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White Papers
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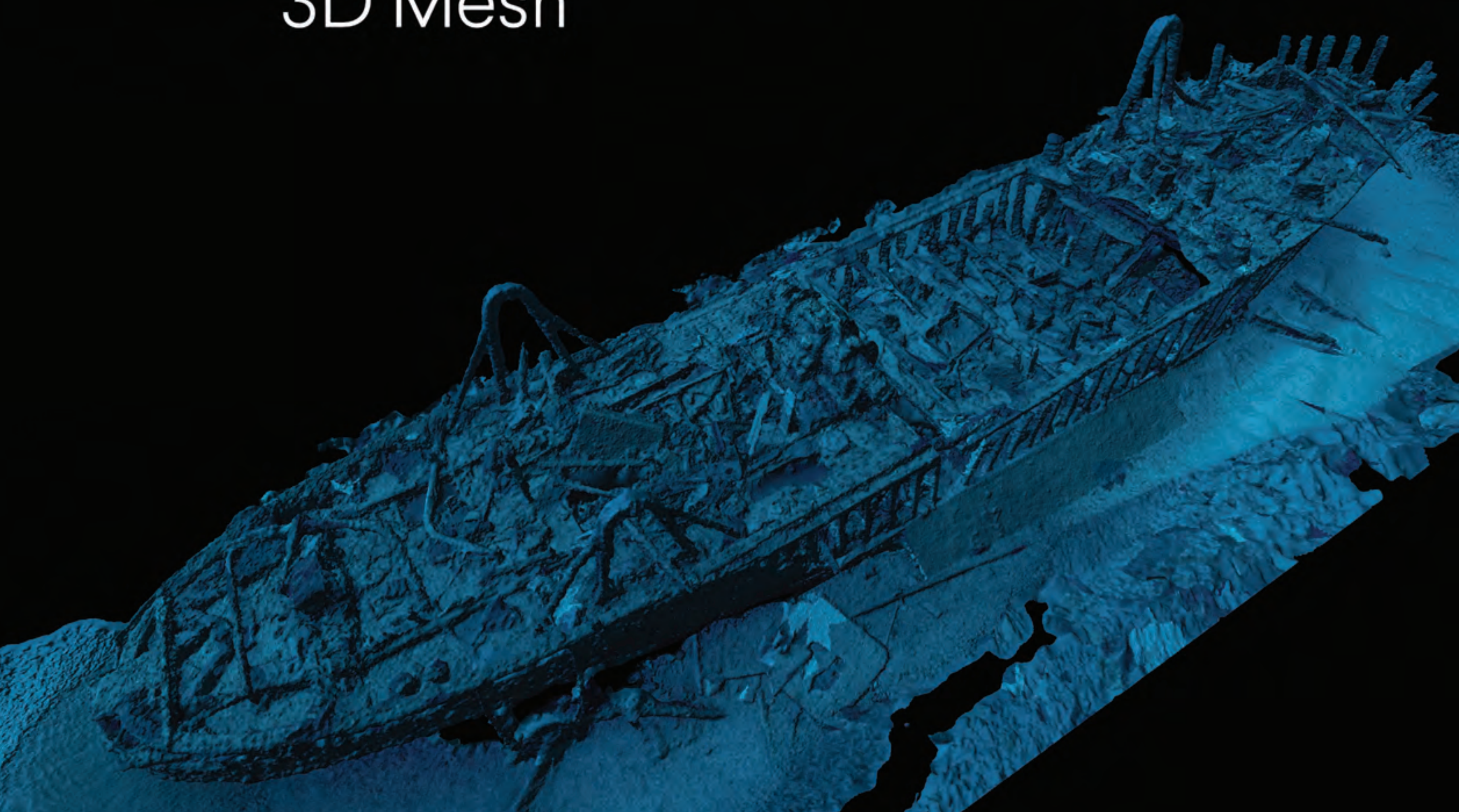
Hydrographic Edition

fledermaus.
3D Mesh



MTR White Papers / No. 1

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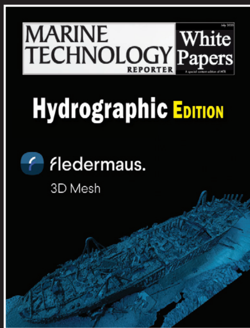

Photo Credit: NOAA/Project Baseline and the 3D meshing performed in Fledermaus

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Using high resolution 3D meshes for improved shape reconstuction of marine survey data

When using dense, high-precision survey data, the method for management and visualization of the data can have a large impact on the final decision making process. This is an important factor when accurate shape reconstruction is required, as there are significant trade-offs with traditional approaches. For applications where it is critical to know exactly the shape and size of surveyed objects, a high-resolution 3D mesh is likely the best option.

Gridded surfaces, even with variable resolution, cannot adequately model complex overlapping or vertical structures. Though we think of grids as 3D objects, they are referred to as having 2.5 dimensions because of this limitation of being able to only represent a single vertical value per grid cell. Alternatively, point clouds can represent any shape or structure, but by themselves pose challenges for visualization and quantitative analysis. To address these limitations and bridge the benefits of both point clouds and gridded surfaces, QPS has created tools for creating and working with high resolution 3D meshes, directly in the QPS Fledermaus software package. The new techniques can be used with the majority of common survey formats, with data coming from photogrammetry, LiDAR, or multibeam. The primary requirement is that the data is dense enough to support the 3D reconstruction process.

For a full overview of the 3D mesh creation process and examples of them in use, please view: **https://qps.nl/webinars/fledermaus-8-webinar-3d-meshes-and-more/#**

Supporting Structure From Motion

Before adding functionality for creating new meshes, Fledermaus supported the importing of meshes created using Structure From Motion (SfM) techniques in 3rd party software, such as Agisoft Metashape and Pix4D. Users desired improvements for better handling of large meshes, and wanted the same functionality they were used to when working with gridded surface. This included operations such as applying

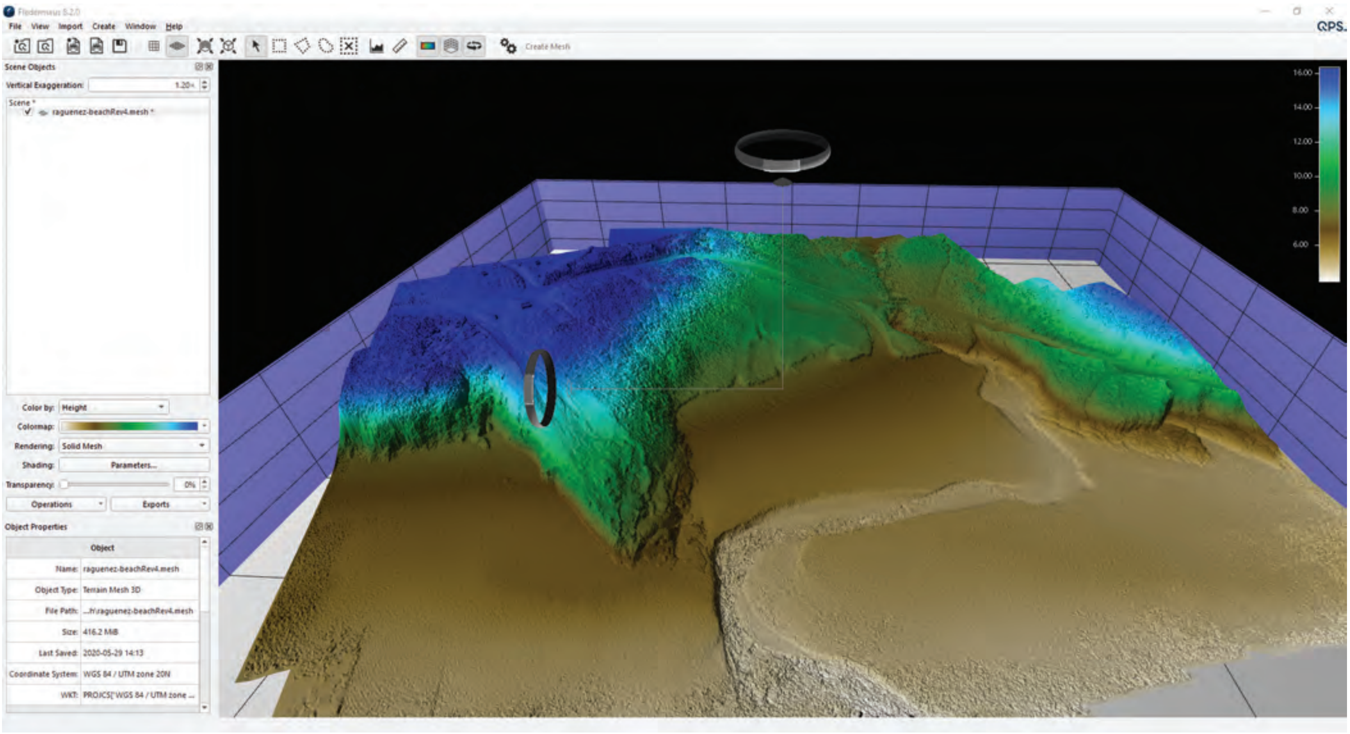

Figure 1

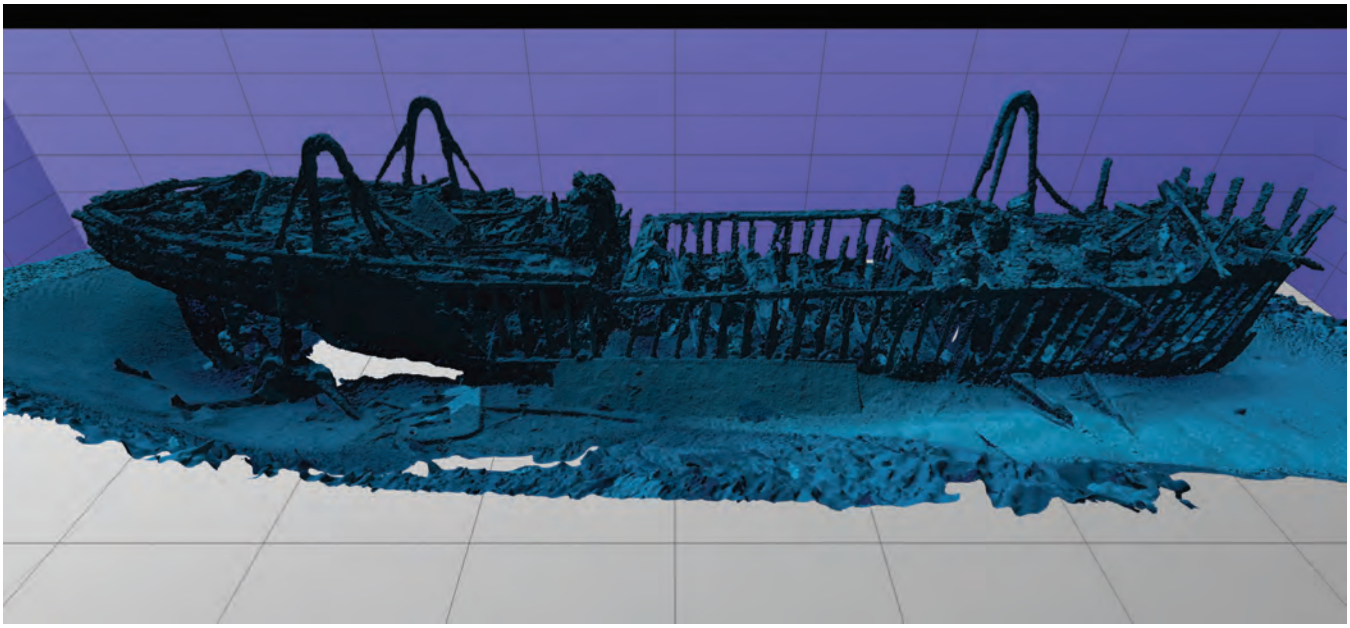

Figure 2

color maps, measurement tools, and interactive profiling.

Initial applications for these tools were coastal and near shore mapping and analysis, with data acquired from aerial drones. **Figure 1** illustrates an example of an inter-tidal area represented as a mesh in Fledermaus. Flying the drone at low water can provide orthophotos of the intertidal zone, and a reference shoreline for companion multibeam mapping.

With rapid advancements in lighting and camera technology, SfM tools were also applied underwater, with impressive high density point cloud produced from ROV and AUV video, as shown in **Figure 2** (Data source: USS YP-389 NOAA/Project Baseline). One of the key benefits of a 3D mesh can be seen in the overlapping and protruding structures of the wreck. These features would be averaged out when using a grid, and would be more difficult to see in a point cloud.

After adding support for meshes created in 3rd party software, the next major step was adding the ability to create new meshes from point clouds. This ability was first introduced in Fledermaus 8.0, and the process has been improved in each follow up release. To maximize the benefits of adding a new data structure to your workflow, the creation process needs to be accessible, and well integrated. To achieve these goals, the Fledermaus mesh creation tools were designed to be almost as simple as creating a standard gridded surface.

In addition to opening up the mesh creation process to both multibeam and LiDAR data, this also allows SfM derived point clouds to be improved before mesh creation. There are often times when SfM data requires further processing, because of deficiencies in the original pre-built mesh. By using the point editing and QC tools in Qimera software, the point cloud data can be improved, and a more accurate mesh created in Fledermaus. There are also specialized tools, such as the SfM add-on for Qimera, which can be used to correct for refraction errors in submerged data acquired from airborne photogrammetry, as shown in **Figure 3 (Data courtesy 4DOcean)**. The image shows a beach profile running from land to underwater with the original terrestrial and bathymetric SfM points, and the refraction corrected SfM terrain model derived from the same source, but after the correction. The original terrain model's profile is colored in Red and the corrected one in Green.

Within Fledermaus, the mesh tools use the Poisson surface reconstruction algorithm (Kazhdan et al. 2006) for creating a best-fit surface of a dense point cloud. A key part of the mesh construction is determining the orientation, or shape from the point cloud. By using a data source with recorded navigation and orientation data, Fledermaus can make an improved mesh compared to generic mesh creation algorithms.

Applications of a 3D Mesh

In terms of applications, this technology is beneficial anywhere that accurate shape reconstruction is of utmost importance. This can apply when proper identification and measurement of features is critical to risk management, and to a greater extent in situations where there will be close interaction with the surveyed objects. When performing marine salvage, construction, or asset inspection, it is critical to have the most comprehensible and accurate representation of the data.

These applications highlight the differences between historical usages of mesh structures, and the new techniques now being introduced. Representations such as triangulated irregular networks (TIN) have been a common part of surveying for many decades. However, there have been major changes

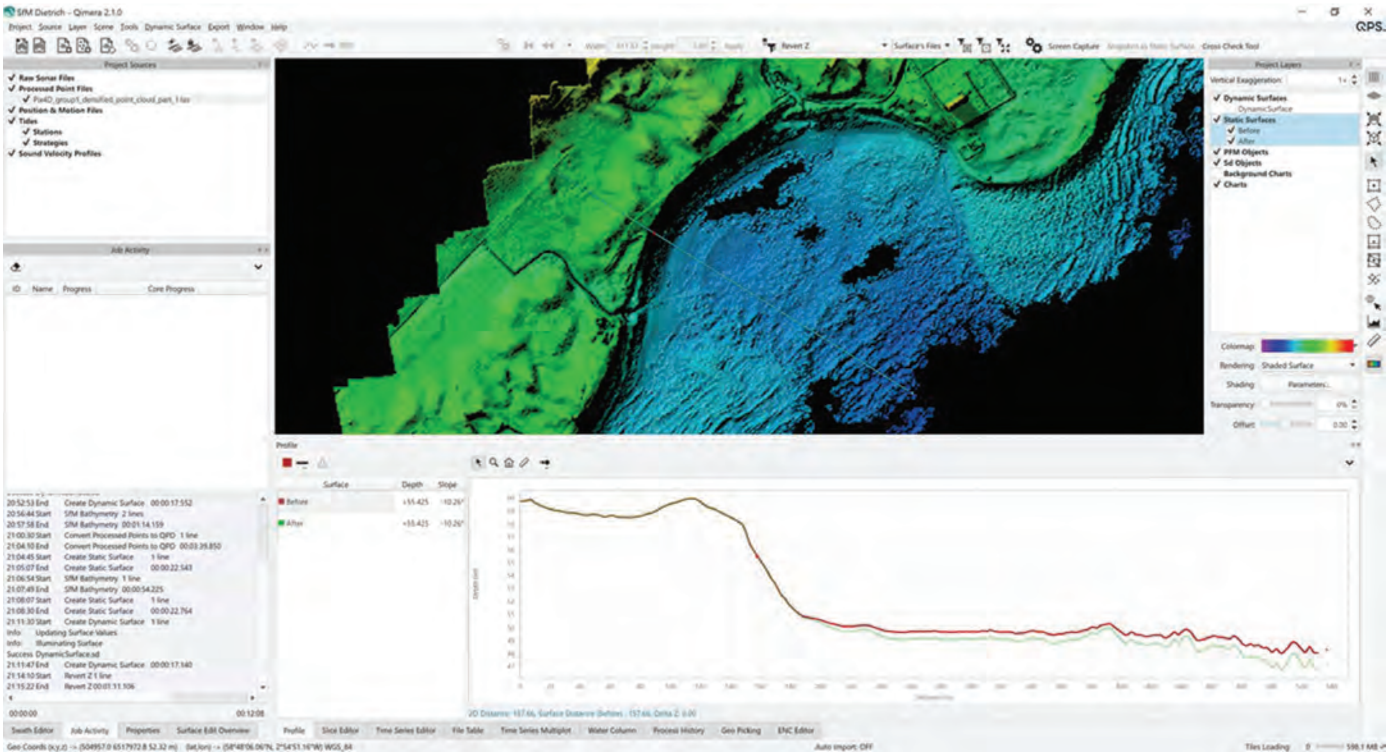

Figure 3

driving a completely new approach to how meshes are created and used. Instead of using a mesh as a way to create an interpolated shape from a sparse set of points, the abundance of dense point data now allows for the most accurate representation possible from the source point cloud. In addition, there has also been the transition from 2.5D meshes, to true 3D structures.

The change to high resolution 3D meshes has been enabled by three factors:

- Growth in CPU and GPU capacity, especially in regards to multi-core processing
- Advancement in shape reconstruction algorithms
- Increased availability of dense, high precision point cloud data

Multibeam Sonar

Applying the mesh tools to a traditional multibeam survey, **Figure 4** shows an example in shallow water of data collected with a Kongsberg EM2040D of 4 shipwrecks. At this scale, there is no discernible difference between the 10cm mesh and the 10cm grid.

Looking closer at the data, **Figure 5** can better highlight the differences between data structures. The grid still provides some details, but comparing it to the original point cloud, there are missing details and the overall dimensions are distorted. The mesh provides a much better preservation of the shape, and full dimensions of the object.

The most immediately visible benefit of a 3D mesh is the ability to model areas with overlapping z values, such as slopped walls, or protruding structures. This is easily visible in the wreck show in **Figure 2.** A complimentary benefit is that the mesh is a variable resolution structure. When creating a mesh, you provide a minimum resolution, and the creation algorithm will adapt the resolution as needed based on point density and the shape itself. Lastly, mesh creation can also reduce the data volume while still preserving shapes and structures. In the example from **Figure 4 & 5**, the original point cloud had just under 8 million points, but the mesh was able to reduce that to 2.5 million vertices, while also helping to improve visual analysis.

Revisiting the comparison of a 3D mesh with a standard grid, the downside is that a grid is limited as a 2.5D surface, which can only represent one Z value or depth, for each grid cell. This prevents accurately representing quickly changing slopes, overhangs, or any protruding structures. The advantage is that grids are quick to build, and easy to understand. A variable resolution grid can address some of the limitations of a standard grid, but ultimately it is still restricted by it being a 2.5D surface that cannot accurately represent certain shapes. In situations where accurate reconstruction is required, a grid should not be used for detailed planning or measurements.

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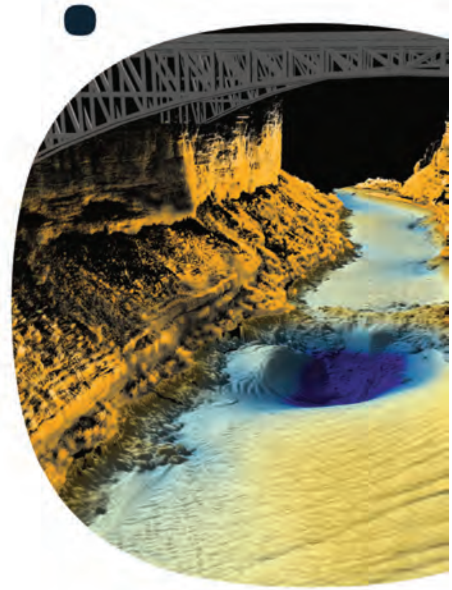

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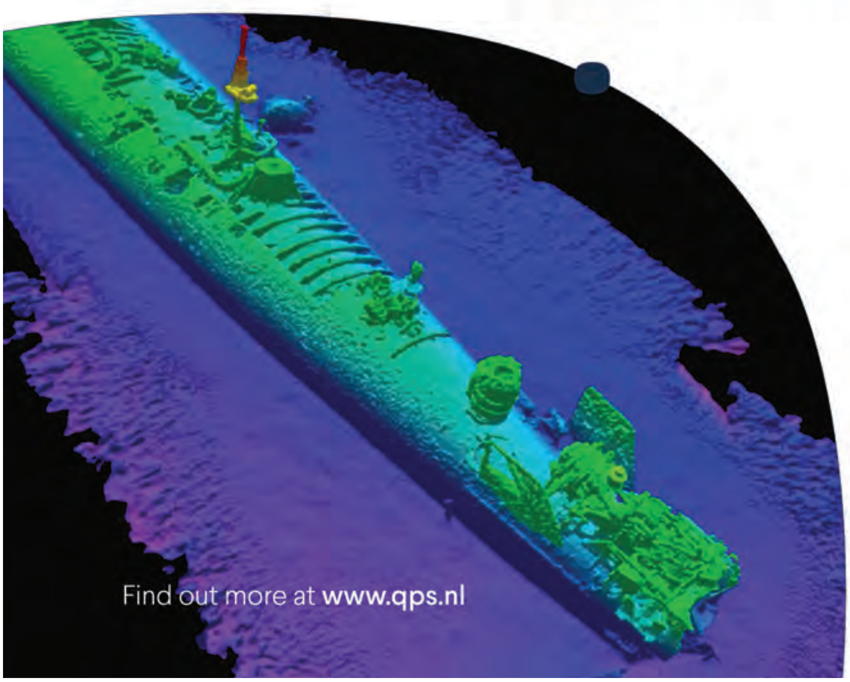

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Data credit to NOAA/Project Baseline

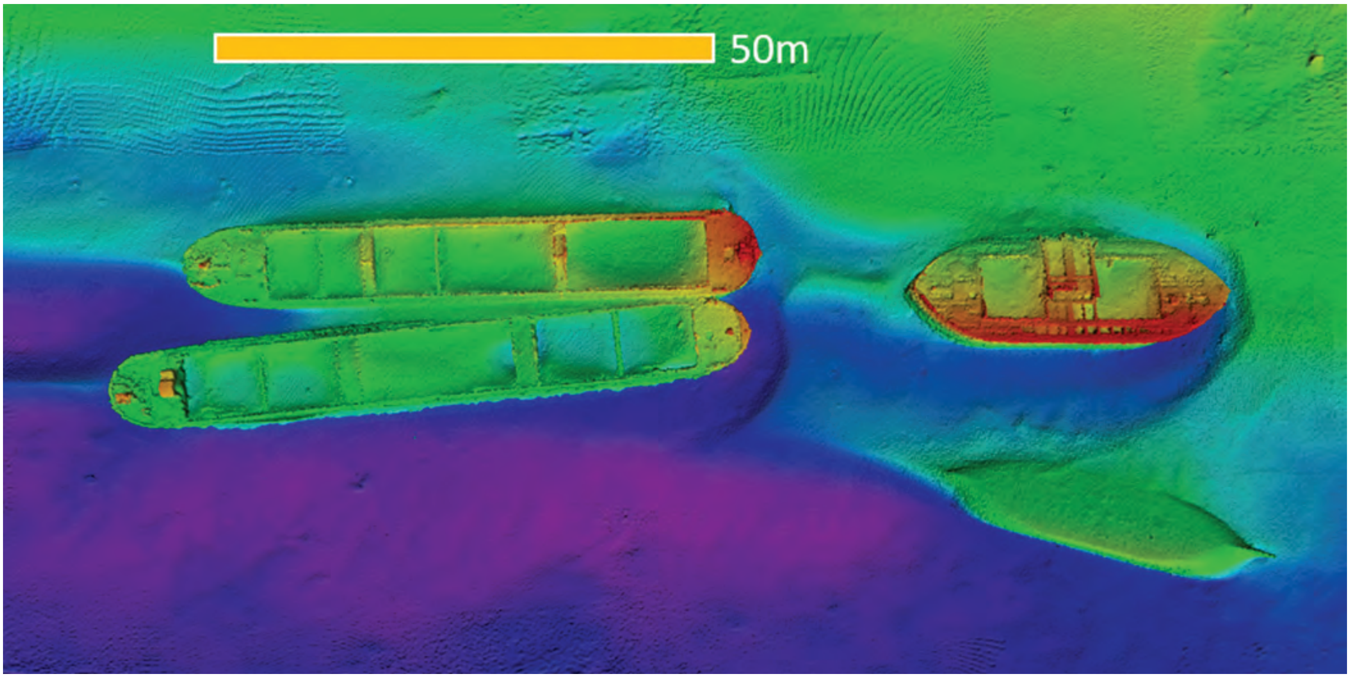


Figure 4

Comparison with Point Clouds

In a similar comparison for point clouds, we can see that points have the advantage of no additional building time, compared to grids and meshes. As your point density and resolution increases, mesh construction can be resource intensive. However a modern multi-core machine can help offset this, with a close to linear reduction in build times with each additional CPU core. Points naturally represent objects at the full resolution of the sensor, with 3D meshes usually coming close to the same.

The largest potential downsides of a point cloud are that it is not a connected shape, which complicates quantified analysis, such as slope or volume calculations. Also point clouds can be challenging for visual perception, as you are seeing either too many points at once, or obstructing fine details.

Coastal Structures

Structures such as breakwaters, jetties, groins, and revetments are import for the protection of coasts and harbors. They provide navigation support, shelter and calm waters, and protect against siltation of the harbor. Over time these structures can be damaged, so adequate inspections are required for early detection of structural damage and deterioration. While above water damage is easy to observe, problems such as scouring, settlement, or breakage underwater may be less evident. Traditional survey methods can be inadequate for properly inspecting these structures, so high density point clouds and 3d meshes provide a better approach. **Figure 6** is an overview image of a scene containing combined LiDAR and multibeam data as a mesh, and an aerial photo. A close up of the breakwater is shown in **Figure 6**, with the combined Reson 7101 multibeam and Riegl VZ1000 scanning LiDAR system.

Quay Walls

Vertical quay walls are an additional part of coastal engi-

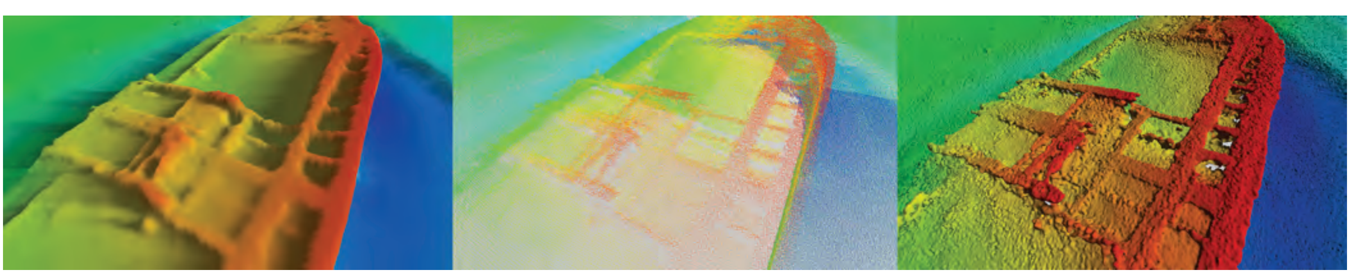


Figure 5

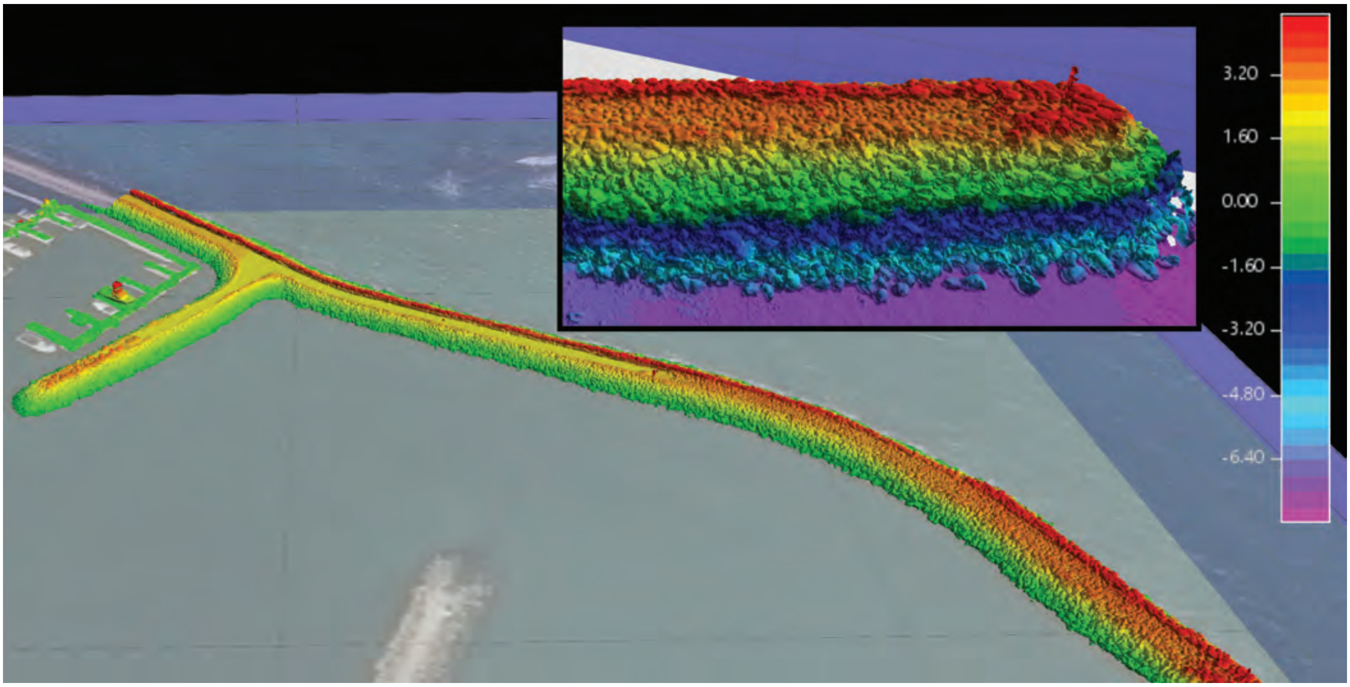


Figure 6

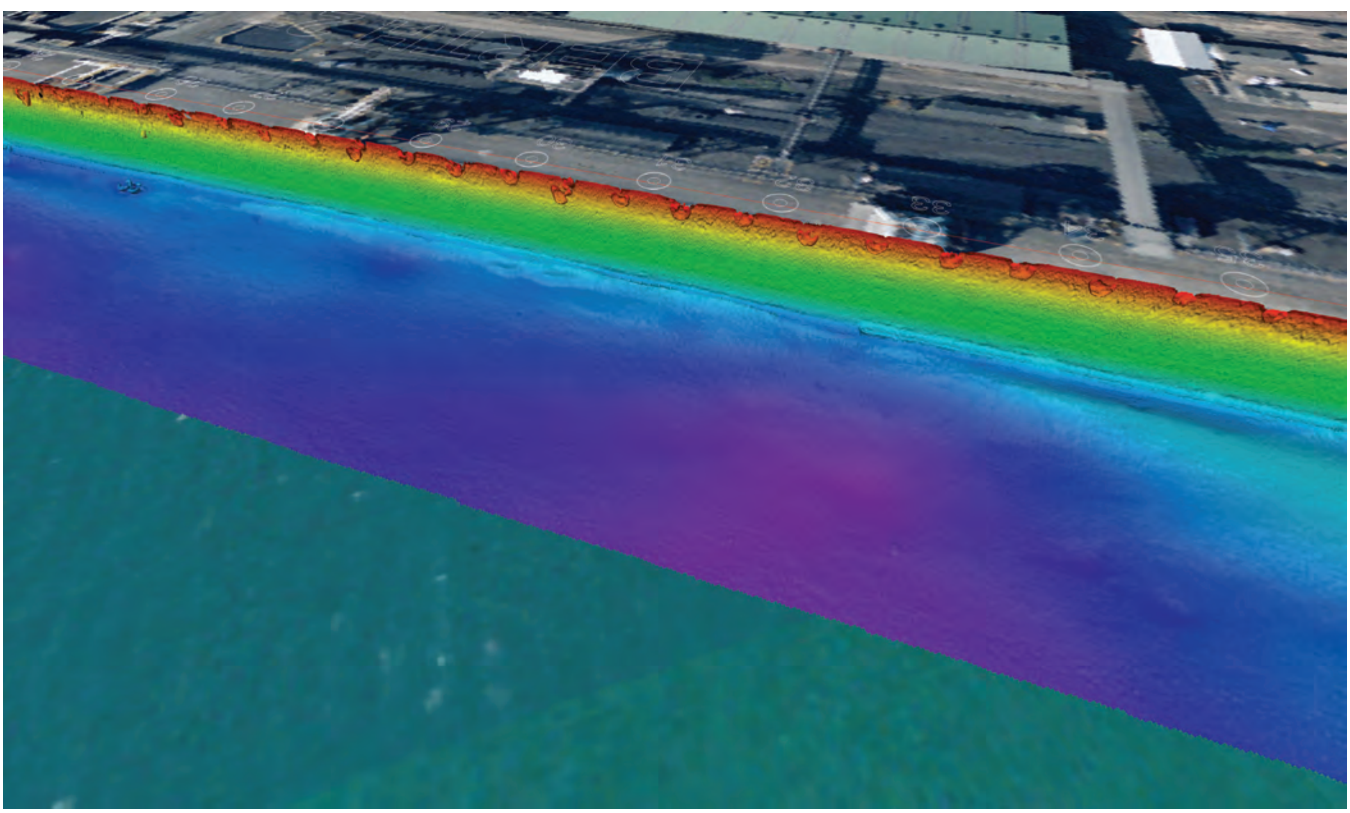


Figure 7

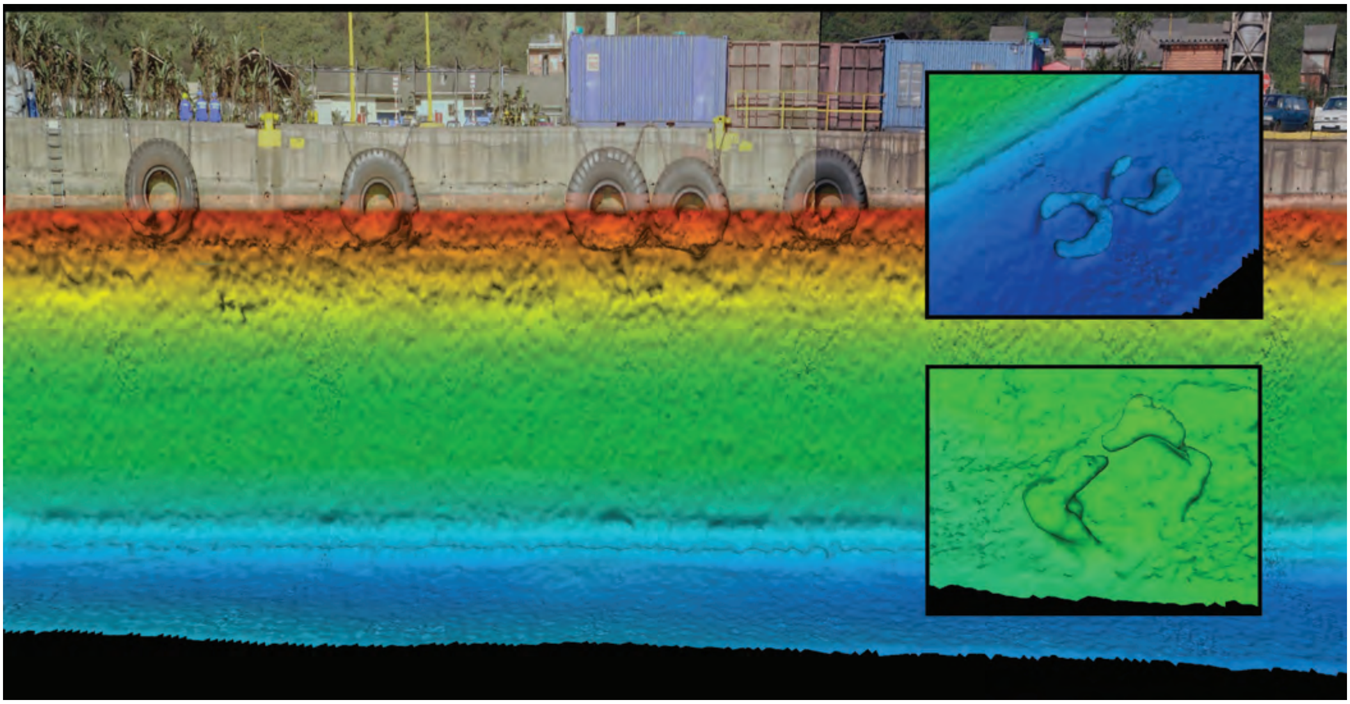


Figure 8

neering, and benefit from a high quality integrated visualization for regular inspections. Damage to the quay wall, foreign objects, and scouring causing slope deformation are all potential issues. After multibeam and laser surveys, targeted inspections and repair is often carried out by divers. Having a complete visualization, with additional contextual information, can reduce risk and improve the efficiency of the dive operations. This additional data can be GIS vector data, aerial or satellite photographs, and vertical images.

A common technique for surveying quay walls is by tilting the multibeam sonar head sideways, allowing data to be collected from the bottom up to water surface. **Figure 7** is an example scene with a quay wall surveyed with a Reson 7101 multibeam rotated 40 degrees. A 3D mesh was created from the multibeam data, and combined with an aerial photo, and CAD reference data. For further context, vertical images can also be added, as illustrated in **Figure 8**. The shape reconstruction capabilities of the 3D mesh are visible along the wall, and in objects on the sea bed, such as the fallen tires in **Figure 8**, and a coal loading grab in **Figure 8**.

What is best?

Considering the complimentary benefits and trade-offs, the best approach is to work with a combination of data structures, to best fit the situation and data. There can also be complementary applications between data structures, such as combining a medium resolution mesh with a point cloud to help create structure, and occlude points on the backside of the point cloud. This improves the visual perception of the points, without needing the time to create a high resolution mesh.

A more complex example is when working with a large multi-sensor survey. This can be examined using a sample data set from Bibby Hydromap, a former survey company based in the UK. The asset inspection survey combined data from a Reson SeaBat T20-P multibeam, a Blueview scanning sonar, a Carlson Merlin laser scanner, and also airborne LiDAR. **Figure 9** is an example of one area of the survey, and shows multiple different data structures used together in one scene.

The multibeam data of the riverbed is represented with a regular grid, as that is quick to produce and is a good match for the bathymetry. Areas of interest on the riverbed can be selected and 3d meshes created as needed. To best identify problems, the bridge is a 3d mesh combining the laser scanner, the scanning sonar, and the aerial LIDAR points. Additional laser points, such as the surrounding vegetation, are left as a point cloud, as direct analysis is not needed for those points.

By integrating the multiple surveys into one, the combined data links the topographic and bathymetric data in single scene. This allows highly accurate analysis and establishes a baseline for measuring change over time. Additional data such as side scan sonar, or underwater video can also be combined to further aid the interpretation of the river bed and help identification of debris.

Maximizing your Point Clouds

There are significant costs associated with collecting and processing dense, high-resolution point cloud data. To maxi-

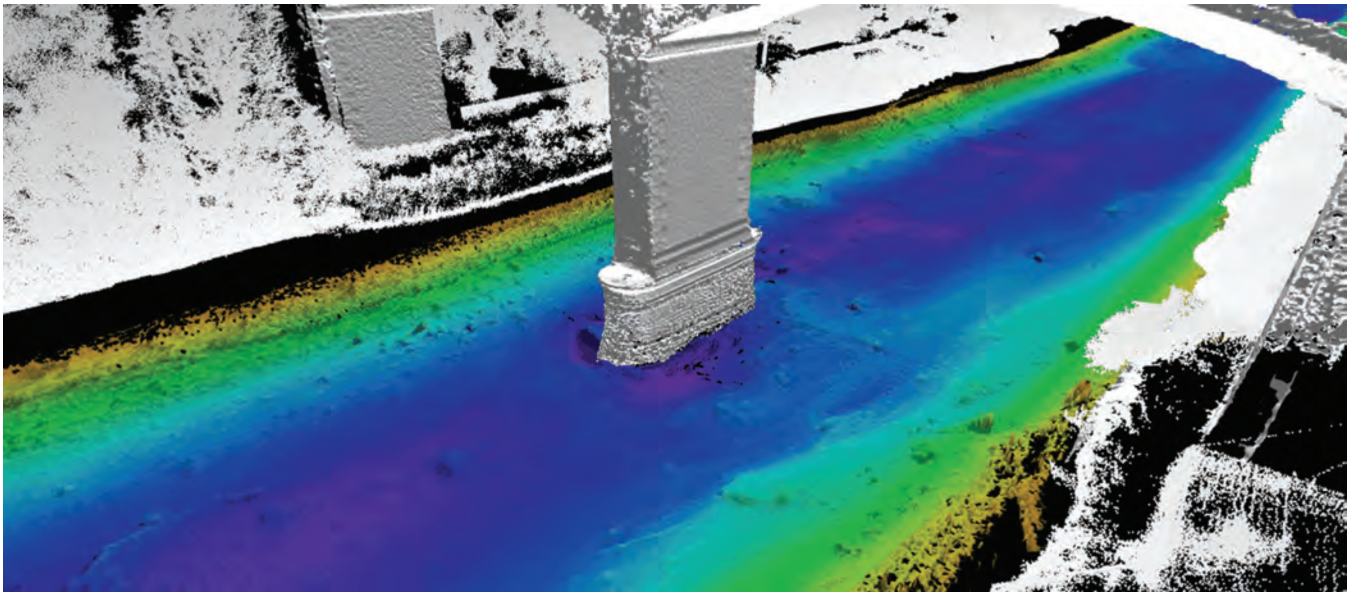


Figure 9

mize the return on those costs, it is important to have a set of tools that can best leverage the investment in collecting the data. The QPS suite of tools can support a workflow focused on creating the highest quality 3d data possible. For example, using the new 3D point filter in Qimera 2.2 with the latest mesh technology in Fledermaus 8.2, is a powerful combination. Applying these tools to a data set collected with an R2Sonic Sonic 2024 multibeam operated in UHR (700kHZ) mode, provides a great example of what can be achieved, as shown in **Figure 10**. In future versions the technology and capabilities for 3D meshes will only improve as more tools are developed to integrate this new data type into various workflows.

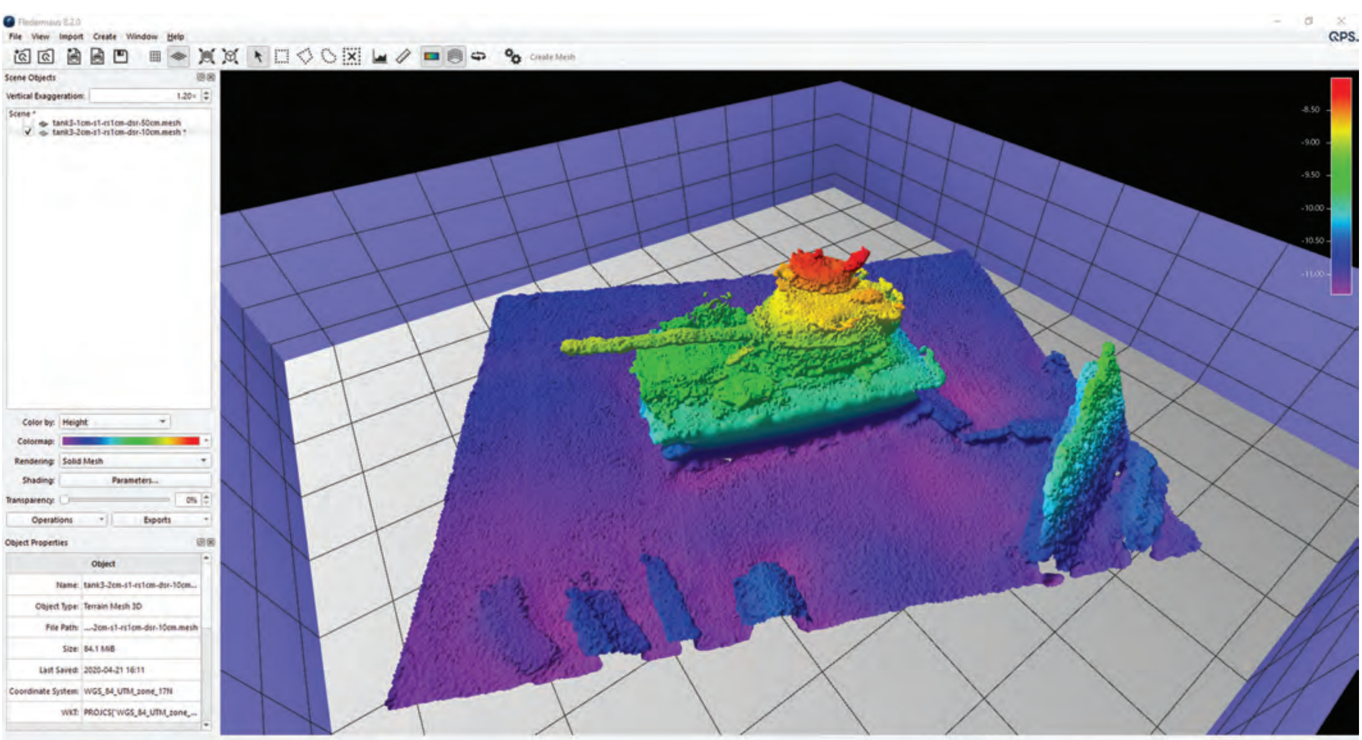


Figure 10

Teledyne CARIS – A Voyage into AI

Why the noise?

There is no doubt that sonar has revolutionized the way in which we are able to map the seafloor. This huge advancement, however came with one key drawback – the introduction of 'noise'.

Conventional sounding techniques involving a lead-line were quite simple and directly measured depth. With sonar, a sound pulse is propagated through the water column and the return is measured based on echo intensity. Distance is now calculated, with time being the actual unit of measurement. If the return echo is incorrectly identified, this will lead to a sounding being incorrectly computed. The common term for this in the hydrographic industry is 'noise.'

Techniques of 'noise cancelling'

Before surveys and final products can be exported, this noise needs to be removed to ensure only 'real' soundings remain. No matter how expensive the equipment being used is or how experienced the operator, some level of noise is inevitable.

Over the years most industry processing software has introduced many standard filters and processes to deal with this, including simple approaches like spike detection up to more complex algorithms like CUBE (Combined Uncertainty and Bathymetric Estimator). While useful, these tools have limitations and can't be applied unilaterally, as they aren't well suited across a broad range of noise patterns. Instead, a user must manually determine where and when each filter is appropriate to apply, which really hinders potential time savings in automating processing pipelines. For areas where these processes don't work at all, the user must resort to manual editing – which is one of the most tedious tasks faced by a hydrographer.

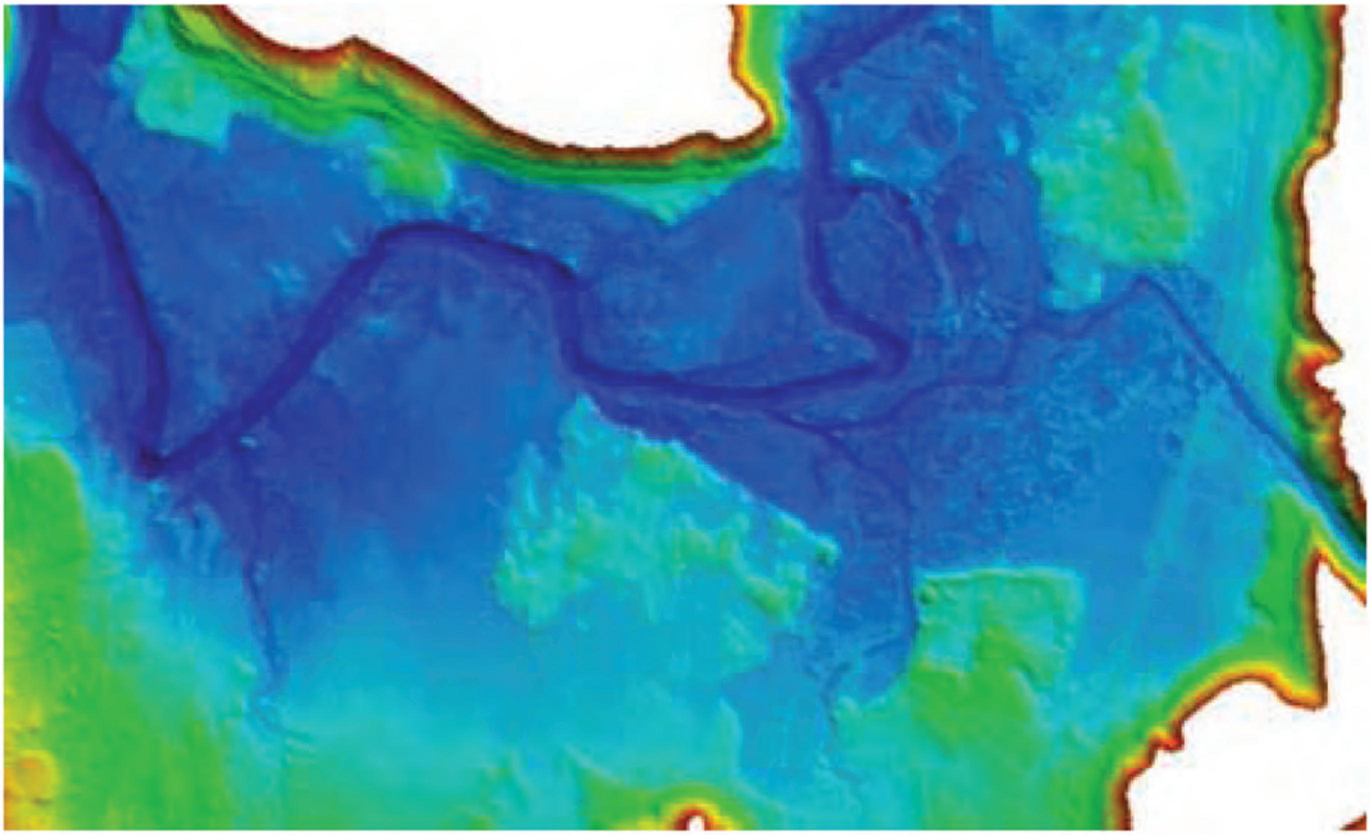


Image courtesy of Veris

Figure 1. A completed bathymetric survey assisted by AI to remove sonar noise.

Fortunately, recent advancements in Artificial Intelligence (AI) mean a generalized algorithm to identify and remove a broad range of noise patterns is now possible.

Training your AI

Development of the AI driven ‘Sonar Noise Classifier’ began in 2018 and Teledyne CARIS’ development team quickly discovered that training an AI to recognize and remove noise is a challenging problem. Within even the noisiest datasets, the number of noise points only makes up about 5% of the total dataset. In AI terminology this is an “imbalanced” dataset, and simply feeding massive quantities of this data into a learning algorithm (which is the standard approach) won’t really work with so few relative samples. The solution to this challenge involved afairly laborious process of hand-picking samples with a more balanced ratio of noise from a variety of public datasets and cleaning each one by hand.

With datasets prepped, the next step was to decide upon the best AI technique. After trialing both old and new methods, it was determined that a state-of-the-art approach using Convolutional Neural Networks would yield the best results. This specific type of architecture is inspired by the assembly of the visual cortex of the brain across most of the animal kingdom and has seen broad adoption in recent years to locate and identify items of interest in images and video. Sonar noise did introduce a particularly unique challenge in that contrary to the 2-dimensional (2D) nature of images and video, soundings are 3-dimensional (3D) in space. This has seen relatively little research compared to its 2D counterpart.

AI – turning the impossible to reality

Teledyne CARIS launched a new CARIS Mira AI platform and officially released the Sonar Noise Classifier at the end of January 2020. This marked the culmination of a long journey into AI for the product development team, part of which involved feedback from several beta testers.

One of these was Geoscience Australia, who have vast amounts of collected data, some of which is yet to be processed to a usable format. With much of this data not having uncertainty information, modern processing techniques such

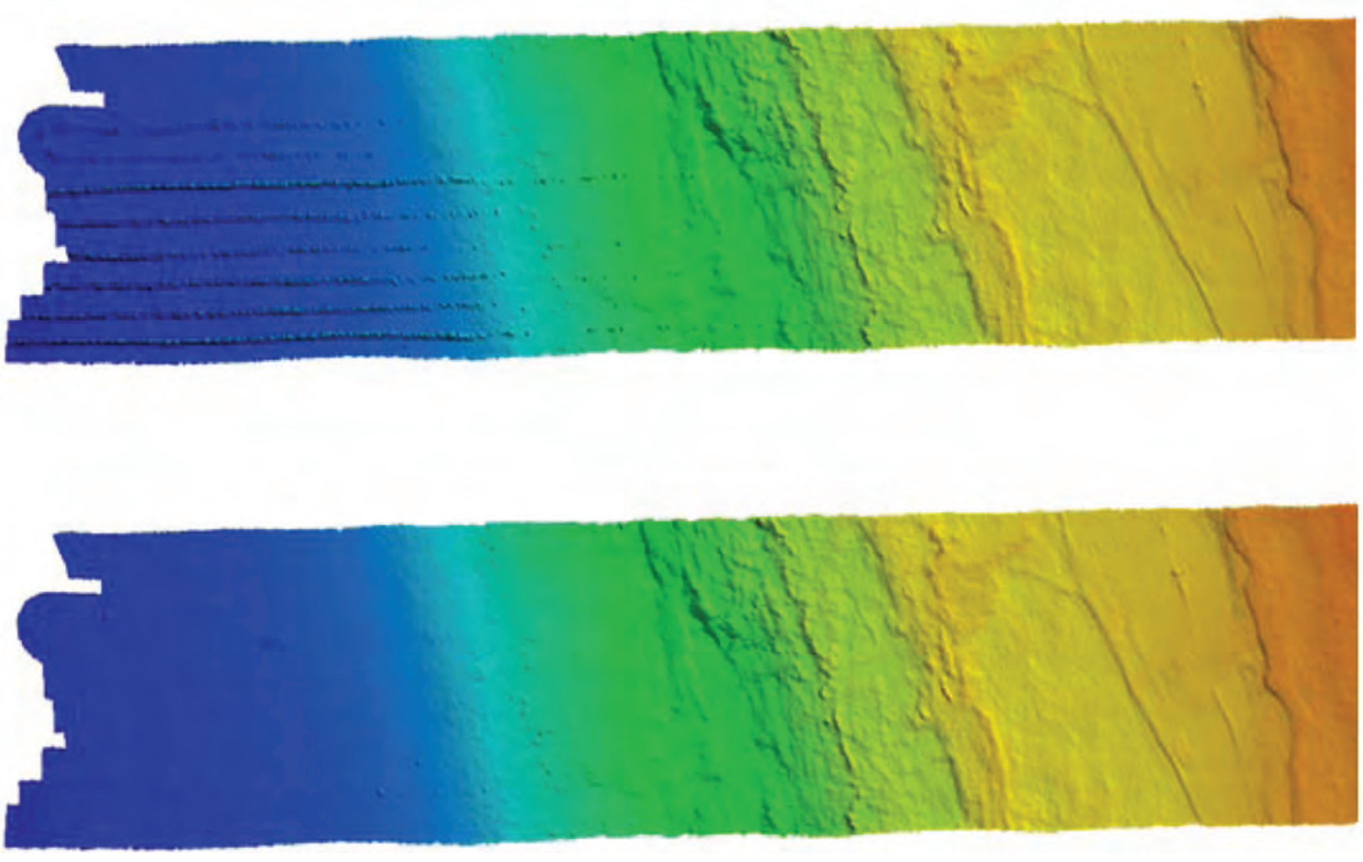


Image courtesy of Geoscience Australia

Figure 2. Bathymetric data before (top) and after (bottom) filtering based on the sonar noise classifier.

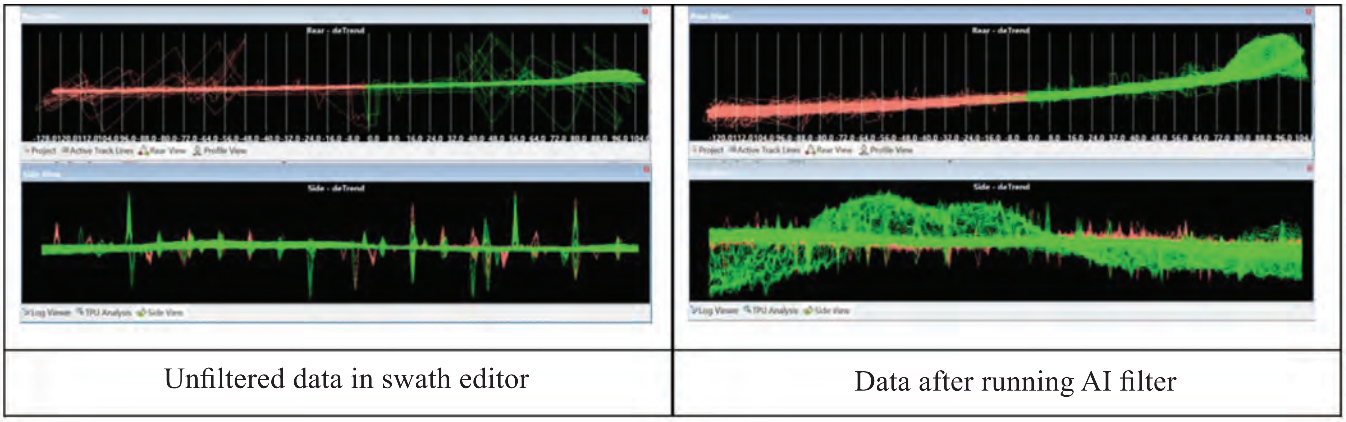


Image courtesy of CSIRO

Figure 3. Bathymetric data before (left) and after (right) filtering based on the sonar noise classifier.

as CUBE are not available. Manually editing and cleaning this data would be a huge and cumbersome task. Fortunately, this is a mission that AI is well suited to.

To tackle this task, Geoscience Australia has started work on establishing an automated processing routine as a pathway towards a scalable solution for managing this backlog of data. In addition to helping with scalability, Teledyne CARIS' sonar noise classifier also provides consistency for the processed datasets.

Using time wisely

Earlier this year, the Geophysical Survey and Mapping team at CSIRO Oceans & Atmosphere put the new tool to test on datasets collected with Kongsberg EM2040, EM710 and EM122 (and some older EM300) sonar systems in a variety of water depths, from very shallow (<50m) to deep (5000m).

In two independent cases, they were able to reduce manual editing time by 65%. One of these was for a transit line, which would have normally taken 25 minutes to edit with manual processing. This was reduced to 90 seconds of AI processing, plus 7 ½ minutes of checking and residual editing, resulting in a total time of 9 minutes. A shorter line was used for testing as it was feasible to spend time manually editing the whole dataset to get a baseline time. While this is a relatively short transit line, the 65% improvement shows promising time savings which will be magnified on larger lines or entire survey areas.

Bringing efficiency and cost savings to projects

Building on the trend of early adopters in Australia, another organization that has seen value in the sonar noise classifier tool is private survey company Veris. Having recently transitioned their multibeam workflow to HIPS and SIPS, Veris' specialist hydrographic team are achieving even greater efficiency on their projects with the help of CARIS Mira AI.

The sonar noise classifier tool analyses every single sounding in a survey, assigning a percentage confidence as to whether the point is likely to be noise. While it isn't feasible for a person to inspect every sounding, they can use this information to adjust filters and visualize the results, providing valuable insight into the decision-making process.

In addition to saving time spent on manual cleaning, Nathan Green from Veris also appreciates what is effectively a 'second opinion' on the data. The AI tool provides an independent check as to what a processor would have considered to be noise. For any questionable areas where data hasn't been classified as noise, this captures the processor's attention to look more thoroughly into that area and ultimately make a more diligent decision.

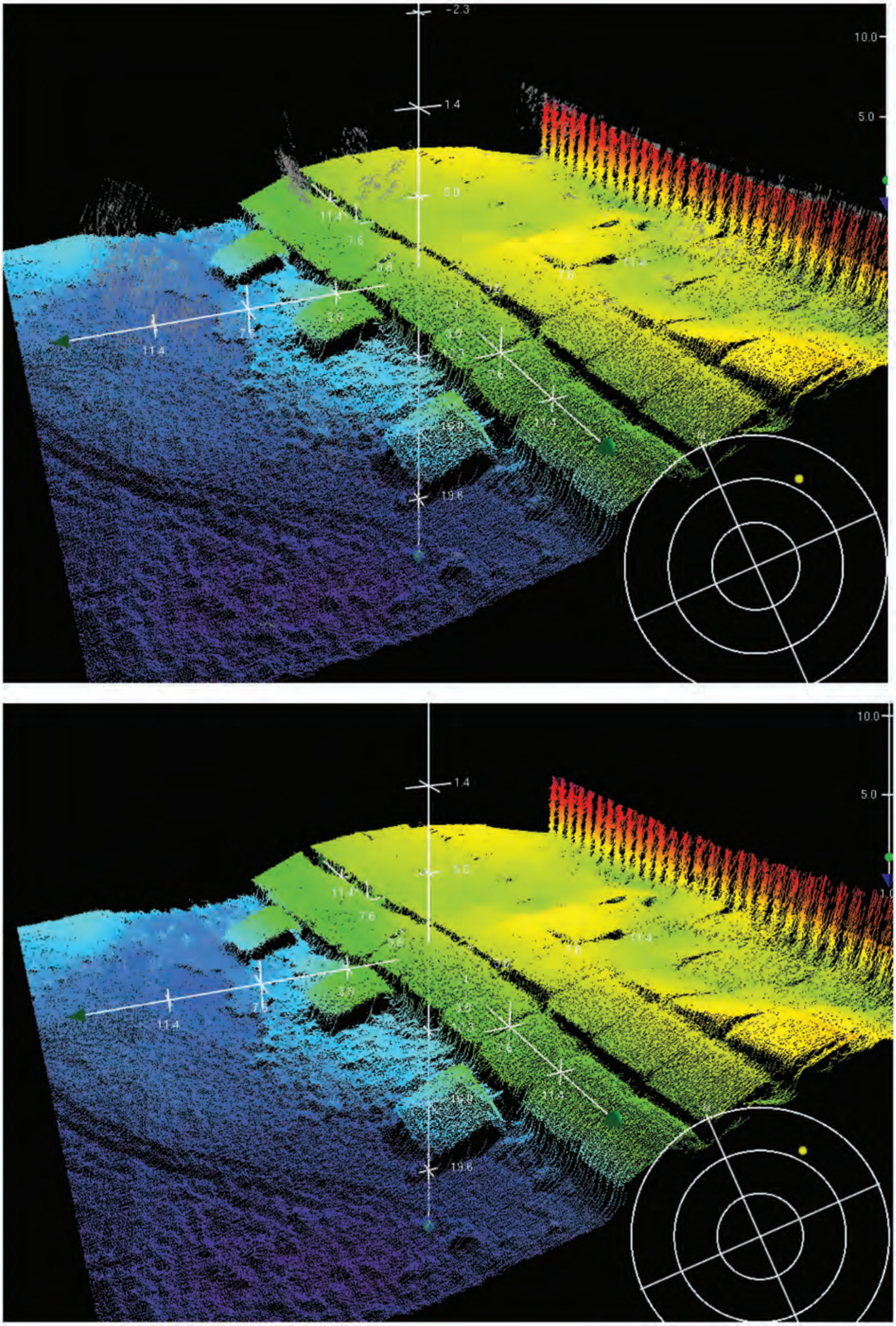
Continuing the voyage

The team at Teledyne CARIS have put great focus over the last few months in educating the hydrographic community on this groundbreaking new technology. Being international by nature and underpinned by standards, adoption of new processes and techniques can take time, especially in relation to surveys for nautical charting and safety of navigation.

Feedback received to date has been positive and the development team have already started looking at what's next. Another feature currently in development is object detection with AI. Examining collected bathymetry and side scan imagery to locate features such as rocks and shipwrecks is critical and once again – an engineering task well suited to AI.

Collaboration with fellow Teledyne business units operating in other domains is providing further insight and learning into best practices for overall architecture on how to best leverage AI. A leading example for this can be seen in cross pollination with Teledyne Optech, a leading LiDAR manufacturer.

Teledyne Optech's CZMIL sensor has a global user base and is being deployed to accurately map challenging environments



Images courtesy of Veris

Figure 4. Bathymetric data before (top) and after (bottom) filtering based on the sonar noise classifier.

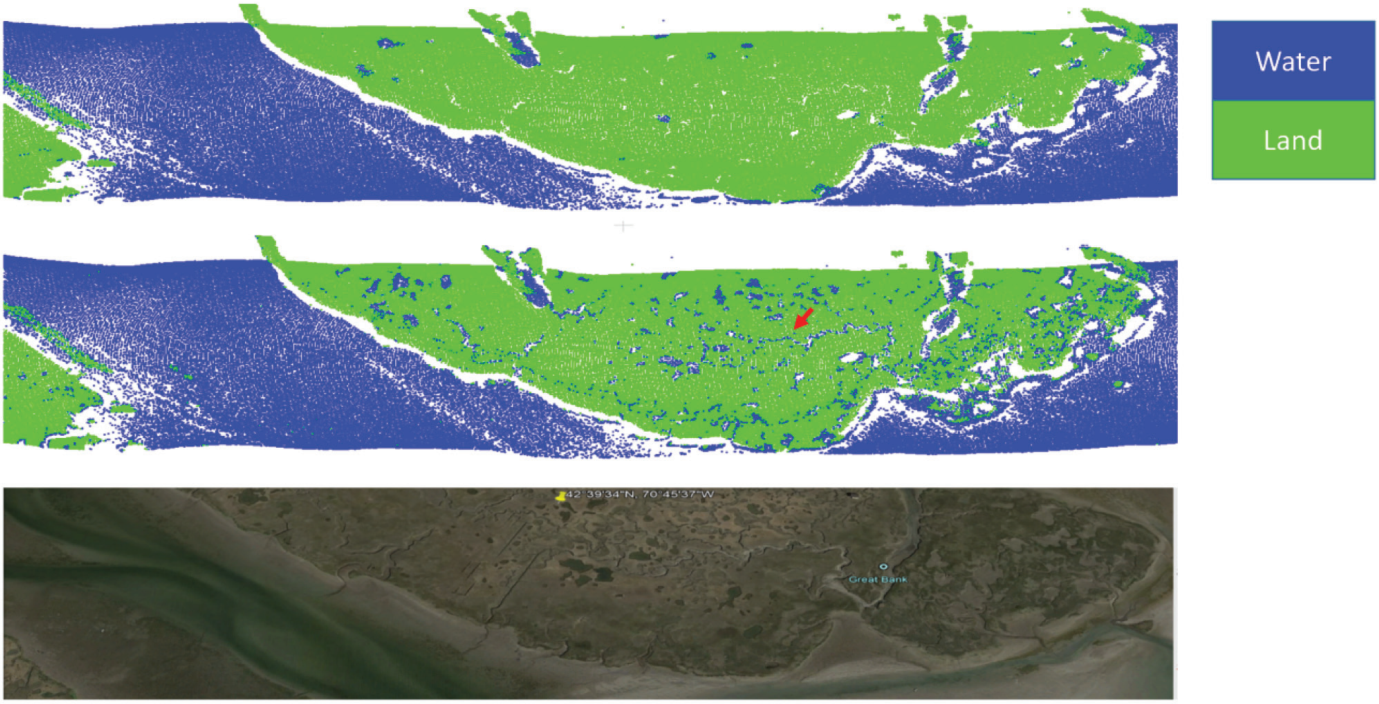


Figure 5. Land / water classification of LiDAR returns by human operator (top), by AI (middle) and a correlated image (bottom) for context.

where water interfaces with land. One of the first and foremost requirements for bathymetric LiDAR data processing is being able to differentiate between returns on land and in water. AI trials for this have vastly surpassed what a human operator capable of, with AI being able to analyze returns at a much finer level of detail than a person can interpret. This is demonstrated in the dataset shown in figure 5.

With this year's theme for World Hydrography Day being '*Hydrography enabling autonomous technologies*,' AI will play a pivotal role in realizing the level of autonomy that is required to efficiently map the Earth's oceans.

About the Authors

Burns Foster is the R&D Projects Manager for New Product Initiatives with Teledyne CARIS, focusing on developing new products and services outside of CARIS' core competencies. He previously spent five years as the Product Manager for HIPS and SIPS, CARIS' flagship processing software suite.

Dan Kruimel has a vast range of international experience on hydrographic, land and aerial survey projects. Having worked over a number of disciplines for both manufacturers and consultants, he has gained exposure to a wide variety of technology and methodologies for generating geospatial data.

A Surveyor's Perspective

By: Mike Mutschler from our partners Seahorse Geomatics

The National Society of Professional Surveyors has, as its first pledge of a professional land surveyor "To give the utmost of performance". While this mantra provides a continued mentorship to the professional as they carry out their geo-scrutiny it also acts as a guiding principal for those of us behind the scenes that deliver the tools, training and support of technology.

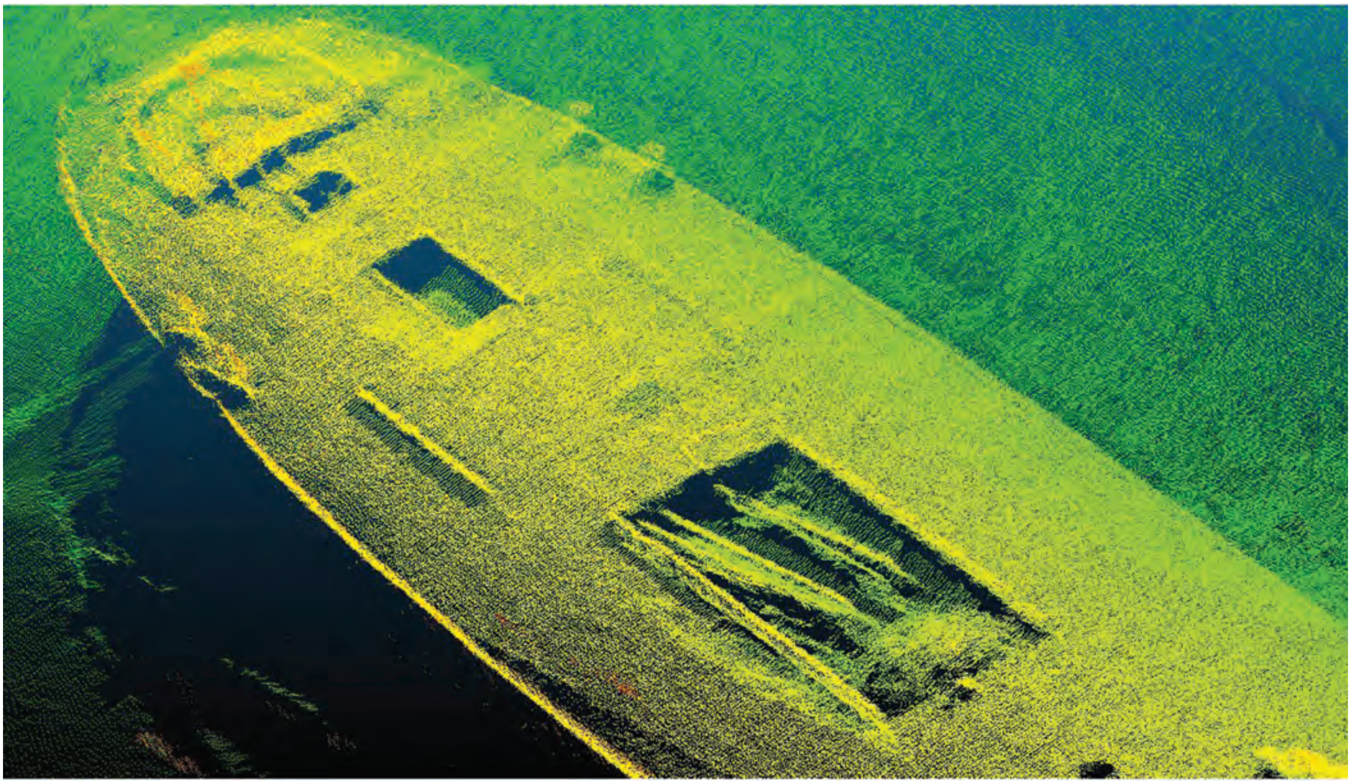
There are many known uncertainty contributors that make up acoustically derived soundings. If the manufacturer holistically considers these and themselves pledge to reduce these insofar as their business allows then our survey industry gains not only better data but increased accessibility as the barrier to new users is reduced.

The Subsea team at NORBIT (Trondheim, Norway) have grasped this focus wherein all engineering decisions, through the development of their family of systems, have culminated in intuitive shallow water mapping suites deployable in hours, not days, onto any surface platform and operated by the novice.

Objective Sonar Tuning & Resolution

Surely, some readers will recall the art and science of sonar tuning. The careful balancing of sonar transmit power versus receiver gain. The tweak (taking years to make intuitive) brings comfort to the operator and earns great respect from the recruit, but tantalizing fear on being left alone to manage the system. We now see these manipulations as subjective sonar tuning that brings the threat of measuring too small a signal to make much use of, or over-saturating the returned echo resulting in increased depth determination uncertainty. Recall that receiver gain only increases the already received signal and therefore will do nothing for the Signal to Noise Ratio (SNR). It shall be used to adjust the signal to prevent the saturation or numerical errors, but it should be done automatically and internally to the sonar without any user intervention.

The key is outputting sufficient energy and keeping the noises as low as possible. More energy going out translates to more energy on return. The signal must transit to the bottom while suffering absorption and spreading losses and possibly scattering from reflectors in its path (weeds, fish, suspended sediments, bubbles, plastic bags, etc.). If the transmission even makes it to the bottom, it now is absorbed and scattered with bottom interaction before sending a small amount of signal along the treacherous journey home. In most modern



Ultra-high-resolution, NORBIT iWBMSh-STX systems today, there is no need to lower the output power as the intelligence in the sonar prevents the hardware saturation. Only in the rare environment (lock chamber, dry dock) might it need to be reduced.

To map to deeper waters or for a wider swath width, there is a need to increase the transmitted energy. This is done by an increase in pulse duration, similar to extending a vowel sound when speaking at a given volume. In Continuous Wave (CW) systems, the increase in pulse duration comes with unwelcome deterioration of resolution which lowers the quality of the bathymetry returns. Manufacturers will offer very short pulse length options on specification sheets to indicate high resolution. But in real life, these values are not useful in a typical environment due to low transmitted energy and poor performance. Give it a try on your CW system and you will see that increasing the pulse duration (TxPulse, Pulse Width, Pulse Length, etc.) will measurably erode resolution while too small of a pulse length will result in a very narrow swath in shallow water. Therefore, in CW systems, one cannot maintain both high resolution and full range performance.

What would be the solution then? Use a pulse compression technique. Pulse compression has been used for decades in radars as they allow use of much longer pulses over a wide frequency range without loss in resolution while keeping long detection ranges. This is possible by employing a long FM signal, called chirp, which sweeps through the frequency range, e.g. 360kHz to 440kHz. The long duration of the signal facilitates the wide swath and the high bandwidth to maintain high resolution.

When working with FM systems, the resolution becomes independent of the transmitted pulse duration as it depends solely on the bandwidth of the signal. The higher the bandwidth the better the resolution. For NORBIT FM multibeam systems, even for water depths of 100m, the bandwidth of 80kHz is used and the sonar range resolution remains 9mm.

FM chirps and pulse compression techniques has been in use in radars for decades and, when correctly employed in multibeam systems, allows for large transmit energy resulting in increased SNR for each beam for reliable sounding determination (cleaner, wider swath of high resolution repeatably measured depths). Shallow water FM for multibeam systems is current state-of-the-art technology and NORBIT systems have been doing this for nearly a decade with many hundreds of satisfied customers globally.

The result is a system that requires, for 99% of applications, minimal manual tuning and minimal user interaction. Simply set the viewing area (swath angle and upper/lower gates) so that the full bottom lies within the maximal range and then turn off the settings tabs and focus on survey management (sound speed, GNSS corrections, line driving for required coverage, avoiding crab pot buoys, etc.)

Surface Sound Speed & Agile Swath

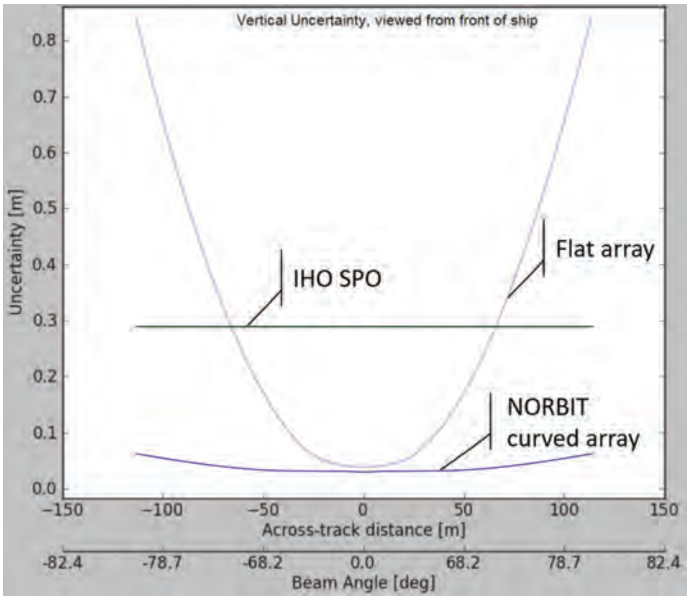
All beamforming multibeam systems today require the input of a timely local sound speed for correct calculation of beam steering angles. Sound speed measurement errors may be due to many factors such as incorrect probe placement, delays from communications or filtering, probes that are out of calibration, etc. The errors resulting from incorrectly applied sound speed have consequences for the determined beam angle for each steered beam.

To understand the role of surface sound speed on beam steering angles we must know the relationship. The system must determine individual ceramic element time delays for a desired steering angle given an array length (distance between the group of ceramics employed) and to do this, the speed of sound is required (consider that time = distance / speed). The formula is something like:

$$\alpha = ASIN\left(\frac{time\ delay\ *\ speed\ of\ sound}{array\ aperture\ length}\right)$$

It goes to show that if the speed of sound differs from known, this error will multiply by the time delay and steer the beams in a wrong direction. The more time delay is needed the bigger error is observed.

If we are able to reduce the needed time delays we are able to reduce the beam steering errors. This can only be done by changing the shape of the receiver array so it faces the direction of the incoming sound wave. A curved array faces the returning sound from all directions and does not require large beam steering as in flat arrays. Therefore, the beams are not



The image is a combination of two simulations from AMUST software done at 20m depth comparing the NORBIT curved array with flat array of the same nadir beam opening angle, the same environment and navigation options but both with a 1m/s random error.

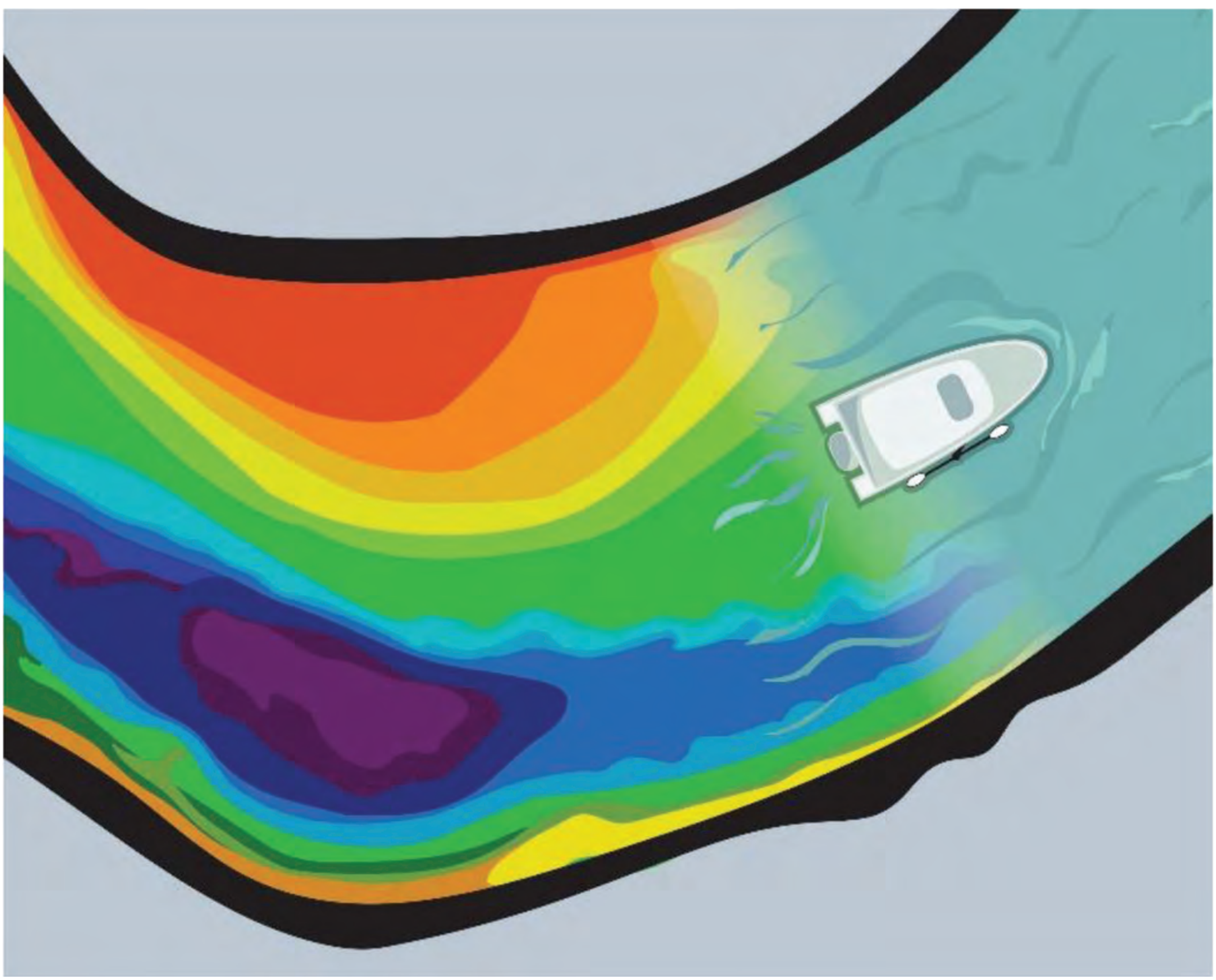
impacted by small variations in surface sound speed. A helpful tool, AMUST by DELFT University, available from Rijkswaterstaat of The Netherlands, will provide insights to the effects of accumulated uncertainty and the effects of incorrect sound speed for beam steering and the resulting uncertainty for depth determination.

NORBIT systems always include a surface sound speed probe tightly integrated into the receiver and sport curved receiver arrays. Therefore, the impact of identical error in local sound speed at a 50° angle with flat array will cause the same beam pointing error as one at 80° in a NORBIT array. That is because NORBIT steering reference angle is roughly 30deg. Another benefit is the ability to map with 180°+ wide swaths in shallow water (bank to bank) from a single sonar head or scan to either port or starboard shoreline without physical head rotation.

Tightly Coupled Integration

The sonar is just a part of the systems kit where each sensor works in concert keeping time and pace. Large errors typically originate from mis-alignment of the Inertial Navigation System (INS) / Motion Reference Unit (MRU) axis frame and the offset measurement frame where the longer the lever arm distances are along each misaligned axis, the greater the error. A vessel with an INS/MRU situated in the belly of the vessel may be well placed for heave determination but if slightly (~0.3°) out of alignment with the vessel frame, which is often used as the offset measurement frame, will be sufficient enough to exceed the ability to meet IHO Special Order and even Order 1 surveys in 10m water depth. Especially with a multibeam sonar mounted to the side of the vessel or some distance away from the navigation center, errors will appear and vary in magnitude with increasing vessel dynamics. The solution is to reduce the separations between sensors.

NORBIT has led the pioneering effort of tightly coupling leading GNSS/INS systems into the sonar frame resulting in a setup with non-existent flexing or movement between the sonar and the INS. The lever arm distances are fixed and known to the sub-millimeter. The GNSS/INS is auto configured to output its solution to the same location as the sonar measurement center. The operator need only measure to the primary antenna and offset the sonar/INS shared measurement location from the best-guesstimated vessel center of rotation moved to waterline while the INS reads a near-zero pitch and roll value.



NORBIT WINGHEAD Kit

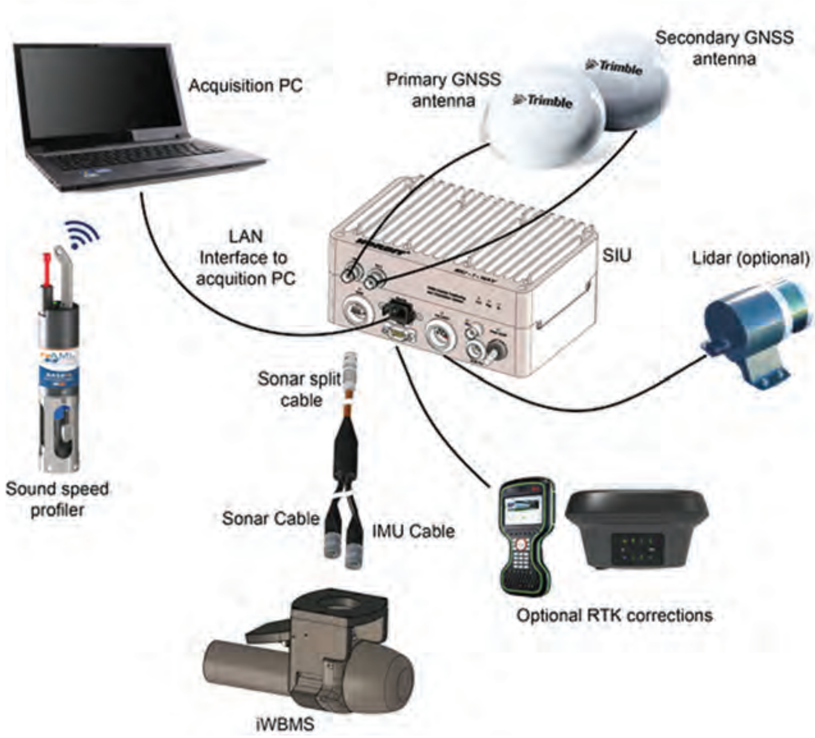
The system is now ready for ellipsoidal referenced surveys or surveys using determined waterlevel (tide) information.

A complete mapping system (with optional LiDAR or Sound Speed Profiler) is now included in a single wheeled hard-case that may be checked onto any commercial airline. Only a laptop is missing for a complete system suite.

Tidy Installation

Systems installation often leads to exhaustion especially when carried out in remote locations and, or when under time pressure and, or when a previously unknown vessel of opportunity is employed. Compromises are often made when deciding sensor locations due to length or path for cables or attempting to maintain alignments or what available hardware to use to brace the system for reduced flexing or vibrations. The larger and heavier the complete system is the greater the size and weight of the mounting hardware. The accumulation of 'making the best of it' decisions often leads, at best, to borderline acceptable data.

With luck, the surveyor is now content that the system is installed as best as they are able given the hardware and tools available and must now carry out the survey. This will still not be day 1. It will be day 2 or day 3, at best. If using the NORBIT integrated multibeam system with their Portus Pole, we are only 1/4 to ½ through day number one. Indeed, the complete integrated NORBIT system requires only four bolts to attach the coupled wet-end (sonar, sound speed probe, IMU, fairing and bracket) to bottom of vessel or pole mount, one deck cable from this coupled wet-end to the water-tight topside unit, one antenna cable for each primary and secondary antenna, a 12-28VDC power cable and one Ethernet cable to a PC or Linux machine or laptop. No timing cables, no PPS connections or splitters, no wrong gender null modems, no urgent trips to an under-stocked and now non-existent Radio Shack.



Rapid mobilizations are enhanced with the new NORBIT Portus Pole, a streamlined, no tools carbon fiber pole mounting setup with telescopic antenna mast that packs into a single wheeled case and may be checked as airline baggage. The ability to fix all offsets as well as the multibeam sonar alignment calibration angles (MAC) allows rapid system setup and immediate operation for repeatable high resolution multibeam data.

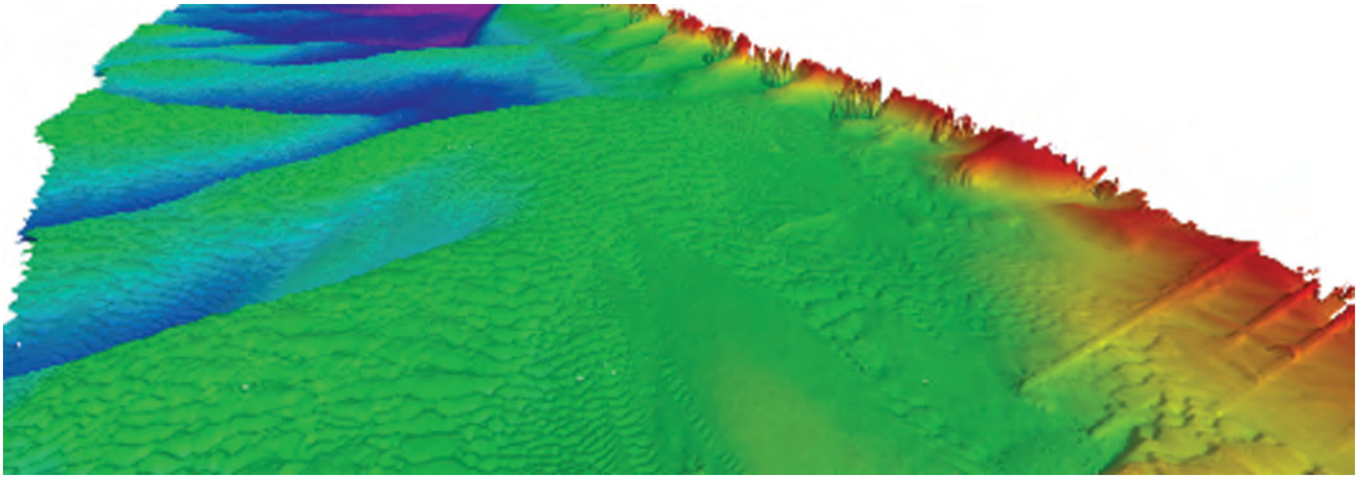
NORBIT will take care of the millimeters/centidegrees and the quality high definition and repeatable survey will take care of itself.

Operations Simplified

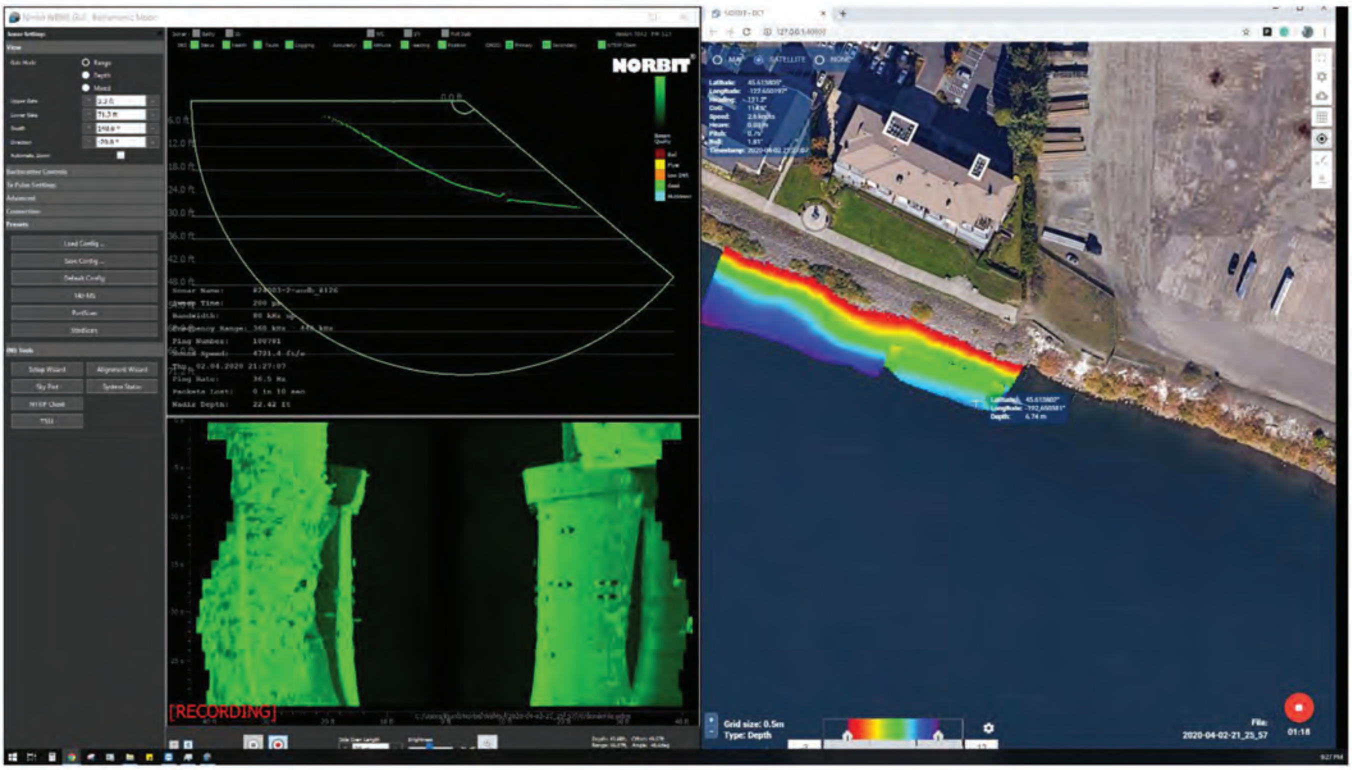
Once afloat with systems installed, the surveyor must now configure the data acquisition system. This requires setup of sensor device drivers, communication protocols, offsets between sensors and the Center of Rotation and project coordinate reference system relationships with respect to the GNSS ellipsoid. Then, the user must configure and upload background imagery, build display databases/grids for bathymetry data to be collected, setup vessel tracking point and arrange 4-12+ various windows on whatever screen real estate is available to them.

The need for multiple data windows during survey acquisition has historical merit and depending on the survey purpose, may still be required for a very small select number of surveys being conducted today. However, for the majority of surveys (especially those that utilize real-time GNSS corrections for a 3D positioning solution or for post processed positioning) most of the display screens are not necessary except for those who have a determined interest in real-time angular rates of acceleration or 3-axis velocities. There can be well over 200 items showing real time quality. What is required and what just confuses the operator?

NORBIT is the first (and still the only) company to have fully integrated a GNSS/INS system for bathymetric mapping. Shoving GNSS cards in a sonar topside is relatively simple. The full system (sonar, GNSS and INS) are monitored and controlled from a single interface and connected without additional cables except to the antennas. Raw GNSS/INS data is recorded automatically for delayed-time heave, for PPP or PPK. Now, let's move this to the left side of our single laptop monitor and open up DCT, shall we? Data Collection Tool is a new NORBIT browser-based data acquisition platform with full open access API and powered by current geospatial imaging techniques. Google satellite view or Open Street Maps backgrounds are available online (with internet connection) or for may be downloaded for offline use. Mouse-controlled operation allows one to acquire ultra-high-resolution data, or, use your finger on another touchscreen tablet or smart phone. All data is recorded when the record-



Testing grounds, Columbia River, Kaiser Shipyard Memorial. NORBIT WINGHEAD i77h

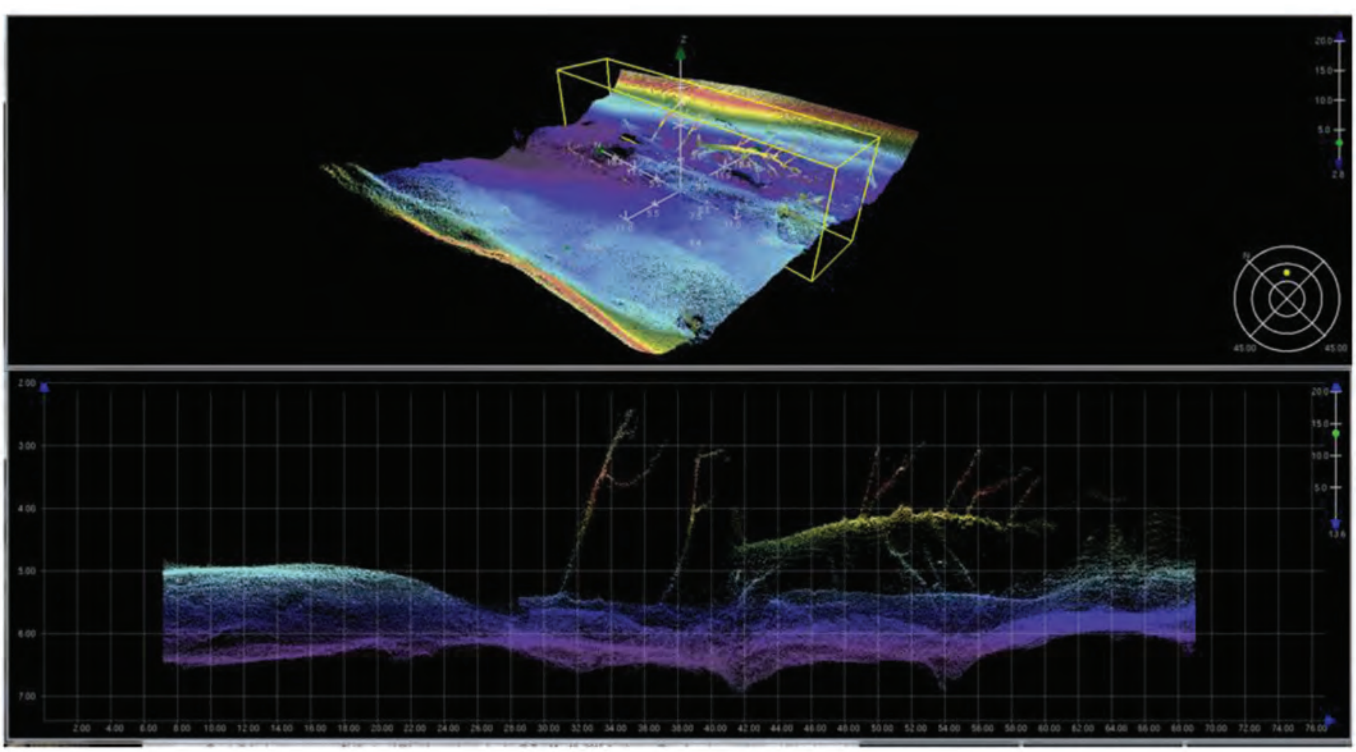


Single laptop screen for full bathymetric data acquisition. NORBIT WINGHEAD i77h with DCT.

ing button is pressed with the file name displayed beside it. Throughout the survey, any critical issues are set to alert the operator (timing synchronization, surface sound speed issues, poor positioning quality, loss of GNSS corrections, poor bottom detection quality, etc.). It conceivably cannot get much simpler (but, my crystal ball says that it will).

A New Day,

As I write this article on behalf of NORBIT, I ponder what the old salts (my career mentors) might complain about the



Courtesy, Louisiana State University, Kory Konsoer

Single swath bank to bank river survey. NORBIT iWBMSh

Somewhere in Newfoundland, Memorial University. NORBIT iWBMSh-STX with Portus Pole

direction that NORBIT goes and if they might proclaim the needs for separation of sonar from INS, that FM doesn't work for shallow acoustic systems, that curved arrays are yesterday's systems, of the need for 22 separate windows to be visible on an acquisition system, on placing the IMU/INS at the vessel COR or perhaps my bad jokes. I say, sorry, but this is progress and currently, this is NORBIT. New blood, new thinking, new energy, fresh pioneering.

The wild success at NORBIT comes from the pure potential of the enthusiastic open-minded team. The genuine desire to engineer practical and efficient solutions. Part of the success comes from NORBIT seeking out groups within the industry to understand the challenges of our survey industry and to build lasting partnerships with. Seahorse Geomatics is one of those partners. It's telling that the fresh pioneering implementations engineered by NORBIT are taking hold throughout the industry. FM, curved array, tight integration of GNSS/INS, simple user interfaces and immediate access to repeatable clean data. As NORBIT continues along the path of reducing the sum of most potential sources of error we can say that "a rising tide floats all ships".

About the Author:

Background in Geomatics Engineering and worked both as a land surveyor, hydrographer and in multibeam R&D since 1998, Mike Mutschler founded Seahorse Geomatics (2011) with Heidi Seger to serve surveyors and those in product development. Bathymetric multibeam courses are held twice annually while on-site training is delivered to navies and Hydrographic Offices worldwide. He has partnered with NORBIT AS since 2012 and is, at the time of this writing, aboard the R&D vessel "SheHorse" on the Columbia River, testing the new WINGHHEAD i77h, a 0.5° x 0.9° (400kHz) ultra-high-resolution mapping beast with Dr. Pawel Pocwiardowski remotely connected from Santa Barbara.

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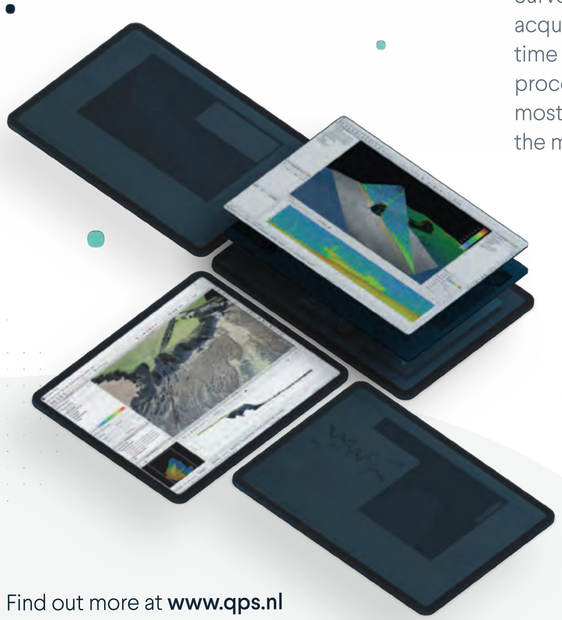

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