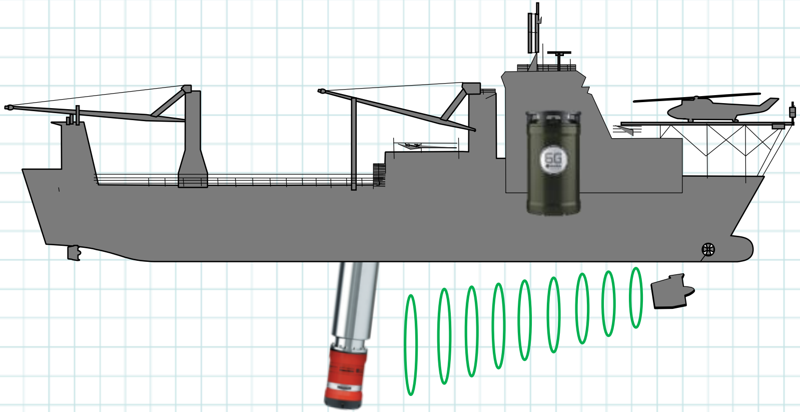
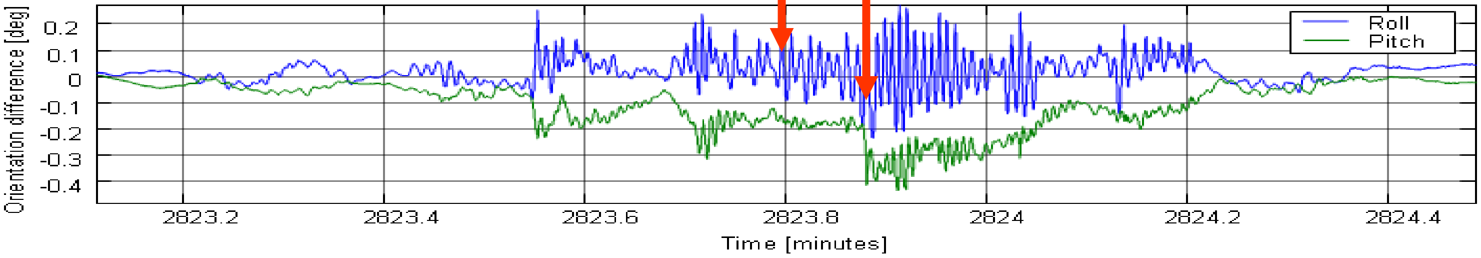
Installation: Analysis of movement of pole AHRS with relation to bridge MRU



Pole resonates at 2Hz approx

<0.3° pitch bias directly affects position accuracy



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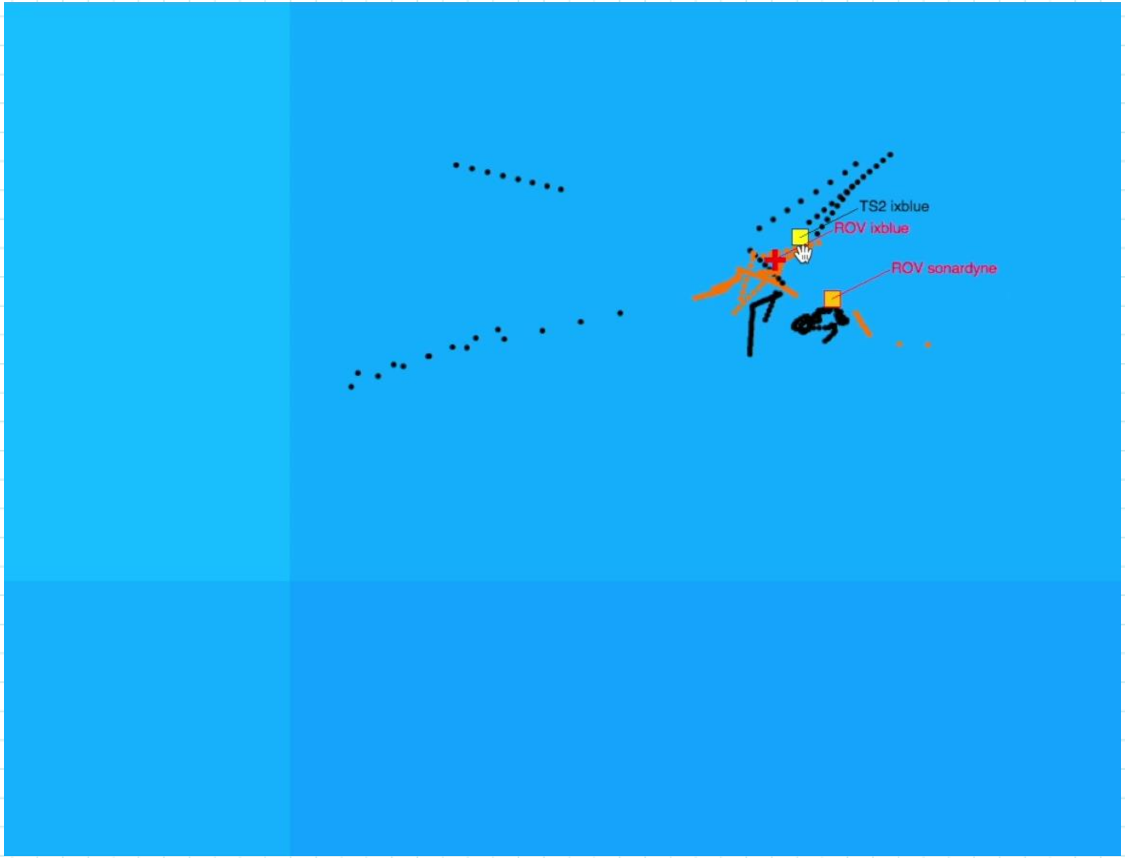
RV Falkor – Installed USBL v Lowered OTS USBL



Courtesy of Blair Thornton, Universities of Southampton & Tokyo

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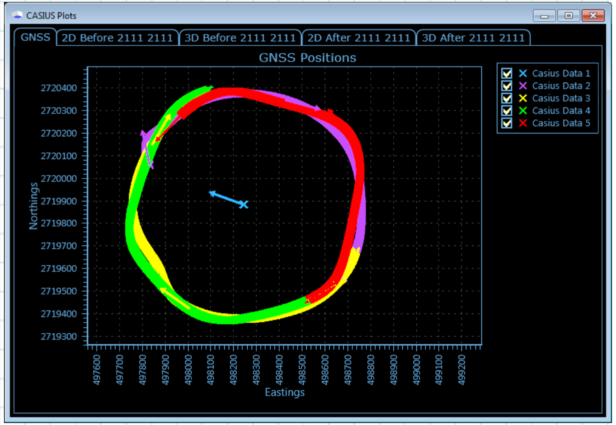
Calibration of Attitude Sensors in the USBL System (CASIUS)

- Collects USBL data as the vessel moves around a transponder deployed on the seabed;
  - Nominal horizontal offset of 1/3 x water depth (Max 500m)
  - Full range of headings maximises any heading errors
  - Sailing closer to the transponder’s vertical maximises pitch and roll errors
  - Reciprocal headings maximise offset errors.
- Observations analysed:
  - Quantify errors
  - Provide corrections
  - Accurate position of the seabed transponder



Errors and how to avoid them

- Random:
  - Range 'jitter' due to acoustic noise
  - Transponder timing
  - AHRS/Gyro sensor drift
  - Angle measurement error
- Systematic
  - Sound speed error
  - Incorrect offsets
  - Uncalibrated on incorrect calibration
  - Sensor latency
- Mistakes
  - Incorrect TAT
  - Multipath
  - Reference beacon movement
  - Tracking the wrong beacon

Use good equipment

Calibrate the equipment and use it properly

Employ good people and train them well

Long Range Tracking

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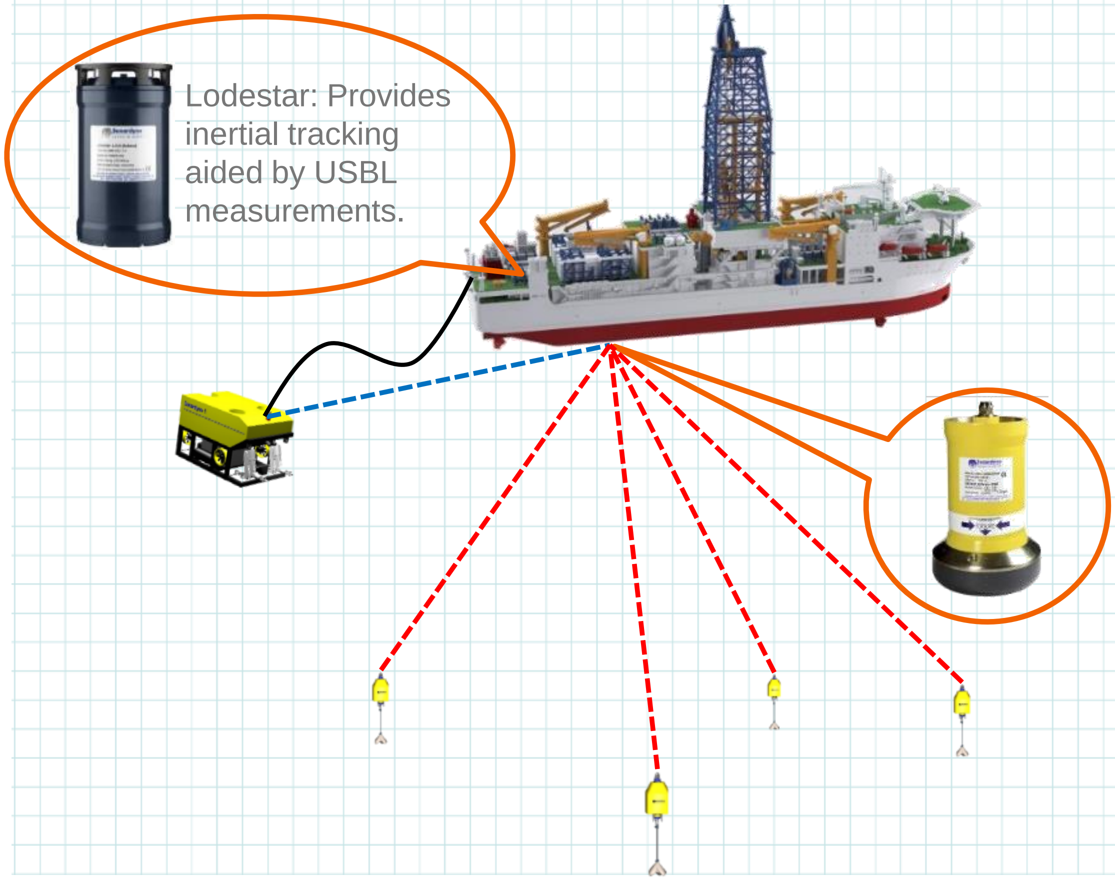
Chikyu DP-INS system



- 2005 - Sonardyne LUSBL first installed on the Chikyu
  - Using 5th Generation MF Compatts (super directional)
  - Wideband range and bearing measurements of seabed transponder array relative to USBL transceiver position.
- 2012 - Upgraded to Sonardyne Wideband DP-INS in 2012
  - Tightly coupled acoustically aided inertial position accuracy better than 0.5m
  - Update rate: Acoustically 0.1Hz, AAINS Typically 1Hz
- Achieved drilling record drilling 854m below seafloor at a depth of 6897m.

JAMSTEC 国立研究開発法人 海洋研究開発機構 JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY

Long Layback Tracking with iUSBL

Pre-calibrated Integrated Gyro and Inverted USBL (GyroiUSBL) on towfish collects acoustic measurements away from noise of the vessel.

- Attitude and heading data with perfect timing collected with the acoustic measurements on the towfish – avoids MUX latency issues.

Directional WMT MF responder on vessel

Tracked to a slant range distance of 9,022m with good SNR
Limited by tow cable, not signal
Responder transmitting 202dB from the vessel
SNR >20dB.

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LMF Trials 2017

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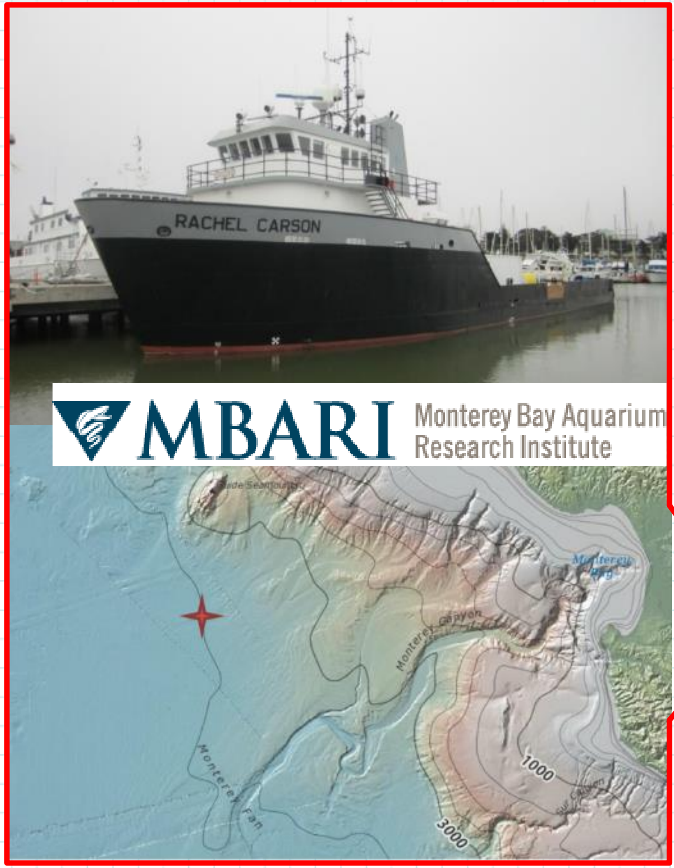
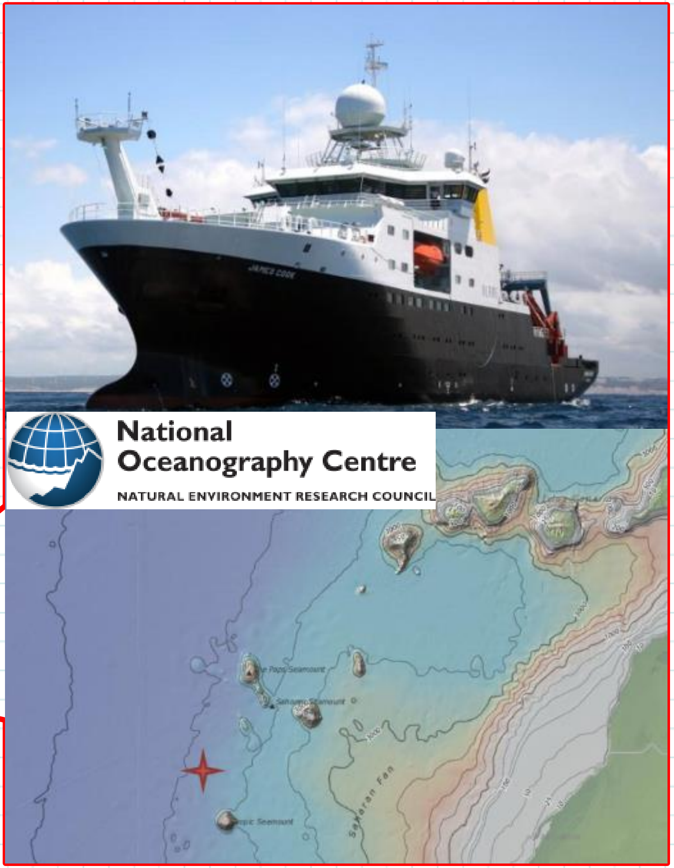


22-23 May 2017
RV Rachel Carson
Trial site: Monterey Bay, California
Water depth: 3,500m

25 Nov – 6 Dec 2017
RRS James Cook
Trial site: SW of Canary Islands
Water depth: 4,300m

Cooperation of MBARI and NOC is gratefully acknowledged

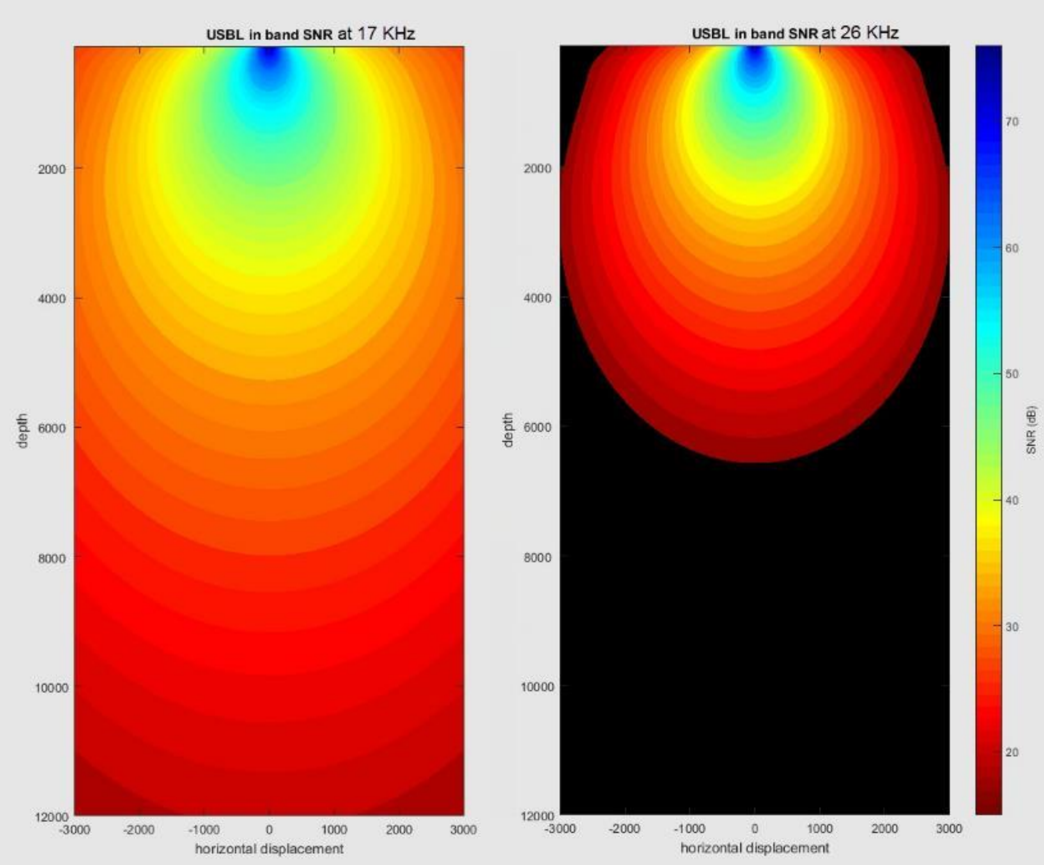


Gyro USBL combines USBL and attitude sensors in one instrument

- Transceiver – LMF (15.5kHz Wideband2™ carrier) GyroUSBL
  - Integrates a high accuracy AHRS with the USBL transceiver – provides perfect timing
  - Out of the box “Calibration free”
  - ~0.3% slant range precision improving to up to 0.1% slant range after the first and only calibration
  - GyroUSBL can be moved from vessel to vessel without a need to re-calibrate with only a quick spin test to verify alignment required
- Beacon – on the Seabed
  - 6th Generation (6G) LMF Compatt (omni) Compatt transponder
  - Omni-directional (SL 193dB re 1µPa @1m) used in the MBARI trial
  - Directional (SL 201dB re 1µPa @1m) used for the NOC trial

Absorption – Benefits of lower frequencies

Frequency (kHz)	Absorption (dB/km)	Δ from 14kHz (dB/km)
14	1.93	-
17	2.71	0.78
19	3.27	1.34
25	5.12	3.19
34	8.01	6.08



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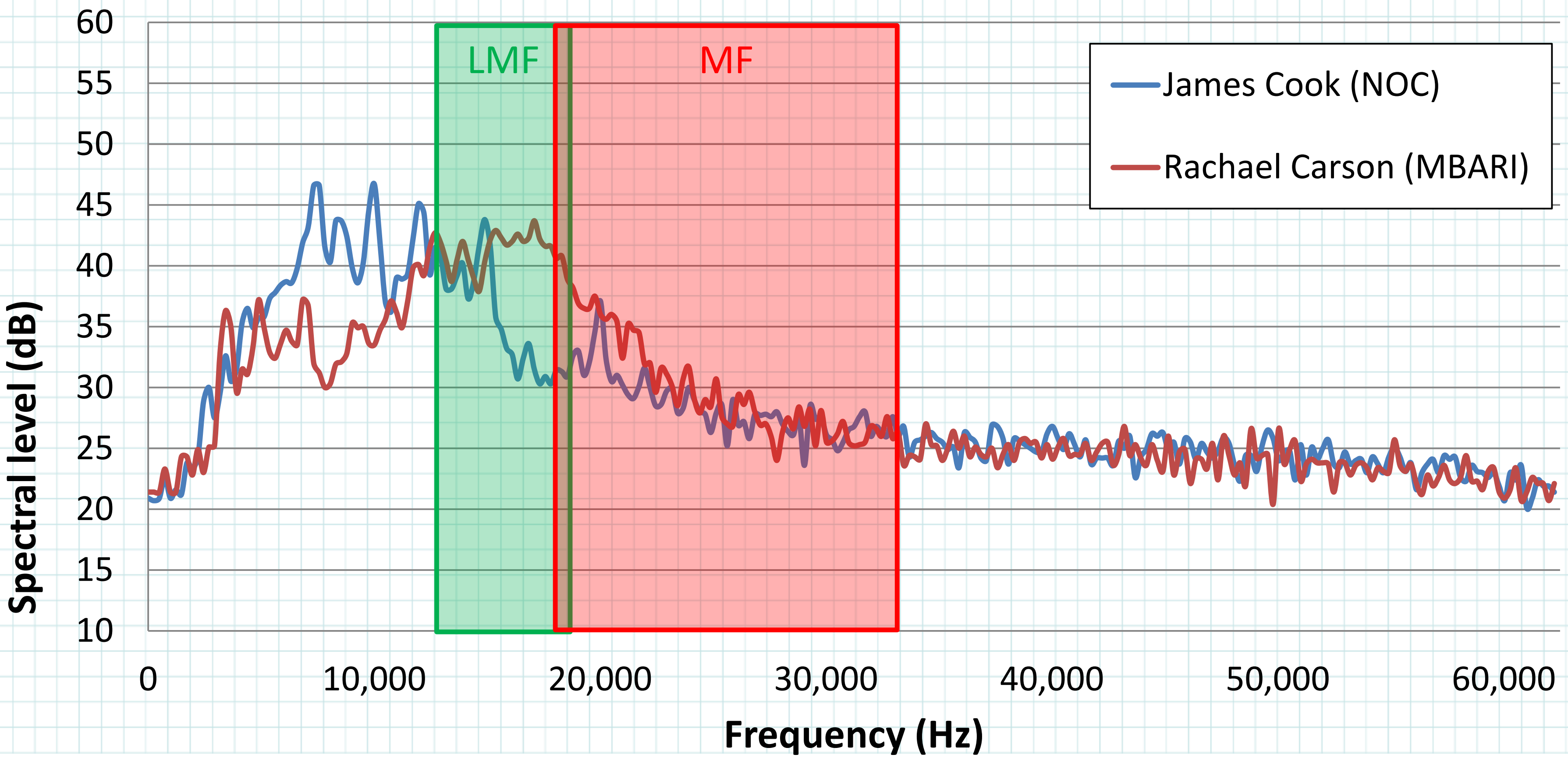
Noise Comparison Between RV Rachel Carson and RRS James Cook



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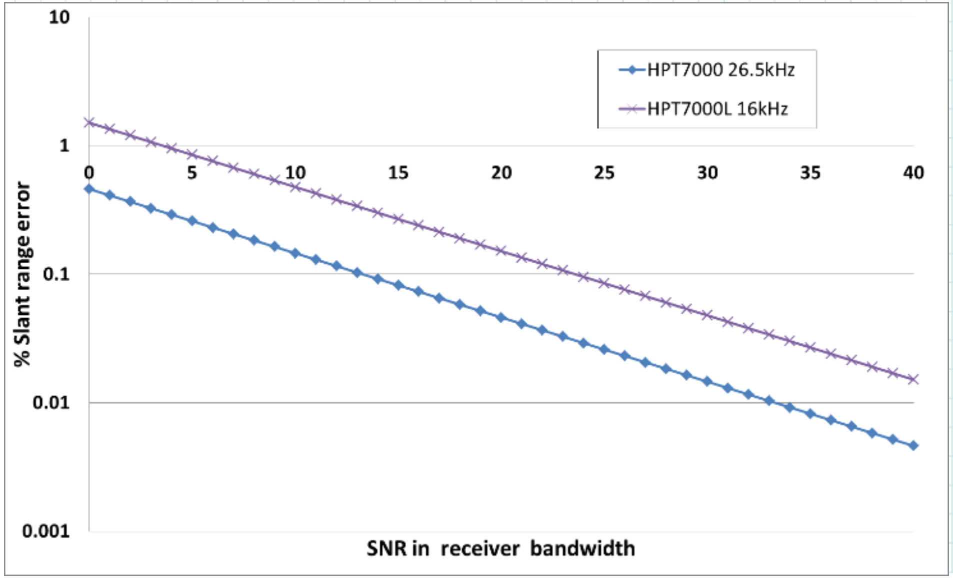
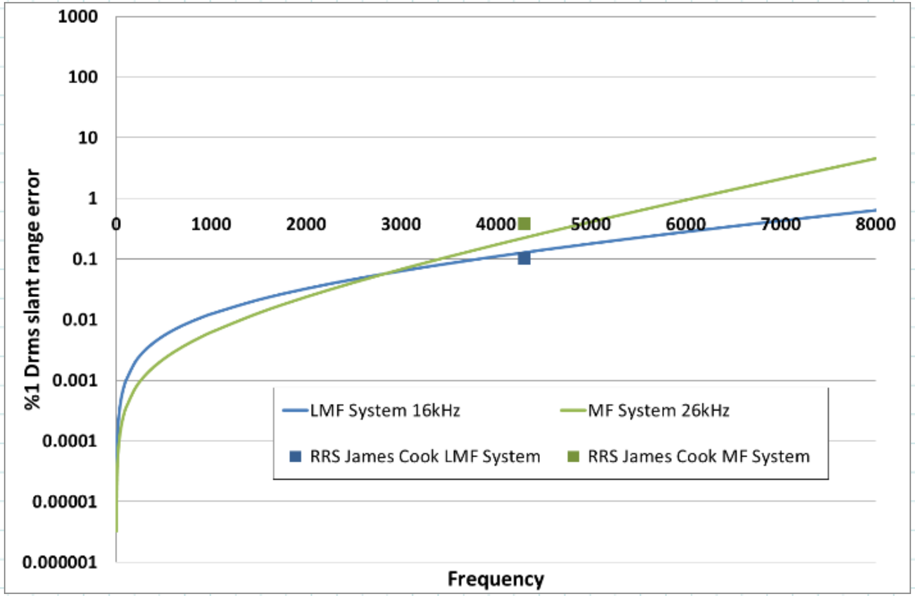
Frequency Effect on Measurement Precision

A greater phase change across the aperture of the array is observed at high frequencies resulting in higher angular precision





But SNR of LMF eventually more significant than phase resolution of MF:

- This is SNR based, so vessel noise base determines at what range this takes place

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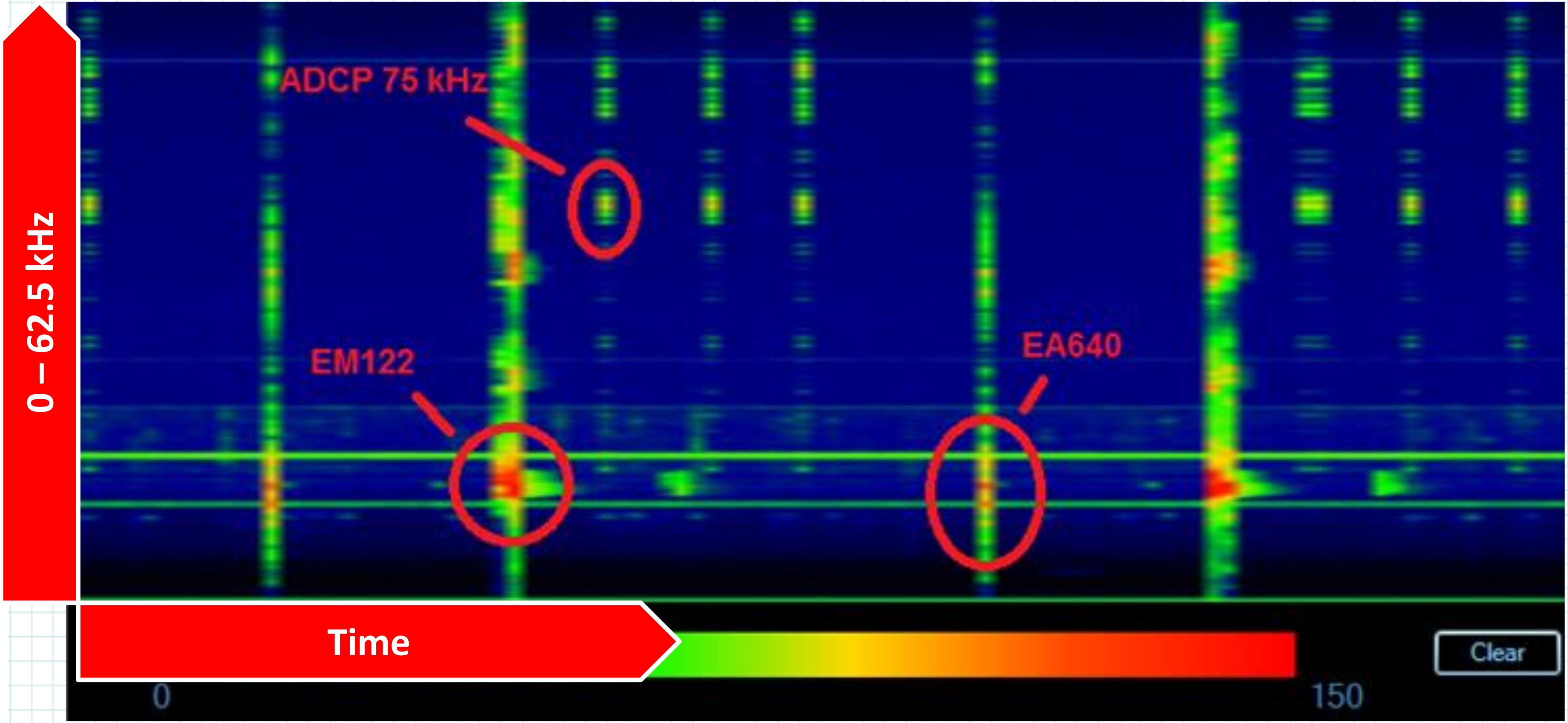
Interference with other acoustic sensors



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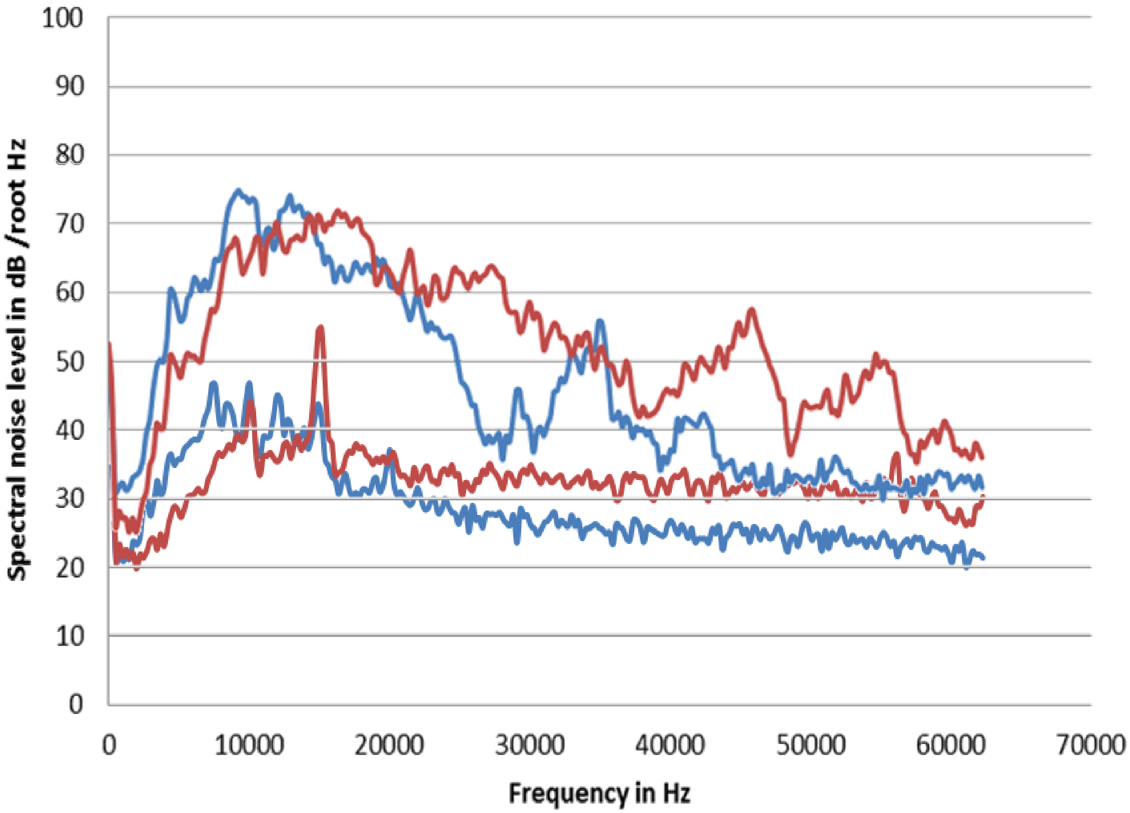
RRS James Cook – Comparison of thruster states

	Stationary	Underway	Station keeping
MF unit 20 kHz	36 dB	36 dB	65 dB
MF unit 26 kHz	35 dB	35 dB	62 dB
MF unit 30 kHz	34 dB	34 dB	58 dB
LMF unit 12 kHz	40 dB	40 dB	70 dB
LMF unit 15 kHz	40 dB	40 dB	65 dB
LMF unit 18 kHz	32 dB	32 dB	60 dB



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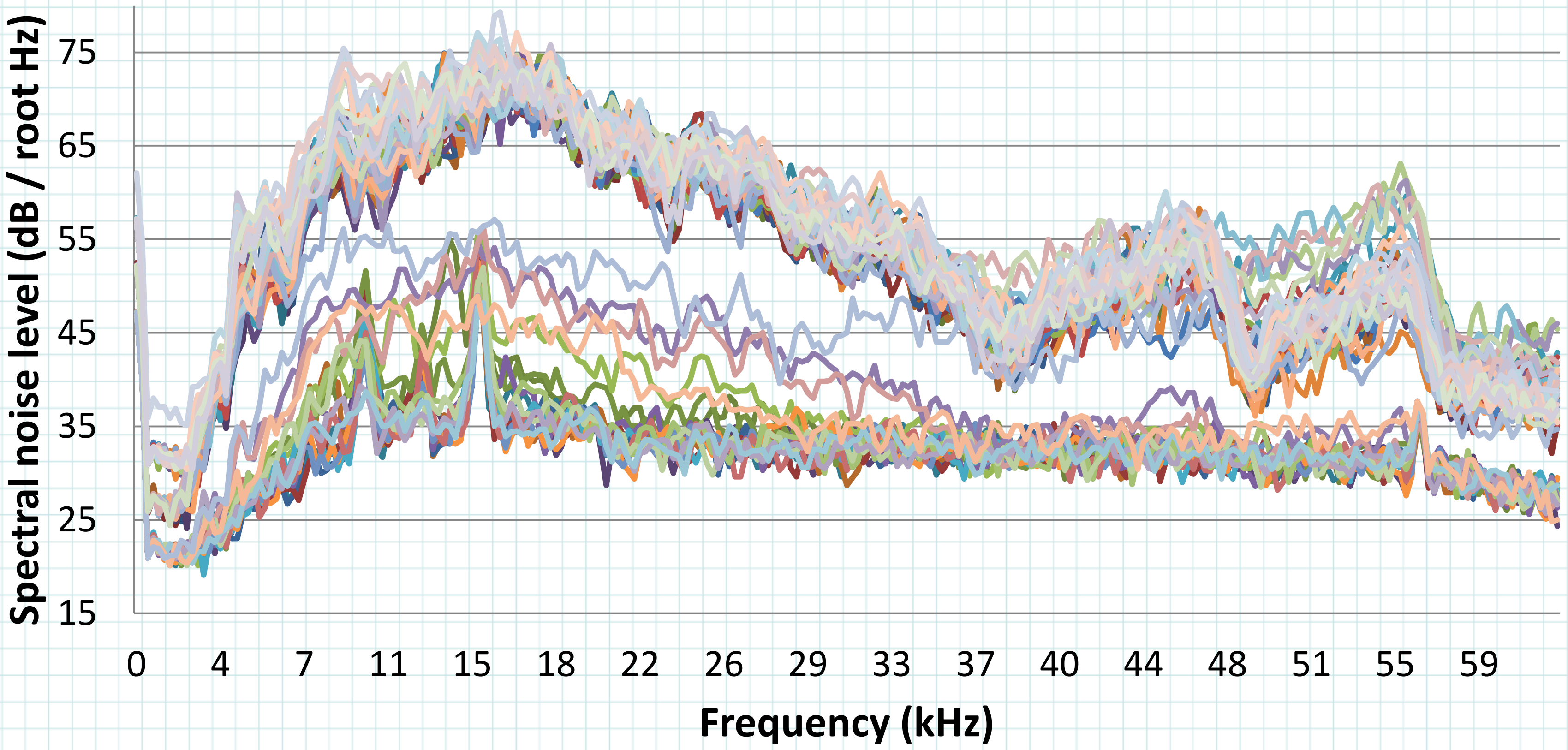
RRS James Cook – Noise level at different thruster states



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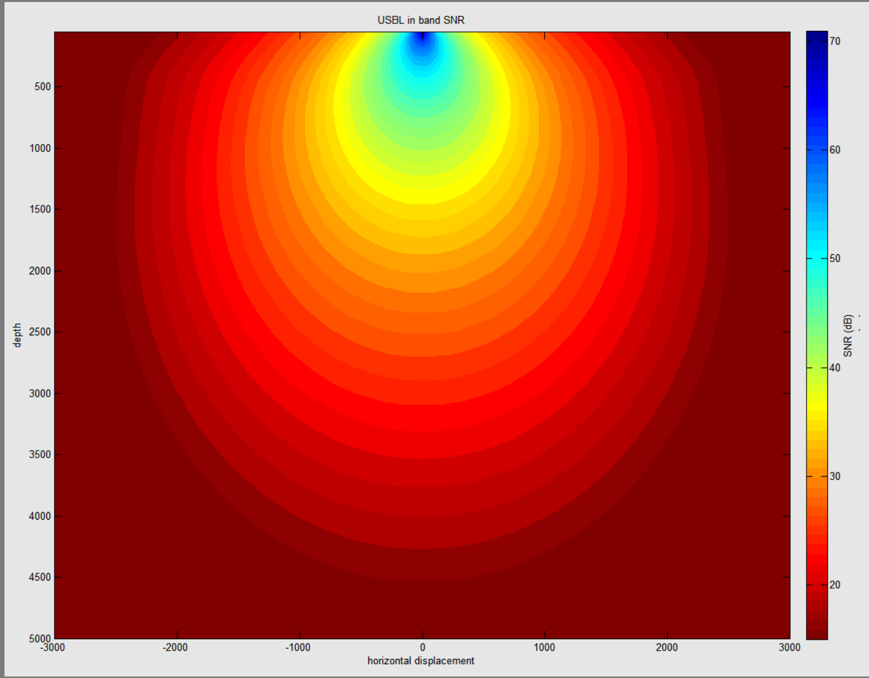
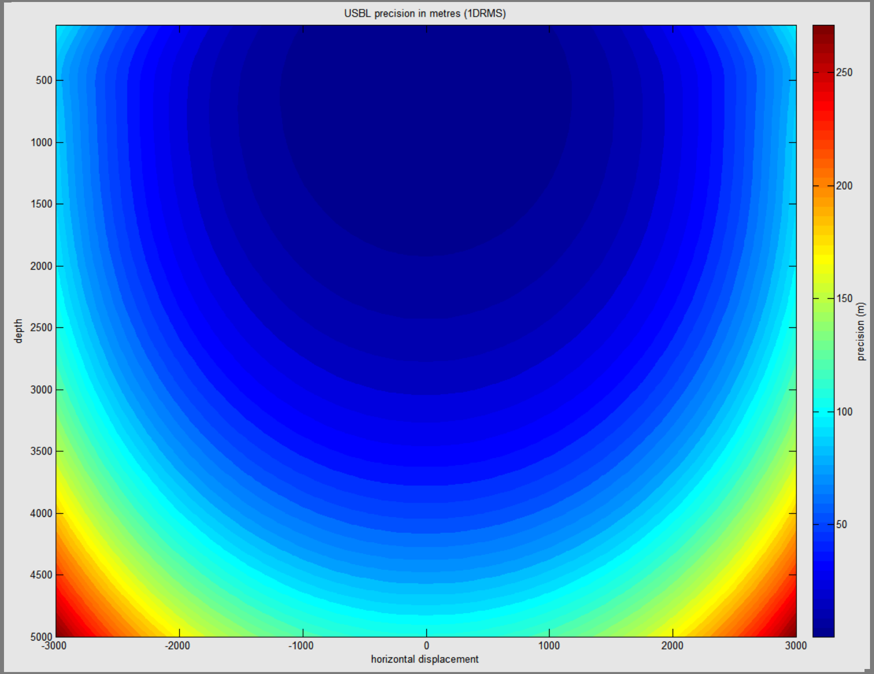
SNR v Precision





In band SNR

Precision in metres (1DRMS)

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RRS James Cook CASIUS LMF HPT

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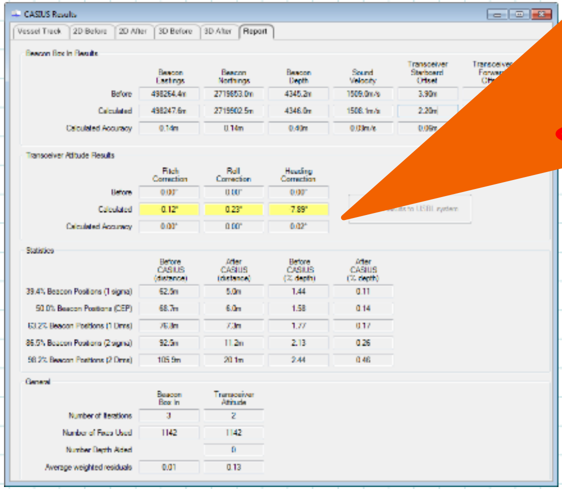

Transceiver Attitude Results

	Pitch Correction	Roll Correction	Heading Correction
Before	0.00°	0.00°	0.00°
Calculated	-0.12°	0.23°	-7.89°
Calculated Accuracy	0.00°	0.00°	0.02°

Export Results to USBL system

Statistics

	Before CASIUS (distance)	After CASIUS (distance)	Before CASIUS (% depth)	After CASIUS (% depth)
39.4% Beacon Positions (1 sigma)	62.5m	5.0m	1.44	0.11
50.0% Beacon Positions (CEP)	68.7m	6.0m	1.58	0.14
63.2% Beacon Positions (1 Drms)	76.8m	7.3m	1.77	0.17
86.5% Beacon Positions (2 sigma)	92.5m	11.2m	2.13	0.26
98.2% Beacon Positions (2 Drms)	105.9m	20.1m	2.44	0.46

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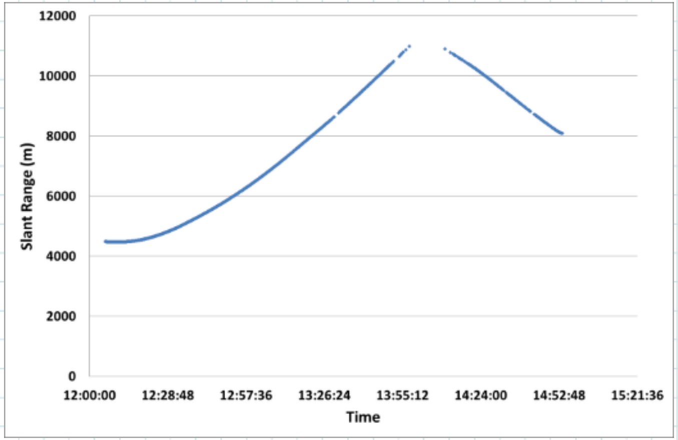
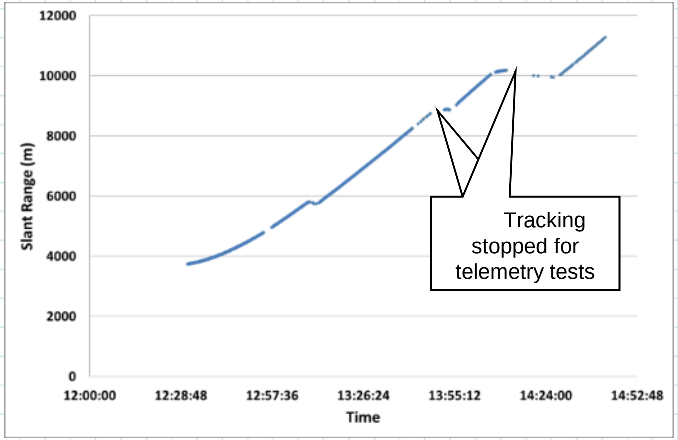
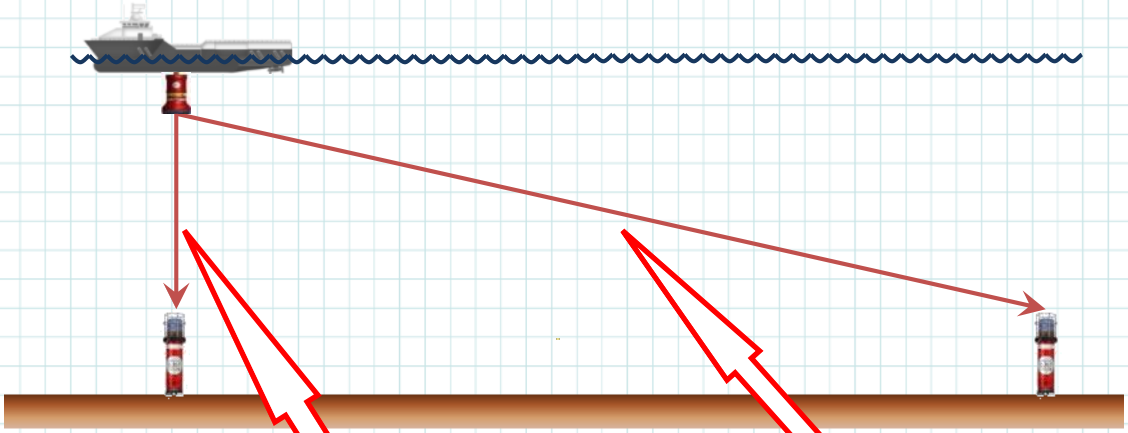
LMF USBL Trials Results







	CASIUS			Max slant range (m)
	Depth	% of depth	1drms (m)	
RV Rachel Carson	3,500	0.12%	4.2	11,300
RRS James Cook	4,300	0.17%	7.3	11,100

Rates achievable are dependent on configuring the delays between packets to minimise errors and consequent retries, which in turn reduce data real-world data-rates.

Rate (bps)	Theoretical bit rate	(4300m)		(7200m)	
		Actual rate	Energy per bit (mJ)	Actual rate	Energy per bit (mJ)
200	192	154	260	154	260
400	352	282	142	256	156
900	737	579	69	535	75
3000	3003	2765	14	2259	18
3500	3281	3021	13	2384	17
6000	6007	3686	11	1327	30
9000	9121	5150	8	-	-

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Summary

- Optimum solution begins with optimum installation:
  - – Optimise noise environment
  - – Optimise equipment (including ancillary sensors)
- Understand the errors and calibrate as per best practice
  - – Train your team

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Keep pushing the boundaries…

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Any questions?