Roinn Cumarsáide,
Fuinnimh & Acmhainní Nádúrtha
Department of Communications,
Energy & Natural Resources

Geoscience Research
GSI
Suirbhéireacht Gheolaíochta Éireann
Geological Survey of Ireland

Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -

Name of Lead Investigator	James Riordan
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Organisation name	SonarSim Ltd.		
Organisation type:	☐HEI	☐Public Sector (other)	☒Private Sector
Department/section	Management		

Project Title	A Hydrographic Programme Demonstrator
Contract No.	2015-sc-033

INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

Tellus
Understanding Underground

Marine Institute
Foras na Mara

2. **Project information**:

Title of project	A Hydrographic Programme Demonstrator
Did you make any formal amendment to the project workplan / budget?	☐ yes ☒ no If yes, please specify:

Project Report (*max 1500 words, excluding figures and headings*):

(i) Objectives and scientific/engineering targets beyond the state of the art

Did the project progress beyond the state of the art? If so, how?

The project contributed to the **transformation of a technology innovation into a disruptive platform** with unique and demonstrable commercial value proposition to accredited Hydrography training providers. From a software engineering perspective, the technical and computational architecture of SonarSim's survey simulator is recognised as one of the most performance optimised implementations in the research and commercial domains. This project supported business development activities focused on leveraging this technical effect and translating it into a state of the art pedagogical tool for underwater SONAR education and training whose benefits can be articulated and demonstrated to a non-technical client base.

The project helped resource and accelerate SonarSim's plans to create a multi-media Hydrography training programme demonstrator, which is capable of achieving IHO accreditation as part of a complete programme, and leverages our real-time Hydrographic Survey Simulator. A series of Simulator mission scenario scripts were prepared to produce a training dataset with a scope of sliding scale scenario variations not possible to achieve in the real-world. A key focus of our **pedagogical methodology** is the gamification of learning objectives to stimulate active learning, improve engagement levels, and provide a task centric hands-on approach to trainee benchmarking. The project R&D output has made contributions to this research field which will be published at a later date once a suitable pilot is commissioned.

The demonstrator has special emphasis on the technology and problems associated with high-resolution surveys in shallow waters. The **training dataset** is readable by industry standard acquisition and processing software and comes with supporting ground truth and metadata information, to enable students to perform hands-on practical tasks on the raw data in commercial off the shelf processing packages. Training exemplars based on real data can be samey when viewed through a non-geologic non-scientific lens; the technical setup rarely changes and faulty data is deleted before inclusion in national repositories. Aside from the prohibitive costs of collecting such a scope of data exemplars and the impossibility of controlling the survey conditions to such a fine degree the training dataset demonstrates the on-demand capability of the underlying technology to generate datasets of any given learning scenario.

Were the objectives met? If not, what difficulties were encountered?

The core objectives were met, i.e. creating and disseminating the programme technology demonstrator, and are discussed in the appropriate project output sections below.

One objective, namely National consortium building was deprioritised and is discussed here. As our technologies have progressed through stages 7-9 in technology readiness levels, SonarSim made the strategic decision earlier this year to begin pivoting away from competing for R&D funding due to the long lead times and significant investment required to prepare competitive proposals. It is more appropriate for SonarSim to pursue revenue through commercialisation activities as we seek to scale the company through industry supply. To this end we did not pursue establishing a H2020 consortium. Furthering this initiative needs to come from the top down and requires significant backing and financial support from a public body. Our decision was informed by the market and cost analysis we conducted towards the beginning of the project which highlighted significant challenges ahead in the hydrography training sector and is discussed below.

Response to Market Challenges

The economic uncertainty caused by volatile oil and gas prices, the result of strategic supply increases by OPEC in an effort to collapse prices and eliminate competition, has resulted in significant job losses in the offshore survey industry as deep ocean exploration has all but ceased for the foreseeable future. As an example, North Sea profitability has plunged to a 20 year low with 2015-2016 revenues down 96% from £1.8bn to £60m resulting in 120,000 direct and supply chain job losses in the UK alone, a 30% drop in employed industry personnel within 24 months.

However, while offshore oil and gas remains far from break even at current energy prices, shale production costs have almost halved as a result of efficiency drives and energy companies are now pivoting away from offshore oil and gas. Offshore wind has also seen multiples in efficiency savings in new installation projects and has added increased priority to shallow water, near shore survey. The outcome is a forecasted decline in demand for entry level training coupled with increase in demand for continuous professional development focused on the low-tolerance low-error margin domain of shallow survey.

Consequently the project sought to emphasise workflow training objectives as opposed to broader education learning objectives in underwater survey. The simulator generated data was piped through 3rd party software packages such as EIVA NaviSuite, Caris HIPS/SIPS, QPS QINSy, Kongsberg SIS, MB-System, etc. which were donated to SonarSim as loaner licences by commercial vendor sponsors of the project. The project also leveraged SonarSim's active involvement in survey operations through its activities with the Marine Robotics Research Centre at the University of Limerick and the Geological Survey of Ireland. In March 2016 SonarSim conducted a pre-dredging survey of the jetty at Foynes Port for the Shannon Foynes Port Company. MAP was also sea trialled a number of times on the RV Keary during its final stages of development and featured heavily in the training exemplars.

Please describe the project outcomes

Business Intelligence informed by Market Research

While SonarSim is not involved in seismic activities, the company is not immune to an industry wide pivot towards aggressive cost savings, with training budgets often first to be cut during periods of recession and over supply. However, renewed focus on shallow survey operations driven by wind energy and increasing prioritisation of automation in industry-wide development roadmaps present opportunity for SonarSim to focus on smart high-resolution survey application. The business intelligence activities conducted during the project were instrumental in helping SonarSim identify the correct target audience for the training components as well informing our overall business priorities.

Exhibition - SonarSim exhibited on the Ireland Pavilion at Oceanology 2016 held in London at the beginning of March. This provided an opportunity to meet with key clients interesting in the Simulator's training application, relationships which we have cultivated into collaboration in the meantime. The exhibition also enabled us to experience first-hand the marked decline in the industry resulting from the withdrawal of offshore oil and gas from the marketplace.

Mapping IHO course locations to key economic drivers - Fundamental to any course specification is knowledge of the target audience requirements and objectives. SonarSim conducted an analysis of IHO course locations and against 3 key metrics, namely naval expenditure, location of offshore oil rigs, and locations of major ports. The slide deck in the attached appendix illustrates the results.

Cost analysis of e-learning course creation - The costs involved in the creation of learning content are often underestimated but the discipline is now ubiquitous and mature and numerous cost analysis studies can be found in the literature. SonarSim's objective is to create and supply Simulator generated training programme content to established Hydrography training providers. Training providers typically maintain Learning Management System infrastructure for internal as well as external delivery of training material. The LMS portal serves as the interface between trainees, course content, and interaction with instructors. Numerous independent studies have concluded that the preparation of instructor led training consumes man-hours at a rate of at least 50:1, i.e. 50 hours of preparation time per hour of teaching time. Preparation of e-learning training consumes at a minimum 150:1 given the range of tasks involved (interactive exercises with simulation components, multi-media content, front-end analysis, instructional design, lesson plan development, creation of handouts, visual development, exam creation, etc.). Given that the production requires both a multi-disciplinary and expert team, drawing talent from many branches of engineering, survey, software, ICT from academia and practice, conservative estimates cost the man-hour rate at €65 per hour. In other words, a 210 hour IHO e-learning course (providing just 30 hours per essential module and not addressing the optional components) requires investment of in excess of €2m. Future SonarSim project plans in this area will be benchmarked against these findings.

Profile the competitor landscape – The findings are commercially sensitive but one notable and high profile development in the recent past is the organisational re-structuring of Kongsberg Digital.

(ii) Implementation (including reference to timelines, milestones, management)

Project activities were conducted primarily during early 2016, centring on Oceanology in March, and mostly completing before company activities changed to offshore testing during the summer months. Activity recommenced in September due to commercial interest and requirement to complete outstanding reporting tasks.

The demonstrator content was produced in February. The white paper journal essay was submitted for publication in March and appeared in print in May. Two funding proposals were submitted in June, outcomes expected in October. Reporting was concluded before October INFOMAR seminar to provide opportunity for informed discussion.

(iii) Outputs (please use bullet points)

- **Publications**
  [Journal Essay] Flannery, F.; Riordan, J.; "Outside The Matrix – Simulation In The Real World.", The Journal of Ocean Technology, vol 11, no. 1, 2016 (attached)

- **Marketing**
  Oceanology International 2016, ExCel London, Company Exhibition - Ireland Pavilion, Marketing campaign to raise commercial awareness of project output as well as seed future R&D partnerships

- **Programme demonstrator**
  Evaluation version of Hydrographic training platform

- **Funding Proposals**
  Science Foundation Ireland Discover Programme Call 2016 - 2nd level STEM outreach focused on Hydrography – "Simulator Game Physics Primer to the World of Underwater Exploration" – notification due end of October 2016

  SmartBay NIAP call – in partnership with UL – installation of physical SONAR training infrastructure at Galway Bay cabled observatory site – – notification due end of October 2016

- **Reporting**
  INFOMAR seminar presentation (attached)
  Midterm and final report

Impact/value of the project (M*ax 500 words*):

Immediate Impact

The demonstrator is a key SonarSim marketing asset as it enables prospective clients to easily evaluate the benefits of our technologies within their own training environment. SonarSim's Simulation platform is not particularly mobile; it requires dedicated hardware, which albeit comes in laptop based as well as server versions, and demands an overly involved and expensive process to ship demonstrator systems around the globe to perspective clients. While cloud based interfaces to the various Simulator modules can solve some of these problems they require a certain level of technical expertise and client training to be easily used. The demonstrator dataset and supporting material provides a tangible resource which can be verified by clients above and beyond showcase multi-media marketing material. In fact SonarSim is the only organisation which has demonstrable capability in simulator based Hydrographic training.

The commercial impact of the demonstrator is evidenced by the fact that SonarSim are currently collaborating with a leading European Maritime Academy to resource the integration of the Simulator with their new Hydrography training programme in preparation for submission to the IHO for accreditation at Cat A/B level. SonarSim are leading the pursuit of the virtual hands-on training experience through smart simulator technology and will continue to partner with ambitious and innovative knowledge providers on projects of interest.

SonarSim are primarily focused on commercial proliferation of our vessel software MAP, which performs automated runline planning during survey operations to minimise the time and costs of multibeam survey by steering the vessel along the optimal survey transects. The MAP product development roadmap identifies the integration of MAP with the Simulator platform as a key priority. The synergy of the resulting integrated system, available either as a survey planning as a service cloud platform or dedicated enterprise server platform, is expected to unlock a commercially lucrative feature set. This project has helped illuminate some of the use case scenarios as much of the training exemplars focused on shallow water runline planning issues and has provided a solid justification for such a product.

Future Impact

SonarSim are an R&D driven enterprise and operating independently enables us to pursue creative multi-disciplinary research themes. The demonstrator dataset provides a benchmark for planned SonarSim research into gamification of Hydrographic learning, which is a pedagogical approach to motivate students and increase engagement and knowledge transfer by incorporating video game design and game elements in learning environments. The Simulator has its roots in video game design and was initially used to generate gamified scenarios during the training course SonarSim conducted in Jeddah back in 2015. The outputs of this project will serve as a foundation to future SonarSim research and academic contribution.

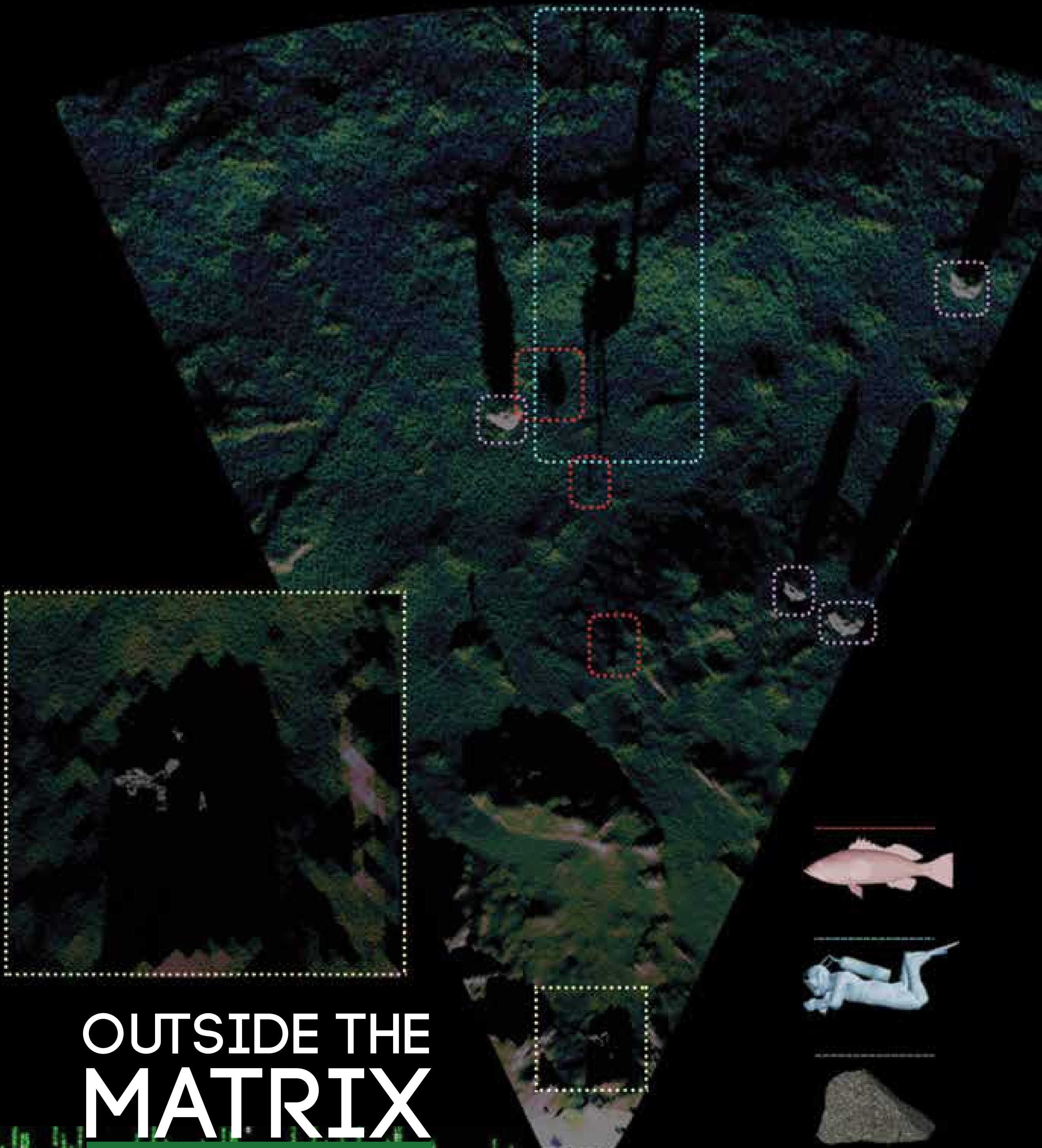
If Ireland is to benefit from growth in the indigenous Blue Economy then the country will require personnel capacity building initiatives to train highly skilled individuals for the new jobs which will be created. SonarSim is positioned to contribute expertise and supply technology into these initiatives which may be necessary sooner rather than later given the implications of forthcoming geo-political events such as Brexit which may erect barriers to the traditional out sourcing of such activities to our nearest neighbour.

Appendix 1 – Publications & Presentations:

[Journal Essay] Flannery, F.; Riordan, J.; “Outside The Matrix – Simulation In The Real World.”, The Journal of Ocean Technology, vol 11, no. 1, 2016

Appendix 2 – Any additional information not included above:

INFOMAR Seminar Presentation (19th October 2016)



OUTSIDE THE MATRIX

SIMULATION IN THE REAL WORLD

BY FRANCIS FLANNERY AND
JAMES RIORDAN

A simulator generated forward looking sonar image for a detection and tracking of moving objects application with features of interest (diver, bubbles, fish, rocks, etc.) tagged according to signature highlight, shadow, and motion characteristics.

SONARSIM

Introduction

Simulation is a key enabling technology in the drive to deliver the second generation of smart maritime platforms. Developing systems to enhance training, planning, operations, procurement, and R&D activities, among many others, cannot be considered in isolation as they subsume a broad spectrum of multi-disciplinary and trans-sectorial R&D effort. In addition, maintaining a highly skilled workforce to maximize the return from what are knowledge and capital intensive technologies is critical. Existing and emerging systems have clearly benefitted to a great extent from relevant exponential engineering advancements over the past decade. By leveraging advancements in computational capacity, battery storage, sensor miniaturization, communications/networking, and software intelligence, R&D teams across the industry are steadily unlocking the potential of autonomous sensing, actuation, and control as the barriers posed by the fusion of unstructured big data sources characterizing subsea workflows are slowly eroded.

Success to date is evidenced by the increasingly automated nature of solutions assimilated into routine subsea workflow processes. Supervised bathymetry data processing algorithms, such as CUBE from the University of New Hampshire, have existed as industry standard solutions for over a decade. Such algorithms decrease manual workload and turn-around time in converting raw data into deliverable products and revolutionize surveyor work and quality control processes by making client-ready data available for assessment within the on-ship acquisition cycle. Our industry, in line with a worldwide movement towards machine learning, is focused on workflow mechanization; for example, Caris's Onboard product line is transferring supervised PC software solutions onto autonomous platforms. This is coupled with reinvigorated moves towards integrating various combinations of autonomous aerial, surface, and underwater platforms into routine oceanographic data acquisition operations. Published sea trial results, such as a series of NOAA ship *Ferdinand R. Hassler* trials with the Kongsberg-Hydroid REMUS AUV, demonstrate significant improvements in efficiency and dataset quality while current efforts in running swarms of such platforms in tandem should offer even greater gains. Finally, in an industry continually reshaping due to mergers and acquisitions, the evolving commercial landscape will undoubtedly reflect disruptive technology trends and many sonar software and instrument manufacturers are now in the same conglomerate stables as AUV manufacturers delivering integrated solutions to target markets. Example pairings include QPS / Saab, Reson / Gavia, Kongsberg / Hydroid, and Seabyte / Bluefin.

As they have matured through operational readiness and widespread industry proliferation, the impact of successive first generation systems has catalyzed R&D focus on broadening the robustness, functionality, and decision making skills of current solutions beyond the boundaries of pre-programmed, supervised, and single mode operations. Next generation systems are required to be predictive and adaptive, equipped with the capability to autonomously make accurate data-driven decisions in real-time, and are expected to be as comfortable in cluttered shallow water environments as in the clear and open deep waters. This requires advanced feature identification, tracking, classification, and intervention capabilities driven by automated sonar based machine vision.

The lack of turn-key machine vision intelligence is one of the principal factors limiting the ubiquitous emergence of these systems. Intensive R&D into sonar-driven autonomous technologies ultimately requires a cost efficient supply of diverse real-world representative data to support a financially feasible design cycle process. The only realistic way is exploiting simulation to cut design cycle costs, improve system reliability, and bring systems onto sea acceptance tests more rapidly. In addition, the smarter the

Figure 1: Simulation scenarios with immersive transparent ocean rendering of vessel motion, seabed geometry/sediment classification, ensonifed footprints, sea surface swell, etc. enhance situational awareness and improve cause and effect feedback through visual cues.

systems become so too the skill sets required by industry personnel as roles become progressively crowded out by automated processes from the low level tasks upwards.

Simulation platforms as distinct from stand-alone simulators are required, supporting an ecosystem of technologies and applications from an integrated systemic framework that can support all aspects of the underwater sonar workflow including R&D, training, planning, and in-the-field operations. SonarSim has conducted a number of pilot projects over the past number of years which have provided insight into the role simulation can play as a key enabling technology in the delivery of wider industry goals. The remainder of this essay will discuss these simulation projects and give a historical background to the sector from a hardware and software perspective.

Historical Background

Modelling and simulation are distinct research topics with unique sets of challenges and their evolution has been characterized by contributions from many different disciplines and sectors throughout the various phases of their respective histories. In general, the simulation community makes software contributions to the field of computational ocean acoustics while subsuming the mathematical equations and physics theory of the modelling literature. Simulation performance requirements need to keep pace with the state-of-the-art in survey technology in an industry traditionally characterized as a technology laggard but is now keeping pace with contemporary ICT trends.

Up to the 1960s the vast majority of technical innovation in the subsea theatre was driven by naval spending and applied to anti-submarine warfare, mine detection, etc. Modelling efforts within academia were mainly focused on understanding of the underlying physical processes and their mathematical representations. The unavailability of computational technology required most modelling tasks to be carried out by hand. However, from the 1960s onwards major industry changes were driven via new enabling technologies, beginning with the advent of digital signal processing.

The 1970s saw the explosion of commodity hardware CPU and FPGA technologies with Moore's law [Editor's note: the principle that overall processing power for computers will double every two years (mooreslaw.org)] driving performance improvements. It was also the beginning of improved graphics due to the advent of GUI driven operating systems and the dawn of video gaming. In the midst of these technical leaps, analogue side scan sonars saw commercial production, with data visualization and sonar control limited to printer based paper plotting and ping triggering. However, increasing computational power coupled with software for programming unlocked tractable complex acoustic simulation for mainstream civilian applications. The mathematical formulas contained in complex models could be translated directly into source code, the output response evaluated over time, variables manipulated, and the resulting information presented onscreen.

The 1990s saw the advent of multibeam systems which exploited increasingly complex parallel FPGA architectures for data processing. Full wave field FDTD and PSTD modelling methods became active areas of research for sonar transducer directivity and acoustic propagation modelling. Offline high-frequency sonar models simulation based on acoustic ray-tracing was another new area of research. Increasingly accurate inverse models of backscatter acoustics in terms of frequency, sediment properties, and angular response opened up the area of forward seabed classification. The area of visualization was becoming increasingly important with many hydrographic software companies formed in the early 1990s and furnished with 3D data rendering.

At the beginning of the 2000s, operational simulators for training such as early ship-bridge and ROV simulators entered the marketplace. Backscatter models for object detection and seabed classification were brought from R&D into industry through products like Geocoder. Major steps in workflow processes became automated through algorithms such as CUBE. The data produced from survey systems steadily increased moving from side scan backscatter, multibeam depth, multibeam backscatter, multibeam snippets to recording full water column data. The quality of data acquisition has steadily increased along with the tightening of tolerances for successful system mobilization. The order of magnitude increase in sonar data volumes has been matched by similar explosions in 3D visualization, animation, and gaming polygon counts providing tailor made advancements in hierarchical data management, spatial segmentation, and parallelization to solve the related problems of maritime data visualization, processing, and simulation.

The past few years has seen the blurring of lines between simulation and operations. Structural analysis simulation of subsea components, previously limited to initial design development, has moved into the area of feeding real-time structural loading readings into simulation for stress and point of failure prediction. The complexity of personnel training has led to the development of training simulation for high-resolution hydrographic survey (Figure 1). The shifting value proposition of survey vessels and equipment due to pressures such as oil prices has led to the sell-off and retooling of survey companies but simulation driven analysis can ensure profitable utilization of capital and personnel resources.

Current market forces, achievements in artificial intelligence (AI) and automation, and limitations of current survey methods are bringing a major focus on autonomous survey systems, through the stepping stones of autonomous desktop data processing. Simulation is required in the development of autonomous survey platform software algorithms. Simulated datasets are required for the initial training of neural networks both though supervised and reinforcement learning. During operations a simulation framework can acquire sonar data, process it, and make real-time decisions in terms of the survey objectives; for example, track towards a feature of interest.

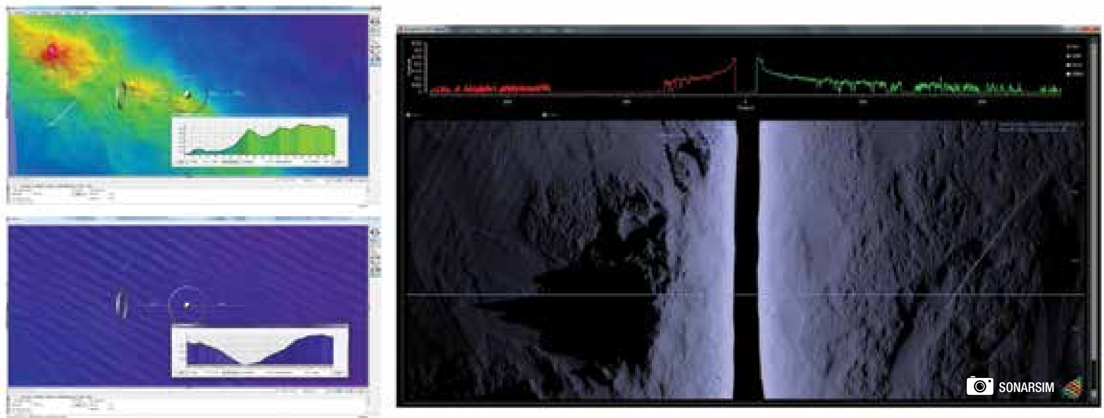


Figure 2: Integration into existing workflows is facilitated by the widespread industry adherence to open interchange formats. (Left) a fully synthetic SonarSim-created seabed being analyzed in Fledermaus (sediment ripple measurements) and (right) the resulting simulator generated high-resolution side scan sonar imagery encoded in XTF format.

Current trends in other industries will have a major impact within the survey industry. The explosion in AI in the recent past with the development of self-driving cars, systems which can beat humans at the intuitive game "Go," and adoption into data analytics has already been felt in survey with the rise of commercially feasible AUV/ASV-based survey systems. A major enabler of the AI trend is the use of heterogeneous computing where a mixture of computational cores (CPU/GPU/FPGA) enables the necessary performance. In addition, the scaling of computational platforms can go from a low-power multi-core GPU enabled smartphone to a cloud based HPC framework. A common sonar simulation framework can be targeted across a range of hardware scales to enable tasks from exhaustive survey fleet simulation to low-power simulation in the loop AUV operations. Current bottlenecks are being caused not only by computational limitations but bandwidth issues driven by the amount of data and the manner of its transfer in heterogeneous systems. Current industry investment is targeting these bottlenecks with new bus technologies for CPU/GPU (NvLink) and CPU/FPGA (Coherent Architecture Processor Interface [CAPI]).

Sonar simulation is a key enabling technology across sonar related R&D, procurement, planning, operations, and training. Rather than develop separate simulators to address each domain separately, the development of an integrated simulation framework which can target overarching problems in all domains is a suitable approach. While the underlying technologies and enabling infrastructure can be adopted from related technical domains to deliver the necessary computational resources, the development of a multipurpose platform ecosystem has requirements bespoke to the maritime sector.

Training Personnel

Our industry has a knowledge transfer choke point which affects new recruit induction, continuous professional development, after sales technical training, and project management. Similar to the experience of the airline pilot training industry, it is a space ripe for simulator enhancement, as evidenced by the successful entry of ship-bridge, dynamic positioning, and ROV simulators. A small subset of the routine day to day training challenges tackled by maritime enterprises big and small include training new staff recruited from different branches of general science and engineering into the distinct challenges of underwater survey while maintaining consistency of standards, knowledge, and expertise across various organizational roles; new procurements integrated into existing workflows; and disseminating expertise to clients.

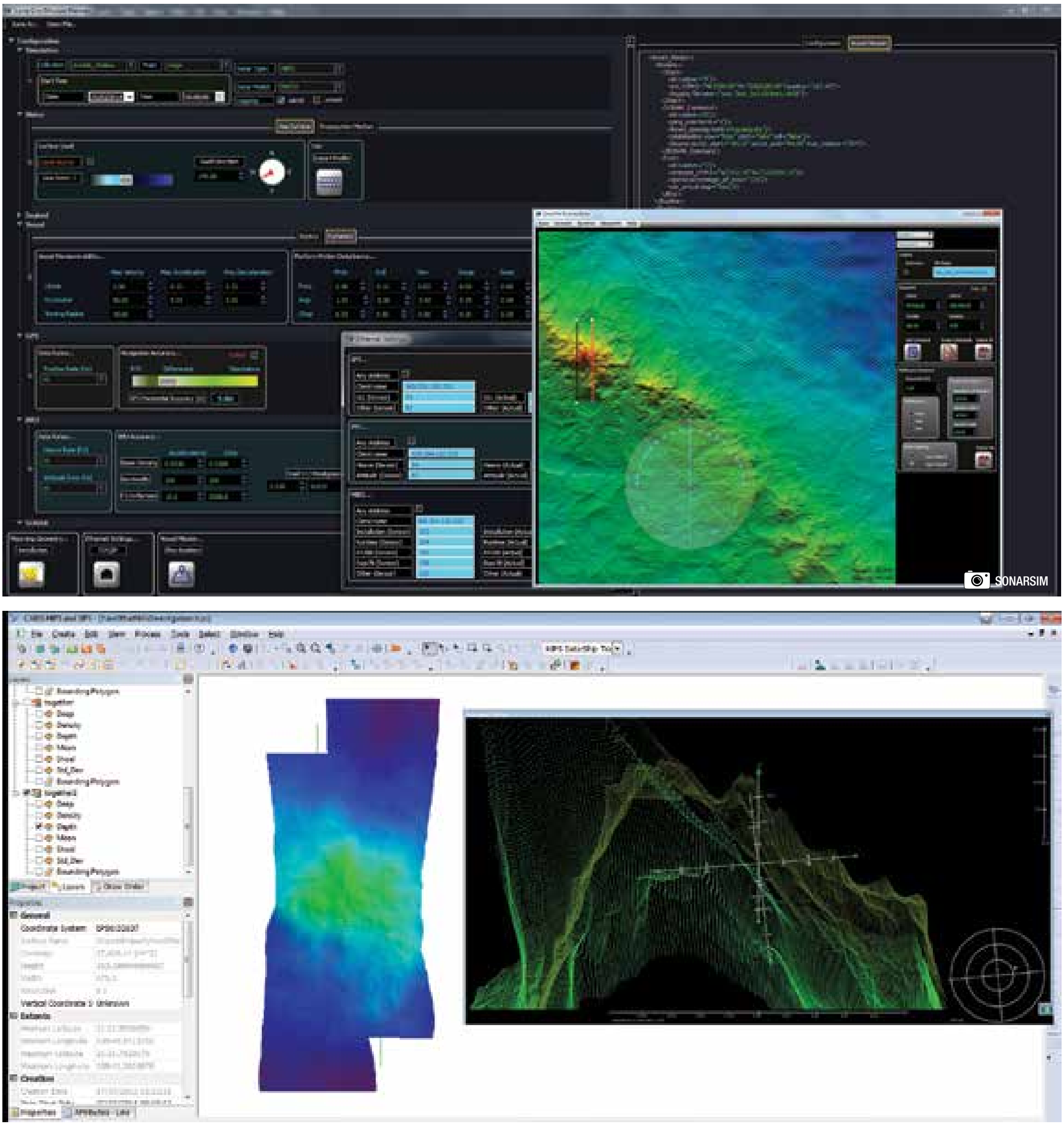


Figure 3: (Top) Planning a set of runlines in a virtual mission planner and (bottom) processing the resulting simulator generated files in Caris HIPS to perform a yaw calibration.

SonarSim was originally established to solve the problems preventing the use of simulation for maritime training, specifically the use of sonar simulation for hydrographic training, as outlined in V6N2 of this journal in 2011. The identified issues, cost-benefit justification, and proposed design tenets to realize simulator based training remain largely unchanged. Technical challenges at the time related primarily to the computational demands of real-time survey-scale high-resolution sonar dataset generation. In the intervening period SonarSim has developed out the technology solution over successive INFOMAR, Science Foundation Ireland, and European Commission FP7 and H2020 funded R&D projects. The company subsequently productized the platform into a hydrography training platform which is targeted at and has sold into the International Hydrographic Organization accredited training academy sector. Having successfully solved the computational issues, SonarSim turned its attention to harnessing this scientific computational capability into a personnel training platform, necessitating the creation of a completely new approach to training program design. Existing training programs do not readily lend themselves to the integration of simulator generated exercises and content into their existing instructor and student material without a significant overhaul and restructuring of how individual topics are delivered. To maximize the benefits of simulation, shrink-wrapped learning content must be formulated and generated from scratch which can leverage survey simulation, learning management system infrastructure, and OEM acquisition and processing software, to best meet hydrography training program learning objectives (Figure 2).

Simulator-based operational case studies unlock novel training techniques, tools, and strategies, which can be applied in designing structured learning experiences, as well as used as a measurement tool linked to targeted competencies and learning objectives. From a content perspective, real-world exemplar hydrographic data covering a wide scope of payload instrumentation configurations, system settings, and operational scenarios is excessively expensive to collect in the field and learning is constrained by only showing an extremely small subset of potential example scenarios with a limited amount of student system interaction. In simulation, practical scenarios can be created, demonstrated, and analyzed; e.g., survey system calibration, line selection, and performance check.

SonarSim has focused heavily on integrating the training datasets with industry standard acquisition and processing software from MB-System, QPS, Caris, Hypack, Kongsberg, and EIVA. The platform also required a custom suite of sonar data visualization and analysis tools as simulation can produce datasets not typically generated in the field and consequently the visualization and analysis tool have certain key features which are unique for training (Figure 3). The use of simulation as a personnel training tool is standard in many industries as is the use of simulation in new technology development. Two SonarSim R&D case study examples are outlined in the following sections.

The Evolution of Platforms

A case study of recent SonarSim R&D activities in extending its existing survey simulation framework from the training domain into a new technology testbed for multibeam sonar acquisition automation illustrates the multiplier achievable from cross-pollination of virtual and real-world functionality. The objective of the endeavour was to prototype a simulator based framework which could, through exhaustive what-if simulator scenario analysis, determine the most cost effective combination of survey vessel, payload instrumentation, and runline regime to achieve prescribed survey specifications and then re-purpose this search and analytics functionality into a smart onboard control architecture to actually deliver these performance metrics in the field. The project was part funded by INFOMAR and subsequently the European Commission, with ship trials conducted by the Geological Survey of Ireland's RV *Keary*. The output has been commercialized under SonarSim's Multibeam AutoPilot (MAP) product line; Figure 4.

One of the key market drivers common to all maritime survey sectors is the desire to increase operational efficiency and vessel utilization when mapping the seabed. This is particularly acute in shallow water sites as the complex topography and resulting swath width variations impose tight positioning tolerances to ensure gaps in coverage are prevented. The continuous on-the-fly recalculation of runlines and deviations from pre-planned vessel waypoints required to maintain desired coverage overlap between successive runlines can quickly fatigue the onboard hydrographer and helmsman with knock-on safety, productivity, and data quality implications. As a repeated problem, the impact on survey

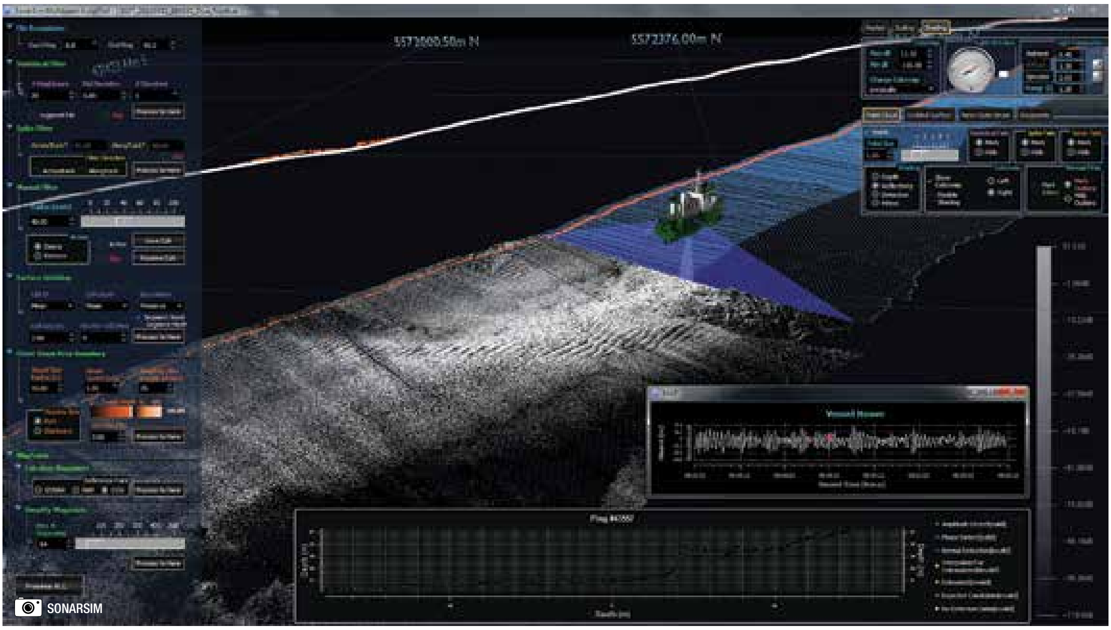


Figure 4: SonarSim's Multibeam AutoPilot is a derivative of its simulation technology for use offshore – it adds low-level data inspection and high-level processing functionality (geo-referencing, outlier detection and removal, gridding, surface generation, statistical metadata generation, 3D replay, etc.). It is designed to verify coverage sounding density and provide data quality assurance and was initially validated in simulation before progressing to sea trials.

efficiency is predictable but remains difficult to control by current methods. Analysis of archive datasets indicates 10-15% of survey time is lost through a combination of infill line elimination of holidays and coverage redundancy in areas of overly tight runline spacing.

SonarSim committed to solving this problem by developing a dedicated onboard runline planner which processes the bathymetry data collected during a runline, calculates the optimized multi-segment vessel route to achieve the next runline sounding density desired by the hydrographer, and communicates these vessel waypoints to the onboard autopilot. The primary objectives are to relieve the hydrographer of the low level task of manual runline calculation and the helmsman of manual steerage. The software is more effective at these formulaic tasks while the hydrographer is better suited to supervisory tasks related to quality control and the helmsman to maintaining safety and watch for hazards. The sought after 10-15% efficiency saving can be mined by the computational capacity of the software which can automate this stage of the planning and acquisition workflow, and significantly improve system precision by establishing a novel high performance computing feedback path between the multibeam and the vessel navigation system.

The use of simulation is central to the ongoing R&D effort. Much of the initial test stages could be conducted on a line-by-line basis using archive raw bathymetry files to verify the datagram parsing, terrain geo-referencing, surface reconstruction, and outlier filtering modules required to process the recorded beam data into a seabed representation. However, while the performance metrics of a previous survey can be accurately benchmarked from recorded data, it is not possible to verify the performance of the adaptive runline planning modules without the ability to control the navigation of the survey vessel over successive runlines. This portion of the verification and validation testing requires sea trials, which are currently underway.

Access to vessels and equipment for sea trials during the roll out phase of R&D is a

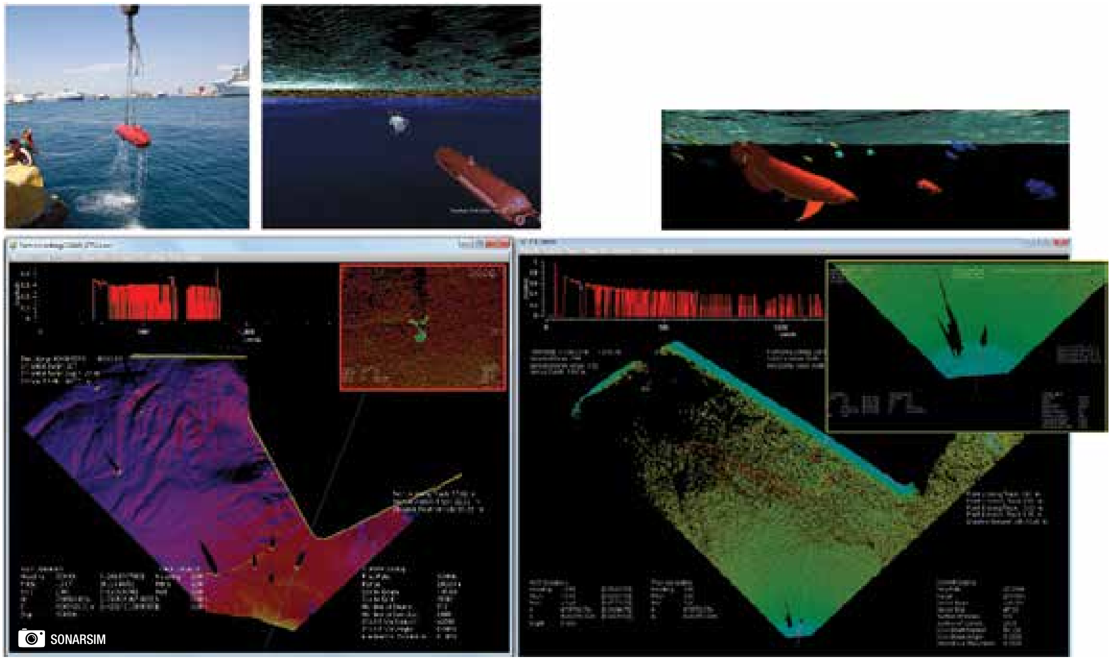


Figure 5: Development of intelligent systems requires simulator intelligence. The forward looking sonar simulator was utilized for development of a diver detection AUV system by BMT UK in the FP7 SUPPORT project which was demonstrated in the Port of Lisbon. The SonarSim-developed project testbed incorporated dynamic and acoustic models of divers, diver gas discharge, fish, passing vessels, as well as a complete port and harbour environment model and autonomous underwater vehicle navigation simulator.

precious resource and for a majority of small organizations requires support from a larger partner institution; in SonarSim's case, the INFOMAR program. Dedicated test vessels are the luxury of very few organizations and time spent mobilizing, integrating, and resolving technical issues at sea typically incurs the opportunity cost of relinquished survey time and can rapidly curtail a planned testing schedule. It is thus crucial that test systems arrive on ship operation ready, which can only be assured through the use of exhaustive simulator testing prior to release. While simulator testing should never displace real-world sea trials, it is an essential component in a hybrid test framework.

SonarSim's long term objective for MAP is to progress the system to ASV and ultimately AUV applications. In tandem, the simulator testbed quality assurance criteria reflect the step change in risk budgets moving from in-situ supervised, to remotely supervised, and on to unsupervised modes of autonomous operation. Simulation as a major driver in AUV/ASV development is outlined in the next section.

Adding Intelligence to Simulations

Simulation can uniquely fulfil R&D test requirements for AUV navigation control, survey runline, target detection and tracking systems which require a plethora of training datasets to achieve supervised and reinforced learning. In 2013 SonarSim was invited to join a Framework Programme 7 European project, "SEcurity UPdate for PORTs" (SUPPORT); see Figure 5. The project scope included developing two AUV systems to detect and track moving object threats in ports via sonar image recognition. The choice of sonar was driven by a low cost bill of materials which could still achieve the necessary fidelity to detect threats in the acoustically noisy cluttered environment of a busy port. The costs and time required to undertake harbour trials made simulation an attractive candidate solution due to the number of training datasets needed in successfully training sonar-based threat detection artificial intelligence.

SonarSim delivered a machine vision support framework to accelerate the design cycle, reduce costs, and offer a level of flexibility and control not available via field trials. The project required the development of novel simulation components for modelling the acoustic signature of schooling fish shoals, mammals, diver gas discharge, diver swim locomotion, moored and passing vessels, port walls, shallow water sea surface reverberation, and seabed backscattering.

Project partner, BMT, identified a number of sonars which fell within initial technical and budget reviews but final decision required an exhaustive what-if simulator scenario analysis of forward looking and mechanically scanning sonar systems. Through an accurate replication of the physical reality, the generated sensor data is driven by a high fidelity physics model, and signal interfaces are characteristic of onboard sensor interconnects, the transition between simulator testing and actual trials was seamless. Accurate simulation of each instrument's operational control and logging in their native formats offered full understanding of system engineering trade-offs for each candidate sonar in terms of data density, number of beams, sampling rate, sonar control flexibility, scanning speed and coherency. Although able to carry out some simple field trials with each sonar, the exhaustive nature of simulation offered a much greater confidence level in final sonar choice. While relevant AI techniques could be identified as the final structure of data acquired, platform motion disturbance, etc. were brought to the fore by initial simulation testing.

Exhaustive simulator runs allowed thousands of execution runs to be completed and used in AI training datasets. Through following simulation driven development, two autonomous underwater vehicles were successfully demonstrated to key stakeholders at the Port of Lisbon on May 22, 2014.

Conclusions

The driver of sonar technology until the 1970s was military investment. From the 1970s on the commoditization of hardware allowed the commercial exploitation of technology which to this point was commercial infeasible. In addition, the 1970s was a time when much of the military research of previous decades was released to the public domain. The separate hardware innovations of digital signal processing, advent of Moore's law, graphics cards, multi-core, and mixed core computational led to specific innovations in marine survey. These technical leaps allowed simulation to move through a number of phases from pure research and development, offline analysis, training of personnel and software algorithms, simulation driven decision making to finally simulation being the driver of fully automated acquisition and processing workflows.

It is possible to utilize simulation across applications, as a platform technology, with the marginal investment in training, support tools, and testbeds diminishing as the technology is introduced into successively new applications. Complementing the enhancements bestowed by simulation in smart pedagogical delivery, simulation can uniquely fulfil R&D test requirements for verifying and validating new technologies designed to improve the smart capabilities of in-the-field operational support tools. As in the context of the personnel training paradigm, once the simulator virtual environment is an accurate replication of the physical reality, the generated sensor data is driven by a high fidelity physics model, and signal interfaces are characteristic of onboard sensor interconnects, the transition between simulator testing and real-world ship trials is seamless.

The capabilities inherent at this stage of simulation technology readiness presents an opportunity for derivative and integrated technologies to emerge which can fulfil a plethora of multipurpose supporting roles such as smart resource planning, scheduling, equipment selection, and performance prediction, thereby maximizing the value added technology output and commercial impact achievable from a common underlying platform; e.g., the simulator allows one to investigate, discover, and demonstrate optimal survey methodology solutions to advanced operational scenarios.

The disruptive move to commercial AUV/ASV systems has increased the importance of simulation in terms of both the training of AI algorithms and increasing system capabilities with simulation as a feedback and feed forward decision-making mechanism during operations. Current AUV/ASV operations are limited by the need to remove systems from the water for task reprogramming and downloading of acquired data. Increasingly complex simulation leads to greater system autonomy through automated data processing, analysis, and decision tree heuristics lessening the need for costly reprogramming; e.g., incorrect manual input of runlines, data gaps, and faults identified only after expensive off-line data processing is complete.

Although the technical challenges to increasingly automated systems are decreasing, a number of other barriers need to be overcome for broad market adoption. Important regulatory and legal responsibility questions need to be considered when humans are taken out of the loop and transition into supervisory and quality control roles. Technology can go through periods of false dawns such as artificial intelligence in the 1990s. While maritime operations are a complex and error prone process, simulation has gone through decades of use across a number of operating domains which gives the technology a strong level of maturity and integrity. The potential move towards self-driving cars and the massive impact it could have on automobile insurance and regulatory requirements, the current explosion in drones and current regulatory flux, and the general global trend to automation all have interesting parallels with the maritime sector. Simulation-driven automation allowing operational tasks to be defined in terms of what needs to be done rather than how to do it will be both a technical and regulatory challenge.

The case studies outlined along with industry trends display how simulation has gone through a number of development phases and by focusing on simulation as a platform feeding into different domains rather than as an add on to each, simulation has moved from limited R&D projects to being the major driver in improving both human and machine capabilities.

Francis Flannery, B.Eng., M.Eng., is a Director and co-founder of SonarSim. He has over 10 years software R&D commercialization experience across multinationals, research organizations, and start-ups. Previous to SonarSim, Mr. Flannery worked in software R&D for both University of Limerick (2008-2010) in sonar simulation and Intel (2005-2008) in cryptography firmware development.

James Riordan, B.Eng., PhD, is a Director and co-founder of SonarSim. He holds a PhD in Computation Ocean Acoustics with a background in Electronic and Computer Engineering and has been engaged in subsea technology R&D since 2002. Prior to SonarSim, Dr. Riordan was a Research Principal Investigator at the Marine Robotics Research Centre at the University of Limerick.

Dr. James Riordan
Director – SonarSim Ltd.

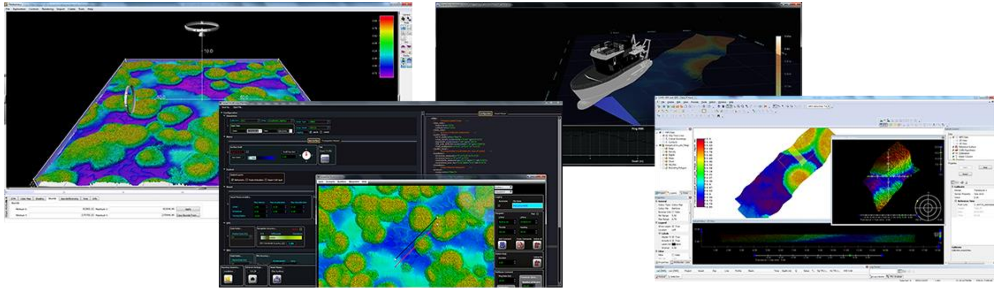
A hydrography training programme demonstrator

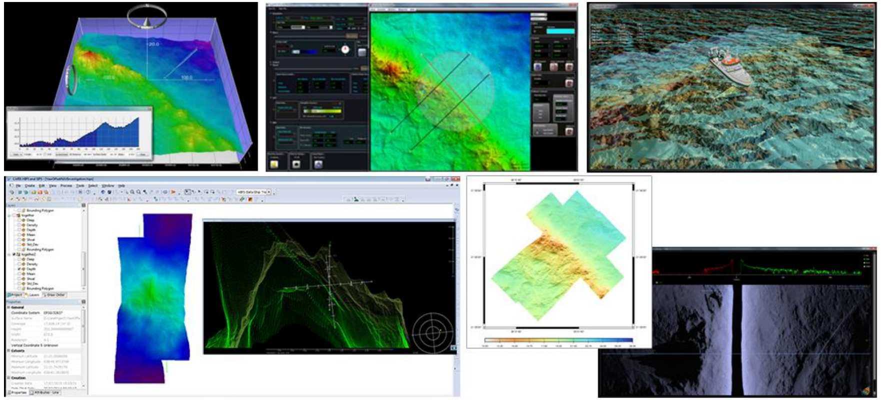
Presentation outline

Context – IHO accredited training snapshot

Project objectives – Transform unique technical-leading demo into unique pedagogical-leading demo

Rationale – strategic importance to Ireland & SonarSim



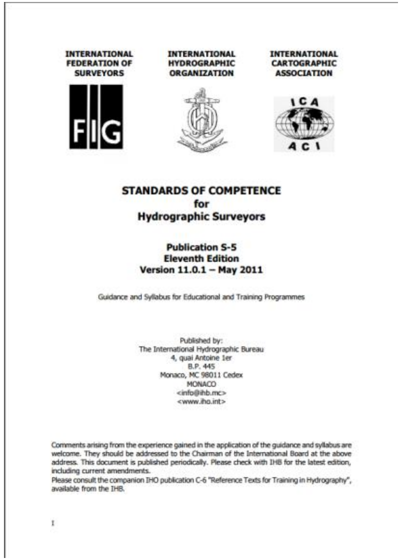


State of the art – SonarSim's Simulation platform

Training demonstrator examples – practical workflow focus

Project Outputs & Impact

Snapshot - IHO Accredited Training



INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE
for
Hydrographic Surveyors

Publication S-5
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Comments arising from the experience gained in the application of the guidance and syllabus are welcome. They should be addressed to the Chairman of the International Board at the above address. This document is published periodically. Please check with IHB for the latest edition, including current amendments.
Please consult the companion IHO publication C-6 "Reference Texts for Training in Hydrography", available from the IHB.

I

82 IHO member states

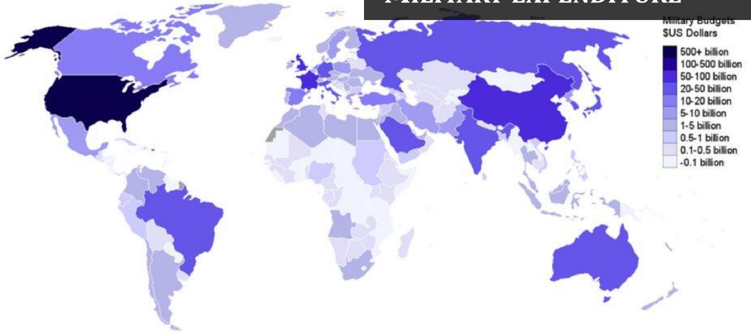
50+ recognised Category A/B programmes in 29 countries

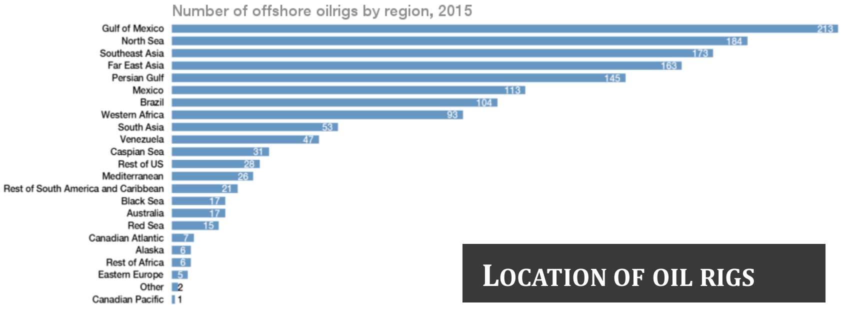
12 weeks minimum for Cat B

Drivers & Indicators of Demand

Catalyst – Large scale public & private procurement
Effect – emergence of strong industrial complexes
Demand – personnel capacity building

Military expenditure

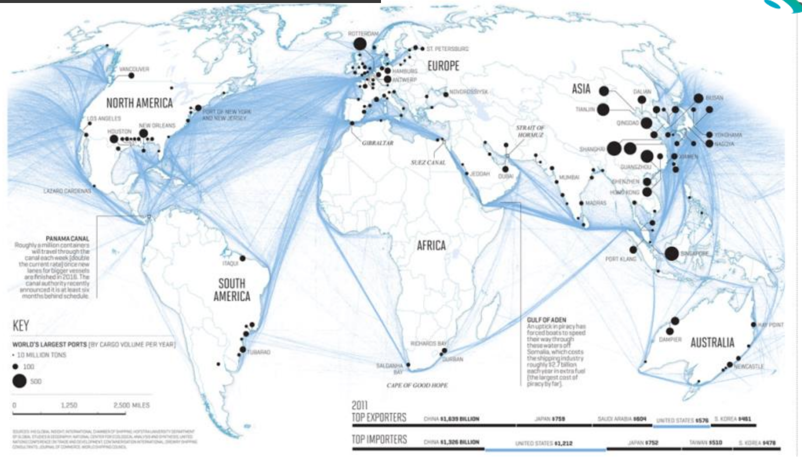


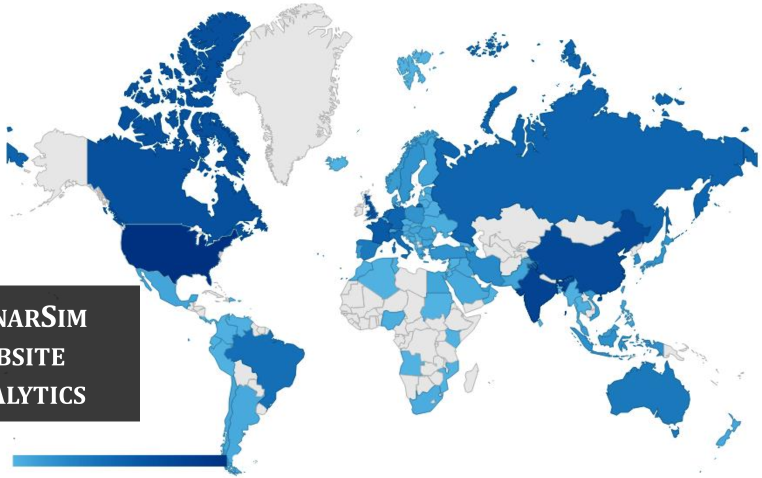


Location of oil rigs

Source: Statista

Global supply chain





SonarSim website analytics

Rationale - Strategic National Importance

Global market for training technology

e-Learning – opportunity to export & lead

Increased ICT employment diversity

STEM outreach – less reliance on big 10

Existing Capacity

Critical mass of infrastructure, equipment, suitable locations, & multi-disciplinary expertise

Potential growth in Ireland's blue economy

The blue economy cannot grow unless we feed it highly educated and skilled workers

Cost Analysis

Benefits of e-learning well established - What about the costs?

Syllabus – 7 essential modules, 7 optional

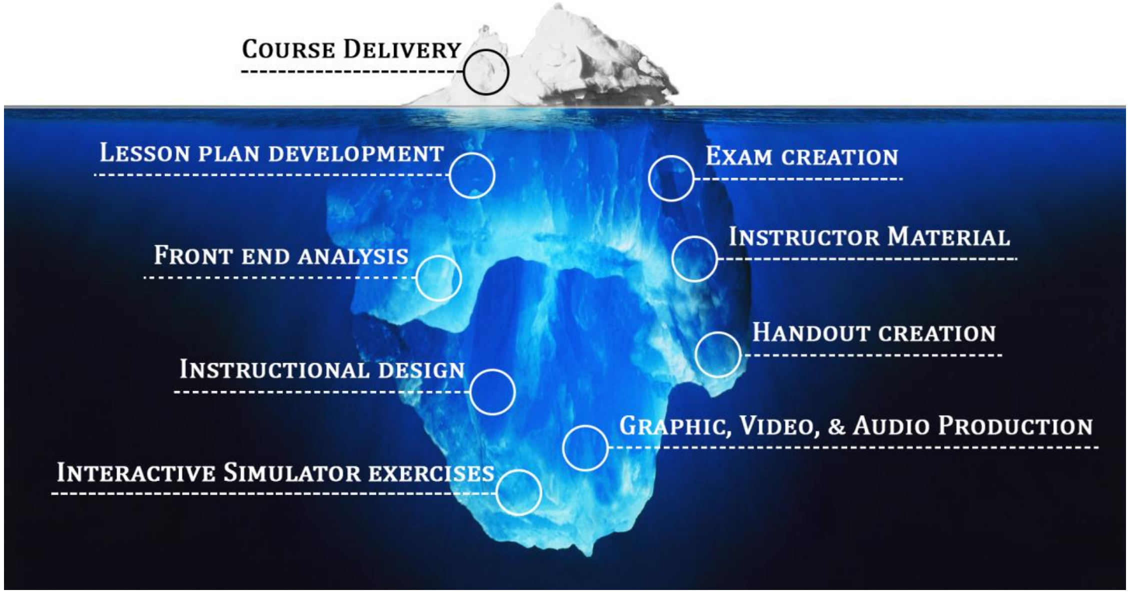
Est 30 hrs teaching content / module

200+ hrs programme content

100-150 hours to generate 1 hour of high-quality e-learning content

Multi-disciplinary team of experts

€65 per hour personnel costs



Minimum €2m learning management system set-up costs

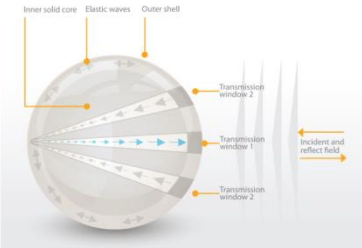
(excl. infrastructure, software, equipment, running costs, etc.)

SonarSim Simulator TRL

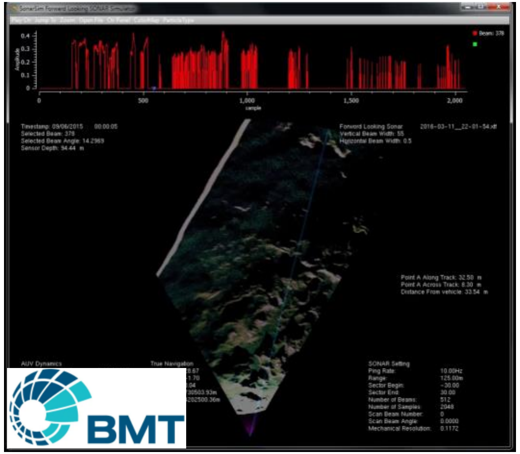
PILOT – KSA IHO academy, Jeddah

General Commission for Survey

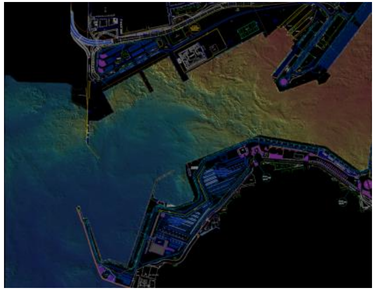
SonaTag



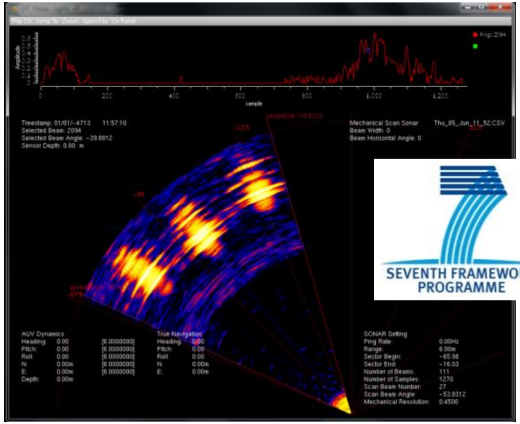
DEMO – Port security AUV



BMT

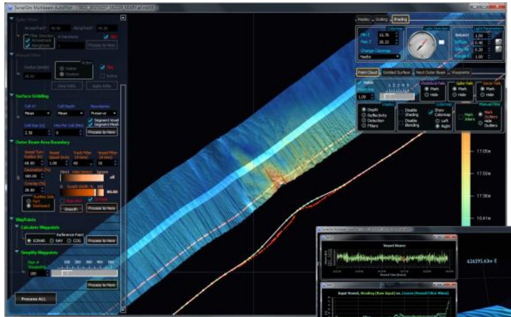


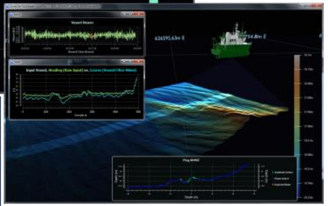
R&D – Oil & gas asset tagging



SEVENTH FRAMEWORK PROGRAMME

DEMO – survey planning as a service





Objectives – Commercialisation Focus

Project Pipeline

Transform technology innovation → disruptive product

- Technical specifications → customer value propositions
- Usability / training dataset / Gamify learning objectives

R&D → **Pilot** → **Demo** → **Mature**

Technological

Commercialisation

Commercialisation Finance

Transition to self-sustaining & scalable product line

- Raise awareness → Dissemination literature
- Marketing → Output demonstrator
- Revenue generation → sales, funding, repurposing

Project approach – adapt to industry trends

Industry Trends

Transition to Shale – Displacement of Offshore Oil
Deepwater exploration on hold industry-wide
Rise of wind – near shore, Shallow water
Expenditure contraction – Job losses – focus on bottom line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Scotland business

Huge drop in oil and gas jobs since 2014

By Douglas Fraser
Business/economy editor, Scotland

27 September 2016 | Scotland business

Share

REUTERS

The number of jobs relying on the UK's offshore oil and gas sector has fallen by more than quarter in the past two years, according to an industry report.

In a second year of severe cuts in cost, the industry is thought to be supporting 120,000 fewer jobs than in 2014.

The annual economic report from Oil and Gas UK shows the impact this year is increasingly on the supply chain.

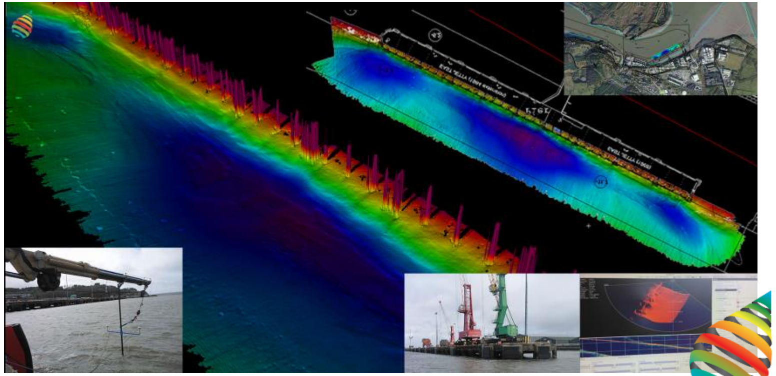
Spending is down by 30% in two years as a result of the oil price fall.

SonarSim strategy

- Focus on projects / applications in the water
- Push towards increased workflow efficiency & automation (cost savings)
- Special emphasis on the technology and problems associated with high-resolution surveys in shallow waters

Execution

- Received donor software from major industry vendors
- Focus on training exercises which demonstrate established survey practices in 3rd party workflow software
- Survey-data task-centric approach to competency based training



Focus on Workflow Processes – Prioritise CPD Training over Education

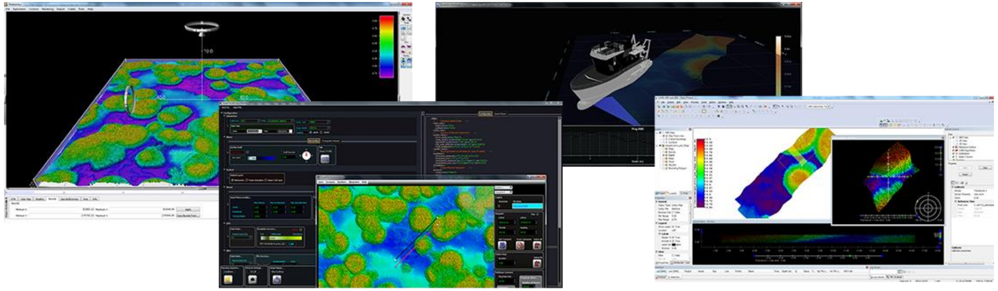
Patch Test

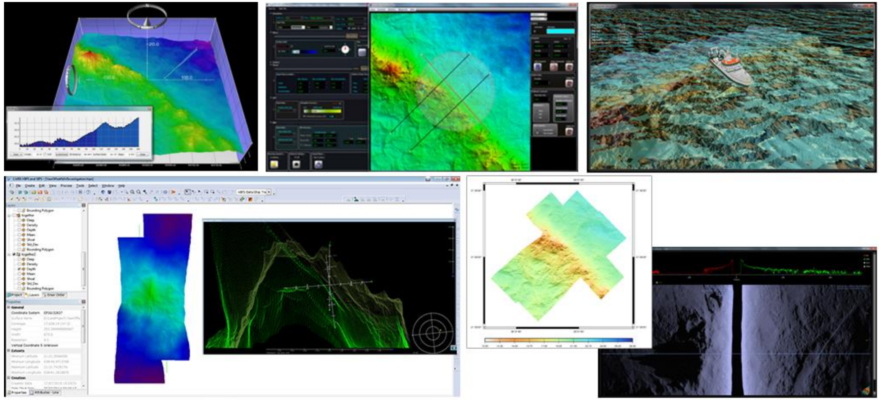
Touches majority of a multibeam data workflow

- Configure vessel
- Import lines
- Merge Navigation
- Clean data
- Generate gridded surface
- Select area for investigation
- Perform calibration
- Apply corrections

Learning: ground-truth available - self-learn correct processing steps

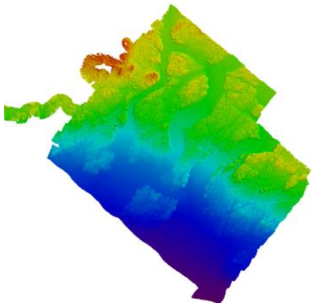
Assessment: Simulator generates datasets with known errors – student's task to find correct values

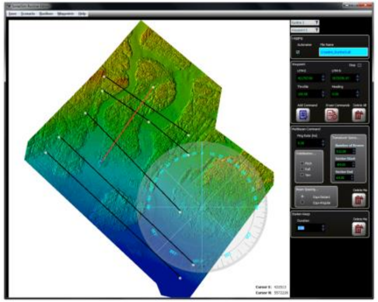




Generated Simulator outputs are readable by industry acquisition & processing software, with supporting ground truth and metadata information

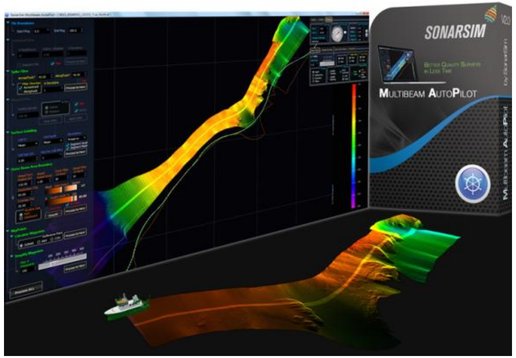
Focus on Survey Planning – high-resolution shallow-water coverage prediction

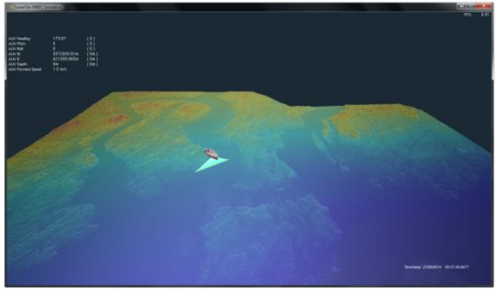


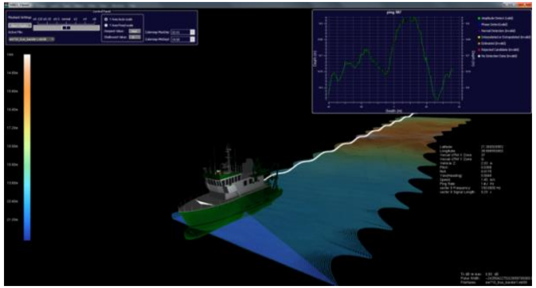


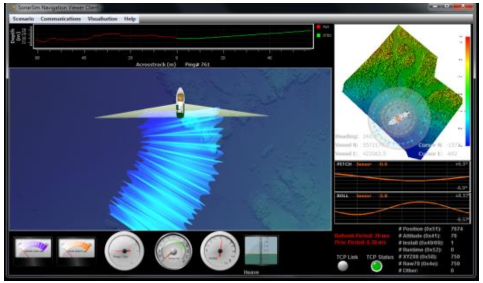
Simulator coupled to runline planning tool

Real-world bathymetry scenarios
Automated runline planning
Cloud deployed platform
Survey planning as a service



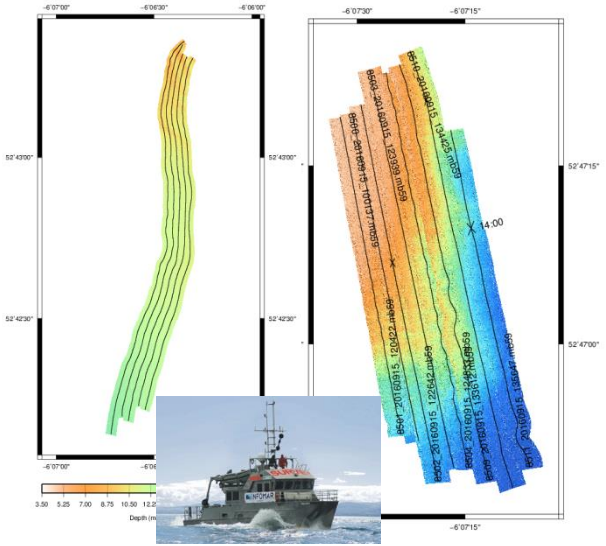






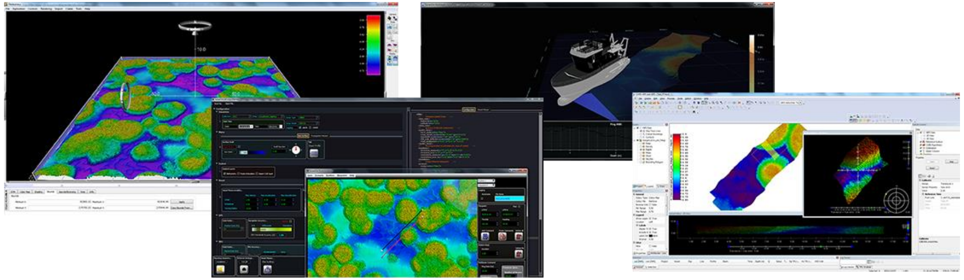
Challenges Addressed

Tender pricing & resource scheduling
Cost effective equipment selection
In-the-field runline regimes
Platform stability requirements
ASV / UUV investigations



Impact – Project outputs & next steps

Programme Demonstrator



SonarSim is the only organisation with demonstrable capability in simulator based hydrographic training

Working with a European Maritime Academy to integrate Simulator into new IHO course submission

Physical training infrastructure – Planned Galway Bay Multibeam Pan & Tilt webcam installation

Cross pollination – Plan to launch MAP & Simulator integration as Survey-Planning-as-a-Service

A number of tender and funding proposals currently out for evaluation

Dissemination

Funding Proposals

SMARTBAY IRELAND

Sfi Discover
Science Foundation Ireland

Business Development

oceanology international 2016
15–17 MARCH 2016, LONDON, EXCEL

Business Intelligence