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Breaking the 500m Barrier: Safety-Driven Development of Long-Range, Targetless Relative Position Sensors for DP Operations

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ABSTRACT

Safe offshore operations should depend on strict adherence to the 500-meter safety zone surrounding oil rigs and other fixed structures. Within this zone, vessels must operate under Dynamic Positioning (DP) mode using relative positioning sensors to maintain safe separation. However, currently available targetless sensors, such as laser-based systems, typically operate at ranges below this threshold, this forces operators to choose between compliance, classification, and practicality.

At Guidance Marine, we have a long-established range of targeted relative position sensors, both laser and microwave modalities. We recognise the inherent weaknesses of discrete targets in the marine DP industry. As such, we are addressing this critical gap by developing a new generation of targetless relative positioning systems capable of operating safely and accurately beyond 500 meters. Our current SceneScan laser sensor offers highly precise, targetless positioning, but is limited to approximately 200 meters due to eye-safe laser power constraints and detector sensitivity. Since SceneScan was developed advances in optical detectors has advanced by orders of magnitude, thanks primarily due to the requirements of the medical sector. The next generation of laser sensors will allow targetless dynamic positioning beyond the 500m zone. To complement and extend this capability, we are also developing a 77GHz microwave radar system engineered to deliver reliable range and bearing data to offshore installations well beyond the 500-meter mark, without the need for discrete targets or reflectors.

This paper explores the safety-driven motivation behind this technology roadmap, the challenges of achieving targetless operation at extended ranges, and the trade-offs between laser and radar-based approaches. It will include an overview of regulatory drivers, system design strategies, and anticipated performance in real-world marine environments. By overcoming the 500-meter limitation, these next-generation sensors aim to eliminate the need for operational compromises—enhancing safety, simplifying procedures, and supporting full compliance with DP class requirements in offshore operations.

INTRODUCTION

Dynamic Positioning is indispensable in offshore operations, enabling vessels to maintain station for drilling, construction, and subsea intervention. The safety of DP operations depends on the quality and diversity of its position reference systems. Class rules and industry guidelines emphasize the need for multiple, independent sensors that can provide reliable measurements under a wide range of conditions, including GNSS outages.

Traditional relative position reference sensors fall into two broad categories:

Target-based systems, such as radar transponders or laser prisms, which require cooperative equipment on the target.

Targetless optical systems, such as laser-based sensors, which provide line-of-sight measurements but are limited in range (typically < 200m), weather resilience, and target reflectivity.

Both approaches have proven effective but impose operational constraints. For targetless sensors to be useful for DP operation around oil and gas platforms they must achieve the measurement performance of existing targeted system but at ranges > 500m.

This paper describes Guidance Marine's efforts to break the 500m barrier by developing two complementary sensor families -SceneScan Digital (laser) and RS77 with RadaScene (radar) designed to meet the stringent safety, performance and redundancy requirements of DP operations.

SYSTEM OVERVIEW

The projects to extend targetless relative position sensing have progressed along two complementary technology paths: optical (laser) sensing and radar sensing, optical is supported by a proven localisation engine which is already deployed for DP integration.

Optical Sensor – SceneScan - The legacy SceneScan sensor pioneered the use of Simultaneous Localisation and Mapping (SLAM) for DP, using a single pencil-beam, LiDAR-like optical channel to generate targetless relative position measurements. While successful in service, its range is limited to ~200m, constraining its use in offshore operations.

The next-generation SceneScan Digital addresses this limitation by incorporating a redesigned optical front end with ~10,000 greater optical sensitivity. It retains the SLAM localisation engine from SceneScan but is hosted on the proven CyScan AS Digital Signal Processing platform, providing both de-risking and continuity of proven hardware performance. SceneScan Digital is designed to deliver reliable targetless measurements well beyond 500m.

Radar Sensors – RadaScan (RS) Family: In parallel, Guidance Marine has advanced radar-based relative positioning through the RS24 K-band FMCW radar, paired with the RadaScene localisation engine. RS24 has demonstrated functional targetless performance but lacks the resolution required for DP.

The RS77 E-band radar addresses this by delivering higher range and azimuth resolution. When integrated with RadaScene, RS77 is expected to achieve DP-grade localisation performance at extended ranges, complementing SceneScan Digital by offering redundancy.

Complementary Redundancy: Together, SceneScan Digital (optical) and RS77 with RadaScene (radar) form a complementary, redundant sensor suite: independent modalities (optical and radar), diverse physical principles reducing common-mode failures, and seamless Ethernet-based integration with DP controllers

DEVELOPMENT & METHODOLOGY

Safety-Driven Requirements: Industry drivers have sharpened the need for targetless sensors. At least one oil major now mandates targetless laser sensors for vessels attending its assets, recognising that target-based systems introduce risks: dependence on installed targets, maintenance burden, and operational uncertainty. Targetless systems, by localising directly against the offshore asset itself, avoid these risks entirely.

Parallel Development Streams: Optical Path – SceneScan Digital: redesigned optical front end, +10,000× sensitivity, SLAM-based localisation, built on CyScan AS platform. Radar Path – RS77 with RadaScene: transition from K-band RS24 to E-band RS77, providing the resolution required for DP when processed by RadaScene. The engineering team was deliberately split into two groups, pursuing optical and radar approaches in parallel to reduce risk and accelerate development.

Integration with DP Systems: Both sensors are designed for DP integration via standardised Ethernet outputs (UDP, NMEA/IEC 61162-450), continuous self-monitoring and health status reporting, and operation as independent redundant references meeting class requirements.

INTRODUCTION TO SCENESCAN

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

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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, we can infer the sensor motion between the scans by taking the translation and rotation required to correctly overlay the scans.

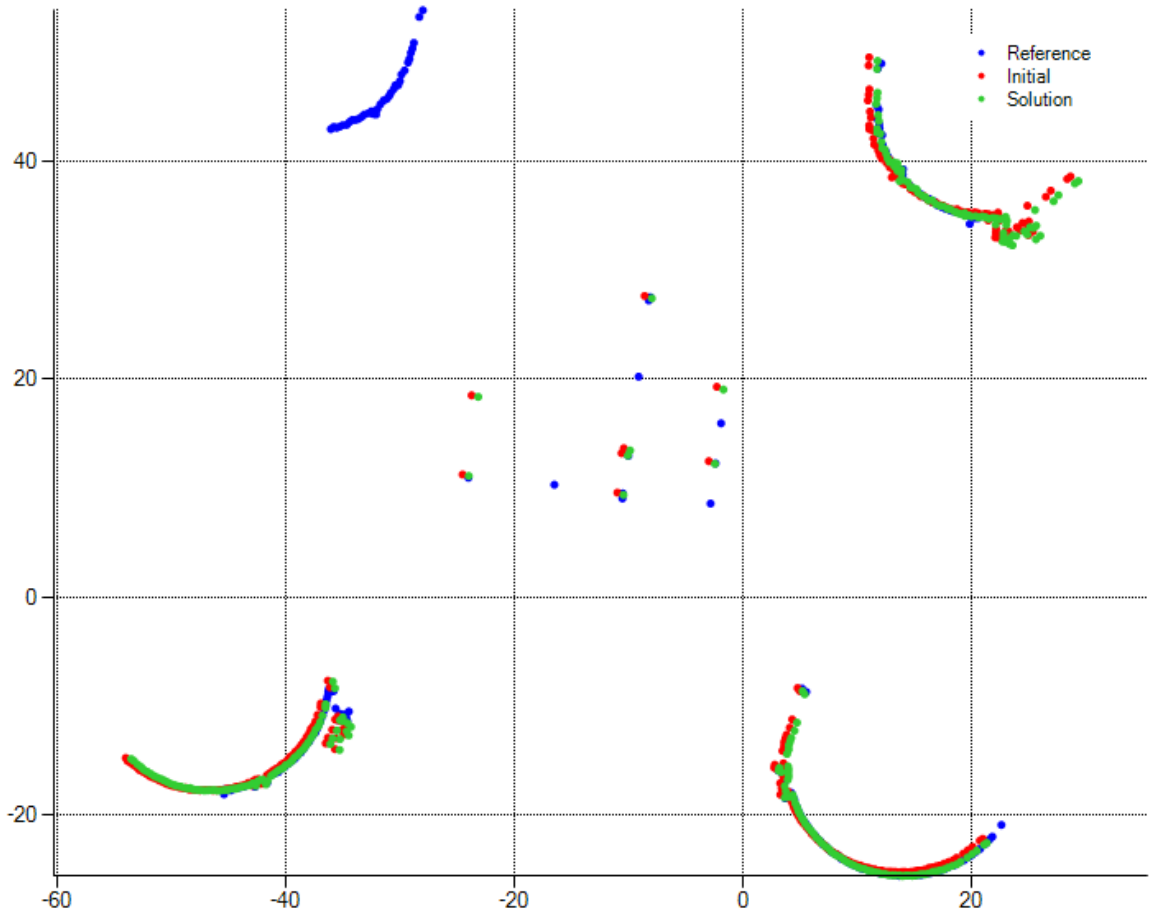

Figure 1 - Example scan and scan match from SceneScan sensor

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 different viewpoints. Subsequent scans are then matched to the updated reference scan; 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. 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.

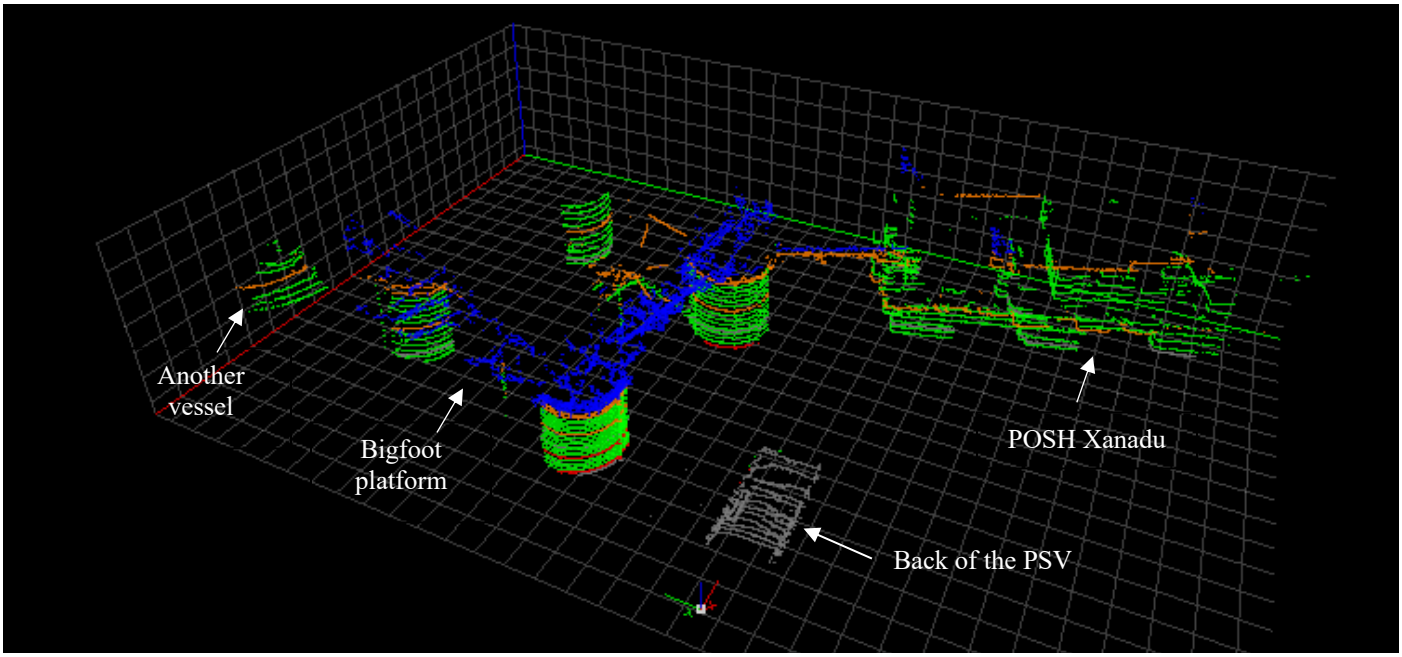

Figure 2 - 3D reconstruction from tilt optimisation

SceneScan performance is based on a laser with a Pulse Repetition Rate (PRF) of 7.5kHz. The performance of the SLAM engine will be degraded for longer tracking ranges. To this end the PRF of the SceneScan Digital platform has been increased to 65kHz. The increased point cloud density offsetting the longer tracking range. This increase remains within the Class 1 Laser Safe limit of IEC 60825-1. The increase is only possible my migrating from the current SceneScan platform to the DSP of the CyScan AS sensor.

INTRODCTION TO RADASCENE

The RadaScene localisation engine is a targetless position reference software package, which accepts a radar video feed from an RS24 or RS77 sensor. It utilises a number of fused complimentary mathematical techniques including the simultaneous location and mapping (SLAM) algorithm to localise the sensors position relative to the scene

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Abstractly RadaScene operates as previously described for SceneScan, however as the image comes from a radar the scene has intensity and depth, this is both an advantage and a disadvantage when it comes to solving the localisation problem.

RadaScene development is a step-by-step approach, different scenes present different computational challenges. The initial development targeted inland water way navigation, inland waterways provide a plethora of objects to derive position from and is essentially the easiest environment to track.

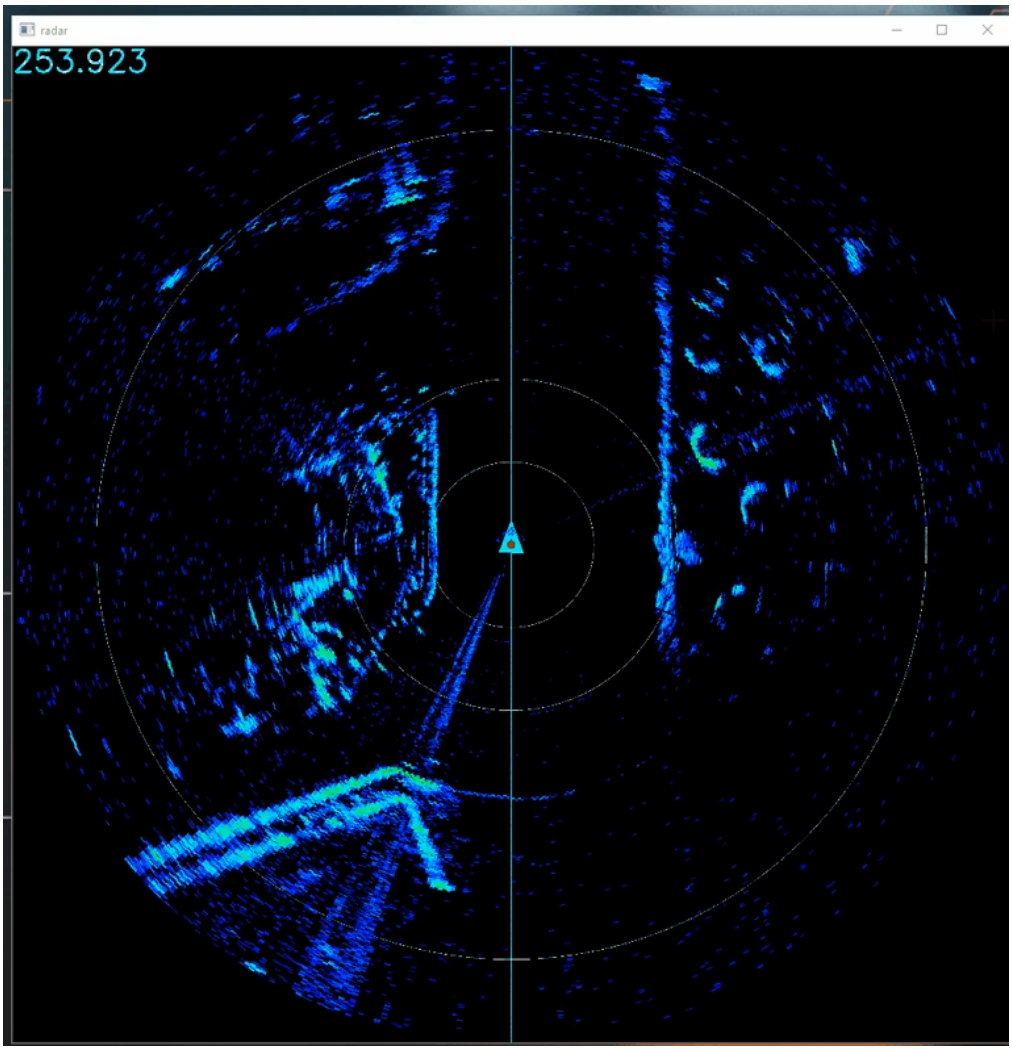

Figure 3: Inland waterway RS24 radar image

As discussed earlier, optical sensors such as SceneScan are constrained to ranges of ~200 m due to eye-safety limitations, which restricts their use for targetless relative positioning in compliance with the 500 m safety zone. To address this limitation, we have extended the principle of targetless positioning to marine radar, leveraging SLAM (Simultaneous Localization and Mapping) techniques to extract stable georeferenced navigation solutions from radar returns.

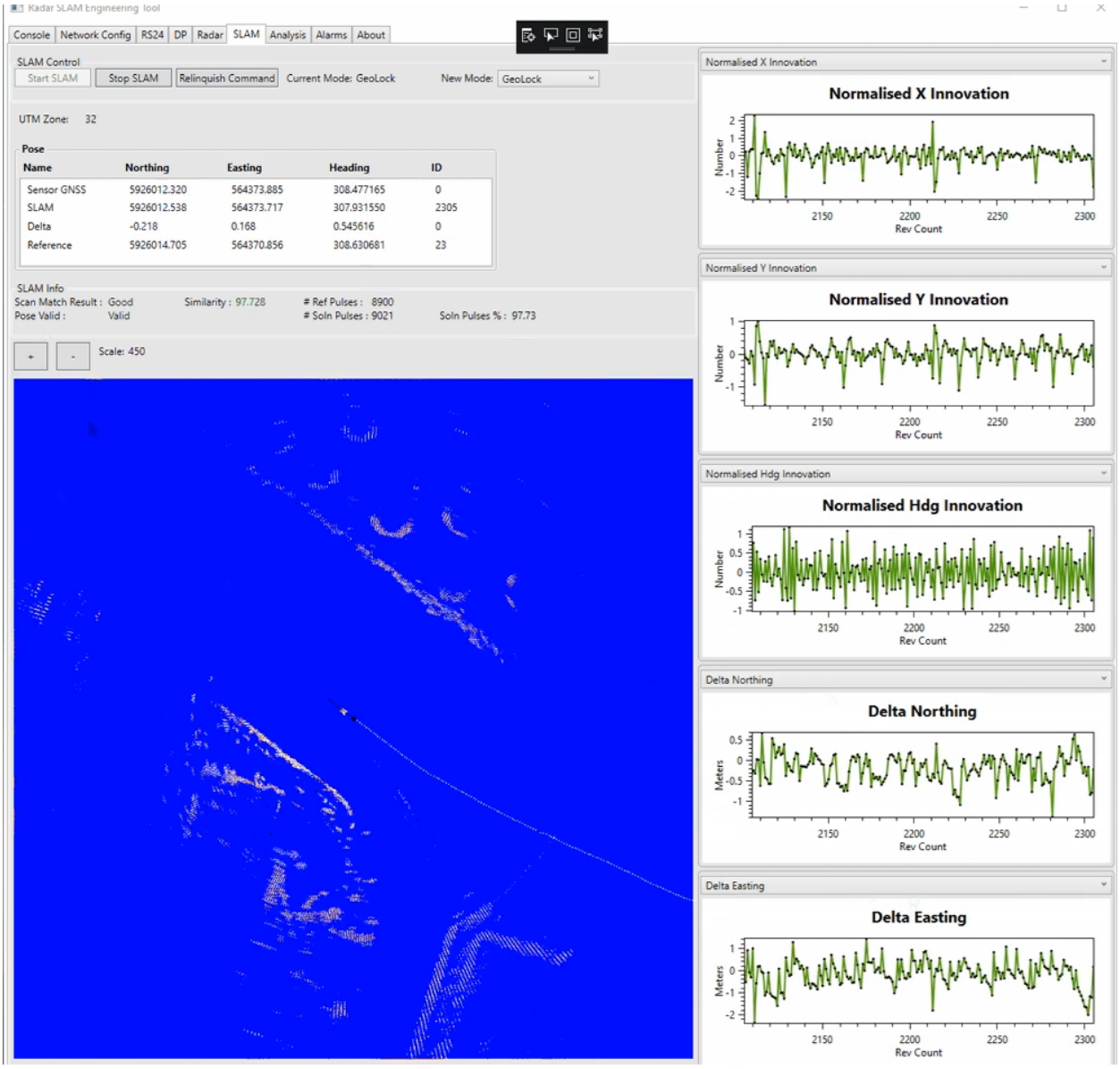

Figure 4: RadaScene Engineering Console

Figure 4 presents the operational interface of the radar-SLAM system during live trials. The system was operated in GeoLock mode, whereby the SLAM-derived pose is continuously compared to a GNSS baseline to quantify performance. The navigation table shows northing, easting, and heading values from GNSS, SLAM, and a reference track, with the delta row reporting the difference between SLAM and GNSS. These

deltas remain on the order of a few meters in position and fractions of a degree in heading, confirming that the SLAM solution is aligned with the baseline. The errors are directly correlated to the resolution of the radar sensor.

The radar-derived environmental map, shown in the lower left panel, highlights quaysides and other harbor structures as persistent radar features. The vessel trajectory is plotted across this scene, illustrating how the SLAM algorithm exploits environmental geometry to maintain a consistent position fix even in GNSS-challenged conditions.

To validate filter stability, the right-hand diagnostic plots show the normalized innovation sequences for X, Y, and heading, all remaining bounded within $\pm 2\sigma$, consistent with statistically well-behaved filter dynamics. The delta northing and delta easting plots, referenced against GNSS, demonstrate that residuals are constrained within the meter bounds throughout the trial.

These results confirm that radar-SLAM provides robust and accurate navigation. By delivering reliable, georeferenced positioning that remains tightly correlated with GNSS, radar-SLAM provides a practical pathway to targetless relative positioning beyond the 500 m zone, thereby addressing a critical gap in current dynamic positioning operations.

Figure 5: RS24 Data Gathering - Cromarty Firth

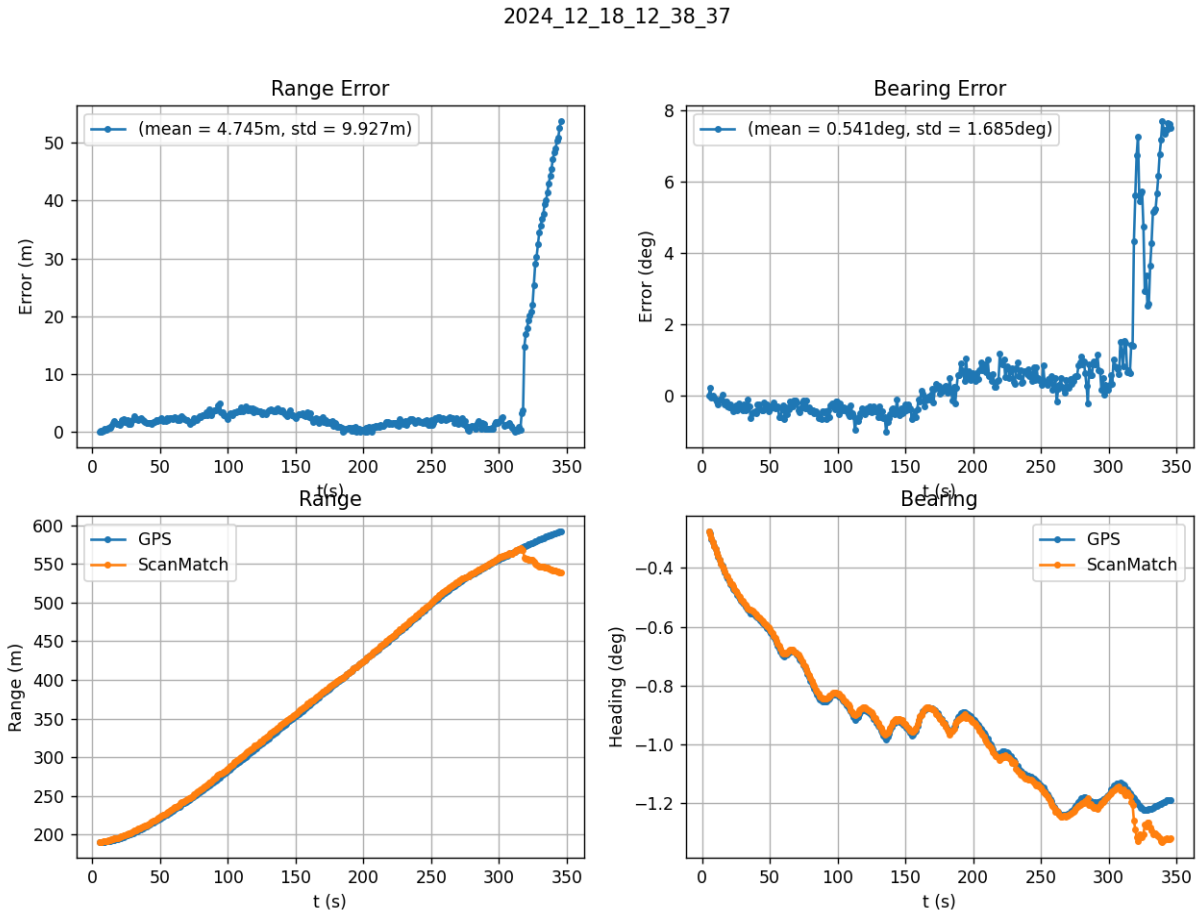

Figure 6: Vessel departure from oil rig - 200m to 600m

Scan matching is one of the algorithms employed by RadaScene. The ScanMatch using an RS24 sensor demonstrated good agreement with the GNSS baseline during the initial stages of departure. Across the first 300 s (~600 m range), the mean range error was 4.7m (σ = 9.9 m) and the mean bearing error was 0.54° (σ = 1.69°), indicating stable and reliable tracking within the 500 m safety zone. Beyond this distance, performance degraded: range error increased sharply to >50 m and bearing error rose above 7°, reflecting reduced feature overlap and growing drift. These results show that ScanMatch is viable approach, but that the accuracy using an RS24 sensor as the radar image feed is not at a level adequate for relative positioning around offshore structures but requires complementary sensing to achieve performance at extended ranges. The RS77 essentially increases the resolution of the radar image by 15x, this with a multiple algorithm fused tracking approach is expected to exceed the required performance for DP operation.

DISCUSSION

The key operational advantage of both SceneScan Digital and RS77 with RadaScene is that they are environmentally referenced: they use the asset itself as the target, not external prisms or transponders. This delivers four benefits for DP operations:

1. Eliminates Target Dependency – reliable localisation even if cooperative targets are absent.

2. Reduces Maintenance – no upkeep of external targets on offshore assets.

3. Provides Flexibility – works with any visible structure, widening operational use.

4. Enhances Safety Margins – 500m+ range provides additional time and redundancy during approaches, especially under GNSS outages or in congested environments.

By combining optical and radar modalities, the system ensures resilience across different conditions—optical sensors excel in clear visibility, radar performs reliably in poor weather. This dual approach strengthens redundancy and supports class requirements for independent references.

CONCLUSIONS

Breaking the 500m barrier for targetless relative position sensing represents a major step forward for DP safety and redundancy. Guidance Marine's parallel development of SceneScan Digital (optical) and RS77 with RadaScene (radar) addresses both operational and regulatory drivers, including oil major mandate for targetless sensors.

Measured trials with RadaScene and RS24 confirm the feasibility of radar-based localisation, while laboratory testing of SceneScan Digital demonstrates its potential to extend optical performance far beyond current limits. Together, these systems form a complementary, redundant suite that eliminates the need for cooperative targets, reduces maintenance, and enhances safety margins for offshore DP operations.
Future work will focus on field trials of SceneScan Digital and RS77, with the goal of achieving full DP-class integration and adoption across the offshore industry.

References

1. IMO MSC/Circ.645 – Guidelines for Vessels with Dynamic Positioning Systems.
2. MTS DP Conference Proceedings (various years).
3. Technical literature on FMCW radar and SLAM-based localisation.