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Towards safer and more efficient acoustic DP reference systems

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Abstract

The latest generation of acoustic position reference systems can match GNSS levels of performance due to the tight integration of precise digital acoustic measurements and inertial navigation.

With the current oil price and vessel utilisation there are now obvious drivers and calls to increase the efficiency of all operations in all upstream offshore operations.

So, the development of future system capability is focussed on achieving efficiency savings for both the owner and contracting Oil Company by reducing the number of seabed transponders, reducing overall system maintenance requirements and employing the vessel's acoustic reference system to perform survey, construction and monitoring tasks as well as DP.

This paper uses a series of case studies to explain how these efficiency savings are achieved and how potential failure modes are addressed so that DP reliability and performance is maintained and guidance based on the 7 pillars of incident free DP operations as laid out in MTS documents [1] is met.

New sensors that support efficiency savings are reviewed including combined gyros and MRUs that don't need to be returned to shore for regular calibration, DP transponders that can last for 2 years of continuous operational use and "SMART" instruments that can provide the driller with information to help extend riser life.

Introduction

Our ability to reliably position an offshore vessel has improved significantly over recent years due to advancements in the fields of electronics, acoustics, and GNSS. Inertial navigation systems (INS) have long shown their value in this area, and the benefits have been well documented [2], [3] and presented at previous MTS DP conferences. INS is beginning to be mandated in critical operations; however, simply specifying an inertial input into the DP system does not guarantee that the expected benefits will be achieved [4].

Looking beyond the immediate benefits of increased integrity and availability of position data for DP, the correct choice of INS can also deliver operational savings which are being sought throughout the supply chain given current market conditions. As an example, a state of the art position reference system (PRS) which delivers these operational savings is shown below in Figure 1.

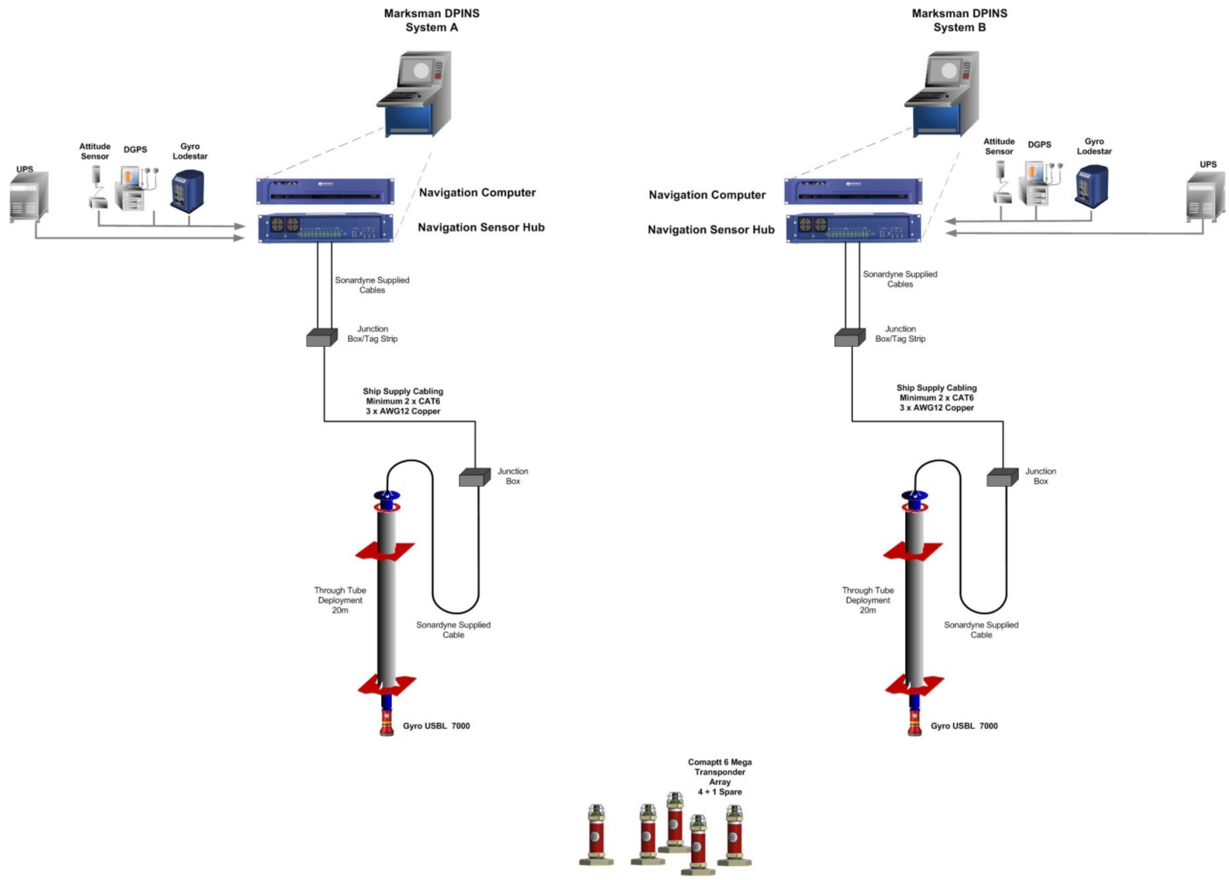

Figure 1 : Marksman DP-INS

At the heart of the Marksman DP-INS system is a tightly integrated acoustic-inertial navigation system (AINS) that provides accuracy, update rate, robustness and hence DP weighting that is on par with state-of-the-art GNSS (GPS). Enabled by DP-INS, future system capability is focussed on widening the benefits of tightly coupled acoustic inertial references to deliver safer and more efficient acoustic DP references including:

- Using increased performance to reduce the number of transponders and the acoustic update rate required. This in turn extends the battery life of seabed equipment and reduces operational cost by saving vessel time [1].

- Further operational savings can be made with transponders supporting "multi-user" operations on independent signal allocations without compromising integrity

- The reduced acoustic update rate is important to enable "freeing up" of the acoustic system for other tasks, offering an acoustic gateway that can be used for survey, ROV and monitoring applications.

- Lodestar, a combined Attitude Heading Reference Systems (AHRS) and INS is a "multi-role" sensor which offer precise pitch, roll and heading measurements with flexibility of offering DP Gyro and MRU inputs and / or position reference augmentation within the same redundancy group.

Tightly coupled acoustic inertial reference systems

Choosing the correct INS architecture is important if the operational benefits listed above are to be fully realized. The first generation of acoustic-inertial systems were loosely integrated. The INS would in principle simply be inserted between the acoustic positioning system and the DP desk in order to reduce noise, increase update rate and bridge brief gaps in acoustic positioning. The performance depended not only on the position being generated by the acoustic system, but also it depended largely on whether the telegram being used by the acoustic system supplied reliable quality metrics for use in weighting the data within the INS.

In a tightly integrated system the INS has full access to the raw acoustic measurements and the associated low level quality metrics in their native format with effectively perfect timing. This allows a much more precise and optimal use of the available information which adds **fault tolerance**, particularly in challenging acoustic conditions, where the good, useable acoustic observations can easily be identified.

Tightly integrated solutions have greater **autonomy** as they do not require the DP to monitor position standard deviations. Instead, the internal integrity monitoring based on the abundance of acoustic and inertial observations can report an error for the DP to use and also flag a loss of integrity or confidence. Figure 2 below shows the functional difference between tight and loosely coupled.

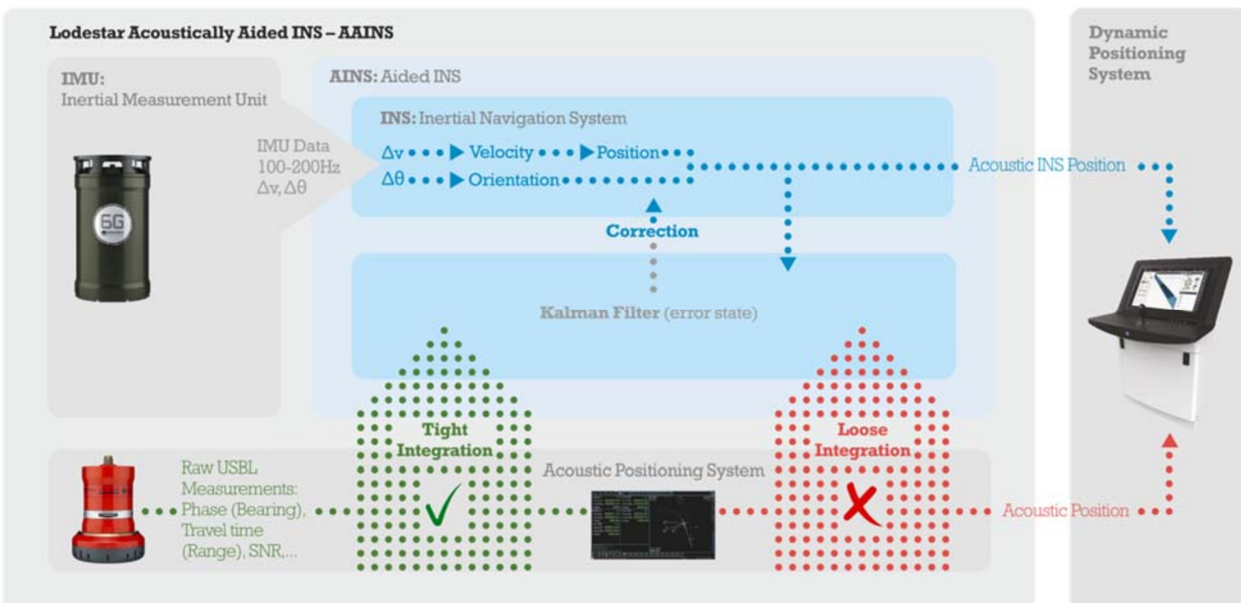

Figure 2 : Tight and loosely coupled architectures

In a tightly integrated solution the INS can model each individual measurement, and even use an individual range measurement, despite the fact that this would not be sufficient in itself to compute an acoustic position – it enables a tightly integrated system to continue operating in even the harshest environments long after a loosely coupled system would have lost integrity. Figure 3 below shows the **fault ride through** advantages of a tightly compared to the loosely coupled solution.

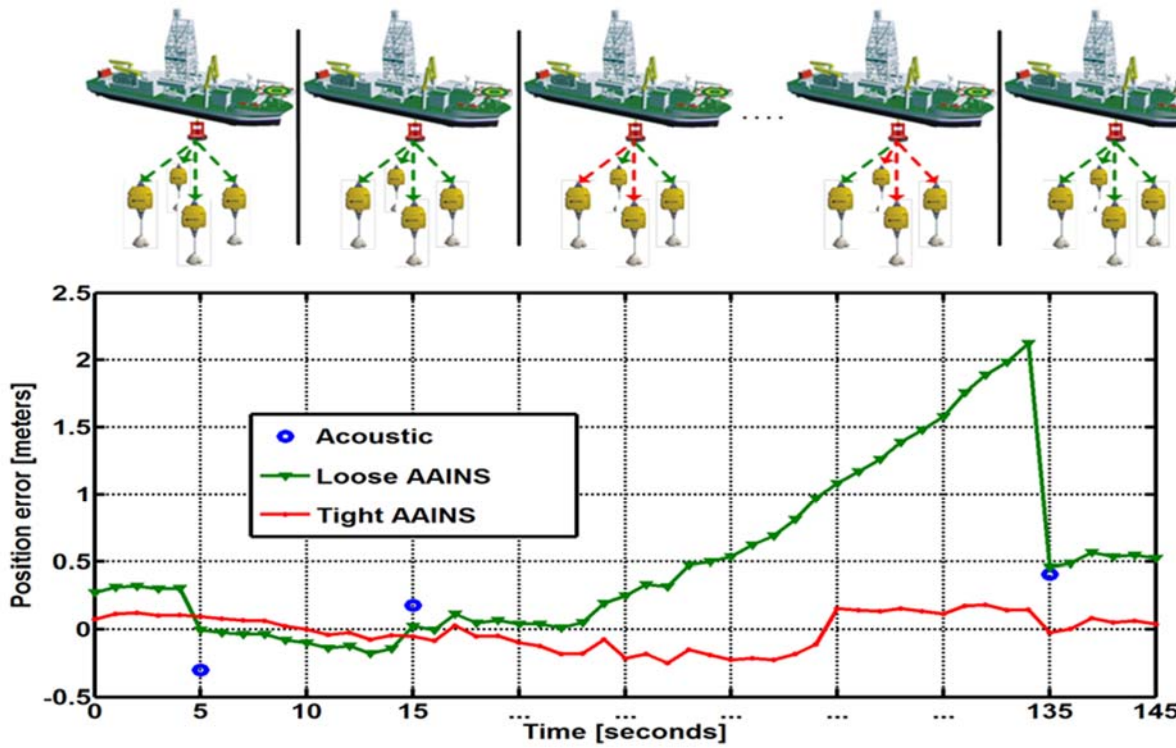

Figure 3 : Fault ride through advantage of tightly coupled

Initially, replies are received every 10s from all transponders (green lines), but for a period of time some kind of interference (possibly noise of thruster wash from a workboat coming alongside) prevents 2 or 3 replies being detected (indicated by red returns). The loosely coupled solution loses aiding immediately, while the tightly coupled is able to maintain integrity using the remaining measurements.

It is the improved positon integrity and availability from a tightly coupled architecture which enables vessel owners to benefit from the operational advantages discussed below.

Reduced number of seabed transponders

Traditionally, 10 seabed transponders are deployed around each operating location for a dual independent L/USBL acoustic reference system. It will typically take 3 trips with an ROV to deploy 10 transponders to the seabed and up to 20 hours to calibrate the system. Future system capability is focused on reducing this deployment and calibration time and this section explains how the number of seabed references can be reduced from 10 to 4 in two steps, without compromising position data integrity.

The first step takes advantage of the superior performance of tightly coupled INS explained in the previous section. The abundance of independent range and angle measurements, combined with precision inertial sensors means that fewer seabed transponders are needed to maintain or exceed the typical **Fault Tolerance**, **Fault Resistance and Fault Ride Through** capability of a conventional system without INS. As a result, instead of the recommended 5 transponders per system, it is feasible to operate with a 3 transponder seabed array.

As shown in Figure 4 in a deep water drillship example operating in Asia, the accuracy achieved over a 30 minute sample period with 3 transponders is approximately 20 cm compared to GNSS.

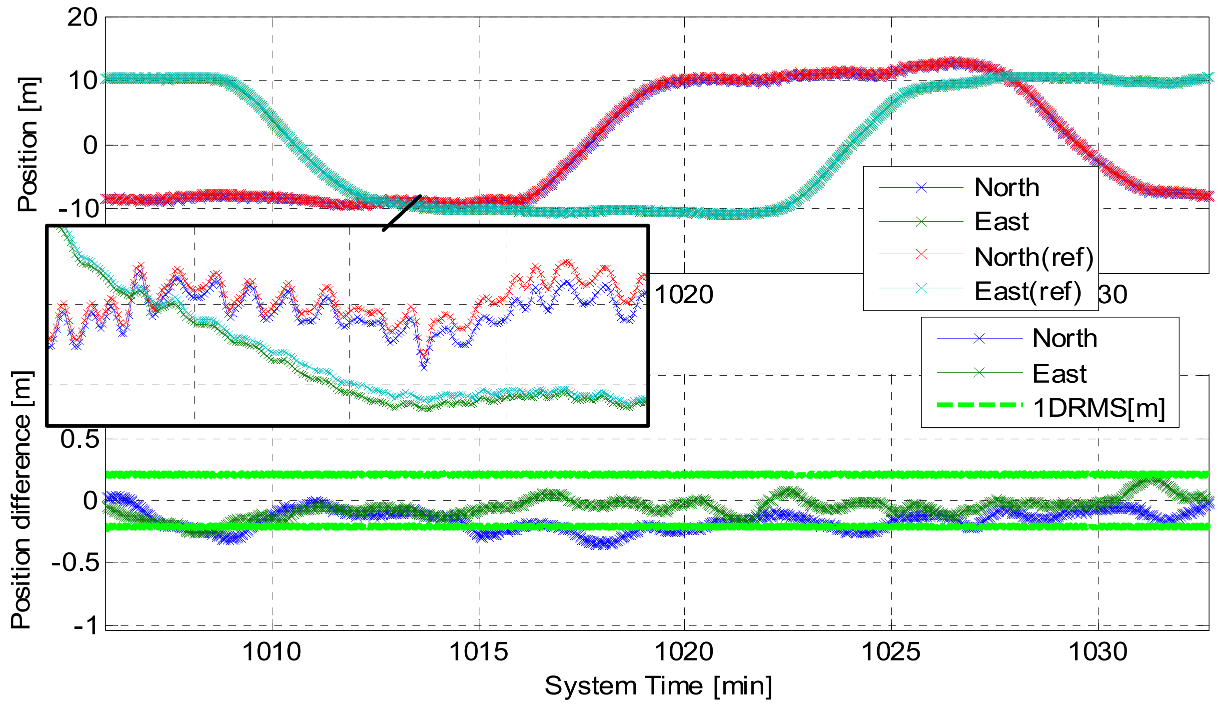

Figure 4 : Accuracy with a reduced number of transponders

The top chart in Figure 4 shows the DP_INS position of the vessel compared to the GNSS. The lower chart shows the difference between those positions and also the computed 1 DRMS of the DP-INS with respect to the GNSS. It can be seen from the 1DRMS (bright green) that an accuracy of approximately 20 cm is achievable compared to a Precise Point Position (PPP) GNSS solution that has been taken as "truth". The enlarged portion of Figure 5 shows close correlation between the independent Marksman DP-INS and GNSS solutions.

The second step to reduce seabed transponder deployment and calibration time is to consider alternative transponder array designs. An array of 5 transponders can be shared, either between two dual independent systems on the same vessel, between 2 vessels or between vessel and subsea operations. Shared arrays are not a new concept and are being used in some DP operations today. Traditionally, arrays have been "time –shared" meaning system 1 and system 2 only interrogate and listen for replies during their assigned time window. This approach has the disadvantage of potentially slowing down update rates and additional risk of cross system interference and common failure modes as system A and B could both be affected by external interference on their shared frequency or even interfere with each other. The sharing of transponder arrays using a common acoustic frequency between independent systems does not therefore provide the **segregation** recommended in [1]

An operational mode called "multi-user" is available within the current generation subsea transponders. Multi User assigns independent interrogate and reply frequencies to up to 4 independent users of the same seabed array. **Segregation** of signals in this way ensures no acoustic single points of failure exist due to interference and eliminates the risk of false detections from another system. There is also a reduced risk of interference affecting both systems due to physical frequency separation.

In the example of a DP3 vessel with a dual independent acoustic system installed, the number of seabed references could be halved if a shared array of multi-user transponders is deployed as shown in Figure 5.

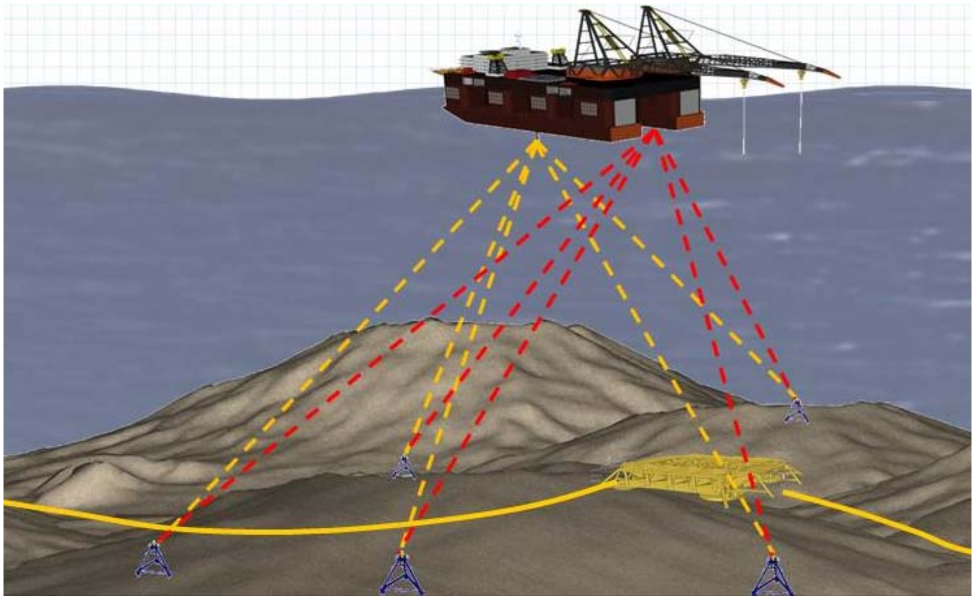

Figure 5 : A dual independent acoustic system sharing a seabed array with Multi-User transponders

Based on data taken from a customer drill rig, operating in the Gulf of Mexico and drilling 5 wells per year, the operational saving shown in Table 1 equates to a saving of 2 days per year. Savings on smaller vessels will be greater as transponders are deployed and recovered more frequently.

Acoustic Reference System	**Original**	**L/USBL**	**DP-INS**
Set-up	Dual Independent		
Generation	5G	6G	6G
Transponder type	Standard	Mega Multi User	
Acoustic Update rate	6	6	12
Deployment and calibration			
Number of transponders	10	5	4
ROV payload (tpdrs)	4	5	4
ROV trips	3	2	1
Average array set-up time (hours)	18	14	9

Table 1 : Operational saving due to reduced transponder numbers

Reduced transponder maintenance

The latest acoustic reference transponders shown in Figure 6 is a long endurance L/USBL transponder with a form factor which can provide up to three times the battery life of a standard transponder. The ultra-long battery life enables Compatt 6 Mega transponders to be deployed on the seabed for a significantly longer duration, with the potential to provide vessel positioning throughout all drilling and construction activities, resulting in significant set-up and operational cost savings during extended acoustic positioning campaigns.

Up-to three standard Compatt 6 lithium or alkaline batteries can be fitted inside the Compatt 6 Mega, giving over 10 years of listening life and an operational life of up to 798 days during typical DP operations.

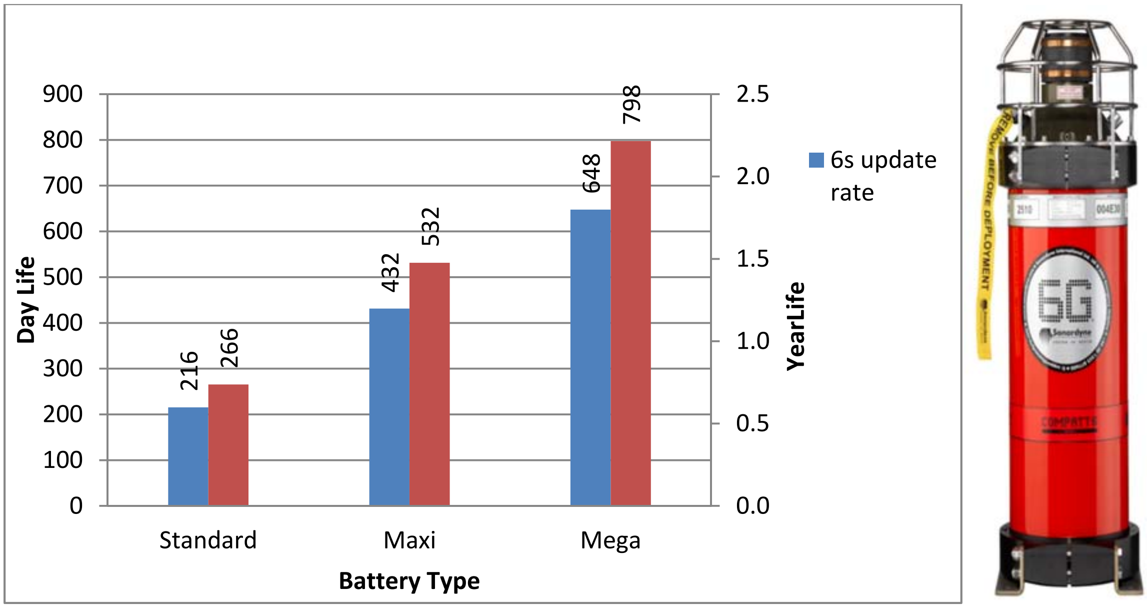

Figure 6 : Over 2 years of continuous operational use.

Compatt 6 Mega transponders are also suited to multi-user operations where power consumption increases with the number of users.

Shared Sensors

One of the unique advantages of any DP-INS system is the independent attitude, heading reference system (AHRS) and INS algorithms which run in parallel within the single unit. As shown in Figure 7, whilst the basic hardware components are shared, the heading, pitch and roll outputs are computed independently. Not only does this provide an additional quality check to aid DP integrity monitoring [2] but it provides an independent gyro and MRU output.

In addition, the precision sensors within a Lodestar can accurately calculate heave at any remote point on the vessel. This is an advantage on some vessels and rigs where up to 7 MRUs are installed for dynamic monitoring of drilling top drives, crane and winch wires, ROV launch and recovery systems and helidecks. Where redundancy rules permit dynamic monitoring requirements can be combined and met by a Lodestar AHRS or INS that could already be installed on the vessel. Sharing sensors in this way can offer significant savings in the purchase, installation training and calibration of heading, attitude and heave sensors.

Some of the additional roles a Lodestar INS can be considered for include:

- Provide precise pitch and roll in the same format as an existing MRU, acting as a replacement or backup.
- Provide precise heading in the same format as an existing Gyro, acting as a replacement or backup.
- Augment the position reference sensors by providing an aided inertial input to the DP.
- Calculate heave at any XYZ offset on the vessel from where the Lodestar is installed.

Class rules will dictate how many of these functions can be operated in parallel but multi-role sensors are becoming more common within the same redundancy group and usually offer **differentiation** or diversity of design compared to spinning mass gyros and micro electro mechanical systems (MEMS) MRUs. Even where the multi-functions are not used in parallel there are cost savings through more efficient spares, training and equipment deployment if the same sensor is capable of serving multiple dynamic monitoring requirements.

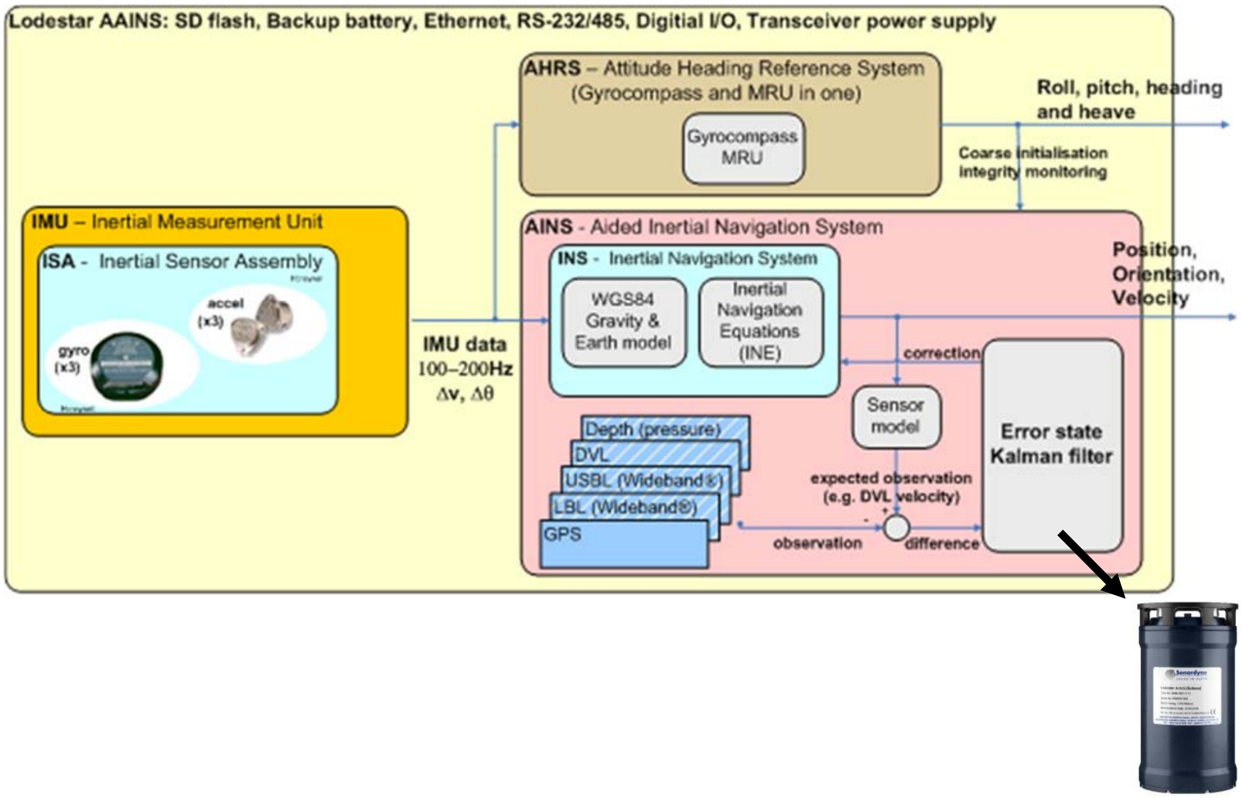

Figure 7: Independent AHRS and INS output

Reduced MRU maintenance

Significant operational expenditure is currently expended on the unnecessary shore based re-calibration of MRUs. Removing units from a vessel not only creates logistical challenges as a replacement needs to temporarily installed but the cabling, connectors and most importantly installation mounting angles are also put at risk.

Through a unique data analysis service and technology within the AHRS, Sonardyne can remotely validate performance without removing the unit from the vessel. This can provide significant operational savings as the units don't have to be returned to base for periodic calibration. Instead, the vessel crew log a few minutes of data whilst pitch, roll and heading degrees of freedom are exercised by performing low dynamic vessel manoeuvres. The log files are sent to Sonardyne where the data is replayed through a proprietary algorithm and gyro and accelerometer biases estimated. If these estimates differ from when the unit was last characterised a new configuration file is sent to the vessel containing a new set of static bias corrections, These corrections can easily be applied to the system by the vessel crew, supported remotely by Sonardyne if required.

Acoustic gateway for ROV, Survey and monitoring

As shown in Table 1 the acoustic update rate for a vessel operating DP-INS is typically once every 12 seconds while faster, 1Hz position solution provided to the DP by the Lodestar INS. Some vessels have extended this acoustic update rate to 15 seconds and still operate reliably. Not only does this preserve battery life and therefore extend the maintenance interval of subsea transponders it creates 15 second acoustic “windows” where other activities can be implemented without interrupting the input to the DP.

For many years, drilling vessels have installed a Marine Riser Angle Monitoring System (MRAMS) which have been using the acoustic position reference transceiver to recover highly accurate differential angle data across the flex joint between the riser and LMRP in order to reduce excessive wear on wellhead components. DP-INS allows more time for this data to be collected and reduces the likelihood of DP positioning being adversely effected.

Now included as part of Sonardyne’s 6G product range, SMART (Subsea Monitoring, Analysis and Reporting Transponder) has been developed as an evolution of the MRAMS principle to cover a diverse range of subsea asset monitoring applications, including riser monitoring. SMART brings together low power electronics, long duration data logging, on-board data processing and acoustic telemetry into a single, easily deployed wireless instrument. SMART can be attached to risers or other subsea assets as required and has the flexibility to interface with a wide range of internal and external sensors utilising standard or bespoke data analysis algorithms.

Figure 8 below shows current data collected wirelessly from a SMART sensor over an acoustic link in the Gulf of Mexico. This data can be scheduled to be collected between acoustic DP updates if required.

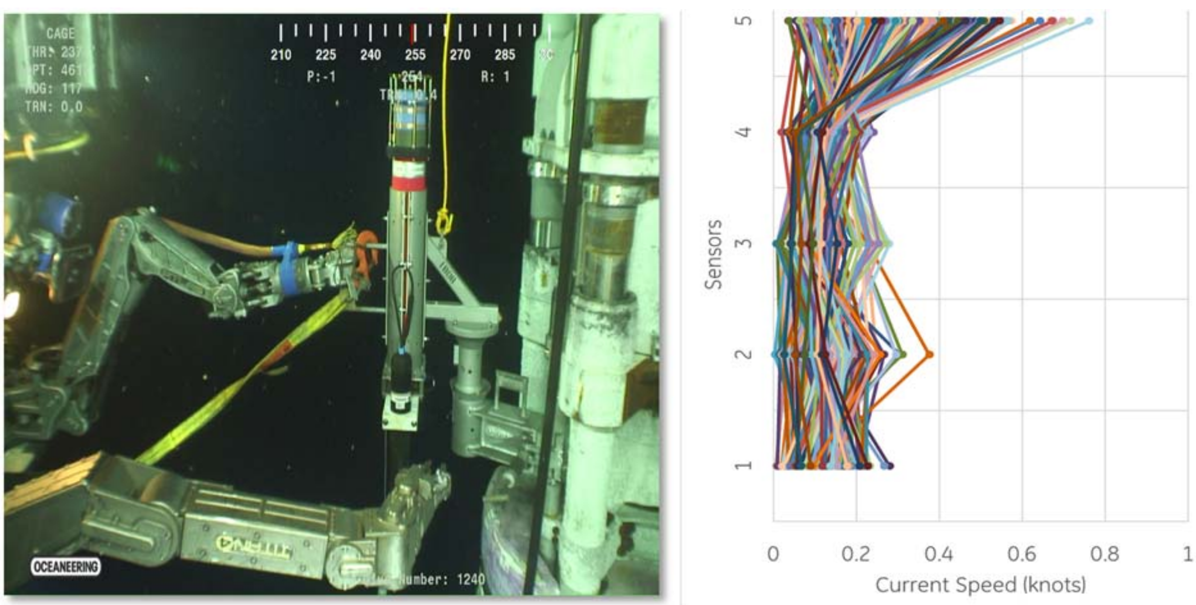

Figure 8 : Current data collected by SMART transponders

Conclusion

Although covered to some extent within previous publications it has been explained for completeness how the latest generation of acoustic position reference systems can match GNSS levels of performance due to the tight integration of precise digital acoustic measurements and inertial navigation. As these systems are becoming increasingly common and track record builds future system capability is focussed on the efficiency savings which can be delivered for both vessel owner and contracting Oil Company.

Examples for offshore operations have been used to explain how efficiency improvements can be achieved including:

- A reduction in the number of seabed transponders decreasing deployment and calibration time
- A reduction in system maintenance requirements, specifically relating to transponder and MRU sensors.
- Using the "acoustic windows" created by the low acoustic update needed by DP-INS, enabling survey, ROV and monitoring tasks as well as DP.

Where possible acoustic failure modes have been discussed in the context of the 7 pillars of incident free DP operations as laid out in MTS documents to show how the efficiency savings can be achieved whilst maintaining or extending DP performance.

References

[1] Marine Technology Society, Dynamic Positioning Committee, DP Vessel Design Philosophy Guidelines

[2] Tightly Integrated Second Generation Acoustic-Inertial Position Reference System - Deep Water Operational Results, Mikael Bliksted Larsen, Sonardyne International Ltd, 2013

[3] DP INS – A Paradigm Shift, Mark Carter, Sonardyne International Ltd, 2011

[4] Moving towards a standardized interface for acoustic inertial reference systems, Mark Carter, Sonardyne International Ltd, 2014