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The international RIMPASSE ship signature management trial

A close-out report of DRDC engagement in RIMPASSE

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Abstract

This Reference Document reflects upon DRDC's undertaking of the RIMPASSE trial with CFAV QUEST in 2011-12. We provide the context in which the RIMPASSE trial emerged as a joint international effort led by Canada, Germany and the Netherlands. Presenting only the DRDC perspective, we discuss how the collaboration was fostered and the organizing structures to facilitate trial planning, preparation and execution. We describe the level of ship signature capability and identify the path to improved ship survivability from a better exploitation of ship signature control which form the backbone of the motivation for RIMPASSE. The objectives for each of the ship signature experiments comprising RIMPASSE are presented. The extensive preparations in Canada especially in modifying QUEST are recalled followed by a description of the trial execution at ranges in Halifax, in Scotland, in Norway, in Germany, in France and in Sint Eustatius. We recount some of the notable achievements of the RIMPASSE trial and provide an accounting of the investment made in this effort.

Significance for defence and security

Ship signatures and the capability to monitor and manage them in real time may have a profound effect on the planning, execution and eventual survivability of a navy combatant. The RIMPASSE trial recounted in this Reference Document was an international ship signatures trial in which various capabilities on monitoring, measuring, and managing ship signatures were developed. The results from RIMPASSE will lead to improving naval ship survivability when the capabilities and knowledge that is extracted from the data analysis is implemented in capital ship acquisition programs. Requirements for ship signatures, the methods for evaluating compliance through measurement and modeling, and defining the performance of ship signature management systems are the elements that are most likely to influence the ship signature stealth and its real-time optimization for future naval combatants in today's capital ship acquisition programs. This is where RIMPASSE and work that has followed on will have a significant impact.

Résumé

Le présent document de référence traite de la participation de RDDC aux essais RIMPASSE effectués avec le NAFC Quest en 2011-2012. Nous décrivons le cadre dans lequel ces essais sont apparus comme un effort international interarmées dirigé par le Canada, l'Allemagne et les Pays-Bas. Du point de vue de RDDC, nous abordons la façon dont la collaboration a été encouragée et discutons des structures organisationnelles en vue de faciliter la planification, la préparation et la réalisation des essais. Nous décrivons le niveau de capacité de signature des navires et déterminons la voie à suivre pour accroître leur surviabilité par une meilleure utilisation du contrôle de la signature, ce qui constitue le coeur même de la justification des essais RIMPASSE. Les objectifs de chacune des expériences de signature des navires qui constituent les essais RIMPASSE sont présentés. Les longs préparatifs au Canada, en particulier avec la modification du NAFC Quest, sont évoqués, suivis d'une description de la réalisation des essais dans des polygones à Halifax, en écosse, en Norvège, en Allemagne, en France et à Saint-Eustache (Sint Eustatius) dans les Caraïbes. Enfin, nous rappelons quelques-unes des réalisations remarquables accomplies lors des essais RIMPASSE et fournissons un compte rendu de l'investissement dans cet effort.

Importance pour la défense et la sécurité

La signature des navires, de même que la possibilité de les surveiller et de les gérer en temps réel peuvent avoir un effet considérable sur la planification, la réalisation et la surviabilité d'un navire de combat. Les essais RIMPASSE relatés dans le présent document de référence étaient des tests internationaux de signature des navires au cours desquels on a développé diverses capacités de surveillance, de mesure et de gestion de la signature. Les résultats des essais RIMPASSE permettront d'améliorer la surviabilité des navires de guerre lorsque les capacités et les connaissances provenant de l'analyse des données seront appliquées dans le cadre des programmes d'acquisition. Les besoins en matière de signature, les méthodes d'évaluation de la conformité par mesure et modélisation, ainsi que la définition de la performance des systèmes de gestion de la signature sont les éléments les plus susceptibles d'influencer la furtivité de la signature et son optimisation en temps réel chez les futurs navires de combat des programmes actuels d'acquisition de navires principaux. C'est là que les essais RIMPASSE et les travaux qui ont suivi auront des retombées significatives.

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Table of contents

List of figures

List of tables

1 Context & Perspective

Research and development (R&D) projects in ship signatures and ship signature management have been a mainstay in the defence R&D programs of DRDC and her traditional allies for the last two decades. In the latter part of the 2000s, while DRDC collaboration in ship signatures with her US and UK counterparts remained steady, her R&D efforts in ship signature management with her German and Dutch colleagues became increasingly vibrant. Collaboration in defence science between Canada and the German and Dutch national defence organizations dates to bilateral arrangements initiated in the 1960s[1], which were revised in the 1980s and 1990s[2], and have been relatively recently cemented, with respect to ship signatures and signature management, with the acceptance of the Canadian Department of National Defence represented by DRDC as an observer[3] at the German-Netherlands Centre for Ship Signature Management (CSSM).

In the last 5-10 years, there has been a growing conviction in national defence entities in Canada and her NATO and TTCP partners that signatures and signature management are essential components of new ship and submarine projects. Realizing that the R&D defence underpinnings required strong partnerships to deepen the collaborations through the leveraging of unique assets (research vessels, fixed ranges, etc.), knowledge, expertise and finances, Germany and the Netherlands established the CSSM, a permanent DEU-NLD organization, through a Technical Agreement on July 30, 2008 with the tasking "To take all necessary actions in the field of overall ship signatures and ship signature management in order to support the DEU and NLD navy in their role as ship design authority."

Over the same time span, Canada-Germany-Netherlands initiated in 2007 an international workshop in ship signature management, that has since 2008 been adopted and fostered by CSSM as the annual International CSSM Conference on Signature Management Systems. Through this conference (hosted by DRDC in Halifax in 2012 and in Ottawa in 2017), CSSM and DRDC Atlantic have provided leadership in promulgating the advantages of meaningful international collaboration through

[1] The Memorandum of Understanding between the Government of Canada and the Federal Republic of Germany on The Exchange of Information in Defence Science dated 28th September 1964 and the Memorandum of Understanding between the Government of Canada and the Government of the Netherlands on The Exchange of Information in Defence Science dated 3rd October 1960.

[2] The Memorandum of Understanding between the Government of Canada and the Minister of Defence of the Federal Republic of Germany concerning Defence Materiel Cooperation dated 19th August 1992 and the Memorandum of Understanding between the Department of Defence of Canada and the Minister of Defence of the Netherlands concerning co-operation in Defence Science and Technology dated 10th September 1980.

[3] Terms of Reference concerning the granting of observer status to the Department of National Defence of Canada as represented by Defence Research and Development Canada dated 15th September 2011 under the provisions of the Technical Agreement for the Centre for Ship Signature Management.

joint undertakings to address the substantial impending R&D requirements of signature management systems for future naval vessels. Embarking toward this goal in March 2009, CSSM and DRDC Atlantic organized the extraordinarily ambitious and remarkably successful RIMPASSE [1] (Radar Infrared electroMagnetic Pressure Acoustic Ship Signature Experiments) with CFAV QUEST and the German research vessel RV PLANET, trial[4] in Summer/Fall 2011 and Winter 2012. The organization, execution and summary achievements of the RIMPASSE trial, from the perspective of DRDC, are the subject of this paper.

Well before the notion of the RIMPASSE trial was conceived, questions abounded concerning the state of ship signature management research during a visit by a German-Dutch delegation to DRDC Atlantic in March 2006 [5]. While the discussions then were heavily slanted toward acoustic signatures and vibration monitoring, they set into motion the organization of an international workshop with the primary aim to assess the state of the art in existing and conceptual designs of ship signature management systems. With this favorable disposition, the Canadian-German-Dutch organizers invited an assortment of international experts to the 1st International Workshop on Signature Management Systems in Amsterdam in September 2007 [6]. Attended by 54 participants from eight countries, the workshop concluded "A [advanced][5] signature management system as defined and described ... does not yet exist" and proposed to work co-operatively toward developing the substantive elements (monitoring, predictive and management facets of partial signature management systems addressing individual signatures) of a ship signature management system.

In April 2008, again under Canadian-German-Dutch organization, the 2nd International Workshop on Signature Management Systems was held in Berlin [7]. Here, the 44 attendees from seven countries, identified R&D knowledge gaps for each of four platform signatures (acoustic, electromagnetic, infrared and radar cross section) in the development of partial signature management systems. From this meeting it became clear that the R&D knowledge gaps could not be bridged without a dedicated sea trial. The Canadian CFAV QUEST and German RV PLANET were singled out as especially appropriate platforms for testing and developing signature monitoring and management functionalities. It was noted at the workshop that tasks jointly undertaken by various nations would have to be conducted under a mechanism of co-operation such as a NATO task group. Consequently, the perfunctory steps to set up an above water signature management task group under NATO auspices was initiated by the UK resulting in the standing up of NATO SET 154 "Signature Management System for Radar and Infrared Signatures of Surface Ships"[6].

[4] RIMPASSE is comprised of three DRDC QUEST campaigns: Q340 [2], Q342A [3], and Q342B [4].
[5] Author's insertion.
[6] NATO SET 154 had its initial meeting in Spring 2009 and its final meeting in Fall 2012.

With the appetite for a comprehensive co-operative signature management sea trial increasing, a German-Dutch delegation of four experts led by the then CSSM director Capt(N) B.R. Hendriks visited DRDC Atlantic in March 2009 to firm up Canadian interest and initiate discussions on the scope of the trial: the measurement and monitoring of all ship platform signatures (radar, infrared, acoustic, pressure, and electromagnetic) for QUEST and PLANET as appropriate, at ship measurement ranges in Canada and Europe including an extensive campaign for QUEST at the German Earth Field Simulator. With the general trial outlined, discussions turned to data ownership, data sharing and the consolidation of existing efforts. At the time, discussions had already been underway in NATO SET 144 "Mitigation of Ship Electro-Optical Susceptibility against Conventional and Asymmetric Threats"[7] to conduct a sea trial that would in part fulfill the requirements of the signature management trial. Both NATO SET 144 and the DRDC-CSSM collaboration were interested in using CFAV QUEST in light of her previous use in infrared ship signature management trials. It was also noted that while SET 154 had been recently stood up ostensibly for radar and infrared signatures, however, in reality its primary membership and capacity were solely in radar with the infrared expertise to be leveraged through linkages. It was thus clear that DRDC-CSSM would have to engage NATO SET 144 in conducting a joint trial to fulfill the needs of the signature management community and those of the NATO SET 144 membership. Given the potential for competition versus collaboration, Capt(N) Hendriks and the author, presented the trial options at the NATO SET 144 Spring 2009 meeting at The Hague [8]. Though discussions were contentious, we succeeded in engaging NATO SET 144 to develop and lead the infrared signature management portion of the RIMPASSE trial.

Trial planning commenced immediately after the DRDC-CSSM meeting in March 2009. Having already set up NATO SET 154 and engaged NATO SET 144 to provide the requisite international umbrella agreement for joint trial participation, it remained to establish an equivalent group for the underwater signature community. This was agreed upon during the 3rd International Workshop on Signature Management Systems [9] in Amsterdam in June–July 2009 where the decision to propose a NATO SET panel for underwater ship signature management was reached. NATO SET 166 "Signature Management System for Underwater Signatures of Surface Ships"[8] was stood up to enable the international collaboration.

With three CSSM conferences and workshops completed by 2009, the four signature working groups (infrared, radar, acoustics, and electromagnetics) which had assessed the current state of ship signature management, identified deficiencies and knowledge

[7] NATO SET 144 had its initial meeting in Spring 2009 and its final meeting in Fall 2012.

[8] NATO SET 166 had its initial meeting in Spring 2010 and its final meeting in Fall 2013. Covering both acoustic and electromagnetic signatures, this task group was for the most part divided into two subgroups during meetings. It was rather unwieldy and in the future it is likely that two task groups would be established as is in the above water domain.

gaps and had contributed toward the development of the objectives for ship signature management had to integrate with the newly engaged NATO SET groups. The CSSM workshop working groups generally consisted of a broad section of the maritime scientific, technical and operational communities while the NATO SET groups have traditionally consisted of only the nations' defence science community. To the extent possible the working groups and the NATO task groups were amalgamated and were expected to work in unison toward the objectives of the RIMPASSE[9] trial.

It is from this original dichotomy and the complexity of the RIMPASSE trial that an organizational and management structure emerged. It comprised of an overall organizational/managerial leadership, a scientific leadership and a trial execution leadership. The organizational/managerial leadership was jointly held by Capt(N) Hendriks and the author (Dr Daya) with primary responsibility to ensure the complete readiness and agreement of European and Canadian assets and teams participating in the RIMPASSE trial. The scientific leadership necessary in developing the trial experiments was effected through the NATO SET 144, 154 and 166 task groups, while the trial execution leadership was consigned to lead personnel from the signature measurement range offices.

By Summer/Fall 2009, with the trial organizational structure in place and with excitement surging amongst participants, it became necessary to firm up the RIMPASSE trial schedule. With CFAV QUEST the centrepiece of the RIMPASSE trial, it was up to DRDC to reserve the ship for a continuous duration of about 90 days to meet the many requirements of each of the several trial segments. In March/April 2009, the desire was to schedule for Spring/Summer 2010, however, the competition for CFAV QUEST would have been fierce had a significant push been made for the RIMPASSE trial in 2010. Instead, under advisement, the author, the Canadian Lead, withdrew the request for 2010 and firmed up a scheduling for May 2011. With the suggested dates promulgated to all partners, range facilities were reserved by Fall 2009, when in December an upheaval began to unfold: questions had been raised concerning the stability of CFAV QUEST when damaged and following a study, she was ordered alongside indefinitely. CFAV QUEST trials scheduled for the first half of 2010 were effectively canceled and the risk of cancellation for trials thereafter was significantly raised. The RIMPASSE team was informed of these developments, and while noting the increased risk the team pressed on with planning, as advised by DRDC management, despite the uncertainty.

As details emerged through early 2010 on the magnitude of the modifications necessary to restore CFAV QUEST to service, the author, under advisement, requested as a risk mitigation measure that the proposed RIMPASSE trial be rescheduled from the original request of commencing in May 2011 to a revised date of August 2011. Working through the calendar with the RIMPASSE leadership, reservations at all

[9] RIMPASSE was adopted as the trial name at the trial planning meeting in July 2009.

range facilities were re-scheduled to meet the new time-line, then solidly entrenched in the 2011 CFAV QUEST calendar from 3 August to 31 October 2011. By mid-August 2010, the decision to modify CFAV QUEST to alleviate the concerns over her damaged stability had been undertaken and a way-forward was in place: increase of reserve stability (addition of sponsons), modifying the current distribution of displacement (e.g. emptying the anti-roll tanks) and addition of bulkheads. The work was scheduled for late 2010 and early 2011 with an anticipated return to service for April 2011.

Through 2010 and 2011, RIMPASSE trial preparations and planning continued apace. There were many meetings amongst individual national teams and collectively between international partners. The DRDC and Canadian teams met regularly in sub-groups divided by signature area and in total to ensure progress toward readiness. DRDC hosted the Spring 2011 NATO SET 144 and 166 meetings to permit the non-Canadian members of the RIMPASSE team to tour QUEST and to finalize trial planning. Upon closing the trial program development in May 2011, the RIMPASSE trial had the participation of 16[10] countries (Australia, Belgium, Canada, Denmark, France, Germany, Greece, Italy, The Netherlands, Norway, Poland, South Africa, Spain, Turkey, the United Kingdom, and the United States) and about 30 organizations (government agencies and defence contractors). A RIMPASSE logo commemorating the participants and highlighting the major ship assets (QUEST and PLANET) and lead organizations (DRDC, CSSM and WTD71) is shown in Fig 1.

The trial itself commenced with baseline acoustic (June 1–2) and magnetic (July 28) ranging at the Ferguson's Cove and Bedford Basin range sites[11] in Halifax before setting sail for Scotland on 3 August 2011. After acoustic experiments at Loch Goil and Loch Fyne in Scotland, QUEST rendezvoused with the German research vessel PLANET for joint acoustic trials in deep open ocean. They both continued on to Norway for acoustic and multi-influence trials which they completed in turn at the Heggernes and Herdla ranges. Thereafter, QUEST and PLANET sailed to the Kiel area in Germany, where QUEST was depermed in early September at Friedrichsort-Moltenort range while PLANET docked at her home port. QUEST proceeded after the deperming treatment to Surendorf where she conducted above water signature (radar and infrared) experiments for two weeks during which she launched many decoy flares. At this time, the mid-point of the RIMPASSE trial, ball caps (shown in Fig 2) sporting a RIMPASSE logo were distributed to the participants all of whom were invited to a dinner in Kiel courtesy of CSSM.

[10] In the trial itself 15 of the 16 countries participated with Spain, a member of NATO SET 144 not joining.

[11] Information regarding the range sites Ferguson's Cove, Bedford Basin, Loch Goil, Loch Fyne, Heggernes, Herdla, Friedrichsort-Moltenort, Surendorf, Aschau, Schirnau-Borgstedt-Bünsdorf, Brest and Sint Eustatius can be found in Refs [1, 3].

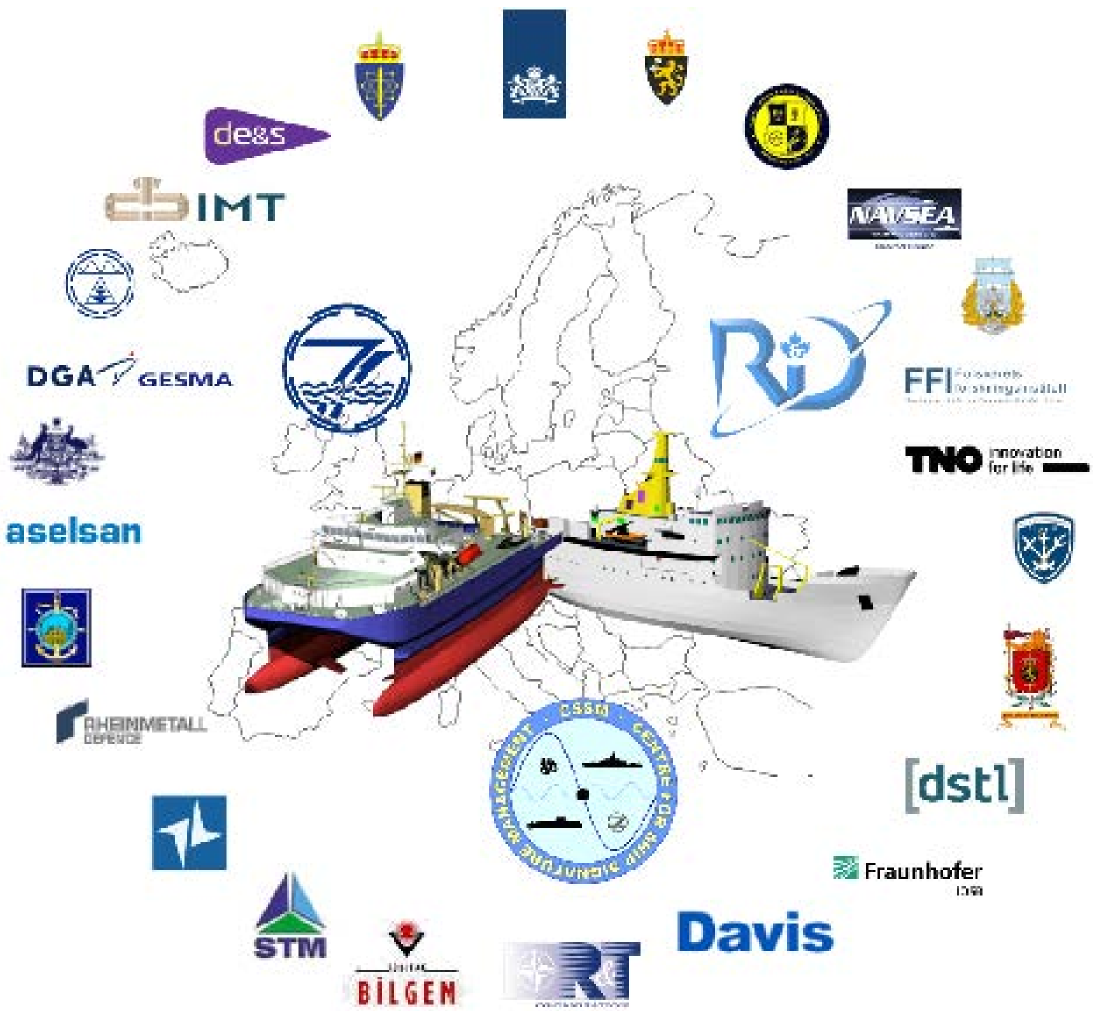

Figure 1: *The RIMPASSE logo consisting of the logos of individual participants and model images of the two ships splayed across a map outline of Europe.*

Figure 2: *The RIMPASSE ballcap distributed to about 300 participants at the mid-point of the trial.*

After the above water trials were concluded, PLANET rejoined QUEST at Aschau for multi-influence trials in late September. QUEST then proceeded to the Earth Field Simulator at Schirnau-Borgstedt-Bünsdorf for a week of magnetic experiments. While QUEST sailed through the Kiel canal, PLANET went through the Baltic Sea, to rendezvous in Brest, France for a final sequence of underwater signature ranging in mid-October. QUEST set sail from Brest on 19 October and arrived in Halifax on 31 October having completed the core trial. Post trial ranging in Halifax was undertaken on 21–22 November with deployed portable sensors alongside the fixed magnetic range. And finally, a magnetic ranging at a latitude relatively southern to the rest of RIMPASSE, was completed in early February 2012 with QUEST measured by a Dutch deployable portable ranging system at Sint Eustatius in the Netherlands Antilles.

All told, during the RIMPASSE trial, QUEST was deployed five times for a total of 108 days at sea (103 days away from her home port), of which 43 days were on station at ranges and PLANET had two deployments for a total of 36 days at sea, of which 14 days were dedicated to trials. The overall success was judged to be excellent: the RIMPASSE trial was largely free of incidents, did not suffer from significant delay, and met the on-board and off-board data collection objectives at better than 90%.

Data collected by various teams at the range sites in different countries, and the data that were recorded on-board QUEST and PLANET, were collected and distributed as needed. Analysis of the data has been on-going since the end of the trial. Results have been reported at NATO SET meetings and at several conferences including Undersea Defence Technology 2012, European Conference on Underwater Acoustics 2012, Marine Electromagnetics Conference 2011 and 2013, the Electromagnetic Silencing Symposium 2012 and the CSSM 5th through 7th International Conferences on Signature Management Systems. Of the latter conferences, the 5th was organized by DRDC in October 2012. It was held at the Canadian Maritime Warfare Centre in Halifax where Commodore Daniel Sing presented a keynote address "Canadian Surface Combatant (CSC) and the case for signature management therein" to an audience that was comprised of 99 scientific staff from 12 countries. In commemorating the RIMPASSE trial, laminated prints of a RIMPASSE poster (shown in Fig 3) were distributed to all conference participants. Since then, a retrospective video narrative that captures the motivation, the spectacle of RIMPASSE trial experiments, the significance and the expected pay-off has been created under funding from DRDC for broader distribution[12] to the public.

[12] Distribution of the video retrospectives by posting on a DRDC web-page is currently stalled pending the creation of English and French transcripts for the hearing impaired.

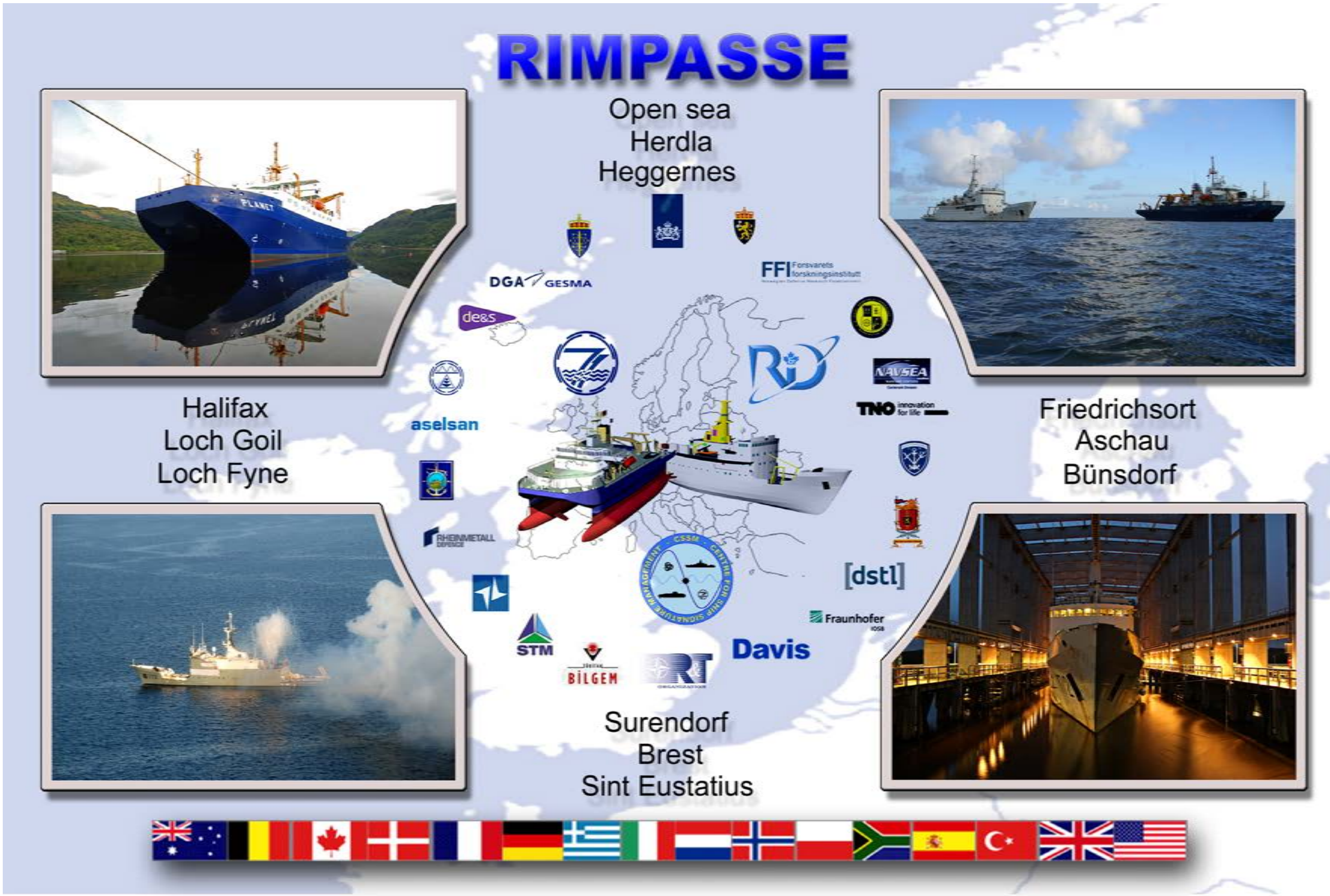

Figure 3: *A RIMPASSE poster commemorating the trial distributed to attendees of CSSM's 5*th *International Conference on Signature Management Systems.*

2 Motivation and Objectives

Ship signature management, as a research and development subject, is faced with a broad and varied set of challenges primarily because of the many interacting components that make up the ship-threat environment schematically shown in Fig 4. The division of this picture into ships and threats, underwater and above-water environments, and operations and countermeasures, underlines the range of expertise that is necessary in developing an all-encompassing ship signature management program. This swath of technical expertise coupled with generally inadequate resources have resulted in pockets of specialization in different countries without the proper and useful integration of the various elements into a ship signature management system.

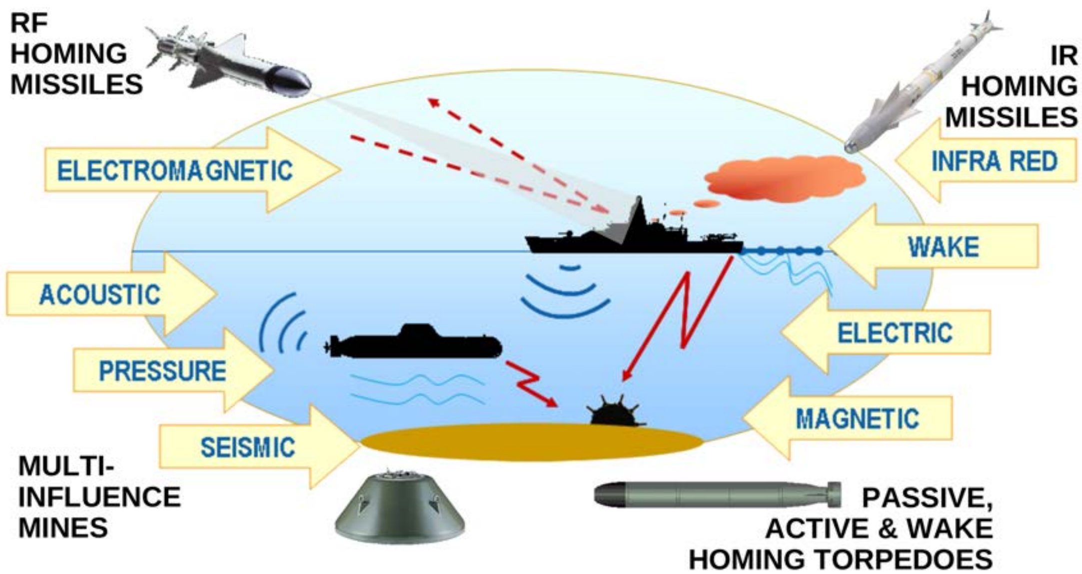

Figure 4: *A schematic of the ship-threat environment emphasizing the role of ship signatures.*

Whereas ship signature research has been ongoing for many years and much progress has been realized on understanding individual signatures, advances in overall signature management as an on-board system integrated with other ship systems have been lacking. Through regular collaboration and consultation between DRDC and her international partners, particularly Germany and The Netherlands it became clear that a joint strategy was needed to assess the existing state of ship signature management research and to provide the necessary momentum to spur advances. The workshop element of the CSSM conferences on signature management systems from 2007 to 2009 [6, 7, 9] was where teams of international experts debated the vision for ship signature management identifying the current state of development, the eventual goal and consequently the necessary intermediate steps. There was such a striking concordance between the vision espoused by individual nations that it was easy to establish a common vision for ship signature management research. The chart, Fig 5, shows the increase in ship survivability with anticipated developments in ship signature management capturing the common vision for the functionality of an on-board operational signature management system.

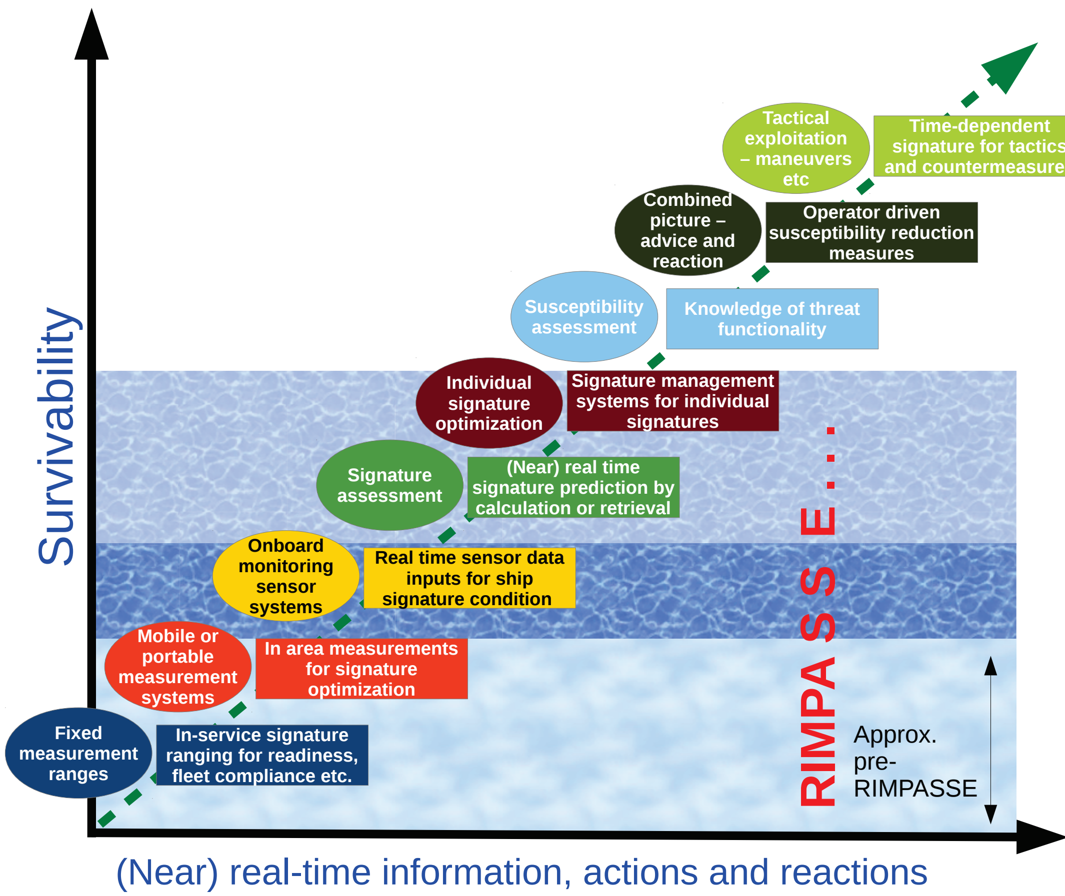

Figure 5: *A chart illustrating the anticipated developments in ship signature management systems and research. The research and development capabilities pre-RIMPASSE (light blue background), and the substantial (deep blue background) and partial (intermediate blue background) advances achieved in RIMPASSE are indicated.*

With a common vision and a clear goal, the path toward developing an on-board operational signature management system was mapped noting the intermediate capabilities. Hence the fundamental functionalities of an on-board operational signature management system consisting of on-board monitoring (ship and environment), signature prediction and susceptibility assessment in near real time, and signature control and optimization (automatic and operator driven), were mapped into almost self-contained modules. Experts at the CSSM workshops had described prior to 2009 their expectations of these modular capabilities and the scientific development (experiments and trials, modeling and computation) that would be required to advance ship signature management research. The motivation for the RIMPASSE trial grew from these capability gaps.

When the RIMPASSE trial was proposed in 2009-10, the primary motivation was to demonstrate the current state of the art in ship signature management (measurements, monitoring, reduction/optimization) and to obtain a comprehensive data set so as to favorably position the subject of ship signature management to be propelled forward. One of the notable deficiencies in ship signatures research was the uncertainty inherent in comparing results obtained from different ship platforms in different environments. The RIMPASSE trial would allow for invaluable data to be collected for two ship platforms in several environments over a relatively short period of time. Such a consistent data set is expected to reduce uncertainty due to environment and different ship states and so be very important to validating existing ship signature prediction models, developing new ship signature management models or algorithms and for developing ship signature and signature management system requirements.

From the foregoing motivation originates the overall objective of quantifying the effectiveness of several ship signature management (monitoring, control and prediction) systems and concepts. This overarching goal was expected to be met by objectives for each of the individual signatures under categories of signature measurements, on-board monitoring, real-time susceptibility assessment, and signature management systems. These objectives are summarized in Tables 1 and 2 for the above water and underwater signatures.

The RIMPASSE objectives and in particular the functional capabilities yet to be attained, show that in RIMPASSE we had accumulated the most pressing challenges in ship signatures management. In comparing to the pre-RIMPASSE years, the attainability in ship signature research was mainly restricted to fixed measurement ranges, some testing with mobile or portable sensors or from airborne platforms. With RIMPASSE came a distinct step forward in wide-scale on-board monitoring (some on-board monitoring for infrared signatures and hull and machinery vibration pre-dates RIMPASSE) and individual signature optimization (not a balanced or multiple signatures approach). The trial served to facilitate the collection of data necessary to develop the capabilities for real time signature prediction, the consequent susceptibility assessment and signature optimization. These technical competencies when developed are essential ingredients of an operational ship signature management system.

The objectives set out for the RIMPASSE trial were very ambitious and could simply not be attained by individual partner nations. A deep and extensive collaboration was necessary to leverage unique assets and capabilities existing within a small number of the different partners (Canada and Germany deserve special mention) for the mutual benefit of the entire collaboration. Canada through DRDC availed the use of CFAV QUEST as the principal test platform which was highly desirable for several reasons: she is acoustically quiet, equipped with degaussing and infrared signature management systems, well characterized from previous trials with several ship signature models already developed, etc. Germany through WTD71, in addition to engaging the secondary test platform PLANET (also very quiet acoustically and well characterized in previous trials), provided access and services of the Earth Field Simulator (EFS) at Schirnau-Borgstedt-Bünsdorf (a unique magnetic ranging facility) and other fixed ranging facilities in Eckernförde Bay.

Table 1: *A summary listing of the RIMPASSE trial objectives for each signature management system functionality organized by individual above water signatures.*

Signature	Function	Objectives
Radar cross section	Signature measurements	–high resolution radar cross section (RCS) measurements over a wide frequency band for various ship configurations in support of model validation; –evaluate the effectiveness of radar absorbing and radar reflective materials; –evaluate the effect of hull infrared signature cooling on RCS measurements.
	On-board monitoring	–Nil
	Real-time susceptibility assessment	–Nil
	Signature management systems	–Nil
Infrared	Signature measurements	–full ship and plume infrared (IR) signatures in high resolution short, mid and long wave IR imagery and by fourier transform IR spectroscopy.
	On-board monitoring	–demonstrate extended monitoring and a real time transmission capability of selected environmental sensors and hull temperatures.
	Real-time susceptibility assessment	–Nil
	Signature management systems	–effectiveness of the IR ship signature management system (hull and plume cooling systems) to detection and tracking by IR imaging seekers; –effectiveness of decoy flares with and without the IR ship signature management system; –demonstrate control of extended hull cooling system and test and develop control loop algorithms for hull and plume cooling signature reduction systems.

The objectives for magnetic signatures in signature measurement and on-board monitoring in the RIMPASSE trial were a significant advance on the signature management capability of QUEST. The de-perming treatment at the Friedrichsort-Moltenort range in Germany opened avenues of research, particularly in degaussing, that had previously been closed due to the forbiddingly strong permanent magnetization of QUEST. The trials in the EFS, where QUEST would penetrate and rest at the center of a large cylindrical arrangement of current carrying coils, would offer a pioneering research opportunity for the global ship magnetic signature community. The EFS enables measuring the magnetic signature of the ship as if it were in any location around the world but much more importantly, it provides the only means for a direct measurement of the permanent magnetization component of the ship magnetic signature. This decoupling of permanent and induced contributions to the total magnetic signature is the crux of developing models, algorithms and technologies for closed loop degaussing, a much desired transformation of a well understood technical concept into a realizable technological capability.

The objectives for infrared signatures in signature measurement, in on-board monitoring and in signature management systems for the RIMPASSE trial were addressed by a rare opportunity to collect IR imaging seeker and radiometric focal plane array camera data of steady state and transient signature behavior of QUEST with her signature management systems operational and with flare countermeasures. Germany provided the use of the Surendorf test site, flare countermeasures and a decommissioned IR imaging seeker. Surendorf is an ideal site for IR measurements allowing for long lines-of-sight with sea and land backgrounds, a controlled air space permitting the deployment of decoys and flares, several shore-based observation posts at different elevations, has low levels of external light at night, and is well equipped with a suite of sensors for measuring meteorological ground truth. The objectives of the radar cross section signature largely focused on obtaining a common data set from extensive RCS measurements of QUEST configurations at Surendorf from various radar systems thus encompassing the different bands, polarizations and resolutions. The comprehensive data set is expected to facilitate the accurate identification of scattering centres and other superstructure clutter, and serve as the common data set for model validation for the various modeling tools and methods.

The objectives of the acoustic radiated noise signature, in particular, the development of transfer functions dependent on environment (shallow, confined, deep, etc.) would be accomplished by ranging the QUEST and PLANET under pre-determined machinery configurations and engine states, at several fixed ranges in different countries. Pressure signatures would be measured during acoustic ranging. The objectives of the underwater electric signature at Aschau range in Germany and Brest range in France would constitute a first measurement of QUEST's underwater electric field and electric potential signature at a fixed range site with results guiding model development and gauging the effectiveness of the advanced active shaft grounding system.

Table 2: *A summary listing of the RIMPASSE trial objectives for each signature management system functionality organized by individual underwater signatures.*

Signature	Function	Objectives
Acoustic radiated noise	Signature measurements	–obtain a data set for the development of acoustic signature prediction, monitoring and management including specifically the development of transfer functions by using controlled on-board noise sources; –evaluate dependence of the ship acoustic signature on the environment at different fixed ranges to improve the use of mobile range systems.
	On-board monitoring	–demonstrate the measurement of on-board noise sources by measuring three axes vibrational accelerations of structural and machinery elements over a wide range of frequencies.
	Real-time susceptibility assessment	–Nil
	Signature management systems	–Nil
Pressure	Signature measurements	–measure the pressure signature for various sea states, water depths and ship speeds in order to develop and validate pressure signature models.
	On-board monitoring	–Nil
	Real-time susceptibility assessment	–Nil
	Signature management systems	–Nil
Magnetic	Signature measurements	–pre and post de-perm magnetic signatures; –measurement of the permanent magnetization; –simultaneous measurement of on-board magnetometers and off-board magnetic signatures; –measurement of eddy current magnetic signatures; –benchmark mobile ranging systems by collocating them at fixed ranges during signature measurements.
	On-board monitoring	–demonstrate the capability to measure and view in real time three axes magnetometer and accelerometer readings from several distributed sensors; –demonstrate the capability to monitor the electric current in the degaussing system.
	Real-time susceptibility assessment	–Nil
	Signature management systems	–determine optimal degaussing system settings.
Electric	Signature measurements	–obtain a data set on the electric signature for various electric currents between the ship hull and propeller.
	On-board monitoring	–demonstrate the capability to measure and view in real time electric current flowing into the sea water due to corrosion and corrosion protection systems.
	Real-time susceptibility assessment	–Nil
	Signature management systems	–evaluate the performance of the advanced active shaft grounding system.

3 Trial Planning, Preparation and Execution

In broad terms trial planning centers around determining the experiments that need to be carried out and the facilities that need to be engaged in order to furnish the data required to meet the trial objectives. Trial preparation, on the other hand, is dedicated to ensuring that the planned experiments can be safely and successfully conducted. Trial execution is the actual carrying out of the experiment. Trial planning for the RIMPASSE trials was largely undertaken by the CSSM-DRDC leader team and the NATO SET task groups. Trial preparations were undertaken by the owners of the ship assets and measurement ranges and trial execution was a joint effort by range and ship complements. While many participants were involved with just one of these three tasks, the inherent connectivity between planning, preparing and executing required several scientific leaders to be engaged in all three stages.

Table 3: *The RIMPASSE trial planning teams.*

Team and Function	RIMPASSE lead members	Meeting schedule
RIMPASSE Lead: schedule, master trial plan production, regulations, oversight.	Capt(N) B. R. Hendriks (CSSM, NLD) and Dr. Z. A. Daya (DRDC, CAN)	March 2009 (DRDC, CAN), July 2009 (Marinearsenal, NLD), September 2009 (DRDC, CAN), March 2010 (DRDC, CAN), October 2010 (DSTL, UK), October 2010 (DRDC, CAN), April 2011 (DRDC, CAN).
NATO SET 144: Infrared signature trial planning.	Chair: Mr. D. Fraedrich (NRL, US) DRDC: Dr. Z. A. Daya WTD71: Dr. B. Rasch	April 2009 (TNO, NLD), October 2009 (DRDC, CAN), April 2010 (WTD71, DEU), September/October 2010 (DSTL, UK), April 2011 (DRDC, CAN).
NATO SET 154: Radar cross section signature trial planning.	Chair: Dr. F. M. Talbot (DSTL, UK) DRDC: Dr. S. R. Legault WTD71: Dr. B. Rasch	April 2009 (DSTL, UK), October 2009 (TNO, NLD), April 2010 (WTD71, DEU), September/October 2010 (DSTL, UK), April 2011 (TUBITAK, TUR).
NATO SET 166: Acoustic radiated noise signature trial planning.	Chair (Overall): Dr. C. A. F. de Jong (TNO, NLD) DRDC: Mr. L. Gilroy DSTL: Mr. Ian Cowie WTD71: Mr. L. Kätow, Mr. S. Schäl DGA/DT/GESMA: Mr. B. Lucas DMO: Mr. D. Rog	July 2009 (Marinearsenal, NLD: CSSM working group, pre-dates SET 166), April 2010 (CSSM, DEU), September/October 2010 (DSTL, UK), April 2011 (DRDC, CAN).
NATO SET 166: Electric and magnetic signature trial planning.	Chair (EM): Mr. T. Richards (DRDC, CAN) DRDC: Mr. J. B. Nelson FFI: Mr. M. Nakjem WTD71: Mr. T. Krämer, Mr. S. Schäl DGA/DT/GESMA: Mr. B. Lucas DMO: Mr. D. Rog	July 2009 (Marinearsenal, NLD: CSSM working group, pre-dates SET 166), April 2010 (CSSM, DEU), September/October 2010 (DSTL, UK), April 2011 (DRDC, CAN).

Trial planning for the RIMPASSE trial commenced in Spring 2009 with the tentative agreement between CSSM and DRDC on the general scope and time schedule. The

NATO SET 144 and 154 groups were engaged and the NATO SET 166 group was created to take over trial planning from the CSSM conference underwater working group. In each of the NATO SET groups, DRDC was represented by scientists to ensure that the trial plans being formulated addressed Canadian objectives and were experimentally feasible. In addition range site leaders were also members of the NATO SET groups and were fully engaged in the development of trial experiments. Contractors and other specialists were invited to some of the planning meetings to contribute their expertise. In Table 3 we have listed the meeting schedules of the RIMPASSE lead and NATO SET trial planning teams as well as the names of key RIMPASSE leaders. In addition to these trial planning meetings, video conference calls were used to discuss progress between smaller number of RIMPASSE participants.

While RIMPASSE trial planning was very much an international co-operative activity, trial preparations were distinctly national responsibilities. As such preparatory measures for the ship assets QUEST and PLANET were the sole responsibilities of Canada and Germany. Similarly, arrangements at range sites were to be made through the hosting nation's representatives. Since QUEST was the primary test platform, significant preparatory work had to be undertaken to have her ready for the trial. In particular, QUEST had to be modified so as to be able to enter the Earth Field Simulator, she had to be equipped with an on-board system of magnetometers, accelerometers and temperature sensors, and with extensive hull water film cooling and plume cooling systems.

In Table 4, we have summarized the main modifications and installations on QUEST for the RIMPASSE trial. Preparations undertaken by other partners are not described in detail here though they are substantive undertakings in preparing PLANET, several fixed ranges in various countries, and a handful of mobile systems. Some of the other preparatory undertakings included preparing and mounting shakers on QUEST, testing mobile measurement systems, developing and updating ship models (geometry and finite element versions), dry-run of the EFS configurations, etc. Preparatory costs for materials and equipment, but excluding salary and labour, to DRDC was about $500k during the lead up to the trial. In addition, leverage of services through DND in-service agreements was about $100k, excluding salaries and labour, and in particular zero-costing of the lease of two high-pressure, high-water-flow centrifugal pumps for the IR signature reduction system. The DRDC planning and preparation teams and primary members are listed in Table 5.

Table 4: *Modifications and installations on QUEST for the RIMPASSE trial.*

QUEST modification or installation	Requirement/Function	How accomplished
Installation of a bolted connection on the ship mast and documenting a manual for mast reconfiguration.	The full height of the ship mast exceeds the maximum permissible height for entry to the Earth Field Simulator. The ship mast was thus required to be detachable at about 3m from the top.	Engineering Change Specification undertaken by SNC-Lavalin under the in-service support contract at a cost of approximately $43k (pre-tax) [10, 11]. See Fig 6 for an engineering drawing of the new bolted connection.
Installation of an on-board magnetometer sensor chain.	Magnetometers distributed in the ship and a simultaneous sampling acquisition system were required to measure the on-board variation of the local magnetization in support of research to develop closed loop degaussing technology.	Development of the system undertaken by Omnitech Ltd under an R&D contract at a cost of approximately $195k (pre-tax). Installation on QUEST completed by DRDC personnel.
Removal of existing and installation of new degaussing system power supplies.	Existing QUEST degaussing system power supplies were manually operated constant current sources and had to be replaced with programmable, variable current high precision DC power supplies.	Purchased and installed by DRDC and DND personnel. Purchase cost was approximately $20k (pre-tax).
Installation of an advanced shaft grounding system.	Monitoring of shaft-to-hull voltages and suppression of shaft electric signatures through passive and active grounding of the shaft.	Developed, designed and constructed in-house at DRDC at a cost (materials and electronics) of approximately $25k (pre-tax).
Modification of the ship portside and funnel paint schemes.	Infrared signature experiments required a dark grey portside paint scheme so as to increase the infrared contrast, and mimic grey war ships, in studying the efficiency of infrared reduction technologies.	Completed by Fleet Maintenance Facility Cape Scott through a standing offer to MacKinnon & Olding at a cost of approximately $59k (pre-tax) with no net cost to DRDC.
Installation of a sea water delivery system.	The active hull cooling system, an infrared signature reduction technology, required the controlled delivery of a film of sea water to the port hull.	Specification of sea water system requirements completed under contract by W.R. Davis Engineering Ltd at a cost of approximately $55k (pre-tax). Plumbing and nozzles purchased by DRDC at a cost of about $8k (pre-tax) and assembled by DRDC and ship personnel. Off-board water suction inlet and distribution system Engineering Change Specification completed by SNC-Lavalin under the in-service contract at a cost of approximately $50k (pre-tax) [12]. Two centrifugal pump units were borrowed through the Canadian Forces Supply System at no cost to DRDC. See Fig 7 for an engineering drawing of the overall sea water supply installation.
Installation of an infrared masking structure.	Portside superstructure had to be masked to provide a controlled viewing surface for infrared experiments.	Masking system designed in-house. Materials (cable, winch and metal stock) purchased (approximately $5k), stanchions machined and built in-house. Canvas curtain fabricated by the Sail Loft Shop at Fleet Maintenance Facility Cape Scott with no net cost to DRDC.

Table 4: *Modifications and installations on QUEST for the RIMPASSE trial.*

QUEST modification or installation	Requirement/Function	How accomplished
Installation of breezeway covers.	Portside breezeways had to be bridged from bottom to top to provide a controlled viewing surface for infrared experiments.	Climatite covers were prepared by the Sail Loft Shop with hooks welded to QUEST's breezeways by the Plate and Boiler Shop both at Fleet Maintenance Facility Cape Scott with no net cost to DRDC.
Installation of the vibration and cavitation monitoring system.	Measurement of accelerations of the hull and internal machinery for cavitation monitoring.	Upgrades to the existing DRDC system included hardware and software components for an approximate cost of $10k (pre-tax).
Installation of radar absorbing and radar reflecting materials.	Configurations for radar cross section experiments required the application of radar absorbing and radar reflecting materials on selected ship structures.	Radar absorbing mats and radar reflecting sheets provided by UK DSTL, at no cost to DRDC, were fastened into the required configurations on the day preceding the measurement by RIMPASSE SET-154 team members and ship personnel.
Installation of a differential GPS system with radio telemetry.	Provision of real time position information and other meta data measured on-board QUEST to measurement teams at range sites.	GPS units, serial radios and antennas were purchased and assembled in-house into a DPGS telemetry system supplemented with meta data from ancillary sensors. The hardware cost approximately $50k (pre-tax).
Installation of a data storage system.	Data storage and backup system for all data collected on-board QUEST during the trial.	A data storage system consisted of mirrored backup system with total storage of about 20 terabytes was installed at a cost of approximately $15k (pre-tax).
Certification of a pyrotechnics storage locker and the provision of two flare launcher platforms.	IR decoy flares were to be launched to test the effectiveness of the IR hull water cooling suppression system.	Storage locker was certified for the Rheinmetall flares and two platforms were built to mount the flare launchers in fore and aft locations on QUEST. A standard operating procedure was developed.[13]

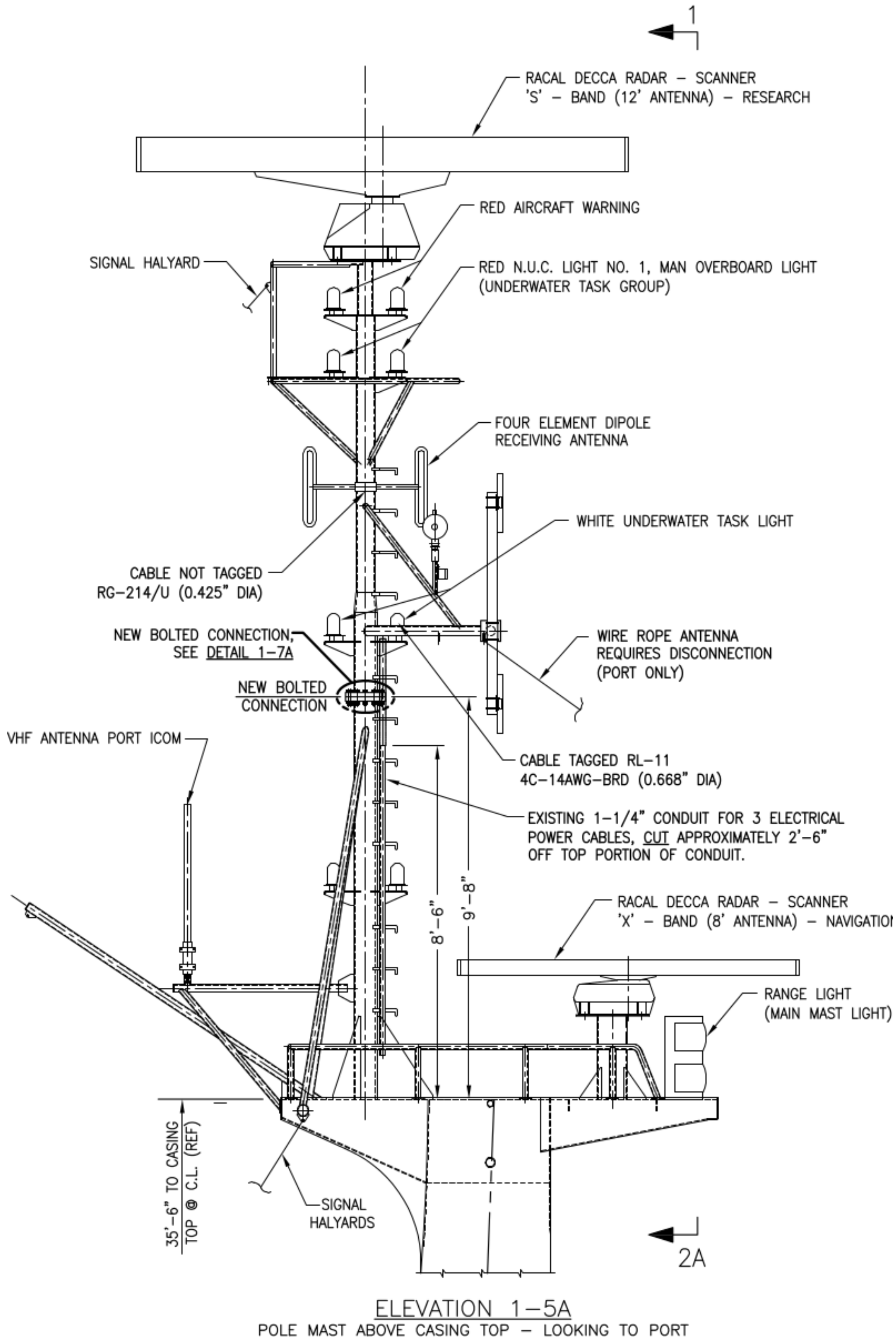

Figure 6: *An engineering drawing from Ref [10] showing the new bolted connection required for unmounting the upper part of the QUEST mast.*

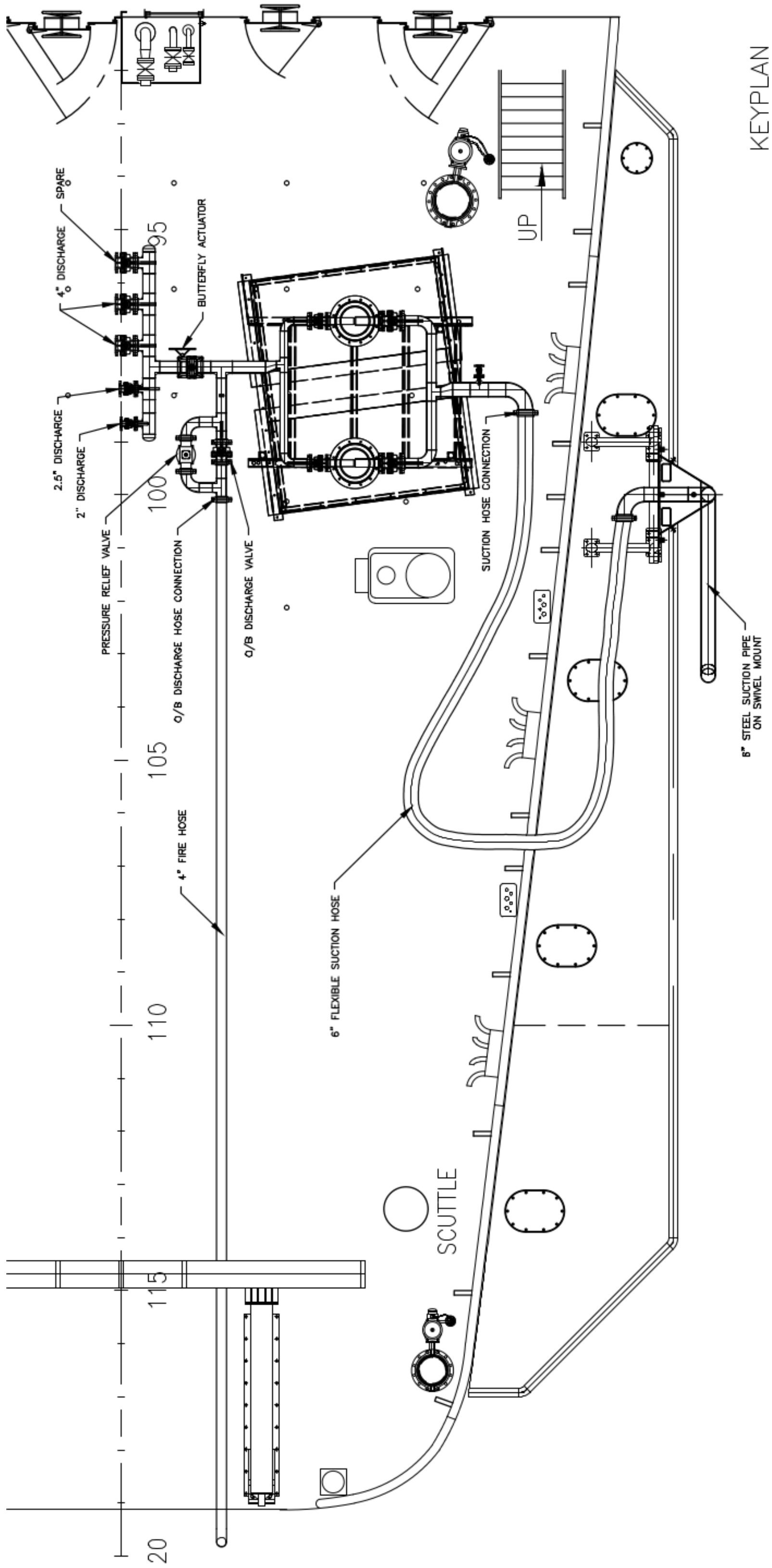

Figure 7: *An engineering drawing from Ref [12] showing the general arrangement of the sea water supply installation.*

Table 5: *The DRDC planning and preparation teams for the RIMPASSE trial.*

	Person	Primary Role/Responsibility
Chief Scientist	Dr. Zahir A. Daya	Overall leader. Responsible for delivering on overall DRDC readiness for RIMPASSE.
Core team	Mr. David W. Wheaton	Lead for readiness for trial aboard QUEST.
	Mr. Robert T. MacDonald	Lead for readiness of QUEST for RIMPASSE.
	Mr. Trevor A. Ponee	Lead, readiness of mechanical aspects of systems for trial aboard QUEST.
	Mr. Courtney G. Greene	Lead, data acquisition, storage and communication system readiness for trial aboard QUEST.
Acoustic signatures team	Mr. Layton Gilroy	Deputy chief scientist, acoustic signature trial plan, on-board measurement system and machinery configuration.
	Mr. Scott Hall	Readiness of on-board accelerometer data recording system.
	Ms. Tara Leblanc	Contributor to acoustic trial plan development.
	Mr. Timothy Murphy	Readiness of the passive acoustic re-deployable bouys.
Electric and magnetic signatures team	Mr. Troy C. Richards	Lead in the development of all EM trials and readiness of on-board magnetic monitoring.
	Mr. J. Bradley Nelson	Deputy lead in the development of all EM trials and readiness of on-board magnetic monitoring.
	Dr. Marius S. Birsan	Contributor to the development of all EM trials and on readiness of a topside magnetic array.
	Mr. George Schattschneider	Designer and developer of the advanced active shaft grounding system. Contributor to underwater electric field trial plan development.
	Dr. Yueping Y. Wang	Contributor to the development of the underwater electric field and cathodic current measurement trial plan.
	Mr. Richard Religa	Technician (electrical and mechanical) for assembling EM measurement sensor systems.
Infrared signatures team	Dr. Jean-Luc Forand	Co-lead in the development of IR trial planning. Lead for range-site IR and EO measurement systems from DRDC Valcartier. The DRDC Valcartier team consisted of Mr. Luc Gauthier, Mr. Vincent LaRochelle, Mr. André Morin, Dr. Guy Potvin and Mr. Gilbert Tardif.
	Ms. Vivian Issa	Contributor to IR trial plan development.
Radar cross section signatures team	Dr. Stéphane R. Legault	Lead, development of RCS experiments on QUEST.
	Mr. Robert Charbonneau	Contributor to the development of RCS experiments on QUEST.
Technical and organizational support team	Mr. Yves Perron	Lead, liaising with QHM and DMSS auxiliary vessel class desk in readiness of QUEST for RIMPASSE. Head for internal DRDC technical support for QUEST readiness for RIMPASSE.

Table 5: *The DRDC planning and preparation teams for the RIMPASSE trial.*

	Person	Primary Role/Responsibility
	Mr. Mark Baldin	Deputy lead for the readiness of QUEST for RIMPASSE.
	Mr. Paul Anstey	Deputy lead for the readiness of mechanical aspects of systems for trial aboard QUEST.
	Mr. Mel Mackenzie	Lead for developing pyrotechnics standard operating procedure for RIMPASSE.
Non-DRDC Canadian team	W.R. Davis Engineering Ltd. (Dr. David A. Vaitekunas, Dr. Srinivasan Ramaswammy and Mr. Jordan Cross)	Design and development of IR signature management system for QUEST.
	Omnitech Inc. (Mr. Stephen D. Locke and Mr. Gregory S. VanSlyke)	Design and development of magnetic monitoring system for QUEST.
	FMF Cape Scott (Mr. JC Robert Dewey)	Contributor to the development of magnetic ranging trial plan.

The execution of the RIMPASSE trial was a highly co-ordinated exercise requiring the two ships QUEST and PLANET to be at various ranges at specific time slots. In this document, which describes the Canadian effort, we focus on the deployment of QUEST in executing the relevant parts of the RIMPASSE trial. With the all-signature comprehensive outlook of the RIMPASSE trial, it was divided into 16 individual trials for QUEST which were completed in five deployments between June 1, 2011 and February 14, 2012. The dates and trials for each of the five deployments are listed in Table 6 where we note that QUEST was engaged for 108 days for RIMPASSE with 103 days away from her home port of Halifax, and with 43 days on station at range sites. The first two deployments were in local waters near Halifax to conduct baseline measurements and preparations to test new equipment installations. The main deployment was to Europe starting in Scotland, proceeding to Norway, Germany, and France. The fourth deployment was a repeat of the magnetic baseline measurements at the home port in Halifax. The fifth and final deployment for RIMPASSE was to the Dutch island, Sint Eustatius, in the Caribbean. The overall route that QUEST took for the RIMPASSE trials is shown in Fig 8.

Each trial in the RIMPASSE trials had specific objectives grouped either by individual signatures (acoustic, magnetic, etc.) or by a combination of underwater signatures. In Table 7 are listed each of the 16 trials that comprised RIMPASSE. Also listed in this table are the geographical locations for the range sites and the principal objectives. In between the dates listed, QUEST was in transit from one range to the next. When there were similar experiments for both QUEST and PLANET, the ships generally leapfrogged each other in the schedule.

Table 6: *Breakdown of the five deployments by QUEST during RIMPASSE.*

Deployment	RIMPASSE trial number	Primary objective	Dates	Days on station	Days at sea away from home port
1 (local waters)	1	Prep and acoustic signature baseline.	June 1–2, 2011	2	0
2 (local waters)	2	Prep and magnetic signature baseline.	July 28, 2011	1	0
3 (Europe)	3–13	See Tables 1 and 2.	August 3 – October 31, 2011	36	89
4 (local waters)	14	Magnetic signature upon return to home port.	November 21 – 22, 2011	2	0
5 (Caribbean)	15–16	Magnetic signature at southerly latitude.	January 31 – February 14, 2012	2	14
				43	103

Figure 8: *The overall route for QUEST in the handful of deployments during the RIMPASSE trials.*

Table 7: *Dates, locations and principal objectives for the 16 trials that comprised RIMPASSE.*

Trial	Dates at station	Measurement range and location	Principal objectives
1	June 1–2, 2011	Ferguson's Cove acoustic range, near Halifax, CAN	Baseline acoustic static and dynamic ranging.
2	July 28, 2011	Bedford degaussing range, near Halifax, CAN	Baseline magnetic signature and coil effects. Testing of the active hull cooling water delivery system in particular the suction pole. Multiple preparatory tests (on-board magnetometers, off board DSIMS-MAG, etc.)
3	Aug 16, 2011	Loch Fyne acoustic range, near Campbeltown, UK	Acoustic dynamic ranging with controlled noise sources and auxilliary ship systems.
4	Aug 17, 2011	Loch Goil acoustic range, near Cambeltown, UK	Acoustic transfer function measurements in a source-receiver reciprocity configuration and acoustic static ranging.
5	Aug 20–23, 2011	Open ocean off Cape Wrath, UK	Acoustic dynamic in-situ ranging (*i.e.* in open deep ocean by deployed I-LAND buoys and PLANET's vertical line array); wavefield measurements by a wave rider buoy.
6	Aug 28–31, 2011	Heggernes acoustic range, near Bergen, NOR	Beam and keel aspect acoustic dynamic ranging.
7	Aug 31 – Sept 2, 2011	Herdla multi-influence range, near Bergen, NOR	Acoustic, electromagnetic and pressure signatures. Keel aspect acoustic dynamic ranging. Active shaft grounding signature effects.
8	Sept 6–7, 2011	Friedrichsort-Möltenort deperming range, near Kiel, DEU	Deperming in preparation for experiments in the Earth Field Simulator.
9	Sept 11–16, 19–23, 2011	Surendorf above water range, near Surendorf, DEU	Radar cross section signatures in different configurations. Infrared signatures and suppression efficiency/effectiveness using active methods.
10	Sept 26–28, 2011	Aschau multi-influence range, near Eckernförde, DEU	Acoustic, electromagnetic and pressure signatures. Keel aspect ranging over fixed range sensors and deployed transportable ranges. Active shaft grounding signature effects.
11	Oct 1–6, 2011	Earth Field Simulator at Schirnau-Borgstedt-Bünsdorf, DEU	Measuring the permanent magnetization, onboard versus off-board magnetic measurements, AC hull shielding effects, coil effects and eddy current signatures.
12	Oct 17–18, 2011	Brest multi-influence range, near Brest, FRA	Acoustic, electromagnetic and pressure signatures with large tidal variation. Active shaft grounding signature effects.
13	Oct 29–30, 2011	Open ocean off Halifax, CAN	Aeromagnetic sensing.
14	Nov 21–22, 2011	Bedford degaussing range, near Halifax, CAN	Magnetic ranging post-deperm at fixed range and alongside deployed transportable ranges.
15	Feb 6–7, 2012	Off Sint Eustatius, NLD	Multi-influence ranging by the PRIME deployed transportable range.
16	Feb 13, 2012	Open ocean off Halifax, CAN	Aeromagnetic sensing.

The trial execution teams changed during the course of the trials with the change in scientific objectives and location. Various participants joined and disembarked from QUEST at various stages while execution teams at range sites were mainly from the host country. In Table 8 we have listed the main members of the execution teams during the RIMPASSE trials.

The RIMPASSE trials began with baseline acoustic ranging at Ferguson's Cove acoustic range in Halifax on June 1, 2011. The location of Ferguson's Cove acoustic range is shown in Fig 9. QUEST was in the preparatory work ups to return to service after a significant length alongside to address damage stability issues. In particular, sponsons had been added to the stern and were thought to have an impact on her acoustic profile. The baseline dynamic ranging was completed to the extent that the conditions permitted with about 60% of the runs being executed. On June 2, 2011, QUEST was ranged in a static acoustic configuration at Ferguson's Cove cycling through a long list of machinery states. A lightning storm resulted in the loss of a range hydrophone and the consequent schedule delay led to a re-prioritization of the machinery configurations. In all about 80% of the baseline configurations were successfully ranged.

July 27 and 28 were reserved on QUEST for pre-trial testing of scientific systems for RIMPASSE and for baseline magnetic ranging in Halifax prior to the scheduled August 3 departure for Scotland. As July 27 approached, though QUEST was prepared, her crew was required to undertake training. Since it was impossible to postpone or reschedule the training which was required in order to sail for RIMPASSE, the trial team was left with no choice but to squeeze the pre-trial testing and baseline magnetic ranging into a one-day trial on July 28, 2011. There were many systems that needed to be tested. These included the active hull cooling system consisting of an over-the-side water-inlet or suction pole, the water delivery system to the port hull, an on-board magnetometer system, new degaussing power supply operation, the advanced active shaft grounding system, etc.

It was thought that the magnetic ranging could be done while the other systems, in particular the sea water delivery system were tested. Unfortunately, the deployment of the suction pole revealed certain shortcomings. A picture of the suction pole being deployed over the side in trial 2 in Bedford Basin is shown in Fig 10. The design criteria for the suction pole were that QUEST should be able to operate at 10 knots with the pole deployed. However, in the trial it was clear that exceeding five knots set the suction pole in oscillations of growing amplitude such that it was prudent to operate at low speeds while testing the rest of the active hull cooling system: the actuator control and fine tuning of the water distribution over the port hull, the temperature and water pressure sensor suite, etc. To our dismay, QUEST was unable to hold course accurately at speeds as low as four knots and thus magnetic ranging was delayed to after the suction pole could be retrieved and stowed. The trial

Table 8: *The RIMPASSE trial execution teams aboard QUEST and at range sites.*

Trial	Location	QUEST team	Range site team
1	Ferguson's Cove, CAN	Gilroy, Hall, LeBlanc, Baldin, Greene	FMF Cape Scott team
2	Bedford range, CAN	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey, Schattschneider, Religa, Nelson, Richards, Hall, Stredulinsky Vaitekunas & Ramaswammy (WR Davis, CAN)	FMF Cape Scott team (Dewey), Issa, Corbin
3	Loch Fyne range, UK	Daya, Wheaton, MacDonald, Greene, Baldin, Anstey, Gilroy, Stredulinsky, Hall, LeBlanc, Murphy McLeod, Penman & Douglas (QinetiQ, UK) Moore & Dylejko (DSTO now DSTG, AS)	Constable (QinetiQ, UK), international team hosted by QinetiQ for DSTL, UK.
4	Loch Goil range, UK	As for Loch Fyne.	As for Loch Fyne.
5	Open seas off Cape Wrath, UK	Daya, Wheaton, MacDonald, Greene, Baldin, Anstey, Gilroy, Stredulinsky, Hall, LeBlanc, Murphy Moore & Dylejko (DSTO now DSTG, AS)	N/A. Note LeBlanc was on RV PLANET for this trial.
6	Heggernes range, NOR	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey, Gilroy, Hall, LeBlanc Moore & Dylejko (DSTO now DSTG, AS) Locke & Van Slyke (Omintech, CAN)	Schäl (WTD 71, DEU), Birsan, Nelson, international team hosted by FFI, Norway.
7	Herdla range, NOR	As for Heggernes plus Nelson.	Nakjem (FFI, Norway), Birsan, international team hosted by FFI, Norway.
8	Friedrichsort-Moltenort range, DEU	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey	Krämer (WTD 71, DEU), Nelson, international team hosted by WTD 71, DEU.
9	Surendorf range, DEU	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey, Legault Vaitekunas & Ramaswammy (WR Davis, CAN) Bauregar & Gaisbauer (Rheinmetall, DEU) Santfleben & Bastian (WTD 71, DEU).	Rasch (WTD 71, DEU), Forand, Issa, Corbin, Charbonneau, Alain, Larochelle, international team hosted by WTD 71, DEU.
10	Aschau range, DEU	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey, Hall, LeBlanc, Nelson Douglas & McLeod (QinetiQ, UK)	Schäl (WTD 71, DEU), Birsan Dewey, X & Y (FMF Cape Scott, CAN)international team hosted by WTD 71, DEU.
11	Earth Field Simulator, DEU	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey	Krämer (WTD 71, DEU), Nelson, Richards, international team hosted by WTD 71, DEU.
12	Brest range, FRA	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey	Chapelier (DGA/DT/GESMA, France), Nelson, international team hosted by DGA/DT/GESMA, France.
13	Open seas off Halifax, CAN	Daya, Wheaton, MacDonald, Ponee, Greene, Baldin, Anstey	CFB Greenwood CP-140 crew and operators, Nelson.
14	Bedford range, CAN	Richards, MacDonald, Greene, Baldin	FMF Cape Scott team (Dewey), Dutch PRIME system team.
15	Off Sint Eustatius, NLD	Daya, Wheaton, MacDonald, Greene, Baldin, Anstey	Nelson Rog (DMO, Netherlands), Dutch PRIME system team.
16	Open seas off Halifax, CAN	MacDonald	CFB Greenwood CP-140 crew and operators, Nelson.

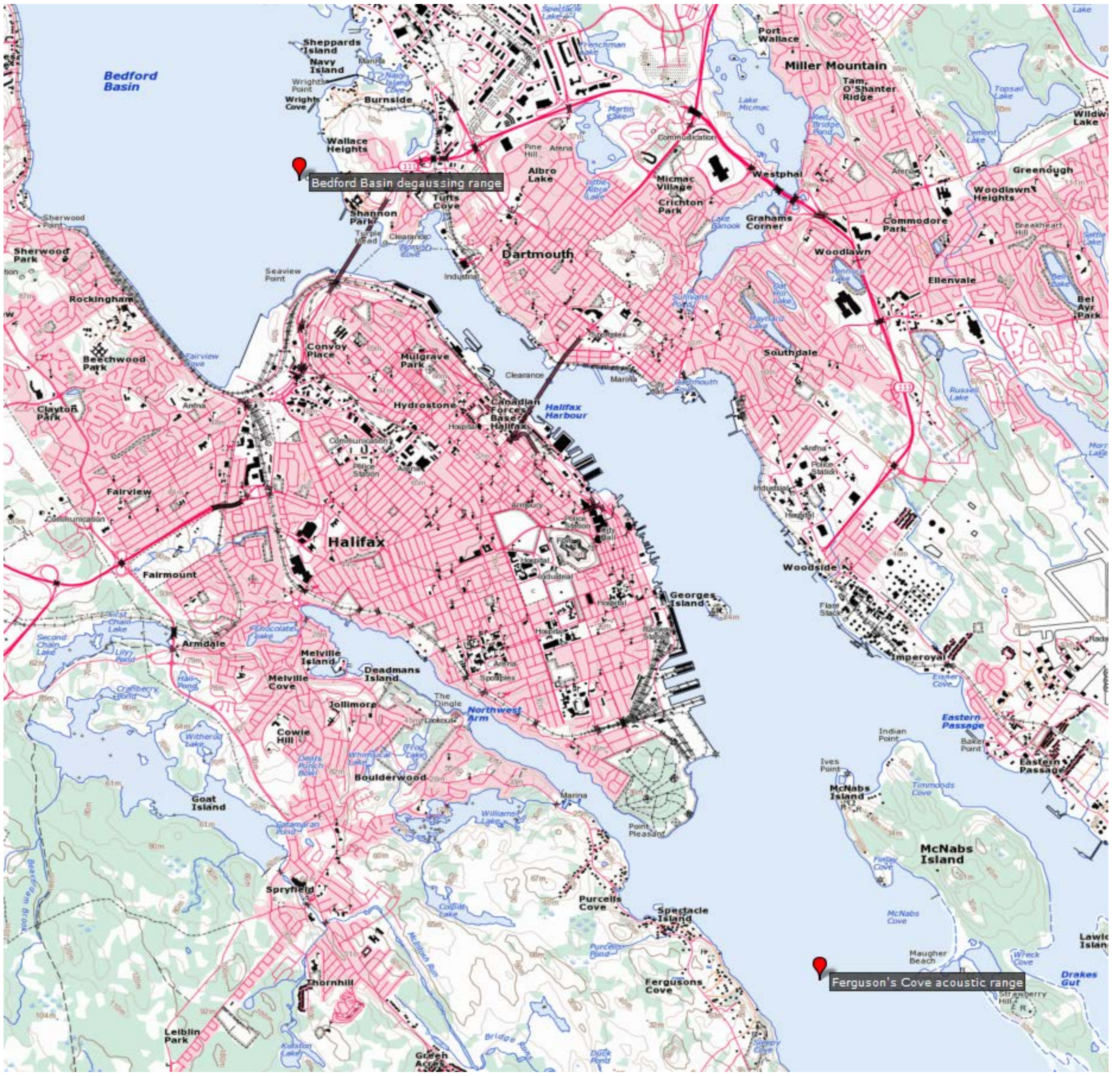

Figure 9: *The approximate locations of the Bedford Basin degaussing range and the Ferguson's Cove acoustic range near Halifax.*

continued late in to the night with most of the scheduled degaussing runs completed with the exception of one of the coil effects.

In terms of trial data collection 90% of the objectives were met. On the other hand, in terms of preparedness for the upcoming trials specifically those involving the use of QUEST's degaussing system, QUEST's ICCP (impressed current cathodic protection) system and the use of the suction pole, there were some deficiencies that needed to be addressed. The QUEST degaussing power supplies were operated manually during the test day while they were required to be operated under computer control. Consequently Omnitech Limited were retained under contract to build a control interface for the power supplies ahead of trial 7 at Herdla, Norway. The ICCP system

Figure 10: *The suction pole which was the water-inlet for the sea water active hull cooling system is being deployed over-the-side in trial 2 in Bedford basin on July 28, 2011.*

is a ship system and it's inoperability was reported to the class desk. The vibration of the suction pole at ship speeds far below those desired for the infrared ship signature experiments required that the suction pole and its mounting point on QUEST be re-designed. Stiffeners were added to the mounting point and fairings were attached to the pole length before departing Halifax on August 3. These would extend the suction pole stability to greater speeds. The suction pole with fairings stowed temporarily is shown in Fig 11.

Figure 11: *The suction pole with fairings temporarily stowed between experiments.*

QUEST set sail for Scotland on August 3, 2011. Almost immediately upon leaving her home port of Hailfax, she encountered malfunctions with her X-band radar. Luckily she was not too far along the way that she was able to return to port and have the radar repaired. In the end, QUEST was delayed 11 hours from her scheduled departure. It would be August 14 that she would reach her first port-of-call Campbeltown, Scotland. DRDC scientists and technicians, as well as UK and AUS-colleagues would meet QUEST at Campbeltown on August 14, 2011. Joining QUEST the morning of August 14, 2011, the author was informed of three issues that would force some of the plans to be changed. The S-band radar had failed and needed to be repaired before the ship could sail, the Gas Turbine engine was under repair, and the Campeltown jetty that QUEST was berthed at was not equipped to refuel QUEST as it did not have the capacity to take the compensation water from QUEST that the fuel would displace. Both the refueling and the repair of the S-band radar would have to take place at the RN base at Faslane, while use of the Gas Turbine at Loch Fyne was in doubt. With the arrival of the QinetiQ and DSTO staff that evening, the team began transferring UK equipment for the acoustic trials on board QUEST. The equipment consisted of various shakers, amplifiers and data recorders as well as a miscellany of backup parts and tools.

Following the schedule set out in the Master Trial Plan (Ref [1]), a pretrial briefing for the Loch Fyne and Loch Goil trials was held on QUEST on August 15. A map of the general area is shown in Fig 12. Discussions on sea traffic on route between Campbeltown and the Lochs ensued from which QUEST Captain Cahn Nguyen consented to sail with only one radar operational so long as transit was in daylight when passing through the narrows. We were thus, on schedule for the Loch Fyne trial.

The DRDC acoustic lead, Mr. Layton Gilroy and his team working with QinetiQ and colleagues from AU DSTO set out to install and test the acoustic control and monitoring system (shakers, accelerometers, etc.). Much of the installation and testing of the shakers and accelerometers was undertaken en-route between Campbeltown and Loch Fyne on the morning of August 16. Mr. Gilroy working with his international counterparts would also prioritize the runs selected for Loch Fyne and the settings for Loch Goil. The trial at Loch Fyne was a dynamic or underway trial. The runs consisted of reciprocal runs along a fixed bearing with an initial familiarization pass with the QUEST sub-bottom profiler running. A sequence of reciprocal runs at various speeds/shaft rpm settings were undertaken and included runs with the hull cooling system (suction pole, pump, water delivery over port hull) running to assess its impact on acoustic levels. There was some rain during runs and a few small pleasure craft that fouled the range, but essentially all objectives were met. The fairings on the suction pole would be adjusted so that the pole was easier to deploy and recover without being trapped by the sponson. With the Loch Fyne trial completed, QUEST sailed to Loch Goil through the night passing the narrows in twilight.

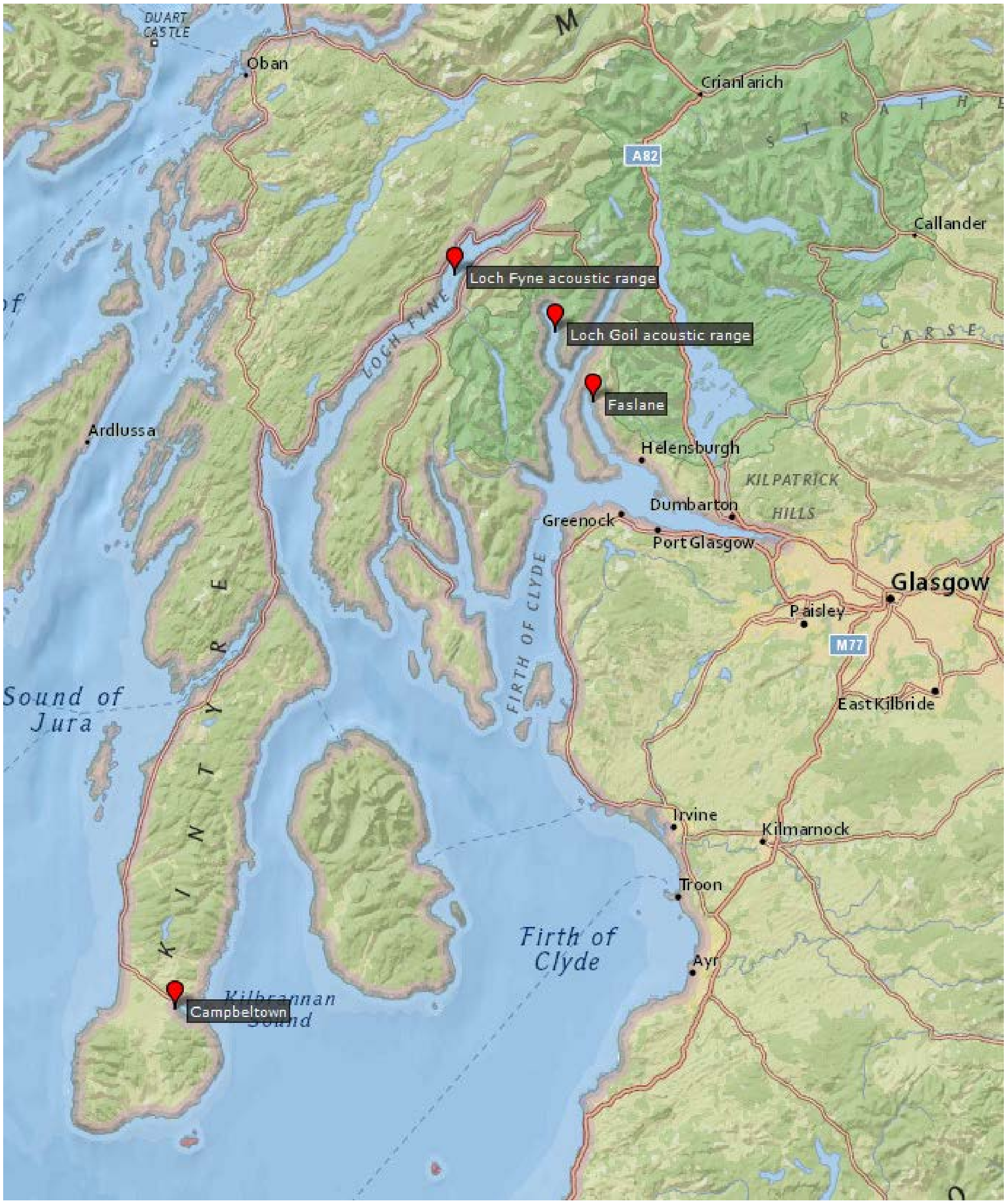

Figure 12: *The first port of call Campbeltown, Scotland and nearby range sites Loch Fyne and Loch Goil.*

At Loch Goil, range support vessels and QUEST crew moored the ship at the centre of a four point mooring range as shown in Figs 13 and 14. The range hydrophone cables were relayed to QUEST for recording on board and a reference hydrophone was deployed. Reciprocity measurements were started a few hours behind schedule. These had an active source at the barge off on QUEST's starboard side. Shaker runs or controlled noise source were undertaken next. Static ranging with a long list of machinery states went through the night and included the infrared water cooling system. With the Loch Goil trial completed, a small team transferred to PLANET for preparations and discussions on the Deep Water trial. DRDC technicians installed receiving equipment for the DRDC I-LAND buoys on PLANET and DRDC scientists discussed the options and priorities for the next trial. Ms. Tara LeBlanc, a DRDC scientist would stay on PLANET for the Deep Water trial before re-uniting with QUEST. The rest of the DRDC team disembarked PLANET and returned to QUEST by boat. At this point QUEST made for Faslane to refuel and to have its S-band radar repaired.

Figure 13: *QUEST arriving at Loch Goil range. The four yellow buoys are the mooring points for static ranging at Loch Goil.*

Following repairs, refueling and blackwater disposal, QUEST set sail from Faslane toward the deep water ranging site. In light of the wind and sea forecasts, the con-

Figure 14: *QUEST moored at Loch Goil for acoustic experiments. The raft off the starboard side had an active source for reciprocity measurements.*

ditions at the original deep water site would be too rough to launch and recover equipment, so it was decided to initially work in a more sheltered location off Cape Wrath. On August 20 and 21, experiments in ranging QUEST in the relatively deep water location near Cape Wrath (see Fig 15) by the Passive Acoustic Re-deployable Buoy (PARB) were conducted. The PARBs were deployed by the QUEST crew off quarter deck and they were monitored by Mr. Tim Murphy who was responsible for their maintenance and functioning. The PARBs would record the acoustic data and their position over several hours. Recovery of the PARBs was by a RHIB escorting them into position near the quarter deck of QUEST without coming alongside where there was risk of damage by collision with the sponsons. The ranging consisted of sailing past the freely drifting PARB, initially with one PARB on August 20 and then with two and more on August 21. With the acoustic ranging in these waters, a Triaxys wave buoy was deployed on the morning of August 20. It would measure the directional wave spectra for comparison to and merging with radar-based wave heights. The radar-based wave height measurements and the local wave field measurements by the deployed buoy were handled by Dr. Dave Stredulinsky. Recovering all the buoys, QUEST departed the Cape Wrath site and headed toward the deep water site, roughly a day's sail due East.

At the deep water site, where sea bottom depths exceeded 1000m, QUEST rendezvoused with PLANET to perform joint ranging. PLANET would deploy a vertical line array while QUEST deployed four PARBs with a linear spacing of about 200m between buoys. At the same time the Triaxys wave-buoy was deployed. QUEST and PLANET were ranged by sailing past the free floating PARB array at different offsets. Ambient data were also collected by sailing away from the PARB array. PLANET runs were conducted mainly on August 22 with QUEST runs mostly on the 23rd. The data were lines that approached the array from 600m before to 600m after and had offsets at CPA of about 25-150 m. Runs at different speeds and internal noise source settings were conducted as discussed in the trial plan. Wave height spectra from the buoy and from radar measurements were also recorded. Completing the deep water trial with the transfer of Ms. Tara LeBlanc back from PLANET, QUEST set sail for Bergen, Norway (see Fig 15).

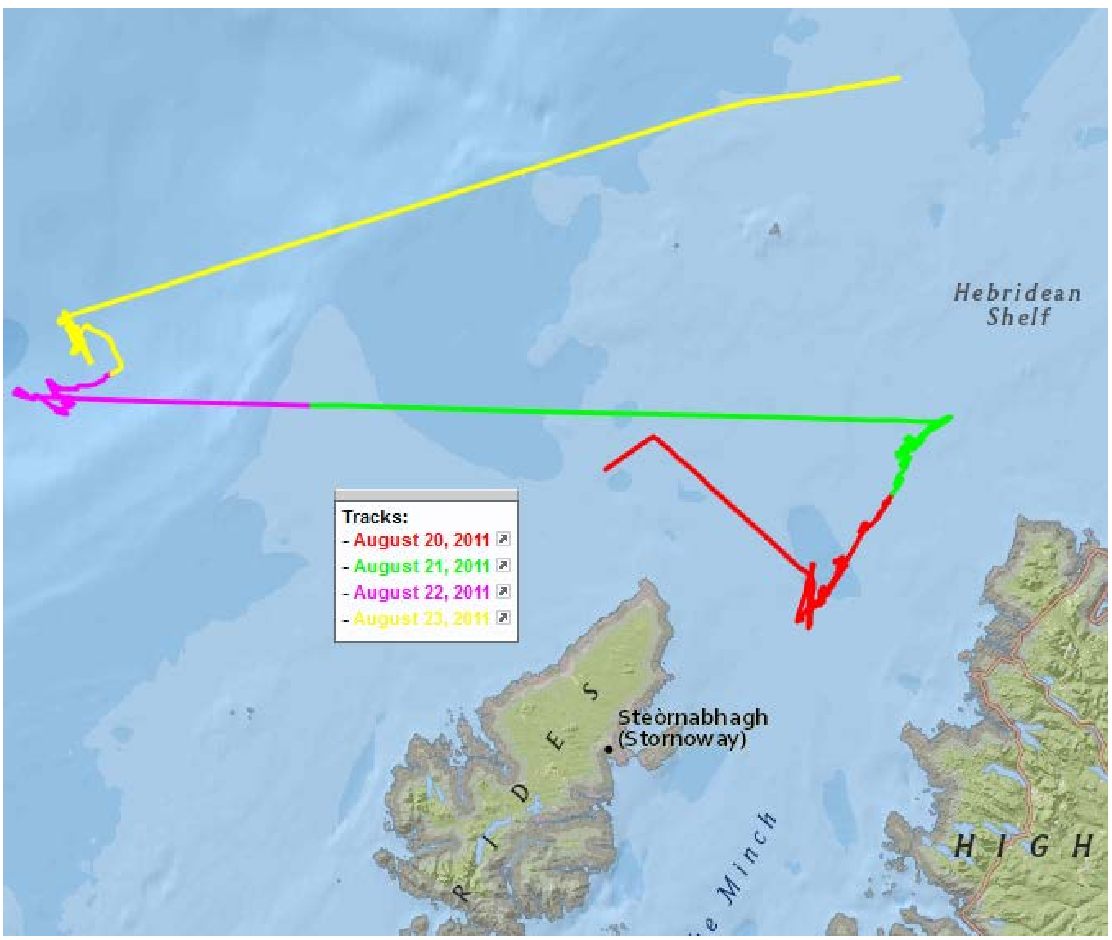

Figure 15: *QUEST stopped twice to conduct sustained acoustic ranging operations in open waters in the transit between Scotland and Norway. Wave spectra were concurrently measured using wave radar and ship motion data.*

QUEST arrived in Bergen on August 25 where the first order of business was the embarking of scientific personnel for the electromagnetic trials scheduled for Herdla in the days ahead. Preparations for the Heggernes and Herdla trial started while the QUEST crew went about its own preparations. On August 28 all QUEST personnel were invited for a brunch on PLANET where the scientists also had a meeting to discuss the final changes to the trial runs. QUEST presented PLANET with a commemorative certificate on the visit. QUEST started ranging at Heggernes acoustic range where she did dynamic ranging in a wide variety of source conditions and ship speeds. This ranging had about three days with long shifts each day, exceeding 13 hours of range time daily. The QUEST scientific team and the scientific visitors from Australia worked exceptionally to fit in the 124 runs at Heggernes. Figure 16 shows QUEST tracks at the Heggernes acoustic range and at the Herdla multi-influence range in the fiords near Bergen.

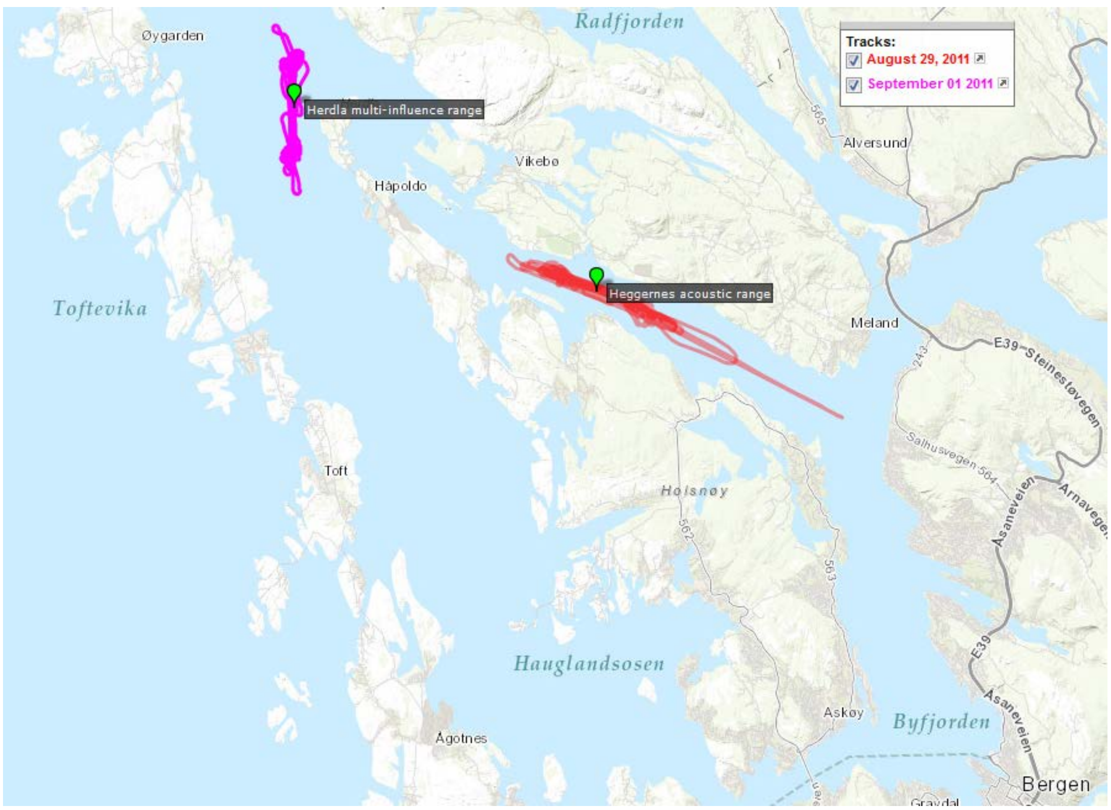

Figure 16: *QUEST at Heggernes acoustic range and Herdla multi-influence range.*

The multi-influence signature runs were conducted at Herdla starting the night of August 31 with most runs on September 1 and 2. Mr. Brad Nelson who had joined QUEST in Bergen oversaw the 101 passes that were completed at Herdla with a systematic variation over the degaussing coils settings and active shaft grounding settings aboard QUEST, though unfortunately without the impressed current cathodic protection system. The trial was conducted at several speeds, along north and south headings and at the standard offsets runs at Herdla for mine influence trials. A battery of mine influence data consisting of acoustic, pressure, magnetic and electrical signatures were collected. Having leapfrogged with PLANET at Heggernes and Herdla, QUEST headed to Germany where the next stop was Kiel. On route the roughly two-day transit, some re-wiring and testing of the QI degaussing coil on QUEST had to be undertaken as it seemed to have no effect at Herdla. This involved re-wiring a junction box and then making measurements of the current using clamp-on meters and the changes in the magnetization using the on-board magnetometer system. The testing was successfully completed prior to arrival in Kiel.

In Kiel QUEST was depermed for the first and only time. The deperming took place on September 6 at the Friedrichsort deperming range with a check ranging to monitor the magnetization relaxation on September 7 at the nearby Möltenort range. The deperming at Friedrichsort is an iterative process with repeated transits over the measurement array ahead of the deperming z-coils. The East-West Friedrichsort range had coils to null out the Earth's vertical and horizontal field and a slowly oscillating z-field coil to deperm the permanent magnetization of QUEST. On September 6, QUEST made a total of 18 passes (see Figure 17) over the Friedrichsort range array (see Figure 18) and deperm coil followed by four passes on September 7 and 9 passes at Möltenort North-South range.

The trial at Friedrichsort allowed for the measurement of QUEST's magnetic signature in its pre-deperm state and so facilitated the comparison to prior measurements at the Bedford degaussing range and Herdla multi-influence range. The variation measured may be attributable to transit effects on the magnetic signature. The coils effects were measured at Friedrichsort and the deperming allowed the calculation of the optimal coil current settings for the subsequent experiments in the Earth Field Simulator. In addition, the on-board magnetometers captured the deperming and the relaxation of the magnetization from within QUEST.

QUEST left Kiel and headed to Eckernförde (see Figure 19) where over the next two weeks, QUEST was on station in excess of 12 hours/day off Surendorf for above water signature measurements. As with every change in signature trial focus, the infrared and radar cross section teams joined QUEST while the electromagnetic and acoustic teams departed. DRDC's Dr. Stéphane Legault and the author led the radar and infrared trials respectively. Each day had the first six hours in the morning dedicated to radar cross section measurements while the next six hours when solar loading was greater were reserved for infrared signature experiments. The radar and infrared trials at Surendorf during RIMPASSE were a subset of the NATO SQUIRREL trial that included radar and infrared propagation measurements on other vessels and targets. The subset of QUEST experiments were part of RIMPASSE. Measurement radars and infrared cameras were located at the various sites at the Surendorf range. These included portable containers on a long pier, several floors of the main building and

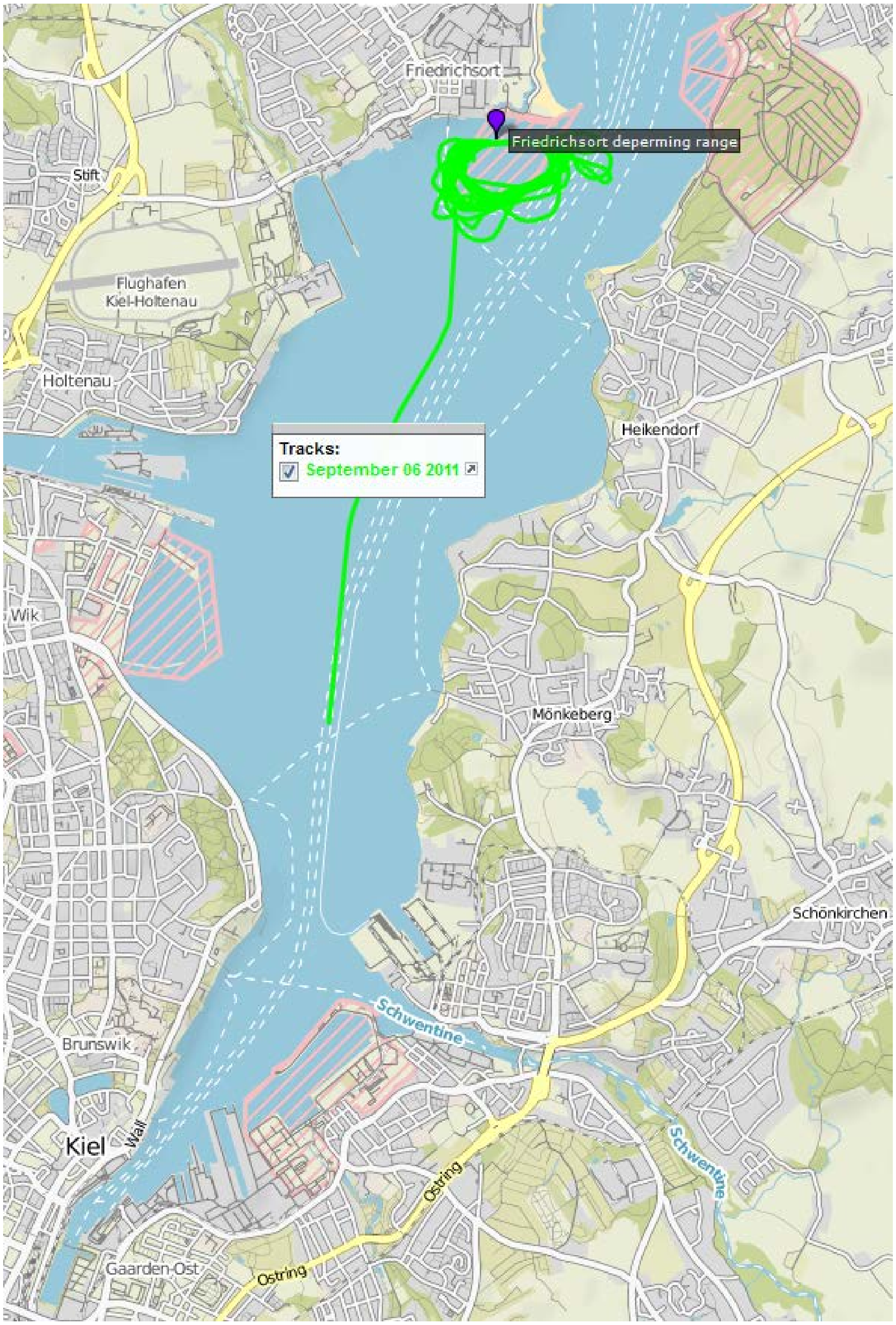

Figure 17: *QUEST tracks over the Friedrichsort range and deperming facility on September 6, 2011.*

Figure 18: *QUEST passing over the Friedrichsort range array before the compensating and deperming coils.*

Figure 19: *QUEST and PLANET on opposite sides of a jetty at Eckerförde.*

on hill overlooking the pier. Figures 20 and 21 show some of the equipment at the measurement sites at the Surendorf above water range.

The radar cross section trials off Surendorf were designed to expose the QUEST above water hull and superstructure to various radars across a broad range of frequencies and spectral resolutions situated at Surendorf range. The baseline QUEST configuration was measured at several ranges (distances) and consisted of tracks that had clockwise and counterclockwise circles, exposing port and starboard aspects, as shown in Figure 22. Reduced radar cross section configurations that were tested included covering high RCS centres on QUEST with radar absorbing material (RAM) panels and radar reflecting flat sheets. RAM lining QUEST's starboard breezeway was used in one of the reduced RCS configurations and is shown in Figure 23. The dressing of QUEST in RAM panels and sheets had to be done alongside before departing the jetty in the morning or after sundown and was accomplished in a fine display of team work led by Dr. Stéphane Legault with all colleagues and QUEST crew helping out. Several other experiments were conducted including radar imaging studies and studying the effect of infrared water cooling suppression on the RCS.

Figure 20: *A view of the Surendorf above water range showing the locations of equipment installations at the pier head and near the beach. An additional hill top site is not shown in the picture.*

Figure 21: *The main building at the Surendorf above water range housed infrared sensors for measuring QUEST and other targets.*

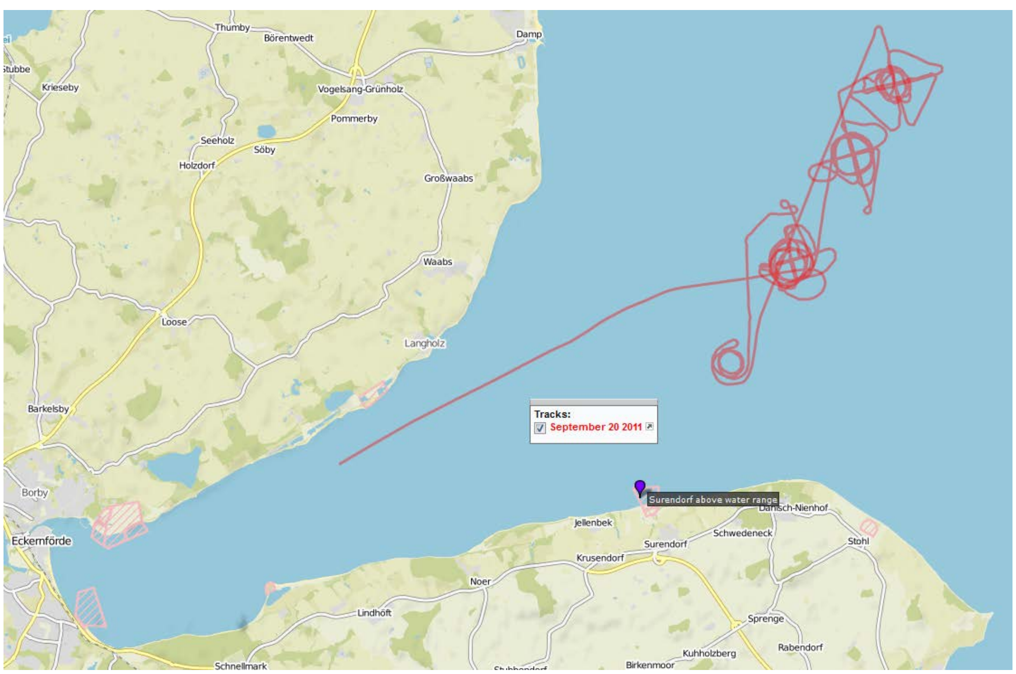

Figure 22: *Circular tracks presenting QUEST at all angles and at various ranges were undertaken by QUEST at Surendorf.*

Figure 23: *Radar absorbing pads line QUEST's starboard breezeway in a radar cross section trial at Surendorf range.*

The infrared (IR) signature experiments followed the RCS morning session. QUEST whose port hull and superstructure were painted grey to mimic the color of Navy ships in an attempt to obtain better solar loading on the hull surface, was measured in the IR bands in a baseline and actively suppressed configurations. Since the IR suppression was two-fold, on the hull/superstructure and in the plume, short range (500-1500 m) and long range (4500 m) runs were required. On these runs baseline measurements without suppression were followed by runs with either the active hull cooling system running or the sea water injection system operating. At the Surendorf range several teams imaged the QUEST with IR cameras and measured the spectral content of the plume with FTIR (fourier-transform infrared spectroscopy) spectrometers. Aboard QUEST the IR suppression systems were operated by Davis Engineering and DRDC. To directly gauge the effectiveness of the signature reduction, Rheinmetall launched their ROSY (rapid obscuring system) decoy flares in runs with QUEST in baseline and suppressed configurations. Figures 24 and 25 show QUEST with the active hull water cooling system operating and firing a ROSY decoy flare.

Considering the long days on station and the preparatory work before and after the daily trials, the DRDC RCS and IR leads, Dr. Stéphane Legault and the author,

Figure 24: *The active hull cooling system on QUEST's port side in operation at Surendorf range.*

consulted with the teams and negotiated a one day pause mid-trial on September 16, 2011. As it turned out the weather was not ideal either on that day. The above water ranging trials came to an end on September 23, 2011, roughly the mid-point of the main deployment. In all over 70 runs were completed and over 120 flares had been launched. CSSM had organized a festive dinner in Kiel for all trial participants on September 24 which was attended by DRDC and QUEST teams and crew.

The two-week above water ranging at Surendorf was designed to provide a a window of time for the recently depermed QUEST to re-equilibrate or relax magnetically before being ranged at the Aschau multi-influence range. The deperming at Friedrichsort was on September 6 with the first Aschau multi-influence trial on September 26. At Aschau, in addition to the fixed range hydrophones, pressure, electric and magnetic sensors, deployable ranges were also used so as to benchmark them against the fixed range. The deployable systems consisted of the Dutch PRIME system and the Polish IGLOO system. DRDC's DSIMS system was withdrawn before QUEST departed Halifax. QUEST had many passes over the sensors at Aschau (see Figure 26) with various objectives in line with the previous measurements at the Herdla multi-influence range. Of particular importance was the measurement of QUEST's magnetic signature after the de-perm and prior to the experiments at the Earth Field Simulator.

Figure 25: *QUEST fires a Rosy decoy flare at Surendorf. The cloud from the first flare in the sequence is seen on the right.*

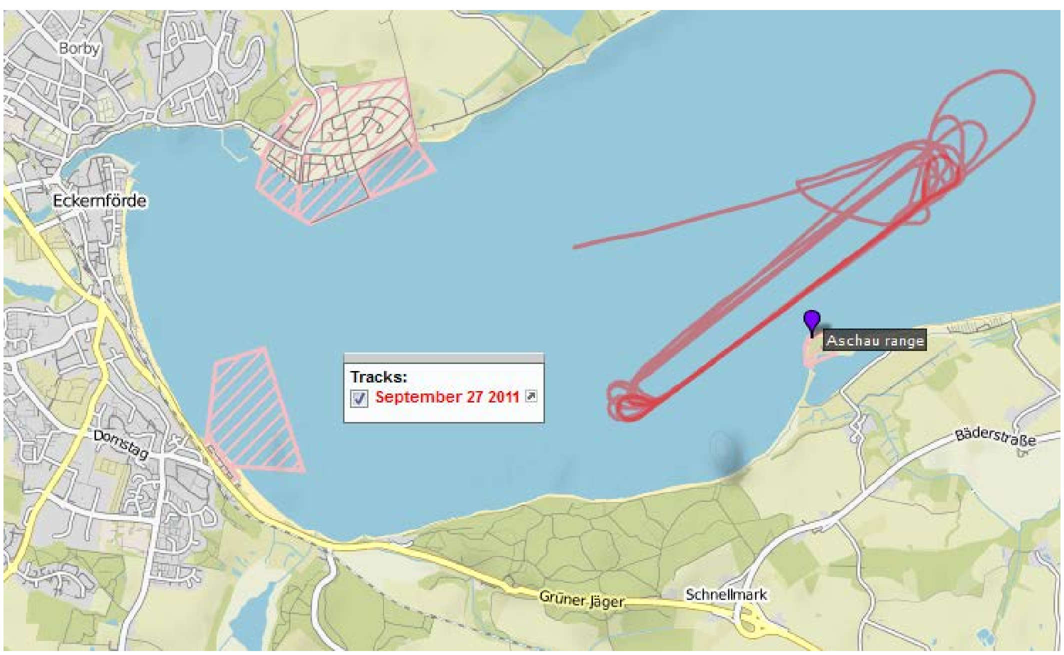

Figure 26: *QUEST tracks over the the multi-influence range at Aschau.*

At Aschau several acoustic configurations with shakers were run to complement the data already collected and the active shaft grounding was investigated given the electrical range and different sea water conductivity compared to Herdla. Ungrounded, passive and advanced active grounding configurations were tested. Completing the Aschau trials in just under three days, QUEST returned to Kiel for a unique operation: the removal of the mast and effectively one radar.

Whereas the bolted mast connection was designed and implemented in Halifax by the QUEST service provider SNC Lavalin, it was a courtesy service from Germany's Marine Arsenal to detach and re-attach the mast before and after the trials in the Earth Field Simulator. In Figure 27 is shown the removable portion of the QUEST mast with a radar system in the process of being lowered for re-attachment. With the upper portion of the mast removed QUEST was short enough to enter the Earth Field Simulator at Schirnau. On October 1, German re-unification day, QUEST sailed with one radar along the Kiel canal to Schirnau/Borgstedt where she was guided by a tug into the Earth Field Simulator (see Figures 28 and 29). At Schirnau the DRDC team was complemented by magnetic range personnel from the Bedford degaussing range.

Over the next week the scientists at the Earth Field Simulator and aboard QUEST reeled through over 600 magnetic settings for which the magnetic signature of QUEST was measured by both the off-board underwater grid of magnetometers and the on-board magnetometers. These data have provided the most comprehensive picture of QUEST's magnetic signature in a world-wide deployment. The nature of the experiments were extensive: coil effects, optimal degaussing settings, separation of permanent and induced components, on-board vs off-board measurements, linearity and nonlinear effects, eddy current effects, hull shielding effects, etc. QUEST returned to Kiel on October 6 and had the mast re-attached the next day when, with our hospitable stay in Germany coming to an end, the ship hosted all trial members to a barbecue on the well deck. Preliminary results from experiments in the Earth Field Simulator suggested that some further testing for hysteresis effects was required which was undertaken along the dock in Kiel on October 10. QUEST was then prepped for the sail to Brest, France for which she traversed the full length of the Kiel canal and the English Channel. QUEST was delayed leaving Kiel due to a changeover in some of the key members of the crew.

En-route through the English Channel on October 12, QUEST received a mayday broadcast alerting her to a capsized sailing boat in our vicinity. As QUEST was closest to the vessel in distress she quickly executed a U-turn and headed to the search area. QUEST crew quickly deployed a RHIB and promptly rescued father and son from the cold waters and subsequently transferred them to the Dover Coast Guard. The remainder of the transit to Brest was uneventful. The Brest range, like Herdla and Aschau, is a multi-influence range where there are fixed sensors for the magnetic, electric and acoustic fields. The large tidal variation in Brest allowed for

Figure 27: *The QUEST mast that was removed for experiments in the Earth Field Simulator is re-attached in Kiel.*

Figure 28: *QUEST sails along the Kiel canal to Schirnau for experiments in the Earth Field Simulator.*

a range of depths at both the medium and deep ranges (see Figure 30). QUEST sailed over the two ranges in various configurations of the DG coil settings and the active shaft grounding settings. A total of 44 passes were completed on October 17 and 18. The data will allow meaningful comparisons to those from the other ranges. With the Brest trial completed, QUEST was loaded with the PRIME system in two containers. We would be transporting the Dutch PRIME system to Halifax for deployment there. Departing on October 19, 2011 QUEST set sail from Brest to

Figure 29: *A tug guides QUEST into the Earth Field Simulator near Schirnau. Note that QUEST has a partial mast to accommodate safe entry into the simulator.*

Halifax. En-route the on-board magnetometer system would record the changes in QUEST's magnetic environment as she traversed the Atlantic ocean.

Figure 30: *Electric and magnetic ranging off Brest.*

With anti-roll tanks empty and sponsons along the quarter deck as per the modifications due to the damaged stability report, QUEST's sail across the Atlantic was rough. Three times the Captain altered course to the south to avoid stormy weather but alas on October 30 and 31, QUEST had to sit nose in the wind and weather

Figure 31: *A rough ride duirng the sail home from Brest to Halifax.*

it out as the eye of a storm went by. Barely making one knot, rolling in excess of 20 degrees, with winds averaging 60 knots and gusts of 77 knots, every wave crash sent shudders from the sponsons to the bridge. With sounds that had thereto not been heard, QUEST moaned and weathered the storm less than a half day's sail from Halifax.

When within a couple of days sail from Halifax, it became clear that the weather systems were unfavourable to deploying an electric towed source for which the CP-140 Aurora was to make airborne measurements. Although we had following seas, the QUEST crew would have attempted to deploy the electrode system had the CP-140 Aurora been available. We were informed by Mr. Brad Nelson following a dawn briefing at CFB Greenwood that the CP-140 Aurora would not be deployed due to high winds and stormy weather. The opportunity to measure the low frequency electric field signatures from the air was thus lost. However, magnetic data was collected by the on-board magnetometer system at a lower sampling rate for the duration of the journey from Brest to Halifax. QUEST returned to her home port on October 31 having endured a rough 12 days at sea (see Figure 31 for a view from the bridge on October 23, 2011).

Upon arrival alongside in Halifax, Dr. Jack Cornett, then Director General at DRDC Atlantic, had come to the dockside to receive us home. It was a uniquely kind gesture and a tribute to QUEST and the RIMPASSE team. Long time employees aboard QUEST and from DRDC had never had a Director General come alongside to welcome the team home. Hats off to Dr. Jack Cornett! Customs had to be cleared especially since QUEST was transporting the Dutch PRIME system, valued at over a million Euros, for use in Bedford Basin and thereafter in St. Eustatius.

QUEST and her crew had a respite for a couple of weeks before a deployment to Bedford Basin degaussing range for a magnetic ranging after the main RIMPASSE deployment. The trial, Q342B was led by DRDC's Mr. Troy Richards (see Ref [4]). The trial started with deploying the transportable ranges near the Bedford degaussing North-South range during the week preceding the trial. These were the Dutch PRIME system which was deployed and positioned on November 9 and DRDC's DSIMS-MAG system which was deployed on November 17. Once both ranges were deployed and tested, QUEST sailed over the degaussing range and over both the deployable ranges in various magnetic configurations: undegaussed, various coils operating, and optimally degaussed. A total of 18 runs, nine in each direction were planned for November 21 and 22. On-board magnetometer data was also recorded. The deployable ranges were recovered after the trial and PRIME was commercially shipped to St. Eustatius.

To complete the RIMPASSE trials, a deployment to the Dutch Antilles island of Sint Eustatius remained. It would be the southernmost location where QUEST could be ranged magnetically against the Dutch PRIME system. From a value perspective, it was clear that the deployment of QUEST to Sint Eustatius for the relatively small trial with limited payback was not going to be a profitable use of ship time. Consequently, only if QUEST were to be in the vicinity of the Caribbean would the small trial at Sint Eustatius be a possibility. As it turned out, DRDC's Dr. Brian Maranda was leading a trial on QUEST near Key West, Florida during trial Q343 between January 9-28, 2012 (see Ref [14]). When QUEST set sail from Halifax on January 9, 2012 she was carrying the electric field source to tow astern in the event that a CP-140 Aurora would be available for an airborne measurement. Having been unable to complete this experiment upon returning from Europe, we asked for the availability of a CP-140 Aurora either when when QUEST departed January 9 or when she returned on February 14. Unfortunately the CP-140 was not available on either of these occasions and so all 3 attempts to conduct an airborne low frequency electric field measurement through the CP-140 magnetic anomaly detection system were unfruitful.

In order to leverage QUEST further, the author engaged colleagues at US NRL to a joint trial US-CAN trial off Port Everglades, Florida to study a high angle infrared suppression of QUEST. The trial plan in Ref [3] describes the US-CAN IR trial on January 30 and 31, 2012 after a change of scientific personnel on QUEST with Dr.

Brian Maranda's team disembarking and the author's team joining on January 28, 2012. After the IR trial (not part of RIMPASSE but included to maximize the value of ship time), QUEST sailed toward St. Eustatius. Mr. Brad Nelson would join the Dutch team running PRIME at the St. Eustatius shore site. While underway QUEST was informed that the berthing facilities at Gallows Bay in St. Eustatius were inadequate for a ship of QUEST's displacement and thus we were obliged to berth at Basseterre Bay, St. Kitts about two-hours sail away. (see Fig 32).

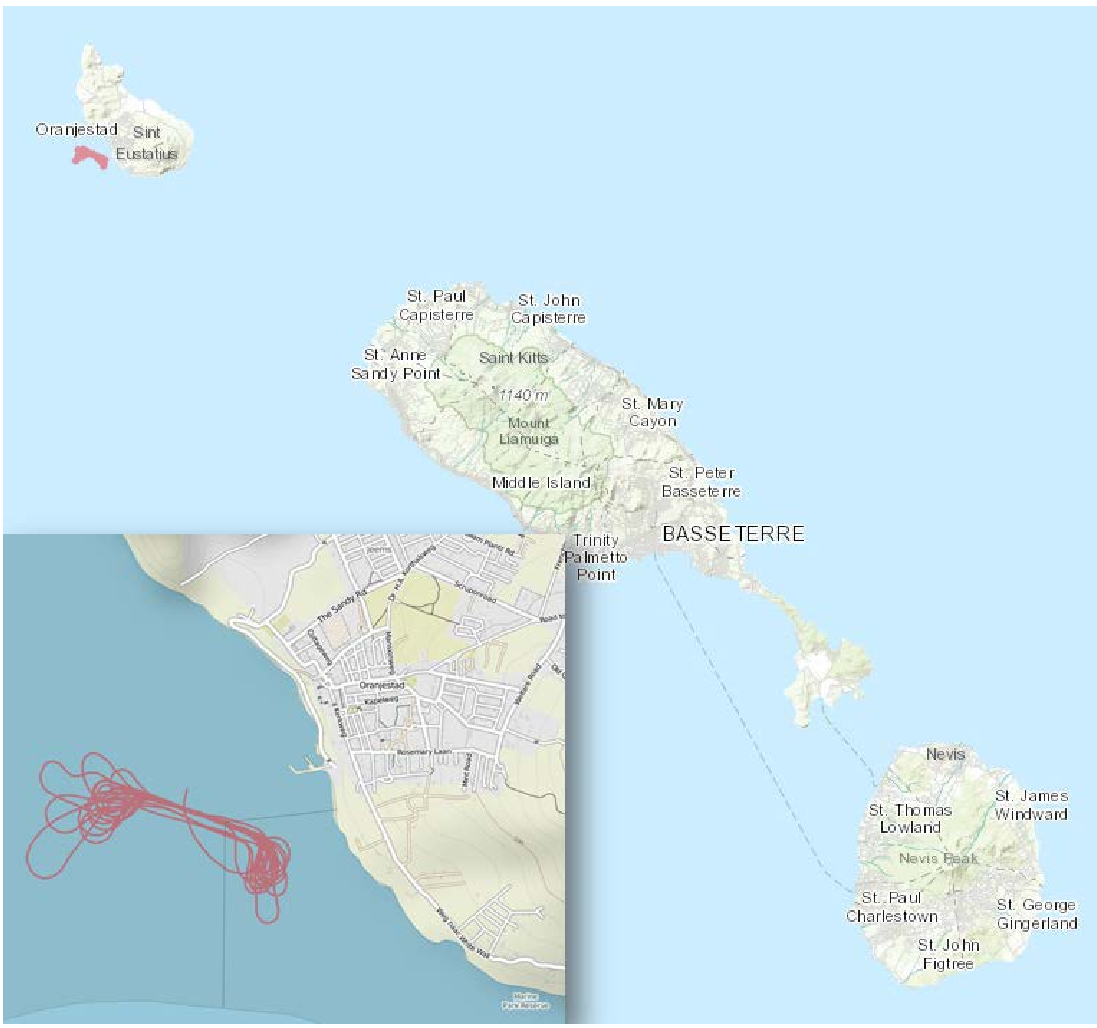

Figure 32: *QUEST sailing on the Dutch PRIME portable range off the Dutch island of Sint Eustatius near St. Kitts and Nevis. Sint Eustatius is in the top left corner. The inset shows the QUEST tracks over the PRIME range in Gallows Bay. The PRIME team were at the jetty shown in the inset.*

At Gallows Bay, the Dutch team with DRDC's Mr. Brad Nelson had the PRIME system deployed and tested against a calibrated source target ahead of the trial with QUEST. The sensors were laid such that QUEST would sail approximately from north-west to south-east instead of north to south. Optimal settings for the degaussing system were calculated based on measurements at the Earth Field Simulator and from those at Bedford degaussing range. On February 6 and 7, QUEST sailed approximately 30 times over the PRIME range with a systematic variation over the degaussing system and active shaft grounding system configurations. In particular, an undegaussed ship, one with some coils activated and one that was optimally degaussed sailed over PRIME. Additionally the three shaft grounding states were measured: brushes lifted, passive and advanced active modes. In making the magnetic measurements, QUEST was ranged at the southernmost latitude of about 17°N while most of the previous magnetic ranging has been in the 40-60°N range. After a difficult recovery of PRIME from the seabed by QUEST, she set sail for home. An engine failure necessitated diverting to San Juan, Puerto Rico where the latest updates from CFB Greenwood on the availability of a CP-140 Aurora for a rendezvous off Halifax looked doubtful. Consequently, the option of releasing scientific crew to return home by commercial air was explored and being cost-effective it was selected. RIMPASSE came to an end on February 10 with scientific crew departing QUEST in San Juan. QUEST sailed back to Halifax after repairs arriving on February 14, 2012.

RIMPASSE set out with the objectives of collecting data and executing certain experiments that are summarized in Tables 1, 2 and 7. Judging to what extent the objectives were met on collection and execution (not post-processing and analysis) we find that in RIMPASSE the success rate was in excess of 90%. In Table 9, we have listed the adjudged success rate for each of the 16 trials in RIMPASSE based on the extent to which the data collection and trial execution were completed. More importantly, we have identified the sources of failure and noted them in the table.

The ICCP system is a ship system and it's availability, maintenance and operation are a ship responsibility. Given that QUEST was returning from a stability modification and a replacement/refurbishment of electrical systems, the ICCP system repair was simply not addressed within the time frame for the RIMPASSE trial. It affected electromagnetic data collection at several range sites. The shaft grounding system provided some cathodic protection in the absence of the ICCP. The sea suction pole was designed and re-designed by a ship contractor and unfortunately did not meet the requirement that the ship be able to sail at 10 knots. The vibrations of the suction pole at 6-7 knots limited QUEST from going faster which was desirable for ship-flare separation and for full plume loading with active hull cooling simultaneously. It had been planned that the DRDC DSIMS-MAG system would be used at Aschau alongside the Dutch PRIME and Polish IGLOO systems but it was not transported to Germany for the trial.

Weather limitations, the opportunistic availability of the CP-140 and the requirements for crew retraining given that QUEST was alongside are outside the planning envelope of RIMPASSE. Their impact, though minuscule, was felt.

Table 9: *Success rate as a % of objectives achieved for the RIMPASSE trials.*

Trial	Location	Days on station	Failures/notes	Success
1	Ferguson's Cove, CAN	2	Poor weather affected range hydrophone operations.	70%
2	Bedford range, CAN	1	ICCP system not functional. Coil effects not completed. Time pressure due to crew training reduced a planned 2-day trial to a very long 1-day operation.	90%
3	Loch Fyne range, UK	1.5	Nil	100%
4	Loch Goil range, UK	1.5	Nil	100%
5	Open ocean off Cape Wrath, UK and the deep water site	3	Nil	100%
6	Heggernes range, NOR	3	Nil	100%
7	Herdla range, NOR	3	ICCP system not functional.	95%
8	Friedrichsort-Moltenort range, DEU	1.5	Nil	100%
9	Surendorf range, DEU	11	Sea water suction pole for infrared active hull cooling prevented QUEST from sailing at desired speeds.	95%
10	Aschau range, DEU	3	ICCP not functional. DSIMS-MAG not available.	90%
11	Earth Field Simulator, DEU	6	Nil	100%
12	Brest range, FRA	2	ICCP not functional.	95%
13	Open ocean off Halifax, CAN	0.5	CP-140 Aurora not available due to stormy weather.	0%
14	Bedford range, CAN	2	ICCP not functional.	95%
15	Off Sint Eustatius, NLD	1.5	Nil	100%
16	Open ocean off Halifax, CAN	0.5	CP-140 Aurora not available.	0%
ALL			weighted by days at station	$\sim$ 93%

4 Notable Achievements

In this section, we describe some measures of the achievements of the RIMPASSE trials. These encompass NATO awards, dedicated conference sessions, scientific publications, and general publicity. The ship signature scientific achievements are not described in this section but can be extracted from the list of published papers.

As has been described in Section 1, RIMPASSE found its scientific leadership in the NATO SET 144, 154 and 166 groups. Consequently after completion of the RIMPASSE trials and some post-trial analysis, the leaders of the three NATO task groups completed their project reports with a large portion of each dedicated to RIMPASSE. These reports are in References [15], [16] and [17]. NATO SET 144 covering infrared ship signatures was the recipient to two NATO STO awards: the NATO STO Panel Excellence Award in 2013 and the NATO STO Scientific Achievement Award in 2014.

With RIMPASSE completed in early 2012, results of analysis from the RIMPASSE trials have been discussed at many scientific venues such as the CSSM annual conference, the UDT and Marelec conferences. In Table 10 we have listed the open (unrestricted) conferences at which RIMPASSE data has been discussed. We only list work that is directly based on RIMPASSE data and not work that is a follow on from RIMPASSE of which there is a growing body. Furthermore, it is important to realize that given the classification of QUEST's acoustic signature and some elements of her suppressed infrared and underwater electric signatures, an open forum is not the appropriate venue for discussion.

To date, there have been over 27 open conference and journal papers that are based directly on the data collected in RIMPASSE. Twenty-five conference papers and two journal papers are listed in Table 10. Papers presented at closed conferences such as those with limited attendance from selected countries like the CSSM conference and the German DAGA meetings have not been included. In addition, given the sensitive nature of some of the signature results, much of the exchange has happened within scientific discussions at the NATO panel meetings and CSSM signature working groups. Interestingly, the Marelec 2013 conference had a session on two consecutive days specifically devoted to the RIMPASSE trials which included a keynote presentation as part of seven papers out of a total of 43 papers at the biennial meeting.

Since 2016, RIMPASSE data analysis is not directly discussed as much as it was in 2012-2015. However, the RIMPASSE data and analysis has led to the development of ideas that are being applied to the development of sophisticated signature modeling tools (particularly by the Dutch TNO and the UK division of Atlas) and signature monitoring methods.

Table 10: *A summary listing of the open conference and journal papers rooted in the RIMPASSE trials.*

Conference or journal	# of papers	Reference (Note)
Undersea Defence Technology (UDT), May 2012	2	1. B. Lucas, DGA/TN & GESMA Ranges: focus on ElectroMagnetic ranges (Discusses both QUEST and PLANET electric and magnetic signatures from Brest range). 2. H. Hasenpflug, S. Schäl, A. Constable, J. Burrows, L. Gilroy, C.A.F. de Jong, N. Keech and R.C.N. Vermeulen, RIMPASSE Quick Look Acoustic Analysis.
Electromagnetic Silencing Symposium (EMSS), May 2012	2	1. E. Lepelaars, Non-linear effects in magnetic structures (Discusses QUEST in the Earth Field Simulator). 2. L. Kätow, RIMPASSE overview.
European Conference on Underwater Acoustics (ECUA), July 2012	3	1. V. Nejedl, A. Stoltenberg, J. Schulz: Free-field Measurements of the Radiated and Structure Borne Sound of RV PLANET. 2. C. Zerbs, I. Pascher, A. Müller: Application of a signal theoretic approach for the online monitoring of radiated sound. 3. S. Schäl, A. Homm, Radiated underwater noise levels of two research vessels, evaluated at different acoustic ranges in deep and shallow water.
Joint Italian and German conference on acoustics (AIA-DAGA), March 2013	2	1. V. Nejedl, A. Stoltenberg, J. Abshagen, R. Lühder, Free-Field Measurements of RV PLANET – Aspect Angle Variability. 2. A. Homm, Data evaluation of underwater radiated noise of ships in relation with directivity.
Marine Electromagnetics (Marelec), July 2013	7	1. Y. Wang, Evaluation of factors affecting the measurement of underwater electric potential fields. 2. D. Schaefer, Comparability of UEP signatures measured under varying environmental conditions. 3. M. Birsan, Comparison of predicted and measured UEP signatures of the German research vessel PLANET. 4. J. Rhebergen, Overview of the RIMPASSE 2011 electromagnetic signature trials with CFAV QUEST and PLANET. (Keynote presentation). 5. D. Bekers, Degaussing system design optimization. 6. M. Birsan, AC degaussing coil effects and hull shielding in the CFAV QUEST. 7. J. Ashton, Permanent magnetization changes in steel hulled ships.
Marine Electromagnetics (Marelec), June 2015	8	1. M. Birsan, Monitoring the ship's permanent magnetization at sea using on-board sensors. 2. R. Tan, Development of magnetic signature management in the COSIMAR project. 3. H. Alqadah, High resolution holographic imaging using sparse dipole expansions. 4. Y. Wang, Effect of sacrificial anodes inside hull openings on underwater electric signatures. 5. E. Lepelaars, The static E&M source modeler. 6. E. Lepelaars, CAD model quality checking: the key to a smooth work-flow from ship design to signature calculation. 7. N. Valdivia, Holographic Imaging of Ship Sources from Silencing Ranges Signatures. 8. C. E. Lucas and T. C. Richards, A novel technique for modelling ship magnetic signatures
Journals in 2016	2	1. M. Birsan and R. Tan, The effect of roll and pitch motion on ship magnetic signature, Journal of Magnetics, vol. 21(4), pp. 503-508, 2016. 2. D. Schaefer, J. Doose, M. Pichlmaier, A. Rennings and D. Erni, Conversion of UEP Signatures Between Different Environmental Conditions Using Shaft Currents, IEEE Journal of Oceanic Engineering, Vol. 41(1), pp 102-111, 2016.
Marine Electromagnetics (Marelec), June 2017	1	1. Lt Cdr Hendrik Jacob Vink, Closed loop degaussing - MASTERCODE project.

In addition to the open literature publications, RIMPASSE data has been analyzed and reported internally in several reports with much of the electromagnetic signature analysis in Refs [18] and [19]. DRDC has received some reports from the Dutch TNO, from AU DST Group, from the Polish Defence academy, etc. Yet there were a handful of requests from the UK MOD to permit the sharing of RIMPASSE data with UK academia and UK defence contractors from which it is not clear what reports have been returned. One can say likewise for the US which undertook some RIMPASSE earth field simulator data analysis with a German WTD71 colleague but it is not clear what reports were released to DRDC.

While not a notable achievement, the RIMPASSE trials captured the spotlight in local newspapers in Germany and France, and upon returning to Canada was written up in the Vanguard Magazine (http://www.vanguardcanada.com/2014/03/18/quest-signature-management/).

5 Exploitation Plan

With new ship projects underway in Canada, Germany and the Netherlands, there has been a refocusing of the effort in ship signature management. The Canadian Navy had in 2012 succinctly recommended[13] that the national defence R&D effort "Develop new approaches and relevant technologies to reduce platform signatures and introduce real-time signature monitoring and management methods, with regards to acoustic, electromagnetic, infra-red and radar cross section signatures, by 2020." RIMPASSE and the follow-on work directly address this guidance. The principal benefit of a well developed exploitation plan of RIMPASSE would have been to ensure that the tangible conclusions from RIMPASSE were actionable to meet the Canadian Navy guidance from the 2012 MSTPG.

In effect, upon completing RIMPASSE, DRDC hosted CSSM's 5th International Conference on Signature Management Systems in Halifax in October 2012. In part the strategy was to solicit the RIMPASSE analysis results from all partners. Soon after, the author was named DRDC's Special Advisor on Ship Signatures with the specific tasking of providing guidance on ship signature requirements to the Canadian Surface Combatant (CSC) project team. The author was able to exploit RIMPASSE data and results as well as leverage the partnership with Germany and the Netherlands to furnish the CSC team a timely and comprehensive ship signatures requirements and evaluation guidance [20].

With DRDC, on behalf of DND, being the Canadian observer at CSSM, it appeared that a strategy after RIMPASSE would have been to field a DRDC posting at CSSM

[13] See the "Maritime Science and Technology Programme Guidance (MSTPG, version 8, March 2012)."

for a duration of 6-12 months. In addition to growing the CSSM structure and aiding in aligning ship signature research at DRDC with counterparts in Germany and the Netherlands, it would have afforded DRDC the opportunity to be highly proactive in exploiting the results from RIMPASSE. This unfortunately was overcome by events and did not come to pass. Consequently, a full exploitation of the RIMPASSE data has not been accomplished. Given that our primary interest was in ensuring that the data from RIMPASSE was studied as fully as possible, DRDC generously allowed the QUEST RIMPASSE data to be shared with third parties on a case by case basis. In each instance in which a partner nation applied to DRDC for permission to share the data with third parties in order to meet specific project goals (or NATO SET group objectives), DRDC provided a letter stipulating that the data was to be used for the project goals and that the reports were to be shared back with DRDC.

In light of the arm's length relation between DRDC and third parties in partner countries, it was difficult to monitor the progress being made and to fully appreciate any reports that were received. This deficiency in the DRDC ship signature project's ability to exploit the results of RIMPASSE from third parties in partner countries probably arises from the lack of depth in staffing in the ship signature project during and preceding the RIMPASSE years. Two consequences of this were firstly the lack of a cohesive project in ship signatures prior to RIMPASSE and secondly the lack of emphasis on knowledge synthesis. The former would not have facilitated a developed strategy for post-trial analysis and exploitation (for example in a deeper collaboration with partners). And the latter is a cultural practice (to collect, assimilate and synthesize knowledge from various parts making sense of an information overload that is pervasive in scientific research these days) that had not caught on until the author wrote the ship signature requirements for the CSC in 2013-14. Perhaps to some extent both of these drawbacks are being mitigated and that collaborations with partners are deepening and the extraction and synthesis of knowledge in ship signatures from partners is improving.

6 Investment

The RIMPASSE trial was a major investment for DRDC and her international partners, particularly Germany. In order to grasp the size of the investment that Canada made in RIMPASSE, we have collected in Table 11 an approximate breakdown of the commitment in time and money made by DRDC and DND in three periods: the two years before the RIMPASSE trial, during the RIMPASSE trial and the two years after the trial.

In the periods preceding and after the trial, the estimate of the commitment in time is the author's impression of the RIMPASSE workload for the DRDC staff that were responsible for the various tasks. During the RIMPASSE trial, the author as the

Chief Scientist aboard QUEST, had an accurate log of the DRDC staff on the ship and at the range sites. Thus the average number of personnel amongst the various DRDC professional groups is a good estimate for the salary invested in RIMPASSE.

Table 11: *An estimate of the costs to DRDC and DND associated with the RIMPASSE trial.*

Period	DRDC FTEs	DRDC Travel	DRDC Goods and Services	DND cash costs	DND facility costs (ranges, QUEST, etc.)
June 2009 to June 2011	3 DS, 2 EG, 1 CS	25k	350k	100k	nil
July 2011 to February 2012	3.5 DS, 3.5 EG, 0.5 CS	75k	150k	nil	1700k
March 2012 to March 2014	4 DS, 0.5 EG, 1.0 CS	15k	25k	50k	nil
Overall: June 2009 to March 2014	10.5 DS, 6 EG, 2.5 CS	115k	525k	150k	1700k

The travel costs include accommodations and meals and are all related to RIMPASSE preparations or to deployment to and from various trial sites or for RIMPASSE analysis. The costs for good and services covers mainly the preparation period but also trial support. The largest cost is estimated for the cost of QUEST at $15k/day and for the services provided by the acoustic and degaussing ranges. There was a significant amount of leverage that is difficult to account for such as the lease of pumps, the time and effort of DND personnel assisting with QUEST's deployment, etc. Adding it all up, over roughly five years around RIMPASSE, the Canadian investment is about $4 million with ball park estimates for salaries. Most of this is in salaries and facility costs, with travel accounting for only about 3% and contractor outlays at about 13%.

Germany having provided PLANET and range services for QUEST and PLANET at several ranges in Germany has likely made a contribution equivalent to Canada's. Norway, the UK, the Netherlands and France would be next in line in terms of their total financial investment in RIMPASSE.

7 Conclusions

RIMPASSE was an intricately organized research trial that was the outcome of a collaborative NATO-wide scientific community which sought to address the challenges that it faced in developing ship signature management capabilities. It had its origins in the Canada-Germany-Netherlands workshops on acoustic ship signatures from which came the broader DRDC-CSSM collaboration. The latter set up RIMPASSE and expanded its membership to be NATO-wide.

RIMPASSE was a trial of many firsts for QUEST: a first deperm, the first steel ship in the Earth Field Simulator, the first time firing flare decoys, the first QUEST-PLANET trial, etc. The trial was well orchestrated given the demanding schedule and itinerary. The many results from RIMPASSE have advanced the understanding of ship signatures (monitoring, measuring, modeling, and managing) to various extents in each of the individual signatures and collectively in working toward a ship all signatures management capability.

RIMPASSE's legacy is the enduring collaboration that has emerged in the development of a ship signature management system. The full impact of RIMPASSE is yet to be realized—it will likely have its hand in any closed loop deguassing technology that the DRDC-CSSM-plus-others consortium develops as well as in the overall ship signature management system simulator that is a centrepiece of the collaboration since RIMPASSE and the decommissioning of QUEST.

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This Reference Document reflects upon DRDC's undertaking of the RIMPASSE trial with CFAV QUEST in 2011-12. We provide the context in which the RIMPASSE trial emerged as a joint international effort led by Canada, Germany and the Netherlands. Presenting only the DRDC perspective, we discuss how the collaboration was fostered and the organizing structures to facilitate trial planning, preparation and execution. We describe the level of ship signature capability and identify the path to improved ship survivability from a better exploitation of ship signature control which form the backbone of the motivation for RIMPASSE. The objectives for each of the ship signature experiments comprising RIMPASSE are presented. The extensive preparations in Canada especially in modifying QUEST are recalled followed by a description of the trial execution at ranges in Halifax, in Scotland, in Norway, in Germany, in France and in Sint Eustatius. We recount some of the notable achievements of the RIMPASSE trial and provide an accounting of the investment made in this effort.

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