Imaging Sonar Testing at NRC IOT Tow Tank

Trial Report

Anna Crawford
Sean Spears
Warren Connors
Defence R&D Canada – Atlantic

Defence R&D Canada – Atlantic

Technical Report
DRDC Atlantic TR 2012-041
November 2012

© Her Majesty the Queen in Right of Canada as represented by the Minister of National Defence, 2012

© Sa Majesté la Reine (en droit du Canada), telle que représentée par le ministre de la Défense nationale, 2012

Abstract

This report describes work that was performed at National Research Council Institute of Ocean Technology (NRC IOT), St John's, in February 2012. There were several overall aims of the testing: to assess the suitability of the sensors for detecting small foreign objects on ship hulls or other underwater structures; to assess the true resolving power of the sensors; to assess optimal geometries for deployment of the sensors; and to provide high quality sonar data for ongoing imaging sonar data mosaicking software development. During the testing a variety of small imaging sonars were transited above small targets laid on the bed of the tank. Having the sonars mounted to the tow carriage of the test tank allowed precise control of the sensor–target geometry which is critical for achieving the stated trial goals. The purpose of this report is to document the testing that was performed for later reference, to assist in interpretation of the collected sonar data in later analysis.

Résumé

Le présent rapport décrit les travaux réalisés à l'Institut des technologies océaniques du Conseil national de recherches du Canada (ITO-CNRC), à St John's, en février 2012. Les essais comportaient plusieurs objectifs généraux : l'évaluation de l'efficacité des capteurs pour la détection de petits corps étrangers sur la coque des navires ou d'autres structures sous-marines, l'évaluation du pouvoir séparateur réel des capteurs, l'évaluation des géométries optimales pour le déploiement des capteurs et la prestation de données sonar de haute qualité pour le développement en cours d'un logiciel de mosaïquage de données des sonars d'imagerie. Pendant les essais, divers petits sonars d'imagerie sont passés au-dessus de petites cibles au fond du bassin. Les sonars montés sur le chariot de remorquage du bassin d'essai ont permis un contrôle précis de la géométrie capteur-cible, laquelle est essentielle à l'atteinte des objectifs d'essai indiqués. Le présent rapport vise à rendre compte des essais réalisés aux fins de référence ultérieure en vue d'aider à interpréter les données sonar recueillies dans le cadre d'analyses subséquentes.

This page intentionally left blank.

Executive summary

Imaging Sonar Testing at NRC IOT Tow Tank

Anna Crawford, Sean Spears, Warren Connors; DRDC Atlantic TR 2012-041; Defence R&D Canada – Atlantic; November 2012.

Background: DRDC Atlantic performed tests to determine imaging sonar capabilities at the National Research Council Institute for Ocean Technology in February of 2012. Small imaging sonars are typically used for performing underwater inspections of ship hull and jetty structures. The tests provided sonar data with very well controlled geometry in order to assess resolution, optimum sensor deployment and other factors affecting imaging sonar performance. As well, high quality sonar data was collected for use in development of sonar data mosaicking software.

Principal results: The testing program resulted in a valuable imaging sonar data set. The purpose of this report is to document the testing that was performed for later reference, to assist in interpretation of the collected sonar data in later analysis.

Significance of results: The optimal imaging geometries (look–angle, ranges) determined during the testing will contribute to development of best practices in the use of Remotely Operated Vehicle–mounted imaging sonars for underwater inspection tasks. Assessment of the resolving power of the different imaging sonars will allow decisions to be made on which sensors can best perform inspection tasks.

Future work: The imaging sonar data set that was collected during the trial will be used in on–going work on imaging sonar data mosaicking software that is currently in development under contract. Detailed analysis of the data collected during this testing will be reported in future reports.

Sommaire

Imaging Sonar Testing at NRC IOT Tow Tank

Anna Crawford, Sean Spears, Warren Connors ; DRDC Atlantic TR 2012-041 ;
R & D pour la défense Canada – Atlantique ; novembre 2012.

Contexte : En février 2012, RDDC Atlantique a réalisé des essais pour déterminer la capacité des sonars d'imagerie à l'Institut des technologies océaniques du Conseil national de recherches du Canada. On utilise en général des petits sonars d'imagerie pour effectuer les inspections sous-marines de la coque des navires et des structures de jetée. Les essais ont produit des données sonar avec une géométrie très bien contrôlée en vue d'évaluer le pouvoir séparateur et le déploiement optimal des capteurs, et d'autres facteurs qui influent sur le rendement des sonars d'imagerie. De plus, on a recueilli des données sonar de haute qualité aux fins d'utilisation pour développer un logiciel de mosaïquage de données sonar.

R´esultats principaux : Le programme d'essai s'est soldé par un excellent ensemble de données des sonars d'imagerie. Le présent rapport vise à rendre compte des essais réalisés aux fins de référence ultérieure en vue d'aider à interpréter les données sonar recueillies dans le cadre d'analyses subséquentes.

Port´ee des r´esultats : Les géométries d'imagerie optimales (angle de visée et portées) déterminées pendant les essais contribueront à développer des pratiques exemplaires liées à l'utilisation de sonars d'imagerie montés sur véhicule téléguidé pour effectuer des tâches d'inspection sous-marine. L'évaluation du pouvoir séparateur des divers sonars d'imagerie permettra de déterminer les meilleurs capteurs à utiliser pour les tâches d'inspection.

Recherches futures : L'ensemble de données des sonars d'imagerie recueilli pendant les essais sera utilisé dans le cadre des travaux continus sur le logiciel de mosaïquage de données des sonars d'imagerie en développement sous contrat. Une analyse détaillée des données recueillies pendant ces essais fera l'objet de rapports ultérieurs.

Table of contents

List of figures

List of tables

This page intentionally left blank.

1 Introduction

A one–week imaging sonar testing program was carried out at the National Research Council Institute for Ocean Technology (NRC IOT) Tow Tank facility in St John's, Newfoundland (Monday February 6 – Friday February 10, 2012). The facility is a 12 m wide by 200 m long tank with water depth about 6 m. A testing plan is published elsewhere [1] and this report serves to document details of the execution of the testing and some preliminary discussion of the lessons learned. Detailed analysis of the imaging sonar data that was collected is ongoing and will be documented separately in the future.

The purposes of the testing were as follows:

- To assess the suitability of the sensors for detecting small foreign objects on ship hulls or other underwater structures;
- To assess the true resolving power of the sensors;
- To assess optimal geometries for deployment of the sensors; and
- To provide high quality sonar data for ongoing mosaicking software development.

Motion of the sensors was required to simulate either passage of a ship hull past a stationary sensor or forward progress of an Remotely Operated Vehicle (ROV)–mounted sensor past a jetty or other structure, but with exact control of sensor–target geometry and tow speed, which is not possible in either of these two situations operationally. NRC IOT, in St John's, is one of the few tow tank facilities of its kind in North America, and the only one in Canada where the sensor–target range can be made sufficiently large to provide a realistic test environment.

Figure 1 is an illustration of the concept of using an imaging sonar from the tow tank carriage to image targets on the floor of the tank. Imaging sonars work best in a forward–looking configuration, as pictured. The sonar ensonifies a sector ahead of it with total horizontal angular width typically 30° to 45° wide. Multiple sonar beams are arrayed across the sector, typically 1° wide horizontally, but quite wide in the vertical direction, typically 15° to 30°. The sonar imagery is a plan view map of objects in the field of view, with anything standing proud casting a shadow. Each sonar transmission (ping) produces a map and forward progress of the sonar between consecutive pings is generally limited to a fraction of the maximum imaging range so that there is overlap in the maps produced from one ping to the next. In this way, the overlap can be used to build up a mosaick of a series of ping images.

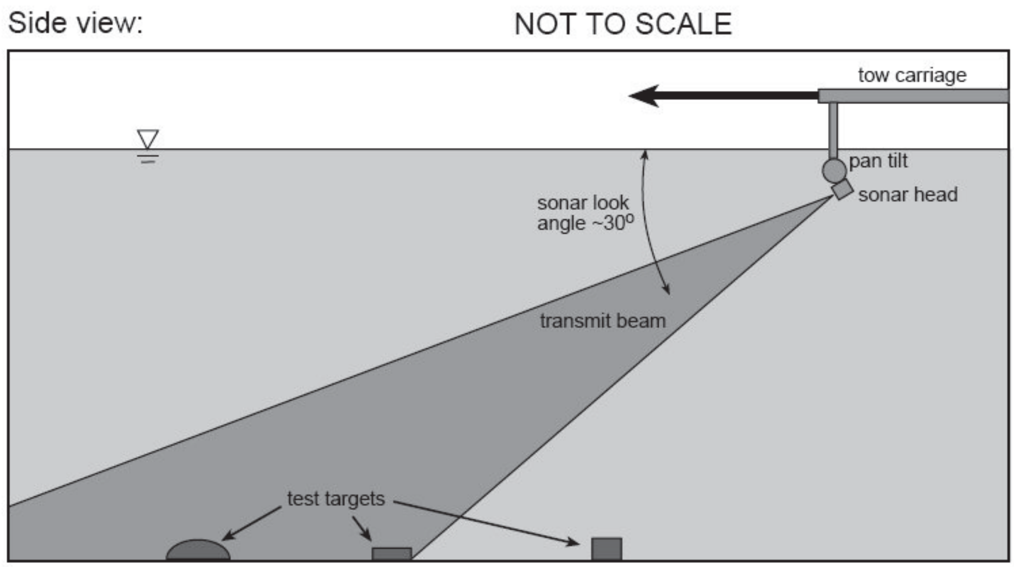

Figure 1: *Cartoon illustrating the concept of imaging targets on the tank bed.*

2 Equipment

The following subsections describe the equipment used in the testing. The targets and their deployment are described in a separate section later in this report. With the exception of the sonar mounting pole which was sent ahead, and the SonarBell target which went in checked baggage, the equipment for this trial fit in one standard "tri–wall" crate and was shipped by surface. All of the equipment was packed into the same tri–wall for return ground shipment.

2.1 Imaging Sonars

Figure 2 shows photos of the four imaging sonars that were tested and Table 1 lists technical specifications. They are all small in physical dimension, with the DIDSON (Dual-frequency Identification SONar) being the largest at 12.25" long, 7.7 kg weight in air. All four sonars are controlled from a surface laptop running manufacturer–supplied software. The Imagenex requires a separate DC power supply (24 VDC, <12 Watts), but the other three use an integrated power/communications interface box that plugs into a standard wall power outlet.

2.2 Pan–Tilt Motor and Sonar Mounting Pole

The sonars were mounted to a Remote Ocean Systems PT–25–FB pan-tilt motor which itself was fixed to the bottom of a pole with the matching bolt pattern. The pole was made

Table 1: *Technical specifications of the small imaging sonars used in the testing. ΔR is the range resolution.*

Make/Model	Freq (kHz)	Horiz. Sector	Beams	Beam Width	ΔR (cm)
BlueView P450	450	45°	256	$1° \times 20°$	5
BlueView P900	900	45°	256	$1° \times 20°$	2.5
DIDSON 300	1100 (LF)	29°	48	$0.4° \times 14°$	1–8
	1800 (HF)	29°	96	$0.3° \times 14°$	0.25–2

Figure 2: *Small imaging sonars. Left to right: BlueView P450E, BlueView P900E, DIDSON and Imagenex Delta-T.*

previously for the DRDC Maritime Force Protection Technology Demonstration Project (MFP TDP) for use with imaging sonars on the response boats. NRC IOT fabricated a mounting bracket from large aluminum channel stock to attach this pole to the tow carriage. Figure 3 shows the pole and mounting bracket, with pan–tilt motor and sonar attached, on the tow carriage at NRC IOT. The small sonars were each mounted to the pan–tilt motor using customized mounting plates that matched the bolt patterns on the sonars and on the pan–tilt motor. These were also made previously for the MFP TDP project. As mounted, the sonar heads were about 1 m below the water surface.

The pan–tilt motor requires a 24 VDC power supply and is controlled using manufacturer–supplied software from a laptop, in this case, the same laptop used to control the sonars. The pan-tilt motor uses RS–485 communications for control and also gives feedback of its position, discussed later in this report. A spare pan–tilt motor was brought, but not used.

2.3 Mini-ROV

The VideoRay Pro4 mini–ROV was used to perform a complete underwater video and sonar (BlueView P900) survey of the target layout and surrounding tank environment. This will be very useful for interpretation of the sonar imagery in post–processing, to identify objects and landmarks in the tank that are seen in the sonar data. The mini–ROV was also used for inspection of the clearance between the sonar connector and the mounting plate on the pan–tilt motor, to verify safe limits on the tilt range of motion for some of the sonars.

Figure 3: *Photos of the pole mount and bracket, with sonar and pan–tilt motor attached. The photo on the right shows the large channel bracket in more detail.*

2.4 Laptops and Software

One laptop ran the control software for the ROS pan–tilt motor (Helios version 1.1.0.1) and for the various imaging sonars: Imagenex Delta-T (version 1.01.56), BlueView ProViewer (version 3.5) for both the P450 and P900, and DIDSON (version 5.25.33). The software version numbers are important as there are backward compatibility issues with the recorded data files.

The RS–485 serial connection to/from the pan–tilt motor was split and purpose–written software (implemented in Visual Studio C++) on a second laptop logged the motor commands and feedback to text files. The messages are encoded, as described in a Communications Protocol Document released by Remote Ocean Systems [3]. A Matlab script has been written post–trial to translate the encoded messages stored in the text files into time–stamped pan and tilt angle data. This will be used in the mosaicking contract work. The pan–tilt logger was started each morning and restarted, usually around mid–day, each day so that the log files did not become too large to manage.

The deck control unit for the mini–ROV contains a third laptop. This runs the controller interface for the ROV, a version of the BlueView sonar control software and video recording software for the underwater camera.

3 Set–up of Equipment

A control station for the sonars and pan–tilt motor was set up on the tow carriage, within cable length of the sonar pole mount — the sonars and pan–tilt motor all have cables around 10–15 m in length, limiting options for setup. Figure 4 shows the small table, with the sonar/pan–tilt control laptop, the pan–tilt logging laptop and the power supply for the pan–tilt motor and Imagenex sonar.

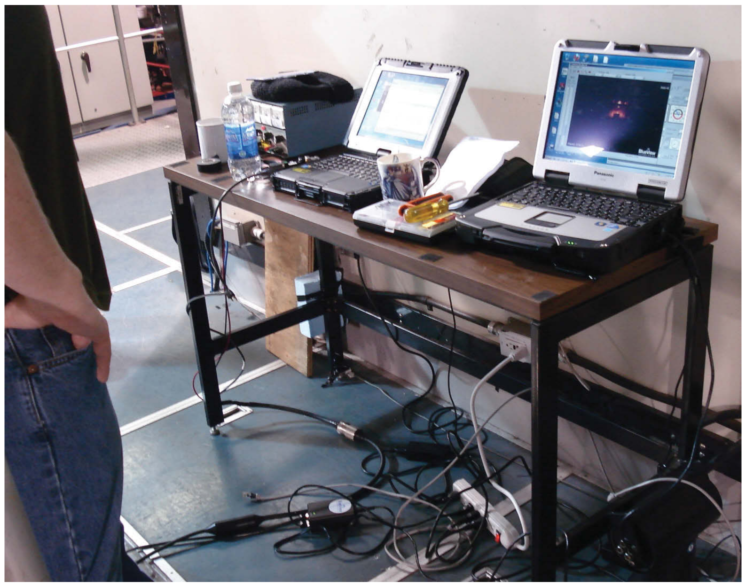

Figure 4: *Photo of the laptops and power supply set up on the tow carriage.*

A mounting bracket to mate DRDC's sonar pole to the NRC IOT tow carriage was constructed from aluminum channel stock on Monday. The bracket is shown in Figure 3. The bracket and pole were installed first on Monday afternoon by NRC IOT personnel, who use a small boat to paddle out to the carriage and work from the underside. The imaging sonars were swapped out several times this way during the testing. This was done by unbolting the pole from the bottom of the tow carriage (done from a small boat), passing it up to the deck of the carriage through the well hole, replacing the mounting plate and sonar on the bottom of the pan–tilt motor, passing it all back down through the hole to the boat below and rebolting the pole to the tow carriage. Figure 5 shows DRDC and NRC IOT personnel working on swapping the sonar head and installation of the pole on the tow carriage.

The targets were deployed by divers on Monday evening, after the target beds were constructed and set in the water to soak earlier on Monday. Soaking was necessary to reduce the amount of air that might be trapped within the carpet, so that it provided a less reflective acoustic background for the targets. Target deployment is discussed further in the following section.

Figure 5: *Photos of Brad Butt and Kent Brett in small boats, and Sean Spears on the deck of the tow carriage, installing the DIDSON sonar.*

The control unit for the mini–ROV was also set up on the deck of the tow carriage. Figure 6 shows a photo of ROV operations during a survey of the targets. The ROV was lowered into the water through the well in the tow carriage, and the tow carriage followed the ROV at slow speed while it drove over the targets down the center of the length of the tank. In the photo, the sonar display is shown on the ROV deck unit above the underwater video display on the laptop, next to the yellow cable reel, all set up on the deck of the tow carriage.

4 Targets and Target Beds

A selection of small targets were imaged, of the size and shape representative of the types of objects that might be of interest in underwater inspection operations. Two inert limpet mine shapes were borrowed from the CF Fleet Diving Unit Atlantic, a hemi–spherical dome shape and a so–called "clam" shape. Two resolution targets were constructed, one from ping pong balls strung in a line at varying spacings and the other a pyramid stack of small sheet metal boxes (electronics project boxes). The resolution targets were designed to test the angular resolving power of the sonars. A SonarBell resonating sphere target was also imaged. Finally, three rocks of varying sizes were used as natural targets, again intended to test sonar resolving power.

It was not possible to simply place targets on the bottom of the tow tank at NRC IOT due to the recent installation of a flow suppression system on the floor of the tank, designed to damp out circulating flow that can build up during tow testing of larger hulls. The

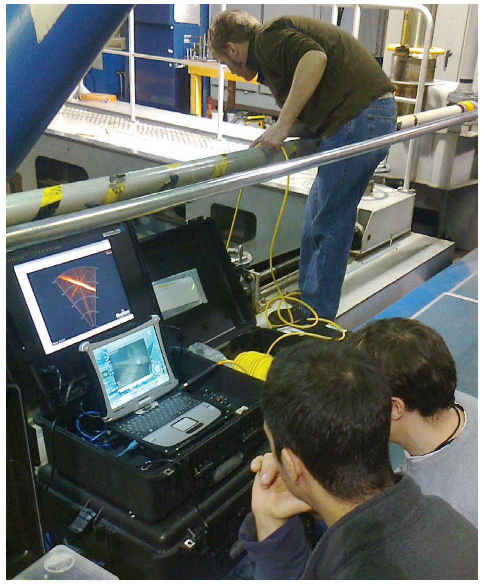

Figure 6: *Photo of Sean Spears (right) and Geoffroy Rivet–Sabourin (left) operating the mini–ROV and Warren Connors (standing) tending the cable, during an ROV survey of the targets.*

flow suppressor consists of large rectangular sections of plastic meshwork that rest on the floor of the tank when not in use. There is also a network of polyvinyl chloride (PVC) pipe on the floor of the tank which is part of a bubbler system and also provides air for buoyancy to raise the sections of the flow suppression system to a vertical position when in use. The problem of providing a flat surface to image the targets against was solved by constructing "target beds". Six of these were constructed by NRC IOT out of 4' $\times$ 8' sheets of plywood, covered with indoor–outdoor carpet and set on 1' legs to raise them above the PVC pipe. Lead weights were fixed to the back sides of the target beds for ballast. The target beds were allowed to soak before the sonar testing to allow air bubbles trapped in the carpet to disperse. The targets were placed by divers on each of the six target beds during deployment. Figure 7 shows photos of the six targets and target beds prior to deployment.

4.1 Resolution Targets

One of the goals of the trial was to assess the true resolving power of the imaging sonar systems being tested. This aim is complicated by the geometry of the individual beams across the imaged sector, narrow in angle in the horizontal direction, but wide in the vertical direction. The critical resolution limitation is the horizontal beamwidth and to a lesser extent, the horizontal beam spacing across the imaged sector. Two targets were designed specifically to test the resolution of the sonars.

The ping pong ball arrays (pictured in Figure 7) were designed with varying spacings be-

Figure 7: *Photos of the targets and target beds prior to deployment in the tow tank. Upper row, left to right: pyramid, ping pong ball arrays, and dome limpet. Lower row, left to right: SonarBell sphere, clam limpet and rocks. Note that the targets were intentionally placed closer to the leading edge of the target beds, relative to the sonar look direction, except for the clam limpet.*

tween the balls to test whether two separate balls could be resolved as a function of range from the sonar. Each string of balls was mounted between brackets on each side of the target bed that suspended the balls about 6" above the bed. The balls were held in a sleeve of nylon netting, tied off on each side of the balls to hold their spacings. At a range from the sonar of 10 m, a beam with 1° width has an arc–width of $L = 17.5$ cm. The spacings of the first ball array were ranged from approximately $1/4L$ to $1.5L$ in $1/4L$ increments and the second array from $1.5L$ to $2L$. The ping pong balls have a diameter of 4 cm, so the closest spacing $1/4L$ had them touching. The last, farthest spaced, ball in the string with the closer spacings broke free during deployment of that target bed when the netting snagged and broke, however that spacing was repeated by the closest pair of balls in the other wider spaced array. Figure 8 shows the spacings of the ball array as constructed, in centimeters. The spacings between the balls in the arrays after they were constructed were within a centimeter of the planned spacings, but were not exact due to the stretch in the nylon netting. A photo of the arrays pre–deployment is shown in Figure 7, showing the mounting brackets on each end to raise the arrays off the target bed.

The pyramid target was designed using the same arc–width criteria as a rough guide, though the size of the boxes used was determined by what was available at DRDC. The width of the smallest boxes at the top of the pyramid was 5.7 cm, or about $1/3L$. The dimensions of the pyramid are shown in Figure 9. Figure 7 shows a photo of the pyramid prior to deployment. The boxes were arranged to test the resolving ability of the various sonars, both in the highlight return from the facing surfaces of the boxes and in the shadows that are cast behind the pyramid. The pyramid was constructed of two 10" × 6" × 2" (bottom

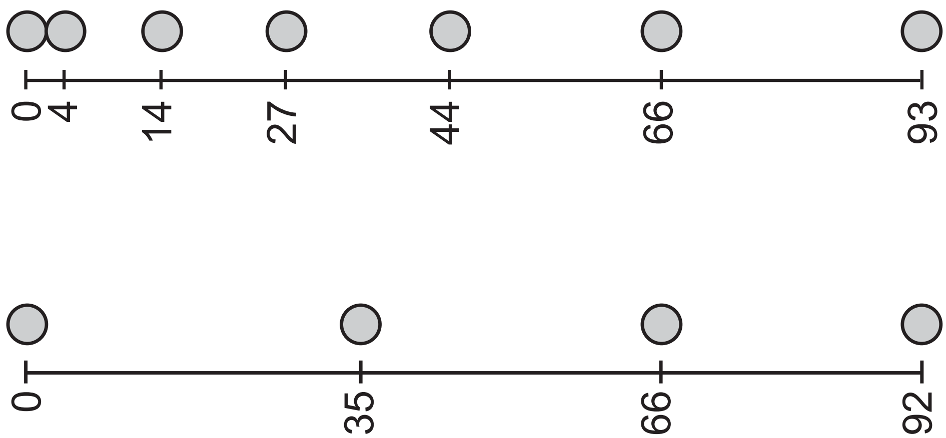

Figure 8: *Diagram of the ping pong ball arrays with measurements after construction, with distances in centimeters.*

layer), three 7” × 5” × 3” (middle 2 layers) and two 2.25” × 5” × 2.25” boxes (stacked on top). The gap between the two bottom layer boxes is the same width as the middle sized boxes, 7”, and the gap between the boxes on the second layer is the same width as the smallest boxes, 2.25” (see diagram, Figure 9). The boxes are free flooding and should have been cleared of air pockets when deployed. The pyramid of boxes was epoxied together prior to deployment.

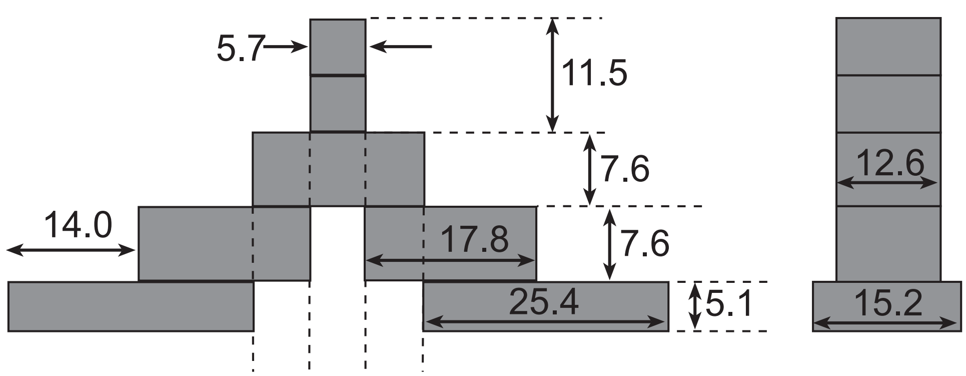

Figure 9: *Diagram of the pyramid target with measurements after construction, with dimensions in centimeters.*

4.2 SonarBell Sphere Target

The SonarBell spherical resonator target was designed to resonate at 900 kHz. The response curve provided by the manufacturer, Subsea Asset Location Technologies Ltd (SALT), shows a wide frequency response with a second resonance peak at around 800 kHz. The operating frequencies of the imaging sonars used in this testing are 450 kHz (BlueView P450), 900 kHz (BlueView P900), 260 kHz (Imagenex Delta-T) and 1.1 and 1.8 MHz

(DIDSON) (see Table 1). The SonarBell is shown in Figure 7, prior to deployment. The shell of the sphere is free flooding and it is neutrally buoyant, however a small weight was inserted into the netting around it to ensure it stayed where it was deployed. The weight was positioned under the sphere by the divers when it was deployed, so as not to interfere with sonar imaging.

4.3 Natural Targets (Rocks)

A large bucket of rocks was collected in advance of the trial by Jack Foley, Physics and Physical Oceanography Department, Memorial University of Newfoundland. The smallest rocks were about 1.5–2" and the largest, about 1'. One small, one medium and one large rock were spaced across the width of one of the target beds, shown in Figure 7. The approximate cross–sectional areas of each of the three rocks are: 48 cm^2, 103 cm^2, and 215^2 (the dimensions along three roughly orthogonal directions were averaged and squared). The remainder of the rocks of random sizes, mostly about the same size as the smallest of the set of three, were distributed across the large carpet area.

4.4 Mosaicking Targets

To provide a larger area to collect sonar data while translating and rotating the sonar heads in support of the mosaicking work, a bigger piece of the same indoor–outdoor carpet as on the target beds, about 10 m long by about 8 m wide, was laid out on the floor of the tank. It was spread between weighted 2" $\times$ 4" planks. Small targets, rocks and miscellaneous metal parts and weights were scattered over this surface, along with two 10' lengths of 2" diameter pipe at random orientations, oblique to the long axis of the tank. It was found that the small targets were not imaged very well on the carpet and two large truss structures scrounged from NRC IOT were placed in the tank to provide large linear features for that work. The background environment of the tank itself, the flow suppression system and PVC pipes, provided lots of features naturally. Figure 10 shows a photo of one of the two identical trusses while it is being deployed from a raft. The trusses were 164.5" long, made from 2" square stock and 1/2" rod, with 16" square end pieces. The two trusses were laid on the tank floor in a $>$ configuration, shown in the upper right of Figure 10. The Figure also shows two captures from the mini-ROV video showing the carpet area with scattered small targets and the trusses after deployment.

5 Personnel

From DRDC Atlantic, Warren Connors and Sean Spears provided technical support and Anna Crawford was the Chief Scientist. From NRC IOT, technical support was provided by Brad Butt and Kent Brett, supervised by Craig Kirby. Their work included fabrication

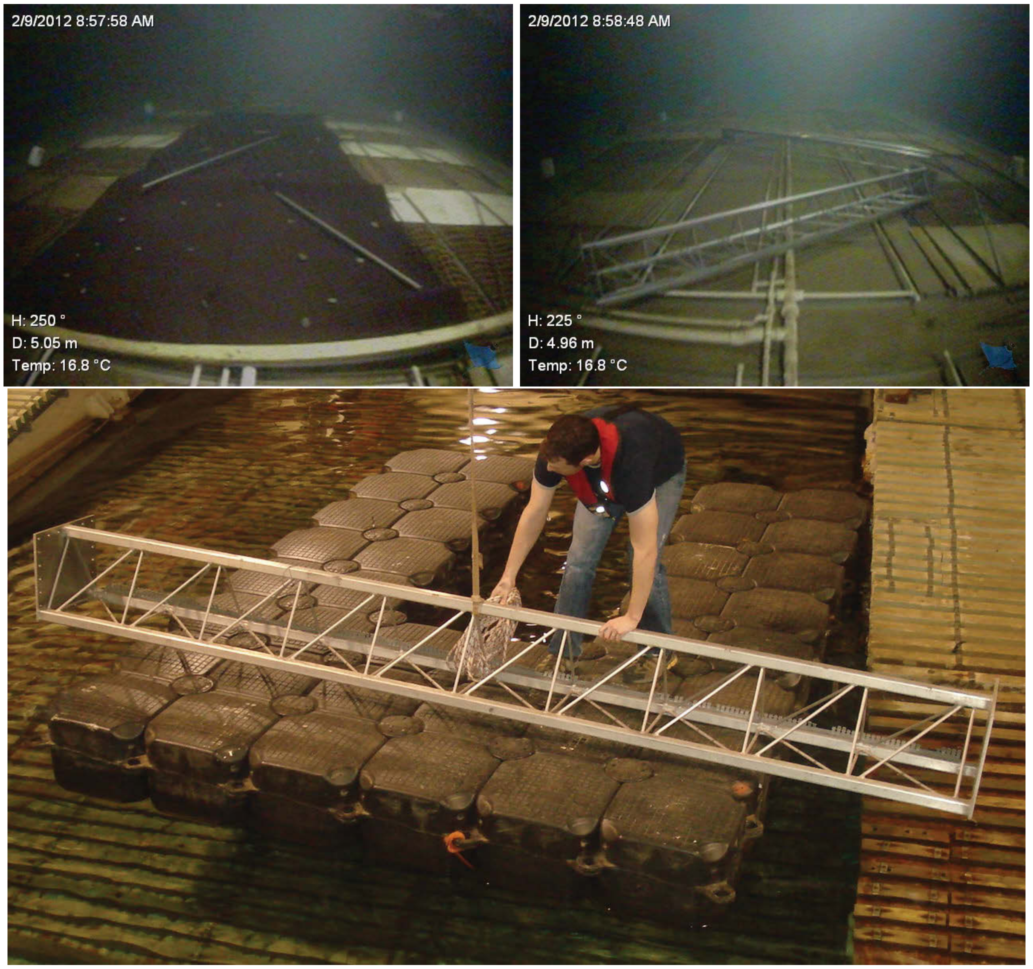

Figure 10: *Frame captures from the ROV video showing the carpet area with scattered small targets (upper left) and the trusses (upper right), both looking West. The lower photo shows one of the trusses during deployment. The apparent bow of the plank holding the leading edge of the carpet (upper left) is distortion by the wide–angle lens on the mini-ROV camera.*

of mounting hardware and target beds, mounting and changing out of the sonar heads, diving for target deployment and recovery, driving the tow carriage, escorting visitors, and providing the carriage data files. Geoffroy Rivet–Sabourin of Intelligence Image Inc., Stoneham, Quebec, attended the trial in support of contract work on mosaicking of imaging sonar data (W7707–125396/001/HAL).

6 Schedule

A week of tow tank time was booked at the NRC IOT facility, Monday February 6—Friday February 10, 2012. DRDC personnel flew in to St John's on the Sunday prior and returned Friday evening. An overview of the activities for the week is shown in Annex A and a detailed listing of the run configurations and data files that were collected is included in Annex B.

Weather played a role since indications on Thursday were that the NRC IOT facility was likely to be closed on the Friday due to heavy snow. A snowfall warning was issued Thursday morning for Thursday night. Sonar testing was progressed to a point by the end of Thursday afternoon where if there was a weather closure on Friday, the bulk of the testing required to meet the goals of the trial was completed. The equipment was left in a state where little would be required of the NRC IOT personnel to pack it for shipping back to DRDC. The testing was intended to end at noon on Friday in any case due to scheduling requirements at NRC IOT – the tow carriage was to be dismantled prior to the end of the week so that servicing work could begin on the following Monday. As it turned out, the weather was not as severe as predicted and the facility was not closed, so a further set of runs was performed on Friday morning and the equipment was completely packed before leaving the site early Friday afternoon.

No firm schedule of test runs was established prior to the start of the trial because it was not known how long it would take to complete a set of repeats of a particular run configuration, nor whether particular targets would be successfully imaged with each of the sonars. Priority was established among the sonar systems to be tested: first the DIDSON, followed by the BlueView P900 and P450 which were about equal, and lastly the Imagenex Delta-T. A protocol of running 10 repeats of a particular test configuration (target, sonar look angle) was established during the first full day of testing (Tuesday) and this was followed for sets of runs for the remainder of the week. There were several sessions of making adjustments to the sonar look angle and moving the carriage small amounts to establish optimal sonar imaging geometry. Runs were also made where sonar pan angle was varied as the carriage moved and finally, with carriage cross–tank position varying, called "sway" in NRC IOT terminology, at the same time as pan and along–tank position. These runs support the contract work on imaging sonar data mosaicking.

7 Data Logging

Approximately 7.4 GB of sonar and mini-ROV video data were collected during the trial. All the imaging sonar data was recorded on the laptop used to control the sonars and the pan–tilt motor. The pan–tilt motor log text files were all stored on the second laptop. ROV sonar and video data were recorded on the ROV controller deck unit laptop. Tow carriage position and speed (time stamped) were logged on NRC IOT's system and those data files were provided to DRDC in .csv format at the end of the trial, along with a summary table of the file names and summary plots of the individual runs data. A complete chronological listing of the data files collected is given in Annex B.

All the carriage, sonar, video and pan–tilt data were backed up to one external USB drive periodically. DVD backup copies were made back at DRDC. A complete copy of the data set up to the end of Thursday was given to Geoffroy Rivet–Sabourin before his departure from St John's for the mosaicking contract work.

7.1 Time Synchronization

Trial time in logs and data files was local time in St John's, i.e. Newfoundland Standard Time (GMT - 3:30 hrs). The two laptops were manually synchronized to NRC IOT tow carriage time on Tuesday morning before logging any data, and checked again on Thursday morning. The third laptop, the deck controller for the mini–ROV, was not synchronized, though a logbook note on Thursday Feb 9 states "8:13 AM videoray = 09:41 AM local".

8 Layout of Targets

The target beds were placed at about 10 m intervals down the center line of the Eastward half of the 200 m length of the tank. The carpeted area was laid out West of the Westmost target bed. Later in the trial, 2 large trusses were placed West of the target bed. One of the ping pong ball array targets was damaged during deployment. The last ball in the closer spaced string broke free when the nylon netting broke.

The along–tank positions of the targets after deployment were measured using the tow carriage positioning system and a plumb bob lowered to each target from the center line of the tow carriage. The plumb bob was positioned even with the center of the sonar mounting pole on the tow carriage, which was aligned to the tow tank coordinate system, and the carriage position was adjusted along–tank until the plumb bob was on each target. Table 2 lists the measurements, with comments about the positioning of the bob in each case. In tank coordinates, the tow carriage moves in the East-West direction, with the East end of the tank at 0.0 m.

With the exception of the clam target, the targets were placed on the beds closer to one edge of the bed so that the acoustic shadow was cast behind a target, falling completely on the bed with surrounding background for contrast. The clam target was placed in the middle of that bed, since it had a low profile and did not cast a long shadow. When the target beds were deployed by the divers, the West–East orientations of the beds were essentially random. The layout of the target beds along–tank is shown in Figure 11, with the measured

Table 2: Measured deployed target positions in tank coordinates, in meters.

Target	Position (m)	Comment
Pyramid	34.7	center of target
Ping Pong Balls	44.5	West edge of target bed, arrays at 3' and 6' from edge
Dome	51.0	center of target
Sphere	60.5	center of target
Clam	69.0	center of target
Rocks	77.3	center of center rock
Carpet	85.8-95.3	East and West edges of carpet area

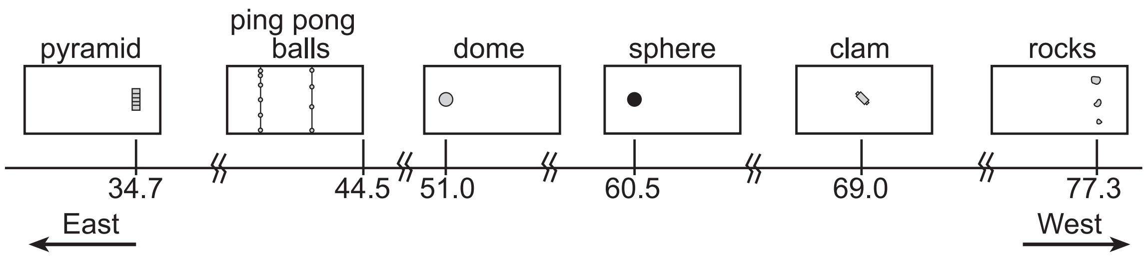

Figure 11: *Diagram of the target bed layout in the tank, after deployment, with the measured along–tank coordinates in meters.*

positions in meters (same as listed in Table 2). Combined runs over several targets in a pass were possible over the ping pong ball arrays, dome, sphere and clam targets. The pyramid and rocks target beds were oriented in the opposite direction.

9 ROV Surveys

Two ROV surveys of the targets were performed during the trial using the VideoRay Pro4 mini-ROV. The first was a higher altitude pass down the entire length of the section of the tank where the targets were deployed. During the second survey, each target was surveyed in detail at lower altitude with several approaches at different angles. In both cases, sonar (BlueView P900) and video data were recorded. Figure 12 shows frame grabs of the targets captured from the video that was recorded during the second survey. The video and sonar mini-ROV surveys will provide useful imagery that will assist in post-trial analysis, to help in positioning the tow carriage sonar data by matching up tank landmarks seen in the video footage.

The network of white PVC piping on the floor of the tank can be seen clearly in the photos from the ROV survey. The large rectangular gridded sections of the flow suppression system can be seen resting on the floor of the tank, along both sides. The photo of the clam target shows the 1' legs supporting the target bed above the PVC pipes. The photo of the ping pong ball arrays shows where the end ball of the closer string is missing at the

Figure 12: *Frames captured from the recorded ROV video of the targets post–deployment. Upper row, left to right: pyramid, ping pong ball arrays, and dome limpet. Lower row, left to right: SonarBell sphere, clam limpet and rocks.*

rightmost end.

10 Sample Sonar Images

Detailed analysis of the collected sonar data is ongoing at time of writing and results will be presented in later publications. Figure 13 shows several samples from the data set.

One sample of DIDSON data that was shown in Figure 13 is shown again in Figure 14 with annotations on the image explaining what the main features are. The most visible features in the image are the shadow of the target bed and further in range, the highlight from a junction in the PVC piping. The target bed edges have been outlined in red in the image. Two rectangular sections of the flow suppression system on the floor of the tank can be seen to either side of the PVC piping highlight. Darker color in the images indicates lower acoustic backscatter level, so the rectangular flow suppression grids have lower target strength than the surrounding floor.

11 Lessons Learned

In a general sense, the sonars performed in a ranking according to the priorities for the different systems that were established for the testing prior to the trial. The Imagenex Delta-T did not provide any usable imagery of the targets – it will require careful synchronization of the carriage position data and the video imagery with the Imagenex sonar data to determine

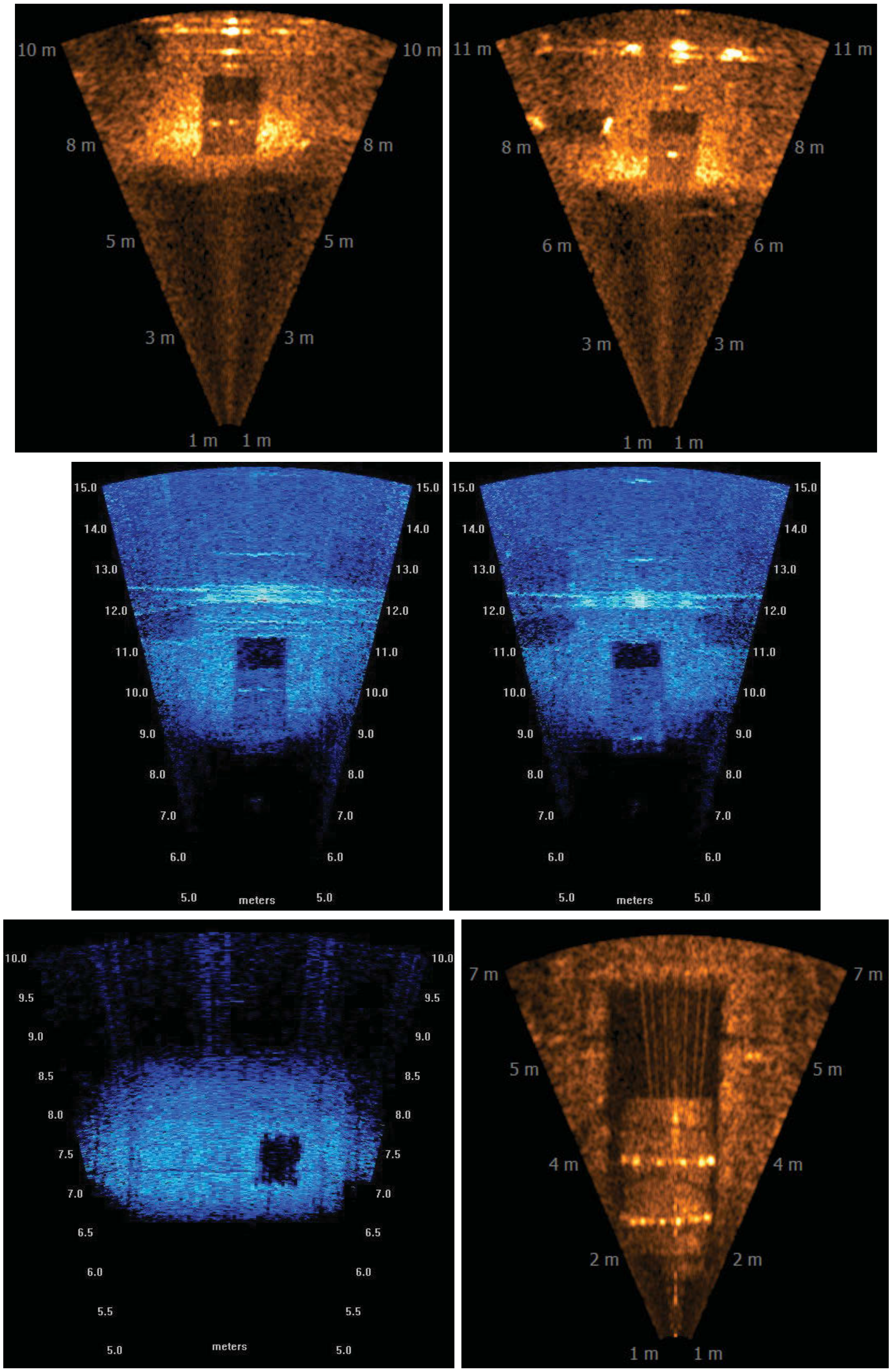

Figure 13: *Samples of sonar data. Upper row: BlueView P900 data from the carriage of the rocks (left) and the dome (right). Middle row: DIDSON data of the rocks (left) and the dome (right). Lower row: DIDSON data showing the shadow of the ROV (left) and BlueView P900 data from the ROV of the ping pong ball arrays (right).*

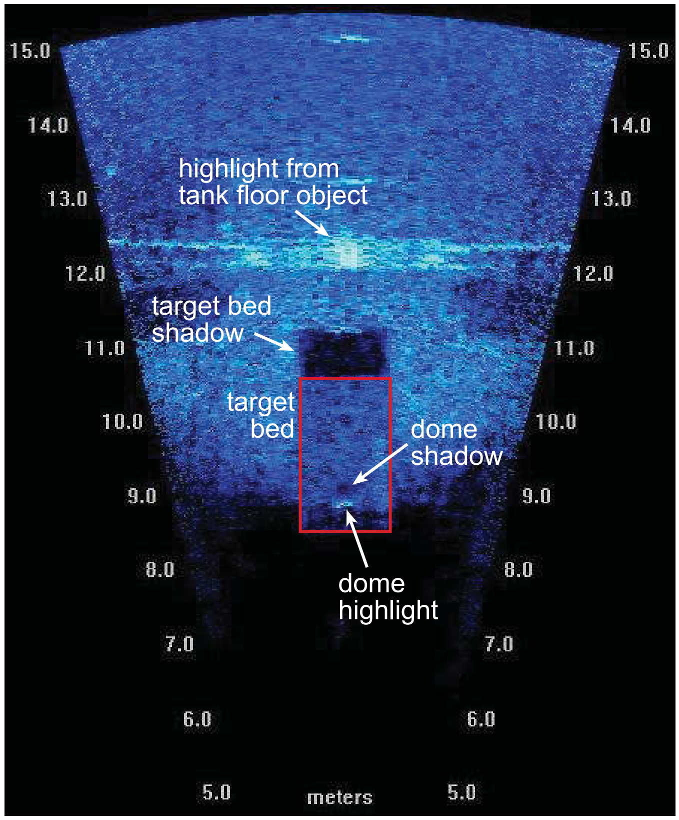

Figure 14: *Annotated DIDSON sonar sample data image showing the target bed, dome target highlight and shadow, and other features.*

whether the targets were seen at all. The DIDSON, in high frequency (1.8 MHz) mode, provided the best imagery, with the exception of the pyramid target which resonated, as discussed later in this section. The BlueView P450 provided some good imagery, though not as clear as hoped and the P900 was operating almost outside its maximum operating range when mounted on the tow carriage. The most consistently imaged targets were the three natural rocks, which showed up well with all systems (examples are shown in Figure 13).

11.1 Acoustic Environment

Performing acoustic measurements in tank environments is always problematic due to acoustic backscatter and multiple reflections from the boundaries and other objects that are part of the tank structure. One of the reasons for choosing the NRC IOT facility for this testing was that the width of the tank was quite large (12 m) – it was hoped that this would lessen the effect of interference due to multiple reflections. This was indeed the case, as spurious reflections from the side walls were practically never observed. The presence of structures on the floor of the tank, specifically the network of PVC piping that was part of the flow suppression system (see Figure 12), was a source of problems for two different reasons. Firstly, the piping itself was an extremely strong acoustic reflector at the many junctions, which probably contained air pockets in addition to having facetted surfaces. An example is shown in Figure 14. In some cases, where a junction in the PVC piping was located near the leading edge of a target bed, the acoustic ringing from the junction extended in range past the target, masking it completely in the sonar imagery.

The second reason for this PVC piping causing trouble was that the target beds were built with legs to provide clearance so they would not be resting on the pipes. This meant that with the elevation and look angle geometry best for imaging with the sonars, as a target was approached, the sonar was imaging the tank floor under the leading edge of the bed, including this piping system. The targets were placed closer to the leading edge to allow for the shadow, however the strong return from the floor below usually overwhelmed the return signal from the target itself at the same range from the sonar. It was found that in some cases, better target imaging results were obtained approaching from the opposite direction than was intended when the layout of the target beds was planned.

In hindsight, the targets should have been placed nearer to the center of the target beds, and the beds themselves should not have been placed on the centerline of the tank. A site visit prior to the trial would have been invaluable in making these decisions.

11.2 Resolution Targets

The pyramid resolution target was constructed from hollow metal boxes. It was assumed that this structure would resonate over some range of frequencies, however without detailed modeling or testing being possible beforehand, it was impossible to predict what that range of frequencies would be. It turned out that the pyramid did not resonate at 450 kHz (BlueView P450), but resonated very strongly at the higher frequencies (BlueView P900 and DIDSON). The ringing echo return from the target fills in the acoustic shadow behind. The highlight from the target, received at the sonar ahead of the ringing, may still be useful for determining resolving ability and work on that is planned. The placement of the pyramid was unfortunately very near to a junction in the PVC piping (the pipes leading into that junction can be seen behind the pyramid in the frame shown in Figure 12), which means that the pyramid imagery is often contaminated with strong ringing from that structure as well.

The ping pong ball arrays were not imaged as well as hoped. Since the height of the sonar above the target beds was fixed, it was not possible to reduce the range to the targets and still maintain a reasonable look angle, between 30° and 45° down from horizontal. Some good closer range imagery was obtained with the BlueView P900 on the ROV (an example is shown in Figure 13).

11.3 Mosaicking Targets

The small rock targets that were scattered across the carpet were not imaged well by any of the sonars. The objects already on the floor of the tank (piping and flow suppression system, as well as other objects) provided plenty of features in the sonar imagery, so in retrospect, the carpet area was unnecessary.

12 Recommendations and Future Plans

Careful consideration is recommended if further sonar testing is going to be done at this facility. The technical support from NRC IOT staff was excellent and the tank and tow carriage are world class, however the acoustic environment was particularly unfavorable due to the flow suppression system installed on the floor of the tank, specifically the network of PVC piping that was the air supply for that system. It is not clear that any choice for placement of the targets would overcome this. Having the targets placed along the centerline of the tank was a very poor choice.

Analysis of the sonar data that was collected is ongoing in support of the trial goals that were stated in the Introduction of this report. The imaging sonar data mosaicking contract work by Intelligence Image Inc. is also ongoing, with the contract end date in August of 2012.

References

[1] Imaging Sonar Testing at NRC IOT Tow Tank; Trial Plan, Anna Crawford, DRDC Atlantic TR2012–040, in review.

[2] Model A–type Annex, SA_2521_FY1112_A, “Sonar Over Small Targets”, Attachment to the Memorandum of Understanding between DND and NRC, with attached Statement of Work.

[3] RS–485 Communication Protocol for ROS Positioners Cameras and Lights, version 1.06, Document 21-30022K, Remote Ocean Systems Inc, June 2009.

This page intentionally left blank.

Annex A: Schedule of Events at NRC IOT , February 6 to 10, 2012

Date & Time	Activity
Feb 5 2012, PM	travel to St John's (Crawford, Spears, Connors), arrive after midnight
Feb 6 2012, AM	on site 8:45 AM
	constructed target beds (NRC) and arranged targets
	large carpet piece prepared for mosaicking targets (NRC)
	set up electronics on tow carriage
	built bracket for sonar pole (NRC)
Feb 6 2012, PM	**BlueView P450** mounted on carriage & tested
	pan-tilt calibration, zeroing
	target beds and carpet set to soak
	unpacked ROV
	left site 3:30 PM
	NRC divers deployed target beds and carpet in the evening
Feb 7 2012, AM	on site 8:40 AM (Rivet–Sabourin joins)
	time synced sonar and pan-tilt logger laptops
	measured target positions along–tank using carriage
	sonar testing, angle adjustments
	10 passes over pyramid target
	assessed 0.25 m/s as good stable tow speed
	pan angle rate experiment
Feb 7 2012, PM	10 passes over ping pong balls, dome, sphere, clam
	10 passes over rocks
	2 passes over carpet
	switch sonar to **DIDSON**
	test sonar over pyramid (target is ringing)
	left site 4 PM
Feb 8 2012, AM	on site 8:40 AM
	planning meeting
	measure depths to pan–tilt axis & target bed below
	10 passes over ping pong balls, dome, sphere, clam
	test ROV and monitor clearances between sonar connector and pan–tilt
	reorient sonar tilt, 10 passes over ping pong balls, dome, sphere, clam
	visit from REALM collaborators from MUN
	2 passes over carpet
	pass down to end of the tank and adjusting pan angle
Feb 8 2012, PM	truss targets scrounged and deployed
	ROV survey of the tank
	passes over trusses, experiment with sonar pan angle

Schedule of events during the week of Feb 6–10 2012.

Date & Time	Activity
	translate and pan simultaneously visit from MUN Physical Oceanography friends check sonar cable slack for runs including carriage sway motion passes over carpet and trusses with translation, sway & pan left site 3:50 PM
Feb 9 2012, AM	on site 8:45 AM discuss possibility of snow day tomorrow, contingency planning DIDSON showing high internal humidity, but settles time sync check on laptops 2 passes over ping pong balls, dome, sphere, clam ROV survey of individual targets, **BlueView P900** and video switch sonar on tow carriage to **BlueView P900** 10 passes over pyramid (ringing)
Feb 9 2012, PM	10 passes over ping pong balls, dome, sphere, clam reverse look direction & another 10 passes over same targets 3 passes over trusses and carpet switch sonar to **Imagenex Delta–T** tilt restricted by connector clearance 2 passes over all targets packed up most equipment (sonar still on pole) complete data backup, including NRC files left site 4:20 PM (Rivet–Sabourin leaves)
Feb 10 2012, AM	on site 9 AM (not a snow day) switched sonar to **BlueView P900** and re-setup experiments with tilt angle and range to targets (ping pong balls) experiments with pan (rocks and clam) start packing up at 11:15 AM backed up final day's data
Feb 10 2012, PM	left site 12:15 PM return flights delayed somewhat home by evening

Annex B: Chronological Listing of Data Files

Table B.1: *Chronological listing of run configurations and data files.*

Date & Time	Sonar Data File Name	Sonar	Target	Sonar Orientation (tilt, pan)	PTU Log File	Sonar Travel Direction	NRC IOT file	Comment
07 Feb 2012, 09:40								sonar and PTU logger laptops synced to NRC time manually
07 Feb 2012, 09:57							target_location_001	fixing deployed target locations centred on carriage; pyramid = 34.7 m, West edge of ping pong ball bed = 44.5 m, dome = 51.0 m, sphere = 60.5 m, clam = 69.0 m, rocks = 77.3 m, carpet = 85.8-95.26 m
07 Feb 2012, 11:28	2012_02_07_11_28_09.son	BlueView P450	pyramid	30 deg down, 348 deg (East)	1328627004.txt	Forward		aligning & testing
07 Feb 2012, 11:32	2012_02_07_11_32_43.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_001	
07 Feb 2012, 11:36	2012_02_07_11_36_04.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward		repositioning
07 Feb 2012, 11:37	2012_02_07_11_37_59.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_002	
07 Feb 2012, 11:40	2012_02_07_11_40_40.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward		repositioning
07 Feb 2012, 11:42	2012_02_07_11_42_14.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_003	
07 Feb 2012, 11:45	2012_02_07_11_45_59.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward	pyramid_004	
07 Feb 2012, 11:49	2012_02_07_11_49_05.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_005	
07 Feb 2012, 11:51	2012_02_07_11_51_03.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward	pyramid_006	
07 Feb 2012, 11:53	2012_02_07_11_53_27.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_007	
07 Feb 2012, 11:55	2012_02_07_11_55_20.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward	pyramid_008	
07 Feb 2012, 11:57	2012_02_07_11_57_09.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Forward	pyramid_009	
07 Feb 2012, 11:59	2012_02_07_11_59_20.son	BlueView P450	pyramid	30 deg down, 348 deg (East)		Backward	pyramid_010	
07 Feb 2012, 12:05	2012_02_07_12_05_03.son	BlueView P450	pyramid	varying, 348 deg (East)		Forward	pyramid_011	
07 Feb 2012, 12:08	2012_02_07_12_08_13.son	BlueView P450	pyramid	varying 125-180 spd 4, 348 deg (East)		Forward		
07 Feb 2012, 12:12	2012_02_07_12_12_02.son	BlueView P450	pyramid	varying 125-180 spd 2, 348 deg (East)		Forward		
07 Feb 2012, 13:00	2012_02_07_13_00_20.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward	Targets_001	
07 Feb 2012, 13:08	2012_02_07_13_08_07.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Backward	Targets_002	
07 Feb 2012, 13:12	2012_02_07_13_12_25.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward	Targets_003	
07 Feb 2012, 13:17	2012_02_07_13_17_21.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Backward	Targets_004	
07 Feb 2012, 13:22	2012_02_07_13_22_08.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward	Targets_005	
07 Feb 2012, 13:25	2012_02_07_13_25_46.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Backward	Targets_006	
07 Feb 2012, 13:29	2012_02_07_13_29_25.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward	Targets_007	
07 Feb 2012, 13:33	2012_02_07_13_33_20.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Backward	Targets_008	
07 Feb 2012, 13:36	2012_02_07_13_36_58.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward	Targets_009	
07 Feb 2012, 13:40	2012_02_07_13_40_26.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Backward	Targets_010	
07 Feb 2012, 13:45	2012_02_07_13_45_28.son	BlueView P450	balls, dome, sphere, clam	30 deg down, 168 deg (West)		Forward		repositioning
07 Feb 2012, 14:06	2012_02_07_14_06_22.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Forward	Rocks_001	
07 Feb 2012, 14:08	2012_02_07_14_08_50.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Backward	Rocks_002	
07 Feb 2012, 14:11	2012_02_07_14_11_04.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Forward	Rocks_003	
07 Feb 2012, 14:15	2012_02_07_14_15_18.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Backward	Rocks_004	
07 Feb 2012, 14:17	2012_02_07_14_17_42.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Forward	Rocks_005	
07 Feb 2012, 14:19	2012_02_07_14_19_54.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Backward	Rocks_006	
07 Feb 2012, 14:22	2012_02_07_14_22_11.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Forward	Rocks_007	
07 Feb 2012, 14:24	2012_02_07_14_24_30.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Backward	Rocks_008	
07 Feb 2012, 14:26	2012_02_07_14_26_42.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Forward	Rocks_009	
07 Feb 2012, 14:28	2012_02_07_14_28_56.son	BlueView P450	rocks	30 deg down, 348 deg (East)		Backward	Rocks_010	
07 Feb 2012, 14:31	2012_02_07_14_31_53.son	BlueView P450	carpet	30 deg down, 348 deg (East)		Backward		repositioning
07 Feb 2012, 14:34	2012_02_07_14_34_00.son	BlueView P450	carpet	30 deg down, 348 deg (East)		Forward	Carpet_001	
07 Feb 2012, 14:36	2012_02_07_14_36_21.son	BlueView P450	carpet	30 deg down, 348 deg (East)		Backward	Carpet_002	
07 Feb 2012, 15:31	2012-02-07_153149_HF.ddf	DIDSON 3000	pyramid	30 deg down, 345 deg (East)	1328641445.txt			testing sonar
07 Feb 2012, 15:48	2012-02-07_154859_HF.ddf	DIDSON 3000	pyramid	30 deg down, 345 deg (East)				testing sonar
07 Feb 2012, 15:50	2012-02-07_155016_HF.ddf	DIDSON 3000	pyramid	30 deg down, 345 deg (East)		Forward	pyramid_012	
07 Feb 2012, 15:52	2012-02-07_155221_HF.ddf	DIDSON 3000	pyramid	30 deg down, 345 deg (East)		Backward	pyramid_013	
08 Feb 2012, 09:00								measured depth to axis of PTU 1.3 m, depth to surface of target bed 6.52 m
08 Feb 2012, 9:21	2012-02-08_092128_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)	1328704522.txt	Forward	Targets_011	
08 Feb 2012, 9:25	2012-02-08_092533_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Backward	Targets_012	
08 Feb 2012, 9:29	2012-02-08_092908_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Forward	Targets_013	
08 Feb 2012, 9:32	2012-02-08_093245_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Backward	Targets_014	
08 Feb 2012, 9:45	2012-02-08_094525_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Forward	Targets_015	

Date & Time	Sonar Data File Name	Sonar	Target	Sonar Orientation (tilt, pan)	PTU Log File	Sonar Travel Direction	NRC IOT file	Comment
08 Feb 2012, 9:48	2012-02-08_094858_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Backward	Targets_016	
08 Feb 2012, 9:52	2012-02-08_095228_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Forward	Targets_017	
08 Feb 2012, 9:55	2012-02-08_095550_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Backward	Targets_018	
08 Feb 2012, 9:59	2012-02-08_095916_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Forward	Targets_019	
08 Feb 2012, 10:02	2012-02-08_100236_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	30 deg down, 167 deg (West)		Backward	Targets_020	
08 Feb 2012, 10:15	2012-02-08_101559_HF.ddf	DIDSON 3000	ROV passes through beam	30 deg down, 167 deg (West)				playing with ROV
08 Feb 2012, 10:15	02_08_12_08_51_30.avi	ROV Camera	DIDSON sonar & PTU					ROV PC clock incorrect
08 Feb 2012, 10:26	2012-02-08_102609_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Forward	Targets_021	
08 Feb 2012, 10:29	2012-02-08_102942_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Backward	Targets_022	
08 Feb 2012, 10:49	2012-02-08_104904_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Forward	Targets_023	
08 Feb 2012, 10:52	2012-02-08_105234_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Backward	Targets_024	
08 Feb 2012, 10:56	2012-02-08_105614_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Forward	Targets_025	
08 Feb 2012, 11:00	2012-02-08_110008_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Backward	Targets_026	
08 Feb 2012, 11:03	2012-02-08_110335_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Forward	Targets_027	
08 Feb 2012, 11:07	2012-02-08_110720_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Backward	Targets_028	
08 Feb 2012, 11:10	2012-02-08_111058_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Forward	Targets_029	
08 Feb 2012, 11:14	2012-02-08_111446_HF.ddf	DIDSON 3000	balls, dome, sphere, clam	50 deg down, 167 deg (West)		Backward	Targets_030	
08 Feb 2012, 11:23	2012-02-08_112324_HF.ddf	DIDSON 3000	carpet	50 deg down, 167 deg (West)		Forward	Carpet_003	
08 Feb 2012, 11:25	2012-02-08_112554_HF.ddf	DIDSON 3000	carpet	50 deg down, 167 deg (West)		Backward	Carpet_004	
08 Feb 2012, 11:45	2012-02-08_114513_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167 deg (West)		Forward	Tank_scan_001	
08 Feb 2012, 11:53	2012-02-08_115330_HF.ddf	DIDSON 3000	tank objects, sidewall	50 deg down, 197 deg (30 deg port)		Backward	Tank_scan_002	
08 Feb 2012, 13:43	2012-02-08_134350_HF.ddf	DIDSON 3000	all targets	50 deg down, 167 deg (West)	1328722115.txt	Forward	Targets_ROV_001	ROV scan West down tank over all targets
08 Feb 2012, 13:45-14:00	2012_02_08_12_03_44.son	BlueView P900	pyramid	ROV, forward look, 0 deg pan & tilt wrt ROV chasis		Forward		ROV laptop not time synced
	02_08_12_12_04_15.avi	ROV Camera	pyramid	ROV, forward look, 0 deg pan, down 45 deg tilt wrt to ROV chasis		Forward		
	2012_02_08_12_17_35.son	BlueView P900	all targets	ROV		Forward		
	02_08_12_12_16_04.avi	ROV Camera	all targets, carpet & trusses	ROV		Forward		
	2012_02_08_12_18_57.son	BlueView P900	all targets, carpet & trusses	ROV		Forward		
	2012_02_08_12_22_56.son	BlueView P900	trusses	ROV		Forward		
	02_08_12_12_22_51.avi	ROV Camera	trusses	ROV		Forward		
08 Feb 2012, 14:07	2012-02-08_140751_HF.ddf	DIDSON 3000	trusses	50 deg down, 347 deg (East)		Forward	Truss_001	
08 Feb 2012, 14:09	2012-02-08_140958_HF.ddf	DIDSON 3000	trusses	50 deg down, 347 deg (East)		Forward	Truss_002	
08 Feb 2012, 14:27	2012-02-08_142754_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-122 deg (West to stbd)		Panning stbd		pan using ROS GUI joystick
08 Feb 2012, 14:29	2012-02-08_142938_HF.ddf	DIDSON 3000	tank objects	50 deg down, 122-212 deg (stbd to port)		Panning port		pan using ROS GUI joystick
08 Feb 2012, 14:31	2012-02-08_143118_HF.ddf	DIDSON 3000	tank objects	50 deg down, 212-122 deg (port to stbd)		Panning stbd		pan fast using "GoTo" button
08 Feb 2012, 14:32	2012-02-08_143241_HF.ddf	DIDSON 3000	tank objects	50 deg down, 122-212 deg (stbd to port)		Panning port		pan fast using "GoTo" button
08 Feb 2012, 14:33	2012-02-08_143332_HF.ddf	DIDSON 3000	tank objects	50 deg down, 212-122 deg (port to stbd)		Panning stbd		pan fast using "GoTo" button; timed 13.2 s
08 Feb 2012, 14:41	2012-02-08_144158_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-122.5 deg (West to stbd)		Forward & Panning stbd	Truss_003	pan & translate
08 Feb 2012, 14:45	2012-02-08_144504_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-135.5 deg (West to stbd)		Backward & Panning stbd	Truss_004	pan & translate
08 Feb 2012, 14:48	2012-02-08_144817_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-134 deg (West to stbd)		Forward & Panning stbd	Truss_005	pan & translate
08 Feb 2012, 14:50	2012-02-08_145032_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-134-171 deg (West to stbd to port)		Backward & Panning stbd, port	Truss_006	pan & translate
08 Feb 2012, 14:54	2012-02-08_145401_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-122.5-212-177 deg (West, stbd, port, stbd)		Forward & Panning stbd	Truss_007	pan & translate
08 Feb 2012, 14:56	2012-02-08_145658_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-122-214.5-180.5 deg (West, stbd, port, stbd)		Backward & Panning stbd, port, stbd	Truss_008	pan & translate
08 Feb 2012, 15:28	2012-02-08_152845_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167 deg (West)		Forward & sway	Truss_Sway_001	sway ctr-port-stbd

Date & Time	Sonar Data File Name	Sonar	Target	Sonar Orientation (tilt, pan)	PTU Log File	Sonar Travel Direction	NRC IOT file	Comment
08 Feb 2012, 15:32	2012-02-08_153230_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167 deg (West)		Backward & sway	Truss_Sway_002	sway ctr-port-stbd
08 Feb 2012, 15:37	2012-02-08_153724_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-121.5-210-194 deg (West, stbd, port, stbd)		Forward & sway & pan	Truss_Sway_003	sway ctr-port-stbd
08 Feb 2012, 15:40	2012-02-08_154057_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-121.5-213 deg (West, stbd, port)		Backward & sway & pan	Truss_Sway_004	sway ctr-port-stbd
08 Feb 2012, 15:45	2012-02-08_154535_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-121.5-213 deg (West, stbd, port)		Forward & sway & pan		mis-cue on record start
08 Feb 2012, 15:48	2012-02-08_154809_HF.ddf	DIDSON 3000	tank objects	50 deg down, 167-122-213-195 deg (West, stbd, port, stbd)		Forward & sway & pan	Truss_Sway_005	sway ctr-port-stbd
08 Feb 2012, 15:58	2012-02-08_155837_HF.ddf	DIDSON 3000	tank objects	50 deg down, 348 deg (East)		Forward & sway	Truss_Sway_006	sway ctr-port-stbd
09 Feb 2012, 09:13	2012-02-09_091305_LF.ddf	DIDSON 3000 (LF)	balls, dome, sphere, clam	45 deg down, 167 deg (West)	1328790977.txt	Forward	Targets_031	
09 Feb 2012, 09:20	2012-02-09_092041_LF.ddf	DIDSON 3000 (LF)	balls, dome, sphere, clam	45 deg down, 167 deg (West)		Backward	Targets_032	
09 Feb 2012, 09:36	2012_02_09_08_11_35.son	BlueView P900	pyramid	ROV		Forward		ROV laptop not time synced, 8:13 ROV = 09:41 local (time offset)
	02_09_12_08_11_36.avi	ROV Camera	pyramid	ROV		Forward		
09 Feb 2012, 09:40	2012_02_09_08_21_25.son	BlueView P900	ping pong balls	ROV		Forward		
	02_09_12_08_22_28.avi	ROV Camera	ping pong balls	ROV		Forward		
	2012-02-09_094603_LF.ddf	DIDSON 3000 (LF)	ping pong balls	45 deg down, 167 deg (West)		Forward		repositioning
09 Feb 2012, 09:56	2012_02_09_08_28_22.son	BlueView P900	dome	ROV		Forward		
	02_09_12_08_28_24.avi	ROV Camera	dome	ROV		Forward		
	2012-02-09_095425_LF.ddf	DIDSON 3000 (LF)	dome	45 deg down, 167 deg (West)		Forward		repositioning
09 Feb 2012, 10:00	2012_02_09_08_33_16.son	BlueView P900	sphere	ROV		Forward		
	02_09_12_08_33_17.avi	ROV Camera	sphere	ROV		Forward		
	2012-02-09_095852_LF.ddf	DIDSON 3000 (LF)	sphere	45 deg down, 167 deg (West)		Forward		repositioning
09 Feb 2012, 10:09	2012_02_09_08_40_23.son	BlueView P900	clam	ROV		Forward		
	02_09_12_08_40_17.avi	ROV Camera	clam	ROV		Forward		
	2012-02-09_100643_LF.ddf	DIDSON 3000 (LF)	clam	45 deg down, 167 deg (West)		Forward		repositioning
09 Feb 2012, 10:17	2012_02_09_08_50_46.son	BlueView P900	rocks	ROV		Forward		
	02_09_12_08_50_18.avi	ROV Camera	rocks	ROV		Forward		
	2012-02-09_101534_LF.ddf	DIDSON 3000 (LF)	rocks	45 deg down, 167 deg (West)		Forward		repositioning
09 Feb 2012, 10:17	2012_02_09_08_57_44.son	BlueView P900	carpet & trusses	ROV		Forward		
	02_09_12_08_57_41.avi	ROV Camera	carpet & trusses	ROV		Forward		
09 Feb 2012, 11:22	2012_02_09_11_22_31.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Forward	pyramid_014	
09 Feb 2012, 11:24	2012_02_09_11_36_04.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Backward	pyramid_015	
09 Feb 2012, 11:26	2012_02_09_11_26_51.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Forward	pyramid_016	
09 Feb 2012, 11:28	2012_02_09_11_28_51.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Backward	pyramid_017	
09 Feb 2012, 11:30	2012_02_09_11_30_53.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Forward	pyramid_018	
09 Feb 2012, 11:32	2012_02_09_11_32_49.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Backward	pyramid_019	
09 Feb 2012, 11:34	2012_02_09_11_34_44.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Forward	pyramid_020	
09 Feb 2012, 11:36	2012_02_09_11_36_47.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Backward	pyramid_021	
09 Feb 2012, 11:38	2012_02_09_11_38_48.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Forward	pyramid_022	
09 Feb 2012, 11:40	2012_02_09_11_40_07.son	BlueView P900	pyramid	45 deg down, 347 deg (East)		Backward	pyramid_023	
09 Feb 2012, 12:28	2012_02_09_12_28_56.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (West)	1328803053.txt	Forward	Targets_033	
09 Feb 2012, 12:33	2012_02_09_12_33_28.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (East)		Backward	Targets_034	
09 Feb 2012, 12:36	2012_02_09_12_36_54.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (West)		Forward	Targets_035	
09 Feb 2012, 12:43	2012_02_09_12_43_43.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (East)		Backward	Targets_036	sonar autogain off, 35%-63%
09 Feb 2012, 12:47	2012_02_09_12_47_15.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (West)		Forward	Targets_037	
09 Feb 2012, 12:50	2012_02_09_12_50_36.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (East)		Backward	Targets_038	
09 Feb 2012, 12:54	2012_02_09_12_54_10.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (West)		Forward	Targets_039	
09 Feb 2012, 12:57	2012_02_09_12_57_59.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (East)		Backward	Targets_040	
09 Feb 2012, 13:01	2012_02_09_13_01_08.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (West)		Forward	Targets_041	
09 Feb 2012, 13:04	2012_02_09_13_04_28.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 167 deg (East)		Backward	Targets_042	
09 Feb 2012, 13:15	2012_02_09_13_15_14.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Backward	Targets_043	
09 Feb 2012, 13:19	2012_02_09_13_19_34.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Forward	Targets_044	
09 Feb 2012, 13:23	2012_02_09_13_23_06.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Backward	Targets_045	
09 Feb 2012, 13:26	2012_02_09_13_26_36.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Forward	Targets_046	
09 Feb 2012, 13:30	2012_02_09_13_30_12.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Backward	Targets_047	
09 Feb 2012, 13:34	2012_02_09_13_34_46.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Forward	Targets_048	
09 Feb 2012, 13:38	2012_02_09_13_38_17.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Backward	Targets_049	

Date & Time	Sonar Data File Name	Sonar	Target	Sonar Orientation (tilt, pan)	PTU Log File	Sonar Travel Direction	NRC IOT file	Comment
09 Feb 2012, 13:42	2012_02_09_13_42_02.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Forward	Targets_050	
09 Feb 2012, 13:45	2012_02_09_13_45_24.son	BlueView P900	balls, dome, sphere, clam	45 deg down, 347 deg (East)		Backward	Targets_051	
09 Feb 2012, 13:48							Targets_052	sonar software glitch, lost sonar file
09 Feb 2012, 13:55	2012_02_09_13_55_41.son	BlueView P900	balls, dome, sphere, clam, trusses	45 deg down, 347 deg (East)		Backward	Targets_053	travel to far end of tank
09 Feb 2012, 14:04	2012_02_09_14_04_53.son	BlueView P900	trusses & carpet	45 deg down, 347 deg (East)		Forward	Truss_008	
09 Feb 2012, 14:08	2012_02_09_14_08_07.son	BlueView P900	trusses & carpet	45 deg down, 347 deg (East)		Backward	Truss_009	
09 Feb 2012, 14:11	2012_02_09_14_11_30.son	BlueView P900	all targets	45 deg down, 347 deg (East)		Forward	Targets_054	
09 Feb 2012, 14:46	09feb2012_144612.837	Imagenex Delta-T	all targets	45 deg down, 347 deg (East)		Backward	Targets_055	
09 Feb 2012, 14:54	09feb2012_145401.837	Imagenex Delta-T	all targets	45 deg down, 347 deg (East)		Forward	Targets_056	
10 Feb 2012, 09:48	2012_02_10_09_48_06.son	BlueView P900	ping pong balls	141.5 deg, 347 deg (East)	1328879092.txt			48.0 m carriage pos.
10 Feb 2012, 09:49	2012_02_10_09_49_08.son	BlueView P900	ping pong balls	141.5 deg, 347 deg (East)				"test file"
10 Feb 2012, 09:51	2012_02_10_09_51_57.son	BlueView P900	ping pong balls	141.5 deg, 347 deg (East)				48.497 m carriage pos.
10 Feb 2012, 09:55	2012_02_10_09_55_45.son	BlueView P900	ping pong balls	138 deg, 347 deg (East)				48.497 m carriage pos.
10 Feb 2012, 10:03	2012_02_10_10_03_15.son	BlueView P900	ping pong balls	115 deg, 347 deg (East)				46.5 m carriage pos.
10 Feb 2012, 10:05	2012_02_10_10_05_01.son	BlueView P900	ping pong balls	120 deg, 347 deg (East)				46.5 m carriage pos.
10 Feb 2012, 10:15	2012_02_10_10_15_08.son	BlueView P900	ping pong balls	125 deg, 347 deg (East)				47 m carriage pos.
10 Feb 2012, 10:18	2012_02_10_10_18_45.son	BlueView P900	ping pong balls	140 deg, 347 deg (East)				50 m carriage pos.
10 Feb 2012, 10:24	2012_02_10_10_24_53.son	BlueView P900	dome	140 deg, 347 deg (East)				58 m carriage pos.
10 Feb 2012, 10:28	2012_02_10_10_28_05.son	BlueView P900	dome	140 deg, 347 deg (East)				56 m carriage pos.
10 Feb 2012, 10:29	2012_02_10_10_29_34.son	BlueView P900	dome	135 deg, 347 deg (East)				56 m carriage pos.
10 Feb 2012, 10:58	2012_02_10_10_58_04.son	BlueView P900	rocks & clam	130 deg, 167-100, 100-50, 50-25, 25 1, 1-358 deg (West, port, stbd)				73 m carriage pos. , GoTo button pan
10 Feb 2012, 11:01	2012_02_10_11_01_26.son	BlueView P900	rocks & clam	130 deg, 358-1 deg (East, stbd)				73 m carriage pos. , GUI joystick pan
10 Feb 2012, 11:30								Water Temp = 16.84 deg C, < 1 m from surface

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)

   Defence R&D Canada – Atlantic
   PO Box 1012, Dartmouth NS B2Y 3Z7, Canada

2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.)

   UNCLASSIFIED
   (NON-CONTROLLED GOODS)
   DMC A
   REVIEW: GCEC APRIL 2011

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

   Imaging Sonar Testing at NRC IOT Tow Tank

4. AUTHORS (Last name, followed by initials – ranks, titles, etc. not to be used.)

   Crawford, A.; Spears, S.; Connors, W.

5. DATE OF PUBLICATION (Month and year of publication of document.)

   November 2012

6a. NO. OF PAGES (Total containing information. Include Annexes, Appendices, etc.)

   40

6b. NO. OF REFS (Total cited in document.)

   3

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

   Technical Report

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

   Defence R&D Canada – Atlantic
   PO Box 1012, Dartmouth NS B2Y 3Z7, Canada

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

   11cf05

9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)

   DRDC Atlantic TR 2012-041

10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

   (X) Unlimited distribution
   (   ) Defence departments and defence contractors; further distribution only as approved
   (   ) Defence departments and Canadian defence contractors; further distribution only as approved
   (   ) Government departments and agencies; further distribution only as approved
   (   ) Defence departments; further distribution only as approved
   (   ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (Any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11)) is possible, a wider announcement audience may be selected.)

   Unlimited

13. ABSTRACT (A brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual.)

This report describes work that was performed at National Research Council Institute of Ocean Technology (NRC IOT), St John's, in February 2012. There were several overall aims of the testing: to assess the suitability of the sensors for detecting small foreign objects on ship hulls or other underwater structures; to assess the true resolving power of the sensors; to assess optimal geometries for deployment of the sensors; and to provide high quality sonar data for ongoing imaging sonar data mosaicking software development. During the testing a variety of small imaging sonars were transited above small targets laid on the bed of the tank. Having the sonars mounted to the tow carriage of the test tank allowed precise control of the sensor–target geometry which is critical for achieving the stated trial goals. The purpose of this report is to document the testing that was performed for later reference, to assist in interpretation of the collected sonar data in later analysis.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

imaging sonar
resolution