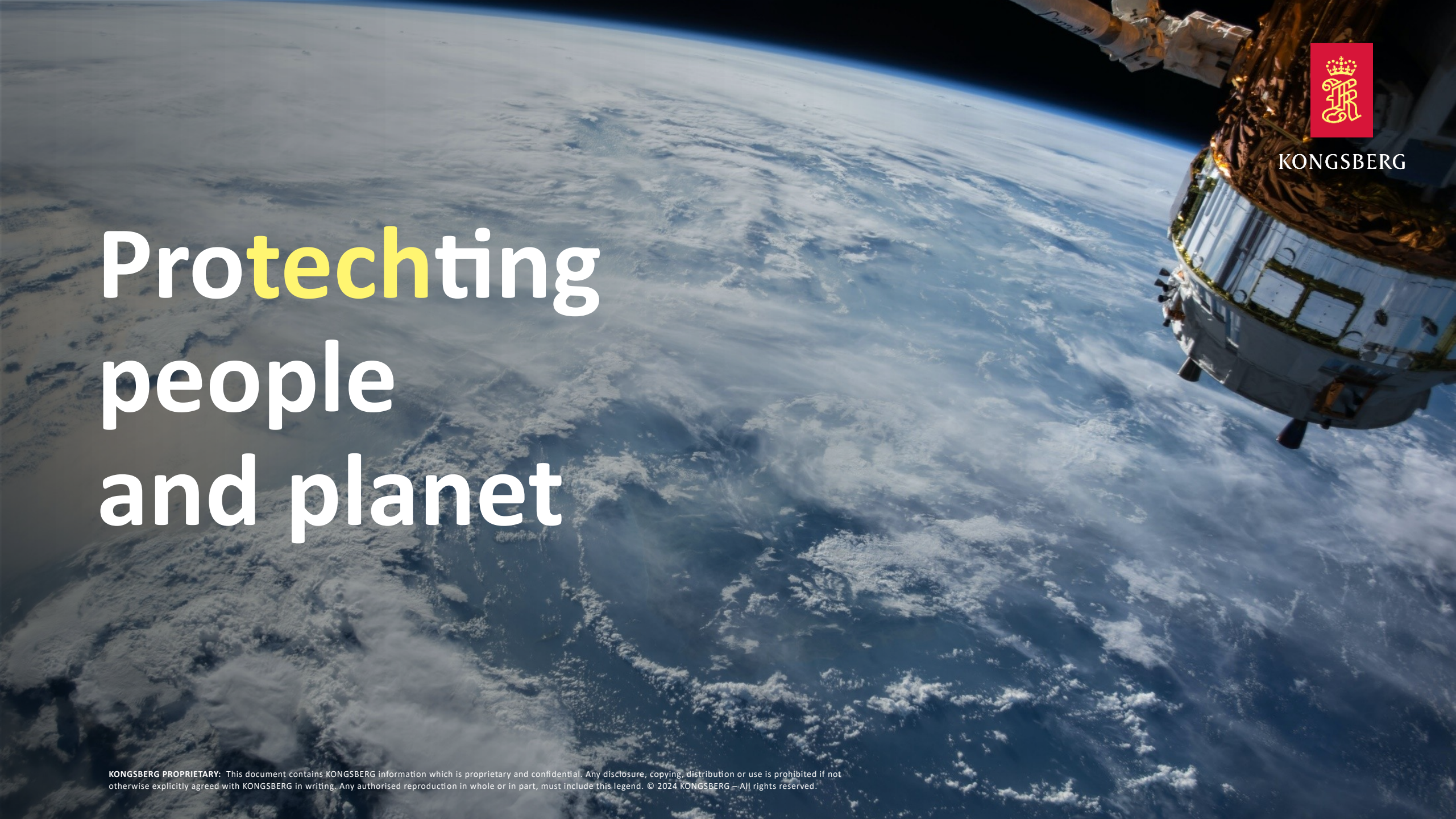

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Technology Advances Providing Extreme Acoustic Positioning Repeatability for Deepwater Drilling and Minerals Recovery

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MTS Dynamic Positioning Conference
October 2025

Spencer Collins
VP Sales
Kongsberg Discovery

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What is deepwater?

Shell spudded record setting well in 297ft of water from the Bluewater 1 in Jan 1962 (photo coutesy Ronald L Geer)

1947 16ft of water (Photo courtesy Tidewater and Kerr-McGee)

Total contracts Maers
ultradeepwater wells
11 903ft (2021)

MARS Project – TLP Installed 1996 after well spudding started in 1993- 2940ft (Photo Courtesy Shell)

cNODE Low Frequency Transponders with Pressure balanced Transponders for operatuions in 36 000ft- 2019

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Deep-sea polymetallic nodule collection
15 000ft to 20 000ft Water Depth

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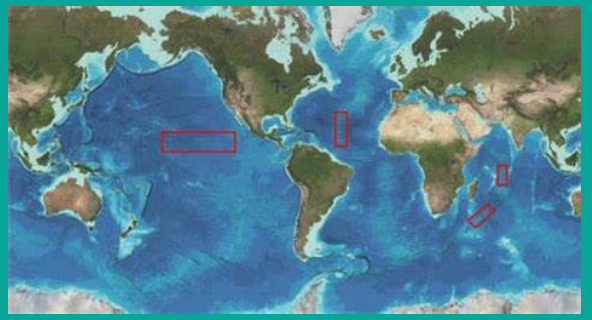
Courtesy: DeepGreen

- New Frontier of seabed minerals recovery
  - Crawler test in Atlantic Q4 2021
  - Full mining trial in the Clarion Clipperton Zone, Pacific Ocean in 2022
  - International waters UN International Seabed Authority developing regulatory framework.
- Hidden Gem formally Drillship Vitoria 10 000 has been converted for deep sea recovery of polymetallic nodules
  - Copper, Nickel, Manganese and cobalt for green energy battery revolution.

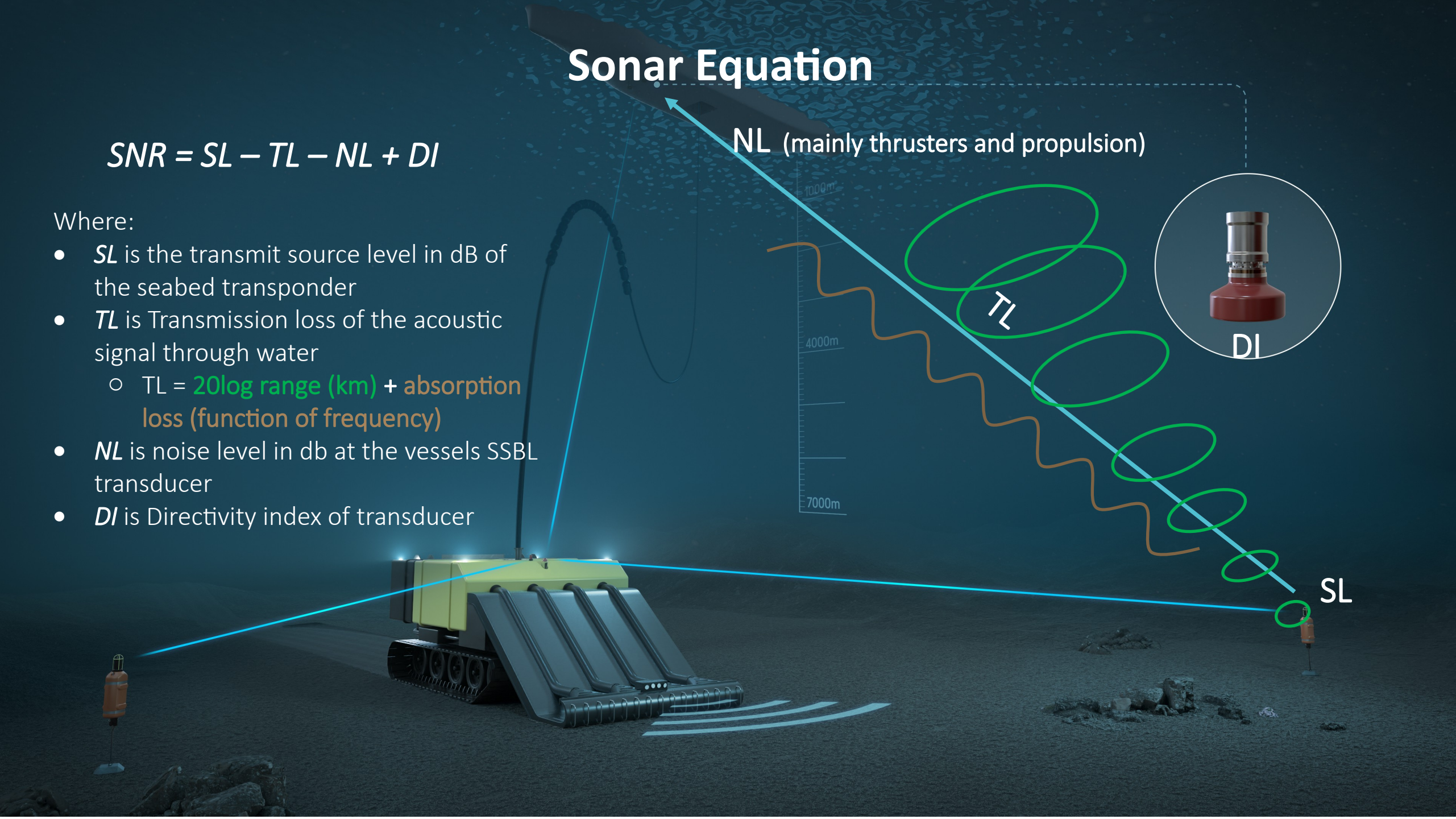


Sonar Equation

$$SNR = SL - TL - NL + DI$$

Where:

- ***SL*** is the transmit source level in dB of the seabed transponder
- ***TL*** is Transmission loss of the acoustic signal through water
  - TL = 20log range (km) + absorption loss (function of frequency)
- ***NL*** is noise level in db at the vessels SSBL transducer
- ***DI*** is Directivity index of transducer



Why Have Different HiPAP transducer models?

HiPAP502 5000m/16500ft

HiPAP 352 7000m/23000ft

HiPAP602 4000m/13000ft

MicroPAP

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HiPAP – 3D Beam Forming

Beamforming
- Optimizes the signal from the “antenna”
- Increase sensitivity in a specific direction

Advantages
- Improves range capability
- Improves directional accuracy
- Reduces noise impact
- Reduces multipath impact

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Spherical vs Planar Transducer Arrays

- Accuracy and range capability are defined by the received signal to noise ratio (SNR) and the beam width. The beam width is dictated by the area of the transducer face pointed towards the transponder.

- In the example on the next slide the spherical HiPAP 502 array has the same transducer area pointing at the transponder in all elevation angles, so range and angular accuracy are the maintained in all directions.

- However, for the Planar transducer the area pointing at the transponder gets smaller at higher elevation angles, which therefore reduces angular accuracy and maximum range performance.

- Specifications for PLANAR transducers are valid within a cone under the transducer. Outside this cone the maximum range and angular accuracy are progressively reduced as elevation angle increases!

HiPAP 502 vs 602 transducer array

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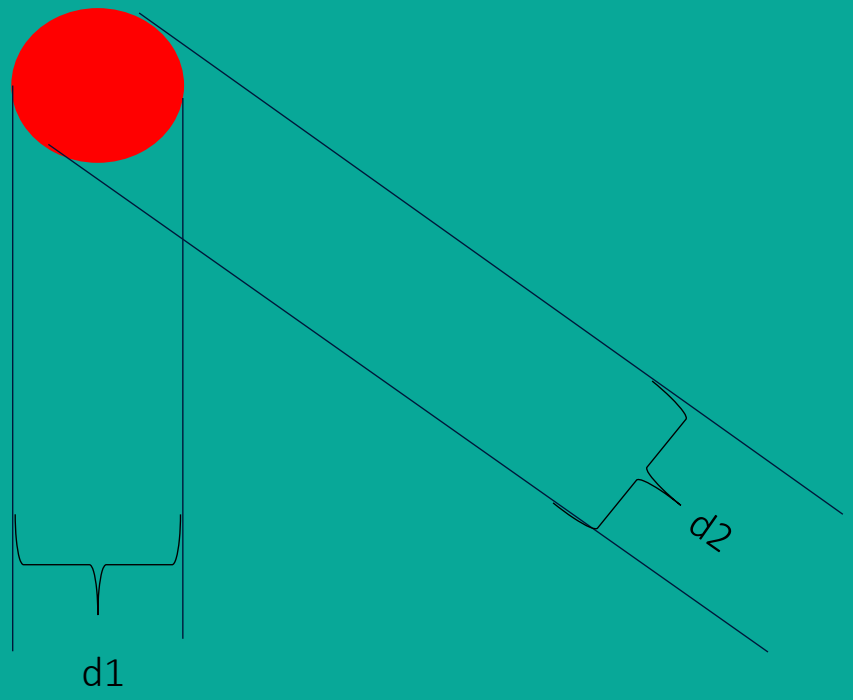
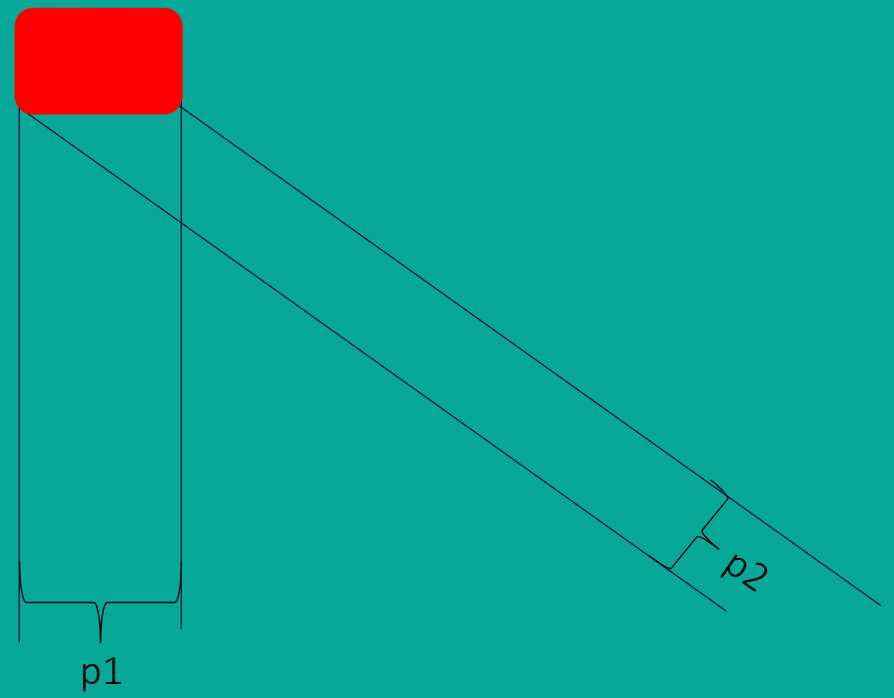
Spherical Array



Planar Array



- Accuracy and range capability is defined by received Signal/Noise Ratio and beam width.
- Beam width is defined by the area of the array pointing to the transponder.
- For the spherical array d1=d2 for any elevation angle
- For the planar array p1>p2, and p2 will get smaller as the elevation angle increases

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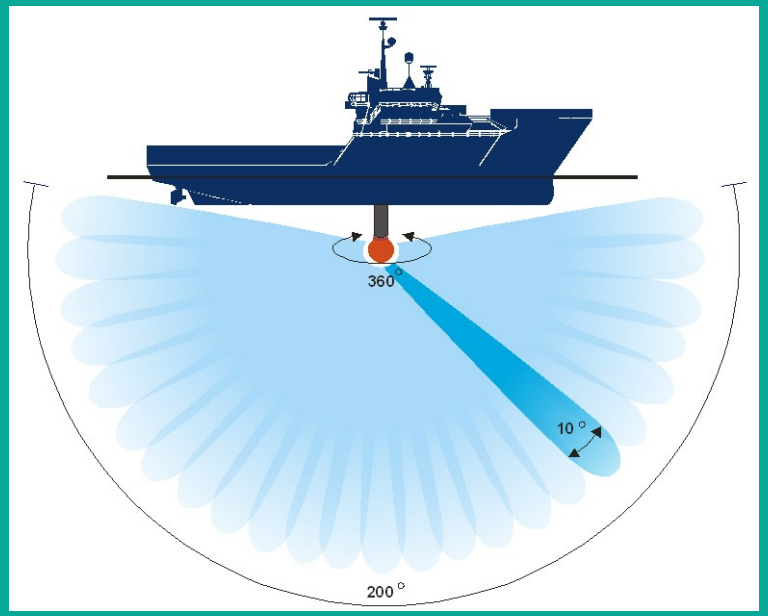
Beam width

The angular accuracy of an SSBL system is a function of beam width which is proportional to the transducer size. The larger the transducer the narrow the beam width as described by the simplified formulae below:
(A Narrower Beam = Higher Angular Accuracy)



$$b = \frac{l}{L} * \frac{180}{\rho}$$

Where:
β = opening angle in degrees.
λ = wave length = (c/f)
c = sound velocity
f = frequency
L = length of active transducer area in meters

Beam width is inversely proportional to the size of the transducer

Ø = 400mm Ø = 460mm

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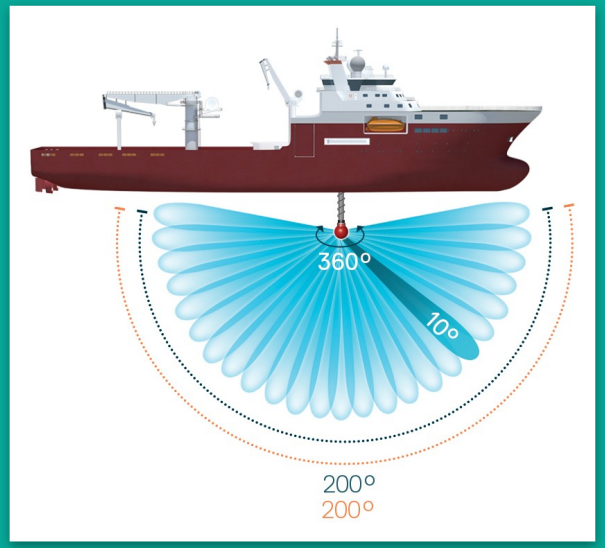
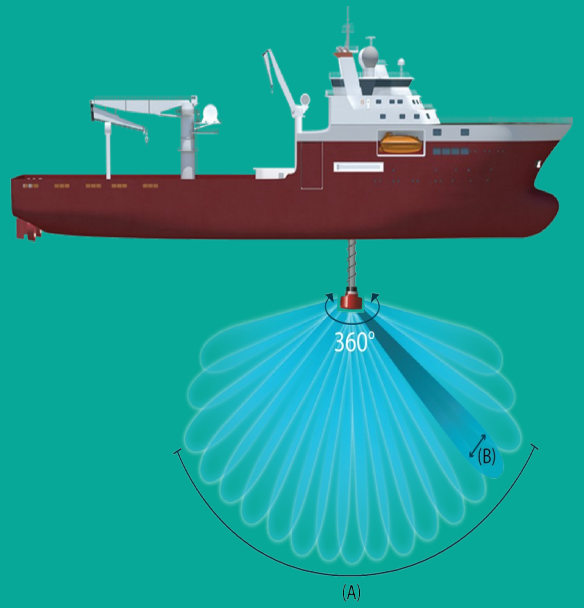
HiPAP 502 vs HiPAP 602



- 200° operational envelope
- Narrow beam (10°) can be pointed towards the target in any direction within 200°cone
- Same accuracy, noise reduction and multipath suppression achieved in all direction

HiPAP 502



- (B) Narrow beam (≈8°) can be pointed towards the target in any direction within (A) main cone of operation, +/-60°
- Angular Accuracy 0.04° within +/-30°cone
- Max Range 7000m
- Due to the planar array, the accuracy and range performance will be reduced outside the main cone

HiPAP 602

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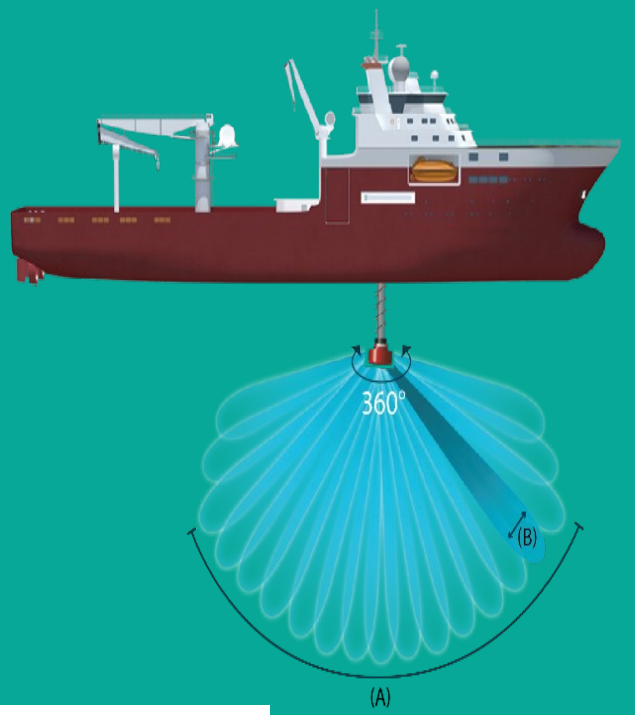
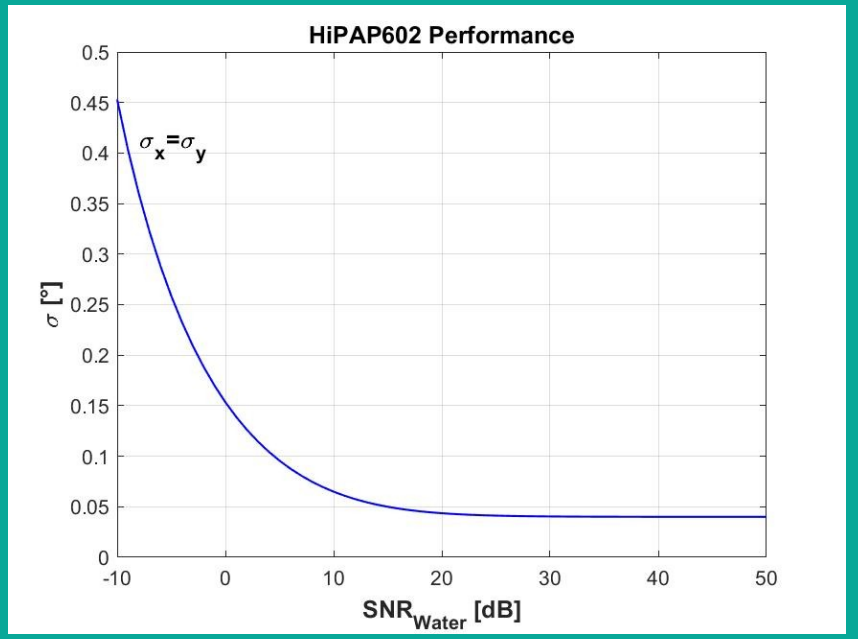
HiPAP 602 Specification



Accuracy, direction (1)	0.04° within ±30° sector >0.06° from ±30° to ±60° sector
Repeatability, direction	0.01°, within ±30° sector
Accuracy, range	± 0.02 m
Ray bending compensation	Yes
Frequency	20-30 kHz (MF)
Operational coverage (3) Main coverage	±90° ±60°
Receiver beam	8° Ref B in figure
Source level (re 1µPa)	207 dB
Range capability (m) (2)	7000+
Navigation Channels	560 Cymbal, 56 FSK, cNODE Compatible
Operation mode	SSBL, LBL, acoustic modem
INS	Integration to HAIN for improved performance
Transducer deployment depth	< 50 m
Temp. operating/storage	0°C to +35°C/-20°C to +70°C
Storage humidity	95 % relative, non-condensing
Vibration	5-100 Hz, 5-13.2 Hz ±1.5 mm, 13.2-100 Hz 1 g



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HiPAP 602

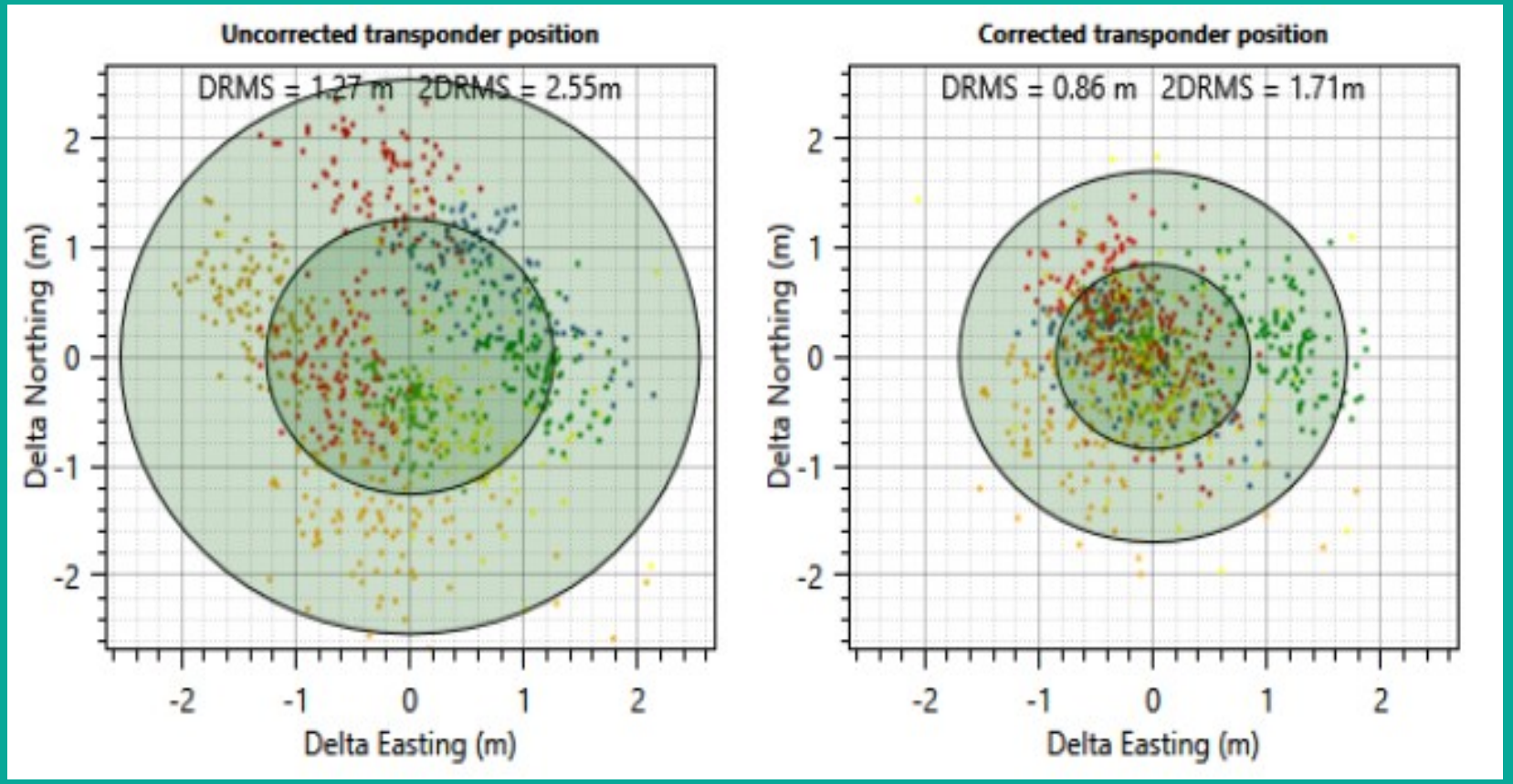
Calibration Results from 750m WD

From transducer alignment

- 4 headings on top
- 4 cardinal points at 300m offset
- Position DRMS: 0.86m
- Std dev N: 0.56m or 0.0428°
- Std dev E: 0.65m or 0.0497°

Note:

The position error includes all errors from GNSS, AHRS, Lever arms and sound velocity.



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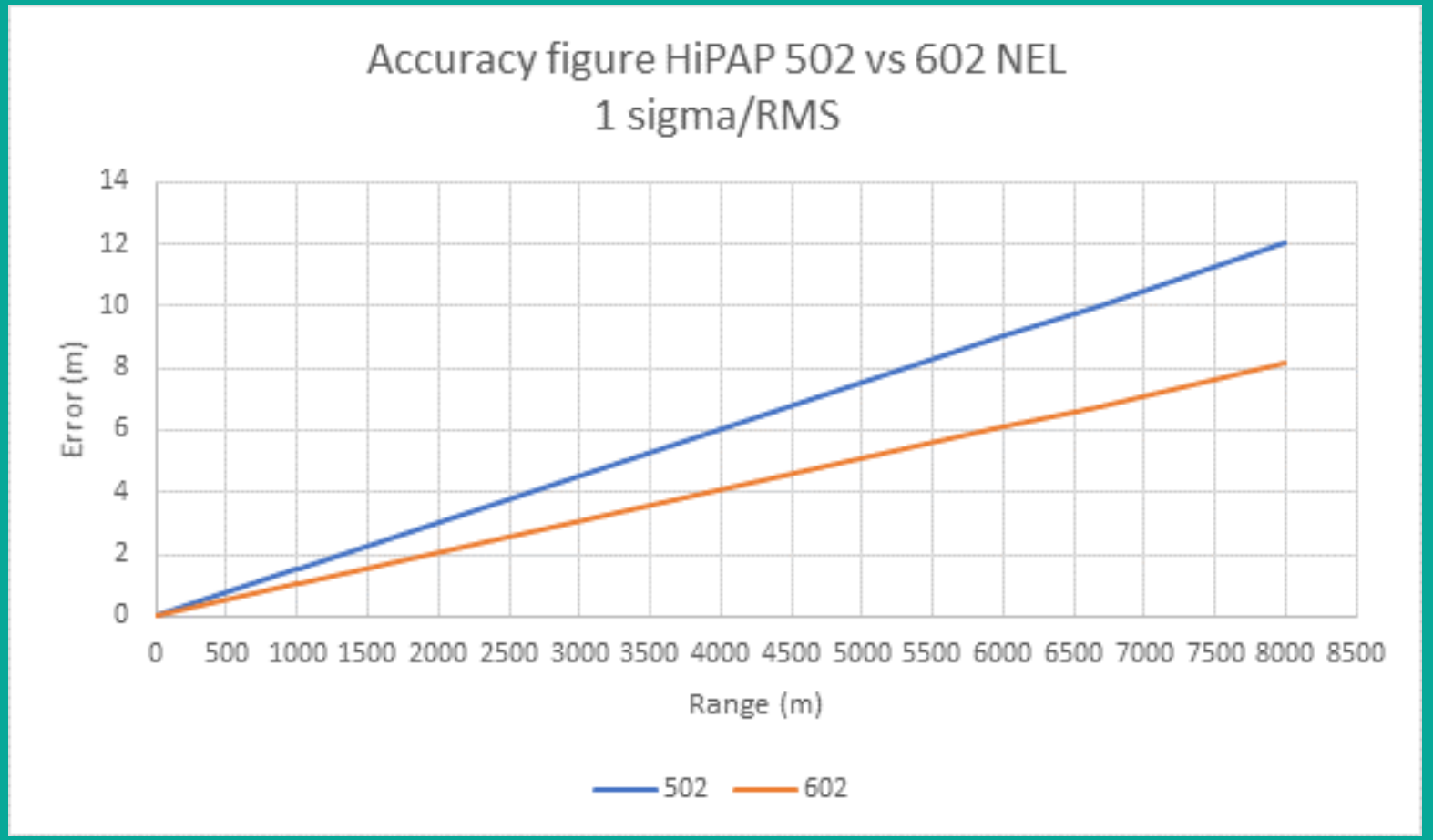
HiPAP 502 vs 602



Note: HiPAP 602 position error standard deviation is valid in a cone of operation directly under the transducer

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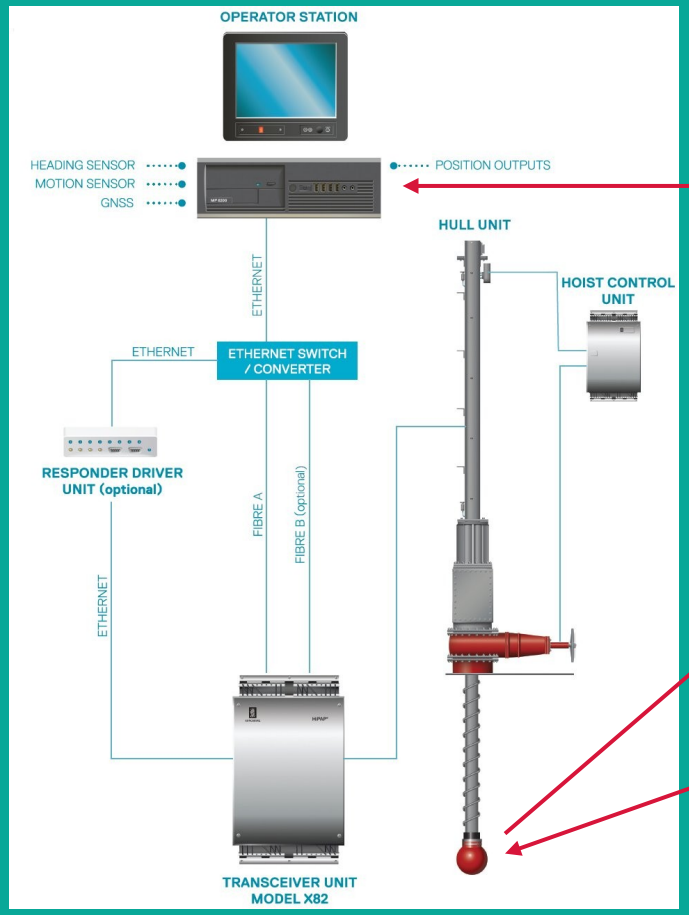
Simple Refit of HiPAP 502 to 602



- Install HiPAP 602 SSBL Software
- Remove HiPAP 502 Sphere Transducer from Hull Unit
- Install HiPAP 602 Transducer on Hull Unit / at 460mm diameter transducer fits through the standard DN500 Gate valve

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HiPAP HAIN Reference – What is it?

- HAIN- Hydroacoustic Aided Inertial Navigation
- A Position Reference System for DP systems
- An Add-On to any HiPAP system.
- Improves position accuracy, update rate, and stability.
- Provides added safety to DP operations in case of HiPAP dropout.

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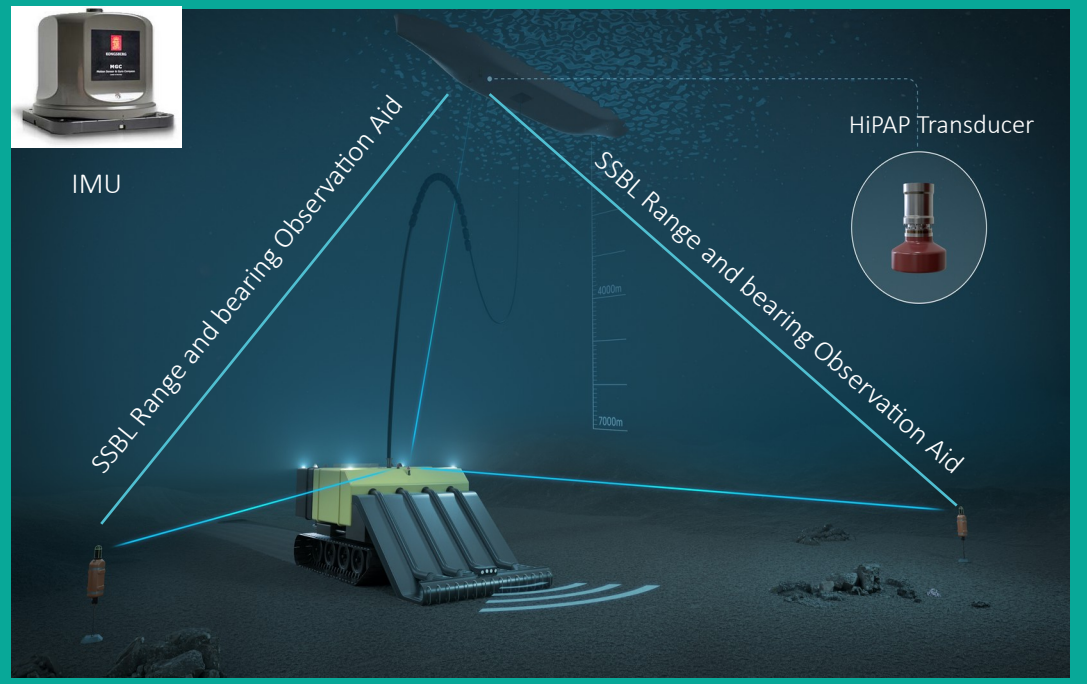
HAIN Reference - Introduction

- The Inertial Measurement Unit (IMU) is a core component of an INS and measures its own movement.
- The IMU contains accelerometers and gyroscopes
- The IMU provides angular rates and velocity to the Inertial Navigation Computer for processing into position.
- Timestamped acoustic observations from HiPAP are sent to the HAIN computer for “aiding” the corresponding INS position.
- This “aiding” results in a new position which is sent back through HiPAP and into the DP system.



Acoustic and Inertial Navigation
Noise and Drift in Position

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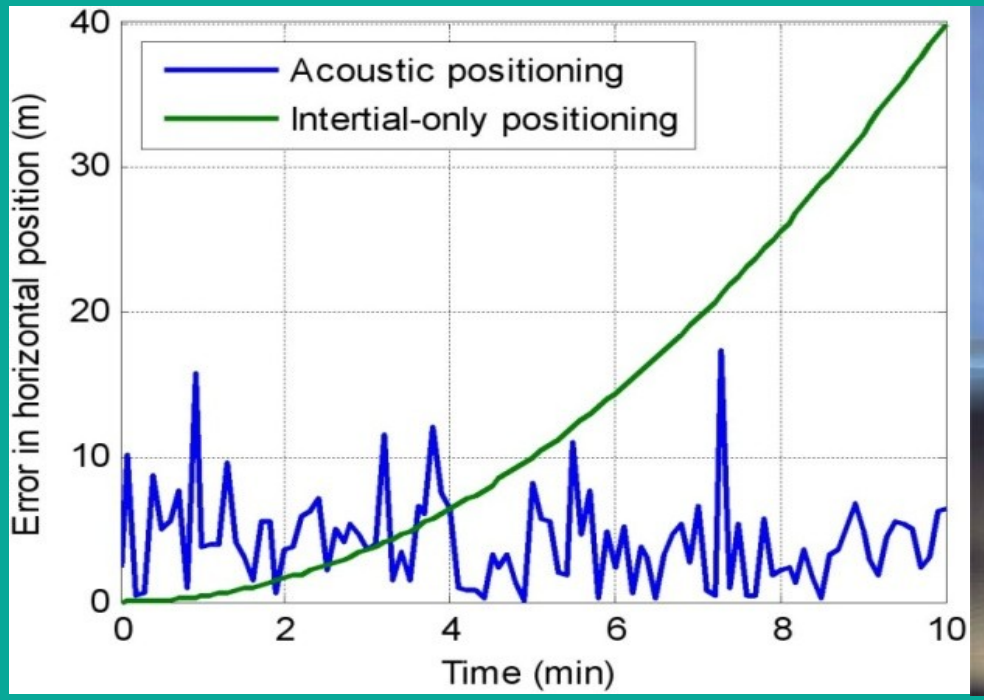
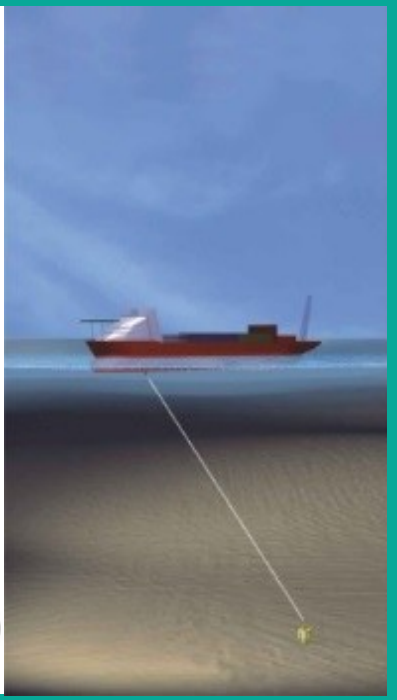
- **Acoustic positioning provides**
  - Positioning with relatively high and evenly distributed noise
  - No drift in the position
  - Slow update rate
- **Inertial positioning provides**
  - Very low short term noise
  - Relatively large drift in the position
  - Fast update rate
- **Main advantages Acoustic Aided INS**
  - Increased position accuracy
  - 1 hz position update rate
  - Increased operating window
  - Extended use of SSBL prior to LBL
  - Results in Equivalent weighting of position in the DP system





HAIN Reference – DP weighting

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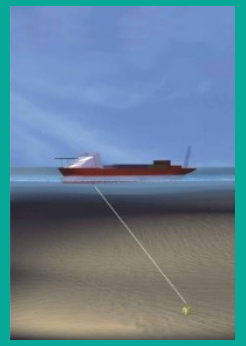
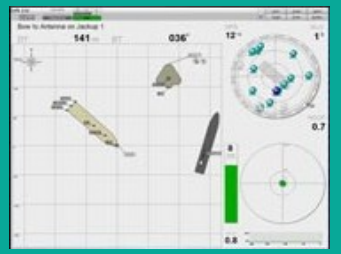
- Any reference system with accuracy (standard deviation) less than 1 meter and with an update rate of minimum 1 second is allocated equal weight in the DP system; the GPS (Global Positioning System) is of such nature
- In an example where HiPAP® operating in 2000 meters water depth, the table below shows typical data with and without HAIN Reference

Reference Systems in water depth of 2000m	**HiPAP SSBL** 	**HiPAP LBL**	**GPS** 
Standard deviation	2.5 meters	0.25 meter	0.5 meter
Update rate	3.5 seconds	3.5 seconds	1.0 second
Standard deviation with HAIN	< 1.0 meter	< 0.5 meter	0.5 meter
Update rate with HAIN	1.0 second	1.0 second	1.0 second

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HAIN Reference

HAIN Free Inertial Performance After Loss of Acoustic Aiding

SCENARIO	HiPAP	IMU: MGC R4	IMU: MGC R3
Typical operation SSBL in 2000m	2.5m	1.0m	1.2m
Acoustic aid dropout after 1 minute	NA	1.7m	2.6m
Acoustic aid dropout after 3 minutes	NA	4.0m	9.1m
Acoustic aid dropout after 5 minutes	NA	7.9m	21.0m
Typical operation LBL	0.25m	0.5m	0.5m
Acoustic aid dropout after 1 minute	NA	1.0m	1.4m
Acoustic aid dropout after 3 minutes	NA	2.7m	6.1m
Acoustic aid dropout after 5 minutes	NA	6.0m	16.0m

- The table shows a comparison of HAIN position accuracy with use MGC R3 and MGC R4 IMU units
- The figures are estimated standard deviation 1 sigma, in meters
- Acoustic position update rates are 4.2 sec for SSBL and 5 seconds for LBL.
- The actual accuracy experienced will often be better than the provided figures.
- The reported standard deviation for HAIN has a lower limit of 0.5m as HAIN accuracy figures incorporate colored errors, like lever arms and sound velocity.

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SSBL Aided HAIN Performance for HiPAP 502 versus HiPAP 602

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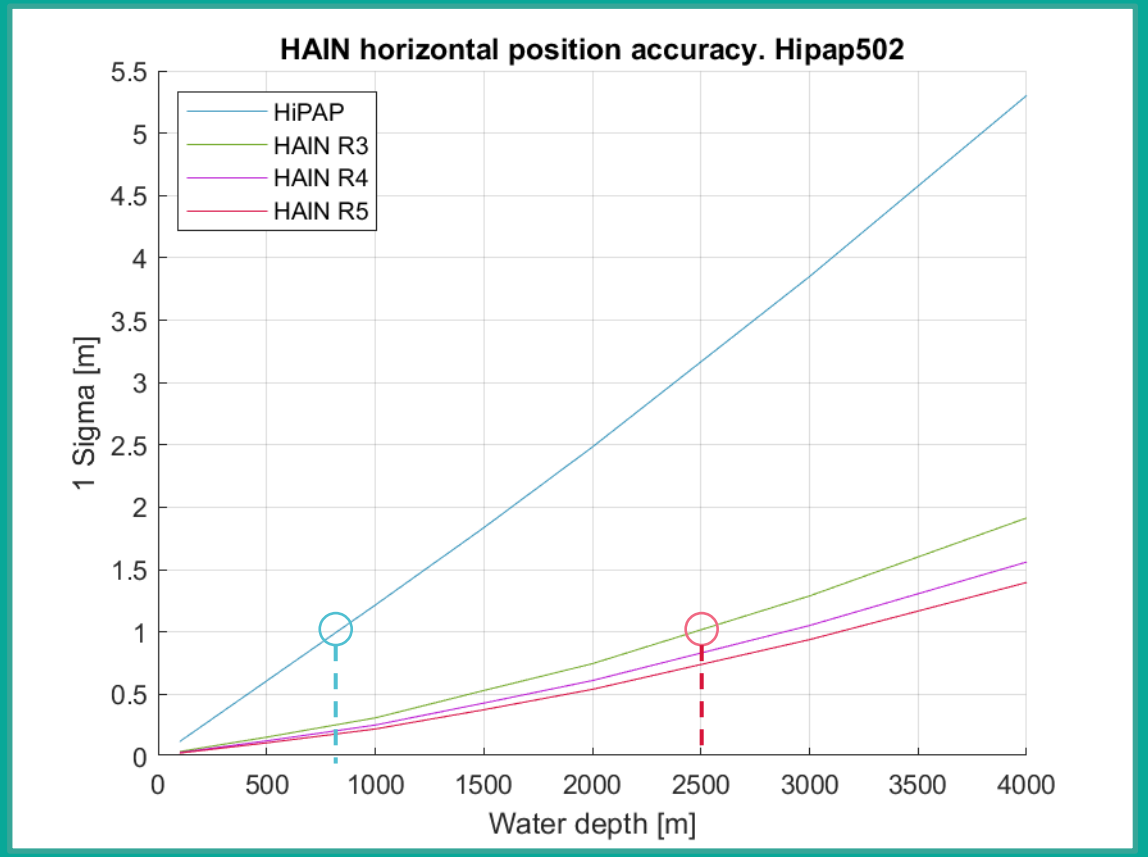

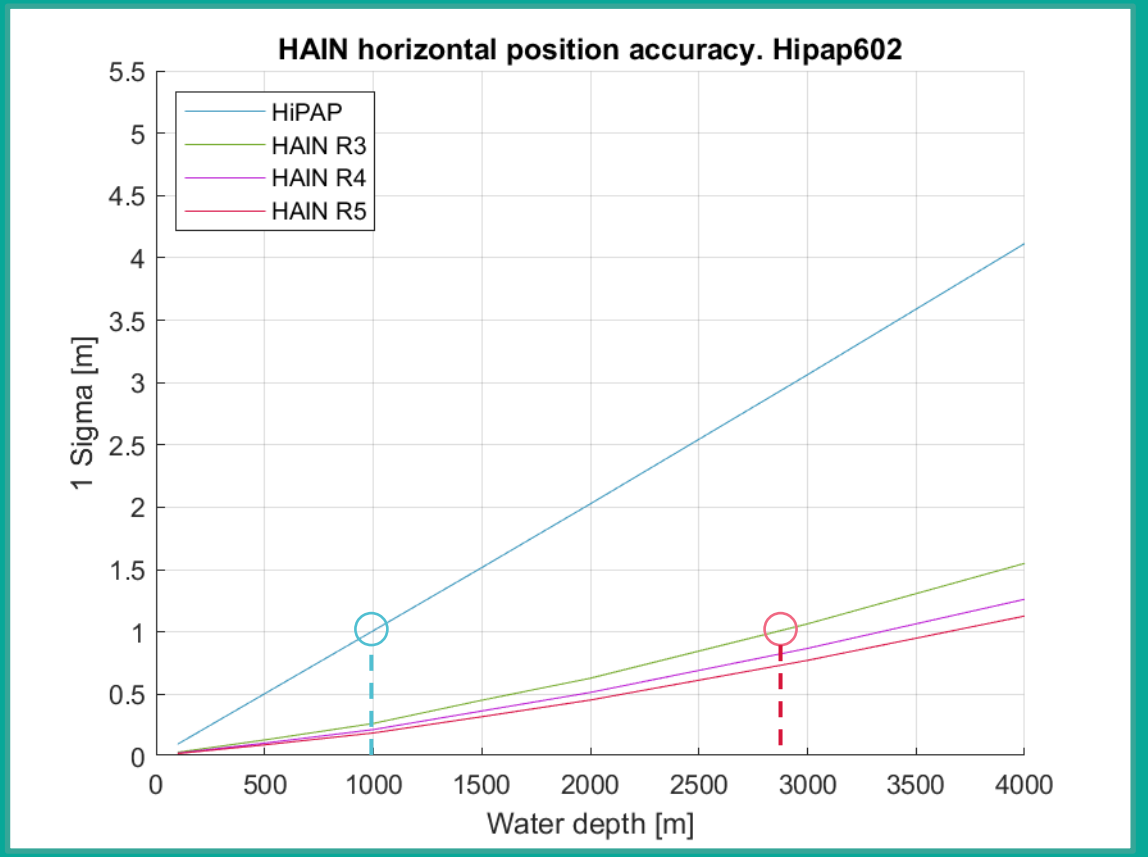

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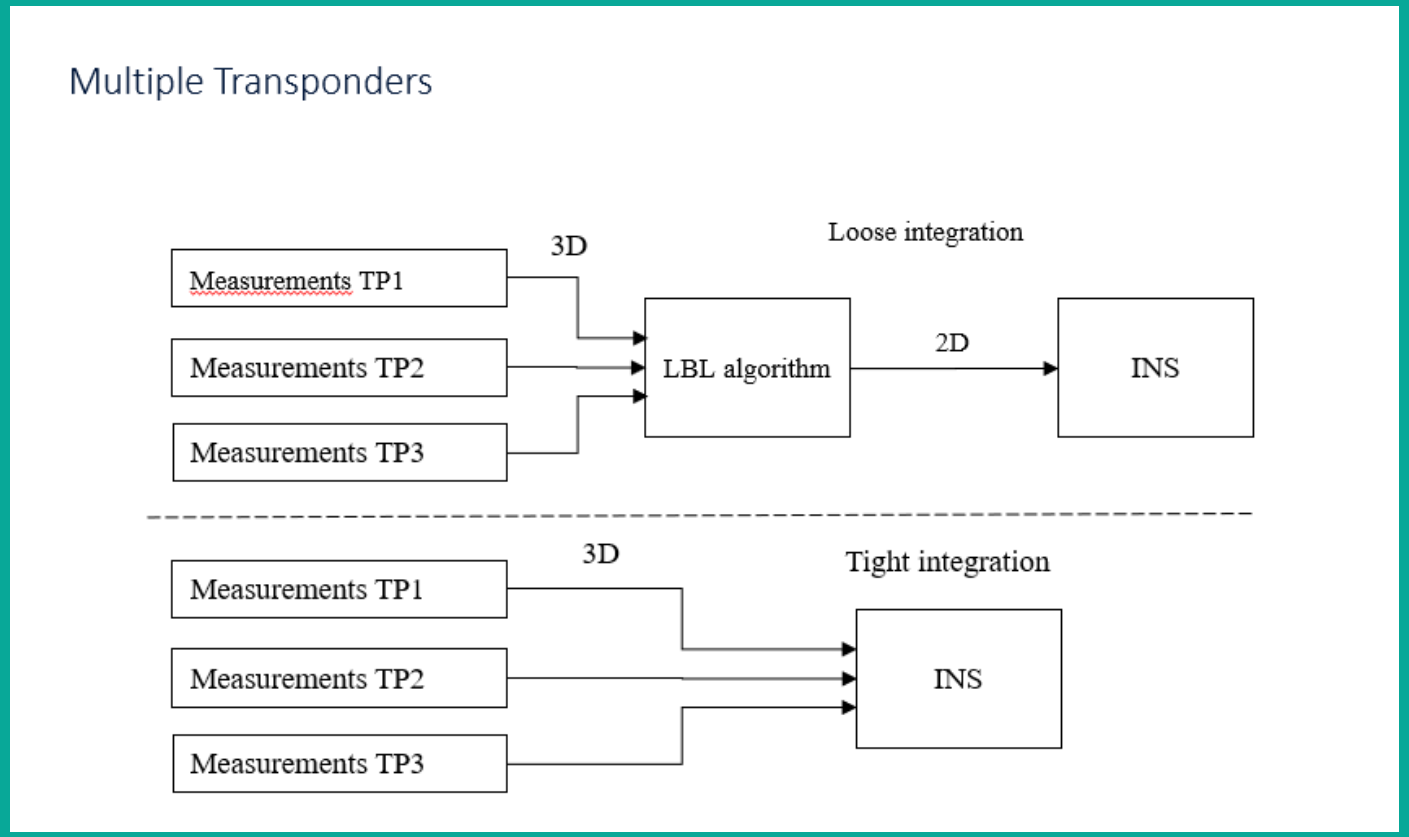
Multi-SSBL Software



The latest HAIN software includes '***HAIN Multi SSBL'*** which uses a tight integration of SSBL measurement data directly into the INS rather than an LBL position fix.

If an LBL position is not calculated by HiPAP due to few transponder ranges the Inertial Navigation will still have useful acoustic observations to aid the INS solution.

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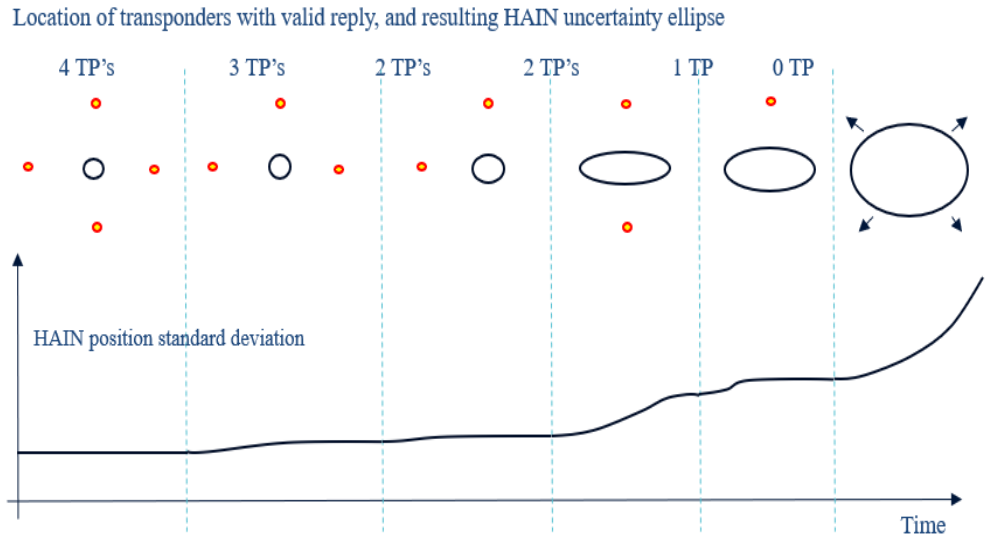
HAIN Error Ellipse

Error ellipse with different reply situations



Tight integration of SSBL observations vs loose integration

Tight integration is advantageous in that there is a seamless degradation in the error ellipse as reference transponders are dropped from the solution.

An illustration of the effect on error ellipse with varying number of transponder references using the Multi SSBL tight integration is shown to the left.

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SSBL Aided HAIN Performance for HiPAP 602 with different grade of IMU

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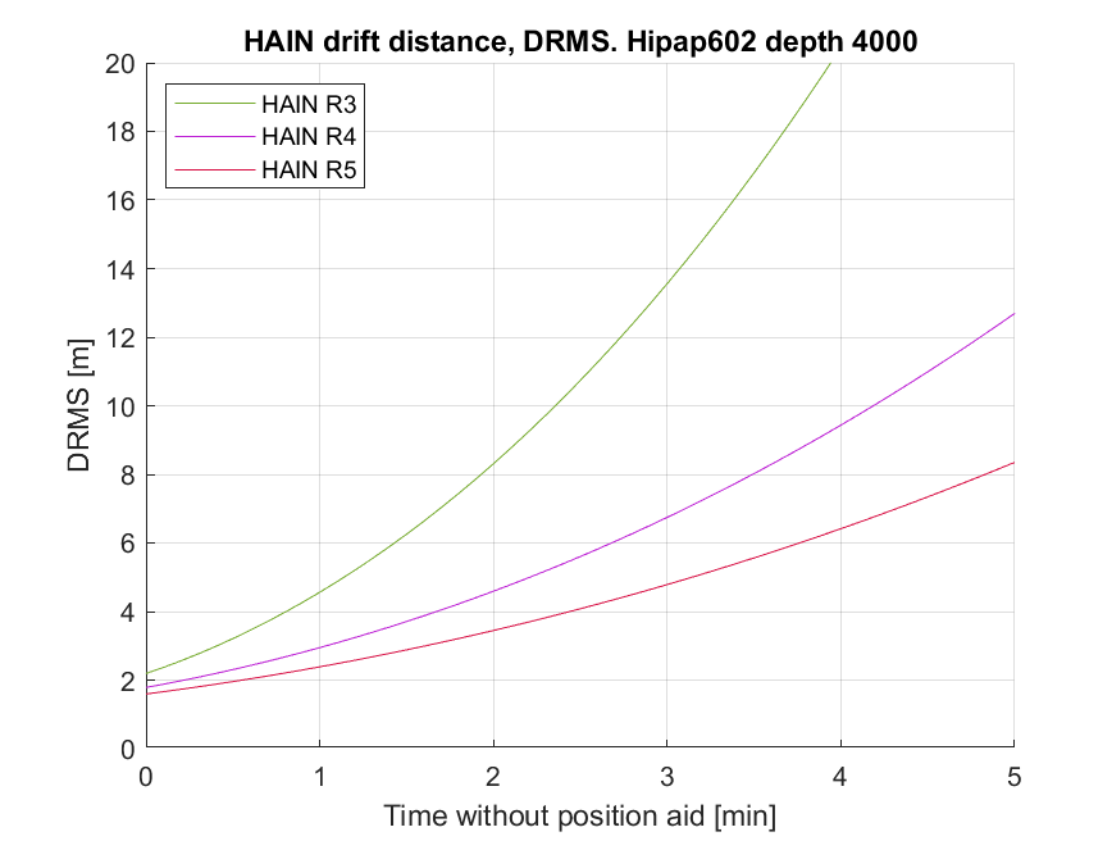

DP rejection of Free Inertial HAIN

Method 1

Configurable timeout in Acoustic Positioning System (default = 300s aka 5 mins), will switch a status bit in the HAIN message to DP.
DP will ignore the HAIN measurement when this status bit is switched.

Method 2

Standard deviation (SD) in HAIN will increase approximately quadratically with time, when it doesn't receive acoustic observations.
HAIN will get less weight in the DP system with increasing SD.
Time before HAIN reaches a threshold weight level is dependent on factors, including, IMU performance and accuracy of acoustic observations, before loss of aiding.

Both methods are used simultaneously

Rejection happens only when time since last position measurement reaches the timeout (regardless of DP's other sensors), but mechanism 2 above will make HAIN in practice be rejected (carry no weight in DP) possibly quite a bit sooner.

Summary

- Wider Beamforming Transducer provides up to 50% increased SSBL angular observation accuracy.
- Increases operational range to 7000m / 23 000ft
- HiPAP 602 with Multi-SSBL observation input to HAIN increases robustness and availability of position to DP System.
- Transducer refit maintains existing HiPAP Electronics and Hull units

- Main operational window +/- 30 degrees below the Transducer

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