DYNAMIC POSITIONING CONFERENCE
October 09 - 10, 2018

SENSOR SESSION

Challenges of performance testing an environmentally referenced sensor

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Abstract

Traditional laser or microwave local position reference sensor systems comprise a sensor located on the vessel and one or more targets which are positioned on the asset being tracked. The sensor measures the range and bearing between the sensor and the target.

This then provides a measurement with a very clear physical analogue and thus provides a mechanism to measure a ground truth in a test environment against which the measurement can be compared.

Targetless sensors must construct their view of the environment around them before working out how they are moving through that particular environment. The positioning performance may be dependent on the local environment around the sensor and thus additional variables impact on the tracking performance.

This paper discusses how we have been characterising the performance of targetless sensors in order to evaluate how to best include them in DP operations.

Abbreviation / Definition

Introduction

A traditional Position Reference Sensor (PRS) system will typically consist of a sensor, mounted on a vessel and connected to its DP system, and one or more cooperative targets which the sensor will track. The presence of cooperative targets as part of the system gives the sensor a clear signal onto which it can lock.

The cooperative targets also can cause specific difficulties which are well known to DPOs. These include lack of available targets on assets, target obscuration during DP operations and poor target placement causing difficulties with the availability and continuity of the position measurement.

Because of these difficulties there is a desire to have available targetless PRS systems which can mitigate these problems [MTS Techop.]

The performance testing of a targeted PRS can be characterised on land at a suitable location. Large open areas which are substantially flat are required, however locations such as test tracks or former airfields provide a good opportunity to characterise performance which can be subsequently ratified at sea.

Targetless local positioning sensors will generally utilise some aspect of the environment to allow the tracking of pose. This environmental dependence results in the characterisation of performance being a more complex task which also requires a more complex way of looking at the system performance.

Introduction to the SceneScan

The SceneScan sensor is a targetless laser position reference sensor. It utilises a simultaneous location and mapping (SLAM) algorithm.

To track off a targetless scene the sensor first takes a reference scan of the scene. This forms our initial map. Each subsequent scan is then matched to this initial reference scan and we can infer the sensor motion between the scans by taking the translation and rotation required to correctly overlay the scans.

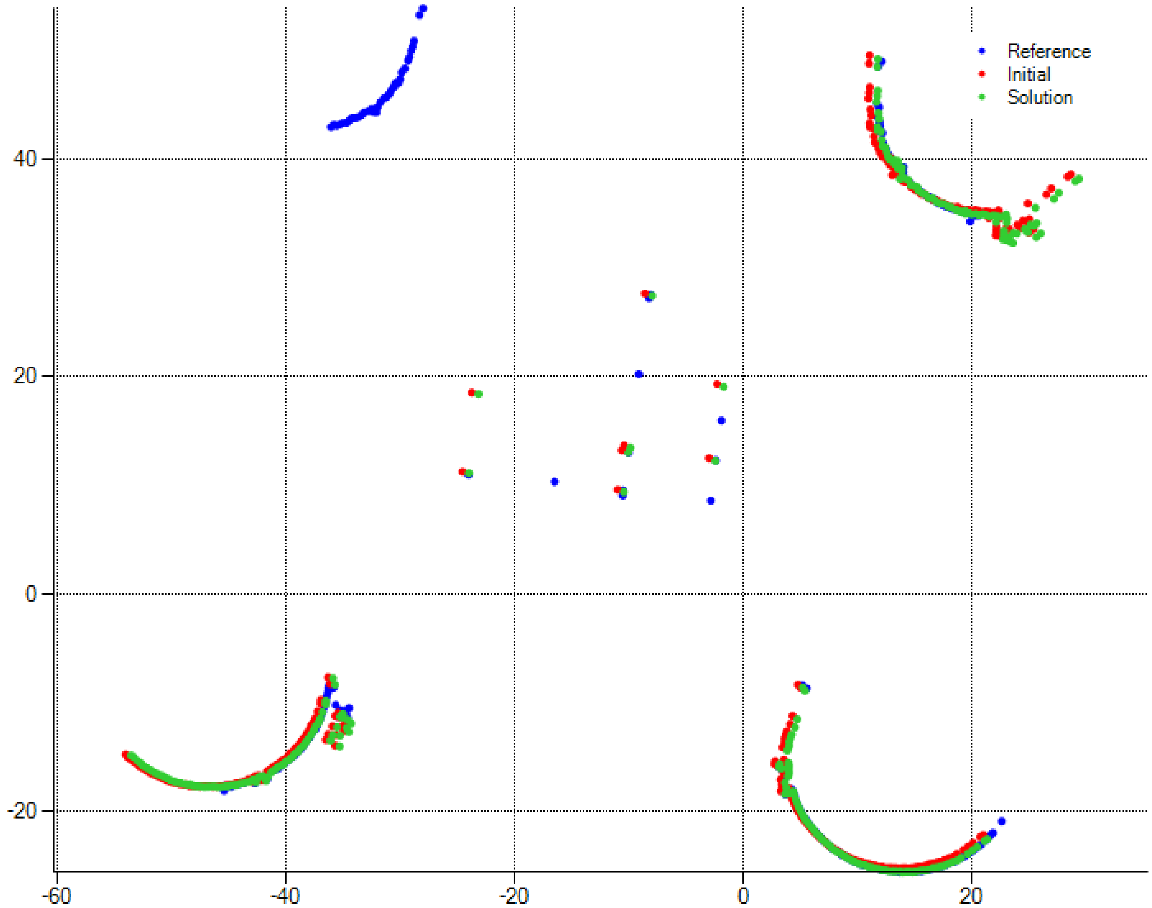

Figure 1 - Example scan and scan match from SceneScan sensor

This process is repeated until what is observed by the sensor no longer closely matches the reference scan data. The system then updates its map by incorporating new data from the different viewpoint. Subsequent scans are then matched to the updated reference scan and this process continues throughout the tracking session. This allows us to continue tracking as we navigate around an asset.

The SceneScan generates its map in a 2D plane however at the start of a tracking session it optimises which 2D slice the tilt angle of the sensor to choose the best 2D slice to scan. This optimisation can be shown in the form of a colour coded 3D plot. In the plot below we have the following colour code:

Green: Acceptable or better tracking performance from this slice
Red: Poor tracking performance from this slice
Gray: Excluded (part of the sensor vessel)
Blue: Sensor tilt angle out of range for tracking should the vessel move in close to the asset.

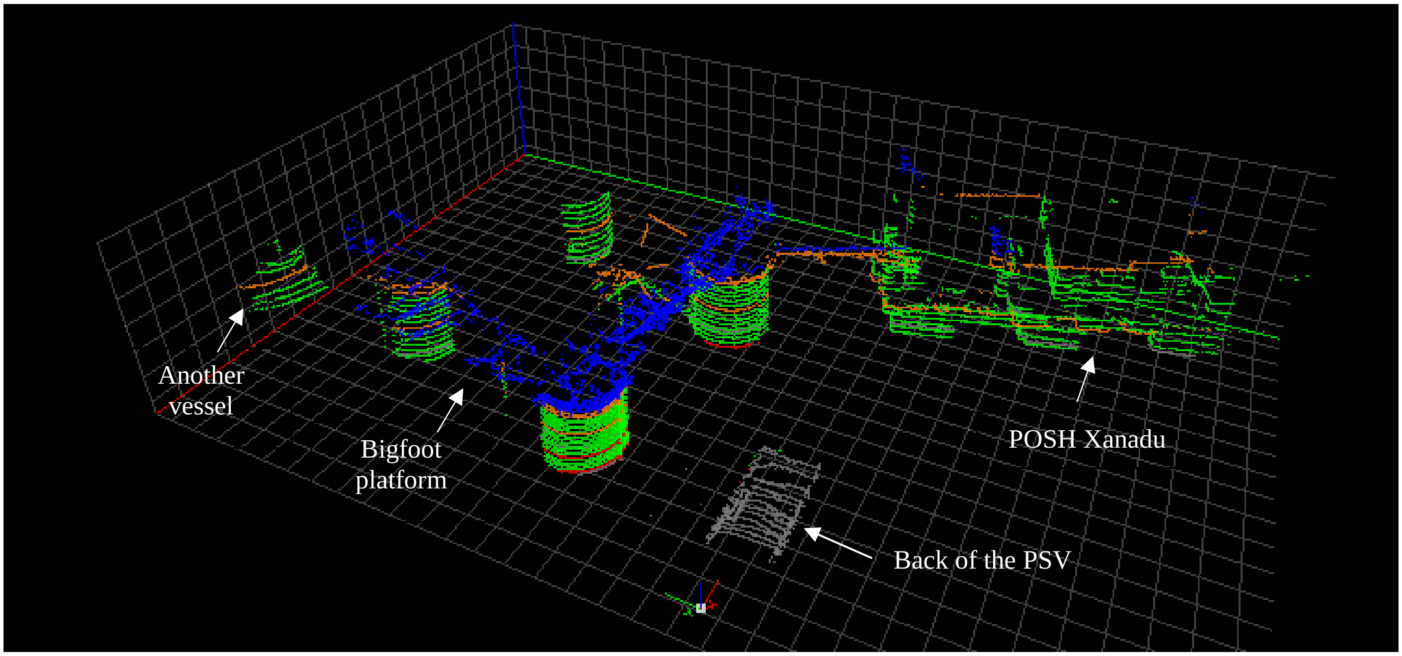

Figure 2 - 3D reconstruction from tilt optimisation

Static assets and performance evaluation

One of the key advantages of on-land testing of PRS systems is the static nature of the testing. It is possible to have a known static test as opposed to on the water where everything is under the influence of waves and current.

This is possible to achieve with the targetless system by utilising a dry-dock. This approach was taken with early development.

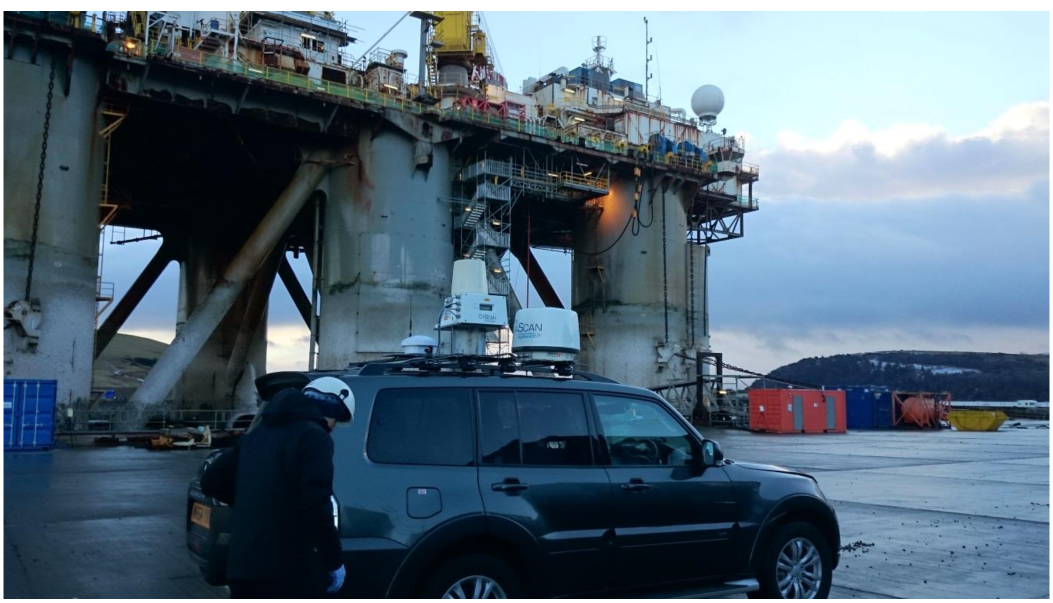
Figure 3 - Dry dock testing

This approach was used to test both Tension Leg Platform (See figure 3) and Jack-up rigs.

Table 1- Static position noise on preproduction algorithm

Structure type	**Range to structure**	**Position noise on pre-production algorithm (0.8.0)**	
TLP	75m	0.028m radial	0.057m tangential
TLP	25m	0.006m radial	0.010m tangential
Jackup	90m	0.031m radial	0.076m tangential

Components of motion and internal positioning metrics

Whilst the system is at sea the testing must be compared against either

1) The internal position metrics
2) Other sensors

The SceneScan system logs the scans that it takes of the vicinity along with the processing outputs and intermediate stages of the localisation algorithm. It is possible to process those logs to estimate the internal consistency of the position measurement.

Graphs of the tracked position against time can be shown in several diverse ways each of which have positive and negative aspects depending on what the viewer wishes to visualise:

A 2D plot showing a position track over time concisely conveys movements however it can be difficult to extract an impression of the measurement noise from this plot. If the plot is shown whilst station keeping the resulting plot is characterised by the holding box of the DP system convolved with the measurement noise of the PRS system. Since the measurement noise of a DP position sensor must be less than the holding box of the DP system it is not possible to use this to effectively illustrate the sensor measurement noise. This is shown in figure 4 below.

It can be used to show overall movement in a trial. If it is to be used in this way then it is instructive to include the map of the environment with the track data to show context. This is shown in figure 5 below.

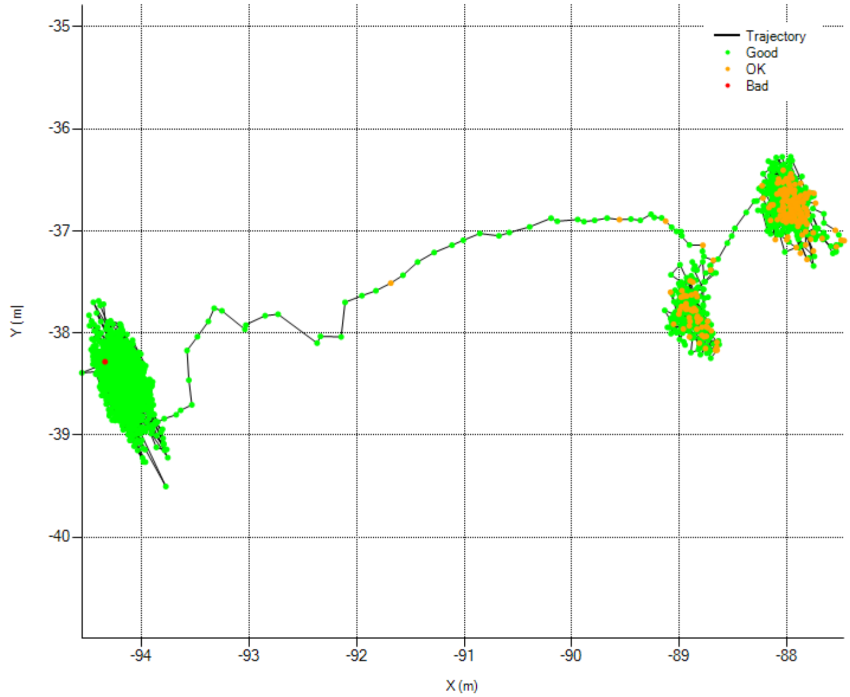

Figure 4- Trajectory map

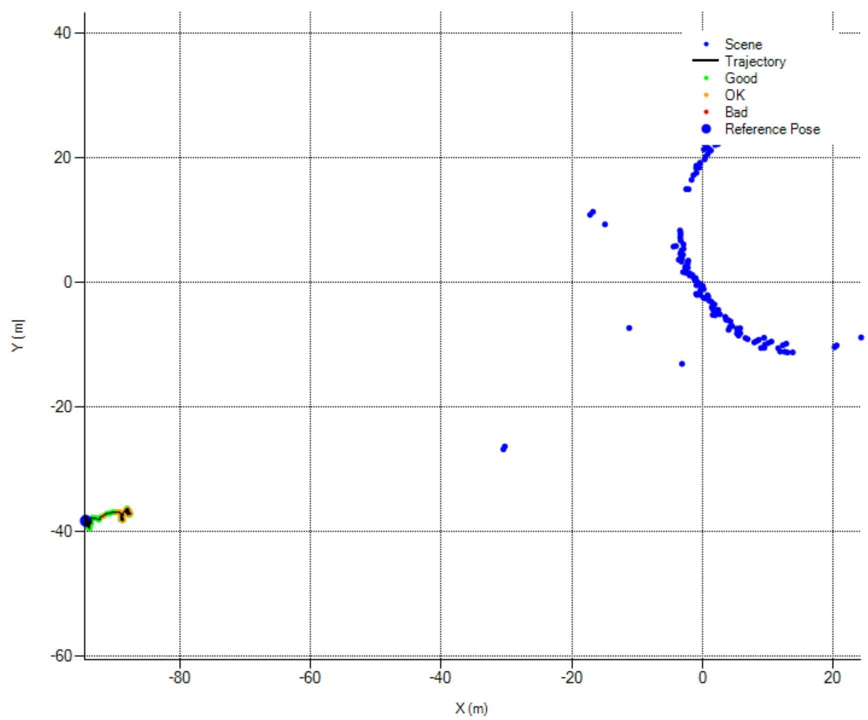

Figure 5 - Trajectory map including scan data

Multiple 2D plots, showing different components of position (Range, Bearing, Relative Heading or equivalent) can be shown. This has the advantage of showing tracks being formed visually by virtue of showing continuous lines in the plot. Such a visualisation can also be readily overlaid with positioning information from other sensors.

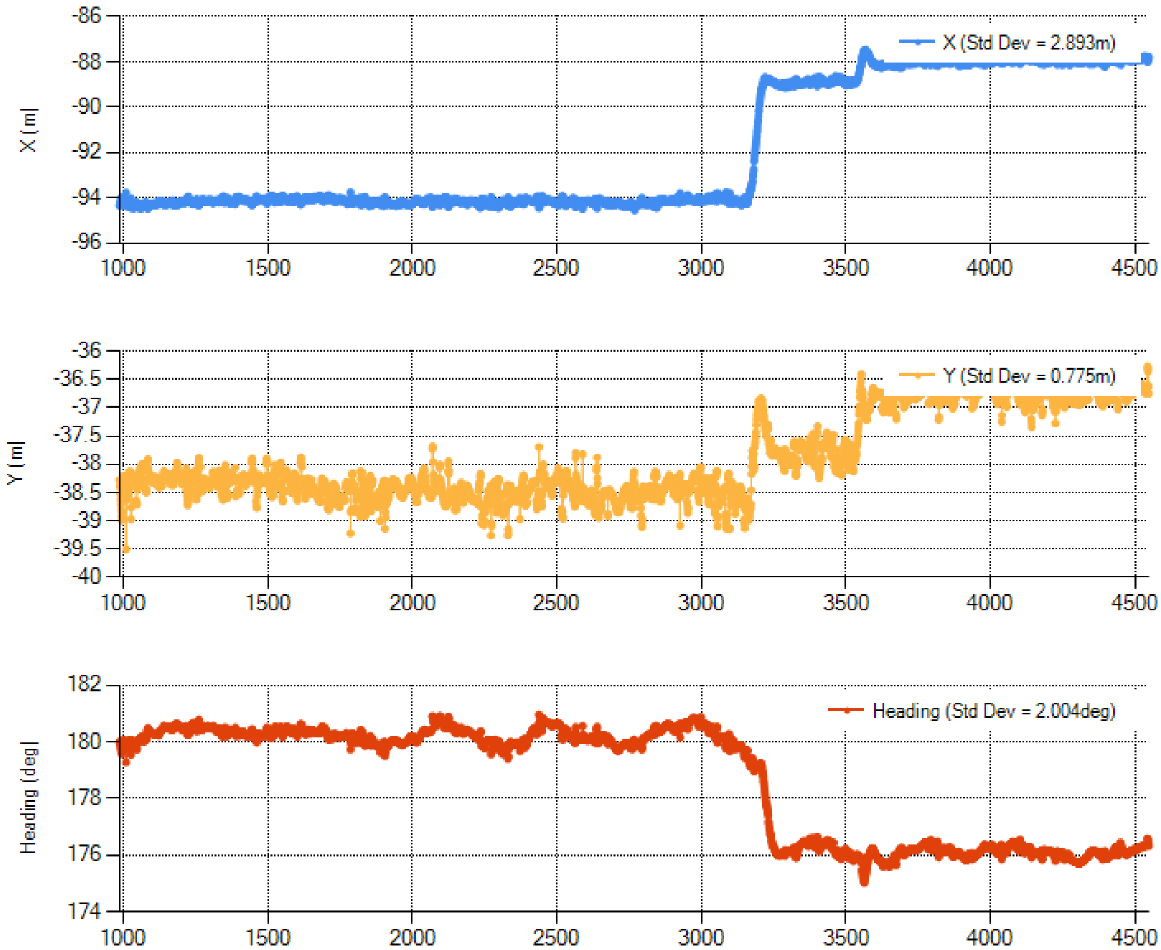

Figure 6 - x,y,H plot of track shown on figure 4.

As well as showing graphical representations of aspects of position it is also possible to derive other variables from position data. The most basic one of these is the difference between consecutive readings of the same variable. This will also preserve information about long term movements and will contain information components coming from any wave driven motion of the sensor. In order to overcome these issues it is possible to filter with signal processing methods in order to remove the low frequency components of a pose measurement.

We utilise a 2^{nd} order Butterworth filter with a cut-off at 0.2Hz to filter out vessel movement and wave motion. This does have the additional effect that we remove 0.2Hz of noise bandwidth from any noise estimates produced by this method, which we must keep in mind when evaluating the results.

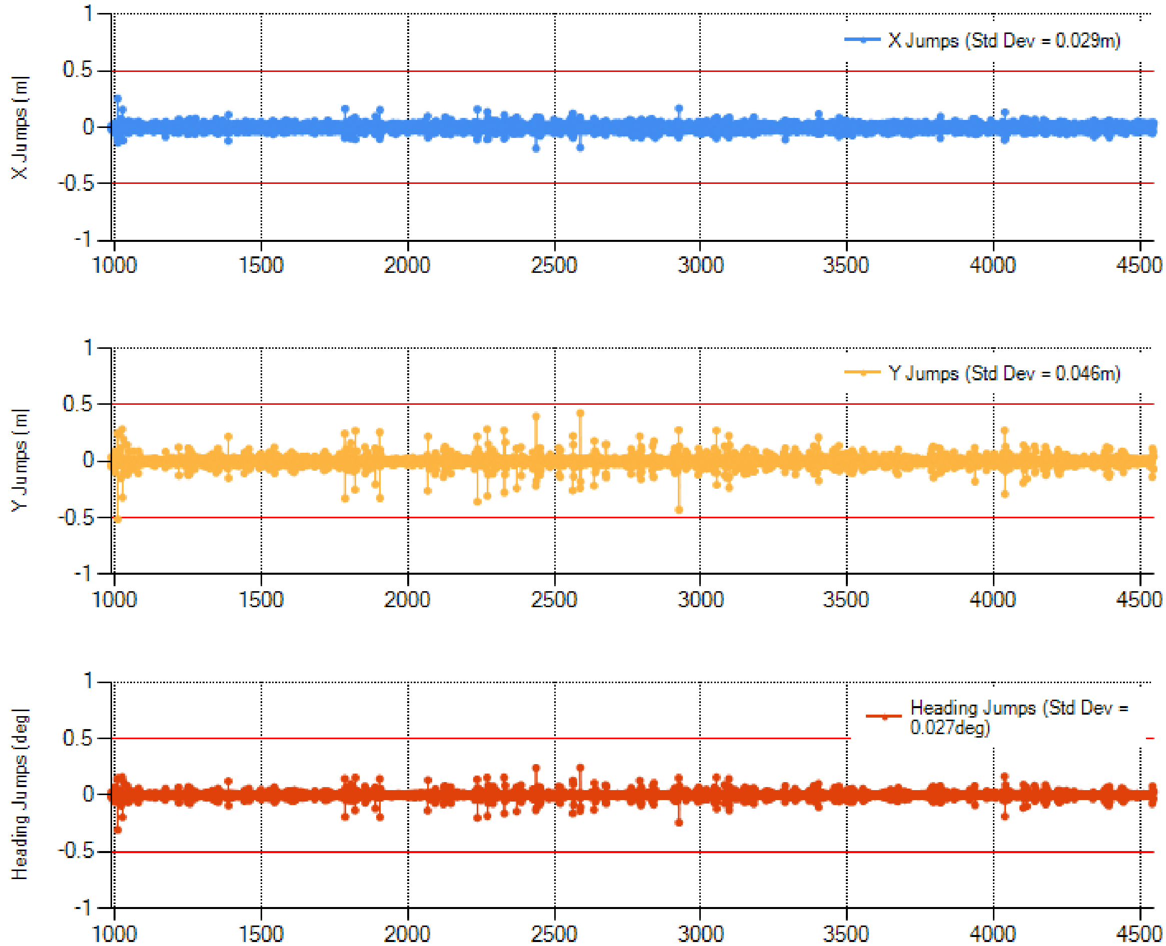

Figure 7 - High-pass filtered positional plot

Verification against other sensors

We can use data recorded from the CyScan and RadaScan to compare performance of the three sensors. Looking at the overall trend in range and bearing for the station keeping we can see that the three sensors remain consistent with each other.

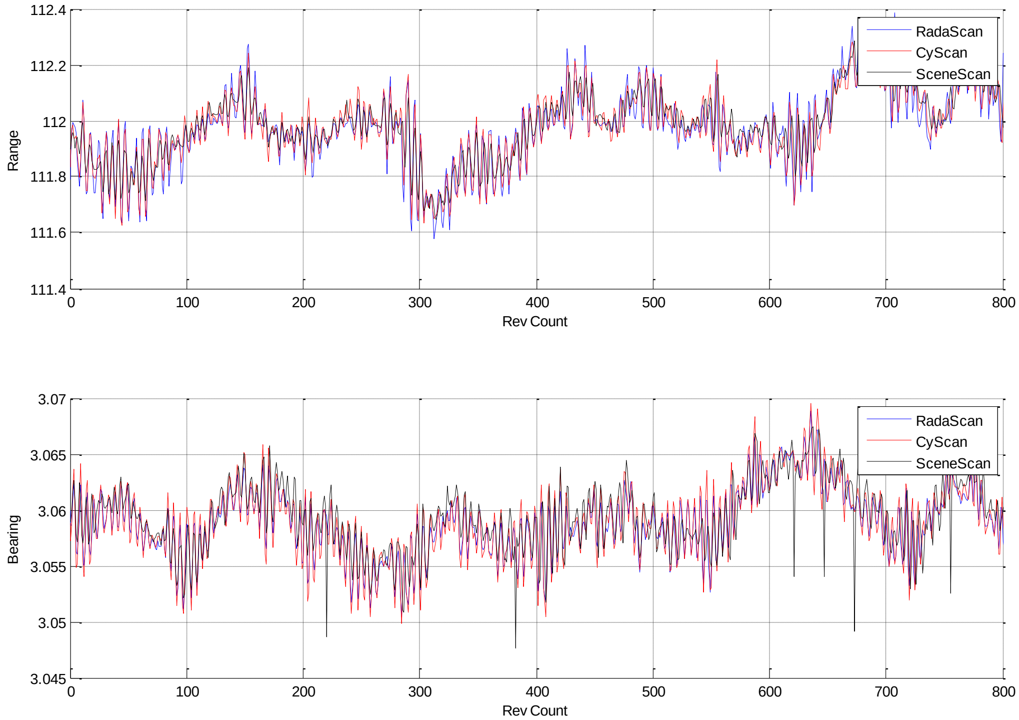

Figure 8 - Range and bearing measurements from multiple sensors tracking a TLP

Looking closer at a small period of this run we can see that the three sensors look to be in good agreement about the vessel motion. The SceneScan was reporting a smaller overall level of wave motion due to its lower mounting height. The locations of the reference frames for each sensor were slightly different as well.

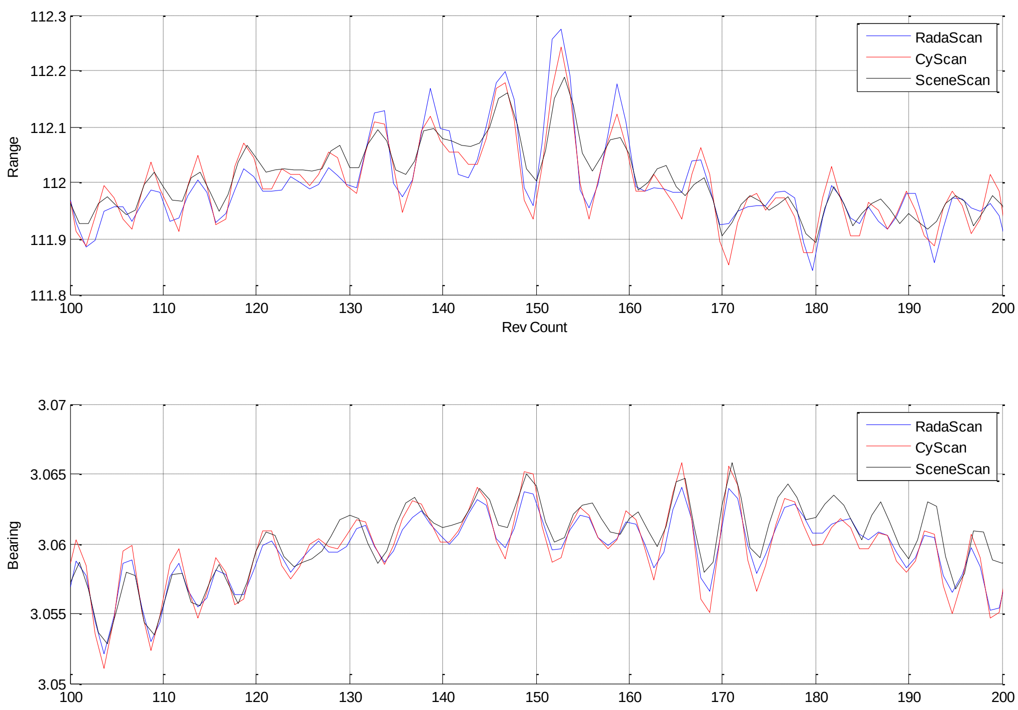

Figure 9 - Range and bearing measurements from multiple sensors tracking a TLP

Example results – Position holding against a Tension Leg Platform

Figure 10 below shows both the scene which we were viewing, and the track generated. We started at the point shown by the larger blue dot at (-60, -50), stayed there for most of the log and then moved along the green track.

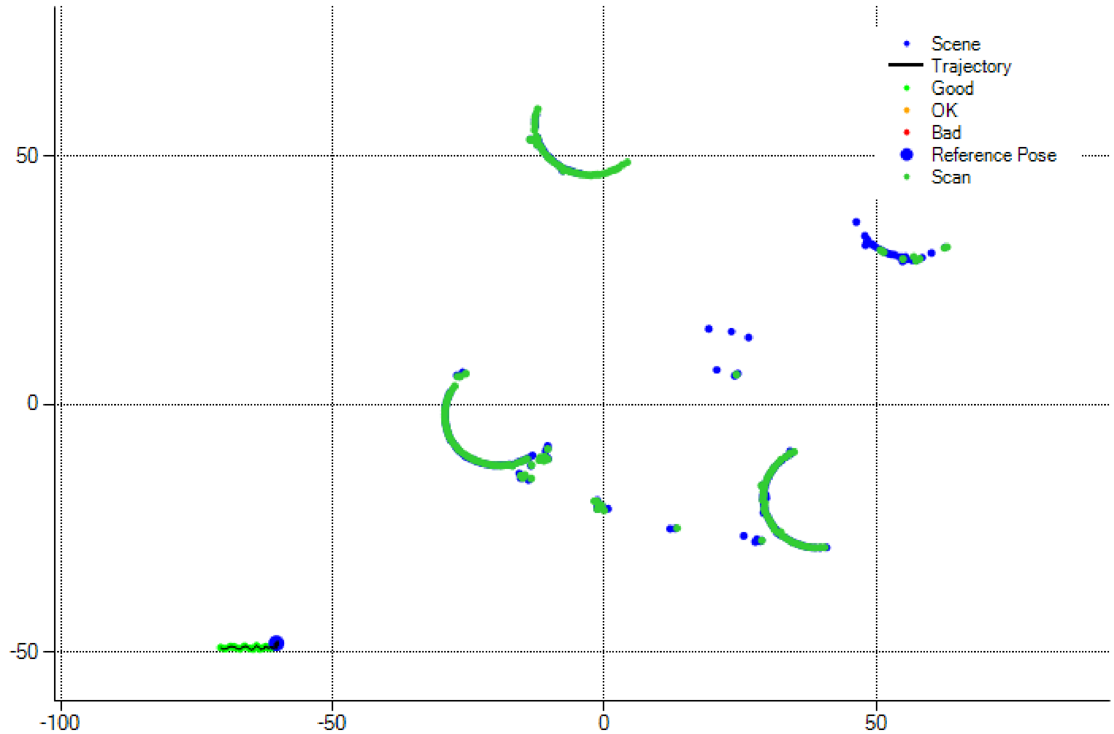

Figure 10 – May and trajectory of vessel station holding then moving away from a TLP

Figure 11 shows our position measurements through the run. We measure X position and Y position from the averaged center of the scan.

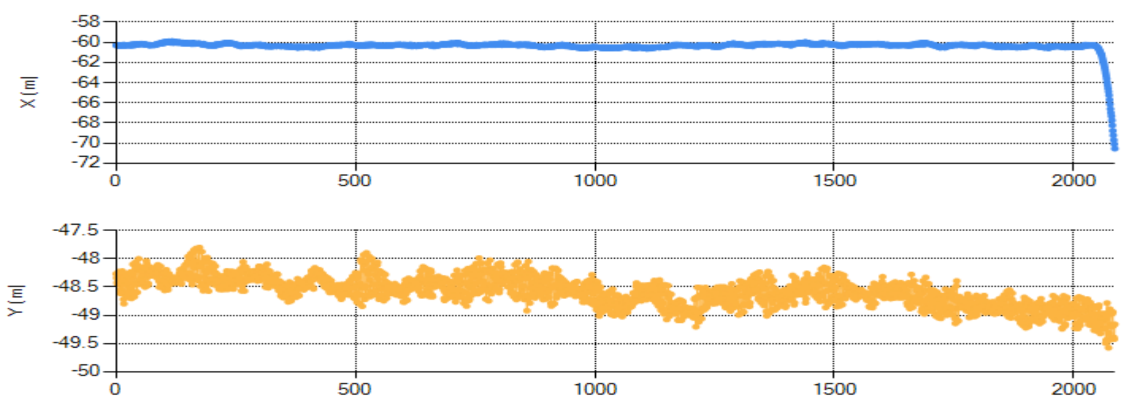

Figure 11- Position measurements through the maneuver in figure 10

In order to evaluate the position noise we use digital filtering to remove slow trends in the data. It can be seen from this data that whilst we were position holding the noise passed through to the DP system was of order 0.1m.

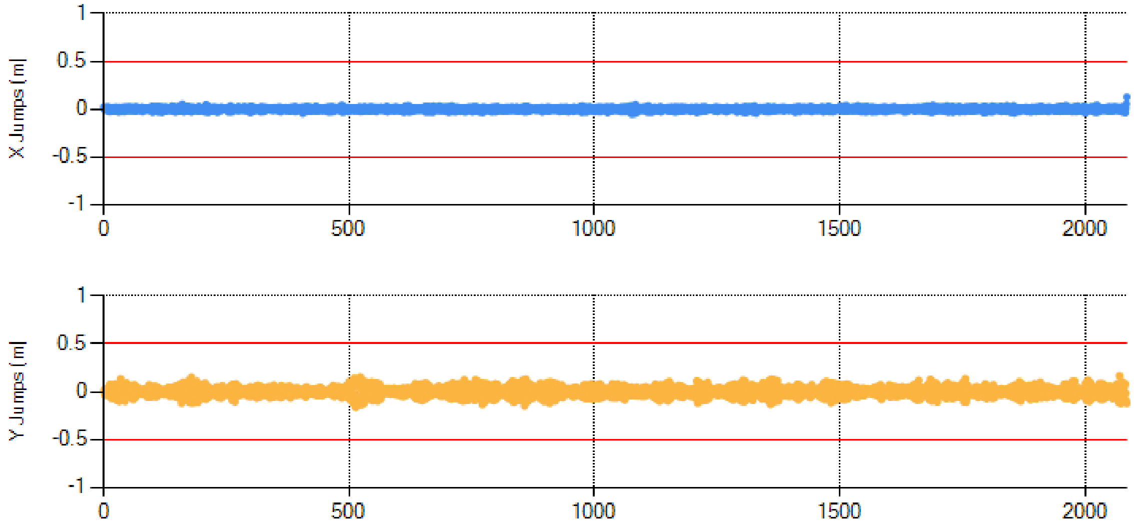

Figure 12 - Filtered position measurements from figure 11

Example results – TLP and accommodation vessel

Data presented here was taken from a 30 hour track with the SceneScan used as a DP sensor throughout that 30 hour session. I have presented only one hour, however each hour was very similar to the data shown.

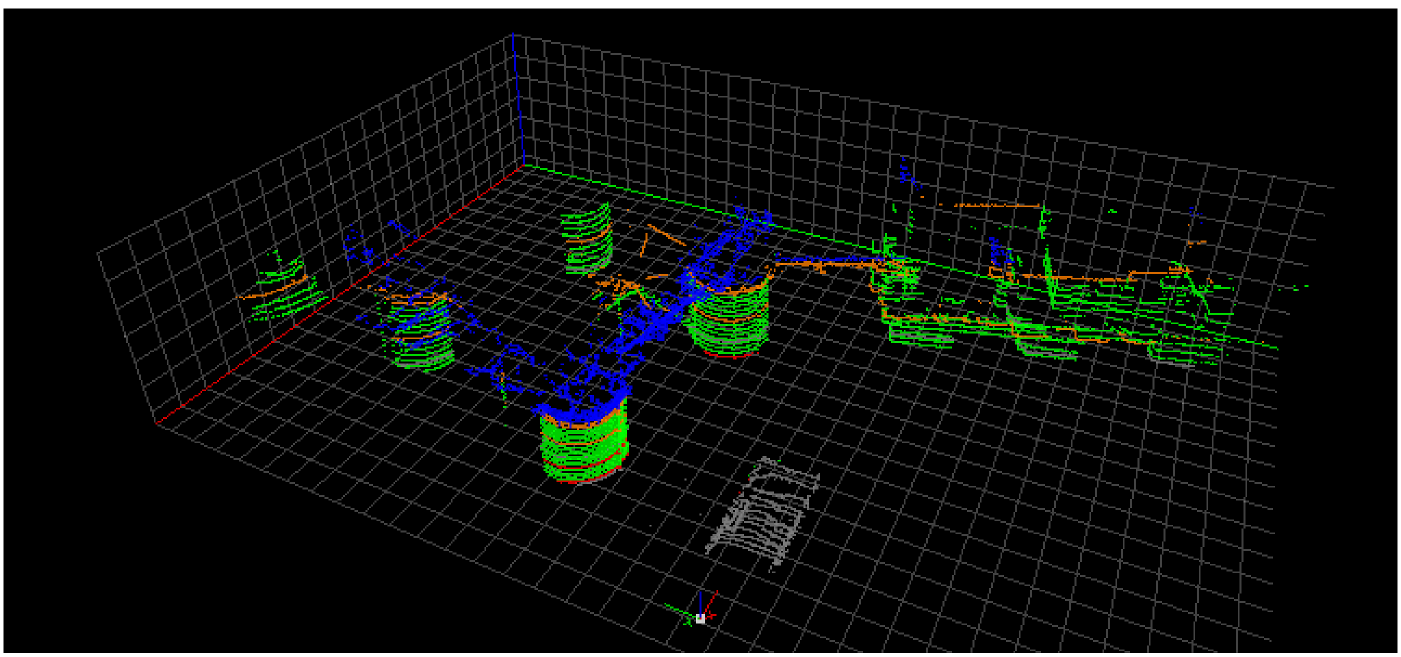

Figure 13 - 3D reconstruction for TLP and accommodation vessel

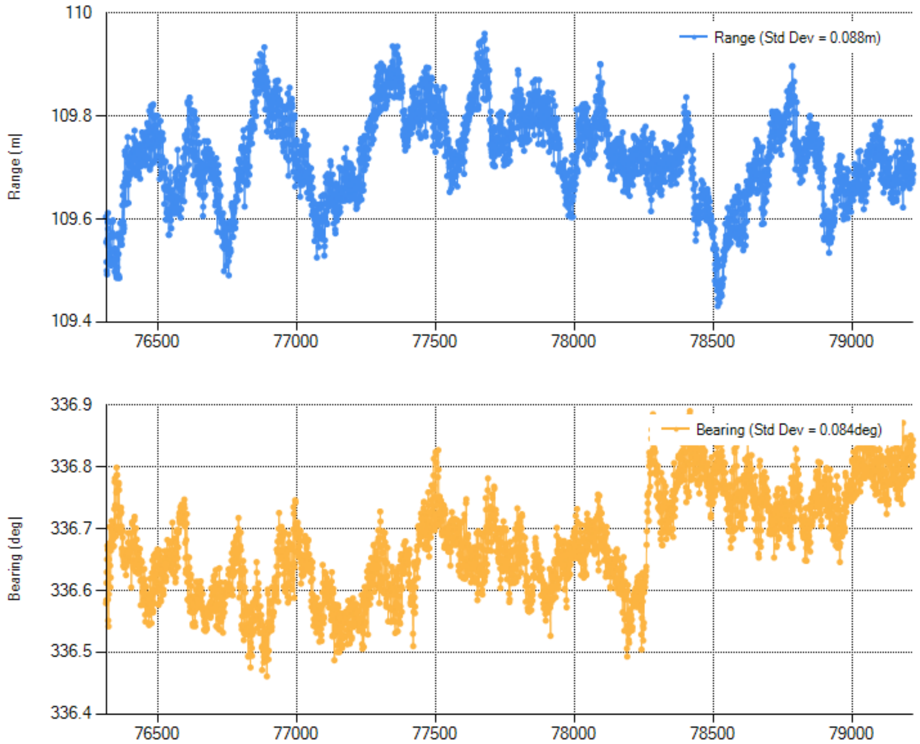

Figure 14 - Position plot for TLP and accommodation vessel maneouver

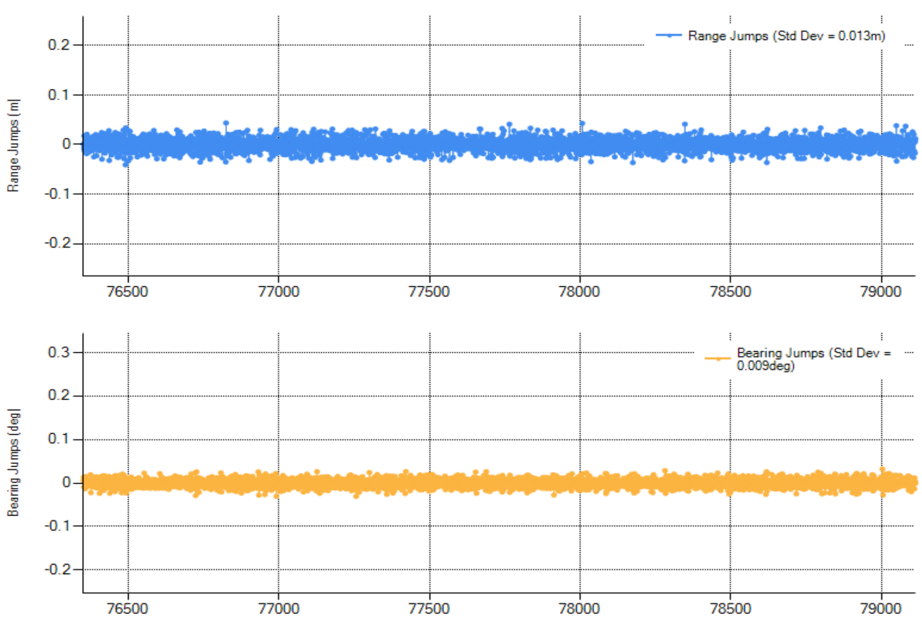

Figure 15- Highpass filtered position data from figure 14

We can compare the DP position holding performance against the position noise estimate we produce the SceneScan sensor. It is also useful to calculate the bearing noise into a distance referenced equivalent noise, by which we mean taking the bearing noise and by taking the range into account we can convert this into a tangential position noise.

The SceneScan has noise figures which are suitable for the DP application.

Table 2 - Sea trial results against a TLP and accommodation vessel

Results against a TLP at 110m on production algorithm (1.0.2)	**Position noise – radial**	**Position noise – tangential**
DP position holding performance	0.088m	0.084 degree (0.161m distance referenced)
SceneScan position noise	0.013m	0.009 degree (0.017m distance referenced)

Results against a drillship

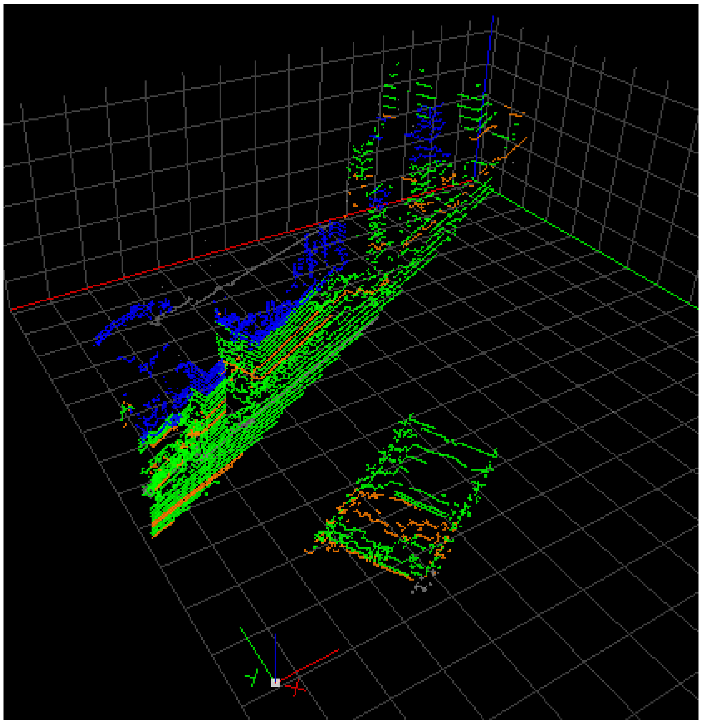

Figure 16 - 3D reconstruction of a drillship

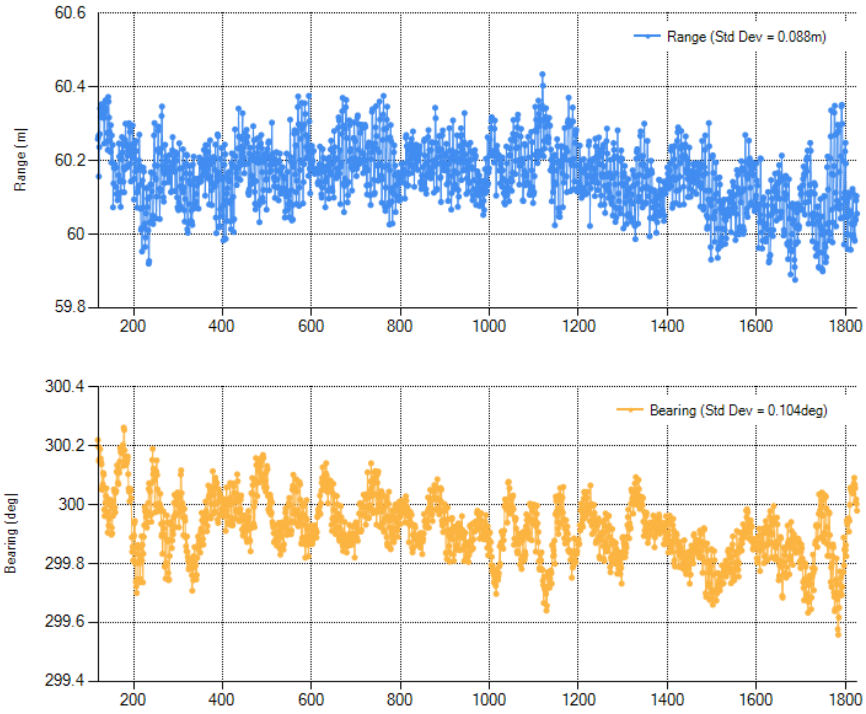

Figure 17 - Position plot for holding at a drillship

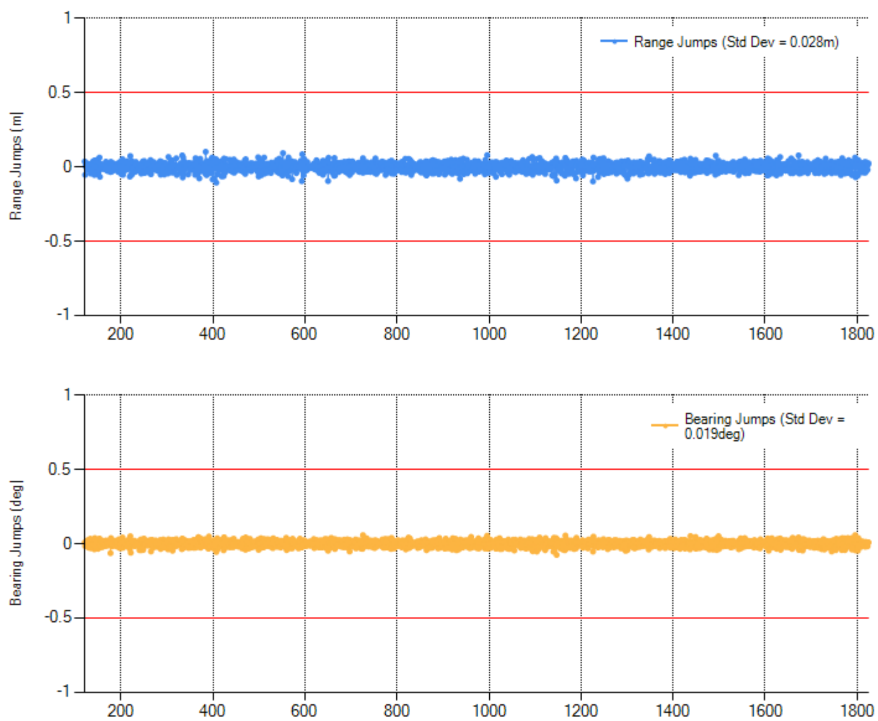

Figure 18 - Highpass filtered position data from figure 17

Table 3 - Sea trial results against a drillship

Results against a drillship at 60m	Position noise – radial	Position noise - tangential
DP position holding performance	0.088m	0.104 degree (0.109m distance referenced)
SceneScan position noise	0.028m	0.019 degree (0.020m distance referenced)

Conclusion

We have shown techniques used to evaluate the performance of a targetless position reference sensor and shown these used to evaluate a laser position reference sensor. We have shown the targetless sensor evaluated both on land against rigs in dry-dock and on sea trials in actual use against a variety of assets.

Acknowledgements

Guidance Marine would like to thank the crews and owners of all the vessels who have hosted Guidance Marine engineers on trials.

Able UK Seaton Port
Island Champion
Harvey Hurricane
Edda Ferd
Demarest Tide
Grand Isle
Windea La Cour

References

MTS TechOp OPD 14 – PRS and DPCS handling of PRS, September 2017