FULL SPECTRUM SIMULATION TOOL FOR DEEP SEA POSITIONING

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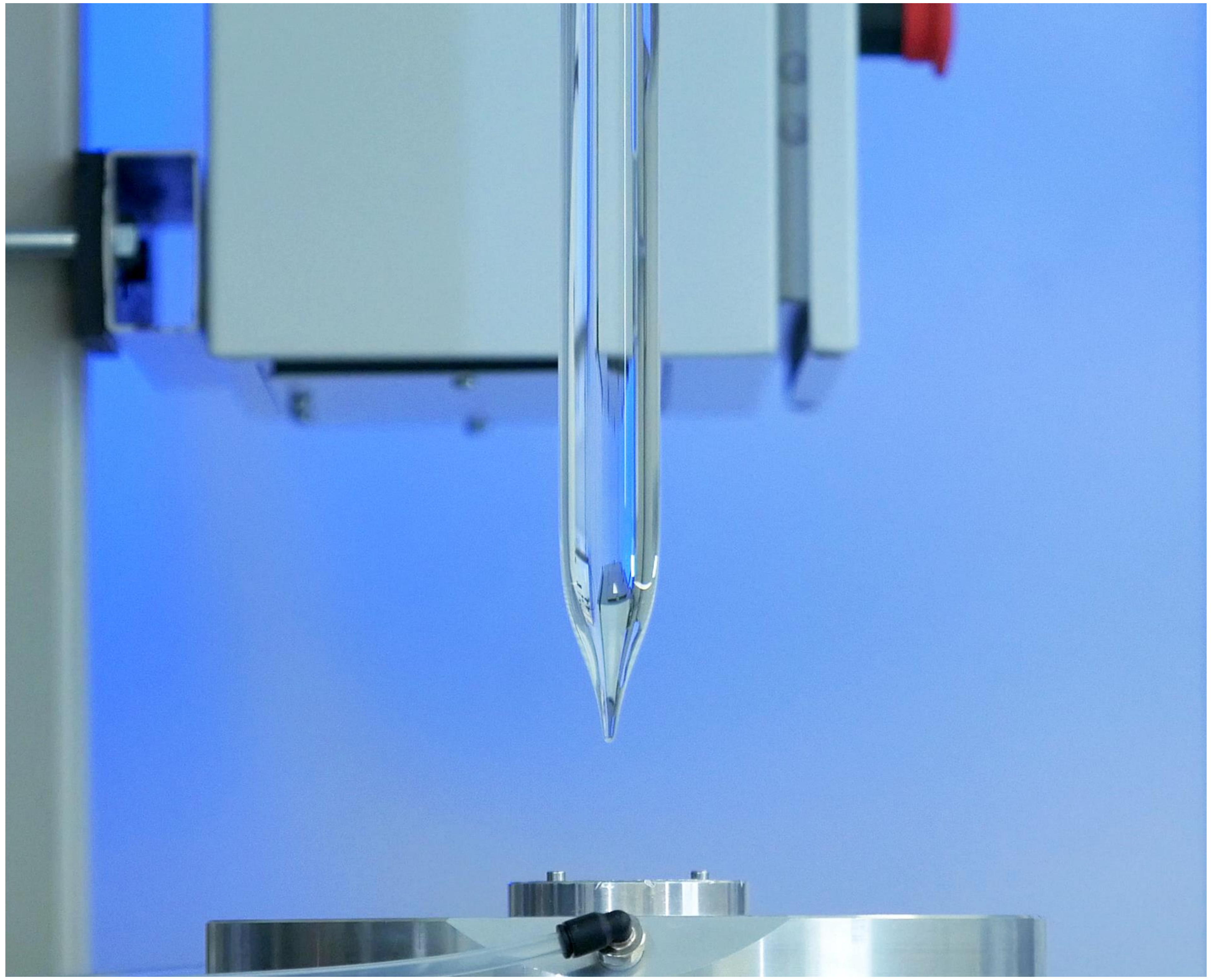

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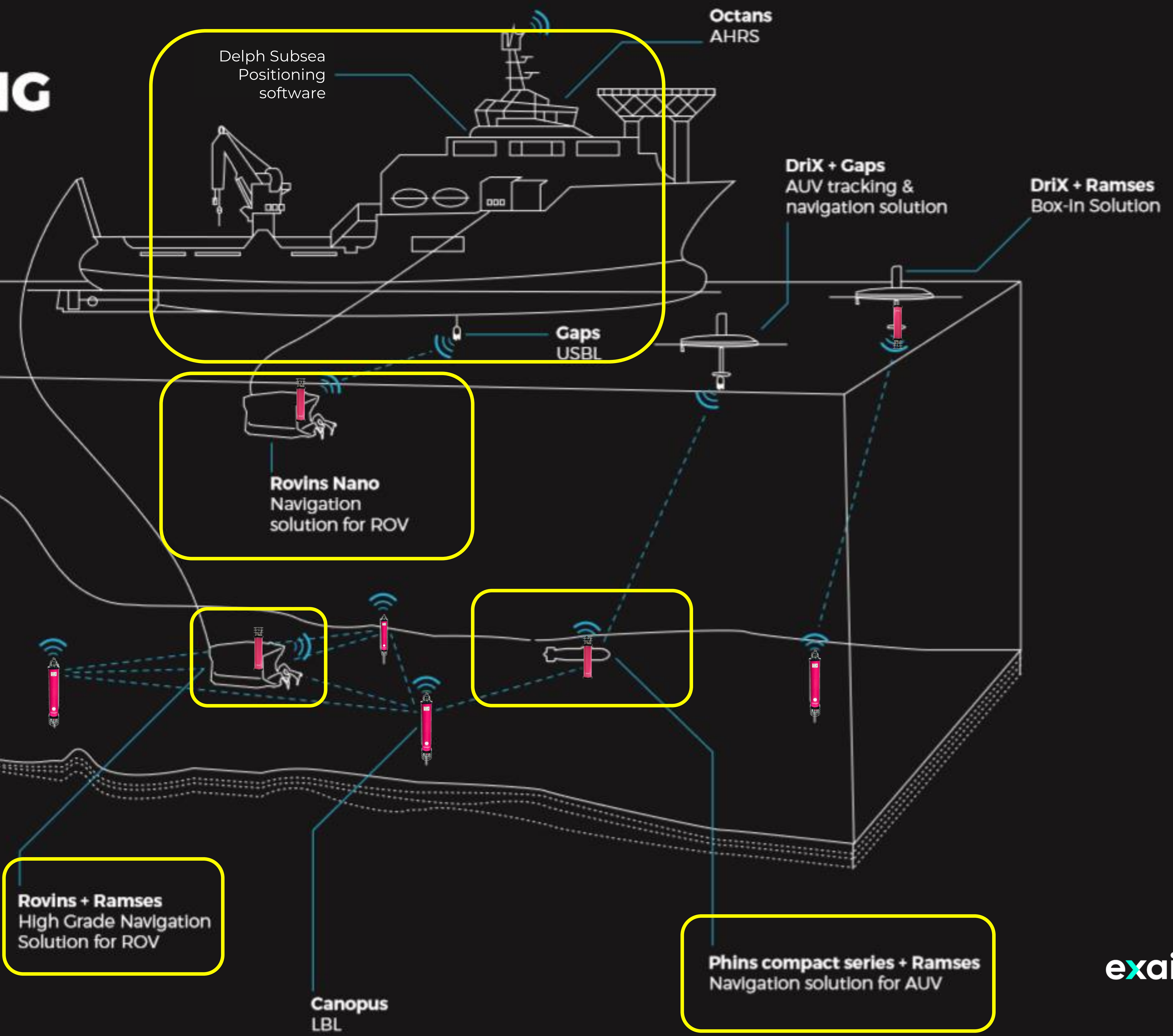
NAVIGATION AND SUBSEA POSITIONING SOLUTIONS

INERTIAL SYSTEMS

ACOUSTIC SYSTEMS

SOFTWARE



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Surface & Subsea positioning and communication

➤ INERTIAL SYSTEMS

SUBSEA AHRS / INS

SURFACE AHRS / INS

INS


INS TITANIUM

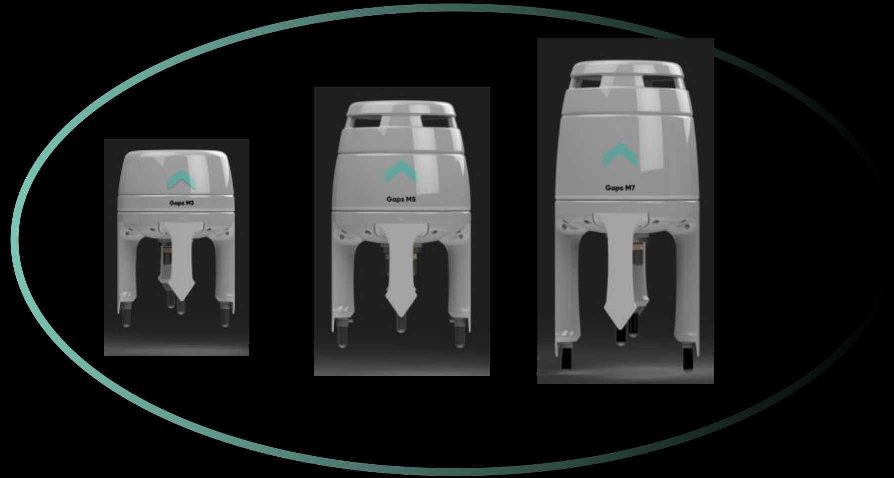

INS OEM


Survey & IMO Gyro


Hydrographic INS

➤ ACOUSTIC SYSTEMS

USBL


GAPS

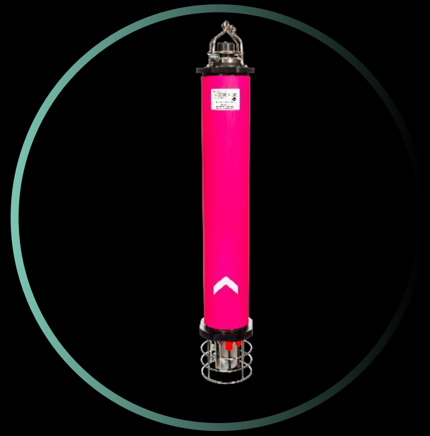

POSIDONIA


LF & MF Beacons

LBL

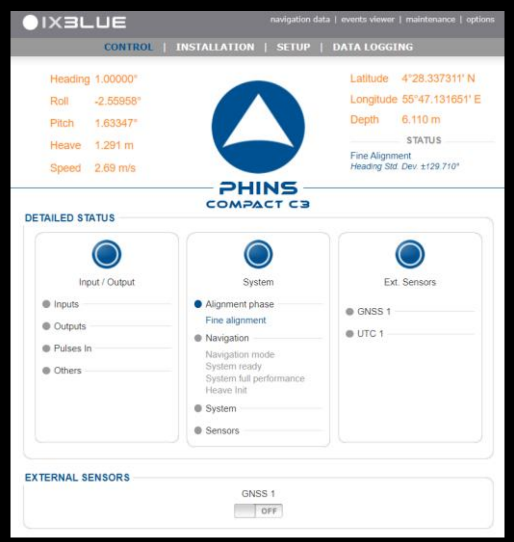

LBL TRANSCEIVER


OEM LBL TRANSCEIVER

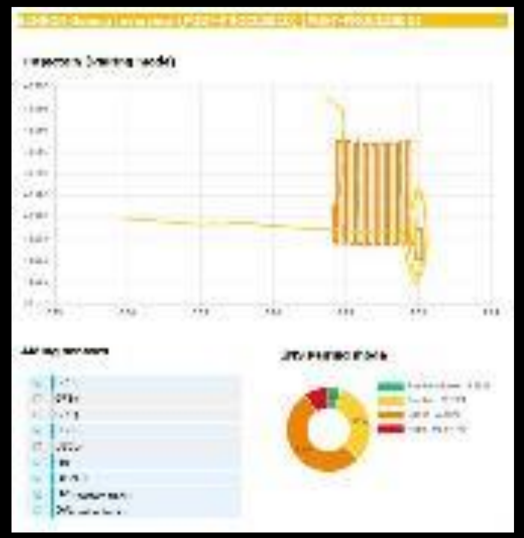

LBL TRANSPONDER

SOFTWARE

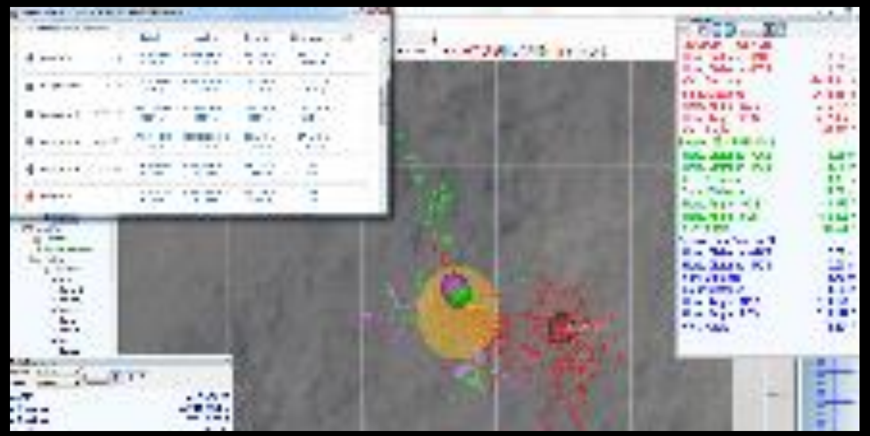
ONLINE SOLUTION



OFFLINE SOLUTION



Delph INS
Navigation &
Post-Processing



Delph Roadmap
2D/3D visualization

Delph SP
LBL array design &
operation

Full Spectrum Simulation

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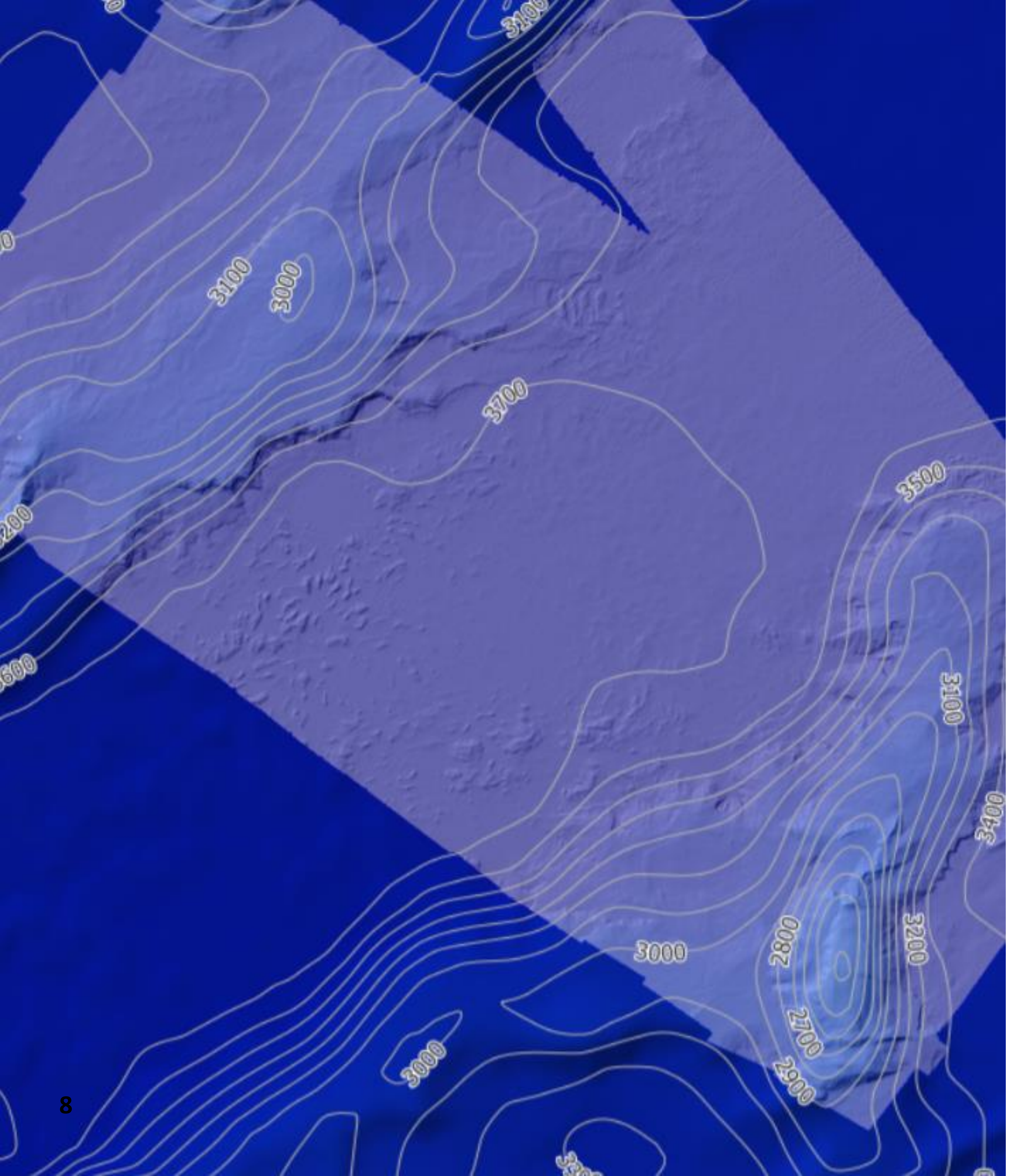
INTRODUCTION



Introduction

- Seabed operations are going deeper and requiring higher accuracy positioning and navigation.
- The use of advanced techniques including INS & LBL is becoming mandatory to reach the required level of accuracy or repeatability.
- Those complex operations require array design, proper planning, and evaluation of performance to define equipment that will have to be deployed on vehicles, optimize operating time and guarantee efficiency.
- Large areas in 3 or 4 km water depth will require seabed transponders and inertial navigation if positioning is to be at all repeatable.
- Do you know how sparse you can go?

← GeoNorge

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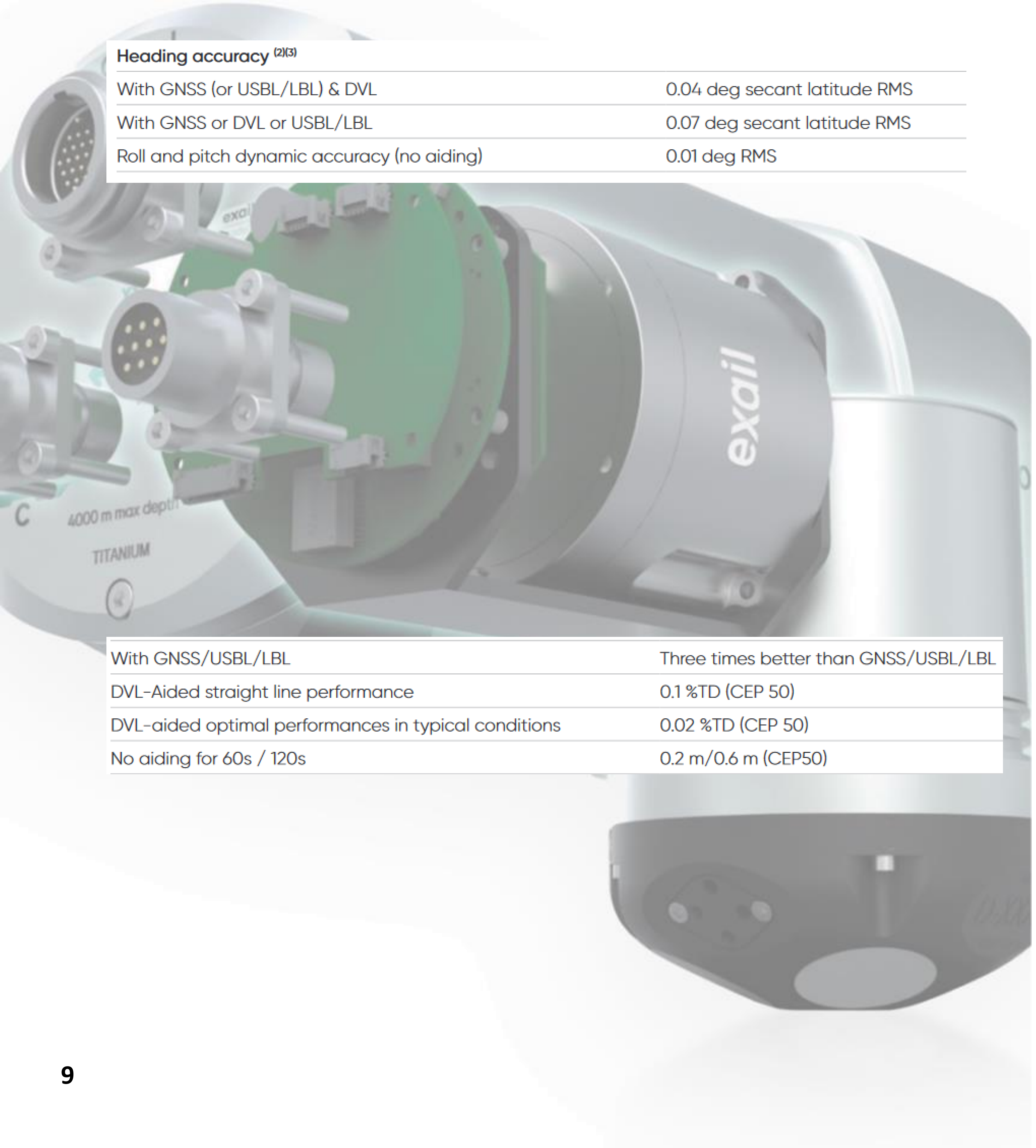
Error budgets

Heading accuracy (2)(3)	
With GNSS (or USBL/LBL) & DVL	0.04 deg secant latitude RMS
With GNSS or DVL or USBL/LBL	0.07 deg secant latitude RMS
Roll and pitch dynamic accuracy (no aiding)	0.01 deg RMS



With GNSS/USBL/LBL	Three times better than GNSS/USBL/LBL
DVL-Aided straight line performance	0.1 %TD (CEP 50)
DVL-aided optimal performances in typical conditions	0.02 %TD (CEP 50)
No aiding for 60s / 120s	0.2 m/0.6 m (CEP50)

- Historically, error budgets were a complex but straight forward calculation.
- By examining manufacturers data sheets for all items within the overall positioning systems and combining their performance can give a reasonable estimation of the final position accuracy.
- INS performance is not only based on the device's fundamental rotation and acceleration measurement accuracy, but also what movements have been experienced since switch on, and the quality of the aiding data applied.
- Rules of thumb such as “Three times better than GNSS/USBL/LBL are vague at best.
- Used correctly far better performance may be achieved.
- Used poorly, far worse performance may be achieved.

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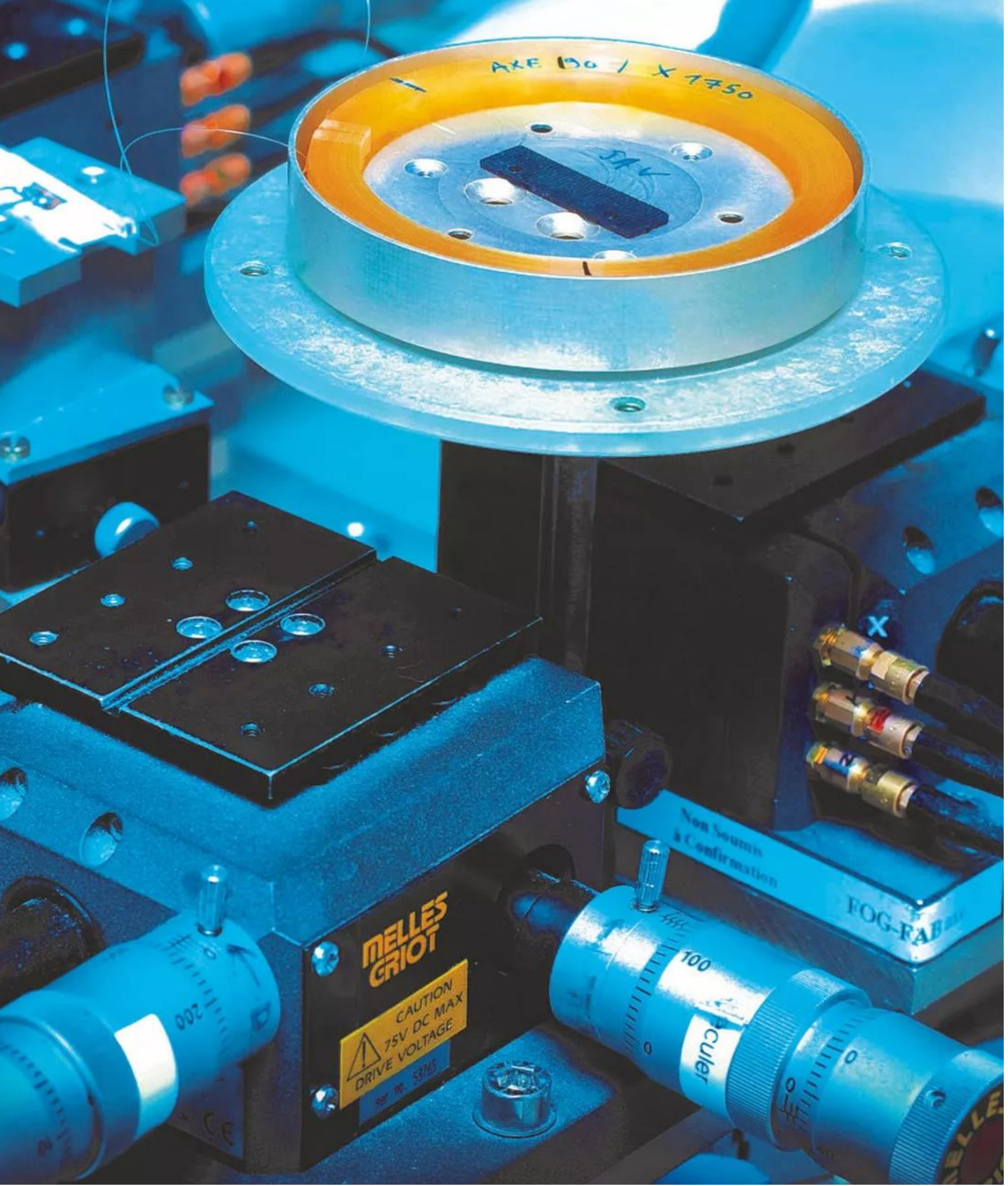
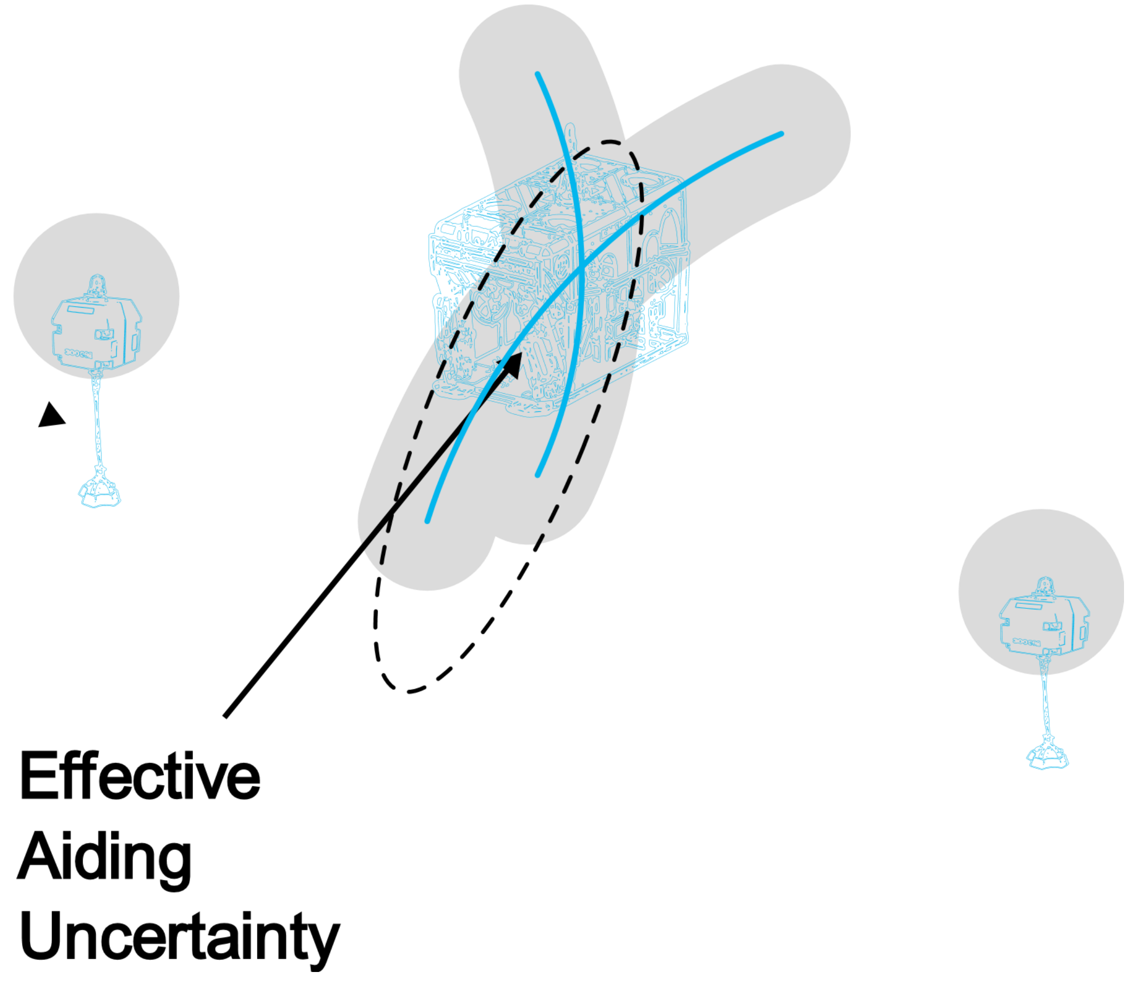
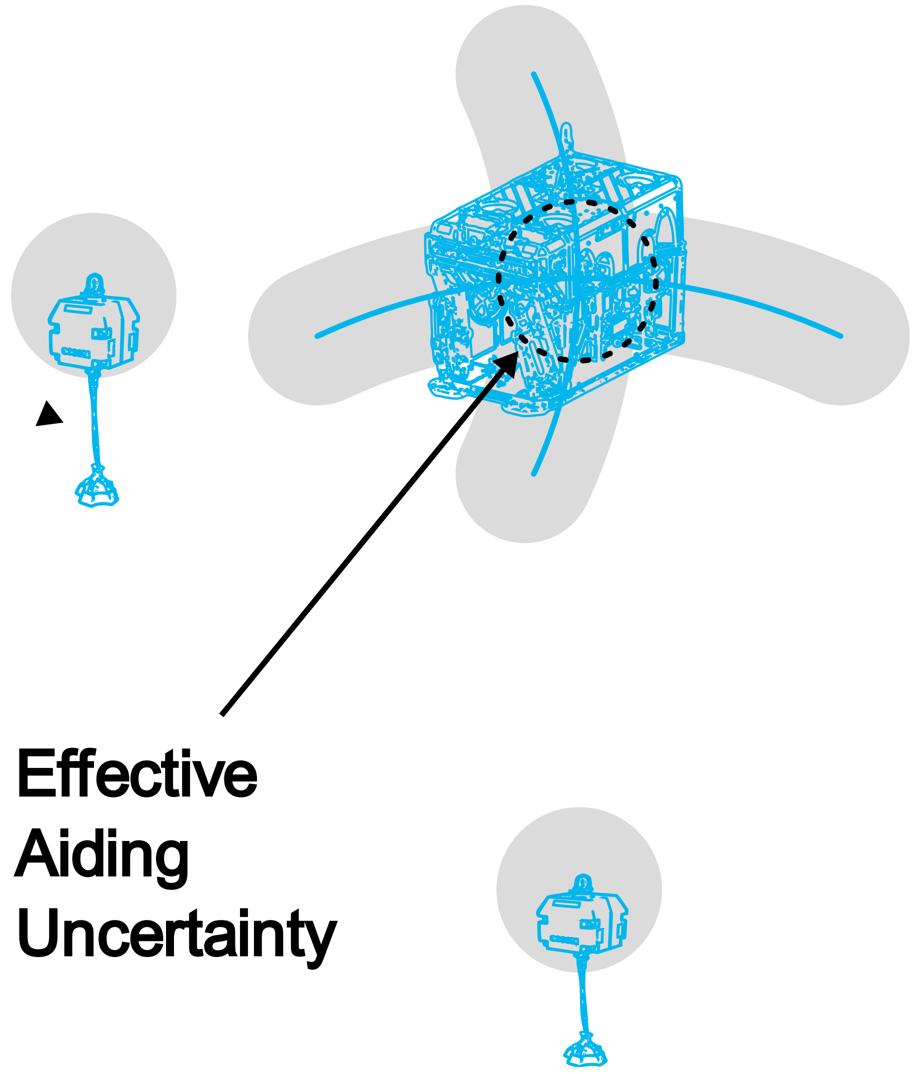


Benefits of Vertical Integration

- At Exail we design and manufacture all the critical components of the INS, from the fibre that makes up the gyrometer, the optical components that split and modulate the light, the MEMS accelerometers, and the algorithm that brings it all together.
- This means we have all the knowledge needed to accurately simulate the function of the INS given a suitable trajectory.
- Delph Subsea Positioning Software is able to simulate sensor data as a “Device” transits along a predefined route.
- Applying the simulated sensor data to the inertial algorithm results in a set of results that include an estimation of the accuracy at any point in that trajectory.
- Comparison with real world navigation has repeatedly confirmed the validity of this approach.
- **The simulation will only be accurate if the accuracy estimation of the simulated aiding data is realistic.**





Sparse LBL accuracy

It's not just range accuracy

- **The performance of sparse LBL is dependent on a number of factors.**
  - Acoustic travel time accuracy – transponder and transceiver electrical performance.
  - Pulse discrimination – pulse length and bandwidth
  - Sound velocity accuracy – converting travel time to distance.
  - Tide – vehicle Z measured in relation to sea surface. Transponder Z measured in relation to project datum.
  - Transponder XYZ position accuracy
  - Overall Geometry
- **Vehicle position accuracy will vary throughout an area and cannot simply be distilled down to a single value.**

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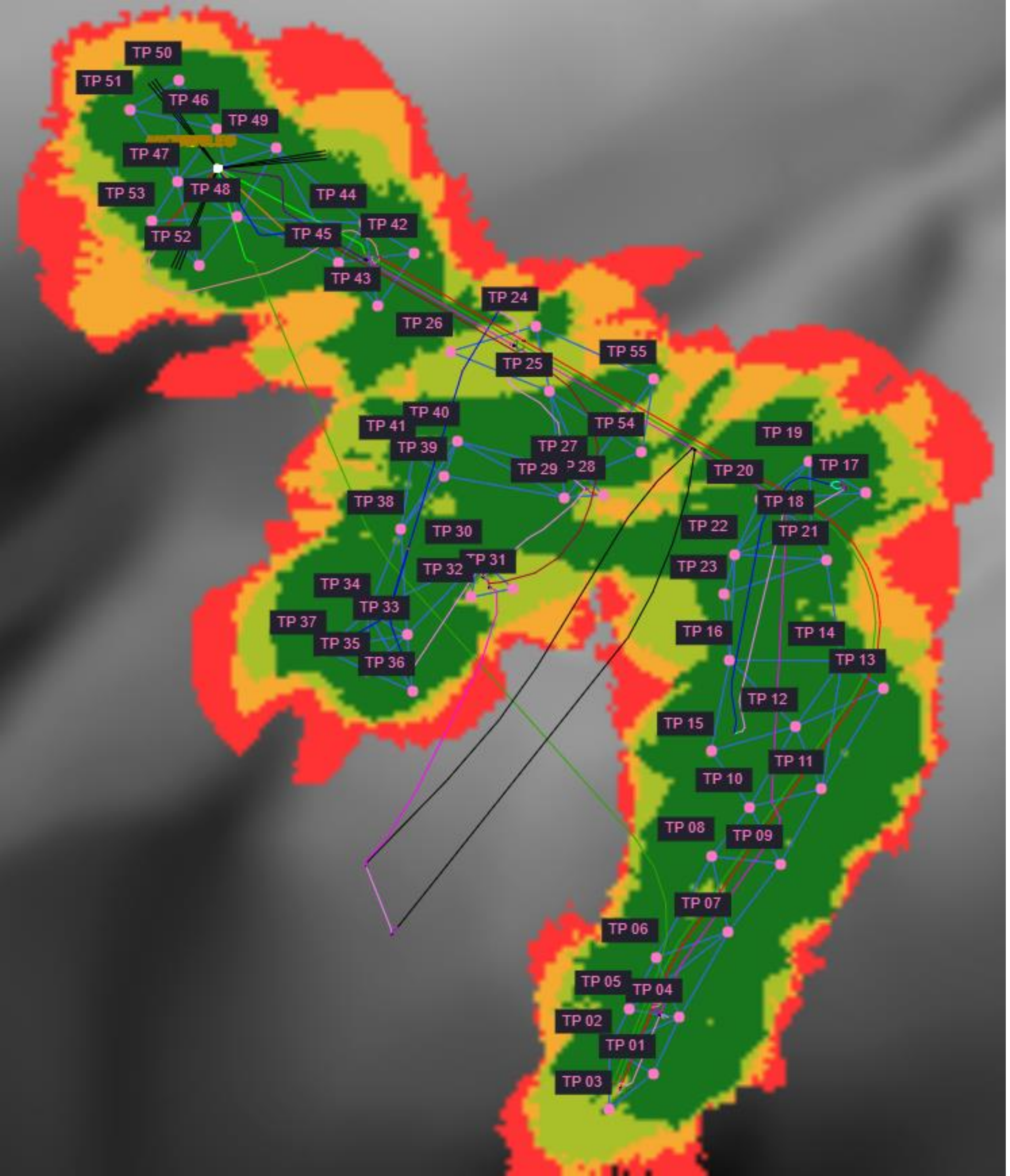
CASE STUDY



Case Study

- **In early 2023 a client asked us to design an extension to an array so that a series of new wells and flow lines could be installed.**
- **They needed to meet stringent positioning accuracy in the new area.**
- **The existing array (unpopulated frames) had been installed quite some time.**
- **The end client considers the existing array as "True"**
  - It was unacceptable to consider that the original calibration might be improved on.
- **It was important for the end customer that there was not a positioning discontinuity between the existing field infrastructure and the new structures.**
- **This presentation will use a simplified example field to explain the principals of how this study was achieved.**

← not the actual area

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Objectives

1. Better than 50cm absolute accuracy.
2. Agree with existing array.
3. Use as near to zero transponders as possible.
4. Minimise calibration cost.

- In order to realistically simulate the positioning that we will achieve we first need to know how well the new array will be calibrated.
- But we need to tie the new array in to the old array.
- We could just assume an easting and northing accuracy for each transponder.
- But then I wouldn’t have a presentation.

“In terms of accuracy the array was well adjusted, with baseline RMS of 0.044m and given that the average box in residual was 0.58m the absolute coordinates given will be in the region on +/-0.58m error – given the accuracies of the combined positioning systems. The largest potential errors for users of the frame array are likely to arise from unknown sound velocity parameters”

“For positioning within the array – as long as the sound velocities are well controlled the positioning repeatability will normally be better than 0.2meters. “

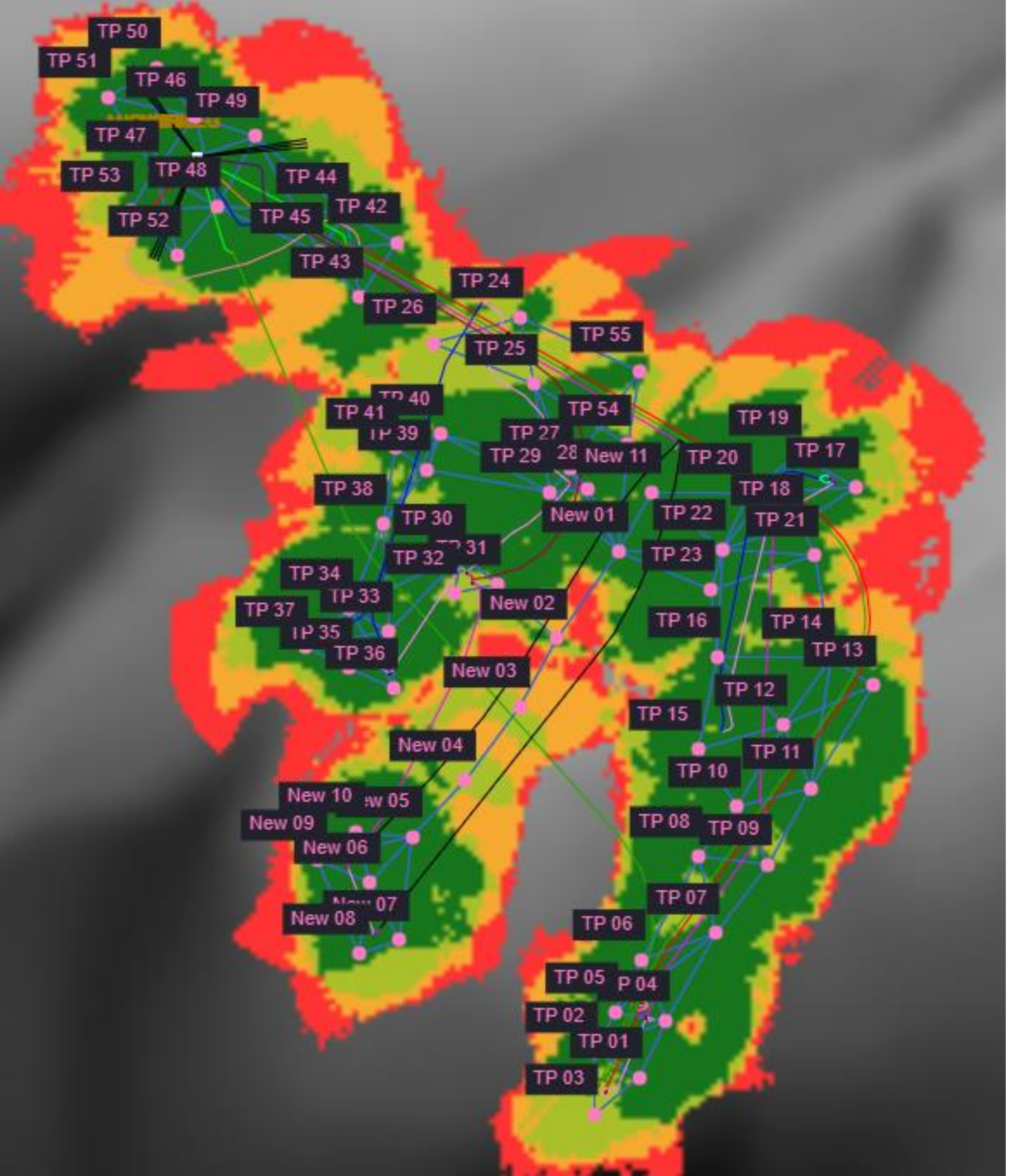
#Id	Latitude	Longitude	Height	Easting sd	Northing sd	Height sd
[illegible]	29826812	12550226	-641.50	0.535	0.426	0.1
[illegible]	489393967	.08543758	-601.77	0.889	0.899	0.1
[illegible]	566105398	.13098488	-713.50	0.976	0.589	0.1
[illegible]	66030208	12597563	-715.50	1.006	0.529	0.1
[illegible]	71641163	.09604441	-748.50	0.615	0.764	0.1
[illegible]	15281091	08592672	-649.50	0.448	0.373	0.1
[illegible]	14600793	08684572	-703.50	1.619	0.831	0.1
[illegible]	31815832	08623209	-680.50	1.745	0.794	0.1
[illegible]	10809543	08571386	-642.19	0.944	0.524	0.1
[illegible]	56808084	04800403	-783.50	1.034	0.771	0.1
[illegible]	587387737	.13225591	-761.50	0.828	0.705	0.1
[illegible]	560345622	08695987	-733.50	0.893	0.713	0.1
7017	542984788	09147617	-696.62	1.66	0.813	0.1

Understanding the existing array

- The requirement to ensure no positioning discontinuity between existing area and new area mean we need to integrate the existing transponder locations into the new array.
- This means we need to understand the existing array calibration.
- Our system relies on knowing both the X,Y,Z position of each transponder, but also the X,Y,Z standard deviation of those positions.
- The existing array consisted of over 100 frames being a mix of permanent and temporary frames.
- The calibration report for the existing array contains 1814 pages, at 101MB of data.
- No single summary table contains the position and accuracy for each transponder.
- Boxin results were reported, but deep inside the overall document.

CASE STUDY PART 2

LAYING OUT THE ARRAY



Laying out the New Array.

- Standard array layout operation.
- Complying with the requirement to minimise transponders we start by placing a line of transponders between the two pipes.

← not the actual area

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Laying out the New Array.

- Standard array layout operation.
- Complying with the requirement to minimise transponders we start by placing a line of transponders between the two pipes.
- **The two well locations at the end of the pipes should have at least three ranges available all round.**
  - The actual area was easier to cover due to having a flatter seabed.

← not the actual area

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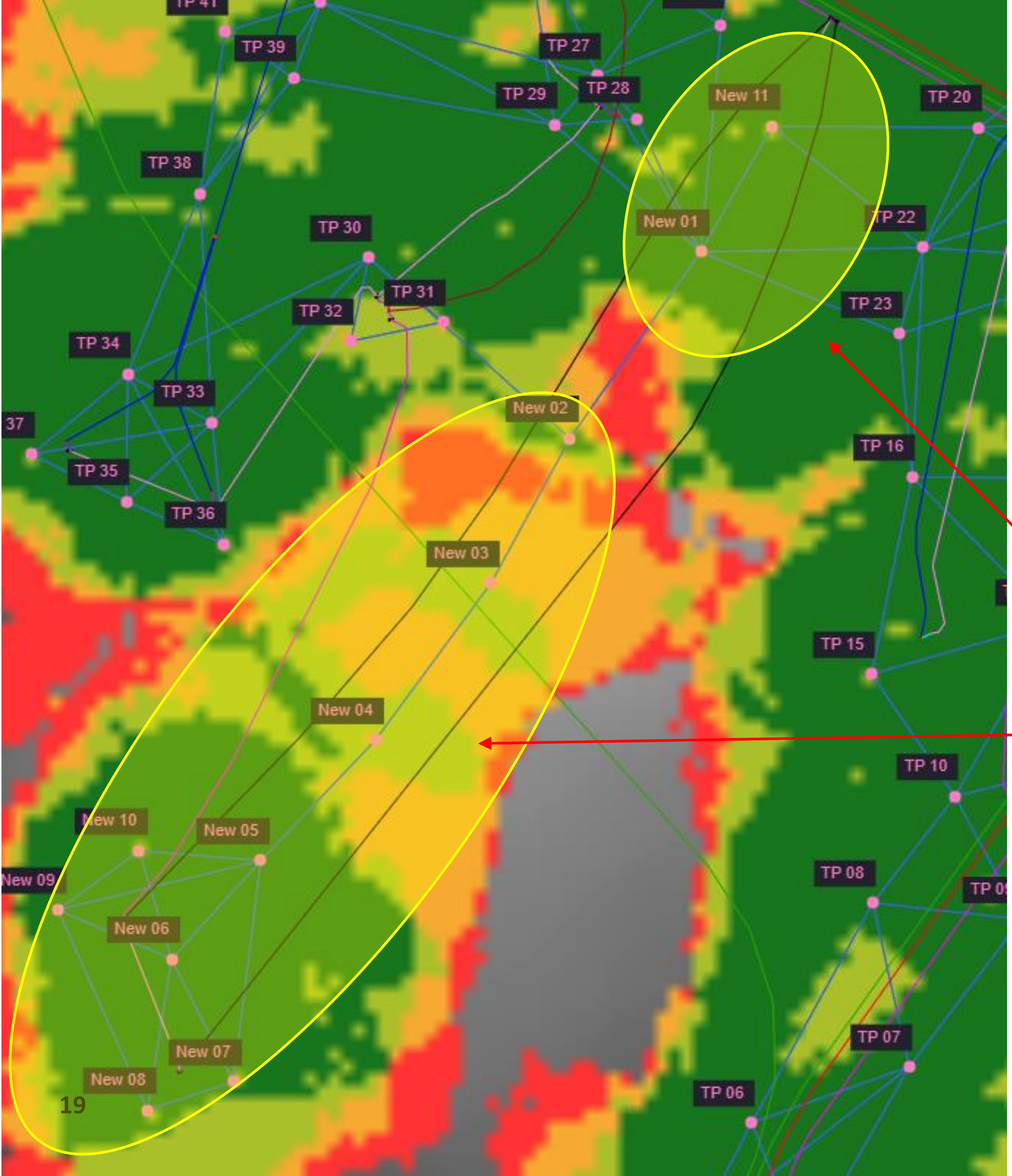
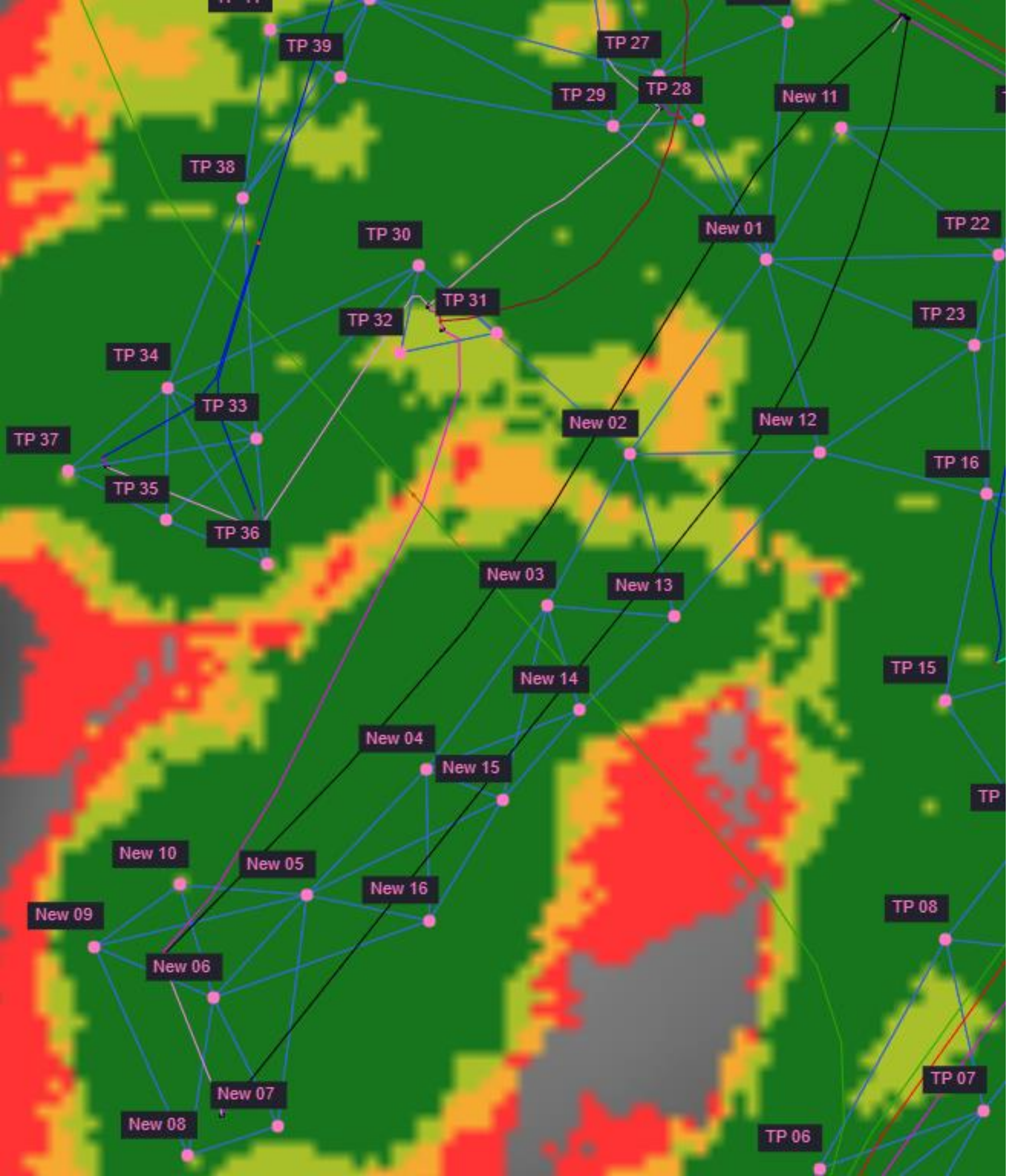


Laying out the New Array.

- Standard array layout operation.
- Complying with the requirement to minimise transponders we start by placing a line of transponders between the two pipes.
- The two well locations at the end of the pipes should have at least three ranges available all round.
  - The actual area was easier to cover due to having a flatter seabed.
- **These transponders can be adjusted relative to the existing transponders.**
- **These transponders could be calibrated with 5 boxins + adjustment, but they won't be well tied to the existing array.**

← not the actual area



Laying out the New Array.

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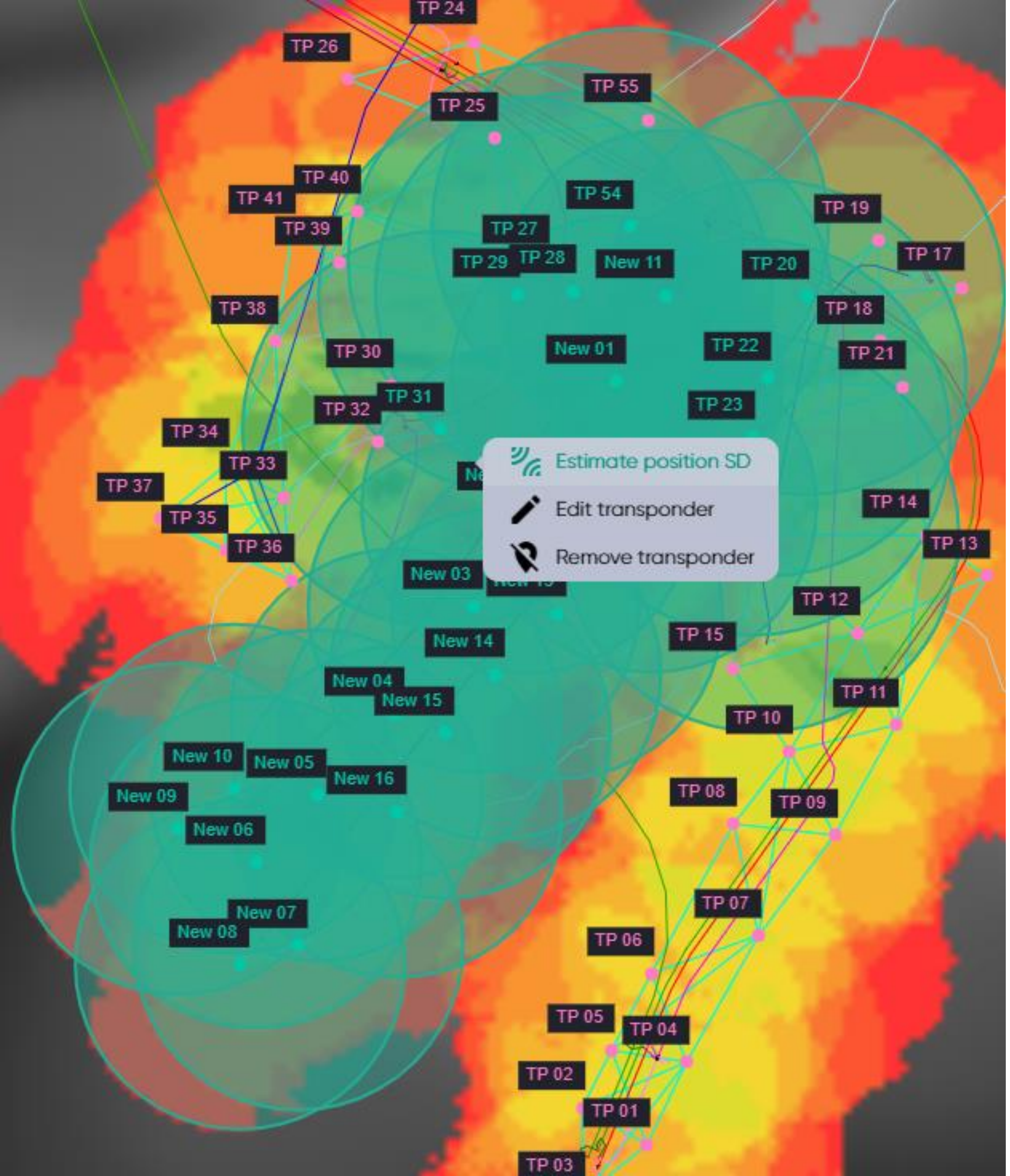
- These transponders can be adjusted relative to the existing transponders.
- These transponders could be calibrated with 5 boxins + adjustment, but they won’t be well tied to the existing array.
- **Now we have an array that can be calibrated through adjustment.**
- **We need to decide if we want to boxin additional transponders, but we can proceed with the calibration & check the results.**

← not the actual area

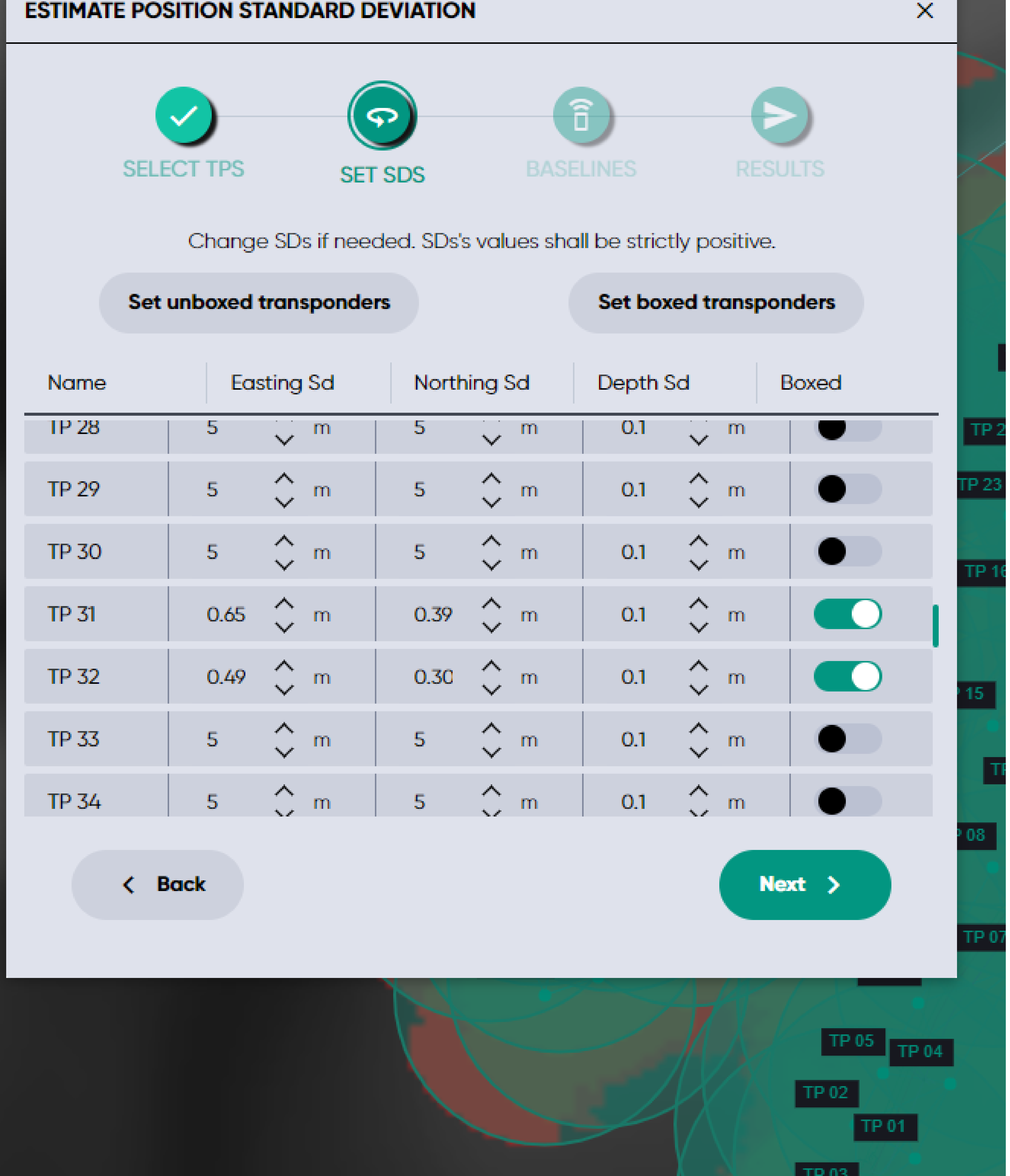
SIMULATE THE ARRAY



Calibration Simulation

- DSP takes in to account topography, ray bending, and acoustic conditions to evaluate if a baseline is viable.
- The user can specify a maximum acceptable range.
- The same algorithm as used in a real array adjustment is used to simulate the calibration.
- Baseline SD's are evaluated based on the equipment specified along with an allowance for the length of the baseline.
- Combining the SD of the known transponders – Boxin estimates or real transponder accuracies – with the range SD give a realistic final set of transponder SD's after the algorithm is run.

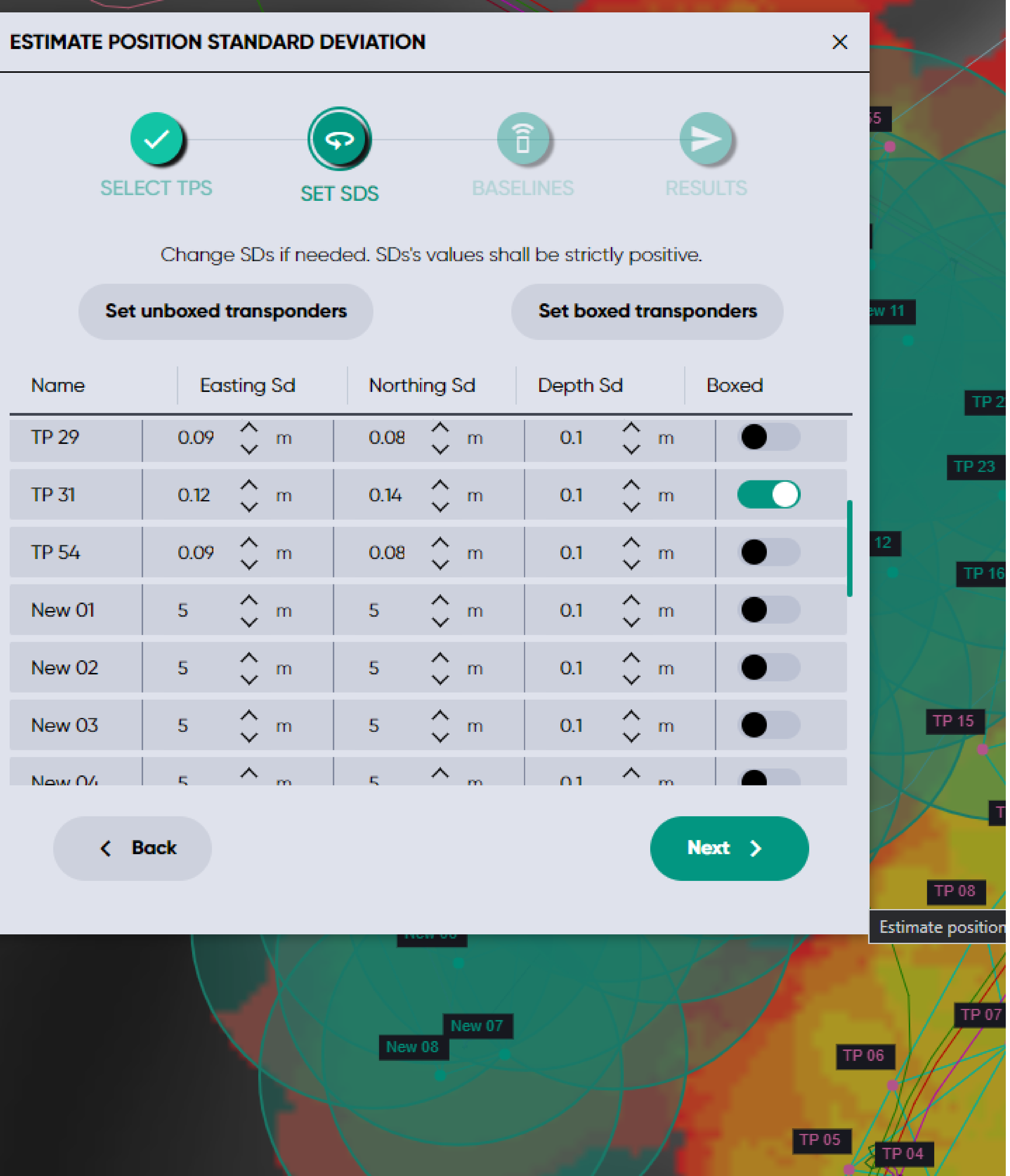
← not the actual area



Simulating the Calibration

- First Setting the SD of the originally boxed transponders to check the consistency of the calibration simulation tool with the original calibration results

← not the actual area



Simulating the Calibration

- First Setting the SD of the originally boxed transponders to check the consistency of the calibration simulation tool with the original calibration results
- Now tying in the new transponders with the existing array.

← not the actual area

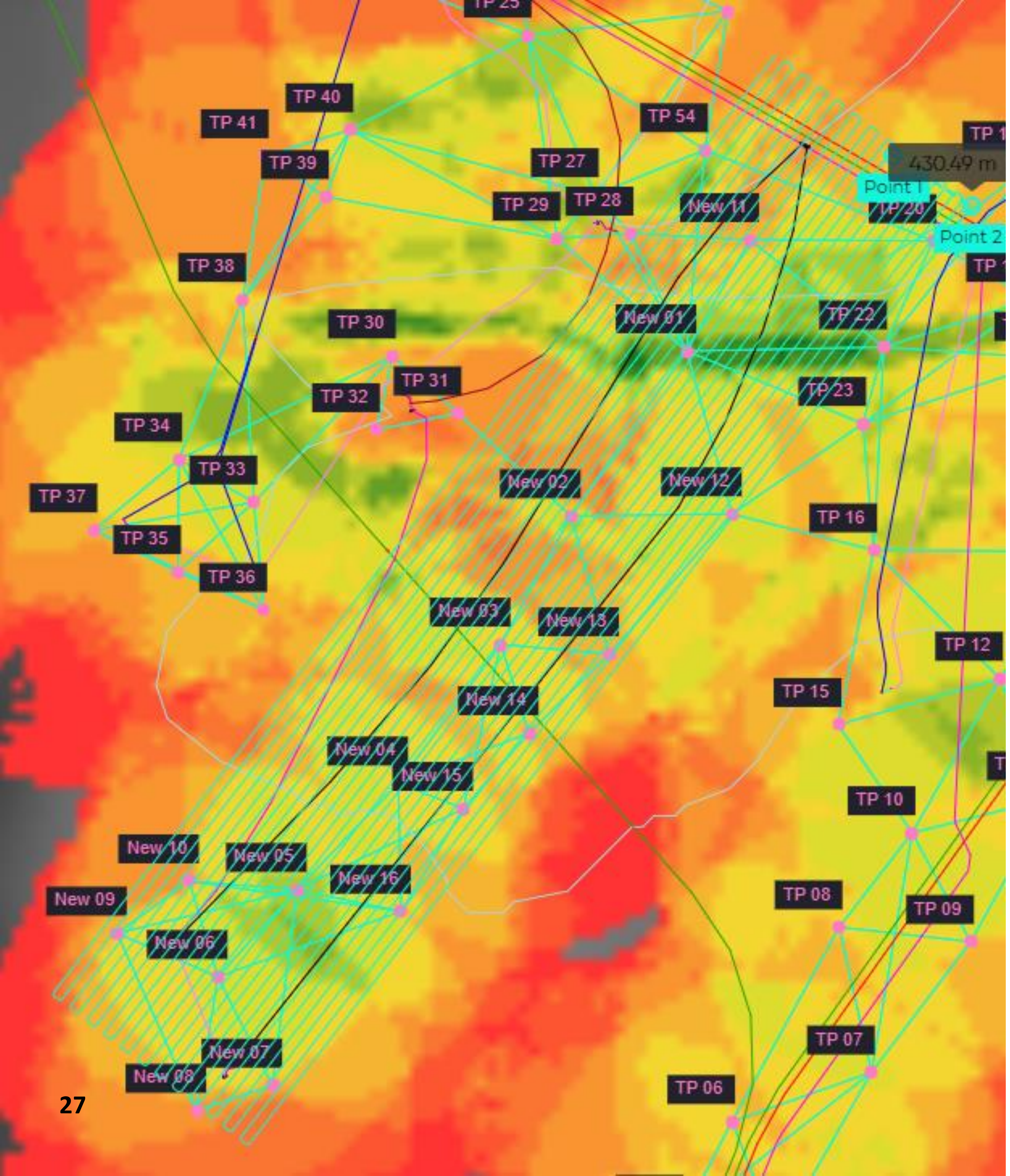
	Lat (anonymised)	Long (anonymised)	Depth	Northing S	Easting SD	Depth SD
101	-0.384051725	0.11142195	-398.082	0.441	0.45	0
102	-0.385701683	0.1065651	-404.354	0.604	0.65	0
103	-0.389607311	0.11235829	-401.674	0.652	0.796	0
104	-0.390117129	0.10730556	-407.873	0.391	0.425	0
105	-0.388611968	0.10070287	-414.502	0.39	0.418	0
106	-0.389514324	0.09690016	-420.464	0.567	0.651	0
107	-0.393148514	0.09678837	-424.854	0.421	0.448	0
108	-0.391853642	0.10188422	-416.582	0.515	0.57	0
109	-0.415290148	0.09768315	-453.184	0.535	0.531	0
110	-0.415217768	0.09434494	-457.971	0.428	0.449	0
111	-0.417768516	0.09435293	-461.952	0.601	0.544	0
112	-0.418021048	0.09845048	-456.386	0.418	0.431	0
113	-0.434481754	0.10789734	-469.406	0.421	0.424	0
114	-0.438655274	0.10804672	-476.992	0.611	0.635	0
115	-0.439846098	0.10498891	-483.601	0.643	0.55	0
116	-0.436460298	0.10396093	-479.421	0.386	0.419	0
117	-0.440342942	0.09538408	-499.737	0.549	0.521	0
118	-0.44353388	0.09562634	-505.111	0.391	0.407	0
119	-0.443920185	0.09247417	-511.396	0.547	0.532	0
120	-0.441125852	0.09213301	-506.946	0.396	0.432	0
121	-0.421938255	0.10621028	-450.88	0.942	0.942	0
122	-0.399771694	0.10687091	-418.972	0.474	0.4	0
123	-0.406933285	0.10643503	-428.215	0.48	0.423	0
124	-0.459603297	0.10068617	-528.205	1.755	0.955	0
125	-0.472797887	0.10407513	-548.725	1.191	0.915	0
126	-0.466117924	0.10768555	-530.642	0.473	0.479	0
127	-0.46797061	0.09814177	-550.303	0.466	0.482	0
128	-0.479129935	0.10802535	-557.585	0.491	0.448	0
129	-0.488387711	0.1089963	-578.494	1.226	1.036	0
130	-0.497740768	0.10934195	-588.081	1.408	0.935	0
131	-0.507315413	0.1104103	-607.102	0.477	0.457	0
132	-0.516684812	0.11323624	-623.5	1.281	0.941	0

Actual Results

- **Simulated array adjustment matches the SD's achieved on the original array adjustment.**
- **We can now simulate navigation inside this array to really understand expected performance.**
- **Easily identify where additional boxins might be beneficial**

← Actual calibration results

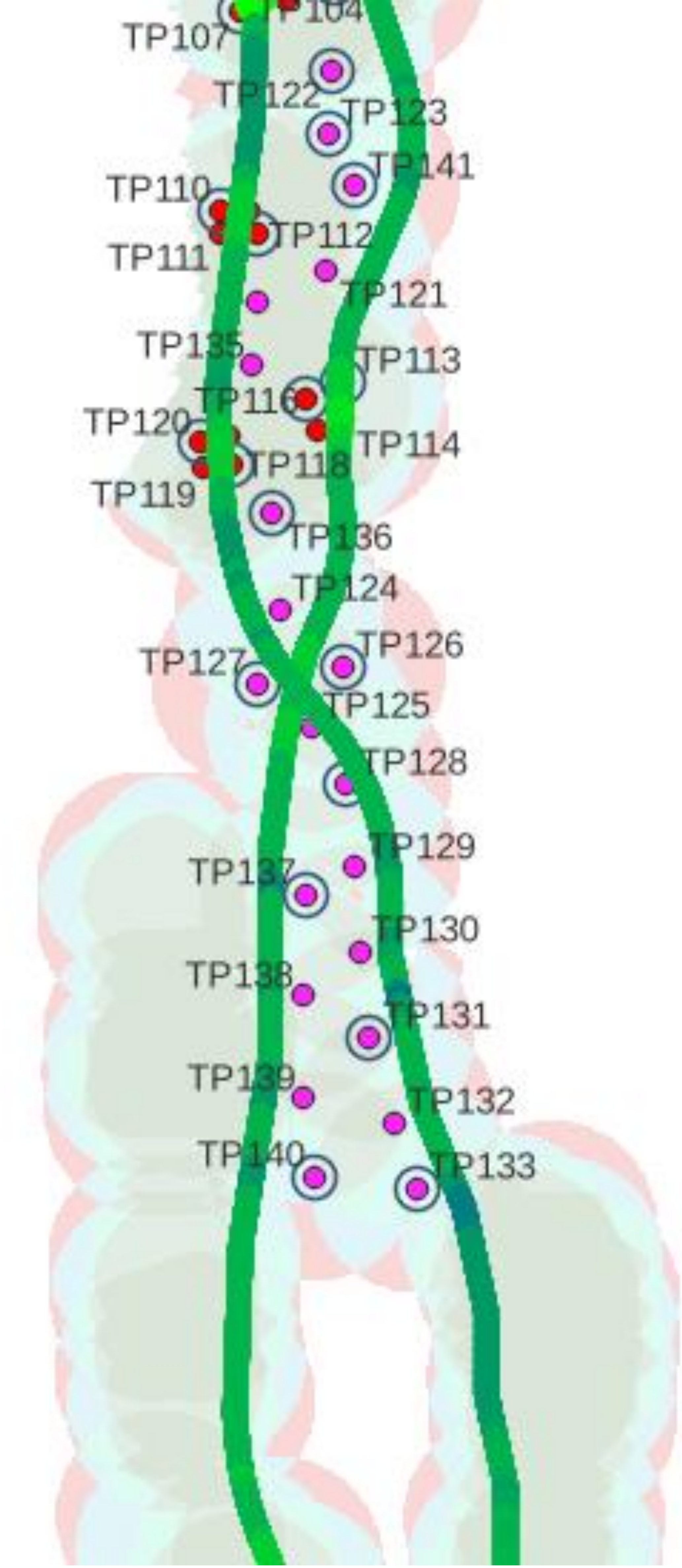
SIMULATE NAVIGATION



Design the survey trajectory

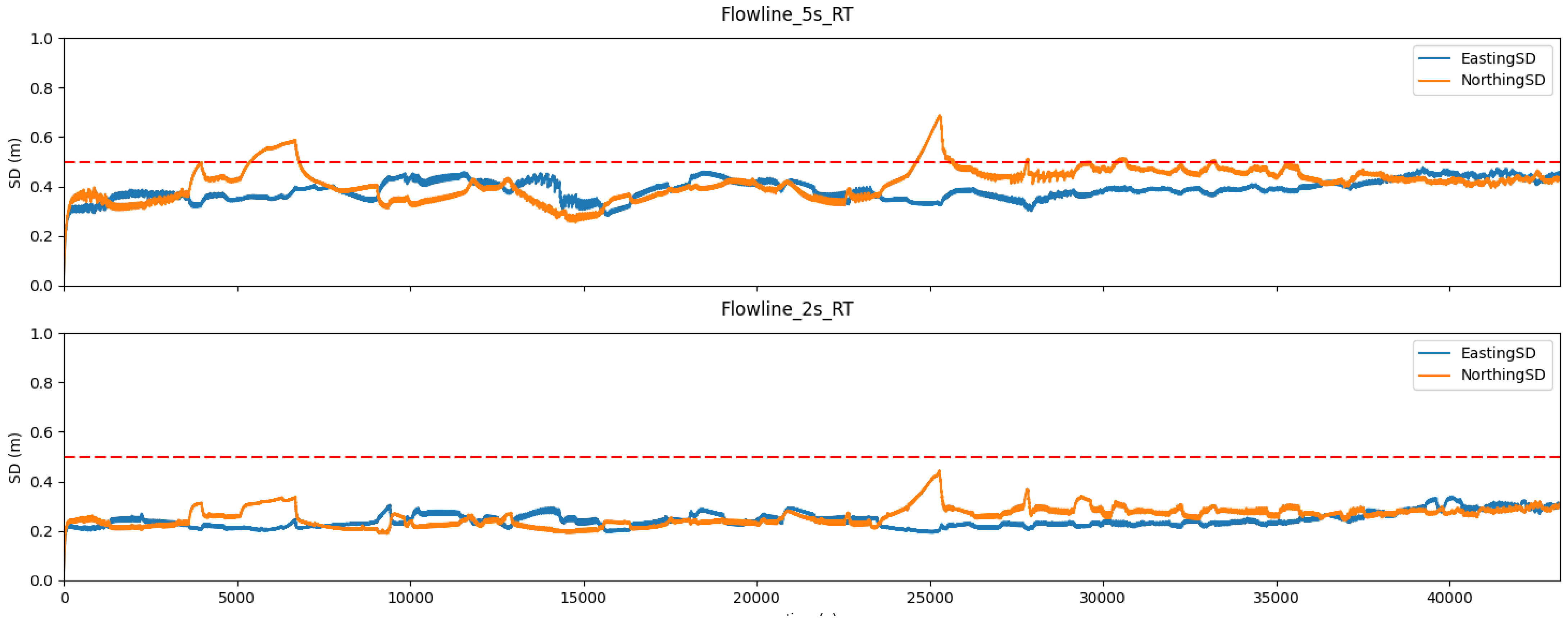
- Add waypoints, Lines, Circles, Figure 8's, Surveys (parallel lines), follow layer in a DXF, and stop for a period.
- Define the Vehicle equipment, LBL transceiver, INS model, USBL Model, GPS if appropriate, DVL model, & Pressure sensor.
- Launch the simulation to create the inertial data & Aiding data.
- Data is run through the inertial algorithm to produce the results.

← not the actual area



Simulation Results

- Now that we have our first set of results we can change parameters to view the impact.
- Colour coded INS navigation (Green – Blue – Red) shows the expected navigation performance 0 – 0.5 – 1 m
- The initial 5second ping rate was not meeting the specification in two area.
- Increasing the interrogation rate improves the accuracy.



← Really the actual area

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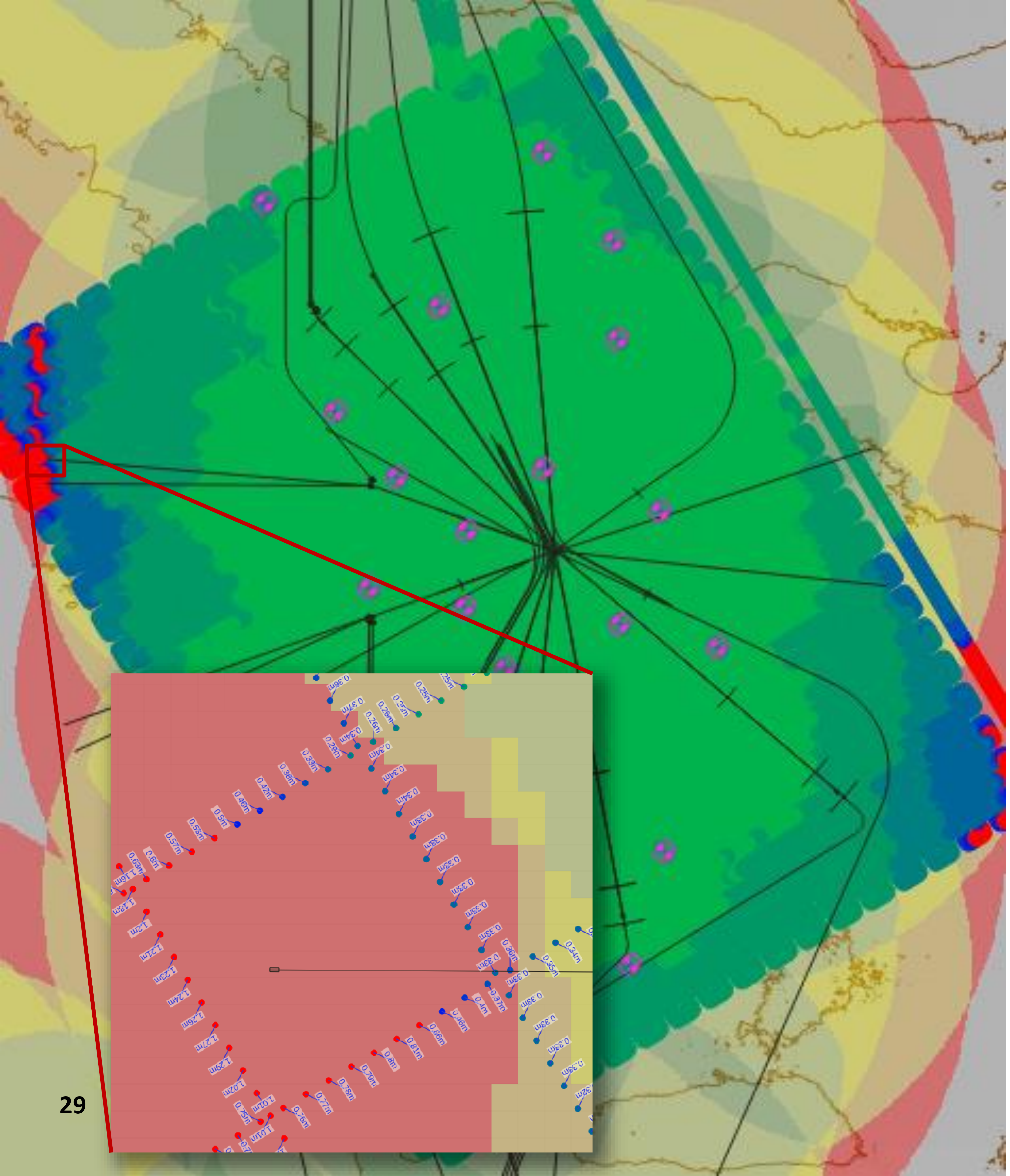

Conclusion

- Last year, Error budgets for acoustic INS operations involved rules of thumb such as 3 times better than USBL.
- This year, we can simulate the whole process to produce error estimations for INS LBL or INS Sparse LBL that accurately reflect the results you will get in the field.
- As we move in to deeper and deeper water, potentially using high altitude transponders on moorings, understanding the potential impact on positioning accuracy becomes more and more important.
- Repeatability of positioning will be very important for harvesting the seabed.
- Our tools allow our customers to prove to their customers that the methodology they propose will meet the requirement or not.